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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

COLLECTION AND ANALYSIS OF DATA ON THE LIFE-EXPECTANCY OF ORGANIC PLANT COMPONENTS

by

S. CAPOBIANCHI, J.P. ROUGEAU and G. VOLTA

1966

ORGEL Program

Joint Nuclear Research Center
Ispra Establishment - Italy

Scientific Data Processing Center - CETIS
and
Engineering Department
Technology

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SUMMARY

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1. INTRODUCTION (°)

The choice of components for a new plant and the evaluation of their reliability can be based on laboratory test data or on field data obtained from operating experience with such plants.

The number of such data must be large enough to give a statistically well-founded life-expectancy and reliability evaluation.

A restriction is imposed by the cost of laboratory tests, so that in order to plan accurate and significant laboratory tests it is necessary to have as much information as possible on the experience acquired with the component examined.

The total number of data available on organic plant components is limited.
The data relating to the operating and environmental conditions are also frequently of doubtful significance.

We have therefore considered it worth-while to develop a scheme for recording and analysing comparable data originating from all the organic plants operated by EURATOM and possibly also outside EURATOM in the atomic and chemical field.
The scheme is suited for automatic data-processing. It has been studied for organic plant components, but its application can be extended with some code modifications to any type of component. We have chosen an automatic processing possibility, taking into account the great number of organic installations already operated by EURATOM for different

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purposes.
Examples of systematic field data collection and analysis can be found in the literature dealing with electronic components (1). Some statistical surveys ón the behaviour of mechanical components in nuclear reactor plants are also given, but they are limited to faults analysis. No statistical correlation is given between component life and operating conditions (2, 3).

The system adopted by us is operated in three stages.

The first stage, all plants, loops and components are recorded as " stock data".

The second stage consists in collecting periodical information on operating conditions and stock variations during the period.

In the third stage, periodical statistical analyses are effected.
This paper will set out by giving an outline of the system of data collecting and analysing with their significance and then go on to provide an explanation of the manner in which the automatic processing can becarried out.

2. DATA SYSTEM

2.1. General Remarks

Each organic plant considered is identified by a code. The code is fixed by the data-processing.
The operating staff should fill out for each plant an

"inventory form" in which the plant is subdivided into "loops" and the loop into "components".
The loop is considered as a basic unit from an operational and safety stand point.
The main design and operational conditions of the loop are identified by a "class code" which gives information about design pressure, temperature, flow rate, operational objectives and quality.

All the loop components are considered normally to operate at the same operating conditions as those given for the loop. The stand-by components at rest are identified by an appropriate code.

The nature and type of the components are identified by a group of codes representing the most important characteristics.
An example of this codification is given in fig.1 for a pump. The position of all components in the loop will be identified by a "position code". The position corresponds to a specific fonction.

2.2. Inventory data

Periodical information will be sent to the data-processing center for bringing the data stock up-to-date.
An inventory form will be filled out for each new loop.
All the identification codes (nature and type) and the position in the loop will be given for each new component.
Lastly the dead or eliminated components will be indicated.
A "succession code" will give the number of replacements of the same type of component occupying the same position.

It should be pointed out that in the first inventory data stock the successive code for all the components must be 01.

2.3. Loop operating data

The operating staff must give four typical operating conditions for each loop.
A limited number of operating conditions must be assumed to simplify the data-processing.
In any case, the number of operating conditions can be increased without changing the philosophy underlying the system. The number of start-ups, the total operating time during the period, the number of faults (type 1) that have required immediate unscheduled corrective action or shutdown and the number of faults (type 2) involving abnormal loop operation will be indicated for each condition.

2.4. Component operating data

Data will be given only on the components requiring notice. The components for which no information is given are presumed to operate at the same time and in the same conditions as the loop. The information relater to particular maintenance operations, faults, operating time (if it is different from that of the loop) and life conditions.

The faults are classified in two types:

- faults that are caused by intrinsic flaws in the components;

- faults due to damage caused by the failure of other components, human errors or other external factors.

If the component is dead or stopped during the period its partial operating time is given.

When a component is replaced temporarily for maintenance purposes or any other reason during operation loop, no information is given about the replacement component unless a stand-by position code is provided for.

All the operating information is given for the actual operating conditions.

2.5. Data analysis

Among the statistical data that can be sorted by automatic processing, three groups of information have been chosen, one dealing with the loops, the others bearing on the nature and type of component.

A fourth information group, very helpful indeed for a general survey of the field considered, is given by the inventory stock.
The number of faults and operating hours for each typical condition, and the number of start-ups over the entire lifetime from the beginning of operation are given for each loop.
The faults, operating hours, both partial and total, will be listed for each component of a certain type and nature from the beginning of its life-time.
These faults and times will be added up and the number of

components given to which this statistic is ascribed. This total will be computed with respect only to the nature of the component may be with reference to the first type-code (which gives more specific information). The decision to go deeper into this analysis will depend on the number of information items available.

At least a life-expectancy curve for certain natures, or, natures and types of component, should be sorted by means of a statistical analysis of the dead components.

We would point out that a knowledge of the form assumed by the curve of the number of failures versus time for a component allows in the one hand an exact definition of its reliability and on the other hand makes it possible to plan laboratory tests correctly should it prove necessary to go further.

