Proceedings of the

FORTY-FIRST ANNUAL CONGRESS

of the
South African Sugar
Technologists'
Association

HELD AT MOUNT EDGECOMBE
l Oth- 14th APRIL, 1967

Published by

South African Sugar Technologists' Association

SOUTH AFRICAN SUGAR ASSOCIATION EXPERIMENT STATION
MOUNT EDGECOMBE, NATAL

PRICE FOR EXTRA COPIES R5.00

Printed in the Republic of South Africa by The Natal Witness (Pty) Ltd.

Proc. Annual Cong. S. Afr. Sugar Tech. Ass. No. 41, pp. 1-219, Durban, 1967

THE SOUTH AFRICAN SUGAR TECHNOLOGISTS ASSOCIATION

The South African Sugar Technologists' Association was founded in 1926. It is an organisation of technical workers and others directly interested in the technical aspect of the South African Sugar Industry. It operates under the aegis of the South African Sugar Association, but is governed under its own constitution by a Council elected by its members.

The office of the Association is situated on premises kindly made available to it by the South African Sugar Association at the latter's Experiment Station at Mount Edgecombe.

CONTENTS

OFFICERS

1967-1968

Life Patron
DR. H. H. DODDS

President
L. F. CHIAZZARI

Vice-President
T. G. CLEASBY

Hon. Secretary
(Mrs.) M. WELLS

Hon. Technical Secretary
D. J. COLLINGWOOD

Former Presidents

1926–27	M. McMASTER
1927–28	M. McMASTER
1928–29	H. H. DODDS
1929–30	H. H. DODDS
1930–31	G. S. MOBERLY
1931–32	G. C. DYMOND
1932–33	G. C. DYMOND
1933–34	B. E. D. PEARCE
1934–35	E. CAMDEN-SMITH
1935–36	G. C. WILSON
1936–37	G. C. WILSON
1937–38	J. RAULT
1938–39	P. MURRAY
1939–40	P. MURRAY
1940–41	E. P. HEDLEY
1941–42	F. W. HAYES
1942–43	A. McMARTIN
1943–44	G. BOOTH
1944–45	G. S. MOBERLY
1945–46	G. S. MOBERLY
1946–47	W. BUCHANAN
1947–48	W. BUCHANAN
1948–49	J. L. DU TOIT
1949–50	H. H. DODDS
1950–51	A. McMARTIN
1951–52	G. C. DYMOND
1952–53	G. C. DYMOND
1953–54	G. C. DYMOND
1954–55	G. C. DYMOND
1955–56	J. B. GRANT
1956–57	J. B. GRANT
1957–58	J. P. N. BENTLEY
1958–59	J. P. N. BENTLEY
1959–60	J. P. N. BENTLEY
1960–61	J. L. DU TOIT
1961–62	J. L. DU TOIT
1962–63	J. L. DU TOIT
1963–64	J. R. GUNN
1964–65	J. R. GUNN
1965–66	J. R. GUNN

Former Vice-Presidents

1926–27	L. E. ROUILLARD
1927–28	H. H. DODDS
1928–29	G. S. MOBERLY
1929–30	G. S. MOBERLY
1930–31	G. C. DYMOND
1931–32	A. C. WATSON
1932–33	A. C. WATSON
1933–34	G. C. DYMOND E. CAMDEN-SMITH
1934–35	B. E. D. PEARCE
1935–36	E. CAMDEN-SMITH
1936–37	J. RAULT
1937–38	P. MURRAY
1938–39	E. P. HEDLEY
1939–40	E. P. HEDLEY
1940–41	F. W. HAYES
1941–42	A. McMARTIN
1942–43	G. BOOTH
1943–44	F. B. MACBETH
1944–45	G. BOOTH
1945–46	W. BUCHANAN
1946–47	G. C. DYMOND
1947–48	G. C. DYMOND
1948–49	G. C. DYMOND
1949–50	J. L. DU TOIT
1950–51	O. W. M. PEARCE
1951–52	O. W. M. PEARCE
1952–53	K. DOUWES-DEKKER
1953–54	J. B. GRANT
1954–55	K. DOUWES-DEKKER
1955–56	G. C. DYMOND W. G. GALBRAITH
1956–57	W. G. GALBRAITH
1957–58	J. L. DU TOIT
1958–59	J. L. DU TOIT
1959–60	J. L. DU TOIT
1960–61	J. DICK
1961–62	J. P. N. BENTLEY
1962–63	J. P. N. BENTLEY
1963–64	L. F. CHIAZZARI
1964–65	L. F. CHIAZZARI
1965–66	L. F. CHIAZZARI

Council of the Association

J. B. ALEXANDER
W. J. G. BARNES
J. P. N. BENTLEY
L. F. CHIAZZARI
T. G. CLEASBY
D. J. COLLINGWOOD
J. DICK
K. DOUWES-DEKKER
J. L. DU TOIT
J. R. GUNN
D. J. L. HULETT
M. MATIC
G. W. SHUKER
G. D. THOMPSON
J. WILSON

List of members and guests who attended the

Forty-first Congress
10th-14th April, 1967

ADAM, D. L.
ALEXANDER, J. B.
ALEXANDER, K. E. F.
ALLAN, G. N.
ALLEY, L. vJ.
ANNETTS, J. R.
ARCHIBALD, R. D.
ARMSTRONG, N.
ASHE, vj.
ATKINSON, A.

BAWDEN, SIR FREDERICK
BAWDEN, LADY
BARTLETT, G. S.
BAX, G.
BEATER, B. E.
BENTLEY, J. P. N.
BESTER, MISS L.
BISHOP, R. T.
BOAST, W. B.
BOOYSEN, S. S.
BORCHERS, O.
BOURNE, J. H.
BOULLE, P. F.
BOWES, N. L
BRASSEY, T. B.
BRETT, P. G. C.
BREWITT, A. J. D.
BROKENSHA, M. A.
BROUARD, J. E.
BROWN, J. W.
BROWNE, E. L.
BRUDN, J.
BUCHANAN, E. J.
BUCK, W. R.
BUTLER, M. J. W.

CAIRNS, P. A.
CARGILL, J. M.
CARNEGIE, A. T. J. M.
CARNOCHAN, R.
CARTER, C. A.
CARTER, R. A.
CHANCE, W. J. F.
CHANCE, MRS. W. J. F.
CHESTER, J. W.
CHEVES, R.
V—.HIAZZARI, L-I. r.
v_^LEASB I , I. vJ.
CLEASBY, MRS. T. G.
COLE, B
COLLINGS, D. J.
COLLINGWOOD, D. J.
CORNELISSEN, MISS M.
COUVE, J.
COVAS, T.
CovAS, MRS. T.
COWNIE, P. J.
CROOKES, D. V.
CROOKES, L. N.
CROOKES, P. J. M.
v^ROOKJES, I. o.

DE GRANDPRE, T., Ph.D.
DAVIES, W. F.
DAWES, V. H.
DEDEKJND, E. T. J.
DENT, C E.
DICK, J.
DICK, J. Mc.D.
DICK, MRS. J. Mc.D.
DIXON, A. E.
DODDS, H. H. (Patron)
DODDS, MRS. H. H.
DOUWES DEKKER, K.
DREW, B. L.
DREYER, A. C P.
DE FROBERVILLE, P.
DE ROBILLARD, M.
DU BUISSON, G. A.
DU COUDRAY, C R. D,
DU PREEZ, P.
DU TOIT, J. L.
DU TOIT, MRS. J. L.

EDDINGS, E.
EDWARDS, B. R.
EICHHORN, H.
ELLIS, MRS. E.

FARQUHARSON, J. C
FEN WICK, J. W.
FLETCHER, M. E.
FLEWELLEN, C G.
FLEWELLEN, MRS. G. C
FOURMOND, T.
FRANCIS, D. W.
FRANGS, G. B.
FRANK, J. C.
FROESLER, H. P.

GARNETT, C H.
GILFILLAN, E. C
GILLATT, I. F. G.
GIRDLER, J.
GLOVER, J.
GOSNELL, J. M.
GOURLEY, I. N.
GRAHAM, W. S.
GRENFELL, D. J.
GRINDLEY, E. R.
GROOM, R. C
GUNN, J. R.

HALSE, R. H.
HAMLYN, D.
HAMMOND, A. G.
HARDMAN, C R.
HARRIS, V. G.
HARRIS, R. H. G.
HAVENGA, C.
HEATH, J. P.
HEATHMAN, C. R.
HEDGECOCK, G. W.
HEENAN, J. F. C.
HIBBERT, A.
HILL, J. N. S.
HOWES, A. M.
HULETT, D. J. L.
HULETT, J. R.
HURTER, A. G.

JENNINGS, R.
JOHNSTON, F. S.

KARLSON, M.
KELUERMAN, G. H. P.
KING, N. C.
KING, S.
KOENIG, M. J. P.
KLUSENER, W. B.
KRAMER, F. A.

LAAPER, J. N.
LALOUETTE, H.
LANDREY, P.
LANDSBERG, J. J.
LARGE, S. M.
LARSEN, A. W.
LAX, R.
LECLEZIO, R.
LENFERNA, F. G.
LESUR, G.
LIBBERTON, J.
LINTNER, J.
LOUDON, T. R.

MANDY, S.
MANN, Q. V.
MARITZ, G. J.
MARSHALL, D.
MARTIN, D. M.
MATIC, M.
MAUD, R. R.
MAY, W. B.
MEYER, C. F. J.
MILLAR, J.
MILLAR, N.
MOERDYK, J. R.
MOBERLEY, P. K.
MOOR, B. ST. C.
MOULD, R.
MORRIS, R.
MORROW, K.
MULLER, E. L.
MURDOCK, M. G.
MACLEOD, D. M.
MACRITCHIE, A. J.
MACVICAR, C. N.
MCCARTHY, C.
MCKENNA, H. G.

NAPIER, J.
NEILSON, L.

ODENDAAL, C. J.
O'DONOVAN, G. P.
OOSTHUIZEN, D. M.

PATTESON, R. R.
PEARSON, C. H. O.
PENFOLD, P. G.
PFOTENHAUER, V. O,
PHIPSON, M. A.
POWELL, P.
PREEN, P. P.
PRESTON, W. H.
PYNE, J.

RABE, A.
RAULT, J.
REILLY, G.
RENAUD, C. L.
RENNIE, L. L.
RENTON, R.
RIC-HANSBN, R. W.
RITCHIE, N. A. D.
ROBERTSON, J. M.
ROBINSON, R. C. S.
*V.OGERJ>, LJ * C 0.
JcvOODT, A. O.
ROTH, G.
ROUILLARD, M. J. R.
ROUTLEDOE, D. A.

SANDIFORD, T.
SCOTT-BARNES, R. T,
SEYMOUR, R. W.
SHUKER, O. W.
u*w*J V* rtv/ iN|vd*ii#
TBFFEN, J. fc, r.
STEWART, M, J.
O iRACHAN, IVIRS• Ki» Jhv»
SWART, MRS, E. M. J,

TAYFIELD, D.
TERNENT, M. J.
THOMSON, G. M,
THOMPSON, G. D.
THUMANN, J. D.
TIJL, J.
TOURNOIS, P.
TREWREN, F. G.
TUCKER, A, B.

TURNER, R. C.
TURNER, Q, A.

UDAL, W. N.

VAN DUYKER, W. R.
VAN KEPPEL, MISS H.
VAN HENGEL, A.
VAN DER RIET, C. B.
VAN DER SPUY, L. B.
VON DER MEDEN, E.

WAGNER, C. L.
WAGNER, D. O.
WALSH, G. H.
WALLIS, F.
WALTON, J. R.
WARDLE, G. J. F.
WARNE, D. E.
WHITEHEAD, C.
WHITMARSH, A.
WHITLEY, W.
WILKES, B. S.
WILLIAMSON, B. B.
WILSON, J. S.
WILSON, J,
WILSON, MRS, J.
WISE, C. T.
WOOD, G. H.
WOOD, R. A.
WORMALD, T. C.

WYATT, R,

YOUNG, C. M.

FORTY-FIRST ANNUAL CONGRESS

Proceedings of the Forty-first Annual Congress of the South African Sugar Technologists' Association, held at the South African Sugar Association's Experiment Station, Mount Edgecombe, from the 10th to 14th April, 1967.

L. F. CHIAZZARI *(President)* was in the Chair.

The President: Ladies and Gentlemen—I have great pleasure in asking Sir Frederick Bawden, Director of Rothamsted Experimental Station, England, to open our Forty-first Annual Congress.

OPENING ADDRESS

Sir **Frederick Bawden:** Mr. President, ladies and gentlemen, I much appreciate the compliment of being invited to open your meeting today, all the more because the crop you are concerned with is not one of which I have had any practical experience. However, it greatly interests me because it seems to combine the characters of three crops that we have in the United Kingdom. First, if I may mention a rival crop, sugar beet, there is the shared feature of producing large amounts of sucrose. Secondly, cane seems to grow like grass in our perennial pastures and thirdly, it resembles the crop that is perhaps closest to my heart, the potato, in that it is propagated vegetatively and not from true seed. Probably then, cane problems are similar to those in these three crops.

It would only be impertinent and arrogant of me to try to tell you experienced gentlemen anything about the growing of sugarcane, so instead I shall say something about what I think is the role of research in agriculture and what research can and cannot do for agriculture. The purpose of the agricultural research worker is to find out first what factors are limiting yields of crops and then how these limiting factors can be overcome. When he has succeeded in this, his next job is to show the industry what can be done to increase productivity. But the research worker cannot determine what will be done. This can be determined only by those who are concerned with production and management. The research worker can often measure what the cost of any change in practice that increases yield would be, but he cannot determine its profitability. This is a decision for management. Hence, the first point that I would like to make about agricultural research is that the worker should never be too troubled by what are current economic possibilities. How can a research worker decide whether something that he has discovered will be profitable when, in your industry, world prices of sugar have fluctuated over the last few years between something over R200 per ton and something under R40 per ton? A practice that is wholly unprofitable at R40 per ton can be, as you will not need me to tell you, very profitable at R200 per ton.

The research worker can only work on the assumption that knowledge of how to improve the yield and productivity of crops is in itself a desirable thing and will ultimately be valuable, even if it is not profitable at the moment. I am old enough to have lived through several eras of British agriculture and it is impossible to have done this without seeing that whether or not the results of agricultural research get applied depends on economic and social conditions. In the 1930's, to be in agricultural research in the United Kingdom was a frustrating activity for people interested, not only in satisfying their own curiosity, which basically is what research is, but also in seeing their results applied. The mood of British agriculture then was restrictive and not expansive. From the beginning of the second world war, however, things changed and the change has continued at an accelerating pace and agriculture has changed dramatically, especially during the last fifteen years. British agriculture has in effect undergone a revolution, produced by applying the results of research.

I will try to indicate the size of some of the changes there have been in British agriculture. Since 1955 the number of farm workers in the United Kingdom has decreased by more than a third and production has increased by more than a third. This, of course, has involved large capital investment in machines and buildings, and the adoption of many new novel methods. The most striking change has been the enormous increase in the cereal acreage, particularly of barley. The acreage of barley in England used to be something under two million acres, rather less than the acreage of wheat; in 1966 it was over eight million acres. The acreage of wheat has changed little and that of oats steadily diminishes. The total replacement of farm horses by tractors has accounted for the diminishing acreage of oats and has freed at least a million acres to come into other uses. Cereal growing has become an intensive and specialist activity and the traditional crop rotations taught at most of our agricultural schools have been abandoned. A successful barley baron, when I asked what was his rotation, replied, "five years of barley and one year on the Mediterranean".

The many reasons for these changes include the amount of capital investment that has gone into combined harvesters, grain driers and stores. Such capital investment has to be used to the full, which means maximum acreage of cereals. A further reason is the shortage and the cost of labour, for cereals can be grown with few workers. However, it is only changes in cultural practices that permit intensive cereal growing to be profitable. First among these is the use of weed killers. The whole picture of South East England has changed during recent years. No longer do cereal fields carry the flowers that our poets used to speak of so eloquently —the blue cornflowers, the yellow charlock and the red poppies—cereal crops are now uniformly green until they reach maturity.

The development of weed killing by spraying has had many effects. It is often assumed that the farmer is a man who likes hard work, but, of course, nobody does. Until recently, weeds could only be dealt with by hard work, either hand hoeing or mechanical hoeing of one kind or another. Farmers everywhere may be sceptical about the damage done by pests and diseases, but the presence of weeds is only too obvious and clearly must be controlled if the crops are not to be smothered. When laborious ways of dealing with weeds could be replaced by the relatively easy method of sitting on a tractor drawing a sprayer, the farmer soon adopted it. This also conditioned him to spraying and, having his own sprayer, he became very much more receptive to the idea that he should also spray to protect his crop against pests and diseases. The resultant increase in the use of insecticides and fungicides, either as seed dressings or as spray, has greatly increased the yields of many kinds of crop.

The increased yields of cereals also owes much to the breeding of new varieties, varieties that are more resistant than the old ones to pests and diseases, varieties that respond better to fertilizers, particularly to nitrogenous fertilizer, varieties that lodge less when they are generously treated with fertilizers. It is especially the increased use of nitrogen fertilizer that has allowed cereal crops to be grown year after year without impoverishing the land. How slowly the results of research get applied is, I think, most vividly shown by the use of nitrogenous fertilizers on cereals. We date the foundation of Rothamsted Experimental Station from 1843, when Lawes. our founder, with Gilbert, the chemist he employed, laid down perhaps the most celebrated experiment in agricultural history, the continuous wheat experiment on Broadbalk field, which still continues and will be producing its 124th consecutive wheat crop this year. Since 1843, one plot of wheat on that field has received 6 cwt of sulphate of ammonia every year. Now the benefits from this are evident simply by looking at the field and they have been evident every year since 1843. But it wasn't until about 1960 that most British farmers got around to using 6 cwt of sulphate of ammonia, or its nitrogen equivalent, per acre and most of the world hasn't yet started to use anything like this amount. It is a sad comment on world yields that the unmanured plot on Broadbalk, which has received neither any organic manure nor inorganic fertilizer for 124 years yields more than what is returned on the average wheatfield the world over.

Our official figures for average wheat yields changed little in the 50 years before the outbreak of the first world war, but since then have more than doubled. However, the official figures as given are still less than half of what we expect to get on our best wheat at Rothamsted, which is about three tons of grain per acre. The enormous increase in barley acreage, while wheat has stayed steady, is probably not wholly in the national interest, and partly reflects a failure on the part of the research worker. It is because wheat, and particularly winter wheat, which gives us the yield of three tons or so that I quoted, is much more susceptible than barley to soil-borne pests and diseases. On much land where barley can be grown profitably for four or five years in suecession, two or three successive winter wheat crops is the most that can be taken without serious losses. This is because the only adequate control known for our soil-borne pests and diseases of cereals is crop rotation, that is by including a period when non-susceptible crops are grown.

Many pathologists, not only ours, preach the virtues of crop rotation almost as though it were a religion. You in the sugar industry may not understand this, for you have grown sugarcane after sugarcane after sugarcane without any break and without any major disasters. In this respect cane resembles our permanent pastures, which continue year after year being bountiful, provided they are well fertilized. However, cereals, although relative of the grasses, are entirely different and suffer large losses unless grown in a suitable crop rotation. Our traditional crop rotations had two purposes; one to conserve fertility, but fertility is much better supplied by fertilizers and can be assured only by fertilizers; the second is to decrease the incidence of soil-borne pests and diseases. However, as I often tell our pathologists, it may be good advice to tell a man who wants to grow wheat or barley that he can solve his disease problems by growing some other crop, but it is not always welcome advice, for a farm equipped for cereals cannot readily grow other crops. I doubt that anyone whose business was making woollen blankets and who had trouble with moth would think that somebody had solved his problems by telling him to turn over to cotton sheets. Monoculture is often condemned, and it certainly can be a dangerous practice, but its equivalent in other industries is called specialisation, and is usually praised. I regard the job of an agricultural research worker as finding out how a grower can grow bountiful crops of the kinds he wishes to grow and not the ones that he is forced to grow because of pests and diseases.

I said I wasn't going to talk about the sugarcane crop but I must say that I shall be extremely surprised if growers are not suffering losses from soil-borne pests and diseases. I cannot imagine a crop that can be grown continuously on the same land without being troubled. In seeking direct methods of attacking our soil-borne pests and diseases we have been doing much work recently with soil disinfectants of various kinds, fungicides, nematicides and general biocides—to use the jargon. The effects of some of these have been quite dramatic on our land, particularly light land and where cereals have been grown frequently. From land that previously, however well manured, and whether irrigated or not, would not yield much above 20 cwt per acre of wheat, we have got, after treatment with a suitable disinfectant, more than 50 cwt. I think agricultural research workers should make experiments of this kind, not necessarily because I think the treatments will be immediately of any economic value, but to measure the losses being suffered. Only by planting the healthiest possible material, in soil that is free from pests and diseases, by then keeping the crop free from pests and diseases, and by manuring and watering, will we know what is the potential yield of any one crop in any one area. It is part of a research worker's job to measure these potential yields, because until he has done so, the grower will not know what he could be getting and will still remain content with half a crop provided it is profitable. The fact that the treatments that can now be applied to soil may never be applied economically to agricultural field crops should be no deterrent from using them, for they will give a measure of what yield is now being lost, and may stimulate the chemical industry to look for cheaper and better soil disinfectants. And who knows, they may be as successful as they have been in providing excellent insecticides.

The glasshouse industry in Britain already vividly illustrates the value of soil sterilisation. Where the soil is disinfected annually, either by steam or chemicals, crops of tomatoes of 80 to 100 tons can be produced every year, but without such treatments the yields are miserable, regardless of how well they are treated otherwise. I think a most useful thing the chemical industry could now produce for agriculture would be a chemical that, applied to the leaves, would kill pests and diseases in the soil.

It is not only cereals where yields have increased greatly over recent years. In the 1930's at Rothamsted, potatoes rarely yielded much more than seven tons per acre, whereas in 1966 we averaged about 20 tons, and the national average was near 11 tons of saleable potatoes per acre. This increase has been achieved partly by better manuring, earlier planting, and the better treatment of the seed tubers before they are planted, but most important, and this may be very relevant to the sugarcane industry, by improving the health of the seed tubers that are planted. In the 1930's our potato crops were riddled with virus diseases. In the 1960's you have to search to find potato plants with these virus diseases to demonstrate them to students. This improvement came from the certification schemes introduced for seed crops grown largely in parts of Scotland and Ireland, where the vector does not favour the aphid vectors of the important potato varieties. I am a pathologist and my main interest is in virus work and I spent much time in the 30's and 40's advocating improvements in the certification schemes and urging English potato growers to plant only certified seed. This has been immensely successful and is the biggest single measure in increasing our potato yield. However, the research worker always needs to challenge practices, however successful they may be, and if I were now a potato grower in the South East of England I would no longer do as I have long advocated and plant only tubers from the seed-growing areas. This is because with new knowledge and modern insecticides it is possible to check the spread of these virus diseases in South East England. A single application of a granular insecticide in the row when the tubers are planted keeps the plants aphid free for many weeks, and although Scotland must continue to produce the highest grade of seed stocks, farmers in England can safely retain their stocks for much longer than previously.

The potato is propagated in essentially the same way as sugarcane, and I expect that yields of sugarcane the world over would probably be much increased were similar measures applied to producing virus-free seed cane, as are applied in Britain to producing virus-free potatoes and several other vegetatively propagated plants. When plants show leaf symptoms or are crippled and miserable from virus infection, then it is obvious that their yield is affected* But a crop that looks vigorous can still be virus-infected and its yield increased by freeing it from infection. Our most popular potato variety in the United Kingdom, King Edward, has been known for 30 years to be infected with a virus, paracrinkle, The plants show no evident symptoms and the virus was considered harmless, i.e. this was an assumption that could not be tested until a virus-free clone was produced. This we did by the technique of apical-meristem culture, and when the virus-free clone had been bulked it was put into yield trials with the best commercial stocks of King Edward that could be obtained; on average over several years its yield exceeded the other stocks by more than 10 per cent, and soon it will replace the commercial stocks. This means that to get the same yield we shall need 15,000 fewer acres of King Edward than previously, which is a happy event because potato growers in the United Kingdom annually become fewer and our needs can be met only by increasing yields per acre.

Sugar beet, your rival crop, was first introduced into the United Kingdom for strategic and political reasons, but is now fully competitive with sugarcane. The reason that its acreage in South East England is not bigger is because it is restricted by Commonwealth agreements. During the last 20 years, the average yield of roots has increased from less than nine to nearly 16 tons an acre and the manner of dealing with the crop has so greatly changed that this increased yield is produced by very many fewer workers. From being all harvested by hand 15 to 20 years ago, the whole crop is now harvested by machine and the spring operations are increasingly being mechanised. The use of monogerm seed, precision drillers and weed killers is obviating the need for most of the hand labour that previously made the crop difficult. Fertilizer use has greatly increased in the last 15 years, nitrogen by five times, potash by four, while knowledge gained on the control of pests and diseases has also been applied. One of the main things responsible for increasing the yield has been acceptance of the advice of the research worker to drill as early as possible, so that the leaf is covering the ground during the long days of May and June. The beet plant is a biennial, with the seed crop in the ground over winter. Until a few years ago the root crop and the seed crop were grown wherever anybody liked, often next to one another, and the annual root crop used to contract all the pests and diseases from the seed crop which had carried them through the winter. Now, the seed crop is all grown under specific regulations so that it no longer menaces the root crop. The most important disease is a virus disease spread by aphids, and for this we operate a spray-warning scheme, to tell growers when the aphids are likely to be on the wing so that they may immediately spray to kill them, and prevent them spreading the yellows viruses.

Among our crops, the one that has changed least is permanent grass, which in its type of growth reminds me of sugarcane. It forms the largest acreage of any crop in the United Kingdom, amounting to about 12 million acres, which by South African standards is small, but in the United Kingdom represents a lot of land, most of which is still being farmed by traditional methods. This is partly because the pastoralist is less receptive to novel ideas than the arable farmer, but partly because he has not yet been satified that the use of fertilizers and weed killers can be as profitable as they are for the arable crops. To increase fertilizer use has long been national policy in the United Kingdom, and fertilizers have been subsidised. Why people should need to be subsidised to turn a penny into a shilling I am at a loss to understand, but apparently they have to be; but it is gratifying that research work can influence Government policy. Sometimes it does so rapidly.

I have already mentioned the difficulty of growing wheat frequently on our land because of soil-borne pests and diseases, and the need for interposing other crops. It is no good telling the specialist cereal grower to grow potatoes or sugar beet, because he hasn't the labour to handle them. To introduce another crop, one must make sure that it is one that can be handled in the same kind of way and by the same machines. So for some years now we have had our eye on the bean crop, that is field beans, stick beans, horse beans, *Vicia faba*—I don't know what you call them here, where you almost certainly don't grow them anyway. This was a crop of great importance in Britain during the last century, but almost disappeared; many of the practical farmers who came and saw us experimenting with beans used to say this was Rothamsted carrying on the tradition of Lawes and Gilbert, but we said what was good for the 1870's might also be good for the 1970's. The main reason the crop went out was because of devastating attacks by an aphid. Before advocating the crop, this pest had to be controlled and this we showed could be done by a single, timely spray with a systemic insecticide. Further work on the crop has established its benefits as a break between wheat crops. At Rothamsted, we will get more wheat from two crops with one of beans between them, than from three successive wheat crops. Also, as the bean plants *fix* nitrogen, less nitrogen fertilizer is needed to get this amount of wheat, and the crop of protein-rich beans is another considerable bonus. Its value is already beginning to register with some of our farmers, but will no doubt now do so on many more, because this year the government is paying farmers £5 an acre to grow beans.

Agriculture is peculiar in that, unlike other industries, a discovery made in one place will not necessarily apply elsewhere. A factory process that is established somewhere will apply everywhere but agriculture is conducted with such diverse crops on such different types of soil and in such different climates that practices need to be tested locally. However successful central research stations may be, there is always a need for experimentation elsewhere. Of course, the basic principles for growing bountiful crops apply everywhere, but the details needed to ensure success differ from place to place. The basic principles can be expressed quite simply by stating that bountiful crops need freedom from hunger, and freedom from pests and disease. To grow, plants need to be supplied with water, radiant energy, carbon dioxide and various elements, some of which, like nitrogen, potassium and phosphorus, they need much more of than in the case of such others as manganese or boron, which are toxic if in excess. Indeed, nearly everything is harmful in excess, and it is as much the job of the research worker to make sure that growers don't use too much of anything—however necessary it may be—as it is to make sure he does not use too little. This is true of water, even in a country where drought is obviously the main limiting factor; the first thing in these circumstances is to supply plants with enough water, but they should not be given more than they need. It is often assumed that if a crop benefit from x inches of irrigation water, it will do twice as well when given 2x inches, but this is quite unfounded. The double amount may well undo a lot of good done by the single amount.

Another essential reason for local experiments is that manuring, spacing, the suitability of varieties, and time of planting, all differ in different places and climates. That there are enormous local differences is shown clearly enough by the differences between indigenous flora. Different plants vary not only in their ability to tolerate drought or acidity, but also in the amount of the individual elements they need and the range of temperatures in which they can survive and grow. It is these differences between the requirements of different plants that determine the natural flora. 1n conditions undisturbed by agriculture, plants get the twelve essential elements from the weathering of rocks, and these elements are continually recycled through the plants, returning to the soil when leaves fall or plants are eaten by animals, the elements being excreted in the dung. In such conditions, nutrient elements brought up by the roots from deep in the soil enrich the top soil, so virgin land usually gives a reasonable crop when first used for agriculture. In many parts of Africa, there has been a tendency to farm simply by trying to conserve the original fertility, but even this level of fertility is usually much less than is needed to give good yields of crops.

It is important to remember that agriculture is not a natural activity. Politicians, particularly Ministers of Agriculture, often like to speak of agriculture being a natural occupation, but by this they mean only that it takes people out in the open air, and to that extent is less artificial than working in a factory. But nature never produces a stand of any arable crop. None of you gentlemen have ever seen a natural field of sugarcane, and I have never seen one of wheat. A part of Broadbalk field provides a salutary demonstration to those who like to talk of agriculture as a natural occupation. One wet autumn, when the harvest was difficult, and after wheat had been grown on the land for more than forty years. Sir John Lawes, going over the field when five-sixths of it had been reaped, told the men to stop, and leave the other sixth to see what would happen. He is quoted as having said to the wheat, "for more than forty years you have been carefully tended, now let's see how long you can fend for yourself". The last wheat plant was found there only three years later, though the wheat was left to seed, and the land is now perhaps the only natural piece of woodland in the whole of Hertfordshire.

The point I am trying to make from this is that agriculture introduces a wholly new element into an area, and requires different treatment from the indigenous plants. The idea that virgin soils are right for arable crops and simply need maintaining in their initial state of fertility, is wholly misguided. In particular, crops need more nitrogen than wild plants if they are to yield bountifully, and by fertilizer use it is possible, not simply to maintain soil fertility but to enhance it and to provide individual crops with nutrients in accordance with their need. The idea of farming to conserve fertility has, in fact, led to the loss of fertility over vast areas of the world. The store of nutrients in virgin top soil which has been built up under indigenous flora is soon exhausted, in most cases probably less by what the crops actually remove, than by leaching, soil erosion and run-off. This exploitive kind of agriculture, carried out over vast areas of land, fully justifies the forester's condemnation, when he complains that agriculturists cut down wealth to sow poverty. Where crops are grown, let us grow them well, accepting that it is as artificial as the making of motor cars or detergents, and let us get what we would expect from a factory, which is the maximum production from the minimum area. To do this means making the best use of our water supplies, of our fertilizers and of our pesticides, which in turn means applying them intensively and not extensively.

Fertilizers free agriculture from the limintations imposed by the natural compositions of soils. They allow any deficiences to be made good and the fertilizer mixture to be adapted to suit the particular crop or the particular soil type. But to do this requires knowledge, not only of the general principles of crop nutrition but of local conditions. Local experimentation is essential to discover what factors are limiting yields. It also needs continuing, because a research result should not be expected to hold indefinitely. For example, on land where, initially, experiments show, say, that nitrogen gives a big response but phosphorus and potash do not, the situation needs repeated examination; for as soon as bigger crops are removed because of the extra nitrogen applied, the previous status of the soil will be changed and before long, yields may be limited by a shortage of potash, phosphorus or some other element. Research is a continuing business, because every time a research result is applied in practice, the conditions of the crop are changed. Even changes from furrow irrigation to overhead irrigation may change your pest and disease problems considerably. Thus any change in practice, itself becomes a subject for further research, Only in this way, by adding success to success, can research continue to be fully productive. Only when in fact its results are applied can it be fully useful.

When considering what to say today, I re-read my talk to the International Sugarcane Technologists' Conference in Mauritius, and I decided that I couldn't improve upon my final remarks there with your forbearance, my I conclude by quoting the last two paragraphs.

"Research, or rather the translation of research results into practice, sometimes has unwelcome consequences, for increased production can glut markets and depress prices. I shall conclude my remarks with a few comments on the sad fact that growers often do better financially in years of scarcity than in years of glut—although I realize I am probably being unwise to do so, for I am no economist and know that attempting to foresee the future is a hazardous occupation. I would like first to stress that, in my opinion, those working on the growth of crops should not be the slightest bit deterred in their efforts to increase production by the fact that their success may prove politically or economically embarrassing. Markets are sometimes glutted, but this is a different thing from over-production. There never has been too much of any of the staple foods; what there has always been is very many people so poor that they cannot buy what they need, let alone as much as they would like. The great majority of these people, let us remember, are engaged in or dependent on agriculture of one kind or another. Their needs and wants will not be met except by increasing yields, which will work in two ways by raising their incomes and lowering the prices of what they buy. Satisfying the needs and wants of these people would abolish talK ot over-production and is likely to replace it with talk of scarcity. But even if markets do not expand, there is still no salvation in seeking higher prices by restricting yields. IF PRODUCTION NEEDS RESTRICTING, THEN LET RESTRICTIONS BE ON ACREAGE, NOT ON YIELDS. Agriculture has been profligate in its demands on land and the practice of increasing production by increasing the area under a crop is one that cannot go on much longer. Nor should it, for it not only perpetuates low standards of living, but it threatens to destroy unnecessarily the rich indigenous flora and fauna of many parts of the world.

Short of a catastrophe, such as a world war with nuclear armaments, the human population seems almost certain to double by the end of the century. If standards of living are also to rise, agricultural production must more than double by then. This increase must be sought by raising yields and not by increasing acreage, which means agriculture must become intensive and efficient. Finding the necessary knowledge is obviously the prime role of research. Past experience suggests there is no need to doubt that the knowledge can be gained, although it also suggests that it will not be gained unless research is increased and intensified. But getting the knowledge will not alone ensure that production is doubled, and this returns me to my starting point. Research can benefit an industry only when the industry is willing and able to apply its results. Much existing knowledge now goes unapplied, and there is little purpose to be served from increasing the rate of discoveries unless the discoveries get put into practice. How best to get knowledge applied in different stages of agricultural development is perhaps itself a subject that deserves research, and might well prove highly rewarding. Certainly, with the future needs to increase production, the research worker must not rest content with the intellectual satisfaction of having solved a problem in crop production. He has the responsibility to see that the possible practical benefits from his work are amply demonstrated to those who are immediately responsible for deciding agricultural policies. *Practice with Science* is the motto of the Royal Agricultural Society of England and aptly summarizes what should be the goal of research in developing agriculture.'

Mr. President, ladies and gentlemen, it gives me very great pleasure to declare this, the Forty-first Annual Congress of the South African Sugar Technologists' Association, open.

Mr. J. Wilson, in reply to Sir Frederick Bawden's opening address:

Mr. President, Sir Frederick, Lady Bawden, Ladies and Gentlemen.

It is once again my happy privilege to thank our guest speaker on your behalf for opening our Association's annual congress.

Each year, some six months or more in advance of the proposed congress date, your Council prepares a short-list of potential victims who are to be approached, in order of merit, to undertake the onerous task of delivering the opening address to our congress. It is then the task of the President, assisted by the Secretary, to pin down the least reluctant of the victims, however unwilling he may be, and place him on the rostrum on the due date and at the due time. To the best of my knowledge our previous victims, among whom we have numbered many eminent men of science and industry, have been drawn from organizations, institutions or government departments within South Africa having at least a degree of association with our industry.

You, sir, other than being an eminent man of science, fall into none of these categories. You are from England, not South Africa, and have no connections at all with our industry. Furthermore, far from being a reluctant victim, you accepted the Council's invitation to deliver this opening address with alacrity and, unlike many, you have obviously enjoyed the occasion. Ladies and gentlemen, your Council's choice for its first venture into bringing distinguished guest speakers from overseas has clearly been a happy one and, judging by the ovation you have just accorded Sr Frederick, a most popular one. In fact, this year your Council was on pretty safe ground for there will be many present to-day who will well recall Sir Frederick's memorable opening address at the 11th Congress of the International Society of Sugar Cane Technologists held in Mauritius in 1962, which set the seal on the success of that congress at its very outset. I am sure that he has done the same for our congress to-day.

The value of research, particularly agricultural research, is an oft-debated subject and none more so than in South Africa, but in so far as your own country is concerned, sir, you have illustrated with admirable clarity some of the tremendous benefits which can accrue to a farming community from the intelligent application of the findings of research. It would seem that you have even convinced Her Majesty Queen Elizabeth II on this score, for she has recently conferred a knighthood on you while awarding only the M.B.E. to those whom we here, at least, have been led to believe are England's foremost money spinners—the Beatles!

Be that as it may be, we, as technologists, are confident that like benefits can accrue to our own industry from the efforts of our various research organizations.

It has been a great pleasure to have you and your gracious wife with us for the past week and I trust that you both will enjoy to the full the rest of your stay in South Africa.

It affords me great pleasure to propose on behalf of all present a most sincere vote of thanks to you for so ably opening our Congress.

Sir Frederick Bawden, Ladies and Gentlemen, the theme of my address to you today is "Efficiency". I sincerely hope that this choice of subject will not be misconstrued to give the impression that our industry is basically inefficient. Far from it, as I, for one, believe that in many aspects of cane production and sugar manufacture we lead the world. My chief desire is to put forward certain points of view, to give food for thought and encouragement to those of us who are keenly desirous of keeping production costs low, while, at the same time, improving the quality of our product.

When I first made the choice of subject, I had in mind a few points on the cultivaton of cane, the extraction of sucrose and the processing of raw and refined sugar, but, when I commenced writing, I began to realise the enormity and complexity of our industry. The subject grew and grew until I found it stretched from the Chairman of the Board of a Company to the housewife stirring sugar in her cup of tea or the little boy eating his sucker.

The ramifications of our industry now are so wide and diversified that it has become impossible to expect the individual to have full knowledge of the whole. We find, therefore, a greater degree of specialisation than ever before and, for this reason, I have had to lean heavily on my fellow technologists, particularly Council members, for assistance in the preparation of this address. My thanks go to all who have aided me.

What is efficiency? The meaning of the word varies with almost every industry, with each calling, in different spheres. The agronomist, the chemist, the engineer and the accountant all have various approaches and ideas on efficiency, yet in our industry a clear understanding, a perfect blending and co-operation of each and every facet is vital to success. A high target must be set and the individuals making up the whole must be capable of the tasks confronting them—only when this is accomplished can it be said that "efficiency" is achieved. It means there must be respect for one another's status, knowledge and ability. No one section can be superior to another. All must work together enthusiastically as a team, convinced of what is to be accomplished, and this is where the organising ability and ingenuity of management must give the lead.

Today management is a profession all of its own and, apart from certain basic principles, it must be geared to its own particular industry and even further, to certain specific spheres of that industry. This planning must inevitably involve personnel. Scientific business administration, computerisation and technological knowledge are developing so rapidly that extensive training programmes become a necessity.

Human relations is also a most important aspect in improved efficiency and one which often does not receive the attention it should. This applies to all fields of endeavour, in commerce, industry, agriculture and, if I may say so, even in our homes. It stretches from the top of the ladder to the bottom rung. It is our very existence as all human beings are happier when they are regarded as individuals with human hopes and aspirations and not just as "a commodity" under the heading of "labour" on a cost sneet. As you all know, the most efficient worker is the contented one both at work and in his home. Unfortunately, it is not always possible to keep everyone happy. To achieve this would be to create Utopia. It should, however, be the aim to have happy and contented workers, who would automatically possess a high morale. When morale is high, productivity and hence profitability increases. There is pride in work, devotion to duty and loyalty to the employer. There will also be willing co-operation to achieve a purpose desired by all and a contentment in the accomplishing of a given task. This emphasises the importance of job selection and underlines the value of the Personnel Department.

Though the production of cane in South Africa in relation to conditions in other parts of the world can be considered difficult, we are most fortunate in having at our disposal one of the finest Agricultural Experimental Stations in the world, to assist us in dealing with our problems and so improve our efficiency. It is manned by a first-class staff in all spheres and has the resources and equipment to assist it.

In any breeding, whether it be animal or vegetable, the original stock is of the foremost consideration. So, with our cane, seed selection is of paramount importance, and here I feel that every attention must be paid to the establishing of seed beds, so that propagation continues at the highest level. The correct choice of variety can mean a great deal. We have a wide range of varieties to choose from and we have produced varieties here in South Africa which are now world famed and our breeding techniques are quite renowned.

Soil type is a further important aspect and I doubt whether a more conclusive survey than ours has ever been undertaken anywhere. This is a most important aspect, even if only from the physical angle, for it determines the carrying ability of the soil for irrigation purposes and its ability and capacity for retaining moisture. Moisture content, as you know, is one of the governing factors in the uptake of available nutrient in any plant.

I think I can say we have practically attained the stage of near perfection in our fertilizer advisory services. Soil analysis and advice on the use of fertilizer, the quantity and type, is readily available, free of charge. The ultimate result can only be an improved stand of cane, established at a lower cost because fertilizer is applied to the best advantage. Wastage of an expensive commodity is therefore avoided.

Irrigation has been practised in the cane belt the early 1930's and the efficiency of water use has improved progressively since then. However, there still remains room for additional improvements which are particularly important in a country such as ours where water is so often in short supply. Today about 12 per cent of the land under sugarcane in the Republic is irrigated.

Looking to the future and bearing in mind the disastrous consequences of the drought which hit not only our industry, but almost the whole of South Africa, there is a crying need for water conservation. There are many rivers along the eastern seaboard which flow unhindered into the sea, carrying with them millions upon millions of gallons of precious water. Those rivers, unfortunately, also carry with them millions of tons of valuable top soil.

There is no doubt in my mind that, in a country such as South Africa, insufficient attention is given by the State to this problem of water conservation. Farmers do play their part in the establishment of dams, but the biggest potential lies in State schemes, particularly in our Bantu homelands, through which most of our rivers flow on their way from the mountains to the sea.

Progress so far in improving irrigation within the cane belt has mainly been due to the introduction of overhead sprays as a substitute for, or in preference to, furrow irrigation. Many of our soils are either shallow or very sandy, which could lead to the inefficient use of water when applied by way of furrow irrigation. In addition, the steepness of our hillsides in some parts of the industry is also not conducive to efficient furrow application of water. These factors have led to the great predominance of overhead spray irrigation in our industry.

The rate at which many of our soils can absorb water tends to be rather slow, and the industry has been quick to recognize the advantage which small sprinklers have to offer under these conditions. Surface run-off in many instances was excessive where "big guns" were used to spray water at a high rate on a large area at a time. Our farmers and estates have adapted themselves successfully to the requirements for using numerous sprinklers, applying water at a slow rate over a protracted period of time.

The water requirements of sugarcane fields may vary a great deal from month to month. The results of experiments conducted in the industry have shown that fully canopied sugarcane uses about 0.24 inches of water per day in January and only about 0.09 inches per day in June. The evaporation of water from a bare soil is much greater than that from a trash-covered soil. A field of partially canopied cane normally requires less water than a field of fully canopied cane. All these factors contribute to making scientific control of irrigation the most important factor in the effiecient use of water.

It should be obvious that, with the country's population growth, accelerating development rate, coupled with wage-labour problems, our industry, like industries in other parts of the world, is being forced to resort to mechanisation as far as possible in all the stages of cane production and handling.

That this is in fact happening at the present time is evident by the large numbers of tractors, self-loading transport equipment and transhipment cranes which have been used during the past few years. While this has resulted in the out-of-field manual handling of cane being almost entirely eliminated, the present economic and labour positions are such that major steps forward must occur in the fields of planting, cultivation and in-field loading if South Africa is to keep pace with the times. It is now known that the efficient use of such equipment on all but the very steep terrain will result in a reduction of at least 50 per cent of the harvesting labour and up to 40 per cent of the total field labour force requirements on the average cane farm.

Field trials with such equipment conducted by the industry's Field Mechanisation and Labour Saving Committee do indicate, however, that there are three major factors influencing the degree of value these forms of mechanisation will be to us.

The first is the efficient use of the capital required for the purchase of the variety of equipment and machines involved. Ownership and operating cost studies of in-field cane loaders, for example, show that even with the simplest and least expensive production-made machine, the optimum economic efficiency is only reached at an annual output of about 7,000 tons, while the more expensive and complex, high-capacity machines require a minimum output of 17,000 tons.

The second factor influencing the value of mechanisation is the technical know-how, management skills and efficiency of the grower or field management. The introduction of machines necessitates an industrial engineering approach being made to cane growing in that definite standards of field planning and organisation, machine control, operation and output must be determined and insisted upon.

The third factor concerns the labour expected to do the job. Existing methods of selection, training and supervision may have to be changed. Often the quality and efficiency of our labour is justly criticised, but experience both in the sugar industry and elsewhere has shown that with correct selection, training and supervision, the efficiency of hand labour and machine operators can be raised to a point where it will compete with labour working on cane estates anywhere in the world.

I am sure that most cane growers and miller-cum-planters are fully aware of these basic principles affecting the efficiency of their operations.

Turning now to factory performances, the average time efficiency of all our factories this past season has been 88 per cent. The 12 per cent deficiency, while disappointing to many, does have its good points, as it is valuable to the engineer in enabling him to effect repairs and thus reduce mechanical and electrical defects and so improve the overall mechanical time efficiency. It also aids the process side to liquidate stocks so that an increased throughput can be pursued. Summing this up, it reveals that a factory's performance is rather erroneously portrayed by the tons of cane milled per hour. A more realistic figure is the total cane milled and the sugar produced over a period of a week at least.

Plant efficiency has been considerably increased by employing "Planned Maintenance". No longer need the engineer tax his memory with the past history of dozens of bits and pieces of equipment, viz. when was it last overhauled, when is the next one due? The planning office notifies, with ample warning, the conditions of all items of machinery.

Judging by the amount of extraneous fuel being purchased by some of our factories, it appears that there is room for improving the thermal efficiency. A careful study of the use of live and exhaust steam, the correct generation and utilisation of vapour from evaporators and condensates, higher density syrups and molasses, lower moistures in bagasse, proper insulation—all contribute towards steam economy and improved efficiency.

Standardisation is another avenue where efficiency can be furthered, with effect on economy, time-saving and store accountancy. Items such piping, gear-boxes, chains and electrical motors, contactors, switch-gear and light fittings come to mind as examples in this respect.

In almost every industry, the quality of the raw material is the first consideration. As already mentioned, in cane cultivation good seed and soil preparation is the start of a good crop. So in the raw sugar factory, clean freshly harvested cane is a prime factor. This calls for no extraneous matter such as tops, trash, roots or soil and in general, a high sucrose and purity content. The same pattern goes for the refinery. The quality of the raw sugar is the most important factor in a high retention figure and throughput rate.

To maintain maximum efficiency at all times, there must be complete staff co-operation, calling for maximum team spirit between laboratory, process and engineering personnel. Without these, irregularities such as mechanical stoppages, faults, etc., can take much longer to rectify and become expensive in loss of efficiency.

The role of the laboratory is constantly assuming a more important part of processing. An accurate and complete balance sheet of not only sucrose, but non-sugars and dissolved solids is regularly desirable. All losses are determined, their source located and finally prevented and the engineer must expect guidance on mill performance, boiler water treatment, etc. The process calls for numerous factory control data, and now that diffusion is coming into reality, it seems that sucrose extraction from the cane will devolve more responsibility on the laboratory.

I feel we are fast approaching a revolution in the industry, with more and more emphasis on efficiency and quality, whereby the laboratory will eventually assume control of the process from the cane to the sugar in the bag. The era of the chemical engineer is at hand; he must have a knowledge of accountancy with emphasis on costs and works, and this could well be the qualification desirable in the future factory manager.

The efficiency of our sugar production today has become more of a scientific problem where hundreds of different measurements are required and correlated to give the management an overall "picture" of the process control, from the early seed cultivation right through to the end product.

The increasing use of instrumentation has therefore become a major factor in assisting to continually improve and ensure consistent efficiency of production.

The "human error", where the old rule of thumb and approximations were evident, is now being supplanted by complex automatic control loops, multipoint recorders, and so on. Examples of this are the automatic control devices regulating the speed of the cane carriers as a function of the load on knives, the control of bagasse feeding to the boilers by a series of instrumented panels, fitted with steam-flow recording, temperature indication, level alarms, air/fuel ratios, all continuously monitored and controlled by damper actuators, receiving a signal charge as low as 0.25 p.s.i.g.

Improved processing during the liming stages is now effected by automatic density and P.H. control, also heat regulation through juice heater complexes to the evaporators and vacuum pans, where recent improvements in vacuum control, liquor feed and steam heating and finally Brix control, can be maintained within the tolerances laid down by process management. All this results in a better end product produced in the shortest possible time within the cost structure of an undertaking of this kind.

One could continue on this theme for hours. The message I have tried to convey to you this morning is that, despite the tremendous strides that have been made in all aspects of our agricultural and industrial undertaking, there is no room for complacency or apathy. As the world moves into the nuclear age, so must we too advance. It is a tremendous challenge but one which I know our technologists are capable of meeting. Let "Efficiency" be their watchword.

Dr. T. G. Cleasby, in reply to the President's address:

Mr. President, Sir Frederick, Ladies and Gentlemen,

In thanking you, Mr. President, for your excellent address to us to-day, I would like to say that your subject, although dealing with the importance of efficiency in our industry, has been a record of its technical achievements over many years. I believe emphatically that by any standards we are a technically efficient industry and although we must never be complacent, there are many achievements of which we can be justly proud.

It is appropriate that you should have referred to some of the industry's achievements in the presence of our distinguished guest, Sir Frederick Bawden, who has kindly travelled a long way to open our conference. May I also say—perhaps as an aside—that it is appropriate to have referred to these achievements in view of some of the comments and letters which have appeared in the local press in recent weeks relating to this very subject. As one who recently has been concerned with the industry's submission to Government Commissions of Enquiry on agricultural and water resources, I am firmly convinced that we should make our achievements more widely known and do more to keep them in the public's eye.

You have been very kind, Mr. President, in letting me mention a recent achievement which I feel is a most important one. I can only think that you have allowed me to do so because it quite often happens in our industry that the agriculturist likes thinking of himself as an expert in the factory, and the factory man enjoys telling the agriculturist just what he ought to do.

Some three years ago a past President of our Association referred in his presidential address to sugar quality and the need for South Africa to produce the world's best raw sugar. Two years ago the Council of our Association submitted a memorandum, based on known facts, to the Chairman of the South African Sugar Association on the same subject and said, amongst other things, that if the industry wanted to improve the quality of its raw sugar in the short term, then this would have to come through a modification of the manufacturing process. In this connection the recent work of Mr. Rabe at the Umzimkulu factory is a major breakthrough in improving sugar quality, and as technologists we must acknowledge it as an outstanding achievement, and give great credit to the work that has been done. There will naturally be modifications and developments of the Rabe process, and some of them will no doubt be discussed at our congress during the coming week. We must not, however, forget the fact that the Rabe process has been the inspiration giving rise to new thinking, which will do a lot to take us nearer our goal of producing, economically, the world's best raw sugar. It is most encouraging and typical of our industry that all factories have agreed to install and operate the Rabe process in order to improve raw sugar quality still further.

Mr. President, thank you again for your address to us this morning, and also for all the time you have given up, and for the sterling work you have done for our Association during your first year in office.

FORTY-SECOND ANNUAL SUMMARY OF LABORATORY REPORTS

OF SUGAR FACTORIES IN SOUTHERN AFRICA FOR THE SEASON 1966/67

by CHARLES G. M. PERK
Sugar Milling Research Institute

N.B.—All data in this Summary are as declared by the Mills in their laboratory Reports.

A. THE SOUTH AFRICAN CANE CROP OF THE 1966/1967 SEASON

We quote from the Experiment Station's Weather Reports:

"January, 1966, provided optimum growing conditions which followed into mid February. From this stage onwards, however, the soils became increasingly drier and the Industry suffered a short but severe drought. Good rains fell over most of the sugar belt during May. Thus by May 31st 1966, the cane fields (with the exception of those in Northern Zululand) were quite moist, and the crops were green and healthy.

By the end of July, conditions were very dry and good soaking rains would have been extremely welcome throughout the area. Much of the cane in the Natal midlands had been adversely affected by both drought and frost. The eastern part of the midlands was not as badly frosted as the western area. Severe frost damage at Melmoth had been confined mainly to the low-lying valleys. At Pongola frost damage had been negligible.

By the end of October, 1966, the cane belt was still dry. During the month of November 3.61 inches fell compared with a mean of 4.31 inches for this month. The average rainfall for December was 3.66 inches, exactly one inch below the mean for December. Taken over the year 1966, the sugar belt received a mean rainfall of 29.98 inches, compared with an average of 38.23 inches during the past 42 years."

After reading this account of the weather conditions, one would not expect a record sugar output for the 1966/67 season. However, owing to the extension of existing areas and the opening of new cane lands in the Natal midlands and the lower South Coast a record cane crop was harvested resulting in a sugar output of ±1.8 million tons.

Tons of 2,000 lbs Season	Tons Sugar	Tons Cane	Cane/Sugar Ratio
1962/63 . . .	1,193,279	10,731,263	9.01
1963/64 .	1,264,704	10,970,338	8.66
1964/65 . . .	1,395,446	11,752,031	8.42
1965/66 . . ,	1,001,784	9,266,324	9.21
1966/67	1,794,423	15,545,625	8.66

Tons of 1,000 kg Season	Tons Sugar	Tons Cane	Cane/Sugar Ratio
1962/63 . . .	1,082,525	9,751,707	9.01
1963/64 . . .	1,147,321	9,939,529	8.66
1964/65 . . .	1,265,921	10,661,207	8.42
1965/66 . . .	908,803	8,406,269	9.21
1966/67 . . .	1,627,869	14,102,756	8.66

N.B.—The sugar productions as shown in the above two tables as well as those in Table I (at the end of the text of this Summary) are the official tonnages as supplied by the S.A, Sugar Association. In all other tables in this Summary the sugar productions are as stated in the factories' laboratory reports. There is a material difference between the latter and the official production figures because neither Gledhow nor Sezela record on their laboratory reports the sugar actually made, but only the weights of sugar transferred from one department to another department of their Mills.

The average yearly sugar production for the decade 1941/1950 was 557,000 tons; in the following decade the average production rose to 867,000 tons, while for the period 1961/1966 the average seasonal figure is 1,291,000 tons tel quel. These figures show clearly the expansion of the South African Sugar Industry 1949.

With regard to the ripening process of the cane, in the following table the trend of the past crop is compared with a ten year average:

COMPARISON OF SUCROSE % CANE BY MONTH

Month	This Season's average	Ten year average
May	12.91	12. 35
June	13.45	13. 00
July	14.13	13. 57
August .	14.28	14. 20
September	14.45	14, [illegible]
October.	14.34	14. 21
November	14.06	64
December	13.48	13, 11
January	13.16	12. 59
February	11.84	12. 35
March	11.97 .	N.A.

The comparison reveals that the increase and decrease of the sucrose content of the past season's cane is similar to the general trend as indicated by the 10-year average.

We want, however, to draw attention to the fact that it is better not to compare the first months or the last months of any season with those of other seasons because the same cane areas may not be involved, particularly as it was most unusual that certain of the mills that were still crushing in February should be operating so late.

COMPARISON OF THE RESULTS OF THE OPTIMUM PERIODS

N.B.—Results of seasons before 1961 can be found in the 36th Annual Summary (1960/1961 Season), where a review is given of all results from 1928 to 1960, inclusive.

	% of Crop	Percent Cane		Cane to Sugar Ratio	Purity of Mixed Juice
		Sucrose	Fibre		
Season 1961/62					
Optimum Period .	69	14.11	14.46	8.23	86.69
Balance of Crop .	31	12.98	14.63	9.18	84.52
Total Crop . .	100	13.75	14.52	8.51	86.04
Season 1962/63					
Optimum Period .	56	13.77	15.32	8.58	83.51
Balance of Crop .	44	12.65	15.73	9.63	83.15
Total Crop . .	100	13.30	15.50	8.96	83.36
Season 1963/64					
Optimum Period .	59	13.91	15.38	8.36	86.09
Balance of Crop .	41	13.02	15.66	9.06	84.10
Total Crop . .	100	13.55	15.50	8.63	85.30
Season 1964/65					
Optimum Period .	60	14.41	15.20	8.06	86.01
Balance of Crop .	40	13.17	15.62	9.01	84.74
Total Crop . .	100	13.90	15.38	8.38	85.52
Season 1965/66					
Optimum Period .	67	13.10	15.44	9.06	84.53
Balance of Crop .	33	12.76	15.83	9.50	83.50
Total Crop . .	100	12.99	15.57	9.20	84.22
Season 1966/67					
Optimum Period .	55	14.14	14.76	8.33	85.65
Balance of Crop .	45	13.20	15.50	9.02	84.29
Total Crop . .	100	13.72	15.09	8.63	85.06

MB.—Please note that all data are based on the tonnages of sugar as declared in the Laboratory Reports. This is the reason why the cane/sugar ratios do not always tally with those based on the Official Sugar Tonnages.

The highest sucrose content for the Optimum Period, i.e. 14.45%, was obtained in the 1955/56 season. In the Optimum Periods of 1960/61 and 1961/62 the sucrose content was 14.11% and in the 1964/65 season it was as high as 14.41%, a near approach to the 1955/56 record. This year's sucrose content is just the average of the six years period shown in the table.

In addition we draw attention to the variations in the percentages of cane crushed in the Optimum Periods. The "highest ever" was recorded in the period 1928-34 when an average 76% of the cane crop was harvested in the Optimum Periods. A percentage as low as 56% was recorded in 1962/63. This season's 55 per cent is just as unsatisfactory for grower and mill engineers as in 1962/63.

VARIETAL CHANGES

The cane varieties planted by the two Midland factories brought new life to the old variety Co.331 and a boost to the percentage of N:Co.293. The South and the North Coast Mills caused the average percentage of N:Co.376 to increase further. The increase in percentages of these three varieties i.e. N:Co.293, N:Co.382 and N:Co.376 decreased the average percentage of N:Co.310 as the following table reveals:

Season	1962/63	1963/64	1964/65	1965/66	1966/67
Co.331 . .	8.89	6.32	4.41	2.70	1.83
N:Co.310 .	54.00	50.75	46.91	40.15	33.63
N:Co.292 .	2.28	2.03	1.32	0.89	0.41
N:Co.293 .	4.62	4.93	3.72	4.51	5.98
N:Co.339 .	3.67	3.23	2.57	1.76	0.97
N:Co.376 .	18.04	21.45	23.36	32.19	36.45
N:Co.382 .	1.92	1.81	2.87	3.35	4.89
N:20/211 .	0.22	1.23	2.84	3.52	3.56

The stronghold of N:Co.310 is in Zululand, especially at Pongola and Amatikulu, where 90 % of all cane crushed is still N:Co.310. Felixton crushed more N:Co.376 than N:Co.310 and in addition about 10% N:Co.382, while Entumeni's main varieties were N:Co.293 and N:Co.376.

The highest percentages of N:Co.376 were crushed by Renishaw, Sezela and Umzimkulu, respectively, 78%, 76% and 80%.

Jaagbaan and Union Co-op crushed the highest percentages N:Co.293, respectively 56% and 53%. They crushed also the highest percentages of Co.331, respectively 14% and 16%.

With regard to the Rhodesian Mill Triangle and the two Mocambique factories Luabo and Marromeu, their variety menu can best be compared with that of Felixton i.e. approximately the same percentage N:Co.310 as N:Co.376. Triangle has in addition 15% of Co.331.

TIME ACCOUNTS AND CRUSHING RATES OF SOUTH AFRICAN SUGAR MILLS

The starting sequence of the Mills was as follows: 13th April AK; 14th April EM; 27th April TS; 28th April FX and DL; 29th April UF and IL; 4th May GD; 7th May GH and MV; 10th May PG and JB; 11th May ME; 16th May DK; 24th May RN; 25th June UK; 26th June SZ; 21st July EN and finally on the 1st of August UC.

The sequence in which the Mills completed their crushing season was as follows: 10th December PG; 20th January MV; 28th January UC; 1st February UF; 5th February DK; 12th February TS; 18th

February FX; 20th February AK; 21st February EM; 26th February GD, DL and JB; 27th February RN; 1st March GH, ME and UK; 4th March SZ; 15th March EN and 19th March IL.

Season	1964/65	1965/66	1966/67
Total Tons Cane Crushed	11,752,031	9,266,324	15,545,625
Total Crushing Hours.	85,266	67,090	95,229
Mean Crushing Rate .	138 tch	138 tch	163 tch
No. of Mills Crushing.	17	17	19
Average of Days Crushing . . .	209 days	164 days	209 days
Total Hours Mills open	92,457	76,751	109,216
Average Length of Season	37¾ weeks	31⅜ weeks	40 weeks
Mean Time Efficiency.	92%	87½%	87%
Hours of Stoppage due to Cane in short supply in % of Hours Mills Open . . .	3½%	6%	5%

Because of the ever increasing total tonnage of cane being crushed, we are of course interested in knowing if the crushing rates of the Mills have kept pace with this increase.. In the following table, the total tons of cane crushed in the 1950/51 season has been taken as 100% and the same holds for the sum of the average crushing rates of the Mills in that season:

Cane crushed in 1950/51: 5.71m tons =100%

Sum of Crushing Rates: 1,300 t.c.h. = 100%

Season	Total Tons Cane Crushed	Sum of Crushing Rates
1950/51 . . .	100.0%	100.0%
1951/52 . . .	84.2%	99.6%
1952/53 . . .	100.1%	102.9%
1953/54 . . .	108.8%	104.9%
1954/55 . . .	128.8%	117.6%
1955/56 . . .	139.6%	128.1%
1956/57 . . .	131.8%	130.2%
1957/58 . . .	150.0%	135.8%
1958/59 . . .	179.6%	143.7%
1959/60 . . .	159.8%	144.8%
1960/61 . . .	151.5%	150.9%
1961/62 . . .	164.4%	156.4%
1962/63 . . .	187.9%	149.6%
1963/64 . . .	192.1%	165.1%
1964/65 . . .	205.8%	171.4%
1965/66 . . .	162.3%	185.7%
1966/67 . . .	272.3%	227.2%
1967/68 . . .	Estimated at: 240%	

GENERAL IMPRESSION OF THE SOUTH AFRICAN CRUSHING SEASON 1966/1967

In one respect the past season was better than the previous one, i.e. the total sugar output was *not* disappointing.

As in the previous season a number of Mills started too late, because construction or re-construction work was not completed on time. (See the sequence of starting dates.) In addition one of the new Mills had .more than its fair share of the teething troubles which are to be expected in a first season.

Three Mills had to cope with the difficulties arising from crushing drought and frost-stricken canes. In some instances the growing points of newly planted cane was killed by frost and this immature and very short cane had also to be crushed. In all three cases the Mills had to slow down for full house as the back-end of the factory could not cope with the increase in volume and stickiness of the final massecuites.

Other factories reported crushing consignments of cane with abnormally low juice purities as a result of the drought.

C-Massecuite Heat Exchangers: The abnormal quantities of C-strikes with their high degree of viscosity brought to the fore in some instances the inadequate heating systems for C-massecuites. In such cases the C-m.c. either had to be dropped at too high a purity and/or the massecuite had to be diluted with water in the crystallisers, both cases resulting in a too high final molasses purity.

Air Conditioning

Even the most efficient heating system cannot prevent the molasses film cooling down and drying out during the spinning process resulting in a highly increased viscosity of the molasses film around the crystals of the C-sugar. The only way to prevent this phenomenon is by blowing into the basket air with a R.H. of 100% and of the same temperature as the massecuite. By preventing the molasses film drying out and cooling down a greater part of the molasses film will be removed and the result will be a single-cured C-sugar as good as and sometimes better than a double-cured C-sugar.

NEWLY INTRODUCED FEATURES

(a) The Rabe Process:

Though this process, invented and developed by Mr. A. E. Rabe, factory manager of the Umzimkulu Mill, has been running at this Mill for two seasons it can now be mentioned as during the past season the process was made public. The features of the Rabe Process will not be discussed as we may assume that they are known to us all, but we should like to congratulate Mr. Rabe on the success 'his' sugars have had when sent to refiners in different parts of the world. Not only were all refiners satisfied with the quality, but one of them even said that it was the best refining sugar he had handled for a very long time!

(b) Milling-cum-Diffusion:

Attention this season was focused on the two newly installed diffusion plants and the results they would achieve. Both diffusers started up without a hitch and any difficulties encountered at Entumeni as well as at Dalton were not in the diffusion part of the installations, but with the mills and their carriers..

As a diffuser designed for the combined process of milling and diffusion has about half the number of circulation compartments of a diffuser intended for cane diffusion, the overall result is strongly correlated to the effectiveness of the milling section of the combined process, in particular to the performance of the mill preceding the diffuser proper.

In the coming season, i.e. 1967/68, two more milling-cum-diffusion plants will come into operation, viz. one at EM where it will replace part of the existing milling tandem and the other at Malelane in the Eastern Transvaal as part of the new factory plant.

(c) Starch Removal.

In addition to the Rabe process and the enzymatic starch removal, it appears that the diffusion process also removes starch provided the temperature is not raised above 70°C. It was also found during the past season that cane stricken by frost contained less starch; it is assumed that the starch is broken down by the plant into glucose.

(d) Further Development of the Rabe Process.

It should be mentioned here that tests carried out by Van Hengel at Darnall revealed that when the underflow of the Rabe vacuum tank was led directly to the evaporator without further clarification, a heavy scaling occurred in the first vessels of the evaporator. The same had been experienced at Umzimkulu, but here the capacity of the first vessel was such that it was *not* necessary to stop for cleaning in the middle of the week.

To reduce the rapid scaling the underflow of Darnall's vacuum tank was heated to 103°C. and settled in an ordinary clarifier. Here the greater part of the calcium triphosphate and proteins present in the underflow was removed and scaling brought down to normal proportions.

A combination of two starch removing procedures will come into operation in the middle of the 1967/68 season at Empangeni Mill, where starch will be removed from the primary juice by the Rabe flotation process, while the starch content of the secondary juice will be reduced during passage through the dif-
1 Llovl •

B. OPERATION OF THE MILLING TANDEMS:

Why does the S.M.R.I. prefer to indicate the milling results in the form of lost absolute juice % fibre in final bagasse' ? The reason for this was explained as far back as 1951 in the Communication of the S.M.R.I. No. 7 entitled *A Review of Terms Used for Indicating Milling Results.* Here it was explained that the only operation a mill can do is to *squeeze out a certain volume of liquid,* irrespective of whether the liquid contains sucrose, another substance or nothing at all. The term we are to use for indicating what the mill or mills are doing should, therefore, be based on 'squeezing out liquid[5] and as it means a separation of liquid from fibre, it should be expressed 'per 100 fibre'. However, looking only at how much is gained will give a misplaced feeling of satisfaction, and therefore we should always look at the portion which is still lost.

Lohmann (Java Archief 1904; p. 969) was the first to recognise these facts when he introduced as a yardstick for mill performance 'Lost Normal Juice % Fibre in Final Bagasse'. From this term 'Lost Undiluted Juice' as well as 'Lost Absolute Juice % Fibre in Final Bagasse' have been derived in later years. 'Lost Juice' is therefore a yardstick of sixty years standing.

In the following table the Mills are arranged according to the average percentages of lost juice obtained in the past season. The next columns show:

(a) the specific feed rate, being the number of lbs fibre milled per hour divided by the cubic feet of Total Roller Volume of the tandem concerned;

(b) the imbibition per 100 fibre;

(c) the reduced extraction of Noel Deerr, i.e. the extraction figure converted to cane with a standard fibre content. We chose as "standard" 15|% fibre in cane as this is the average percentage of fibre for S.A. conditions and using the average percentage will reduce the magnitude of the corrections to be applied, which will improve the accuracy of the results;

(d) the sucrose content of the first expressed juice as the richness of the cane juice also affects the extraction which can be obtained;

(e) the drop in purity from first to last expressed juice as a reduction of 0.1% in pol in bagasse (in the region of 2.0% pol in bagasse) raises the extraction figure by $^1/_4$ to $^1/_3$% depending on the fibre content of the cane.

Mill	Lost Absolute Juice % Fibre	Specific Feed Rate (lbs/h/cu ft T.R.V.)	Imbibition % Fibre	Reduced Extraction (15½% fibre)	Purity Drop from First of Last Expressed Juice	Sucrose % First Expressed Juice
ME . . .	27	51	300	98.84	17.39	16.66
DL . . .	29	52	368	95.54	15.84	17.42
TS . . .	31	46	214	94.92	10.68	17.19
IL . . .	33	49	281	95.38	22.17	17.24
AK . . .	33	54	308	94.56	11.62	17.30
FX . . .	34	39	250	94.61	14.72	17.23
EN . . .	36	—	297	94.55	19.60	16.68
UR . . .	36	60	187	94.24	13.18	16.73
UF . . .	37	28	261	93.96	12.68	17.99
UC . . .	37	—	220	94.12	15.16	15.73
MV . . .	40	46	285	93.47	11.20	17.38
RN . . .	43	63	193	93.33	11.90	17.79
SZ . . .	42	48	230	93.51	15.82	17.95
JB . . .	43	28	269	93.48	16.82	16.04
LB . . .	43	56	234	93.35	15.59	17.58
GH . . .	44	58	199	93.32	16.60	16.92
DK . . .	46	52	234	92.51	11.72	17.93
MH . . .	48	53	177	92.23	12.26	16.94
EM . . .	48	60	296	92.20	11.71	17.75
PG . . .	47	38	269	92.60	14.71	18.06
GD . . .	50	53	284	92.04	14.00	16.75
UK . . .	51	54	178	91.66	9.98	17.82
TR . . .	51	54	213	91.43	9.70	17.58
MR . . .	53	63	172	91.01	8.71	16.05

The general trend revealed by the table is as expected, viz. with an increase in lost juice' the 'reduced extraction' decreases. There are a number of discrepancies which are caused by the fact that—

(a) Noel Deerr's formula is only an approximation; and

(b) the correction of Noel Deerr as well as the origi-

nal extraction are both based on pol instead of on Jzinx .

The natural drop in purity from first to last expressed juice as well as any loss of sucrose due to inversion, enzymatic or bacteriological action flatter the results. In this respect Brix Extraction and Reduced Brix Extraction are better figures, because there is not a pronounced drop in Brix from first to last expressed juice and the Brix is only affected when enzymatic or bacteriological action leads to gaseous products.

In addition the richness of the juice also has its effect on sucrose extraction, a richer juice leading to a higher extraction figure. For instance, the difference in sucrose % first expressed juice between Pongola and Dalton i.e. 18.06—15.73=2.33% is according to De Haan **a** disadvantage of 0.4 x 2.33 or 0.93 % in sucrose extraction for the Union Co-op Mill.

Milling-cum-Diffiision:

The fact that the overall results of the two factories applying this combined process did not come up to expectation was caused by the milling section of the plants, viz. in the case of the Dalton installation due to unsatisfactory performance of the first mill and in the event of the Entumeni by the first mill as well as by the de-watering mills.

The number of circulation compartments, i.e. the length of the diffusers in question was so chosen that a low pol % bagasse can be achieved if the preceding mill squeezes out 65% of the cane juice (in the case of cane with 13% fibre). When the mill fails to do this then a low pol % bagasse can only be achieved by the use of an excessive amount of water, or by increasing the number of circulations.

With respect to the effect of the performance of the milling part on the overall result we refer to the graphs by Bruniche-Olsen in his article in the August 1966 issue of 'Sugar and Azucar'.

Dalton in particular had in the beginning to put up with unsatisfactorily knived cane and crushing slowly with **a** 'high speed' mill did not improve matters. When the blockage of the backend of the factory gradually cleared, the crushing rate could be increased which improved performance materially. However, the season was too short to turn the unsatisfactory figures of the beginning of the season into **a** satisfactory average for the whole season.

Entumeni, like Dalton, in the first week of the season had **a** full house, caused by crushing of drought- and frost-stricken cane. The many hours of stoppages caused by full house meant that the bagasse stayed too long in the diffuser with a resulting abnormal low sucrose % bagasse figure due to inversion and fermentation. Later, difficulties were encountered with the first mill, while the setting of the de-watering mills led to a very high moisture content of the last bagasse. Though the average pol % bagasse is flattered by the figures of the first weeks the average would have been better if the performance of the de-watering mills had come up to standard.

In anticipation of improved performance of the milling section of the two milling-cum-diffusion plants in the coming season we would mention here what the first season has brought to the fore:

(a) that provided the temperature is not raised higher than 70° C. part of the starch in juice is removed by the diffuser;
(b) that soil adhering to the cane *can* interfere with the percolation of the juice through the bagasse layer in the diffuser;
(c) that a proper control should be carried out on the pH and the reducing sugars/sucrose ratios of all circulating juices; and
(d) that the diluted juice squeezed out by the de-watering mills should be limed to at least a pH of 9.5 for flocculation, otherwise difficulties will be encountered with the juice percolation.

Experience has shown that the return of the alkaline overflow of the diffuser clarifier is not always sufficient to maintain a pH high enough to prevent inversion of sucrose and consequent corrosion of the mild steel parts of the diffuser; additional injections of milk of lime along the line of diffuser pumps seems to be required.

The Milling **Tandems:**

The score board with regard to "Lost Juice" reads as follows:

Season	1966/67	1965/66	1964/65	1963/64	1962/63
ME . .	27	25	39	34	31
DL . .	29	29	30	28	27
TS . .	31	30	35	32	38
IL . .	33	34	31	37	40
AK . .	33	33½	—	—	—

Holding itself extremely well between its stronger rivals is Illovo's tandem, composed of six units of 'a certain age' and the mills driven in pairs by three

Hulett's Mount Edgecombe 21 -roller tandem is at present in the lead. Though it has the advantage over Darnalls tandem by having one unit more, it has the disadvantage of a smaller and weaker part in the middle of the train.

Amatikulu, also a 21-roller tandem and of stronger and bigger construction than all the other tandems, gained J % in lost juice compared with the previous season.

C. BOILING HOUSE PERFORMANCE

The Assessment of Recoverable Sucrose:

The Committee for Chemical Control decided in 1950 to introduce another yardstick to evaluate boiling house performance other than the figure of "B.H. Recovery". As this new yardstick, called the Boiling House performance, was based on and derived from the wellknown formula "S-0.4(B-S)", the background of Dr. Winter's formula should be known to prevent incorrect conclusions being drawn.

In the Java Sugar Archief Dr. Winter pointed out that the old formula "S—(B—S)" gave **a** figure for 'expected sugar in the bags' which was 25 % lower than the actually bagged sugar. The next year (1897) therefore he proposed to use in future the formula "S—0.4(B—S)" which would lead to a sugar weight closer to the actual weight of the bagged sugar. We draw attention to the fact that the result of the formula was then still "Tons of Sugar" and not as at present 'Tons of Crystal in Sugar". In addition we have to point out that the formula covers all losses incurred, viz. sucrose losses in filter cake, in final molasses and 'undetermined'. Winter derived the formula from *a statistical investigation* into the results of a number of efficiently operating Java factories over a number of years. In his publications he never mentions that the constant 0.4 was related to or based on a final molasses purity of (100—0.4)/(l— 0.4)=28.56°. Winter only stated that the formula was easy to memorise viz. "subtract 0.4-times NS or (B—S) from the sucrose, and you arrive at the expected weight of the sugar, taking muscovado at its full weight and jelly sugar at half its weight."

Because processing methods gradually improved and more sugar was recovered, the time came when the Winter yield was also exceeded, like before 1897 when more sugar was made than indicated by the formula 'S—(B—S)\ In 1930 therefore it was decided to raise the standard. This was easily achieved by assuming that from then on the result of the formula would indicate "Tons recoverable crystal in sugar" instead of "Tons of recoverable sugar". This change in indication raised the standard by about 5%. However, before very long the carbonatation factories started to exceed "Winter" again. This was caused by better understanding of the carbonatation procedure resulting in a higher NS removal (mainly due to a lower lime salt content in the clarified juice). Even carbonatation factories with final molasses purities far above 28.57° purity made more than 100% "Winter".

When the Chemical Control Committee decided to introduce the Winter formula it was with a variable factor, which was on average about 0.1 higher than Winter's constant factor of 0.4. The factor introduced by the Committee varied slightly according to the mixed juice purity and was based on the opinion that a lower mixed juice purity would be accompanied by a higher reducing sugars/ash quotient in the final molasses.

In the following two tables the B.H.P. figures calculated the official way are compared with the B.H.P. obtained when, instead of the variable factor, a constant factor of 0.5 is used. For further simplification the crystal content of the sugar is also calculated with a constant factor, i.e. 0.6, instead of the variable factor adjusted to the final molasses purity obtained.

These two tables are drawn up to demonstrate how small the difference is if instead of the variable Winter factor a constant factor of 0.5 is applied. The change over to a factor of 0.6 for the sugar end is considered to be more appropriate in view of the different degrees of exhaustion of the final molasses and also because of the different ways of expressing purity, i.e. apparent purity and gravity purity based on spindle Brix and apparent and gravity purity based on refracto-brix.

Comparison of the B.H.P. calculated the official way and when using the constant factors 0.5 and 0.6

Season	Purity of Mixed Juice	Official B.H.P.	New B.H.P.
1965/66 . . .	84.22	95.65	96.12
1963/64 . . .	85.30	97.19	97.39
1962/63 . . .	83.36	96.61	96.92
1961/62 . . .	84.31	97.01	97.17

Mill	Official Calculation	Using constant factors	Difference
PG	95.68	95.76	+0.08
UF	95.47	96.14	+0.67
EM	95.84	96.44	+0.60
FX	95.28	96.65	+0.37
EN	92.64	92.84	+0.20
AK	98.06	98.43	+0.37
DK	96.06	96.05	+0.01
GD	96.38	96.70	+0.32
DL	97.13	97.66	+0.53
GH	96.60	97.04	+0.44
MV	95.82	95.92	+0.10
JB	86.98	87.57	+0.59
UC	92.20	92.91	+0.71
TS	97.08	97.29	+0.21
ME	96.95	97.52	+0.57
IL	94.89	95.10	+0.25
RN	96.07	95.95	−0.12
SZ	95.74	95.79	+0.05
UK	96.14	95.97	−0.17
LB	95.05	95.21	+0.16
MR	95.15	95.86	+0.71
UR	97.24	97.78	+0.54
MH	96.27	96.36	+0.09
TR	97.29	97.47	+0.18

The comparison shows that the variable factor is not the cause of low B.H.P. recorded during the past season. It is particularly low when compared with the average result recorded in 1957/58 i.e. 98.5% B.H.P. In the latter season there was one Mill which made 100.0% B.H.P. i.e. Sezela with a final molasses purity of 34.1°, while another factory made 99.7% B.H.P. i.e. Illovo with 33.4° final molasses purity.

FINAL MOLASSES PURITIES

Seeing these low final molasses purities and high B.H.P. figures makes us realise why the B.H.P. was again this season so low, viz. too high sucrose losses in final molasses. These high losses are not always caused by a high final molasses purity alone, but sometimes also by the combination of a high purity and a larger quantity of molasses than commensurate with the mixed juice purity.

COMPARISON OF FINAL MOLASSES PURITIES

Mill	Spindle Brix Apparent Gravity		Refracto Brix Apparent Gravity	
PG	38.91	—	—	—
UF	41.29	41.58	—	—
EM	—	39.84	41.30	42.76
FX	—	39.35	—	42.53
EN	43.13	—	—	—
AK	—	37.72	38.04	40.32
DK	39.87	40.62	—	—
GD	33.88	—	—	—
DL	—	39.73	42.00	42.50
GH	—	39.72	—	—
MV	40.40	41.24	—	—
JB	—	41.52	—	—
UC	43.78	—	—	—
TS	39.90	41.16	—	—
ME	—	37.85	40.97	40.47
IL	36.60	39.16	—	—
RN	40.71	—	—	—
SZ	41.46	41.65	—	—
UK	37.54	40.35	—	—
LB	39.61	40.32	—	—
MR	36.37	39.87	—	—
UR	36.00	39.90	—	—
MH	38.61	—	—	—
TR	32.64	36.68	—	—

For proper evaluation of the obtained purities, these purities should be compared with the Target Purity according to the D.D. formula. In this respect the fact should not be overlooked that the D.D. formula is based on the composition of the obtained final molasses and not on the composition of the original mixed juice. This implies that when the R.S./Ash quotient is adversely affected by a too high pH during processing, the final molasses purity will go up, but so does the Target Purity. A small difference between 'Obtained purity' and 'Target purity' is, therefore, not synonymous with a good clarification technique.

NON-SUCROSE ACCOUNT

The loss in final molasses is not only governed by the purity but also by the quantity of final molasses, the latter being dependent on the purities of mixed juice and final molasses and the amount of non-sucrose added, formed and removed during processing of the mixed juice.

Though the composition of the non-sucrose in mixed juice is quite different from that in final molasses, the only check we have on non-sucrose formation and non-sucrose removal is by comparing the two quantities we "calculate" by subtracting tons sucrose from tons Brix in mixed juice as well in total final molasses. The ratio of these two quantities for all factories (which recorded their final molasses weights) is shown below:

Mill	Ratio
PG	0.84
UF	0.81
EM	0.85 (0.755)
FX	0.88 (0.805)
EN	0.91
AK	0.83 (0.74)
DK	0.77
GD	1.02
DL	0.78 (0.701)
GH	0.82
MV	0.89
JB	0.92
UC	0.90
TS	0.83
ME	0.82 (0.736)
IL	0.85
RN	0.86
SZ	0.86
UK	N.A.
Mean	0.84
LB	0.78
MR	0.73
UR	0.82
MH	0.87
TR	0.91

NB.—The ratios between brackets are based on refracto-brix as far as the final molasses is concerned.

Actually this ratio is an unsatisfactory yardstick, not only because the composition of the NS at the beginning and at the end are quite different, but also because we know beforehand that °Brix and purity of mixed juice are disputable. An investigation carried out in Queensland revealed that the rise in purity from mixed to clarified juice is for the greater part the result of a more correct Brix determination in clarified juice than in mixed juice; the assessment of the Brix in mixed juice being affected by suspended matter. In his conclusion Clayton (26th Conference of the Q.S.S.C.T.) says: *"as for the clarification process, what efforts have been wasted in the careful measurement of purity rise"*

When we peruse the previous table (notwithstanding its shortcomings) we see that the ratio ranges from 0.72 to 1.02. It is obvious that a combination of a low or normal ratio and a low final molasses purity will lead to a high B.H.P. figure.

N.B. Cane grown under "normal" conditions, as for instance in the years between 1956 to 1960, gave an average value of 0.81.

REDUCING SUGARS ACCOUNT

The reducing sugars account gives us a fair insight into processing conditions as it can indicate destruction of reducing sugars by high pH or their formation by low pH. There is, however, the complication that both reactions, i.e. formation and destruction, are also governed by time and temperatures and the further complicated owing to the phenomenon that the H-ion and the OH-ion concentration *both* increase with an increase in temperature (I.S.J. 1966; p. 361). It can therefore happen that inversion and reducing sugars destruction take place simultaneously as owing to a higher temperature both concentrations (the H-ion as well as the OH-ion concentration) increased. A prolonged residence time under such conditions is therefore to be condemned.

During the discussions of one of our first Annual Summaries we remarked that we should try to find which pH of the clear juice led to the highest B.H.P. adding at the same time that we had found that this pH was 7.3 to 7.4, i.e. higher than usually assumed as being the 'best' pH. In this respect the investigations of Schlegel (Zeitschr. Zuckerind. 1963; p. 14) should be mentioned. Schlegel has found that a pH of 7.4 measured at 20°C drops to 6.2 and the pOH from 6.6 to 5.9 when beet juice is heated to 110°C. This finding implies that at a vapour pressure of 6 psig in the first vessel or pre-evaporator the H-ion concentration increases 16-fold and the OH-ion concentration 5-fold compared with conditions at 20°C. This 'complication' should always be kept in mind, also when perusing the reducing sugars tables.

REDUCING SUGARS ACCOUNT TABLE

N.B.—Reducing Sugars present in mixed juice=100%

Mill	Percentages of R.S. present in: Clear Juice	Syrup	Total Final Molasses
PG	92	75	N.A.
UF	90	92	109
EM	94	89	98
FX	89	85	N.A.
EN	98	66	N.A.
AK	98	86	111
DK	N.A.	95	101
GD	99	85	N.A.
DL	97	94	93
GH	68	75	66
MV	96	103	110
JB	93	70	109
UC	N.A.	71	N.A.
TS	93	90	98
ME	99	100	107
IL	102	79	99
RN	87	65	N.A.
SZ	88	72	128
UK	103	104	N.A.
LB	97	70	94
MR	102	83	63
TR	93	87	82
MH	100	80	N.A.
UR	103	79	N.A.

There are a number of figures which require further investigation. For example: the low percentage of reducing sugars in syrup at PG, EN, GH, JB, UC, RN, SZ and LB, the low R.S. percentage in total final molasses at GH, and MR and the high R.S. percentage in total final molasses at SZ. With regard to the high percentage of R.S. in MV's syrup we know that a purity drop as well as inversion takes place in the vapour cell.

THE NS CIRCULATION RATIO

$$\frac{\text{Tons NS in C-massecuite}}{\text{Tons NS in weighed Final Molasses}}$$

When this item was introduced in the 35th Annual Summary, it was stated that:

"The quantity of C-massecuite depends on different factors such as juice purity, the C-massecuite purity and last but not least on the purity of the (pre-cured) C-sugar."

In the Annual Report "1960" of the Mauritius Sugar Research Institute the following table is published by J. D. de R. de Saint Antoine:

Influence of C-sugar Purity on Volume of C-massecuite

Purity C-sugar	Cu ft/hour C-massecuite	% Increase in volume of C-m.c. for C-sugar purities below 90°
94.0	100.8	—
90.0	105.1	—
86.0	110.8	5.4
82.0	118.1	12.4
78.0	128.1	21.9
74.0	142.5	35.6
70.0	174.8	56.8

N.B.—The table is based on the following assumptions: Purities of Syrup, C-massecuite arid Final Molasses respectively 87.5°, 56.0° and 36.5°. Crushing Rate=100 t.c.h.

The following table shows the NS-circulation ratios in the system "C-massecuite/C-sugar/final molasses" for the last seven years:

Non-Sucrose Circulation Table

Mill	1966	1965	1964	1963	1962	1961	1960
PG	124	100	126	132	121	114	117
UF	139	125	148	159	123	105	122
EM	134	119	137	132	114	125	121
FX	135	124	152	130	114	124	134
EN	106	120	111	121	111	124	126
AK	133	143	129	126	125	119	132
DK	153	142	163	155	130	129	131
GD	110	132	142	144	118	N.A.	108
DL	143	131	124	116	104	118	121
GH	121	119	121	137	111	144	144
MV	136	124	141	135	121	111	132
JB	N.A.	—	—	—	—	—	—
UC	124½	—	—	—	—	—	—
TS	137	138	146	143	N.A.	N.A.	N.A.
ME	148½	117	132	139	132	140	130
IL	146	115	146	172	147	137	140
RN	126	115	166	130	100	114	117
SZ	187	N.A.	125	133	120	127	126
UK	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
LB	200	165	137	151	148	144	—
MR	142	135	156	155	146	N.A.	—
MH	106	N.A.	N.A.	121	106	102	—
UR	147	128	115	143	115	108	—
TR	141½	—	—	—	—	—	—

Some percentages require further investigation, e.g. the low percentage of GD (110%) in connection with the high non-sucrose ratio (1.02) indicates a too high final molasses weight. It is recommended that this weight be checked.

Needless to say the NS circulation can not be reduced by double-curing as double curing does not reduce the NS returned to the C-massecuite by the pre-cured sugar. Whether we use the C-sugar, single- or double-cured, as a footing in the form of a magma, or whether we dissolve the C-sugar in water, clear juice or syrup, the magnitude of the NS circulation remains the same as long as the purity of the pre-cured C-sugar is not altered.

EXHAUSTION OF THE STRIKES:

The following tables are compiled from figures recorded in Tables 4 and 5 at the end of this Summary.

Mill	Recovered Crystal per 100 parts sucrose in massecuite			
	A-m.c.	B-m.c.	C-m.c.	Mean
PG . .	63.0	62.8	58.8	61.5
UF . .	63.4	52.3	53.2	56.3
EM . .	61.1	60.8	54.2	58.7
FX . .	64.3	57.3	53.0	58.2
EN . .	57.9	52.2	54.9	55.0
AK . .	68.8	63.6	57.7	63.4
DK . .	69.6	60.0	59.5	63.0
GD . .	66.5	51.2	52.0	56.6
DL . .	61.9	58.5	51.9	57.4
GH . .	66.6	60.5	58.2	61.8
MV . .	60.7	65.9	51.9	59.5
JB . .	59.9	55.8	55.0	56.9
UC . .	64.8	59.6	55.4	59.9
TS . .	67.1	58.2	55.0	60.0
ME . .	59.8	50.7	50.7	53.7
IL . .	56.1	60.7	64.1	60.3
RN . .	62.0	60.6	59.1	60.6
SZ . .	56.6	55.9	56.7	56.4
UK . .	62.1	59.6	52.8	58.5
LB . .	59.9	51.9	53.8	55.2
MR . .	61.5	63.9	58.9	61.4
MH . .	60.6	58.2	62.0	60.3
UR . .	61.1	61.5	61.3	61.3
TR . .	65.3	64.7	68.3	66.1

The highest mean value was obtained by TR, i.e. 66.1 % while the lowest was booked by ME i.e. 53.7. In this connection it would be interesting to compare the exhaustion figures with the cu. ft. of massecuites boiled; however, some factories remelted, others did not, which makes comparison impracticable.

CU. FT. OF MASSECUITES

The last column of the table (purity rise) indicates the difference between the degrees purity of A-mc. and syrup; a negative sign denoting that the purity of the A-mc. was lower than that of the syrup.

The highest number of cu. ft. massecuites is recorded by MR i.e. 91 cu. ft. per ton of Brix in mixed juice (MR applies the Illovo boiling system "for producing mill white at a defecation factory"). The lowest number of cu. ft. is boiled by GD applying the single-magma system.

Mill	Cu. ft. of Massecuite per ton of Brix of Mixed Juice				
	A-m.c.	B-m.c.	C-m.c.	Total	Purity Rise
PG . .	26.6	9.20	7.80	43.7	+0.45
UF . .	31.6	9.95	9.21	47.0	+1.09
EM . .	35.4	11.37	9.44	56.2	+1.49
FX . .	28.4	8 52	9.09	46.0	+0.65
EN . .	25.2	10.38	8.56	44.7	+0.01
AK . .	29.6	8.24	7.80	45.6	+1.09
DK . .	28.6	9.59	9.11	47.3	+2.37
GD . .	20.1	10.31	8.13	38.5	−1.80
DL . .	29.3	9.79	7.98	47.0	+2.10
GH . .	25.7	11.94	8.47	46.1	+2.40
MV . .	35.8	12.06	8.56	56.4	+1.40
JB . .	N.A.	N.A.	N.A.	N.A.	−0.27
TS . .	24.7	·11.24	8.73	44.9	+0.20
ME . .	32.8	16.55	8.89	58.3	+1.00
IL . .	43.0	13.66	10.04	66.7	+2.55
RN . .	24.6	11.74	7.81	44.2	−1.40
SZ . .	22.3	12.85	11.97	47.1	−1.73
LB . .	34.3	19.70	12.57	66.6	−2.00
MR . .	69.2	14.41	9.73	91.0	+1.28
UR . .	29.0	10.67	10.39	50.1	+1.90
MH . .	20.8	13.4	7.89	42.2	−2.69
TR . .	36.0	8.32	10.96	55.0	+3.35

Before concluding the chapter "Boiling House Performance", we want to refer back to the first table of this chapter showing the B.H.P. figures obtained by all factories. Hereunder follow the five Mills with the highest B.H.P. percentages, giving their final molasses purities, undetermined sucrose losses and, last but not least their NS ratios.

Mill	B.H.P.	Final Molasses Purity	Undetermined Sucrose Losses	NS Ratio
AK . .	98.1	37.7	0.89	0.83
TR . .	97.3	36.7	1.37	0.91
DL . .	97.1	39.7	1.24	0.78
TS . .	97.1	41.2	0.39	0.83
UR . .	97.0	39.9	0.73	0.82

N.B.—The refracto-sucrose purities of AK and DL were converted to gravity purities in order to make them comparable with those of the other Mills.

We draw special attention to the fact that (with the exception of TR) all Mills in the table above show low or normal NS-ratio figures, which indicate that these Mills did *not* produce more final molasses than commensurate with their mixed juice purities. TR shows a high NS-ratio indeed, i.e. 0.91, but since the molasses purity is low, it did not prevent TR recording a good B.H.P. figure.

VACUUM IN THE LAST VESSEL OF THE EVAPORATOR

Condenser tests carried out by the Bureau of Experiment Stations (Brisbane, Queensland) showed that the last Vessel gave off more vapour at 26" Hg vacuum than at 27". This result recalls the statement of Claassens that the optimum vacuum for the last vessel is 25" as a higher vacuum increases the viscosity of the syrup too much and a lower vacuum reduces the temperature drop across the heating surface too iar.

Estimated viscosities of syrup of different Brix at vacua from 27" to 24" Hg (the B.P.E. has been taken into account)

Vacuum	27″	26″	25″	24″
55° Brix .	8.0	6.9	5.8	4.7
60° „ .	14.0	11.8	9.7	8.5
65° „ .	27.6	22.8	18.0	15.8
70° „ .	65.0	52.0	39.0	32.0

The above table reveals why Queensland's Mills would experience more the effect of vacuum on the capacity of the last vessel than S.A. Mills, the average density of the syrup in Queensland Mills being about 68° Brix against 60° for S.A. Mills.

Season S.A.	Average ° Brix	Season S.A.	Average ° Brix
1950	54.5	1960	56.9
1951	53.2	1961	57.8
1952	53.8	1962	57.9
1953	55.0	1963	58.1
1954	54.2	1964	58.8
1955	55.1	1965	59.3
1956	54.5	1966	60.4
1957	55.2		
1958	55.7		
1959	57.0		

According to this table the average density of the S.A. Mills increased from 1950 to 1966 by 5° Brix. However, this should be only the beginning as another 5 Brix rise is required to arrive at the target density of 65° Brix.

Replacement of the sulphitation process by the defecation method by raw sugar Mills and the installation of bigger evaporators with vapour bleeding brought about the first rise of 5° Brix. The second rise of 5° Brix depends for a great part in bringing up the backend. In this respect it should be mentioned that even sulphitation factories can achieve an average density of 65° Brix if they use a spare last vessel which can be put into operation (clean) on a Wednesday. Even better is a completely interchangeable outfit as, for instance, at Umfolozi.

TABLE 1

SUGAR PRODUCTION 1966-1967 SEASON
(Subject to final adjustment)

SHORT TONS

MILL	LOCAL MARKET			General Export Raws	Japanese Assortment	Canadian Assortment and Umzimkulu	TOTAL
	Raws for Refining	Whites	Golden Brown				
Darnall . .	44,876	—	375	64,917	43,468	—	153,636
Amatikulu . .	34,533	—	282	77,048	50,307	—	162,170
Felixton . .	73,830	—	1,660	34,534	42	—	110,066
Empangeni . .	110,165	—	4,967	8,403	—	—	123,535
Mt. Edgecombe	52,882	—	1,171	41,650	—	25,985	121,688
Tongaat . .	94,965	—	504	100,705	—	—	196,174
Melville . . .	1,898	394	3,052	29,548	—	6,907	41,799
Illovo . . .	5,526	—	4,164	61,006	10,830	—	81,526
Jaagbaan . .	53,443	—	10	—	—	—	53,453
Umfolozi . .	—	—	13,168	27,917	128,628	—	169,713
Glendale . .	22,986	—	121	—	—	—	23,107
Sezela . . .	17,346	82,265	16,730	20,191	—	—	136,532
Renishaw . .	—	4,640	40,764	—	—	—	45,404
Pongola . .	—	28,495	43,565	—	—	—	72,060
Gledhow . .	534	113,062	3,500	33,806	—	—	150,902
Umzinkulu . .	1,253	—	70	—	—	73,462	74,785
Doornkop . .	—	—	3,210	24,975	14,059	—	42,244
Dalton (U.C.) .	763	—	27	2,334	10,926	—	14,050
Entumeni . .	—	9,008	2,276	10,295	—	—	21,579
TOTALS . .	515,000	237,864	139,616	537,329	258,260	106,354	1,794,423

TABLE 2 CANE CRUSHED, SUGARS MADE, CANE

SYMBOL INDICATING THE FACTORY	PG	UF	EM	FX	EN	AK	DK
ushing Season started on	10.5.66	29.4.66	14.4.66	28.4.66	21.7.66	13.4.66	16.5.66
ushing Season ended on	10.12.66	1.2.67	21.2.67	18.2.67	15.3.67	20.2.67	5.2.67
ns Cane Crushed	**601,298**	**1,378,463**	**1,102,396**	**981,322**	**196,346**	**1,379,623**	**354,125**
NE COMPOSITION							
Sucrose % Cane	14.36	14.48	13.78	13.42	13.38	13.57	14.14
ibre % Cane	13.91	13.05	15.89	16.22	13.37	15.90	15.13
ava Ratio	79.54	80.46	77.67	77.86	80.15	78.45	78.87
ons Cane per Ton Sugar	8.34	8.12	8.92	8.91	9.08	8.51	8.38
ons Cane per Ton 96° Sugar	8.10	7.96	8.67	8.67	8.80	8.30	8.18
NE VARIETIES CRUSHED							
Co.331	0.05	0.67	0.10	0.55	0.33	0.08	1.79
N:Co.310	92.70	82.12	82.84	37.87	5.34	88.78	13.95
N:Co.293	0.68	0.11	0.14	0.01	34.02	0.41	13.33
N:Co.339	0.12	1.24	0.54	1.21	1.03	0.07	0.18
N:Co.376	5.68	6.80	11.70	39.13	52.37	8.60	58.40
N:Co.382	0.20	7.93	1.43	10.73	2.39	0.68	6.58
N:50/211	0.25	0.81	2.62	3.50	4.41	1.02	3.93
Remainder	0.32	0.32	0.63	7.00	0.11	0.36	1.80
TAL RAINFALL YEAR 1966 (inches)	26.00	22.91	30.75	40.85	36.17	29.79	33.11
s Sugar Made	**72,060**	**169,712**	**123,535**	**110,079**	**21,628**	**162,170**	**42,244**
White or Refined Sugar Made	40%	Nil	Nil	Nil	42	Nil	Nil
rage Pol of All Sugars Made	98.96	97.90	98.82	98.80	99.02	98.34	98.26
IE ACCOUNT							
Hours crushed % Hours Mill Open	90.26	96.52	87.87	92.02	83.29	85.26	92.78
Hours Cane Shortage % H.M.O.	4.45	0.09	1.70	1.77	2.12	1.98	6.30
ROUGHPUTS per hour actual crushing							
ons cane crushed	154.24	215.54	187.41	171.79	46.63	250.92	71.14
ons fibre milled	21.45	28.13	29.78	27.86	6.24	39.89	10.76
ons brix processed	24.10	34.47	28.44	25.62	6.94	37.91	10.74
ons sugar bagged	18.48	26.54	21.00	19.27	5.14	29.49	8.49
CROSE BALANCE							
ost in bagasse (A)	6.52	4.94	8.03	5.69	4.59	5.61	7.27
ost in filter cake (B)	1.21	1.43	0.69	0.49	1.12	0.55	0.42
ost in final molasses (C)	7.77	9.75	9.68	9.19	10.84	7.76	7.13
ndetermined Losses (D)	1.93	0.63	1.26	2.02	1.91	0.89	2.26
LING HOUSE LOSSES (B)+(C)+(D)	10.91	11.81	11.63	11.70	13.87	9.20	9.81
M OF ALL LOSSES (A)+(B)+(C)+(D	17.43	16.75	19.66	17.39	18.46	14.81	17.08
rall Recovery	**82.57**	**83.25**	**80.34**	**82.61**	**81.54**	**85.19**	**82.92**

VARIETIES, THROUGHPUTS and SUCROSE BALANCE

GD	DL	GH	MV	JB	UC	TS	ME	IL	RN	SX	UK	Total and Mean
4.5.66	28.4.66	7.5.66	7.5.66	10.5.66	1.8.66	27.4.66	11.5.66	29.4.66	24.5.66	26.6.66	25.6.66	13.4
26.2.67	26.2.67	1.3.67	20.1.67	26.2.67	28.1.67	12.2.67	1.3.67	19.3.67	27.2.67	4.3.67	1.3.67	19.3
210,251	**1,270,869**	**1,363,472**	**355,086**	**545,771**	**141,882**	**1,702,458**	**1,077,945**	**709,163**	**389,510**	**1,164,815**	**620,831**	**15,545,**
13.28	13.85	13.50	13.93	12.84	12.26	13.43	13.12	13.53	13.92	14.27	14.27	13
14.92	15.02	15.61	15.10	13.72	14.45	15.76	15.52	15.15	16.37	14.31	14.65	15
79.28	79.50	79.04	80.09	80.02	77.93	78.14	78.82	78.45	78.20	79.50	80.12	79
9.10	8.27	8.86	8.52	10.23	9.98	8.68	8.86	8.69	8.58	8.29	8.30	8
8.87	8.09	8.59	8.28	9.95	9.78	8.42	8.62	8.48	8.32	8.05	8.08	8
6.49	2.66	0.74	4.32	13.90	15.80	0.61	2.90	2.78	0.46	1.35	1.57	1
8.45	26.87	7.63	7.11	0.21	0.38	8.86	3.50	14.72	9.60	6.16	12.57	33
4.86	0.93	1.33	0.50	56.26	53.47	1.66	9.65	27.06	1.76	2.38	3.08	5
0.13	0.84	1.33	5.98	Nil	Nil	2.04	0.83	1.34	0.18	0.30	0.66	0
42.45	45.92	58.23	37.60	13.30	9.93	32.63	33.82	42.50	78.76	76.03	80.26	36
1.02	1.79	3.41	1.42	14.82	19.23	6.86	4.75	8.18	8.96	3.77	0.45	4
4.29	5.76	3.96	7.50	0.20	0.99	9.55	4.78	1.95	1.64	3.13	0.99	3
32.31	15.23	23.37	35.57	1.31	0.20	37.79	54.90	1.47	3.64	6 88	0.42	12
24.19	35.02	30.23	30.45	31.85	35.13	25.42	32.93	31.74	29.42	33 68	31.44	29
23,111	**153,638**	**153,920**	**41,799**	**53,716**	**14,210**	**196,172**	**121,688**	**81,581**	**45,404**	**140,467**	**74,785**	**1,801,**
Nil	Nil	75	Nil	Nil	Nil	Nil	Nil	Nil	10	60	Nil	
98.51	98.15	98.95	98.50	98.00	98.00	98.85	98.66	98.35	98.83	98.95	98.62	98
78.27	93.23	93.61	83.97	68.61	79.19	89.95	88.45	86.74	85.33	81.24	86.62	87
9.00	4.09	1.46	7.04	11.10	2.03	6.17	7.10	7.09	8.65	1.67	5.12	4
43.54	207.84	234.39	81.16	153.96	50.23	277.67	197.09	118.11	80.45	272.00	140.12	163
6.50	31.22	36.59	12.25	21.13	7.26	43.75	30.60	17.90	13.17	38.92	20.53	24
6.34	32.55	34.55	12.27	22.27	6.95	41.44	29.61	17.90	11.90	42.17	20.87	24
4.79	25.12	26.46	9.55	15.15	5.03	31.97	22.25	13.59	9.38	32.80	16.88	18
7.61	4.30	6.74	6.33	5.65	5.41	5.18	4.17	4.50	7.12	5.91	7.80	5
0.24	0.68	1.17	0.54	1.17	0.48	0.69	0.31	0.47	0.97	1.26	0.76	0
9.49	8.10	8.55	8.65	11.25	11.96	8.86	8.94	8.32	7.48	8.79	6.74	8
1.14	1.24	0.80	1.21	6.79	2.07	0.39	1.71	3.07	1.48	0.42	1.48	1
10.87	10.02	10.52	10.40	19.21	14.51	10.04	10.96	11.86	9.93	10.47	8.98	10
18.48	14.32	17.26	16.73	24.86	19.92	15.22	15.13	16.36	17.05	16.38	16.78	16
81.52	**85.68**	**82.74**	**83.27**	**75.14**	**80.08**	**84.78**	**84.87**	**83.64**	**82.95**	**83.62**	**83.22**	**83**

TABLE 3 BOILING HOUSE PERFORMANCE, LOST ABSOLUTE JUICE %

SYMBOL INDICATING FACTORY	PG	UF	EM	FX	EN	AK	DK
oiling House Performance	**95.68**	**95.47**	**95.71**	**95.28**	**92.64**	**98.06**	**96.06**
oiling House Recovery	88.33	87.58	87.35	87.59	85.46	90.26	89.42
ost Absolute Juice % Fibre	**47.22**	**36.96**	**47.69**	**34.13**	**35.80**	**32.98**	**45.86**
Imbibition % Fibre	269	261	296	250	297	308	234
Specific Feed Rate*	38	28	60	39	—	54	52
SUCROSE EXTRACTION	93.48	95.06	91.97	94.31	95.41	94.39	92.72
Imbibition % Cane	37.40	34.10	47.11	40.57	39.68	49.04	35.49
NAL BAGASSE							
Sucrose % Bagasse	2.94	2.32	2.87	2.05	1.89	2.12	2.93
Moisture % Bagasse	52.35	54.63	54.83	53.62	56.09	53.00	53.01
Fibre % Bagasse	43.60	42.25	41.26	43.52	41.22	44.22	43.15
Bagasse % Cane	31.89	30.89	38.51	37.25	32.45	35.96	35.07
C.V. of Bagasse (btu per lb)	**3,074**	**2,888**	**2,861**	**2,980**	**2,770**	**3,033**	**3,017**
ailable btu per lb Brix	**6,276**	**5,423**	**7,258**	**7,440**	**6,037**	**7,218**	**7,007**
ixfree Water % Fibre	32	23	25	21	31	16	26
bibition Efficiency	45	41	52	42	43	44	58
lution Ratio	**67**	**80**	**72**	**81**	**84**	**81**	**69**
RST EXPRESSED JUICE							
Degrees Brix	20.72	20.75	20.81	19.86	19.11	19.76	20.31
Degrees Purity	87.16	86.72	85.30	86.75	87.30	87.53	88.27
AST EXPRESSED JUICE							
Degrees Brix	3.23	2.24	3.42	2.14	2.06	2.22	3.92
Degrees Purity	72.45	74.04	73.58	72.03	67.70	75.91	76.55
Purity Drop	**14.71**	**12.68**	**11.72**	**14.72**	**19.60**	**11.62**	**11.72**
IXED JUICE							
Degrees Brix	14.81	15.93	13.97	14.44	13.89	13.36	15.04
Degrees Apparent Purity	86.02	83.64	—	—	—	—	86.84
Degrees Gravity Purity	85.89	—	83.54	84.83	85.70	84.77	86.82
Purity Drop	**1.14**	**3.08**	**1.76**	**1.92**	**1.60**	**2.76**	**1.43**
Reducing Sugars/Sucrose Ratio	3.09	3.35	3.90	3.90	2.94	3.36	2.92
ARIFIED JUICE							
Degrees Brix	15.46	16.08	13.01	13.22	14.43	11.38	15.29
Apparent Purity	87.13	84.81	85.47	85.42	85.30	86.41	87.44
Reducing Sugars/Sucrose Ratio	2.87	3.19	3.71	3.50	2.93	3.28	—
Average pH	**7.25**	**7.12**	**7.33**	**7.10**	**7.17**	**7.48**	**7.00**
LTER CAKE							
Sucrose % Cake	4.00	4.12	1.66	1.01	3.94	1.31	1.18
Cake % Cane	4.35	5.00	5.73	6.50	3.80	5.71	5.00
RUP							
Degrees Brix	62.82	61.78	63.20	61.48	59.17	60.14	59.49
Apparent Purity	86.17	85.36	85.72	86.36	84.80	87.15	87.54
Reducing Sugars/Sucrose Ratio	2.36	3.25	3.49	3.34	1.96	2.90	2.76
Average pH	**6.91**	**6.45**	**6.52**	**6.50**	**6.67**	**6.64**	**6.50**

*Specific Feed Rate=Lbs of Fibre milled per hour, per cu. ft. of Total Roller Volume.

FIBRE, ANALYSIS OF Bagasse, Juices, Syrup, Filler Cake and Purity Drops

GD	DL	GH	MV	JB	UC	TS	ME	IL	RN	SZ	UK	Means
96.38	**97.13**	**96.60**	**95.82**	**86.98**	**92.20**	**97.08**	**95.95**	**94.89**	**96.07**	**95.74**	**96.20**	**95.9[illegible]**
88.24	89.54	88.71	88.89	79.64	84.66	89.41	88.56	87.59	89.31	88.87	90.30	88.[illegible]
50.11	**28.78**	**44.09**	**40.06**	**42.81**	**37.34**	**30.92**	**27.30**	**32.93**	**43.09**	**41.77**	**50.67**	**37.9[illegible]**
284	368	199	285	269	222	214	300	281	193	230	178	2[illegible]
53	52	58	46	28	—	46	51	49	63	48	54	
92.39	95.70	93.26	93.67	94.35	94.59	94.82	95.83	95.50	92.88	94.09	92.20	94.[illegible]
42.35	55.24	31.01	42.97	36.90	32.08	33.79	46.65	42.64	31.66	33.00	26.04	39.[illegible]
2.97	1.80	2.52	2.51	2.33	2.00	1.98	1.65	1.75	2.65	2.54	3.12	2.[illegible]
51.98	52.21	53.11	53.63	52.61	52.75	52.47	50.85	53.74	52.49	53.32	54.98	53.[illegible]
43.89	43.42	43.26	43.06	44.05	44.39	44.92	46.76	43.54	43.86	43.17	41.05	43.[illegible]
33.99	33.18	36.08	35.06	31.19	32.56	35.08	33.20	34.81	37.33	33.15	35.68	34.[illegible]
3,105	**3,107**	**3,016**	**2,969**	**3,063**	**3,056**	**3,081**	**3,227**	**2,975**	**3,067**	**3,088**	**2,842**	**2,9[illegible]**
7,244	**6,583**	**7,382**	**6,884**	**6,602**	**7,190**	**7,244**	**7,128**	**6,831**	**7,741**	**6,600**	**6,810**	**6,7[illegible]**
21	17	15	23	27	33	27	16	25	21	24	N.R.	
42	34	40	35	45	73	55	47	43	48	52	N.R.	
62	**83**	**70**	**75**	**70**	**76**	**82**	**83**	**82**	**71**	**73**	**70**	
19.50	20.01	19.58	19.88	18.80	18.32	19.82	19.31	19.87	20.17	20.27	20.05	19.[illegible]
85.90	87.04	86.40	87.40	85.32	85.86	86.73	86.28	86.76	88.20	88.55	88.88	86.[illegible]
3.09	1.60	2.56	2.01	2.73	3.70	2.59	2.11	2.09	3.07	3.19	4.17	2.[illegible]
71.90	71.20	69.80	76.20	68.60	70.70	76.05	68.89	64.59	74.30	72.73	78.90	72.[illegible]
14.00	**15.84**	**16.60**	**11.20**	**16.82**	**15.16**	**10.68**	**17.39**	**22.17**	**13.90**	**15.82**	**9.98**	**14.[illegible]**
13.46	12.83	15.53	14.01	13.69	13.91	15.12	13.24	14.06	15.08	15.53	16.46	14.[illegible]
84.22	—	—	—	—	83.74	—	—	84.85	87.36	86.41	88.40 }	85.[illegible]
—	84.61	85.41	86.30	83.71	83.76	85.35	83.70	85.20	—	86.61	88.46 }	
1.68	**2.43**	**1.00**	**1.10**	**1.61**	**2.12**	**1.38**	**2.58**	**1.91**	**0.80**	**2.14**	**0.48**	**1.[illegible]**
4.77	3.32	4.01	2.94	5.11	4.48	3.85	3.70	4.26	3.35	2.98	2.61	3.[illegible]
13.27	12.24	14.36	13.24	13.55	14.19	14.50	11.45	13.64	16.89	15.81	16.63	14.[illegible]
84.80	85.33	86.00	87.70	83.54	83.76	86.40	85.12	86.66	87.90	86.59	88.82	86.[illegible]
4.74	3.24	2.75	2.84	4.83	3.36	3.61	3.69	4.36	2.96	2.67	2.70	3.[illegible]
7.20	**7.50**	**7.26**	**7.30**	**7.40**	**7.10**	**7.10**	**7.56**	**7.26**	**N.A.**	**7.28**	**7.40**	**7.[illegible]**
1.09	1.62	2.61	1.51	3.35	1.98	1.89	0.73	1.79	2.43	3.47	2.73	2.[illegible]
3.00	5.87	6.04	5.00	4.50	3.00	4.87	5.53	3.54	5.54	5.18	4.00	5.[illegible]
61.39	60.26	54.86	60.58	58.48	60.97	60.90	62.16	62.07	54.29	61.40	57.39	60.[illegible]
85.10	85.60	86.20	86.70	82.97	83.85	86.50	84.97	86.18	88.20	86.66	88.50	86.[illegible]
4.07	3.15	3.03	3.05	3.60	3.21	3.48	3.74	3.40	2.20	2.17	2.68	3.[illegible]
6.90	**6.90**	**7.12**	**6.90**	**6.30**	**6.40**	**6.30**	**6.85**	**6.66**	**N.A.**	**6.83**	**6.80**	**6.[illegible]**

TABLE 4 DATA regarding Boiling,

SYMBOLS INDICATING FACTORY	PG	UF	EM	FX	EN	AK	DK
Brix in Mixed Juice % Cane	**15.62**	**16.45**	**15.18**	**14.92**	**14.89**	**15.11**	**15.10**
A-MASSECUITE							
Cu. ft. per ton of brix*	26.62	31.56	35.42	28.42	25.16	29.58	28.60
Brix of massecuite	92.12	93.16	91.59	92.57	90.43	93.28	93.71
Purity of massecuite	86.62	86.45	87.21	86.91	84.90	88.24	89.91
Purity of A-molasses	70.54	70.01	72.61	70.32	70.30	70.04	73.07
Drop in purity	16.08	16.44	14.60	16.59	14.60	18.20	16.84
EXHAUSTION	63.00	63.41	61.12	64.31	57.90	68.84	69.60
PURITY A-m.c.—PURITY SYRUP	**+0.45**	**+1.09**	**+1.49**	**+ 0.65**	**+ 0.01**	**+1.09**	**+2.37**
B-MASSECUITE							
Cu. ft. per ton brix*	9.24	9.95	11.37	8.52	10.38	8.24	9.59
Brix of massecuite	94.98	95.63	92.96	93.03	92.41	94.58	93.84
Purity of massecuite	74.39	72.00	73.91	71.55	71.30	71.58	75.13
Purity of B-molasses	51.96	55.11	52.63	51.78	54.30	47.83	54.75
Drop in purity	22.43	16.89	21.28	19.77	17.00	23.75	20.38
EXHAUSTION	62.76	52.26	60.78	57.30	52.20	63.60	59.95
C-MASSECUITE							
Cu. ft. per ton brix*	7.80	9.21	9.44	9.09	8.56	7.80	9.11
Brix of massecuite	98.45	98.44	94.56	94.33	94.80	95.62	97.18
Purity of massecuite	60.72	60.03	60.57	61.15	62.7	59.23	62.06
Purity of C-molasses	38.91	41.29	41.30	42.53	43.1	38.04	39.87
Drop in purity	21.81	18.74	19.27	18.62	19.6	21.19	21.19
EXHAUSTION	58.80	53.17	54.20	52.98	54.9	57.74	59.46
CRYSTAL % MASSECUITE	35.15	31.42	31.04	30.56	32.6	32.70	35.86
TOTAL CU. FT. OF ALL MASSECUITES							
Per ton of Sugar made	56.92	67.78	76.33	61.20	60.46	58.63	59.87
Per ton of brix*	43.66	47.02	56.20	46.03	44.72	45.63	47.29
FINAL MOLASSES							
Degrees Brix (undiluted)	94.07	94.40	87.23	88.04	88.38	87.13	89.70
Apparent Purity	38.91	41.29	41.54	—	43.13	37.25	39.87
Gravity Purity	—	41.58	—	—	—	—	40.62
Refracto/Sucrose Purity	—	—	42.76	42.53	—	40.32	—
Reducing Sugars (%)	—	12.32	12.95	—	—	14.63	12.59
Sulphated Ash (%)	—	14.84	15.41	—	—	15.22	—
Reducing Sugars/Ash Ratio	—	0.83	0.84	—	—	0.96	—
Molasses of 85° Brix % Cane	3.37	3.99	3.67	3.41	3.97	3.08	2.97
CLARIFYING AGENTS							
Per 1,000 *tons Cane:*							
Tons Limestone	2.92	—	—	—	—	—	—
Tons Coke	0.34	—	—	—	—	—	—
Per ton Cane:							
Lb Lime	1.32	1.11	1.37	1.29	5.25	1.08	1.06
Lb Sulphur	0.01	Nil	Nil	Nil	2.16	Nil	Nil
p.p.m. Juice:							
Phosphoric Paste	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Separan	1.42	2.70	0.56	Traces	1.19	Nil	1.41

* Per ton of Brix in Mixed Juice.

