DETERMINATION OF DIFFERENCES BETWEEN CHIPS WITH RESPECT TO MOISTURE CONTENT, PH LEVEL, AND SIZE

by

Michael C. House

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The goal of this study is to determine possible differentiations between metro chips from total tree harvesting, sawmill chips from sawmill scraps, roundwood chips from a conventional logging operation, and turntable chips, a mix of all three. The differences studied will be in relation to their size, pH level, and moisture content. The chips studied were from the Stone Container Corporation in the city of Coshocton, Ohio.

ACKNOWLEDGEMENT

I would like to express my indebtedness and gratitude to Professor R. D. Touse, who with knowledge and patience helped me in completion of this project and my B.S. degree in natural resources. I also acknowledge E. Malesky of Stone Container Corporation for his advice and help, and Professor J. D. Kasile for his help with the statistical analysis. Thanks also to Stone Container Corporation and the employees I met there for their cooperation and patience.

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I. OVERVIEW

The objective of this project is to determine the differences between four types of chips in relation to their size, pH, and moisture content if such differences do exist. The results can then be related to the purchasing of the raw material and its usage in the production process.

For this project to be complete, each chip type should be followed through the manufacturing process and evaluated in the final product. But because of the time factor involved and the near impossibility of manufacturing the paper by chip type in a mill of this size, this was not attempted. In spite of this, it is hoped that the results of this project can be utilized by Stone Container Corporation in evaluating its purchasing and usage of the chips.

II. PROCESS

With the rising demand by environmentalists and other groups for better logging practices and total usage of a tree, many new methods of operation have resulted. One of the recent developments in this area of total tree usage is the metrochipper or total tree chipharvester. The metrochipper was first introduced in 1968 and has come on strong ever since.[1] The production of wood chips from a metrochipper increased 14% from 1971 to 1972 while roundwood decreased 10%.[2] With metrochipping increasing, it is important to find any differences between this new type of chip and the other types previously used in the production of pulp, and then determine where these differences could affect the manufacturing process.

A metrochipper is a machine about the size of a semi tractor-trailor which can take a tree up to 22 inches in diameter and chip it up into chips about the size of a quarter. The chipper chips the whole tree, including the leaves, bark, and branches (picture 1). Therefore, the logging operation is cleaner and the yield is greater. Many landowners who wouldn't sell their timber before because of the mess left after a conventional logging process will sell when a metrochipper is used. Production, according to two articles in Forest Industries, can be increased from 50% to 95% over a conventional logging operation; the amount of increase depends on the stand.[3,4]

Trucking costs are cut as a truck can haul about three times as many trees in the form of chips as opposed to pulp logs.

The chipper itself is a revolving disc with knives. They chip a log at a 45 degree angle to present a maximum of open fiber ends for the chemicals in a digester to enter through. The chips produced are of variable size (2-5% dust and 3% coarse material), but they average about ½-1 inch in length and 1/8 inch thick. Approximately 1/3 of the chips used at Stone are metrochips.

Another aspect of total utilization of a tree is the sawmill chip. Waste scraps that are produced when sawing a log, such as edgings and slabs, are run through a chipper and blown into a chip truck. These chips are then transported to the mill. The chips are cleaner as they have no branches or leaves; and they have been debarked so the bark fiber is not included. Sawmill chips also account for 1/3 of the chips used at Stone.

The remaining 1/3 of chips used at Stone are roundwood chips (picture 2). These chips are produced from a pulp log which was produced in a conventional logging process. The logs are chipped by an outside organization and transported back to the mill by truck.

The turntable chips are a mixture of the three types above. The turntable is where chips are mixed prior to entering the digester for cooking.

Almost all of the chips used at Stone are transported there by semi tractor-trailer. Each truck is weighed before entering the yard and after leaving the yard. The tonnage of chips recieved is the difference between the two weights.

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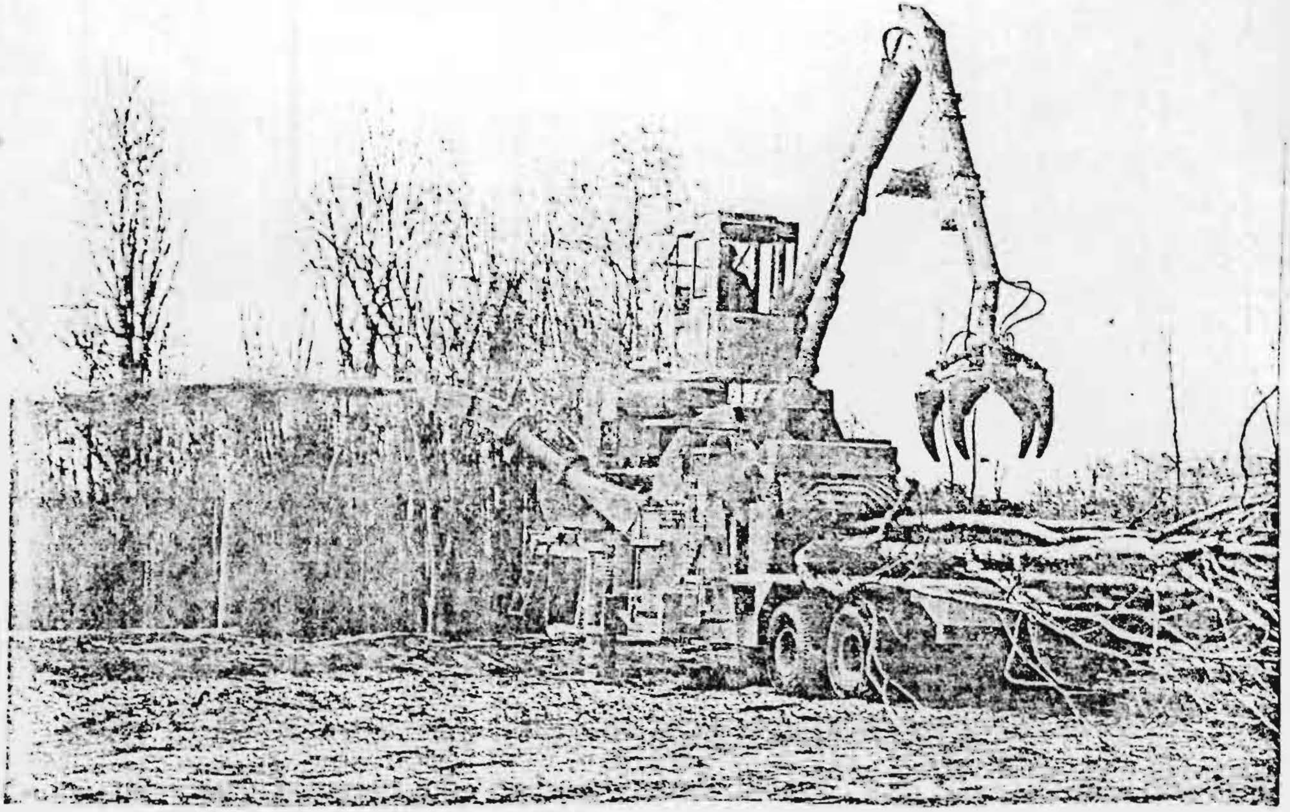
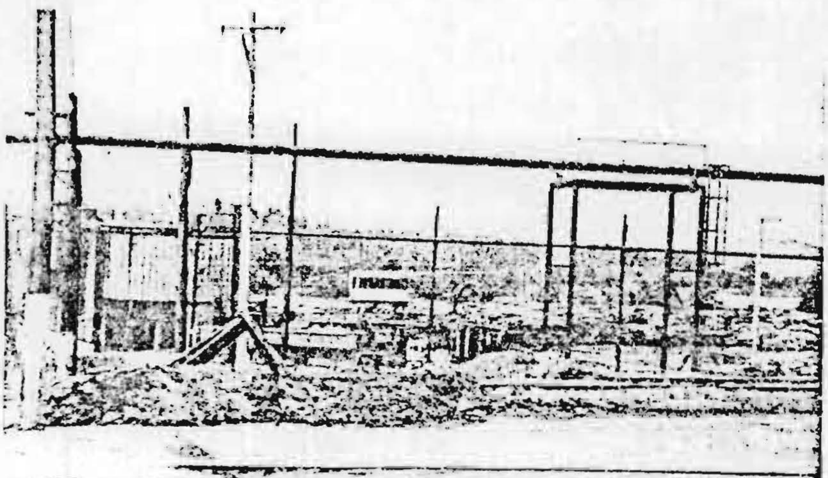