3. AUTOMATIC DATA PROCESSING

3.1. General description of the system

The automated procedure for data processing can be divided logically into two distinct phases:

- phase of data sorting and elaboration;

- phase of data input and results output.

Taking into account the available computers at the Scientific Data Processing Centre, Ispra, it is reasonable to arrange for the first phase programme to be run on the IBM 7090,

whereas the second will be programmed for the IBM 1401.
The most ticklish problem that has been encountered in the procedure study has certainly been connected with the accurate organisation of an easy and precise system for input data collection.
It is indeed evident that the calculating potential and the enormous capacity for the storage of data and results possessed by a computer would be wasted if the information fed into the machine were systematically inexact, incomplete, and inadeguate for the necessary automatic controls.

The data that enter the machine are used, as described in a former section, to modify the stock of information on the inventory stored by the system, to update the total statistical data and to form the periodical statistical data; the technicians responsible for the collection of these data should, to give give these correctly, thus consult:

- the normal plant operation records, from which the necessary information for the system can be extracted;

- a record, to be kept permanently up-to-date, describing the situation of the inventory of all the components operating in the plant, to ensure the delivery of an exact code (note in this respect the difficulty involved in following manually the succession of the components in the same position in the loop).

Furthermore, they should be able to give information that permit automatic controls (for instance, in the case of replacement of a component) lest the stock of data contained in the system should be changed erroneously.

These considerations have led to the study of such an organization of data that, during data collection:

1) permits the human operator to fill in only one type of form in which he gives, at the same time, the data of stock-modification and those relative to the plant's operation, thus lessening the possibilities of error due to the repetition of some data;

2) makes it possible to keep continual sight of an updated inventory of all components working at the end of the preceding period;

3) delivers, practically without requiring any human effort, the items necessary for an accurate automatic control of the input information;

4) cuts to a minimum the manual work of codification and in any case precludes its repetition.

It is therefore proposed to perform the periodical collection of information on forms as given in fig.2; their principal characteristic is that they are delivered by the computer and already automatically filled in with all the fixed coded data concerning the loops and all the operating elements.

These tables may thus constitute, at the same time, a complete and analyzed inventory of the periodical situation of the plants (a copy may be kept for that purpose) as well as a preprinted and preceded form; thus cutting out a large proportion of the human work and potential source of error. The operator will generally only fill in those squares which deal with the details of loop operation (only for the operating conditions that have in fact obtained in the course of the period) as well as those concerning the components that were defective or that have been involved in replacements, stoppages, etc. Only for these components, in fact, need short mnemonic codes and or the operation data differing from those of the loop be filled in.

3.2. Printing of the forms

In fig.2 an asterisk denotes the fields printed by the machine, whereas in fig.3 a real example of such a form is shown. For each loop the machine delivers the identification codes (plant, loop number), the classification code (class), the operating conditions (with their temperature and pressure data) and the period for which the human operator must enter the data on the form. One printed line is provided for each operating condition.

Two printed lines are provided for each component that was alive at the time of the preceding automatic elaboration:

- on the first are printed the identification codes of the component (position in the loop succession), its classification codes (nature, type), its status (that is, whether it was stopped or not at the beginning of the new period) and a coded reminder of the four operating conditions (which appear in the same line);

- the second line is reserved for the technician who enters the identification codes, etc. of new component replacing the preceding one, and who gives the data concerning its operation.

Furthermore, the machine prints a number of lines, already sub-divided in squares but without codes, at the foot of each page reserved for a loop; these lines are to be used in the case of more than one component replacement and are intended to permit the entry of new positions in the loop. Also, the internal page and line number will be printed for each loop.

For the collection of the data stock required to set up the first inventory to be introduced in the system, a number of forms (fig.4), preprinted with the necessary squares but completely devoid of information, will be delivered; the starting information must naturally be entered on these by hand. These forms must also be used should a new loop be constructed, and in all exceptional cases where the normal forms, delivered by the system, would not be sufficient.

3.3. Transcription of the data on to the forms

Details of the work to be done by the technician in filling up the periodical forms:

1. Concerning the loops information must be given for all the operating conditions which actually obtain, and for these only; the required data are: operating time, type 1 and type 2 faults number.
   The total number of start-ups in the period is also recorded.
   In the square for the loop life code, an E must be writ-

ten only if the loop has been eliminated. When a new loop has been set up, the empty forms must be used and an N (new) must be written in the square for the loop code.

2. As regards the components, the principal rule to be observed when collecting data is:

   - If a component has worked well during the period - that is, without failures and without any modification in its status or its life code - the line reserved for it must be left completely blank. The computer will then automatically ascribe to that component the operating data of the loop to which it belongs.

   - If, on the other hand, the above-mentioned conditions are not satisfied, and the technician would therefore have to enter some data or particular codes, than <u>all</u> the information concerning the operation of the component must be specified, as indicated on the form, for all the effective working conditions. In this case a blank square will be taken to contain zeros, because for security reasons the operating data of the loop will not be attributed to the component.

More specific rules for the data concerning a component:

- If a component has been stopped during the period, the code S must be written in the square for the status code.

- If a component had been stopped in the preceding period the letter S is thus found printed in the status square code. If the component has now been started up again, then it suffices to cross out the S to apprise the system of this new status.