EXHAUSTION = Parts Recovered Crystallised Sucrose per 100 Parts Massecuite.

Final Molasses and Chemical Consumption

GD	DL	GH	MV	JB	UC	TS	ME	IL	RN	SZ	UK	Mean
14.57	**15.66**	**14.74**	**15.12**	**14.47**	**13.84**	**14.92**	**15.03**	**15.16**	**14.79**	**15.51**	**14.87**	**15.2**
20.06	29.28	25.72	35.77	N.A.	27.76	24.73	32.85	43.05	24.64	22.26	30.87	29.0
93.16	93.2	92.46	91.41	92.11	92.10	92.6	93.9	90.42	91.63	92.40	92.48	92.3
83.29	87.7	88.6	88.1	82.7	86.06	86.7	86.0	88.73	86.8	84.93	86.91	86.6
62.56	73.1	72.2	74.4	65.7	68.50	68.2	71.2	77.56	71.4	70.98	71.54	70.7
20.73	14.6	16.4	13.7	17.0	17.56	18.5	14.8	11.17	15.4	13.95	15.37	15.9
66.48	61.9	66.6	60.7	59.9	64.78	67.1	59.8	56.10	62.0	56.60	62.14	62.8
— 1.80	**+2.10**	**+ 2.40**	**+1.40**	**—0.27**	**+2.21**	**+0.20**	**+1.00**	**+ 2.55**	**— 1.40**	**— 1.73**	**— 1.59**	**+ 0.6**
10.31	9.79	11.94	12.06	N.A.	11.74	11.24	16.55	13.66	11.74	12.85	8.61	10.3
95.51	94.1	94.53	94.17	93.89	93.58	94.5	95.2	92.31	94.80	95.42	95.54	94.2
71.32	74.2	73.6	74.9	72.5	73.24	73.2	70.6	77.10	74.1	72.06	71.92	73.0
54.80	54.4	52.4	50.4	53.8	52.48	53.3	54.2	56.95	53.0	53.23	50.88	53.0
16.52	19.8	21.2	24.5	18.7	20.76	19.9	16.4	20.15	21.1	18.83	21.04	20.0
51.24	58.5	60.5	65.9	55.8	59.65	58.2	50.7	60.71	60.6	55.87	59.56	58.3
8.13	7.98	8.47	8.56	N.A.	10.94	8.73	8.89	10.04	7.81	11.97	6.48	8.8
97.84	95.7	96.36	96.74	95.95	94.22	97.4	97.4	96.02	96.64	99.91	98.73	96.6
54.23	60.1	61.3	59.3	61.2	63.57	59.6	58.0	61.64	62.7	61.93	58.98	60.4
36.23	42.0	39.8	41.2	41.5	43.78	39.9	40.5	36.60	40.7	41.34	39.92	40.4
18.00	18.1	21.5	18.1	19.7	19.79	19.7	17.5	25.04	22.0	20.59	19.06	20.0
52.05	51.9	58.2	51.9	55.0	55.37	55.0	50.7	64.07	59.1	56.68	53.79	55.5
27.62	29.9	34.4	29.8	32.3	33.17	31.9	28.6	37.92	35.8	35.07	31.32	32.4
51.02	60.96	60.22	72.40	N.A.	69.73	57.90	77.60	87.94	56.08	60.54	56.75	64.0
38.48	47.05	46.12	56.39	N.A.	50.44	44.93	58.31	66.74	44.19	47.07	43.96	48.
93.51	85.6	91.88	90.67	85.06	86.79	91.78	85.19	87.25	93.68	92.26	86.65	**93.4
36.23	42.0	—	—	—	43.78	39.90	40.47	36.60	40.71	41.46	37.54	
—	—	39.72	41.24	41.52	—	41.16	—	39.16	—	41.65	40.35	**40.6
—	42.5	—	—	—	—	—	40.97	—	—	—	—	
—	17.4	10.21	12.94	12.36	—	13.96	13.76	15.33	—	14.54	10.98	
—	—	—	—	—	—	12.18	12.94	10.28	—	12.93	14.00	
—	—	—	—	—	—	1.15	1.06	1.49	—	1.12	0.78	
4.09	3.10	3.16	3.43	4.09	3.94	3.43	3.37	3.38	3.01	3.54	2.20	**3.4
—	—	7.75	—	—	—	—	—	—	—	5.37	—	
—	—	0.99	—	—	—	—	—	—	—	0.54	—	
1.24	0.85	5.28	1.10	N.A.	1.21	1.35	1.24	1.16	4.73	6.67	0.90	
Nil	Nil	1.21	Nil	Nil	Nil	Nil	Nil	Nil	1.59	1.65	Nil	
Nil	42.99	Nil	Nil	N.A.	Nil	Nil	Nil	Nil	106	Nil	219	
4.39	2.43	Nil	5.74	N.A.	2.48	0.29	2.63	8.01	Nil	Nil	N.A.	

**Converted into Spindle Bri

NAME OF MILL	Luabo	Marromeu	Mhlume	Ubombo R.	Triangle
The season started on	23rd May	9th May	23rd May	1st May	1st May
Closing date of reporting	15th Oct.	28th Nov.	19th Jan.	30th Dec.	23rd Jan.
TONS (2,000 lbs) CANE CRUSHED	446,512	604,001	705,402	693,268	1,103,313
TONS SUGAR MANUFACTURED	51,496	66,784	81,385	78,012	130,400
Tons Cane crushed per hour	153	169	140	143	228
Overall Time Efficiency %	96	93	83	94	79
Percentage of White Sugar made	71	58	3	7	10
SUCROSE % CANE	13.91	13.71	13 68	13.29	14.09
FIBRE % CANE	13.81	13 36	13 32	14.32	13.59
Tons Cane per ton Sugar	8.67	9 04	8 67	8 89	8.46
JUICES					
Purity First Expressed Juice	86.69	84.90	87.77	85.51	86.00
Purity Last Expressed Juice	71.10	76.19	75.51	72.33	76.30
Purity Drop	15.59	8.71	12.26	13.18	9.70
Purity of Mixed Juice	85.38	82.93	85.79	83.73	84.51
Red. Sugars/Sucrose Ratio	4.09	3.96	3 85	5.04	5.91
MILLING AND BAGASSE					
Imbibition % Fibre	234.21	171.73	176 95	187.08	212.76
LOST ABSOLUTE JUICE % FIBRE	43.46	52.97	47.72	36.09	51.07
Imbibition % Cane	32.34	22.94	23.57	26.80	28.92
SUCROSE EXTRACTION	94.19	92.44	93.49	94 75	92.65
Sucrose % Bagasse	2.52	3.39	2.98	2 21	3.27
Moisture % Bagasse	52.28	51.84	51.40	51.50	52 80
Lower Calorific Value (btu/lb)	**3,088**	**3,110**	**3,155**	**3,161**	**3,029**
Available btu per lb Brix	**6,443**	**6,220**	**6,316**	**6,624**	**6,205**
RECOVERIES					
BOILING HOUSE PERFORMANCE	95.05	95.14	96.27	96.99	97.29
Boiling House Recovery	87.36	86.36	88.87	88.46	89.15
Overall Recovery	82.29	79.83	83.09	83.82	82.60
SUCROSE BALANCE					
Lost in Filter Cake	0.83	1.14	0.48	0.62	0.33
Lost in Final Molasses	8.14	8.90	7.82	9.58	8.39
Undetermined Losses	2.93	2.57	2.10	0.73	1.37
Lost in Boiling House	11.20	12.61	10.40	10.93	10.05
Lost in Bagasse	5.81	7.56	6.51	5.25	7.35
TOTAL OF ALL LOSSES	17.71	20.17	16.91	16.18	17.40
Filter Cake % Cane	5.00	4.57	2.47	5.00	2.25
Sucrose % Filter Cake	2.31	3.42	2.63	1.71	1.80
GRAVITY PURITY OF FINAL MOLASSES	40.32	39.87	—	39.90	36.68
Apparent Purity	39.61	36.37	38.61	36.00	32.64
Degrees Brix of Final Molasses	94.01	91.72	88.72	90.70	93.91
Weight at 85° Brix % Cane	3.30	3.60	3.12	3.78	3.82
DENSITY OF SYRUP (°BRIX)	59.10	64.50	57.67	59.60	57.18
CU. FT. MASSECUITE PER TON BRIX					
A-massecuite	34.34	69.17	20.82	29.03	35.96
B-massecuite	19.70	14.41	13.43	10.67	8.32
C-massecuite	12.57	9.73	7.89	10.39	10.96
TOTAL	66.60	90.97	42.15	50.09	54.96
CRYSTAL % SUCROSE IN MASSECUITE					
A-massecuite	59.91	61.52	60.64	61.1	65.28
B-massecuite	51.92	63.91	58.16	61.5	64.67
C-massecuite	53.76	58.89	62.00	61.3	68.26
Crystal % C-massecuite	31.42	34.09	36.39	36.3	41.65
Purity of Evaporation Syrup	84.82	85.00	86.88	84.1	84.90
Purity of A-massecuite	82.82	86.28	84.19	86.0	88.25
Difference in Purity	−2.00	+1.28	−2.69	+1.9	+3.35

TABLE 6 AVERAGE MANUFACTURING RETURNS by Monthly Periods (SEASON 1966-1967) for South African Mills

END OF MONTHLY PERIOD		April 30 1966	May 28 1966	July 2 1966	July 30 1966	August 27 1966	October 1 1966	October 29 1966	Nov. 26 1966	Dec. 31 1966	January 28 1967	March 4 1967	March 19 1967
TONS CANE CRUSHED	Month	107,235	907,266	1,659,097	1,557,944	1,607,049	2,071,038	1,639,423	1,651,179	1,808,639	1,435,552	978,209	59,875
	To-date	107,235	1,077,501	2,736,717	4,294,661	5,901,710	7,972,748	9,612,171	11,263,350	13,071,989	14,507,541	15,485,750	15,545,625
TONS SUGAR MADE AND ESTIMATED	Month	10,403	104,173	191,048	187,161	195,088	254,645	200,226	195,043	207,980	155,716	92,625	5,806
	To-date	10,403	114,576	305,605	492,766	687,854	942,499	1,142,725	1,337,768	1,545,748	1,701,464	1,794,089	1,001,856
TONS CANE CRUSHED PER HOUR	Month	188	162	168	165	162	163	169	168	150	168	168	27
	To-date	188	165	166	166	165	164	165	165	163	164	164	163
SUCROSE % CANE	Month	13.04	12.91	13.45	14.13	14.28	14.45	14.34	14.06	13.48	13.16	11.84	11.97
	To-date	13.04	12.83	13.20	13.54	13.74	13.93	14.00	14.00	13.93	13.86	13.73	13.72
FIBRE % CANE	Month	15.80	14.85	14.83	14.67	14.74	14.88	15.01	15.11	15.46	15.64	15.93	15.69
	To-date	15.80	14.07	14.87	14.80	14.78	14.81	14.84	14.88	14.96	15.03	15.09	15.09
TONS CANE PER TON SUGAR	Month	10.30	9.31	8.68	8.32	8.24	8.13	8.19	8.47	8.70	9.22	10.56	10.31
	To-date	10.30	9.40	8.95	8.72	8.58	8.46	8.41	8.42	8.46	8.53	8.63	8.63
LOST ABSOLUTE JUICE % FIBRE	Month	41	36	36	37	36	39	37	37	40	41	41	36
	To-date	41	37	36	36	36	37	37	37	36½	37	38	38
IMBIBITION % FIBRE	Month	340	271	270	227	263	256	263	248	267	259	256	275
	To-date	340	278	273	247	269	266	265	263	263	263	262	262
EXTRACTION	Month	93.15	94.44	94.61	94.47	94.44	94.43	94.30	94.26	93.79	93.75	93.40	94.83
	To-date	93.15	94.29	94.49	94.48	94.47	94.46	94.44	94.42	94.32	94.26	94.22	94.22
SUCROSE % BAGASSE	Month	2.26	2.11	2.16	2.32	2.45	2.28	2.43	2.33	2.41	2.25	2.11	1.67
	To-date	2.26	2.13	2.16	2.21	2.28	2.28	2.30	2.30	2.32	2.31	2.30	2.29
MOISTURE % BAGASSE	Month	54.00	52.81	52.98	52.65	53.11	52.16	53.55	53.40	53.54	53.54	53.76	55.11
	To-date	54.00	53.54	53.25	53.03	53.05	52.81	52.93	53.00	53.08	53.13	53.52	53.52
BOILING HOUSE PERFORMANCE	Month	93.90	95.14	97.14	96.58	96.75	95.67	96.25	96.05	95.47	95.87	95.17	94.31
	To-date	93.90	95.01	96.33	96.35	96.46	96.25	96.25	96.22	96.03	96.01	95.97	95.96
BOILING HOUSE RECOVERY	Month	84.45	86.81	88.79	89.82	88.29	88.87	89.35	88.05	88.05	87.87	86.36	84.23
	To-date	84.45	86.58	87.95	88.66	88.55	88.64	88.76	88.66	88.57	88.51	88.39	88.38
OVERALL RECOVERY	Month	78.67	81.96	84.00	84.86	83.38	83.95	84.26	82.92	82.58	82.35	80.66	79.87
	To-date	78.67	81.65	83.10	83.76	83.66	83.74	83.83	83.69	83.54	83.43	83.28	83.27
PURITY OF MIXED JUICE	Month	80.77	83.31	84.91	85.51	85.50	85.55	85.93	85.78	84.96	84.71	83.10	84.25
	To-date	80.77	83.06	84.20	84.69	84.92	85.09	85.23	85.31	85.27	85.18	85.06	85.06
REDUCING SUGARS/SUCROSE RATIO	Month	6.46	4.38	3.44	3.37	3.50	3.37	3.18	3.24	4.00	4.09	4.78	4.48
	To-date	6.46	4.59	3.80	3.67	3.59	3.53	3.44	3.41	3.53	3.75	3.62	3.63
SUCROSE IN FINAL MOLASSES % SUCROSE IN CANE	Month	12.08	10.16	8.20	8.41	8.56	8.21	8.41	8.64	9.04	8.69	10.56	10.10
	To-date	12.08	10.34	9.02	8.79	8.72	8.37	8.56	8.57	8.63	8.64	8.74	8.75
UNDETERMINED LOST SUCROSE % SUCROSE IN CANE	Month	1.76	1.66	1.76	0.77	1.70	1.39	0.77	1.82	1.27	1.77	1.33	—
	To-date	1.76	1.64	1.71	1.25	1.38	1.59	1.19	1.37	1.34	1.37	1.38	1.38
GRAVITY PURITY OF FINAL MOLASSES	Month	40.09	42.12	39.50	41.20	40.70	42.30	40.57	42.02	41.20	41.60	—	40.90
	To-date	40.09	41.88	40.51	40.76	40.60	40.99	40.92	41.08	41.09	41.14	40.65*	40.65*
FINAL MOLASSES OF 85° BRIX % CANE	Month	4.31	3.66	3.29	3.39	3.59	3.30	3.50	3.48	3.48	3.64	—	—
	To-date	4.31	3.73	3.46	3.43	3.48	3.43	3.44	3.44	3.44	3.46	3.47	3.47*
MONTHLY RAINFALL (INCHES)		2.17	2.81	1.18	0.39	1.69	1.88	2.06	3.61	3.66	6.13	4.96	N.A.
TOTAL RAINFALL FROM JANUARY 1st		12.36	15.51	16.64	17.05	18.78	20.78	22.68	26.26	29.98	6.13	11.12	N.A.

* Refracto Brix converted to Spindle Brix Purities.

TABLE 7 COMPARATIVE MANUFACTURING DATA of RECENT YEARS (S.A. MILLS)

SEASON	1966/67	1965/66	1964/65	1963/64	1962/63
CANE					
Sucrose % Cane	13.72	12.99	13.90	13.55	13.30
Fibre % Cane	15.09	15.57	15.38	15.50	15.49
JUICES					
Brix° First Expressed Juice	19.84	19.27	20.27	19.78	19.69
Purity of First Expressed Juice	86.97	86.30	87.54	87.37	85.52
Purity of Last Expressed Juice	72.43	72.30	74.30	72.66	71.49
DROP in Purity	14.54	14.00	13.24	14.71	14.03
Purity of Mixed Juice	85.06	84.22	85.52	85.30	83.36
Reducing Sugars/Sucrose Ratio	3.63	3.73	3.32	3.44	5.10
MILLING					
Imbibition % Fibre	262.00	260.53	256.00	258.26	266.16
LOST ABSOLUTE JUICE % FIBRE	37.91	37.58	36.98	37.47	37.36
Imbibition % Cane	39.60	40.57	39.37	39.84	41.24
EXTRACTION	94.22	93.99	94.16	94.08	94.15
Sucrose % Bagasse	2.29	2.20	2.34	2.29	2.24
Moisture % Bagasse	53.52	52.98	52.64	52.46	52.17
Bagasse % Cane	34.56	35.42	34.36	34.92	34.70
Lower Calorific Value (btu/lb)	**2,985**	**3,033**	**3,061**	**3,066**	**3,105**
Available btu per lb Brix	**6,788**	**7,414**	**6,870**	**7,166**	**7,173**
RECOVERIES					
BOILING HOUSE PERFORMANCE	95.96	95.65	97.07	97.19	96.29
Boiling House Recovery	88.38	87.67	89.65	89.60	87.80
Overall Recovery	83.27	82.40	84.52	84.30	82.66
Tons Cane per Ton Sugar	8.63	9.20	8.42	8.63	8.96
FILTER CAKE					
Sucrose % Cake	2.16	1.57	1.30	1.37	1.26
Filter Cake % Cane	5.21	5.62	5.25	5.57	5.29
FINAL MOLASSES					
GRAVITY PURITY	40.65*	39.91	39.87	39.45	39.63
Degree Brix	93.45*	91.72	91.58	91.21	89.17
Weight at 85° Brix % Cane	3.47*	3.59	3.33	3.15	3.91
AVERAGE SUGAR POLARIZATION	98.58	98.49	98.60	98.51	98.62
SUCROSE BALANCE					
Lost in Filter Cake	0.82	0.68	0.52	0.56	0.50
Lost in Final Molasses	8.75	9.38	8.13	7.79	9.92
Undetermined Losses	1.38	1.53	1.09	1.43	1.08
LOST IN BOILING HOUSE	10.95	11.59	9.73	9.78	11.50
Lost in Bagasse	5.78	6.01	5.84	5.92	5.84
TOTAL OF ALL LOSSES	16.73	17.60	15.58	15.70	17.34
CU. FT. OF MASSECUITES PER TON BRIX					
A-massecuite	29.02	27.89	27.79	26.67	24.69
B-massecuite	10.30	11.78	11.27	11.03	13.02
C-massecuite	8.83	9.14	7.98	7.92	9.36
TOTAL	48.15	48.81	47.03	45.62	47.07
EXHAUSTION OF MASSECUITES					
A-massecuite	62.85	62.78	62.45	62.18	64.52
B-massecuite	58.36	59.53	60.39	60.54	59.76
C-massecuite	55.59	56.37	56.80	56.95	57.00
PURITY RISE					
A-massecuite purity	86.68	85.91	86.68	86.10	85.01
Syrup purity	86.03	85.06	86.70	86.38	84.26
RISE	+0.65	+0.85	−0.02	−0.28	+0.75
DENSITY (°BRIX) OF SYRUP	60.35	59.33	58.77	58.06	57.80

**Converted into Spindle Brix.

TABLE 8 **COMPARATIVE DATA of REPORTING S.A. MILLS from 1925 ONWARDS**

PERIOD (Season)	Per cent Cane		Cane/Sugar Ratio		Extraction	Lost Absol. Juice % Fibre	Per cent Bagasse		Imbibition per cent		Mixed Juice		Final Molasses Purity	Boiling House Performance	Boiling House Recovery	Overall Recovery
	Sucrose	Fibre	Tel Quel	96° Sugar			Sucrose	Moisture	Cane	Fibre	Purity	Reducing Sugar Ratio				
Average 1925-1934	13.19	15.78	9.86	9.64	89.83	58.4	3.88	50.57	27.6	175	85.09	3.65	45.3	90.6	83.67	75.12
Average 1935-1944	13.53	15.30	8.96	8.73	92.05	48.9	3.11	51.60	32.6	213	86.01	3.22	43.3	95.4	88.36	81.34
1945	**14.28**	15.99	**8.29**	**8.08**	93.28	39.3	2.77	**50.19**	35.0	219	86.23	3.38	42.0	96.4	89.29	83.30
1946	14.21	16.21	8.36	8.14	93.07	40.5	2.79	50.32	35.2	217	85.86	3.30	41.8	96.7	89.12	82.94
1947	13.32	15.80	8.84	8.60	93.44	39.8	2.54	50.46	34.4	218	86.24	2.95	41.1	96.8	89.61	83.73
1948	13.89	15.90	8.55	8.31	93.32	39.8	2.67	50.53	34.1	214	85.92	3.67	41.5	96.5	89.14	83.19
1949	13.52	16.19	8.76	8.52	92.24	41.0	2.66	50.84	33.7	208	86.22	3.11	41.4	96.9	89.68	83.35
1950	14.19	15.80	8.32	8.09	93.33	39.3	2.72	51.22	32.8	206	86.40	3.12	40.5	96.9	89.63	83.65
1951	13.33	16.29	8.98	8.73	92.98	40.2	2.57	51.71	35.0	215	84.92	3.52	40.3	96.7	88.72	82.30
1952	13.87	16.10	8.50	8.27	93.00	40.8	2.65	52.53	34.9	217	86.25	2.92	39.3	97.2	89.96	83.66
1953	13.93	16.31	8.55	8.24	92.67	41.7	2.75	52.47	32.7	200	85.61	3.66	39.5	96.9	89.36	82.81
1954	13.34	16.03	8.87	8.65	92.40	44.1	2.75	62.92	30.7	191	85.86	3.28	39.3	97.4	90.04	83.20
Average 1945-1954	13.79	16.06	8.60	8.36	93.04	40.6	2.69	51.32	33.8	210	85.95	3.29	40.7	96.8	89.46	83.23
1955	13.87	15.74	8.51	8.28	92.32	45.5	2.91	53.18	32.1	204	85.96	3.40	39.6	97.9	**90.51**	83.56
1956	13.35	15.81	8.87	8.62	92.93	42.1	2.60	53.12	35.2	222	84.49	3.32	39.9	97.4	89.79	83.44
1957	13.11	15.38	8.93	8.67	93.36	40.9	2.47	53.06	34.5	224	85.10	3.69	**38.5**	**98.5**	90.43	84.42
1958	13.12	15.92	9.09	8.82	92.87	42.3	2.55	52.38	32.9	207	84.46	4.30	39.1	97.8	89.49	83.11
1959	13.66	15.92	8.74	8.44	92.86	43.0	2.66	53.26	34.6	218	85.52	3.51	40.3	97.1	89.42	83.04
1960	13.69	15.22	8.70	8.41	93.35	42.0	2.60	53.01	36.2	238	85.63	3.31	40.3	96.8	89.40	83.45
1961	13.75	**14.52**	8.54	8.26	94.21	39.0	2.43	52.54	36·7	253	**86.04**	3.31	39.5	97.1	89.72	**84.53**
1962	13.29	15.50	9.01	8.91	94.15	37.4	2.24	52.17	**41.2**	**266**	83.36	**5.11**	39.6	96.6	87.81	82.67
1963	13.55	15.50	8.66	8.42	94.08	37.5	2.29	52.46	39.8	258	85.30	3.44	39.4	97.2	89.60	84.30
1964	13.90	15.38	8.42	8.20	94.16	**37.0**	2.34	52.64	39.4	256	85.52	3.32	39.9	97.1	89.65	84.42
Average 1955-1964	13.53	15.49	8.75	8.46	93.43	40.7	2.51	52.78	36.3	235	85.24	3.67	39.6	97.4	89.58	83.69
1965	12.99	15.57	9.20	8.97	93.99	37.6	**2.20**	52.98	40.6	261	84.22	3.73	39.9	95.6	87.67	82.40
1966	13.72	15.09	8.63	8.40	**94.22**	37.9	2.29	53.52	39.6	262	85.06	3.63	40.6	96.0	88.38	83.27

Discussion

Mr. du **Toit:** It is stated in the paper that "richness of the juice also has its effect on sucrose extraction, a richer juice leading to a higher extraction figure".

Mr. Christianson, in a statistical analysis some years ago found no correlation between sucrose in cane and percentage extraction.

Mr. **Dowes** Dekker (reading the paper on behalf of Mr. Perk): The intention was to point out that it is more difficult for a mill crushing high sucrose cane to improve its extraction than it is for a mill crushing low sucrose cane. This is open to argument and the time has come when further data should be obtained in this connection.

Mr. Buchanan: As milling is a combination of juice dilution and juice expression then the state of dilution of the juice coming into the mill will have an effect on extraction, and this clearly is what Mr. Perk is referring to.

Mr. Covas: Mr. Perk mentions cubic foot of massecuite per ton of mixed juice. Luabo's figure appears high but the factory produced mill white sugar only and had to convert all *B' massecuites to white and triple cure them, causing additional circulation in the system. 'C massecuites could not be double cured and were remelted and returned to the pan floor.

Dr. Graham: Why is Mr. Perk using extraction as a yardstick for evaluation the effectiveness of the extraction process whereas the S.M.R.I. has always advocated lost absolute juice % fibre as a far more reliable figure.

He mentions enzymatic loss of sucrose in the diffuser but it is not certain that there are many enzymes or bacteria present at that stage because of scalding at the head of the diffuser. Destruction of sucrose in the diffuser is more likely to be tied up with pH. In tests recently carried out at the S.M.R.I. very much higher inversion rates have occurred than would have been predicted by Stadler's Table.

He mentions the poor dewatering mill performance at Entumeni but what effect would a drop in moisture from 56% to 53% have on extraction?

Dr. Douwes Dekker: Mr. Perk is not particularly concerned with the reduced extraction figure but has included it because others may be interested in it.

Regarding a drop in moisture content of final bagasse having an effect on extraction, this is an important point requiring further investigation.

LABORATORY CARBONATATION

by V. H. DAWES
Huletts South African Refineries Ltd,

The shortcomings of the current filterability tests in predicting the filter performance of sugars in Hulett's Refinery have recently been shown (3, 4). It would seem logical for a carbonatation refinery to use laboratory carbonatation to predict the filterability of incoming sugars. Although very little has been published, work into carbonatation techniques has been done by Dr. T. Yamane (5) as well as Tate & Lyle (1).

It has been found that the flow rate of factory carbonatated liquor through filter cloth in a C.S.R. filterability apparatus, modified to operate at SOX, gives a good reflection of actual factory performance (3). Laboratory carbonatation should therefore be able to predict factory performance, provided that a satisfactory, reproducible method, based on factory techniques, is used.

During preliminary work using a carbonatation tank borrowed from the Sugar Milling Research Institute, it was found that filterability results comparable with those of factory carbonatated liquor were obtainable only with a much higher lime/solids concentration than that used in the factory. The large amount of precipitate so formed, however, caused even the poorer sugars to behave well after carbonatation—in some cases better than factory carbonatated liquor. Since Yamane (5) has found a very good correlation between his laboratory carbonatation data and factor) performance, even though the flow rate which results from laboratory carbonation is much lower than in the factory, it was decided to fix the lime at 0.8% on solids and collect sufficient data to compare results with factory carbonatation.

To enable several methods to be compared, a carbonatation apparatus was designed and built to allow six batches of liquor to be carbonatated separately. The design is based on that of the S.M.R.I. tank, but each unit has been scaled down to contain only 500 grams of liquor—sufficient for the filterability test. The units are cylindrical with a conical bottom into the apex of which gas may be introduced through a sintered metal disc. An outlet valve is provided for each. The six units are enclosed in a common water tank through which water at 80 °C is circulated by means of a constant temperature water bath. Separate needle valves and flow meters control the flow of gas to each unit from a common supply. (See Fig. 1.)

Results achieved with this apparatus were found to be reproducible and comparable with those obtained using the S.M.R.I. tank.

In addition to fixing temperature and lime, gas flow rates were established to give a duration of gassing of 90 minutes as in the factory. A programme was then devised to compare filterabilities of laboratory carbonatated liquors with the filterability of corresponding samples of factory carbonatated liquor.

Melt liquor samples were taken in the factory at 15 minute intervals over four hours and composited. The brix was adjusted to 65° and the liquor divided into 500 gram aliquots. The samples were heated in the water bath to 80°C and lime slurry corresponding to 0.8% on solids added. The limed aliquots were transferred to the carbonatation tank at 15 minute intervals, gassed to pH 9.0 and filtered immediately.

Pure CO_2 was used in preference to an air-CO_2 mixture, as less frothing occurs with no apparent difference in results. Four different methods of gassing were used in the examination with duplication of each:

1. Constant rate gassing with slow stirring by of a mechanical stirrer.
2. Constant rate of gassing but no stirring.
3. Two stage gassing, the second half at a slower rate.
4. Two stage gassing, the second half at a faster rate.

Filterabilities (2) of the carbonatated melt liquor obtained in this way were compared with the filterability of factory carbonatated liquor collected over a corresponding period of time.

Results (See Fig. 2)

In each case, a higher filterability was obtained when slow stirring was employed. A faster rate had been found to reduce filterability. In addition, the filtrates obtained were clearer than those from the unstirred batches.

In contrast, the best correlation coefficient, 0.78, resulted from unstirred, constant rate gassing, with 0.63 for the stirred carbonatation. The other two methods gave correlation coefficients of 0.64 and 0.66 respectively. The trends as shown in the graph are similar. Taking into consideration the fact that over the period during which these tests were run, difficulties were being encountered in the carbonatation process in the refinery, these results seem sufficiently significant to warrant further investigation. Testing will be continued during the year ahead to accumulate sufficient data for a full evaluation.

Acknowledgements

In conclusion, the author would like to express his appreciation to Messrs. Bowes and Grenfell of the Sugar Milling Research Institute for their assistance in the construction of the new carbonatation tank, and to Miss Laughton of Hulett's Research Laboratory who assisted .with a lot of the testing, Thanks are also due to the Director of the Sugar Milling Research Institute for permission to use the facilities of the Institute, in particular the carbonatation tank.

Summary

Laboratory carbonatation as a means of evaluating the filterability of raw sugars received at Hulett's refinery is investigated. The design of a laboratory carbonatation apparatus is discussed and results of the first tests given.

References

1. Allen, C. H., and Orchard, W. J. H. Private communication 1958.

Archibald, R. D. "Variation of Filterability with Brix" proc. S.A.S.T.A. Vol. 39, 1965, p. 50.

Jennings R P. "A Modified Method for Determining Filterability" proc. S.A.S.T.A., vol. 40, 1966, p. 199.

Jennings, R. P., and Alexander, J. B. "A Comparison between Laboratory Filterability Tests on Affined Raws and the Filterability of Factory Carbonatated Liquors.' 2nd Technical Session, Cane Sugar Refining Research Project, 1966, in press.

Yamane, T., et al. "Filtration Impeding Materials in Raw Sugars of Various Origins. I.S.J., vol. 67, 1965. page 338. Vol. 68, 1966, pp. 3, 259.

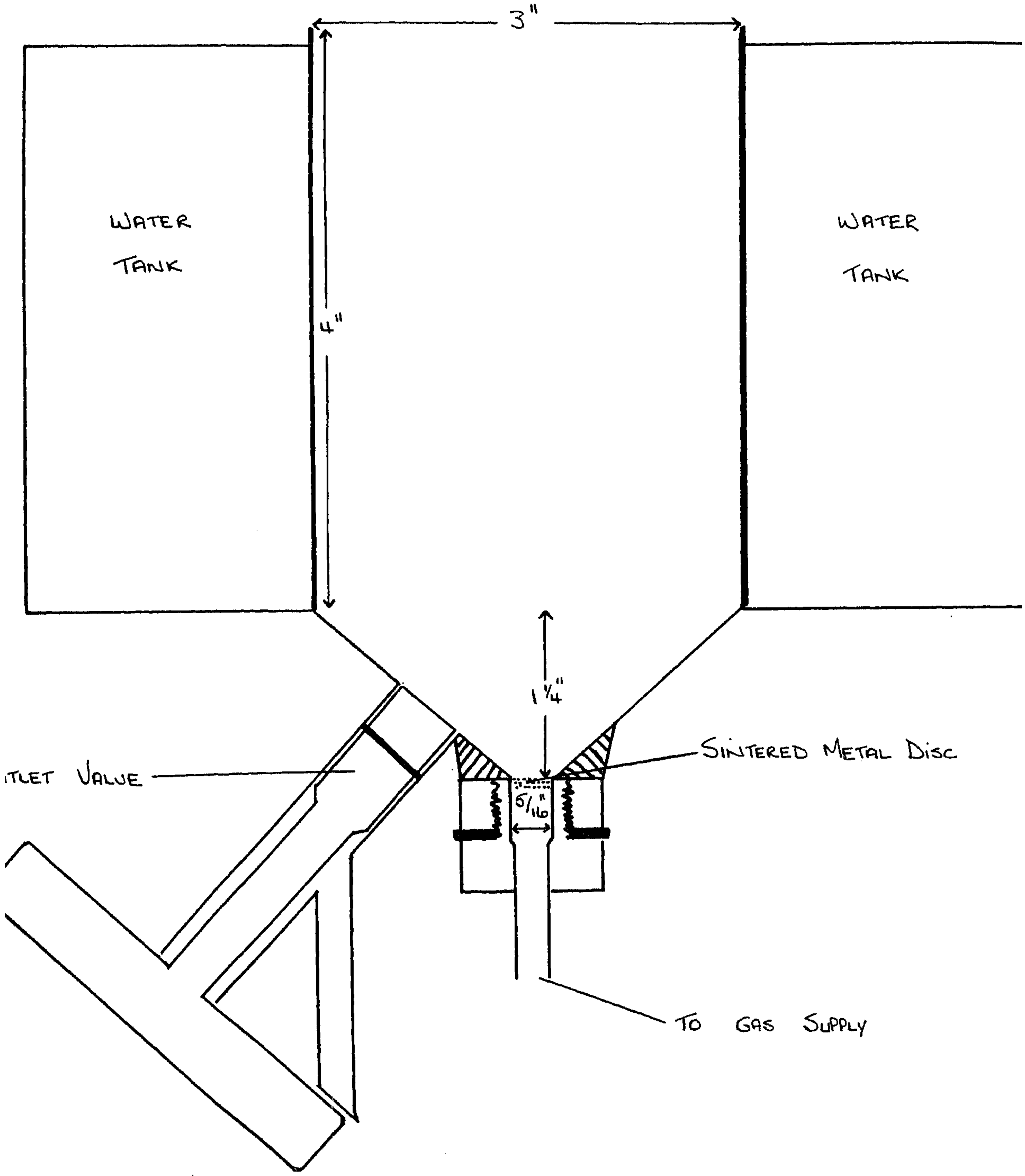


FIGURE 1

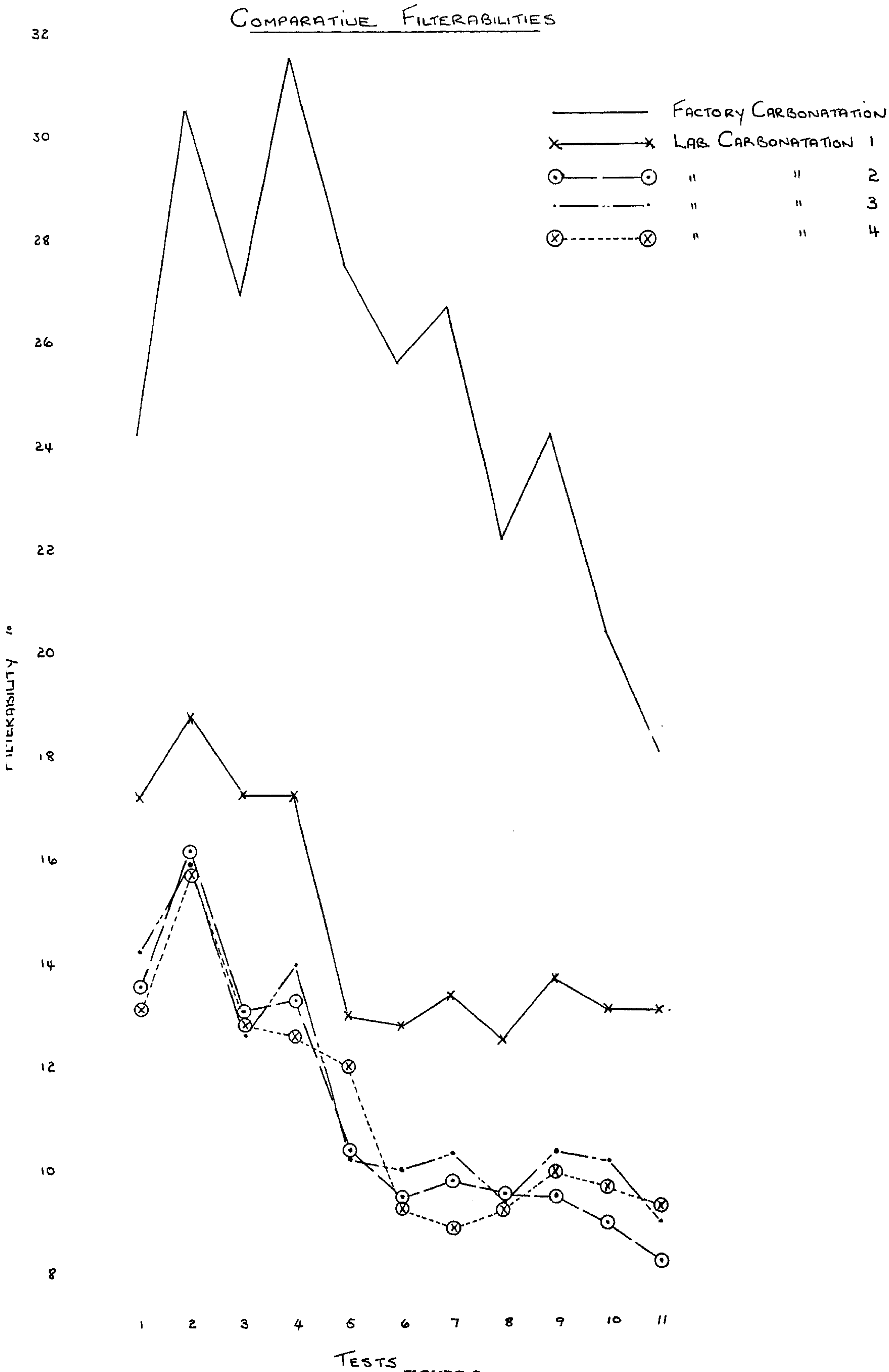

COMPARATIVE FILTERABILITIES
FACTORY CARBONATATION
LAB. CARBONATATION 1
" " 2
" " 3
" " 4
FILTERABILITY
32
30
28
26
24
22
20
18
16
14
12
10
8
1
2
3
4
5
6
7
8
9
10
11
TESTS

FIGURE 2

Dr. Matic: Yamane, using a rough method of carbonatation, obtained as good, if not better, co-relation with filterability than Mr. Dawes. It would be interesting to know why different figures were obtained when other methods of carbonatating were used. Has any effort been made to determine the impurities arising from the different methods e.g. have filter impeding impurities like starch been determined? The correlation appears to be better at high filterabilities than low filterabilities.

Mr. Dawes: The factory carbonatated liquors used in the refinery were not always typical of the liquors produced, but work is continuing and we hope next year to get better correlation. No work has been done at this stage on correlating impurities with filterability.

Mr. Chiazzari: Why was filtration done at 80°C and why was gassing not done at the normally accepted temperature of 50°C? I note also that a pH of 9 was chosen instead of 8 for gassing down.

Mr. Dawes: The modified C.S.R. test was designed for 80°C and carbonatation is done at the same temperature, as below that we run into trouble with our filters. The average pH of the carbonatated liquors we used from the refinery was 9, although sometimes it was as low as 8.4.

Mr, Alexander: Most filterability tests are carried out at a pH of 9 because this is the average figure for carbonatation refineries. Similarly, 80°C is the average temperature used for gassing in carbonatation refineries although we know that Tate and Lyle has gone as high as 90° with certain sugars. In South Africa the quality of the lime we use is important, with particular regard to the effect of manganese, and also the effect of oxygen on the reaction.

Mr. Chiazzari: Is there not some confusion between gassing temperature and filterability temperature.

Mr. Dawes: In the laboratory the test has been kept as simple as possible so as not to introduce other complications.

Mr. Buchanan: It appears that agitation rate affects filterability and it would be interesting to know what agitation rate was used.

Mr. Dawes: When a high rate of stirring was used results were poor but they improved when the rate was reduced. The average rate was 100 r.p.m. using a small stirrer. We tried to get a series of results at one constant rate of stirring—at this stage various rates have not been investigated.

CLARIFICATION WITH EMPHASIS ON STARCH REMOVAL

by G. G. CARTER
Tongaat Sugar Co. Ltd.

The removal of starch has, with the advent of the Rabe process, sprung into great prominence and this paper attempts to cover briefly the range of work done in this connection at Tongaat.

(1) *The Enzymatic Process*

Tongaat has, for some years, due to work done by P. N. Boyes,[1] been actively engaged in starch removal by the enzymatic process.

Briefly, this process involves the heating of Juice at pH 6.5 to 165°F (at which temperature the starch gelatinises) and then passing the Juice through destarching tanks where the starch, during a specified time interval, is removed by enzymatic action.

A typical analysis of the starch removal in these tanks is seen in Table I, Graph I.

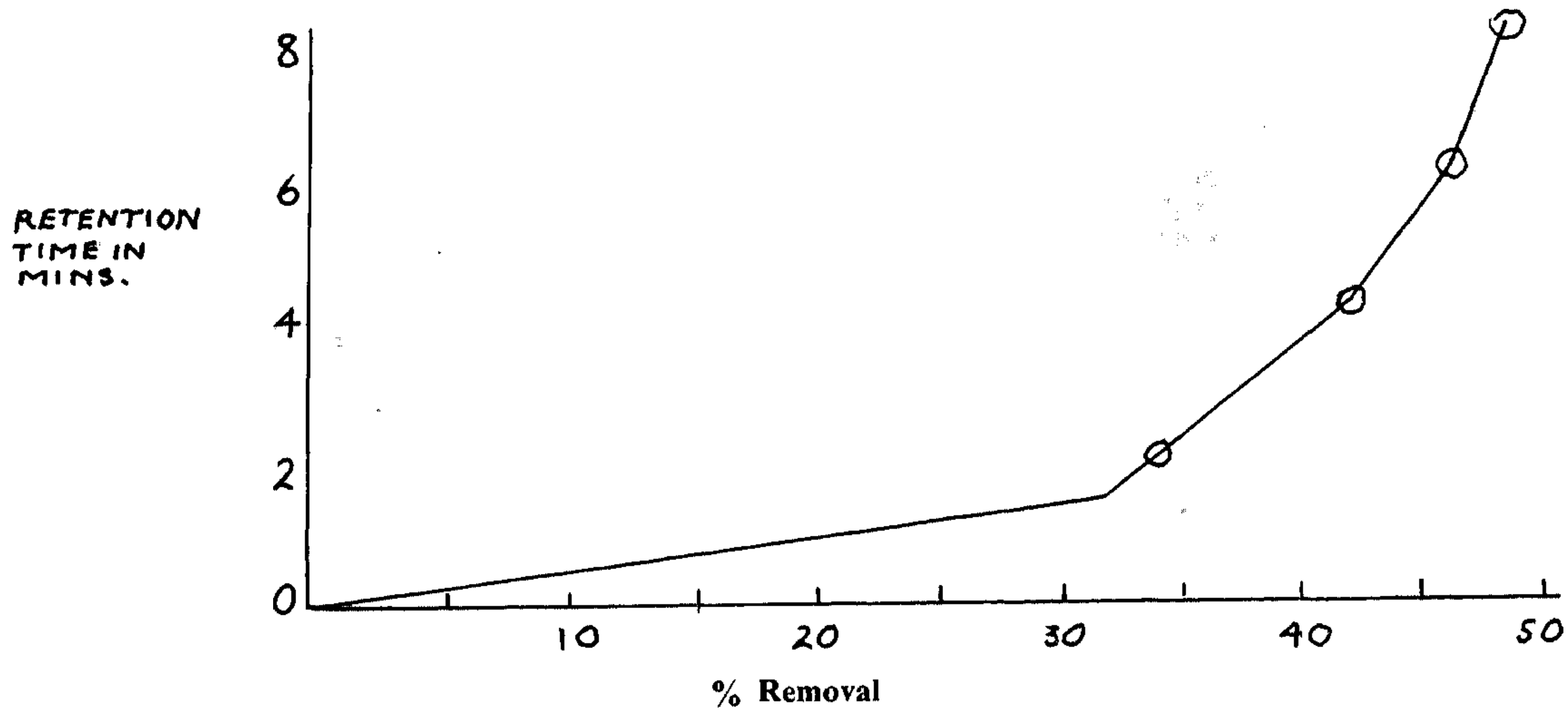
TABLE I

Starch content of juice in ppm and removal % in brackets

	Original	Tank 1	Tank 2	Tank 3	Tank 4
No. 1	350ppm 100%	200ppm (43 %)	160ppm(54%)	145ppm(59%)	155ppm(56%)
2	450ppm 100%	230ppm (49 %)	290ppm(36%)	270ppm(40%)	230ppm (49 %)
3	230ppm 100%	150pprn(35%)	100ppm (23%)	90ppm (61 %)	90ppm (61 %)
4	270ppm 100%	200ppm (26 %)	153ppm(43%)	110ppm(59%)	127ppm(53%)
5	370ppm 100%	183ppm(50%)	210ppm(43%)	180ppm(51%)	220ppm (41 %)
6	440ppm 100%	275ppm (37 %)	261 ppm (40%)	260ppm (40 %)	250ppm (43 %)
7	170ppm 100%	120ppm (30 %)	130ppm(24%)	170ppm(0%)	70ppm(59%)
8	255ppm 100%	205ppm (20 %)	140ppm(45%)	100ppm 60%	135ppm(47%)
Av.	316ppm(100%)	203ppm(36%)	181ppm 43%	166ppm 47%	157ppm 50.32

GRAPH I

THE REMOVAL % OF STARCH VS. TIME



From the graph of time vs. starch removed it is evident that the removal slows down after ten minutes and the possible loss of sucrose does not warrant further retention times in the tanks.

The sucrose loss in these tanks is given in Table II.

It is seen that the brix is higher in the exit Juice due to evaporation along the starch tanks. Thus the sucrose in the exit Juice when converted back to its original brix gives a loss of sucrose of 0.15%.

On the season's production this loss of sucrose is estimated to be R 10,000. The loss of this sucrose results in non sugars which are detrimental to the Boiling House, but on the other hand there could be

TABLE II

Study of sucrose and reducing sugars in juice before and after starch tanks

(A) Raw juice and O.F. to heaters:

	Brix (corr.)	Sucrose	Purity	Glucose %	Glucose Ratio
1	13.66	11.20	82.0	0.86	7.90
2	13.54	11.09	81.9	0.71	6.40
3	13.74	11.23	81.7	0.82	7.30
4	13.96	11.45	82.0	0.73	6.38
5	14.19	11.29	79.6	0.71	6.29
6	14.23	11.64	81.8	0.69	5.93
7	12.92	10.59	82.0	0.63	5.94
8	13.92	11.50	82.6	0.56	4.87
9	14.76	12.10	82.0	0.77	6.36
10	14.51	12.30	82.9	0.73	5.93
Average ..	13.94	11.43	81.99	0.72	6.33

(B) Juice after heating and digestion in starch tanks:

	Brix (corr.)	Sucrose	Purity	Glucose %	Glucose Ratio
	13.63	11.10	81.4	0.86	7.75
	13.63	11.14	81.7	0.69	6.19
	13.93	11.19	80.3	0.82	7.33
	13.97	11.47	82.1	0.71	6.19
	14.09	11.27	80.0	0.71	6.30
	14.43	11.60	80.4	0.71	6.12
	12,97	10.61	81.8	0.69	6.50
	14.01	11.50	82.1	0.56	4.86
	14.90	12.60	84.6	0.73	5.79
	14.58	12.26	81.85	0.71	5.79
Average ..	14.02	11.48	81.85	0.72	6.27

benefits to the boiling scheme by having lower viscosity massecuites.

From investigations during this season into sucrose losses in the clarification station, the present defecation system with its long retention time was estimated to lose ± R25,000 worth of sucrose per season.

Thus the present system of clarification and starch removal costs an estimated R35,000 per season or 18 cents a ton, based on 200,000 tons, in sucrose lost and removes 50% to 60% of the starch.

(2) *Middle Juice Carbonation*

Due to Natal's geographical position in an area of deficient rainfall sugar manufacture is made more difficult and additional techniques are required to produce world class raw sugars.

The most promising clarification process derived when this work started in 1965 seemed to be the Carbonation process. There was one point governing its use however, namely that the cost was considerably greater than simple defecation.

It was decided that the most promising process was the Middle Juice carbonation process developed extensively in Taiwan by T. Y. Chou,[2] but instead of a full scale double carbonation, we would merely "polish" the defecation liquors in a single carbonation stage thus reducing costs.

After some time suitable batch type operations were performed using laboratory apparatus, kindly lent us by Hulett's, and for many months the process seemed to work best on a syrup of 40 Brix at a carbonation temperature of 60 °C and maximum pH of 10.0.

Under these conditions the removal of impurities was expected to be:

(a) Phosphates 97%
(b) Starch 55%
(c) Gum 55%
(d) Silica 63%

The cost of the process was estimated to be 59 cents per ton for chemicals and 84 cents per ton including depreciation on equipment required for the process.

(3) *The Rabe Process*

At the time of the work on carbonation the industry began to rumble with the news of the Rabe process at Umzimkulu and by March 1966 we had the news from R. Jennings[3] of Hulett's Refineries that this sugar had processed with excellent results through the Rossburgh refinery.

Not being in a position to assess the process under factory conditions until July, it was nevertheless felt that some indication of its clarification potential was necessary on a laboratory scale.

Thus a series of comparisons were made with the developed carbonation process and the existing factory conditions.

For comparative purposes the Rabe process was done on Mixed Juice and the resultant clear Juice concentrated to 60 Brix. Three and a half hours later the Factory syrup was collected and part analysed, part subjected to the carbonation process.

After a series of twelve runs, the analyses of the known filter impeding compounds in these syrups were averaged and are presented in Table III.

TABLE III

Analysis of filter impeding impurities in three processes

		Starch ppm on Brix	Starch free Gum ppm	Silica ppm	Phosphate ppm	Ash %
(1)	Tongaat Process	960	15,770	376	114	1.31
(2)	Rabe Process	115(82.5)	13,875 (12)	192 (49)	80 (30)	1.27 (3)
(3)	Carbonation Process	600 42.0	6,500 (59)	84 (77)	10 (92)	0.96(17)

The figures in brackets represent the % Removed by Processes 2 and 3 above the present Factory Process which was taken as the standard.

From the results it is seen that carbonation (with the exception of starch removal) is superior to both defecation and the Rabe process in removing filter impeding compounds. However, in order to attempt to evaluate the Rabe process against carbonation as envisaged, it was decided by the author to arbitrarily multiply each impurity percentage removal over and above the standard process by an appropriate correlation factor given by T. Yamane et al.[4]

This factor is a correlation coefficient between the impurity and its effect on filterability through a carbonation slurry.

The total of these percentages thus modified will give an indication of the performance of the three processes. See Table IV.

Now if the process was perfect all impurity removal would be 100% and the total index would be 217.

From the results obtained the Rabe process appeared to cost 53 cents per ton including depreciation on capital equipment required and from the index of performance seemed to be but 10% poorer in overall performance compared to carbonation, but at only 2/3 of the cost. (The extra 30 cents a ton for carbonation might be covered by an increase in B.H.R., but this seems dubious.) So from the results obtained the evidence seemed to be very much in favour of the Rabe process.

(4) *Starch Removal Based on Sedimentation*

The Rabe process bases its starch removal on the trapping of the starch sack in a floe which is carried up by a flotation process and the scum decanted off to the filter station.

The reverse of the flotation process is sedimentation as in the existing clarification process. The author wondered whether this process could not be used successfully as a single stage clarification process without the high cost of the Flotation set up since it would mean no new equipment and a cheaper chemical bill. On the debit side however, were the facts that:

(i) The floe was likely to float due to incompleted deairation when clarifying at 65 °C.

(ii) There could be considerable microbiological destruction of sucrose at the temperature at which the operation is carried out.

(iii) The muds could well be weak, meaning a higher sucrose loss in filter cake.

From work in the laboratory the removal appeared to be 85% when the Juice was heated to 65°C, limed up to 8.4 pH and settled for 1 1/2 hrs. During this time laboratory tests showed no increase in the Reducing Sugar Ratio, indicating no loss of sucrose and in settling tests at these high pH's the Juice actually settled faster than the process feed.

On the 9th February 1967 a Dorr of 24' diameter was made available for the test and the lime was added by means of a 1/2" pipe as the Juice flowed into the mud thickening chamber.

The first eight hours after filling the Dorr were spent in trying to get some control over the pH which fluctuated between 10.0 and 6.7 as the flow of Juice was very intermittent and the lime cock kept blocking.

Finally however, a working understanding was reached and from 6.00 p.m. until 12.00 p.m. the clarifier behaved well producing Juice of clarity

TABLE IV

Performance index of two processes

Impurity	Coefficient	Rabe process		Carbonation	
		% Removal	Index	% Removal	Index
Starch	0.95	83	79	42	40
Gum	0.66		8	59	39
Silica	0.14	49	7	77	11
Phosphate	0.42	30	13	92	39
Possible Total	217		107		129

TABLE V

Control of Dorr No. 6 under cold clarification

	P.H. of Juice		Reducing Sugars/Pol		Starch content ppm on Brix		Mud vol. of Juice	
	In	Out	In	Out	In	Out	In	Out
	8.5	8.0	*4.09*	3.87	*2300*	510	30	83
	7.4	8.1	*3.61*	3.34	*3100*	350	34	95
	9.3	7.6	*4.63*	3.98	*2000*	440	29	98
	8.4	8,3	*4.51*	3.78	*1750*	390	29	97
	7.8	8.0					32	98
	6.7	7.7					30	98
	9.4	7.3					28	98
							29	98
Average	8.21	7.86	4.21	3.74	2288	423	50	96

equal to its twin next door, which was operating under the normal defecation process.

During this period the following control figures observed. See Table V.

From 12.00 p.m. until 6.00 a.m. the following morning the flow of Juice once more became erratic and the Juice became turbulent with a drop in starch removal to 67%—no better than the enzymatic process.

At 8.00 a.m. the process was stopped and the following points had emerged:

(1) Sedimentation can remove starch and the maximum seems to be + 85 %.

(2) During the 24 hours under observation no apparent loss in sucrose occurred but this is not sufficient proof that during a season's work there would not be bacterial build up and sucrose destruction.

(3) No flotation of the mud occurred but the settling rate of the mud was slower than expected and the Dorr's capacity did not reach its designed 100 tons per hour.

(4) The mud volume had compacted down to 98% showing that the actual retention time in the clarifier must have been + 3 hrs.

Acknowledgements

I should like to thank all those people who helped in this work and especially the Tongaat Sugar Company for their permission to publish this report.

References

Boyes, P. N. 34th Conf. S.A.S.T.A. p. 91 (60).
Chou, T. Y. *Middle Juice* Carbonation Honig Vol. 1. pp. 711-725.
3. Jennings, R. 40th Conf. S.A.S.T.A. p. 199 (66).
4. Yamane, T. *et ai* I.S.J. 67 pp. 333-337. 68 pp. 3-6 (65-66).

Discussion

Mr. Buchanan: When any process involving the destruction of starch is being used it must not be forgotten that starch consists of two fractions, amylose and amylopectin, and as amylopectin is less soluble there is always the danger that amylose might be selectively destroyed and the amylopectin end up in the sugar, where it apparently causes retardation of filtration rates.

Dr. Matic: According to figures in Table III the ash content in the carbonatation process is considerably less than in the Tongaat or Rabe process, using a pH of 10. At the S.M.R.I. our results were different as residual calcium was always extremely high.

Mr. Carter: The ash content of carbonatation liquors will depend to a large extent on the process used.

Dr. Matic: We tried various processes without success to try and reduce the figure. Mr. Carter was simply carbonatating defecated liquor from the factory and when we did this our results were even worse.

Mr. Carter: At the time, Tongaat was producing a sugar with a filterability of 26 and with a high ash content, possibly due to carry-over.

The Rabe process was carried out on a laboratory scale and the clarification could have been improved.

The carbonatation juice had been filtered before the ash determination was made and this would have decreased the ash figure.

Dr. Graham: At the S.M.R.I. we were not measuring total ash but calcium and calcium plus magnesium and these were the figures we could not reduce. The table shows a reduction in silica also, which would constitute part of the ash, and therefore we are discussing different figures.

Mr. Alexander: Were you not possibly doing two totally different carbonatations? Mr. Carter carbonatating at 40° Brix and the S.M.R.I. at 15° Brix? This would alter the solubility of silica and of many other salts. Where Glucose is mentioned in the paper it would be better to use Reducing Sugars and when the removal of starch by the enzymatic process is discussed the breakdown should be given—starch is not removed as such.

Mr. Rault: In a paper I read at the 1960 Congress on the carbonatation process it was shown that the ash figure for M.E., which had used this process for many years, was lower than for any other Natal factory. We found that magnesia decreased but that calcium increased correspondingly.

SOME NOTES ON THE OPERATION OF VACUUM CLARIFIERS

by A. E. RABE

The Umzimkulu Sugar Co. Ltd.

The Vacuum Clarifier installation at Umzimkulu was introduced to the Sugar Industry in July 1966, and has been in operation since October 1965. Since then 100,000 tons of sugar have been manufactured from juices clarified by this "cold" phospho-defeeation process. As a starch removal process it has been highly efficient, producing sugars which have been well received in refineries both at home and overseas.

In order to maintain a high standard of efficiency however, it is necessary to observe basic principles, which, while being of an elementary nature can lead to poor results if they are overlooked.

The object of this short description of the process therefore, is to give future operators the benefit of some of our experiences, and to remove some of the "mystery" of this entirely new, but recently proven technique.

The Process Stages are as follows:

Mixed Juice is heated to 60°C without prior liming.
Liming to pH 8.1 or higher as required.
Mono-calcium phosphate added to reduce pH to 7.4.
Coagulating agent added.
Vacuum Flotation of precipitates.
Separation of mud from clear juice.
Treatment of mud and filtration.
Treatment of clarified juice.

Temperatures

The primary object of the process is the removal of undissolved starch from the juice before it is heated above the starch solution temperature which is in the region of 67°C.

The juice is therefore heated to 60°C in the primary heaters. This temperature is considered safe and, provided the velocity through the heater is high enough, should give no local over-heating.

At this temperature it is also fairly safe to add lime to high pH values without excessive colour formation by the destruction of reducing sugars.

Temperatures of starch-containing material should at no time be raised to more than 65 °C, or be mixed with juices or other products of a higher temperature.

Lower temperatures should be avoided, as the growth of Leuconostoc is accelerated, and apart from the loss of sucrose, this growth can be a serious problem in the clarifier, pipelines and pumps.

Liming and Phosptiating

After heating to 60° C, the juice is limed to a pH of 8.1 or higher as required, and is then phosphated back to pH 7.4 with a solution of mono-calcium phosphate (3°Be). This final pH with phosphate is regulated to give a syrup pH of 6.8-7.0.

By increasing the primary pH above 8.1 there is a corresponding increase in the amount of phosphate required to lower the pH to 7.4. This results in an increase in the volume of precipitate formed, and gives an improvement in the clarity and brightness of the juice. The brightness of the clarified juice in turn can be related to the starch removal which has been found to be poor when clear juice is even slightly turbid.

Increasing the volume of precipitate excessively will increase chemical costs unnecessarily. Once a satisfactory pH has been established it needs to be increased only in exceptional cases such as when excessively muddy cane is being processed. (To illustrate this a laboratory test was carried out on juice to which 10% of mud had been added. Lime was added to 10.0 pH, phosphate to 7.4 pH, then the juice was coagulated and subjected to vacuum. It was found that only a few of the larger grains of sand were not floated, but the juice was brilliantly clear. This would be rather a costly way of removing heavy field dirt, which should be first removed by a battery of Dorr-Clones or other means before being treated.)

As starch analysis is of necessity time consuming it may be an aid to process control to utilise a photoelectric turbidity meter to give immediate indication of changes in clarity.

Coagulation

This stage of the process is the key to the successful flotation of precipitates. The reason why coagulation is so important is explained as follows: Juice passing through vibrating screens, pumps, and scales is well saturated with air (i.e. air in solution). If after treatment with lime and phosphate this were subjected to vacuum, the air would be brought out of solution and rise to the surface rapidly, raising only a minute part of the loose floc which adheres to the micro-bubbles.

During coagulation the loose floc is drawn together to form larger globules of mud. These are closely knit so that when air is released from solution in the mud it is trapped and so lifts the coagulated portion of floc to the surface with it.

With incomplete coagulation the floc, being less dense, allows the micro-bubble to escape and rise to the surface showing up as a white froth on the mud layer. When this happens, juice clarity is invariably impaired even though a part of the mud has been floated. This is the result of poor dispersion of the coagulant in the juice.

Uniform coagulation is essential and is achieved by very rapid mixing of flocculant with the juice so that every particle of floc comes in contact with the correct amount of flocculant.

In order to apply a dosage of 5 ppm of coagulant 1 gallon of 0.5% solution is required per 1000 gallons of juice. Dilution of this solution to 0.05% ensures a more accurate dispersion. It is recommended that clarified juice rather than water should be used for dilution, to avoid an additional load on the evaporator.

To ensure that the maximum amount of air is in solution we have made it a rule that cold water only is used for dissolving the flocculant to give the 0.5% solution.

Separation of Mud from Clear **Juice**

As the prepared juice passes into the clarifier, it comes into the reduced pressure zone and, as described above, the mud floats to the surface leaving the clear juice below. The mud is continually skimmed into several mud troughs, from where it flows to the extraction pump to be pumped to the filter. The clarified juice is also continuously withdrawn by means of an extraction pump.

Control of levels is essential to ensure that mud is continuously removed and that no accumulation takes place. If this is not done the small vessel soon fills with mud, which results in a heavy carry-over within a short time.

While the Umzimkulu system of extraction of mud and clear juice is by means of pumps, we realise that it is not the ideal. We have no recourse but to use them because of the present location of the clarifier.

Given adequate height the recommended method is to allow for juice and mud to be extracted by means of barometric legs from which they can be gravitated to the next point of treatment. This applies especially to the mud. If this is pumped the floc is so badly damaged that further coagulation at the filter station becomes necessary.

Treatment of Mud

Filtration of mud is normal and the procedure need not be altered except with regard to temperature. Where filters are operated with a continuous overflow which is re-cycled through a reheating tank it will be appreciated that heating here would result in re-solution of starch. Filter cake wash water must be kept at the safe temperature of not more than 65 °C.

This in itself will tend to keep the filter sweet, as the temperature drop through the cake layer in the drying cycle should be kept at a minimum. Danger of inversion increases when muds are kept long enough for temperatures to drop appreciably.

It may be necessary to add lime to muds to re-adjust pH which tends to drop rapidly in juice which has cooled off. Periodic cleaning and sterilisation with formalin is recommended.

Further Treatment of **Clarified** Juice

Single Stage Clarification: Clarified juice at Umzimkulu has been passed to the evaporator after final heating since the process was originally brought into operation. Some comments here are necessary. It has always been felt that with the "cold" clarification, the elimination of proteins would not be effected as temperatures have to be kept low because of starch.

The proteins have been accepted as the lesser of two evils. They have caused heaters to scale up to a point where temperatures for protein removal could not be attained. This caused scaling in the first vessel of the evaporator. By periodic cleaning of heaters during the week this unpleasant feature was overcome, and should be completely eliminated with secondary clarification.

During recent weeks tests have been carried out with a view to further clarification. The heated Mixed Juice (60°C) was limed to pH 8.5, then phosphated to 8.0, coagulated in the normal way, and clarified in the vacuum clarifier. The clear juice was now phosphated to pH 7.4, then heated and pumped to the settlers (two 14' Bach clarifiers). Settling rates were exceptionally high, with no carry-over of mud. This is remarkable as the two clarifiers were handling juice at the rate of 140 tons per hour with ease, whereas with the defecation (hot liming) process 75 tons per hour could be handled with difficulty.

These tests have shown the way for future procedure, and indicate that the original concept of utilising the process as an intermediate step lends itself to greater flexibility without increasing production costs unduly, retaining the advantage of low retention times. A variation which suggests itself in the secondary stage is sulphitation and this should be utilised by factories already equipped to put it into operation.

In the secondary stage the hot mud from the settlers should either be filtered separately or cooled to safe temperatures before mixing with "cold" mud from the vacuum cell.

It is hoped that this short paper will be of assistance to those who are about to use this process.

Discussion

Mr. van Duyker: Mr. Rabe suggests that the Separan be diluted with clear juice instead of water down to 0,5%. We were using clear juice but, having double clarification, we were phosphating to 8 pH, clarifying in the Rabe Clarifier and then re-phosphating to 7.4. This juice was then used again for dilution and affected the Separan dosage to the Rabe Clarifier, destroying its coagulating effect. We therefore either added phosphate after extracting the dilution juice or did not add phosphate at all.

Mr. Ashe: I would like to know the cost per ton of sugar for liming and phosphating in the secondary clarification.

Also, is the mud from these clarifiers sent back to the filters and mixed with the mud from the Rabe Clarifier or is it treated separately, otherwise it appears that the hot mud will redissolve starch?

Mr. Rabe: The tests with secondary clarification were carried out at the end of the season merely to test the equipment so costs are not yet available. However, the process appears to be costly and a possibly better method would be sulphitation of the clarified juice but I am not sure how effective or practical this would be and would appreciate advice from the **S.M.R.I.** on this point.

As far as mud is concerned, it is mentioned in the paper that the mud has to be cooled before mixing the cold mud from the vacuum cell, or it could be filtered separately.

We intend at Umzimkulu to run the secondary mud through the Eimco belt so that the filtrate can be returned straight to the evaporator.

Mr. Robinson: Darnall was treating the juice in the vacuum clarifiers, phosphating it and settling it in the Bach clarifiers and such a small amount of mud was produced that it was returned straight to the cold mud. Juice was limed to 8.6, phosphated back to 8.2, passed through the vacuum clarifier then pumped to the Bach clarifiers without further treatment. A small amount of mud collected in the Bach clarifiers and it was flushed out for five minutes every hour.

I notice Mr. Rabe limes first, then phosphates. Darnall used to do the opposite but could not get more than 80% starch removal and it was more expensive. Better results were achieved when we changed to liming first and phosphating afterwards.

Mr. Rabe: We tried phosphating first because it is so much easier but we reverted to liming followed by phosphate.

Regarding mud in the Bach clarifier, there is so little that almost certainly no starch will be dissolved if it is mixed with the cold mud. At times, at Umzimkulu, in order to keep sucrose in niter cake down we have used a lot of dilution water, which we added as cold water to the secondary mud, thus reducing its temperature.

Dr. Graham: During the coming year the S.M.R.I. hope to carry out systematic tests at Tongaat which will include an investigation of phosphating and liming procedure. This should clarify the whole problem.

Mr. **Rault:** You mention sulphitation of a clear juice at a pH of 8. Our experience with double carbonatation was that our final pH was about 8.4 to 8.5, due to a potash alkalinity and we were able to sulphite the second carbinatation juice to about pH 7 without any precipitation. We got very little encrustation in our evaporators, which had a capacity of 9 pounds per square foot per hour.

Mr. Rabe: One factory, using sulphitation at the moment, is also going to apply the vacuum clarification process at a much higher pH, then sulphite down with the addition of lime to give a secondary precipitation which will be settled out in the normal way.

Mr. Ashe: Since you changed to the new process at Umzimkulu the ash content of your sugar has increased considerably. If a secondary process such as sulphitation or carbonatation is used might there not be an even bigger increase?

Mr. Rabe: With this cold clarification process, because of the solubility of lime salts the ash would tend to be higher without a secondary clarification process. When we phosphated the clarified juice to lower the pH and to get secondary clarification the phosphate in sugar increased, but sugar ash is no higher than it was before the introduction of this process.

Dr. Matic: In our work at the S.M.R.I. we found that scale obtained from the heaters and evaporator contained protein and calcium phosphate. If sulphitation is used the calcium salts, being soluble, will not precipitate. Therefore if a factory using the Rabe process introduces sulphitation after liming there will be an even bigger increase in ash because only the calcium phosphate already in the juice will precipitate.

As far as carbonatation is concerned, sulphiting will bring down the pH but is generally applied only after eliminating calcium carbonate formed. If this is done before elimination of calcium carbonate residual ash will be very high.

Mr. Buchanan: The author says that for Leuconostoc he applied quaternary ammonium compounds without success. What quantities were used and was it to prevent or remove growth?

Mr. Rabe: I cannot remember the dosage, but we first applied by drip for prevention and then used it by the gallon but once the Leuconostoc was established we could not remove it.

Dr. Graham: In a paper to be read by Mr. Jennings later to-day he gives .02% as the crystal ash figure for Umzimkulu whereas the average for Hulett's refinery is .10%. You therefore appear to be producing a low ash, not a high ash, sugar.

Mr. Rabe: Our sugar is no higher in ash than any other Natal sugar. When we introduced secondary clarification and added additional phosphate the phosphate figures increased to 60 ppm instead of the normal 30 ppm.

Dr. Graham: Although your lime salt figure may have increased other salts are possibly being eliminated because you end up with a low crystal ash figure.

Mr. Rabe: It should be explained that the sugar ash determined by the S.M.R.I. is made on unaffiliated sugar, which will vary with polarisation. The crystal ash determined by Hulett's gives a true reflection and should be used when making comparisons.

DESIGN AND PERFORMANCE OF AN IN LINE TURBIDITY METER FOR CLARIFICATION CONTROL

by E. J. BUCHANAN
Sugar Milling Research Institute

Introduction

Mud solids entrained in clarified juice have an adverse effect on subsequent sugar curing and may retard refinery filtration rates if occluded in raw sugar crystals. Entrainment may be caused by refractory juices or instability of process control and may itself lead to unstable processing rates due to retarded curing rates and molasses recirculation. The adverse effects may therefore be quite prolonged.

Instruments for the continuous monitoring of turbidity are readily available and may be constructed cheaply.. It is therefore surprising that factories rely solely on visual checks when a continuous in line turbidity recorder would provide a constant check on turbidity of juice actually entering the evaporators and a means of correlating entrainment with cane quality or other process variables. This would indicate the direct cause of entrainment and probably facilitate more rapid and positive corrective action.

A simple in line turbidity meter has been developed and tested by the S.M.R.I. for the purpose of providing a continuous indication of suspended matter in clarifier cane juice. This paper describes the design and application of the instrument.

Basis of Design

The instrument was designed on the basis of intensive laboratory tests during which it was shown that, within the normal range, variation in colour of cane juice had no significant effect on absorption of light from a tungsten lamp. This avoided the necessity of measuring scattered light which, for particles greater than the light wavelength, is an extremely complicated function of particle size, scattering angle, etc. and would therefore not provide any predictable quantitative measure of suspended solids. On the other hand light extinction by transmission through suspended particles follows an exponential relationship which may be corrected to a linear output and therefore facilitate calibration.[1]

Exact quantitative relationships between turbidity and suspended matter are however not possible since, for particles smaller than the wavelength, extinction is dependent on the sixth power of their radius, the fourth power for particles near the wavelength and the second power for large particles.[1] Fig. 1 shows the range of turbidity (arbitrary units) recorded after the progressive addition of small amounts of mud to clear juice. The variation in turbidity for the same suspended solids concentration may be attributed mainly to different particle size characteristics. In practice, entrainment caused by process instabilities would probably fall within a more restricted size range since it represents a size group with a settling velocity close to liquid velocity.

On the basis of this theory and background work an in line turbidity meter was designed bearing in mind the above limitations, mainly for detecting abnormal entrainment in clarifiers.

Description of Turbidity Meter

The electrical circuitry of the turbidity meter is shown in Fig. 2. The detecting element is a light-dependent resistor (l.d.r.) which forms one arm of a resistance bridge. A variable resistance is placed in an opposite arm of the bridge to facilitate zero adjustments (usually on water). A stabilised power supply is fed to the bridge, the main element being a cadmium cell. A 4 volt projector lamp is powered from the same source. The turbidity cell is constructed from standard 1/2 in. pipe fittings, the main item being a standard cross fitted with two nipples, one being connected to a tee and the other to a reducer. The l.d.r. is secured firmly within the reducer by means of a shaped nylon bush and the lamp is fixed within the tee, its filament being aligned along the axis of the cross. The vertical limb of the cross is fitted with a concentric 1/4" i.d. Pyrex glass tube, sealed at each end with nylon bushes, so that liquid may pass through the vertical limb of the cross without entering the horizontal one. This arrangement is shown on the left. The lamp circuit is equipped with two relays which prevent overcharging of the battery when the lamp filament fails and draining of the battery power when mains supply fails. A millivolt recorder is connected across the bridge with suitable matching to provide for measurement over the normal range of juice turbidities. Apart from the recorder, the most expensive item is the cadmium cell and the other items add very little more to the total cost.

Conclusion

The turbidity meter has been installed at several factories and has given reliable service. It has provided useful information on the causes of intermittent entrainment. Temperature and feed rate fluctuations have been found to coincide with adverse clarification performance. Since the cost of the actual detector is very low it may form the basis for automatic clarifier operation. The instrument is robust and requires no maintenance under normal process conditions apart from cleaning the glass tube at the end of each week.

Acknowledgements

The author wishes to thank the managements of Tongaat Sugar Co., Hulett's, Darnall and Noodsberg Sugar Co. for providing facilities for testing prototypes and the final model turbidity meter. The author gratefully acknowledges the co-operation of Mr. Bruijn in the development of a prototype model and for design of the circuitry of the final model which was constructed by Mr. N. I. Bowes of the

Summary

An in line turbidity meter suitable for recording the turbidity of clarified juice is described. It is mainly intended for indicating periods of entrainment so that corresponding instability in other process variables may be correlated. Preliminary tests indicated that colour of juice had no significant effect on the turbidity and the instrument was therefore designed to measure the intensity of transmitted light using a light dependent resistor. The meter has been successfully applied to "trouble shooting" in several clarification plants.

Reference

[1] Orr, C. Jr„ and Dallovalle, J. M. "Fine Particle Measurement," 1st Ed., 1959, 101-5, MacMillan Co., N.Y.

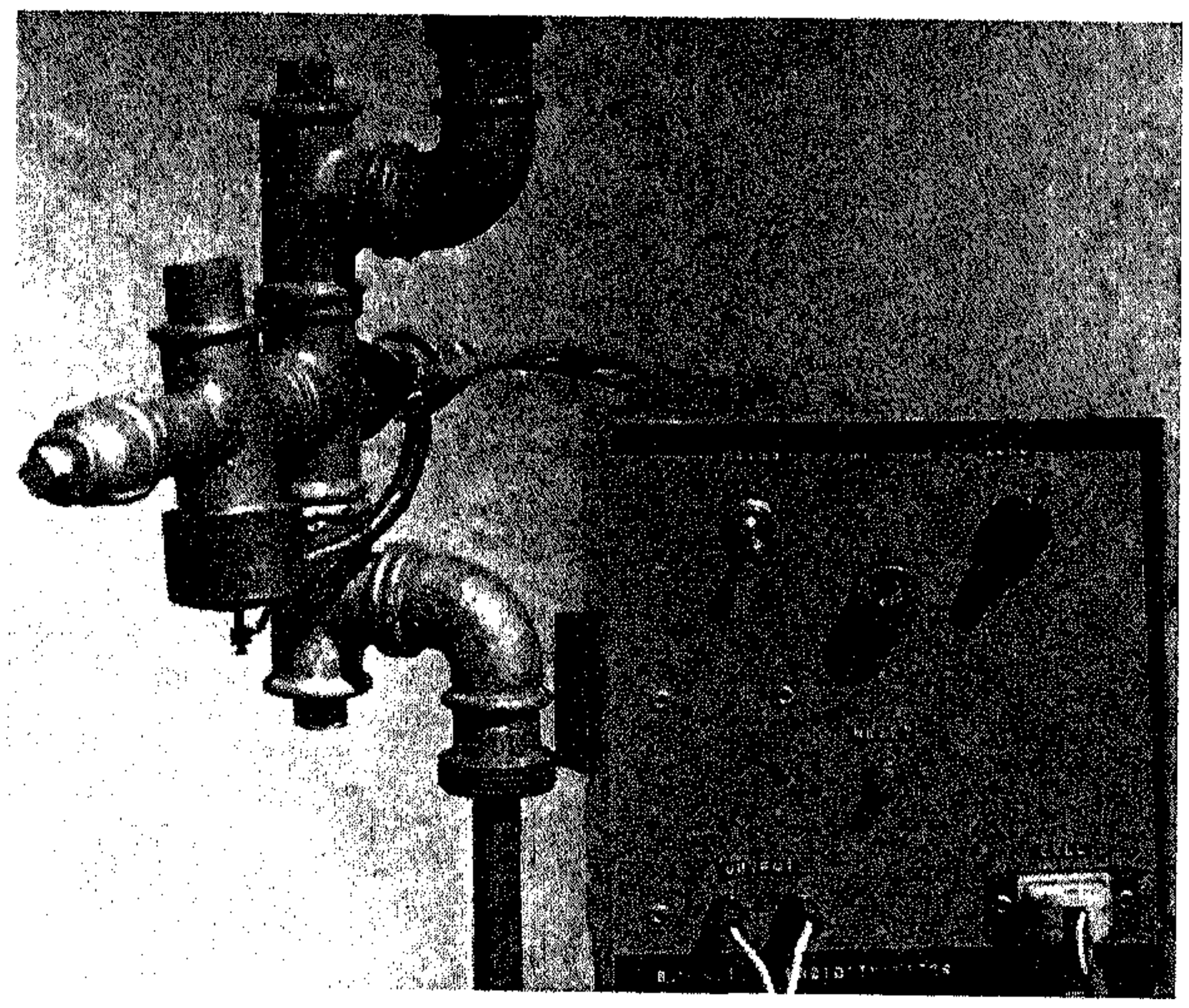


PLATE I: Photograph showing turbidity cell and housing for stabilised power supply

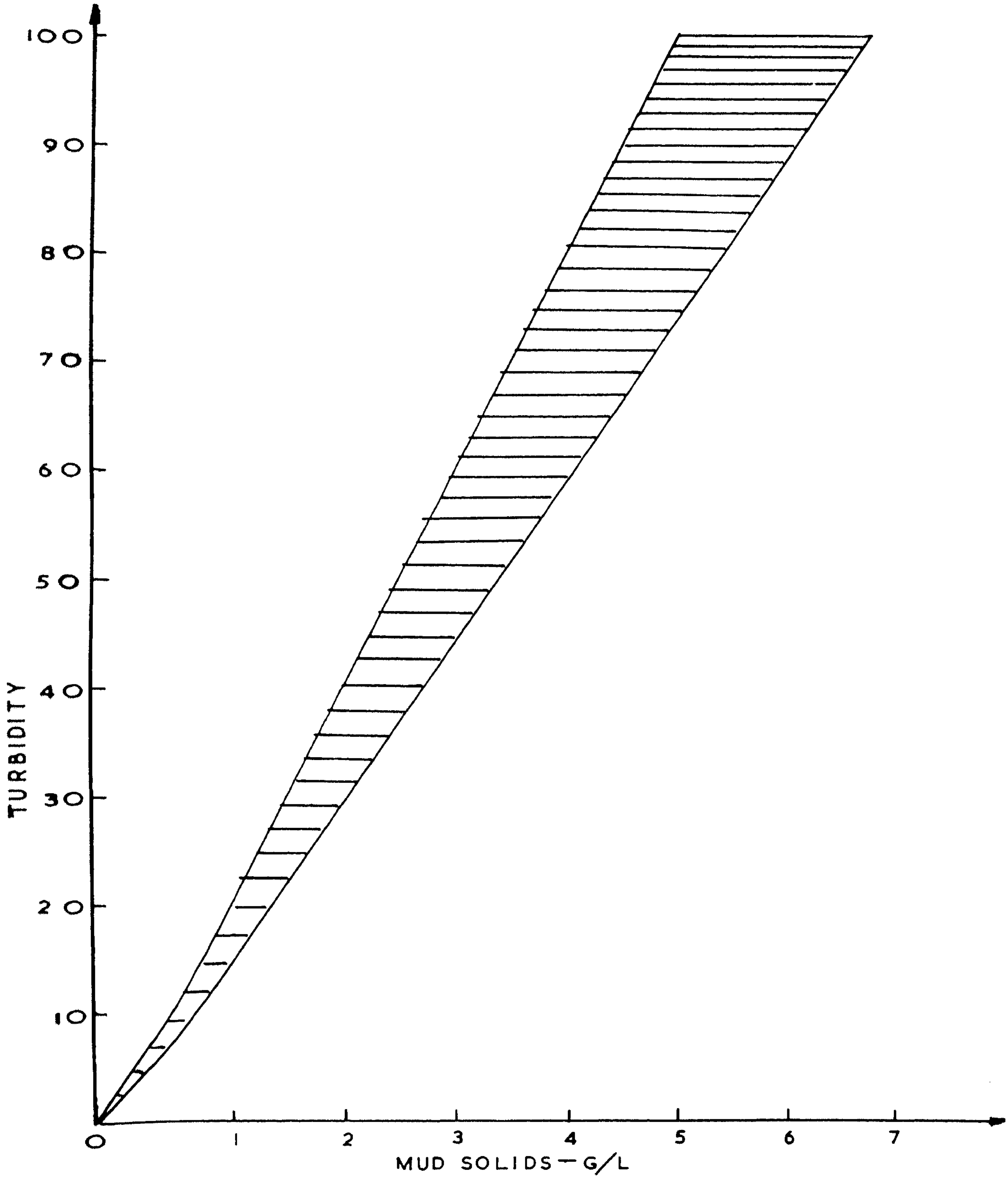


FIGURE 1: Graph showing turbidity range for various concentrations of mud added to clarified juice

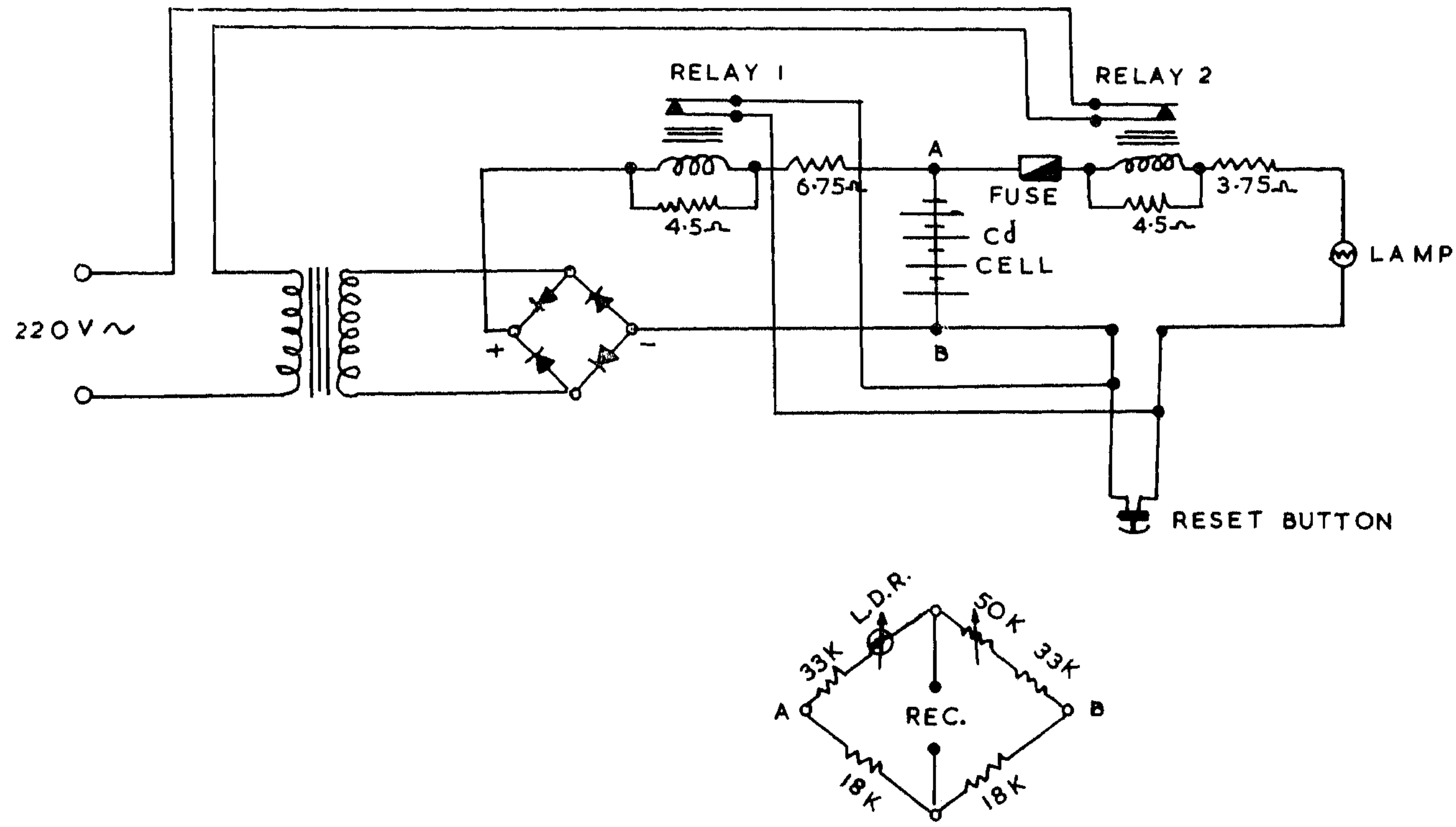


FIGURE 2: Circuit diagram for turbidity meter, stabilized power supply and resistance bridge

Discussion

Mr. Bentley (in the chair): The industry has needed an instrument like this for a long time, particularly as it is reliable and inexpensive. In the past we have trusted to the human element to control the clarification station, and this is likely to be unreliable, particularly in the small hours of the morning.

Mr. Rabe stated earlier that the turbidity of the clarified juice was an indication of its starch content and this meter will therefore indicate the starch content of juice coming from the clarifiers. I am surprised that the glass tube only requires cleaning once a week as I would have expected it to discolour rapidly and require frequent cleaning.

Mr. **Renton:** At Darnall we had to clean the tube daily to get consistent readings.

Mr. Buchanan: We operated the meter at Jaagbaan for two months and even if the tube was left uncleaned for longer than a week effects on readings were negligible. Possibly the flow rate of the juice through the meter was much faster at Darnall.

Mr. Robinson: We could get readings after a week at Darnall but sensitivity was lost so we arranged to clean it every day.

Mr. Buchanan: When the instrument was used at Darnall it was in its earlier stages of development and had not been set to its final sensitivity. After it was used at Darnall we reduced its sensitivity, which we found had previously been higher than was required, and this probably reduced the significance of scaling.

The instrument is easily cleaned by removing two plugs and using a bottle brush.

CLEANING THE OUTSIDE OF EVAPORATOR TUBES

by W. F. DAVIES
Hulett's Sugar Corporation Limited, Felixton

During the past ten years several attempts have been made at Felixton to remove the carbon-like deposit which forms on the outside of the evaporator tubes of the first vessels. The results were in all cases disappointing. The use of toxic or inflammable detergents was undesirable so the choice was somewhat limited.

At the end of the 1965/66 Crushing season, tubes were removed from the Juice heaters, evaporators and pans. Tubes from the vapour cells and the second vessel - which had for many years operated as a first vessel - were heavily coated with a carbon deposit. The Juice heater and pan tubes were also dirty, but to a lesser degree and the scale on them appeared to be softer and flakey. Light syrup during the 1965/66 season put an extra load on the pan station and imbibition had to be reduced at times when the evaporator could not cope. As a higher throughput was decided upon for the 1966/67 season it was imperative that the evaporator should function properly.

Gamlen Treatment

After several enquiries had been made, a so-called carbon solvent by the name of Gamlen at R1.90c. per gallon was recommended and despite the high cost, arrangements were made to attempt to clean the evaporator tubes with this chemical. A representative of the firm which supplied the Gamlen visited Felixton to discuss methods of application. After various laboratory tests on the tubes had been carried out a mixture of two parts paraffin and one part Gamlen was agreed upon.

Procedure

The steam inlets to the evaporator calandrias were blanked off, also the steam traps from these vessels. An old boiler shell was used as a storage tank for the mixture, from where it was circulated through the calandrias by means of a pump. The juice space of the vessels was filled with water to *2"* above the tube and two 1" steam pipes placed in the downtake to maintain a temperature of 80°-85°C. After twenty-four hours the Gamlen mixture was drained back to the storage tank and the calandria immediately several times with cold water.

Result

Four tubes were removed from different points of the tube plate; on some the deposit had been completely removed, whilst on others a thin film remained. After all the vapour cells had been cleaned the remaining four vessels of the evaporator were treated, then all the Juice heaters and pans. The effectiveness of the solution lessened towards the end of the exercise but all treated tubes were fairly well cleaned.

Conclusion

The syrup Brix for the 1965/66 season was 55.9, and 61.5 for the 1966/67 season, and in addition evaporation per square foot of heating surface increased from 5.10 to 5.90 lbs. At a cost of approximately R2,500 the results obtained can be considered as highly satisfactory.

Caution

It is claimed that Gamlen is non-poisonous but the paraffin Gamlen mixture fumes cause nausea so the vents should be extended well above floor working level. Contact with the skin must also be avoided. At a temperature above 85°C, the mixture may become explosive.

Discussion

Mr. Bentley (in the chair): This cleaning operation cost R2,500 for the season. It seems to me that this money might have been better spent in eliminating the contamination in the steam supplied to the evaporators so that no scaling occurred. It is possible to prevent oil from getting into exhaust steam and this may be the best way to approach the problem.

Mr. Robinson: We used Gamlen with some success at Darnall. A fairly hard carbon scale was still left on our vapour tubes but the loose carbon in an oily film came off easily. We have recently installed an oil separator and have not yet gauged its effectiveness, but we shall still use Gamlen.

Mr. Davies: After the treatment we installed an oil separator on each of our two tandems but the vessels close to the two engines are still getting oil in them.

Mr. Dick: Many years ago, in India and elsewhere, there was a process for cleaning the inside of tubes whereby a solution was made by diluting molasses with water; a few tubes in the calandria were removed and both sides of the calandria were filled with the solution to about six inches above the tube plate. A yeast was put into the solution to start fermentation and over a period of a month or more the solution was allowed to drip down slowly and the tubes were cleaned very effectively.

Mr, Davies: It was tried out on pans at Felixton but was not effective. The insides of the tubes were cleaned but not the outsides.

Mr. van Duyker: There is a paper in the 1940 proceedings of S.A.S.T.A. on the molasses fermentation cleaning method.

Mr. van Hengel: The Gamlen representative stressed that the liquid must not be allowed to stand in the calandria—it must circulate. We used two one inch open steam pipes in the calandria in an attempt to create 'water hammer'.

Mr. Davies: The steam pipes worked until the temperatures were balanced and then they became ineffective.

Mr. Rabe: Some time ago at Illovo we used a product called Mercol in a similar way to Mr.

Davies. To reduce quantities we floated it up on water, in a fairly high paraffin concentration, and then the level of the water was slowly raised and lowered.

Mr. **Davies:** Gamlen is soluble in water.

Mr. Dick: Mr. Davies says the tubes were heavily coated with a carbon deposit. From my experience I don't remember getting a carbon deposit; it was more a soft oily deposit. Our steam then had a moisture content of up to 5%. Could Mr. Davies tell us the steam temperature entering these vessels because I have known cases of steam at 100°F superheat entering juice heaters?

Mr. Davies: High temperatures might cause it, but our temperatures aren't excessively high—about 13 p.s.i., which is approximately 245 °F. But even when low pressure steam at 226°F is present, if it has been there some time the deposit is a carbon and not a sludge.

Mr. **Dick:** I am referring to high pressure boilers with reducing valves where sometimes engineers are not certain of the degree of superheat entering the

Mr. Hulett: We have possibly had superheat in the calandrias at Felixton and Darnall but nowadays not much live steam is going into exhaust.

Mr. Hurter: When we installed a new turbo-alternator at Umfolozi a year ago we investigated this and found we had in excess of 100°F superheat and we had to install a de-superheater in the exhaust

Mr. Buchanan: It is a pity the author has not given overall heat transfer figures for the surface concerned.

I have seen in literature an example from Australia where there was a 60% loss in overall heat transfer coefficient due to scaling on the steam side of the tube. What has been the effect of this chemical on the steam surfaces of the 2nd, 3rd and 4th effects of evaporators which are influenced by entrainment, compared with the first effect where there is an oil type scale.

Mr. Davies: There was very little scale on the 2nd, 3rd and 4th effects despite any entrainment.

Mr. **Renton:** At Darnall the Gamlen cleaned our 2nd and 3rd effect vessels very well.

There are savings when using this treatment because we have found that for about a week after using it we have been able to use 1 1/2 to 2 lbs. less exhaust steam pressure.

Mr. Fourmond: I think that an increase in rate of evaporation per square foot from 5.10 to 5.90 lbs., combined with an increased throughput rate, indicates a highly successful result.

BOILING HOUSE PERFORMANCE

by A. van HENGEL
Hulett's South African Sugar Mills and Estates Ltd,

Introduction

For a long time there has existed a desire amongst sugar technologists to gauge the quality of work in the boiling house by one simple expression. In 1950 Gundu Rao[1] criticized the existing yardsticks and made some suggestions. In 1953 Douwes Dekker[2] gave a summing-up of the different views and came to the conclusion that the target purity (a purity based on the exhaustibility of the final molasses) should be the basis of the calculations of crystallisable sucrose in mixed juice. Earlier, this same principle led to the introduction of the Boiling House Performance in Natal (unique in the world) and the exhaustibility of the molasses was arbitrarily presumed to be a function of the mixed juice purity.

In Table I of the Laboratory Manual for South African Sugar Factories, the factor "f" is given for different juice purities. Now, the factor "f" represents the fraction

$$\frac{p}{100 - p}$$

Here, "p" represents the purity of the final molasses and if "r" stands for the purity of mixed juice, Table I can be drawn up.

From the accompanying graph it is evident that the curve (A), representing the assumed relationship between "p" and "r" is very nearly a straight line **(B).**

Factors Affecting the Boiling House Performance

From many sides, strong criticism has been delivered on the value of Boiling House Recovery. As this figure is a direct function of S, J and M, nobody doubts the influence of the non-sucrose content of sugar, molasses and the mixed juice.

Hitherto, it has been assumed that the use of Boiling House Performance would avoid this disadvantage and the outcome of our calculations would show a "quality figure" which was only dependent on:

(a) The Effectiveness of the Clarification.

(b) The Quantity of the Undetermined Sucrose

(c) The Purity of Undetermined Sucrose Loss.

(d) The Purity of the Final Molasses.

(a) *The Effectiveness of the Clarification:*

Boiling House Performance is based on the effectiveness of the clarification in two ways, i.e. the loss of sucrose in cake and the rise in purity of the juice. As more water is used at the filter station, the pol of the cake will be lower. However, as a result of using excessive amounts of water, a part of the precipitated non-sugars may go into solution again and then the extra recovery of sucrose will be partly undone. Also, a fair amount of sucrose is added to the filters in the bagacillo, but this quantity is normally disregarded.

It seems feasible, however, to see the clarification effect as one single process, and for the purpose of this paper we assume:

1. Sucrose lost in cake % sucrose in mixed juice
2. Purity increase from mixed juice to clar. juice = d

If purity of the mixed juice is "r", we can evolve the following equations:

Sucrose in the clar. juice % sucrose in mixed juice

$$= 100 - c \quad \ldots\ldots (1)$$

Brix in clar. juice % sucrose in mixed juice

$$= \frac{100 - c}{r + d} \times 100 \quad \ldots\ldots (2)$$

Equation (2) minus equation (1) equals

Non sucrose in clar. juice % sucrose in mixed juice =

$$\frac{(100 - c)}{(r + d)} \times 100 - (100 - c)$$

$$= (100 - c)\frac{(100 - r - d)}{(r + d)} \quad \ldots\ldots (3)$$

(b) *The Quantity of the Undetermined Loss:*

There is little to say about this: obviously, what is lost is not recoverable. We will call the percentage of sucrose in mixed juice lost in undetermined "u".

(c) *The Purity of the Undetermined Loss:*

This is a very important factor. If sucrose is lost at a purity of 100, the loss of recoverable crystal will be identical to the sucrose loss. But if sucrose is lost at the purity of final molasses, the loss of crystal will be zero. If the nature of the loss is chemical, it will show up in the purity rise of the clarified juice, which will be lower as a result of the inversion. We will call the purity of the undetermined loss "z". (For calculation of "z" see Appendix 1.)

Again a number of equations can be evolved:

Sucrose in sugar and molasses % sucrose in mixed juice = (100 - c - u) . . . . . (4)

If "u" parts of sucrose are lost at a purity of "z", $\frac{100u}{z}$ parts of brix will be lost. Hence, by subtracting this term from formula (2), we get:

Brix in sugar and molasses % sucrose in mixed juice

$$= \frac{(100 - c)}{(r + d)} \times 100 - \frac{100u}{z} \quad \ldots\ldots (5)$$

Now the loss of non-sucrose is the difference between equations (5) and (4) and therefore:

Non-sucrose in sugar and molasses % sucrose in mixed juice =

$$\frac{100\,(100 - c)}{(r + d)} - \frac{100u}{z} - (100 - c - u)$$

$$= \frac{100\,(100 - c)}{(r + d)} - (100 - c) - \frac{100u}{z} + u$$

$$= \frac{(100 - c)\,(100 - r - d)}{(r + d)} - \frac{u(100 - z)}{z} \quad \ldots\ldots (6)$$

(d) *The Purity of the Produced Final Molasses:*

If the purity of the final molasses is P, then one part of non-sucrose will prevent the crystallisation of $\frac{P}{100 - P}$ parts of sucrose.

Hence, from equation (6) it follows that the non-crystallised sucrose in molasses % sucrose in mixed juice will be:

$$\frac{P}{(100 - P)} \left[\frac{(100 - c)\,(100 - r - d)}{(r + d)} - \frac{u(100 - z)}{z} \right] \quad \ldots\ldots (7)$$

The Equation for the Boiling House Performance

After suffering the losses in cake and undetermined, the sucrose available for crystallisation per 100 sucrose in mixed juice is

$$(100 - c - u) \quad \ldots\ldots (4)$$

The crystallised sucrose % sucrose in mixed juice is, therefore, the difference between equations (4) and (7):

$$(100 - c - u) - \frac{P}{(100 - P)} \left[\frac{(100 - c)\,(100 - r - d)}{(r + d)} - \frac{u(100 - z)}{z} \right]$$

$$= (100 - c - u) + \frac{uP(100 - z)}{(100 - P)z} - \frac{P(100 - c)\,(100 - r - d)}{(100 - P)\,(r + d)}$$

$$= (100 - c) - u\left[1 - \frac{P(100 - z)}{z(100 - P)} \right] - \frac{P(100 - c)\,(100 - r - d)}{(100 - P)\,(r + d)} \quad \ldots\ldots (8)$$

The percentage of crystallisable sucrose in mixed juice is by definition

$$100 - \frac{100p(100 - r)}{r(100 - p)} \quad \ldots\ldots (9)$$

and, hence, the Boiling House Performance is:

$$\text{B.H.P.} = 100 \times \frac{100 - c - u\left[1 - \frac{P(100 - z)}{z(100 - P)} \right] - \frac{P(100 - c)(100 - r - d)}{(100 - P)\,(r + d)}}{100 - \frac{100p(100 - r)}{r(100 - p)}} \quad \ldots\ldots (10)$$

(See Appendix 2.)

Performance

Equation (10) can be rewritten as follows:

$$\text{B.H.P.} = 100 \times \frac{B - D}{A - C} \text{ if}$$

$$A = 100$$

$$B = 100 - c - u \left[1 - \frac{P(100 - z)}{z(100 - P)} \right]$$

$$C = \frac{100p(100 - r)}{r(100 - p)}$$

$$D = \frac{P(100 - c)\,(100 - r - d)}{(100 - P)\,(r + d)}$$

(A) The term A = 100 is simply stating that we start with 100 parts of sucrose in mixed juice.

(B) The term

$$B = (100 - c) - u \left[1 - \frac{P(100 - z)}{z(100 - P)} \right]$$

will normally be very near to 100. In South Africa, the average loss of sucrose in cake % sucrose in mixed juice is 0.6, the average undetermined loss 1.5 and the purity at which the loss takes place approximately 50. For a molasses purity of 40, the value of the term becomes 98.90. Moreover, if this figure becomes significantly lower than 98.90 this will be due to factors which can be influenced, such as by reducing the loss in filtercake and preventing undetermined loss of high purity material. In fact, it states the percentage of the sucrose in mixed juice still available for crystallization after clarification and pan-boiling, but disregarding the loss in MOLASSES .

(C) The term

$$C = \frac{100p(100 - r)}{r(100 - p)}$$

states the "unavoidable" loss of sucrose in final molasses. It is obvious that

$$\frac{100p}{100 - p}$$

indicates the sucrose as a percentage of non-sucrose that will not crystallize under the condition that the final molasses reached the "target" purity "p". The term

$$\frac{100 - r}{r}$$

refers to the quantity of molasses to be expected from mixed juice with a purity r. Therefore A - C states the amount of sucrose that will crystallize if no losses other than the "normal" losses in molasses will occur.

(D) This term states the percentage sucrose lost in molasses at the *actual* purity of the final molasses, produced in a quantity as may be expected from clarified juice with a purity (r + d). The amount available for crystallization is then not 100 as under (C) but 100 - c.

Under normal circumstances the term B will be very nearly A and for our further considerations we concentrate on the terms C and D.

In South Africa, under normal conditions

$$\frac{P(100 - c)}{(100 - P)} > \frac{100p}{(100 - p)}$$

Every factory which is not able to reduce P to the pre-determined level of "p" is at a disadvantage. But, if the standard "p" is set fairly, the penalty can be reduced by better work or even turned into a bonus.

However, considering the two terms

$$\frac{(100 - r - d)}{(r + d)} \text{ and } \frac{(100 - r)}{r}$$

we can say that these are very definitely *not* under human control. We all know that "d" will be larger for a carbonatation factory than for a defecation factory or a sulphitation factory. But, if we speak only for defecation and sulphitation factories now, the variance of "d" will be between 0.5 and 1.5 and if we assume 0.5 it will certainly be conservative.

Under South African conditions

$$\frac{(100 - r)}{r}$$

$$\text{may vary between } \frac{18}{82} = 0.220 \text{ and } \frac{12}{88} = 0.136$$

$$\text{and } \frac{(100 - r - d)}{(r + d)} \text{ between } \frac{17.5}{82.5} = 0.212$$

$$\text{and } \frac{11.5}{88.5} = 0.130$$

(the extremes of the purities of mixed juice are assumed at 82 and 88 purity).

If any factory is able to satisfy the condition that:

$$\frac{P}{100 - P} = \frac{p}{100 - p}$$

or, in other words, that the final molasses purity is equal to the "target" purity, then the value of the terms

$$\frac{(100 - r)}{r} \text{ and } \frac{(100 - r - d)}{(r + d)}$$

is of no consequence. But if, e.g., P becomes larger than p, which it nearly always is by a considerable margin in South Africa, then the value of the terms

$$\frac{(100 - r)}{r} \text{ and } \frac{(100 - r - d)}{(r + d)}$$

becomes of extreme importance. Hence, as soon as a factory is not able to produce final molasses with a purity identical to the target purity, then this factory is at a disadvantage not only for the higher purity, but also for the quantity at which this final molasses is made, which, in turn, is dependent on the mixed juice purity.

Numerical Example of the Influence of the Mixed Juice Purity on the Boiling House Recovery

Let the mixed juice purity for two factories A and B be 82 and 88 respectively. This means that according to our table the "target purity" of factory A must be 31.5 and 34.0 for factory B. In the event that both factories exceed these "targets" by 6 points, the factory A will produce molasses with 37.5 purity and factory B molasses with 40.0 purity. If in both factories the loss in cake is 0.6% on sucrose in mixed juice, the undetermined loss is 1.5% on sucrose in mixed juice and if both factories suffer their undetermined loss at 50 purity, then factory A will record a B.H.P. of 95.86 and factory B a B.H.P. of 96.54.

Factory A, achieving a B.H.P. of 95.86, *is doing the same quality of work as factory B,* which is making a B.H.P. of 96.54. This is 0.68 higher and a considerable margin if compared with the accepted maximum realistically achievable of 100 — 95.86 = 4.14.

But is it realistic to assume that a factory working with 82 purity would make 37.5 purity molasses and a factory, equally well run, 40 purity molasses out of mixed juice of 88 purity?

Assuming for one moment that the exhaustibility of molasses resulting from mixed juice of low purity is better than of molasses made of high purity mixed juice (a fact which is difficult to prove) then still this would not be the only factor influencing the final molasses purity. Graham[3] states that:

> "Under normal factory operating conditions it is found that as the purity of molasses decreases its viscosity increases."

As curing time and viscosity are proportional, and available curing time depending on the quantity of massecuite to be treated by available machinery, it is therefore certain that the mixed juice purity will influence the final molasses purity inversely as low purities will lead to large quantities of molasses and large quantities of molasses to short curing times, in turn necessitating lower viscosities with, as a result, higher purities.

It is, therefore, reasonable to assume that the two influences off-set each other and that both factories in one example do well, according to South African standards, if they produce molasses with 37.5 purity. In that case, the B.H.P. for factory A would remain 95.86 and would become 97.90 for factory B. This is a tremendous difference, too much to be allowed to depend on a factor which is not under one's control. And, in fact, the B.H.P. suffers from exactly the same disadvantage as the Boiling House Recovery, be it to a lesser degree.

Suggestion for a Revised Boiling House Performance

As previously said, there is little reason to assume that low mixed juice purities will lead to low molasses purities in practice and for this reason we need not allow for a variation in the "target purity". If a constant factor "f" of 0.5 is assumed, then the target purity will be 33.33, still a highly ambitious one.

Further, it is suggested to fix the value of "r" (the mixed juice purity) at a standard 85.0, which is a reasonably average figure for Natal.

It appears now that in equation (10) the only variables are:

1. the loss of sucrose in cake,
2. the loss of sucrose in undetermined,
3. the purity rise in mixed juice,
4. the purity of the undetermined loss,
5. the actual purity of the final molasses.

In other words, the formula states the percentage of crystallisable sucrose that would have crystallised after suffering the normal losses in cake, undetermined, etc., but with the loss in molasses corrected for the quantity which would have been made if the purity of the mixed juice had been 85.0.

So, the Revised Boiling House Performance is:

$$\text{R.B.H.P.} = 100 \times \frac{100 - c - u\left[1 - \frac{P(100 - z)}{z(100 - P)}\right] - \frac{P(100 - c)(15 - d)}{(100 - P)(85 + d)}}{91.176} \quad \ldots\ldots (11)$$

This equation is too cumbersome for practical use and some simplification should be made. The term

$$\frac{P}{100 - P}$$

can be substituted by "f" In Table II the values of f for purities ranging from 30 to 45 are given. The term

$$\frac{100 - z}{z}$$

can be replaced by F (see Table III). The term

$$\frac{15 - d}{85 + d}$$

is accurately replaced by D = 0.1765 — 0.0135d and the value of D is found in Table IV.

Then our final equation becomes:

$$\text{R.B.H.P.} = 100 \times \frac{(100 - c) - u(1 - fF) - fD(100 - c)}{91.176}$$

$$= \frac{(100 - c)(1 - fD) - u(1 - fF)}{0.91176} \quad \ldots\ldots (12)$$

Example: A factory is losing 0.5% of its sucrose *in mixed juice* in cake and 1.2% in "undetermined'*. The undetermined loss is suffered at 65 purity. The purity-rise from mixed juice to clarified juice is 0.95 and the molasses purity 39.0. The Boiling House Performance under these circumstances will be:

$$\text{R.B.H.P.} = \frac{(100 - 0.5)(1 - 0.639 \times 0.1634) - 1.2(1 - 0.639 \times 0.538)}{0.91176}$$

$$= \frac{99.5 \times 0.8956 - 1.2 \times 0.6562}{0.91176}$$

$$= 96.87$$

On the other hand, one can ask the question: "Which purity of final molasses will a normal factory have to make to obtain a R.B.H.P. of 100?" (All losses the same as in our previous example.)

$$100 = \frac{(100 - 0.5)(1 - f \times 0.1634) - 1.2(1 - f \times 0.538)}{0.91176}$$

OR f = 0.456 and hence
P = 31.3

Conclusion

The suggested Revised Boiling House Performance is independent of the purity of the mixed juice and only on the losses in cake, undetermined and molasses. Correction is made for the purity of the undetermined loss. It is fully realised that the Revised Boiling House Performance is one, but not necessarily the best, solution. It is hoped that enough interest has been raised in the subject to have the Boiling House Performance in its present form re-examined critically by a committee, preferably within the Council of our own S.A. Sugar Technologists' Association.

1. Gundu Rao, S. N.: Boiling House Efficiency Indicators, Proceedings I.S.S.C.T. 1950, page *665.*
2. Douwes Dekker, K.: Judging Boiling House Work, Proceedings I.S.S.CT. 1953, page 671.
3. Graham, W. S.: Some Notes on Natal C Massecuites and C Molasses S.M.R.I, Bulletin No. 30.

