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Automatic System for Data Processing on the Behaviour in Exploitation of Production Equipment

Taking into account that in modern production, the efficiency performances are based on automated technological processes, the safety in functioning-or, with a term which is ever more used — the reliability of the production apparatus, has acquired particular importance. The efficiency of the means of labour, but, also the efficiency of labour — productivity — directly depends on the level of reliability and, indirectly, but, substantially the efficiency of the entire activity. In these conditions, the knowing of the way of functioning, of the behaviour in exploitation, of the reliability with which the production apparatus fulfils its mission is an important objective of the scientific management and organization of production. The data necessary for the control and adjustment of the fabrication processes are obtained from the informational-decisional system, from its subsystem which refers to the behaviour in exploitation of the machines, installations, units, equipment, of the automation and control apparatus, etc. [11]

The set of installations of an enterprise is regarded as a complex system with multiple hierarchical levels as part of its technological and organizational structure.

To meet with the present demands of the science of economic management, the reliability subsystem is achieved in the following way:

— as an organic part of the informational-decisional system of the industrial unit, modularily interconnected with the other subsystems, especially with that concerning the administration of capital goods;

— as a component of the system achieved and maintained with the means of informatics, with the techniques of electronic data processing, based on statistical — mathematical methods and models;

— as a source of information and of adjustment decisions for all factors contributing to the implementation of a level of reliability: the designer, the producer and user of the means of labour.

The modular structure of the system allows easily to adapt it to the concrete conditions and specific character of a given enterprise.

The system is functioning at the economic unit which uses the respective production apparatus. The primary, intermediate and especially the final data are of particular interest for the designer and the producer of various component elements and subsystems of the production apparatus.

The organization of data collection ensures the uniqueness of the primary documents for all applications concerning the production equipment. At the same time, the demand for data on the functioning of the entire production apparatus, of the component subsystems up to details, parts and elementary components, is taken into account. The possibility of a synthesis of the reliability parameters at each constructive level: part, loop, subunit, aggregate, fabrication line, the entire production apparatus, is also ensured.

From the point of view of the content, the file comprises two kinds of data:

1. **Description of the elements** of the production apparatus, with the necessary details for carrying out the established objectives (the modular connection to the other subsystems of the informational-decisional system of the enterprise, the description of the needs of improving the designs, the fabrication technologies, the exploitation, analysis and synthesis at any constructive level, etc.). Identification in each stage is achieved with the aid of the installation coding system. These data are completed with technical-constructive, efficiency parameters, etc. necessary for complex analyses.

1.2. *The observation programme* represents the enumeration of the data collected for each element (observation unit) of the production system. The routine has a concrete and local character; it is drawn up for each type of installation in keeping with the concrete conditions of exploitation, with the need of data, with the aim pursued, etc.

This routine cannot omit data on:

a) — the moments when changes occur in the condition or behaviour of the apparatus:

— the moment of putting into service,

— the moment of break of operation,

— the moment of putting into service again,

— the moment of fall,

— the moment of putting into service again after removing the causes of the fall;

b) the causes of falls on classes of falls (total, partial, parametric, etc.), on the primary source of the fall (fallen elements), the factor responsible for the fall, etc.;

c) expenses linked with the re-establishment of the fallen element (expenses for manual labour, spare parts, materials, punishments, etc.);

d) data about indirect losses caused by the fall (production losses with the user, with the beneficiaries, losses at the level of the entire national economy, etc.).

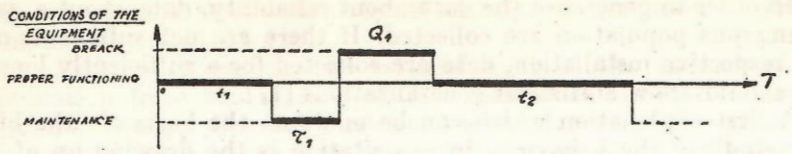


Fig. 1

The file of data about the proper functioning and nonreliability of the production equipment is at the basis of the *analyses* of reliability.

A first group of applications is achieved with the aid of descriptive statistical methods. The *grouping of falls* on causes (up to primary causes) is carried out as a result of which the series of distribution of falls is obtained. This distribution is analysed for outlining the comparative importance of the various causes (the relative frequency of causes, the cummulated relative frequences, the concentration curve),the average frequency of falls $\bar{k}$ on elementary components, subunits, etc., the average rate of falls $\bar{\lambda}$, etc. For a better knowing of the causes of falls, combined groups, correlation tables, etc. are drawn up.