- If a position in the loop has been dispensed with, an E (eliminated) must be written in that square.

- If a component has been replaced or eliminated, a D (dead) must be written in the square for the component life code.

A replacement element my be inserted maintaining the same "position in the loop code" as that of the component which it replaces and the death of which has been indicated with a D.

- If the replacement element is of the same nature and type as the preceding one, then the entry of the succession code is sufficient for its identification. The former number + 1 must thus be entered in the square for the succession code. Neither the position in the loop nor the nature or type need be repeated.

- If, on the other hand, the replacement component is different from its predecessor in nature, or type or both, the new classification codes must be noted and the succession code must start again from the number 01.

3.4. Punching of the data

Just as the technician examines only those information items that introduce new elements in the system, using the rest of inventory list solely for checking, in the same way the transmission of the data to punched cards should be confined to the data that are new to the system; classification codes already known should not be punched again.

Generally speaking, only these lines in the form of fig.2, on which the technician has written, must be punched. All other lines must be ignored.
Two different kinds of punched cards (see fig.5) are extracted from the forms:

- loop cards (one for each operating condition that has actually obtained in the period);

- component cards (one for each component line filled in by the technician).

Columns 1 trough 13 will be duplicated for all the cards that belong to the same loop, from the first card of that loop. The classification codes which have been printed by the machine do not need to be punched again for each component, the same applies to the information on the operating temperature and pressure.

3.5. Data treatment

Fig.6 shows a schematic flow-chart illustrating the proposed system for the data manipulation with the obtained results. The sequence of the different phases of elaboration is as follows:

After the punched cards have been loaded on the G.I.D. (General Input Data) the data on this tape are ordered on plant and loop codes, so that the data, punched on cards from the blank lines at the end of a form, are inserted in the right order.
The contents of the so obtained S.I.D. (Sorted Input Data)

tape are then subjected to various controls, to verify as much as possible the validity and correctness of the data.

Any errors will be printed in an Error List; with this list the technicians can make correction cards. S.I.D. tape will be run through with correction cards until no more errors are found.
The resulting tape is the I.D.C. (Input Data Checked) tape.

With this I.D.C. tape the O.D.D. (Old data) tape will now be updated; the O.D.D. tape contains the inventory and the total statistical information for loops and components that existed at the end of the preceding period.

From the elaboration of the I.D.C. and O.D.D. tapes results the U.D.D. (Updated Data) tape, the contents of which are thus two-monthly and total data of all elements that have been examined during the period in elaboration, that is for all elements that appear in the inventory forms of the period just ended. On the U.D.D. tape, obviously are also found information items concerning elements that have died or been eliminated during the period in elaboration.

The U.D.D. tape can now deliver as a first result the Loop Statistics List, in which data relating to every working loop are shown. Fig.7 gives an example of this list.

During the printing, the A.L.D. (Actual Data) tape will be formed by copying the U.D.D. tape, leaving out all the loops and components that have died or been eliminated during the period. This A.L.D. tape will be the O.D.D. tape of the next elaboration.

From the A.L.D. tape, the forms for the data collection are

printed.
The U.D.D. tape is now sorted to order the components according to their nature code, and thus forms the U.S.D. (Updated Sorted Data) tape. This U.S.D. tape gives the second result of the system, the Component Statistics List, which contains the analytical data for each component and the totals for each nature (see fig.8).

During this print-out, the component Life-expectancy data, that are found on the O.L.D.(Old Life-Expectancy Data) tape, are updated to form the N.L.D.(New Life-Expectancy Data) tape.
The N.L.D. tape, when printed, gives the third result of the system: the Component Life-Expectancy Statistics List (see fig.9).
As can be seen from fig.7 and 8, the statistics given concern both two-monthly and total data (total from the starting time of the system).
The data of fig.9 are to be interpreted as follows:

For all components of any nature the working hours till their death are counted. The working hours are divided up into intervals of ten hours and the number of elements that have eliminated during that interval is entered in the column for the "dead components number". If no component has died during an interval, this interval will not figure in the list.

3.6. Remarks

The solution of the problem, as proposed above, is naturally based on the way in which the plant operating records are actually organized. If, in the future, it were possible to arrive at a standardization and partial codification of the contents of the records, the data collection could be extended to a greater number of elements and the data punched directly from the records, thus obviating the need to fill in any special forms.

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January 11-13, 1960

2. - Gilbert Associates, Inc, "RELIABILITY STUDY, EQUIPMENT AND COMPONENTS IN NUCLEAR POWER PLANTS", Report GAI-1512, July 1960