① Metrochipper



② Roundwood yard at Stone Container Corp.

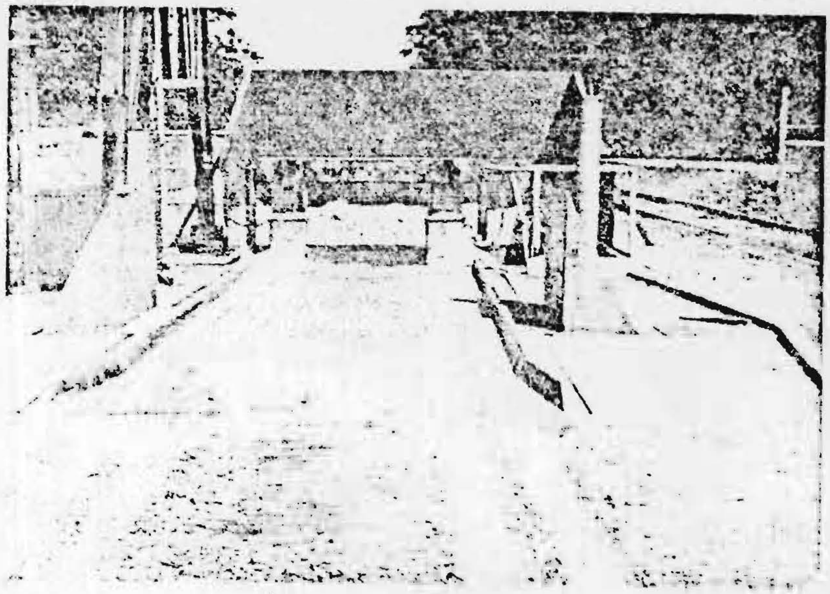
Moisture Content is important in determination of the price per ton. The higher the moisture content, the heavier the chips per unit of volume, the less chips per ton received, and therefore the higher the price per dry ton paid.

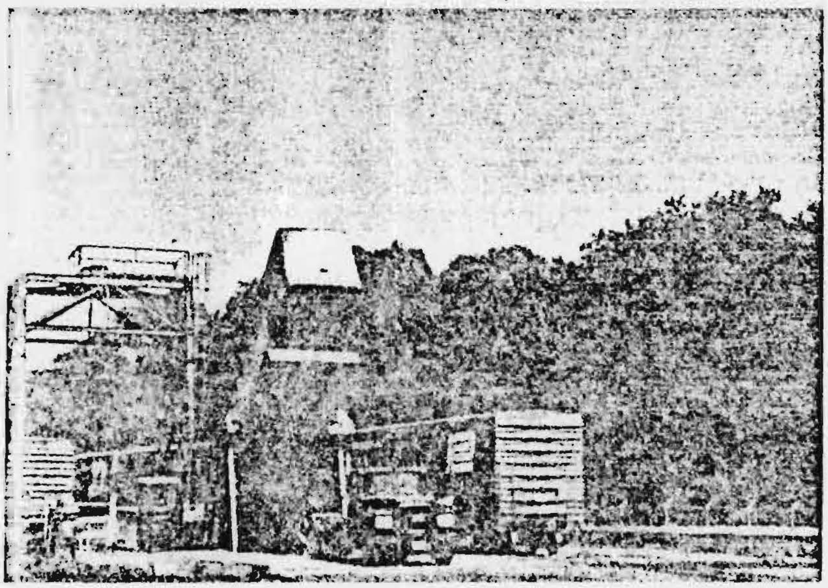
While in the yard, the trucks are raised and the chips are dumped into a hopper (pictures 3 and 4). The chips are then conveyed from the bottom of the hopper and dumped onto the chip pile for storage (see picture 5).

Storage of chips presents problems in relation to moisture content and pH level. When chips are stored in piles under wet conditions, there is more biological activity and the chips get hotter. In some samples I took off the top of the chip pile, the moisture contents as a % of the oven dry weight were 114%, 170%, 173%, and 156%. The pH of the hot, wet chips got quite low, some as low as 3.1,2.9,and 3.2. The result of a high moisture content and a low pH in relation to hot temperatures leads to an increased level of acid hydrolysis, which in turn degrades the chips. When the chips are degraded too much, they break down into the smallest units possible. As the units are cooked in a digester, they are broken down even further, and become so small as to not be usuable for paper production.