The applications on the *costs* of nonreliability hold the main place in the analysis of reliability. In the first place, one calculates the cost of the fall of an elementary component (loops, subunits, etc.), in general and on various causes. Equally important is the analysis of costs on various expenditure elements.

The data about the moments of a change in the condition or behaviour of the equipment are at the basis of the calculation of the times of proper functioning, of maintenance (upkeep, repairs, trouble shooting, etc.) about breaks in functioning (although the condition of the equipment is good) etc. The synthetic levers are calculated from these data, such as: the mean of the time of proper functioning (MTBF), the mean of the maintenance time, the mean of the break time, the availability of the equipment, etc. [4], [5] [7,] [15].

The data about the time of maintenance of the equipment in various conditions allow the carrying out of the application on the *historical background* of the life of the equipment. Generally, a complex equipment after fall is repaired and put into service again. That is why the "historical background" of its functioning along the observation horizon T will be made up of the proper functioning time (t), the maintenance time (τ) and, possibly, the break time (θ):

In many cases, the fallen elementary components, even loops or subunits are no longer repaired (the repair is impossible from the technical point of view or irrational from the economic point of view), they are replaced. In this case, for each element, the term of life is the proper functioning time until the fall (Fig. 2).

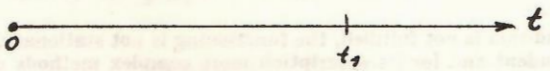


Fig. 2

In order to generalize the data about reliability, data about a sufficiently numerous population are collected. If there are not sufficient numbers of the respective installation, data are collected for a sufficiently long period which should allow statistical generalizations [17].

A first explanation which can be made on the basis of "the historical background" of the behaviour in exploitation is the drawing up of *survival curve* of the equipment. This method lends itself to primary data processing, especially when the fallen components are replaced. By setting out from the initial population made up of n parts submitted to observation, at the moment of the fall of a component the effective number decreases by one unit, until all parts are out of repair. The evolution curve of the parts still in operation is the survival curve presented in Fig. 3.

In the event of the repair and putting into operation again, the following condition must be fulfilled in order to be able to build the survival curve:

— after repair, the equipment is put into service again as a new equipment whose condition and functioning do not depend on its previous „historical background".*

The fulfilment of this condition means the stationary functioning of the equipment. Thus, each putting into service again is treated in the same way as the putting into operation of a new equipment. Thus, the historical (longitudinal) data are homogeneous in time and are considered as the elements of a homogeneous population. The "longitudinal" data of the other parts of the same type of equipment being treated in the same way, resulting from the reunion of the data recorded in relation to all parts observed in parallel (transversely) is a homogeneous mass of data which are treated as if they were the direct result of the replacement of components.

The **study of the reliability law** is based on the equipment survival curve. The establishment of the theoretical reliability law is necessary for

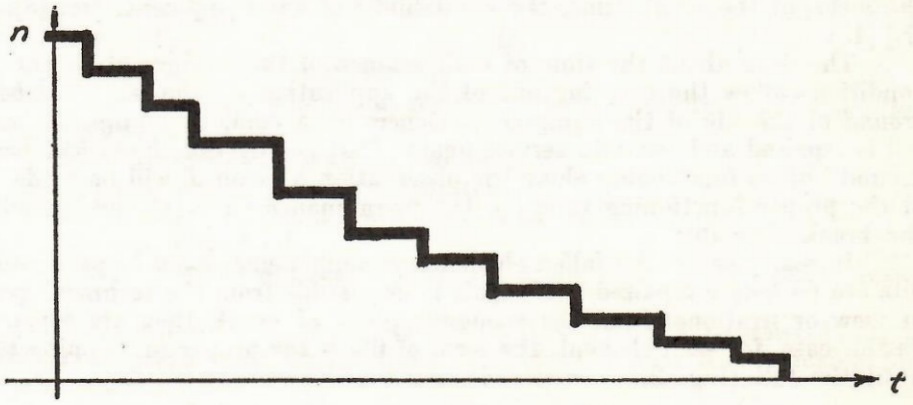


Fig. 3

* If this condition is not fulfilled, the functioning is not stationary, the successive conditions are interdependent and for its description more complex methods must be used, such as the theory of stochastic processes or the Markov chains method.

carrying out of normative calculations and for a synthesis of the reliability of subsystems [10], [16].