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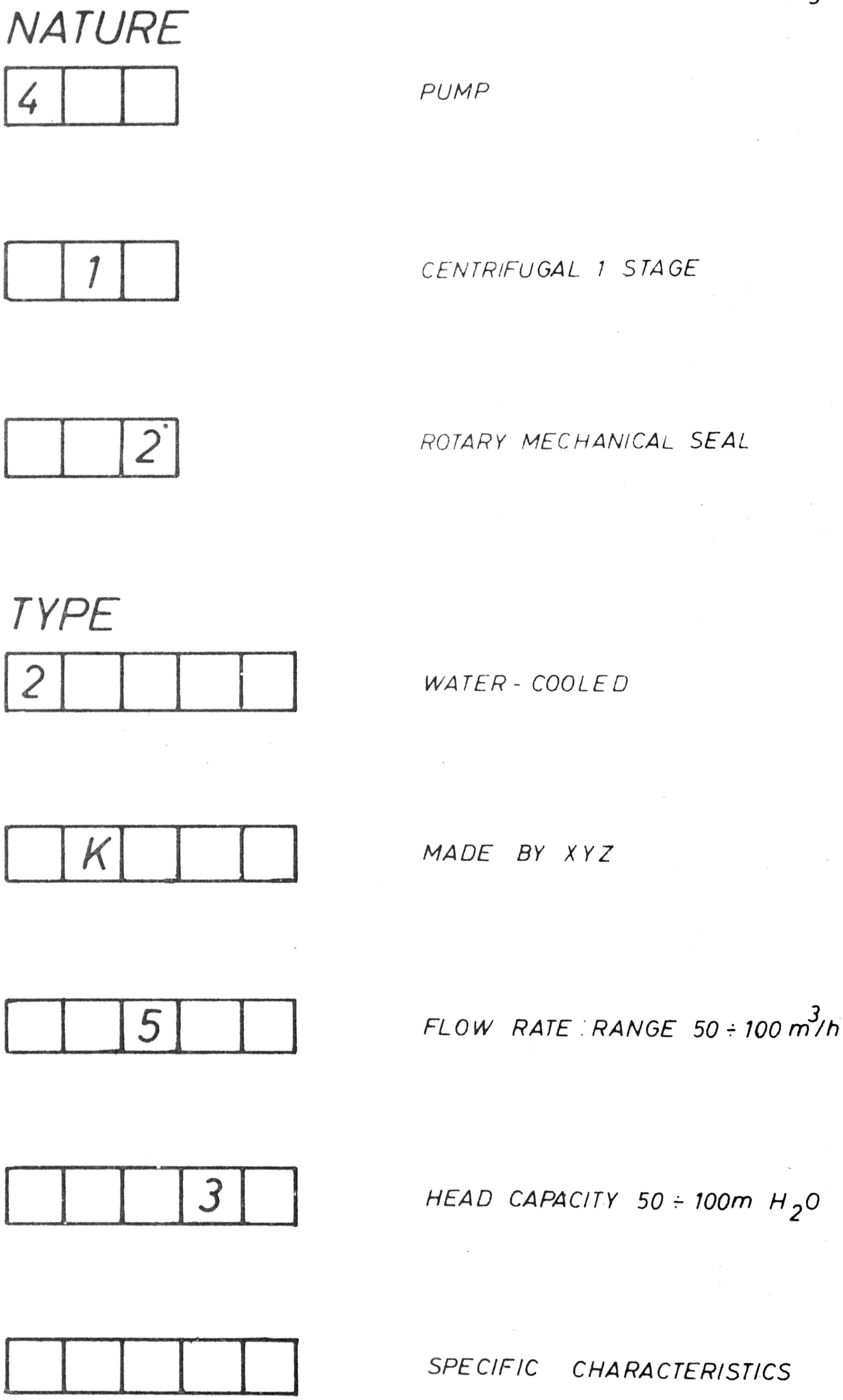
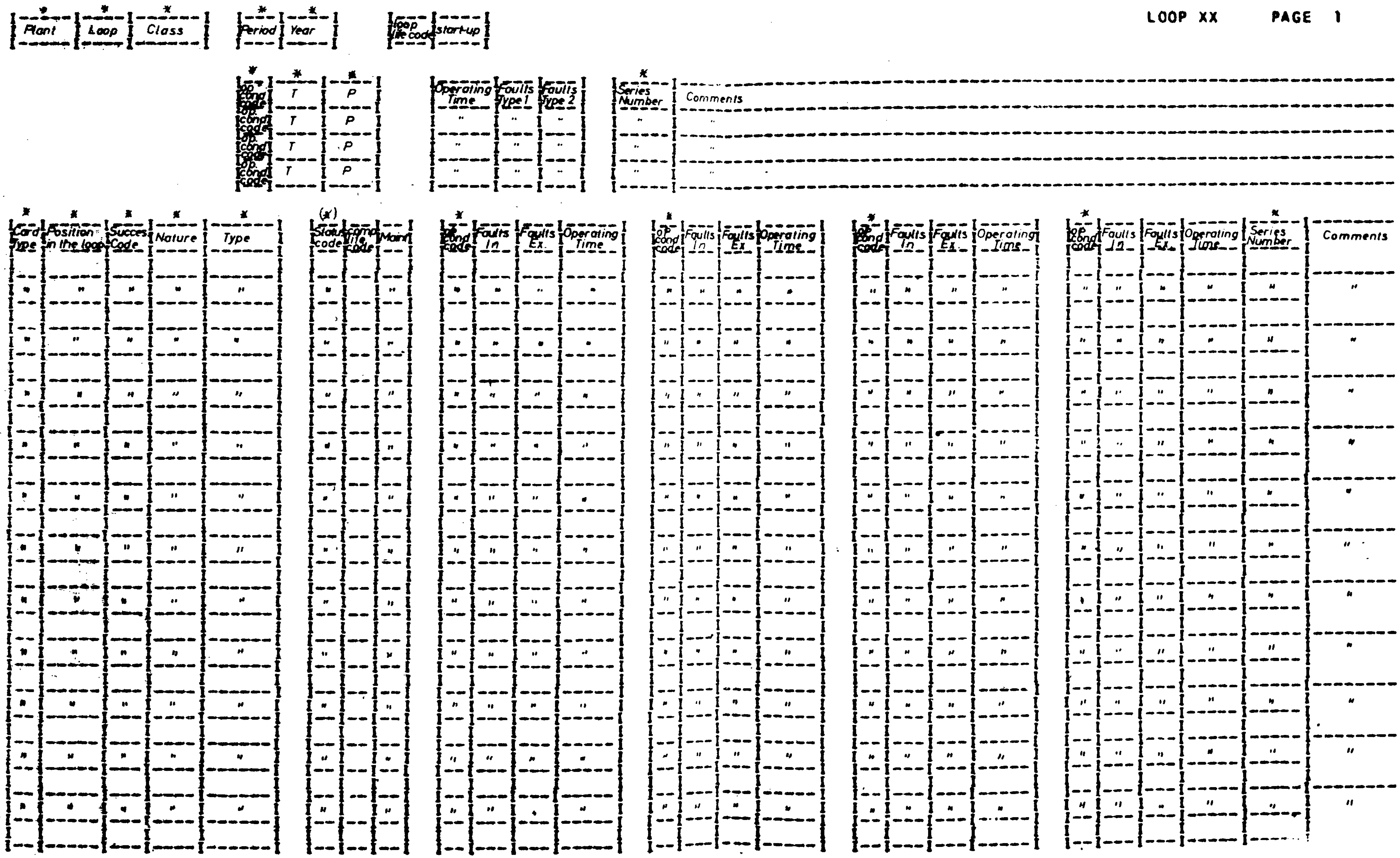
Fig.1