In a study done by Hajny and Springer at the Forest Products Lab in Wisconson on the effect of storing chips at high temperatures, pulp yield decreased significantly over a 3 month and a 6 month period using aspen and Douglas-fir chips.[5] In addition to the decreased pulp yield, pulp strengths were reduced 10-35% (picture 6). The results of this study show

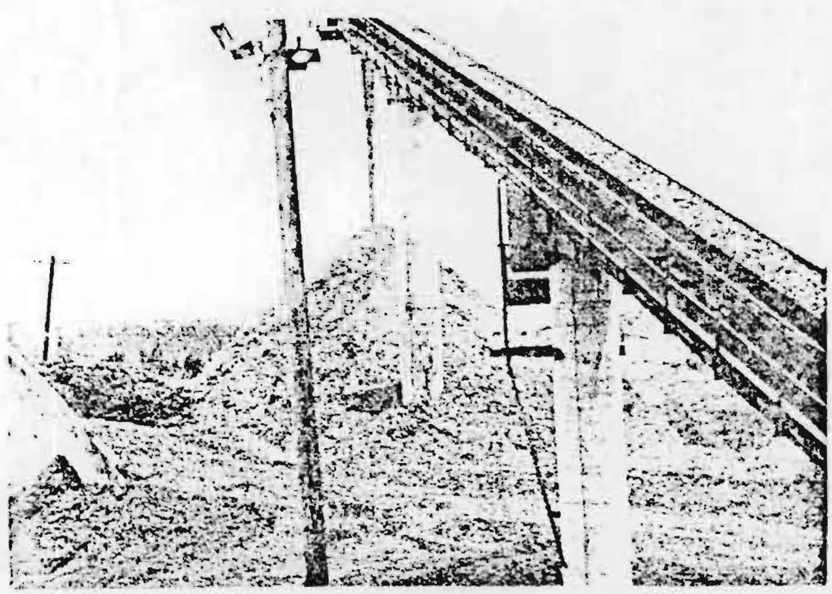
(3) Dumping Station At Stone.





(4) Truck being dumped at above station.

(5) Chips being conveyed and dumped on pile.



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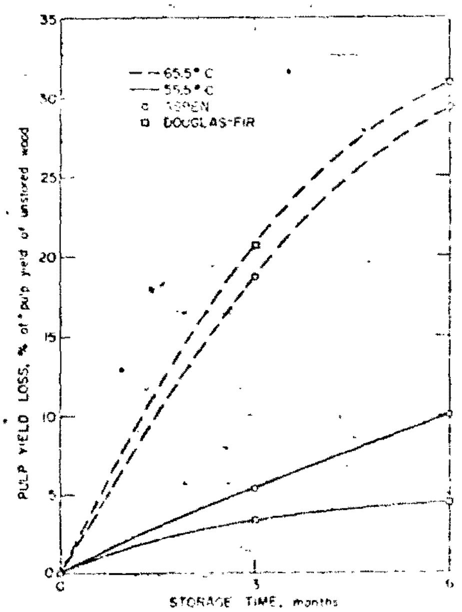


Fig. 1. Relationship of loss of pulp yield as a function of temperature to length of time in storage.

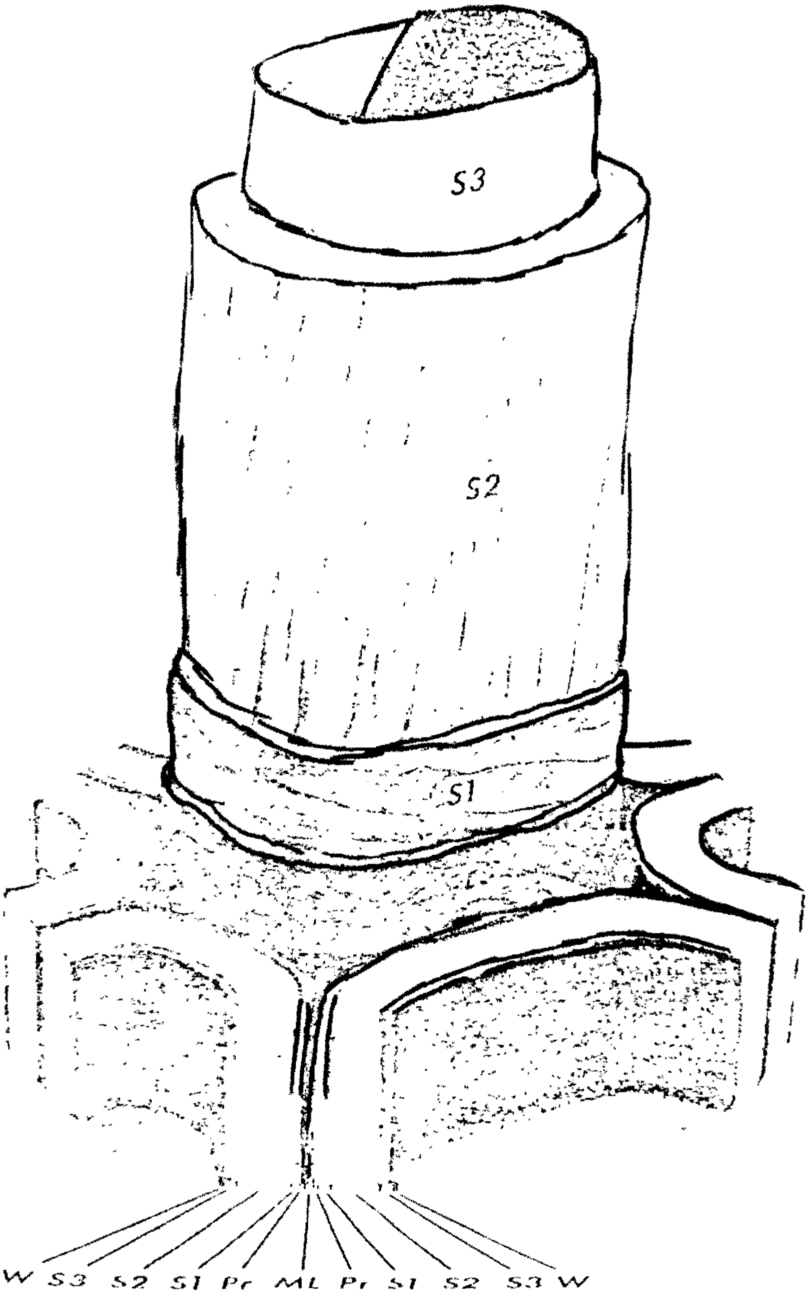
(footnote 5)

that chips should not be stored at high temperatures for more than one or two months, and there should be a move toward reducing heat levels in wood chip storage. Moisture content levels play an important part in controlling the heat level in the chip piles.

When the chips are sent into the mill, they are mixed in a turntable. This is where the turntable samples were taken. From there they enter the digester.