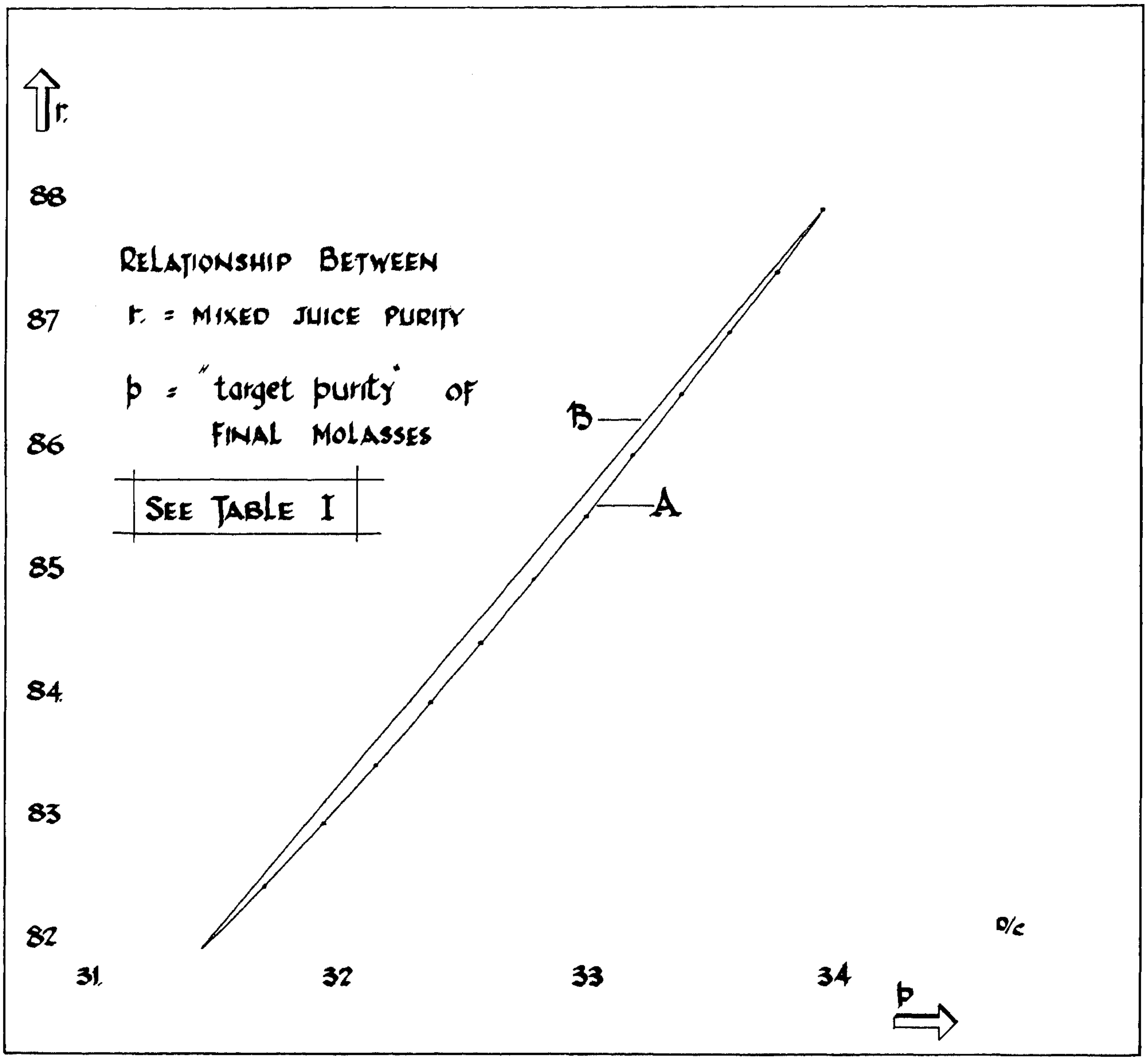

r.
88
87
86
85
84
83
82
RELATIONSHIP BETWEEN
r. = MIXED JUICE PURITY
p = "target purity" OF
FINAL MOLASSES
SEE TABLE I
B
A
%
31
32
33
34
p

TABLE I

r	p	f	r	p	f	r	p	f
82.0	31.51	0.460	84.1	32.48	0.481	86.1	33.27	0.499
82.1	31.57	0.461	84.2	32.52	0.482	86.2	33.31	0,500
82.2	31.61	0.462	84.3	32.56	0.483	86.3	33.35	0.501
82.3	31.65	0.463	84.4	32.60	0.484	86.4	33.39	0.502
82.4	31.70	0.464	84.5	32.64	0.485	86.5	33.43	0.502
82.5	31.75	0.465	84.6	32.68	0.486	86.6	33.47	0.503
82.6	31.79	0.466	84.7	32.72	0.487	86.7	33.51	0.504
82.7	31.84	0.467	84.8	32.76	0.488	86.8	33.55	0.505
82.8	31.88	0.468	84.9	32.80	0.489	86.9	33.59	0.506
82.9	31.93	0.469	85.0	32.84	0.489	87.0	33.63	0.507
83.0	31.97	0.470	85.1	32.89	0.490	87.1	33.66	0.508
83.1	32.03	0.471	85.2	32.93	0.491	87.2	33.70	0.509
83.2	32.07	0.472	85.3	32.97	0.492	87.3	33.74	0.509
83.3	32.13	0.473	85.4	33.01	0.493	87.4	33.78	0.510
83.7	32.16	0.474	85.5	33.05	0.493	87.5	33.82	0.511
83.5	32.20	0.475	85.6	33.08	0.494	87.6	33.85	0.512
83.6	32.26	0.476	85.7	33.12	0.495	87.7	33.89	0.513
83.7	32.31	0.477	85.8	33.16	0.496	87.8	33.93	0.513
83.8	32.35	0.478	85.9	33.20	0.497	87.9	33.97	0.514
83.9	32.39	0.479	86.0	33.23	0.498	88.0	34.00	0.515
84.0	32.43	0.480						

TABLE II

The value of $\frac{P}{100 - P}$ for purities from 30 to 45

Purity	.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
30	0.429	0.431	0.433	0.535	0.437	0.439	0.441	0.442	0.445	0.447
31	0.449	0.451	0.453	0.456	0.458	0.460	0.462	0.464	0.466	0.468
32	0.471	0.473	0.475	0.477	0.479	0.481	0.484	0.486	0.488	0.490
33	0.493	0.495	0.497	0.499	0.502	0.504	0.506	0.508	0.511	0.513
34	0.515	0.517	0.520	0.522	0.524	0.527	0.529	0.531	0.534	0.536
35	0.538	0.541	0.543	0.546	0.548	0.550	0.553	0.555	0.558	0.560
36	0.563	0.565	0.567	0.570	0.572	0.575	0.577	0.580	0.582	0.585
37	0.587	0.590	0.592	0.595	0.597	0.600	0.603	0.605	0.608	0.610
38	0.613	0.616	0.618	0.621	0.623	0.626	0.629	0.631	0.634	0.637
39	0.639	0.642	0.645	0.647	0.650	0.653	0.656	0.658	0.661	0.664
40	0.667	0.669	0.672	0.675	0.678	0.681	0.684	0.686	0.689	0.692
41	0.695	0.698	0.701	0.704	0.706	0.709	0.712	0.705	0.718	0.721
42	0.724	0.727	0.730	0.733	0.736	0.739	0.742	0.745	0.748	0.751
43	0.754	0.757	0.761	0.764	0.767	0.770	0.773	0.776	0.779	0.783
44	0.786	0.789	0.792	0.795	0.799	0.802	0.805	0.808	0.812	0.815
45	0.818	0.821	0.825	0.828	0.832	0.835	0.838	0.842	0.845	0.848

TABLE III

The value of $F=\frac{100-z}{z}$ for values of 30 to 100

	0	1	2	3	4	5	6	7	8	9
30	2.333	2.226	2.125	2.030	1.941	1.857	1.778	1.703	1.632	1.564
40	1.500	1.439	1.381	1.326	1.272	1.222	1.174	1.128	1.082	1.041
50	1.000	0.962	0.924	0.887	0.852	0.818	0.786	0.755	0.724	0.695
60	0.667	0.639	0.614	0.588	0.563	0.538	0.516	0.493	0.471	0.449
70	0.429	0.408	0.389	0.370	0.352	0.333	0.316	0.295	0.282	0.266
80	0.250	0.235	0.220	0.205	0.191	0.176	0.163	0.149	0.136	0.124
90	0.111	0.099	0.087	0.075	0.064	0.053	0.042	0.031	0.020	0.010
100	0.000									

TABLE IV

The value of $D=\frac{15-d}{85+d}$ (or $D=0.1763-0.0135d$) for values of d from 0 to 2.0

	0	0.02	0.04	0.06	0.08
.0	0.1763	0.1760	0.1758	0.1755	0.1752
.1	0.1750	0.1747	0.1744	0.1741	0.1739
.2	0.1736	0.1733	0.1731	0.1728	0.1725
.3	0.1723	0.1720	0.1717	0.1714	0.1712
.4	0.1709	0.1706	0.1704	0.1701	0.1698
.5	0.1696	0.1693	0.1690	0.1687	0.1685
.6	0.1682	0.1679	0.1677	0.1674	0.1671
.7	0.1669	0.1666	0.1663	0.1660	0.1658
.8	0.1655	0.1652	0.1650	0.1647	0.1644
.9	0.1642	0.1639	0.1636	0.1633	0.1631
1.0	0.1628	0.1625	0.1623	0.1620	0.1617
1.1	0.1615	0.1612	0.1609	0.1606	0.1604
1.2	0.1601	0.1598	0.1596	0.1593	0.1590
1.3	0.1588	0.1585	0.1582	0.1579	0.1577
1.4	0.1574	0.1571	0.1569	0.1566	0.1563
1.5	0.1561	0.1558	0.1555	0.1552	0.1550
1.6	0.1547	0.1544	0.1542	0.1539	0.1536
1.7	0.1534	0.1531	0.1528	0.1525	0.1523
1.8	0.1520	0.1517	0.1515	0.1512	0.1509
1.9	0.1507	0.1504	0.1501	0.1498	0.1496
2.0	0.1493				

APPENDIX 1

Calculations of the Purity of the Undetermined Loss

This calculation is best shown in a calculation scheme:

Tons of sucrose in mixed juice	....	
Tons of sucrose in cake ...	....	—
Tons of sucrose in clarified juice ...	....	
Purity of clarified juice/100 ...	....	÷
Tons of brix in clarified juice	....	
Tons of brix in sugar made ...		
Tons of brix in molasses ... — +		
Tons of brix recovered ...	....	—
Tons of brix lost ...	....	
Tons of sucrose lost (except bagasse) ...	....	—
Tons N.S. lost ...	....	

It is obvious that

$$\frac{\text{tons sucrose lost}}{\text{tons brix lost}} \times 100 = \text{Purity of Loss}$$

APPENDIX 2

Test of Derived Formula (10) with Actual Figures

The following example was taken from the 41st Weekly Report Sheet of Amatikulu (all figures to Date: 28/1/1967).

Sucrose loss in cake % sucrose in cane	=	0.54
Sucrose loss in undetermined % sucrose in cane	=	0.89
Extraction	=	94.40
Purity Clarified Juice	=	86.54
Purity Mixed Juice	=	84.93
Gravity Purity Final Molasses (refractometer)	=	40.43
Purity of Undetermined Loss	=	31.10
Boiling House Performance	=	98.05

Hence: $c = \frac{0.54 \times 100}{94.40} = 0.572$

$$u = \frac{0.89 \times 100}{94.40} = 0.943$$

$$r = 84.93$$

$$d = 86.54 - 84.93 = 1.61$$

$$P = 40.43$$

$$z = 31.1$$

When these figures are substituted in formula (10) the result is that B.H.P. = 98.08. The slight difference with 98.05 should be explained by the fact that the undetermined loss etc., are only known in two decimals.

These figures were chosen purposely because r = 84.93 is very near the assumed standard purity of 85.0. Also, p for r = 84.93 is 32.81 (see, Table I), which is very near the assumed "standard target" of 33.33. So if the figures are used in formula 12, the R.**B.H.P.** should in this case be *very near* the B.H.P. In fact the result is 98.13.

Discussion

Dr. Douwes Dekker: When, in 1950, the Chemical Control Committee discussed the introduction of a figure which would indicate the performance of a factory better than Boiling House Recovery does, the merits of the old Winter Rendement based on the formula Crystallizable Sucrose=S - 0.4(B-S) were considered. It was rejected, in the first place because the factor 0.4 was deemed too small for Natal conditions and secondly because the formula does not reflect a possibly better exhaustibility of final molasses produced from lower purity mixed juice. At that time it was already known that a higher reducing sugar content and a lower ash content of the nonsugars in final molasses corresponded to a better exhaustibility than a lower reducing sugar content and a higher ash content.

It was also known that low purity mixed juice, in particular if extracted from unripe cane, contains more reducing sugars than high purity juice. The continued evidences prompted the Committee to carry out a simple statistical investigation which showed that taken over several years and taking all factories into account, a slightly lower purity final molasses was produced from lower rather than from higher purity mixed juice. It was subsequently decided—and this decision should not be called "arbitrary"—to use the new knowledge in the formula to be used in future as an indicator of the performance of the factory by replacing the fixed factor 0.4 of the Winter formula by a factor "f" which increased from 0.460 for 82 to 0.530 for 90 purity mixed juice. The new criterion which was called Boiling House Performance has been used for the past sixteen years and one can agree with Mr. van Hengel when he suggests that the time has come to examine again the basis of its method of calculation.

In the first place I have tried to answer the question whether the B.H.P. as calculated annually by tne S.M.R.I. is a function of mixed juice purity or not. I divided all data available from 18 factories over a period of thirteen years in groups of 20. The first group of 20 comprised all mixed juice purities between 81.09—83.52, the second group all purities between 83.57 and 84.20, etc. For each group I calculated the average purity of the final molasses produced by these twenty factories, and their average B.H.P. The following data were found:

Mixed Juice Purity	Mean Purity Final Molasses	Boiling House Performance
81.09-83.52	39.35	96.42
83.57—84.20	39.40	96.95
84.20—84.80	38.70	97.27
84.81—85.14	39.44	97.46
85.15—85.40	40.31	96.96
85.41—85.80	39.34	97.10
85.80—86,10	40.02	97.48
86.10—86.40	39.32	97.41
86.40—86.86	40.17	96.78
86.88—87.57	39.50	96.91
87.67—88.55	39.88	96.33

If the above molasses purity data are divided in two groups and the average purity is calculated for each group, the average figure for the lower mixed juice purity group is lower than the average figure for the higher mixed juice purity group, whether the dividing line between the groups is drawn at mixed juice purity 85.14, 85.40 or 85.80. The differences between the average molasses purities are small but their existence seems to indicate that there has been a definite trend for lower purity mixed juice to yield a final molasses of a somewhat lower purity. This conclusion obviously refers to exhaustion as achieved and not to theoretical exhaustibility. Since the data are industrial averages the applicability of the conclusion to a single factory and the inference to be drawn from such application are matters which need further study.

As to the B.H.P. data shown above, they do not seem to indicate that a higher mixed juice purity has led to a higher B.H.P. or vice versa. The lowest B.H.P. data are found for the groups of extremely low and extremely high mixed juice purities, and when the means are calculated for a high and a low purity mixed juice group, they do not differ more than a few units in the second decimal, whether the dividing line is taken at 85.14, 85.40 or 85.80 mixed juice purity.

Altogether I do not think that the present B.H.P. figure can be accused of tending to prejudice factories working mixed juice of low purity. Within its obvious limitations it seems to have worked fairly well. This however does not mean that a better criterion cannot be arrived at, and I think that it is the task of the Chemical Control Committee, of which both Mr. van Hengel and myself are members, to examine the use we can make of Mr. van Hengel's new criterion.

There is one point which is worrying me, and that is the use of the purity rise by Mr. van Hengel. In this connection I refer to the latest Annual Summary by Mr. Perk in which he quotes Mr. Clayton as having written: "As for the clarification process what efforts have been wasted in the careful measurement of purity rise." Obviously I am aware of the fact that the inaccuracy in our measurement of mixed juice purity also affects the B.H.P. calculation in its present form.

Mr„ van Hengel: I withdraw the word "arbitrarily", but stand by the word "presumed". As Dr. Douwes Dekker states, a simple statistical investigation was carried out but such an investigation could easily lead to wrong conclusions. It is incorrect to try to prove the dependence of such a complex figure as the B.H.P. on one factor only, especially if it be such an imperfectly proved one as the influence of reducing sugars in low purity juices. From the statistics produced by Dr. Douwes Dekker, the following questions arise:

1. Are molasses from high purity mixed juices more difficult to exhaust with available machinery than those of low purity juices with the same machinery?
2. Does not the comparative ease with which a reasonable B.H.P. or B.H.R. is obtainable, or even sucrose lost in molasses % sucrose in cane, possibly allow a certain amount of carelessness on the part of the process manager?
3. Is not the absence of a formula like the revised B.H.P. which makes it harder to obtain a good B.H.P. when the purity of mixed juice is high, the reason why it was never found that equally low or lower purities could be produced when ample boiling time and centrifugal capacity were available (all for standard installations).

I once more refer to Graham's statement—quoted on page 3—"Under normal factory operating conditions . . ." etc. and the ensuing paragraph.

Coming to a practical comparison in my calculated examples, the factory producing 37.5 purity final molasses can still not match the same B.H.P. as the factory with 40.0 purity final molasses, the values being 95.86 and 96.54 respectively. If 2.5 points difference cannot compensate the mixed juice purity advantage, how can the maximum one point as shown by Dr. Douwes Dekker's "simple statistics"? Obviously other influences, such as undetermined losses, etc., play a role.

Dr. Douwes Dekker is worried by my use of the purity rise from mixed juice to clarified juice. The B.H.P. is based on the mixed juice purity and I can assure you that if one takes the trouble of substituting actual factory data in my formula, the identical answer is obtained as the one derived in the normal way. The term 'd' simply has to be there to represent the purity increase which is recorded, whether the difference is apparent or not.

I feel that my formula (10) states clearly what is actually happening in a sugar factory. The accuracy of the formula should be either disproved or accepted, but not vagely discredited on account of "simple statistics".

Mr. Alexander: (in the chair). Do you agree that the use of the refractometer could possibly allow the 'd' to be removed from your formula?

Mr. van Hengel: Yes, if the refractometer could also be used for mixed juice. As it is now, the refractometer is used for clarified juice and molasses purities and brix is recorded as 85 instead of 92. As the sucrose determination remains unaltered, this represents a sucrose loss of 7% in molasses, not compensated by the mixed juice purity.

Mr. **Fourmond:** Mr. van Hengel says that the B.H.P. in its present form does not correctly express the efficiency of a boiling house as it does not take into account losses in filter cake, undetermined losses, purity or the efficiency of clarification. He is incorrect as the S.A.S.T.A. Chemical Control Committee made a 'hidden' allowance for these losses and for efficiency of clarification by fixing the targets for factor 'f. The fact that in 1957 Sezela and Illovo achieved a B.H.P. of 100.0 and 99.7% respectively is proof that such provisions were made.

He also assumes that the purity of mixed juice has no influence on the purity of final molasses. Again he is incorrect as many years ago Prinsen Geerligs proved that salts have more affinity for reducing sugars than for sucrose and it is common knowledge that juices of high purity have a lower reducing sugar ash ratio than juices of low purity. The Douwes Dekker formula for target purity is based on this and sugar technologists know that the purity of molasses varies directly with the purity of mixed juice, B.H.P. was formulated with this in mind, based on practical findings, in order to take care of the mixed juice purity.

In the paper it is also assumed that the purity of mixed juice influences B.H.P. and to prove the point a series of calculations are given, but these are misleading as they are based on assumptions.

Let us take two factories processing mixed juice of 82 and 88 purity respectively. If both suffer losses in cake of 0.50%, undetermined losses, at same purity levels, of 1.50% and both exhaust their molasses to target purity then both will achieve a B.H.P. of 97.8%. This is proof that purity of mixed juice has no effect on B.H.P. in its present form.

Mr. van Hengel is correct in saying that efficiency of clarification and the purity level of undetermined losses will influence B.H.P. One degree rise in clear juice corresponds to 0.3% rise in B.H.P. and a difference of purity level of 20 in undetermined losses for a loss of 1.5% corresponds to .2%.

Mr. du Toit: I am pleased that Dr. Douwes Dekker has pointed out that after seventeen years the B.H.P. figure is possibly due for revision.

I do not agree with Mr. van Hengel's comments on the figures presented by Dr. Douwes Dekker. He referred to the purities and the differences with target as irrelevant. I do not consider them irrelevant. If the figures were not affected by purity or final molasses the differences should have had a definite trend, which they did not have. The fact also that the difference in final molasses purity between mixed juice above and below 85 is small does not mean that the argument on which it is based is not sound, because the differences between the purities could also have been small. I think it is necessary that a proper statistical evaluation be made to determine if final molasses purity does, within the range that we experience, depend on the purity of mixed juice.

Dr. Douwes Dekker: Mr. van Hengel has asked why his calculations have not been criticised. The reason is that as such one can agree with them. I have merely been trying to find out if there is any good reason why we should reject the present B.H.P. figure and as far as I can see there is still no evidence that the B.H.P. figure provides an unrealistic criterion.

Mr. van Hengel: The fact that the figures are more or less the same through the years does not prove that the B.H.P. is a realistic criterion; in fact it proves the opposite. An accurate mass balance shows that every factory is losing progressively more crystal with lower mixed juice purities if the molasses purity is higher than the assumed "target" purity. So, factories producing an average B.H.P. from high purity mixed juice have a lower than average performance.

Mr. Fourmond: When the present formula for B.H.P. was derived provision was made for losses in filter cake and undetermined, but what was the standard determined?

Dr. Douwes Dekker: The evidence of past figures is usually used for setting standards.

One advantage of the old B.H.P. formula is the target figure of 100. If I understand the proposed new formula correctly we would have to set targets for all five variables.

Mr. van Hengel: I do not at all suggest the introduction of five standards. I take the losses in cake and undetermined as they are. We know what is normal or abnormal, but I correct for the purity of the loss, e.g. a defect at the mixed juice scale may cause a certain undetermined loss, and a defect at the molasses scale may cause an identical one. But in the first case, crystal is lost and the **B.H.P.** is affected, in the last case it is not. Does Dr. Douwes Dekker maintain that the present B.H.P. gives a fair comparison of the work done in our factories, so that a process manager obtaining 98 **B.H.P.** is really doing better than the man obtaining 97, and that it is not necessary to take into account other relevant factors?

Dr. Douwes Dekker: We are dealing with the past performance of our factories. From the figures I gave if factories were working mixed juice of a purity between 86.88 and 87.57 the average B.H.P. was 96.91. If the mixed juice purity was between 83.57 and 84.20 the B.H.P. was 96.95. So if you have mixed juice purities of 83 and 87 factories apparently should show the same B.H.P.

Mr. van Hengel: That is not a straight answer to my question. Different factories, different circumstances, different years are compared. My question was: Are the B.H.P. figures calculated at present a fair reflection of the quality of the performance?

FURTHER IMPROVEMENTS IN RAW SUGAR QUALITY

BY R. P. JENNINGS
Hulett's South African Refineries Ltd.

Introduction

The improvement in the quality of raw sugars sent to Hulett's Refinery during the three seasons, 1963/64 to 1965/66, was the subject of a paper presented to this association last year. (1) These improvements have been maintained and even accelerated during the 1966/67 season.

Criteria used for assessing quality of raw sugar

The factors which have been used in assessing changes in the quality of raw sugars are those which most affect the refining characteristics of that sugar, namely grain size, filterability, and the concentration in the crystal of ash, starch and total gums.

While polarisation and moisture are of considerable significance to the refiner, especially as far as storage and affination techniques are concerned, Hulsar's demands regarding these factors are less strict than is the case with overseas refineries. For this reason, the criteria used for the comparisons have been restricted to those concerned with the washed sugar.

The list includes filterability, although the use of current laboratory filterability tests for predicting the filter performance of sugars at Hulsar is now open to serious doubt (2, 3).

The Improvement in Quality

Table one summarises the average analyses of all Natal raw sugars received at the refinery during the past few seasons. Figures for the 1966/67 season represent sugars received up to the end of January, 1967.

Table I

Season	1963 /64	1964 /65	1965 /66	1966 /67
Specific Grain size (mm) . .	0.59	0.58	0.60	0.69
% 'Fine Grain' (-Tyler 28) . .	37.9	36.9	35.0	22.7
Filterability % (CSR 20°C) .	30	36	36	43
Starch in crystal (ppm) . . .	730	520	470	380
Sulphated Ash in crystal (%)	0.15	0.11	0.11	0.08
Total Gums in crystal (%) . .	—	0.20*	0.17	0.14

***Note:**
Gum in crystal for 1964/65 season refers only to the period December to February.

In table two, the sugars sent to the refinery have been grouped according to filterability, and the distribution per season of sugars in each filterability group expressed as a percentage of the total raws received.

Table II

Season	Filterability % (CSR 20°C) >40%	40–30%	30–20%	<20%
1963/64 . . .	20.0	32.6	28.4	19.0
1964/65 . . .	36.1	35.1	21.9	6.9
1965/66 . . .	39.8	32.2	17.2	10.8
1966/67 . . .	64.1	23.0	11.7	1.2

Table three compares the quality of sugars produced during the seasons 1965/66 and 1966/'67 by the Refinery's main contributors. Only those mills which have contributed more than 5,000 tons of sugar in both seasons have been used for these comparisons.

Discussions

The overall improvement in the quality of sugars sent to Hulsar during the past few seasons is obvious from a study of the tables. In particular the very rapid improvement in quality recorded last season should be noted. Crystal impurities have been reduced, filterability increased and grain size improved to a figure which would obtain substantial bonuses for the sugar in question if assessed according to the specifications of at least one overseas refinery.

While the quantity of impurity in the crystal has been reduced considerably, it is interesting to note that sugar sent to the refinery this season by Umzimkulu contained 20 ppm starch, 0.02% ash and 0.07% gums in the crystal. The effect of the new clarification techniques on the crystal purity of sugars from other mills will be watched with great interest.

Also interesting is the analysis of the small parcel of sugar received at the refinery from Union Bark Co-operative, where a B.M.A. diffuser is used. This sugar, with a filterability of 67%, contained 60 ppm starch, 0.04% ash and 0.06% gums in the crystal. While the good quality of this sugar must be due in part to the nature of the cane at Dalton, it will be interesting to see the changes in quality of Empangeni sugar following the introduction of diffusion.

Summary

The greatly improved refining quality of raw sugars sent to Hulett's Refinery during the 1966/67 season compared with previous seasons, is assessed in terms of filterability, grain size and crystal purity.

References

1. Jennings, R. P. Improvements in Raw Sugar Quality. Proc. S.A.S.T.A. Vol. 40, 1966, page 192.
2. Jennings, R. P. A Modified Method for Determining Filterability. Proc. S.A.S.T.A. Vol. 40, 1966, page 199.
3. Jennings, R. P., and Alexander, J. B. A Comparison between Laboratory Filterability Tests on Affined Raws and the Filterability of Factory Carbonated Liquors. 2nd Technical Session, Cane Sugar Refining Research Project, 1966, in press.

TABLE III

Mill	Empangeni		Felixton		Amatikulu		Darnall		Glendale		Tongaat		Mt. Edgecombe		Sezela	
Season	65/66	66/67	65/66	66/67	65/66	66/67	65/66	66/67	65/66	66/67	65/66	66/67	65/66	66/67	65/66	66/67
Specific grain size	0.61	0.75	0.66	0.70	0.62	0.77	0.62	0.66	0.41	0.56	0.56	0.69	0.65	0.74	0.51	0.55
% Fine Grain	30.3	14.9	26.3	20.1	32.4	13.2	29.5	24.3	75.4	38.7	41.9	21.5	24.9	17.6	49.7	41.6
% Filterability	32	40	42	43	47	57	36	40	34	36	26	52	47	37	48	38
ppm crystal starch	590	560	500	470	410	370	460	370	390	420	530	270	370	400	260	290
% crystal ash	0.09	0.09	0.08	0.08	0.10	0.06	0.09	0.05	0.15	0.14	0.14	0.08	0.05	0.08	0.13	0.13
% crystal gums	0.17	0.16	0.16	0.14	0.15	0.13	0.16	0.14	0.18	0.16	0.22	0.13	0.14	0.15	0.12	0.14

Notes: 1. Amatikulu results for 1965/66 refer to sugars produced at both old and new mills, whereas 1966/67 results refer to new mill sugars only.
2. During 1966/67 season, Mount Edgecombe changed from sulphitation to defecation clarification.

Discussion

Mr. Bentley (in the chair): The figures in Table III show that Mount Edgecombe, after changing from sulphitation to simple defecation now shows a higher starch figure in its sugar, whereas starch has declined in most other factories' sugar.

I am interested to know why starch is always shown as ppm whereas gums are shown as a percentage.

Mr. Alexander: I am from the refinery and I must congratulate the mills on the better sugar we received this season. However, this may not be entirely due to the efforts of the mills because at the end of the season we received some sugars with over 1,000 ppm starch, so possibly the mills received the best cane early in the season.

Mr. Ashe: At the end of the paper the low starch content of Union Co-op. Bark sugar is mentioned, so we await with interest Empangeni's figures next year when their diffuser is installed.

Are there any figures for starch in Entumeni's sugar?

Dr. Graham: The S.M.R.L has been working at Entumeni since December.

As long as the diffuser operates below 70 °C the starch content in the juice is small. At higher temperatures the starch concentration is about the same as in the mill juice. As the diffuser operated most of the season above 70°C starch was fairly high. A reservation about operating at 70° is a possible drop in extraction but we are not yet sure of this. Dalton had cane of very low starch content, and this probably contributed largely to the low starch content of their sugar.

Mr. Fourmond: I believe that Mr. Bruijn has found that frosted canes have a very low starch content, and Dalton cane was affected by frost.

Mr. Bruijn: That is true but I do not have figures to show how much of the cane at Dalton was frostbitten.

Mr. **Box:** In connection with what Dr. Graham said, the starch in diffuser juice, even when it is operating at 75°C, is still lower than in the juice from a 2nd, 3rd or 4th mill.

Dr. Graham: In the S.M.R.L Annual Report a few years ago we gave figures for starch in different mill juices and our conclusions were that primary juice contains only about a quarter of the starch contained in secondary juice. However, these figures were unreliable as the juice samples analysed, which were from Mount Edgecombe, were taken at periods as much as a month apart. Recent analyses have shown the starch content of primary and secondary juice to be of the same order of magnitude.

For high temperature operation Entumeni juices showed similar starch contents for primary and diffuser juices. While some aspects of sugar quality cannot be easily controlled, others are, and the mills are to be congratulated on the improvement in grain size during the past season.

Mr. Fourmond: Seeing what is being done to solve the starch problem, I hope the engineers will not spoil the effect by applying hot imbibition.

Mr. **Buchanan:** When a solution of starch is studied under a microscope it is apparent that even if the temperature is raised to boiling point the granules take some time to swell, burst and release the soluble portion into solution, and it takes even longer for the husk of the starch granule to dissolve. A milling tandem has a very short imbibition time so hot imbibition should have very little effect unless it is very hot and the normal retention time is extended,

A USEFUL YARDSTICK FOR VOLUME OF C-MASSECUITE

by L. T. FOURMOND
Hulett's Sugar Corporation Ltd., Amatikulu

It is common practice in the sugar industry to calculate the ratio cu. ft. 3rd massecuite boiled per ton of solids in mixed juice as a guide to whether we boil too many thirds or not. Process Managers swear by this yardstick and even Mr. Perk quotes this figure in his Annual Report of Chemical Laboratory Control.

If quantity of molasses is directly proportional to non sucrose present in mixed juice, it is obvious that the quantity of 3rd massecuite boiled will follow the same pattern. We can, therefore, conclude that cu. ft. 3rd massecuite will be inversely proportional to the purity of the mixed juice. Hence this yardstick has only a relative value which can easily lead to confusion and the following figures, taken at random from the 1964 Annual Chemical Laboratory Report, will clearly prove the fact.

Mills	Purity Mix. Juice	Cu. ft. 3rd massecuites boiled per ton solids in mixed juice
Umzimkulu	88.2	6.58
Entumeni	87.8	6.18
Renishaw	87.2	8.85
Illovo	85.8	9.18
Tongaat	85.6	8.61
Amatikulu	85.5	7.73
Natal Estates	85.4	7.83

It can be seen that Umzimkulu and Entumeni have the lowest figures on account of the high purity mixed juice. On the other hand, Illovo and Renishaw have extremely high figures which could be due to bad clarification, high inversion, excessive recirculation of non sucrose, inaccurate calibration of crystal-Users and wrong measurement of strikes or high purity 3rd massecuite.

Amatikulu and Natal Estates have the lowest figures for the same purity of mixed juice. However, nobody can say what the ratio should be at any given purity of mixed juice and the aim of this paper is to discuss this issue.

The problem, therefore, is to find a yardstick which will take care of the mixed juice purity level, have an absolute value, and give accurate guidance.

If quantity of molasses is directly proportional to non sucrose in mixed juice and the quantity of 3rd massecuite boiled follows the same pattern, then the answer appears to be quite simple, i.e. "Cu. ft. massecuite boiled per ton non sucrose in mixed juice", as this will take care automatically of the mixed juice purity at any level. If we wish to be really precise, we can also bring the brix of the massecuite into the picture and relate it to 100 brix.

It is, therefore, suggested that for the control of 3rd massecuite boiling, the following yardstick be used; *CU. FT. 3RD MASSECUITE BOILED AT 100 BRIX PER TON NON SUCROSE IN MIXED JUICE.*

What would this figure be like in practice? To arrive at it the following factors must be taken into consideration;

(a) removal of non sucrose during clarification, which for a 1.5 rise in the purity of clear juice represents some 13% non sucrose removal;

(b) loss of sucrose in F.C. which is usually 0.50% sucrose in mixed juice,

(c) the % undetermined losses through entrainment and the purity level. As a rule such losses average 1.5% at a 50 purity level, which represents some 8% of non sucrose lost;

(d) the increase in volume of the massecuite at striking temperature;

(e) the purity of the 3rd massecuite, which is taken at 60.

If we agree to the above figures, we arrive at a ratio of 46-47 cu. ft. per ton non sucrose.

In practice we shall never reach this target for two reasons, namely, the appreciable quantity of massecuite which adheres to the wall and stirrers of the crystallisers and the impossibility of draining completely the bottom of crystallisers, factors which lead to an apparent higher volume of massecuite boiled.

A realistic mean would be in the vicinity of 48-50 cu. ft.

Interpretation of Yardstick

A high ratio of massecuite boiled can be as a result of many factors:

(a) The higher the purity of the massecuite, the greater will be the volume of massecuite boiled. We should always bear in mind that there is a relative fixed quantity of non sucrose to be eliminated in the molasses and the selection of the 3rd massecuite purity should be with an eye to achieving target purity in the final molasses.

There are two factors governing the crystallisation of sucrose and the exhaustion of molasses.

(1) The chemical aspect where one non sucrose will immobilise a certain amount of sucrose according to reducing sugars ash ratio.

(2) The physical aspect (viscosity), as the rate of crystallisation is inversely proportional to viscosity. Any attempt to lower the 3rd massecuite purity to a dangerous zone of viscosity will only create bad circulation in the pans and in the crystallisers, with consequent bad massecuites which will cure poorly and result in excessive recirculation of non sucrose and higher purities of final molasses.

Rule of thumb: Boil the 3rd massecuite at the highest purity permissible to still achieve the target purity in the final molasses, because such massecuites will boil and cure better and there will be less non sucrose recirculated. After all, our aim is only to achieve target purity (true D.D) and the hypothesis that target purity of final molasses can be lowered by lowering the purity of the massecuite has proved to be fallacious in practice.

(b) Removal of non sucrose during clarification will have a marked effect on massecuite boiled and molasses produced and will vary indirectly. As a rule we can expect a minimum removal of 10% in the defecation process.

(c) Recirculation of non sucrose through bad massecuites, which cure poorly, will also contribute to a higher ratio of massecuite boiled.

(d) Inversion of sucrose and high destruction of reducing sugars will also increase the ratio of massecuite boiled.

On the other hand, a low figure for this ratio does not necessarily mean that good work is being achieved. It could be the result of either high losses In filter cake or of high undetermined losses through entrainment, and the level of Its purity.

The purity level of entrainment will influence the ratio of 3rd massecuite boiled. The ratio will vary Indirectly to purity level of entrainment. However, parity level of entrainments will also affect indirectly, the boiling house performance, as the higher the purity level the greater Is the loss of crystallisable

Conclusions

The rules which lead to high recovery of sugar are as follows:

(1) Removal of as much non sucrose as possible during the clarification process and the minimisation of losses in filter cake.

(2) **Avoidance** of unnecessary destruction of **sucrose** or reducing sugars through too high or too low a pH In tempering the juice.

'(3) Minimisation of tosses through entrainment especially at high purity levels.

(4) Taking advantage of the high rate of crystallisation in the 1st **and** 2nd massecuites in **order** to recover as much crystallisable sucrose as possible from these massecuites, bearing in mind the relatively lower exhaustion which is achieved in the 3rd massecuite.

(5) Avoidance, by all means, of unnecessary recirculation of non sucrose as this constitutes the worst crime which can be committed in sugar boiling. Viscosity retards tremendously the rate of crystallisation and recirculation of non sucrose is bound to affect the exhaustion of the 1st and 2nd massecuites, especially when 2nd and 3rd sugars are remelted.

(6) Selection of 3rd massecuite purity according to cane quality. The purity of mixed juice can easily lead to confusion. A cane deteriorating from 88 to 80 purity is a totally different proposition from a fresh immature cane of 80 purity, the difference being that the deteriorated cane contains organic compounds such as gums and pectins etc. which by increasing the viscosity of the juice, retard tremendously the rate of crystallisation hence leading to bad massecuites and poor exhaustion. It is common knowledge that after severe droughts, cane containing a higher % of organic non sucrose will yield a poor boiling house performance.

The yardsticks are useful to provide guidance. However let us bear in mind that to interprete them correctly, we often have to correlate different factors as otherwise we could easily be lead up the garden path.

Chief Chemists and Process Managers are well advised to remember that crystallisers must be accurately calibrated and volumes of strikes correctly measured should they wish to use this yardstick as a measure of good pan boiling. Also, the variance in stock should be taken into consideration and the quantity of 1st and 2nd molasses which have not been boiled into massecuites at weekends.

The following represent the figures for Amatikulu:

Purity rise in clear juice	1.6
Non sucrose removal during clarification	14.5
Lost in F.C % sucrose in Mx. juice ..	0.58
Undetermined loss % sucrose in mixed juice	o.94
True purity—D.D. target purity	+0.7
Cu. ft. 3rd massecuite boiled @ 100 brix per ton non sucrose in mixed juice ...	49.0
Purity 3rd massecuite	59.2

Great attention is paid to the calibration of the crystallisers and the measurements of every strike at Amatikulu.

Summary

The suggestion has been made to correlate the volume of 3rd massecuite, boiled at 100 brix, to tons non sucrose in mixed juice as this yardstick will take care of the mixed juice purity at any level.

Some guidance is also given for the correct interpretation of this yardstick.

Discussion

Dr. Graham: Mr. Fourmond says on page two, "our aim is only to achieve D.D. target purity". This is not correct as our aim is to recover as much sugar as possible and to achieve maximum exhaustion. The D.D. target purity was evolved as a result of a statistical analysis of data from some Java factories which were considered to be operating satisfactorily. The data were collected in 1939 and with improved equipment we should nowadays achieve lower purity. If we apply this D.D. formula in South Africa the purity it predicts need not be the minimum purity that can be achieved.

There is the criticism that the formula may not apply exactly here but in the absence of any other more suitable formula we are at present obliged to use it.

We carried out tests some years ago and Umzimkulu regularly produced purities about 2 1/2 degrees below the target figure.

Mr. Fourmond: Very few factories in South Africa reach the D.D. target purity. Amatikulu, which had the lowest purity of molasses, was however + .7 above D.D. target purity.

I am surprised at your figures for Umzimkulu because their BHP that year was not particularly good.

Mr. Hulett: Mr. Fourmond says that it has been proved fallacious that lowering the purity of the third strike lowers the purity of the final molesses. I checked a whole year's third massecuites at Darnall and some of the highest purity strikes produced the lowest purity molasses. Someone in Puerto Rico plotted the massecuite purity from every third strike for all the mills of Puerto Rico and he definitely showed that the lower purity massecuites on average produced lower purity molasses.

The odd high purity massecuite does produce a low purity molasses but this may be tied up with pan boiling.

Mr. Fourmond: I think we should stick to figures from South Africa. At Amatikulu a massecuite of 60 did give a lower purity molasses than one of 57 —but the purity of the first sugar cured was 95 and the other was 91 respectively, indicating the amount of recirculation of non-sucrose.

Mr. Robinson: Figures from all Hulett mills showed that the lowest average final molasses purity came from the lowest average C- massecuite purity. Provided the factory can be kept running at the desired speed we must endeavour to keep our massecuite to the lowest possible boiling purity to get the lowest possible molasses purity.

Mr. Fourmond: In my paper it is said that there is a limit to which massecuite purity can be lowered as otherwise the viscosity of the massecuite is so high that it defeats the object. This will depend on cane quality.

It might be advisable to determine the viscosity of the second molasses as a guide to the process manager.

Mr. van Hengel: Mr. Hulett referred to a paper by Mr. Serbio from Puerto Rico. As a result of this paper all Hulett factories carried out an investigation into the relationship between C- massecuite purity and final molasses purity. We plotted the figures and the graph showed that there is a 1° purity drop per 2 1/2 massecuite purity drop. If you go from 60 to 57 1/2 you will go from 40 to 39.

It also appeared that below 58 spindle purity there is very little advantage to be gained.

Last year Amatikulu worked their C- massecuite at 59.3 and their final molasses purity was 37.25 on spindle.

Mr. Fourmond: Mount Edgecombe, boiling from a lower purity, 58.0, got 37.37 purity molasses. So where is the advantage? Masses-cuites of 59.3 are easier to boil and cure than masses-cuite of 58.0.

Mr. Hulett: It is not possible to compare one factory against another in this fashion owing to a completely different set of conditions. It is only possible to follow one factory's own performance figures,

Mr. Hulett: Mr. Fourmond says it is important to get as much exhaustion as possible from the first and second strike of high grade purity. If you do this how can you boil a third strike on B- molasses at 60 purity? You would have to add a lot of syrup.

Mr. Fourmond: At Amatikulu we got 68 exhaustion in the first massecuite, 66 in the second and only about 57 in the third. Whatever sugar you are going to boil in the third massecuite will be the difference in exhaustion between those two.

In drought years it pays to raise the purity of the third massecuite because of the higher viscosity.

Mr. Chiazzari: Invert sugar appears to have a pronounced effect on the purity of final molasses.

Do we not stress purity too much? I have often observed that molasses purity may increase but recovery will improve. **We should** pay **more attention** to total sucrose losses in molasses.

Mr. Fourmond: It is possible to estimate fairly accurately what the losses in molasses should be by applying factor 'f', but differences in juice quality must be kept in mind.

In my paper it is clearly said 'boil the 3rd massecuite at the highest purity *permissible to still achieve target purity in the molasses* I did not say that the higher the purity of the 3rd massecuit, the lower will be the purity of the molasses. The purity of the 3rd massecuite must be selected according to cane quality, viz. reducing sugar's ash ratio and viscosity.

VACUUM PAN CONTROL

PROGRESS REPORT NO. 2

by G. N. ALLAN and D. E. WARNE
Sugar Milling Research Institute

Continuing the project started at Gledhow last year (1965) it was decided to divide the work into two inter-related aspects:

(1) Temperature measurements in order to establish a circulation pattern and,

(2) Installation of controls to stabilise conditions in the pan.

Temperature Measurements

Nine 2 1/2" diameter pipe probes were built into the pan at three levels, below calandria, above calandria and four feet above the tube plate. (See Fig. 1). The probes were arranged vertically in three planes at 10°, 45° and 90° to one of the steam inlets, thereby ensuring that a symmetrical cross-section of the massecuite could be obtained. The platinum resistance thermometers were mounted in brass capsules on each probe, one on the pan centre-line, one at the edge of the downtake and one clear of the outside wall. The three centre thermometers were common to the three vertical planes.

Numerous readings were taken throughout the season, both with and without control, in all three vertical planes and these were then plotted out on a large scale. No significant circulation pattern can be deduced from the readings so obtained. The readings show very small differences in temperature across the calandria, mainly of the order of 1.8 °F. As this is a seed pan and is cut over at 85°Bx. the mobility is still reasonable and it is hoped to boil a pan up tight and see if any significant difference appears. Owing to operational demands this has not so far been possible, but next season a seed mixer is being installed and this will facilitate pan floor operation, enabling this point to be checked.

The three top level thermometers are clear of the massecuite for the early stages of the boiling and thus record the vapour temperatures in the pan. This has averaged about 16°F super-heat above saturated vapour temperature for the set point vacuum. With vacuum control the condenser tailwater has averaged 126°F. Lyle[6] maintains that vapour cannot be superheated and any measurements which purport to show this are merely measurements of droplets which have condensed on the thermometer. These droplets will be at the elevated boiling point of the solution. Badger together with Webre and Robinson disagree and say that vapour can be superheated. We are carrying **out** more detailed checks of tailwater and injection water temperatures.

The pan temperature readings show that despite accurate vacuum control sudden syrup feeds, water feeds and closing of the steam valve can create undesirable temperature fluctuations in the pan. Two temperature charts are shown, Figs. 2 and 3, one without control and the other with vacuum and liquor feed control. It can be seen that temperatures can be held to within about 2°C in a controlled boiling. The tolerance of a resistance thermometer is within 0.2 °C and the curves shown are the averages of three points at the three levels. The curves of both boilings show that the temperature below the calandria is higher than that above it at some points, but we feel that further checks are required before offering an explanation for this. Boiling a complete strike should show us a greater spread of temperatures across the calandria, and when we have done this type of boiling we shall feel more confident to comment. Temperature readings of massecuite can also be used for Boiling Point Elevation measurement and it is planned to correlate these figures with Webre Chart readings and again with conductivity values to give two workable systems of pan control.

Pan Control

A control panel (Fig. 4) comprising absolute vacuum control, calandria steam pressure control and a syrup feed control based on a conductivity signal was installed at Gledhow. All three instruments record and are of the proportional plus reset type of controller.

A 10" diameter butterfly valve and a 6" diameter bypass valve have been fitted to the injection water inlet main (Fig. 5) and a 12" diameter butterfly valve on the steam main. These valves are operated by Hagan Power positioners. An air pressure controlled rubberlined pinch valve has been supplied for the liquor feed but a null-balance controller to balance the vacuum on the inside of the valve has not yet arrived from America. Temporarily, a double-seated 2 1/2" diameter Fischer and Porter valve (Fig. 6) is in use on the pan control system. A small bore water valve is still required.

The steam control system proved disappointing owing to the rapid rate of condensation in the calandria. No more than two or three p.s.i.g. could be obtained as a signal and for the initial part of the boiling no pressure at all was registered. With a maximum syrup brix of 55, and it was quite often around 51, the pan is called upon to do a considerable amount of evaporation before graining, and during this period the condenser and/or cooling water just cannot cope and vacuum is reduced. The 12" steam valve itself presented some mechanical difficulties, but is now coupled up to work on an over-riding signal from the absolute vacuum controller. The steam is opened with the isolating valve which is then infrequently adjusted until completion of the boiling. Should the evaporation rate be too high for the condenser to maintain vacuum, the 12" steam butterfly valve slowly closes off until equilibrium is maintained, the controller being set with a wide proportional band.

The conductivity electrodes are supplied with an alternating current at 8 volts, and the measuring circuit current is converted to D.C. and then measured by a Conoflow electro-pneumatic transducer having a linear output of 0-20 p.s.i.g. air pressure. This signal is fed into a pressure recorder controller and thence to the liquor feed valve.

Electrodes are positioned as shown in the sketch, but for control we have so far used the pair in the centre of the downtake. Frequent stops for low syrup supply occur and to cope satisfactorily with this, and to supply mobility water, a 1" bore water valve has still to be installed. A change-over switch from syrup to water would effect the necessary change of controller output signal to the required valve.

Accurate vacuum control is absolutely essential for any form of pan control and in addition there is a marked smoothing of temperature and vacuum curves once the automatic syrup feed valve is switched in (Fig. 7). A simple vacuum control valve devised by Webre is shown (Fig. 8) and a full description is in Sugar Y Azucar, April, 1965, issue. This type of valve does not, of course, reduce water supply to the condenser but merely bleeds in air at a set vacuum and maintains a steady condition.

There is a difference in conductivity signal which varies from boiling to boiling and this has still to be calibrated.

Conductivity is sensitive to temperature, crystal content and molasses purity,[3] as indicated in Fig. 9, and therefore before graining syrup purity and temperature differences must be taken into account.[1] Possibly the Ash/R.S. ratio must also be examined.

The difference in "slackness" or crystal content of a boiling can be readily controlled by alteration of the set point on the syrup feed controller. There is a timelag of about 10 minutes to follow up a 2% shift.

Saturation Point

A paper was published in Spanish by Diago giving tables for saturation and super-saturation based on refractometer brix.[4] One of these tables (86 A.P.) has been plotted on a Webre B.P.E. Chart[2] (Fig. 10) and refractometer Bx's were read before seeding several pans. Manual judgment of the seeding point by the pan boiler coincide closely with the values which he gives. This is of the order of 78.5 Bx. i.e. at about 1.15 super-saturation which is in the middle of the metastable zone and the correct point for seeding.

General

To give some idea of the extent to which pan control is used overseas a summary of a survey conducted in Hawaii by W. S. Haines in 1963 is given below.[5] Of a total of 116 pans, 94 have vacuum automatically controlled by varying water to condenser and 6 are automatically controlled by Air Bleed. 46 use B.P.E. or Massecuite consistency (circulator or probe motor load) to control syrup, molasses or remelt feed. 54 receive feed with density automatically controlled at evaporators. Conductivity of massecuite is not used as a basis of control in Hawaii.

As a general background to pan performance and an estimate of condenser water requirements the steam consumption of the pan was noted for some controlled boilings.

The following tests remain to be carried out in the coming season;

1. An A.C. milli-ammeter is at present being constructed by the S.M.R.I. workshop in order to calibrate the conductivity charts into electrical units.
2. Checks of syrup purity, mother liquor purity and crystal content throughout some boilings including a complete strike.
3. An assessment of consistent improvement in sugar quality once pan boiling control is used as a routine procedure.
4. Correlation of conductivity control with B.P.E. from temperature measurement.

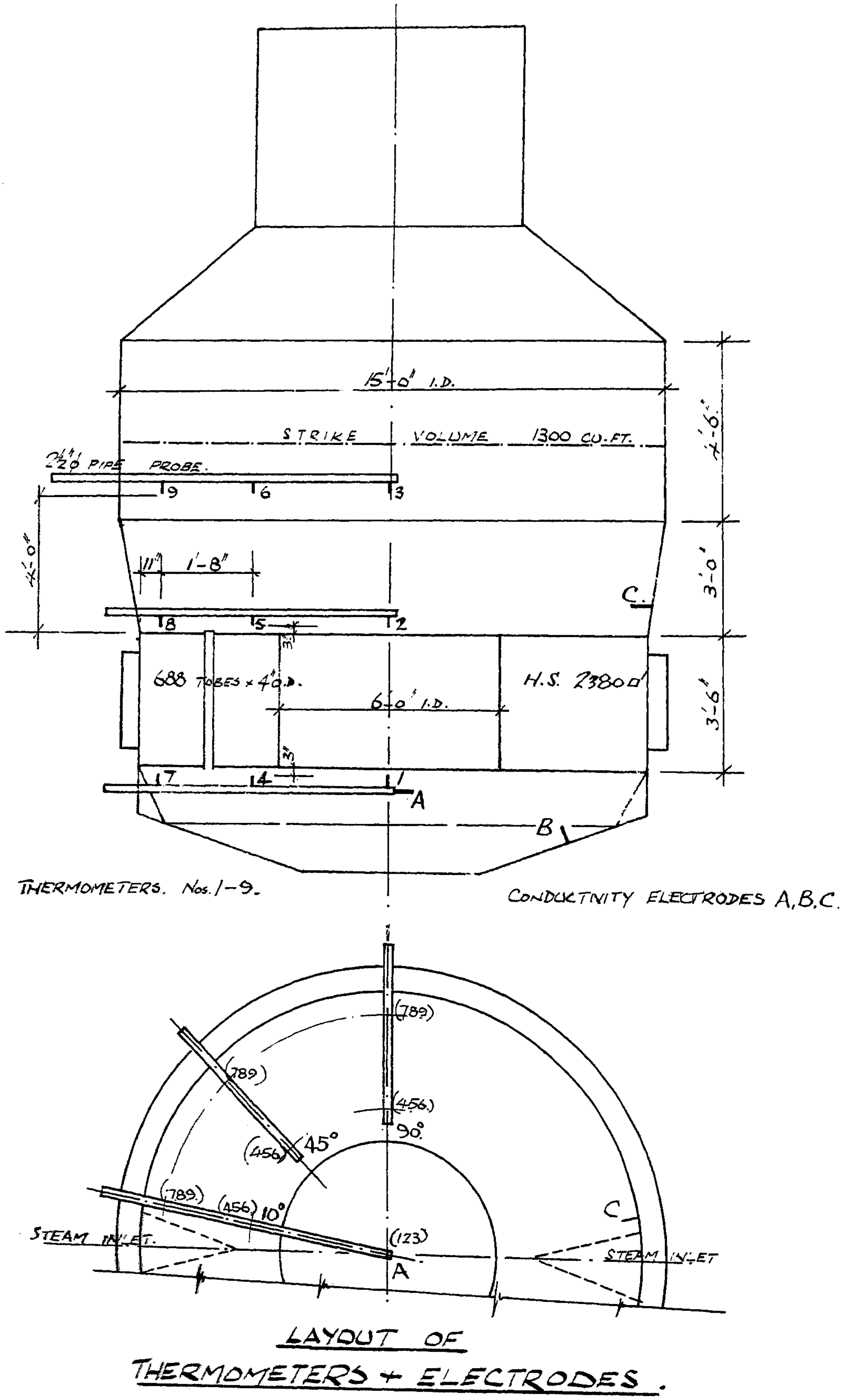
Acknowledgements

Appreciation is expressed to the Management, Engineering and Process Staff at Gledhow for their co-operation and assistance during the past season and also to Messrs. Negretti & Zambra for providing the control equipment with which we have carried out this work. Thanks are due to Messrs. Hulett's Refineries Ltd. for the loan of the Syrup Control Valve.

Messrs. Bruijn and Bowes of the S.M.R.I. designed and built the electric measuring devices used in these tests.

References

1. Ahari, D., Genotelle, J., Hoclent, Michel, R. Validity of Electrical Conductivity for Control and Automatic Boiling in Beet Sugar Factory. British Sugar Corporation Ltd. 18th Technical Conference, 1966.
2. Fischer and Porter Publication No. 11353. B.P.E. Tables.
3. Wright, P. G. Control of High Grade Boilings. 28th Congress Q.S.S.C.T. 1961.
4. Diago, R. E. Refractometric Determinations to Assist Graining by Seeding. Sugar Y Azucar. Oct. 1965.
5. Haines, W. S. Pan Control Survey. Hawaii Sugar Technologists Congress, November, 1963.
6. Lyle, O. Sugar Technology for Refinery Workers.


15'-0" I.D.
STRIKE VOLUME 1300 CU.FT.
2½" Ø PIPE PROBE.
4'-6"
3'-0"
3'-6"
4'-0"
11" 1'-8"
688 TUBES × 4" O.D.
6'-0" I.D.
H.S. 2380□'
THERMOMETERS. Nos. 1-9.
CONDUCTIVITY ELECTRODES A,B,C.
(789)
(456)
(123)
45°
90°
10°
STEAM INLET.
STEAM INLET
LAYOUT OF
THERMOMETERS + ELECTRODES.

FIGURE!

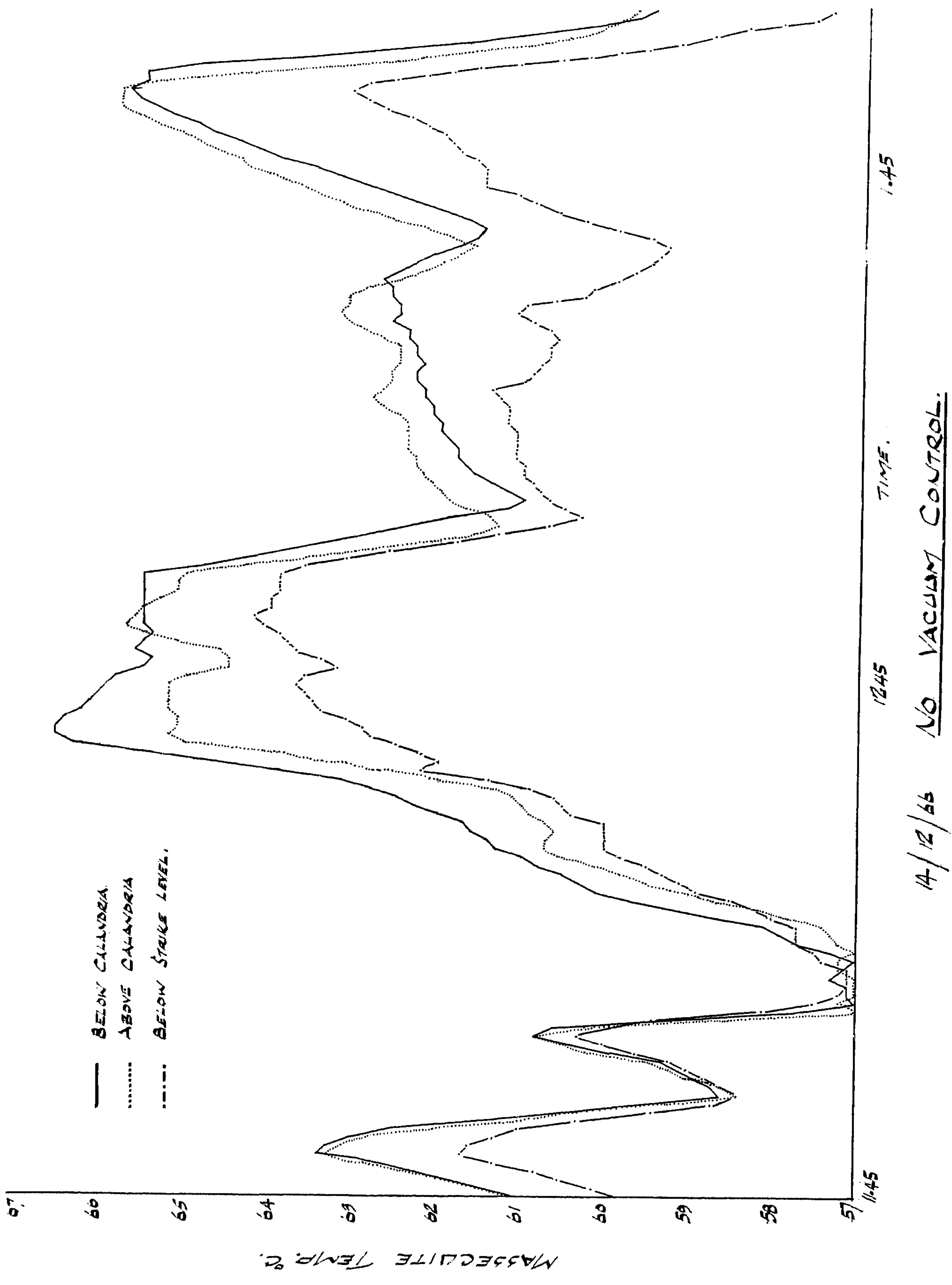

BELOW CALANDRIA
ABOVE CALANDRIA
BELOW STRIKE LEVEL.
14/12/66
NO VACUUM CONTROL.
TIME.
11.45
12.45
1.45
MASSECUITE TEMP. °C.

FIGURE 2

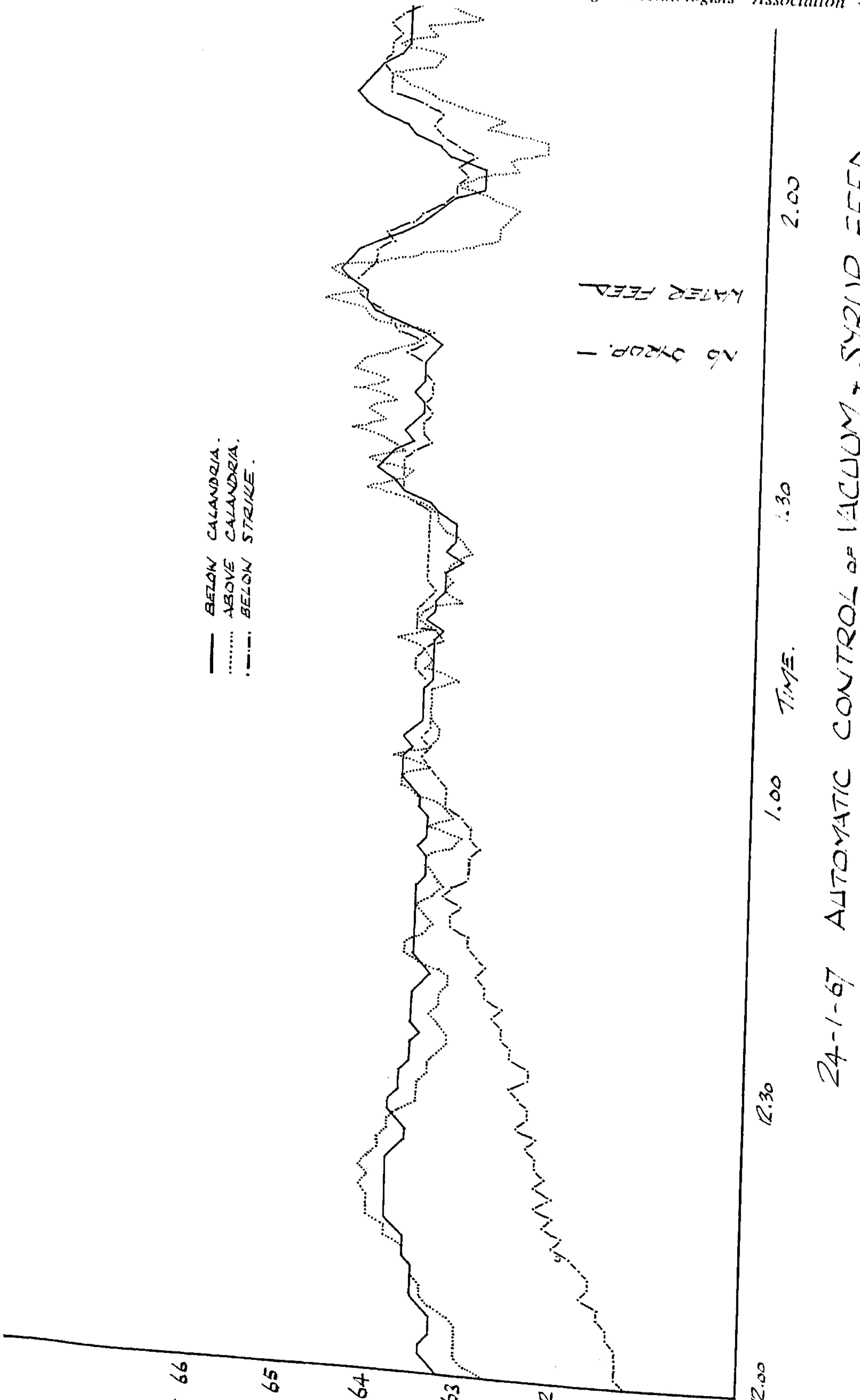

BELOW CALANDRIA.
ABOVE CALANDRIA.
BELOW STRIKE.
NO SYRUP.
WATER FEED
12.00
12.30
1.00
TIME.
1.30
2.00
TEMPERATURE °C.
66
65
64
63
MASSECUITE
62
61
63
24-1-67 AUTOMATIC CONTROL OF VACUUM + SYRUP FEED.

FIGURE 3

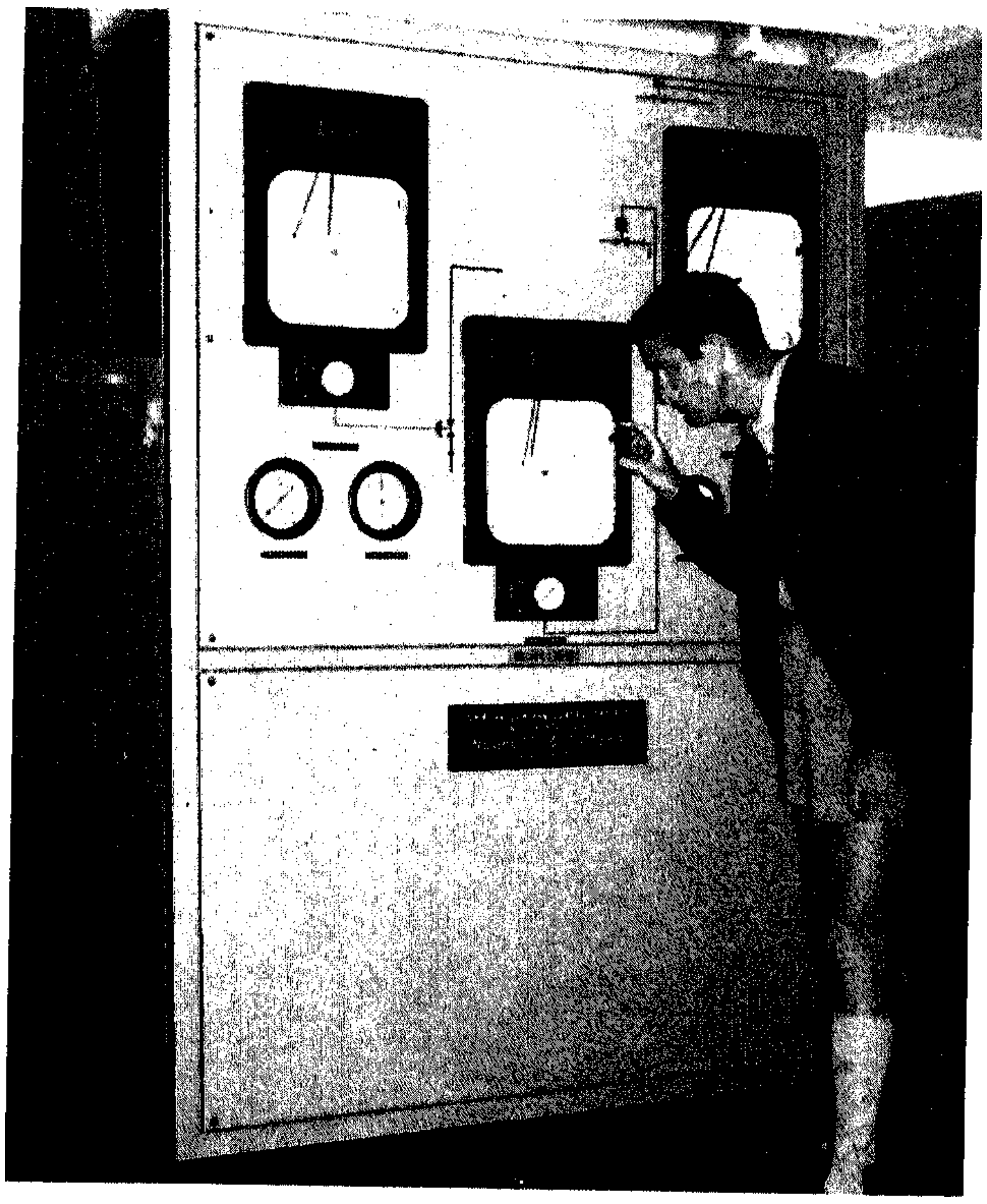


FIGURE 4: Control Panel showing Vacuum, Steam and Syrup Feed Controllers together with ancillary gauges

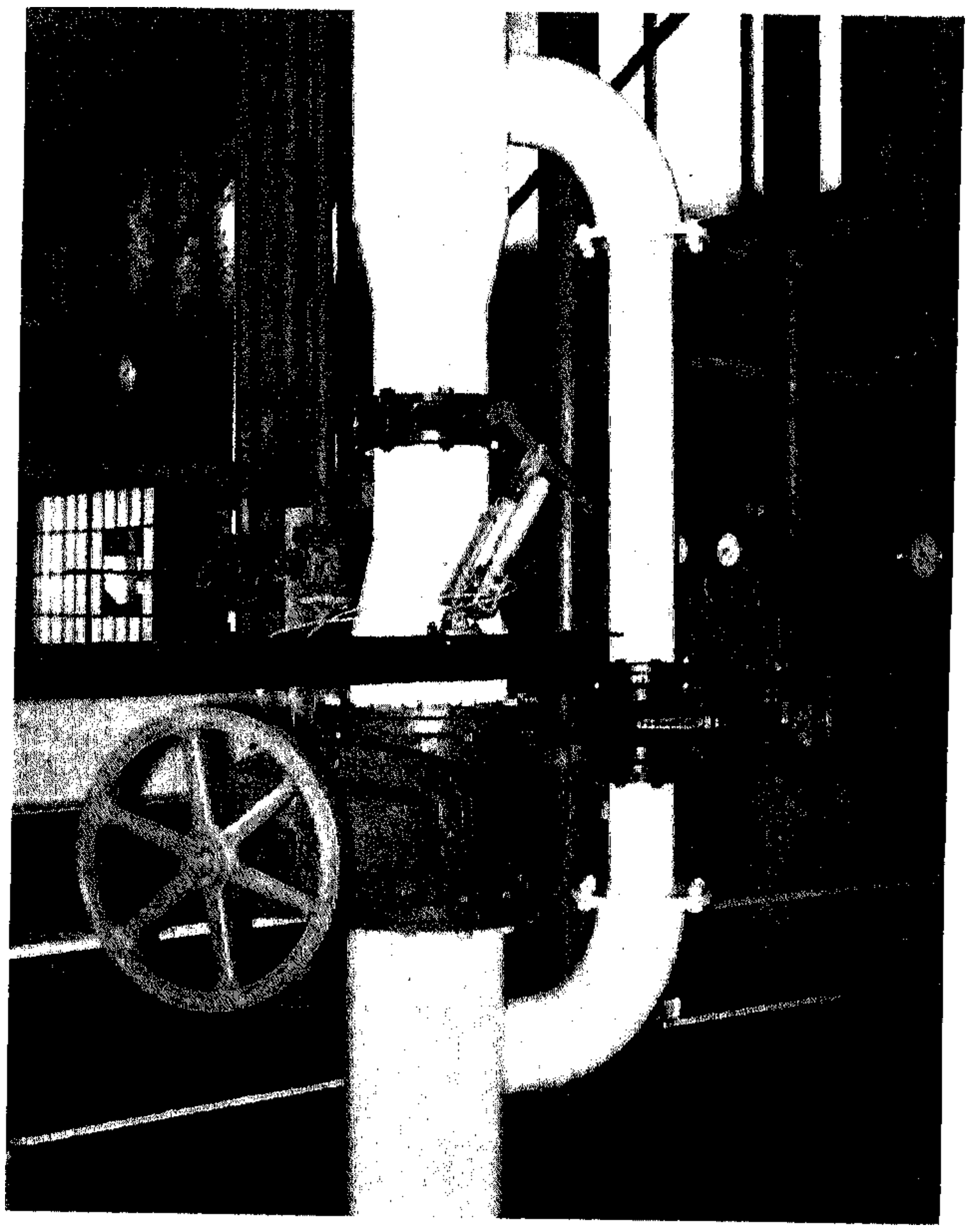


FIGURE 5: Injection water main showing Hagan Power Positioner operating 10" diameter butterfly valve

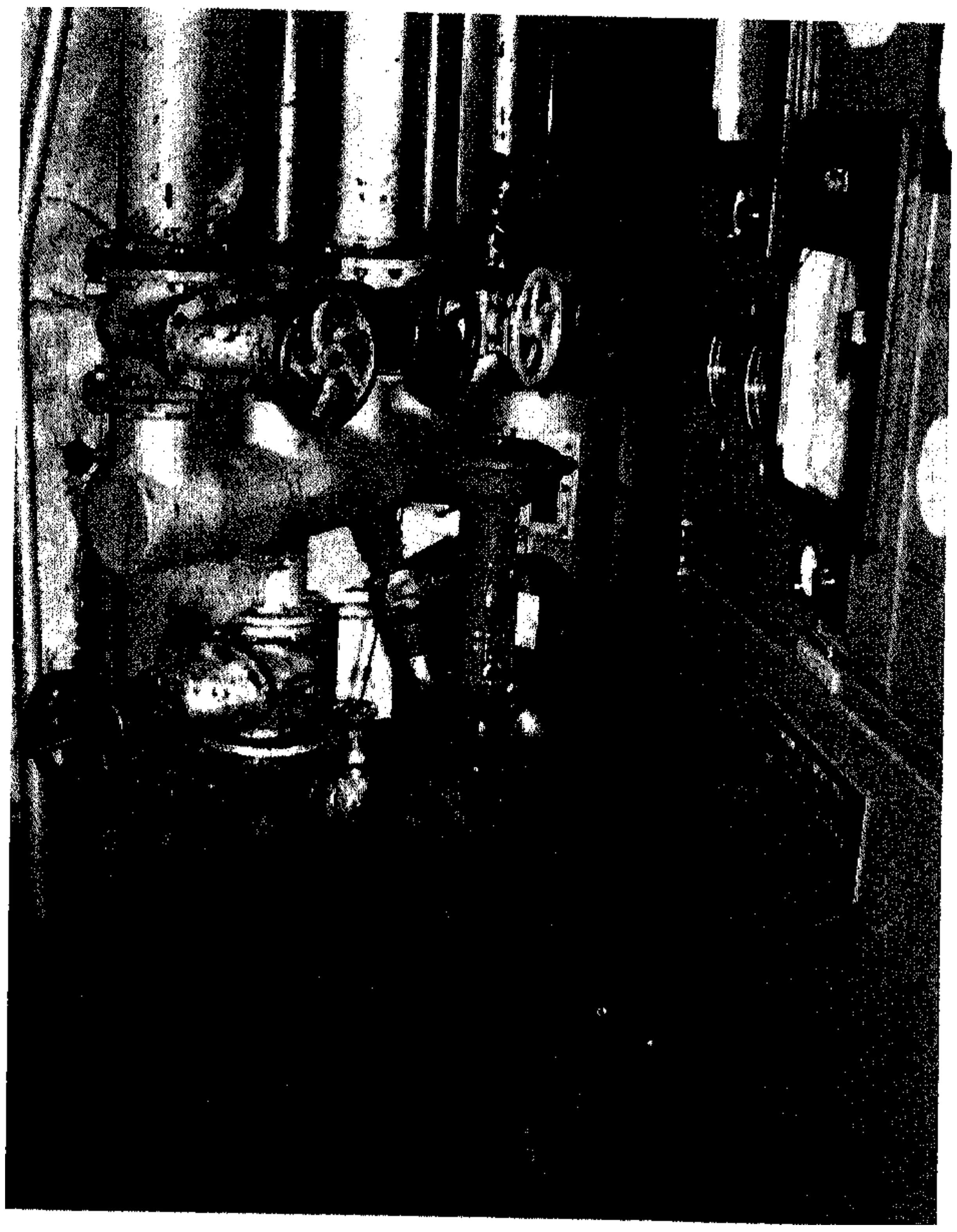


FIGURE 6: Syrup Control Valve with Main Control Panel on the right

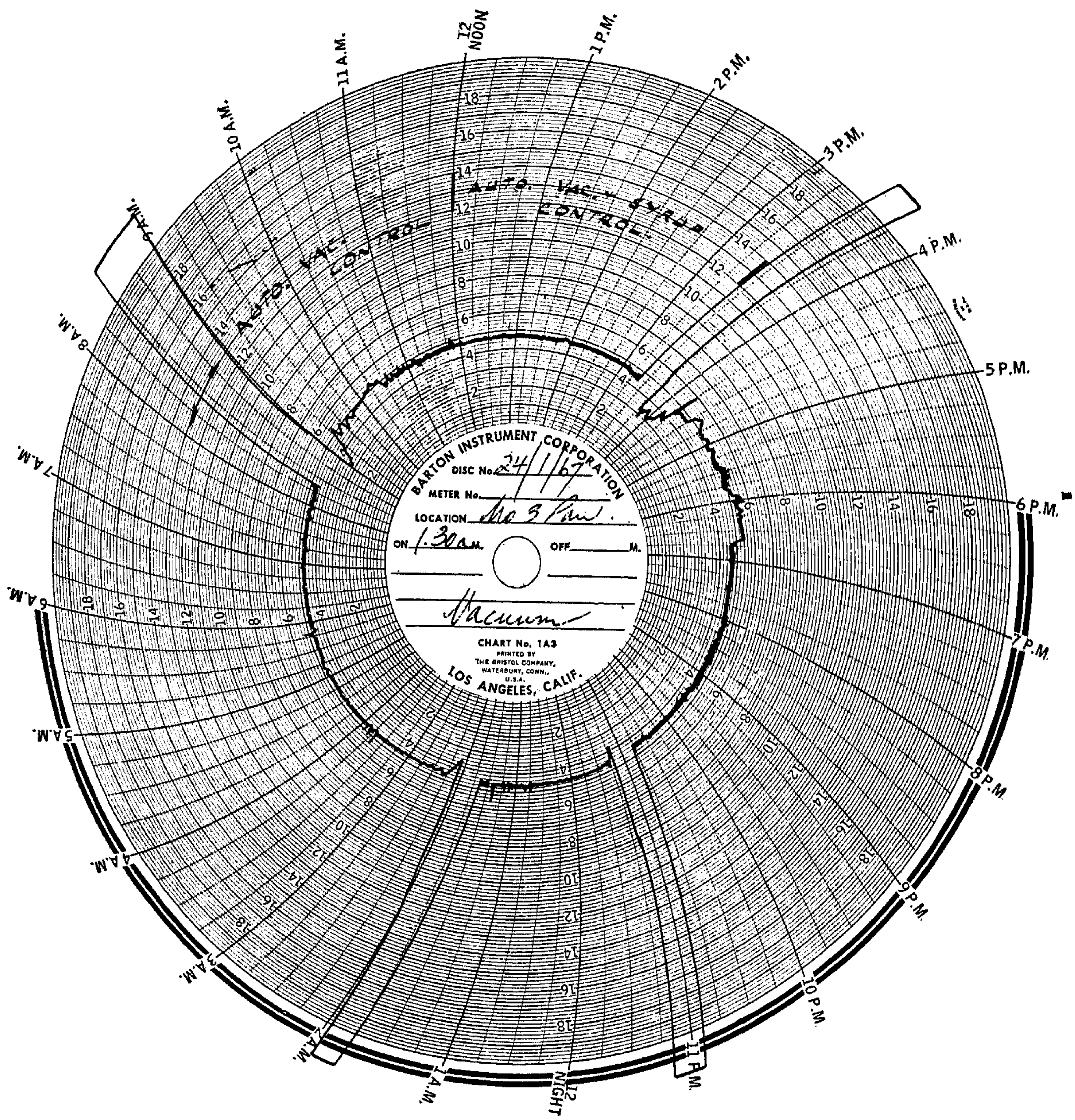

12 NOON
1 P.M.
2 P.M.
3 P.M.
4 P.M.
5 P.M.
6 P.M.
7 P.M.
8 P.M.
9 P.M.
10 P.M.
11 P.M.
12 NIGHT
1 A.M.
2 A.M.
3 A.M.
4 A.M.
5 A.M.
6 A.M.
7 A.M.
8 A.M.
9 A.M.
10 A.M.
11 A.M.
BARTON INSTRUMENT CORPORATION
DISC No.
METER No.
LOCATION
ON
OFF
CHART No. 1A3
PRINTED BY
THE BRISTOL COMPANY,
WATERBURY, CONN.,
U.S.A.
LOS ANGELES, CALIF.

FIGURE 7

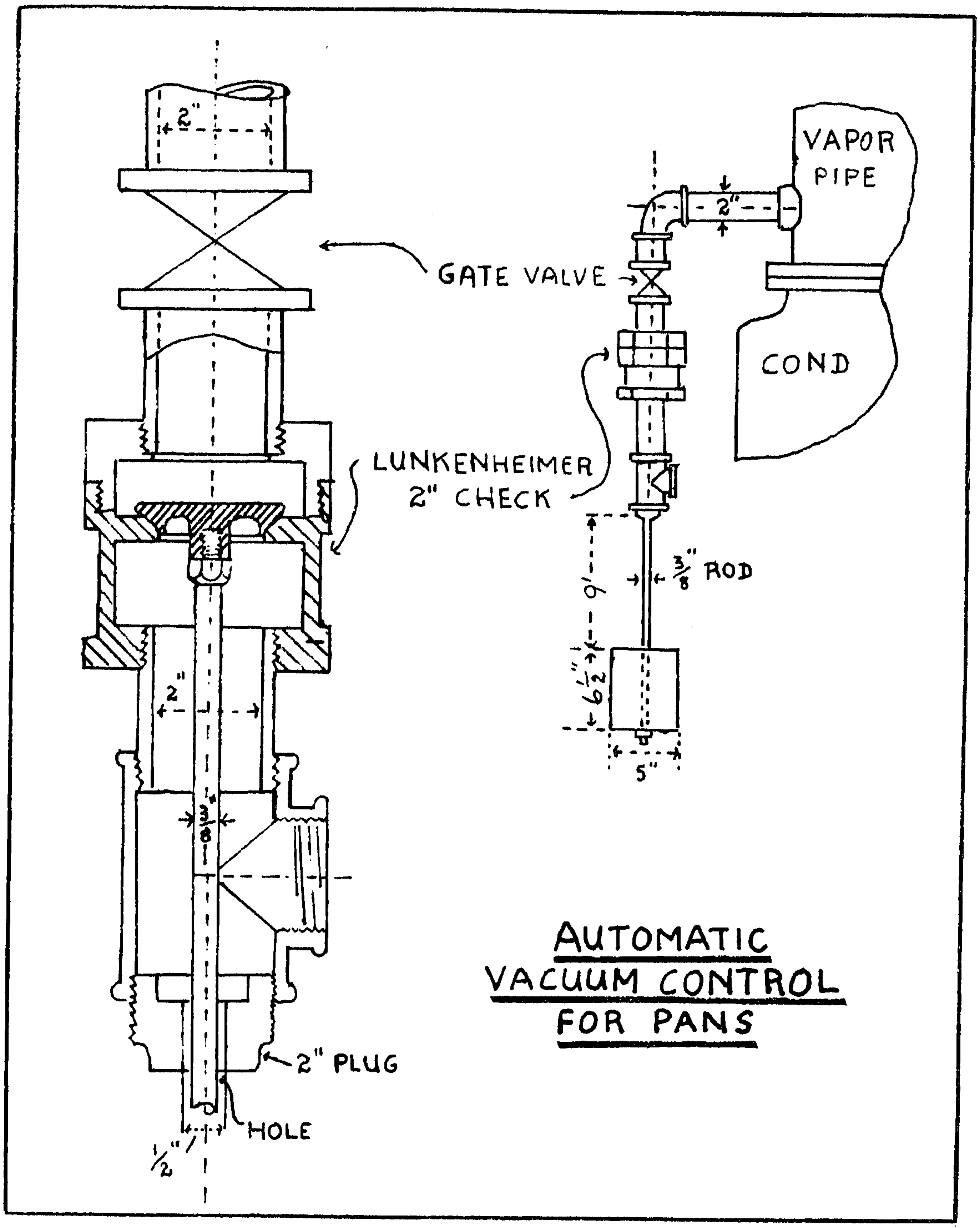

2"
GATE VALVE
LUNKENHEIMER
2" CHECK
VAPOR
PIPE
COND
3/8" ROD
9'
6 1/2"
5"
3/8"
2" PLUG
HOLE
1/2"
AUTOMATIC
VACUUM CONTROL
FOR PANS

FIGURE 8

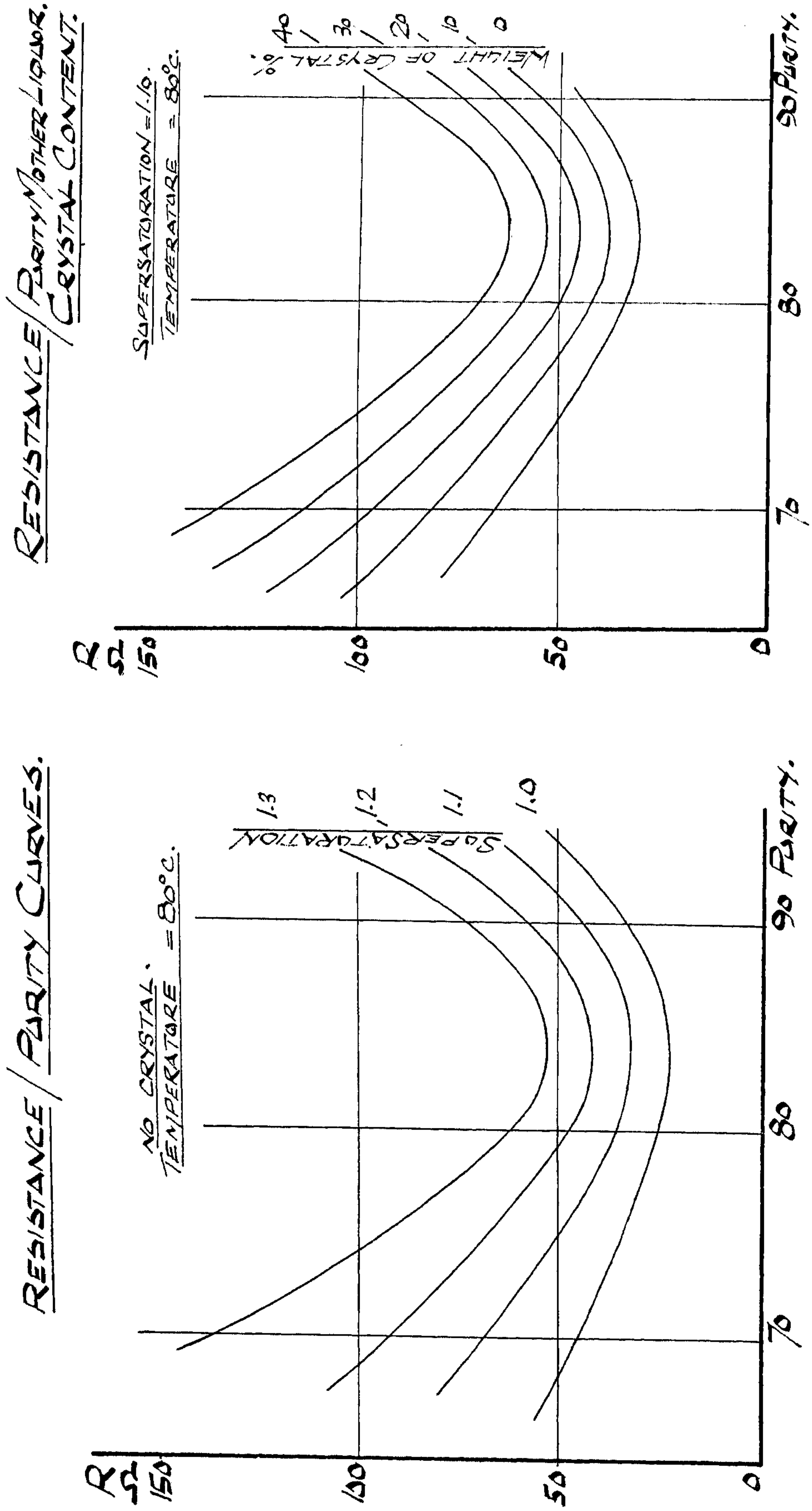

RESISTANCE / PURITY / MOTHER-LIQUOR. CRYSTAL CONTENT.
SUPERSATURATION = 1.10.
TEMPERATURE = 80°C.
WEIGHT OF CRYSTAL %.
40
30
20
10
0
R Ω
150
100
50
0
70
80
90 PURITY.
RESISTANCE / PURITY CURVES.
NO CRYSTAL.
TEMPERATURE = 80°C.
SUPERSATURATION
1.3
1.2
1.1
1.0
R Ω
150
100
50
0
70
80
90 PURITY.

FIGURE 9

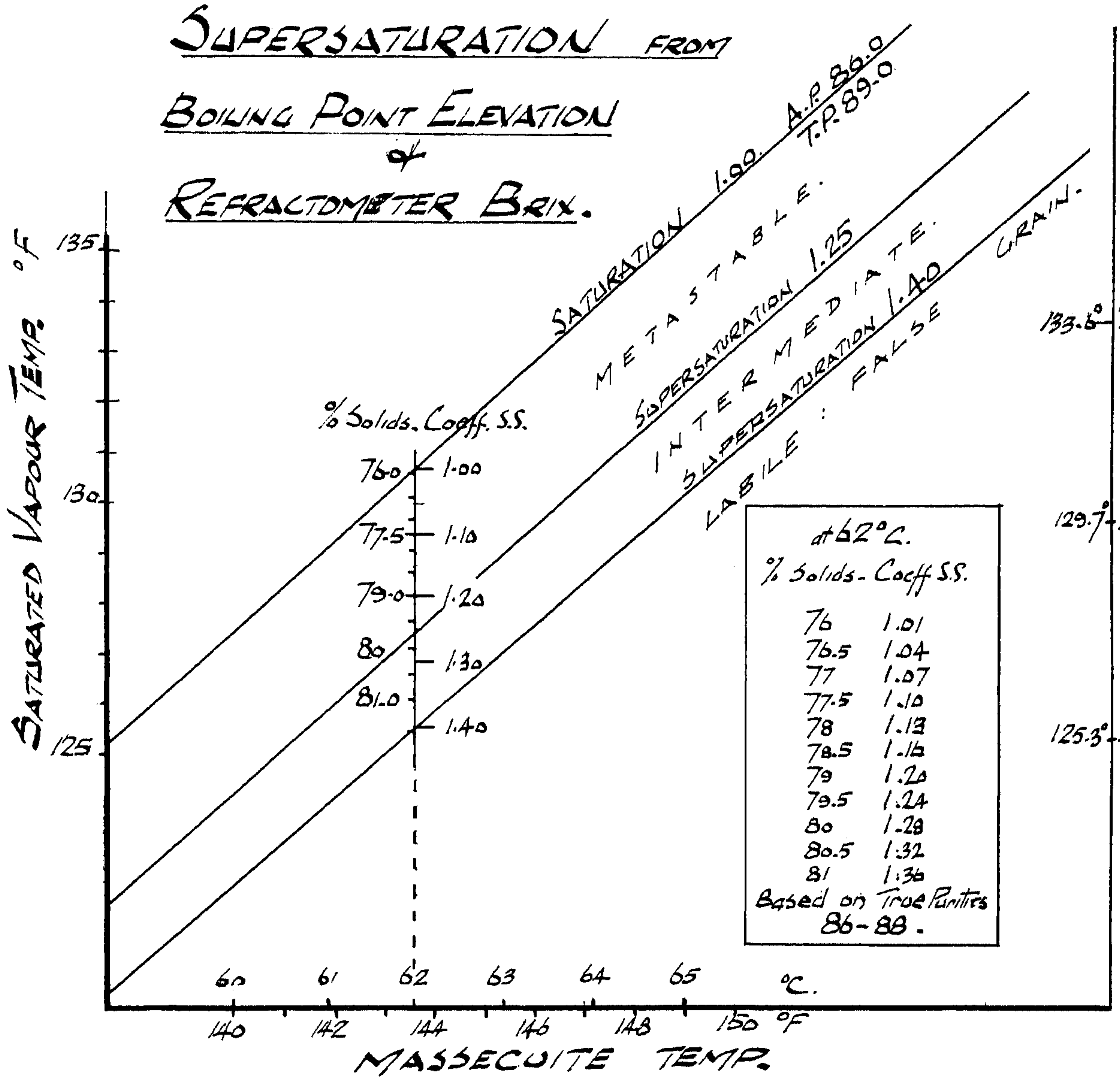


FIGURE 10

Discussion

Mr. Gunn (in the chair): We have had various commodities offered to us by manufacturers to aid pan boiling but in not one instance has a claim made been substantiated, at any rate in this country. Possibly the designs of pans in South Africa are such that they do not require these aids.

At the start of his paper Mr. Allan said they were getting superheated vapour temperature on top of the strike. If this is so it must be very difficult to measure boiling point elevation in the massecuite and I would like to know how it is done.

Mr. Allan: There is a high temperature above the massecuite and normally a pilot pan is built on to the side of the big pan to measure absolute saturation temperature. Noodsberg built a smallish vessel which is coupled into the vacuum system; water is fed into this pan and heated by some device and the pressure in the pilot pan is identical to the big pan. The saturated vapour pressure is obtained from the water in the pilot pan.

Mr. Buchanan: If the saturation temperature in a pan is controlled at a constant level then the boiling elevation can easily be determined.

Mr. Hulett: From the curve given it looks as if it is important to ensure that there is sufficient syrup or molasses to boil the pan uninterruptedly in the syrup feed.

Mr. Allan: If there was a float control on the pan supply tanks it could operate a solenoid valve which could commence to feed water into the pan. As the syrup level drops an electrical signal would switch over air control to the water valve instead of the syrup valve. One need not worry about syrup storage capacity as long as one can get water into the pan to keep circulation going.

Mr. **Hulett:** With a pan with a mechanical stirrer you switch off the steam and the water, and the condenser water

Mr. Renton: What experience did Mr. Allan have with the automatic vacuum control as pictured in his paper? We have started using one at Darnall and although it obviously works we have had insufficient experience with it as yet.

Mr. **Robinson:** We do know that it draws a straight temperature chart so we assume it is maintaining good vacuum.

Mr. Allan: This was included in the paper as the equipment is inexpensive and some factories might like to try it.

Mr. **Hulett:** The air-bleed is expensive on water and on vacuum pump horsepower.

Mr. Warne: There was an acute water shortage at the factory last year when we were carrying out this investigation and by installing Vacuum Control we saved a lot of water, horsepower and steam for the factory.

Dr. Matic: Regarding the type of pans in South Africa, when we started the investigation it was hoped to use a bad pan and show how its performance could be improved. However, the pan we chose proved that it had a very good circulation which was encouraging even though it did not assist our investigation.

Mr. Fourmond: Were any photographs taken of the seeds to give an indication of the regularity of the crystals when using this method?

Mr. Allan: So far we have not worked on the quality of sugar boiled in this way but we intend to do so, as obtaining a regular crystal size and getting good exhaustion is the object of the investigation.

Mr. Lenfema: Was there a difference in dirt accumulation between top and bottom electrodes, and how often were they cleaned?

Mr. Warne: The tests were conducted over short periods and we did not have to clean the electrodes.

Mr. **Renton:** We have had the electrodes in at Darnall for two seasons and they have not yet been cleaned.

Mr. Hulett: They should remain clean seeing that an alternating current is passing through them.

Mr. **Lenferna:** We found the electrode in the bottom of the pan difficult to remove for cleaning and the pan had to be entered for that purpose. We also found that the electrodes were erratic shortly after being cleaned.

Mr. **Robinson:** What type of electrode is being used at Tongaat, and is the current DC or AC?

Mr. Gunn: They are stainless steel with a DC current. We have a very sensitive conductivity meter at Tongaat and possibly a small amount of dirt causes quite a bit of trouble which is why we have to clean our electrodes at least once a week.

Mr. Robinson: We found the resistance between our electrodes on a C- boiling in the region of 500 ohms with a current of 50 milliamps which would indicate that the high sensitivity is not required.

Mr. Hulett: We made our own conductivity probes at Darnall and at first the milliammeter on the conductivity meter flickered a lot. The trouble was due to an air leak in the probe.

RELATIONS BETWEEN CENTRIFUGAL BASKET DESIGNS AND MASSECUITE CHARACTERISTICS

by Dr. HELMUT EICHHORN
Salzgitter Maschinen AG

Introduction

Because of the variety of the massecuites produced during the manufacture of sugar, difficulties arise frequently in the course of the separation process. The design of centrifugal baskets must be adapted to such conditions.

The following paper, applying theoretical principles, published investigations and empirical values, deals with the design of centrifugal baskets, taking into consideration the massecuite characteristics and the conditions of technical procedure.

Massecuite Characteristics **and** their Utilization **for** the Basket Design

Important factors for the separation process, but also for the loading of centrifugal baskets, are size, form and uniformity of the crystals, the crystal content of the massecuite, as well as viscosity, surface tension, and composition of the syrup.

The separation process is essentially influenced by the centrifugal power

$$c = m \cdot r \cdot \omega^2$$

This equation shows that the radius affects the centrifugal power linearly, the angular velocity, however, squarely.

Some papers[1 2 3] deal in detail with the influence of the centrifugal power with the separation process in case of various massecuites.

The centrifugal power has two important aspects in connection with basket design:

1. It influences the basket design under consideration of strength factors, viz. all forces due to gravity produced by the sugar layer, the syrup, the screens, and the weight of the basket casing, must be absorbed with multiple safety by the basket design.
2. The centrifugal power influences the basket form as well as the screen design under considerations of flow—which are decisive for the total pressure of the syrup flowing off.

Whereas the difference between the individual massecuite characteristics is of little importance for the factor mentioned under 1, the statement under 2 shows that different viscosity is decisive.

Generally, massecuites can be classified as follows:—

(a) High-Grade Massecuites
(b) High-Low-Grade Massecuites
(c) Low-Grade Massecuites

(a) *High-Grade Massecuites*

These are refined or white sugar massecuites of high purity, the syrup of which has only a low viscosity of about 50—200 cP. These massecuites can be easily cured, and at uniform crystal size they require low separating factors. White sugar massecuites having different crystal (mixed crystals) complicate the separation process. For this reason centrifugal baskets of a centrifugal power of $c > 1100$ are mainly used for the massecuites.

The fact that these pure massecuites can be separated easily, complicates on the other hand a steady loading of the centrifugal baskets and requires suitable steps to prevent premature separation. We shall deal with this problem in detail later.

(b) *High-Low-Grade Massecuites*

The conditions during curing of high-low-grade massecuites whose sugar is dissolved again and added to a purer crystallization product, are more similar to those of white sugar massecuites, though the viscosity of syrup is higher by about 250 cP.

(c) *Low-Grade Massecuites*

During curing of low-grade massecuites the very fine crystal and the high viscosity of the syrup complicate the separation process. In this case you can count upon syrup viscosity values of about 60,000—70,000 cP. The centrifugal power should exceed $c > 1500$; in this connection reference is made also to Behne[5], Antoine and Wiehe[6], Eklund and Pratt[7].

According to Tromp[8], centrifugal powers of up to $c = 3000$ are used for low-grade massecuites.

v^n toe one hand, the high viscosity complicates the separation process, on the other hand, however, it assists the loading process.

Centrifugal Basket Designs

The following deals in detail with the centrifugal baskets used in practice today.

Illustration 1 shows a basket with uniform holes covering the whole basket height. Baskets of this type with a horizontal plate as a charging device are frequently used. At the basket height of 800 mm low-grade and high-low-grade massecuites can be charged easily without separation of the massecuite at the loading zone of the basket wall.

In case of very pure massecuites containing large uniform crystals premature separation happens, partly due to the low viscosity of the syrup. This causes irregular charging and may result in rough running of the centrifugal

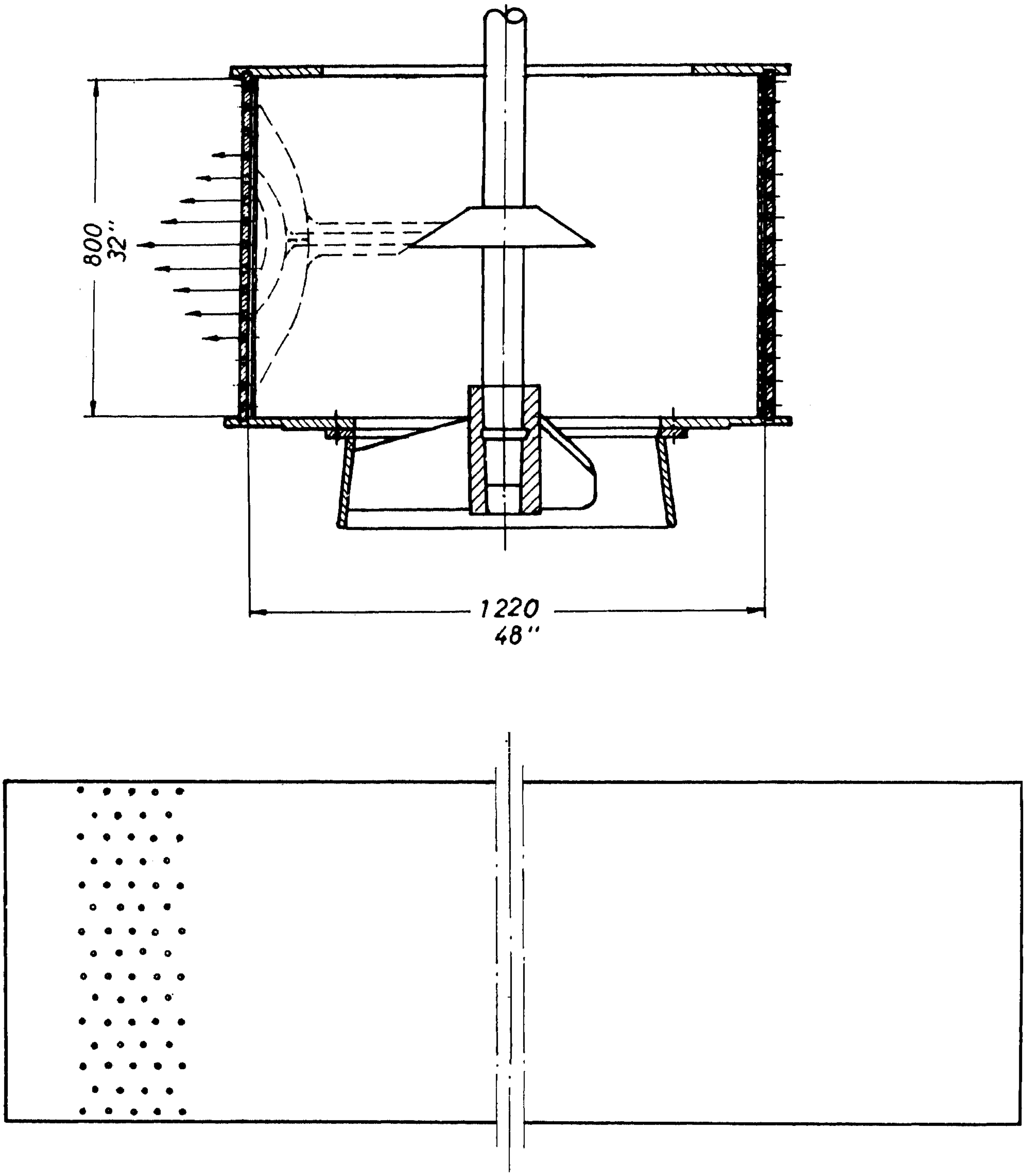


FIGURE 1: Usual baskets with equal perforation

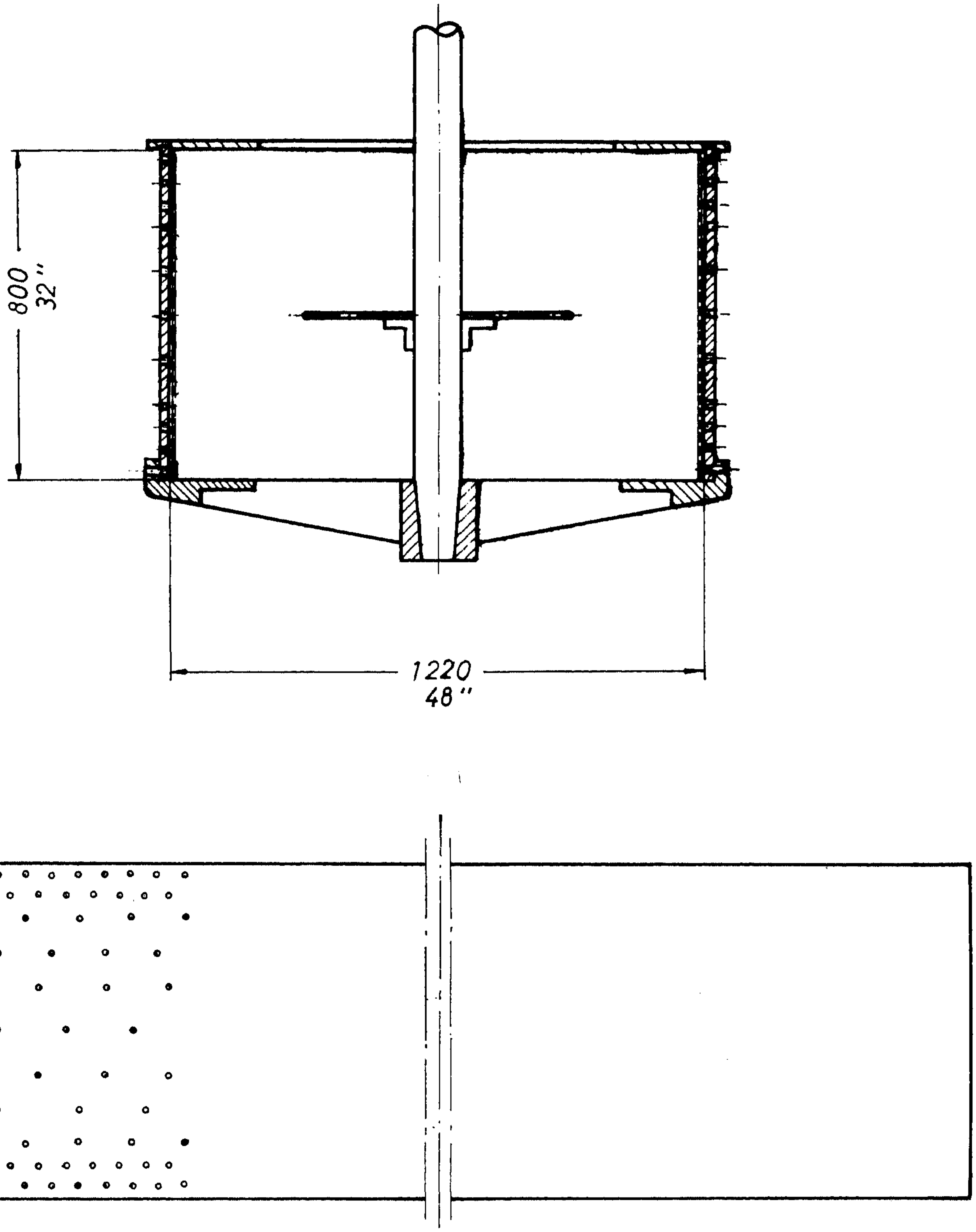


FIGURE 2: Basket with unequal perforation

Illustration 2 shows a similar basket provided with suitably arranged syrup discharge holes which prevent premature separation of the pure massecuites[9]. There are only a few discharge holes in the loading zone; their number increases, however, steadily in the direction of the basket cover and the bottom.

During the last few years centrifugals have been developed with larger units for charges of about 1000 kg of massecuite. When the centrifugal baskets were enlarged, the usual diameter of about 1200 mm was often maintained, and the basket height was extended to 1000 mm and more[10, 11].

Such a basket cannot be loaded with the plate charging method, even if the basket holes are made in accordance with illustration 2.

This results in the necessary substitution of a complicated charging method[12] in the place of the approved and simple plate device, as shown in illustration 3.

8;

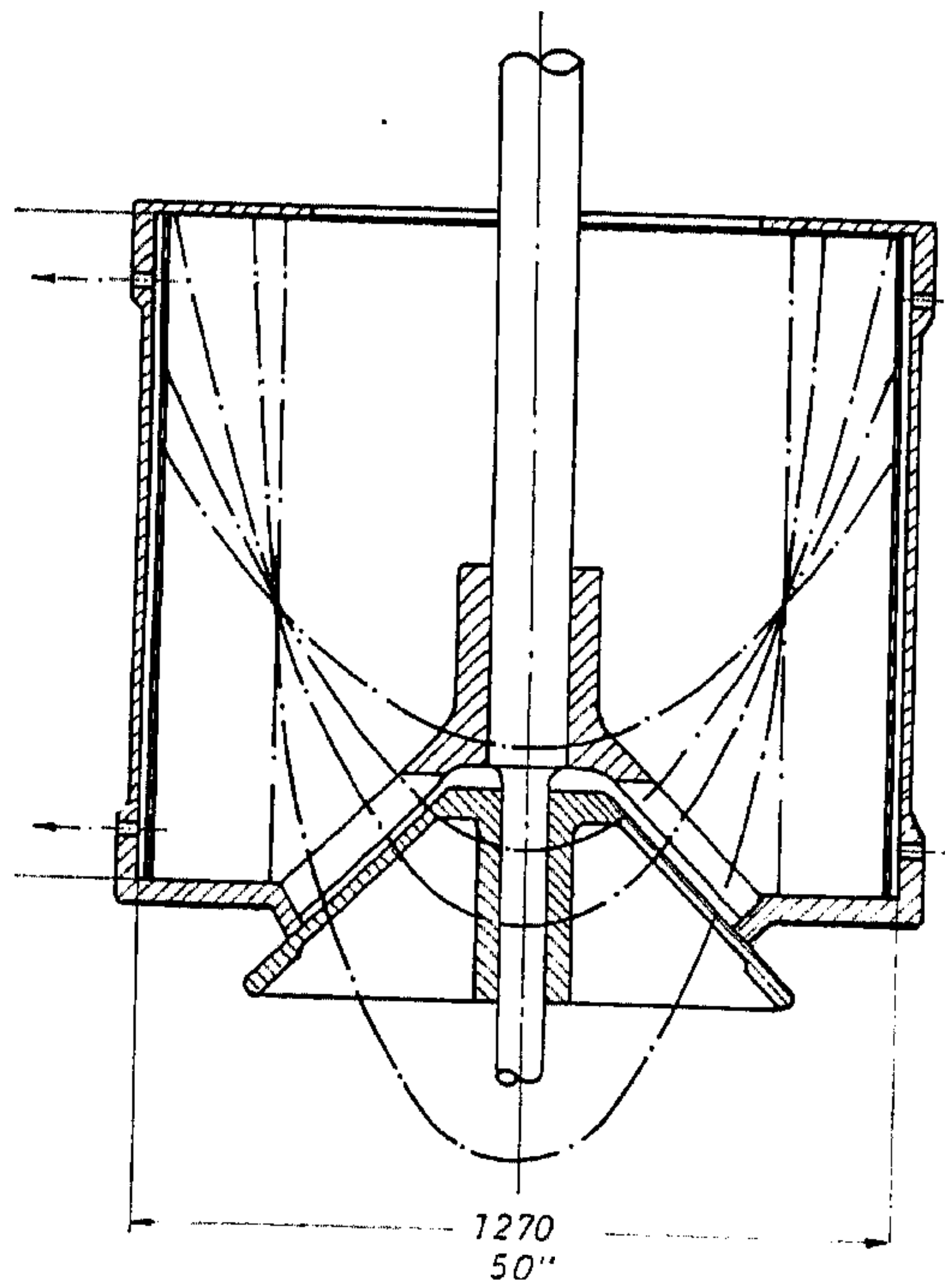


FIGURE 3: System of charging for a basket with holes in the wall only near the top and near the bottom

The perforation of the basket has been shifted to the top and bottom end of the casing[13].

During loading the bottom of the basket is closed, and it is charged at about 50 r.p.m. After charging the centrifugal is accelerated, effecting the building up of the massecuite in a position parallel to the basket wall.

Besides this complication, the disadvantage of the method is an extended charging time; Holme[14] gives charging times of an average of 23 seconds.

Because of the problems of the charging procedure a high centrifugal basket was developed which prevents premature separation even in the case of tugh-purity massecuites. Thus the centrifugal basket can be charged by means of the simple plate device.

85

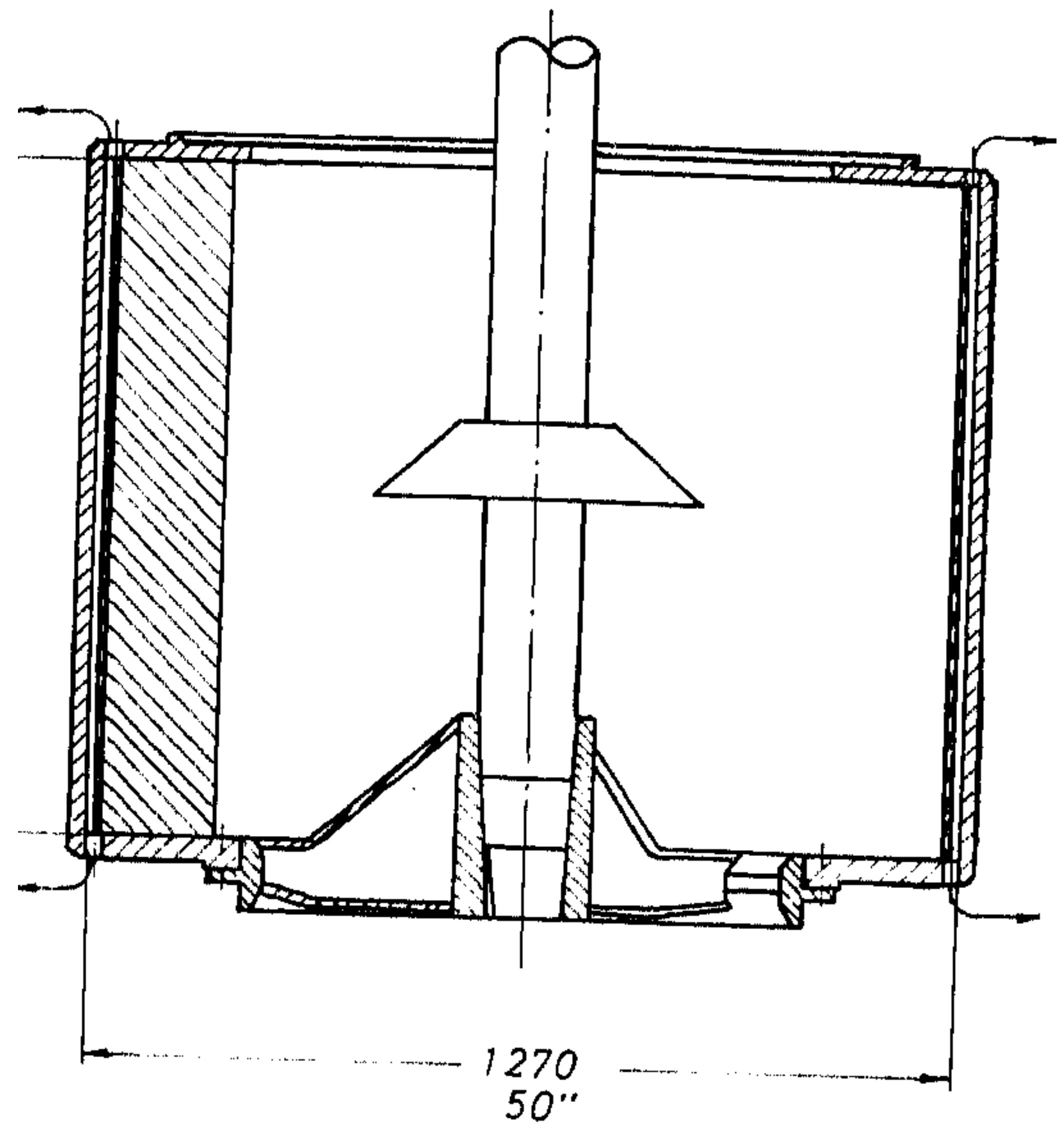


FIGURE *4:* Basket without any hoi es in the wall, holes only on the top and in the bottom

Illustration 4 shows this basket with openings for the passage of the syrup only in the cover and the bottom. Accordingly the syrup must cover the longest possible distance in the basket[15].

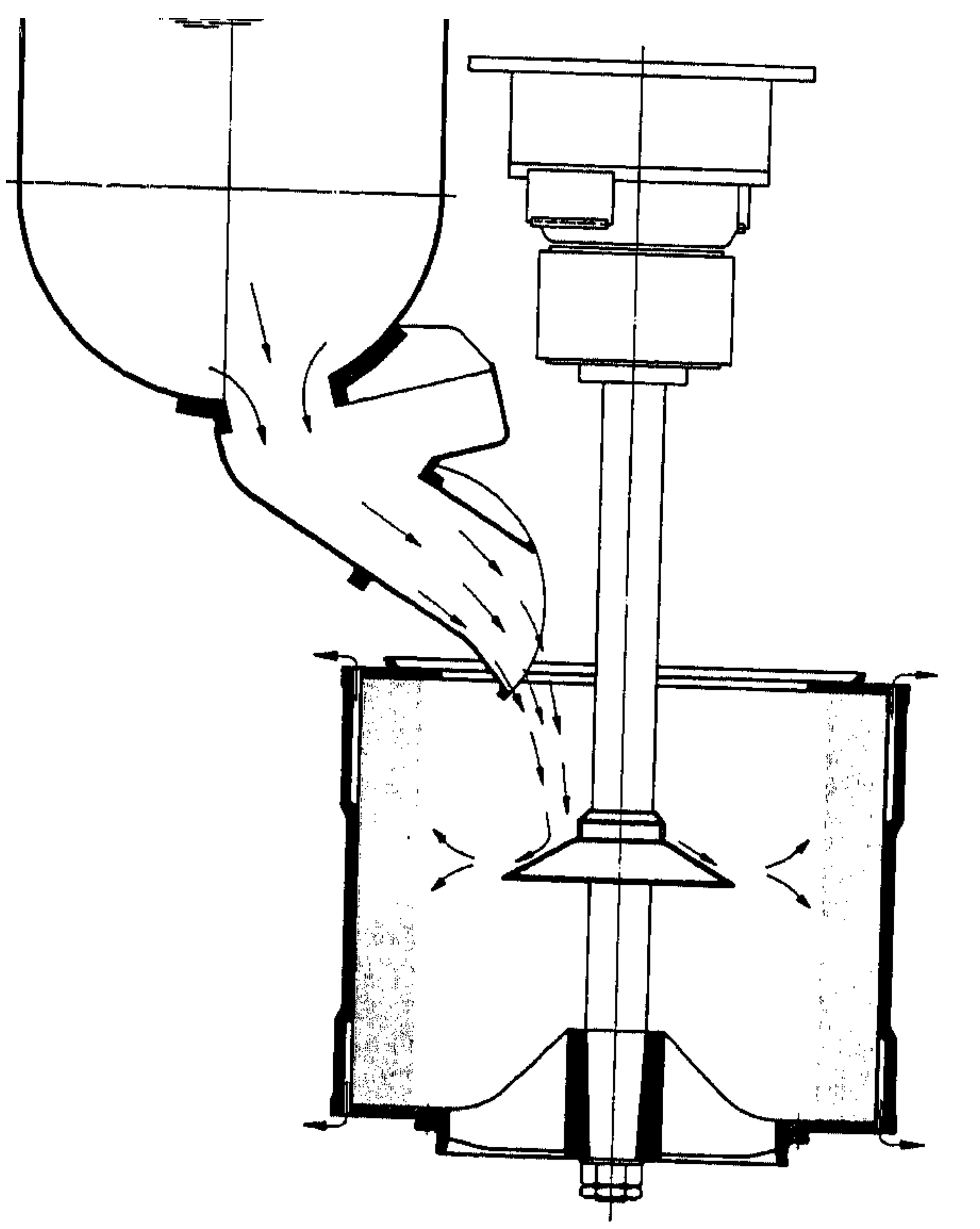


FIGURE 5: Method of operation of the unperformed basket with the plate system of filling

No syrup can flow from the massecuite striking the impermeable basket wall, i.e. the syrup remains with the crystals, in this way the massecuite maintains its fluidity. Thus the massecuite flows equally to the top and to the bottom. The number of holes in cover and bottom is limited in such a way that there is a delay in the discharge of the syrup.