NATURE
4
PUMP
1
CENTRIFUGAL 1 STAGE
2
ROTARY MECHANICAL SEAL
TYPE
2
WATER - COOLED
K
MADE BY XYZ
5
FLOW RATE : RANGE 50 ÷ 100 m3/h
3
HEAD CAPACITY 50 ÷ 100m H2O
SPECIFIC CHARACTERISTICS


LOOP XX
PAGE 1
Plant
Loop
Class
Period
Year
loop life code
start-up
op. cond. code
T
P
Operating Time
Faults Type 1
Faults Type 2
Series Number
Comments
Card Type
Position in the loop
Succes Code
Nature
Type
Status code
comp. life code
Maint.
op. cond. code
Faults In
Faults Ex.
Operating Time
Series Number
Comments

- FIG. 2 -

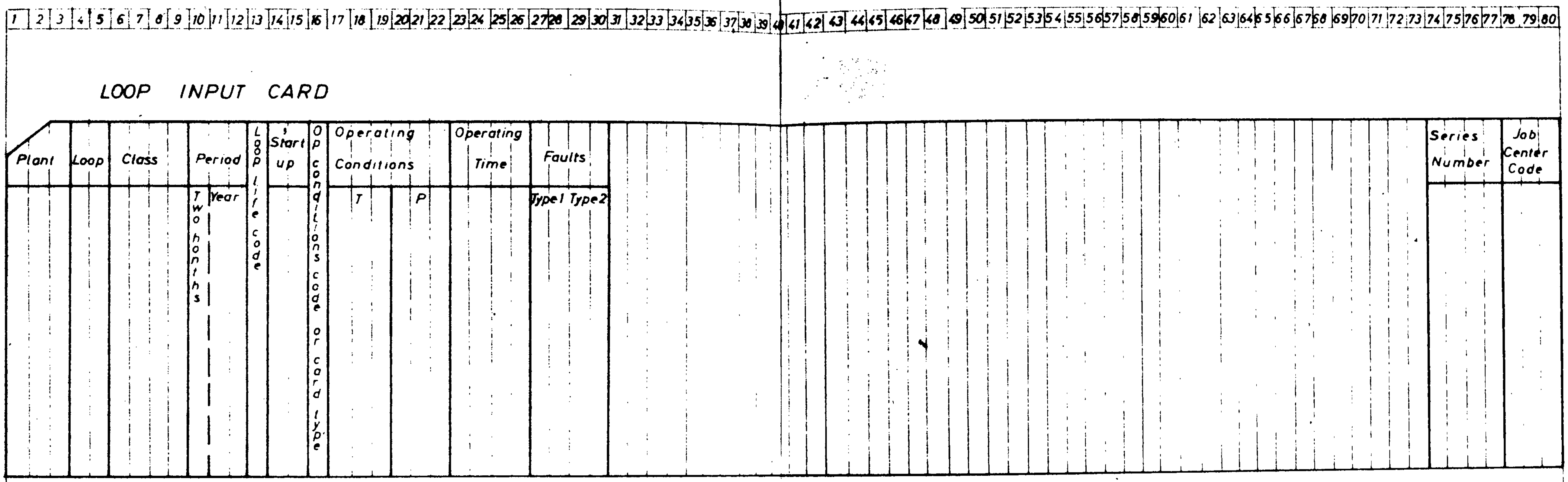
LOOP 02 PAGE 1

009	02	3122	2	64		15	

1	200	005	50	01	00	0001	relief valve failed
2	200	010	110	01	00	0002	pressure alarm failed
3	300	005	20	00	01	0003	short-circuit on preheating system
4	300	010	300	00	08	0004	leaks on valve packings -