There are several pulping processes which can be used to break down the chips. As the major raw material is hardwood, Stone Container Corporation uses a semi-chemical sulfate process to produce pulp. In the semi-chem process, the chips are first cooked in a digester, where they are partially broken down, and then ground up in a defibrator. A digester is a cylinder, 10-17 feet in diameter and 40-70 feet in height, with a dome top and cone shaped bottom. This is where the chips are broken down chemically by cooking the chips in a sulfate liquor. The sulfate liquor at Stone contains Na_2S as well as NaOH (caustic soda). The alkali reacts with the wood and an alkali pulp results.

The size of the chip, i.e. the three dimemsional cross section, is extremely important in this cooking process. To understand this, one has to have a knowledge of the construction of the wood cell (pictures 7 and 8). The outermost layer of the wood cell, i.e. the tracheid, is the lamella. It is composed mainly of lignin and it functions to support the cell and the fibers. The next part of the cell is the secondary wall. As seen in the table in picture 8, this is mainly composed of



(7)

IG. 3-6 Model of a portion of a conifer tracheid with the walls cut away to show the ...al organization of the microfibrils in the secondary wall. The relation to adjacent tracheids, ... thickness of the true middle lamella, and the appearance of layers in cross section are ...n by the pieces of tracheids attached to the base. The warty layer is visible as a lumen ...ng.

(See Reference 2)

(8)

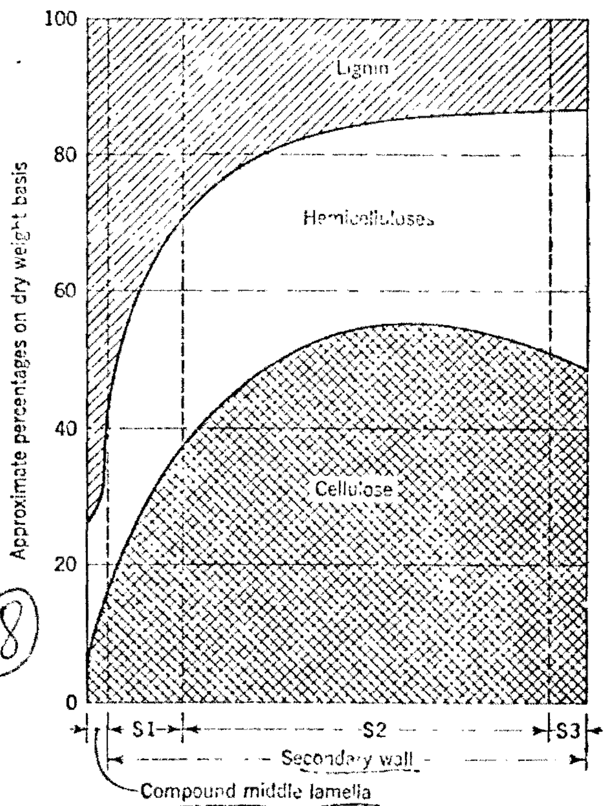


FIG. 3-10 Distribution of the principal chemical constituents within the various layers of the cell wall in conifers.

hemicellulose, also part of the support system of the fibers, and cellulose. The cell cavity, or lumen, is in the center. In the production of pulp, one removes as much lignin and hemicellulose as needed to get the wood fibers made of cellulose in the condition necessary for production of paper. In the semi-chem process, not all of the lignin and hemicellulose is removed because a high quality pulp is not needed for the type of paper made at Stone.

As a chip is cooked, the lignin and hemicellulose of the outer layers are attacked by the alkali first, and the reaction moves toward the center of the chip. In a chip 1/4 in. by 1 in., there may be 10,000 or more fibers. The liquor must travel throuh at least 15 cells to reach the innermost fibers.[6] To get an equal amount of breakdown on each chip before it is sent to the defibrator, the chips should all be of uniform size. The cooking time and other variables should be adjusted to this size. This way, the liquor will penetrate to the center of each chip simultaneously. If a chip is too large in cross section, the liquor will not be able to reach the inner fibers on the chip in time to breakdown the cell structure and release the fibers. The chip will have to be recycled and cooked again. This procedure costs money and time. In the situation of a small chip, the liquor will not only break down the chip to the degree necessary, it will continue working and could break down the fibers themselves, resulting in a loss of material. It is therefore necessary for the chips to be as uniform in cross section to as high a degree as possible.

The chips are then run through a defibrator for further breakdown through mechanical means. From there the chips have become pulp. The pulp is mixed with other chemicals used in the recipe for the paper, and then run through a Fordrinier machine for the actual production of the paper.

III. PROCEDURE

A. Sieve Analysis - Size Classifications

1. Several sieve screens were stacked with the largest holed screen being on top and successively smaller holed screens below. A dust pan was on the bottom.

2. A sample of approximately 10 pounds was weighed out on a scale.

3. The weighed sample was dumped onto the top screen.

4. The sieve was then run for five minutes using a stop watch to time the interval.

5. The chips from each screen were weighed separately and the weights were recorded.

* The size of a chip is important in the digesting process of the semi-chem pulping process.

B. Moisture Content Analysis

1. A sample of 200 grams of chips was weighed out

2. A pan of foil was constructed to contain the the chips; it was then weighed.

3. The weighed sample of chips was added to the foil pan, placed in the oven (150° C) and left there for approximately two days.

4. The sample and pan were then removed from the oven and weighed.

5. The results were then recorded.

* Chip moisture content is important in purchasing the raw material when purchased by weight; and moisture content is important in pile storage.

C. pH Level Analysis

1. A sample of 200 grams of chips was weighed out and put into a buchner funnel.

2. The buchner funnel was inserted into a suction flask and was hooked up to a vacuum pump.

3. One liter of boiling water was poured over the chips and the combination was allowed to sit for approximately 15 seconds.

4. The resulting liquid was suctioned off.

5. The liquid was mixed evenly and read with a pH meter.

6. The pH was recorded.

* It should be pointed out here that the pH results are not absolute, but they are relative to each other and are adequate in determining any differences in the chip types. The pH is important in chip storage in relation to acid hydrolysis on the pile.

IV. ANALYSIS

A. Size - Chi-squared Test for Independence

The purpose of this test is to determine if all the samples of each type of chip come from the same uniform population. It was assumed that the metro, roundwood, and sawmill samples (75) were selected at random from all possible samples entering the mill, and the turntable samples (23) were selected at random from all possible samples. For the purposes of the test, the size classes of the chips were broken down into four categories: Large (L), Big (B), Medium (M), and Small (S). Each type of chip - Metro (M), Sawmill (S), Roundwood (R), and Turntable (T) - was then put into tabular form as shown in Appendix I. The degrees of freedom and the significance level were combined to find a critical number. The values were then run through the following equation:

$$\chi^2 = \sum \frac{(\text{ observed - expected})}{\text{expected}}$$

For the sample to be uniform, the χ^2 number resulting must be less than the critical number. In all four cases, the χ^2 number was greater than the critical number. Therefore, the results of this experiment indicate that there is no uniformity between the samples, i.e. they are too diversified to be from the same population. Since the samples are highly variable, further testing for differences was not possible.