Practice has shown the theoretical considerations to be correct. The co-ordination of the above mentioned features — basket wall without holes, and a certain number of holes in cover and bottom — effects a satisfactory filling of the basket by means of the plate filling system which is shown in Fig. 5. The basket can be charged satisfactorily even with coarse-grained refined massecuites.

This simple filling system has been maintained for a high basket. Another advantage of the system is its short filling time. It takes about 10 seconds to fill the basket at 200 r.p.m.

Flow Considerations of the Centrifugal Basket without Holes in the Shell

In the previous sections the suitability of a centrifugal with an unperforated shell was explained. Now the theoretical operating principles of such a basket are described.

1. *Survey of Quantities*

For calculation of the necessary free axial sections of the discharge zone as well as of the syrup discharge holes, it is necessary to know the quantities of syrup to be discharged.

During the charging process part of the syrup will be spun off. The fluidity of the massecuite, however, must be maintained during the whole charging process to assure correct filling. So only a quantity of syrup "Q Syrup Max" may be discharged during the charging period, which must not exceed 10 seconds.

The charge of the basket is 1200 kg. of massecuite. The supposed syrup-crystal ratio is 600 : 600. The limit of fluidity of the massecuite is achieved when the free spaces in the aggregation of crystals are filled by syrup and an additional 10% of the free syrup is available.

600 kg of crystallite aggregation ($\gamma_1 = 1.0$) $V = \frac{G}{\gamma_1}$

$= \frac{600}{1} = 600$ l of aggregation of crystals.

600 kg of crystals ($\gamma_2 = 1.6$) $V = \frac{G}{\gamma_2} = \frac{600}{1.6} = 375$ l of volume of crystals.

So there will result the free space of 600 — 375 = 225 l in the crystallite aggregation.

The free space is filled by syrup of $\gamma = 1.35$.
The weight is calculated as follows:

$$g = V \cdot \gamma = 225 \cdot 1.35 = 304 \text{ kg of syrup}$$
$$+\ 10\% = 30.4 \text{ kg of free syrup}$$
$$334.4 \text{ kg of syrup}$$

600 kg of crystals + 334.4 *kg of syrup* results in 934.4 kg of flowable massecuite.

From the difference of 1200 kg of massecuite, basket load — 934.4 kg of flowable massecuite, the maximum syrup quantity which may be separated during loading results. "Q Syrup Max." = 265.6 kg.

It is assumed that the syrup quantity "Q Syrup Max." is produced equally over the whole basket height of 1000 mm.

As evidence that there is no separation of massecuite in the basket during the charging procedure, the calculation of the actual flow speed of the syrup in a basket approved in practice shall be sufficient. A comparison of the actual flow speed shows the filling quality of the massecuite in the basket.

2. *Maximum Syrup Flow Speed in the discharge Holes in the bottom and the cover of the basket.*

The quantity of syrup which may be discharged in the whole basket is 265.6 kg/10 sec. = 26.6 kg/sec

The free cross section of the syrup discharge holes in cover and bottom is $F = 42 \text{ cm}^2$.
The flowing syrup volume is

$$V = \frac{G}{\gamma} = \frac{26.6}{1.35} = 19.7 \text{ l/sec.} = 19700 \text{ cm}^3\text{/sec.}$$

So the maximum flow speed is

$$v_{max} = \frac{V}{F} = \frac{19700}{42} = 470 \frac{\text{cm}}{\text{sec}} = 4.70 \frac{\text{m}}{\text{sec}}$$

3. *Actual Syrup Flow Speed in the Discharge Holes*

The calculation of the actual Syrup Flow Speed is based on the fluid pressure of the syrup layer which results from the centrifugal force at a speed of 200 r.p.m. and the syrup layer thickness of 8 mm.

The following data of a refined syrup were taken as a basis:

Solids Bx $= 73.7°$
Temperature t $= 60.5°C$
Viscosity $\eta = 67$ cP (1 cP $= 1.02 \cdot 10^{-4}$) $\frac{\text{kg} \cdot \text{sec}}{\text{m}^2}$

For the estimation of the flow the Reynold's Number is important.

$$Re = \frac{v\ a\ \rho}{\eta}$$

The diameter of the syrup discharge holes is 7 mm, their length 15 mm.

For the calculation of the Reynold's Number the maximum syrup speed of $v = 4.7 \frac{\text{m}}{\text{sec}}$ is taken as basis first.

$$Re = \frac{v\ a\ \rho}{\eta} = \frac{4.7 \times 7 \times 1.35 \times 10^3 \times 10^4}{67 \times 1.02 \times 9.81} = 660$$

The value of the Reynold's Number shows that the flow in the syrup discharge holes is laminar.

The fluid pressure is calculated:

$$P = \frac{m \quad r \quad \omega^2}{F_1}$$

$$P = \frac{G \cdot v \cdot \left(\frac{\pi n}{30}\right)^2}{g \cdot F_1}$$

$$P = \frac{F_1 \quad h \quad \gamma \quad r \quad n^2 \quad \pi^2}{g \quad F_1 \quad 30^2}$$

$$= \frac{1 \times 0.008 \times 1350 \times 0.630 \times 200^2 \times \pi^2}{9.81 \times 1 \times 900}$$

$$P = 306 \ \frac{kg}{m^2}$$

The formula for the fluid pressure and the flow speed under consideration of a pipe friction and body resistance is:

$$P = \gamma \frac{v^2}{2g}\left(1 + \lambda \frac{1}{d} + \zeta_E\right) \ldots\ldots\ldots\ldots\ldots (1)$$

λ is a dimensionless factor depending only on the Reynold figure and the roughness.
In the laminar flow range is

$$\lambda_{lam} = \frac{64}{Re} = \frac{64}{660} = 0.097$$

The resistance coefficient ζ_E takes into consideration an entrance shock loss of the flow into the syrup discharge holes and can be put with sufficient accuracy $\zeta_E = 0.5$.

By transformation of the equation (1) the flow speed results

$$v = \sqrt{\frac{P \cdot 2g}{\gamma(1 + \lambda\frac{1}{d} + \zeta_E)}}$$

$$= \sqrt{\frac{306 \cdot 2 \cdot 9.81}{1350\ (1 + 0.097(\frac{15}{7}) + 0.5)}}$$

$$v = \sqrt{2.61} = 1.61 \frac{m}{sec}$$

The speed must be considered as approximate since for its calculation the Reynold's Number was taken for too high a speed. In another approximate value the result will be corrected. The Reynold's Number will be defined instead from the speed ratio before and after the first calculation.

$$Re_1 = Re\frac{v}{V_{max}} = 660\frac{1.61}{4.7} = 226$$

then is:

$$\lambda lam_1 = \frac{64}{Re_1} = \frac{64}{226} = 0.283$$

and then:

$$V_1 = \sqrt{\frac{P \cdot 2g}{\gamma\,(1 + \lambda_1 \frac{1}{d} + \zeta_E)}}$$

$$= \sqrt{\frac{306 \cdot 2 \cdot 9.81}{1350\ (1 + 0.283(\frac{15}{7}) + 0.5)}}$$

$$V_1 = \sqrt{2.5} = 1{\cdot}5 \ \frac{m}{sec}$$

So the actual speed in the syrup discharge holes is $1.58 \frac{m}{sec}$

4. *Utilization of Results*

In accordance with the calculation shown under 3 the syrup flow speeds are calculated for the whole charging period. The curve resulting from this is shown in Fig. 6.

A speed is taken for maximum flow speed where just so much syrup can flow off that the fluidity of the massecuite can be maintained.

At the beginning of the charge period the actual flow speed has the value ZERO and then increases in accordance with the increasing fluid pressure caused by the increasing strength of the syrup layer during the charging operation.

The surfaces below the curves are proportional to the quantity of syrup just flowing off.

The surface below the curve for the actual speeds is smaller than the surface limited by the medium maximum speed. This means that at the end of the filling procedure the massecuite is still fluid; assuring an equal distribution of the massecuite in the basket.

After the charging is completed, the speed of the basket is increased, which will raise the fluid pressure materially.

The deceleration occurring as a result of the charging of the basket is counteracted by increasing the speed. This assures a quick discharge of the syrup.

It was found possible to charge 1200 kg of massecuite into a basket designed for 1000 kg only.

Applied Abbreviations and Formula Symbols

c	= centrifugal force	kg
m	= mass	$kg\frac{m}{sec^2}$
r	= radius	m
ω	= angular velocity	sec^{-1}
V	= volume	$dm^3 = l$
G	= weight	kg
γ	= specific gravity	$\frac{kg}{dm^3}$
V	= speed	$\frac{m}{sec}$
Bx	= solids	%
t	= temperature	°C

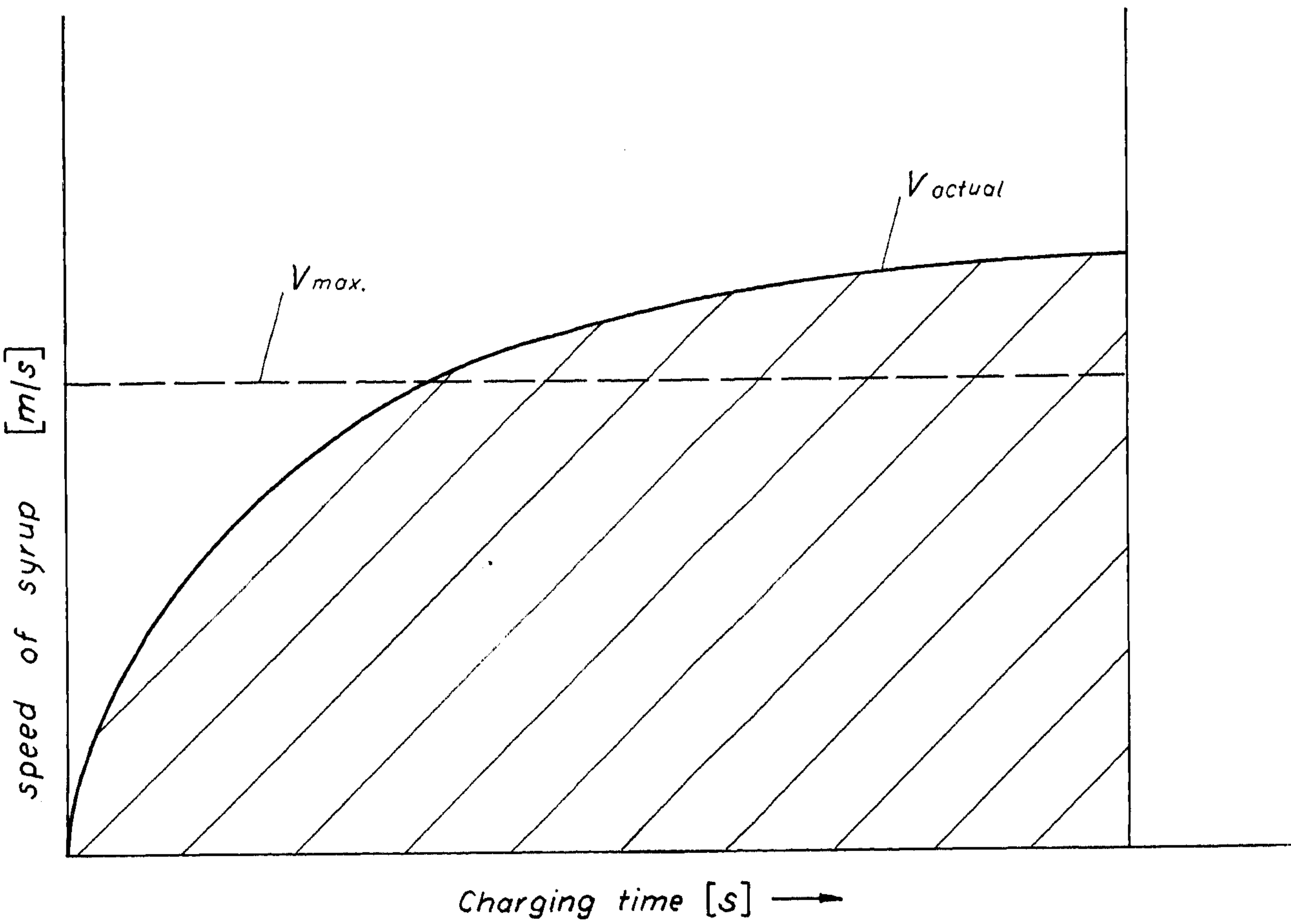


FIGURE 6

ρ	= density	$\frac{kg \cdot sec^2}{m^4}$
η	= viscosity	$\frac{kg \cdot sec}{m^2}$
Re	= Reynold figure	1
P	= fluid pressure	$\frac{kg}{m^2}$
F	= surface	m^2
g	= acceleration due to gravity	$\frac{m}{sec^2}$
n	= speed	min^{-1}
λ	= resistance coefficient	1
ζE	= resistance coefficient	1
l	= length	mm
d	= diameter	mm

Summary

By means of diagrams the loading potential of various types of centrifugal baskets is compared.

Utilizing different perforations of the basket shell, an endeavour is made to cater for various qualities of the massecuites.

It is difficult to load these baskets with the plate loading method in the case of very pure massecuites whose syrup has low viscosity.

A basket design is described whose shell is not perforated. The syrup is discharged through holes in the cover and the bottom. The theory of filling of this basket is described in detail.

It is shown that this basket can be loaded with the simple plate filling method.

References

1. Magnusson, O. High efficiency centrifugals. Socker 5 (1949), 65-95.
2. Kiessling, C. High efficiency centrifugals for the sugar industry. Socker 8 (1952), 53-69.
3. Eichhorn, H. Über das Trennen von Kristall-Sirup-Gemischen mit Zentrifugen Zeitschr. f. d. Zuckerindustrie 16 (1966), 463-468.
4. Stevens, G. E. Advantages of high-speed centrifugals. Int. Sugar J. 52 (1950), 9.
5. Behne, E. R. Separation of molasses from the sugar crystals in centrifugals. Techn. Comm. B.S.E.S. Queensland 1938, Nr. 8, ref. Int. S. J. 41 (1939), 283.
6. Antoine, J. D. de Saint and Wiehe, F. Untersuchungsergebnisse beim Schleudern von Nachprodukt-Füllmassen in hochtourigen Zentrifugen Zeitschr. Zuckerind. 13 (1963), 511-514.

7. Eklund, W. N. and Pratt, J. H. Drying low grade sugar at higher speeds. Facts about Sugar, 30 (1935), 95-96.

8. Tromp, L. A. High-speed centrifugals. Int. Sugar J. 54

9. D.A.S. 1 120 378. Diskontiniiierlich arbeitende Trennzentrifuge fur kristallhaltige Fullmassen. Selwig u. Lange.

10. Pause, K. Die Zentrifugenentwicklung am Scheidewege. Zeitschr. f. d. Zuckerind. 13 (1963), 138-141.

11. Eichhorn, H. The Salzgitter 1000 kg-centrifugal Salzgitter Machinery Technical Bulletin. 1966, No. 2.

12. Pause, *K.* Ober das Fallen laufender Pendelzentrifugen mit Zuckerfullmassen. Zeitschr. f. d. Zuckerind. 5 1960), 238-243.

13. DGBM 1 865 091. GroBtromrnel fur Zuckerzentrifuge Buckau-R. Wolf.

14. Hohne, K. Vergleich von drei diskontinuierlichen vollautomatischen WeiBzucker-Zentrifugen. Diplomarbeit, Techn. Universitat Berlin, 1964.

15. D.A.S. 1 209 957. Vollmantel-Schleudertromniel. Salzgitter Maschinen AG.

Discussion

Mr. Chiazzari: It is generally thought that low-speed pre-curing has certain advantages, chiefly because it increases basket capacity.

Holes in the top of the basket should be of assistance in curing low grade sugars, especially if they are false grained.

>ent: How are the screens fixed in this type of basket so as to avoid leakage?

Dr. **Eichhorn:** There are three screens in the big basket, and they are secured by rings at the top and the bottom.

Mr. Renton: We had a problem in charging B™ massecuites at Darnall. If we did not reduce the charging rate when the massecuite was slack a surge occurred in the basket which unbalanced the centrifuge. Apparently the massecuite was not consolidating itself while being charged and the way to correct this was by reducing the charging rate. Would Dr. Eichhorn recommend the Salzgitter basket for the type of B- massecuite we have in this country?

Dr. Eichhorn: We have charged the basket with three types of massecuite—refined sugar, B- and C-.

Leakage has been prevented by running the centrifugal at 1,000 revolutions per minute for about three minutes and then increasing the speed.

With coarse-grained crystals in refined sugar massecuites it is sometimes difficult to get a parallel laver of sugar in the basket but this centrifuge copes well with this, and also with B- massecuites.

Dr. **Douwes Dekker:** What is the cosity of syrup that this type of basket can deal with? In the beet sugar industry viscosities are lower than in the cane sugar industry.

Dr. **Eichhorn:** We have tested viscosities of from 300 to 400 cP. For a C- massecuite the basket needs holes in the wall in addition to those in the top and bottom.

SPECIFIC RESISTANCE OF REFINERY PROCESS CARBONATATION FILTER CAKE (MUD)

By C. M. YOUNG
Hulett's South African Refineries Ltd.

Introduction

A simple means of measuring the filterability of the Carbonatated Liquor, in practice, at the filter station is required:—

Basically, the instantaneous flow rate of the filtrate is inversely proportional to the specific cake resistance and other factors, and proportional to the pressure and area:

$$\frac{dv}{d\theta} = \frac{PA^2}{\eta(r_1cV + RA)} \quad \ldots 1$$

The development of this approach has been covered in Chemical Engineering text books.

Purchas[2] states that in this form it is scarcely practical to proceed with tests on *samples* unless one is certain the sample represents the material handled on large scale.

In this exercise, use is made of Carman's equation[1] for constant Pressure conditions.

$$\frac{\theta}{V} = \frac{\eta r_1 c}{2PA^2}V + \frac{\eta R}{PA} \quad \ldots 2$$

wherein, the effect of the resistance of the filter cloth and pre-coat is separated from the effect of the resistance of the cake under the controlled test conditions. Carman[1] also warns that the "primary layer of cake should be deposited at low velocity, i.e. at low pressure, since, otherwise the cloth becomes plugged and the initial resistance becomes unduly high."

This form is difficult to use in production, and since we can measure $\frac{dv}{d\theta}$ and θ in Production, the above equation was modified into the following form:— (See Appendix 1.)

$$\left(\frac{d\theta}{dv}\right)^2 = 4\left(\frac{\eta r_1 c}{2PA^2}\right)\theta + \left(\frac{\eta R}{PA}\right)^2 \quad \ldots 3$$

and theoretically, if we plot graphically

$$\left(\frac{d\theta}{dv}\right)^2 \text{ against } \theta$$

we should obtain a straight line of slope

$$4\left(\frac{\eta r_1 c}{2PA^2}\right)$$

and hence r_1 since the other terms are readily determined in a well controlled factory.

Thus if a filter in the production line is fitted with a rate indicator, then we should be in a position to measure the specific resistance r_1 at constant pressure, in terms of standard units, where r_1 is an inverse function of the filtration characteristics of the carbonatated liquor, as *produced and filtered in the factory*.

Method

The filter used for the tests (in parallel with the production filters) was fed by a centrifugal pump and the inlet pressure controlled. The flow rate out of the filter was measured by means of a flow rate indicator. Time and temperature were noted and samples of the Carbonatated Liquor and filtrate were collected for analysis.

For the exercise it was assumed that the Calcium Carbonate precipitate was incompressible.

Discussion

Initially, the pressure control valve was too large, and later, when a smaller (gate) valve was fitted control of pressure was also found to be difficult. However, sufficient tests were carried out to show the merit of the system, and no doubt with a feed pump of good characteristics and possibly an automated pressure control system, we may arrive at a system where three readings will be sufficient for an operator to record the filterability due to any changes he may make to the process. The system may possibly be enlarged to dictate the economic level for changing filter cloth, milk of lime addition and so on.

It should be noted, however, that any error in measuring $\frac{d\theta}{dv}$ is squared.

Summary

A simple method of determining the filterability of Carbonatated Liquor in terms of the specific resistance of the filter cake (r_1) is given for constant pressure conditions.

Results of tests, under rather crude conditions, show merit for the system, and using readily available control systems, this method could be used to measure the effect of process changes.

Symbols[1]*:*

V = cm^3 of filtrate in time θ secs.

$\frac{dv}{d\theta}$ = rate of flow of filtrate, in cm^3/sec.

A = Area of filtering surface in cm^2.
P = Pressure of filtration i.e. pressure difference across the cake and cloth, in grams/cm^2.
c = Grams of dry cake solids per 1 cm^3 of filtrate.
η = Viscosity of liquid in poises.
r_1 = Specific Resistance, as resistance per 1 gram/cm^2 of dry cake solids.

Acknowledgements

Thanks are due to the Management of Hulett's South African Refineries Limited for permission to publish this paper.

Thanks are also due to the Chief Chemist for supplying the personnel who assisted in carrying out the tests.

Particular thanks are due to Mr. A. Chattaway (Natal University Student) for the derivation of the flow rate and time relationship.

References

(1) Carman, P. C., Trans. Inst. Chem. Eng. (London). **16,** 168-188 (1938).

(2) Purchas, D. B. Filtration, Sept./Oct. 1964, **1,** No. 5, 256-258.

APPENDIX 1

Deprivation of equation used

$$\frac{dv}{d\theta} = \frac{PA^2}{\eta(r_1 cV + RA)}$$ which integrates at constant pressure to:—

$$\frac{\theta}{V} = \frac{\eta r_1 c}{2PA^2}V + \frac{\eta R}{PA}$$ Reference 1.

Put $m = \frac{\eta r_1 c}{2PA^2}$ and $k = \frac{\eta R}{PA}$

Then $\frac{\theta}{V} = mV + k$ 1

Also $\frac{d\theta}{dv} = 2mV + k$ 2

substitute for V in equation (2) into equation (1)

then $\left(\frac{d\theta}{dv}\right)^2 = 4m\theta + k^2$ ———>

APPENDIX 2

TABLE I

Time	Test 5		Test 6		Test 8 (*a*)		Test 8 (*b*)		Test 9 (*a*)		Test 9 (*b*)		Test 10	
	$\frac{dv}{d\theta}$	$\left(\frac{d\theta}{dv}\right)^2$	$\frac{dv}{d\theta}$	$\left(\frac{d\theta}{dv}\right)^2$	$\frac{dv}{d\theta}$	$\left(\frac{d\theta}{dv}\right)^2$	$\frac{dv}{d\theta}$	$\left(\frac{d\theta}{dv}\right)^2$	$\frac{dv}{d\theta}$	$\left(\frac{d\theta}{dv}\right)^2$	$\frac{dv}{d\theta}$	$\left(\frac{d\theta}{dv}\right)^2$	$\frac{dv}{d\theta}$	$\left(\frac{d\theta}{dv}\right)^2$
$\theta \times 10^3$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$
Secs.	cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec	
0.0	1233	0.66	1783	0.31	3167	0.10	1425	0.49	2817	0.13	1425	0.49	2159	0.22
0.3	1050	0.90	1517	0.44	2700	0.14	1259	0.62	2434	0.17	1309	0.59	1792	0.31
0.6	933	1.14	1167	0.74	2100	0.23	1133	0.77	2097	0.23	1217	0.67	1409	0.50
0.9	783	1.64	900	1.23	1817	0.31	1050	0.90	1850	0.29	1133	0.77	1134	0.77
1.2	700	2.04	800	1.56	1575	0.40	1000	1.00	1658	0.37	1067	0.88	967	1.06
1.5	683	2.13	792	1.59	1425	0.49	942	1.12	1542	0.42	1000	1.00	834	1.42
1.8	650	2.37	642	2.43	1333	0.58	883	1.28	1425	0.49	933	1.14	725	1.87
2.1	633	2.50	583	2.96			834	1.44					625	2.62
2.4	583	2.92	508	3.88									550	3.27
2.7	555	3.31	508	3.88									492	4.12
3.0	533	3.53	483	4.28									458	4.75
3.3	533	3.53	442	5.11									442	5.11
3.6	483	4.28	433	5.34									417	5.76
3.9	467	4.58											400	6.25
4.2	450	4.93											375	7.08
4.5	442	5.11											358	7.78
4.8	442	5.11												
5.1	417	5.76												
5.4	408	6.00												
5.7	408	6.00												
6.0	392	6.50												
6.3	383	6.81												
6.6	383	6.81												

Test 12		Test 13		Test 17		Test 18 *(a)*		Test 18 *(b)*		Test 19 *(a)*		Test 19 *(b)*	
$\frac{dv}{dQ}$	$\left(\frac{dQ}{dv}\right)^2$	$\frac{dv}{dQ}$	$\left(\frac{dQ}{dv}\right)^2$	$\frac{dv}{dQ}$	$\left(\frac{dQ}{dv}\right)^2$	$\frac{dv}{dQ}$	$\left(\frac{dQ}{dv}\right)^2$	$\frac{dv}{dQ}$	$\left(\frac{dQ}{dv}\right)^2$	$\frac{dv}{dQ}$	$\left(\frac{dQ}{dv}\right)^2$	$\frac{dv}{dQ}$	$\left(\frac{dQ}{dv}\right)^2$
	$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$		$\times 10^{-6}$
cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec		cm^3/Sec	
2900	0.12	2167	0.21	2100	0.23	2667	0.14	1800	0.31	1367	0.53	2357	0.18
		1570	0.41	1484	0.45	1416	0.50	1423	0.49	1154	0.76	1717	0.34
2500	0.16	1242	0.64	1142	0.77	1042	0.92	1234	0.66	892	1.25	1483	0.45
1758	0.32	1066	0.88	892	[illegible]	837	1.42	1100	0.83	783	1.62	1248	0.64
1617	0.38	900		783	1.63	717	1.93	995	1.02	685	2.13	1134	0.77
1375	0.53	792	1.58	675	2.19	595		900	1.23	608	2.69	944	1.00
1200	0.68	708	1.98	633	2.50	550	3.31	823	1.46	567	3.10	920	1.17
1133	0.77	641	2.43	558	3.20	503	3.92					846	
1000	1.00	583	2.94	525	3.61	450	4.93					793	1.59
942	1.12	550	3.02	500	4.00	417	5.71						
			3.63	458	4.75	383	6.81						
		492	4.12	433	5.29	357	7.84						
		458	4.75	420	5.66	337	8.82						
		450	4.93	395	6.25	320	9.79						
		433	5.33	383	[illegible]	300	11.09						
		417	5.76	355	7.89								
				350	8.12								
				338	8.70								

TABLE II

Date	Test number	Pressure	Brix	Temp.	Viscosity	Insoluble solids concentration	Filter area	Slope of curve	Specific resistance	Reciprocal of r_1	Laboratory filterability	Work done per filter cycle
		$P\times10^3$			$\eta\times10^{-2}$	$c\times10^{-3}$	$A\times10^5$	$m\times10^{-10}$	$r_1\times10^8$	$\frac{1}{r_1}\times10^{-9}$	F	W.D.
		Grams/cm²		°C	Poises	Grams/cm³	cm²	Sec/cm⁶	Sec²/Gram	Grams/Sec²	%	Tons filtered as sugar
29. 9.66	5	3.0	64.8	88.0	7.6	11.1	2	2.4	0.7	14	34	68
30. 9.66	6	3.0	62.7	86.0	6.1	9.6	2	3.8	1.6	6	24	18
7.11.66	8 (*a*)	2.5	64.8	82.2	8.0	10.7	2	0.7	0.2	50	31	17
7.11.66	8 (*b*)	5.0	64.8	82.2	8.0	10.7	2	1.1	0.5	20	31	17
8.11.66	9 (*a*)	3.0	64.0	82.2	7.3	10.7	2	0.6	0.2	50	33	26
8.11.66	9 (*b*)	3.0	64.0	82.2	7.3	10.7	2	0.9	0.3	33	33	26
9.11.66	10	3.0	63.5	82.2	6.9	11.9	2	5.2	1.5	7	25	20
22.11.66	12	3.0	63.7	79.4	7.8	10.9	2	1.0	0.3	33	—	42
23.11.66	13	2.5	62.7	79.4	7.0	9.1	2	3.4	1.1	9	37	25
6.12.66	17	4.0	60.9	79.4	5.8	9.0	2	4.3	2.6	4	28	19
9.12.66	18 (*a*)	1.0	63.3	77.8	7.8	9.4	2	8.0	0.9	11	33	42
9.12.66	18 (*b*)	3.0	64.5	80.3	8.2	9.4	2	1.5	0.5	20	33	31
12.12.66	19 (*a*)	1.0	62.2	78.3	6.8	9.1	2	7.8	1.0	10	33	32
12.12.66	19 (*b*)	3.0	63.4	81.7	7.0	12.3	2	1.7	0.5	20	33	32

Worked Example:

Test No. 9(*a*): $\left(\frac{d\theta}{dv}\right)^2$ plotted graphically against θ: Slope of curve$=4m=2.2\times10^{-10}$ secs/cm⁶; $m=0.6\times10^{-10}$ secs/cm$^6=\frac{\eta r_1 c}{2PA^2}$.

Hence $r_1=0.2\times10^8$ sec²/gram. To convert r_1 to chemical engineering units, multiply by the gravitational constant (g) and change units.

e.g. $r_1=(0.2\times10^8)\times14.6\times10^3$ ft/lb$=2.9\times10^{11}$ ft/lb.

Work done per filter cycle

Refers to the average work potential per filter cycle at the main production line.

i.e. W.D.$=$M$\times$S; where M$=$Av. melt/hour, in tons; and S$=$Average filter "start", in hours.

a

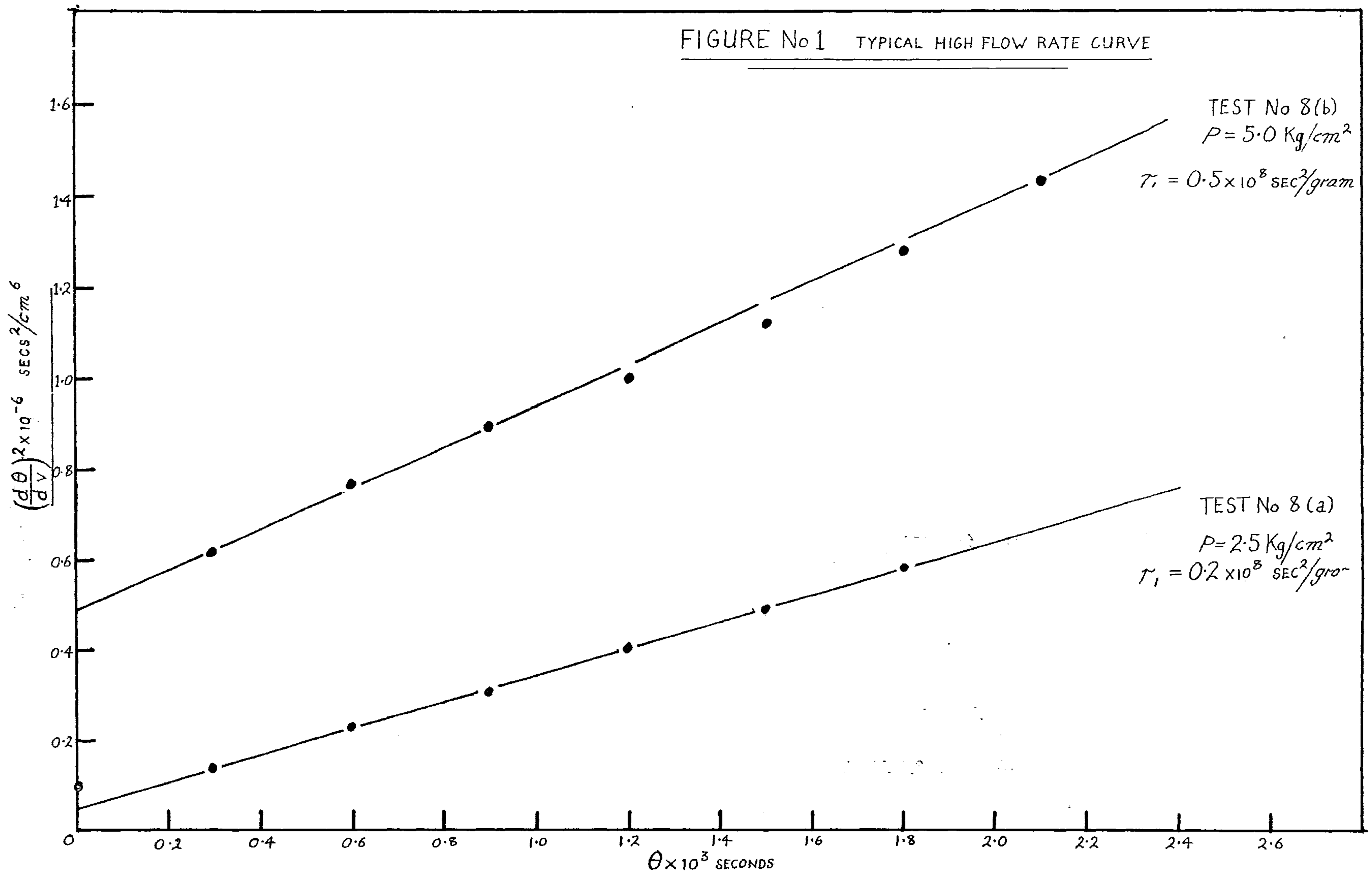


FIGURE No 1 TYPICAL HIGH FLOW RATE CURVE

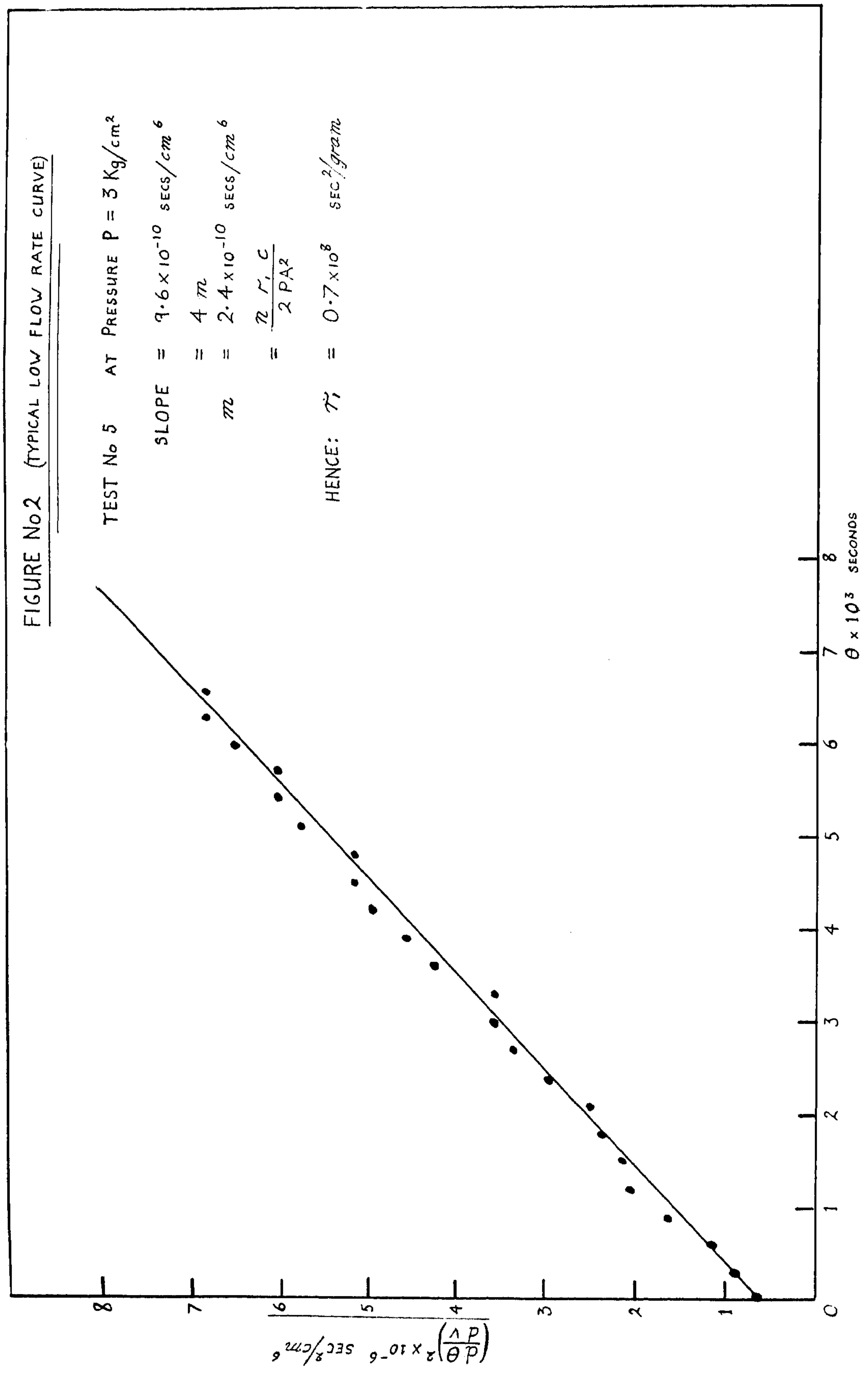


FIGURE No 2 (TYPICAL LOW FLOW RATE CURVE)

Discussion

Mr. Young: Referring to the tables in the appendices, it is the data items which are multiplied by the factors as given. To be mathematically correct, the exponents, as printed, should have the signs changed. In the text, R = Initial resistance per 1 cm^2 of filtering surface.

Dr **Douwes Dekker:** Mr. Young used a centrifugal pump for pressure in his experiments and it might have damaged the precipitate and affected its specific resistance.

In the last column of Table II, work done per filter cycle is given as tons filtered as sugar. What is the purpose of these figures? There seems to be no correlation between them and the specific resistance oi xne caK.e.

Mr. Young: The pump used was oversized, which would give an even more adverse effect.

My quantities for specific resistance are about ten times greater than expected, possibly because of the pump and restriction in valves.

Work done per filter cycle, in Table II, was inserted to give a measure of the performance in the factory. This work becomes directly proportional to filterability only under unique conditions. I can see no correlation with any of the data in Table II. The purpose of this paper is to establish a means of measuring filterability. Further investigations on correlation and significance should be carried out.

Mr. Alexander: I think the filtering quality of the sugars might have had something to do with the high specific resistance figures. Overseas refiners who use calcium carbonate filter cake have come to the conclusion that when they refine Natal raws the resistance does increase.

Mr. Young: It is difficult, at this stage, to take into account the raw sugar filterability. When sugar arrives in the factory and goes through processing, the method by which it is treated has a bearing on its filterability. The churning in the pump does not account wholly for the high specific resistance.

Dr. **Matic:** A specific resistance of cake is measured and there is constant pressure. Why cannot these be correlated with the behaviour of the sugar in the refinery?

I know that the permeability coefficient of slime dump material has been been successfully measured on the gold mines, using Carman's method. Owing to a difference in particle size there was some difficulty in packing the bed uniformly but when this was achieved the filtration of the bed was constant.

Mr. Young: The filterability in the factory can be assessed by the specific resistance of the filter cake for any particular carbonatated sugar liquor coming into the process but at this stage we have no correlation with the filterability of raw sugar as such. For instance, the raw sugar solution has not been carbonatated.

Mr. Robinson: Why did Mr. Young plot the square of the differential on his specific resistance graph? The result would have been the same.

Referring to what Dr. Matic said, the specific resistance is a function of porosity and particle density and is given as a figure of surface area per volume.

In a test carried out at the refinery to test the effect of starch, we added starch to a sugar solution, carbonatated it and found that with a high starch concentration the particles settled more slowly, indicating they were much smaller. Specific resistance depends very much on particle size. Possibly impurities in the sugar prevent the formation of reasonable size particles.

Mr. Young: If in the original form you plot dv/di9 against v, the difficulty is in measuring v.

If you look at the equation in Appendix I, $(d0/dv)^a$ is plotted against 0, thereby eliminating the volume.

If particle sizes get small they become colloidal and the floe formed is such that the cake is no longer incompressible and other factors come into account.

The specific resistance r_L is the resistance per 1 grm/cm^2 of dry cake solids. The true specific resistance is the resistance per cm^3 of cake as collected. It is not easy to measure volume of cake but the dry material can be measured. The relationship between the two is given by $r_xc = rv$. I have used Carman's advocated specific resistance r_x as it is the one used in most chemical engineering text books.

Dr. Matic: The impurities in a sugar will determine the type of cake and its porosity and that is what we should try to measure.

The particles produced are not incompressible and, according to Dr. Bennett of Tate and Lyle, our sugar is such that the calcium carbonate precipitate formed is different, when viewed under a microscope, from any other sugar. The reason for this is not certain.

Mr. Dedekind: In Table II, the first test was done on 29th September and the figures are rather interesting. Was this sugar fresh, or had it been stored and are any figures available as to its starch content? It has been stated that filterability of a sugar improves with storage.

Mr. Young: I do not have the figures for starch; however, all data is on record at the factory. The purpose of this paper is to establish a method and then subsequently we can investigate the effect of various conditions and constituents on filterability.

THE APPRAISAL OF DIFFUSION PERFORMANCE WITHOUT CONFUSION

By E. J. BUCHANAN
Sugar Milling Research Institute

Introduction

During the 1966-7 season three continuous counter current cane diffusers were commissioned in Southern Africa, one at Nchalo Sugar Estates in Malawi and two in Natal at Dalton and Entumeni. As may be expected, the performance of these units has not been *consistently* impressive, due mainly to various adjustments made while gaining experience with the new equipment. However, extractions of 97 per cent (lost absolute juice per cent fibre in final bagasse of 23) have been recorded and this together with the promise of a considerable saving in installed and running costs suggests that milling will in future be superseded at least partly by diffusion. With this prospect in view it is important that performance data available from the first "diffusion season" be appraised and expressed in a manner least conducive to confusion.

The purpose of this paper is to provide, on the basis of experience gained from the S.M.R.I Mutual Milling Control Project, a basis for the assessment of diffusers in general using specific performance data from existing diffusers as an example. It is hoped that this will eliminate some of the anomalous conclusions which could be drawn on the basis of more superficial data available at present.

Specific Performance of Diffusers

In order to illustrate the various facets of diffuser and associated milling performance the discussions in this paper are based on the mean data up to the end of January, 1967, for the three factories mentioned above. These data are shown in Tables I and II. The mean data represent a wide variety of operaing conditions and their use avoids anomalies which may result from selection of short period data.

(a) *Diffuser Capacity*

The comparison of feed rates for diffusers of various sizes and processing different cane varieties on the basis of tons cane per hour is certainly anomalous. The only fixed characteristic of a diffuser is the effective length and breadth, i.e. the area covered by cane. The only constant material in the feed is fibre since the juice to fibre ratio changes after the first mill. This suggests that the specific diffuser feed rate should be expressed as lb fibre/sq ft/hr. Table I (data 3 and 10) shows that while the capacity in ton cane/hr varies by a maximum of 18 per cent, the difference in specific feed rate between the two particular diffusers is only 4 per cent and in fact there is very little difference between the specific feed rates of all three diffusers.

(b) *First Mill Performance*

This may be assessed most logically by the residual absolute juice % fibre in first mill bagasse and the lb fibre/cu ft t.r.v.-hr* (data 24 and 25 in Table I). It has been shown under local conditions that the first mill has a bearing on overall milling performance.[2] Similarly, experience in Reunion and Tanzania indicates that juice per cent fibre in first bagasse has a direct bearing on the pol in bagasse in a diffuser.[5] The data in figure 1 also support this contention and seem to show that the overall performance is dependent solely on the first mill performance. For this reason it would be misleading to quote overall performance as an indication of diffuser performance without reference to first mill performance, or to the first mill bagasse analysis.

Comparing the data quoted above with Table II, it appears that for good first mill performance preparation should be efficient and the mill should not be overfed. The importance of shredding before milling was shown by the Mutual Milling Control Project and while this may not apply in the case of certain soft caae varieties, diffuser suppliers who find their machinery incompatible with shredders should bear this aspect in mind, particularly in view of the relationship in figure 1.

(c) *Diffuser Performance*

As discussed in an earlier paper[3] the performance of continuous multistage leaching equipment may be expressed in terms of the stage efficiency which compares the number of actual stages with the number of ideal stages under conditions of complete mixing. In the case of fully continuous operation as in cane diffusion it may be possible to make use of a diffusion coefficient based on analysis of the various diffuser juices or alternatively the "height of a transfer unit" concept. Until some such assessment has been evolved, more superficial criteria will have to suffice.

In general Chemical Engineering leaching calculations, the work done by the diffuser is expressed by the change in solute/underflow inert solid ratio. In cane diffusion this would be equivalent to comparing the sucrose/fibre ratio in first and last bagasses.

Unfortunately only data 12 and 17 (Table I) are available but a comparison of absolute juice per cent fibre in bagasse entering and leaving the diffuser is equally applicable (data 14 and 15). The straight line relation between these data (fig. 1) passes

t.r.v. = total roller volume.

through the origin showing clearly that absolute juice extraction is identical for all three diffusers and that the lost absolute juice is dependent only on the first mill performance.

(d) *Diffuser Imbibition Control*

An important controlled process variable is the imbibition ratio on fibre. This is usually controlled basically by a signal from either a first bagasse belt weigher or a killer plate resting on the cane fed to the first mill after knife preparation. The stability of control may be assessed from the mean percentage deviation in imbibition per cent fibre (data 20 in Table I). The lower value corresponds to a greater stability.

(e) *The Effect of Inversion on Extraction*

It has been said that calculated extraction efficiency would be enhanced if abnormal inversion occurred during diffusion. This is incorrect since if inversion occurred it would reduce not only the *total* sucrose determined by mass balance but also the *recovered* sucrose. Calculated extraction efficiency would therefore not be significantly affected by inversion.

Comparative figures for reducing sugar ratios in mixed juice at local diffusion factories do not give rise to undue concern. For example, at Dalton this figure averaged 4.48 compared to 5.04 for the neighbouring mill at Jaagbaan. At Entumeni the diffusion season's average was 2.79 compared to 2.89 for the 1965–6 milling season. At Nchalo the ratio was considerably higher due to immature cane.

From the above discussion it appears that any conclusions regarding the relative rates of inversion during milling and diffusion should be regarded as speculative, particularly in view of the primary dependence of reducing sugar ratios on cane quality.

(f) *Extraction of Impurities*

Experienced millers frequently comment on the possibility of additional non-sugar extraction by diffusion due to the use of hot water. However, owing to the separate clarification of press water and the filtering action of the bagasse mat through which the juices are percolated, the diffuser juice can be brilliantly clear. This partial elimination of colloidal matter before boiling the juice reduces the load on clarifiers and filters (data 31 in Table I) and should be expected to enhance the quality of clarified juice.

This deduction is probably best illustrated by considering the extraction of starch from cane during diffusion. In fig. 2 two sets of analyses[6] for starch in consecutive diffuser juices are shown. The two runs were conducted at high and low temperature levels. These results infer that the starch on brix in diffuser juice may be reduced by about 70 per cent by lower temperature operation and (from previous tests on secondary mill juices)[1] the level of the starch is considerably lower than for a normal milling tandem. Subsequent tests have indicated that starch dissolves slowly at 70°C and that enzymatic destruction appears to occur at almost the dissolution rate. This infers that starch displaced from the bagasse into the juice may be removed by a combination of enzymatic destruction and filtration.

The peaks in the curves of fig. 2 correspond to the return of clarified press water and this high starch level after milling confirms that milling extracts a higher amount of suspended colloidal matter from bagasse than diffusion. It also suggests that starch (which is not removed by clarification) may be removed by filtration through the bagasse bed.

The last expressed juice purity (data 32 in Table I) is generally commensurate with the low level of sucrose in final bagasse and any abnormally low results could be attributed to the fact that the dewatering mills express an abnormal amount of low solubility non-sugars which are not extracted by the diffuser (e.g. starch).

(g) *Performance of Dewatering Mills*

The dewatering mill capacity may be assessed on the same basis as the first mill. Data 28 and 29 of Table I indicate considerable discrepancy when comparing the moisture in final bagasse against the specific capacity of dewatering mills based on the total roller volume of *all* dewatering units. However, if the moisture in bagasse is compared against the specific capacity for only *one* mill (data 30 in Table I) then a direct relationship between moisture and capacity is evident even when comparing installations with one and two units. This obviously infers that the dewatering effect of the third mill (second dewatering mill) is not very significant. Data 29 and 30 suggests also that under 52 per cent moisture could be achieved using only one dewatering unit provided it is fed at a rate of less than 180 lb fibre/cu ft t.r.v.–hr and that for fibre rates exceeding the capacity of a single unit it would probably be more advantageous to operate two mills in parallel than in series.

These conclusions are supported by theory. Firstly, the bagasse discharged from a diffuser is a saturated porridge-like mass with little rigidity compared with normal final bagasse from a milling tandem. Hence, after passing through a dewatering mill its consistency does not facilitate further dewatering by a second unit. Secondly, the Burke-Plummer equation[4] (which relates pressure drop through a porous bed to the velocity of a liquid passing through the bed in the turbulent flow region) indicates that the pressure drop through the bagasse bed is proportional to the height of the bed and the square of the superficial liquid velocity through the bed. In a certain sense, the velocity of the draining liquid is directly proportional to the height of the bed since during rapid expression the amount of liquid expressed through unit area increases with bed height. In this sense the pressure drop through the bed is proportional to the third power of the bed height. This condition would be most likely to occur in a highly saturated bed undergoing rapid dewatering. Hence the bagasse bed height is rather critical in determining the efficiency of dewatering. Obviously mill speed and bed height are inter-related so that there is no advantage in running the mill fast in order to thin out the bed. This simply increases the liquid velocity until reabsorption occurs when the pressure drop equals the pressure on the bagasse bed.

Summary and Conclusions

This paper has pointed out that the indiscriminate use of superficial capacity and efficiency ratings can lead to confusion in the appraisal of diffusion performance. Diffuser capacity should be based on the fibre rate and a fixed characteristic of the diffuser size, viz. the effective area. Mills may be similarly rated by the use of fibre rate and total roller volume.

In assessing efficiency, mills and diffuser should be treated individually and on the basis of absolute juice per cent fibre in preference to extraction of sucrose. Since diffusion is dependent on concentration difference it is incorrect to compare diffusers on the basis of residual absolute juice per cent fibre in final bagasse alone and the residual juice in first mill bagasse should be taken into account. Hence the change in absolute juice/fibre ratio through the diffuser should be used.

On the above basis it has been shown that the three diffusers operating in Southern Africa have (for practical purposes) the same specific capacity and efficiency and that efficiency differences can be directly attributed to the first mill performance. This has clearly pointed out the importance of first mill efficiency. The conclusion is supported by results from other diffusers.

In passing, it has been shown that inversion should not effect extraction as calculated by standard methods and there is no conclusive evidence to show that inversion is higher in diffusion than in milling. Furthermore, there is no evidence to show that non-sugar extraction is higher in diffusion. In fact the reverse may apply, particularly with respect to starch.

There is some evidence to show that the imbibition rate control may be more stable when based on the feed rate of first bagasse. It appears that diffuser bagasse may be more efficiently dewatered by the use of a single over-sized mill than by two normal-sized units in series. At high feed rates it is suggested that two units be operated in parallel.

By the use of specific performance data experience in diffusion may be applied to advantage in the design of future installations.

Acknowledgements

The author wishes to thank the management of Nchalo Sugar Estates, Malawi, Entumeni Sugar Milling Co. (Pty) Ltd. and the Union Co-operative Bark and Sugar Co. Ltd., Dalton, for permission to publish process data from their diffusion plants.

Bibliography

[1] Anon., Comm. S.M.R.I., "Annual Report for 1965", (67) 1966, 13.

[2] Buchanan, E. J., Douwes Dekker, K. and van Hengel, A., "Cane Milling Research and Development in South Africa 1961–64", Proc. 12th Congr. I.S.S.C.T. Puerto Rico, 1965.

[3] Buchanan, E. J., "The Significance of Stage Efficiency in the Cane Milling Tandem", Proc. 39th Ann. Congr. S.A.S.T.A., 1965, 34–45.

[4] Burke, S. P. and Plummer, W. B., "Pressure Drop for Flow Through Packed Beds", Ind. and Eng. Chem., *20* 1947, 537 and **703.**

[5] Bruniche-Olsen, H., "Recent Experience With the DDS Cane Diffuser", Sugar, *61* (8) 1966, 27-29.

[6] Graham, W. S. and Oosthuizen, D. M., "The Effect of Operating Temperature of the de Smet Diffuser at Entumeni Mill on Starch Extraction", S.M.R.I. Tech. Rep. No. 798, Feb. 1967.

TABLE I

Diffuser performance data

Factory	NS†	EN	UC
1. Type of diffuser	de Smet	de Smet	B.M.A.
2. Rated ton cane/hr	63-99	63-99	55-109
3. Actual ton cane/hr	41	46	50
4. Effective length	77′-6″	77′-6″	93′ 6″
5. Effective width	8′-2½″	8′-2½″	7′ 2⅝″
6. Effective area, sq ft	636	636	675
7. Fibre % cane	15.99	13.32	14.45
8. Ton fibre/hr	6.56	6.13	7.23
9. Lb cane/sq ft-hr	129	145	148
10. Lb fibre/sq ft-hr	20.6	19.3	21.4
11. Sucrose % cane	12.19	13.63	12.26
12. Sucrose % fibre in cane	76.24	102.33	84.84
13. Absolute juice % fibre in cane	525	651	592
14. Residual abs. juice % fibre first bag.	224	295	328
15. Lost abs. juice % fibre final bag.	28	34	37
16. Sucrose % final bagasse	1.62	1.87	2.00
17. Sucrose % fibre final bag.	3.55	4.42	4.51
18. Extraction % overall	95.34	95.66	94.59
19. Imbibition % fibre	235	299	222
20. Imbibition mean % deviation	—	11.0	14.3
21. Speed of diffuser conveyer, ft/hr	118	118	138
22. Retention time of bagasse, min.	39.4	39.4	40.7
Milling data:			
First Mill:			
23. Total roller volume, cu ft	73.7	55.6	127.3
24. lb fibre/cu ft t.r.v.-hr	178	220	114
25. Residual abs. juice % fibre first bag.	224	295	328
Dewatering mills:			
26. No. of units	1	2	2*
27. Total roller volume cu ft	73.7	111.2	147.3
28. Lb fibre/cu ft t.r.v.-hr.	178	110	98
29. Moisture % final bagasse	51.94	55.78	52.75
30. Lb fibre/cu ft t.r.v.-hr (one unit only)	178	220	196
31. Filter cake % cane	2.24	4.00	3.00
32. Purity last expressed juice	69.2	67.8	70.7

*preceded by dewatering drum †Nchalo, Malawi

TABLE II

Preparatory and milled equipment

Unit	NS	EN	UC
Primary knives:			
No. of knives	32	32	32
Pitch, in	2	3	5½
Pitch, circle diam., in	60	54	59
Speed, r.p.m.	580	600	588
Installed h.p.	150	120	268
Secondary knives:			
No. of knives	48	32	64
Pitch, in	1½	3	1¾
Pitch, circle diam., in	60	54	59
Speed, r.p.m.	580	600	588
Installed h.p.	200	150	335
Shredder:			
Type	N.A.	Gruendler	N.A.
Size, in		30 x 40	
No. rows hammers		4	
No. hammers operating		32	
Speed, r.p.m.		960	
Installed h.p.		120	
First Mill:			
Type	Mirrlees	Stewart	B.M.A.
Size, in	30 x 60	28 x 52	36 x 72
Installed h.p.		175	375
No. dewatering mills	1	2	2
Second Mill:			
Type	Mirrlees	—	Mirrlees*
Size, in	30 x 60	28 x 52	30 x 60
Installed h.p.		300	275
Third Mill:			
Type	N.A.	—	Stewart
Size, in	N.A.	28 x 52	30 x 60
Installed h.p.	N.A.	coupled	275

*preceded by dewatering drum

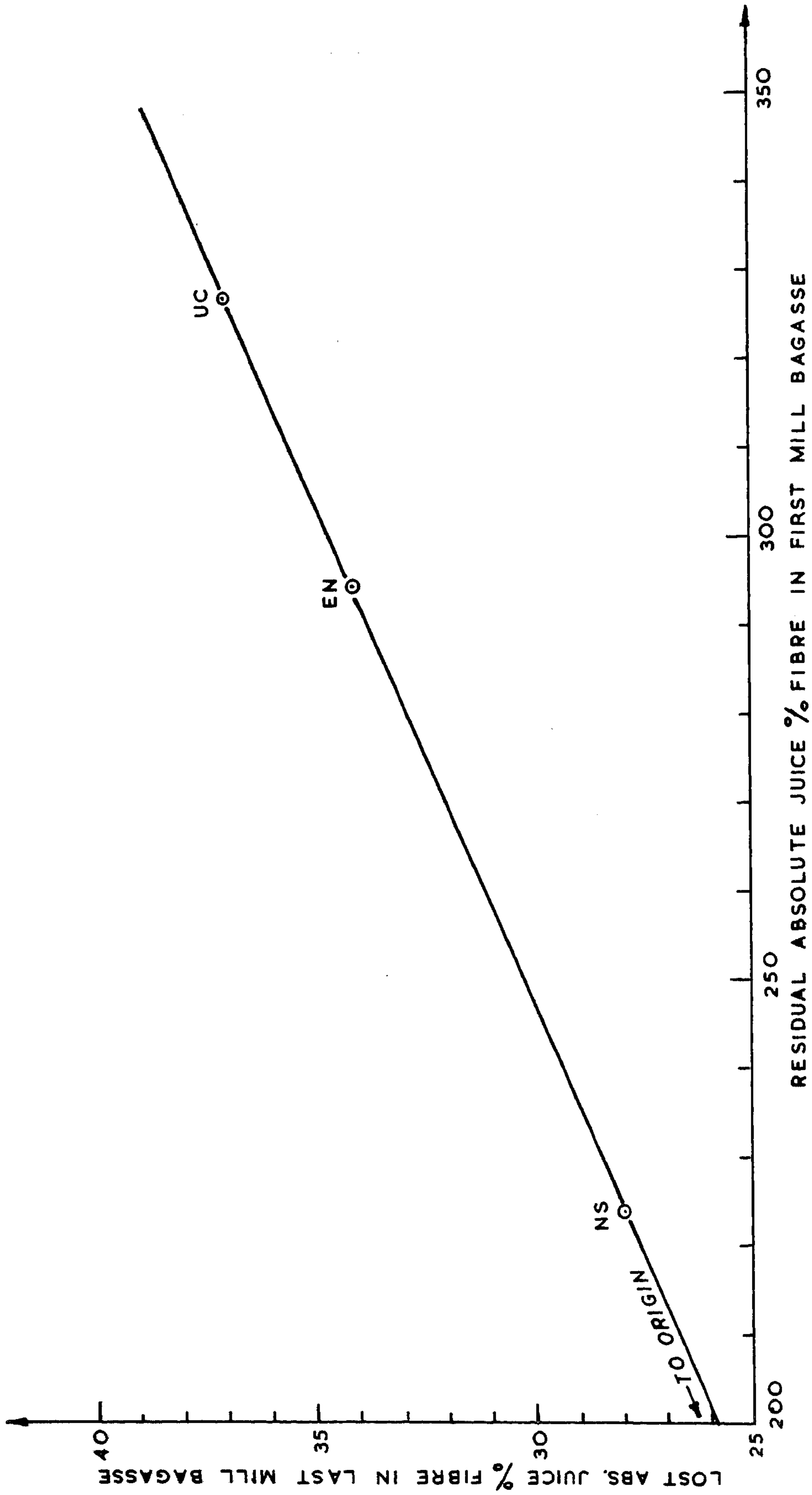


FIGURE 1: Relation between first mill and overall diffusion performance

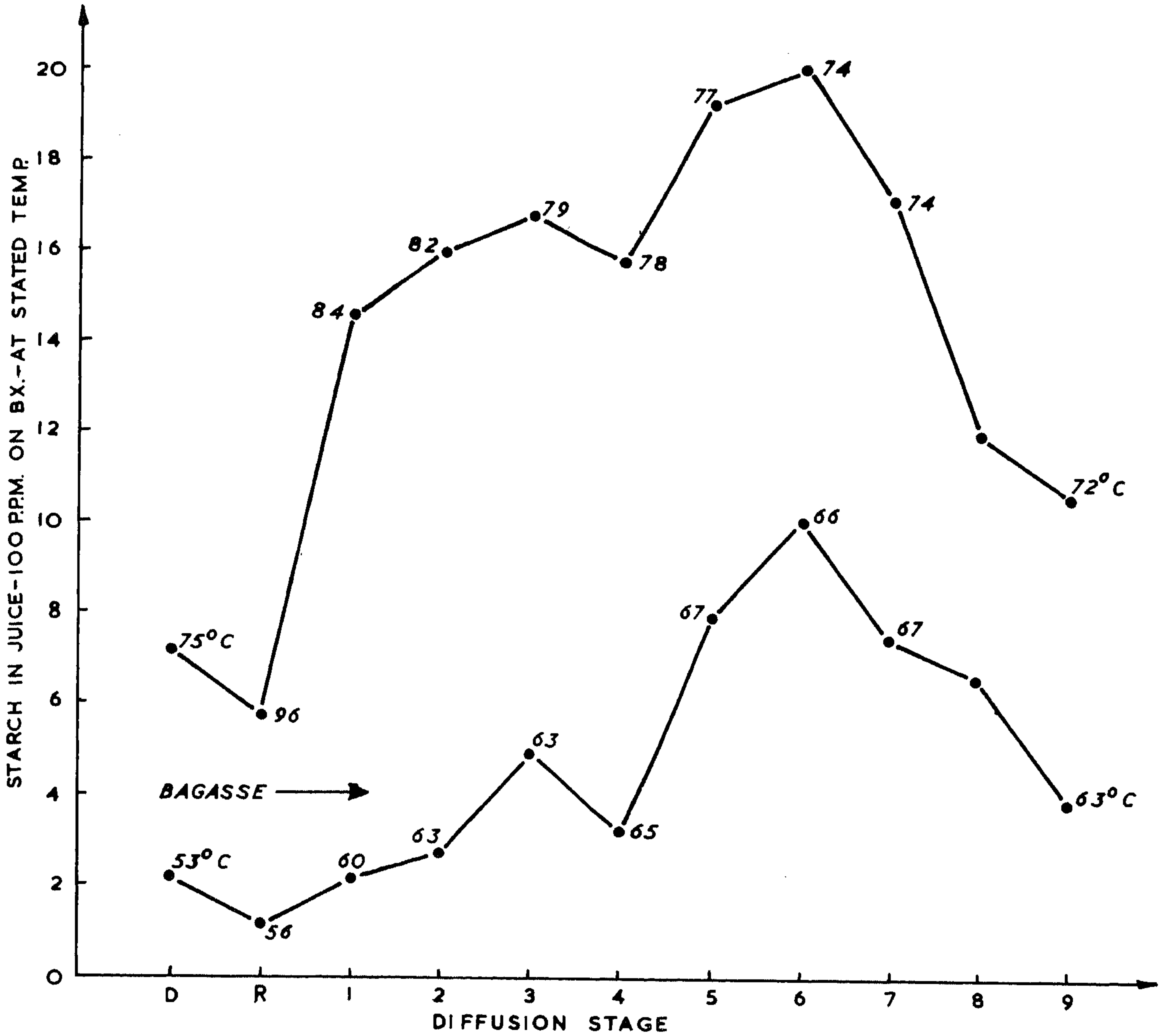


FIGURE 2: Starch extraction with diffuser operating at high and low temperatures
D: diffuser juice R: recirculation juice

Discussion

Mr. Hulett: Mr. Buchanan says that better results would be achieved by dewatering the diffusion bagasse with two mills in parallel instead of in series and, going by our experience at Darnall, where very heavy imbibition is applied, I am sure he is correct.

Mr. Renton: You cannot compare milling and diffusion regarding retention time. At Darnall our retention time is at the most fifteen minutes, whereas in a diffuser it is at least thirty minutes. There are five leaching stages in our mill whereas there are as many as nine in a diffuser. There is probably some diffusion going on in the Darnall tandem, particularly in view of the heavy imbibition.

Mr. Buchanan: When a mill roller is fed with bagasse, no matter what sort of mixing device is put between two mills to get better mixing, e.g. Rivere carriers, very little additional mixing is achieved.

The effective diffusion time in a milling tandem is so limited, and mixing so poor that very little diffusion can take place within the bagasse particles.

Mr. Renton: At Darnall imbibition is applied immediately after the preceding mill so that only while the bagasse is moving through the rollers is it not subject to diffusion. There is therefore time for it to take place. Also, enough water is applied to saturate the bagasse and allow for good mixing.

Mr. Buchanan: The diffusion rate from within the bagasse particle to the surface is controlling. In a milling tandem there is no relative movement between bagasse and juice during conveying and some time is required for the bagasse to absorb the imbibition. Hence the efficiency of the controlling diffusion is low.

Mr. Bentley: Honolulu Iron Works have produced a plant consisting of a series of presses fed by chutes which it is claimed overcomes the disadvantage of a diffuser. The bagasse is fed by a large chute, liquid is poured on to it, the juice is squeezed out by the press and the bagasse is then transferred to the next chute.

What are the so-called disadvantages of a diffuser?

Mr. Buchanan: Possibly the rather cumbersome vessel that has to be installed in a factory and the potential disadvantage of a high retention time, although the danger of inversion has not yet been proved.

Mr. van Hengel: What was the quality of the cane at Nchalo—was is very clean or very dirty? If it was very clean is it not perhaps presumptuous to assume that one small dewatering mill is sufficient?

Mr. Buchanan: The cane was neither particularly clean nor particularly dirty. There was not much mud attached to it and trash was not particularly high. I maintain that the lack of rigidity of the bagasse fibre discharged from the diffuser makes the bagasse almost impermeable after passing through one dewatering mill.

Mr. Covas: When I visited Nchalo some months ago and expressed surprise at the high figure of 16% I was told that a proper factory control method was not yet in operation and that all figures should therefore be treated with reserve.

The cane was fairly clean by South African or Moçambique standards.

Mr. Buchanan: Apart from a possible discrepancy through not weighing the final bagasse factory control seemed adequate. During my visit I concluded that any errors would not detract significantly from the conclusions in this paper.

Mr. Bax: On page 2 the figure of 180 lbs. fibre per total roller volume per hour is given as the maximum efficient figure for a dewatering mill. I think that a much higher figure is allowable provided adequate juice grooving is provided.

In a Walker mill provided with a pressure feeder, are five rollers or three rollers taken into account when assessing total roller volume?

Mr. Buchanan: I do not think mill grooving would have much effect on the impermeability of the bagasse, which is the chief factor.

We are not very impressed so far by the achievement of Walker mills and are awaiting with interest results from Malelane. Only three rollers are considered since the first two are mainly for feeding.

Mr. Hurter: The wattle industry operates a diffusion process and the experience has been that in order to diffuse with minimum impurities in juice the bark must be cut as cleanly as possible without rupturing cells. Would it not be advisable to do away with a shredder and replace it with a machine that could chop cane without rupturing cells?

Mr. Buchanan: If cane was chopped into cossettes without rupturing individual particles removal of the sugar would have to take place by osmosis or, in order to avoid this, the temperature would have to be raised to 85°C to make the cells permeable and starch would be dissolved. This is precisely what we are trying to avoid.

Mr. Carter: In order to prevent inversion in a diffuser is it beneficial to add lime?

Mr. Buchanan: It is essential to add lime along the diffuser to maintain a consistent pH and avoid inversion.

THE REDUCTION OF SUCROSE LOSSES IN CLARIFIERS AND MILLING TANDEMS

by J. CROWTHER

Illovo Sugar Estates Ltd.

(Paper read by Mr. Bruijn)*

Introduction

The first part of this paper deals with the reduction of sucrose losses in the clarifier during hours of stoppage. The second part describes experiments carried out to prevent the formation of slimes in the milling tandem and subsequent destruction of sucrose.

Part I

CLARIFIER LOSSES

During the latter half of the 1963-64 season an investigation was carried out at the Illovo factory into the deterioration of juices in the clarifier during stoppages.

Samples of clarified juice were taken from each level of a 60,000 gallon Rapi-dorr clarifier at hourly intervals, and the pH and apparent purity determined. The pattern of results was similar for all levels of the clarifier, and in this paper the figures shown are those taken from the bottom level.

To ascertain the effects of high temperatures and normal operating pH, the mixed juice was limed to pH 7.5 after primary heating to 180°F, with secondary heating to 220°F for three hours prior to a shut-down. The juice pH, apparent purity and drop in purity after various intervals of time are tabulated in Table I.

Table I

Hours of Stoppage	pH	Apparent Purity	Cumulative Purity Drop
0	7.1	86.4	—
4	6.5	84.9	1.5
8	6.4	83.0	3.4
12	6.0	82.0	4.4

After 24 hours the pH was 4.7 and the apparent purity 79.6.

This rapid deterioration of juice in the clarifier was confirmed by subsequent tests. During one shut-down of 42 hours, the apparent purity fell from 86.2 to 68.0, representing a pol loss of 7.6 tons.

In order to observe the effect of reducing the temperature and increasing the pH before shut-down, observations were made and data collected for a shut-down, for three hours prior to which the juice final temperature was dropped to 190°F and the pH raised to 8.0. The results obtained are tabulated in Table II and indicate that the purity drop was 0.9 less than for the same period in the first experiment, when the temperature was not lowered nor the pH raised.

Table II

Hours of Stoppage	pH	Apparent Purity	Cumulative Purity Drop
0	7.3	86.7	—
4	6.9	85.7	1.0
8	6.6	84.6	2.1
12	6.3	83.2	3.5

To ascertain the effect of a further reduction in temperature and a higher pH, the juice final temperature was lowered to 180° F and the pH raised to 8.5 for three hours before shut-down. The results tabulated in Table III indicate that a further reduction in the purity drop occurred.

Table III

Hours of Stoppage	pH	Apparent Purity	Cumulative Purity Drop
0	7.6	87.2	—
4	7.4	87.1	0.1
8	7.1	86.4	0.8
12	6.5	84.8	2.4

Subsequent tests followed the same general pattern as the results shown above.

A series of laboratory tests was conducted on a group of substances known as quaternary ammonium compounds. Several were tried and the most effective (taking the cost into account) was found to be a compound marketed under the brand name of Leucosan.

Leucosan is non-toxic, practically odourless and tasteless in use and is extremely soluble in water.

To examine the effect of Leucosan when used on a factory scale, an experiment was conducted over a shut-down utilizing Leucosan added to the juice in conjunction with reduced temperature and raised pH. The mixed juice was limed to pH 8.5 after primary heating to 150°F, with secondary heating to 180°F for three hours prior to a shut-down. During this period 100 ppm of Leucosan were added to the juice by a drip-feed arrangement. The pH and apparent purity of the juice in the clarifier were determined at four-hourly intervals and these are listed in Table IV.

*Owing to the author's absence discussion on this paper has not been recorded.

Table IV

Hours of Stoppage	pH	Apparent Purity	Cumulative Purity Drop
0	7.8	86.4	—
4	7.2	86.2	0.2
8	7.2	86.3	0.1
12	7.2	86.2	0.2
16	7.1	86.0	0.4
20	7.0	86.0	0.4
24	7.0	85.8	0.6

In this case crushing was resumed after 30 hours. A bulk sample of clarified juice was withdrawn from the clarifier before crushing commenced and its temperature maintained at 180°F in the Laboratory. After a total elapsed period of 36 hours, the pH was 6.6 and the apparent purity 84.8. The purity drop over 36 hours was thus 1.6.

These results indicate a considerable reduction in the purity drop of the juice compared with previous experiments where no bactericide was added.

In order to ascertain whether any Leucosan finds its way into raw sugar, the clarified juice was treated with 400 ppm of this compound, and a strike of "A" sugar boiled from the resulting syrup. The analyst's report on analyses carried out on a sample of this sugar stated that all tests for quaternary ammonium compounds were negative, and that it contained less than 10 ppm, the limit of sensitivity of the analyses.

The results of the tests described above are illustrated graphically in Figure 1.

Summary

The lowering of the temperature of the juice entering the clarifier in conjunction with raised pH does result in a reduction of the deterioration rate of the juice. However the addition of 100 ppm of Leucosan for three hours before shut-down results in sucrose losses in the clarifier being reduced to almost negligible proportions.

Part II

SUCROSE LOSSES IN THE MILLING TANDEM

Introduction

Intermittent spraying of the milling tandem with Leucosan resulted in a marked lowering of the reducing-sugars/sucrose ratio of mixed juice at Illovo and Mhlume, indicating that this product is effective in reducing sucrose losses during the milling process.

Experiments were conducted at Illovo during June and July of 1965 and at Mhlume during July and August of 1966.

Analyses

It was felt that pol, sucrose and purity figures were an unreliable guide in the evaluation of a mill sanitation programme. It was thus decided to carry out analysis for reducing sugars (by the Lane & Eynon method) on four-hourly composite samples of first expressed juice and mixed juice.

ILLOVO TEST

Spraying Equipment

At Illovo a "Hydro-air Washer" spray gun was attached to 50 ft. of oxy-acetylene hosing and 50 ft. of $\frac{3}{8}''$ plastic tubing. The hose and tubing were taped together at 18″ intervals, resulting in a light and flexible piece of apparatus which is very simple to operate. The hose was connected to a 100 p.s.i.g. compressed air line, and the plastic tube led into a 10 gallon drum containing the stock solution. The spray gun has controls for both compressed air and the liquid to be sprayed.

For ten days prior to the commencement of spraying four-hourly composite samples of first expressed juice and mixed juice were analysed and the average for each day is shown in Table V.

Table V

REDUCING SUGARS—SUCROSE RATIO

Day	First Expressed Juice	Mixed Juice
1	2.7	4.6
2	2.7	4.7
3	2.8	4.5
4	2.9	4.1
5	2.8	4.4
6	2.8	4.3
7	2.8	4.6
8	2.7	4.5
9	3.0	4.5
10	2.7	4.1
Average	2.8	4.4

Spraying with Leucosan was started on the eleventh day. One pint of Leucosan was diluted to two gallons with cold water. This was found to be sufficient for spraying the entire milling train, including juice screens and gutters. Spraying was done every four hours from the 11th to the 30th day of the test. A gradual lowering of the R.S./sucrose ratio for mixed juice occurred from the eleventh to the twentieth day.

The results of analyses done during the last ten days are shown in Table VI.

Table VI

REDUCING SUGARS—SUCROSE RATIO

Day	First Expressed Juice	Mixed Juice
21	2.8	4.0
22	2.8	4.0
23	2.6	3.4
24	2.8	3.9
25	2.8	4.0
26	2.9	4.1
27	3.0	4.0
28	2.7	4.0
29	2.7	3.9
30	2.8	4.0
Average	2.8	3.9

It can thus be seen that although the average figure for first expressed juice was slightly higher during the period that spraying was carried out, the figure for mixed juice was 0.51 lower.

Although purity figures do not have much significance it should be noted that the purity drop from first expressed juice to mixed juice decreased by 0.2% during the period when spraying was done.

It would be very simple to calculate an amount of sucrose saved from the above figures, but the author feels that there are too many unknown factors involved, and that such a calculation would not necessarily be valid.

The results obtained are illustrated graphically in Figure 2.

Table VII

REDUCING SUGARS—SUCROSE RATIOS

	1st Expressed Juice	Mixed Juice	Difference
1st week	3.39	4.07	0.68
Leucosan used	3.82	4.43	0.61
	3.46	3.96	0.50
	3.57	4.10	0.53
	3.23	3.65	0.42
	3.78	4.46	0.68
	3.62	4.23	0.61
Average	3.55	4.13	0.58
2nd week	3.62	3.90	0.28
Leucosan used	3.17	3.55	0.38
	2.86	3.54	0.68
	2.78	3.49	0.71
	2.91	3.57	0.66
Average	3.07	3.61	0.54
3rd week	3.78	4.27	0.49
No Leucosan	4.18	5.16	0.98
	5.21	6.20	0.99
	5.32	6.03	0.71
	5.59	6.76	1.17
	4.36	5.83	1.47
Average	4.74	5.71	0.97
4th week	4.84	6.39	1.55
Leucosan used	4.78	6.06	1.28
	4.14	5.28	1.14
	2.86	3.34	0.48
	3.03	3.79	0.76
	2.90	3.59	0.69
	3.14	3.92	0.78
Average	3.67	4.63	0.95

MHLUME TEST

In order to confirm the results of previous tests on the use of Leucosan for mill sanitation, the following experiment was carried out.

For two weeks Leucosan was applied in the usual manner i.e. it was added to the water to wash down the mills as well as to the imbibition water. During the third week no Leucosan was used and during the fourth week it was again applied normally. At each weekend stop the mills were thoroughly washed with a detergent.

The reducing sugars—sucrose ratios of first expressed juice and mixed juice were determined on eight hourly composite samples, and the daily averages are shown in Table VII.

Graphs were plotted of the difference between the reducing sugars-sucrose ratios of mixed juice and first expressed juice, and are shown in Figure 3.

It can readily be seen that the difference between the figures for mixed juice and first expressed juice rose sharply after four days when the use of Leucosan was discontinued. When it was again applied during the fourth week, the difference returned to the level obtained during the first two weeks.

The cost of Leucosan used during the test was approximately R150.00 per week.

Summary

Tests carried out at both Illovo and Mhlume indicate that Leucosan is effective in reducing sucrose losses and preventing the formation of slimes in the milling tandem. The optimum amount to be used and the method of application would best be determined for each individual factory.

Acknowledgements

The author expresses his thanks to the managements of Illovo Sugar Estates Limited and Mhlume (Swaziland) Sugar Company Limited for permission to publish the results used in the paper. Thanks also to Messrs. Cremark Chemicals (Pty) Limited and especially to Mr. Tom Russell for his advice and co-operation.

FIGURE 1

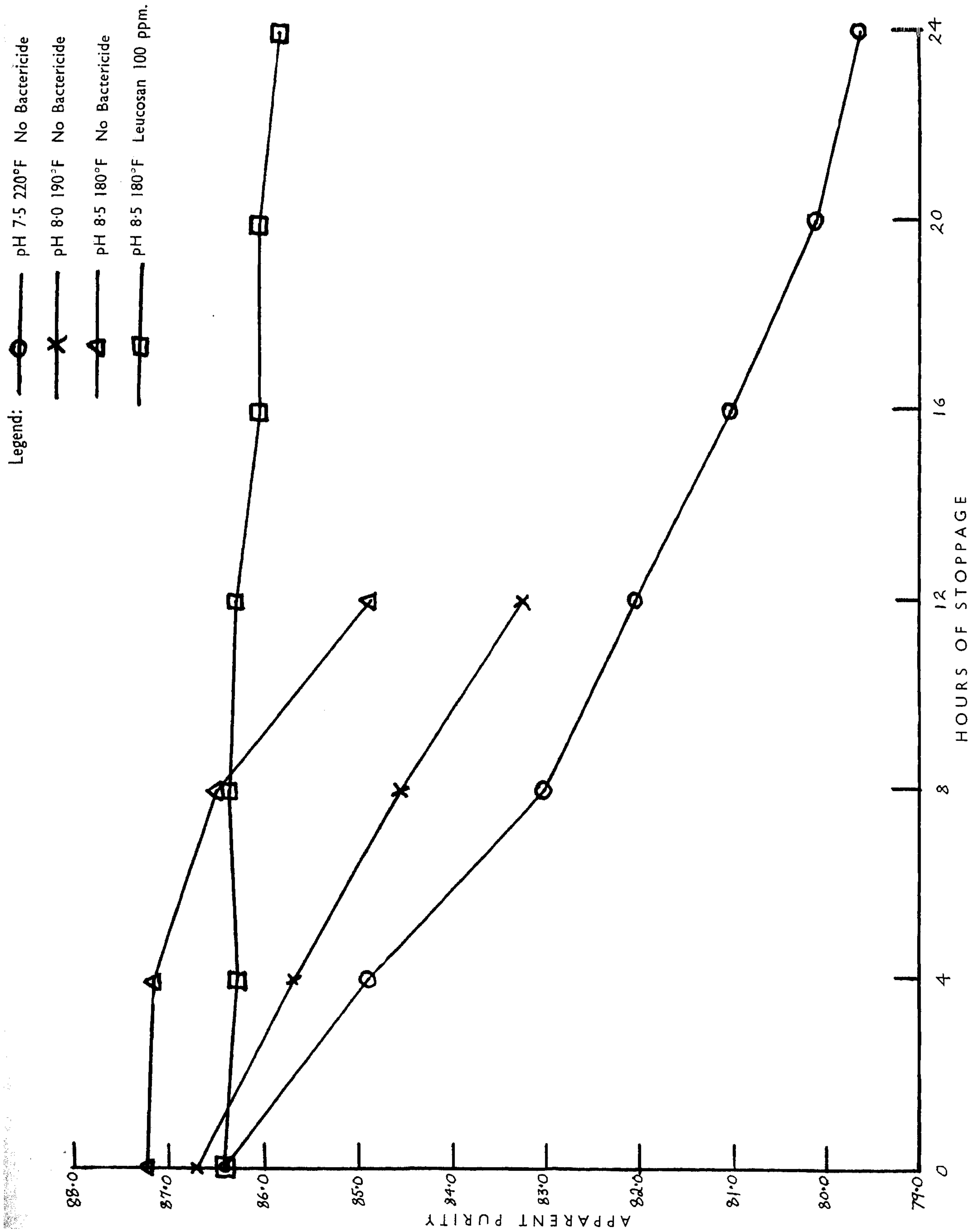

Legend:
pH 7·5 220°F No Bactericide
pH 8·0 190°F No Bactericide
pH 8·5 180°F No Bactericide
pH 8·5 180°F Leucosan 100 ppm.
APPARENT PURITY
88·0
87·0
86·0
85·0
84·0
83·0
82·0
81·0
80·0
79·0
HOURS OF STOPPAGE
0
4
8
12
16
20
24

FIGURE 2

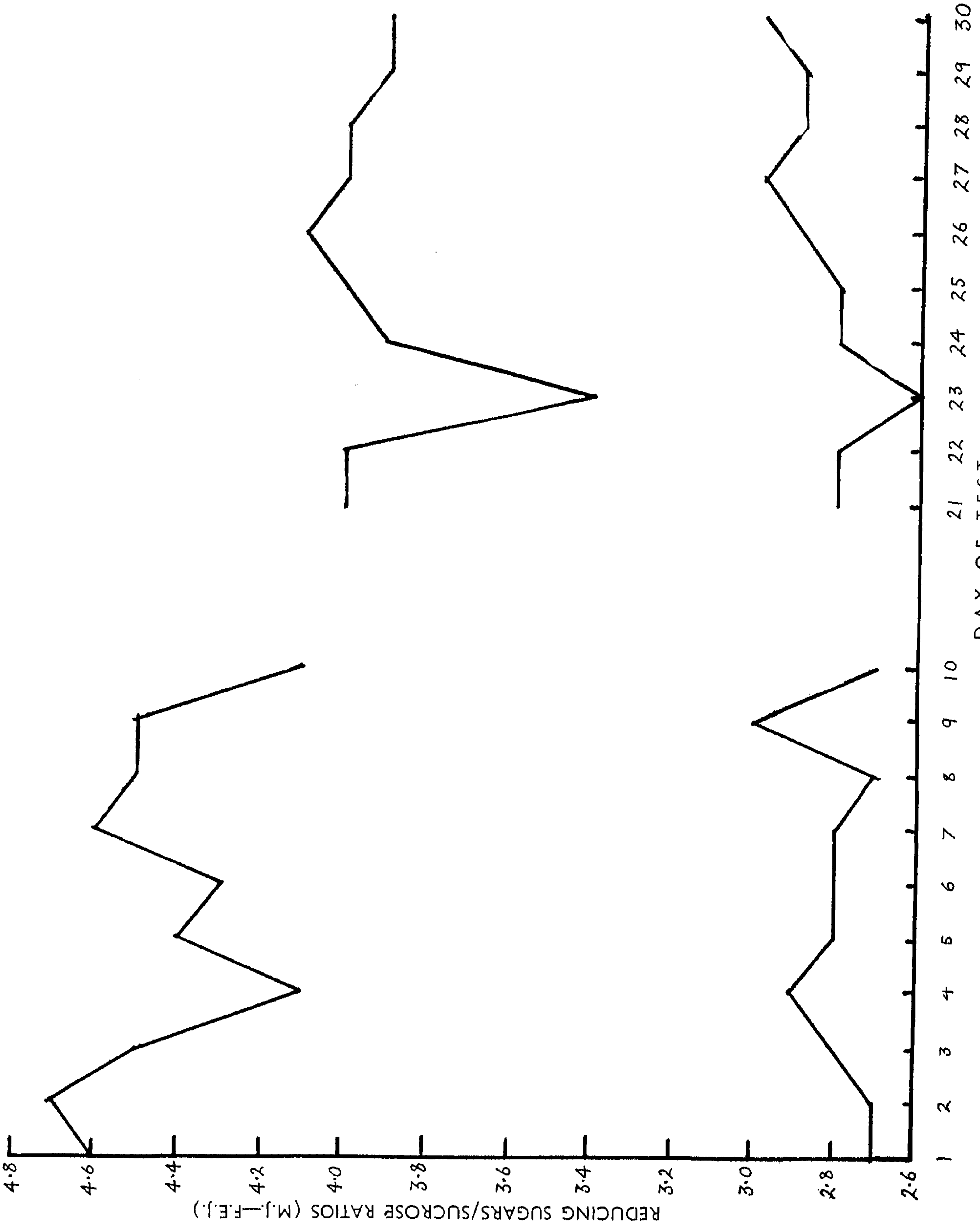
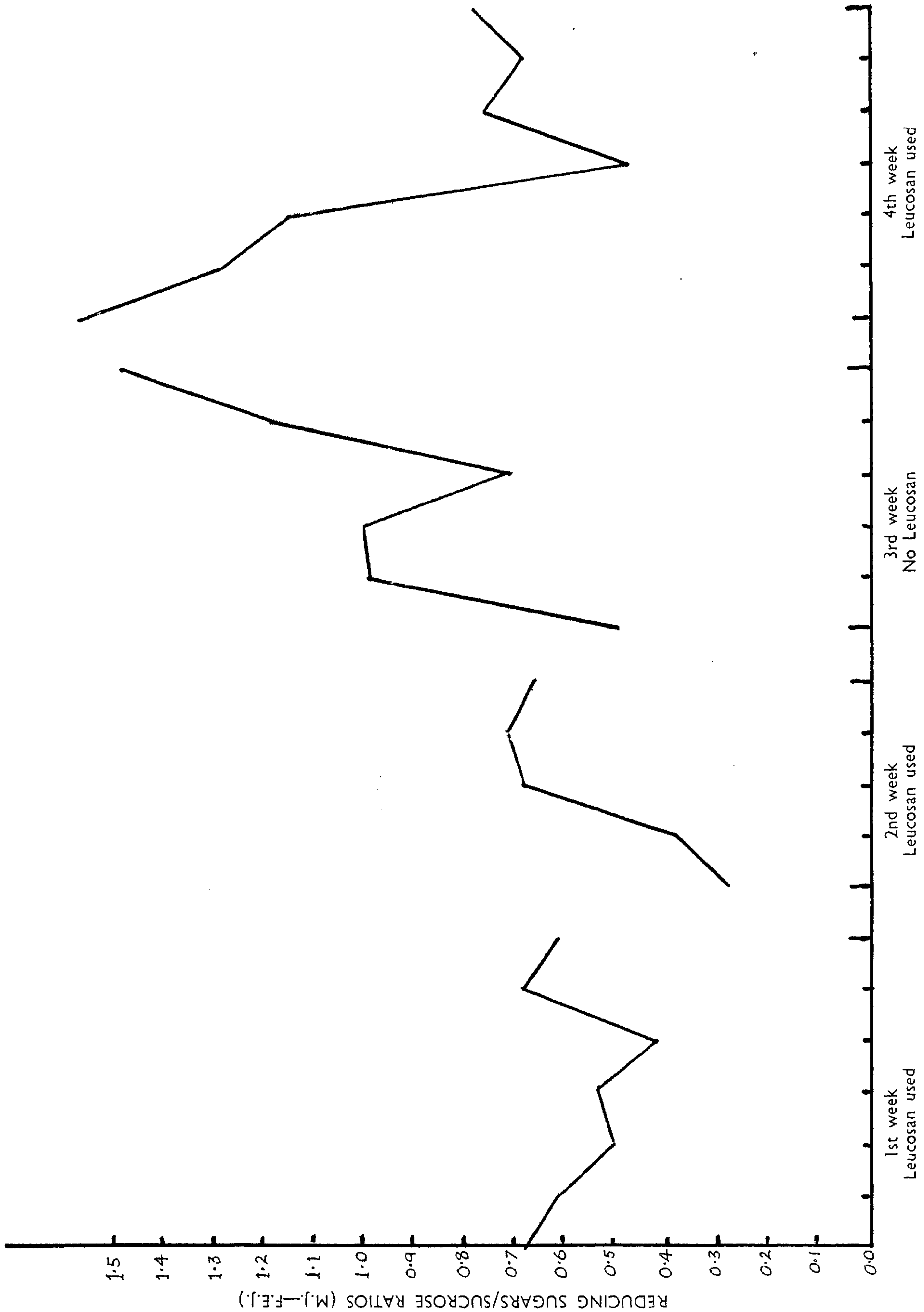

REDUCING SUGARS/SUCROSE RATIOS (M.J.—F.E.J.)
4·8
4·6
4·4
4·2
4·0
3·8
3·6
3·4
3·2
3·0
2·8
2·6
DAY OF TEST
1
2
3
4
5
6
7
8
9
10
21
22
23
24
25
26
27
28
29
30

FIGURE 3


REDUCING SUGARS/SUCROSE RATIOS (M.J.—F.E.J.)
0·0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
1·1
1·2
1·3
1·4
1·5
1st week
Leucosan used
2nd week
Leucosan used
3rd week
No Leucosan
4th week
Leucosan used

EXPERIENCE WITH AUTOMATIC BOILER CONTROLS

by A. G. HURTER
Umfolozi Co-operative Sugar Planters, Ltd.

Automatic control of steam boilers is not new, and many boilers of different kinds are being controlled automatically, but there are very few in the sugar industry.

The reasons are not hard to find—load fluctuations are high, the fuel is difficult to handle, to meter and to burn, and it is erratic in both quantity and quality. However, the increasing need to reduce manufacturing costs and eliminate expenses such as auxiliary fuel has made automation essential to maintain operating efficiency.

During 1965, it was decided at Umfolozi to purchase a turbine to give 6MW of power, and a boiler rated at 125,0001bs/hr at 450psig. The question arose of how to control the new boiler. We were not satisfied that any of the controls fitted to the older boilers would be suitable for the new boiler, so we started analysing what was installed and investigating where the weaknesses lay. The results were as follows:

(1) *Drum Level Control*

The simplest controller is the self acting on/off type, that opens the feed water valve fully when the level drops to the lower set point, and shuts off when it reaches the upper set point. This is very robust and easy to maintain, but it places a very intermittent load on the feed water pumps, and causes the boiler to steam sporadically, especially if the feed water temperature is low.

A refinement of this type is the controller that opens the valve in proportion to the drop in level. We have two of these fitted. The sensing element is an inclined steel tube connected to the boiler drum above and below the waterline, and mounted at the water level. The expansion of the tube is affected by the water level in this tube and is linked to act on the water valve. The disadvantages are:

(1) The expansion of the tube is also affected by the pressure in the boiler, so a change in pressure can upset the level set point.

(2) A change in steaming rate has the effect of upsetting the setpoint, because the valve is opened in proportion to the drop in water level only. At higher steaming rates, the valve needs to be wider open to keep the same level.

(3) A change in feedwater pressure also upsets the set point as the quantity passing through the feedwater valve is no longer in relation to its

We also have three controllers of this type to which has been added a compensation for steam flow. This is an improvement, but it is very difficult to get the mechanical linkages correct. This is a two term controller.

In the light of this we decided to install a three term controller. The steam flow is measured, as is the water flow, and these signals are balanced by altering the valve position accordingly. The drum level applies a further signal.

(2) *Steam Pressure Control—Fuel and Air Flow*

We have three boilers fitted with a master steam pressure controller, hydraulically operated. The only adjustment on the controller is the pressure set point. This is coupled by linkages to the fuel feeder variable speed gearboxes, and also to the F.D. fan damper. The equipment is very robust and reliable, but unsuccessful, because:

(a) The feeder variable speed gearboxes do not run at the same speed each time the lever is brought back to the same position. There is always some variation.

(b) The air flow through the F.D. fan is not directly proportional to the damper position, whereas the fuel flow is roughly proportional to damper position, so it is possible to obtain a correct air-fuel ratio for one position of the linkage only. Also, the bed of fuel on the grate has a varying resistance to air flow, altering the delivery pressure from the F.D. fan and hence the flow.

(c) Hunting takes place, and there is no means of stopping it.

(d) The pressure set point is offset by the steaming rate.

We decided therefore:

(a) It is necessary to measure the air flow into the combustion chamber.

(b) It is necessary to measure the feeder speeds, to compare with the desired value.

(c) The steam pressure controller must have proportional, integral and derivative action.

(3) *Flue Gas Analysis*

Several years ago a complete set of $C0_2$ analysers was purchased and installed in the boilerhouse. Successive generations of engineers and instrument mechanics attempted to maintain these in working order, but eventually the conclusion was reached that the moisture content of the flue gas was too high for these instruments. One oxygen analyser, working on the paramagnetic property of oxygen, was installed and proved very successful. Since then several more have been installed.

It was also decided to attempt, on the new installation, to correct the fuel air ratio automatically from the 0_2 content of the flue gas.

(4) *Furnace Pressure Control*

All the older Combustion Engineering boilers are fitted with a hydraulically operated furnace pressure control, acting on the ID. fan damper. These have operated very successfully.

Choice of Instruments for the New Boiler

It now had to be decided what type of instruments to install. The only range of hydraulically operated instruments available could not offer the type of control we wanted, so the choice was between (a) electronic with pneumatic actuators, (b) electronic with electric actuators and (c) pneumatic.

The electronic instruments with pneumatic actuators seemed to combine the worst of both fields. The electric actuators have a "Hold on Failure" feature which is essential for boiler operation, but most instrument mechanics hold up their hands in horror at the sight of an electronic circuit. We have always been plagued by wet and oily air in our pneumatic controllers, so included with the pneumatic scheme would have to be an instrument air scrubbing and drying plant.

It was eventually decided to install a fully electronic scheme with electric actuators. The cost was considerably higher than the pneumatic, but the advantages were:

(a) Standardised controllers with plug-up units facilitate maintenance and save downtime.

(b) Because of the standardised measuring signals, it is possible to reconnect from one control loop to another.

(c) Fault finding appeared to be easier in the electric and electronic circuits.

(d) Calibration is easier and remains stable.

No. 10 Boiler Control Scheme

This panel automatically controls the desired ratio of bagasse and coal. The air flow may be controlled as (a) air flow-fuel flow, (b) air flow-steam flow, (c) air flow-steam flow with automatic correction for flue gas oxygen content, (d) air flow-fuel flow with oxygen correction, (e) a combination of (a) and (b) with or without oxygen correction. The feed water flow may be controlled as (i) drum level only or (ii) drum level with the anticipatory signal of steam flow balanced against water flow.

Referring to Fig I; steam pressure is transduced to a 0-10V DC signal in pressure transducer 1010, and is fed into the pressure controller 1020. This is a **PID** (proportional, integral, and derivative) controller and provides the pressure set point. The output from this controller is the demand signal.

This demand signal is split up in the ratio desired between coal and bagasse, and fed into the bagasse controller 1051 and the coal controller 1052. These controllers are in cascade, as the setpoint is dictated by the pressure controller. Each controller sends a signal to the respective actuators 1071 and 1072, connected to the feeder variable speed gearboxes, the balancing signal back to the controller coming from the tachometers 1061 and 1062 on the feeders themselves.

The air flow controller 2050 is also in cascade, the command signal being derived from either the summated fuel flow or from the steam flow transducer, or partially from each, or from the demand signal. This signal can be modified by the 0_2 correction controller circuit (not shown). The demand signal from this controller controls the actuator 2070 on the forced draught fan damper, and is satisfied by the signal from the air flow transducer 2060.

The drum level transducer 3010 feeds a signal to the drum level controller 3050. The signal is increased or decreased by the difference in the water flow and steam flow signals, and controls the opening of the feed water control valve 3070.

The furnace pressure control is a simple loop consisting of the furnace pressure transducer 4010, the furnace pressure controller 4050 and the induced draught fan damper actuator 4070.

Operating Experience

After one season's operating, we are very enthusiastic about the results obtained with this control. The boiler has a very low thermal inertia, and when burning bagasse there is virtually no fire on the grate at all—combustion takes place in suspension. The result is that the response of the boiler to change in fuel rate is less than 30 seconds. If the fuel is cut off while steaming at 80% capacity, the pressure drops from 425psig to 325psig in 4 minutes. It is therefore very difficult to control the steam pressure manually, as illustrated by the steam flow and pressure charts in Figs. 2 and 3. Trouble arises if there is any interruption of the fuel supply, as the boiler partially loses combustion, causing small furnace explosions when the fire takes again. We have installed alarms to detect shortage of bagasse in the chutes. The operator then has to add a very small quantity of coal to restore combustion on the grate. Only two of each set of six feeders are fitted with tachometers, these two being assumed to represent the average of the rest. This is false economy, as it is very difficult to get these feeders running at the same speed. Individual tachometers will be fitted at a later date.

Various combinations were tried to control the air flow, but the most satisfactory was found to be air flow following steam flow in a fixed ratio. This has the effect of increasing or decreasing the combustion to follow short term fluctuation in the steam demand. The oxygen analyser worked satisfactorily, but the air correction controller was found to be rather superfluous, and did not operate satisfactorily.

The signal from the drum level transducer had to be decreased relative to the steam flow/water flow difference, but its proportional band was made very small. The water level remained unbelievably constant (Fig. 4).

Several faults occurred on the instrumentation side of the panel in the first few months, most of them being broken leads within the transistorised circuits. They were all located without difficulty.

Future Plans

Now that the H.P. boiler is being satisfactorily controlled, the next step is to control the L.P. boilers. As there are normally five boilers on the L.P. range, the system inertia is very much greater. Two or three boilers will be used as base load boilers, and the control will be done on the three C.E. watertube boilers. These all have variable speed bagasse feeders. No allowance will be made for coal

To ensure that the boilers share the load proportionately, a steam pressure transducer will be connected to the range to feed the master pressure controller. The demand signal from the pressure controller will be split six ways, two for each boiler. One will be the demand signal for the fuel controller, and one for the air controller. Tachometers connected in series on the fuel feeders supply the feedback signal for the fuel controller, and the air flow transducer on the F.D. fan the feedback for the air signal.

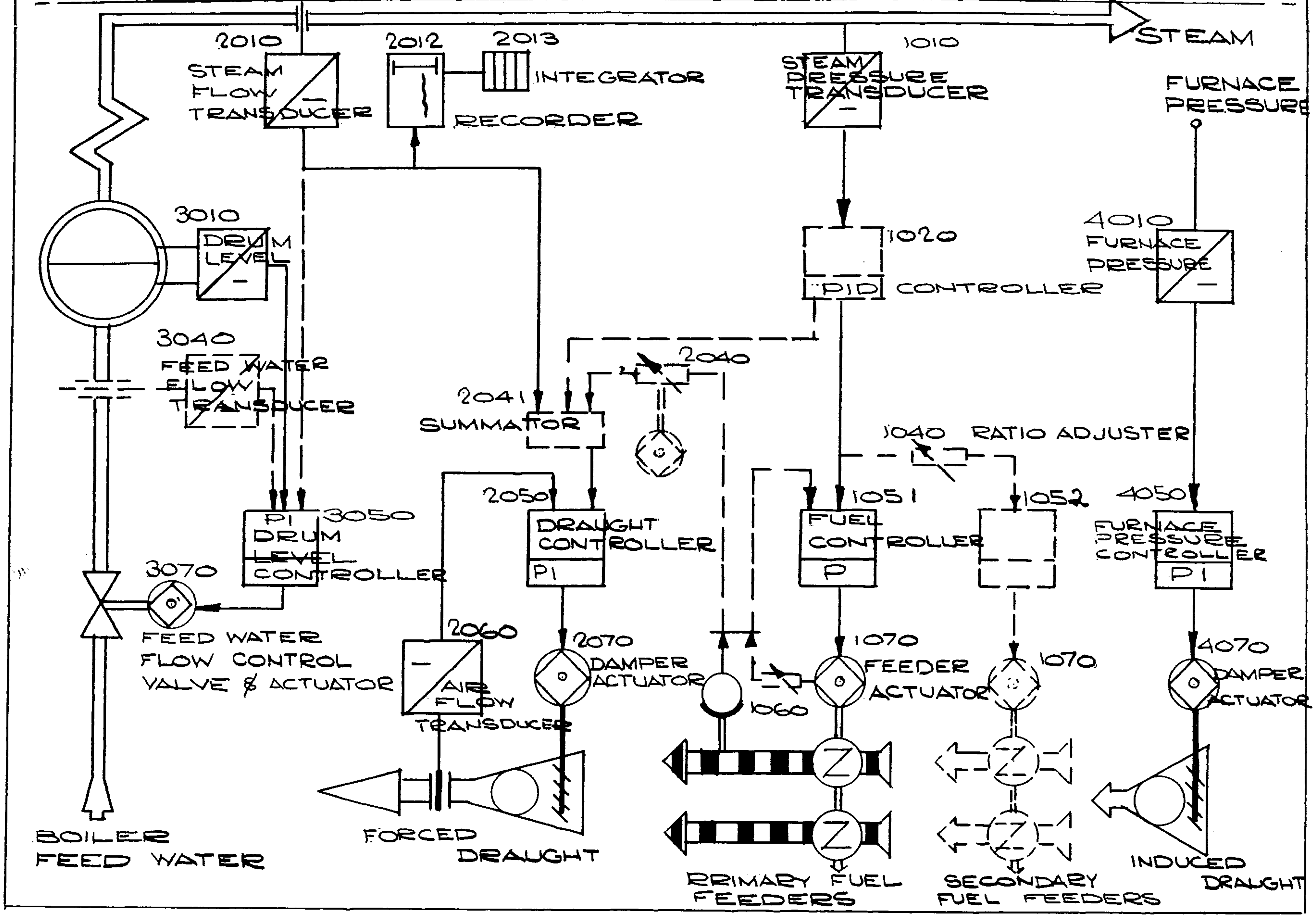
Summary

Transistorised electronic controls have become an extremely useful addition to the instruments available. While they may be classed as an extravagance in the simpler controls, their versatility and ease of maintenance more than justifies the higher initial cost for involved instrument schemes.

Acknowledgement

Thanks are due to A. Keller and Co for assistance in supplying information used in the preparation of this paper.

FIG.1. AUTOMATIC BOILER CONTROL: SCHEMATIC LAYOUT



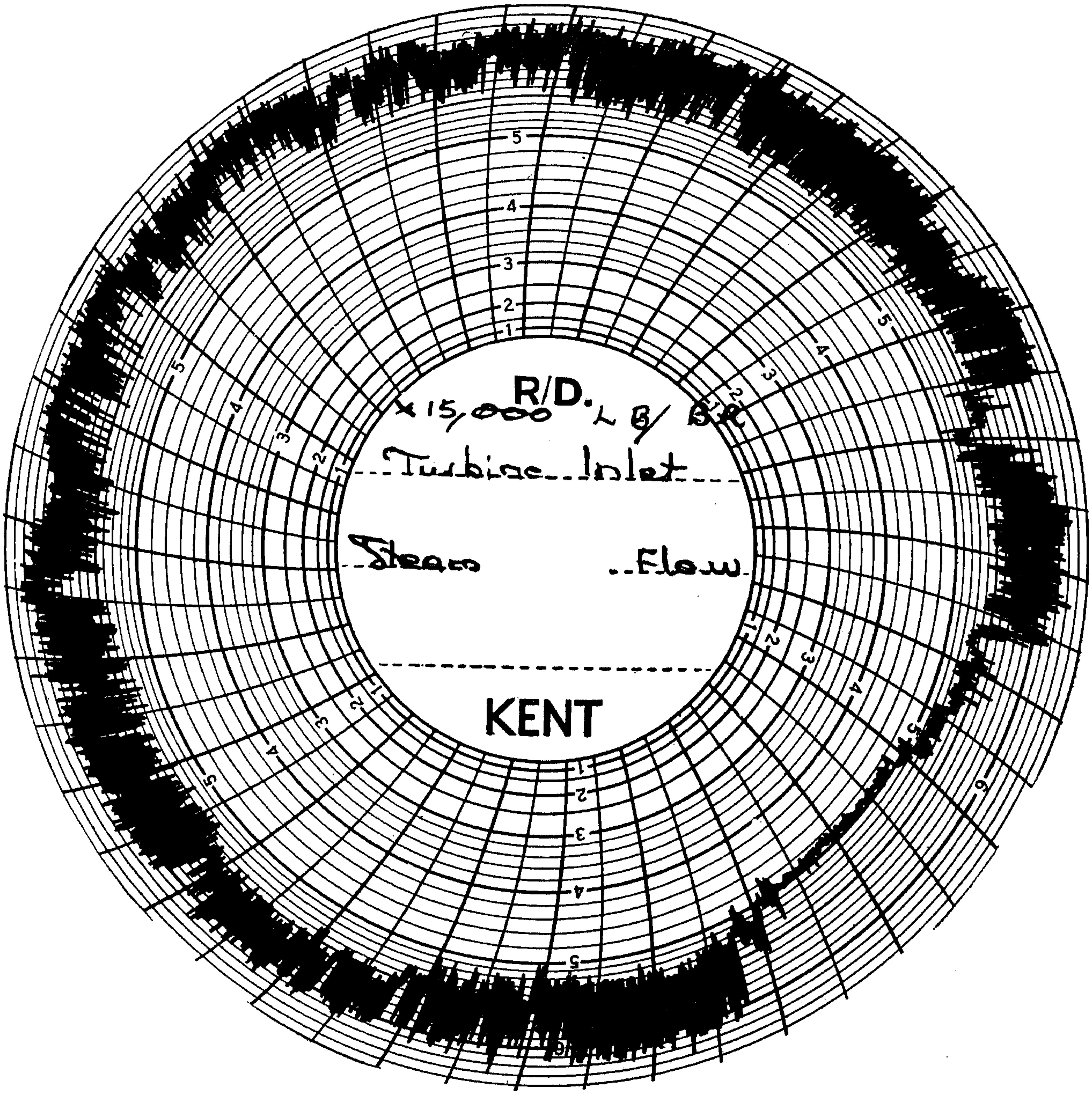


FIGURE 2

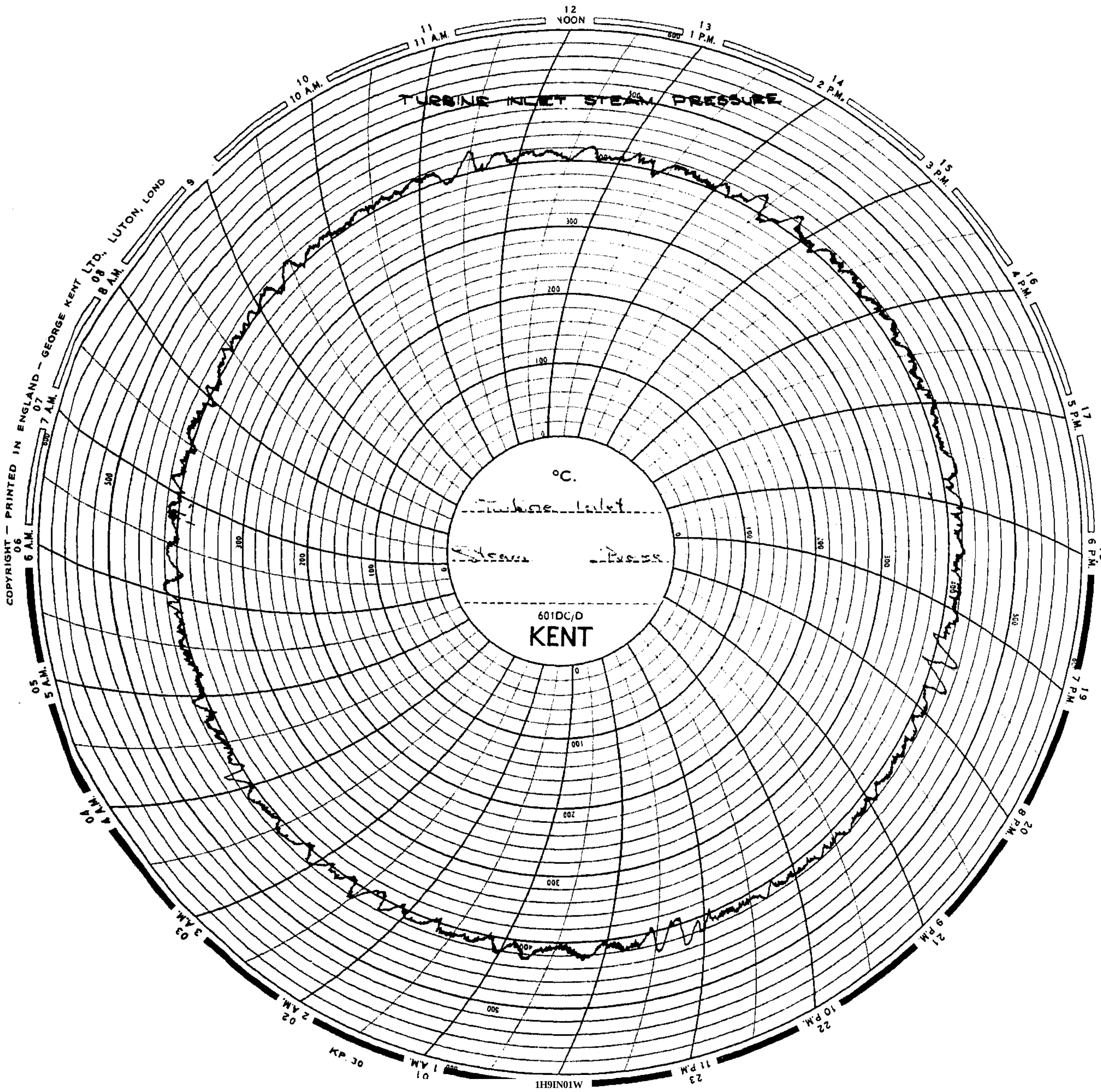

TURBINE INLET STEAM PRESSURE
°C.
601DC/D
KENT
COPYRIGHT — PRINTED IN ENGLAND — GEORGE KENT LTD., LUTON, LOND
12 NOON
13 1 P.M.
14 2 P.M.
15 3 P.M.
16 4 P.M.
17 5 P.M.
18 6 P.M.
19 7 P.M.
20 8 P.M.
21 9 P.M.
22 10 P.M.
23 11 P.M.
01 1 A.M.
02 2 A.M.
03 3 A.M.
04 4 A.M.
05 5 A.M.
06 6 A.M.
07 7 A.M.
08 8 A.M.
10 10 A.M.
11 11 A.M.
KP. 30

FIGURE 3

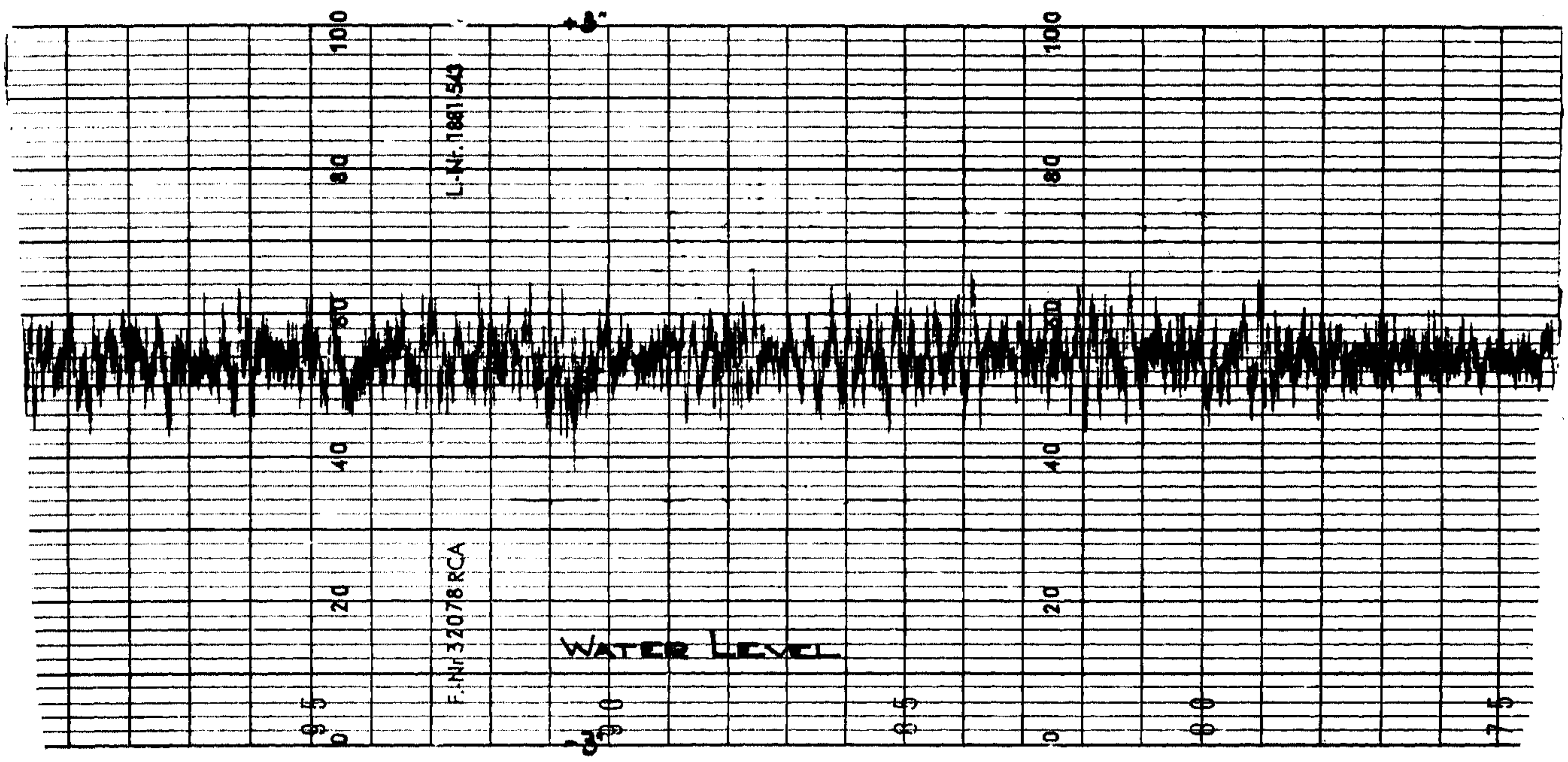


FIGURE 4

Discussion

Mr. Allan: How do you measure air flow on the F.D. fan?