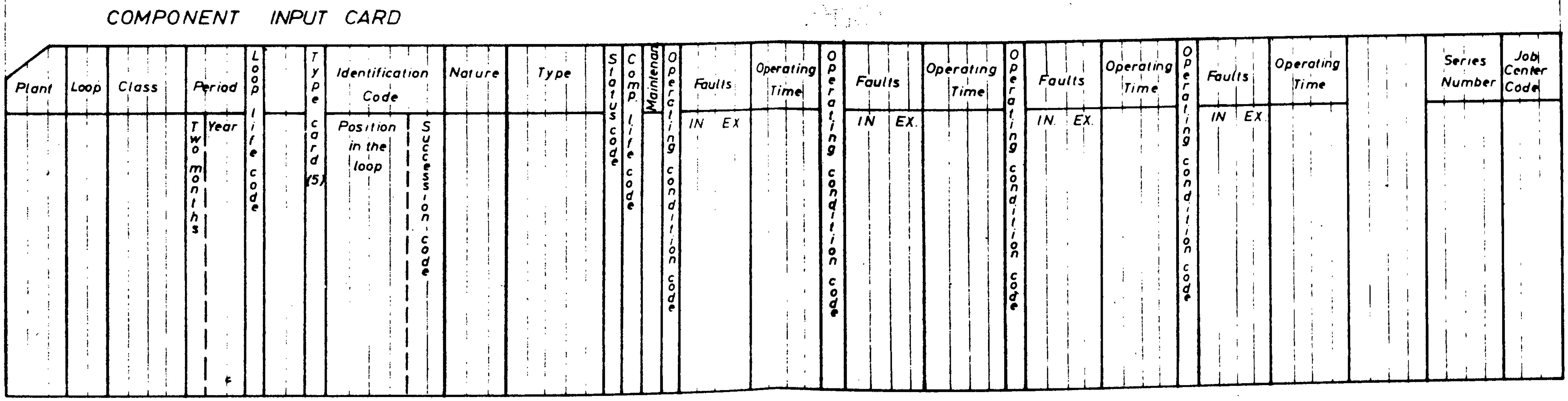
5	0001	01	161	2K110				1				2				3				4			0005	
5								1				2				3				4			0006	
5	0002	02	161	2F110				1				2				3				4			0007	
5								1				2				3				4			0008	
5	0004	05	233	2E100	S		0	1	00	00	50	2	00	00	110	3	00	00	20	4	01	00	30	0009	
5								1				2				3				4				0010	
5	0005	02	233	2E100			1	1	00	00	00	2	00	00	00	3	00	00	00	4	00	01	300	0011	
5								1				2				3				4				0012	
5	0006	01	233	2E100	S	E	0	1	01	00	50	2	01	02	75	3	00	00	00	4	00	00	00	0013	
5								1				2				3				4				0014	
5	0007	03	461	6K132		D	0	1	01	00	50	2				3				4				0015	Relief valve
5	007	04	461	6K232			1	1				2	00	01	110	3	01	00	20	4	00	01	300	0016	Replaced

- FIG. 3 -



LOOP LIFE CODE : BLANK (living)
N (new)
E (eliminated)

OPERATING CONDIT. CODE : 1 1th condit.
2 2th condit.
3 3th condit.
4 4th condit.



STATUS CODE BLANK (working)
S (stopped)

COMP. LIFE CODE BLANK (living)
D (dead)
E (position eliminated)