B. Moisture Content - One-Way Analysis of Variance

For the purpose of this test, moisture content is expressed as a percentage of the oven dry weight of the chips.

$$M.C. = \frac{\text{wt. of chips wet} - \text{wt. of chips dry}}{\text{wt. of chips dry}}$$

This part of the analysis is to determine if there are any differences in the chip types in relation to moisture content. It was assumed that the metro, sawmill, and roundwood samples (77) were selected at random from all possible samples entering the mill, and the turntable samples (23) were selected at random from all possible samples. First, two hypothesis were formed:

H_o: average metro = average sawmill = average roundwood = average turntable

H_i: at least one of these is different

Again a critical number was found through degrees of freedom and a 5% level of significance. When the analysis was run and the result compared with the critical number, the null hypothesis was accepted. These results indicate that there is no significant difference in moisture content between the four types of chips at the 5% level of significance (see Appendix II).

C. pH level - One-way Analysis of Variance

pH is defined as the negative logarithm of the hydronium ion concentration.

$$pH = -\log (H_3O^+)$$

This is a measure of acidity and ranges on a scale from 0-14. 7 is neutral; below 7 is acidic; above 7 is basic.

The One-way Analysis of Variance was again used. The assumptions of the moisture content samples also hold for this test. The hypothesis (H_o and H_i) were set up as in the moisture content analysis, a critical number was found as before, and the test was run. The comparison of the result of the analysis with the critical number indicated that the null hypothesis was accepted, i.e. the results indicated that there is no significant difference in pH at the 5% level of significance between the four types of chips. But when the test was run at the 10% level of significance, a difference was found to exist.

Scheffe's Test - All Possible Combinations - was used to determine which types were different. The results of this test indicate that the pH of the sawmill chips is significantly different from the pH of the roundwood chips at the 10% level of significance. These types were the only two which showed any significant difference at the 10% level (see Appendix III).

V. CONCLUSION

With the increase in total usage of a tree and more efficient harvesting methods, metro chips are becoming increasingly important. A company using this new type of chips has to watch the manufacturing variables affected by the chips.

With respect to size, the samples were too diversified to draw any conclusions.

With respect to moisture content and pH level, the tests indicate that there is no difference between the four chip types at the 5% level of significance. The difference in pH between the sawmill and roundwood chips at the 10% level, in my opinion, is not enough of a variable to worry about in the production process.

Since the metro chips show no significant difference from the roundwood and sawmill chips, it could be postulated that a combination of the three types should show no difference, and this conclusion was supported by the test results. Thus, the variables in the purchasing and manufacturing process affected by moisture content and pH should not have to be adjusted due to an increased usage of metro chips in the raw material "recipe" for pulp production.

VI. FOOTNOTES

[1]Morbarck Industries, Inc., New Ideas in Harvesting and Preserving our Wood Resources, (Winn, Michigan, 1972) p.4.

[2]James T. Bones and David R. Dickson, Pulpwood Production in the Northeast 1972, (Upper Darby, Pennsylvania, USDA Forest Service Resource Bulletin NE-31, 1973) p.4.

[3]Richard W. Bryan, "Pulpwood Producer Increases Output in Switchover to Chips and Sawlogs," Forest Industries, Vol. 101 - No. 13, (December, 1974) p.38.

[4]Richard W. Bryan, "Michigan's 'Mr. Chips' Geared to Small Trees, Small Tracts," Forest Industries, Vol. 102-No. 4, (April, 1975) p.46.

[5]W. C. Feist, G. J. Hajny, and E. L. Springer, "Effect of Storing Green Wood Chips at Elevated Temperatures," Tappi, Vol. 56 - No. 8, (August, 1973) p.91-95.

[6]William J. Nolan, "Variables Affecting Yield, Quality," Chem, (May, 1972) p.47.

VII. REFERENCES

1. Panshin, Harrar, Bethel, and Baker, Forest Products, Their Sources, Production, and Utilization, McGraw Hill Book Company, New York, N.Y., 1962, p.321-392.

2. Panshin, De Zeeuw, Textbook of Wood Technology, Vol. 1, McGraw Hill Book Company, New York, N.Y., 1970, p.67-110.

VIII. APPENDIX

Appendix I

Chi-Square (χ^2) Test for goodness of fit

1. Assumption: All samples were chosen at random.

2. Each chip type is put into tabular form by sample number and size class:

Sample no.	Large (L)	Big (B)	Medium (M)	Small (S)	Total
1	observation 1_L	1_B	1_m	1_s	100%
2	2_L	2_B	2_m	2_s	⋮
⋮	⋮	⋮	⋮	⋮	⋮
n-1	$(N-1)_L$	$(N-1)_B$	$(N-1)_m$	$(N-1)_s$	⋮
n	N_L	N_B	N_m	N_s	⋮
Averages	L_{ev} ↳ expected value	B_{ev}	M_{ev}	S_{ev}	100%

degrees of freedom = (Rows - 1)(Columns - 1) = (3)(N - 1)
Level of significance = 5%
N = Number of samples in chip type being tested
i = samples individually
j = category, i.e. chip types sizes (L, B, M, S)

3. Each chip type is run through the following equation:

$$\chi^2 = \sum_{i=1}^{N} \sum_{j=1}^{4} \left(\frac{(\text{observed value} - \text{expected value})^2}{\text{expected value}} \right)$$

$$\chi^2 = \frac{(1_L - L_{ev})^2}{L_{ev}} + \frac{(1_B - B_{ev})^2}{B_{ev}} + \frac{(1_m - M_{ev})^2}{M_{ev}} + \frac{(1_s - S_{ev})^2}{S_{ev}} +$$

$$\frac{(2_L - L_{ev})}{L_{ev}} + \circ\circ\circ + \frac{(N_m - M_{ev})^2}{M_{ev}} + \frac{(N_s - S_{ev})^2}{S_{ev}}$$

4. X^2 is then compared with the critical number for 5% level of significance and X degrees of freedom. If X^2 < Critical number, then the population is uniform. If X^2 > Critical Number, the population is not uniform and no further testing can be performed.

5. In all four cases, the X^2 number was greater than the critical number; therefore, no further statistical analysis was performed as the samples were to variable.