Mr, Hurter: Normally there would be an orifice in the duct. Instead of this we measure the pressure drop across the air heater.

Mr. Main: Can you control the dew point in your flue gas supply?

Mr. Hurter: There is no control in the circuit but it would be possible by by-passing the air heater. However, we do measure the O_2 content, which is more positive than the CO_2 content to keep steady flue gas conditions.

Dr. Douwes Dekker: Umfolozi is trying for maximum efficiency from the boilers, which means they are trying to reduce heat losses as much as possible, one of the most serious being incomplete combustion whereby CO is produced instead of CO_2.

CO must therefore be measured to check this. The heat of combustion difference between CO and CO_2 is large and it is not possible to determine how incomplete the combustion is merely by measuring O_2. I see you have had trouble with CO_2 analysers so may I suggest you let a chemist work on them.

Mr. Holton: I understand the small heating unit in the recorder is affected by hydrogen and deteriorates very quickly. The big power stations now have oxygen meters in conjunction with their automatic controls.

Dr. Douwes Dekker: The trouble occurs if you are burning coal which contains sulphur but bagasse has no sulphur. To measure exactly how the fire is burning CO and CO_2 must be measured.

Mr. Hurter: CO certainly is very important in combustion but with a boiler always burning approximately the same fuel and with approximately the same load, if you compare the CO and O_2 content of the flue gas you will find they are remarkably constant. Once the desired flue gas analysis has been achieved one should not be worried about formation of **CO.**

Mr. **Bruijn:** I think there is some confusion. Dr Douwes Dekker is referring to the Mono Recorder, which is chemical, and Mr. Hurter to an electrical bridge.

Mr. Ashe: When we were using the CO_2 recorder we were using a lot of coal and that caused the deterioration of the analysers.

Mr. Main: The variation between coal and bagasse being burnt might also have affected the recorders.

Mr. Hurter: On one leg of the recorder a sample of flue gas was drawn through and air through the other leg. The CO_2 content was given in terms of thermal conductivity of these two gases. The first complication was pumping the same amount of gas through each leg and then the flue gas inside the measuring cell condensed and formed a corrosive

Mr. Renton: We have a boiler at Darnall similar to Umfolozi's and it has a fairly simple pneumatic control which works quite well. The pneumatic control cost us about R6,000, so what did Mr. Hurler's more elaborate system cost?

Mr. Hurter: It cost about double that figure. We are also going to apply the system to our low pressure station, which will not need such precise control, and it will cost about R11,000 for two boilers.

Mr. Connor: A pneumatic master controller can also be used, and in fact power stations use up to twelve boilers with one controller. They work on the 3 - 15 p.si. signal and are interchangeable.

IMPROVEMENT OF HEAT BALANCE AT UMFOLOZI FACTORY

by G. ASHE
Umfolozi Co-operative Sugar Planters Ltd.

For years Umfolozi has had "Steam trouble", due to the fact that the factory has been operating with an unfavourable heat balance.

One reason for this steam trouble is the fact that the fibre content of the cane is very low, the average for the last ten years being only 13.6%. With this low fibre content it is essential that highly efficient steam raising and steam usage plant be used in the production of sugar. This was not so at Umfolozi. Exhaust steam was blowing off most of the day while, at the same time, coal at a cost of R5.65 a ton was being burned to produce live steam. There were many reasons for these conditions, the major one being that the type of installed plant was uneconomic in the use of steam. No vapour bleeding of any significance was being used, and if it were used, it meant that more exhaust steam was available for blowing off to atmosphere. Umfolozi also has a high "outside" load consisting of power being supplied for the village and surrounding farmer members, plus pumping of water from the Umfolozi River, a distance of some three miles.

The boilers for raising steam were as follows:

Unit No.	Make	Capacity	Maximum Working Pressure	Fuel	Year of Manufacture
1	Combustion Engineering	30,000 lb./hr.	250 psig	Coal & Bagasse	1953
2	Babcock & Wilcock	20,000 lb./hr.	160 psig	Bagasse	1926
3	Babcock & Wilcock	30,000 lb./hr.	160 psig	Bagasse	1934
4	Babcock & Wilcock	35,000 lb./hr.	160 psig	Coal & Bagasse	1949
5	Babcock & Wilcock	35,000 lb./hr.	200 psig	Coal & Bagasse	1942
6	Babcock & Wilcock	30,000 lb./hr.	200 psig	Bagasse	1916
7	Babcock & Wilcock	30,000 lb./hr.	200 psig	Bagasse	1918
8	Combustion Engineering	55,000 lb./hr.	250 psig	Coal & Bagasse	1956
9	Combustion Engineering	55,000 lb./hr.	250 psig	Coal & Bagasse	1958
		320,000			

has a high ash content and a low fusion temperature, the operation of the coal fired boilers present a problem.

Five furnaces were fitted with dump grates for coal burning but due to the quality of the coal, very severe clinkering took place on the grate and if not cleaned in time it is impossible to dump the grates and the clinker had to be broken up and raked out of the furnace doors. This caused untold damage to the grates and fire cleaning took over an hour and longer. During this period of cleaning the furnace doors were open and no fuel was being fired and so the boiler being cleaned was virtually off range for the whole period of fire cleaning. This meant that in order to maintain steam pressure the remaining boilers had to be forced.

It was found that on the boilers burning coal, fires had to be cleaned every two hours, and with dump grates the whole fire was dumped into the ash pit with the result that a large proportion of unburnt coal was lost in this way, thus reducing the boiler efficiency.

To overcome this problem one of the C.E. boilers was converted to a chain grate and this improved the efficiency to a certain extent because all the coal was burnt out before falling into the ash hopper.

The Boiler Efficiency was of the order of 60% and even lower on occasions due to many reasons, such as low feed water temperature due to excessive make up caused by good water being blown out in the form of exhaust steam, the quantity of make up varying between 50,000 and 100,000 lb./hr. This was partly rectified by injecting exhaust steam into the boiler feed tanks and thus raising the temperature to 200°F.

By having to use so many small boilers their combined losses added together were quite considerable.

The biggest contributor to low boiler efficiency was the fact that coal had to be burnt on certain boilers, together with bagasse. This in itself is no problem but, due to the fact that the coal we receive

$C0_3$ and 0_2 analysers were fitted to the boilers to ensure that they were being operated correctly and this helped to improve the efficiency.

The quality of the bagasse at Umfolozi, due to the abnormal amounts of clay and sand which adhere to the cane, seriously interferes with its burning, and at times tends to put the fires out. This also gives a false idea of the fibre content of the bagasse, a fact which cannot be overlooked.

There are lots of other small faults which all tend to lower the overall efficiency but we will pass on to the usage of the steam.

The live steam was used in the power house to drive three turbines and produce 4000 KW, on the

84" x 39" tandem to drive six steam engines of 450 h.p. each and one multi stage turbine of *600* h.p., and on the 66" x 34" tandem to drive three steam engines of 180 h.p. and one of 260 h.p. plus one single stage turbine of 500 h.p. Live steam was also used to drive the turbines of the Induced Draught and Forced Draught Fans. A small amount was also used in the factory.

The exhaust steam produced was in excess of what the factory could use, the excess being blown to atmosphere.

Due to the design of the prime movers mentioned above, the exhaust pressure was limited to ± 6 p.s.i.g. The turbines driving the alternators were using almost 40 lb kWh, and when the back pressure was raised this figure was also raised, and if the live steam pressure dropped the sets became overloaded.

The exhaust steam was used in the Primary Juice Heaters to raise the temperature to 175°F and in the Secondary J Heaters to raise the temperature

Two quadruple evaporators were used and the exhaust was fed to the first vessels of each one which was designed for vapour bleeding. This vapour at about 1/2 p.s.i.g. was used for part of the Primary Juice heating, but this did not help much as there was an excess of exhaust steam most of the time. All the vacuum pans were boiled on exhaust.

Steam Production

From the list of boilers installed it can be seen that with all boilers in operation, 320,000 lbs. of steam should be produced per hour. In theory this is correct, but in practice it is not possible.

Firstly, as Umfolozi crushes seven days a week, the boilers Nos. 2, 3, 6 and 7, have to be cleaned while crushing, which means that for most of the week one of these boilers is off for 24 hours.

Secondly, due to the difficulties experienced with coal firing, boilers Nos. 1, 8 and 9 have to be cleaned every two hours, (see Fig. 1), so that every forty minutes one of these boilers is off range and, depending on the time taken to clean the fires, virtually only two of these boilers are steaming all the time.

All repairs to boilers have to be carried out during crushing operations and consequently yet another boiler may be off range. From this it can be seen that, for most of the time, the rated output of the boilers on line would be approximately 260,000 Ib./hr.

The live steam used in Prime Movers (turbo alternators, mill engines and turbines, fans, etc.) amounted to 259,000 lb./hr., which is 66% steam on cane.

This basically was the position we were in up to the 1965/66 season.

In 1964 an investigation was made into the use of extraneous fuel and the steam available for prime movers and processing.

In assessing the steam which could be raised with the fuel available, reference was made to the 39th Annual summary of Chemical Laboratory Reports by C. Perk for the following information. (1963/64 Season).

Heat in fuel per lb. Brix in Proc.	= 8277 Btu
Brix Processed	= 29.72 tons/hr.
Cane Crush	= 745,577 tons
	or 190.55 tons/hr.

Total heat available in bagasse

$$\frac{29.72 \times 2000 \times 8277 \times 745{,}577}{190.55}$$

$= 1.92 \times 10^{12}$ Btu

Average total heat of steam generated	= 1307 Btu/lb.
Average feed water temperature	= 199°F
.*. heat added to the steam	= 1307 -(199- 32)
	= 1140 Btu/lb.

100% Boiler Efficiency total amount of steam produced during season would have been

$$\frac{1.92 \times 10^{12}}{1140 \times 2000} = 0.8425 \times 10^{6} \text{ tons}$$

giving a ratio of steam on cane of

$$\frac{842{,}500 \times 100}{745{,}577} = 113\%$$

At a normal demand of 65%, steam on cane the boiler efficiency would have been

$$\frac{65}{—} \times 100 = 57\%,$$

which is unusually low.

Process Steam Requirements

The process steam requirements for conditions existing at the time, neglecting the small amount of vapour bleeding, was as follows (1963/64):

Cane Crushed	= 190.55 tons/hr.
Brix % in Clarified Juice	= 13.82%
Brix % Syrup	= 58.74%
A Massecuite per ton Brix	= 35.55 cu. ft.
B ,, ,, ,, ,,	= 9.83 cu. ft.
C ,, ,, ,, ,,	= 8.55 cu. ft.
Exhaustion of B Massecuite	= 57.11%
,, ,, C ,,	= 56.69%
Brix in Mixed Juice % Cane	= 15.60%

Evaporators

As the Brix in the clarified juice was approximately 96%, of the brix in the mixed juice, the weight of the clarified juice was:

$$\frac{190.55 \times 15.60 \times 0.96 \times 100}{100 \times 13.82} = 206.54 \text{ tons/hr.}$$

and the amount of water evaporated was:

$$206.54 \times \frac{(58.74 - 13.82)}{(58.74)} = 157.95 \text{ tons/hr.}$$

The amount of steam required for this evaporation in quadruple effect was:

$$\frac{157.95}{4} \times 2000 = 78975 \text{ lb./hr.}$$

Juice Heaters

The juice heating is done in two stages.

Primary Heating—the cold mixed juice + 20% returned filtrate is heated from 100°F to 175°F.

Secondary Heating—(after liming) from 170°F to 215°F. As the juice leaving the clarifiers is at I95°F this juice will have to be heated in the first vessel of the evaporator to 212°F before evaporation takes place.

Taking the specific heat of mixed juice as 0.9 and the mixed juice weight of 204.68 tons/hr., the amount of steam used for heating is:

$$\frac{0.9 \times 1.2 \times 204.68 \times (175 - 100 + 215 - 170)}{961} \times 2000 + \frac{0.9 \times 206.54 \times 2000\ (212 - 195)}{961}$$

$$= 61772 \text{ lb./hr.}$$

Vacuum Pans

The steam consumed by vacuum pans can vary considerably and depends on the amount of wash water, diluted molasses, etc. Average figures show that for a brix of 65°, the steam required to evaporate the water from the syrup is equal to twice the weight of the water.

Additional steam will be required for remelting purposes and for evaporating water from syrup with a brix of less than 65.

Brix in clarified juice $= 0.1382 \times 206.54$
$= 28.66$ tons/hr.

Water in syrup at 65° Brix $= \frac{35}{65} \times 28.66$
$= 15.43$ tons/hr.

Syrup of 58.74° Brix contains $= \frac{41.26}{58.74} \times 28.66$
$= 20.13$ tons/hr.

A difference of (20.13 − 15.43) 4.7 tons/hr.
Therefore steam consumption including remelt
$= 2000 \times (4.70 + 2 \times 15.43)$
$= 71120$ lb./hr.

Steam will also be required for remelting Quantity of "B" Massecuite
$= 29.72 \times 9.83$
$= 292.1$ cu.ft./hr.
$= 292.1 \times 94.7$ lbs./hr.
$= 27662$ lb./hr.

$$\text{Sugar \% massecuite} = \frac{100 \text{ bm } (J - M)}{\text{bs } (S - M)} \text{ *}$$

where bm = Brix massecuite
bs = Brix Sugar
J = Massecuite purity
M = Molasses purity
S = Sugar purity

$$= \frac{100 \times 95.83\ (73.87 - 54.80)}{99\ (98 - 54.80)}$$

$= 42.7\%$

and the weight of sugar $= 0.427 \times 27662$
$= 11{,}812$ lb./hr

The same calculation for C Sugar will give 11260 lb./hr. after single curing and 0.7 x 11260 = 7888 lb./hr after double curing. Thus the total amount of sugar to be remelted is

11,812 + 7888 = 19,700 lb./hr.

This sugar requires $\frac{19\,700}{\sim}$ = 9850 lb. water/hr.

and the steam consumed is $= 1.5 \times 9850$
$= 14775$ lb./hr.

Other Steam Consumers

Into this category fall sugar drying, steaming out centrifugals, pans, etc., which may be done with exhaust steam.

At 1½% steam on cane this gives

$$\frac{1.5 \times 2000 \times 190.55}{100} = 5717 \text{ lb./hr.}$$

Total steam requirements without vapour bleeding

Plant	*lb./hr.*	*% on Cane*
Evaporators	78,975	20.7
Juice Heaters	61,772	16.2
Pans	71,120	18.7
Remelting	14,775	3.9
Sundry	5,717	1.5
Total	232,359	61.0

Thus without vapour bleeding to produce a syrup of 58.74° Brix and remelt all B- and double-cured C-sugar requires 61 % steam on cane.

Allowing a reduction for vapour bleeding and additions for losses from radiation, leaks, etc., the factory should require about 65% *on* cane for processi ng, which is 254,000 Ib/hr.

As was shown earlier on the steam used by prime movers amounted to 259,200 lb./hr. and therefore an excess of some 5,000 lb./hr. was being blown

*Hulla-Suchomel formula.

It was obvious from the above that in order to reduce extraneous fuel being burnt it would be necessary to reduce the usage of exhaust steam for process, as well as the live steam consumption by the prime movers.

In order to get exhaust steam at 15 psig it would be necessary to install an efficient turbo alternator to produce about 5MW at about 20 lb. of steam per kW. (Existing Turbines use 40 lb./kW). This turbo alternator would require 100,000 lb. of steam per hour at full load and would have to operate at 450 psig 750°F. This meant that a new boiler would also be required.

A comparison is now made to see what advantage would accrue by installing a pre-evaporator operating at 15 psig and producing vapour at 5 psig.

Steam requirements under these new proposed conditions would be:

Juice Heating

Primary Heating (100°F to 175°F) will use vapour from the first vessel of the quad at about | psig and require;

$$\frac{204.68 \times 0.9 \times 1.2\ (175 - 100) \times 2000}{971}$$

34184 lb./hr.

Secondary Heating (170 to 215°) will use exhaust steam at 5 psig

$$\frac{204.68 \times 0.9 \times 1.2\ (215 - 170) \times 2000}{961}$$

20702 lb./hr.

The heating of the clarified juice in the pre-evaporator using steam at 15 psig will be

$$\frac{206.54 \times 0.9 \times 2000\ (227 - 195)}{946}$$

12576 lb./hr.

The amount of water to be evaporated to produce a brix of 65° will be

$$\frac{206.54 \times (65 - 13.82) \times 2000}{65}$$

= 325253 lb./hr.

The steam requirements of the pans will be

2000 x 2 x 15.43

= 61720 lb./hr.

Assuming the turbine will use 4,000 kW at 20 lb./hr then 80,000 lb./hr. of 15 psig steam will be available

.*. Exhaust steam at 15 psig available for pre-evaporator will be

80,000 - 12,576

= 67,424 lb./hr.

Water to be evaporated in normal quadruple effect

= 325253 - 67424

= 257,829 lb./hr.

less the vapour to the primary heaters

= 257,829 - 34184

= 223645 lb./hr.

Steam for first vessel

$$\frac{223645}{4}$$

= 55911 lb./hr.

Total in first vessel

= 55911 + 34184

= 90095 lb./hr. in first vessel

Therefore total steam requirements will be

Pre-evaporator (15 psh)	. . . . . .	12576
Evaporator (5 psig)	. . . .	90095
Juice Heaters	„	20702
Pans	„	61720
remelt A)	• • t • • • • * •	14775
Sundry	„	5717
Total		205585

This represents

$$\frac{205585}{381100} \times 100$$

= 54% on cane

As before, allowing for losses, radiation, etc., we get approximately 58% steam on cane, which is 228,000 lb./hr.

This constitutes a considerable saving over the prevailing condition of 65% steam on cane.

Therefore 26,000 lb./hr. less steam would now have to be produced and as 1 lb. of coal produces 7 lbs. of steam this would mean a saving of 208 tons of coal per week, and although the scheme would not eliminate the use of coal completely, it was decided to go ahead with the additions.

Subsequently it was decided to increase the crushing rate of 250 tons/hr. and the following plant was installed during the 1966 off-season:

One Combustion Engineering boiler having an evaporation rate of 125,000 lb./hr. at 450 psig and at 750°F.

A 6,000 kW A.E.G. turbo alternator of the back pressure type operating at 450 psig and 750°F and back pressure of 15 psig.

A 9,000 sq./ft. (Dorman Long) Semi-Kestner pre-evaporator was first installed to take all the exhaust from the turbine and later it was decided to increase the back pressure from the mill engines to the same as that of the turbine, i.e. 15 psig and install another pre-evaporator of 20,000 sq. ft. (Elgin) thus passing all available exhaust steam at 5 psig through pre-evaporators and producing vapour at 5 psig for Secondary Juice heating and Pan Boiling. Primary heating would be done with vapour II from the first vessel of the Quad Evaporator.

Two Juice Heaters to heat clear juice to 235 °F.

This scheme was not finished at the start of the 1966/67 season but was completed during the season and, therefore, the final figures for this past season do not show the full benefit obtained from the additions but nevertheless show a marked improvement over previous years.

Evaporation rates of over 12 Ib./sq. ft. of heating surface have been obtained on the Semi-Kestners and the operation of this plant is a subject on its own.

The installation of the new boiler made it possible to dispense with some of the older low efficiency boilers and thus raised the boiler efficiency to over 70%.

The steam produced when crushing 250 tons/hr. was 275,000 lb./hr., or 55% on cane, which is better than the 58%, on cane calculated in 1964 and shown above.

The reason for this is the fact that all the exhaust steam produced was passed through the pre-evaporator at 15 psig and produced vapour at 5 psig.

Extraneous Fuel

The following example is worked out to show if and when Umfolozi will have to burn coal to produce 275,000 lbs. of steam per hour:

Moisture % Bagasse = 52.5%
Sucrose % Bagasse = 2.2%
Purity of Last Mill Juice = 70%

$$\text{Brix \% Bgse.} = \frac{2.2}{70} \times 100 = 3.17$$

$$\text{Fibre \% Bagasse} = 100 - 52.5 - 3.17 = 44.33$$

With a fibre % Cane of 12

$$\text{Bagasse \% Cane} = \frac{\text{Fibre \% Cane}}{\text{Fibre \% Bgse.}} \times 100 = \frac{12}{44.33} \times 100 = 27.1\%$$

Tons of bagasse per hour at 12 Fibre % Cane at 250 tons/hr.

$$= \frac{27.1 \times 250}{100} = 67.6 \text{ tons bagasse/hr}$$

For 13 Fibre % Cane = 73.2 tons bagasse/hr
For 14 Fibre % Cane = 78.9 tons bagasse/hr

Amount of bagasse required to produce 275,000 lb./hr. of steam with bagasse having a L C V of 3140 **BTU/lb.** and steam of 1160 BTU/lb.

$$\text{Tons Bagasse} = \frac{275{,}000 \times 1160}{3140 \times 2000} = 51 \text{ tons}$$

With a boiler efficiency of 70% we will require

$$\frac{51}{70} \times 100 = 73 \text{ tons/hr.}$$

Therefore when the Fibre % Cane is only 12 we will be (73 - 67.6) tons = 5.4 tons short and coal will have to be burnt. At 13 Fibre % Cane we will be just square. At 14 Fibre % Cane we will have (78.9 — 73) tons = 5.9 tons surplus.

A surplus bagasse store is essential to be able to store excess bagasse when available and feed this back in times of low fibre.

over 95% is essential if extraneous fuels have to be saved, because mill stoppages are the major cause of surplus fuel and extraneous fuels being used.

The average ratio for the previous six years was 4.14 tons sugar /ton coal. On this basis, during the last season, when we made a record of 169,711 tons of sugar, if no changes had been made we would have used 42,250 tons of coal whereas we used only 12,080 tons giving a ratio of 14.12 ton sugar/ton coal.

Most of the new plant was installed by the end of August and from August to the end of the season the ratio was 23 tons sugar/ton coal.

Conclusion

With the price of coal landed at Umfolozi approximately R6.00 per ton it can be seen from the above that a considerable saving has been effected due to the improved heat balance made possible by the additional plant, despite a one per cent lower fibre in cane than the previous season.

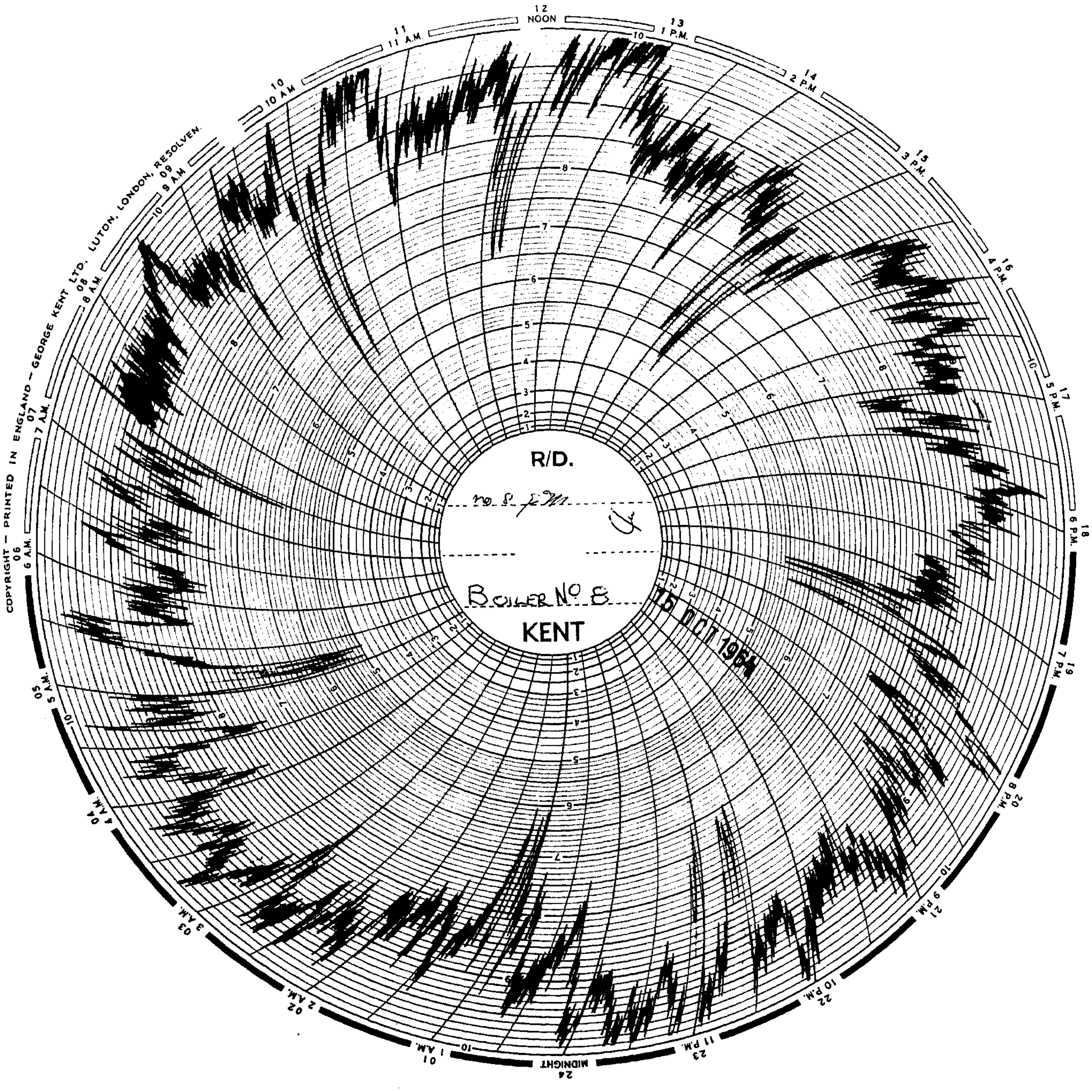

R/D.
KENT
Boiler No 8
15 OCT 1964
12 NOON
13 1 P.M.
14 2 P.M.
15 3 P.M.
16 4 P.M.
17 5 P.M.
18 6 P.M.
19 7 P.M.
20 8 P.M.
21 9 P.M.
22 10 P.M.
23 11 P.M.
24 MIDNIGHT
01 1 A.M.
02 2 A.M.
03 3 A.M.
04 4 A.M.
05 5 A.M.
06 6 A.M.
07 7 A.M.
08 8 A.M.
09 9 A.M.
10 10 A.M.
11 11 A.M.
COPYRIGHT — PRINTED IN ENGLAND — GEORGE KENT LTD. LUTON, LONDON, RESOLVEN.

FIGURE 1

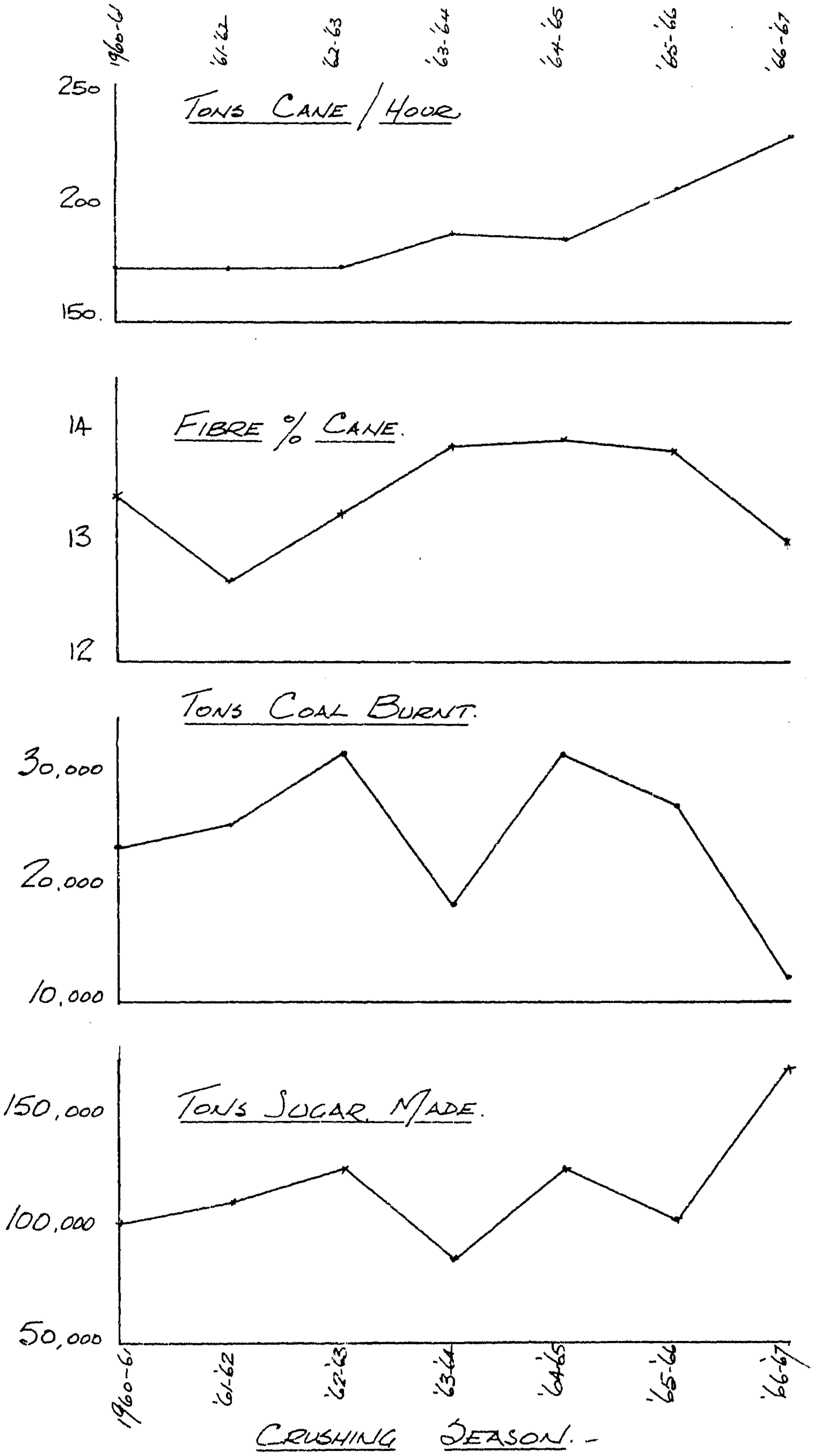

1960-61
'61-'62
'62-'63
'63-'64
'64-'65
'65-'66
'66-'67
Tons Cane / Hour
250
200
150
Fibre % Cane
14
13
12
Tons Coal Burnt
30,000
20,000
10,000
Tons Sugar Made
150,000
100,000
50,000
Crushing Season

FIGURE 2

Discussion

Mr, Steffen: What is the maximum period at Umfolozi between boiler cleaning?

Mr. Ashe: There are three types of boilers. Those with chain grates and dump grates hardly ever require cleaning. The conventional hearth furnace of the Babcock boilers require cleaning about every six days. This is due to ash accumulation behind the bridge wall.

Mr. Calder: Was it an expensive and a long job to convert from a dump grate to continuous stokers?

Mr. Ashe: It can be done during an off-season. The cost of conversion was R70,000 on a boiler producing 55,000 lb/hr. The saving in fuel paid for the conversion in a short time. This cost is almost halved if the grate is installed at the same time as the boiler.

Mr. Renton: I think one reason. for your unfortunate experiences with a dump grate was the fact that you were burning coal in it.

Mr. Main: How do you calculate the steam efficiency of your boiler?

Mr. Ashe: We are given tons of bagasse figures from the laboratory daily and also tons of coal used. The total heat put into the boiler house is compared with total steam produced, every steam pipe being metered. Boiler feed water is also metered and from these figures we work out a daily efficiency figure, using both higher and lower calorific values of the fuel, and then taking an average.

A PLANT NUMBERING SYSTEM IN A SUGAR FACTORY

by A. G. HURTER
Umfolozi Co-operative Sugar Planters Ltd.

The need of a system of plant identification is generally recognised, and most mills have one system or another. The most basic method is to number each piece of equipment in sequence. Carried to its fullest extent, this serial number can indicate several facts, e.g. year of purchase, maker, type of unit, etc. It is essential that each item carries such a number, and a history card should be made out for this unit from its arrival at the Plant. In order to preserve the identity of that particular unit, the number must never be changed or re used.

If these serial numbers are the only ones issued, one arrives at the situation where, for example, No. 1 Mill is No. 1001, its gearbox 007, and its engine 596. Unrelated numbers such as these are very difficult to remember, and the chances of the system being generally applied, except where enforced by management, are very slight. Attempts are made to juggle the serial numbers around to improve the sequence, but this leads to confusion as soon as there are any plant changes.

Serial numbers cannot be dispensed with, but an additional system of *Site Numbering* should be introduced for day to day use.

The Factory is divided into sections, e.g. cane yard section 100, mill section 200 etc., and each *site* in the section is given a number. A site is defined as the position of a unit of plant within the Plant, and is best explained as being the foundation of that unit. The site number is determined by (a) the section it is in and (b) the duty of the driven unit associated with the site.

In order to break down the number into easily recognisable pieces, a letter prefix is used to indicate the type of driven unit, e.g. C for Conveyor, or B for Boiler etc. Each site in a section is given a number, the first of the three digits indicating what section it is in. Numbers start from the section number for each prefix, i.e. C201, C202, . . . and J201, J202 . . . etc. Then a conveyor in the mill section would be numbered C203, indicating that it is a conveyor and it is in section 200. The motor driving this conveyor is C203M, and the gearbox would be C203G. Should this gearbox be replaced, the new unit will be C203G, and the redundant gearbox will retain only its serial number.

Ancillary equipment such as an oil cooler on an engine could be numbered J201E/01. Identical units performing the same function can De suiiixeu, /\, o, v», etc. e.g. J203/A, J203/B etc. Site numbers may be chosen in the sequence of the process flow or from South to North, East to West, and bottom to top. It is preferable to use a definite system such as East to West etc. and in most factories this can be chosen to conform to the process flow.

The following list of prefixes and suffixes are suggested:

i rciixcs. J£\ - Alternators, Generators, Frequency changers.
B – Boilers.
C -- Conveyors, Elevators, Carriers.
F —- Evaporators, Heaters, Pans.
J _- Rotating equipment in general — Pumps, Mills, Knives, Crushers, Compressors.
V ~™ Cranes and Hoists.
T -™ X d. 11 iv J.

Suffixes: M —- Motor.
E ~- Engine.
T—- Turbine.
G – Gearbox.
/01 . . . . Ancillary equipment.

The record card for each unit should be filed under the site number where the unit is installed, and when changes are made, the cards are transferred accordingly. If all works orders and stores requisitions carry the appropriate site number, the records office can enter the details on to the record card for each unit, and a history of cost and performance can easily be built up.

This system is not original, and has been applied with much success in other industries.

Table I

TYPICAL PLANT INVENTORY SHEET

Site Number	Serial No.	Description
J201	2818	No. 1 Mill (Crusher)
J201E	0011	No. 1 Mill Engine
J201G1	0806	No. 1 Mill Primary Reduction Gearbox
J201G2	0530	No. 1 Mill Secondary Reduction Gearbox
J202	2819	No. 2 Mill
C201	2558	Intercarrier Shredder to No. 1 Mill
C201M	5030	Motor for C201
C201G	0591	Gearbox for C201
C202	2559	Intercarrier No. 1 to No. 2 Mill
C202M	5031	Motor for C202
C202G	0598	Gearbox for C202

WEATHER REPORT FOR THE YEAR 1st JUNE, 1966 - 31st MAY, 1967

By K. E. F. ALEXANDER
South African Sugar Association Experiment Station

General Scope of Report

This report records the weather experienced along the South African sugar-belt during the year ending 31st May, 1967, and compares it with data accumulated in the past. As in previous years, the report will deal primarily with the rainfall recorded by 54 measuring stations scattered throughout the cane-growing areas from Port Shepstone in the south to Pongola in the north. Other climatic data quoted, such as evaporation rates and soil and air temperatures, refer specifically to Mount Edgecombe where these readings were taken. These figures will, however, reflect broadly the conditions prevailing in the rest of the area.

Rainfall during the year under review will be discussed in some detail. In addition, the rainfall experienced during the year June 1965 to May, 1966 will be referred to, since the crop being harvested this season will have been influenced by the weather during both years.

Tabulated Data

Table I gives the annual rainfall recorded at each of the 54 measuring stations for the past 5 years.

Table II indicates the mean monthly rainfall during the past year for each of the magisterial districts covered by this survey, as well as for each of the 3 main sub-divisions.

In Table III can be seen the calculated mean rainfall for the past 43 years, as well as the monthly percentage distribution. Also given are the actual mean monthly rainfall figures for all recording stations, plus the corresponding evaporation figures for the Experiment Station. The evaporation figures are recorded from an open water surface in a square "Symons" tank.

Table IV gives the rainfall distribution for 2 years according to growing periods for the magisterial districts and for the main sub-divisions.

Table V gives the monthly rainfall for the 54 centres for the past 4 years, and also the rainfall deficiency, if any, per month.

Table VI is a list of the maximum, minimum, and mean screen temperatures as recorded at the Experiment Station during the past year, plus the comparative mean figures over the past 39 years.

Table VII lists the mean monthly earth temperatures at Mount Edgecombe over the past year, as well as the figures for the past 32 years for comparison.

Comments on Rainfall

sugar-belt had a mean rainfall of 38.65 inches for the year ending 31st May, 1967. This is only fractionally higher than the 43-year average of 38.25 inches. More than 60% of the total fell during the first four months of 1967, with the result that the current cane crop is in excellent condition.

With the exception of August, every month from June to December, 1966 was drier than the past average. This factor, coupled with above average evaporation figures, resulted in retarded cane growth up to that stage. Good rains and ample heat produced rapid growth from January to April, 1967. Although May has been very dry, satisfactory growth has taken place during this, the last month of the period under review.

Monthly Details

The following is a more detailed month by month report for the past year. The good rains experienced during May, 1966, did not follow on into June, which was a dry month. Cane fields became even drier in July, when only 0.39 inches fell, compared with the 1.17 inches average during the past 43 years. Only 4% of the recording centres reported more than one inch of rain for the month, whilst 8% reported no rain at all. In the Midlands and at Melmoth frost put further stress on crops already affected by drought. Although August brought slightly above average rains, the sugar-belt was still dry. The lack of rain was carried on through September, October, November and December. Above average evaporation rates during this period increased the adverse effect of the low rainfall. Evapotranspiration losses dissipated what rain fell, and soil moisture reserves were not being replenished. Taken over the calendar year of 1966, rainfall for the area was 29.99 inches. This is unusually low, and compares with the 38.25 inches of the mean annual figure.

The rainfall picture, however, changed dramatically during 1967. Excellent rains, averaging 6.16 during January. All centres with the exception of the Hluhluwe/Mtubatuba area reported ideal growing conditions. Further good rains fell in February. Hot and humid conditions kept the cane growing rapidly. The March rainfall of 7.06 inches left no grounds for complaint, with the exception of the Hluhluwe area where only 1.76 inches was recorded for the month. The adjacent Mtubatuba area had received less than 10 inches of rain during the first three months of 1967. Very satisfactory rains fell again in April, and optimum cane growth continued. It is not often that the sugar industry has enjoyed such a long period of uninterrupted hot humid weather virtually ideal for cane growth. By the end of the month, cane yield estimates made at the end of 1966 could be revised sharply upward. The response of the crop to good growing conditions, and its subsequent recovery are quite remarkable.

The year under review ended on a very dry note. The month of May had a mean rainfall of only 0.47 inches. Some centres on the South Coast recorded no rain at all, whilst the mean figure for the whole South Coast was only 0.12 inches. Nevertheless, the cane in most areas is reported to be in good condition. This is, of course, due mainly to the really pleasing rains which fell during the previous four months.

Two-Year Summary

The following paragraph is a brief review of weather conditions experienced over the past two years. In June, 1965, frost damaged cane in many areas. The June rainfall was very satisfactory, but by the end of August cane fields were dry. Copious early spring rains fell during the last few days of August. Reasonable rains continued until November, but low soil and air temperatures restricted growth. December was relatively cool and dry. Excellent rains and warm weather got the cane growing really well for the first seven weeks of 1966. However, the lowest rainfall ever recorded in the cane belt for the month of March heralded a sharp and most unwelcome autumn drought. It was not until May that adequate rains supplied enough moisture to green up the crop again. From June to December, 1966 cane growth was hampered by lack of rain. Odd showers which fell during this period were soon dissipated. The first four months of 1967 saw a complete reversal of the situation when ample rains fell. Accelerated growth during this period enhanced prospects of much higher yields. Although there was very little rain in May, satisfactory cane growth was nevertheless maintained during the month.

Temperatures

The mean screen temperature for the year under review was 68.2°F at the Experiment Station. This was half a degree cooler than the past 39 year mean. With the exception of June and December, all months from June, 1966 to May, 1967, were below the past average in regard to air temperature. Soil temperatures were also below average, particularly at the depth of four feet, where it was consistently cooler than the average for the past 32 years. The minimum temperature at grass level did not once fall below freezing point. On two nights during July, 1966, however, the temperature fell to just over one degree above freezing level.

Evaporation

Evaporation from a free water surface was 52.82 inches for the year. This was 4.97 inches more than the average for the past 32 years. Rainfall deficiency, as expressed in Table V, was reasonable during the past year. The earlier part of the optimum growth period had a somewhat high rainfall deficiency, but the first four months of 1967 had virtually no deficiency at all, and excellent growth resulted.

TABLE I

Rainfall **for** *54* Centres

	Rainfall for year 1st June 1962 to 31st May 1963	*Rainfall for year 1st June 1963 to 31st May 1964*	*Rainfall for year 1st June 1964 to 31st May 1965*	*Rainfall for year 1st June 1965 to 31st May 1966*	*Rainjall for year 1st June 1966 to 31st May 1967*
Port Shepstone:					
Mahlomnyama	46.13	43.89	33.32	36.03	35.41
Umzinto:					
Hibberdene	42.95	37.43	51.11	42.19	35.57
Mtwalume	36.52	37.17	45.91	39.32	29.29
Sezela Mill	39.66	42.62	52.44	48.75	35 60
Esperanza Mill	46.48	42.10	41.02	45.67	33.68
Renishaw Mill	42.50	40.88	40.87	45.20	33.36
Dumisa	39.85	35.97	42.20	48.95	35.91
Durban, Camperdown, etc.					
Illovo Mill	46.80	40.15	43.06	42.86	34.80
Umbumbulu	36.93	32.21	29.51	44.40	36.67
Thornville	27.23	35.41	24.53	33.75	37.98
Inanda:					
Mount Edgecombe—					
Effingham	34.17	37.92	26.78	35.02	31.66
Experiment Stn.	36.46	35.00	23.50	35.20	30.88
Burnside	38.52	33.49	26.12	36.08	31.81
La Mercy	37.51	34.85	29.08	35.20	35.75
Canelands	47.89	42.26	24.73	48.14	34.33
Tongaat—					
Frosterly	44.17	36.99	26.28	32.29	35.93
Inyaninga	41.06	36.62	22.50	32.88	34.71
Inanda	42.90	43.47	32.34	41.06	44.25
Tongaat—					
Mwawine	36.10	37.50	30.47	38.30	38.61
Lower Tugela:					
Maidstone Mill	38.04	33.38	25.74	31.74	34.42
Sinembe	40.18	32.21	26.90	37.77	40.26
Upper Tongaat	42.33	38.85	31.02	37.92	42.02
Frasers Estate	39.11	33.78	27.70	37.62	42.43
Chaka's Kraal Experimental Farm	40.68	34.88	26.82	38.76	43.74
Chaka's Kraal	43.14	35.15	26.69	41.14	43.72
Groutville	34.10	31.55	23.46	35 22	40.17
Kearsney	41.42	39.63	28.77	44.85	48.13
Doornkop Mill	33.71	33.25	22.71	33.21	45.47
Doornkop Sprinz	43.83	38.78	25.54	46.08	52.29
Gledhow Mill	38.41	35.14	24.99	37.50	37.38
Darnall Mill	46.49	40.97	26.33	43.30	43.16
Tugela Mouth	43.22	41.37	37.16	50.21	45.96
Mtunzini:					
Mandini	40.24	42.98	24.87	45.32	44.22
Amatikulu Mill	35.61	43.67	24.50	37.29	38.50
Inyoni	37.39	41.54	24.52	43.70	43.38
Mtunzini	43.26	54.33	37.16	48.75	63.73
Blackburn	37.72	46.30	27.34	38.66	44.78
Eshowe:					
Entumeni Mill	43.51	38.39	25.07	37.21	43.86
Eshowe	51.32	54.56	29.10	45.72	46.56
Nkwaleni	30.26	35.04	15.69	26.48	32.68
Lower Umfolozi:					
Felixton Mill	44.52	57.21	41.19	57.41	57.60
Empangeni West	32.48	52.45	24.66	31.92	37.94
Empangeni Mill	38.60	53.33	30 90	42.45	44.26
Kulu Halt	38.21	54.67	26.55	38 97	41.61
Ukulu Properties	31.32	47.87	27.55	33.19	37.20
Mposa	33.05	53.71	25 94	37.95	32.97
Kwambonambi	36.88	56.60	31 24	47.68	38.17
Eteza	33.76	47.70	27.69	43.88	33.61
Hlabisa:					
Mtubatuba Mill	30.86	40.89	22.06	29.47	27.43
U.L.O.A.	39 37	54.76	31.09	43 50	31.81
Nyalazi River	30.62	41.18	21.04	36.36	34 97
Hluhluwe	24.47	43.85	14.49	28.03	25.23
Ubombo:					
Mkuzi	22.27	32.05	17.48	19.54	32.39
Piet Retief:					
Pongola	24.92	21.59	16.95	25.21	28.71
Mean	38.32	40.92	29.02	39.17	38.65

TABLE II

Rainfall in Inches by Districts for Months of June, 1966, to May, 1967, inclusive

District	No. of Centres	1966 June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1967 Jan.	Feb.	Mar.	Apr.	May	Total June 1966 to May 1967
Port Shepstone	1	3.02	0.00	1.25	1.70	1.32	3.43	2.99	6.88	3.80	4.17	6.85	0.00	35.41
Umzinto	6	2.06	0.24	1.25	1.50	1.45	3.89	2.91	5.74	4.13	5.93	4.76	0.05	33.91
Durban Pinetown etc.	3	1.36	0.22	1.24	1.62	1.62	4.53	3.05	5.62	5.61	7.66	3.66	0.29	36.48
Mean: S. Coast	**10**	**1.94**	**0.21**	**1.25**	**1.56**	**1.49**	**4.03**	**2.96**	**5.82**	**4.54**	**6.27**	**4.64**	**0.12**	**34.83**
Inanda	9	0.88	0.34	1.58	1.45	2.29	4.62	3.84	6.26	3.25	6.75	3.83	0.23	35.32
Lower Tugela	13	0.96	0.52	1.62	2.22	2.46	4.14	4.59	8.28	5.46	8.60	3.83	0.33	43.01
Mean: N. Coast	**22**	**0.93**	**0.45**	**1.60**	**1.90**	**2.39**	**4.33**	**4.29**	**7.45**	**4.56**	**7.84**	**3.83**	**0.29**	**39.86**
Mean: S. of Tugela	**32**	**1.25**	**0.37**	**1.49**	**1.80**	**2.11**	**4.24**	**3.87**	**6.94**	**4.55**	**7.35**	**4.08**	**0.24**	**38.29**
Mtunzini	5	1.86	0.65	2.39	2.53	2.63	3.15	3.97	6.93	4.55	9.87	7.81	0.58	46.92
Eshowe	3	1.03	0.18	1.19	2.07	2.22	4.33	4.16	7.84	5.37	7.58	4.78	0.27	41.03
Lower Umfolozi	8	1.13	0.52	2.80	2.14	2.05	2.29	2.51	4.07	4.84	6.79	10.31	0.97	40.42
Hlabisa	4	0.60	0.25	1.42	1.41	1.52	1.98	2.72	2.58	7.51	2.58	6.30	0.99	29.86
Ubombo	1	0.10	0.00	0.56	0.44	0.50	2.22	4.04	4.93	10.24	4.86	2.35	2.15	32.39
Piet Retief	1	0.62	0.00	0.40	0.41	1.37	2.36	6.56	4.66	4.19	4.42	3.22	0.50	28.71
Mean: Zululand and Piet Retief	**22**	**1.11**	**0.40**	**2.02**	**1.93**	**2.01**	**2.71**	**3.36**	**5.03**	**5.55**	**6.64**	**7.58**	**0.82**	**39.16**
General Mean	**54**	**1.19**	**0.39**	**1.71**	**1.85**	**2.07**	**3.62**	**3.66**	**6.16**	**4.96**	**7.06**	**5.51**	**0.47**	**38.65**

TABLE III

Rainfall and Evaporation Data

	Mean Percentage Rainfall Distribution 1924-1967	Computed Mean Rainfall for 54 Centres 1924-1967	Actual Rainfall for 54 Centres June 1966 to May 1967	Evaporation at Experiment Station: Mean 1936-67	Evaporation at Experiment Station: June 1966 to May 1967
June	4.16	1.59	1.19	2.38	2.17
July	3.06	1.17	0.39	2.54	2.77
August	3.71	1.42	1.71	3.00	3.38
September	6.51	2.49	1.85	3.69	4.29
October	9.41	3.60	2.07	4.24	4.87
November	11.24	4.30	3.62	4.80	5.66
December	12.10	4.63	3.66	5.52	6.88
January	11.82	4.52	6.16	5.73	6.39
February	12.00	4.59	4.96	4.80	4.80
March	13.26	5.07	7.06	4.67	5.22
April	7.66	2.93	5.51	3.52	3.58
May	5.07	1.94	0.47	2.86	2.81
	100.00	**38.25**	**38.65**	**47.85**	**52.82**

TABLE IV

Rainfall in Inches by Districts for the Two-Year Period June, 1965, to May, 1967, inclusive

District	No. of Centres	1965 Winter Growth June to August	1965 Early Growth Sept. and October	1965-1966 Optimum Growth Nov. to March	1966 Late Growth April and May	1966 Winter Growth June to August	1966 Early Growth Sept and October	1966-1967 Optimum Growth Nov. to March	1967 Late Growth April and May	Total for two years June 1965 to May 1967
Port Shepstone	1	7.50	5.54	15.76	7.23	4.27	3.02	21.27	6.85	71.44
Umzinto	6	10.59	8.84	18.83	6.75	3.55	2.95	22.60	4.81	78.92
Durban, Pinetown, etc.	3	9.59	6.34	19.29	5.13	2.82	3.24	26.47	3.95	76.83
Mean: South Coast	**10**	**9.98**	**7.76**	**18.66**	**6.31**	**3.40**	**3.05**	**23.62**	**4.76**	**77.54**
Inanda	9	9.65	6.21	15.69	5.59	2.80	3.74	24.72	4.06	72.46
Lower Tugela	13	9.53	6.17	18.59	5.35	3.10	4.68	31.07	4.16	82.65
Mean: North Coast	**22**	**9.59**	**6.18**	**17.39**	**5.45**	**2.98**	**4.29**	**28.47**	**4.12**	**78.47**
Mean: South of Tugela	**32**	**9.71**	**6.68**	**17.78**	**5.72**	**3.11**	**3.91**	**26.95**	**4.32**	**78.18**
Mtunzini	5	9.39	9.40	18.26	5.70	4.90	5.16	28.47	8.39	89.66
Eshowe	3	6.73	6.55	18.96	4.23	2.40	4.29	29.28	5.05	77.50
Lower Umfolozi	8	8.69	11.12	18.27	3.60	4.45	4.19	20.50	11.28	82.10
Hlabisa	4	7.63	6.55	17.92	2.24	2.27	2.93	17.37	7.29	64.20
Ubombo	1	3.18	2.66	11.74	1.96	0.66	0.90	26.29	4.50	51.93
Piet Retief	1	2.01	3.18	17.29	2.73	1.02	1.78	22.19	3.72	53.92
Mean: Zululand and Piet Retief	**22**	**7.83**	**8.53**	**17.96**	**3.80**	**3.53**	**3.94**	**23.29**	**8.40**	**77.28**
Mean: General	**54**	**8.95**	**7.42**	**17.86**	**4.94**	**3.29**	**3.92**	**25.46**	**5.98**	**77.82**
Computed Mean for 43 years	**54**	**4.18**	**6.09**	**23.11**	**4.87**	**4.18**	**6.09**	**23.11**	**4.87**	**76.50**

TABLE V

Rainfall and Evaporation in Inches for the Past Four Years

	1963/64			1964/65			1965/66			1966/67		
	Evaporation	Rainfall	Rainfall Deficiency	Evaporation	Rainfall	Rainfall Deficiency	Evaporation	Rainfall	Rainfall Deficiency	Evaporation	Rainfall	Rainfall Deficiency
June	2.41	4.47	0.00	2.66	1.81	0.85	2.70	4.29	0.00	2.17	1.19	0.98
July	2.36	6.62	0.00	2.56	1.30	1.26	2.18	1.38	0.80	2.77	0.39	2.38
August	3.47	0.44	3.03	3.50	0 69	2.81	3.05	3.28	0.00	3.38	1.71	1.67
September	3.68	0.87	2.81	3.58	1.73	1.85	3.59	2.78	0.81	4.29	1.85	2.44
October	4.59	3.57	1.02	3.61	6.71	0.00	4.84	4.64	0.20	4.87	2.07	2.80
November	5.93	3.50	2.43	5.54	3.09	2.45	4.40	4.04	0.36	5.66	3.62	2.04
December	6.41	3.98	2.43	6.55	3.76	2.79	6.31	3.25	3.06	6.88	3.66	3.22
January	6.53	8.52	0.00	6.10	2.65	3.48	6.11	6.65	0.00	6.39	6.16	0.23
February	5.96	2.67	3.29	5.81	2.64	3.17	5.02	3.24	1.78	4.80	4.96	0.00
March	5.28	2.11	3.17	6.34	1.22	5.12	6.18	0.68	5.50	5.22	7.06	0.00
April	4.91	3.71	1.20	4.22	1.32	2.90	3.95	2.13	1.82	3.58	5.51	0.00
May	2.63	0.46	2.17	3.00	2.10	0.90	3.15	2.81	0.34	2.81	0.47	2.34
Total	**54.16**	**40.92**	**21.55**	**53.47**	**29.02**	**27.55**	**51.48**	**39.17**	**14.67**	**52.82**	**38.65**	**18.10**

[illegible]

The following are the Screen Temperatures by Months In Degrees Fahrenheit **at the Experiment** Station for the Year June, 1966, to May, 1967, compared with the Means for the **Period 1928 to 1967**

	THIS PERIOD					AVERAGE 1928 to 1967 INCLUSIVE			
	Maximum	Minimum	Mean	Plus or minus average	Daily range	Maximum	Minimum	Mean	Daily range
June	73.4	54.0	63.7	+ 0.9	19.4	72.8	52.7	62.8	20.1
July	72.1	50.4	61.2	-0.9	21.7	72.3	51.9	62.1	20.4
August	71.8	54.1	62.9	-0.7	17.7	73.2	54.0	63.6	19.2
September	72.9	56.3	64.6	-1.3	16.6	74.3	57.5	65.9	16.8
October	74.5	59.5	67.0	-1.3	15.0	75.6	60.9	68.3	14.7
November	76.3	63.3	69.8	-0.7	13.0	77.5	63.5	70.5	14.0
December	80.1	66.7	73.4	+0.6	13.4	79.8	65.8	72.8	14.0
January	80.1	67.5	73.8	-0.4	12.6	80.9	67.4	74.2	13.5
February	79.9	68.0	74.0	-0.6	11.9	81.4	67.7	74.6	13.7
March	78.6	65.1	71.8	-1.5	[illegible]	80.4	66.2	73.3	14.2
April	76.5	63.0	69.6	-0.2	13.5	78.0	62.2	70.1	15.8
May	74.3	57.6	66.0	-0.3	16.7	75.6	57.0	66.3	18.6
[illegible]	75.9	60.5	68.2	-0.5	15.4	76.8	60.6	68.7	16.2

[illegible]

The following Table gives the Mean Monthly Earth Temperatures

Month	Experiment Station 1935-1967			Experiment Station June 1966 to May 1967		
	1 foot	2 feet	4 feet	1 foot	2 feet	4 feet
June	63.8	66.3	69.3	63.5	65.3	68.2
July	62.5	64.3	66.8	61.5	63.3	66.2
August	64.5	65.5	66.6	63.9	64.0	65.1
September	67.8	68.1	68.0	66.9	66.6	66.2
October	70.7	70.7	70.0	69.3	68.5	67.8
November	73.5	73.3	72.4	73.0	72.0	69.8
December	76.5	76.1	74.3	77.2	75.4	72.3
January	78.7	78.7	76.4	78.3	77.0	74.1
February	79.5	79.3	77.7	78.4	77.4	[illegible]
March	78.2	78.7	77.9	77.4	77.2	75.6
April	74.7	76.0	76.4	73.6	74.8	74.5
May	69.1	71.2	[illegible]	69.3	70.7	72.5
Mean	71.6	72.3	72.4	71.0	71.0	70.6

Hours of Sunshine

During the year, Mount Edgecombe had had 2409.6 hours of sunshine, representing one per cent more than the 40-year average. November, January, February and April were cloudier than in the past, while all other months were more sunny than the average of previous figures.

Wind

The anemometer in themeteorology site at the Experiment Station recorded 39,330 miles of air as having passed the site during the year. This represents an average wind speed of 4.5 m.p.h. over the entire period. Based on figures for only three years, the wind pattern ranges from 3.2 m.p.h. for the month of July up to 5.9 m.p.h. for November and December.

Conclusions

Fluctuating weather conditions have prevailed in the sugar-growing areas of South Africa during the past two years. The winter of 1965 brought frost damage to some cane crops. Spring and early summer were moist but cool. The first seven weeks of 1966 provided ideal cane growing weather. This deteriorated into a short severe autumn drought which was relieved only in May. From June to December, crop growth was limited by a shortage of moisture. The first four months of 1967 had ample rain and heat for most satisfactory cane growth. Although May was very dry, the crop continued growing well, and it can be said that present prospects are very bright.

SUMMARY OF AGRICULTURAL DATA: SUGARCANE CROP 1965/66

by J. L. DU TOIT and M. G. MURDOCH
South African Sugar Association Experiment Station

Introduction

The Summary of Agricultural Data for 1965/66 is, like that of last year, based on a survey by the Sugar Industry Central Board. In fact the questionnaire used and the method of collecting the data were practically identical for the two years. The method of processing the data will however differ somewhat from that used last year and experience has helped to assess the reliability of some of the replies received. As a result of this experience future questionnaires are likely to be modified.

Total areas and **yields**

year's summary quoted the following estimates:

Area under cane 1st May, 1965	*Acres to he cut 65/66*
833,328	376,075

At the time of the survey the extent and effect of the drought could not have been foreseeen and no estimate of expected yield was quoted.

Total production is determined by both yield per acre and area harvested and a drought such as was experienced will restrict both.

The Sugar Industry Central Board Survey of Cane Production 1964/65 to 1968/69 CB 46/20, i.e. the survey on which the present report is based shows:

Area under cane 1st May, 1965	*Acres harvested 65/66*	*Total tons*	*Tons cane per acre harvested*
807,949	293,465	9,267,188	31.58

Whereas it was estimated in 1965 that 45.1 per cent of the area under cane was to be harvested that season, this year's survey shows that only 36.3 per cent of the area was actually harvested. This exceptionally low figure is the result of two factors working in the same direction. The one, expansion, which inflates the area under cane, has already been referred to last year and the other is of course the drought, which because of poor growth, prevented many fields from being harvested last year.

Expansion of the acreage under cane will have the effect of reducing the proportion of acres harvested in an industry where annual harvesting is the exception rather than the rule.

It is suggested that to obviate this, the figure for the proportion of acres harvested should be the acreage harvested expressed as a percentage of the total cane acreage for the previous year.

Further, as a measure of productivity per acre, it is suggested that the total tonnage produced in a season be related to the total acreage under cane, thus combining the proportion of the area harvested and the yield per acre harvested into a single figure. To allow for the effect of the expansion of acreage, tons cane per acre under cane at the beginning of the previous season is used.

In Table I areas, yields and per cent harvested are expressed in the conventional manner together with the two other figures suggested above. Discrepancies between the figures now used and those reported last year are due to actual results replacing estimates for 1965 and further to later and more up-to-date estimates now being given. The results before 1966 should reveal the actual situation while estimates are used for the later years.

The per cent area harvested given in column C seems more realistic than that depicted in column A, while yield in T.C.A. in column D gives a clear picture of the seventy of drought effects on the 1965/66 crop it also indicates the anticipated increase in real productivity.

TABLE I

Total area under cane—1st May		Area harvested		A % Area harvested	B Yield T.C.A. area harvested	C* % Area harvested	D* Yield T.C.A. area under cane
1963	616,900	63/64	299,084	48.5	36.6	—	—
1964	718,043	64/65	326,387	45.5	35.9	52.9	19.0
1965	807,949	65/66	293,465	36.3	31.6	40.9	12.9
†1966	835,938	66/67	466,728	55.8	35.3	57.8	20.4
†1967	840,094	67/68	475,231	56.6	36.9	56.9	21.0
†1968	840,369	68/69	484,729	57.7	36.8	57.7	21.2

*Area under cane for previous year †Estimates

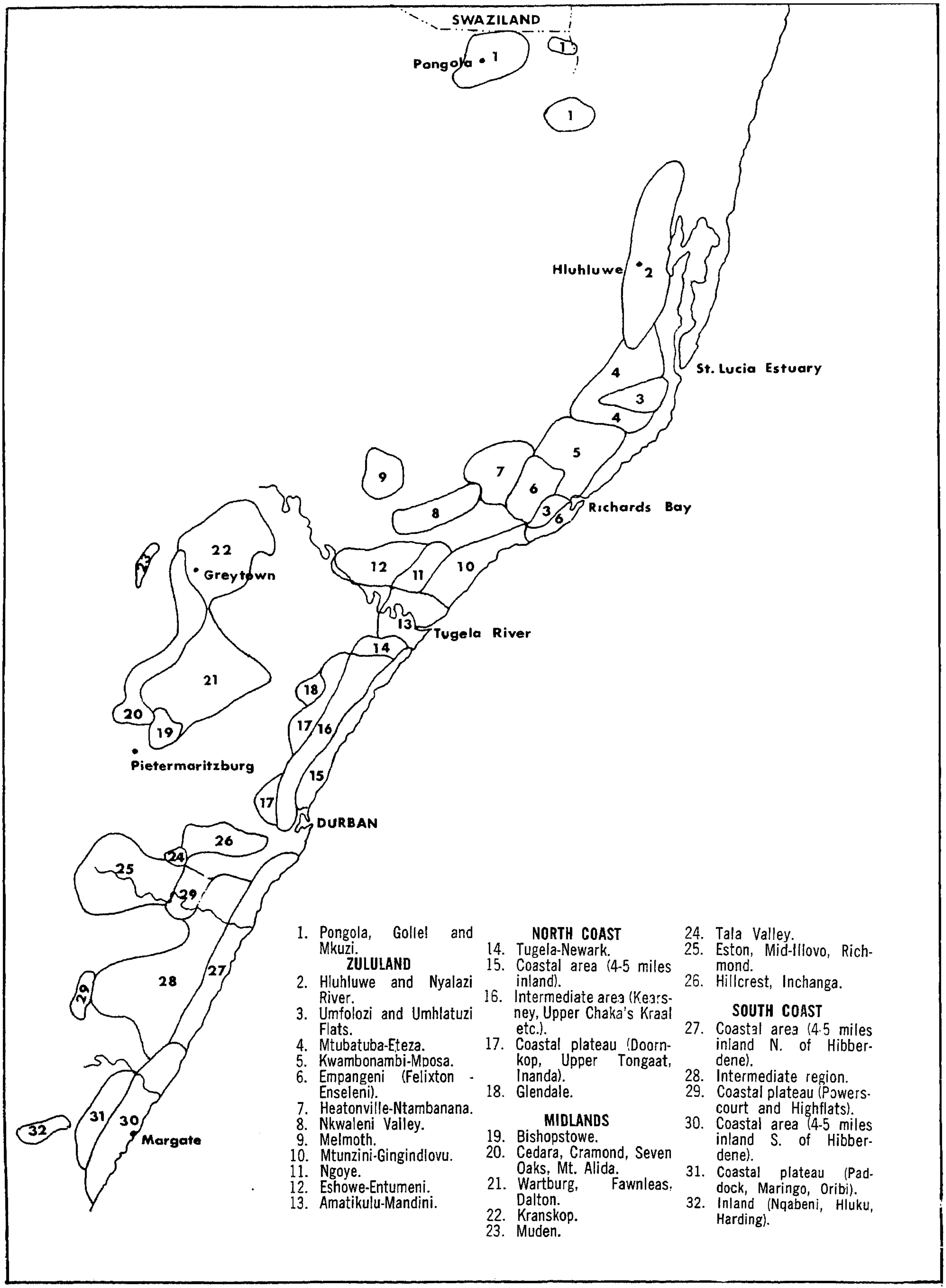


FIGURE 1: Regional Cane Areas

Rainfall and yield

In Table II the yield in tons cane per acre of cane harvested as well as the yield in T.C.A. with reference to area under cane the year before harvest are given and these yields are compared with the annual rainfall as compiled by the Experiment Station from 54 centres scattered throughout the sugar belt.

TABLE II

Yield in tons cane per acre			Rainfall for the year ending 31st May	
Season	On area harvested	On area under cane	Rainfall	Year
1959/60	32.4	15.4	33.34	1959
1960/61	33.8	14.1	35.66	1960
1961/62	39.4	14.9	46.43	1961
1962/63	37.8	16.9	34.10	1962
1963/64	36.6	18.0	38.32	1963
1964/65	35.9	19.0	40.92	1964
1965/66*	31.6	12.9	29.02	1965
1966/67†	35.2	20.4	39.17	1966

*Yield figures subject to future slight adjustments.
†Yield figures based on estimates.

*Yield figures subject to future slight adjustments.
fYield figures based on estimates.

The column in Table II where yield per total area under cane is given, indicates very clearly the severity of the 1964/65 drought but it also appears to show a phenomenal increase in sugarcane productivity since 1960. It should be pointed out that the very low yields during 1960 and 1961 expressed as T.C.A. based on total areas under cane, were largely the result of restriction. The cane was there but it was not cut. It was not cut until 1962/63 and it then inflated the T.C.A.

The two important features of production viz. increased productivity and the effects of the 1964/65 drought are much better revealed where we are dealing with yields based on total areas than where these yields are based on areas harvested. The reasons are of course that where productivity or rate of growth increases, the tendency is to cut cane at a younger age and the yield per acre harvested does not show the corresponding increase and furthermore during a drought only higher yielding fields will be cut and this on the basis of yield per acre harvested tends to underestimate the severity of the drought. Thus yields on area harvested show that the 1965/66 crop dropped only some 12 per cent compared with the previous crop but yields based on total area indicate a drop of no less than 32 per cent.

Group production

According to the Sugar Industry Central Board Survey of Cane Production CB 46/20 European growers occupied 578,799 acres out of a total of 835,938 under cane on the 1st May, 1966. The area under cane for the miller-cum-planters was 152,504 acres while Indian and Bantu growers had respectively 73,963 and 30,672 acres under cane. European growers had the best yield of cane per acre harvested for the season 1965/66 and averaged 33.2 compared with only 16.6 tons cane per acre for Bantu growers. There is evidence to show that the miller-cum-planters as a group harvests a greater proportion of land under cane while the average age of cane at cutting is apparently highest in the case of Bantu growers.

Table III summarises cane production statistics for the various groups of the industry for the 1965/66 season.

Although the Bantu growers had 3.7 per cent of the area under cane on the 1st May, 1966, they were only responsible for 1.6 per cent of the 1965/66 production. Extremely poor yields, particularly on the basis of total area under cane, severely lowers the total cane production by this group and the same applies to a somewhat lesser extent to the Indian cane growers. As a group, the miller-cum-planters had the highest yield per total area under cane.

Regional production

It is customary to divide the sugar industry into three or four main regions. In recent years the Midlands has been added to the South Coast, North Coast and Zululand. The Pongola area has often been separated because conditions there differ so much from the rest of the industry. To a certain extent this is understandable; but the Nkwaleni Valley and the Tala Valley have probably more in common with Pongola than with their respective areas Zululand and Midlands. It has therefore been decided to divide up the industry into as many regional areas as can be justified on a basis of rainfall, temperatures, altitude etc. which tend to make one area differ from the other. In this manner the industry has been divided into 32 different cane regions, from which greater groups such as South Coast, North Coast or high, medium and low altitude etc. can be built up if so desired.

TABLE III

	Area under cane 1st May, 1966 as per cent of total	Yield T.C.A. area harvested 1965/66	Yield T.C.A. area under cane 1st May, 1964	Per cent production
European growers ..	69.2	33.2	13.5	70.7
Miller-cum-planter ..	18.2	32.5	14.2	22.2
Indian growers	8.8	21.7	8.2	5.6
Bantu growers	3.7	16.6	5.8	1.6
Industry	100.0	31.6	12.9	100.0

In Figure 1 a map of these areas is given. The extent of a particular region on the map gives no indication of the importance of the area or the total cane production. It only indicates approximately the boundaries of the area where cane can be grown in that region. Thus No. 2, Hluhluwe, covers a large area. Not much cane is at present grown in this area but the fact is that a little cane is grown in most of the area roughly indicated here. There are of course further differences within a region e.g. differences in soils. An attempt was made to evaluate some of these factors but there are complications. Thus the soil on an estate or farm is often so variable that it has to be omitted from a general soil group and one is left with so few units which can be used, that these finer comparisons are not justified and may be misleading.

In Table IV particulars are given for these regional cane areas and the following symbols are used.

Altitude: 1 Low altitude (coastal)
2 Intermediate
3 Plateau
4 midlands

Rainfall: 1 Below 30 inches per annum
2 30-40 inches per annum
3 Above 40 inches per annum

Yields

The yield data for Midlands and some South Coast areas have been omitted. The reason is that these areas are largely in the development stage and the area harvested is relatively small compared with the area under cane. Under these circumstances yield data cannot be very reliable as they are based on very small areas and yield per acre based on total area under cane may be misleading. These considerations hold also for other areas which are still in the development stage.

The highest yields were obtained, as was to be expected in the Pongola and the Umfolozi-Umhlatuzi regions. Here high fertility and good moisture conditions (irrigation at Pongola and a higher water table on the flats) combined to ensure that a relatively young crop yielded some 45 tons cane per acre harvested or nearly 32 tons cane per acre under cane cultivation. In these two areas plant cane formed the lowest percentage of total cane harvested. Here plant cane forms only 16 to 17 per cent of the total cane harvested which seems to indicate an average of some 5 ratoons. The average for the whole industry is 26.6 per cent plant cane, indicating about 3 ratoons. Expansion may affect these deductions to a limited extent.

The yields of cane per acre, and more so where based on total areas, have been severely depressed, as already pointed out, by the **1964/65** drought. The fact that the average yields in T.C.A. from the South Coast compare very favourably with those of the other main regions is due to a number of factors. There has in recent years been a general improvement in yields in the existing cane belt of the South Coast and new and relatively productive areas have been brought under cane but it should also be mentioned that the drought was not as severe on the South Coast as on the North Coast and parts of Zululand.

Irrigation

Apart from Tala Valley and Muden (Muden data not available as yet) very little irrigation is practised in the Midlands. Appreciable areas are however under supplementary irigation at Illovo on the South Coast as well as at Glendale and the coastal area of the North Coast. Pongola and Nkwaleni can be considered 100 per cent under total irrigation and about half the area in the Hluhluwe-Nyalazi sector is also under total irrigation. In the industry as a whole 12.6 per cent of the area is now under either supplementary or total irrigation.

Fertilizer

Table IV indicates that the European growers and miller-cum-planter groups use 527 lbs. of fertilizer per acre under cane or a total of 187,000 tons, which agrees very well indeed with a figure of 189,000 tons supplied by the fertilizer trade for the whole industry. An interesting comparison is the very large difference in fertilizer usage at Pongola and Nkwaleni Valley. These two areas have a lot in common but at Pongola the yield was 31.6 T.C.A. on a total area under cane basis whereas at Nkwaleni it was only 16.0 T.C.A.

During the 1965/66 season Zululand produced 37.3 per cent of the crop given in Table IV, North and South Coast respectively 31.9 and 19.4 per cent while the Midlands and the Pongola-Mkuze area produced 4.0 and 7.4 per cent.

Age of cane

The age of cane at cutting is a most important factor in the economics of cane production. Table IV indicates that the average age of the crop at harvest was 18.3 months varying from an average of 13.2 months at Pongola to 22.3 months for the South Coast inland area. There does, however, appear to be a tendency to underestimate the age of the crop at cutting and the age given here is generally appreciably less than the age calculated from area under cane and area harvested.

Theoretically the age in months of a crop at harvest can be calculated as follows:

$$\frac{\text{Area under cane} \times 12}{\text{Area harvested}}$$

If a reduction of 10 per cent is allowed, to account for fallow periods (and this may well be a somewhat high figure), we get the following:

TABLE IV

Region	Altitude	Rainfall	% acres Irrigated	T.C.A. area harvested	Age Months	% harvested acres under cane 1st May 64	T.C.A. acres under cane 1st May 64	Fertiliser (lb./acres under cane 65/66	Plant acres as % of Total acres harvested	Acres under cane May 1965 (,000)	Tons Cane (,000)
1 Pongola	1	1	100	44.8	13.2	71	31.8	1072	17	19.6	561
1b Gollel, Mkuze	1	1	100	33.7	14.1	62	20.7	410	23	3.4	58
1 Pongola—Mkuze			100	43.5	13.3	69.7	30.3	973	19	23.0	620
2 Hluhluwe, Nyalazi River	1	1—2	42	24.7	16.3	43	10.6	458	28	11.4	102
3 Umfolozi and Umhlatuzi Flats	1	3	4	47.2	14.5	67	31.5	616	16	20.0	625
4 Mtubatuba, Eteza	1	2—3	9	32.8	17.6	49	16.0	391	27	22.5	315
5 Kwambonambi, Mposa	1	3	10	27.2	16.7	45	12.3	578	37	13.9	162
6 Empangeni, Felixton, Enseleni	1	2—3	10	34.2	17.3	43	14.7	383	27	36.1	543
7 Heatonville, Ntambanana	1	1—2	15	20.0	19.8	29	5.8	286	21	19.3	93
8 Nkwaleni Valley	1	1	95	37.1	16.5	43	16.0	393	28	12.3	169
10 Mtunzini, Gingindhlovu	1	3	8	32.1	17.8	54	17.4	610	27	39.6	660
13 Amatikulu, Mandini	1	2—3	7	21.5	20.7	45	9.7	401	24	15.9	148
11 Ngoye	2	3	2	23.9	19.6	40	9.5	308	28	8.7	72
12 Eshowe, Entumeni	3	2—3	3	31.3	21.4	37	11.6	526	34	22.8	246
9 Melmoth	3	2—3	0	—	—	—	—	1166	—	5.9	—
Zululand			14.1	32.5	17.7	46.3	15.1	482	26	228.4	3,137
14 Tugela, Newark	1—2	2—3	6	22.1	19.5	33	7.3	346	38	2.5	18
15 Coastal (4-5 miles inland)	1	3	20	30.9	17.7	45	14.1	409	29	104.8	1,463
18 Glendale	1—2	2	47	32.3	18.9	33	10.5	481	39	3.7	36
16 Intermediate area, Kearsney, Upper Chaka's Kraal	2	2—3	3	28.4	20.0	43	12.1	449	25	50.6	593
17 Coastal Plateau, Doornkop, Upper Tongaat, Inanda	3	3	0	34.2	20.0	46	15.6	546	23	23.8	365
North Coast			13.3	30.6	19.1	43.0	13.6	445	27	202.9	2,688
19 Bishopstowe	4	2—3	1					571		6.3	
20 Cedara, Cramond, Seven Oaks, Mt. Alida	4	2—3	0					817		10.2	
21 Wartburg, Fawnleas, Dalton	4	3	0					631		40.6	
22 Kranskop	4	3	0					684		11.3	
23 Muden											
24 Tala Valley	4	2—3	53					562		4.5	
25 Eston, Mid-Illovo, Richmond	4	3	0					541		24.1	
26 Hillcrest, Inchanga	3—4	2—3	0					810		5.6	
Midlands			2.5	32.2	22.2	15.0		638	38	106.8	334
27 Coastal North of Hibberdene	1	3		31.4	20.9	44	13.7	369	28	12.9†	171†
30 ,, South of Hibberdene	1	3		30.5	19.6	45	13.7	637	26	26.9†	294†
28 Intermediate Region	2	3		40.5	20.0	41	16.4	572	23	13.3†	185†
29 Coastal Plateau Powerscourt, Highflats	3	3						657		3.5†	27†
31 Coastal Plateau Paddock, Maringo, Oribi	2—3	3	2					811		13.8	109
32 Inland Nquabeni, Hluku, Harding	3	2—3	0					523		3.6	4
South Coast			3.7	35.3	21.2	44.2	15.6	558	30	127.2	1,636
Total Industry			12.6	32.9	18.3	42.1	13.9	527	26.6	688.3 (709.5)*	8,415 (8,604)*

Note: Under the main regions and Total Industry a certain amount of unclassified cane, mainly from the South Coast, is included.

*Figures in brackets are the Central Board totals.
†Omissions from these regions amount to 53,000 acres, 847,000 tons.

Per cent area harvested	*Age at harvest in months*
100	10.8
90	12.0
80	13.5
70	15.4
60	18.0
50	21.6
40	27.0
30	36.0

With expansion, little of the increased acreage under cane at the beginning of the harvesting season would be cut during that year and for that reason it was decided to the acres harvested as a percentage acres under cane at the beginning of the previous season in Table IV. In this table the industrial average area harvested as a percentage of area under cane is 42.1 and consequently the calculated age of the crop at harvest was 25.6 months. These figures, as indeed all data in Tables IV and V, apply only to European growers and miller-cum-planters. The indicated age of crop for Indian and Bantu growers will be appreciably higher.

Our calculated age for the 1965/66 crop was therefore 25.6 months and that of the previous crop 20.0 months compared with 18.3 months (Table IV) and 18.0 months (last year's report) which are the averages compiled from direct replies from these planters groups. The calculated values seem more realistic and although the comparison 20.0 and 18.0 for the 1964/65 season is not very bad, the 1965/66 comparison 25.6 and 18.3 is decidedly poor. In view of the severe drought experienced it would seem logical to expect the 1965/66 crop to be appreciably older than the 1964/65 crop.

Considering all these facts, it would seem reasonable to accept 20 months as the approximate average age of cane in the industry under present conditions.

The variety position

Although the questionnaire did ask for details of the varieties N:Co.339, N:Co.292 and N:Co.334, it was found that so little of these varieties are now grown in the industry, that these data have been omitted.

Table V reflects the percentage of areas under plant cane and total cane for the more popular varieties. This table also gives the percentage area under plant cane, ratoons and fallow for all varieties.

N:Co.310 is now mostly grown in the northern areas of the sugar industry and in the northern areas only. With the exception of the Kwambonambi-Mposa and Felixton-Enseleni areas it remains the predominant variety from Pongola down to the Nkwaleni Valley. In the Pongola, Mkuze-Gollel area there is no evidence that N:Co.310 is being replaced by other varieties and the proportion of area under plant cane is at least as high as that under total cane. This is however not the case in most other areas, where there are definite indications of N:Co.310 being replaced by N:Co.376 and other varieties. Other areas with a fairly high proportion of N:Co.310 are: the Tugela-Newark area, Glendale, Kearsney-Upper Tongaat and the coastal area south of Hibberdene. The latter area is unexpectedly high in N:Co.310 and it is also surprising that quite such a high proportion of this variety is grown in the Heatonville-Ntambanana area.

If N:Co.310 is the variety of the north then N:Co.376 is pre-eminently the variety of the southern areas. Excluding the Midlands, there is not one area south of the Nkwaleni Valley where N:Co.376 occupies less than 60 per cent of the area under plant cane and in some of the South Coast regions from 85 to 90 per cent of the plant cane is N:Co.376. The average percentages of plant cane under N:Co.376 is 41.4 for Zululand, 64.5 for the North Coast and 81.9 for the South Coast. This variety is also quite popular in the following Midlands areas: Hillcrest, Inchanga, Tala Valley, Eston-Mid-Illovo-Richmond and Bishopstowe.

The popularity of N:Co.382 is still on the increase and in the Kwambonambi-Mposa area it now constitutes nearly half the total area under plant cane. It is far more popular in the north of Zululand than in the south of Zululand. It is quite extensively grown in the Midlands area north of Pietermaritzburg and also in the coastal area of the South Coast north of Hibberdene. This variety does well on poor sands but it is somewhat difficult to explain its pattern of distribution.

N:Co.293 is a high altitude cane and it is mostly found in these areas of the South and North Coasts as well as Zululand, and it is very popular in the whole of the Midlands where it forms 39 per cent of the area under cane.

With the exception of a few areas in the Midlands Co.331 has virtuallv disappeared as a commercial variety in the industry.

N.50/211 is largely confined to the North Coast and some of the Zululand areas. It has not become popular on the South Coast and only negligible areas are planted in the Midlands.

TABLE V

Percentage areas under Plant Cane, Total Cane, Ratoons and Fallow

Region	N:Co.310		N:Co.376		N:Co.382		N:Co.293		Co.331		N.50/211		Plant % Total area	Ratoon % Total area	Fallow % Total area
	Plant	Total	Plant	Total	Plant	Total	Plant	Total	Plant	Total	Plant	Total			
1 Pongola	90.2	89.2	7.0	8.5	0.5	0.1	0.1	1.0	0	0	0.9	0.7	28.0	70.2	1.8
1b Mkuze, Gollel	97.8	97.4	2.2	2.5	0	0	0	0	0	0	0	0	38.1	50.9	11.0
2 Hluhluwe, Nyalazi River ..	34.8	53.3	20.7	15.7	42.3	25.0	0	0	0	3.7	0	0.3	43.1	49.2	7.6
3 Umfolozi, Umhlatuzi Flats ..	57.0	70.2	12.1	10.6	26.3	11.6	0	0	0.5	1.8	1.3	1.1	22.3	75.9	1.8
4 Mtubatuba, Eteza	45.6	48.3	8.5	13.5	36.8	24.6	0.9	0.9	0.2	2.9	4.2	3.9	43.8	52.7	3.5
5 Kwambonambi, Mposa ..	10.5	15.7	25.3	26.8	47.7	33.9	0	0	2.0	4.2	10.6	11.5	30.8	62.6	6.6
6 Empangeni (Felixton, Enseleni)	30.7	48.0	39.8	31.0	15.4	8.1	0	0.1	0.1	0.5	8.0	7.0	25.6	71.9	2.5
7 Heatonville, Ntambanana ..	74.6	82.3	15.0	11.0	1.4	0.8	0	0.1	0	0	4.7	3.4	48.5	47.3	4.2
8 Nkwaleni Valley	50.4	68.3	32.2	20.9	1.9	0.7	1.2	0.9	0.1	0.3	11.1	6.6	29.5	67.8	2.7
10 Mtunzini, Gingindhlovu ..	5.3	19.1	70.0	59.0	9.6	7.9	0	0.2	0.3	1.2	11.1	10.7	24.9	72.3	2.7
13 Amatikulu, Mandini	6.6	23.9	75.0	57.7	2.1	1.9	0	0.1	0.1	0.8	5.4	8.8	30.4	61.4	8.2
11 Ngoye	7.5	31.0	72.1	51.0	8.5	5.5	2.5	1.8	0.3	0.7	8.0	8.0	39.4	56.2	4.4
12 Eshowe, Entumeni	0.6	3.3	65.4	47.4	7.6	4.4	17.0	28.8	0	1.8	7.9	9.9	36.2	60.4	3.4
9 Melmoth	2.2	2.1	74.7	74.4	4.7	4.8	9.2	9.3	0.7	0.8	6.6	6.8	98.7	1.3	0
Zululand	28.7	39.5	41.4	34.4	16.5	10.6	2.6	3.1	0.3	1.5	6.6	6.9	34.5	61.7	3.8
14 Tugela, Newark	21.1	39.5	65.9	45.8	0	0.3	0	0.5	1.8	4.4	10.5	8.1	40.2	56.3	3.5
15 Coastal Area (4–5 miles inland)	5.7	18.1	61.7	50.3	12.3	10.9	0.4	0.6	2.0	3.4	13.6	10.0	24.1	74.6	1.2
18 Glendale	20.2	20.7	63.0	63.1	5.3	3.8	1.9	1.7	2.3	3.4	6.5	5.8	54.2	45.9	0
16 Intermediate area (Kearsney, Upper Chaka's Kraal etc.) ..	12.1	22.0	63.1	51.1	4.0	2.1	1.8	3.2	1.4	5.3	14.0	9.1	25.2	72.0	2.8
17 Coastal Plateau (Doornkop, Upper Tongaat, Inanda) ..	0.3	7.0	74.2	54.7	8.7	5.1	10.0	18.7	0.5	2.7	3.9	7.1	29.9	67.8	2.3
North Coast	6.7	17.1	64.6	51.5	9.7	8.2	2.6	4.3	1.6	3.6	11.2	9.2	25.9	72.5	1.6
19 Bishopstowe	1.3	1.6	41.5	39.2	18.3	15.7	31.6	30.1	4.8	11.5	0.6	0.5	78.2	21.0	0.8
20 Cedara, Cramond, Seven Oaks, Mt Alida	1.5	1.6	19.8	19.9	17.5	16.6	44.8	44.3	14.6	15.7	0.1	0.1	91.2	8.8	0
21 Wartburg, Fawnleas, Dalton..	0.2	0.2	5.8	7.0	34.3	27.1	38.7	37.5	19.8	26.3	1.0	0.9	68.9	29.7	1.3
22 Kranskop	1.5	1.5	16.7	16.7	25.8	25.7	43.8	43.8	10.5	10.8	1.6	1.6	98.5	1.5	0
23 Muden															
24 Tala Valley	3.7	3.7	49.4	51.8	10.6	9.7	35.8	34.1	0.2	0.2	0.3	0.5	84.4	13.2	2.4
25 Eston, Mid-Illovo, Richmond	0.1	0.2	45.3	40.7	9.8	8.7	41.6	42.7	1.3	5.2	0.8	0.6	76.3	21.9	1.8
26 Hillcrest, Inchanga	0.1	3.5	63.0	59.7	3.3	3.3	30.9	30.1	1.5	1.3	1.4	1.8	69.3	29.6	1.2
Midlands	0.7	0.9	25.6	24.5	21.7	18.7	39.3	38.9	10.7	15.0	0.9	0.8	77.4	21.5	1.1
27 Coastal area (4–5 miles inland, North of Hibberdene)	0.8	11.9	73.4	62.1	22.3	11.5	0.1	0.1	0.1	4.6	2.8	2.0	31.0	63.0	6.0
30 Coastal area (4–5 miles inland, South of Hibberdene)	9.4	23.2	85.4	66.3	2.0	2.0	0.2	1.8	0.4	2.3	2.2	1.9	43.4	52.1	3.5
28 Intermediate region	3.0	2.7	88.4	77.2	4.5	2.9	3.4	9.2	0	1.6	2.9	3.0	45.7	47.9	6.3
29 Coastal Plateau (Powerscourt, Highflats)	0.5	3.6	75.7	65.8	1.1	2.1	19.1	23.7	0.6	0.9	3.0	2.8	68.1	28.8	3.1
31 Coastal Plateau (Paddock, Maringo, Oribi)	1.1	2.4	90.5	85.8	2.1	1.5	5.0	6.7	0.3	0.9	0.9	0.9	66.9	32.3	0.7
32 Inland (Nquabeni, Hluku, Harding)	1.2	2.1	52.1	50.3	0.4	0.4	44.3	43.1	1.8	3.5	0	0.3	91.0	8.2	0.8
South Coast	4.1	12.1	81.9	70.2	4.4	3.6	6.9	6.6	0.4	2.3	1.9	1.9	49.4	46.8	3.8
Total Industry	13.8	25.2	45.6	41.1	14.8	10.0	14.9	9.7	4.0	4.4	4.5	5.6	41.0	56.3	2.7

Discussion

Mr. GUMH: Mention is made of cane varieties grown in different areas—does the experiment station agree always that a certain variety should be growing in a particular area?

Mr. du Toit: In general the variety distribution is not very different to what we would recommend. Thus N:Co.293 would be recommended for the high altitude areas and not for the coastal areas and Table V proves that this advice is followed in practice. One would, however, think that N:Co.376 could be grown more in the North and there is a risk in depending on one variety to the extent of 80 and 90 per cent as is sometimes done.

Dr. Qeasby: Has there been any change in the distribution of phosphate, nitrogen and potash?

Mr. du Toit: There has been a remarkable change in the ratio of nitrogen, phosphate and potash used in recent years. From 1960 to 1963 the ratio of N:P:K: was of the order of 3.8:1:3.6 but in 1965 the ratio of phosphate rose appreciably to about 2.9:1:2.6. This was the result of expansion and a very large planting programme. During 1966 the ratio changed dramatically to 4.8:1:4.0. The planting programme had eased and apparently phosphate dressings were cut as an economy measure.

Dr. Matic: The main reasons for choosing varieties is yield per acre and disease and pest resistance. Are likely processing characteristics of a cane also taken into account?

Mr. du Toit: Some consideration is now being given to this. Starch is determined on varieties about to be released and it can be arranged for the Sugar Milling Research Institute to test these varieties for their manufacturing properties. The cane breeder has, however, to take into consideration a large number of factors and yield, disease resistance and ratooning properties are of prime importance in deciding which varieties are to be released.

LEACHING IN SANDS AND ITS EFFECT ON NITROGEN RECOVERY BY YOUNG CANE*

by R. A. WOOD

South African Sugar Association Experiment Station

Introduction

It is probable that one of the main causes of reduced fertilizer N efficiency; especially on sandy soils, is the loss of nitrogen through leaching, usually in the form of nitrate—N ($N0_3$-N). Lysimeter studies[2,3,6] have shown that varying amounts of NO_3-N may be removed, potential losses depending on time, method, and rate of N application, and the presence or absence of a growing crop. Soil texture also has a noticeable effect on the distance to which a given quantity of water will move nitrates, being largely associated with differences in water holding capacity and porosity. This has been well illustrated by Bates and Tisdale[1] and Maud[7].

Where precipitation exceeds evapotranspiration over long periods, nitrates may link up with ground water and be lost to the plant. Usually however movement down the profile is limited by insufficient rainfall, or physically due to textural changes, so that eventually some of the leached $N0_3$-N can be utilized, particularly by deep rooted crops such as cane and maize. Upward movement of nitrate has been noted when evapotranspiration exceeds precipitation[31]. Mineral N moving down the profile may also be temporarily immobilized by microbial action and become available subsequently to a future crop, this residual N effect having been demonstrated on cane by Takahashi[10].

Generally however it would appear that it is only in the lighter soils that serious leaching losses may occur, particularly where fertilizer N is applied at planting or the early stages of growth. This might deprive young cane of much of its N supply before this can be properly utilized, especially if added in the nitrate form, or where nitrification readily occurs on addition of an ammonium carrier to the soil. These losses can probably be reduced when applied N is retained by the soil in the NH_4-N form, nitrification being partially delayed either naturally due to acid conditions or artificially by the addition of an inhibitor to the soil via the Fertilizer

A greenhouse experiment to study the effects of leaching and delayed nitrification on N uptake by young cane on two coastal sands was therefore undertaken, details of which are now reported.

Procedure

Fertilizer treatments: 1500 g air dry samples of two sands (Clansthal and Lytton
and 4.60 respectively) were weighed into polystyrene pots and the following fertilizer treatments applied to each of 16 replicates of the Clansthal, and 12 replicates of the Lytton sand.

1. 150 mg N as $(NH,)_3S0_4$ — 100 ppm
2. 150 mg N as $(NH.,)_2S0_4$ — 100 ppm treated with *2%* N - Servef: 2 - chloro - 6 - (trichloro methyl) - pyridine.
3. 150 mg N as NaNO., — 100 ppm

were uniformly mixed with the soils beforehand after which they were moistened to 50% WHC (water holding capacity) with a basic nutrient solution supplying 100 ppm K and 80 ppm P. As in previous greenhouse experiments all solutions were applied clown a perforated nylon tube situated in each pot, the latter having a plastic seal at the base to eliminate drainage losses.

Ten of the Clansthal and six of the Lytton replicates were planted with previously germinated single-eyed cane setts (Variety N:Co,310) of uniform weight, while the remaining pots in each treatment were left unplanted. Apart from the time when leaching treatments were imposed, all pots were weighed daily, being maintained at 50% WHC. After eight weeks tops and roots were harvested and prepared for total N analysis as described elsewhere[12] while the soils were rapidly air dried before being analysed for NH_4-N and $N0_3$-N.

Leaching treatments: The following treatments were imposed on duplicate pots of all fertilizer treatments both cropped and uncropped, except where stated.

Clansthal

1. Control—no leaching.
2. 1 in. water applied 1 week after fertilization (cropped only).
3. 2 in. water applied 1 week after fertilization.
4. 1 in. water applied 3 weeks after fertilization (cropped only).
5. 2 in water applied 3 weeks after fertilization.

Lytton

1. Control—no leaching.
2. 2 in. water applied 1 week after fertilization.
3. 2 in. water applied 5 weeks after fertilization.

During leaching the required amount of, water was applied dropwise to the surface of the pots, the soils having first been brought to 50% WHC, and the plastic seals removed. After drainage was complete the pots were resealed and the leachate from each pot made up to a fixed volume, from which aliquots were taken for inorganic N determination.

* Post-graduate material by the author for submission to the University of Natal, Soil Science Department.

t Registered trade mark of Dow Chemical Co.

TABLE I

The effect of leaching on N recovery by cane grown on Clansthal sand

Treatment	Inches of water applied per pot at leaching				
	Nil	1 in. after 1 week	2 in. after 1 week	1 in. after 3 weeks	2 in. after 3 weeks
150 mg N as $(NH_4)_2SO_4$			*Tops*		
Yield g	16·8	12·7	9·9	11·0	12·2
N content mg/g	11·3	9·7	7·2	8·8	6·9
N in tops mg	189·8	123·2	71·3	96·8	84·2
			Roots		
Yield g	7·6	4·5	3·9	3·8	7·2
N content mg/g	8·0	8·9	7·6	7·9	8·0
N in roots mg	60·8	40·1	29·6	30·0	57·6
Total plant recovery mg N	**250·6**	**163·3**	**100·9**	**126·8**	**141·8**
150 mg N as $(NH_4)_2SO_4$ + 2% N—Serve			*Tops*		
Yield g	15·0	11·7	12·1	10·0	10·9
N content mg/g	12·9	11·3	7·7	11·9	9·1
N in tops mg	193·5	132·2	93·2	119·0	99·2
			Roots		
Yield g	5·8	4·9	6·4	3·8	5·7
N content mg/g	8·8	10·6	8·4	10·0	8·4
N in roots mg	51·0	51·9	53·8	38·0	47·9
Total plant recovery mg N	**244·5**	**184·1**	**147·0**	**157·0**	**147·1**
150 mg N as $NaNO_3$			*Tops*		
Yield g	11·0	10·2	6·1	10·1	7·0
N content mg/g	12·6	10·4	6·6	10·5	6·8
N in tops mg	138·6	111·2	40·3	106·1	47·6
			Roots		
Yield g	5·1	3·6	2·6	4·0	3·5
N content mg/g	9·8	9·6	7·9	9·9	8·0
N in roots mg	50·0	34·6	20·5	39·6	28·0
Total plant recovery mg N	**188·6**	**145·8**	**60·8**	**145·7**	**75·6**

TABLE II

The effect of leaching on N recovery by cane grown on Lytton sand.

Treatment	Inches water applied per pot at leaching		
	Nil	2 in. after 1 week	2 in. after 5 weeks
150 mg N as $(NH_4)_2SO_4$		*Tops*	
Yield g	12·2	9·9	11·5
N content mg/g	11·0	8·7	9·2
N in tops mg	134·2	86·1	105·8
		Roots	
Yield g	3·7	3·4	4·7
N content mg/g	8·6	7·1	6·7
N in roots mg	31·8	24·1	31·5
Total plant recovery mg N	**166·0**	**110·2**	**137·3**
150 mg N as $(NH_4)_2SO_4$ +2% N—Serve		*Tops*	
Yield g	12·5	11·1	13·4
N content mg/g	14·4	10·2	8·1
N in tops mg	180·0	113·2	108·5
		Roots	
Yield g	4·7	4·0	5·9
N content mg/g	8·7	6·6	6·0
N in roots mg	40·9	26·4	35·4
Total plant recovery mg N	**220·9**	**139·6**	**143·9**
150 mg N as $NaNO_3$		*Tops*	
Yield g	11·8	8·8	9·9
N content mg/g	11·8	7·6	8·4
N in tops mg	139·2	66·9	83·2
		Roots	
Yield g	3·3	2·5	3·5
N content mg/g	7·3	5·3	7·2
N in roots mg	24·1	13·3	25·2
Total plant recovery mg N	**163·3**	**80·2**	**108·4**

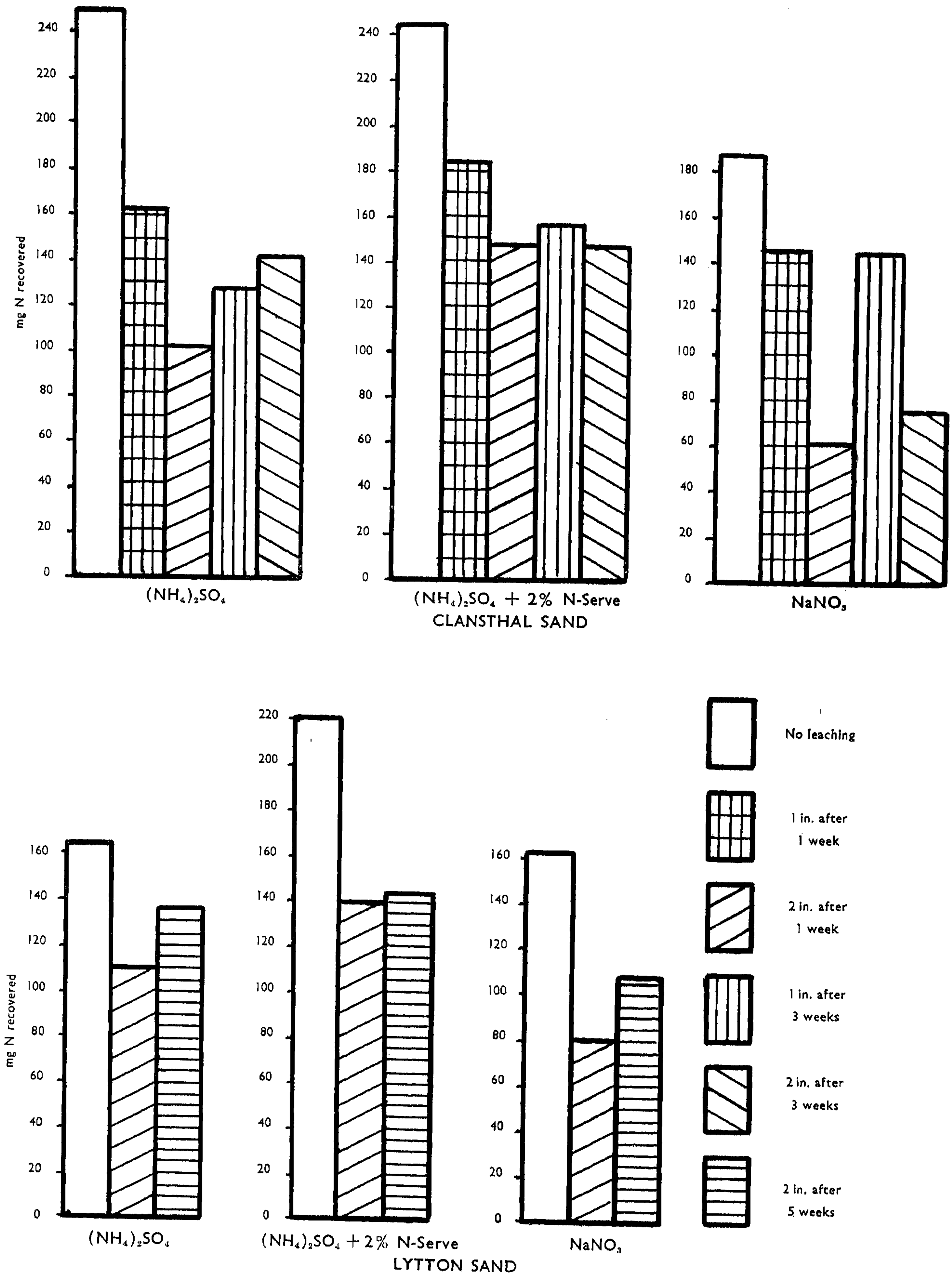


FIGURE 1. Recovery of fertilizer nitrogen by sugarcane after eight weeks under various leaching treatments.

Results and Discussion

Yield data and N recovery by cane grown under the different fertilizer and leaching treatments for a period of eight weeks are presented in Tables I and II, while Figure I illustrates the comparative uptake of N from the two sands.

As expected the effect of leaching was to reduce yield and N recovery from all fertilizer treatments on both soils. Certain factors however obviously affected the degree of leaching and these will now be briefly considered.

Amount and time of water application: Compared with a 1 inch application of water, one of 2 inches removed up to three times the amount of mineral N from the Clansthal sand. This is shown in Table III which details the amounts of NH_4-N and NO_3-N leached from the cropped pots of both soils after various periods. It is of interest to note that considerable quantities of ammonium nitrogen were leached from the soil up to three weeks after application, and smaller amounts after even longer periods. This would appear to be contrary to the

TABLE III

Relative leaching losses of NH_4—N and NO_3—N from two sands under cane at various times after N fertilization.

	Leaching treatment	N Fraction	$(NH_4)_2SO_4$ 150 mg N	$(NH_4)_2SO_4$ +2%N-Serve	$NaNO_3$ 150mgN
			mg N leached*		
Clansthal sand	1 in. after 1 week	NH_4—N	18·0	16·5	Nil
		NO_3—N	10·5	7·5	46·5
		Total N	28·5	24·0	46·5
	2 in. after 1 week	NH_4—N	63·0	60·0	3·0
		NO_3—N	25·5	12·0	114·0
		Total N	88·5	72·0	117·0
	1 in. after 3 weeks	NH_4—N	12·0	12·0	Nil
		NO_3—N	19·5	7·5	52·5
		Total N	31·5	19·5	52·5
	2 in. after 3 weeks	NH_4—N	31·5	54·0	Nil
		NO_3—N	31·5	16·5	120·0
		Total N	63·0	70·5	120·0
Lytton sand	2 in. after 1 week	NH_4—N	54·0	57·0	4·5
		NO_3—N	7·5	7·5	100·5
		Total N	61·5	64·5	105·0
	2 in. after 5 weeks	NH_4—N	9·0	Nil	Nil
		NO_3—N	7·5	4·0	75·0
		Total N	16·5	4·0	75·0

*mean of duplicate pots

TABLE IV

Mineral N remaining in uncropped pots after 8 weeks (mean of duplicate pots in ppm)

Leaching treatment	N fraction	Clansthal sand			Lytton sand		
		$(NH_4)_2SO_4$	S/A+N-Serve	$NaNO_3$	$(NH_4)_2SO_4$	S/A+N-Serve	$NaNO_3$
Nil	NH_4—N	33	105	Nil	114	118	5
	NO_3—N	79	19	102	22	16	96
	Total N	112	124	102	136	134	101
2 in. after 1 week	NH_4—N	Nil	46	Nil	51	66	18
	NO_3—N	39	20	11	24	9	41
	Total N	39	66	11	75	75	59
2 in. after 3 wk. (C) 5 wk. (L)	NH_4—N	Nil	39	Nil	22	49	2
	NO_3—N	35	7	9	8	7	17
	Total N	35	46	9	30	56	19

findings of Maud[7] and others[1,4] who state that downward movement of nitrogen takes place only in the nitrate form. Morgan and Jacobson[8] also obtained substantial amounts of ammonium salts in leachates collected from sandy soils so it is probable that lighter soils which leach rapidly should be excluded from the above observation. While much of the data in Tables I—III suggest that losses of applied N from the cropped pots were reduced the longer leaching was delayed, so increasing N recovery by the plant, this trend was not apparent in all treatments.

Type of fertilizer applied: In both soils losses of N from $(NH_{4})_2SO_4$ were always much less than those from $NaNO_3$, this being reflected in yield and N recovery data. The effect of N-Serve in partially inhibiting nitrification in the Clansthal sand is apparent in the NCVN figures in Table III, but even more clearly demonstrated in Table IV which gives amounts of NH_4-N and NO_3-N remaining in the uncropped pots after 8 weeks.

In the slightly acid Clansthal sand in which nitrification readily occurs, no NH_4-N remained in the two leached $(NH_4)_2SO_4$ treatments without N-Serve, while substantial quantities were retained when N-Serve was present. Nitrification in the highly acid Lytton sand normally only proceeds slowly so that differences between treated and untreated soil were not as marked but obvious nonetheless. Nitrification with time probably accounts for the lower amounts of NH_4-N found in the N-Serve treated soils leached after three and five weeks, when compared with amounts found after leaching at one week.

Textural and pH differences: Although exhibiting similar moisture characteristics, the Lytton sand has a somewhat higher clay content than the Clansthal sand (15% compared with 9%). This is thought to be mainly responsible for the slower movement of water through the former soil and for the higher amounts of mineral N retained by it after leaching. Apart from texture, the difference in pH between these sands is able to affect markedly their behaviour to applied N as discussed in an earlier paper[13]. It would seem therefore that more nitrate-N is likely to be leached to greater depths more rapidly in the Clansthal sand than in the Lytton.

Leaching in the field: Evidence of rapid leaching to depth under young cane growing on Clansthal sand was obtained at the commencement of a fertilizer trial (FT 6/N) at the Central Field Station. N was applied in September 1965 as $(NH_4)_2SO_4$ in the furrow at planting, the levels being 0, 25, 50 and 100 lb. N per acre. After eight weeks three replicate profiles were sampled under each treatment at foot intervals to a depth of four feet, mineral N and moisture determinations being carried out immediately in duplicate on all samples,

The means of the results are presented in Table V, and clearly show that considerable leaching of NO_3-N had occurred to a depth of four feet at all fertilizer levels, and was related to the amount of N originally applied.

TABLE V

ppm **NO_3—N* leached under young cane two months† after N applied in the furrow (Clansthal sand)**

Soil depth (in)	lb N applied as $(NH_4)_2SO_4$			
	0	25	50	100
0 —12	1·9	2·2	4·3	2·9
13—24	3·1	2·7	5·6	8·8
25—36	2·5	7·3	8·3	13·0
37—48	2·8	7·4	6·1	11·4
Total	10·3	19·6	24·3	36·1

* mean of 3 replicate profiles

† rainfall recorded during period = 7.92

Conclusions

Where leaching of nitrates occurs under young cane particularly on sandy soils, and is sufficiently severe it can reduce N uptake considerably and may influence yield. The period of potential loss is obviously greatest before the cane rhizosphere is fully established, after which losses will normally be slight. It is often during this period however that high rainfall is experienced and substantial leaching can take place as shown. Whether the plant is ever able fully to make up for such losses from subsequent absorption of nitrates by roots at depth is not clear, though this undoubtedly occurs. Results of field trials on these soils will help to answer this question.

Application of nitrates to such soils would seem to introduce an additional unnecessary risk which is at least partially overcome by the use of ammonium carriers. If these in turn were rendered slowly nitrifiable then the most efficient use could be made of added fertilizer N.

Unfortunately only little information, of a conflicting nature, is available regarding the use of N-Serve in delaying nitrification in sandy soils under cane in the field, and this is to be further investigated. A field trial in the Philippines[5] indicated that both urea and ammonium sulphate treated with *2%* N-Serve, produced higher yields than the control, but it was not clear whether the differences were economic. Parish[9] states that field trials have not shown any improvement in N fertilizer efficiency following its use, probably because the "set back" to the soil nitrifying organisms is only of a temporary nature, N-Serve being volatile.

142 *Proceedings of The t African Sugar Technologists' Association — April 1967*

Summary

In a greenhouse experiment cane grown on two coastal sands (Clansthal and Lytton series) was subject to various fertilizer and leaching treatments over a period of eight weeks.

The effect of leaching was to reduce yield and N recovery from all fertilizer treatments on both soils, but certain factors namely (i) amount and time of water application, (ii) type of fertilizer applied, (iii) the use of N-Serve, a nitrification inhibitor and (iv) pH and texture, were found to greatly affect the degree of leaching and N uptake by the plant.

Soil sampling on Clansthal sand under young cane, eight weeks after various N fertilizer applications, showed that considerable leaching of nitrate had occurred at all fertilizer levels to a depth of four feet, and was related to the amount of N originally applied.

It is concluded that leaching of nitrates on sandy soils under young cane if sufficiently severe, can result in reduced N uptake and may influence yield, the most critical period probably occurring between planting and the full establishment of the cane rhizosphere.

References

1. Bates, T. E., and Tisdale, S. L. (1957). The movement of nitrate-nitrogen through columns of coarse-textured soil materials. Soil Sci. Soc. Amer. Proc. 21: 525-528.
2. Dreibelbis, F. R. (1954). Soil type and land use effects on percolation of soil water through monolith lysimeters. Soil Sci. Soc. Amer. Proc. 18: 358-363.
3. Harrold, L. L., and Dreibelbis, F. R. (1951). Agricultural hydrology as evaluated by monolith lysimeters. U.S.D.A. tech. Bull. 1050.
4. Krantz, B. A., Ohlrogge, A. J., and Scarseth, G. D. (1944). Movement of nitrogen in soils. Soil Sci. Soc. Amer. Proc. 8: 189-195.
5. Lojo, A. M., Covar, R. R., and Mora, C. R. (1964). Preliminary studies on the use of N-Serve in the conservation of nitrogen in soils. Sugar News. 40: 554, *556*, 558, 560.
6. Maclntire, W. H., Young, J. B., Shaw, W. M., and Robinson, B. (1952). Nitrogen recoveries from applications of ammonium chloride, phosphate, and sulphate, and outgo of complementary ions in rain water leaching through a six-foot soil-subsoil column. Soil Sci. Soc. Amer. Proc. 16: 301-306.
7. Maud, R. R. (1964). A preliminary investigation into the behaviour of soluble nitrogen fertilizers on mulched and unmulched soils in coastal Natal. Proc. Annual Cong. S. Afr. Sugar Tech. Ass. 37: 180-189.
8. Morgan, M. F. and Jacobson, H. G. M. (1942). Soil and crop inter-relations of various nitrogenous fertilizers. Conn, agric. Exp. Sta. Bull. 458: 271-328.
9. Parish, D. H. (1965). The efficacy of nitrogenous fertilizers. Proc. 12th Cong. int. Soc. Sug. Cane Tech. Puerto Rico, (in press).
10. Takahashi, D. T. (1964). N^{15}-nitrogen field studies with sugarcane. Hawaiian Plant. Rec. 57: 198-222.
11. Wetselaar, R. (1961). Nitrate distribution in tropical soils IT. Effect of capillary accumulation of nitrate during a long dry period. Plant and Soil 15: 121-133.
12. Wood, R. A. (1966). The influence of trash on nitrogen mineralization—immobilization relationships in sugar belt soils. Proc. Annual Cong. S. Afr. Sugar Tech. Ass. 40: 253-262.
13. Wood, R. A. (1966). Nitrification in relation to pH —its importance in fertilizer nitrogen utilization by cane in some sugar belt soils. Proc. Annual Cong. S. Afr. Sugar Tech. Ass. 40: 241-246.

Discussion

Mr. du Toit (in the chair): Have there been any indications, in pot work or in the fields, of a difference in the response of a sugar cane plant to the nitrate or ammoniacal form of nitrogen?

Apparently in a sandy soil such as the Clansthal leaching takes place to a marked extent. Growers who cut cane on such sands in February and March and wish to top dress the crop with a 100 lbs. of N often wonder when this dressing should be applied and whether it should be split.

Mr. R. A. Wood: From pot work observations sugar cane appears to have a preference for the ammonium form of nitrogen. Work at Rothamsted shows that grasses also prefer this form.

With a ratoon crop, that has an established root system, a full autumn application of nitrogen is in order but we have no figures to show how effective a split application would be.

Mr. Hempson: Ratoon roots die and therefore will not be effective in taking-up nitrogen.

Mr. R. A. Wood: The root mat, even though it dies eventually, remains effective for some time and will hold back nitrogen.

Dr. Thompson: Mr. Wood has indicated that a plant never fully makes up leaching losses that occur in a Clansthal sand. The neutron probe shows that the potential for recovery of nitrogen leached to a depth of seven feet is good.

Mr. Wilson: Our root laboratory has also indicated that in sands roots reach a depth of four feet in a period of eight weeks.

Mr. R. A. Wood: In sands the root system at depth is dispersed and may not be able to recover all the available nitrogen.

Mr. Moberley: In these experiments in Clansthal sands the poor growth of cane on the site was not due to lack of N but to previous heavy aplications of lime in filter press.

Mr. Cownie: Under total irrigation would you recommend a farmer to hold off irrigation for a few weeks after application of nitrogen?

Mr. R. A. Wood: The movement of water through a heavy soil should not cause much leaching but in a sandy soil it might be advisable to split the application when there is irrigation.

THE SIMULTANEOUS GROWTH OF SUGARCANE ROOTS AND TOPS IN RELATION TO SOIL AND CLIMATE

by J. GLOVER
South African Sugar Association Experiment Station

Because it is difficult to observe the growth of roots in natural conditions there is a tendency to concentrate on their appearance or behaviour without considering the simultaneous growth of the above-ground portion of the crop. Indeed, some methods of root study preclude observation of top growth. These are the various methods which involve the excavation of roots. While they are unrivalled as a means of disclosing the spatial distribution of roots, they present only a static picture of a root system at one instant of time, so in order to study both the distribution of roots at different stages of crop growth and to compensate for soil heterogeneity, which may markedly affect the pattern of growth, many excavations must be undertaken. Such multiple excavations require much delicate hand labour and time, and are extremely expensive. In a rapidly changing environment, such as exists when a drought spell is broken by rains, digging can be too slow to cope with rapid changes in root development.

One is therefore forced to use the method of direct observation of roots growing behind the glass walls of trenches in the soil for, as yet, there is no other satisfactory method of observing the daily changes in root extension and behaviour. The relative inaccuracy of such a method, as compared with partial or total excavation, can be reduced by increasing the number of observation windows and by a suitable spacing of plants near them so that different views of different parts of the system can be obtained. This will be referred to in detail, later.