-FIG. 4 -

AUTOMATIC ANALYSIS FLOW - CHART

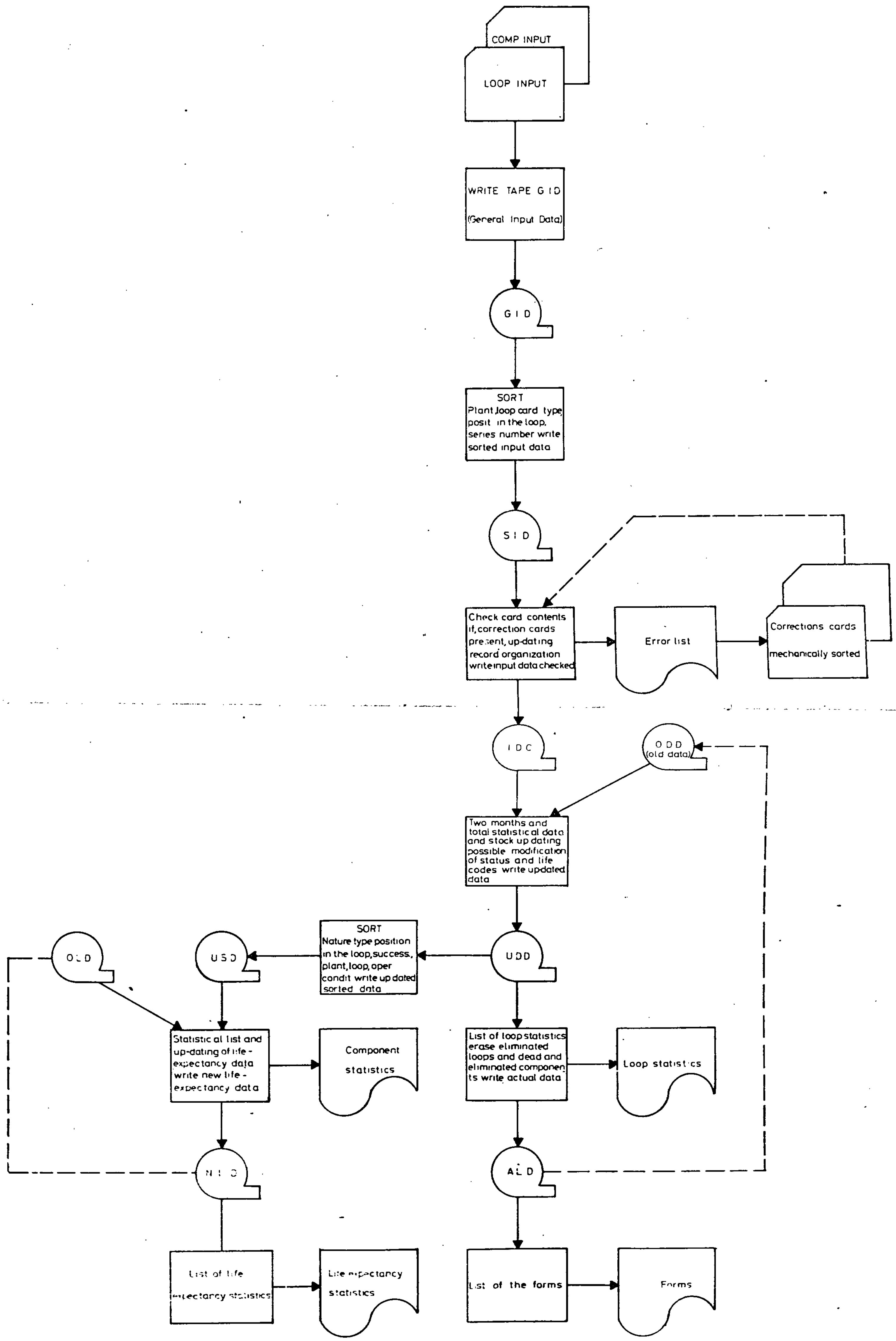


Fig.5

PLANT	LOOP	CLASS	LC	PERIOD					TOTALS					
				SU	OP	FAUL.1	FAUL.2	OPT.TIME	PN	SU	OP	FAUL.1	FAUL.2	OPT.TIME
009	02	3122		30	1	01	01	0400	05	100	1	0007	0006	01200
					2						2	0009	0002	00150
					3	03	02	0110			3	0016	0015	00120
					4	03	04	0085			4	0012	0018	00680
009	03	3122		05	1	00	01	0180	06	43	1	0000	0003	00312
					2	02	05	0102			2	0004	0008	00209
					3						3	0003	0005	00172
					4	03	01	0130			4	0010	0019	01041

L.C. = Loop Life Code

S.U. = Start-up Number

P.N. = Number of Information Periods

O.P. = Operating Conditions Code

- FIG. 6 -

NAT	TYPE	SN	POSIT. IN THE LOOP	SUC. CODE	PLANT	LOOP	LC	OP	PERIOD			TOTALS		
									IN.F.	EX.F.	OP.TIME	IN.F.	EX.F.	OP.TIME
223	2E110	01	0001	07	009	02		1	04	00	0568	05	01	01201
								3	01	01	0510	03	02	00970
								4				02	01	00373
	2E200	02	0003	01	002	03	D	1	01	00	0101	03	01	00272
								2	00	02	0300	02	02	00768
								4	01	C0	0279	02	02	00250
	2S120	03	0017	03	003	01		1	01	01	0182	02	02	00384
								2	00	01	0438	02	03	00986
								3	01	C2	0094	03	03	00160
								4	C2	03	0511	04	05	00608
TOTALS						OP. COND.		1	06	01	0851	0010	0004	001857
						OP. COND.		2	00	03	0738	0004	0005	001754
						OP. COND.		3	02	03	0604	0006	0005	001130
						OP. COND.		4	03	03	0790	0006	0007	000858