Appendix II

One-way Analysis of Variance

1. Assumption: All samples were chosen at random

Assumption: A Linear Additive Model:

$$T_{ij} = \mu + \tau_i + E_{ij} \Rightarrow \mathcal{E} = T_{ij} - (\mu + \tau_i)$$

Each individual sample is a function of the total mean (μ) plus a treatment effect (τ_i) plus a sampling error (E_{ij}).

$$\mathcal{E} \sim N, ID, (0, \sigma^2)$$

The Sampling error is a function of Normal Distribution (N), Independent mean and variance constants

2. Hypothesis stated:

H_0: Average Metro = Average Sawmill = Average Roundwood = Average Turntable
i.e. $\tau_i = 0$

H_1: At least one of these is different
i.e. $\tau_i \neq 0$

3.

Source	degree of freedom	Sum of Squares	Mean Square
Type of Chip	$4-1=3$	$\left\{\sum_{i=1}^{4} \frac{T_i^2}{j} - \frac{GT^2}{Total\#}\right\}$	$\frac{\text{Sum of Squares}}{\text{degrees of freedom}} = \tilde{\surd}$
+	+	+	
Sampling error	$100-4=96$	{by Subtraction}	$\frac{\text{Sum of Squares}}{\text{degree of freedom}} = \mathcal{E}$
Total	99	$\left\{\sum_{ij} Y_{ij}^2 - \frac{GT^2}{Total\#}\right\}$	

Y_{ij} = Sum of all observations (T_{ij})

GT = Grand Total

T_i : total of i^{th} type, i.e. $i=1$: MetroTotal

j = number of observations in each total

T_{ij} = individual observation

$$\hat{F} = \frac{\tilde{\surd}}{\mathcal{E}}$$

4. Reject H_0 if $\hat{F}$ > Critical Number

for 5%, Critical Number = 2.68

for 10%, Critical Number = 2.15

5. Moisture Content One-Way Analysis of Variance

	Metro	Saw	Round	Turn
i	1	2	3	4
j	32	28	17	23
Total	2109	1794.7	1028.5	1528.6
Average	65.91	64.10	60.5	66.46

GT = 6460.8
Total$_j$ = 100
Total Ave. = 64.61

TYPES Sum of Squares $= \sum_{i=1}^{4} \frac{T_i^2}{j} - \frac{GT^2}{Total\#}$

$$= \left[\frac{2109^2}{32} + \frac{1794.7^2}{28} + \frac{1028.5^2}{17} + \frac{1528.6^2}{23} \right] = 427.1$$

Mean Square $= \frac{427.1}{3} = 142.4 = \tilde{V}$

Total Sum of Squares $= \sum_{ij} Y_{ij}^2 - \frac{GT^2}{Total\#}$

$= 426,027.7 - 417,419.4 = 8608.3$

Sampling Error

Sum of Squares = (Sum of Squares of Total) - (Sum of Squares of Types)

$= 8608.3 - 427.1 = 8181.2$

Mean Square $= \mathcal{E} = \frac{8181.2}{96} = 85.2$

$\hat{F} = \frac{\tilde{V}}{\mathcal{E}} = \frac{142.4}{85.2} = 1.6714$

$\hat{F} = 1.6714 < 2.68 \Rightarrow$ No significant Difference

at the 5% Significance Level

6. pH One-Way Analysis of Variance

	Metro	Saw	Round	Turn
i	1	2	3	4
j	32	28	17	23
Total	170.5	121.7	146.85	99.65
Average	5.33	5.29	5.24	5.86

$GT = 538.7$

$Total_i = 100$

$Total_{Avis} = 5.39$

TYPES Sum of Squares $= \sum_{i=1}^{4} \frac{T_{ij}^2}{j} - \frac{GT^2}{Total\#}$

$$= \left[\frac{170.5^2}{32} + \frac{121.7^2}{23} + \frac{146.85^2}{28} + \frac{99.65^2}{17} \right] - \frac{538.7^2}{100} = 4.72$$

Mean Square $= \tilde{\nabla} = \frac{4.72}{3} = 1.573$

TOTAL Sum of Squares $= \sum_{ij} Y_{ij}^2 - \frac{GT^2}{Total\#}$

$$= 2965.41 - 2901.98 = 63.43$$

SAMPLING ERROR Sum of Squares $= 63.43 - 4.72 = 58.71$

Mean Square $= \mathcal{E} = \frac{58.71}{96} = .612$

$$\hat{F} = \frac{\tilde{\nabla}}{\mathcal{E}} = \frac{1.573}{.612} = 2.57$$

$\hat{F} = 2.57 < 2.68 \Rightarrow$ No significant difference at 5% level of significance

But $\hat{F} > 2.15 \Rightarrow$ Significant difference at 10% level of significance

Appendix III

Scheffe's Test - All Possible Combinations

This test is used to tell which type of chips are different from another type where the sample size of the types is variable. From the one-way analysis of variance, $\mathcal{E}$ was determined to be .612. The critical number was 2.15. There are two steps to the test.

① Determination of Θ given $\mathcal{E} = .612$
Critical Number = 2.15
2 types of chips with sizes X and Y

$$\Theta = \sqrt{3(2.15)(\mathcal{E})\left(\frac{1}{X} + \frac{1}{Y}\right)}$$

② The chip types are determined to be significantly different at the 10% level of significance if

$$\Theta < \left| \text{Average type X} - \text{Average type Y} \right|$$

Sawmill vs. Roondwood

$$\Theta = \sqrt{3(2.15)(.612)\left(\tfrac{1}{17}+\tfrac{1}{28}\right)}$$

$$= \sqrt{3.9474(.05882+.03571)}$$

$$= \sqrt{.3732}$$

$$= .611$$

$$\Theta = .611 < |5.86-5.29| = .62$$

$\Rightarrow$ Roondwood is significantly different from Turntable at the 10% Level of sighificance

* Theseare the only two types which are significantly different.