Methods

The most useful tool for the observation of root growth is a root-observation laboratory such as that designed and used at the East Mailing Research Station (1963) in England. In essence it is a long, narrow, roofed trench whose long sidewalls contain windows placed against the soil. Figure 1 shows the outline and dimensions of the Mount Edgecombe root laboratory. It is of similar size to the East Mailing laboratory and also has 48 windows (24 on each side) through which root growth can be studied. The main difference between the two laboratories is that only one long side of the Mount Edgecombe

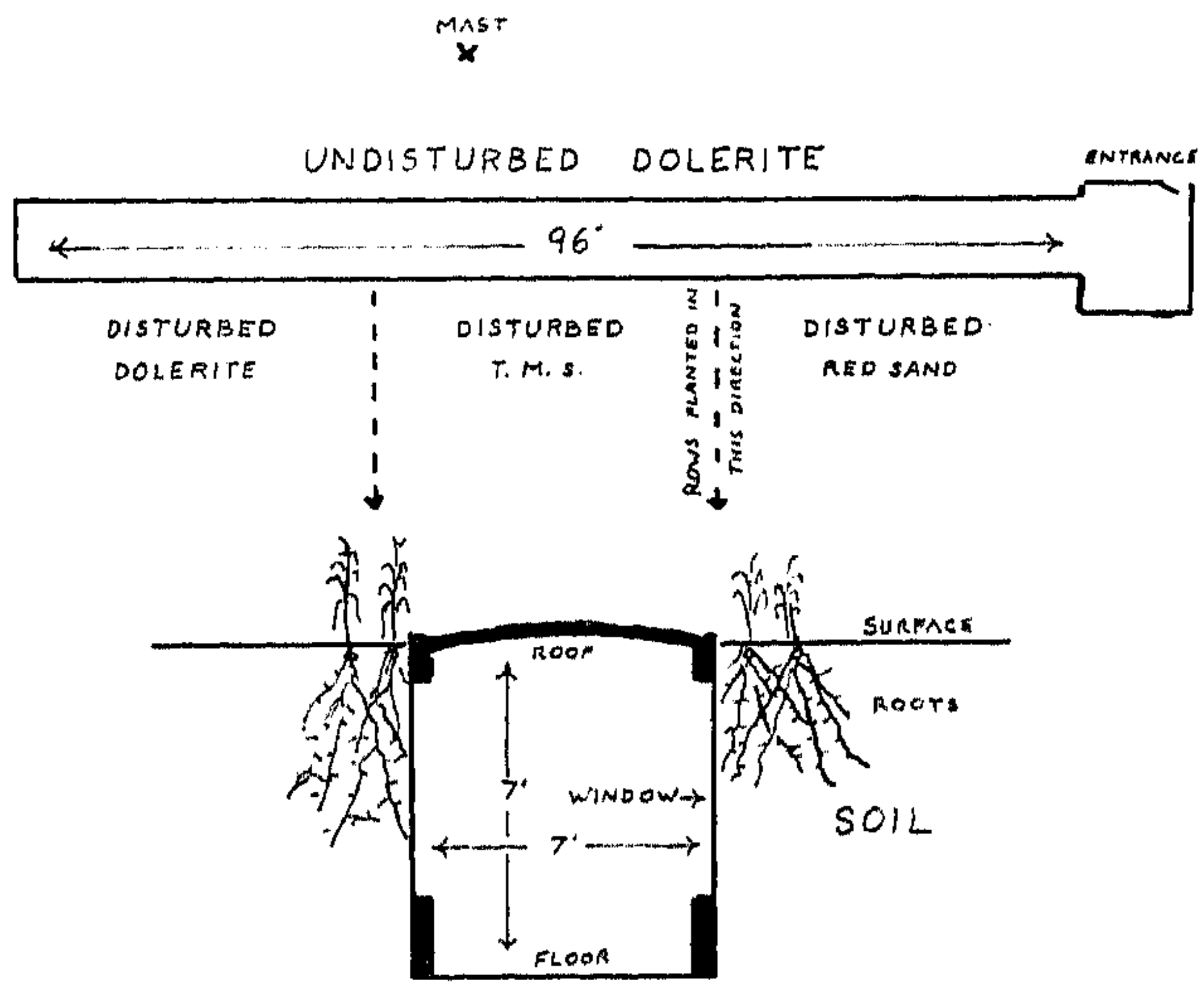


FIGURE 1: Plan and elevation of the root laboratory

laboratory is set into the undisturbed natural soil, whereas that of East Mailing has both sides in such soil. On the opposite side of the Mount Edgecombe laboratory, the windows provide views of root growth in disturbed soils. This was a deliberate choice, so that root behaviour could be simultaneously observed in other soils of different texture.

Twelve of the 48 windows have removable panes behind which lies clear plastic sheeting in contact with the soil. These permit experimentation with roots *in situ* with a minimum of disturbance. For example radio-active phosphorus compounds can be applied directly by a fine hypodermic needle to any selected portion of a root and not in some vague zone where a root is supposed to be. The fine puncture in the plastic sheet is often self sealing but as a precaution a small patch can be applied.

Soils

The natural undisturbed soil of the site is a heavy clay derived from dolerite. Its agricultural qualities and some of its physical characteristics are noted in Table I. Most of the information in this table is derived from Beater (1957).

TABLE I

Soil derived from	Water holding capacity	Drainage	Ability to work	Natural productivity	Actual pH	% Organic Matter	Clay
Dolerite	45%	Free	Difficult	High	5.0	3—5	40—78%
Recent Red Sand	25—30%	Free to excessive	Easy	Moderate	6.2	0.3	6— 8%
Table Mountain Sandstone ..	25%	Free to excessive	Moderately easy	Moderate	4.9	0.9	5—15%

The three disturbed soils were respectively a Recent Red Sand, a coarse sandy loam derived from a Table Mountain Sandstone and the disturbed natural dolerite of the site. Their characteristics are also noted in Table I. Each occupied one third of one side of the laboratory so that eight windows were available for observation of growth in each soil

The disturbed soils were excavated in six-inch layers and transported to the laboratory site, where they were relaid against the side of the laboratory in the natural order of occurrence of these layers in the undisturbed soil. The total depth of these soils was seven feet and they rested on the natural subsoil of the clay. They extended a minimum distance of 15 feet from the side of the laboratory. There are no dividers between the soils so roots in border rows are free to move into another soil. All were allowed to settle for at least four months before planting and during this time they were exposed to good rains which kept the whole depth of each soil moist. In addition, they were trampled upon by the labourers during the relaying operations. Fluorescent sands were spread in thin layers at three different depths so that settling could be observed through the windows and could be sampled at a few points distant from the laboratory. The surface foot of the sand and sandy loam quickly assumed a texture (bulk density and macropore space >25/x) closely resembling that of the undisturbed form of these soils, but at greater depths they remained slightly more open than the natural form. The disturbed heavy soil was also lighter at all depths than the undisturbed form except in the surface few inches, where it was the same as the undisturbed soil. As would be expected, the macropore space was much larger in the disturbed clay, by percentage increases ranging from some 30 to 100% depending on depth.

As a result of this arrangement root growth could be compared in disturbed and undisturbed heavy soil; between growth in each of these soils and each of the much lighter sandy soils and finally between the two sandy soils.

Varieties

Two of our best cane varieties (cultivars) were chosen for the first experiments. One was N:Co.376 and the other, N.50/211. The first of these is of upright habit with numerous tillers and thinner stalks than the second, which has a more spreading habit and fewer tillers.

Planting and Spacing

The ground around the laboratory was prepared in the normal manner and all soils received the equivalent of 800 lb. per acre of commercial fertilizer 2:3:2(18). This is approximately 41 lb. of N : 62 lb. P and 41 lb. K per acre. It was spread in the planting furrow. All setts were planted and covered on the same day, the 14th January, 1966; from which time tne experiment started.

The rows were arranged at right angles to the long sides of the laboratory as shown in Fig. I. The exceptions were at three windows in disturbed soils where setts were placed in line across the top of the window in order to study the development of the earliest formed roots. Since the top of the windows was 12 inches below the surface and normal planting depth was about four inches below the surface, the soil near the windows was hollowed out so that such setts were only four inches below the surface. After emergence these hollows were gradually filled in. With one exception the spacing throughout was a standard four feet six inches between rows and the setts were placed end to end in the furrow. Such a spacing, which is slightly wider than the windows, allows the observation of different parts of the root system. For example, if a row is planted at the side of the first window, the next row will be nearer the centre of the next window, and so on. III LIIIo manner observation of root growth immediately below the plant, below one side of the plant or below the interrow can be observed. The only limitation is that the surface roots from about 0-10 inches deep cannot be observed through the windows, but that is remedied by careful brushing or excavation of the surface soil at some distance away from the windows. It is moderately easy in the light soils but difficult in the heavy clays.

The exception to the standard spacing was in the undisturbed soil, where a close spacing of one foot betwen rows was adopted over a distance of some nine feet, corresponding to two windows underground.

At this time growing conditions were excellent, each soil had all the water it could hold under free drainage, and soil temperatures were high. As a result germination was rapid.

Additional treatments

Plants in the undisturbed soil were treated in two ways; three rows of each variety at the normal wide spacing and half the number of rows at close spacing (five in all) received supplementary irrigation in order to keep the soil at or near field capacity to a depth of at least two metres (6' 6"). The remainder of the rows received no additional water, that is, they were grown under the natural rainfall.

All the rows of plants on the disturbed soils were grown under natural rainfall only, with the exception of two rows. One of these rows was in the red sand, where an attempt was made to see if additional water would give even greater growth than that which was being recorded for the rain-grown crop. The other was in the sandy loam, where it was given for the same purpose, but in addition it was used to study the time required to reduce the high concentration of fertilizer salts which inhibited growth of roots near a small patch of fertilizer.

Two small circular patches of fertilizers (commercial 2:3:2(18)) were supported against the windows by the sand and sandy loam soils. The larger was about one inch in diameter and weighed about six The smaller was about half an inch in diameter and weighed about three grams. These were used to study the reaction of roots as they approached relatively high concentrations of fertilizer.

Measurements of environment

The placing of the measuring devices is summarized in Table II. Air temperature, wind run and the carbon dioxide content of air were all measured at the same fixed heights. The instruments were supported on a seven metre (23 feet) high mast in the growing cane and were arranged to lie across the prevailing winds in order to minimise turbulence from the mast and its supports. The thermocouples were protected from direct radiation by multi-disc reflective screens of the van Bavel (1963) type. They also served to shield the air intake points of the infra-red gas analyzer used for the CO_a measurements. All wiring and piping was carried in large-bore water-piping laid deep underground (at least two metres (6J feet)) and well beyond the range of roots and tops measured during the experiment.

Subsidiary, lighter extensible masts carried other thermocouples and anemometers for the measurement of leaf and air temperatures and wind run at variable heights.

Soil temperatures and samples of soil air were taken together at each of the selected depths, the insulated thermocouple wires ran in the same tunnel as the fine-bore tubing used to extract the soil air. In the undisturbed heavy soils *6.5* mm. (£ inch) diameter tunnels were drilled horizontally outwards from the laboratory to a distance of 2 metres (6^ ft.). The thermocouples and piping were inserted in position and the tunnels repacked with the soil which had been extracted. A 2 metre steel rod tipped with a carpenter's J inch *(6.5* mm.) bit gave a good clean cut in these soils. The object of this method of placement was to avoid vertical disturbance of undisturbed soils which might affect the movement of soil air. Tunnelling was less successful in the disturbed soils so in these the wires and pipes were laid in position after the soils were settled; they, too, were led through the sidewalls of the laboratory.

All thermocouple measurements were recorded on multi-point recording potentiometers. Oxygen measurements were made on a Beckman E_2 oxygen analyzer, a magnetic device which allows the same sample to be used for volumetric determination of CO_a. The flushing of the longest runs of capillary bore piping and the chamber of the instrument required some 30 cc. of air. The extraction of such large amounts of air at the different depths introduced no detectable error. Preliminary experiments in restricted volumes of soils and at much shallower depths had shown that the micro-organisms in soil stabilise the levels of 0_2 very markedly. A Hilger 6 point infra-red gas analyzer was used for the measurement and recording of the $C0_2$ content of air around and above the crop. These instruments and others such as the wind run and radiation recorders were housed underground in the ancillary chamber to the laboratory. Variations in the distribution of moisture in the soil were measured by meaiis of Boyoucos type gypsum blocks.

TABLE II

		Method	Position	Comment
Soil	Temperature	Thermocouples	depth 15, 30, 60, 100, 200 cm.	Temperature and soil air measurements taken side by side at the same depths and 200 cm. away from the sides of the laboratory.
	O_2	Magnetic analyzer	,, 15, 30, 60, 100, 200 cm.	
	CO_2	Volumetric	,, 15, 30, 60, 100, 200 cm.	
	Moisture	Gypsum resistance blocks	,, 30, 60, 100, 200 cm.	Thermocouples of 20 s.w.g. wire.
Air	Temperature	Thermocouples	height 30, 60, 100, 200, 400, 600 cm.	At fixed positions on arms of a mast.
	CO_2	I-R Gas Analyzer	,, 30, 60, 100, 200, 400, 600 cm.	
	Wind	Anemometers	,, as above except for measurements immediately above growing crop.	
	Moisture	Thermocouples and Assman psychrometers	varied with height of crop	Thermocouples of 36 or 44 s.w.g. wire.
	Solar radiation	Thermopile	horizontal surface—freely exposed	
	Net radiation	Miniature thermopiles	varied	
Leaf	Temperature	Thermocouples	Junction placed in leaf tissue	Thermocouples of 44 s.w.g. wire

Results

As the experiment is still in progress only some of the picture of growth can be presented at this time. At first the growth of roots is discussed separately from the growth of tops, but, later, the conjoint growth of both is discussed in relation to changes in environment.

Roots

Sett roots

In each of the three disturbed soils, setts were planted against the glass at the top of one window, so that growth of buds and roots could be studied.

Sett roots grew rapidly in these well aerated, warm, moist soils, and there were no obvious differences due either to variety or soil. The first of the sett roots started to grow from the root band within 24 hours of planting. However, not all the roots in the same root band started to grow at the same time. Roots were produced in succession over a period of about five days so that roots of different sizes were observed at the same time. Growth in length started slowly at the rate of a few millimetres a day, but it soon became quite rapid. Thus, on the third day after planting, some roots were extending at the rate of about 10 mm. (J inch) a day, while by the fifth day the elongation was 20 mm. (f inch) a day. Average peak growth rates were 24
nearly 1 inch per day. These sett roots quickly developed the much branched thin network so often described in the literature. They are illustrated in Fig. 2,

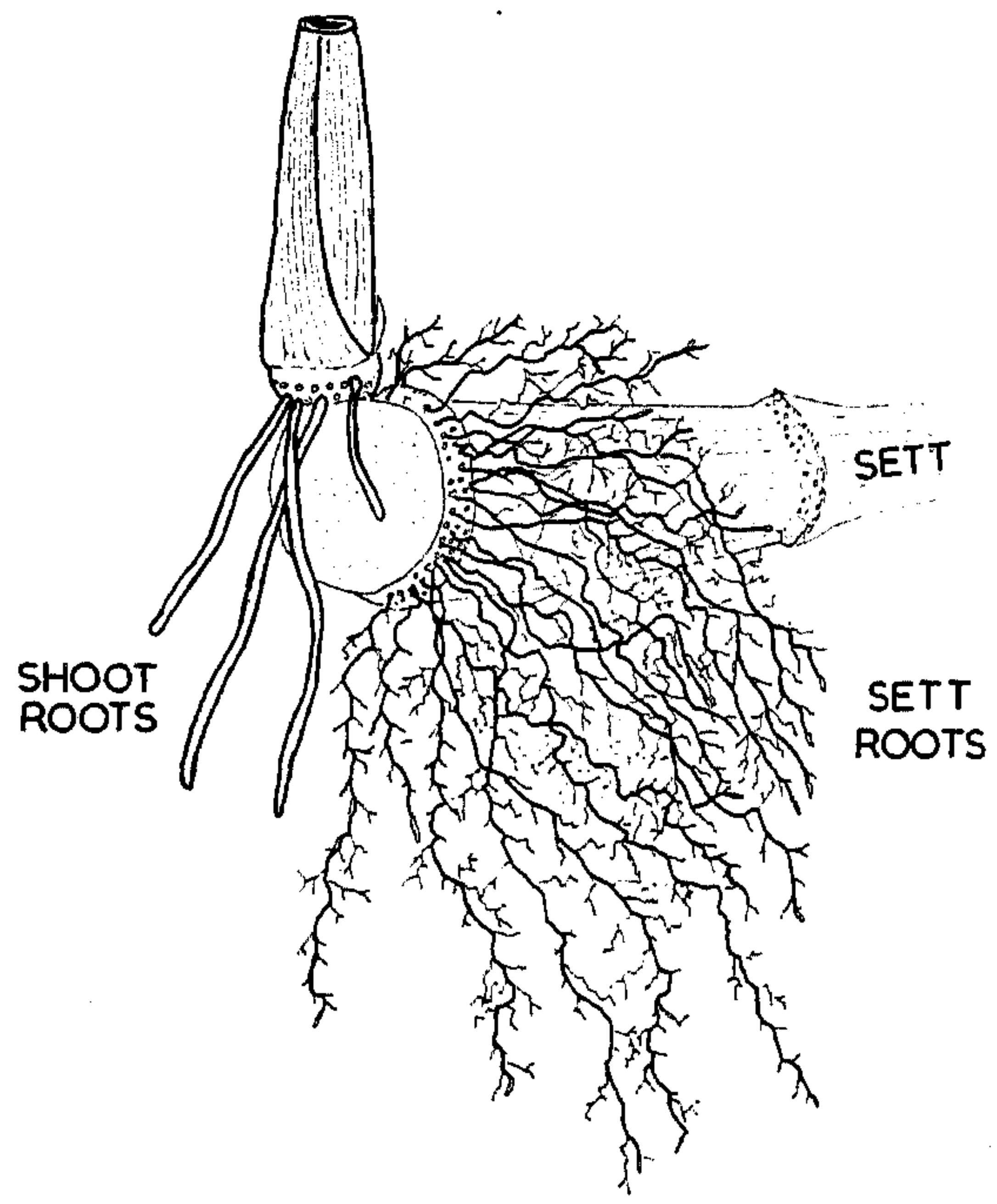


FIGURE 2: The growth of sett and shoot roots following summer planting of varieties N:Co.376 and N.50/211; about 15 days after planting

Growth of the sett roots stopped after a period of about 11 days. At this stage, no significant differences in the development of roots could be found between varieties, their average length being about 8 inches. Extremes in the length of fully grown sett roots ranged from 6 to 10 inches, roots longer than 9 inches being exceptional. On average, N:Co.376 stopped 11.3 days from start, the extremes of the growth range being 6 and 15 days respectively. N.50/211 stopped on average 11.1 days from the start and the extremes of range lay between 7 and 13 days.

By the time the roots were half grown, the older portions had started to develop a pink-brown tinge, indicating suberization. By the eleventh day, this discoloration had spread over most of the root The whole system was in fact a medium reddish-brown colour, flecked with white where late developing roots were still extending. Nearly all growth of the sett roots had ceased by the fifteenth day after planting. By this time, however, shoot roots were growing well, although they were still short.

Subsequent life of the sett roots was brief. They rapidly turned deep brown or almost black in colour, and six weeks after planting only a few could be found in the region they had occupied around the sett. Two months after planting no sett roots could

Shoot roots

As the sett roots elongated, the buds swelled and shoots started to grow. Primary shoot-roots then developed and became visible soon after the sett roots were halt- grown, about 5 to 7 days after planting. These grew slowly at first, as had the sett roots, but the rate of growth increased later. By the time the sett roots had stopped growing, both varieties possessed a number of well developed primary roots 1 to 2 inches long (Fig. 2), but even at this stage, those of N:Co376 were longer than those of N.50/211.

The growth and shape of the root system

The primary shoot roots, which arise from the base of the developing bud, move quickly downwards through the soil, their rate of growth varying with variety and soil. The maximum rate of growth of primary roots of both varieties in light soils was a little over 75 mm. (3 in.) a 24 hour day. But such high rates are only spurts and they are rarely sustained for more than two days. The average maximum growth rates over long periods (10 days) in such soils is about 40 mm. (1^ in.) a day, which is a similar rate to that observed by Hudson (1964) in Barbados. It can be seen from Fig. 4 that growth of the primary root ranged between 29 and 60 mm. a day, during an 8-day period, although the average for this period was 41 mm. a day. In the heavy soils the rates are lower and the average in such soils is about 28 mm. (1 in.) per day and may be less in the heaviest layers.

If this growth of the primary roots is not subject to marked mechanical impedance and if there is adequate soil moisture at all depths in the soil then the whole system of roots assumes a roughly conical shape whose apex is the node or nodes from which the roots arise. Significant development of secondary and tertiary branches does not occur for some time, so that while the soil may be penetrated to a considerable depth during the early stages of root growth, it is not well occupied at this time (Fig. 3). This type of root system is normally quite adequate for young plants, but if there is a drought, then varieties with shallower penetration and poorer branching will be more quickly affected. In this case, the primary shoot roots of N.50/211, which pene-

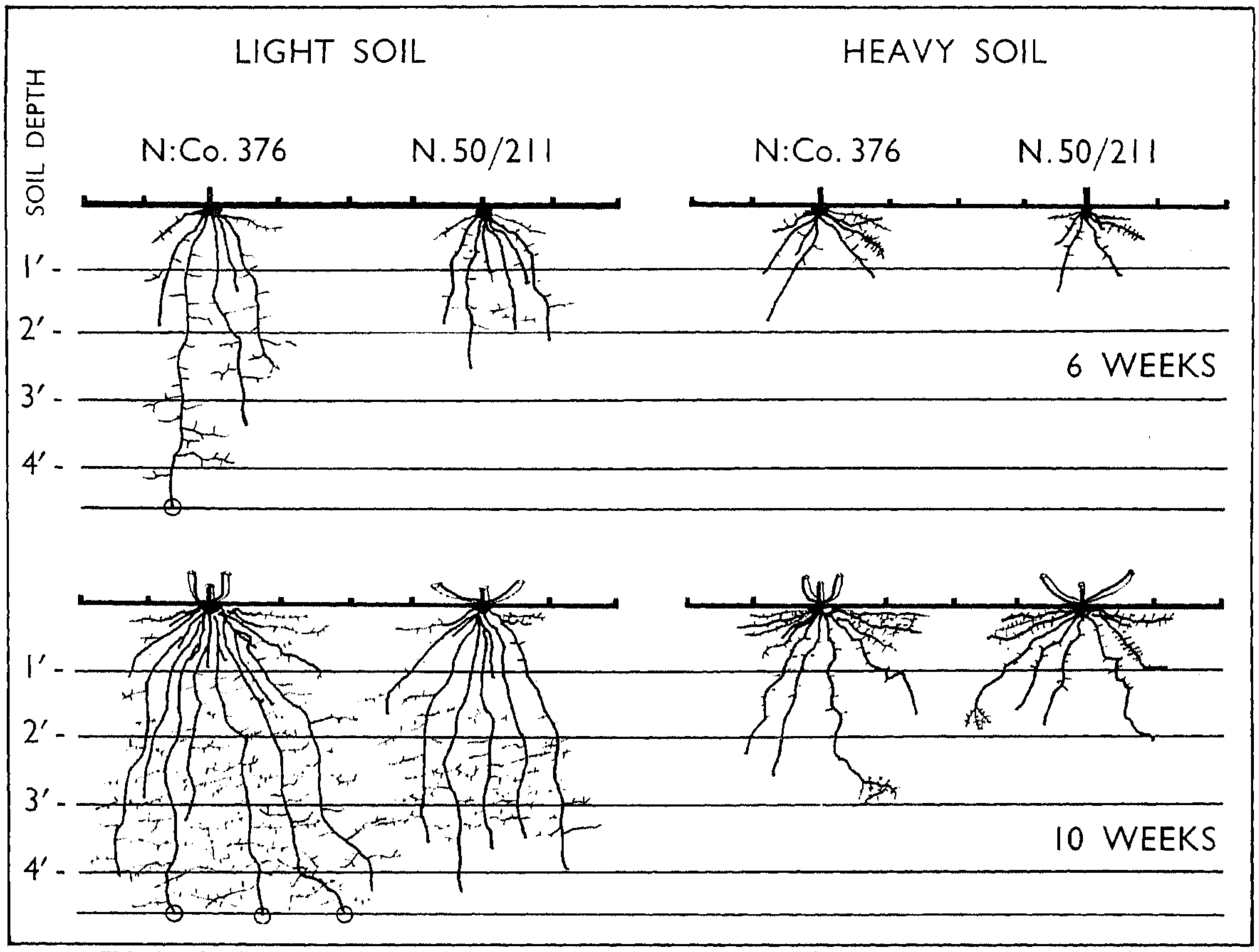


FIGURE 3: The early growth of roots of both varieties in light (sand, sandy loam and disturbed dolerite) soils and a heavy (undisturbed dolerite) soil

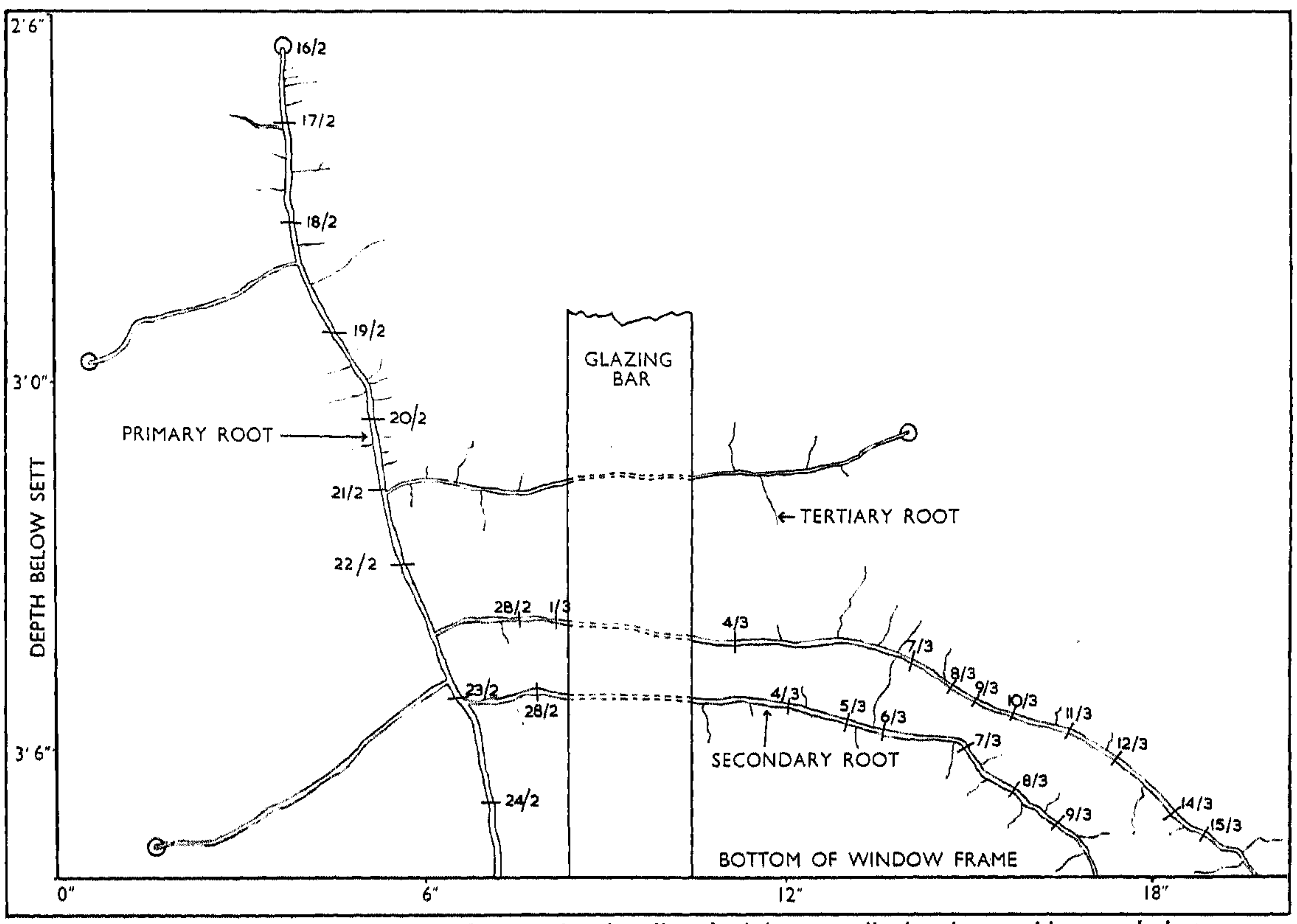


FIGURE 4: The later growth of roots in the disturbed heavy soil showing rapid growth but moderate branching

trate the soil more slowly than those of N:Co.376, are responsible for the known susceptibility of N.50/211 to drought during its early growth in certain heavy soils. The advantages of early, quick growth seem to lie not only in the fact that the roots go deeper in a given time and can therefore tap more water, but also because secondary and further branching starts earlier and gives better support to the developing shoot.

Where marked mechanical impedance of growth occurs the roots tend to develop sideways, particularly in the lighter, loosened soil at plough depth. In extreme cases a flattish disk of roots only a few inches deep may develop around the plant. Such a superficial system may even be found in the light soils, but such shallow development results from moisture stress, not because there are specialized roots which will only grow sideways and not downwards. The light soil may be initially dry or it may be dried out by early deeper penetrating roots. If it is remoistened only by light showers, which are more common than heavy penetrating rain, then the roots will develop only where the moisture lies, that is, in the superficial layers. In other words the shape of the root system in soils where there is little or no mechanical impedance depends on the moisture regime at different depths during root development. The root system of these South African cane varieties seems to be a fairly plastic system and it apparently has no constant shape. In the lighter soils (including the disturbed heavy clay) it assumes a conical form, whereas in the heavy soil, in which there is more mechanical impedance, it is of more spreading habit.

Although, at first, the roots of N.50/211 grew more slowly than those of N:C376, they attained the same average maximum rate of downward growth at a later stage. Nevertheless, N.50/211 always lags about two to three weeks behind N: Co.376 during its early growth, and the relative differences in the rate of root growth were maintained in all the soils examined (Fig. 3). This is apparently an inherent varietal difference.

Root thickness

In the light sandy soils, the primary roots rarely exceed 2 mm in diameter and when they are well extended they branch prolifically. In contrast, in heavy clay, these roots are usually 3-4 mm. in diameter and for much of their length they carry only a few stubby branches. When, as sometimes happens, a lighter patch of soil is encountered, these thick fleshy roots change in appearance and become thinner and relatively well branched.

The diameter of the primary roots is apparently a reaction to ease or difficulty of soil penetration. This was well illustrated by the development of roots in the undisturbed heavy soil. As shown in Fig. 3, the roots which developed in this soil were few in number, thick (3-4 mm.) and relatively unbranched. They penetrated downwards very slowly by comparison with roots in the disturbed soils. However, when they reached the well-defined subsoil some 105 cm. (3| feet) below the surface a transformation occurred. They became thinner and much more strongly branched, although not as vigorously as the roots in the sands or the disturbed heavy soil. This transformation was seen in all the 24 windows on this soil. It first showed in the windows of the irrigated sections, where root growth was slightly faster than in the soil exposed only to natural rainfall. But a little later even the roots in the unirrigated soil showed the same effect. Thus the change in form of root was consistent, irrespective of variety, spacing or available water. Further, the change was not an artifact induced by the thin layer of powdered packing soil behind the windows, for, if that was responsible for the effect, then one should see similar branching in the upper layers and it was practically absent at shallower depths. Finally, as the later shrinkage of the unirrigated soils away from the windows allowed the powdered soil to drop away, the change could be clearly observed in the natural soil. Thus it appeared to be a real change and probably due to some change in the physical or chemical nature of the soil. An investigation of the records of earlier analyses of this type of soil showed no obvious connection between root form and chemical or physical measurements except that it might be connected with clay content at different depths. So a re-examination of a new profile of this soil was carried out by the Soils Section of this Station. The excavation was made at a point about 90 metres (100 yards) away from the root laboratory. Their subsequent report is much too detailed to be included in this paper but the relevant conclusions (von der Meden 1966) are as follows:

"(1) The behaviour of the roots correlates very closely with the penetrability of the soil (as indicated by the number of hammer blows required to drive the core sampler).

(2) The penetrability appears to correlate with the proportion of clay down the profile. The relative proportion of 2:1 and 1:1 clays has little influence on this.

(3) The influence of the moisture profile on the root pattern has been slight.

(4) Bulk density is not a factor in controlling the differential root behaviour."

Figure 5 shows the pattern of root growth in this soil and superimposed on it is the graphical record of apparent penetrability.

Monteith and Banath (1965) have observed a similar correlation between root growth of sugarcane in pots of prepared soils and penetrometer measurements; while Tackett and Pearson (1965), discussing the penetration of compacted soil cores by cotton seedling roots, remark that mechanical impedance of compacted zones restricts penetration and proliferation. Further, Taylor *et al* (1966) suggests that a specific change of soil strength will cause a specific response of underground plant parts providing some other growth factor does not become limiting. The observed transformation of diameter and branching as the cane roots moved into the lighter sub-soil would seem to lend support to this conclusion.

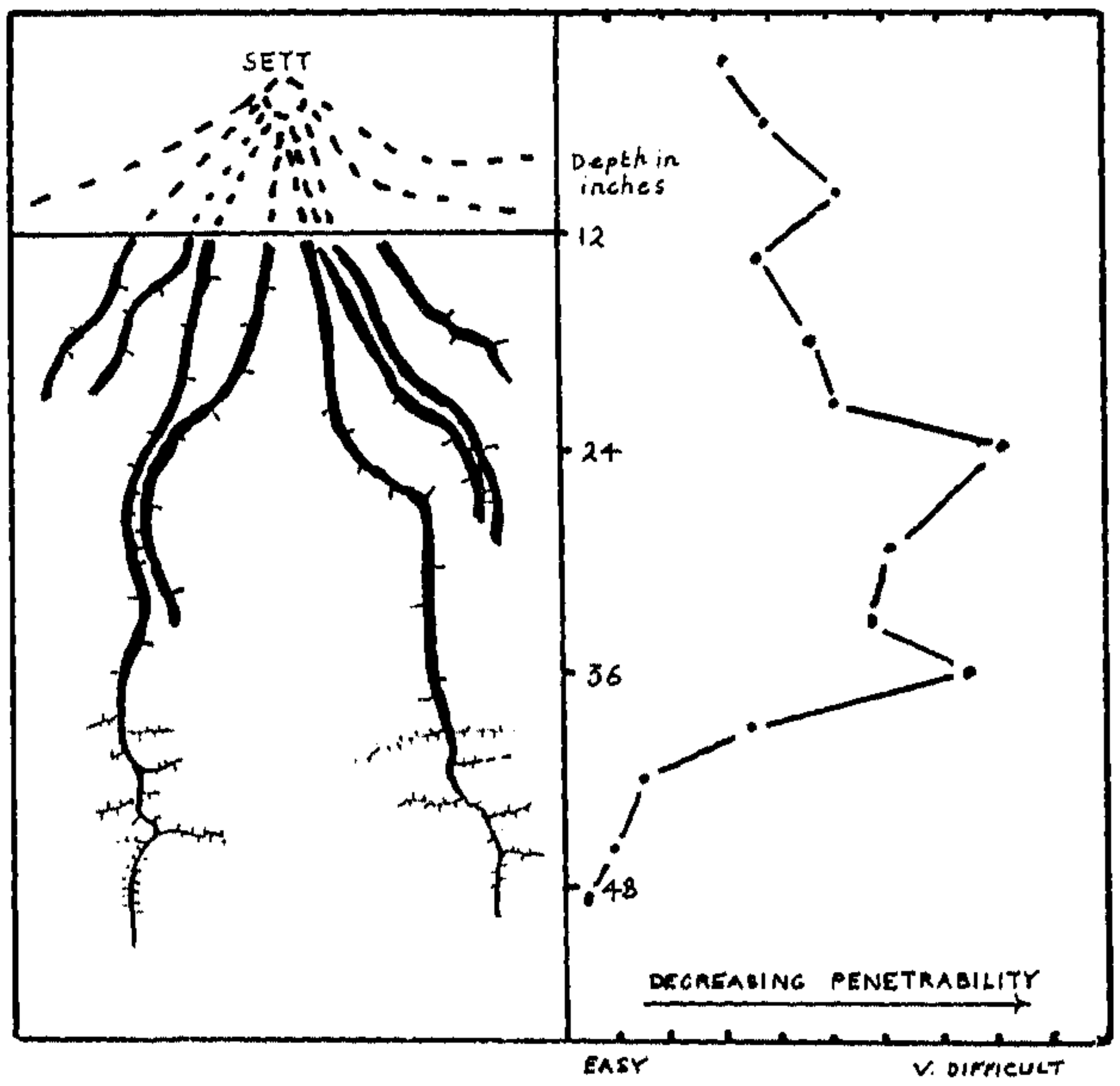


FIGURE 5; Roots in the undisturbed heavy soil and the measured penetrability of this soil at different depths showing the transition of root form at about 100 cm (39 in.) as the soil becomes lighter

The thick relatively unbranched roots which develop in the heavy soil are apparently the "buttress" roots described by Evans (1935). They are ordinary shoot roots which have thickened as a reaction to mechanical impedance. The "rope" roots described by Evans (1935) also occur in this soil where a crack or line of weakness is being exploited by two or more roots at much the same time. Usually the first root exploits the crack and as it ages and becomes furrowed a succeeding root exploits the free space. The largest rope system observed in this soil was one of three primary shoot roots whose intertwined branches produced the characteristic "rope".

No rope roots were found in the light sandy soils. In these soils branching and rebranching by the roots of both varieties was so prolific that no diagram could adequately represent the scene. Such soils are so occupied by fine hair-like roots that every cubic centimetre appears to be exploited.

The roots in the disturbed heavy soil are intermediate in form, leaning more towards that found in the undisturbed heavy soil. The main shoot roots are nearly as thick as those in the undisturbed soil but they branch more prolifically and produce many of the long branches such as are shown in Fig. 4. As a result the exploitation of this soil appears to be intermediate between the prolific exploitation of the sands and the relatively poor exploitation of the undisturbed heavy soil The roots of both varieties grow quickly downwards, nearly as quickly as those in the 'sands.

Root hairs

Turgid root hairs have been observed to persist on roots for periods of up to four months, that is, even when the roots are so aged that they had become furrowed. Similar results have been reported by Evans (1938) and Artschwager (1925),

Branching

In all the soils the branching of the roots of both varieties was always approximately at right angles to the parent root, irrespective of the direction of the parent root. The only exceptions to this were caused by mechanical impedance. Even when a new branch root is impeded by the window glass and is deflected it maintains its rectangularity. Photograph 1 shows this effect as seen in the heavy undisturbed soil and it is also shown in Fig. 4. In the light soils where branches are easily formed, this rectangular system leads to the intensive exploitation of the soil.

In the spring a few old roots which had apparently stopped growing produced a few new branches. One, at a depth of 40 inches, had been cut by an insect some 160 days earlier. It produced three branches several inches long which were well covered by turgid root hairs.

Tops

The height of plants, as measured from the top of a six inch marking peg in the ground to the first visible dewlap, were recorded at weekly intervals. A number of stools, ranging from three to seven, were chosen at random for each variety in each soil and in each treatment, except in the close planted cane, and a detailed record of the height and number of stalks in each stool was maintained.

The interpretation of such growth records is made difficult by the fluctuating population of stalks throughout the year. Averages, in particular, are subject to wild fluctuations as some stalks die and others grow just above the marker pegs and are included in stalk numbers for the first time. Thus it is possible to record negative average weekly increments in growth because short new stalks are included and, at the other extreme, wildly exaggerated increments may be obtained because some small stalks die.

In order to ameliorate this situation and to try to follow the weekly increments of growth in more regular fashion, it was decided to concentrate on the incremental growth of the three largest stalks in each stool. This offers a certain security which is lacking when the growth of all stalks is considered. As so happened less than two per cent of the tallest stalks, first chosen when the plants were small, have died during the experiment to date. Yet, even when one has been lost, a neighbouring stalk of slightly smaller height on the same stool has been automatically included in the record without serious loss of accuracy. Again a few of those which were originally the tallest have been surpassed by others but the transfer of measurement to those too, involves no loss of accuracy. It is recognised that such a method provides only one aspect of incremental growth; nevertheless it provides a consistency which is lacking in methods involving average growth of all stalks and the data which it provides are more satisfactory for correlation studies. The smoothing effect is shown in Fig. 6.

In addition the average apparent total growth in length of all living stalks in each stool is presented,

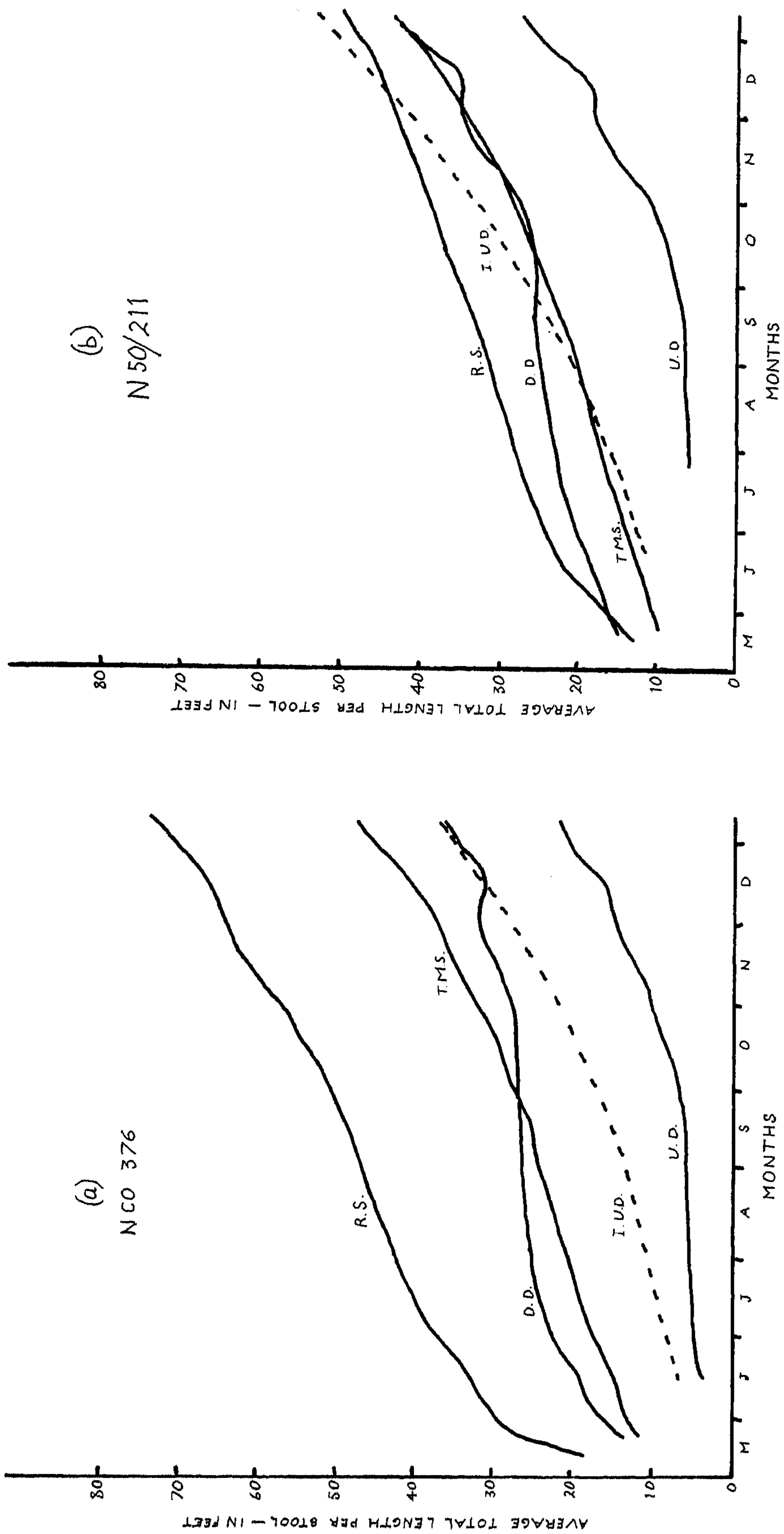


FIGURE 7: (a) N:Co.376 and (b) N.50/211 showing the average length of stalk in each stool on each soil. The continuous lines denote the rain-grown plants; the dashed lines the irrigated plants. The letters are as in Figure 6

Figures 6 and 7 show the weekly records of average height of the three tallest stalks and the average total length of stalk in each stool on each soil. In like manner figures 8 and 9 show the average weekly

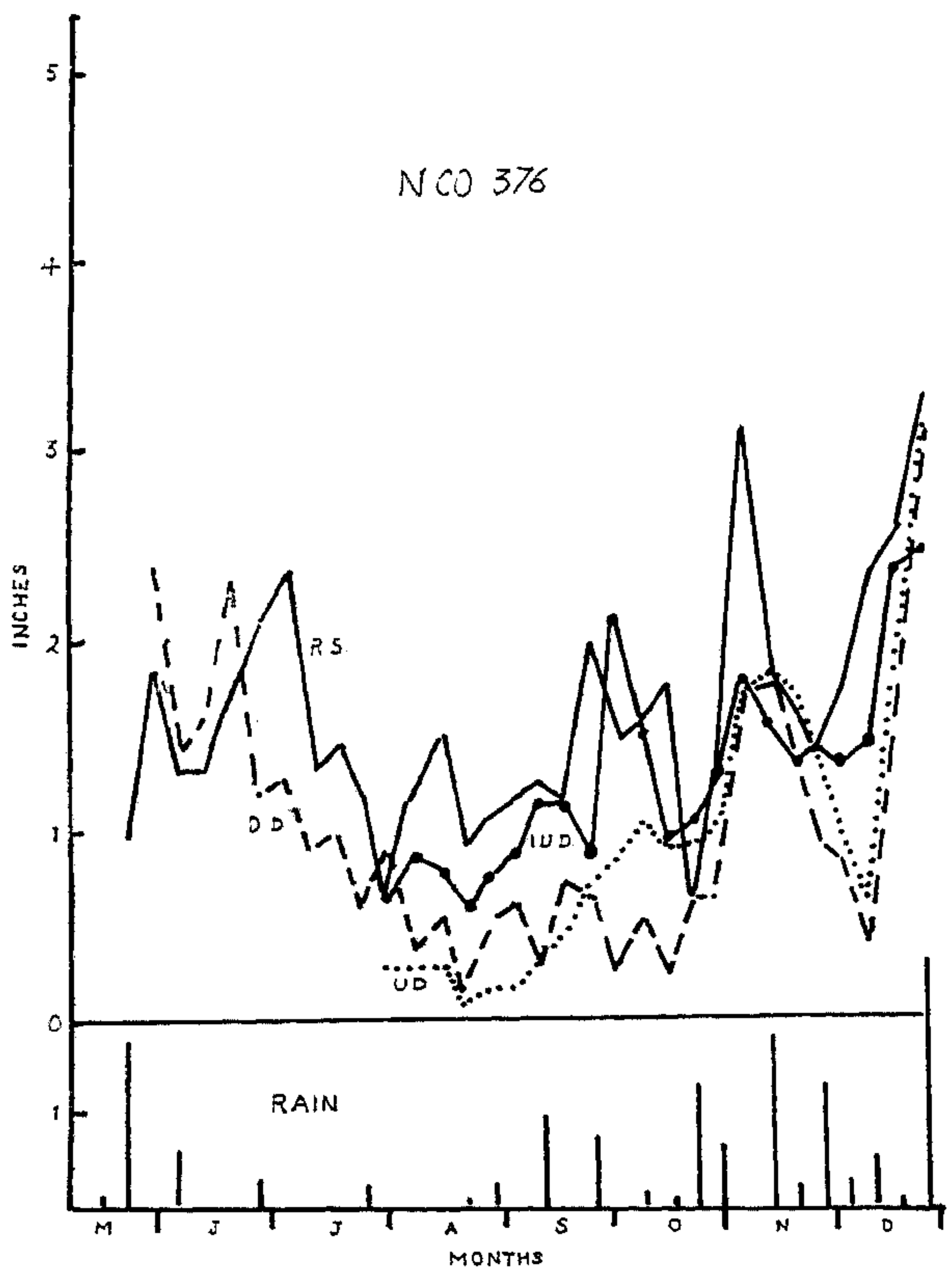


FIGURE 8: The weekly increments of the average height of the 3 tallest stalks in each stool of N:Co.376, together with the total rainfall for the week before height measurement. The dashed lines indicate that the plants on these soils suffered from drought at certain periods. The records for the Table Mountain Sandstone have not been included. They are similar to, but lower than, those for the *red* sand

increments in growth of the three tallest stalks, while Figures 10 and 11 show the average number of stalks per stool. They illustrate the following points:

Tillering

As would be expected from our knowledge of the varieties, N:Co.376 produces more stalks during early growth than N.50/211 on all the soils except in the rain-grown crop on the undisturbed heavy soil.

N:Co.376 grows many tillers early in life, but many of these die so that by the end of a year from planting the difference in stalk number from N.50/211 is greatly reduced. The loss of stalk by N: Co. 3 76 confirms, on an individual stool basis, the results obtained on a crop basis by Thompson and du Toit **(1965).**

Although differences in tillering due to the type of soil on which the plants are grown are very marked in early growth they are greatly reduced in N:Co.376 by the end of the first year. This effect, too, is less well marked for N.50/211 but is still apparent. How-

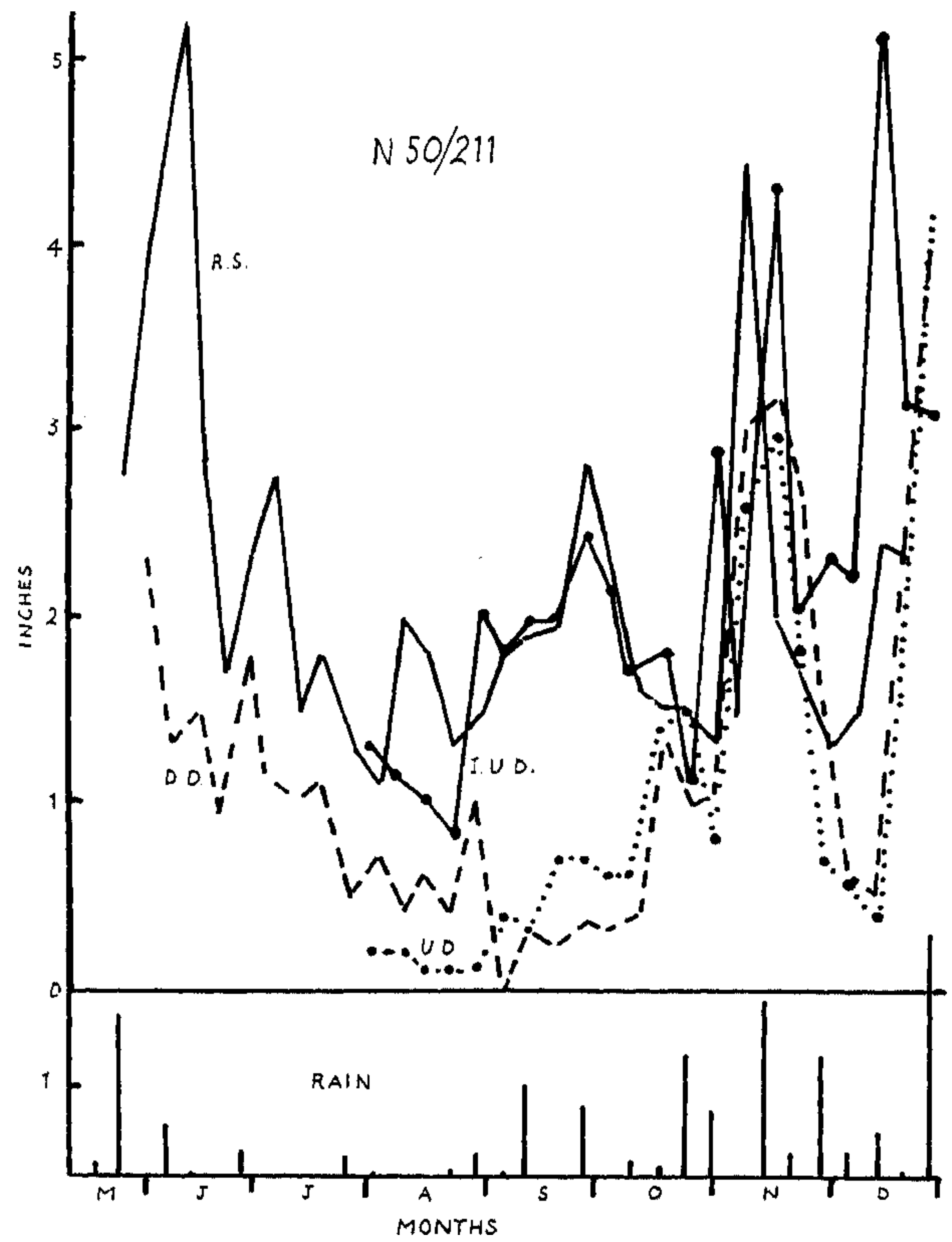


FIGURE 9: The weekly increments of the average height of the 3 tallest stalks in each stool of N.50/211, together with the total rainfall for the week before height measurement

ever, at the end of the year there is still, for this variety, a difference which might be attributed to the nature of the soil. For example, tillering on the heavy soil is still higher than on the sand and sandstone. As the experiment proceeds more will be learned about this.

Height

Perhaps the most impressive feature of a visit to the root laboratory is the very marked difference in

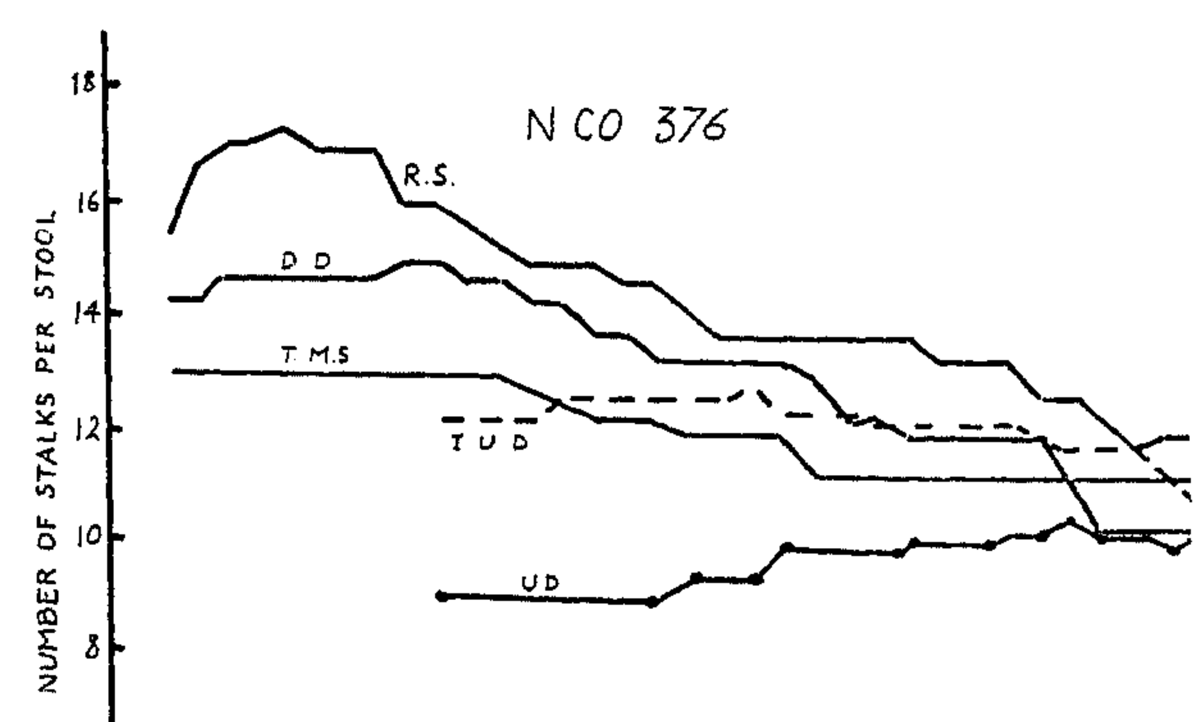


FIGURE TO: The weekly average number of stalks per stool of N:Co.376 in the different soils. The dashed line indicates the irrigated soil

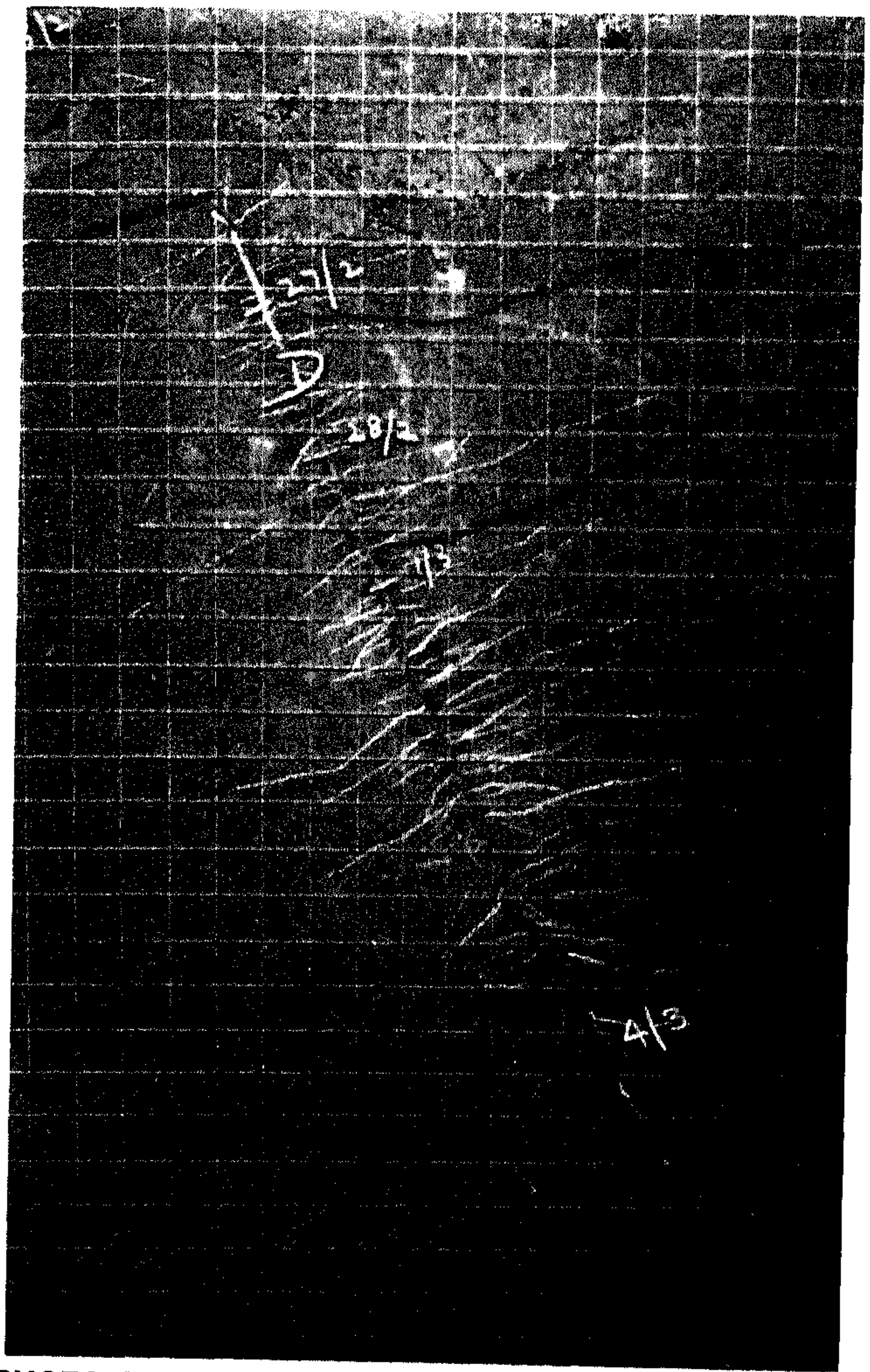


PHOTO 1: The branching of roots at right angles

heights of the plants grown on the different soils. They are reflected in the figures and in photograph 2 As they arise from differences in root development and exploitation of soil moisture they will be commented upon in greater detail later. However, the following points are manifest, after one year's growth which included a dry winter season.

(1) As would be expected, N.50/211 produces taller cane on all the soils.

(2) Of the *rain-grown* plants, the growth in height of both varieties on red sand has consistently and markedly exceeded growth on any of the other soils. Growth on the disturbed heavy soil was next in order until the plants were affected by the severe mid-winter drought lasting for many weeks. Growth on the sandy loam was next lower until it exceeded growth on the heavy soil in the case of N.50/211 at the end of July and of N:Co.376 in mid-September. This difference in time is almost certainly due to differences in root development since the early growth of roots of N.50/211 is slower than those of N:Co.376 and more soil is exploited for moisture by the latter. The lowest height of all was attained by the plants on the undisturbed soil. This was certainly due to the slow growth of roots in this soil which were unable to extend fast enough into the deeper layers where there was plenty of available water.

(3) The *well-irrigated* plants of both varieties grown on the undisturbed heavy soil are shorter than the rain-grown plants of the red sand and sandy loam and in the case of N:Co.376 even below the height of the drought slowed plants on the disturbed heavy soil. Only the irrigated N.50/211 on the undisturbed soil has exceeded the height attained by this variety when rain-grown on the disturbed version of this soil. This is a further reflection on the slow growth of roots in the heavy soil.

As would be expected, the irrigated plants of both varieties on the undisturbed soil are much larger than their rain-grown counterparts.

As will be shown later, all these differences in height can be linked to differences in root form and extension and the consequent exploitation of soil moisture stored in the different soils, as well as to seasonal changes in rainfall and climate.

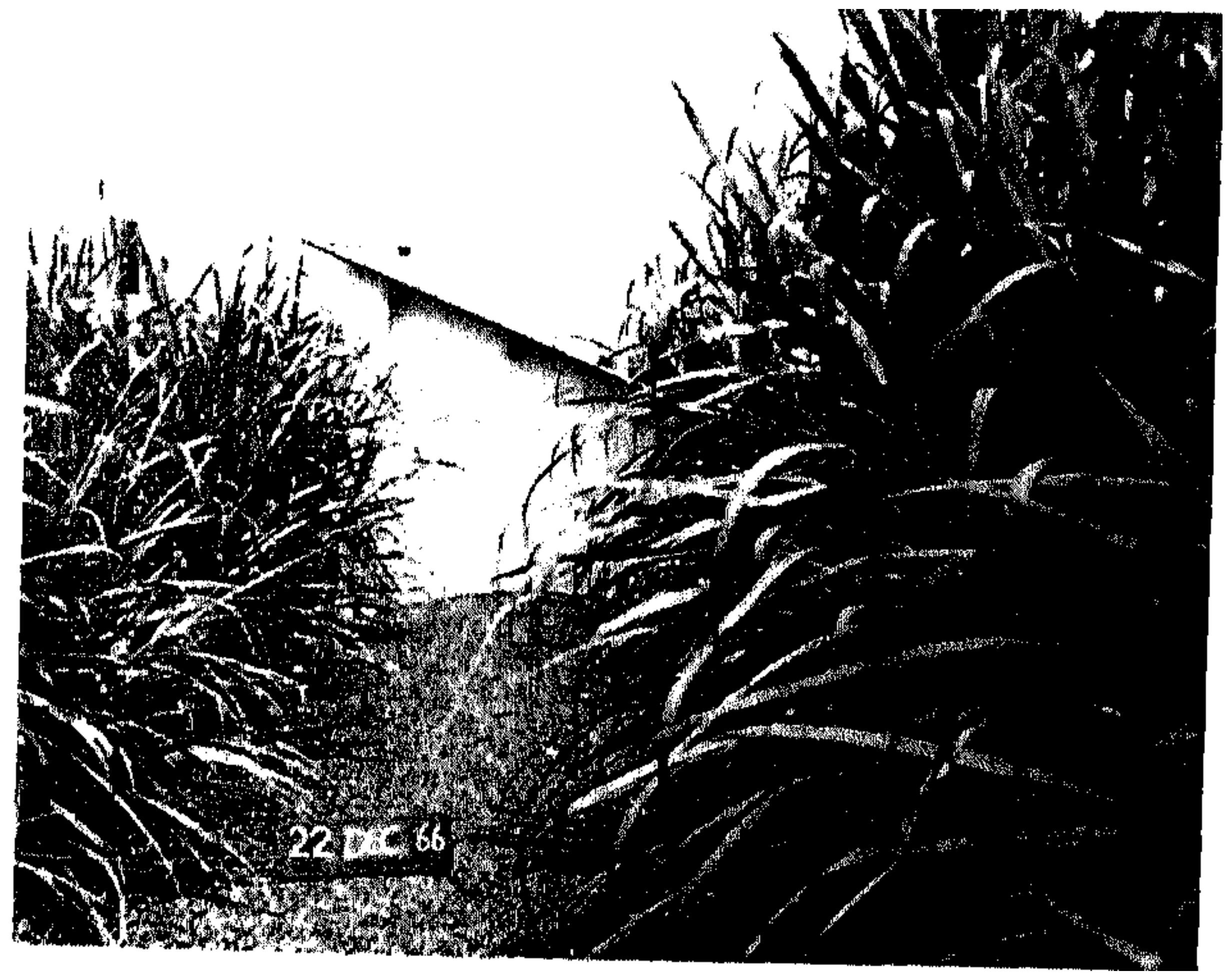


PHOTO 2: The difference in height between rain-grown plants on red sand and on the heavy clay. The plants on *red* sand are much the taller

Average total stalk length

The average total stalk length of both varieties in the different soils under *rain-grown* conditions follows fairly closely the same pattern as the average height of the three largest stalks although there are minor differences. Total growth on red sand continues to be higher than in any other soil, while early growth on the disturbed dolerite was better than on the sandy loam although later the positions were reversed as drought developed. Again, least growth is found on the undisturbed heavy soil

A difference in the behaviour of the varieties emerges on the *irrigated* soil. As with stalk height, the total length of the stalk in each stool of N:Co.376 is less on this soil than on the sandy soils or the disturbed heavy soil However, with N.50/211 the total stalk length has now at the end of a year's growth exceeded that on red sand. This results from the longer retention of tillers by this variety on this soil at this time. There may be changes later as the stools age. Reference to Figure 11 shows that each

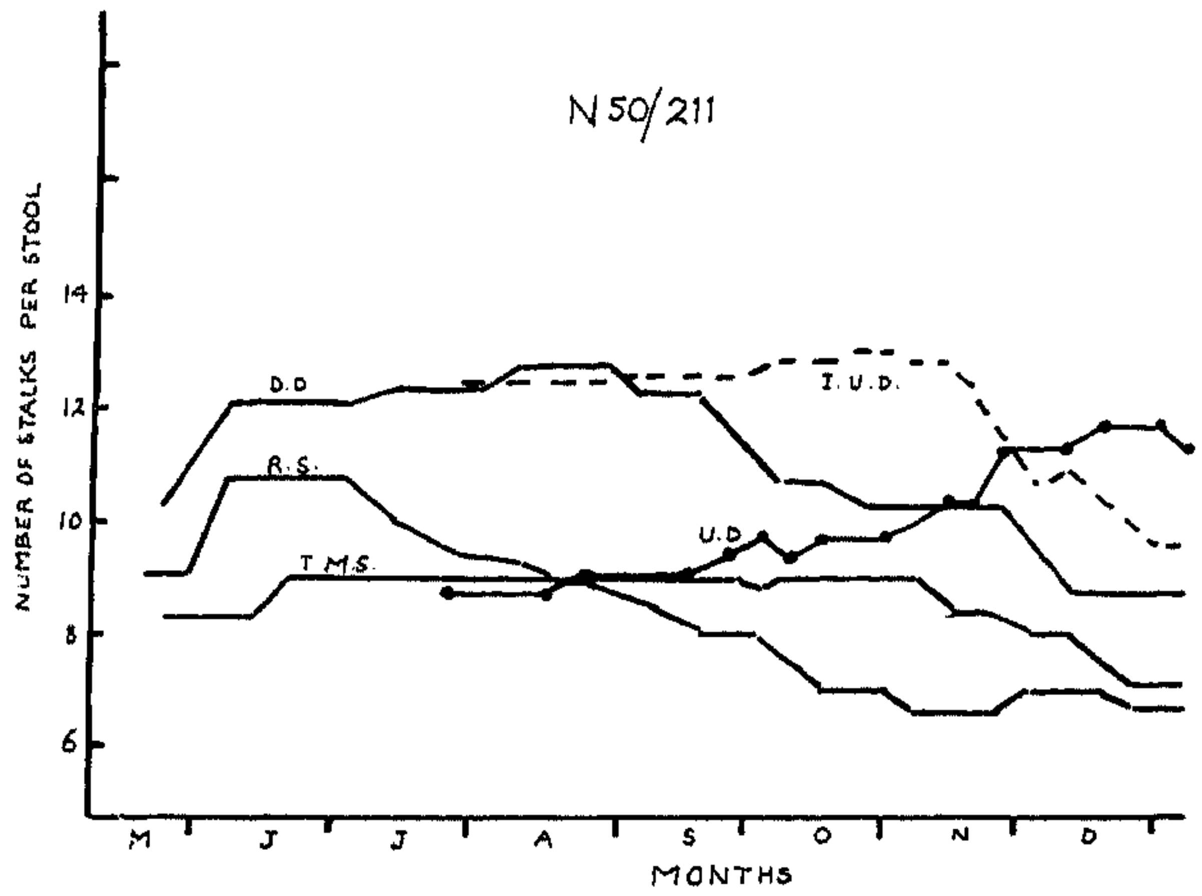


FIGURE 11: The weekly average number of stalks per stool of N.50/211 in the different soils. The dashed line indicates the irrigated soil

stool has on average at least 1J more tillers in the heavy soil than in the sand and, although the tillers are shorted in the heavy soil, the extra number produces a greater total length.

As already mentioned, for stalk height the differences in total stalk length are caused by differences in environment.

Growth in Relation *to* Environment

Because it is the interaction of all the environmental factors which determines the growth of the crop either above or below ground, a series of multivariate analyses will be required to elucidate the relative importance of each factor and these will take a considerable time to complete. Nevertheless, the winter drought has provided such marked differences in moisture patterns in the soils that some of the effect of soil moisture on root growth is so immediately obvious to the eye that no recourse to statistics is required to elucidate its significance. Again the seasonal change in air temperature is sufficiently wide to demonstrate the effect of temperature on the growth of tops. So these preliminary, simple patterns are discussed below.

Before starting this discussion the following points must be emphasized. The first is that only a sample of root growth can be obtained by measurements within the areas covered by the windows, that is from about 20 cm. (8 in.) below the sett in the furrow to a depth of 142 cm. (56 in.) and no regular daily or weekly measurements could be made near the surface or at depths below the window. Further, the measurements were made only on the primary shoot roots or their first branches, the secondaries, because the measurement of the fine tertiary roots and others was impossible, particularly in the sandy soils, where they are most prolific.

The second point is that the weekly increments in root length, such as are used in the following discussion, do not adequately represent the state of the absorbing system. While new roots are likely to be the more effective absorbers there is no doubt that older roots can absorb from the soil, if only in some lesser degree. Again, for obvious reasons there has been no measure of the effective absorbing surface of either old or new roots so it must be emphasized that where the word "root" appears in the following discussion it refers only to the growth in length of new primary and secondary roots.

In spite of these restrictions it has been possible to obtain results which correlate with plant growth in general. Figure 12 shows the average weekly

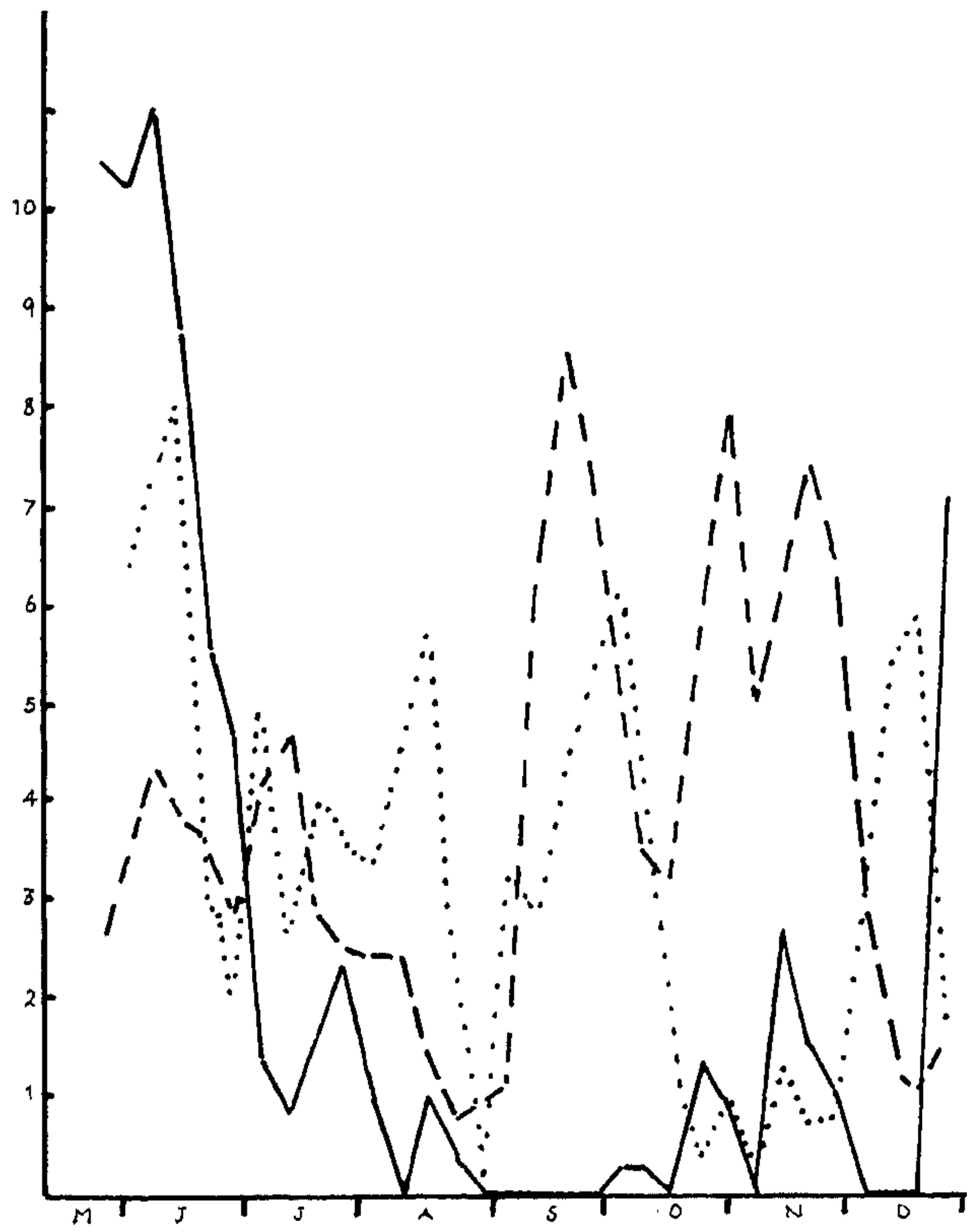


FIGURE 12: Weekly increments of root length by N:Co.376 in sand (———), disturbed heavy clay (——) and irrigated heavy clay (......)

growth in length of roots in different soils of varying moisture content, ranging from an adequate supply in the irrigated soils to a dearth in a completely dried out soil (to wilting point or beyond at all depths to 2 metres (78 in.)). The period is from the 17th May to the end of December (about a year after planting). The full records are available, but the start of this period was chosen to coincide with the start of stalk height measurements in May.

It can be seen that, in the sandy soils and the irrigated heavy clay, root growth was continuous throughout the period, which included our colder winter months, whereas in the disturbed and the unirrigated heavy clay it was halted for long periods. It was the amount of moisture available in the region of the roots which caused most of these differences, not low soil or air temperatures, for, although there were differences in the soil temperatures as shown in Fig. 13, growth of tops and roots during winter was forms of this soil, for such growth is much more vigorous and extend to a greater depth in the same time, in the disturbed form.

The effect of soil moisture on the growth of the

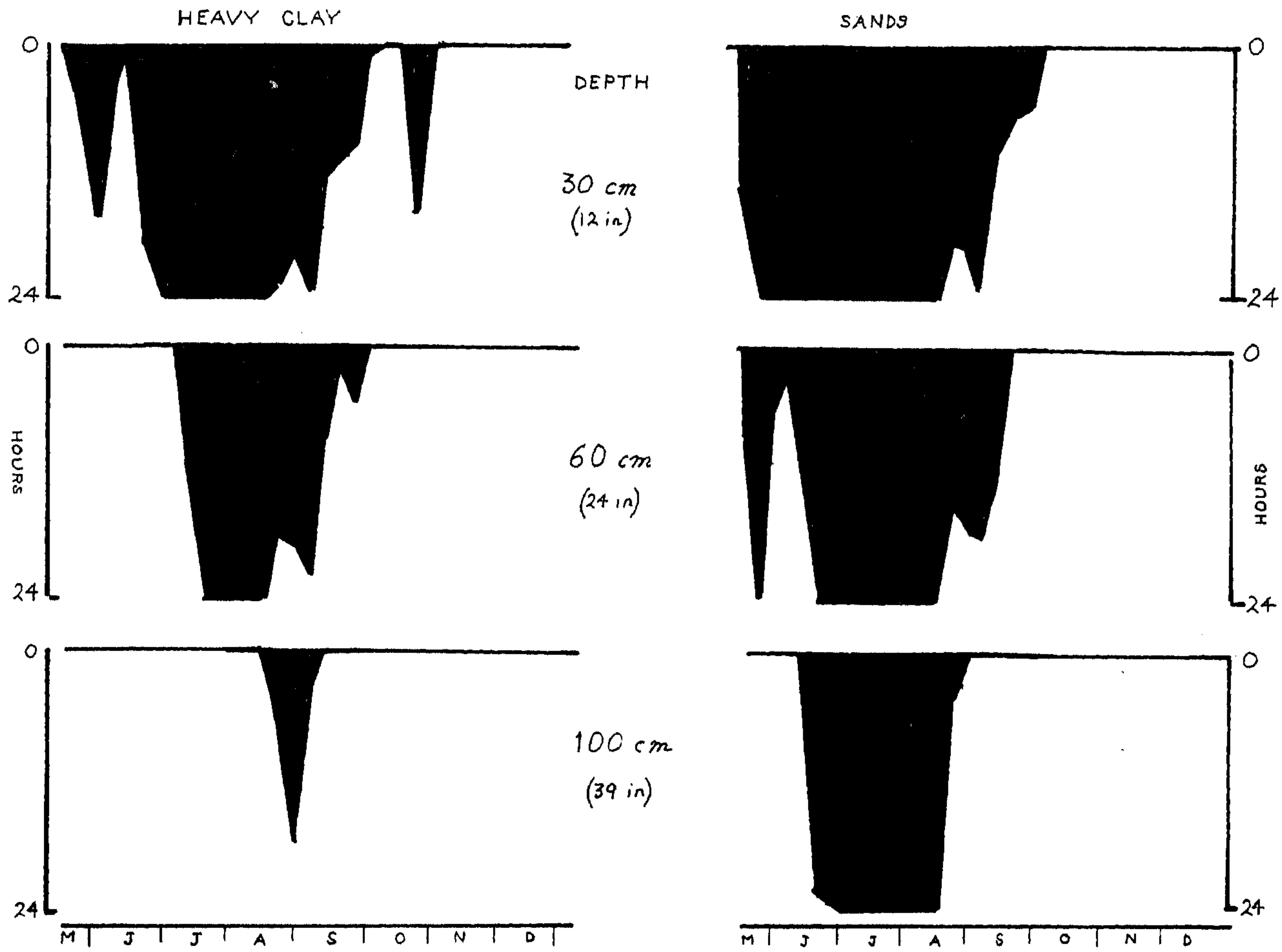


FIGURE 13. Weekly averages of hours per day when the soils were cooler than 18°C (64.4°F). The sands carry the more vigorous plants and shading of the surface started sooner than in the heavy clay

actually greater in the colder light soils, while all the plants on all soils were exposed to the same air temperatures. I specifically mention "in the region of the roots" because in one soil, the heavy clay, the roots of the rain-grown crop exhausted the available moisture in the top few feet and, because they could not extend fast enough, could not tap the underlying layers which were at or near field capacity.

Fig. 14 shows this on the two different forms of the heavy soil. The disturbed form was exploited at least to 2 metres (79 in.) and deprived of all available water, whereas the undisturbed soil was mainly exploited to a depth of 1 metre (39 in.) and there was apparently plenty of available water at lower depths.

The available water in the disturbed soil was almost completely removed to a depth of at least 200 cm. (79 in.) by the middle of August, whereas in the undisturbed soil it had only been exhausted to a shallower depth by this time and there was adequate moisture at deeper levels. This, of course, reflects the differences in root growth in the two

roots and tops of these drought-affected plants is clearly marked, for the growth of both is brought nearly to a halt as the soil is depleted of water. However, the growth of roots in response to rain after the initial drying of the soil is less well marked, simply because the rain did not penetrate very deeply, although it went a little deeper in the sand than in the heavy clay. There is no doubt that root growth responded to the rain, but it was largely confined to the surface layers beyond view from the windows. Nevertheless sufficient growth was observed, particularly in the disturbed soil, to indicate the continued correlation of root growth with water, as indeed is shown by the comparison of the spring rainfall with root growth.

Fig. 14(b) also shows another facet of root development, that resulting from the change in form of root when passing from the less to more easily penetrable soil. Thus the exploitation of soil moisture is more rapid at the 100 cm. (39 in.) level than at the 60 cm. (24 in.) level. The former measurement is taken in

L

the transition zone (see Fig. 5) from difficult to relatively easy penetrability whereas the latter is in the "difficult" layer. It would seem, then, that the more rapid exploitation of the lower layer is associated with the more profuse branching of the roots in this region and the consequent increase of absorbing surface.

In the irrigated heavy soil there has been no stoppage of either root or top growth due to lack of soil moisture, as may be seen in Fig. 15(a). Here the relationship between top growth and air temperature is clearly displayed. Air temperature has been measured as degree-hours above 20°C (68°F). The choice of this level is somewhat arbitrary because a similar result could have been obtained by plotting degree-hours above 19°C (66.2°F) or even 18°C (64.4°F). As would be expected then, the increasing air temperatures, as the seasons change from winter to summer, bring increased growth of tops.

This effect of temperature is also well shown in the sand and sandy loam. Fig. 15(b) illustrates it for the red sand. In these soils, water was never a seriously limiting factor, as may be seen by the soil moisture data presented in the same figure, so a similar increase in rate of top growth is associated with rising temperatures. It is worth noting, however, that at no time were air temperatures low enough to inhibit growth completely. Figs. 15(a) and (b) and 6 and 7 show that in the presence of adequate soil water growth of tops could continue at a moderately high rate even in the midwinter and spring of this year in this coastal region. Lack of moisture was the most seriously limiting factor at this time (Figs. 14(a) and (b)).

Although in both the moist soils (Fig. 15(a) and (b)), the relationship between root and top growth is not sufficiently well marked to be obvious to the naked eye in the diagrams, nevertheless it is there to some extent, as revealed by statistical analyses. However, the direct correlation is slight and the

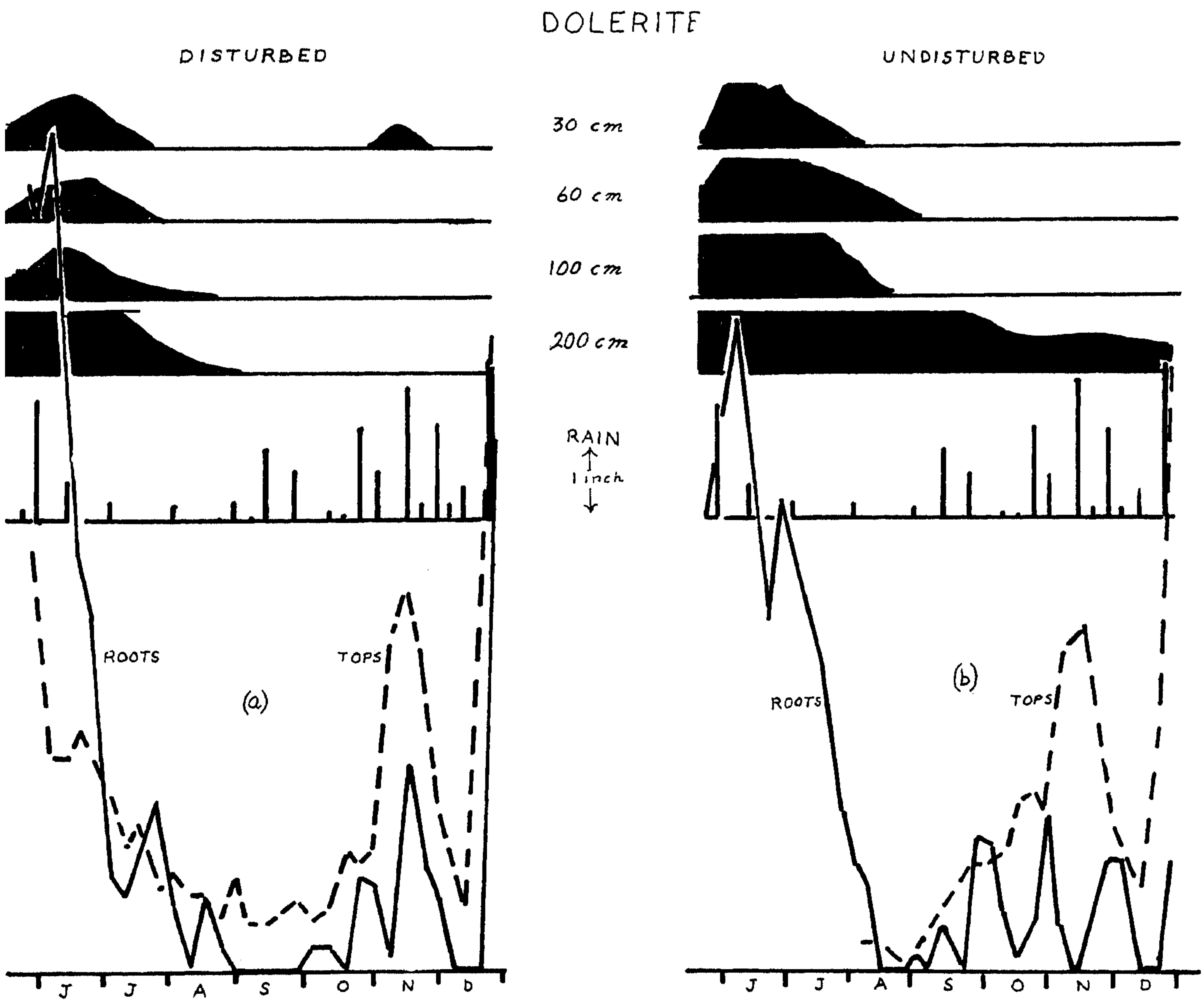


FIGURE 14: (a) and (b). The effect of moisture stress on the average growth of roots and tops of both varieties. In the disturbed dolerite (a) the roots were deep and well branched, but in the undisturbed dolerite (b) they were relatively shallow and poorly branched. The shaded areas represent soil moisture levels above wilting point

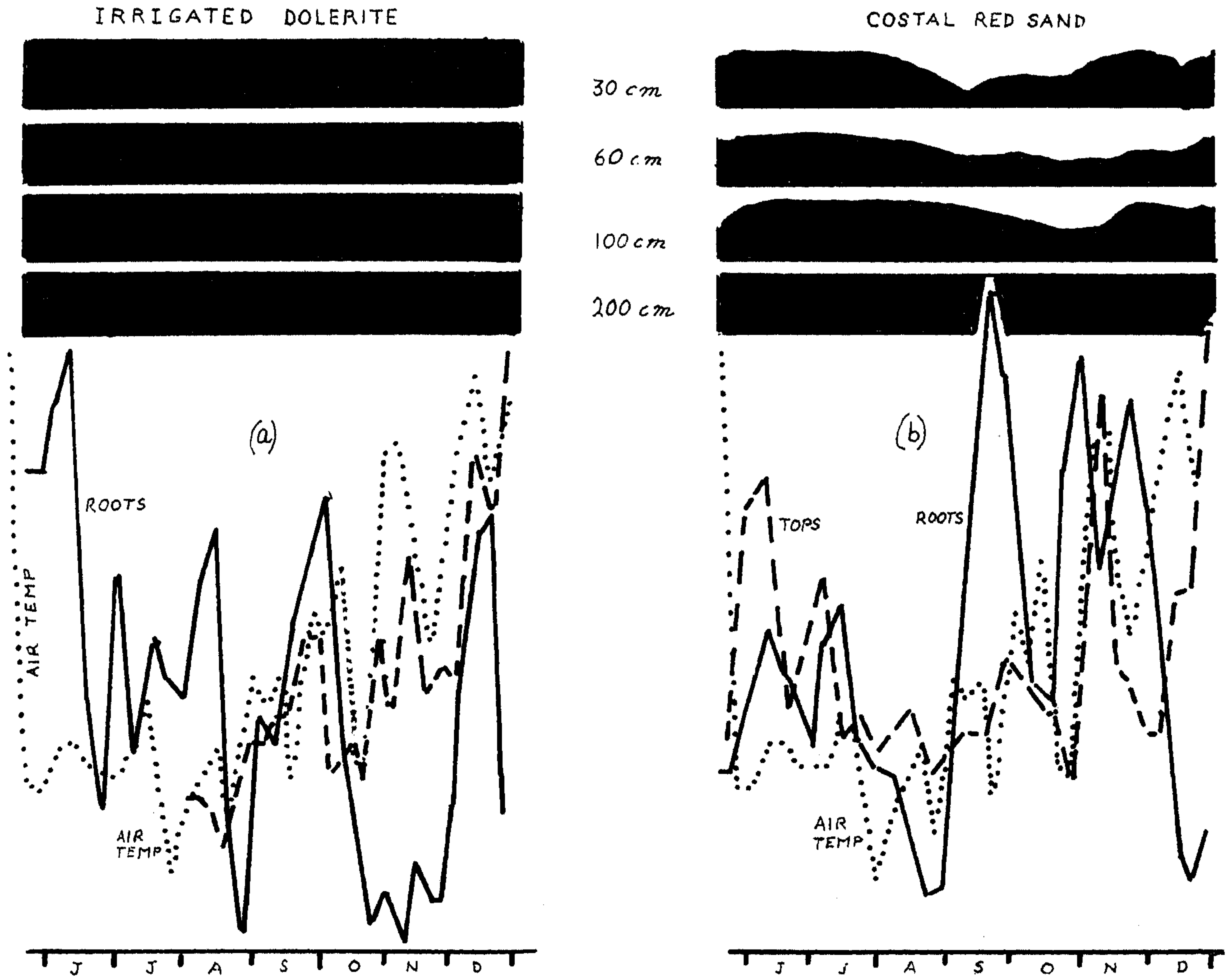


FIGURE 15: (a) and (b). The effect of air temperature (......) on the average growth of the tops (— —) and roots (——) of both varieties in the presence of adequate soil moisture (shaded)

results of the multivariate analysis must be awaited before anything more can be said about it. For example, we must find out why the rapid increase in root growth in the sand (Fig. 15 (b)) from mid-September onwards was not associated with a similar rapid increase in top growth. Perhaps lower air temperatures or solar radiation were responsible for this, for it is noteworthy that at the beginning of November, when root growth was active and air temperatures were consistently high, there was a sharp spurt of top growth, which diminished later as air temperatures decreased. Such a development of roots in excess of immediate needs may be of value during subsequent drought.

Comment on the effects of other environmental factors such as the level of oxygen and carbon dioxide at different depths in the soil must be deferred until the first harvest is taken. However, it is already obvious that even in the heavy soils the amount of oxygen available at depths down to 2 metres (79 in.) was adequate for root growth. Although laboratory tests of the heavy soil showed that anaerobic conditions could be produced at depths of 150 cm. (60 in.) by temporary overwatering yet no such effect could be produced in the undisturbed natural soil. The simple explanation of this was that the soil used in the laboratory was free of ants and other burrowing organisms/whereas the natural soil has many. In consequence the natural soil is better aerated.

Again, a detailed study of air temperatures in and around growing cane shows that even before the leaves close over the interrows the air temperatures during the daylight hours in the partial, or later in the complete, canopy are higher than those of the surrounding air, as measured in a Stevenson Screen over short grass or in the air running a few metres above the crop. At night they may be much colder, particularly during the inversions which are so common during the winter months in Natal. For example, on the 22nd July, 1966, during an inversion, air temperature among the top leaves of cane was 1|°C (34.7°F) and among the lower leaves 30 cm. (12 in.) above ground it was 2°C (35.6°F), while a metre above the crop it was 5°C (41°F). At the same time Stevenson Screen records over short gras$

some 20 metres (65 ft.) distant showed 5.1 °C (41°F). The relevance of this situation to frost damage is obvious but it will be discussed in greater detail in a later paper.

Disturbed vs. Undisturbed Soils

As already mentioned earlier, the whole story of the growth of plants in the soils around the root laboratory will not be available until the cycle of growth from plant crop through at least one ratoon crop is complete. Nevertheless, even at this early stage, only one year after planting, the effect of lightness or otherwise of soil on yield as measured by growth in height of the two varieties is remarkable. Although the final yield by weight at harvest is not yet available, the height differences are so large that they may in some measure reflect later yield. So in anticipation of that result the *average* growth in height of all stalks in the stools of the two varieties at the end of one year's growth are presented in Table III. It will be of interest to see how this relates to final yield.

advantage that there would be a saving in supplementary irrigation, although this might be only partial, for the resulting bigger crop will need more water.

In other words, subsoiling, if it is economic, is likely to be beneficial on some soils. This is not a new suggestion. Evans (1936) has pointed out that "the root-system produced as a result of subsoiling, being superior in depth, spread, and number of roots, to that of the untreated plants, must result in considerable benefit to the plant under conditions of drought, etc." This was his interpretation of the results of his excavation of root-systems. It can be seen that the direct observation of such effects in our soils confirm his deductions.

TABLE III

Average height in inches of all stalks of each variety at the end of one year's growth

Treatment	Rain Grown (26 inches of rain)								Irrigation	
Soil	Disturbed Red Sand		Disturbed T.M.S.		Disturbed Dolerite*		Undisturbed Dolerite*		Undisturbed Dolerite	
Variety	376	211	376	211	376	211	376	211	376	211
Average Height	75	89	52	76	43	59	27	29	44	69

* See figures 14 (*a*) and (*b*) for long drought period associated with growth in this soil.

When it is remembered that the rain-grown crops received only some 26 inches (66 cm.) of rainfall in the year, and from the first of June to the first of October, a period of four months, only some 2.7 inches of rain (6.9 cm.) fell on the growing plants, the differences in height are quite remarkable. The growth on the sandy soils has been as high, or, in the case of the red sand, higher than in the well irrigated undisturbed heavy soil. Even the deeply disturbed heavy soil has produced nearly as much stalk height as the irrigated undisturbed heavy soil in spite of being subject to the great dearth of soil moisture shown in Fig. 14(a). The rain-grown crop on the undisturbed heavy soil lags far behind the others and even the inherent varietal differences in stalk height are muted.

The implications are obvious. Anything that can be done economically to lighten a heavy soil and promote faster root growth and proliferation is likely to be worthwhile in producing an earlier crop and it may produce a heavier one. It may have the added

References

Artschwager, E. (1925). J. Agr. Res. *30* : 197-242.

Beater, B. E. (1957). *Soils of the Sugar Belt.* Natal Reg. Survey Rep. No. 3. O.U.P. London.

Evans, H. (1935). Emp. J. Exp. Agr. *3* : 351-362.
(1936). Emp. J. Exp. Agr. *4* : 325-331.
(1937). Bull. No. 12 Sugarcane Res. Stat. Mauritius.
(1938). Ann. **Bot.** N.S. *2* : 159-182.

Hudson, J. C. (1964). Bull. No. 39 Min. Agr. Fish. Barbados.

Monteith, N. H., and Banath, C. L. (1965). Trop. Agr. Trin. *42* : 293-296.

Rep. E. Mailing Res. Stat, for 1962 (1963). Maidstone, Kent, England.

Tackett, J. L., and Pearson, R. W. (1964). Soil Sci. Soc. Proc. *28 :* 741-743.

Taylor, H. M., *et al* (1966). Soil Sci., *102 :* 18-22.

Thompson, G. D., and du Toit, J. L. (1965). 12th Congress I.S.S.C.T. Puerto Rico.

van Bavel, C. H. M., *et al* (1963). Production Res. Rep. No. 756, Agr. Res. Ser. U.S.D.A.

von der Meden, E. (1966). Dept, Rep. S.A.S.A. Exp. Stat. Natal.

Discussion

Mr. Gilfillan: Why should disturbance of an already open-textured soil lead to such rapid root growth?

Mr. Glover: I cannot give a definite answer but there is no doubt whatsoever that disturbance of sand is beneficial.

Mr. Gosnell: Did N.50/211 show any signs of sun scorch and was there any relationship to root growth at that time?

Mr. Glover: This was not observed.

Mr. James: What effect does severe pruning of root growth have on the growth of a plant?

Mr. Glover: I have observed crickets pruning plant roots. The main roots usually stopped branching, although in some cases branching continued vigorously.

Mr. Cheves: What effect does compaction have on a root system?

Mr. Glover: In a compacted section of soil we observed very thick unbranched roots passing through cracks and following them upwards, downwards and sideways. Top growth was poor, In, our Dolerite soils not until the roots had broken through the compacted layer did adequate top growth follow.

Br. **Thompson:** It is interesting to compare some of the height growths in Mr. Glover's paper with our field measurements also on N:Co.376 on the same Dolerite next to the root laboratory. With a twelve-month third ratoon crop, after 33 inches of rain the average height was 64 inches. With the fourth ratoon, after 28 inches of rain, the height was 31 inches.

In Clansthal sand, the first ratoon crops at Cornubia, irrigated and dry land, were 71 inches and 52 inches respectively.

Mr. Laodsberg: The potential water use in winter is less than 50 per cent that of mid-summer and the assumption is that crop production in relation to water use is more efficient in winter.

Dr. Roth: Mr. Glover says that old sugarcane roots take up P32 although they appear to be dead. Sugarcane roots are in symbiosis with exophytic mycorhiza and these fungi, which are associated with the old roots, are made active by the mycorhiza and the symbiosis of roots and mycorhiza causes the phosphorus uptake.

THE ESTIMATION OF CANE ROOT DEVELOPMENT AND DISTRIBUTION USING RADIOPHOSPHORUS

by G. H. WOOD and R. A. WOOD
South African Sugar Association Experiment Station

Introduction

Soil sampling for the purpose of fertility assessment is normally confined to the plough layer with little or no attention to the rooting pattern of the crop in question or the availability of subsoil nutrients. However, there is little doubt that a thorough understanding of the development and activity of plant roots in their soil environment is essential to a balanced soil fertility research programme.

Most methods of root examination in the field are time consuming and destructive, and do not necessarily indicate the activity of roots at a particular location in the soil. More recent methods involve placement of a substance which can be absorbed by roots and readily detected in the plant, at various positions in the soil. These are relatively non-destructive and are, therefore, suitable for the continuous study of root development. Various soluble substances, such as dyes, elements not normally encountered to any extent in plants, or radio-isotopes of nutrient elements, have been used as tracers, but the latter are most promising. Accordingly, radio-isotope placement techniques have been applied to root development studies on a number of crops. Hall *et al* (1953) used radiophosphorus (P-32) to study the root systems of maize, peanuts, cotton and tobacco, while Boggie and Knight (1962) examined the root development of grasses and other plant species growing on deep peat with the same radio-isotope.

The basic requirements of the radio-isotope technique are as follows:

(a) Injection or placement of the radio-isotope, at a particular depth and distance from the plant, in such a way that there is a reasonable probability of roots reaching the zone encountering it.

(b) No appreciable movement of the radio-isotope from the point of placement during the study.

(c) When taken up, the radio-isotope should be easily detectable and readily distributed throughout the plant.

Requirements (b) and (c) are most closely met by P-32.

Two procedures frequently used to apply P-32 at various depths in the soil are:

(i) *the boring method*—a small diameter hole is augered and P-32 solution or P-32-tagged fertilizer poured down a tube (Lawton *et ah* 1954; Lipps *et ah* 1957), and

(ii) *the injection method*—P-32 solution is injected by means of a needle and syringe (Hall *et ah* 1953; Murdock and Engelbert, 1958).

In the present study a combination of the two methods was employed.

Methods involving placement of fertilizer in solid form are undesirable as it is impossible to estimate the extent to which the large amount of readily available nutrient has affected the normal behaviour of the roots. Injection of carrier-free P-32 solution leaves the phosphate status at the injection site unaltered and is therefore preferable.

Interpretation of results using the P-32 injection method is complicated by a number of important factors; (i) variation from point to point in the soil of the amount of soil P with which the added P-32 exchanges; (ii) continuous exchange between ions in roots and soil; (iii) radiation damage to plant tissue. In addition, P-32 uptake is not necessarily indicative of the activity of roots with respect to the absorption of other ions or water (Newbould and Taylor, 1965).

To eliminate the effect of fluctuations in the total phosphate content of the plant, P-32 uptake is best expressed as a fraction of this quantity, or in other words, as specific activity (Wood, 1964). Both Hall *et al* (1953) and Waugh (1963) contend that this is the most meaningful measure of uptake. Moreover, since the P-32 distribution in the plant tends with time to become the same as that of the natural phosphorus (Wood, 1964), variation in the position on the plant from which a sample is taken should be less critical. The specific activity in a plant arising from a particular depth-distance treatment has little meaning, unless considered in relation to the total possible uptake from all treatments. Results from each sampling should therefore be expressed on a relative basis. Any comparison of specific activities between sampling dates to obtain a measure of the rate of P-32 uptake is invalidated by factors such as changes in specific activity of the soil phosphate resulting from soil reactions.

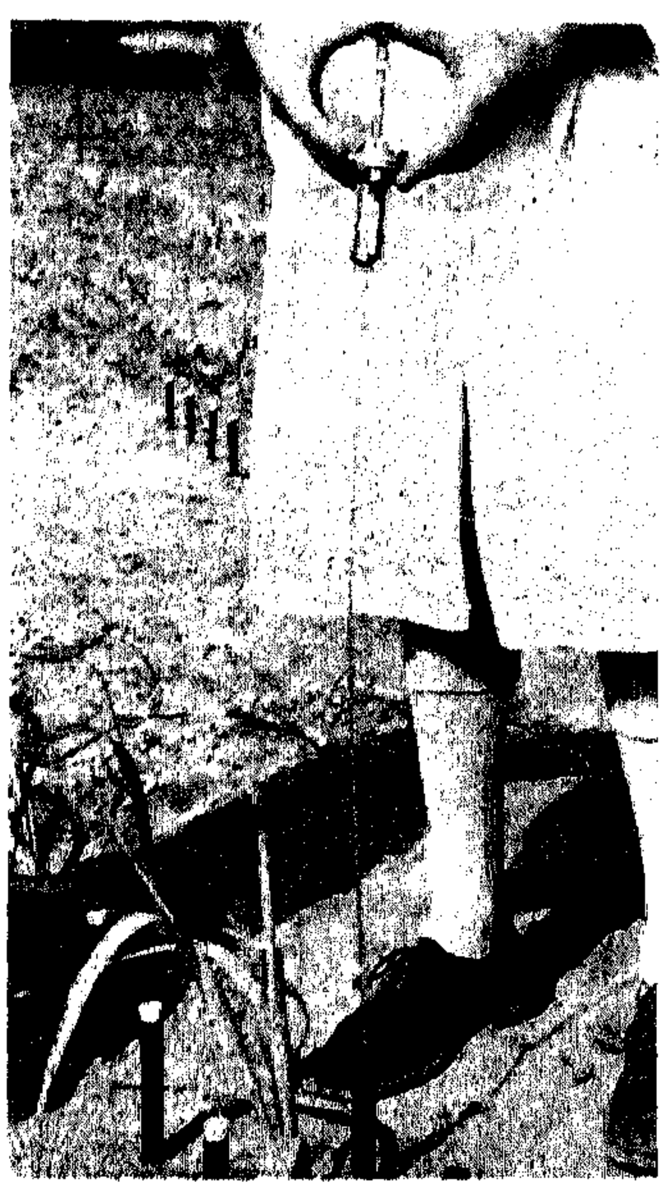
This paper concerns a study of the rate of development and relative activity of different parts of the root system of the sugarcane variety N:Co.382 on deep coastal sands, employing a P-32 injection technique. An attempt has been made to relate the root development and activity to changes in available soil moisture as measured by cylindrical gypsum blocks.

Experimental Method

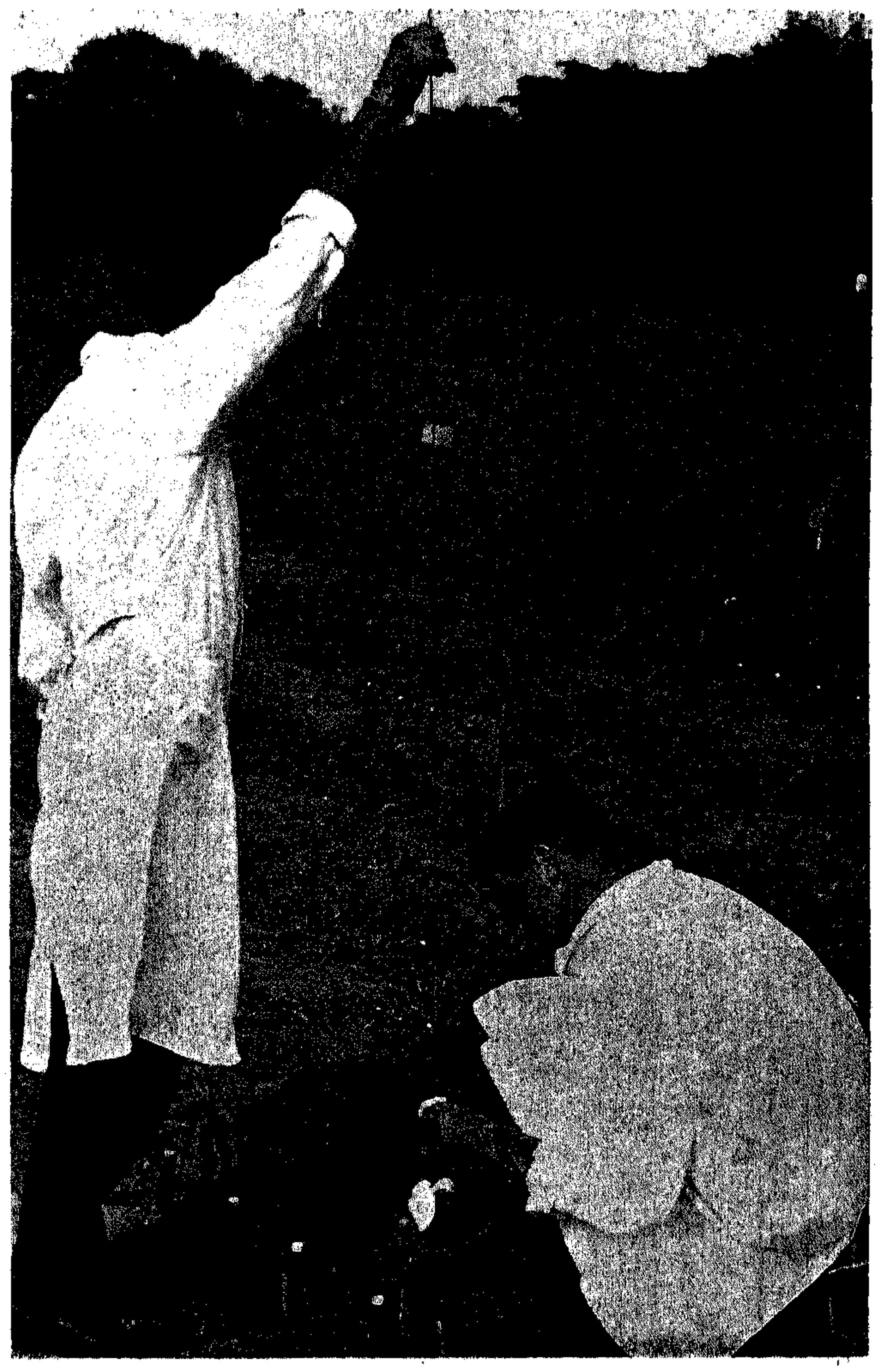
The experiment was located on a Clansthal sand with a ± 6-inch layer of soft weathered sandy ferricrete occurring at" about 5 ft. and overlying a sajidy clay loam. Setts were planted in October 1964 in 4ft. 6in. rows. The cane received superphosphate in the furrow at planting and subsequent topdressings of sulphate of ammonia, muriate of potash and a 4-1-6 NPK mixture.

The treatments involved injecting P-32 solution at six depths (3 in., 9 in., 1 ft., 3 ft., 5 ft. and 7 ft.) and four distances (3 in., 9in., 18 in. and 36 in.) relative to the cane row. A split plot design and three replicates was employed, with depth as whole plot treatments and distance as subplot treatments. Each whole plot consisted of a 50 ft. row of cane with a guard row on either side. Subplots were formed by dividing whole plots into four equal lengths of 12J ft. The nett subplots consisted of a 3 ft. length of row receiving five equally spaced 20 cc. injections on each side of the row at the required distance and depth. Plate 1 illustrates the field experimental layout and injection procedure.

A



B



C

PLATE 1: Field experimental layout and injection procedure.

A. Filling syringe and inserting needle.

B. Injecting P-32.

C. Transferring needle from one polythene pipe to another.

Injections were made with a 20 cc. veterinary syringe and gauge 11 stainless steel needles of various lengths, similar to those used by Murdock and Engelbert (1958). Plate 1 shows clearly the tops of the black polythene pipes, which had been placed in the soil to within two inches of the desired injection depth, to facilitate insertion of the needles to depths of 1 ft. or greater. These were left in position for the duration of the experiment, to permit reinjection at intervals of ten or more weeks to compensate for radio-active decay. Accordingly, seven applications of P-32 were made during the life of the plant crop, with an additional one about three months after harvesting to study the initial feeding pattern of the first ratoon.

Each injection contained 0.05 millicuries P-32, making a total of 0.5 millicuries per treatment. Autoradiographs of cross-sections of injections at different depths in the soil showed that the P-32 spread approximately half an inch from the point of injection. There was little downward movement of P-32 injected six inches below the soil surface, even after being leached with five inches of rain over a period of 50 days and a final ten inches of water within a few hours (Plate 2).

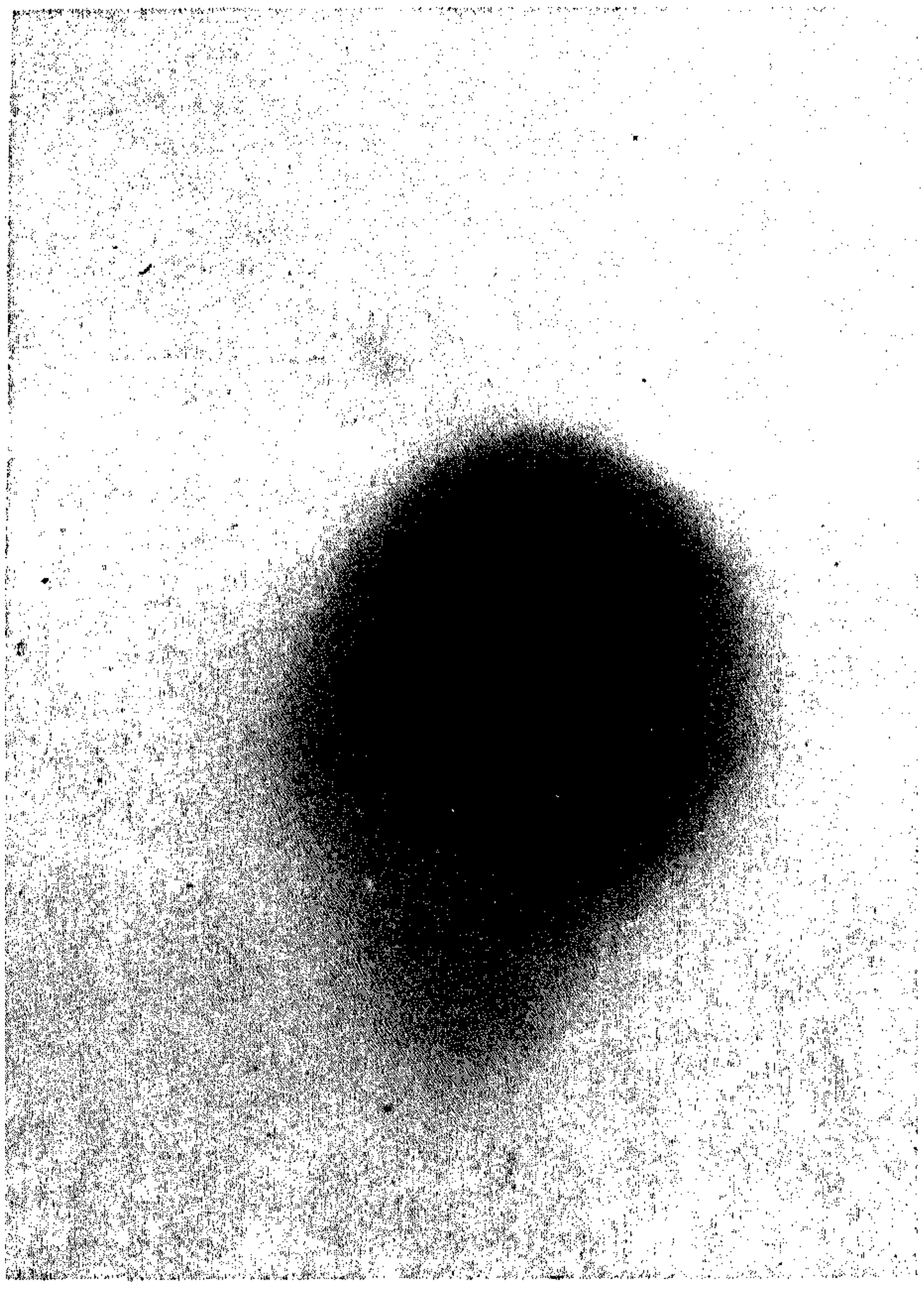


PLATE 2: Autoradiograph of P-32 injection leached with 5 inches of rain and 10 inches of water.

P-32 uptake was determined by taking third-leaf samples from the cane within each nett subplot, using a punch sampler, at one-, two- or three-weekly intervals depending on the growth rate. After wet-ashing, the P-32 content of the samples was measured with a Geiger-Muller pour-in counter and scaler and the total P by a molybdophosphoric blue colour method.

In February 1965 sets of cylindrical gypsum soil moisture blocks, manufactured according to the method of Pereira *et al* (1958), were installed adjacent to each treatment at the corresponding injection depth and distance, omitting the 3 inch depth. Readings of percentage available moisture were taKen at weekly intervals for the remainder of the experiment, using a Bouyoucos moisture meter. To check the moisture block results, the Viatec Ra/Be neutron probe was used to make periodic measurements of absolute moisture at various depths down the profile. For this purpose a ten foot aluminium access tube was installed in each of the three replications, midway between a row of cane and the centre of the interrow.

The experiment was harvested at the beginning of June 1966. As an indication of the degree of uniformity of growth, nett subplot weights, stalk heights and population were recorded.

The variability of phosphate, exchangeable cations, and other soil properties down the profile was estimated from analyses of composite soil samples from each whole plot, taken adjacent to the treatments at the corresponding depth and distance. For resin-extractable P and exchangeable P (E-value) measurements, subsamples ground to 60 mesh were equilibrated with P-32 solution for periods of one or two weeks, and the labelled soil phosphate extracted by shaking the suspension overnight with Dowex 1-X8 anion exchange resin (Cooke and Hislop, 1963).