S.N. = Series Number

L.C.= Component Life Code

O.P.= Operating Condition Code

IN.F.= Intrinsic fanlts

EX.F.=Extrinsic fanlts

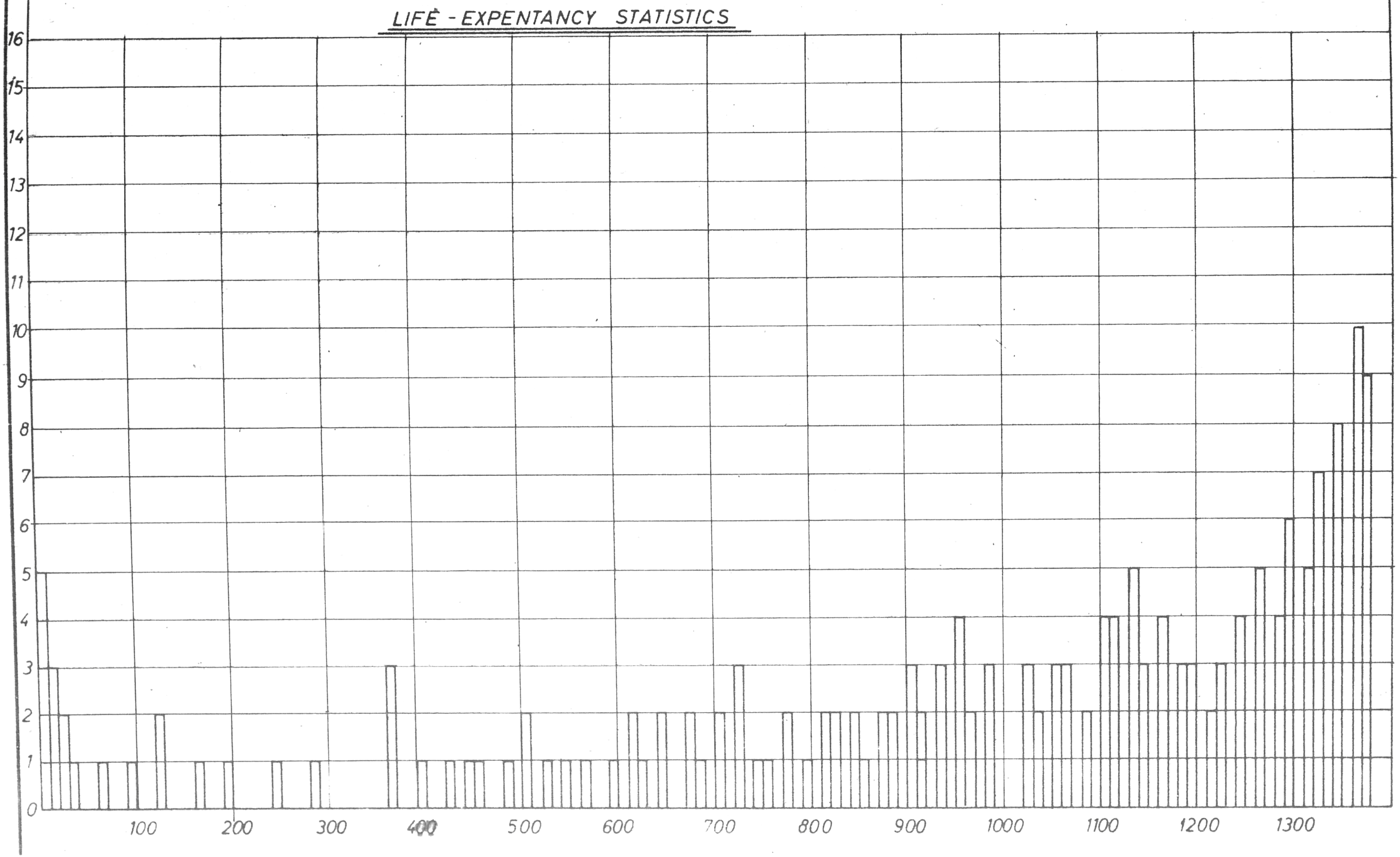
- FIG. 7 -

NATURE	DEAD COMP. NUMB. *	WORK HOURS	DEAD COMP. NUMB. *	WORK HOURS	DEAD COMP. NUMB. *	WORK HOURS	DEAD COMP. NUMB. *	WORK HOURS	DEAD COMP. NUMB. *	WORK HOURS	DEAD COMP. NUMB. *	WORK HOURS	DEAD COMP. NUMB. *	WORK HOURS
152	5	10	3	20	2	30	1	40	1	70	1	100	2	130
	1	170	1	200	1	250	1	290	3	370	1	400	1	430
	1	450	1	460	1	490	2	510	1	530	1	550	1	570
	1	600	2	620	1	630	2	650	2	680	1	690	2	710
	3	730	1	750	1	760	2	780	1	800	2	820	2	830
	2	850	1	860	2	880	2	890	3	910	1	920	2	920
	3	940	4	960	2	970	3	990	3	1010	2	1020	3	1040
	3	1050	2	1070	4	1090	4	1100	5	1120	3	1130	4	1150
	3	1170	3	1180	2	1200	3	1210	4	1230	5	1250	4	1270
	6	1280	5	1300	6	1310	7	1330	10	1350	9	1360		
153	7	10	5	20	3	30	2	40	1	50	2	60	1	80
	2	100	1	110										

PERIOD OF 10 HOURS

- FIG. 8 -

Fig. 9



LIFE - EXPENTANCY STATISTICS
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300

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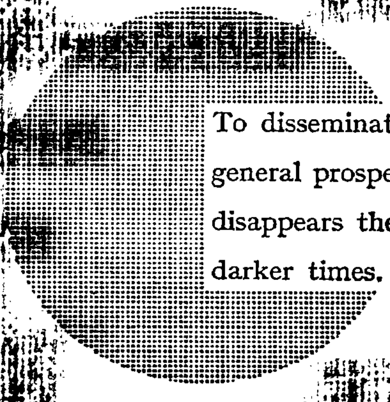

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Alfred Nobel

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