IX. RAW DATA

SIZE

Type	Sample No.	Sample Size (lbs.)	% Large	% Big	% Medium	% Small	%
M	3	9.04	15.7	24.9	33.5	24.9	1
S	4	9.40	5.0	11.4	30.2	46.1	7.3
M	5	10.10	9.5	14.6	34.4	34.4	7.1
R	6	9.78	56.4	21.3	17.3	4.8	.2
T	7	9.89	17.1	20.6	32.5	28.2	1.6
M	8	10.07	18.7	16.3	27.2	33.9	3.9
S	9	9.93	11.0	28.2	39.4	20.1	1.3
M	10	9.85	21.6	24.3	31.1	21.8	1.2
R	11	9.84	52.7	24.7	15.1	6.8	.7
T	12	9.94	9.2	17.5	34.6	35.8	2.9
S	13	9.78	8.7	21.9	37.3	31.7	.4
T	14	9.72	8.1	15.0	30.2	43.9	2.8
T	15	9.61	8.8	13.8	31.2	43.4	2.8
T	16	9.64	7.3	14.3	30.9	44.8	2.7
M	17	8.80	14.1	19.7	26.6	34.7	4.9
S	18	9.78	9.9	13.6	33.6	37.1	5.8
S	19	8.98	.7	5.3	25.6	67.6	.8
S	20	9.88	7.7	14.5	31.1	40.8	5.9
R	21	9.62	25.9	21.8	29.8	21.0	1.5
T	22	9.46	9.0	15.9	33.1	39.4	2.1
R	23	9.94	46.1	23.1	21.0	8.8	1
M	24	9.87	15.5	22.4	30.5	29.0	2.6
M	25	9.97	12.7	27.7	33.3	24.1	2.2
S	26	9.08	16.6	21.9	32.3	23.1	6.1
S	27	9.82	2.7	12.7	45.4	39.0	.2
M	28	9.81	29.8	23.4	24.8	20.3	1.7
M	29	10.03	23.3	23.6	28.2	23.4	1.5
S	30	9.83	15.4	22.0	31.3	29.1	2.2
S	31	8.18	23.8	36.1	28.4	11.1	.6
T	32	9.85	19.3	21.1	32.9	25.1	1.6
M	33	9.86	37.8	22.7	21.7	16.3	1.5
M	34	10.07	30.8	22.3	23.1	21.3	2.5
S	35	7.66	9.5	13.6	27.0	37.6	12.3
S	36	10.03	1.8	7.4	40.4	44.9	.5

SIZE

Type	Sample No	Sample Size (lbs)	% Large	% Big	% Medium	% Small	%
T	37	9.61	12.4	17.0	31.3	37.0	1.8
M	38	9.58	32.3	29.0	13.7	14.5	.5
M	39	9.79	18.9	27.2	27.4	24.7	1.8
M	40	9.69	21.3	28.5	30.1	19.0	1.1
S	41	10.04	45.4	23.3	20.9	10.0	.4
R	42	10.08	51.8	23.4	17.0	6.6	1.2
M	43	9.96	65.9	19.0	11.0	4.0	.1
S	44	8.51	8.7	18.4	42.1	27.7	2.6
R	45	9.75	53.3	19.1	18.1	9.3	.2
S	46	10.02	4.3	8.7	32.4	52.6	2.0
S	47	9.73	14.5	21.2	37.4	25.7	.7
R	48	8.48	55.9	18.3	17.2	8.2	.4
S	49	9.58	5.5	15.0	41.5	36.6	1.4
T	50	9.88	15.8	22.6	33.5	26.1	2.0
T	51	9.74	18.4	22.2	34.2	23.8	1.4
M	52	9.88	21.6	24.1	27.2	25.2	1.9
M	53	9.91	8.8	24.2	31.9	32.1	3.0
M	54	10.11	20.1	26.6	29.2	22.5	1.6
M	55	9.94	30.7	33.5	19.0	15.6	1.2
S	56	6.98	34.4	28.2	27.4	9.7	.3
R	57	9.60	40.5	24.3	25.6	9.3	.3
T	58	9.56	14.4	21.3	36.0	26.6	1.7
S	59	9.74	24.5	30.7	29.6	14.8	.4
T	60	9.65	19.5	21.9	32.7	24.4	1.5
M	61	9.70	21.1	24.7	31.2	21.1	1.9
R	62	9.80	36.6	23.2	24.5	14.1	1.6
M	63	9.82	33.7	19.0	24.2	22.0	.2
T	64	9.63	13.8	17.8	32.7	34.7	1.0
R	65	8.97	8.1	14.4	32.8	42.4	2.3
R	66	9.70	38.4	23.0	22.2	15.5	.9
M	67	10.00	20.8	22.1	27.5	28.5	1.1
T	68	10.02	10.5	16.6	36.2	36.1	.6
M	69	9.61	4.9	25.5	30.8	36.6	2.2
R	70	9.46	15.0	17.3	28.1	36.3	3.3
M	71	9.16	23.7	28.8	26.1	20.6	.8

SIZE

Type	Sample No.	Sample Size (lbs.)	% Large	% Big	% Medium	% Small	% Small
T	72	10.03	22.3	23.0	31.7	21.9	1.1
T	73	10.14	19.8	23.6	34.0	21.4	.8
M	74	10.63	7.3	23.4	33.7	33.1	2.5
m	75	9.78	19.8	15.1	31.8	31.4	1.9
T	76	10.29	26.7	23.0	30.3	18.9	1.1
T	77	10.26	24.0	21.8	28.7	19.0	1.5
S	78	9.47	2.6	5.5	24.3	58.3	9.3
S	79	10.10	5.9	13.8	35.0	44.8	.5
T	80	10.13	8.5	14.6	31.3	42.8	2.8
S	81	10.12	15.9	17.7	30.8	31.2	4.4
R	82	8.13	43.3	22.1	19.9	13.3	1.4
m	83	10.15	17.6	24.6	29.3	25.6	2.9
S	84	10.08	7.5	16.4	36.6	39.4	.1
R	85	9.62	37.3	23.8	23.2	14.1	1.6
S	86	10.14	4.3	13.0	34.3	45.0	3.4
m	87	10.18	26.3	27.8	26.3	18.7	.9
S	88	9.78	12.3	17.9	32.0	37.3	.5
T	89	10.09	16.7	21.6	30.0	30.6	1.1
T	90	9.07	15.8	12.4	35.5	34.8	1.5
S	91	9.03	4.4	7.0	27.9	48.4	12.3
R	92	9.48	42.7	23.8	22.6	10.1	.8
R	93	10.05	48.4	19.9	19.8	11.0	.9
M	94	10.19	12.4	22.4	39.5	23.8	1.9
S	95	10.07	6.9	12.9	34.9	42.5	2.8
M	96	10.18	26.7	23.5	24.5	23.0	2.3
T	97	10.31	16.9	19.8	32.7	29.1	1.5
M	98	8.69	40.6	20.7	19.3	17.1	2.3
T	99	10.00	14.6	20.3	31.9	31.2	2.0
R	100	9.80	57.4	20.4	15.1	6.8	.3

pH Levels

Sample No.	Type	pH
1	M	4.4
2	S	4.55
3	M	4.2
4	S	5.55
5	M	4.25
6	R	5.6
7	T	5.1
8	M	4.45
9	S	5.45
10	M	5.35
11	R	4.85
12	T	4.7
13	S	3.6
14	T	5.05
15	T	5.15
16	T	5.4
17	M	5.35
18	S	4.2
19	S	3.45
20	S	5.75
21	R	4.45
22	T	4.85
23	R	5.25
24	M	5.65
25	M	3.8
26	S	5.1
27	S	5.7
28	M	4.7
29	M	5.45
30	S	5.2
31	S	5.35
32	T	4.55
33	M	5.35
34	M	4.0
35	S	5.2
36	S	3.8
37	T	5.0
38	M	5.15
39	M	4.75
40	M	5.7
41	S	4.8
42	R	6.25
43	M	6.0
44	S	6.05
45	R	6.05
46	S	4.55
47	S	5.7
48	R	5.75
49	S	6.75
50	T	5.2