Results and Discussion

The variability of the soil chemical and physical properties down the profile is shown in Table I, and the effects of repeated heavy dressings of lime-rich filter-cake can be clearly seen. Most striking were the high Ca and P levels in the plough layer, and the very high pH values which persisted down the profile. Initially some of the ratoon cane in this experiment showed the characteristic symptoms of lime-induced iron-deficiency chlorosis.

The phosphate fertility patterns estimated by sulphuric acid extraction, resin extraction and P-32 equilibration for one week were all essentially similar. However, the variation in the measured E-value with depth was drastically reduced by increasing the equilibration period to two weeks. This uncertainty in the E-value, coupled with the lack of a reliable estimate of this parameter at 7 feet, made it difficult to apply corrections to the P-32 uptake so that variations in exchangeable P could be accounted for, as recommended by Newbould and Taylor (1966). However, Hall *et al* (1953) suggest that lower specific activities at sites in the soil with high levels of labile P may be equalized by greater absorption of P by the roots at these sites. The advisability of applying corrections therefore remains uncertain.

In calculating the results, the mean specific activity due to each individual treatment was taken as a percentage of the sum due to all treatments. This was used as an estimate of the relative root activity at the various position in the soil. As an indication of the natural variability of the results, and the significance of treatment effects, analyses of variance of the log-transformed specific activity data from two samplings selected for large apparent depth and distance effects, are presented in Table II, together with the coefficients of variation of the stalk height and weight. The high coefficients of variation, and non-significance of treatment effects in the one instance indicate that the method is only semiquantitative and emphasize the need for caution in drawing conclusions regarding differences in root activity.

TABLE I

Variability with depth of soil chemical and physical properties

Soil Properties	Depth (Ft.)					
	¼	½	1	3	5	7
Phosphate (ppm)						
(i) O.O2N-H_2SO_4 Extractable ..	93	97	10	4	17	3
(ii) Resin Extractable after—						
1-week pre-equilibration ..	22.4	21.4	4.2	1.4	5.1	0
2-week ,, ..	25.0	23.7	5.8	3.3	5.4	0
(iii) Exchangeable (E-Value)						
1-week equilibration	41.9	45.9	10.9	6.2	22.9	—
2-week ,, ...	53.0	54.9	21.4	30.4	38.4	—
Other Chemical Properties						
Ca (ppm)	2250	2720	380	140	330	460
Mg (ppm)	48	55	19	11	23	210
K (ppm)	41	34	23	20	36	29
Na (ppm)	23	25	7	5	8	28
pH (1:2.5 soil:water)	8.83	8.91	8.73	8.38	8.22	6.75
Organic Matter %	1.30	1.46	0.77	0.64	0.87	0.87
Mechanical Analysis						
Clay %	10	11	8	7	13	34
Silt %	4	4	3	2	2	5
Fine sand %	49	52	51	53	50	30
Coarse sand %	37	33	38	38	35	31
Textural Group	Loamy Sand	Loamy Sand	Sand	Sand	Loamy Sand	Sandy Clay Loam

TABLE II

Analyses of variance of log-transformed specific activity data and variability of stalk height and weight

	Sampling Date	
	5 Jul 1965	28 Mar 1966
C.V. %	48	35
F-Values:		
Depth effects	0.79	1.73
Distance effects	30.27**	8.90**
Depth x distance effects ..	6.10**	1.12
C.V. % at harvest:		
Average cane height in nett subplots		12
Average stalk wt. in nett subplots		18

**Significant at 1 % level.
* ,, ,, 5% ,,

The estimated root activity patterns at different stages of growth are illustrated in Figure 1, which shows the mode and rate of root development. When considering this figure, it must be remembered that sampling on a given date provided an estimate of the integrated P-32 uptake over the whole period from the previous application of P-32 to that date. This explains the change in the measured root distribution pattern which sometimes occurred after a fresh injection of P-32, the new pattern being more indicative than the old of the root distribution prevailing at the time of sampling. Although a given P-32 injection sometimes had a small residual effect on the results from the next, radio-active decay prevented this effect being carried over to results from subsequent injections.

Figure 2 presents graphically changes in moisture status that occurred at various depths and distances from the time the pane was 20 weeks old. The shaded areas represent the amount of available water present between the 1 and 15 bar tension limits and are clearly related to the pattern of rainfall distribution occurring during the course of the experiment. Each curve represents the mean of three gypsum block readings.

The effects of the prolonged drought at the beginning of 1965 on available moisture are clearly seen. By the beginning of April the surface foot of soil was almost completely dry, moisture reserves at 3 ft. were dwindling, and even the soil at 5 ft. was showing signs of drying. Figure 1 shows that, at the end of April, P-32 uptake from 5 to 7 ft. accounted for a significant proportion of the total, whereas two weeks earlier there had been little indication of significant root activity at these depths. It is most likely that this sudden stimulation of root activity at depth was largely due to the relatively large supply of available moisture still present there. The neutron probe results for the period January to June 1965, recorded in Table III, reveal a pattern of moisture removal similar to that in Figure 2. Both methods indicated a sudden large decrease in available moisture at 7 ft. at the beginning of May, confirming the arrival of significant quantities of active roots. The decline in the relative contribution of roots near the surface during the latter half of April was probably due mainly to the depletion of moisture.

Good rain from early June replenished profile moisture and caused a renewed flush of surface roots, as shown by the large increase in the relative P-32 uptake from the surface at the beginning of July, and confirmed by root washing. The general pattern at this stage suggests that roots growing six inches to three feet from the surface had not yet recovered from the setback due to the drought, while those at depth continued to make a significant contribution. However, by the end of September, root activity in the surface nine inches again predominated. These results indicate that good rainfall and adequate subsoil moisture favour root proliferation near the surface.

The general root distribution remained fairly constant until late February 1966, when a dry period at the height of the growing season again caused severe moisture depletion in the surface foot of soil. The effects were noticeable at the end of March, an apparent decrease in the relative surface root activity coinciding with an enhanced contribution from five to seven feet. The large removal of moisture at the seven foot depth and 36 inch distance during this period (see Figure 2) implies considerable root activity in this region, confirming the P-32 results. However, since the dry spell was much shorter and less severe than the 1965 drought, the general relationship between soil moisture depletion and P-32 uptake was less clearly defined.

Although the results for the ratoon crop have been included in Figure 1, they can only be regarded as qualitative due to extremely poor tillering in many

TABLE III

Absolute soil moisture measurements made with the neutron probe during the period January—June 1965 (in inches water per 6 inches soil)

Date	Age of Cane (Wks)	Depth (Ft.)						Rainfall (In.)	
		¼	½	1	3	5	7	Previous Week	During Interval
12 Jan	12	0.67	0.65	0.59	0.39	0.97	2.02	1.12	2.18*
28 Jan	14½	0.57	0.52	0.44	0.42	1.03	1.97	0.52	1.40
18 Feb	17½	0.45	0.37	0.29	0.30	1.11	2.18	0.31	0.46
18 Mar	21½	0.39	0.33	0.26	0.21	0.77	2.00	Nil	0.93
25 Mar	22½	0.38	0.31	0.25	0.20	0.72	1.98	Nil	Nil
2 Apr	23½	0.39	0.32	0.26	0.20	0.72	1.95	0.08	0.08
8 Apr	24½	0.43	0.36	0.29	0.20	0.69	1.92	Nil	Nil
14 Apr	25½	0.40	0.33	0.24	0.17	0.66	1.89	0.16	0.16
23 Apr	26½	0.46	0.38	0.29	0.22	0.68	1.88	0.26	0.28
30 Apr	27½	0.46	0.38	0.29	0.22	0.69	1.85	0.26	0.26
6 May	28½	0.34	0.28	0.20	0.11	0.59	1.69	Nil	Nil
20 May	30½	0.36	0.29	0.21	0.12	0.58	1.75	0.01	0.11
3 June	32½	0.66	0.64	0.62	0.40	0.65	1.74	3.38	3.38

* Rainfall during previous three weeks.

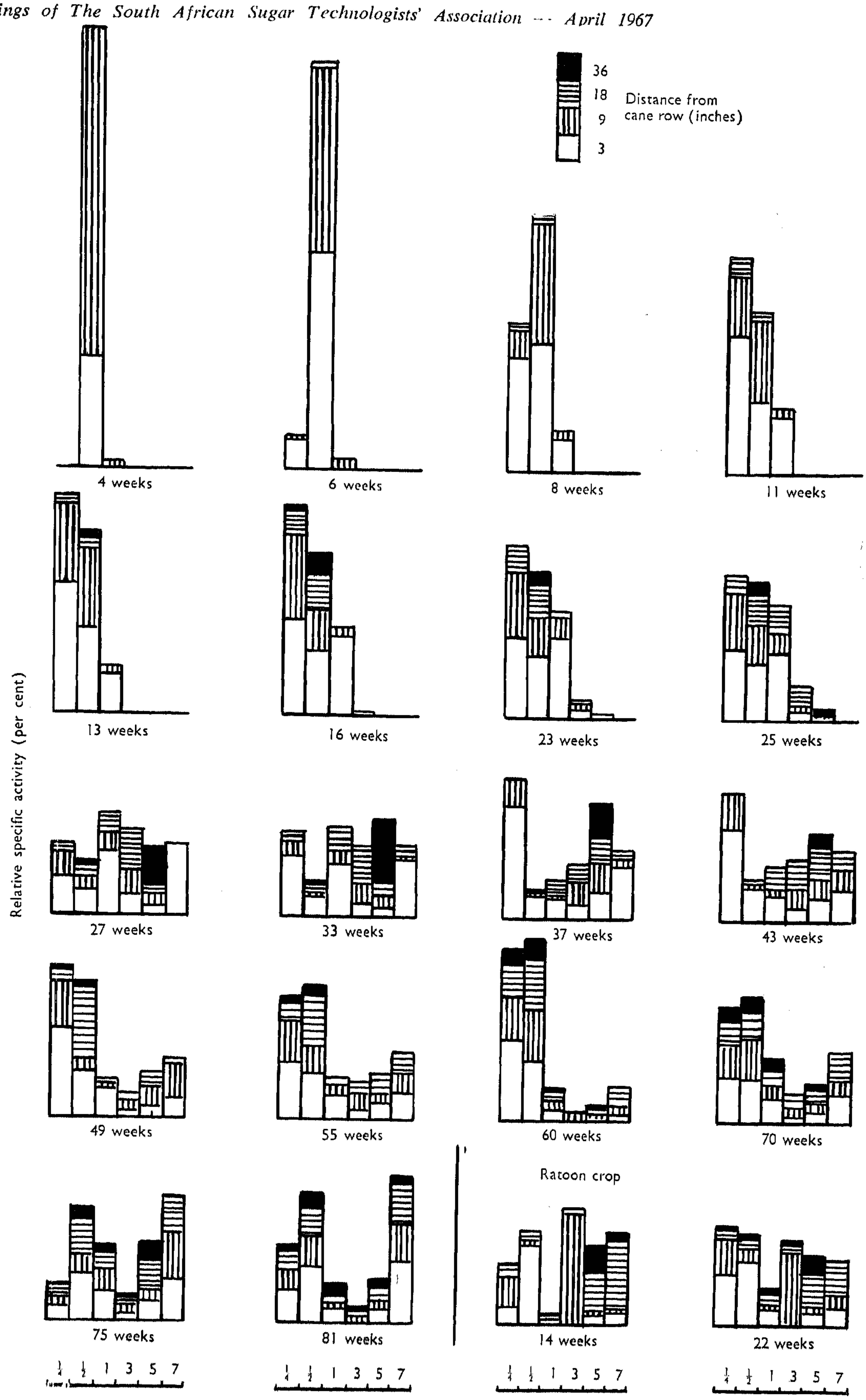


FIGURE 1: Sugarcane root activity patterns (estimated), at different stages of growth

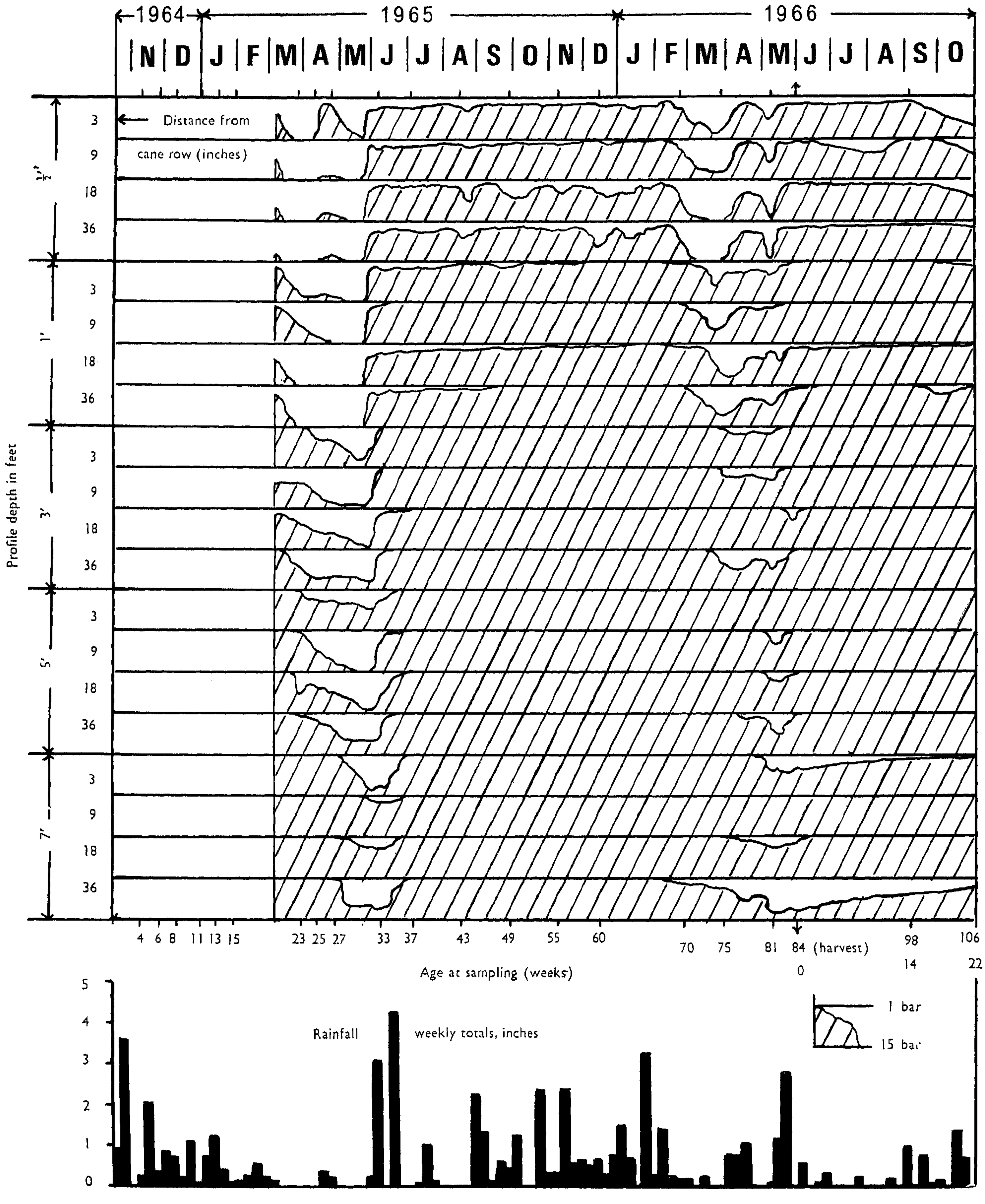


FIGURE 2: Changes in available soil moisture under sugarcane to a depth of 7 feet

subplots and large growth variations. Despite this, they indicate significant P-32 uptake from seven feet only 14 weeks after harvest. Considering that the cane at this stage averaged less than two feet in height due to retarded growth over the winter months, it is considered unlikely that new shoot roots would have reached a depth of seven feet in this time. These results therefore suggest that the plant crop root system, which was still active at this depth shortly before harvest, continued to sustain the ratoon crop to some extent at least four months after cutting. Since the crop was still small, absence of visible moisture extraction at five and seven feet was not unexpected.

Conclusions

The radio-isotope injection method as described is subject to considerable natural variability. For this reason, the results are at best semiquantitative, but nevertheless useful in estimating the development of the sugarcane root system and giving some idea of the comparative activity of roots at different depths and distances relative to the cane row. Despite its drawbacks, it is one of the most promising methods yet devised for studying root patterns in situ in the field.

The results indicate that root activity predominates close to the surface under conditions of normal rainfall. However, the frequently observed drought resistance of sugarcane grown on Natal coastal sands can be attributed to the fact that active roots are able to penetrate to considerable depths in these soils and proliferate where moisture is still available.

The evidence obtained for continued functioning of the plant cane root system for at least four months after harvesting is not surprising, as the stool remains a living entity, and there is therefore no reason to presuppose that all roots attached to it should cease to function immediately. It is quite feasible that some could become dormant, when relieved of much of the task of sustaining growth, and may start functioning again if or when required. In the Root Observation Laboratory at the Sugar Experiment Station, Glover (1967) has noted persistence of turgid root hairs on old suberized roots of living plants for periods of up to four months, and branching of these roots 160 days after growth has apparently ceased.

It must be emphasized that the experiment was not designed as a study of phosphate fertilizer placement and the authors have therefore not attempted to draw any conclusions in this regard. Its value lies mainly in increasing our understanding of the rate of development and distribution of the sugarcane root system on a light textured soil with a deep profile, and root behaviour as influenced by soil moisture

Summary

A description is given of a field experiment, using a P-32 injection method, to study in situ the development and distribution of the sugarcane root system on Natal coastal sands throughout the life of the plant crop, and during the initial stages of growth of the first ratoon. The beghavior of the root system was studied in relation to soil moisture conditions as measured by gypsum blocks, while using the Viatec Ra/Be neutron probe as a check on absolute moisture variations down the profile.

Although initial root development was found to be mainly confined to the surface foot of soil, there were signs that the roots had reached a depth of five feet by 20 weeks. A prolonged drought early in 1965 caused gradual depletion of soil moisture from the surface downwards, giving rise to sudden appearance of significant amounts of active roots at a depth of seven feet.

In general the results indicate that root activity predominates close to the surface under normal rainfall conditions. Drought resistance of cane grown on coastal sands is explained by the ability of active roots to penetrate to considerable depths where moisture is still available. Evidence was obtained that plant cane roots apparently continue to function for some time after harvest.

The advantages and limitations of the P-32 injection technique are discussed.

Acknowledgements

The authors would like to record their thanks to the Agronomy Section for supplying the neutron probe data, and to the Chemical Services Laboratory for analyses of soil samples.

References

Boggie, R., and Knight, A. H. (1962). "An improved method for the placement of radioactive isotopes in the study of root systems of plants growing in deep peat". J. Ecol, *50*, 461-463.

Cooke, 1. J,, and Hislop, J. (1963). "Use of anion-exchange resin for the assessment of available soil phosphate". Soil ScL, *96*, 308-312.

Glover, J. (1967). Private communication.

Hall, N. S., Chandler, W. F., van Bavel, C. H. M,, Reid, P, H., and Anderson, J. H. (1953). "A tracer technique to measure growth and activity of plant root systems". N, Carolina Agric. Expt. Sta. Tech. Bui. No. 101.

Lawton, K., Tesar, M. B., and Kawin, B. (1954). "Effect of rate and placement of superphosphate on the yield and phosphorus absorption of legume hay". Soil Sci. Soc. Amer. Proa, *18,* 428-432.

Lipps, R. C, Fox, R. L., and Koehler, F. E. (1957). "Characterizing root activity of alfalfa by radioactive tracer techniques". Soil Sci., *84,* 195-204.

Murdock, J. T., and Engelbert, L. E. (1958). "The importance of subsoil phosphorus to corn". Soil. Sci. Soc. Amer. Proa, *22,* 53-57.

Newbould, P., and Taylor, R. (1965). "Absorption of nutrients from different depths in the soil: Effect of cultivation on absorption by ryegrass and potatoes". Agricultural Research Council Radiobiological Laboratory, Report ARCRL 14, 58-60.

Newbould, P., and Taylor, R, (1966). Private communication.

Pereira, H. C, Wood, R. A., Brzostowski, H. W., and Hosegood, P. H. (1958). "Water conservation by fallowing in semi-arid tropical East Africa". Erop. J. exp. Agric., *26,* 213-228.

Waugh, D. L. (1963). "A critical study of radiophosphorus injection methods for estimating plant uptake of nutrients from subsoils". Ph. D. Thesis, University of Wisconsin. Univ. Microfilms 63-7691.

Wood, G. H. (1964). "Preliminary report on the root spread in sugarcane as revealed by radio-isotopes". Proc. Annuaf Cong. S. Afr. Sugar Tech. Ass., *38,* 134-143.

Discussion

Mr. Armstrong: In work with radioisotopes has any evidence come to light to show that uptake from one root is distributed to all leaves in the plant?

Mr. G. H. Wood: We intend to investigate this in our new root laboratory. Some work has been done on the distribution of P-32 in a plant but not yet in great detail.

Mr. von der Meden: In Figure 2, did the soil moisture in the top six inches never reach below two bars tension throughout the two years?

Mr. G, H. Wood: In none of the three replications did we ever obtain a hundred percent moisture reading in the top six

Mr. Moberley: The fact that where chlorosis occurs it is more evident in ratoon plants seems to indicate that ratoon roots are not feeding from depths below the high calcium strata.

Mr. G. H. Wood: Results for the ratoon crop are qualitative. The uptake from seven feet may be relatively small. It is now thought that chlorosis is not due to pH but to an excess of phosphate which the plant may take up from new roots it puts out near the surface, thus upsetting the iron phosphate ratio.

Mr. **Coignet:** In coffee, also, when there is an excess of phosphate new shoots show the effects of iron chlorosis although iron is available in the soil.

Mr. G. H. Wood: A recent paper states that there is the same amount of iron in chlorotic and non-chlorotic plants but the chlorotic plants contain a greater amount of phosphate.

Dr. Roth: The higher the amount of carbohydrate that has to be decomposed after the first crop by micro-organisms the more acids will be produced. They may influence the uptake of phosphates in the roots as phosphates are acid soluble.

THE EFFECTS OF HERBICIDES ON *CYPERUS* SPP.

by J. M. GOSNELL
and
G. D. THOMPSON
South African Sugar Association Experiment Station

Two of the most troublesome weeds in Natal sugarcane fields are the sedges *Cyperus esculentus* and *Cyperus rotundas,* known locally as either watergrass or nutgrass. Much of the experimental work conducted with herbicides over the past 18 years has been directed towards the chemical control of these species. McMartin (6) reported that in his early experiments the leaves of both weeds were killed by 4 lb. a.e. 2,4-D per acre, but that regrowth occurred from the underground tubers, and that second and third applications were sometimes necessary. Even then the plants were not entirely controlled. In a subsequent report McMartin (7) stated that pre-emergent applications of 2,4-D reduced the number of nutgrass plants appearing above ground.

These observations were followed by those of Stewart (9) who stated that "in general, pre-emergent applications of 2,4-D formulations, at economic rates (2 lb. per acre), have given little or no positive control of nutgrass. Under particular conditions 2,4-D may retard development of the shoots and delay flowering to a certain extent, but this condition is temporary and the weed soon recovers".

McMartin (7) found that good post-emergent effects were obtained by spraying nutgrass with a mixture of 2 lb. pentachlorophenol (PCP) and 2 lb. of a wetting agent in four gallons of an oil with a high aromatic content. This combination was diluted with 96 gallons of water for spraying on one acre. The treatment was used extensively in the industry, as described by Steward (8), who found that commercial applications of the PCP mixture and 2,4-D destroyed all weed growth within six days, and that watergrass then reappeared after two weeks.

In a report on experiments conducted at Tongaat, Cleasby (1) showed that pre-emergent applications of MCPA with 10 lb. or 20 lb. of TCA per acre gave only slight reductions in the growth of watergrass, but that post-emergent applications of PCP gave up to 87% control four weeks after spraying, with considerable regrowth after a further three weeks. A post-emergent application of 2,4-D caused a 50% reduction in watergrass populations after four weeks, and the addition of TCA or Dalapon to the 2,4-D increased this reduction to 65%. At Illovo, Thompson and Trichardt (M) found that 2,4-D and MCPA, applied pre-emergent at 6 lb a.e. per acre, were not effective against watergrass, but that post-emergent treatments with 20 lb. TCA per acre, or 15 lb. TCA and 2-| lb. a.e. 2S4-D per acre, gave good control. Even better results were obtained with 10 lb. Dalapon and *2* lb. a.e. 2,4-D per acre, but Dalapon at this rate caused the cane to be severely stunted.

Excellent control of *Cyperus esculentus* was obtained at Chaka's Kraal when Karmex and Eptam were sprayed pre-emergent (Thompson and Gosnell, 10), and both Gramoxone and Reglone were shown to be much superior to PCP in suppressing watergrass. Eptam, however, affected germination and cane growth severely. In a separate experiment at Mount Edgecombe, described by the same Karmex gave good control of *Cyperus esculentus* when sprayed post-emergent on a moist soil. The effectiveness of Gramoxone was confirmed in subsequent experiments by Gosnell and Thompson (4), and on an estate scale by Gilfillan (2). The latter author also reported that results varying from good to poor were obtained with post-emergent applications of Afalon on watergrass.

The uracil, Hyvar X, gave excellent control of *Cyperus esculentus* for 12 weeks after application (Gosnell and Thompson, 4), but visually obvious damage to the sugarcane was caused by amounts (4 lb. per acre) which gave the best weed control. The possible relationship between the effectiveness of Hyvar X and soil organic matter content was later described by Gosnell (3), who also confirmed the effectiveness of Karmex as a post-emergent treatment on *Cyperus esculentus* under irrigated conditions. Combinations of Hyvar X and Karmex, in comparison with Hyvar X alone, were studied by Gosnell and Thompson (5), and were found to give good watergrass control without causing any appreciable cane damage when the amount of Hyvar X was limited.

The fragmentary evidence of herbicidal effects on *Cvperus* species has not permitted a full appraisal of the subject to be made. The results of a series of tray experiments and a field micro-plot experiment, conducted during the 1963-66 period, have now been collated and are presented here in an attempt to clarify some of the confusion which exists regarding the effects of 2,4-D on *Cyperus esculentus* and *Cyperus rotundas,* to identify the best conditions for successful use of Gramoxone, and to predict the possible value of other herbicides in controlling watergrass in sugarcane fields.

Materials and Methods

Seven experiments were conducted in trays, 16 inches x 9 inches x 5 inches deep, made of aluminium sheet metal, with perforations in the bottom, and having wooden ends. The trays were filled with a sieved clay loam soil. Fresh tubers of *Cyperus* spp. were collected in the field." Either 6 or 12 tubers of *Cyperus rotundus* were planted per tray, at a depth of about one inch below the surface of the soil. The tubers of *Cyperus esculentus* were washed several times in clean water before planting 12 or 18 tubers per tray. After planting, vigorous growth was ensured by regular watering and the application of a nutrient mixture. In all instances the populations were reduced to six plants per tray after germination had taken place. One experiment was located in the greenhouse but the remainder were conducted out of doors.

The spraying procedure was to transfer the trays from the experiment site to excavations in the field, these being so constructed that the trays fitted neatly and were level with the surrounding soil. The individual trays were located in random positions with respect to the swath of a triple-nozzle boom, thus simulating conditions of field application as closely as possible. Knapsack spraying was carried out in the early morning following calibration of the equipment over measured distances, the herbicide being diluted in water to give a total volume application of 20 gallons per acre. After spraying the trays were immediately returned to the site of the experiment.

Details of each of the seven tray experiments are shown in Table I. There were four replications of the treatments in each trial. Weekly tiller and flower counts were made in some experiments and the weeds were harvested when they were approximately 11 weeks old. At harvest, all of the green foliage was cut at ground level, oven dried and weighed. Roots and tubers were washed free of soil before drying and weighing. In some instances tuber counts and germination tests were also carried out. All results were calculated on the basis of the number of tubers or tillers per tray, and the dry weight of foliage, tubers and roots per tray.

A further experiment consisting of micro-plots was conducted in a field at Chaka's Kraal where a uniform, dense stand of *Cyperus esculentus* had developed. Plots 6 ft. by 1.5 ft. were marked out and sprayed with herbicides at the early flowering stage in September, 1965, about three weeks after emergence. Regular visual ratings of herbicidal effects were carried out. When the weeds were harvested 11 weeks after spraying, foliage from the entire plots was weighed, and the tubers separated from two soil quadrats, each 12 inches by 9 inches by 4.5 inches deep, were washed and weighed. Germination tests were carried out on a sample of tubers from each treatment.

Details of the various herbicides used in the experiments and mentioned in the discussion are shown in Appendix I.

TABLE I

Details of seven experiments conducted with *Cyperus* spp. in trays

Expt. No.	Species	Date planted	Time of spraying	Date sprayed	Age at harvest
1	C. esculentus	19/9/64	Pre-emergent	22/9/64	11 weeks
2	C. rotundus	23/10/64	Pre-emergent	25/10/64	9 weeks
3	C. rotundus	9/9/65	Pre-emergent	10/9/65	12 weeks
			Early post-emergent	27/9/65	12 weeks
			Late post-emergent	20/10/65	12 weeks
4	C. rotundus	4/1/65	Early post-emergent	22/1/65	10 weeks
			Late post-emergent	5/2/65	10 weeks
5	C. esculentus	18/9/64	Post-emergent	Weekly	14 weeks
6	C. rotundus	17/9/63	Post-emergent	Weekly	11 weeks
7	C. rotundus	9/9/65	Pre-emergent	10/9/65	12 weeks
			Post-emergent	20/10/65	12 weeks

Results

Effects of 2,4-D

Experiments 1 and 2 were planted during the early spring period when *Cyperus* spp. are most troublesome in many sugarcane fields. The results shown in Table II indicate that increasing amounts of 2,4-D amine up to 3.6 lb. a.e. per acre did not affect the development of either C. *esculentus* or C. *rotundus* appreciably. An apparent slight trend towards lower foliage and tuber production was not statistically significant.

The failure of pre-emergent treatments with 2,4-D even at 4.8 lb. a.e. per acre, to suppress either foliage or tuber production of *C. rotundus* was confirmed in Experiment 3. As shown in Table III, an apparent reduction in the number of tillers was not reflected in the weight of foliage produced when the weeds were 12 weeks old, but as noted previously flowering was either delayed or inhibited. In contrast to the lack of pre-emergent effects due to 2,4-D, there were highly significant effects due to post-emergent application of 4.8 lb.

TABLE II

Effects of increasing amounts of 2,4-D amine applied pre-emergent on *Cyperus esculentus* and *Cyperus rotundus*

Expt. No.	Species	Treatment lb. a.e./ac	Tillers counted after emergence							Foliage wt., g.	Tuber wt., g.	No. of tubers
			1 wk	2 wks	3 wks	4 wks	5 wks	6 wks	7 wks			
1	C. esculentus	0	35	57	119	137	207	234	293	25.7	4.82	105
		1.2	27	42	97	114	182	209	236	22.2	3.60	82
		2.4	31	37	108	116	167	186	226	23.5	3.64	79
		3.6	31	39	93	102	160	183	213	23.0	3.36	79
2	C. rotundus	0	63	99	139	204	264	420	796	24.4	15.2	98
		1.2	47	83	110	171	222	347	781	20.7	11.3	85
		2.4	57	95	132	194	256	406	819	24.4	12.9	99
		3.6	54	92	127	194	236	413	877	22.1	12.2	75

TABLE III

Effects of spraying *Cyperus rotundus* with 4.8 lb a.e. per acre of 2,4-D at different stages of growth

Expt. No.	Time of application	No. of tillers	Foliage wt. g.	Tuber wt. g.	No. of viable tubers	No. of flowers
3	Control	237	72	100	—	13.7
	Pre-emergence	181	70	100	—	5.5
	Early post-emergence	95	50	60	—	0.5
	Late post-emergence	73	34	46	—	—
4	Control	224	77	141	318	13
	Early post-emergence	68	12	13	13	10
	Late post-emergence	61	10	26	18	1

a.e. 2,4-D per acre on *C. rotundas* in Experiments 3 and 4, which were planted in September and January respectively. Both early and late post-emergent applications of 2,4-D caused highly significant reductions in tiller counts, foliage weights and tuber weights. There was also a marked suppression of flowering, particularly due to the late application. In Experiment 4 the number of viable tubers per tray was also reduced to a highly significant extent due to the 2,4-D treatments. There were no significant differences between the amounts of foliage or tuber produced when the weeds were sprayed * 'early post-emergent", 2.5 weeks after planting, and when they were sprayed "late post-emergent", 4.5 or 5 weeks after planting.

The successful suppression of *C. rotundus* by post-emergent applications of 2,4-D amine increased with increasing amounts of herbicide up to 7.2 lb. a.e. per acre. This is shown by the results of Experiment 7 given in Table IV. It can be seen that approximately 50% reductions in the numbers of tillers, foliage weight and root + tuber weight were effected by 7.2 lb. compared with 4.8 lb. a.e. 2,4-D per acre. The maximum treatment with 9.6 lb. a.e. 2,4-D per acre was not apparently any better than the 7.2 lb. treatment.

TABLE IV

Effects of increasing amounts of 2,4-D amine applied post-emergent on *Cyperus rotundus* in Experiment 7

Treatment lb a.e./ac	No. of tillers	Foliage wt., g.	Tuber & root wt., g.
Control	848	79	102
0.6	1018	59	54
1.2	794	51	62
2.4	486	50	57
3.6	384	43	38
4.8	269	32	29
7.2	125	15	17
9.6	135	17	12

In Experiments 3 and 4 different 2,4-D formulations and MCPA were compared at the rate of 4.8 lb, a.e. per acre. The results are given in Table V for the late post-emergent treatments only, and show that there was no significant evidence of differences between formulations in either experiment in terms of foliage or tuber weights. Treatments with all formulations, however, caused foliage and tuber weights to be highly significantly lower than those in the control trays.

TABLE V

Effects of late post-emergence applications of different 2,4-D formulations at 4.8 lb per acre on *Cypems rotundas*

Expt. No.	Formulation	No. of tillers	Foliage wt., g.	Tuber wt., g.
3	Control	237	72	100
	Amine	125	33	58
	Butyl ester	112	32	42
	Glycol ester	115	25	30
	Iso-octyl ester	133	40	54
	MCPA K salt	96	40	47
4	Control	224	77	141
	Amine	67	11	31
	Butyl ester	84	13	35
	Glycol ester	44	10	15
	Iso-octyl ester	49	7	22

effect due to the amount of Gramoxone sprayed. The trays sprayed three weeks after the emergence of the *C. esculentus* had the least amounts of foliage and tuber, and except for the latest-sprayed trays, also the smallest number of flowers per tray.

In Experiment 6 all treatments caused a complete scorch of the aerial parts of the C *rotundus*, including flowers, within one or two days of spraying. The effects of the time of spraying treatments on live tiller counts, averaged for the two levels of Gramoxone, are shown in Fig. 1. It is apparent that the above-ground competitive effect of watergrass was reduced to a minimum level for the longest period of time following spraying at 2 or 3 weeks after weed germination. Earlier spraying resulted in excessive weed recovery, whilst later spraying would have led to unnecessarily prolonged competition with a crop.

All treatments reduced the green foliage remaining after 11 weeks, compared with control, at a highly significant level, and spraying one week after germination resulted in a significantly greater final amount of green foliage than in any of the other herbicide treatments. These results are illustrated in Fig. 2, where it can be seen that weeds sprayed

TABLE VI

Effects of spraying *Cypems esculentus* and *Cypems rotundus* with Gramoxone at different stages of growth (mean data for 2 pt. and 4 pt per acre treatments)

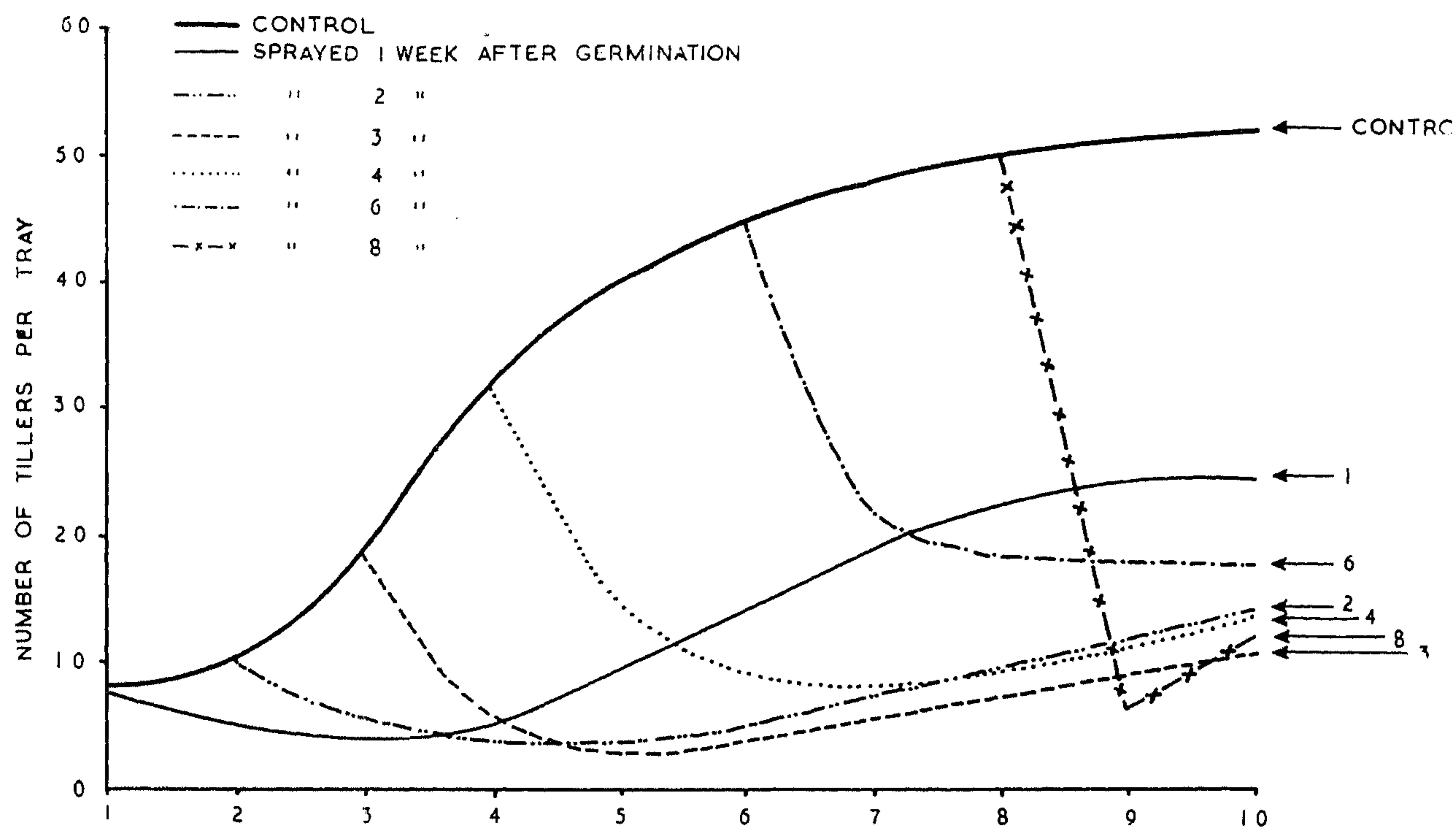
Expt. No.	Species	Stage—weeks after emergence	Foliage wt., g.	Tuber wt., g.	No. of flowers
5	C. esculentus	Control	64	7.7	32.0
		1	38	1.9	17.5
		2	23	0.7	8.9
		3	19	0.6	5.2
		4	37	0.7	15.0
		6	29	1.5	10.8
		8	15	3.3	0.4
6	C. rotundus	Control	145	237	9.8
		1	84	95	1.0
		2	56	57	1.2
		3	42	39	0.4
		4	46	42	0.8
		6	35	69	2.0
		8	34	143	2.5

Effects of Gramoxone

The effects of 2 pt. and 4 pt. of Gramoxone per acre on *C. esculentus* and *C. rotundus* were studied in Experiments 5 and 6 respectively. Both levels of treatment were applied to four replications of each species, I, 2, 3, 4, 6 and 8 weeks after emergence of the weeds. The mean effects for both levels of herbicide on foliage weight, tuber weight and the number of flowers per tray are shown in Table VI. For *C. esculentus* the treatment means were all significantly lower than the control for foliage and tuber weights, and significant differ- existed between the "stage of growth" treatments. There was no significant evidence of any

three weeks after emergence had not recovered at all by the end of the ninth week. In contrast, earlier-sprayed weeds had regenerated considerably, and weeds sprayed after the fourth week were not completely suppressed. No differences between the two rates of Gramoxone were demonstrated.

In the treated trays the weights of tubers were much less than in the control trays, the differences being highly significant- In addition, the tuber production when spraying was conducted 3 and 4 weeks after germination was very much lower than those sprayed 1 and 8 weeks after germination. There was no apparent difference between the effects of different rates of herbicide on tuber weight.



WEFKS AFTER GERMINATION

FIGURE 1: Live tiller counts In a control and at six times of spraying Gramoxone on C. *rotundus*

Inferior results were obtained when Gramoxone was sprayed on *C. rotundus* at a rate of 2 pt. per acre in October, six weeks after planting. Although the reductions in foliage and tuber weights were significant (Table VII), there was no appreciable reduction in the number of tillers per tray due to treatment with Gramoxone. A pre-emergent application of 4 lb. a.e. 2,4-D per acre had no apparent effect on the watergrass, but when an additional application of 4 lb. a.e. per acre was made six weeks after planting, highly significant effects were obtained in terms of reductions in tiller counts, foliage weights and tuber weights. A combination of 2 pt. Gramoxone and 4 lb. a.e. 2,4-D amine per acre post-emergent six weeks after planting gave even better results.

TABLE VII

Effects of Gramoxone and 2,4-D alone and in combination on *Cyperus rotundus* in Experiment 7

Treatment	No. of tillers	Foliage wt., g.	Tuber wt., g.
Control	848	79	102
Gramoxone (2 pt./ac)	822	61	61
2,4-D (4.8 lb a.e. pre- and post-emergence)	269	32	29
Gramoxone (2 pt./ac) and 2,4-D (4.8 lb a.e. post-emergence)..	148	12	15

Other herbicides

various uracils, Afalon, Dalapon and TCA on C *rotundus* were studied in Experiments 4 and 7 and the results are shown in Table VIII. The best results were obtained with the uracils, Hyvar X and Sinbar being outstanding even at 2 lb per acre. Foliage, tubers, roots, flowers and tuber viability were all suppressed almost completely. Experiment 4 was harvested after 10 weeks, and at this stage TCA at 24 lb per acre was slightly better than 6 lb Dalapon per acre, but both these treatments had exercised commercially acceptable control of *C. rotundus.* The lower levels of these two chemicals, however, did not adequately control the weeds. Afalon was not successful in causing significant reductions of either foliage or roots and tubers.

Micro-plots

The efficacy of various post-emergent herbicides in controlling *C. esculentus* in the field was estimated initially by means of visual ratings on the basis of a range from 0 for no weed control to 9 for complete weed control, a value of 7 representing approximately what is considered to be commercially acceptable weed control. Ratings carried out at 2 and 6 weeks after spraying are shown in Table IX together with the harvest data for foliage and tuber weights and per cent tuber viability. The ratings show that all three of the uracils at 4.5 lb per acre gave adequate control of *C. esculentus* after 6 weeks; that Afalon gave fairly good early control which deteriorated between 2 and 6 weeks after spraying; that even at 7.2 lb a.e. per acre 2,4-D was poorly effective; and that 3 pt. of Gramoxone per acre caused the greatest effect after 2 weeks, but after 6 weeks recovery of the watergrass had begun to take place.

TABLE VHI

The effects of different herbicides sprayed post-emergent on *Cyperus rotundus*

Expt. No.	Treatment	Rate/ac.	Foliage wt., g.	Roots & tuber wt., g.	No. of viable tubers	No. of flowers
4	Control	—	77	141	318	13
	Hyvar X	2 lb	0	7	0	0
	Hyvar X	4 lb	0	8	0	0
	Dalapon	3 lb	50	92	233	12
	Dalapon	6 lb	18	35	37	6
	TCA	12 lb	46	59	96	6
	TCA	24 lb	4	19	13	3
7	Control	—	79	102	—	—
	Afalon	1 lb	73	93	—	—
	Afalon	2 lb	70	68	—	—
	Afalon	4 lb	69	76	—	—
	Afalon	6 lb	61	81	—	—
	Hyvar X	2 lb	17	15	—	—
	Sinbar	2 lb	13	12	—	—
	U 767	2 lb	31	24	—	—

TABLE IX

The effects of different herbicides sprayed post-emergent on *Cyperus esculent us* in the field

Treatment	Rate/ac	Visual rating		Foliage wt., g.	No. of tubers	% Tuber via-bility
		2 wks	6 wks			
Control	—	0	0	204	348	53
Hyvar X	1½ lb	5.7	5.7	75	180	67
Hyvar X	3 lb	6.7	6.7	15	123	53
Hyvar X	4½ lb	7.3	8.3	4	179	40
Sinbar	1½ lb	5.7	5.0	75	148	40
Sinbar	3 lb	6.0	6.7	54	171	47
Sinbar	4½ lb	7.0	7.7	3	134	60
U 767	1½ lb	3.3	3.7	126	202	63
U 767	3 lb	6.0	6.0	35	137	33
U 767	4½ lb	6.7	7.0	15	118	47
Afalon	2.4 lb	6.7	4.0	157	204	70
Afalon	4.8 lb	7.0	6.0	76	164	47
Afalon	7.2 lb	6.7	5.3	93	231	63
2,4-D amine	3.6 lb a.e.	0.7	2.3	169	155	60
2,4-D amine	7.2 lb a.e.	2.0	3.3	84	240	50
Gramoxone	3 pt	8.7	6.0	82	153	57

The weights of foliage harvested after 11 weeks correlated well with the visual ratings at 6 weeks, but tuber viability was much higher than observed in Experiment 4, where Hyvar X completely suppressed *C. rotundus* tuber viability. The numbers of tubers in all treatments in the micro-plots, however, were significantly less than those in control plots.

Discussion

It is perhaps important to define the term "weed control" when it is used in local parlance, as either the temporary suppression or the elimination of weeds in sugarcane fields. Thus the control of watergrass does not necessarily imply its elimination, but almost invariably its suppression for a relatively short period, so that the sugarcane crop can develop unhindered to the stage when it effects natural further suppression due mainly to shading.

The suggestion that pre-emergent applications of 2,4-D can give a modicum of control of Cyperus spp. is not supported by the results of these experiments. A possible slight but non-significant reduction in the number and weight of tubers of *C. esculentus* in Experiment 1, as shown in Table II, was not sufficient to warrant the treatment commercially if the suppression of watergrass alone were the reason for a pre-emergent herbicide application. It is reassuring, however, to know that any slight effect of 2,4-D on *C. esculentus* would accrue in any event due to the standard applications of this herbicide which are recommended immediately after planting. In neither Experiment 2 nor Experiment 3 was there any real evidence that C. *rotundus* was affected by pre-emergent 2,4-D treatments, except perhaps in terms of the delay or suppression of flowering.

The effects of post-emergent applications of 2,4-D on *C. rotundus* were marked in Experiments 3 and 4, the extent of control due to both early and late

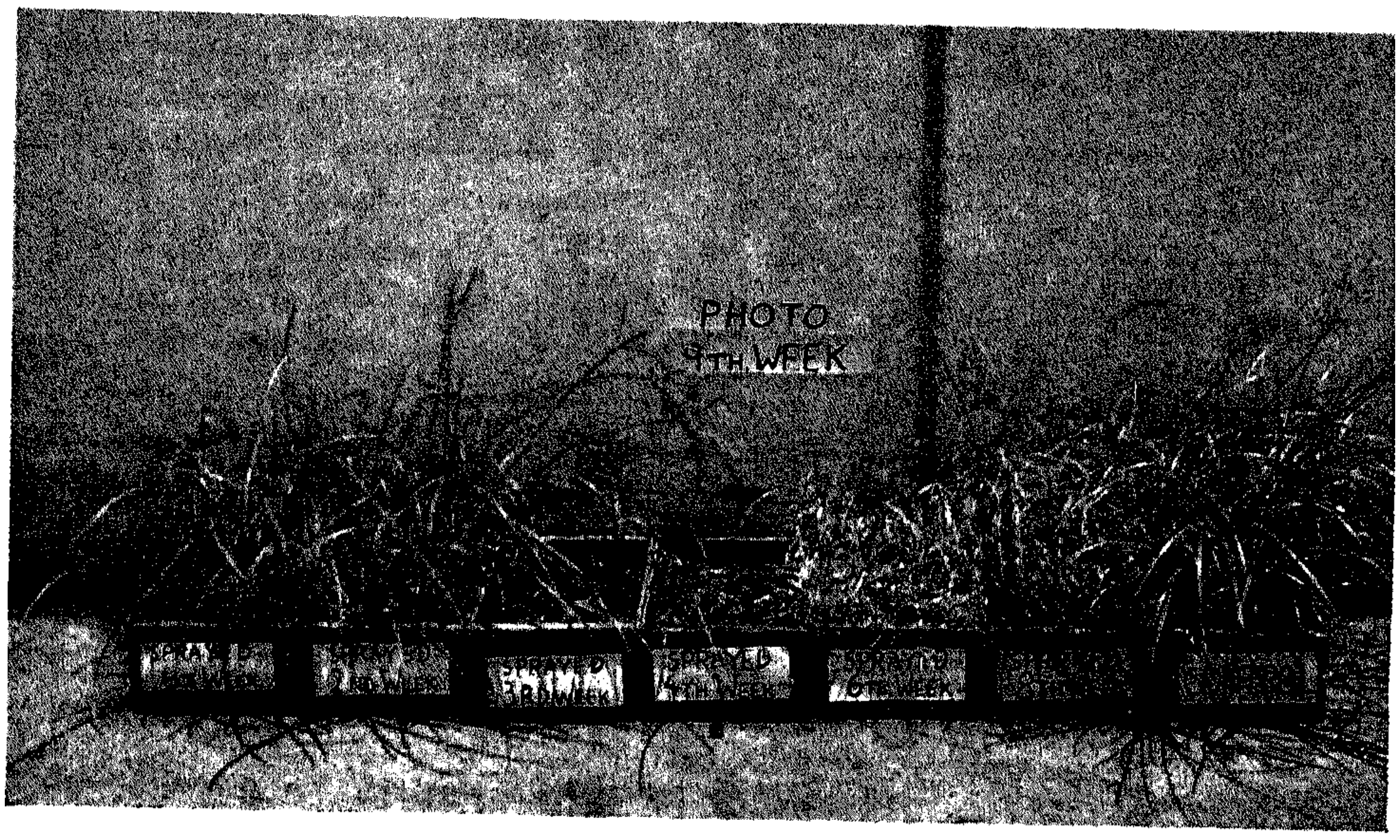


FIGURE 2: Growth* C rotundus. 9 weeks after emergence, in a control and at 6 times or spraying 4 pt. Gramoxone per acre

applications in Experiment 4 being of a commercially acceptable standard. The results shown in Table V confirm the observation made repeatedly in the sugar belt that there are no measurable differences in the effects of different forms of 2,4-D under local conditions.

Contact herbicides have been preferred by many farmers and estates for the control of *C. esculentus* and *C. rotundas* in Natal, mainly because the process is relatively independent of soil moisture conditions, which can vary so widely and unpredictably. There is also little if any disadvantage due to the short-term control which contact herbicides normally give, since the sugarcane canopy itself quickly becomes a weed-deterrent in the cane row. A water-miscible contact herbicide which can be applied at low volume rates per acre has therefore been welcomed, but the high cost of Gramoxone demands that it should always be used to give the greatest and surest possible effect. From the data given in Table VI it is apparent that the optimum time at which *Cyperus* spp. should, be sprayed, in order to reduce the reproductive potential in terms of both tubers and seed, is between 2 and 4 weeks after germination. Spraying at a later stage allowed a large number of tubers and inflorescences to develop before the herbicide was applied. Regrowth of the watergrass was most vigorous following early spraying, especially one week after germination. Tiller counts also indicated that above-ground competition with a crop could be minimized by spraying between 2 and 4 weeks after weed germination, and this was confirmed by the amount of green foliage present 11 weeks after germination. The amounts of foliage harvested from the 6- and 8-week treatments indicated only the small amount of weed recovery between these later sprayings and the harvest date.

The results of Experiment 7 shown in Table VII confirm earlier observations that the effects of Gramoxone applications can be improved by including 2,4-D. It should not be necessary to use as much as 4.8 lb ae. per acre, and current recommendations are that only 2 or 3 lb a.e. of 2,4-D should be included with a Gramoxone treatment. On a row only basis, the additional cost is very small whilst the advantages to be gained can obviously be considerable.

The control of *Cyperus* spp. in young ratoon cane where the previous crop has been burnt remains one of the major weed problems in sugarcane fields. The results of Experiment 7 shown in Table **VIII,** and of the micro-plot experiment shown in Table IX, have been confirmed in more recent observational work, and it is now apparent that neither Afalon nor Karmex controls *C. rotundus,* but that both herbicides control *C. esculentus* adequately. On the other hand, 2,4-D has controlled C. *rotundas* fairly consistently, but has not had a similar effect on *C. esculentus.* At least of the controversial expressed about chemical control of *Cyperus* spp. in sugarcane fields in Natal therefore probably derive from a lack of species identification. The results of the experiments discussed in this paper indicate that both 2,4-D formulations and a substituted urea are selective in their effects and hence combinations of Karmex or Afalon with 2,4-D are required for effective control of mixed watergrass populations.

The use of less expensive herbicides such as TCA or Dalapon may also be recommended where soil moisture conditions are suitable, but damage to cane, particularly by Dalapon, makes these formulations more hazardous than the substituted urea formulations. The uracils remain the most effective chemicals for use on *Cyperus* spp. over a wide range of soil moisture contents, but their phototoxicity to sugarcane also limits their applicability. Hyvar X has been consistently effective, as shown in Experiments 4 and 7 in the microplot experiment, whilst Sinbar has given comparable results. The compound U767, however, has generally given results inferior to those obtained with the other two compounds.

Increasing amounts of 2,4-D up to 7.2 lb a.e. per acre, applied post-emergent on *C. rotundus,* may give progressively better control, but even at this high rate the effects on *C. esculentus* are limited. Pre-emergent applications of 2,4-D are not effective in suppressing either *Cyperus* spp. appreciably.

Gramoxone should be sprayed on *Cyperus* spp. when the weeds are about 3 weeks old or at the commencement of flowering. The inclusion of 2 lb a.e. of 2,4-D with the Gramoxone should improve the efficacy of the treatment.

Mixed watergrass populations in young ratoons can be sprayed with Karmex and 2,4-D when soil moisture conditions are favourable, but where only one *Cyperus* species is present it should be identified and the correct treatment selected.

Summary

Herbicides have been used in experiments and in field practice over the past 18 years to control *Cyperus esculentus* and *Cyperus rotundus* in Natal. The results of recent experiments confirm that little if any pre-emergent effect can be obtained with 2,4-D formulations, but post-emergent applications up to 7.2 lb a.e. 2,4-D per acre gave increasingly better control of *C. rotundus** Limited evidence showed that 2,4-D at this rate was not effective in suppressing *C. esculentus.*

Gramoxone was most effective when sprayed on both *Cyperus* species at a rate of 2 or 3 pints per acre, 2 to 4 weeks after weed emergence. This treatment limited the above-ground development of the watergrass and caused the recovery of the weeds to be least. The addition of 2,4-D to the Gramoxone improved the efficacy of the treat-

Of the other herbicides tested, the uracils were the most consistently successful, but the phytotoxicity of Hyvar X and Sinbar to sugarcane limit their usefulness. Afalon gave fairly good control of *C. esculentus* but did not control *C. rotundus*. Dalapon at 6 lb per acre and TCA at 24 lb per acre caused above and below-ground development of *C. rotundus* to be severely affected, but at half these rates the chemicals were relatively ineffectual.

References

1. Cleasby, T. G. (1957). The control of weeds by chemicals. Three experiments carried out by the Tongaat Sugar Company Ltd. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 31 : 119-123.
2. Gilfillan, E. C. (1966). Problems in weed control on an estate. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 40 : 315-316.
3. Gosnell, J. M. (1965). Herbicide trials in Natal sugar cane. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 39 : 171-180.
4. Gosnell, J. M. and Thompson, G. D. (1964). The results of herbicide trials, 1963/64. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 38 : 166-174.
5. Gosnell, J. M. and Thompson, G. D. (1966). The results of herbicide screening trials in sugarcane during 1965. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 40 : 304-311.
6. McMartin, A. (1949). Chemical weed-killers: their possible use in Natal cane fields. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 23 : 89-91.
7. McMartin, A. (1950). Further developments in chemical weed-killers. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 24 : 106-108.
8. Steward, E. (1956). The control of weeds in plant cane by chemical spray. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 30 : 125-128,
9. Stewart, M. J. (1955). A survey of chemical weed control in sugarcane. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 29 : 126-133.
10. Thompson, G. D. and Gosnell, J. M. (1963). The results of herbicide trials conducted in the cane belt in Natal, 1962/63. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 37 : 143-152.
11. Thompson, G. D. and Trichardt, H. (1957). Observations and results with weedkillers at Illovo. *Proc. Annual Cong. S. Afr. Sugar Tech. Ass.* 31 : 125-128.

APPENDIX 1

HERBICIDE FORMULATIONS

Commercial product	Short chemical name	Composition
Shellamine 7.2 ..	2,4-D amine	7.2 lb a.e./gall
Shell D	2,4-D ester	4 lb a.e./gall
Esteron 10-10 ..	2,4-D glycol ester	4.8 lb a.e./gall
Planotox	2,4-D iso-octyl ester	6.7 lb a.e./gall
Fernimine 4	MCPA K-salt	4 lb a.e./gall
Gramoxone	Paraquat	2 lb a.i./gall
Hyvar X	Bromacil	80% a.i.
Sinbar	U 732	80% a.i.
—	U 767	80% a.i.
Dowpon	Dalapon	85% a.i.
Tricate	TCA	94% a.i.
Afalon	Linuron	50% a.i.
Karmex..	Diuron	80% a.i.

Mr. Wyatt: There is a new compound in Louisiana called Banvel D which is apparently effective in controlling water grass.

Dr. Thompson: Banvel D deals with Cyperus species but we do not recommend it as it damages the cane severely.

Mr. Gilfillan: Our experience with 2,4-D at Tongaat on *Cyperus esculentus,* with pre-emergent control, is completely opposite to what appears in this paper as our control is excellent on all soil types when soil moisture is high.

We are using Karmex as a post emergent treatment and are getting good control under all soil moisture conditions. Moisture seems to have no effect at all on post-emergent treatments.

The Karmex must be sprayed when the leaf length of the water grass is at least ten inches.

Mr. Armstrong: Has Dr. Thompson done any field work on combination of 2,4-D and Gramoxone.

Dr. Thompson: Our conclusions are that the effects of Gramoxone with 2,4-D are better than those of Gramoxone alone.

It is of interest that we are getting reports of 2,4-D toxicity, and in a pre-emergent experiment at Pongola we have visual proof of damage from it.

Mr. Gonggryp: Has the pre-emergent effect of long chain esters been compared against the amines.

Mr. Gosnell: In some instances the residual effect of amine has not been as long as the long chain esters but usually we find very little difference.

Mr. Brown: Is the effect of 2,4-D different on water grass grown from seed and that grown from tubers?

Mr. Gosnell: It is far more effective on water grass grown from seed.

Mr. King: It is claimed that if soil moisture is high weed control is good. It would seem that a high water application, possibly 100 gallons an acre, could be justified commercially.

Dr. Thompson: We get good results with 20 gallons per acre, row only, or 40 gallons full cover. Efficient jets must of course be used.

Mr. Bartlett: I cannot see the value of row only treatment as it will allow the water grass to grow in untreated areas and necessitate further treatment in the next season. In fact I do not see why, by more frequent and intensive overall treatment, the water grass cannot be permanently eliminated.

Mr. Gosnell: I do not think you will ever obtain total elimination and there would also be damage to the cane.

Mr. Brown: After weed spraying at Muden, before planting cane in areas that had carried citrus for forty years, we noticed a big reduction in weed population.

Mr. Gilfillan: Is there possibly a difference in formulation of present day herbicides that could account for reported damage to cane?

Dr. Thompson: Reports of damage by 2,4-D to cane appear to coincide with the introduction of more concentrated formulations.

Mr. Wardle: There may be a cumulative effect of herbicide causing damage to the cane and it would be interesting to know if ratoon crops have been more affected than plant crops.

Dr. Thompson: One of our experiments was carried out with plant cane in an area that had been virgin bush and damage was still caused.

Mr. Date: Was the damage apparent at all levels of application?

Dr. **Thompson:** The application was 3 lb. acid equivalent of 2,4-D per acre.

Mr. Pearson: Has the damage been mainly to N:Co.310?

Dr. Thompson: It has been mainly to N:Co.376 but our current experiments are to test three varieties with different formulations of 2,4-D to gauge the effects of phyto-toxicity.

FIELD POPULATIONS OF *NUMICIA VIRIDIS,* MUIR

by A. J. M. Carnegie
South African Sugar Association Experiment Station

The green leaf sucker *Numicia viridis,* Muir (Homoptera: Tropiduchidae) was first regarded as a pest of sugarcane when there was an unexepected build-up in its numbers. Affected cane turned yellow and appeared flaccid and drooping (Dick 1963). The most conspicuous outbreaks were recorded from Swaziland and Pongola (Eastern Transvaal), but at about the same time considerable numbers were recorded also from the Natal south coast. When a "new pest" of this sort is first noted the impression may be received that its numbers are going from strength to strength, and owners of damaged cane may well wonder where its activities will cease The immediate and understandable reaction is to employ emergency insecticidal measures, so bringing an end to the infestation artificially. This is what happened with *Numicia.*

Since the first noted outbreaks of 1962 it has been possible with subsequent outbreaks to study the form they have taken, and in many cases no insecticide has been used to effect control. It has been possible also to make studies of population numbers under normal field conditions, and this has shown that where no insecticide is used fluctuations in numbers follow a seasonal pattern. At present *Numicia* is regarded as a pest of inland irrigated cane rather than of coastal areas, where numbers have been too small to justify regular population assessments.

From data collected in cane fields of a large Swaziland sugar estate (10,000 acres of inland irrigated cane) it has been possible to study *Numicia* population fluctuations since January 1964. Initially assessments were made of nymph and adult numbers only, but since August 1964 figures for eggs also have been available.

Numbers of nymphs and adults are assessed by shaking growing cane vigorously over a yard square plastic sheet on which there has been smeared molasses, to which the fallen insects adhere and are counted. On each occasion this is done in ten places per field, fifteen fields being sampled each time. At the same time from each of ten fields 100 leaves are collected and the numbers of *Numicia* eggs in them are noted. Preferably, leaves are sampled by walking between cane rows and at every third pace picking the nearest and lowest green leaf until 100 are collected; but where cane is badly lodged this method may be modified. Any leaves which contain no eggs are discarded and the rest are forwarded to the Experiment Station at Mount Edgecombe, where they are counted, and the eggs carefully examined and divided into various categories depending on whether they are hatched, unhatched, parasitised, etc. (Carnegie 1966). Initially these counts were done at weekly intervals, but as the insect became better understood and there was no longer any fear of a sudden build-up, the intervals were changed at first to a month and more recently to two weeks.

Figures for each field are then plotted. For any field, sampling begins when the cane is about four to five months old and ends when the cane is cut. Means of all fields sampled are shown graphically in Figure 1. (Graphs for individual fields reflect the same general pattern, which is considered a fair representation of overall populations.) In the figure *Qgg* numbers are plotted to a scale different from the logarithmic one used for nymphs and adults.

From data so far available various points may be noted.

Relative numbers of each stage of the life cycle (egg, nymph, adult) followed an expected pattern. A fall in numbers of unhatched eggs was followed by an increase in numbers of nymphs, which in turn was followed by an increase in adult numbers. There was a decrease in adult numbers following copulation, oviposition and death. In all but one case (April-May 1965) peaks in adult numbers were always lower than corresponding peaks in nymph numbers, which can be explained by natural mortality during the nymphal stages. In the one exceptional case the inversion is thought to be due to sampling errors, the only alternative possibility being a migration of adults from surrounding grasses which is considered most unlikely.

In the three years for which figures are available there have been three generations each year, with peaks in adult numbers occurring in February, May and October, which indicates that breeding rate was more rapid during the hotter, more humid months. There is little overlap of the various stages of the life cycle, which is probably governed by climatic factors.

Over the last three years, during which very little insecticidal action has been taken, overall numbers have remained fairly constant. Numbers of nymphs, and subsequently adults, were particularly high from August to October 1965, the mean being raised by one field in particular, in which exceptionally high numbers occurred two and a half months after aerial dusting with malathion. But during 1966 the pattern was much the same as it had been during 1964, and this suggests that there has arisen some state of overall equilibrium, which must be governed by natural factors. *Numicia* populations contain approximately equal numbers of males and females and, in the insectary, one female lays between 150 and 200 eggs (Anon. 1964). The potential therefore for population increase is enormous, and the fact that numbers fluctuate only within certain limits means that control by natural factors must be extremely effective. In cane it has been found that during the egg stage up to 60 per cent of eggs may be destroyed by the activities of two hymenopterous parasites, *Ootetrastichus beatus* (Eulophidae) and *Oligosita* sp. (Trichogrammatidae), and that some perish from physical causes. In grass hosts natural egg mortality is even higher (Carnegie 1966). But in cane it is the early nymphal stage which is the most vulnerable. Young nymphs hop when disturbed and, should they land on the ground or on lower dry leaves, may die before they are able to feed again. They are the easy victims of various predators, and may be destroyed also by adverse climatic conditions.

In August of each year adult numbers reached an exceptionally low level. This could be coincidental or in some way related to the more slowly developing winter generation. The possibilities of adult migration to and from grasses are being investigated, but it is felt that if any purposeful or induced migration does occur it would be least expected at this time of year when there is a minimum of green grass available. Since cane sampled is usually more than four months old, a migration of adults to younger cane might cause a drop in numbers of those sampled, but there is at present little evidence that such a migration occurs. In any form of integrated control which might become policy these periods of low adult numbers could prove important, because at this time one would expect a minimum number of unhatched eggs, a stage in the life cycle which is immune to insecti-

From observations made of *Numicia* populations in indigenous grasses, including regular weekly counts which have been in progress for nine months, it is evident that the same pattern is repeated. It is possible that as *Numicia* becomes better adapted to life in permanently green irrigated cane this pattern of three generations a year may change, although so far there is no indication that this is happening.

Summary

Studies of field populations of the green leaf sucker of sugarcane, *Numicia viridis*, Muir (Homoptera: Tropiducidae) made over three years have shown that there are three generations a year with peaks in adult numbers occurring in February, May and October. There is little overlapping of the various stages (egg, nymph and adult) and during the period of study there has been no alarming overall increase in numbers. When planning control measures, advantage might be taken of regular periods of low adult and, therefore, low egg numbers. Observations to date indicate that a similar pattern of population fluctuations exists in indigenous grass communities.

Acknowledgements

The continuing help and co-operation of the management and staff of Ubombo Ranches, Swaziland is greatly appreciated. The paper includes material being used for post-graduate work in the Entomology Department of the University of Natal.

References

Anon. (Dick, J.) 1964. Rep. Exp. Stn. S. Afr. Sug. Ass. p. 55.

Carnegie, A. J. M. 1966. The progress of an untreated outbreak of *Numicia viridis*, Muir. Proc. S. Af. Sug. Technol. Ass. pp. 319-327.

Dick, J. 1963. The green leaf sucker of sugarcane *Numicia viridis*, Muir. Proc. S. Af. Sug. Technol. Ass. pp. 153-157.

For discussions on this paper see page 183.

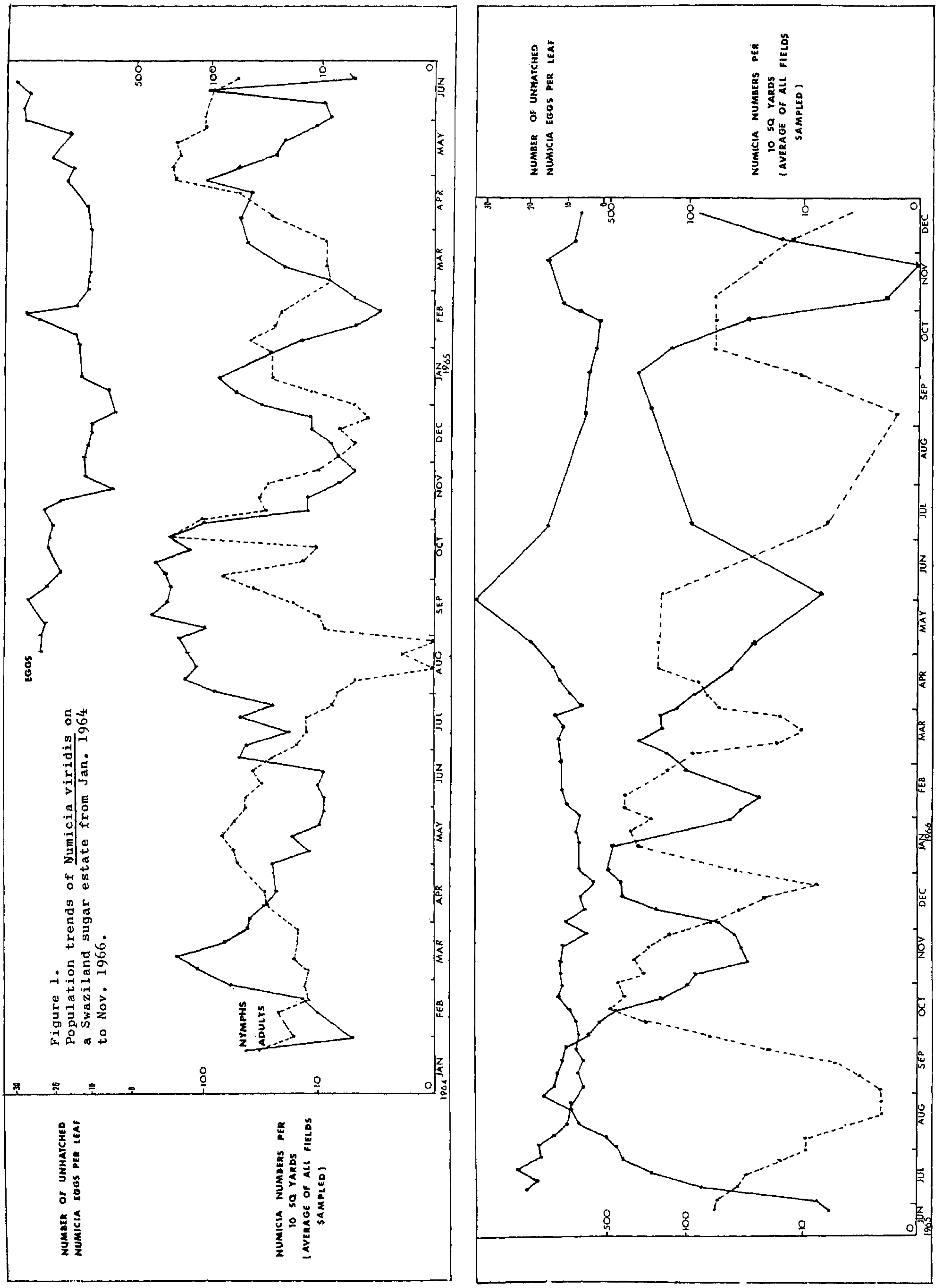


Figure 1.
Population trends of *Numicia viridis* on a Swaziland sugar estate from Jan. 1964 to Nov. 1966.

FOUR YEARS OF NUH1CIA SURVEY

by J. DICK
South African Sugar Association Experiment Station

Since the recognition of *Numicia viridis*, Muir, as a pest of sugarcane (Dick 1963), annual surveys have been carried out with two main objectives. In the first place it has been considered important to study the geographical distribution of the insect within the area covered by the South African sugar industry, to notice any population trends which may occur and to have early warning of increases in particular areas. For example, the 1966 survey revealed the presence of a local infestation near Paddock on the Natal South Coast and, although it has not proved necessary to apply specific control measures, this area has been kept under observation since the survey. Secondly, it was hoped that inspection of several hundred sites under various ecological conditions might yield information on the type of environment in which outbreaks are most likely to occur. Four surveys have been carried out and this paper is an attempt at collating and generalizing upon the information collected. Population studies in Swaziland are not included since these are carried out in a different way and form the subject of a special research project (Carnegie 1967).

Methods

In every selected site five counts are made, each representing the population found in one square yard of cane-field. The area is defined by placing a sheet of black plastic material between the cane rows, where it is kept in position by two strips of wood attached to opposite sides. Nymphs and adults of *Numicia* falling on to the plastic sheet are counted and recorded separately. During the 1963 survey, the sugarcane above and around the sheet was liberally dusted with a 5 per cent malathion powder and the sheet was left in position for five hours, after which the insects which had fallen on it were counted. This method enables fairly accurate counts to be made even when insects are present in large numbers, but it limits the sites which a team of two observers can examine per day to about five. Each site must be visited twice, first to apply the insecticide and later to collect and count the insects. In addition, the sites which can be examined in a day are limited by the number of plastic sheets which can be carried. Since populations found in 1963 were seldom high enough to make counting difficult, it was decided that subsequent surveys would be based on the insects landing on the plastic sheet when the surrounding cane is vigorously shaken. This technique may not be quite as accurate as the malathion method but it enables a team provided with a single sheet to examine up to thirty sites in one day.

Counts are entered on a standard form on which particulars of locality, irrigation, variety, crop. whether plant or ratoon, and age of cane are recorded. Forms are completed even when no *Numicia* is found.

Assessment of Results

During outbreaks in such areas as Pongola and Swaziland, *Numicia* occurs in practically every field although numbers vary considerably from site to site and populations fluctuate seasonally, reaching peaks during which several hundred individuals per square yard can sometimes be found (Carnegie 1966). On the other hand, over the rest of the sugar belt counts exceeding five individuals per square yard are comparatively rare. Since the inclusion of a few very high counts might prejudice generalizations on the effect of environmental factors, it was decided to use the percentage of positive sites in preference to the number of individuals as a standard for comparison.

In 1963, only 93 sites were examined and information on some of the factors now being investigated was too meagre to be included in discussions. Subsequent surveys dealing with a far greater number of sites produced figures on which somewhat greater reliance can be placed.

Some of the information in this paper has appeared in Annual Reports of the Experiment Station of the S.A. Sugar Association (1963-1966). Slight discrepancies in some of the figures are due to the inclusion of records which became available after publication of the Reports or, in one case, to the omission of a few records which were thought to be inaccurate. They do not appreciably affect the results.

In the seven tables appended to this paper, information on the association between certain environmental factors and the incidence of *Numicia* is extracted from the results of surveys. Although some fairly definite trends are indicated, it cannot always be assumed that association necessarily implies causality since some of the factors considered are linked together. Thus Pongola cane is all grown on flat land under irrigation, while most cane in the Midlands area is grown on hills without irrigation. Similarly, the choice of sugarcane variety is largely influenced by environment. Nevertheless, for most of the factors considered here, enough sites have been examined in the various environments for the results to have some value.

Discussion of Results

Since surveys have been undertaken for only four years, the results cannot be expected to yield much evidence on long-term fluctuations. The figures for 1963 were based on a relatively small number of sites which were, however, well scattered over the sugarcane area. If they can be accepted, it would appear that *Numicia* incidence has increased since then (Table I). Some of the apparent trends in particular regions may possibly be explained (Table II). For example, the decrease in Zululand, particularly during 1966, was associated with the presence of a considerable amount of cane obviously affected by drought. The increase in the Midlands has almost certainly been due to the extension of sugarcane to areas more suitable for *Numicia*. On the South Coast, the infestation at Illovo practically disappeared after 1964 but the percentage of sites in which small numbers can be found has remained about the same for the last three years and there has been a slight build-up near Paddock. The Eastern Transvaal was, for the first time, included in the survey during 1966. A few positive sites were recorded but numbers were not high.

TABLE I

Numicia Populations from 1963 to 1966

	Over 5 per sq. yard		Up to 5 per sq. yard		None found	
	Sites	%	Sites	%	Sites	%
1963	3	3.23	23	24.73	67	72.04
1964	86	10.96	425	54.14	274	34.90
1965	36	5.51	294	44.95	324	49.54
1966	28	5.43	266	51.55	222	43.02

TABLE II

Numicia Incidence by Regions

Figures represent percentage of sites positive

	1963	1964	1965	1966
E. Transvaal	—	—	—	8.00
Pongola	33.33	97.06	100.00	97.06
Zululand	48.28	69.86	45.62	36.60
N. Coast	19.44	65.69	65.46	73.68
Midlands	0.00	2.63	4.44	38.24
S. Coast	21.43	65.06	71.30	64.20
Average	27.96	65.10	56.88	57.25

In the South African sugarcane area, alluvial flats constitute a special environment, often noticeably different from the rest of the country. For this reason, figures for *Numicia* incidence from these areas were extracted separately and compared with those from other environments (Table III). For three of the four years under consideration, *Numicia* incidence has been noticeably higher on alluvial flats than elsewhere. In 1966, little difference was shown but this might to some extent be explained by the fact that much of the cane grown on flats in Zululand was suffering from drought when the survey took place.

TABLE III

Numicia Incidence and Topography

	1963	1964	1965	1966	Average
Alluvial flats	37.50	79.44	73.33	57.06	61.83
Other	22.95	61.77	43.00	56.76	46.12

The sites of severe outbreaks of *Numicia* have so far been areas in which cane is grown under irrigation. Figures for incidence on irrigated cane throughout the sugarcane area were therefore extracted separately and compared with those for unirrigated cane (Table IV). This indicated that, for the four years under discussion, incidence was appreciably higher in irrigated cane but no difference could be seen, from this point of view, between furrow and spray.

TABLE IV

Numicia Incidence and Irrigation

	1963	1964	1965	1966	Average
Irrigated	36.11	81.18	68.90	67.72	65.26
Not irrigated	22.81	56.55	42.08	51.43	43.22

Figures for incidence in cane of different ages show little constant trend except that the insects are less often found on very young or very old cane than in cane of intermediate age. There is no appreciable difference in incidence between plant and ratoon cane.

Only five varieties of cane were inspected in a sufficiently large number of sites for comparisons

TABLE V

Incidence by Crop

	Plant cane	Ratoon
1964	70.00	61.55
1965	53.81	50.91
1966	50.00	59.54
Average	57.94	57.33

TABLE VI

Incidence by Age of Cane

	1964	1965	1966	Average
Up to 3 months	35.71	52.38	31.58	39.89
4 to 6 months	58.45	58.11	43.22	53.26
7 to 9 months	70.40	65.49	53.85	63.25
10 to 12 months	72.73	51.51	61.63	61.96
13 to 15 months	69.77	50.00	66.67	62.15
16 to 18 months	74.24	24.19	70.59	56.34
Over 18 months	46.15	7.14	68.42	40.57

TABLE VII

Incidence by Variety

	1964	1965	1966	Average
N.50/211	70.15	60.66	75.00	68.60
N:Co. 310	69.71	58.26	62.41	63.46
N:Co. 376	67.74	49.59	53.59	56.97
N:Co. 382	60.85	35.14	40.62	45.54
N:C. 293	24.49	29.03	48.48	34.00

to be made (Table VII). The results for these show a slightly, but consistently, higher incidence in N50/211 than in N:Co.310. Incidence in N:Co.376 is regularly slightly lower than in N:Co.310. The lower incidence in the other two varieties may be associated with the environments in which they are commonly grown. N:Co.293 occurs most frequently in high altitude areas and N:Co.382 in sandy fields, neither of which appears particularly to favour the presence of *Numicia*.

Summary

Methods for counting and recording numbers of nymphs and adults of *Numicia viridis*, Muir, during surveys from 1963 to 1966 are described.

The incidence of this insect in the major subdivisions of the South African sugar area is quoted for these four years. Incidence was found to be higher on alluvial flats than elsewhere, and higher in irrigated than in unirrigated fields. Fewer positive cases were found in very young or very old cane than in cane of intermediate age and there was no difference between plant cane and ratoons. Among sugarcane varieties, the percentage incidence was slightly, but consistently, higher in N50/211 than in N:Co.310. In N:Co.376 incidence was consistently somewhat lower than in N:Co.310.

Acknowledgements

The extensive surveys carried out from 1864 to 1966 were made possible by the collaboration of the Plant Disease Inspection Service, the Regional Representatives and the personnel of a number of sugar companies.

1. Carnegie, A. J. M. (1966). The progress of an untreated outbreak of *Numicia viridis*, Muir. *Proc. S.Af. Sug. TechnoL Ass.* pp. 319-327.
2. Carnegie, A. J. M. (1967). Field populations of *Numicia viridis*, Muir. *Ibid*, (in press).
3. Dick, J. (1963). The green leaf-sucker of sugarcane, *Numicia viridis*, Muir. *Ibid.* pp. 319-327.
4. *Rep. Exp. Stn. S. Af. Sug. Ass. 1962-63*, pp. 55-57.
5 *Ibid. 1963-64*, pp. 51-57.
6. *Ibid. 1964-65*, pp. 88-94.
7. *Ibid. 1965*66*, pp. 71-78.

Discussion

Dr. Thompson (in the chair): The bad outbreak of *Numicia* in 1962 in Swaziland does not appear to have recurred since.

Dr. Dick: There was a severe outbreak in a field at Big Bend eighteen months ago but *Numicia* may not have been the only cause of damage in this instance.

Mr. Landsberg: Can the presence of *Numicia* be related to climatic conditions?

Mr. Carnegie: We have rainfall and temperature figures for Ubombo Ranches but I do not think a particular climatic condition initiated the original outbreak.

Mr. Date: There was a difference in numbers of *Numicia* recovered per shake—was this reflected in the amount of visible damage to cane?

Dr. Dick: Other factors are involved, such as the stage of the insect and the age and growth of cane.

Mr. **Carnegie:** Varieties also play a part. Where we found the highest populations the cane was eight month old N:Co.376 and the symptoms were slight. That same population in N:Co.310 would produce very conspicuous symptoms of damage.

Mr. Date: I understand experiments have been made with predators from Mauritius?

Mr. Carnegie: Small trial shipments have been received from Mauritius and we have shown that the insects can feed on a diet of *Numicia* eggs alone and on a diet of *Perkinsiella* eggs, but we do not want to import any more until we can rear these hosts in large numbers.

Mr. Armstrong: Have the authors any information about the population trends of *Perkinsiella'?*

Mr. Carnegie: There are large numbers of *Perkinsiella* on Eastern Transvaal cane, where *Numicia* is present at a lower level. Following dusting we have had increases of *Perkinsiella* numbers. We have identified an effective parasite for *Perkinsiella*.

Dr. Dick: *Tytthus* is used in other parts of the world as a predator where another species of *Perkinsiella* is a serious problem. *Tytthus* if introduced could be kept alive by *Perkinsiella* when *Numicia* was not present.

Mr. Harris: Surveys have shown that *Numicia* is most common in lush cane growing in alluvial areas. This may be associated with the fact that such cane is rich in proteins, the presence of which encourages the development of the reproductive system of

STUDIES OF PARASITIC FUNGI ON THE CANE PEST *NUMICIA VIRIDIS* MUIR

by G. ROTH
South African Sugar Association Experiment Station

Numicia viridis Muir, otherwise known as the green leaf-sucker, is an important pest of sugarcane in South Africa (Anon.[2, 3]; Dick[5]). It is capable of causing considerable damage to this crop and has therefore been the subject of repeated pest population surveys. Studies of its life history, pest-host plant-relationships and means of biological control, are all currently receiving considerable attention (Anon.[1]; Carnegie[5]).

Studies, carried out by the Entomology Department of the Experiment Station of the South African Sugar Association, have revealed that natural populations of *Numicia* sometimes fall quite dramatically. The dead insects are usually blown away by the wind, and those recovered from the soil are normally too contaminated to yield information on the cause of death. However, a limited number of dead *Numicia* can sometimes be found loosely attached to cane foliage, and these have been used to determine which organisms were the cause of death.

Material and Methods

Adult *Numicia* used in these studies were collected during entomological surveys in cane fields in various districts both in South Africa and Swaziland. Both live and dead specimens were secured. Live specimens were used for studies of disease infection and they were reared in cylindrical glass jars, 3 x 18 inches in diameter, the open ends of which were covered with a fine mesh and a perforated lid. A rooted cane sett bearing healthy green leaves was placed in each cylinder, the young plant having been reared beforehand in nutrient solution for approximately 6 weeks.

Dead specimens were classified into four groups:

(a) specimens showing no visible symptoms of deterioration.

(b) specimens which had shrivelled but showed no other sign of decomposition.

(c) specimens showing external symptoms of fungus growth.

(d) specimens in an advanced stage of decomposition, the body being distended and liable to disintegrate.

The dead *Numicia* in their separate groups were stored under both dry and moist atmospheric conditions, and were compared with killed healthy specimens treated in the same way. Superficial and internal microflora from previously healthy and diseased specimens were examined histologically and by culturing on various media. The internal microflora were kept distinct from the external by culturing samples only after they had been carefully surface sterilized and then rinsed with sterile water.

Culturing was carried out in petri dishes, using the following media, the pH of which varied from 4.5 to 7.0: sterilized slices of potato; liquid and semi liquid forms of a mixture comprising 10g maltose, 8g peptone, and 25g glycerol; brain-heart infusion gelatine; blood agar and gelatine; potato dextrose agar; and Czapak's agar. Finely pulverised bodies of *Numicia* were spread over the surface of these media, and in some cases fungal mycelium was transferred from the insect to the culture media, using a needle.

Identification of Micro-Organisms

Healthy *Numicia* were found to be contaminated with very many different types of saprophytic fungi, many of which are also found on plants and in the soil on decaying vegetable matter. A wide range of bacteria were also found associated with the insect, all of which appeared to be non painogenic in character. These fungi and bacteria were also present on diseased specimens, but no association was found between them and the state of health of the *Numicia.*

Cultures of inoculum obtained from the external and internal parts of dead and dying insects, yielded quite a number of fungal species which were not present in cultures derived from healthy specimens. The frequency of their occurrence eliminated the possibility of their being caused by secondary contamination. However, in view of the multiplicity of organisms found, an experiment was put down, designed to clarify the association between specific organisms and *Numicia* disease. Fifty six *Numicia* which were dying or had recently died of disease, and 20 healthy specimens, were each used to inoculate ten culture plates. This provides for duplication of the 5 culture media and gives a total of 760 plates. The organisms associated with the diseased insects are listed in Table I.

TABLE I

Parasites associated with natural mortality of *Numicia viridis* Muir

Parasite	Contamination			
	Healthy insects		Diseased insects	
	Number	%	Number	%
Beauveria bassiana ..	3	1.5	94	16.8
Microsporum sp.	0	0	58	10.4
Fusarium semitectum ..	7	3.5	172	31.5
Dactylium fusarioides ..	0	0	35	6.2
Fusarium poae	0	0	126	22.5
Entomophthoraceae ..	0	0	542	96.6
Mucor sp.	2	1	314	56.0
Nematodes	0	0	69	12.2
Total number of insects examined	200		560	

Eight parasites are listed, only three of which were found in cultures derived from healthy insects, and then in only a very few cases. In contrast, cultures from the dead or dying insects revealed relatively high populations of each parasite and a particularly high incidence of a fungus of the family *Entomophthoraceae.* Ninety-six per cent of these cultures contained this group of fungi, 56% were infected with a species of *Mucor*, 31.5% with *Fusarium semitectum* and 22.5% with *Fusarium poae* (Peck) Wollenweber. In addition, in 10.4%, of the specimens examined, *Microsporum* sp. was found associated with the wing parts, while a small percentage of the diseased insects also yielded *Dactylium fusarioides* Frag, and Cif. Nematodes were found infecting about 12%, of the diseased specimens.

Histological Studies

Isolation of fungi from the internal body of the insect for purposes of identification, was followed up by histological studies to determine what parts of the insect were infected. Healthy and diseased adults were compared, the specimens being fixed in Romeis solution (25 ml saturated $HgCl_2$ + 20 ml of 5% Trichloro-acetic acid + 5 ml formalin), and embedded in paraffin wax. Rotary and freezing microtomes and razors were used to provide sections, which were then stained. No evidence of fungal growth was found on the bodies of any freshly killed healthy insects. When, however, healthy specimens were put into a petri dish containing cane leaves, for eight hours, and allowed to mix with *Numicia* which had died from disease, microscopic examination revealed that they in turn had become infected. This infection apparently occurred when the healthy specimens crawled over the bodies of their dead companions, the latter being covered with abundant conidia.

The newly infected *Numicia* were returned to the glass jars in which they were being reared on sugarcane. In those where humidity was constantly maintained at levels in excess of 90%, many of the insects died within 48 hours. Where relative humidity was maintained at 85%, no such mortality occurred but the *Numicia* did start to die after the lapse of a further 60 hours. Within two weeks all the *Numicia* which had been exposed to infection had died, while only 10%, mortality occurred among non-infected and isolated control samples.

Observation of infected insects in their glass jars shows that in the hours preceding death they are unusually active, crawling up and down the sides of the jar for periods varying from 4 to 7 hours. They then hide themselves before they actually die, and it is then quite difficult to find them. At no time before or immediately after death can any external symptoms of infection be seen with the naked eye. (Fig. 1). However, microscopic examination reveals the presence of an internal fungal mycelium, and hyphae sometimes protrude through the external membrane (Fig. 2).

The fungal growth occurs mainly in the abdominal and thoracic region. Where relative humidity is high (95-100%,), the body swells to about twice its size within 24 hours of death, and hyphae grow through the external membranes. Thereafter, under these conditions, the mycelium develops until it eventually covers the whole body with a mass of sporulating hyphae and conidiophores, the latter bearing the infective conidia (Fig. 3, 4 and 5). Microtome sections, shown in Fig. 6, reveal that internally the mycelium extends right through the body tissue and that it bears zygospores. Infective conidia are not normally produced on the body when humidity is low, and it is therefore assumed that a hot humid climate is necessary for rapid spread of natural infection.

Artificial Infection

Two of the fungi isolated in vitro were found to be closely associated with mortal infections of *Numicia,* namely the genera *Mucor* and *Entomophthora.* Logically, pure cultures of both *Entomophthora* and *Mucor* should be tested to confirm that these are in fact primary parasites of *Numicia.* Unfortunately, cultures of *Entomophthora* have not so far been induced to sporulate, but *Mucor* has been used successfully in this manner. Thus, healthy adult *Numicia* were placed in petri dishes containing a pure culture of the isolated species of *Mucor* for 3 hours. They were then transferred to cages attached to cane plants. Histological examination of specimens showed that infection occurred after 3 days, the insects dying soon after. Similar confirmation of the infectiveness of *Entomophthora,* the apparently more important parasite, will have to await the development of techniques to induce sporulation of the cultured fungus.

Entomophthora sp.

Natural infection of *Numicia* by the entomogenous fungus *Entomophthora* has been established, even though it has not been possible to produce suitable pure cultures for artificial inoculation. The vegetative characteristics of this fungus are very variable, but consist of a more or less closed cluster of short, curved tubular branches of hyphae (Fig. 3 and 5), which originate from a common point. These clusters of cells, comprising the thallus, give the surface of the insect a pock-marked appearance (Fig. 2 and 3).

The peripheral cells of the thallus produce tubular structures which are capable of penetrating the adjacent host cells. The hyphae themselves are limited in length and tend to break at their septa into component cells (Fig. 5). These hyphal bodies multiply rapidly by dividing and budding, and any one of them may act as a conidiophore, discharging a conidium from its terminal end (Fig. 4 and 5). The conidia are large, colourless, multinucleate bodies, which vary in shape and size. They sometimes resemble sporangia produced by other genera (Fig. 7), and are formed in millions on the surface of the dead insects. Each conidium is capable of germinating and it was found that germination was stimulated by intervention of dry conditions for 5 or 6 hours, followed by a period of high humidity. The germ tube which is then formed (Fig. 8-12) is able to penetrate the cuticle of *Numicia* on its soft abdomen, whereupon tne multinucleate cytoplasma becomes disseminated in the insect's body. In some cases, the germ tube branches immediately to form a mycelium (Fig. 13 and 14). In other instances a second or even a third conidium was formed before a mycelium was produced (Fig. 15 and 16). Hyphal bodies are sometimes produced within individual hyphae (Fig. 14) and they are eventually released as independent bodies (Fig. 17). They multiply by simple division and, when conditions are appropriate, develop into sporangioles. These sporangioles, in turn, may develop by further modification to form conidia (Fig. 18).

Sexual reproduction was observed as a union of mycelial segments or free hyphal bodies, forming thick-walled cells or resting spores (Fig. 19-24). Fusion of hyphal bodies may result in immediate outgrowth of a germ tube (Fig. 25) or in the formation of zygospores (Fig. 26). These are formed from one of the fusing hyphal cells, at a site which is usually distinct from the point of fusion. The nuclei and most of the cytoplasm from both cells pass into an outgrowth, or budding zygote which then separates from the fused parent cells, so creating an independent zygospore (Fig. 26). Zygospores are thick-walled bodies which germinate after a short rest period (Fig. 27). During this rest period they can survive otherwise critical climatic changes, so preventing the fungus dying out.

Discussion and Conclusion

It has been shown from a limited number of trials that several fungi parasitise *Numicia viridis*, and are the cause of mortal infections of the pest. These pathogenic fungi infect healthy *Numicia* when they crawl over the corpses of victims of the disease. Infection is almost certainly contracted by penetration of germ tubes from the conidia through the soft abdomen of the insect, but it is possible that there are other, as yet unknown means of infection. It is also possible that certain environmental or climatic conditions will reduce insect resistance to infection due perhaps to encouragement of germ tube penetration by enzymes, or weaknesses in the body surface. It is, however, quite certain that given favourable climatic conditions, namely hot humid weather, that infection can spread rapidly, causing very heavy mortality of *Numicia*.

Further studies will be needed to provide information on modes of infection and conditions governing this. In addition, culturing techniques for *Entomophthora* will have to be improved, and means will have to be found for producing infective material in bulk for field experiments. There is, however, good reason to believe that artificial stimulation of some of the factors limiting the spread of natural infection may conceivably provide practical means of ensuring biological control of *Numicia*,

Summary

Micro-organisms associated with dead and dying specimens of the cane pest *Numicia viridis* Muir, have been examined. Seven fungi were isolated, two genera of which appear to be of particular importance, namely *Mucor* sp. and *Entomophthora* sp. These organisms kill their hosts and, in hot humid conditions, continue to develop saprophytically on the corpse, producing conidia which, on contact, can infect healthy specimens. *Mucor* sp. has been raised in pure culture and used to reinfect *Numicia*. So far, pure cultures of the even more virulent *Entomophthora* have not been induced to sporulate, but work on this is to be continued.

References

1. Anon. A. Rep. S. Afr. Sugar Ass. Expt. St, 1963/64: 51-56; 1964/65: 88-93; 1965/66: 71-77.
2. Anon. (1966). A. Rep. 1965/66 S. Afr. Sugar Ass, Expt. St.: 5-6.
3. Anon. (1967). "Numicia is now the major sugarcane pest". S. Afr. Sug. J. 51. 1:41.
4. Carnegie, A. J. M. (1966). "The progress of an untreated outbreak of *Numicia viridis* Muir." Proc. Annual Cong. S. Afr. Sugar Tech. Ass. 40: 319-327.
5. Dick, J. (1964). "Numicia—The green leaf-sucker of sugarcane". Bull. No. 15. S. Afr. Sugar Ass. Expt. St.

Discussion

Mr. Carnegie: Two of the fungi mentioned as possibly being useful for control of Numicia, namely *Beauveria* and *Fusarium*, have been worked on extensively in the last hundred years. There have been some successes, which have been well publicised, but also a lot of failures.

Dr. Roth: I did not claim Beauveria could successfully control Numicia. The promising fungi are *Entomophthora* and *Mucor*.

Dr. Dick: Mr. Carnegie's remarks apply to any fungi that have been tried for the purposes of controlling insects.

Mr. du Toit: Numicia appears to be under control in the coastal areas. Dr. Roth implies that these fungi need a certain amount of humidity and therefore Numicia populations may in fact already be controlled in the coastal areas by these fungi.

Dr. Roth: In a dry irrigated area, the fungus would try and develop from the resting, or zygospore stage during irrigation. But when irrigation ceases, and arid conditions again prevail, it will die immediately. This may be why in irrigated areas biological control by these fungi has not been successful.

Mr. Date: Under the canopy is not the humidity as high in irrigated areas as it is in the coastal belt?

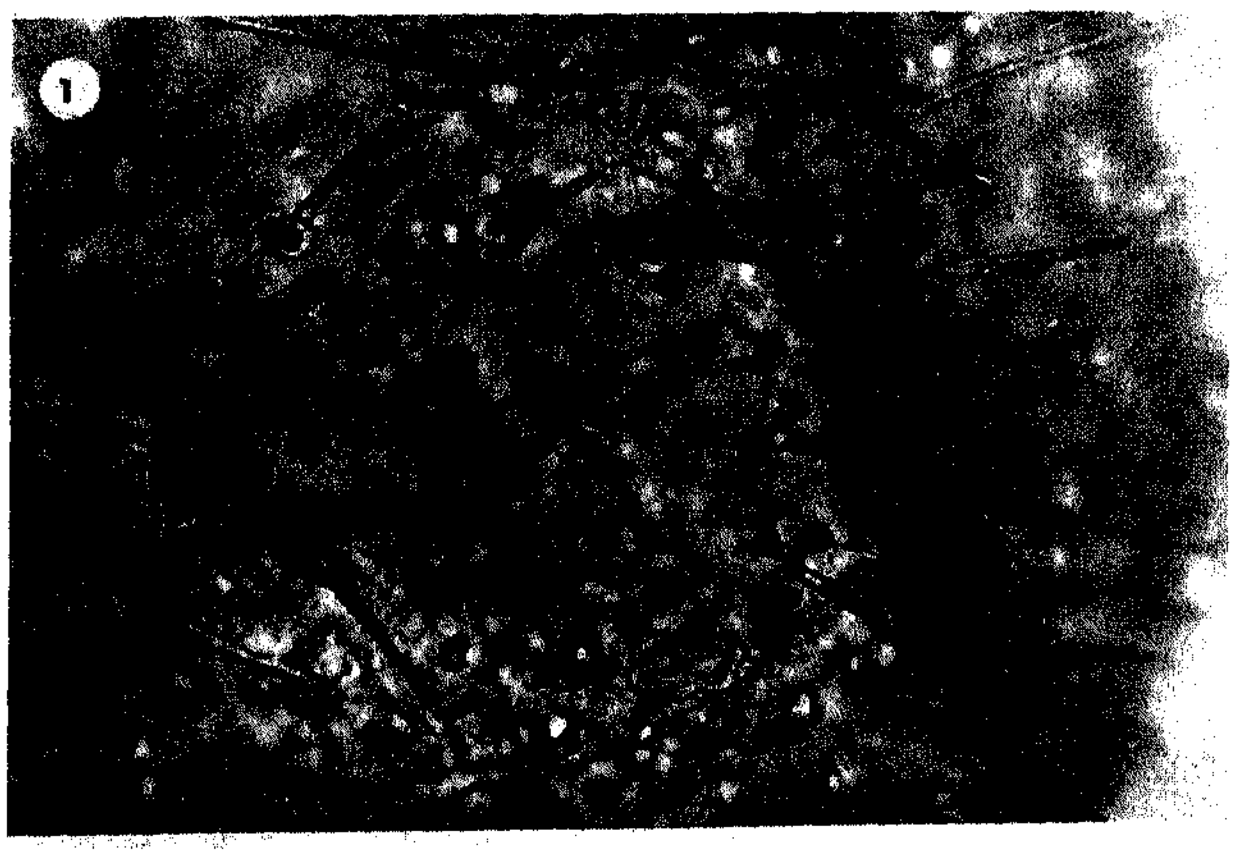
Mr. Glover: Even after showers of rain the humidity under the cane plant remains high for some time under certain conditions.

Mr. Harris: Other factors, including temperature and humidity, must be taken into account. In Florida attacks of a certain fungus take place only every three years, despite efforts to start attacks in the intervening periods by spraying spores over the area.

It appears that fungi are always present but will only attack insects under certain conditions.

Dr. Roth: Under very hot, humid conditions, which are not dissipated by wind, temperature is unlikely to rise high enough to harm the fungus.

N



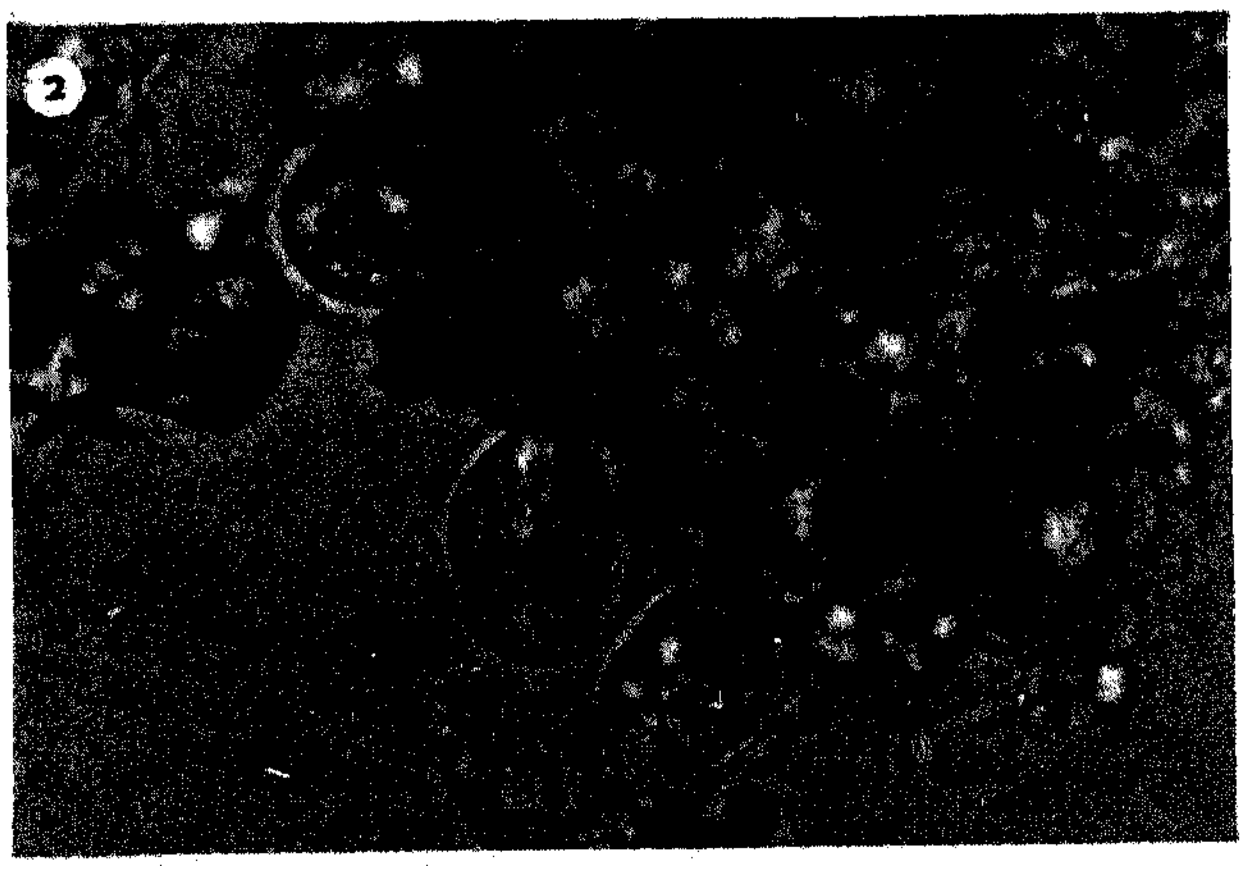


FIGURE 1: Part of the distended body surface of Numicia, three days after death. (x450).

FIGURE 2: The fungal thallus covering the exoskeleton of Numicia. Note the protruding conidiophores. (x 750).

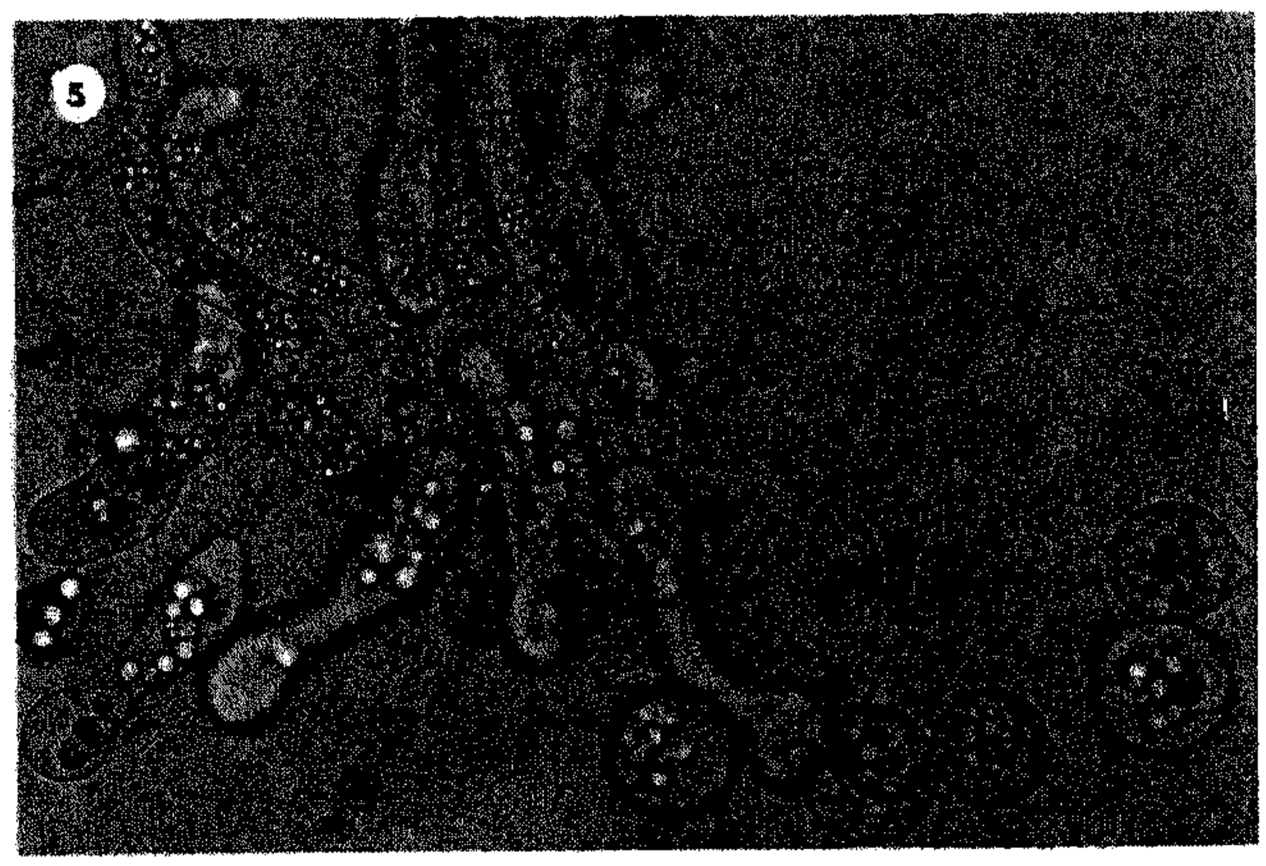
FIGURE 3: Mass of germinating conidia and free hyphal bodies. Note the tubular structure of the peripheral cells of the thallus. (x480).

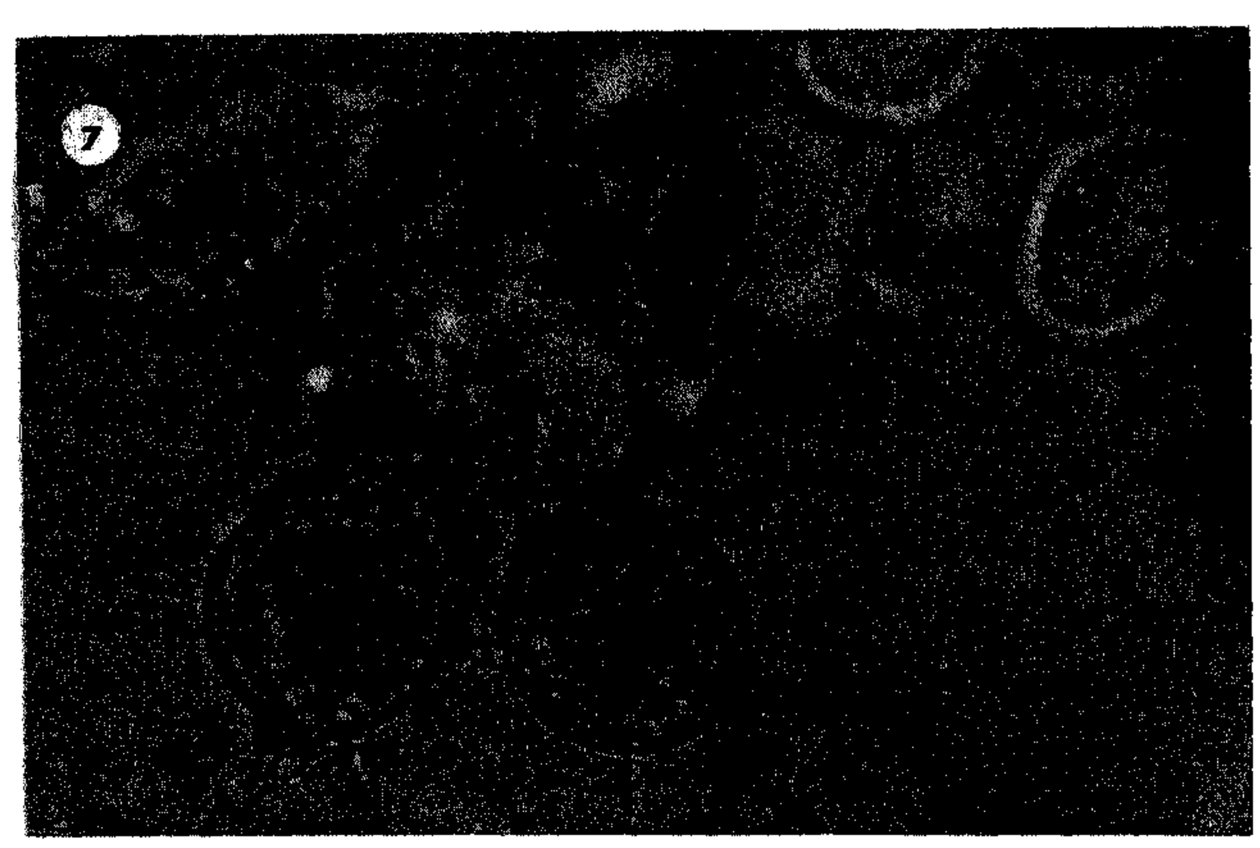
FIGURE 4: Branched conidiophores, each of which terminates in a single conidium. (x 750).

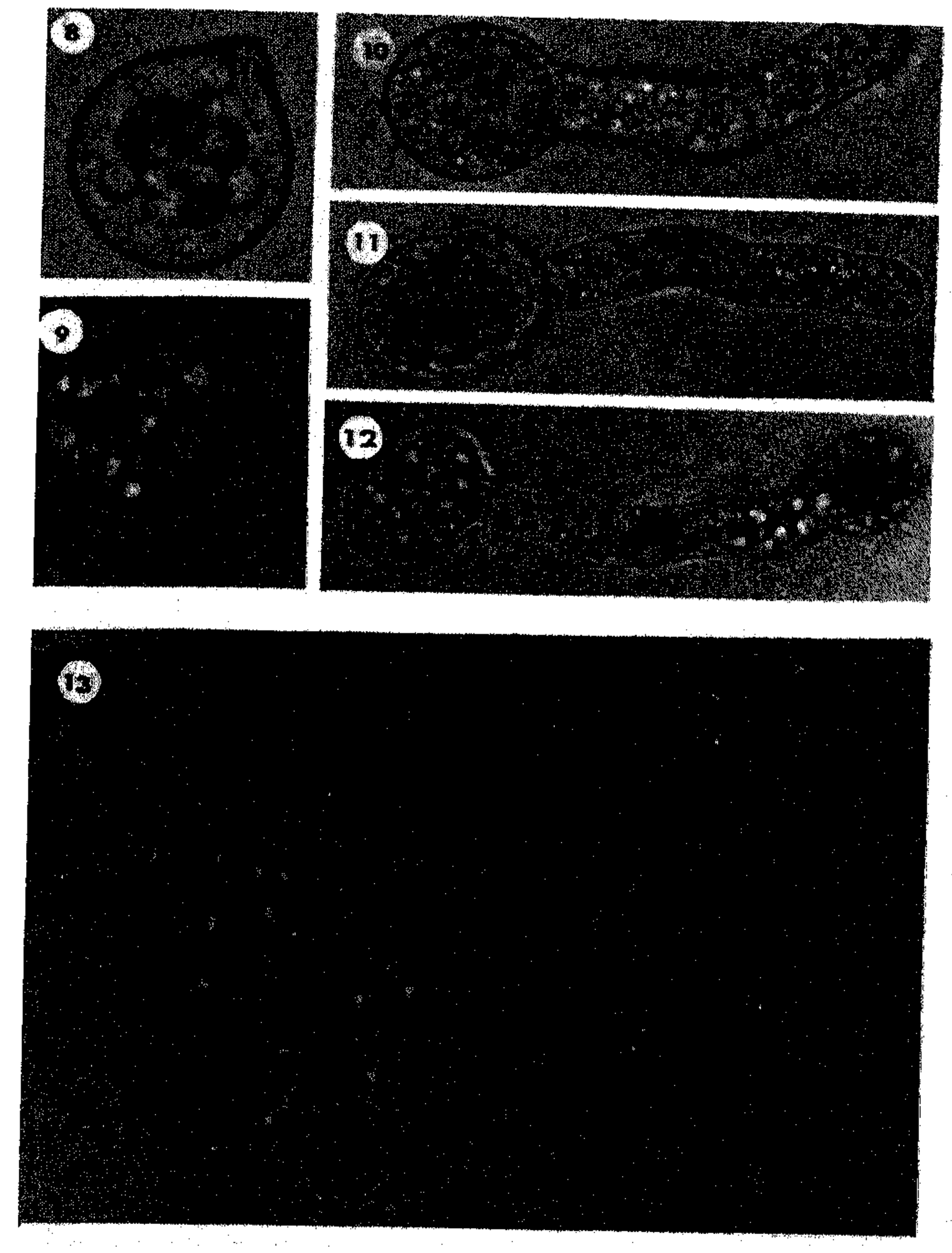
FIGURE 5: Typical short curved hyphae of the entomogenous fungus Entomophthora. Note the formation and release of conidia. (x 550).

FIGURE 6: Development of mycelium, and the formation of zygospores of Entomophthora sp. within the body of Numicia. (x 450).

FIGURE 7: Conidia which differ in shape from those in Fig. 4. Produced on club-shaped conidiophores they resemble sporangia in other genera, (x 850).