Sample No.	Type	pH
51	T	5.3
52	M	6.15
53	M	4.85
54	M	4.75
55	M	6.65
56	S	6.9
57	R	7.45
58	T	6.25
59	S	7.4
60	T	5.83
61	M	5.45
62	R	4.85
63	M	5.7
64	T	5.4
65	R	6.25
66	R	6.5
67	M	5.85
68	T	5.7
69	M	5.6
70	R	5.1
71	M	6.65
72	T	5.7
73	T	5.6
74	M	3.4
75	M	5.65
76	T	4.85
77	T	5.55
78	S	4.0
79	S	5.05
80	T	4.7
81	S	5.75
82	R	6.1
83	M	5.5
84	S	4.3
85	R	5.45
86	S	5.15
87	M	7.1
88	S	5.25
89	T	5.45
90	T	5.75
91	S	6.8
92	R	5.5
93	R	6.0
94	M	6.65
95	S	5.05
96	M	5.45
97	T	5.6
98	M	5.6
99	T	5.55
100	R	7.25

MOISTURE CONTENT

Sample No.	Type	Wt. Chips Wet (gm)	Wt. Chips Dry (gm)	Wt. Water (gm)	Moisture Content (% ODW)
1	M	200gm.	124 gm	76 gm	61.3
2	S	200 gm	127.9	72.1	56.4
3	M	200	128.7	71.3	55.4
4	S	200	104	96	92.3
5	M	"	132.7	67.3	50.7
6	R	"	119.6	80.4	67.2
7	T	"	123.3	76.7	62.2
8	M	"	119.1	80.9	67.9
9	S	"	129.6	70.4	54.3
10	M	"	112	88	78.6
11	R	"	138.2	61.8	44.7
12	T	"	120.31	79.7	66.3
13	S	"	132.1	67.9	51.4
14	T	"	116.8	83.2	71.2
15	T	"	115.1	84.9	73.8
16	T	"	113.1	86.9	76.8
17	M	"	128.5	71.5	55.6
18	S	"	118.5	81.5	68.8
19	S	"	131.9	68.1	51.6
20	S	"	124.7	75.3	60.4
21	R	"	130.4	69.6	53.4
22	T	"	131.2	68.8	52.4
23	R	"	109.7	90.3	82.3
24	M	"	123.3	76.7	62.2
25	M	"	120	80	66.7
26	S	"	131.3	68.7	52.3
27	S	"	116.3	83.7	72.9
28	M	"	132.1	67.9	51.4
29	M	"	126.9	73.1	57.6
30	S	"	116.9	83.1	71.1
31	S	"	146.2	53.8	36.8
32	T	"	123.2	76.8	62.3
33	M	"	123.8	76.2	61.6
34	M	"	116.9	83.1	71.1

MOISTURE CONTENT

Sample No.	Type	Wt Chips Wet (gm)	Wt Chips Dry (gm)	Wt Water (gm)	Moisture Content (% ODW)
35	S	200	144.1	55.9	38.8
36	S	200	117	70.9	70.9
37	T	"	129.6	70.4	54.3
38	M	"	120.6	79.4	65.8
39	M	"	118.9	81.1	64.2
40	M	"	111.4	88.6	73.9
41	S	"	128.9	71.1	52.3
42	R	"	140.2	59.8	42.7
43	M	"	136.9	63.1	46.1
44	S	"	115.7	84.3	72.9
45	R	"	119.2	80.8	67.8
46	S	"	126.5	73.5	58.1
47	S	"	122.2	77.8	63.7
48	R	"	127.8	72.2	56.4
49	S	"	116.2	83.8	72.1
50	T	"	121.6	78.4	64.5
51	T	"	120.6	79.4	65.8
52	M	"	117.9	82.1	69.6
53	M	"	117.1	82.9	70.8
54	M	"	120.1	79.9	66.5
55	M	"	140.4	59.6	42.5
56	S	"	114.4	85.6	74.8
57	R	"	101.5	98.5	97.0
58	T	"	114.1	85.9	75.3
59	S	"	132.8	67.2	50.6
60	T	"	120	80.0	66.7
61	M	"	113.5	86.5	76.2
62	R	"	122.1	77.9	63.8
63	M	"	127.8	72.2	56.5
64	T	"	117.3	82.7	70.5
65	R	"	129	71.0	55.0
66	R	"	134.2	65.8	49.0
67	M	"	102	98.0	96.1

MOISTURE CONTENT

Sample No	Type	Wt. Chips Wet (gm)	Wt. Chips Dry (gm)	Wt. Water (gm)	Moisture Content (% ODW)
68	T	200	121.4	78.6	64.7
69	M	"	124.1	75.9	61.2
70	R	"	131.9	68.1	51.6
71	M	"	106.7	93.3	87.4
72	T	"	122.8	77.2	62.9
73	T	"	118.8	81.2	68.4
74	M	"	123.2	76.8	62.3
75	M	"	121.6	77.8	64.0
76	T	"	116.2	83.5	72.1
77	T	"	118.1	81.9	69.3
78	S	"	127.2	72.8	57.2
79	S	"	120.5	79.5	66
80	T	"	119	81.0	68.1
81	S	"	124.1	75.9	61.2
82	R	"	131.7	68.3	51.9
83	M	"	118.5	81.5	68.8
84	S	"	119.6	80.4	67.2
85	R	"	118.1	81.9	69.3
86	S	"	119.6	80.4	67.2
87	M	"	113.8	86.2	75.7
88	S	"	118.3	81.7	69.1
89	T	"	124.3	75.7	60.9
90	T	"	121.8	78.2	64.2
91	S	"	114.7	85.3	74.4
92	R	"	119.5	80.5	67.4
93	R	"	132.2	67.8	51.3
94	M	"	99.1	100.9	101.8
95	S	"	110.6	89.4	80.8
96	M	"	125.3	74.7	59.6
97	T	"	118	82.0	69.5
98	M	"	132.6	67.4	50.8
99	T	"	120.2	79.8	66.4
100	R	"	127.2	72.8	57.2