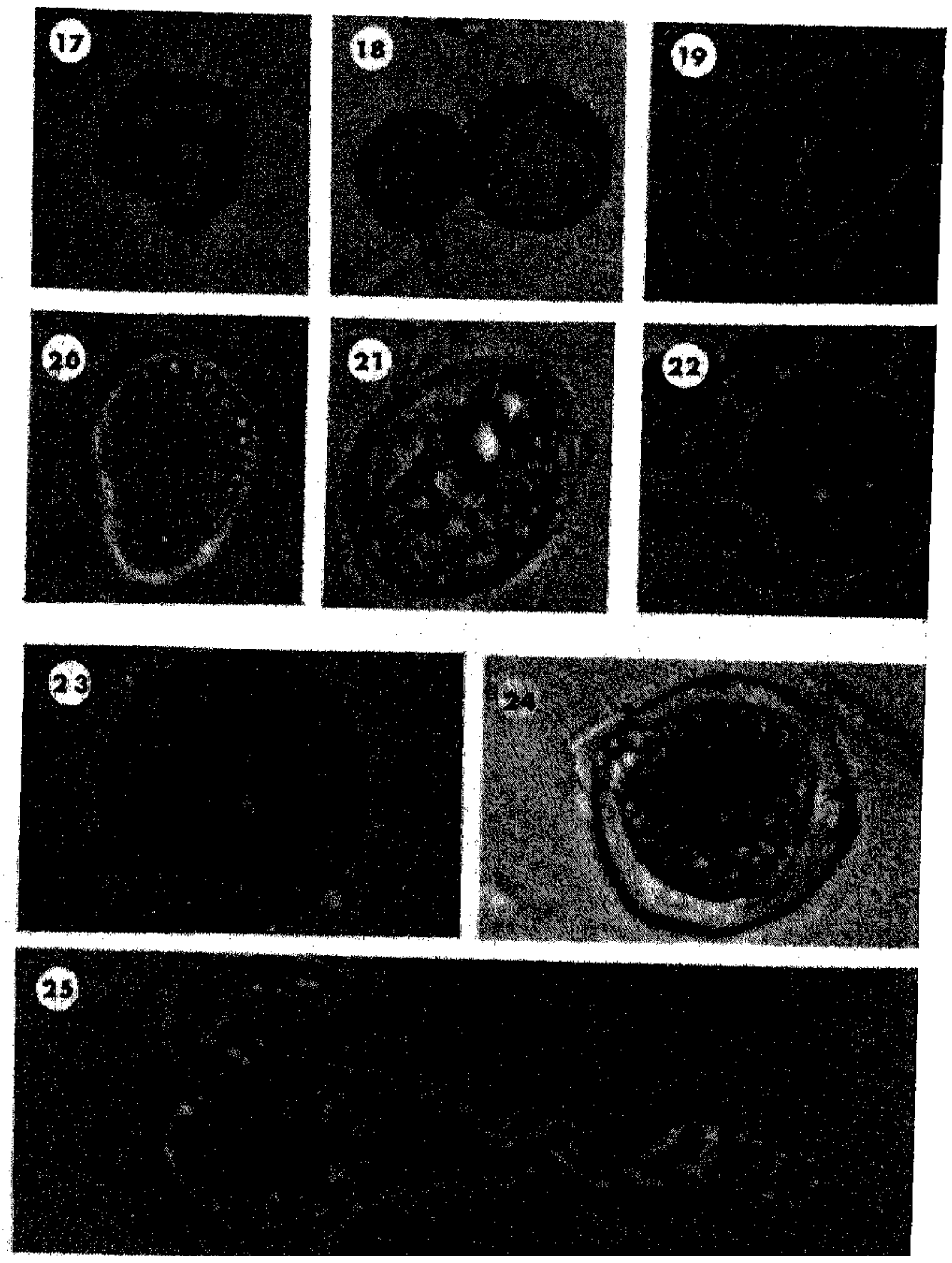
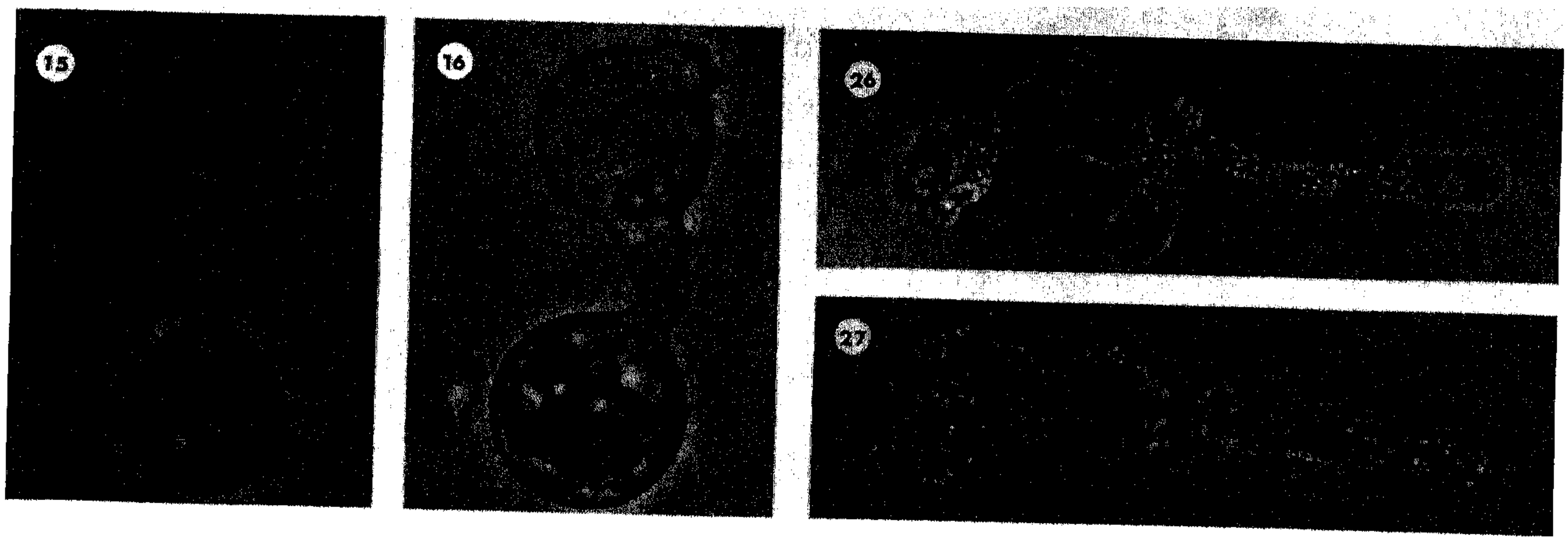


FIGURE 8: Conidium of Entomophthora sp. before germination, (x 750)
FIGURE 9: Conidium which is just starting to germinate, (x 800).
FIGURES 10 and 11: Increasingly advanced stages in the germination of a conidium. (x 600).
FIGURE 12: Germination of a conidium terminating with the formation of another conidium at the apex of the germ tube, (x 600).
FIGURE 13: Germination resulting in the formation of several branches of the germ tube. (x 600).
FIGURE 14: Very young mycelium formed from a germinating conidium, containing hyphal bodies, (x 600).
FIGURE 15: Germinating conidium producing a second conidium at the end of a short germ tube, (x 650).
FIGURE 16: Germinating conidium, producing a second conidium and starting to form a third, (x 700).
FIGURES 17 and 18: Development of conidia from hyphal bodies, (x 600).
FIGURES 19 to 24: Different stages in the development of resting snores or zygospores. (x 850).
FIGURE 25: Sexual fusion of two hyphal bodies and development of a germ tube, (x 750).
FIGURE 26: Sexual fusion of hyphal bodies resulting in the formation of a zygospore (early stage) and its further germination, (x 650)
FIGURE 27: Germination of a zygospore after a period of rest, (x 850)



ALUMINIUM AND SILICA RELATIONSHIPS IN GROWTH FAILURE AREAS

by R. T. BISHOP

South African Sugar Association Experiment Station

Introduction

In 1962 an investigation was conducted to measure the reduction in hydrogen ion concentration of a weak acid (0.02N H_2SO_4 after it had been in contact with different soils. The acid-soil mixture was shaken, filtered and an aliquot titrated against 0.02N NaOH to neutrality. Of some 2,000 soils treated in this way, four were characterised by the formation of a clear gelatinous precipitate (considered to be some compound of Al) when the solutions were rendered alkaline. Subsequently they were found to belong to the Inanda soil series, and all were associated with growth failure areas. With the recent extension of cane cultivation into the Natal midlands, the likelihood of cane being grown on soils of the Clovelly series has increased. The fact that these soils are also high in Al (Skeen and Sumner 1965) increases the urgency of an investigation into the relationship between soil soluble Al and cane growth.

Since Ayres (1966) reported significant yield responses of cane to Si applications on soils with high concentrations of soluble Al, the Si status of crops and soils is included in the present study.

1. A SURVEY OF TWO SOIL SERIES

In the present survey, the extent of which is described by Alexander (1967), two soil series were considered:

(i) Inanda. Derived from a laterite formed on the sandstone and characterised by a high organic matter content (approximately 10%) and low pH value (4.70). It is located in the inland higher altitude, plateau or mistbelt areas. Texturally it is a clay loam.

(ii) Cartref. Derived directly from the sandstone and has a lower organic content (approximately 1%) and higher pH values (approximately 5.50). Texturally it is a loamy sand.

Method

(A) ***Soil***

Ayres (1966) used 0.5N ammonium acetate adjusted to pH 4.8 and a solution to soil ratio of 20:1 to extract soluble Si. This procedure was adopted except that in place of shaking end over end for one hour at 13 rpm, leaching 2.5g of soil with 10 x 5ml aliquots of extractant was used. This solution was analysed for Al and Si. For exchangeable Al determinations, the method of Skeen and Sumner (1965) was used.

For determining the concentration of Al in the soil extract the method of Frink and Peech (1962) employing 8-hydroxyquinoline was followed.

Ammonium molybdate reagent was used for Si determinations (Vogel 1958) with tartaric acid to eliminate phosphate interference and stannous chloride as reducing agent. All solutions were stored in plastic containers.

(B) ***Third Leaf Blade***

For Al, an adaptation of the method for soils was employed.

Following the wet digestion of leaf material with sulphuric acid, a white precipitate remained, which was considered to be almost exclusively dehydrated Si. This material was filtered, ashed and weighed and will be referred to as "acid insoluble residue" (AIR).

Results

A summary of Al and Si contents of samples taken over a wide area from sites on the Inanda and Cartref series is presented in Table I.

As expected, the amounts of soluble Al in the Inanda series (of lower pH value) are considerably higher than in the Cartref series. Areas of poor growth were generally associated with soils high in organic matter (greater than 10%) and soluble Al (in

TABLE I

Soluble Al and Si contents (ppm) of soils and leaves from two soil series

	Inanda				Cartref			
	Soil		Leaf		Soil		Leaf	
	Al	Si	Al	% AIR	Al	Si	Al	% AIR
Lowest concentration	88	7	31	0.408	2	6	39	0.572
Highest concentration	724	44	151	1.504	270	102	147	1.995
Number of sites	50	50	50	50	70	70	70	70
Mean	320	21	70	0.911	73	23	98	1.095

excess of 400 ppm). High Al was often, but not always, associated with low pH and exchangeable Ca values. From observation, the crops at 17 of the sites on the Inanda series were considered to be below average, and of these, the cane at three was severely stunted and was associated with the only soils where the soluble Al content exceeded 550 ppm. The condition of the crop at 10 of the remaining sites was described as fair, poor or patchy, and was associated with soils containing between 400 and 550 ppm soluble Al. Crops growing on soils with contents less than 400 ppm were generally good.

The exchangeable Al in the Inanda series ranged from 0.01 to 3.40 me/lOOg soil with a mean of 1.05. Although the areas of poor growth were generally characterised by high exchangeable Al contents, soils with relatively high exchangeable Al did in some cases support good crops.

The Si content of the soil, and the AIR and Al content of the leaves were apparently not related to the condition of the crop. In fact, soils of high Al content tended to remain the highest amounts of soluble Si indicating that a deficiency of the latter element is not responsible for the poor cane growth.

In the Cartref series the exchangeable Al content ranges from zero to 0.27 me/lOOg of soil. In this series none of the factors studied were correlated with crop yield.

2. EFFECTS OF FILTER CAKE AND LIME

Applications of filter cake (FC) are now known to give significant yield increases in the problem areas. Mr. H. E. H. Garnett has successfully converted regions of growth failure on his farm into areas of high productivity by applying heavy dressings of FC. In an experiment conducted on a problem area (mean yield of control plots was 29.3 tons cane per acre) at Doornkop (Allsopp) a significant increase of over 15 tons cane per acre was obtained by top dressing ratoon cane with 10 tons of FC per acre following normal dressings of N, P and K. The soluble Al (423 ppm) at this site is just above the critical level, and organic matter content (12.83%) is in excess of 10%. To indicate whether FC reduces the level of soluble Al, comprehensive plot by plot analyses were made but no changes in soil composition could be detected. However, since FC is rich in P, Ca and Si, it was considered that sampling errors must have obscured any changes in soil composition. Tests in the laboratory were therefore conducted.

To 2.5g of the Inanda soil increasing amounts of oven-dry FC were added. The mixtures were twice puddled with water, dried at 40°C and then the soluble Al, Si and Ca contents determined.

TABLE II

Effects of FC on the soluble Al, Si and Ca content of an Inanda soil series

	Grams of FC mixed with 2.5g of soil					
	Nil	0.1	0.2	0.3	0.4	0.5
Al (ppm) ..	411	205	111	16	0	0
Si (ppm) ..	34	50	68	78	85	175
Ca (ppm) ..	16	60	100	105	125	155

FC drastically reduced the soluble Al content and increased the soluble Si and Ca content of the soil.

Further investigation indicated that the high concentration of easily soluble P in FC is responsible for precipitating out Al and thus rendering it insoluble. The concentrations of Al and P in the extracting solution after leaching FC and FC plus soil (one wetting and drying cycle) are presented in Table III

Although 959.3 ppm of P was in the leachate from 0.4g of FC less than 1 ppm was present when the same amount of FC was mixed with 2.5 g of soil.

If the observed reductions in yield are caused by Al toxicity, the application of agricultural lime was considered to be the most suitable way of reducing the level of Al in the soil. The effects of different levels of agricultural lime on the soluble Al and Si contents of two soil series are presented in Table IV.

TABLE III

Concentrations of Al and P in extract of O.5N ammonium acetate (pH 4.8)

Treatment	Grams of FC mixed with 2.5g soil						
	Nil	0.025	0.05	0.1	0.2	0.3	0.4
Al (ppm) Soil + FC	21.1	20.4	17.2	14.1	10.6	9.7	8.2
P (ppm) Soil + FC	0.1	0.0	0.3	0.2	0.2	0.4	0.8
P (ppm) FC alone	—	203.4	274.6	394.4	807.0	945.5	959.3

The amounts of Al decreased almost linearly (significant at the 1 % level) with increasing amounts of lime applied. Soluble Si content increased significantly with increasing lime application. Concentrations of Al and AIR in the third leaf blade did not reflect the changes in soluble Al and Si content of the soil.

The above experiments are on soils which are relatively low in soluble Al and, as expected, there was no increase in yield due to the application of lime. However, even in observation plots with soils of a high Al content poor yields were not improved by the application of lime. Since liming does reduce Al content it would appear that the cause of poor growth is not high levels of Al but some factor, or factors, associated with it.

Thus, while FC and lime both reduce Al level, one improves the condition of the crop while the other does not. The two materials must, therefore, be affecting the soil in different ways. The effects of a basic material (which affects soil reaction in a similar way to lime) and FC on soil pH are presented in Table V.

TABLE IV

Effect of agricultural lime on the soluble Al and Si content (ppm) of two soil series

INANDA SERIES

lb fertilizer applied/acre; 4-1-6(31)	Lime applied (lb/acre)							
	Nil		2000		4000		Means	
	Al	Si	Al	Si	Al	Si	Al	Si
Nil	133	18	60	22	29	31	74	24
1000	144	26	75	23	45	33	78	27
2000	126	22	52	28	24	40	67	30
Means	124	22	62	24	33	35		

	5% level	1% level
LSD's of Al due to fertilizer; lime	46;56	61;85
LSD's of Si due to fertilizer; lime	17;6	26;8

WALDENE SERIES

lb fertilizer applied/acre; 4-1-6(31)	Lime applied (lb/acre)							
	Nil		4000		8000		Means	
	Al	Si	Al	Si	Al	Si	Al	Si
Nil	41	16	18	23	13	35	24	25
1000	53	16	23	23	8	40	28	26
2000	43	18	21	25	12	31	25	25
Means	46	17	21	24	11	35		

	5% level	1% level
LSD's of Al due to fertilizer; lime	20;18	30;27
LSD's of Si due to fertilizer; lime	8;6	13;8

TABLE V

Effects of FC and basic Si slag on soil pH

Treatment	Grams of FC and basic Si slag mixed with 2.5g soil						
	Nil	0.025	0.05	0.1	0.2	0.3	0.4
FC alone	6.20						
FC + soil	5.35	5.35	5.38	5.33	5.39	5.38	5.35
Slag alone	11.00						
Slag + soil	5.35	5.67	5.73	5.93	6.20	6.37	6.40

The basic material has increased the pH of the soil while the FC has not. It is possible, therefore, that the difference in yield response between lime and FC is due to their effects on soil pH.

That the correlation between high Al and poor yield is a characteristic of the Inanda series is indicated by a four-months-old trial on the Clovelly series (579 ppm Al) in the Natal midlands. Here

TABLE VI

Yields and analytical data from a Zn:Mo trial on an Inanda series

Treatment	Plot No.	T.C.P.A.		Soil analyses				Leaf analyses			
		Plant	1st R	Sol Al (ppm)	Sol Si (ppm)	Exch Ca (ppm)	pH water	Zn (ppm)	Al (ppm)	AIR %	Ca %
Control	2	36.3	34.7	513	38	230	5.20	17	79	1.10	0.22
	10	29.1	35.4	715	56	180	5.05	10	65	1.08	0.30
	18	33.8	50.1	541	78	180	5.10	11	120	0.98	0.22
	19	32.6	43.3	508	82	200	5.05	10	66	0.97	0.22
	27	26.3	46.7	643	85	160	5.10	9	137	1.27	0.25
	35	14.4	23.8	742	63	100	4.95	10	187	1.30	0.18
Means		28.8	39.0	610	67	175	5.08	11	109	1.12	0.23
0.5 lb/ac sodium molybdate	1	21.9	26.9	688	54	180	5.05	12	127	1.28	0.25
	9	36.6	43.1	652	55	180	5.10	14	134	1.24	0.22
	17	23.3	40.5	706	61	160	5.05	10	138	1.26	0.22
	22	30.0	42.8	597	54	200	5.10	10	113	1.04	0.22
	26	35.9	49.3	593	78	240	5.20	10	166	1.06	0.22
	36	17.4	23.9	768	69	120	5.00	10	232	1.31	0.25
Means		27.5	37.8	667	62	180	5.08	11	152	1.20	0.23
25 lb/ac zinc sulphate	5	41.2	32.6	661	78	220	5.00	14	71	1.24	0.14
	8	35.8	31.1	760	73	180	4.95	16	191	1.20	0.18
	16	43.4	50.5	570	68	220	5.05	13	89	1.22	0.22
	21	36.8	47.4	636	67	140	4.85	15	124	1.25	0.18
	30	34.3	41.1	656	66	160	5.05	14	263	1.05	0.10
	31	29.5	32.7	562	71	130	5.00	13	97	1.30	0.14
Means		36.8	39.2	656	71	175	4.98	14	139	1.21	0.16
25 lb/ac zinc sulphate + 0.5 lb/ac sodium molybdate	6	48.6	47.0	582	33	160	5.10	15	162	1.19	0.18
	7	38.1	32.1	643	37	160	5.05	16	87	0.98	0.14
	15	41.3	49.4	542	54	200	5.15	15	87	1.05	0.14
	20	40.2	46.8	652	69	140	4.85	15	125	1.05	0.10
	29	36.0	46.9	563	62	200	5.15	15	166	0.95	0.25
	34	18.8	25.6	605	59	100	4.85	16	120	1.24	0.14
Means		37.2	41.3	598	52	160	5.03	15	125	1.08	0.16
50 lb/ac zinc sulphate	3	58.9	54.7	429	96	300	5.25	17	127	1.06	0.18
	11	35.2	48.8	509	77	120	5.00	17	102	1.10	0.18
	13	33.3	34.9	589	51	140	5.05	16	56	1.07	0.18
	24	30.6	50.6	450	55	240	5.20	20	186	1.07	0.25
	28	21.2	36.5	634	74	120	5.00	17	170	1.34	0.18
	32	29.7	33.4	634	70	120	4.95	20	269	1.17	0.18
Means		34.8	43.2	541	71	173	5.08	17	152	1.14	0.19
50 lb/ac zinc sulphate + 0.5 lb/ac sodium molybdate	4	39.8	32.0	679	82	150	4.95	19	170	1.25	0.25
	12	45.3	45.7	508	67	140	4.95	19	120	1.04	0.22
	14	31.6	35.3	585	77	120	4.90	17	96	1.08	0.22
	23	34.5	39.3	626	65	160	5.10	16	110	1.10	0.22
	25	21.0	37.5	637	45	120	4.85	13	76	0.83	0.18
	33	33.6	40.6	572	61	90	4.70	14	253	1.08	0.22
Means		34.3	38.4	601	66	130	5.08	16	138	1.06	0.22
Correlations for yield of plant crop..				−0.54	0.04	−0.56	0.32	0.44	−0.12	−0.43	−0.18
Correlations for yield of 1st ratoon..				0.68		−0.52	0.40				
Levels of significance .. .. 5%=0.33, 1%=0.42, 0.1%=0.52.											
LSD 5% level		8.40	8.0	89	36	57	0.38	2	41	0.15	0.05
LSD 1% level		11.5	10.9	122	45	78	0.52	3	56	0.21	0.07

crops receiving only N, P and K are growing well and are, in fact, superior to those receiving FC (30 tons/ac.) N and K.

3. CORRELATIONS WITH CROP YIELDS

High levels of Al in the soil are generally associated with highly leached infertile areas. Excellent yield responses to applications of N, P and K occur on most of the soils of the Inanda series and it is likely that in the problem areas one or more of the other essential plant nutrients are also deficient. Apart from FC the only other material to improve yield has been zinc sulphate (du Toit 1962). An experiment with different levels of Zn and Mo was laid down in 1962 on an Inanda series on the farm of H. E. H. Garnett in the Kearsney area. Although a statistical significant yield response was obtained to Zn, the experiment was characterised by marked fluctuations in yield irrespective of treatment applied. A comprehensive plot by plot analysis of soil (after plant crop) and leaf (from plant crop) samples was conducted so that if the factor causing poor growth was nutritional it might be detected. The more interesting of these results are presented in Table VI.

Yield is significantly correlated with soluble Al, AIR, exchangeable Ca and pH.

The soluble Al results again indicate that at levels in excess of approximately 400 ppm cane yield is adversely affected.

The significant negative correlation between AIR and yield is probably due to differences in the physiological age of the leaf in position number 3. In stunted cane the leaf in this position has matured more than the leaf from a plant which is actively growing and Si had longer to accumulate. Other elements which have been shown to accumulate continuously in the leaf, thus increasing their concentration with time, are Ca, Mg and P (Bishop 1965). This is partly confirmed by the analysis of leaf samples from an experiment in which highly significant increases in yield were obtained from the application of mixed fertilizer. The mean yields in this experiment were 31.0, 53.2 and 63.3 tons of cane per acre while the mean leaf contents for AIR were 1.683, 1.204 and 1.178% respectively.

Since the threshold value for exchangeable Ca is 150 ppm and yield is significantly correlated with this measure, a deficiency of Ca in certain plots is indicated. Leaf analyses, however, indicate that only plots 20 and 30 have Ca levels below the threshold value (0.12%). The limitation of the third leaf blade as a diagnostic tissue for Ca (Bishop 1965), as explained for Si above, could be obscuring the presence of this deficiency, i.e. where Zn applications caused more normal growth, leaf Ca levels were significantly lower.

It is suggested, therefore, that the cane in the poorer plots of the above experiment was suffering from deficiencies of Ca and Zn. In such circumstances FC would improve yield by supplying both these elements (plus other essential nutrients) without seriously changing the pH value of the soil. Liming by changing the pH of the soil would aggravate the deficiency of Zn and not improve yield. In those areas known to be low in Ca and Zn (Alexander 1967) liming should be avoided. To supply Ca, FC or gypsum should be applied.

An experiment using FC, and gypsum and $ZnSO_4$ in combination is being designed to test whether only Ca and Zn (plus N. P and K) are at present limiting cane production in these areas.

Discussions and Conclusions

The fact that FC is reasonably rich in Si increased a suspicion that the beneficial effect of this material on crop yield may be due to the presence of this element. The following evidence tends to eliminate this possibility:

(i) The Si content of soils was generally highest in the areas of poor growth and

(ii) liming did not prove beneficial in these areas even though it increased the soluble Si status.

When the level of soluble Al in the Inanda series exceeds approximately 400 ppm a reduction in yield can be expected. High levels of Al are not thought to affect plant growth directly but are associated with some other growth-inhibiting factor. Evidence leading to this conclusion is as follows:

(i) applications of lime and superphosphate (which should also render Al insoluble) do not rectify problem areas, and

(ii) the experiment sited on the Clovelly series indicates that normal crops may be grown even if the soluble Al content approaches 600 ppm.

Although it has not been diagnosed conclusively what factors associated with Al are depressing yield, the combined deficiencies of Ca and Zn (and perhaps other trace elements) are one possibility. While the third leaf blade will reflect the deficiency of Zn, the effectiveness of this tissue detecting low levels of Ca is suspect. Soil analysis on the other hand only detects the Ca deficiency, and the use of lime should be avoided. Under these conditions lime will not improve yields as it reduces the availability of Zn and most other trace elements.

It is suggested, therefore, that a survey to ascertain the soluble Al, exchangeable Ca and organic matter contents of all fields on the Inanda series be undertaken. In this way the problem areas could be identified and used as a basis for determining where FC allocations should be applied for maximum economic return.

Summary

A survey of the Inanda and Cartref series indicated that in some areas the Inanda series contained high levels of soluble Al. These soils were associated with areas of poor growth.

Applications of lime were found to decrease the levels of soluble Al and increase the levels of soluble Si, but did not improve yield. Samples from field trials showed no significant effects of filter cake on the soluble Al or Si contents of the soil, but did increase yield. Laboratory tests showed, however, that filter cake significantly reduces Al and increases Si content of the soil.

An experiment conducted on another series indicated that levels of soluble Al of the order of 600 ppm are not toxic to sugarcane. Poor growth is apparently associated with high levels of Al but is not caused by it.

Deficiencies of Ca and Zn (and possibly other trace elements) occurring simultaneously are thought to be one possible cause of low yields.

Acknowledgements

P. du Preez for comparing Al results on the Spectrograph and K. E. F. Alexander, L. Allsopp and P. K. Moberly for supplying samples for analysis.

References

1. Alexander, K. E. F. (1967). A nutrient survey of cane on TMS soils in Natal. *Proc. S.A. Sugar Tech. 41.*
2. Allsopp, L. Data to be published.
3. Ayres, A. S. (1966). Calcium silicate slag as a growth stimulant for sugar cane. *Soil Science 101: 140-143.*
4. Bishop, R. T. (1965), Mineral nutrient studies in sugar cane. *Proc. of S.A. Sugar Tech. 39: 128-134.*
5. du Toit, J. L. (1962). Zinc deficiency in the sugar belt indicated. *S.A. Sugar Journal. 42. 399-403.*
6. Frink, C. R. and Peech, M. (1962). Determination of aluminium in soil extracts. *Soil Science 93: 317-324.*
7. Skeen J. B. and Sumner, M. E. (1965). A new method of determination of exchangeable aluminium in acid soil. *Proc. of S.A. Sugar Tech. 39: 209-213.*
8. Vogel, A. I. (1958). A textbook of quantitative inorganic analysis. Longmans Green and Co. N.Y.: 669.

Discussion

Mr. Landsberg: To isolate a deficiency symptom the plant is grown in nutrient media and the element you are interested in is omitted or reduced considerably. Has this been done in respect of boron, zinc, aluminium and silica?

Mr. Bishop: We have tried to use Aspergillus niger to get an estimate of zinc deficiencies in these areas. The spores are grown in a solution and in about two weeks a dense mat forms on the surface and it is removed and weighed. However, this method is unsuitable for routine soil examinations.

Mr. Venn has put down pot trials in Swaziland with tomato and maize plants, omitting one nutrient, and he has been able to classify the soils on the basis of nutrient deficiency.

Mr. Gilfillan: Do growth failure areas develop a particular type of weed population? In Recent Sand we have noticed *Panicum maximum* coming in.

Mr. Bishop: Apparently filter press is often associated with growth of Panicum.

Mr. Moberley: When filter cake was applied at Town hill at thirty tons per acre the Panicum grew very well but the cane growth was poor.

It was suggested that cane grown adjacently with superphosphate thrived as the superphosphate was applied row only, whereas filter cake was broadcast, so in the initial stages the cane roots did not have immediate access to phosphate.

Mr. Lintner: It is difficult to grow maize on an untreated Clovelly Soil. Last year a research project was started which involved a blanket of agricultural gypsum, six thousand pounds, and fifty pounds of zinc sulphate per morgen. N, P_2O_5 and K_2O were calculated at presumed 100% efficiency levels on the basis of the whole plant requirement to produce a bag of maize. The two levels were then adjusted to produce seventy and a hundred and forty bags of grain per morgen. Last year, in spite of the drought, the top yield was 36 bags per morgen. This year the growth is such that, from field observation, it would appear that the maximum target could possibly be achieved. This soil will grow excellent potatoes, root crops and pasture.

Mr. du **Toit:** d'Hotman de Villiers in Mauritius applied a hundred tons per acre of crushed basalt to cane fields and he was the first to stress the importance of silica in cane nutrition.

We have a problem with our leached soils and we cannot always pinpoint the reasons for growth failure.

Mr. Bishop points out, in Table VI, that a lot of the values for calcium are below the threshold value of 150, but in Hawaii the threshold value is only 100 ppm.

On the basis of 100 the only low figure is 90 and that gave one of the best yields.

We need a microbiological examination into soil fertility in addition to these other investigations.

Filter cake plays a part in increased production that cannot easily be explaned from ordinary chemical analysis. The stimulation often affects one crop only and has no carry-over.

Organic manures have in the past rectified growth failure on the Inanda series.

I suggest that the survey being carried out at present on the Inanda series should be extended to the Clovelly and other acid soils in the new Midlands area.

Mr. Lintner: The only explanation I can give for the complete crop failure on the high nitrogen only plots on maize is stultification of the bacterial population of that soil, in addition to a very critical phosphate level.

Mr. Bishop: I do not feel the cause of poor growth is entirely due to a disease effect or a toxic bacteria in the soil.

Mr. Lintner: It has been shown that very heavy dressings of nitrogenous fertilizer initially can retard bacterial activity but the situation rectifies itself.

Mr. Bishop: If it is micro-biological, how can the areas defined in this experiment carry over from one year to the next and from one crop to the next without spreading?

The deficiencies, as mentioned by Mr. Alexander, are worse in cold, cloudy weather and improve as the weather gets warmer, which is not what you would expect if micro-organisms are involved.

Mr. Lintner: If a certain area of a field is pinpointed for the purpose of drawing soil samples for determining pH it will be observed that the pH varies quite considerably. Does not the available soil vary through a season?

Mr. Bishop: There is no evidence of that here. A growth analysis experiment which had six replications and was analysed every week for eighty-eight weeks showed no variation in exchangeable K content. In a laboratory you might get diurnal variations in "availability" due to different temperatures of the extraction solution but it should not affect availability in the field.

Mr. Lintner: It seems that it is the fluctuations in temperature in this country, that is largely responsible for poor maize yields.

A NUTRIENT SURVEY OF CANE ON T.M.S. SOILS IN NATAL

by K. E. F. ALEXANDER
South African Sugar Association Experiment Station

Introduction

Early in 1966 it was decided that a controlled survey of the nutrient status of sugarcane as determined by analysis of leaf samples would be of benefit to cane-growers in South Africa. By locating in this manner which areas are deficient in certain nutrients, and particularly trace elements, it is possible to give growers, regional representatives, and laboratory analysts advance warning of nutrient difficulties. This in turn makes it possible for corrective measures to be applied at an early date.

Sampling Technique

The availability of nutrient in the soil is only one of many factors which can influence the concentration of minerals in cane-leaves. The more important of these other factors are the variety used, its state of maturity, whether it is a plant or ratoon crop, the season of the year, and the preparation of the leaf sample prior to drying. In order to standardize sampling procedure as much as possible, it was decided that the same person should take all samples; that only one variety, N:Co. 376, would be sampled; and then only from ratoon crops. The age of the crop would be standardized between narrow limits by restricting sampling to cane cut between 6 and 7 months previously. Sampling was to be completed in the shortest possible time, and would be confined to the optimum period, January/February.

Areas and Soils

Restrictions imposed by the sampling technique considerably restricted the area that could be sampled. It was decided therefore to sample only those fields in which the soil was derived from Table Mountain sandstone (T.M.S.). This was done for two reasons. In the first place this is the largest soil group in the sugar industry, comprising nearly 20% of the total area under cane, and secondly, one of its series was known to suffer from our most widely distributed trace element deficiency, namely that of zinc. In Natal, the T.M.S. group of soils can be divided into two main series, Cartref and Inanda, and two minor series, Solferino and Trevanian. The Cartref series has been derived directly from the sandstone itself (Beater 1957). Maud (1965) suggests that the Inanda series has been formed by the weathering of a relatively thin lateritic layer, which is now of the order of 10 ft. in thickness, and which caps the T.M.S. in the plateau areas.

The T.M.S. formation is about 2,000 ft. thick in Natal, and was laid down about 500 million years ago. Since quartz is its main ingredient, and its development was mainly from fast-moving sediments, it is not rich in plant minerals. The acid lateritic soil which is characteristic of the Inanda series is high in organic matter, and is frequently referred to as a "mist-belt" T.M.S. soil. It is well-leached, and contains high concentrations of iron and aluminium oxides and hydroxides. It was on this soil that zinc deficiency was first identified on sugarcane in South Africa (du Toit 1962).

Number of Samples

Two hundred and sixty farms out of all those for which soil maps were available at the time of this survey were shown to be partly or wholly on T.M.S. soils. It was appreciated that while some farms might yield up to three suitable samples, others might not yield any, hence an average of one sample per farm visited was made the objective. Sampling began on 17th January, 1966, and was completed six weeks later on 3rd March. At this stage 196 samples had been collected. A few of these had to be rejected later, either because they were located on an incorrect soil or because they were in the wrong cane age-group. Rain prevented sampling on several days. The survey coincided with the seasonal close-down of the mills, and many farm-owners were away on vacation when their farms were visited. The person left in charge seldom had the necessary field particulars, and in these circumstances no sample was taken.

Practical Aspects

When a selected farm was visited, the owner or manager would be asked if any of his fields on T.M.S. soils carried the variety N:Co. 376 which had been cut during July and August, 1965. When there was such a field the grower invariably pinpointed the location. The field number and soil type were then checked on maps carried for the purpose, and the identity of the cane variety confirmed. Fifty "third leaves" (corresponding well with "top visible dewlap leaves") were then collected. The tops and bottoms of the leaves were cut off using a vee-shaped wooden channel as a template. The midribs were immediately stripped out and discarded, leaving only the 12-inch central laminar portion of the leaves. These were tied in a bundle, carefully labelled, and placed in a specially constructed dust-proof box. A soil

TABLE I

Nutrient levels In 3rd leaf laminar samples

	Nitrogen N%	Phosphorus P%	Potassium K%	Magnesium Mg%	Calcium Ca%	Sodium Na%	Zinz Zn ppm	Copper Cu ppm	Manganese Mn ppm
Mean of 68 samples from mist-belt fields..	2.26	0.27	1.33	0.31	0.40	0.023	13.2	5.6	55
Mean of 120 samples from ordinary T.M.S. fields	2.14	0.28	1.38	0.25	0.37	0.042*	16.5	5.7	69
Overall mean of 188 fields	2.18	0.28	1.36	0.28	0.38	0.035*	15.3	5.6	64
Range over all fields sampled	1.57 to 2.84	0.18 to 0.41	0.70 to 1.95	0.12 to 0.47	0.26 to 0.71	0.009 to 0.218	6.2 to 29.4	2.8 to 10.6	22 to 176
Suggested minimum accepted nutrient concentration	1.70	0.20	1.10	0.08	0.12	—	12.0†	3.0	15

*Mated values. See text.

f Evans (1959) suggests adequacy may even be below 10 ppm but later (1965) he quoted 15 ppm as the accepted adequacy level for

TABLE H

Number of samples in deficiency range

	N	P	K	Mg	Ca	Zn	Cu	Mn
Mist-belt fields .	Nil	Nil	14	Nil	Nil	28	2	Nil
Ordinary T.M.S. fields ..	4	1	17	Nil	Nil	4	2	Nil

sample was then taken for associated studies on soluble silica and aluminium toxicity (Bishop 1967).

Up to 14 farms per day were visited and, whenever possible, the day's collection was dried overnight at 110°C, using a forced draught thermostatic oven at the Experiment Station. The leaves were not washed prior to drying and grinding. The grinding was carried out in a steel mill, employing a fine mesh steel sieve. Although this would obviously invalidate any attempts at iron determinations, no contamination by other elements occurs.

Analytical Methods

The analytical methods employed were as follows: Nitrogen was determined by the macro-Kjeldahl technique. Phosphorus was determined by a colorimetric procedure employing molybdic acid and stannous chloride. Potassium, calcium and sodium were all analysed on an "Eel" flame-photometer. The titan yellow method was used for magnesium, while zinc and copper were determined using dithizone as the colour reagent. The manganese figures were also obtained colorimetrically, by oxidising the manganese with potassium periodate.

Results

The main analytical results are given in Tables I and II, Zinc levels were deficient in leaves obtained from cane grown on 28 mist-belt fields and four ordinary T.M.S. fields. There is still some doubt about classification of soil-types in these four fields, and it may well be that zinc deficiency is confined to the mist-belt soils only. Such deficiency symptoms as chlorosis, smallness of the leaves, patchy growth and stunting were prevalent in a number of the fields later found to be low in leaf zinc. Low zinc levels occurred in leaves taken from fields at Paddock, east of Mid-Illovo, Upper Tongaat, Doringkop, Entumeni and Eshowe.

Zinc uptake by plants has been shown to increase as soil temperatures rise. (Ellis, *et al,* 1964); and Bauer and Lindsay, 1965). This means that when sampling is carried out following a warm sunny season an enhanced overall level of zinc will be found in the leaves. Records kept at Mount Edgecombe, which is roughly in the centre of the sampled area, show that during the three months preceding the survey, the mean soil temperature at a depth of 4 ft. was 3°F below the past 31-year average. It is likely therefore that the concentration of zinc found in cane leaves during this survey is a little lower than it would be during some other years. Despite this, the extent of the deficiency indicates that growers in the affected areas should acquaint themselves with the symptoms of zinc deficiency on both sugarcane and maize.

For cane, the corrective treatment for soils known to be deficient in zinc is the application in the furrow of 50 lb. per acre of commercial zinc fertilizing material, containing 22% Zn. Since zinc does not normally move in the soil, it should be placed where the greatest concentration of roots is expected to occur. According to Ellis, *et al* (1964), the presence of phosphatic fertilizer in contact with the zinc fertilizing material sometimes impairs the uptake of zinc by plants. This obviously creates a problem for the grower whose soil needs the simultaneous application of both fertilizers.

Copper deficiency was found in four instances, but three of these were right on the threshold value and must be considered as marginal. No cases of manganese deficiency were found.

Although sodium is not considered to be essential for optimum growth of cane, this element was determined on all samples taken. A considerably higher content of leaf-sodium was immediately detected in 14 samples taken from farms in a small area northeast of Gingindhlovu. The sodium content for these samples averaged 0.171%, which was roughly seven times the level found in the other 174 samples (0.025%). The proximity of the sea was first thought to be responsible, yet other farms which were the same distance from the sea had far lower levels of leaf-sodium. Poor soil aeration may be a factor connected with this phenomenon, but there was no evidence of this in the crops involved. Beater (1967) has pointed out that the samples taken in Zululand were probably from the Solferino series. This is a hydromorphic soil derived from T.M.S., the lower horizons of which are found to contain an appreciable amount of exchangeable sodium.

Good responses are normally expected when nitrogenous fertilizers are applied as top-dressings to cane grown on T.M.S. soils. It was surprising therefore that in only four cases was the level of leaf nitrogen low enough to be classified as deficient. The four fields involved were all on ordinary T.M.S. soil. A further wholly unexpected result was that only one leaf sample (T.M.S. ordinary) out of 188 revealed a phosphorus deficiency. The level of available phosphorus in these soils is frequently very low, and substantial increases in yield often follow the application of phosphatic fertilizers.

In contrast with the result for N and P, potassium deficiency was found in samples representing 16.5% of the area examined. Fourteen mist-belt fields, and 17 ordinary T.M.S. fields were found to be low in potash. This confirms the work of du Toit (1951), whose cane growth-rate experiments on T.M.S. soils showed excellent responses to applied potassic fertilizer. The critical level for K in third leaf laminae in these studies is 1.1%. This is lower than that accepted in some cane-growing countries overseas, and Evans (1965) quotes a figure of 1.25% K for British Guiana. If a compromise level of 1.2% K were to be adopted as the criterion, then the number of fields considered to be low in potash would have been doubled. No deficiencies of calcium or magnesium were indicated by the leaf analysis.

Discussion and Conclusion

From Table I it can be seen that cane fields in both the mist-belt and on ordinary T.M.S. soils are reasonably similar in their ability to provide the crop with nitrogen, phosphorus, potassium and copper. Leaves from cane grown on mist-belt soils were appreciably higher in magnesium and calcium than those from cane grown on T.M.S. (ord.). Leaves from cane grown on ordinary T.M.S. soils, however, contained more zinc and manganese. The level of organic matter in mist-belt soils is often ten times that found in the Cartref series soils (Bishop, 1967). It has been demonstrated by Smith *et al* (1962) that the presence of organic material in the soil tends to fix zinc and this may account in part for the reduced availability of this element in mist-belt soils.

In due course analyses to determine boron and molybdenum will be carried out on the samples collected during this survey. It is not thought that deficiencies of sulphur or chlorine are likely to occur in the cane-belt, as sulphate of ammonia, superphosphate, and potassium chloride are widely used as fertilizers. Iron deficiency is also virtually ruled out on the acid, iron-rich soils in the T.M.S. group.

Summary

Analyses of 188 carefully-gathered leaf samples from cane grown on Table Mountain sandstone soils in Natal and Zululand indicate fairly widespread zinc deficiency. This deficiency is confined almost exclusively to the mist-belt T.M.S., belonging to the Inanda Four samples appeared to be low in copper and are regarded as marginally deficient in this element. No cases of deficiency or toxicity in manganese were found. Determination of boron and molybdenum levels are to be carried out at a later date. The availability of the major elements was also determined on the same samples and the only important deficiency was potassium. It seems likely that a shortage of this element affects at least one-sixth of the sugarcane growing on T.M.S. soils.

References

Bauer, A., and Lindsay, W. L. (1965). The effect of soil temperature on the availability of indigenous soil zinc. Soil Sci. Soc. Amer. Proc. 29 : 413.

Beater, B. E. (1957). Soils of the sugar belt. Part I. Oxford University Press. Cape Town.

Beater, B. E. (1967). Personal communication.

Bishop, R. T. (1967). Aluminium and silica relationships in growth failure areas. S. Afr. Sug. Tech. Ass. Proc. 41 (in the press).

Du Toit, J. L. (1951). Potash: a neglected fertilizer? S. Afr. Sug. Tech. Ass. Proc. 25: 91.

Du Toit, J. L. (1962). Zinc deficiency in the sugar belt indicated. S. Afr. Sug. J. 46: 399,

Ellis, Roscoe, Jnr., Davis, J. R, and Thurlow, D. L. (1964). Zinc availability in calcareous Michigan soils as influenced by phosphorus level and temperature. Soil Sci. Soc. Amer. Proc. 28: 83.

Evans, H. (1959). Elements other than nitrogen, potassium and phosphorus in the mineral nutrition of sugar cane. Int. Soc. Sug. Cane Tech. Proc. 10: 473.

Evans, H. (1965). Tissue diagnostic analyses and their interpretation in sugarcane. Int. Soc. Sug. Cane Tech. irroc, lib. *i*

Maud, R. R. M. (1965). Laterite and lateritic soil in coastal Natal, South Africa. The J. Soil Sci. 16 :60.

Smith, P. R, Rasmussen, G. K., and Hrnciar, G. (1962). Leaching studies with metal sulfates in light sandy citrus soil in Florida. Soil Sci. 94: 235.

Discussion

Mr. Ric-Hansen: Mr. Alexander took leaf samples when the cane was six months old. Possibly the farms had had different top dressings and these would affect his leaf analysis.

Mr. Alexander: Full particulars were taken of each field that was sampled. About 95% had been top dressed but it did not always follow that those with a deficiency had not been top dressed.

Mr. Gilfillan: No deficiencies of nitrogen or phosphorus were found in the leaf although in T.M.S. soils the greatest response is to these applications.

The whole survey was done by leaf analysis but would it not be more satisfactory to determine these trace elements by soil analysis?

Mr. Alexander: The absence of deficiencies in nitrogen and phosphorus did surprise me. It has been suggested that the deficiencies were there but were not disclosed by the leaf sampling.

In most cases the crops examined appeared to be in excellent condition, but deficiencies are not always apparent. Zinc deficiency was apparent in a number of cases and this was confirmed by leaf analysis.

At present we do not have a satisfactory method of determining trace elements by soil analysis but we are working on this.

Mr. du Toit: There are three reasons why not many deficiencies of nitrogen have been found.

The first is the suggested minimum that has been set, in this case 1.70%.

Secondly, 95% of the fields had been top dressed and sampling was done shortly thereafter and consequently nitrogen, as reflected by leaf analysis, would be satisfactory.

Thirdly, there has been a very great increase in the amount of nitrogen used in the industry, in fact filter cake analyses show double the amount of nitrogen, compared with a few years ago.

The phosphate position is not surprising either. Phosphate deficiency in the sugar growing areas is unusual, except in virgin soil.

The number of zinc deficiencies is surprising, and also the four instances of copper deficiency, but again this is in relation to the suggested minimum figures, which may be unrealistic.

It seems to have been established from an analytical and observational point of view that zinc deficiency is more common than we had thought.

In growth failure areas zinc deficiency may play a part but it is not the whole answer.

Dr. Matic: Professor Ahrens at Cape Town University has developed a number of methods for trace element analysis.

In view of the fact that differences appear in the top and bottom of the leaf it may, in the case of potassium for instance, make a big difference where the sample is taken on the leaf.

Mr. Alexander: A definite part of a specified leaf has been decided on for sampling purposes which enables us to make comparisons with overseas results.

Mr. Rogers: Is boron deficiency measured?

Mr, Alexander: We are preserving samples so that in the near future they can be analysed for boron and molybdenum. We know the symptoms of boron deficiency but they have not been observed in this country. Boron is difficult to analyse and is present in very small quantities in cane leaves.

Mr. Bishop: Our Inanda series soil is highly leached and acidic and yet the average calcium value is 0.4%, against a threshold value of 0.12%, and leaf magnesium is also high.

How often have you seen a leaf calcium figure that is below the threshold value and what proportion of your recommendations involving lime would be based on a leaf analysis?

Mr. Alexander: One certainly would have expected cases of calcium and magnesium deficiency or near deficiency.

In our recommendations to growers who send in leaf samples I have never yet recommended lime on the basis of a leaf analysis, although there have been a few cases where Dolomitic lime has been recommended in order to raise a low leaf-magnesium figure.

Dr. Cleasby (in the chair): On certain T.M.S. soils at Tongaat, where calcium has been well below threshold value, based on soil analysis, we have had liming trials without significant response.

Mr. du Toit: I have not seen a single instance in South Africa of a leaf symptom which has been proved to be due to calcium or magnesium deficiency.

Occasionally I thought I had seen symptoms of boron deficiency but in every case it was almost certainly Pokkah Boeng.

Mr. Brown: Why should our soil not be getting the benefit of calcium from the superphosphate supplied?

Mr. Alexander: Superphosphate will usually supply a crop's calcium requirements. Calcium and magnesium are removed by the cane and sent to the mill in larger amounts than is phosphorus, in many instances.

Dr. Cleasby: Are you satisfied that in T.M.S. soils you will always get a response to applications of potash where the leaf shows a deficiency? I ask this particularly in the light of an experiment at Tongaat on a T.M.S. soil which ran in two cycles for sixteen years and did not respond to potash in spite of soil and leaf analyses indicating a deficiency.

Mr. Alexander: In these soils we would expect a response to potassium where either leaf or soil analysis indicates a deficiency of this element. There have been occasional inexplicable instances such as the experiment which you mention.

RECENT DEVELOPMENTS IN CANE HARVESTING IN NATAL

(An Illustrated Talk)

by GEORGE S. BARTLETT
South African Sugar Association Mechanisation Committee

Mr. **Crookes:** I consider grab loaders can be successfully adapted to Natal conditions. In Chirundu most of the cane was brought in by Broussard loader at seventy tons an hour, for twenty-four hours a day.

A bonus payment system was difficult to apply while a grab-loading system was in use.

Cleaning and trash lining added to costs, particularly when operating at night,

A serious draw-back was the introduction of dirt and stones into the factory.

The cane was set up on a ridge six or eight inches high both to enable the gram loader to get underneath and also to pick up a cleaner load.

We eventually converted to the Mascane loader as used by Tongaat.

Mr. Bartiett: I think we must try and retain our system of individual payment for the weight of cane cut by each cutter and this has been achieved in our trials to date.

Unless we go for chopper harvesters we will certainly bring some dirt into the mill when we mechanise; however this can be minimised by sound field planning, correct selection of equipment, operator technique and adequate infield management.

Mr. Turner: When we first started machine loading at Isipingo we achieved only forty tons a day. The second week was sixty and eventually we reached three hundred tons a day. We had to sell the idea to the field labourers and we did not achieve results easily.

We have developed a trailer that has decreased the effect of crabbing on slopes.

Mr. Bartiett: I have weekly figures from Tongaat for tons loaded per hour. In the first week it averaged 5.46 tons per hour and at the end of the season it had reached an overall average of 21 tons per hour, the limiting factor being hours worked per day. At peak loading periods it averaged 36 tons per hour over the entire week.

Dr. Cleasby (in the chair): Infield grab loading worries the agronomist from the point of view of compaction.

Mr. Bartlett: A rear-mounted loader causes less compaction than a front-mounted one by virtue of the larger wheels having to carry the load. By using multi-wheeled vehicles, tyre pressures can be brought down to about 20 p.s.i.

Mr. Tucker: Farmers who are mechanically minded find loaders and tractors easy to handle and relatively cheap to operate.

One farmer in the Nkwaleni area, however, experienced bad compaction from infield loading and his crop did not ratoon.

Mr. Bartlett: In Australia we found that the majority of growers were using old tractors for front-mounted grabs, probably because this proves to be more economical than when using a new tractor.

I think that the case of compaction mentioned by Mr. Tucker was due mainly to the fact that the type of loader being used necessitated that very large bundles be loaded, which increased ground compaction considerably.

Mr. Cownie: Mr. Bartiett says that the human element limits the usefulness of these machines. What efforts can be made to overcome this and what is the target of efficiency that should be aimed at?

Mr. Bartiett: Management must be determined to make mechanisation work, and must be prepared to persevere with it, and this idea must be put across to the field workers.

Our drivers on the whole are good and with sound training there would be no serious problems. The degree of efficiency will depend on the type of loader being used, the availability of transport, terrain, etc.

Mr. de Robillard: These machines take into account the decreasing availability of labour and its increasing cost. But there are other aspects such as compaction, loss of trash blanket, weed control and destruction of stools which must be considered.

Mr. Bartiett: The Mechanisation Committee's task is to endeavour to produce within certain practical limits a suitable machine to meet the needs of the industry as they arise. Various ways of avoiding consequent damage to cane stools have already been mentioned. Tongaat has demonstrated that mechanical loaders can operate under trash conditions, but, of course, the extra cost of trashing cane must be taken into account.

Fields should be laid out and suitable machines used so that the damage to stools is kept to a minimum, while weed control can be adequately achieved at a reasonable cost.

NOTES ON DISEASES OF SUGARCANE AT HIPPO VALLEY ESTATES LIMITED- 1962 to 1967

by M. J. P. KOENIG
Hippo Valley Estates Limited

Hippo Valley Estates Limited is located in the South Eastern Lowveldt of Rhodesia, Latitude 21° 05'S and Longitude 31° 39'E at 1,300 feet altitude. It covers an area of approximately 150,000 acres, of which 24,000 are planted to sugar cane, including 42 Settler farmers. The climate is somewhat different from other sugarcane growing areas of the world. With an annual rainfall of about 20 inches, restricted mainly to the months of November to March, mean monthly temperatures vary from 80 °F in November to 60 °F in June, and diurnal temperature ranges of up to 40 °F, 30 °F are very common. Maximum temperatures of 108°F and minimum of 32°F have been recorded. Generally speaking the atmosphere is dry, except during the rainy season. About 80% of the sugar cane is grown on reddish brown fine grained sandy clay loams derived from Paragneiss. The rest is either on deep forest sands or dark heavy active clays of basaltic origin. The pH varies from neutral to alkaline on the Paragneiss to very alkaline in the basaltic clays. Full irrigation is being practised and the yearly water consumption averages 6.5 acre feet including rainfall and is based on Class "A" pan evaporation figures. The water comes from a large storage dam of a maximum capacity of 1,100,000 acre feet and is of almost perfect quality for sugarcane and, indeed, any crop. It reaches the fields through an extensive system of concrete-lined canals and then fed into a furrow irrigation layout based on a contour system, with an average slope of 1:150.

Only two varieties are grown on a commercial scale. N:Co.310 and N:Co.376. Many varieties have been imported and are being tested- Those showing signs of promise such as Co 462, B4362, B42231, CB 38/22 and M 31/45 are being bulked up to produce sufficient cane for a long factory mill test. Many more varieies have been included in trials but have been rejected because of their susceptibility to either or both of the major diseases of Hippo Valley, namely Smut and Leaf Scald.

The diseases recorded so far at Hippo Valley are: Smut, Leaf Scald, Gumming, Brown Spot, Pineapple Disease, Pokkah Boeng, Red Rot of Leaf Sheath, Red Spot of Leaf Sheath and Leaf Galls, the first two only being of economic importance and the last one of doubtful origin.

SMUT: Ustilago scitaminea Sydow.

In 1962 when Mr. Robert Antoine, Chief Pathologist of the Mauritius Sugar Industry Research Institute, visited the Estate, a warning was given that if immediate steps were not taken to control this disease it might reach epidemic proportions and prove to be a limiting factor to production, a fact which was later proved correct. In 1966, 250 acres of N:Co.310 were ploughed out due to very heavy Smut infestation. At this stage it was found that N:Co.310 was much more affected than N:Co.376. Infection rates varied from 1% to as high as 10% with an overall average infection of *3%.* At the beginning of the first crushing season, in 1962, an extensive rogueing programme was set up. Only 3,000 acres of cane were planted then, but new lands were being prepared and by careful selection of seed material and treatment of the cane setts in a solution of a mercurial fungicide before planting the disease was kept under control. Table I shows some of the results obtained.

TABLE I

		1963		1964		1965—1966	
		N:Co. 310	N:Co. 376	N:Co. 310	N:Co. 376	N:Co. 310	N:Co. 376
Block A, ± 3000 acres	Infected Stools/acre	488	64				
	% Infected	5.6%	0.8%				
Block B, ± 3000 acres	Infected Stools/acre	5.6	4.0	64.0	5.60	24.0	12.0
	% Infected	0.07%	0.05%	0.8%	0.07%	0.3%	0.15%
Block C, ± 8000 acres	Infected Stools/acre			2.4	0.8	6.4	3.2
	% Infected			0.03%	0.01%	0.08%	0.04%
Block D, ± 700 acres	Infected Stools/acre					6.47	0.31
	% Infected					0.08%	0.004%

BLOCK A represents the oldest canes on the Estate. Seed cane to plant BLOCK B was taken from the least infected fields of BLOCK A. Thus BLOCK B supplied seed for BLOCK C and so on, BLOCK D being plant cane in 1966.

Smut control in the commercial plantations is done in the following way: Detection of the disease by trained staff who walk along each cane line and flag the infected stools. Then rogueing is done by a separate gang.

Various rogueing methods have been tried on the Estate, depending on the stage of infection and the size of the cane.

The aim is to detect the disease in the early stages, before the whips have appeared and the spores released, in which case the stools are dug out and carried away for burning.

If whips have been produced but the cane is short, 2-3 feet high, a gunny sack or plastic bag is gently placed over the stool and pulled down to enclose the latter completely. The bag is tied around the cane at soil level, the stool dug out and taken away, the bag being removed only prior to burning. The bags can be used many times by dipping in a solution of a mercurial fungicide. A stool is then removed on each of the four sides of the infected cane. When the cane is bigger, a 44-gallon drum is used, opened at both ends. One end is first covered by means of a piece of plastic tied around the rim and the drum is placed over the infected stool, the cover being to prevent an upward draft carrying away the spores. The cover is then removed and trash and spent oil used to obtain a hot burn inside the drum. If properly done the heat is enough to kill the spores and the stool can then be removed without the need of a bag. The advantages of this method are that the drum can be used for a long time, being more resistant than bags, there is no need for disinfection, and if short of labour the burnt stool may be left in position for removal at a later date.

In addition to control in the fields, all the other imported varieties are being tested for resistance to Smut using a method produced by K. R. Bock. Single bud setts taken from the upper third of cane stalks are incubated overnight at 88 °F. A suspension of fresh Smut spores at a concentration of 10^7

TABLE II

Variety	*No. of Germinated buds per 100 planted*	*No. of infected stools*	*% Infection*
B 3439	80	6	7.5
B 4362	92	2	2.2
Co 419	94	10	10.6
Co 421	93	3	3.2
Co 462	92	0	0
Co 911	77	53	68.8
CB 36/14	95	1	1.1
CB 38/22	81	2	2.5
CP 29/116	85	0	0
M 31/45	93	0	0
NCo 310	93	8	8.6
NCo 376	84	23	27.4
P R 1000	72	0	0

o

spores per ml. is sprayed over the buds. The setts are again incubated overnight and then planted out. Infected plants are uprooted and destroyed. Table II shows the results obtained-

It will be noted that N:Co.376 is showing a higher susceptibility than N:Co.310, but it has been found on the Estate that when this variety has been growing for some time next to a field of badly infected N:Co.310, it would show a very high degree of infection.

Susceptibility rating:

0 - 5%=Very resistant.
5 -10%=Resistant.
10-20%=Susceptible.
20%= Very susceptible.

LEAF SCALD: Xanthomonas albilineans (Ashby) Dowson.

This disease was first recorded at Hippo Valley by Mr. Robert Antoine in April 1965 on B 34104, a recently imported variety. Immediate steps were taken to destroy all infected material in an attempt to contain the disease. Further surveys showed infection in other varieties throughout the Estate. How this disease which had never been recorded in Africa before got into Rhodesia is still not known. Fortunately, the two commercial varieties appear to be tolerant but some of the imported varieties have shown^the acute phase followed by death of the stools. The variety CP 44/155 in one trial had 11% of the stools dead after 4 months. As this disease can exist in a latent or mild form and thus escape detection, the selection of disease-free planting material is difficult. Being easily transmitted by the cutting knife it makes things even more complicated and has set back the programme of release of new varieties. In the meantime, two Leaf Scald resistance trials were established, one of which is now in its second year. No new varieties will be released unless showing resistance or a high degree of tolerance to this disease. Table III shows the results obtained in the first trial. The trial consists of four lines of one variety planted between two lines of a known susceptible variety. When the tillers are about 2-3 feet high and the majority of the growing points are above ground level, the tillers in the 2 central rows of the varieties under test as well as those of the susceptible guard canes are cut just above the growing point and inoculated with a solution of the bacterium. Thus for every variety there is first a line of infected susceptible cane, then one not inoculated of the variety to be tested, then two inoculated rows of that same variety and again one row of the infected susceptible cane. Records of stripes on the leaves and tillers killed by the disease are kept.

TABLE III
Trial No. 1

Variety	Infection: Inoculated: Dead shoots		Inoculated: Leaf St.		Not Inoculated: Dead shoots		Not Inoculated: Leaf St.		Rating
1966	25/4	12/8	25/4	12/8	25/4	12/8	25/4	12/8	
CB 36/14	—	7	7	7	—	31	9	2	16
Co 775	—	16	12	0	—	9	0	1	15
Co 419	—	3	0	0	—	5	0	1	13
PR 1000	—	8	10	3	—	3	1	1	13
CP 29/116	—	6	14	5	—	0	2	4	11
CB 38/22	—	3	0	0	—	2	0	1	10
Co 462	—	10	0	0	—	2	0	0	9
Co 421	—	0	0	0	—	2	1	0	7
B 3439	—	0	0	0	—	2	0	0	7
B4362	—	0	1	0	—	1	0	0	5
N:Co. 310	—	0	0	0	—	1	0	0	5
M 134/32	—	0	0	0	—	1	0	0	5
N:Co. 376	—	0	6	2	—	0	0	0	3
B 4744	—	0	0	2	—	0	0	0	3
B 42231	—	0	0	0	—	0	0	0	1
M 31/45	—	0	1	0	—	0	0	0	1

GUMMING: Xanthomonas vasculorum (Cobb) Dowson.

This disease has been present at Hippo Valley since 1959, showing at times rather numerous leaf symptoms on N:Co.310 but so far is of little economic importance. Both types of stripes can be seen: the one red in colour and with definite margins, and the other yellowish, wider and with less defined margins. The leaf symptoms are only visible for a short time of the year mostly in the young ratoons and disappear, leaving the canes unaffected. The stripes are encountered mostly in fields under spray irrigation, the disease being more easily transmitted under this regime. On one occasion leaf symptoms of the systemic infection were visible in N:Co.310 on a few plants but the acute phase was never recorded. No further planting of N:Co.310 under spray irrigation is contemplated. It is thought that due to the dry climate gumming will never become of economic importance.

BROWN SPOT: Cerocospora longipes. Butler.

It is commonly observed at Hippo Valley, more so in fields under spray irrigation and mostly on N:Co.376. The spots are rather small and reddish brown in colour with a small black central portion. This disease is of no economic importance.

PINEAPPLE DISEASE: Ceratocystis paradoxa (de Seynes) Moreau.

As it is current practice on the Estate to dip all planting material in a solution of a mercurial fungicide* this disease has only been recorded in experimental plots when the cane had not been treated on purpose. Isolated cases in the fields have been found and traced back to improper dipping.

POKKAH BOENG: Gibberella moniliformis (Sheldon) Wineland.

Common in both commercial varieties but of no economic importance. Very rare cases of death of the growing point have been observed. The spindle is usually affected at about an inch above the growing point and the top portion is severed, but growth is not checked and only mild leaf symptoms can be observed later on.

RED ROT OF LEAF SHEATH: Pellicularia rolfsii (Sacc.) E. West.
AND
RED SPOT OF LEAF SHEATH: Cercospora vaginae Kriiger.

Both found at Hippo Valley and generally associated with water-logging. The affected canes are usually thinner and shorter than usual. These diseases are of no economic importance.

LEAF GALLS:

These galls were identified some five years ago and were at first confused with those produced by Fiji disease. The characteristic symptom of the dreaded Fiji disease lies in the production of galls on the lower surface of the leaves. So, when leaf galling was first observed at Hippo Valley with galls produced on the underside of the cane leat, it was feared that Fiji disease had reached the area. However, examination revealed that the Leaf Galls at Hippo Valley were quite distinct in structure and anatomy from those caused by Fiji disease. In addition, none of the other symptoms associated with Fiji disease has been seen. So far the leaf galling does not seem to affect the cane in spite of the presence of a large number of galls on the leaves of the plant. In Madagascar similar leaf galls have been observed on several grasses, thus indicating that it may be transmitted from cane to grass or perhaps from grass to cane.

References

Antoine, R. Miscellaneous reports on Sugar Cane Diseases Hippo Valley Estates. Unpublished.

Bock, K. R. Studies on Sugar Cane Smut in Kenya. T.B.M.S.

Discussion

Dr. Dick (in the chair): I notice that none of the virus diseases such as ratoon stunting has been mentioned.

Mr. Koenig: We fortunately do not appear to have them and by treating our seed material hope to prevent them.

All imported varieties received the long hot water treatment.

Mr. **Gosnell:** We think that Smut is the biggest threat in the lowveld of Rhodesia.

The newly established research station in Rhodesia will, as one of its main functions, study the ecology and epidemiology of Smut.

Mr. **G.** M. **Thomson:** For Smut testing we have recently put out a greenhouse experiment in tins to test our varieties for susceptibility. The most resistant are N:Co.382, N.50/211, both CB varieties and N:Co.334 and the least resistant are Co.301, N:Co.310 and Co.331.

There are certain anomalies. N:Co.339 had the least resistance of all, whereas N:Co.293 behaved quite well.

We also tried a method of inoculation by direct injection into the bud.

Germination was rather poor, Possibly because some of the buds were destroyed by the inoculation, but the percentage infection was very high and the varietal susceptibility was still on the whole what we would expect in the field.

I was surprised to see in this paper that N:Co.376 is more susceptible than N:Co.310.

Mr. Koenig: In our commercial plantations N:Co.376 is fairly resistant but in the presence of a high innoculum, that is, next to a heavily infected field of N:Co.310, shows infection figures of up to 5%.

THE EFFECTS OF HOT AIR TREATMENT AND HOT WATER TREATMENT ON THE GERMINATION OF 12 COMMERCIAL SUGARCANE VARIETIES IN NATAL

by G. M. THOMSON
South African Sugar Association Experiment Station

Introduction

Heat therapy of sugarcane has been used in the past as a cure for the virus disease chlorotic streak. With the discovery some years ago of ratoon stunting disease workers once more turned to heat treatment as a means of controlling this new and more serious virus disease. A new combination of temperature and time was found to be necessary and finally a 2 hour soaking in water at a temperature of SOX was recommended.

This hot water treatment was adopted in most sugarcane growing countries with the exception of Louisiana and Malagasy where for various reasons the alternative hot air system of treatment was recommended.

Although there is apparently no difference between the two methods with respect to efficiency in disease control it has been considered more practicable to employ the hot water method in South Africa. There may, however, be some districts where electricity supply is unreliable or where the farm is a considerable distance from the nearest hot water treatment plant sited at a mill. It is in these situations that the hot air method might be considered. The plant could perhaps be operated with a gas heater or by electricity derived from a portable generator.

Object

Although hot air treatment has not yet been introduced commercially in South Africa, it was felt that certain situations might call for its use in preference to the hot water method. For this reason a complete hot air system was imported by the Experiment Station from Louisiana and the present experiment carried out to determine the effects, if any, of the two methods of treatment for ratoon stunting disease on the germination of a number of our more important varieties.

Methods

(1) *The Hot Air Oven and the Hot Water Tank*

The equipment used for the experiment consisted of a hot air treatment oven supplied by the Barola Electric Company of Baton Rouge, Louisiana imported and installed by the Experiment Station and having a capacity of approximately 1 ton of seedcane. The hot water treatment was carried out in the tanks operated by the Mount Edgecombe mill of Hulett's Sugar Corporation.

(2) *Varieties*

A selection of 12 commercial varieties was made for the experiment ranging from N:Co.293 to the most recent releases, N.55/805 and the two C.B. varieties. The full list was as follows:

N:Co.293
N:Co.310
N:Co.334
N:Co.376
N:Co.382
N.50/211
N.51/168
N.51/539

N.55/805
C.B. 36/14
C.B. 38/22

(3) *Seedcane and Treatments*

The seedcane for the experiment was obtained from variety collections at the Experiment Station and was in the majority of cases 12 months old plant cane.

There were three main treatments namely — Hot air treatment (H.A.), Hot water treatment (H.W.) and untreated (NIL). Within each of these there were sub-treatments of "whole stalks" and "setts" and in the heat treatment of "whole stalks treated and then cut into setts before planting". The full numbered list of treatments is as follows:

(1) HA : Whole Stalks
(2) HA : Whole Stalks cut into setts
(3) HA Setts
(4) HW Whole Stalks
(5) HW Whole Stalks cut into setts
(6) HW Setts
(7) NIL Whole Stalks
(8) NIL Setts

Whole stalks were cut to carry 10 buds each and setts were prepared with 5 buds each. Plots were single lines of 6 feet planted with 30 buds each i.e. 3 whole stalks or 6 setts.

For the hot air treatment the temperature of the air entering the treatment chamber averaged 57.5 °C. Treatment at this temperature was for 8 hours. In the hot water treatment, the seedcane was soaked for 2 hours in water at 50 °C.

All seedcane was treated with fungicide before planting.

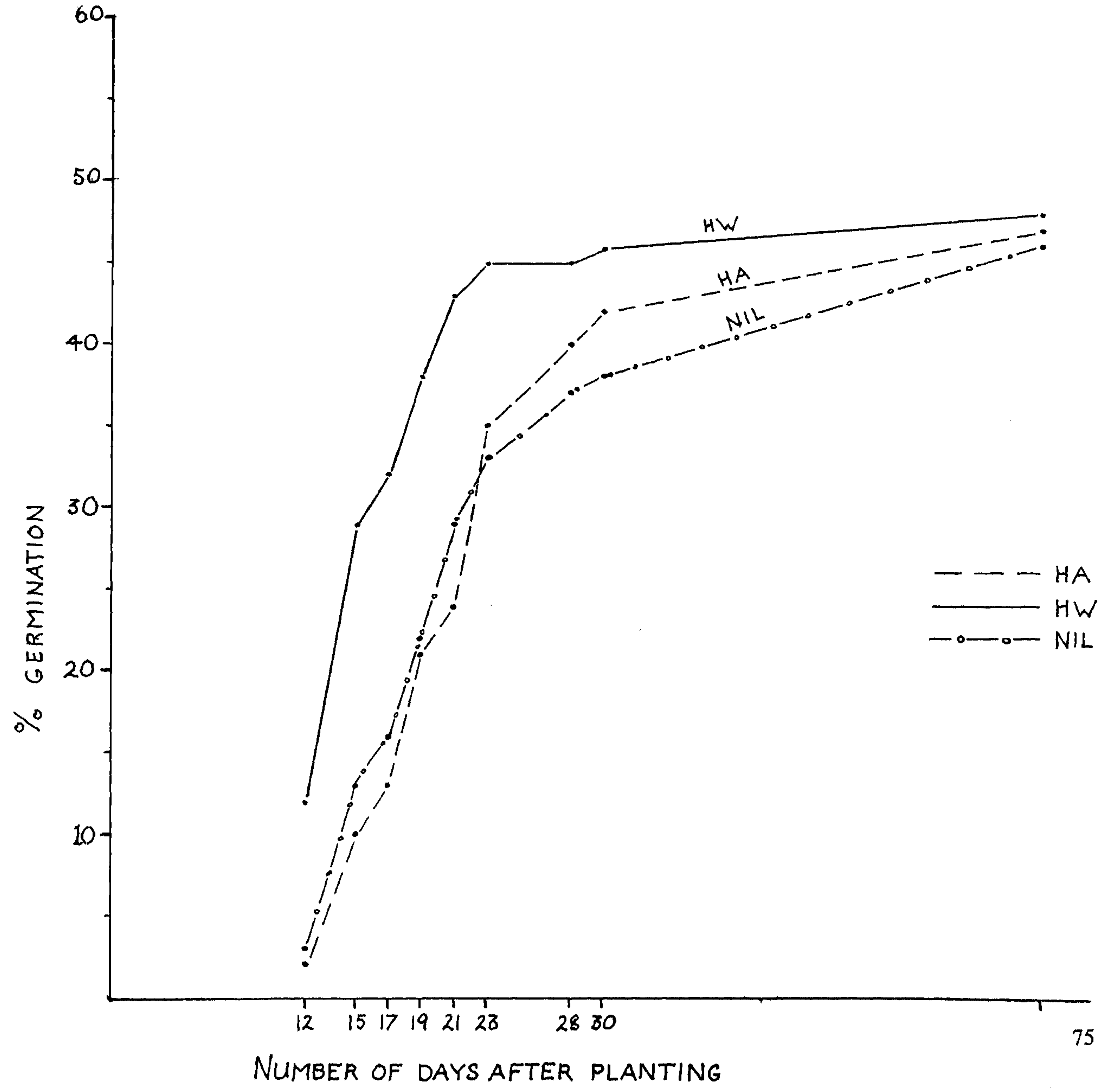
The heat treatments were carried out on 29th November 1966 and the experiment planted on the following day.

Results

Germination counting commenced on 12th December 1966 and the early indications were that hot water treated cane germinated first in most varieties. Hot air treated cane and untreated whole stalks came away very slowly by comparison, (see Fig. 1).

Within approximately 30 days it was apparent that in some plots secondary shoots were beginning to appear, so that in those cases, germination as such was complete. However, to enable any slower growing varieties and treatments to complete their germination the experiment was left until 26th January 1967 when all the cane was unearthed and the actual germination counted for each stalk and sett. Only buds which had actually produced a living aboveground shoot were recorded as having germinated.

FIGURE 1: Mean rate of germination in three main treatments and varieties



A considerable number of cases was found in which the bud had germinated, produced a shoot but then had died for some reason or other. In other cases buds appeared to be still alive but unlikely to produce normal shoots.

The effect of heat treatment on the germination of buds on whole stalks is apparent from the graph in Figure 2. The whole stalks in the experiment carried 10 buds each and in the untreated stalks germination of buds lower than third from the top of the stalk fell off very markedly. By comparison more buds germinated in similar stalks treated either with hot air or hot water.

The main effects of the various treatments on the 12 varieties can be seen in Table I and are illustrated in Figure 3. Generally speaking it shows that certain varieties are apparently stimulated by heat treatment while in others the reverse is the case. It is considered that the germination of untreated cane was rather poor particularly when it is realised that the general average germination for the whole experiment was only 47 per cent.

The following are short notes on the reaction of the 12 varieties to the treatments in the experiment.

N:Co-293

The overall germination of this variety was disappointing; in no treatment did the percentage germination exceed the general average. Hot water treated whole stalks were better than hot air treated stalks. The same was true of setts. There was little difference in germination between untreated stalks and setts. There appears to be no advantage to be gained by cutting stalks into setts after heat treatment.

N:Co310

One of the two varieties in the experiment which gave better than average germination in all treatments (the other variety was N.55/805). Hot water treatment was better than either hot air treated or untreated cane. Treating setts with hot air is considerably better than treating whole stalks.

N:Co334

Germination of untreated material was distinctly inferior to that in either of the heat treatments. This poor germination in N:Co.334 has been noted before. Thus this variety appears to be stimulated by heat treatment. The best results derived from whole stalks treated with hot air.

N:Co376

Apart from an apparent stimulation in hot air treatment the germination in this variety was disappointing. Stimulation by hot water treatment was noted in an earlier experiment but is not very apparent on this occasion. Hot air treated stalks gave the best germination by a considerable margin.

TABLE I

Percent Germination in 12 Varieties following hot air treatment and hot water treatment

Variety / Treatment	N:Co. 293	N:Co. 310	N:Co. 334	N:Co. 376	N:Co. 382	N. 50/211	N. 51/168	N. 51/539	N. 53/216	N. 55/805	C.B. 36/14	C.B. 38/22
HA Stalks.. ..	41.7	50.8	61.7	57.5	40.8	40.8	50.8	34.1	41.7	56.7	35.0	32.5
HA Stalks>Setts	37.5	52.5	50.9	43.3	40.0	50.0	39.1	45.0	50.0	64.2	33.3	45.8
HA Setts	33.3	60.0	50.0	45.0	48.3	40.8	53.3	51.7	51.7	60.0	32.5	50.0
Mean HA ..	37.5	54.4	54.2	48.6	43.0	43.9	47.7	43.6	47.8	60.3	33.6	42.8
HW Stalks ..	46.7	58.3	54.2	41.7	28.3	47.5	40.8	60.0	52.5	58.3	36.7	26.7
HW Stalks>Setts	41.0	61.7	50.0	48.7	34.1	41.7	56.7	46.7	63.3	60.8	40.0	45.8
HW Setts	40.8	61.9	47.5	43.5	46.1	47.5	53.3	60.8	60.0	57.5	34.1	45.8
Mean HW ..	42.8	60.6	50.6	44.6	36.2	45.6	50.3	55.8	58.6	58.9	36.9	39.4
NIL Stalks ..	39.1	59.2	34.1	35.0	34.1	50.0	44.2	40.0	36.7	48.3	32.5	37·5
NIL Setts	40.8	53.8	42.5	46.7	50.8	56.7	47.5	53.3	45.8	55.8	47.5	38.3
Mean NIL ..	39.9	56.5	38.3	40.8	42.4	53.2	45.8	46.6	41.2	52.0	40.0	37.9

N:Co382

Hot water treatment inferior to hot air treatment but in general no marked stimulation by heat treatment. In both types of heat treatment and in untreated cane setts germination definitely superior to that of whole stalks.

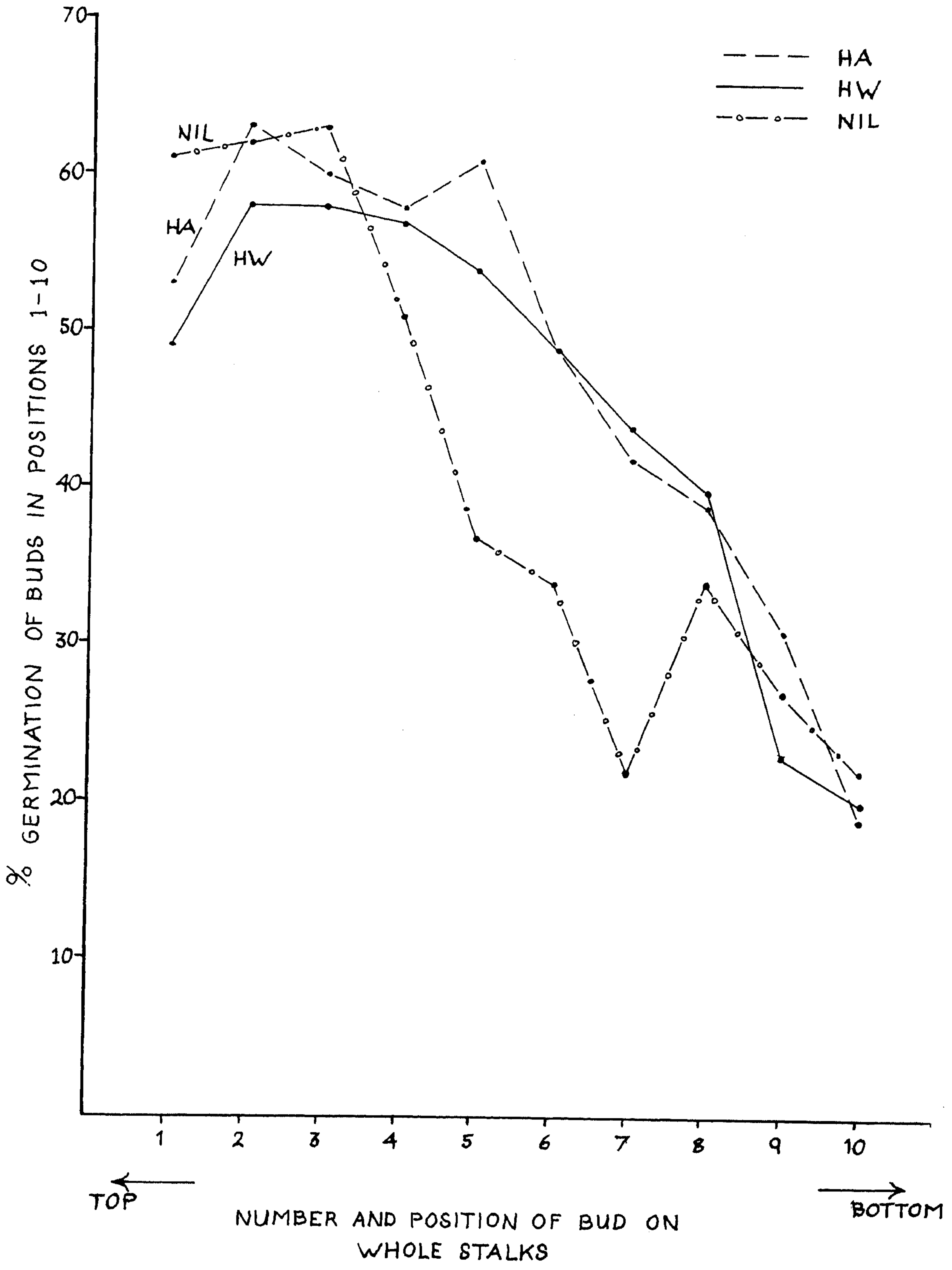
N.50/211

Germination of untreated seedcane superior to that of heat treated cane. Hot air treated cane inferior to hot water treated. Untreated setts better than whole stalks.

N.51/168

Rather poor germination in untreated cane with setts slightly better than whole stalks. Hot water treatment slightly better than hot air treatment on average but in both, particularly in hot water setts better than whole stalks.

FIGURE 2: Germination of buds in various positions on whole stalks after hot air and hot water treatments



N.51/539

There appears to be some stimulation after hot water treatment. Hot air treatment definitely inferior to hot water treatment. Apparently little difference between whole stalks and setts in hot water treatment but in hot air, setts far superior to whole stalks. The latter comparison also holds true for untreated cane.

N.53/216

Germination of untreated cane rather disappointing. Considerable stimulation in hot water treatment by comparison. On the average hot air treatment gave a better germination than untreated. Germination of setts superior to that of whole stalks after hot air, hot water and no treatment.

N.55/805

Considerable germination stimulation after heat treatment of both types. This phenomenon has been observed following hot water treatment in an earlier experiment In untreated cane, setts better than whole stalks. On an average hot air treatment better than hot water treatment.

C.B36/14

Only untreated setts exceeded the rather low general average otherwise the germination of this variety was very disappointing. In heat treated cane both methods gave poor results but hot water treated seedcane germinated slightly better than hot air treated. Poor germination after hot water treatment has been observed before in this variety.

CJB.38/22

Only hot air treated setts exceeded the general average germination. Untreated seedcane germinated very poorly as did heat treated whole stalks. In both types of heat treatment setts were markedly superior to whole stalks.

Summary

Considerable variation is apparent in varietal reaction to the two types of heat treatment carried out in the experiment.

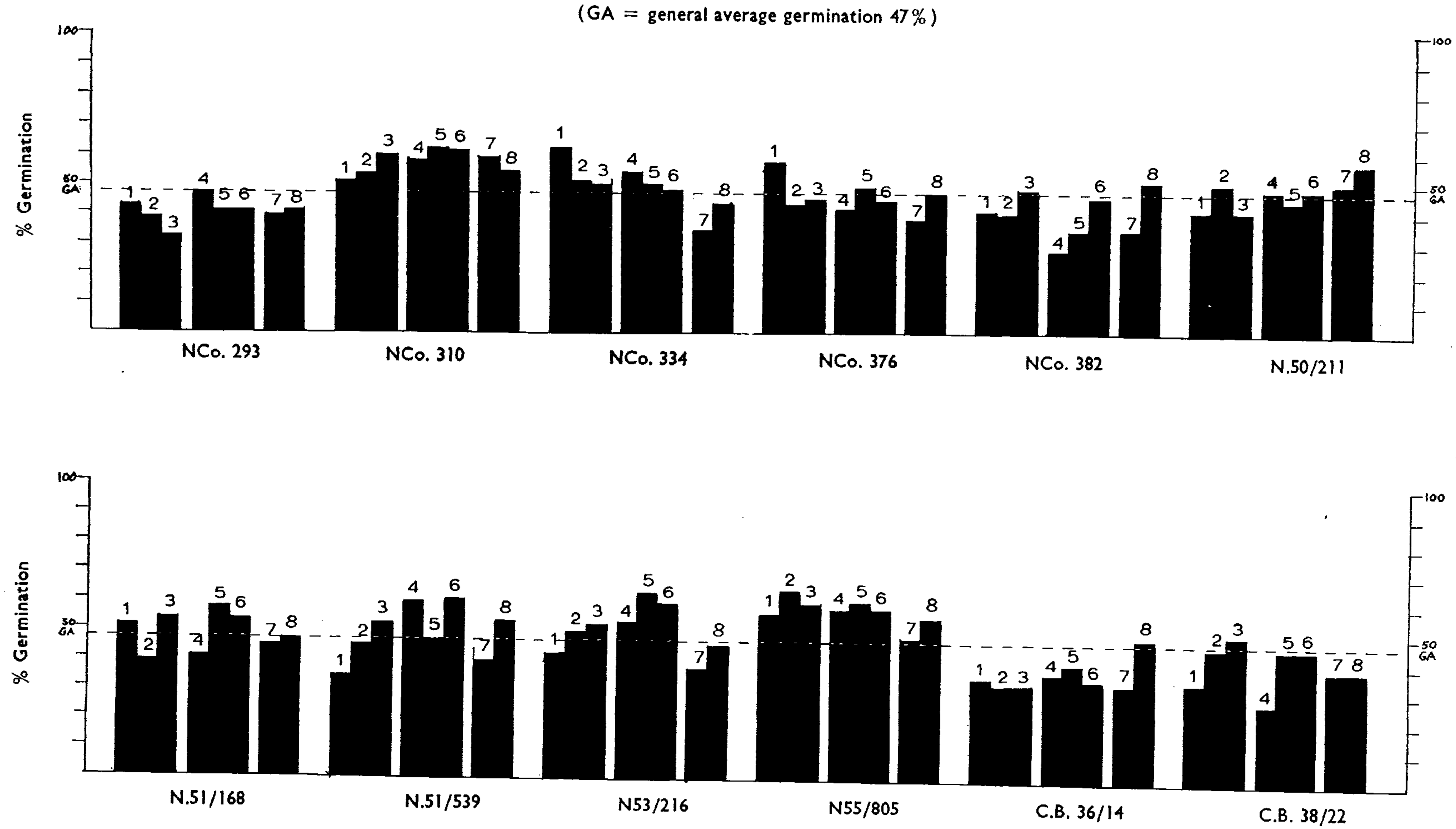
Although the general average germination over the whole experiment was considered to be low at 47%, germination stimulation was clearly observed after heat treatment in the two varieties N:Co.310 and N.55/805.

Overall germination was disappointing in N:Co.293, N:Co.376, N:Co.382, N.50/211, C.B.36/14 and CJB.38/22. The particularly adverse effects on C.B.36/14 have been observed on other occasions.

In most varieties treating whole stalks instead of setts with hot water brings no serious problems in germination. Exceptions to this are apparent in N:Co.382, N.51/168 and C.B.38/22. The picture is somewhat different in hot air treatment where in only N:Co.293, N:Co.334 and N:Co.376 was the whole stalk germination markedly better than that from setts.

As is to be expected, germination of untreated setts is superior to that of untreated whole stalks in most varieties.

FIGURE 3: Germination of hot air treated, hot water treated and untreated Seedcane of 12 Commercial varieties



1. = Hot air treated whole stalks.
2. = Hot air treated whole stalks cut into setts.
3. = Hot air treated setts.
4. = Hot water treated whole stalks.
5. = Hot water treated whole stalks cut into setts.
6. = Hot water treated setts.
7. = Untreated whole stalks.
8. = Untreated setts.

Discussion

Dr. Dick (in the chair): With hot air treatment why does the treatment take so much longer than with hot water, and what prevents dessication of the setts?

Mr. **Thomson:** The sett itself reaches a temperature of 50°C in about five hours in hot air, but takes a much shorter time in hot water.

No attempt has been made to control humidity, moisture derived from the seed cane being considered sufficient to prevent too much desiccation.

Mr. Gilfillan: We also found considerable stimulation of germination of N.55/805 with hot water treatment, especially if the whole stick and not the sett was treated.

What temperature tolerance is allowable in a hot water tank and what is the effect of allowing hot water treated cane to dry out for some days before planting?

Mr. **Thomson:** We recommend a working temperature of 50.5°C and prefer a tolerance of only 0.5°C either way.

It is usually considered advisable to plant cane immediately after hot water treatment.

Mr. **King:** I think Mr. Thomson should be quite satisfied with his percentage germination figures.

Regarding time of treatment, which was in November, cane is normally then in active growth and I suggest the experiments should also be carried out in August.

Hot air treatment may be useful in Louisiana, a nine month crop, because buds are young and soft but I think here we should stick to hot water treatment.

Mr. Thomson: The experiment is to be repeated in August.

Dr. Brett: Cutting stalks into setts has two main effects: the beneficial one of reducing polarity and thereby enabling more buds to germinate, and the harmful one of exposing more buds to attack by micro-organisms. Heat treatment itself can have similar effects. By destroying auxin, it reduces polarity, and by its damaging effect it may render buds more susceptible to rotting. If heat treatment completely eliminates polarity, the only effect of cutting whole stalks into sets is the harmful one of exposing more buds to attack, but if polarity is not completely eliminated, some benefit may accrue from cutting. This is evident in Table I, which shows that when heat-treated whole stalks gave better germination than untreated setts, germination usually deteriorated if these whole stalks were cut into setts. Conversely, an improvement usually resulted from cutting if the heat-treated whole stalks gave inferior germination to untreated setts.

Mr. de Robillard: Last year whole stalks were hot water treated. There was a big labour saving by treating in this way and germination was good.

Mr. Thomson: Treating of whole stalks does save a lot of time and labour and it also cuts down the amount of handling of the seed cane before and after treatment.

Mr. Gilfillan: Tongaat is treating whole stalks on a trial basis at the moment. One problem is to get an even temperature throughout the bundle of stalks during the treatment.

Mr. Thomson: Limitation of size of bundle should be considered.

HERBICIDE APPLICATION — A NEW APPROACH

by G. J. F. WARDLE
Illovo Sugar Estates Limited

Introduction

With diminishing labour supplies, chemical weed control is becoming increasingly important in the South African Sugar Industry. During the past two years Illovo Sugar Estates have made a concerted effort to face and answer this problem of labour shortage by embarking on a comprehensive chemical weed control programme.

It was necessary to decide (a) what chemicals to use and, (b) how to apply them? The former was easily established by employing a policy of non-sophistication and making use of the tried and true growth-regulator type herbicides (2,4-D and 2, 4, 5-T) which, in the main, commercially control the weed complex present in company fields. The most efficient method of application was more difficult to establish.

On the company's coastal sections where topography precludes the use of large mechanical rigs, the choice of manual application by a trained gang of specialist labourers was unavoidable. On areas where mechanical operations are possible a short boom attached to a cultivator and spraying row only, three rows at a time, is employed. Such a system, on land where only relatively small acreages can be treated mechanically, is quite satisfactory. However, on the company's inland sections where approximately 60 per cent of the area is negotiable with a wheel-tractor and where no suitable labour is available for specialist manual operations, the introduction of the short-boom rig has exposed its inadequacies.

Such factors are the slowness of the operation and the relative inefficiency of using a tractor to treat only three rows at a time. Furthermore, if conventional nozzles and jets are used, the use of fairly large volumes of water (25-35 gallons per acre) results in time wastage and expense due to repeated filling operations. Such excessive water usage may be avoided if minute jets are used but this advantage is outweighed by the high frequency of nozzle blockages irrespective of using the cleanest farm water.

The resultant project was to develop a mechanism which could be activated by a small economical wheel-tractor yet carry a fairly large water supply and augment that supply by applying the very minimum amount per unit area of land consistent with efficient weed control. Furthermore, the applicator should present no problems of nozzle blockage and be large enough to treat a wide swath with each pass.

Description

A machine vaguely fitting these requirements has been developed as an orchard sprayer and is widely used throughout South Africa and overseas. Such machines are commonly known as low-volume mist-blowers and as their name implies, they convey the chemical to the plant by means of an airstream, reducing water as the transport medium whilst replacing it with air. The machine consists of a 150 gallon tank mounted behind a F.T.O. operated fan and centrifugal pump. The latter is used to agitate, by recirculation, the contents of the tank while simultaneously delivering the liquid to the airduct venturii. The pump is also used to refill the tank at the approximate rate of 30 gallons per minute.

The fan which is balanced and mounted between two bearings creates an airblast of considerable speed (in excess of 150 miles per hour) which is ducted to the head whence it is distributed through the jets. Inside each jet is mounted a venturi and the air rushing past the same sucks the pump-assisted liquid out at an adjustable rate. The liquid is "atomised" and forms a mist when it passes into the barrier of outside air (see Fig. 1). The venturii are approximately 1/4" in diameter thus blockage is impossible.

Water mainly fulfils the function of a solvent in the mist blowing system with the result that the proportion of water to chemical is less compared with the high pressure conventional systems. An important difference between the two systems is found in the size of droplet in which the chemical is dissolved. Some manufacturers claim that the droplets formed by the mist blower are the key to its success, resulting in a saving of up to 40 per cent of chemicals and 90 per cent of water used. The droplets from a conventional jet system can vary greatly in size but the majority occur in the range of 150 to 300μ while the average droplet from a mist blower is approximately 50μ in diameter. Mathematically, it may be interpreted that one droplet of 300μ diameter can be subdivided into 216 droplets of 50μ diameter. Without delving into the intracacies of mathematics and zones of chemical effectiveness surrounding each droplet, it may be accepted that a large number of small spheres (droplets) with the same total volume as a lesser number of larger spheres, have a greater surface area and hence could produce a superior cover and distribution pattern. In addition, when the airstream and liquid pass out of the jet they break through the relatively static air surrounding the head carrying a portion thereof along, which produces a turbulence thus ensuring that all parts of the plant population are thoroughly covered with chemical

Having seen these machines operating in orchards for pest control and in one area on wheatlands for weed control, in their conventional form, the writer considered that the principle was worthy of a trial at Illovo. However, it was obvious that the conventional cluster of jets spraying a cloud of chemical and water upwards into the air, while completely adequate for tree spraying, would not be efficient for spraying weeds in a row crop such as sugarcane under more windy conditions. A more definite and directed spray pattern would be required while still employing the principle of airblast through venturii. It was decided that the best means of achieving the above was to design a boom system, but that the latter should carry air to large jets containing venturii directed downwards at approximately 40 degrees from the horizontal. The liquid is fed into the venturii via reinforced plastic hoses strung along the boom. (See Fig. 2.) The jets and venturii are also arranged in a set pattern of direction so as to achieve a curtain of spray over the full width of the swath (See Figs. 1 and 2).

The boom had to be ducted with progressively decreasing diameters in order to obtain equal volumes of air passing out of each jet irrespective of the latter's distance from the air source. This need for ducting the boom has subsequently been found to be not highly critical, although if disregarded it would cause uneven delivery of air and varied droplet sizes from the different venturii.

The machine fitted with the boom has been operating on an experimental basis at Illovo for approximately one month. During this period results of post-emergence spraying using a 2, 4-D low volatile ester have been outstanding. These results were obtained by using a 6.7 lbs. acid equivalent ISO-octyl ester at rates of 2 to 3 pints per acre in 13 gallons of water as a full cover operation. The water output of the machine can be varied by finger-tip adjustment to deliver quantities varying from nil to approximately 100 gallons per acre.

The machine is trailed by a 35 horsepower wheel-tractor operating in second gear, low ratio, at 1800 revolutions per minute which produces a forward speed of 1.90 to 2.00 miles per hour. In theory, at this speed and under ideal conditions, the implement can treat approximately 6 to 7 acres per hour. In practice, however, it has been found that 30 to 35 acres are treated in an 8 hour day under Illovo conditions. The discrepancy between theory and practice is due to time wastage on rough narrow headlands, sloping and undulating infield conditions, and refilling. The latter is of least importance as the machine, when delivering water at 13 gallons per acre, can treat over 10 acres before refilling becomes necessary.

Unfortunately the opportunity to test the machine as a pre-emergence sprayer has not arisen. However, it is reasonable to assume that pre-emergence results would be satisfactory especially if water output and chemical concentration were increased by 50 per cent. The spray pattern delivered by the mist blower, as modified, is similar to that of aircraft spray systems and the latter are widely used in South Africa for pre-emergence work.

There is no information available with regard to the efficacy of the airblast system when using herbicides other than the growth regulator type. With most commercial herbicides, however, once the inherent weed killing properties of the chemical are established, their efficiency is largely dependent on an adequate and uniform spray pattern regardless of their mode of action. Such a spray pattern has been established with this machine.

Discussion

As with most prototype machines, certain disadvantages have been noted and are listed below. It should be stated that some of the physical disadvantages were realised at the start of the project but these were temporarily accepted as the main objective of the exercise was to test the principle of air-cum-water spraying for herbicide application.

TABLE I

Pertinent specifications applicable to the air-cum-water herbicide applicator

	Dimensions	Remarks
Width of Boom.	28 ft. 7½ ins.	Swath width approx. 32 ft. due to overlap of jets.
Height of jets.	3 ft. 5 inches	This is an approx. figure depending on uniformity of land surface.
Diameter of boom.	1st segment is 11 in. 2nd segment is 9 in. 3rd segment is 7 in.	Reduced diameters at greater distances from air source in order to maintain constant air pressures.
Diameter of jets.	2¼ inches.	
Spacing of jets.	Approximately 4 ft.	See text re reduced spacing between jets.
Type of fan.		It is a forward curve multiblade single inlet centrifugal fan.
Capacity of fan.	320,000 cubic ft. per hour.	This volume produced at a max. rated speed of the impeller of 3,400 r.p.m.

(a) The machine, being trailed, is clumsy to handle under rough uneven conditions. Furthermore, due to the width of the boom and the fact that it is fixed when in position, difficulty is experienced in turning on small headlands especially if obstacles in the form of trees, hedges, banks or standing cane occur.

(b) The disadvantage of width also exists when the machine has to be transported to a new field. The arms of the boom must be removed and re-positioned on the new site. An associated disadvantage is the frailness of the boom which can be easily damaged with constant removal.

(c) As the jets of the mist-blower are relatively high above ground level (see Table I), spray drift due to wind does present a problem. Droplet distribution tests were carried out in wind speeds of 20 to 25 miles per hour and the results were uneven and not acceptable. However, in wind speeds of up to 8 miles per hour spray drift is negligible for commercial operations.

At the start of the project the eight jets present on the conventional machine were the only stock available and these were fitted to the boom with no specific ratio of boom (swath) width to number of jets. Fortunately, the illustrations indicate that the droplet distribution is satisfactory, although, in the light of subsequent experience, the same could be improved by increasing the number of jets on the boom to fourteen. Such an increase would halve the span from one jet to the next with resultant improvement in droplet distribution and reduction in wind disturbance. These improvements can be achieved without necessitating an increase in volume output per acre as the liquid delivered per jet can be reduced proportionately. The only disadvantage to this is that a larger fan may be necessary in view of the greater drain on the air supply when using more jets.

A further factor which reduces the importance of wind effects as a disadvantage to this machine is that its daily work potential is such that the operator can choose weather conditions under which to operate i.e. work only during those times of the day when no wind occurs.

It will be noted that the disadvantages listed are mainly of a physical nature which can be reduced or eliminated by thoughtful modification. Such modifications will consist of mounting the implement, including water tanks, on to the tractor, constructing a hinged boom which can be fixed in "travelling" position for road-haulage or turning on limited headlands and using heavier gauge material for the central section of the boom on to which the two outer sections will be hinged. The increase in the number of jets on the boom will complete the modification. It is hoped to develop the redesigned version of the machine in the near future.

Criticism may be forthcoming at the lack of cost figures in this paper. Attention is drawn to the fact that the machine is a prototype which has been operating under experimental conditions to date and hence operating costs, if available, would not be valid. It is envisaged that the machine will be slightly less expensive to operate than a conventional rig although the initial capital outlay will be higher. To partially offset the capital costs it may be stated that, once established, the machine should be long lasting without the need for excessive maintenance and spares.

In drawing conclusions it should be borne in mind that to the best knowledge of the writer this is the first attempt in South Africa and possibly elsewhere, to modify the mist-blowing system for the specific purpose of developing a herbicide applicator. Consequently, from the disadvantages described it will be obvious that the machine is not perfect and is very much a pioneer in its field. However, the primary objective of the project has been achieved in that the advantages viz. no nozzle blockage, greater efficiency of water usage and high work potential, of the air-cum-water sprayer for herbicide application have been demonstrated.

It remains to streamline the mechanism as described above to suit the rugged conditions under which it will work at Illovo. For areas of flat country where field layouts have already been prepared and planned with a view to mechanisation, the implement could be of special usefulness and could probably treat almost double the area of land per day as compared with present performance at Illovo.

Acknowledgements

This paper would be incomplete without the writer's acknowledgement of the very real assistance obtained from various organisations and individuals. It is with gratitude that the writer acknowledges the assistance obtained from Lloyds Industrial & Farm Agencies (Pty) Ltd., of Johannesburg and more especially their Mr. P. Bruce from whom the basic mechanism on which to experiment and make modifications, was borrowed. Acknowledgement must also be accorded to Mr. G. Alder of Associated Air Conditioning and Refrigeration Corporation (Pty) Ltd., of Durban, who, in a private capacity, spent many hours assisting the writer and who designed the boom and ducting system.

Finally, the writer wishes to acknowledge the practical assistance, criticism and encouragement received from colleagues at Illovo during the course of this work.

Summary

Due to labour shortages a concerted herbicide programme became necessary at Illovo. At its commencement this necessitated the choice of herbicides and how to apply them. The former was no problem but problems of application in the form of wasted tractor power, slowness of the operation and nozzle blockage became obvious when large areas were treated

The need to develop an economical applicator capable of treating large areas per unit time with no hindrance due to nozzle blockage and excessive time wastage while refilling with water, became necessary. The air-cum-water spraying system used for orchard spraying appeared to have potential but needed modification. Such a modification in the form of a boom carrying air to large jets in which venturii are situated and from which the water and chemical is blown out as an air-cum-liquid mixture, has been developed. The system, although possessing certain disadvantages of clumsiness and frailty has achieved successful results in the field. The disadvantages have been noted and alterations in design to eliminate them are already under way.

References

1. Anonymous. Orchard Sprayer Utilised for Crop Spraying. Farmer's Weekly—7th December, 1966—Page 27.
2. Verloop, N. A. A Treatise on the Origin and Uses of the Low Volume Mist Blower. Farmer's Weekly—15th June, I960—Page 28.

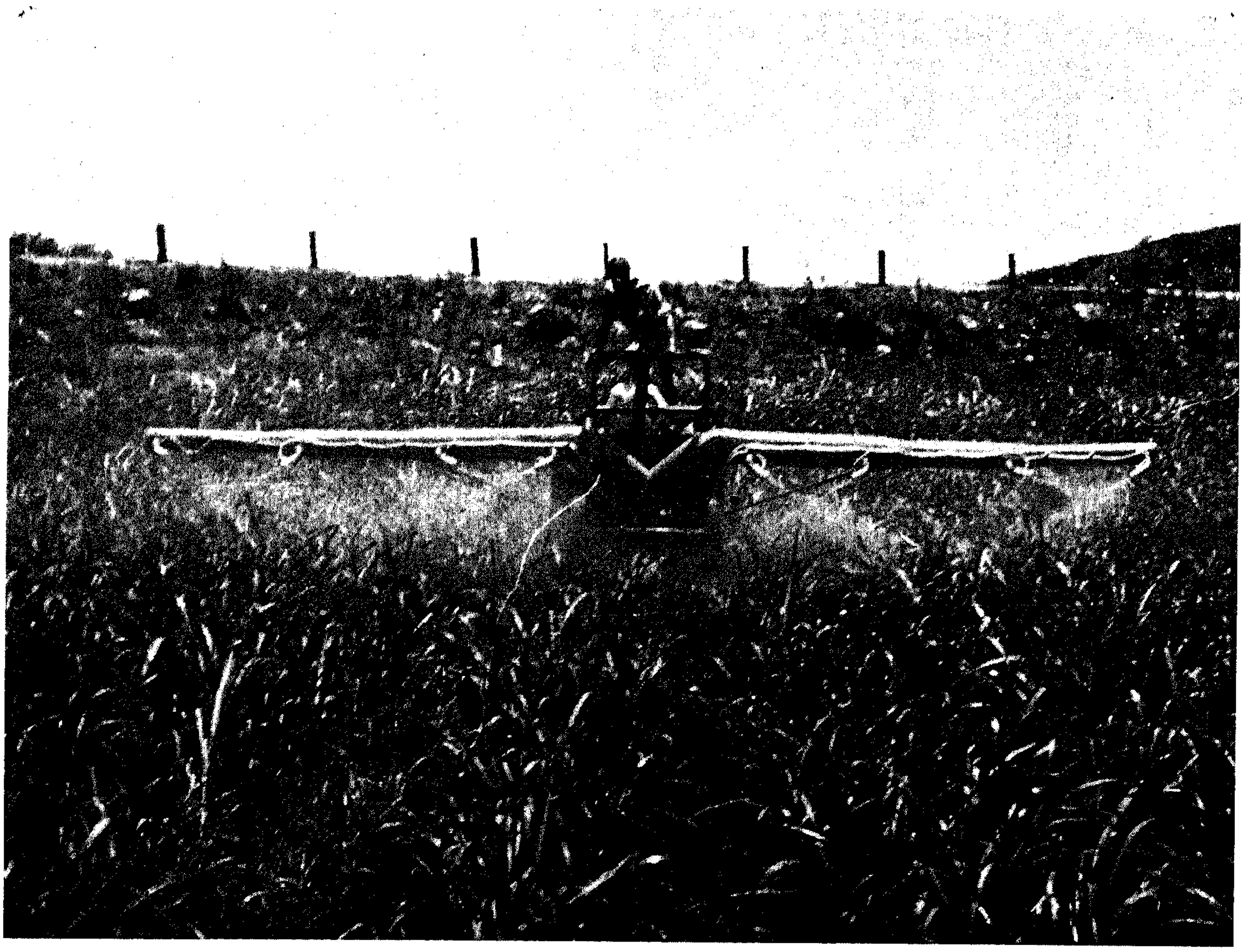


FIGURE 1: The modified mist-blower in operation illustrating the curtain of spray over the full width of the swath

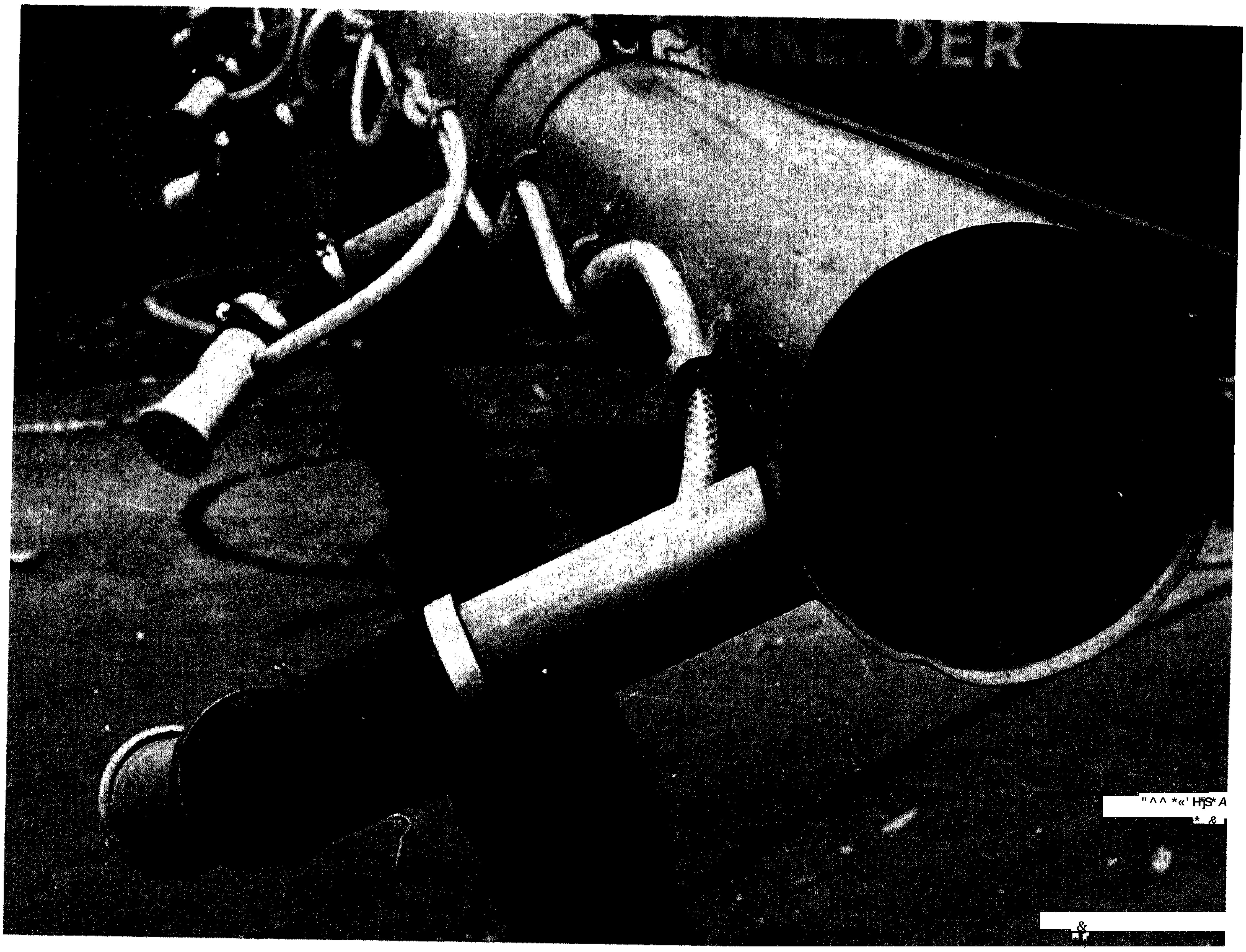


FIGURE 2: The vertical and horizontal angles of inclination of the jets are shown together with part of the boom an7 take-off pipes for air supply to the jets

Discussion

Dr. Dick (in the chair): There is a limit to decreasing the size of droplets. Below a certain size the droplet will not adhere to the plant at all and a bigger droplet will possibly cause slight damage to the plant and allow entrance for the chemical.

Mr. Wardle: I think it would have to be a rather large drop or a very flimsy plant before that type of damage would be caused.

Dr. Thompson: When iso-octyl ester was used as a post-emergent application at Illovo, what was the weed population?

Mr. Wardle: A selection of broad-leafed weeds and water grass. We commercially control the water grass by turning the leaf yellow and retarding its growth for a certain period of time, about three weeks. Damage occurs where the root and stem join when 2,4-D is used but regeneration takes place from that point after three weeks.

Mr. Gosnell: Cannot the water application be reduced below thirteen gallons and adequate cover still be maintained? In the photograph of the paper there appears to be quite a lot of overlap and possibly this could be decreased.

Mr. **Wardle:** We hope to reduce water application. I have used the conventional model of this machine on wheat in the Orange Free State and the rate of water application was only 3| gallons per acre with satisfactory results.

Mr. Gilfillan: Our biggest expense when applying herbicide by machine is the time lost in filling the machine with water.

What are the manufacturing costs of this machine, are running costs high and does it absorb a lot of horsepower?

If drift is a problem could not an amine formulation be used instead of an ester. How much 2.4-D is used per acre to get the stated amount of control of water grass?

If you manufacture a machine with swinging booms in a horizontal plane I suggest you arrange for the booms to swing in a vertical plane in order to avoid damage from jarring when travelling by road.

Mr. **Wardle:** We intend to swing the booms forward, not backward, and clamp them into sockets.

We applied between two and three pints of 2,4-D to the acre, full cover.

We are not particularly worried by spray drift as it is negligible and in any event will be effective wherever it lands. When the vehicle is operated wind direction is allowed for. Spraying can be carried out from one side only if required.

Capital expenditure on this machine will be higher than for a conventional one but cost of operation will be lower because of time saving in filling up with water, use of less water, and coverage of a larger area per operational cycle.

Certain tractors have advantages over others when using this machine. The horsepower required is between 30 and 35.

Mr. **King:** Can this machine be used for a pre-emergent spray and on what sort of topography can it be used?

Mr. Wardle: Wo do not use it on hilly land and so far have not used it for pre-emergent treatment, although it should work. In the Orange Free State we used to spray pre-emergent, by aircraft, with an application as low as $3^1/_2$ gallons per acre. I think results depend largely on soil moisture and soil structure.

Mr. Roodt: Has Mr. Wardle considered the use of a herbicide other than 2,4-D?

Mr. Wardle: When the chemical effectiveness of a herbicide has been proved the next important factor is suitable droplet size and distribution and as these have been established there appears to be no reason why most herbicides should not be effective with this machine.

INSTRUCTIONS TO AUTHORS

1. All papers for Congress must be in the hands of the Technical Secretary not less than sixty days before the meeting.
2. Scripts should be typewritten in English, on one side of the paper only. Double spacing must be used, with a 1 inch margin all round. Pages are to be numbered in the top right hand corner.
3. Layout. The sequence of items in the script should be (1) Title and authors' names; (2) Abstract; (3) Main text; (4) Acknowledgements (if any); (5) References (literature actually cited); (6) Tables; (7) Captions for figures; and (8) Figures.
4. **Titles** should be short and concise, and be followed by the authors' names. A footnote should be used to indicate where the study was carried out, and the present addresses of the authors.
5. **The *text*** should be clearly divided into separate sections, bearing such sub titles as: Introduction, Method, Materials, Experimental results, Discussion, Acknowledgments, and References. Lower case letters should always be used, except for the initial letters of first words and proper nouns. Headings, words or phrases should not be underscored unless they are to be placed in italics. Quotations from publications must invariably be placed within inverted
their source, and those of any diagrams copied, being suitably acknowledged.
6. The **abstract** should be a brief, non critical, informative digest of the important features of the paper.
7. **Tables** must be submitted separately on individual sheets of paper, numbered consecutively in roman numerals. The position of each table must be indicated in the text- Title, column headings and side headings should be in lower case letters, except for the initial letter of first words and proper nouns.
8. **Figures** in the form of graphs, diagrams and photographs must be numbered consecutively using arabic numerals, and initialled lightly in pencil on the back. The approximate location of each should be indicated in the text. Graphs and diagrams should be carefully prepared on smooth, white drawing paper, using indian ink. They should be drawn to either 3 1/2 or 6 1/2|" wide and not deeper than 9" or to sizes proportional to the above measurements. Each to be submitted on a separate sheet. Lettering, including that for the legend, should be written in pencil and located correctly, so permitting easy replacement with printers type. Legends, quoting the appropriate figure numbers, must be typed on a separate and suitably designated sheet,
9. **References.** Literature cited must be arranged alphabetically after the acknowledgements (if any). In the text, the surnames of the authors or a suitable collective title are followed by the number of the reference, placed in a superior position (e.g. Jones[5]). Each citation in the reference list should indicate the names of all
year of publication, complete title, publication, volume number, and inclusive page

   (1) BARNES, A. C. 1964. The sugarcane. Leonard Hill, London. 456p

   (2) KING, N. C. and DICK, J. 1957. A critical comparison of methods of testing for resistance to mosaic. *Proc. S. Afr. Sug. Technol Ass.* 31: (1957), 116-117.

   Abbreviations for periodicals should be as quoted in *The World List of Scientific Periodicals*, 1965.
10. Style and abbreviations not specifically mentioned here, should be in accordance with the second edition of the *Style manual for biological journals*, 1964, published by the Conference of Biological Editors, Committee on Form and Style, American Institute of Biological Sciences, Washington, D.C. Spelling should be in accordance with the *Oxford English Dictionary.*
11. The editorial committee reserves the right to reject any paper. Papers read at Congress and discussions thereon will not necessarily be published in the *Proceedings.*
12. The complete script should be sent to:

    The Technical Secretary,
    Sugar Milling Research Institute,
    University Private Bag,
    King George V Avenue,
    Durban