An operation preceding the establishment of the theoretical law is the elimination from the mass of data collected of the non-homogeneous data which — being a flagrant mistake — are not part of the given allocation. At present, the analysis from this point of view of the gross data is not yet algorithmized and thus it cannot be carried out automatically, the decisive role in this stage being played by the human decision -maker. On the basis of professional knowledge about the logic of manifestation of the behaviour, the hypothesis is formulated on the theoretical law of the reliability followed by the experimental data. In accordance with this option, the non-homogeneous data (the flagrants errors) are eliminated on the basis of the tests known [2], [6].

On the basis of the allocation series which now comprises only homogeneous data, the concordance of experimental allocation with the hypothetical theoretical allocation is being tested. Test χ^2 is used in the procedural model. In the case of the normal reliability law, one works with the known algorithm. [14].

In the case of the exponential reliability law (equivalent to the Poisson law [17] and of the Weibull law, the testing method has become simpler by the fact that the existence or non-existence of the fundamental property of the allocation parameter (parameters) is being tested.

Thus, in the case of the exponential law, they test to see if the experimental rate of falls is maintained constant in time, that is

$\lambda_n(t) =$ constant, and in the case of the Weibull law, if $\lambda_n(t)$ develops as a power function:

$$\lambda_n(t) = \alpha \lambda t^{\alpha-1}$$

(where α and λ are the parameters of the Weibull allocation law).

If the hypothesis about the theoretical law $f(t)$ followed by the reliability of the equipment was confirmed, one calculates [5], [7] [15]:

a) the theoretical parameters of the allocation:

— the mean (of the proper functioning time)

$$M[t] = \int_{-\infty}^{+\infty} f(t)\, dt;$$

— the standard deviation (of the proper functioning time):

$$D[t] = \left\{ \int_{-8}^{+\infty} (t - M[t])^2\, dt \right\}^{1/2}$$

b) the specific reliability parameters:

— the probability of proper functioning in the interval of exploitation t_0:

$$R(t_0) = \int_{-\infty}^{t_0} f(t)\, dt;$$

— the probability of the fall at moment t_0:

$$Q(t_0) = 1 - R(t_0).$$

Further, the reliability intervals for the allocation parameters are established.

The systemic synthesis of the reliability parameters aims to generalize at the level of a system (subunit, machine, technological line, etc.) the results obtained at the level of the component subsystems. The synthesis is achieved by setting out from the reliability of the subsystems by appliyng the addition rule and the multiplication rule of probabilities [12], [13].

Finally, following the study made on the basis of special routines which are modularily connected to the processing system presented above, we obtain:

1. a maintenance strategy for the beneficiary, with practical solutions to problems, such as:

— the control of the maintenance activity (for example, with the critical path method),

— the best dimensioning of the stock of spare parts, materials, etc.,

— the dimensioning of the work teams for the maintenance activity;

2. feed-back data for the designer and producer on the behaviour and exploitation of the equipment, the character and frequency of falls, new specific conditions of exploitation, demands in relation to the level of reliability which has to be ensured, etc. Such data are meant to contribute, through adequate solutions as regards designing and execution technology, to raising the standard of reliability of products.

Figure 4 illustrates the automatic system for the processing of data about the behaviour in exploitation of the production equipment with a block scheme. The succession and the technical solutions adopted can be followed with the aid of the logical scheme.

As a utilization of this general system of processing of data on reliability, we present the particular solutions adopted on the occasion of the implementation of the system for the control and characterization of reliability in exploitation of the automation apparatus [18]. For characterizing the reliability of the apparatus, a special study was organized for the collection of data about the behaviour in exploitation of the apparatus. Two aspects of reliability have been studied: on the one hand, the parametrical falls (by these falls meaning the displacement of the precision of the apparatus above the admitted error) that is the evolution of the error on verification points for hysteresis, on families of apparatus and on, the other hand, the total, sudden, obvious falls, on causes: mechanical, electric and analytic up to the primary component which had generated the fall.

The system of automatic data processing follows, in general, the block scheme which was presented above. We present in brief the case of total falls (see Fig. 5).

BLOCK SCHEME OF THE PROCESSING SYSTEM

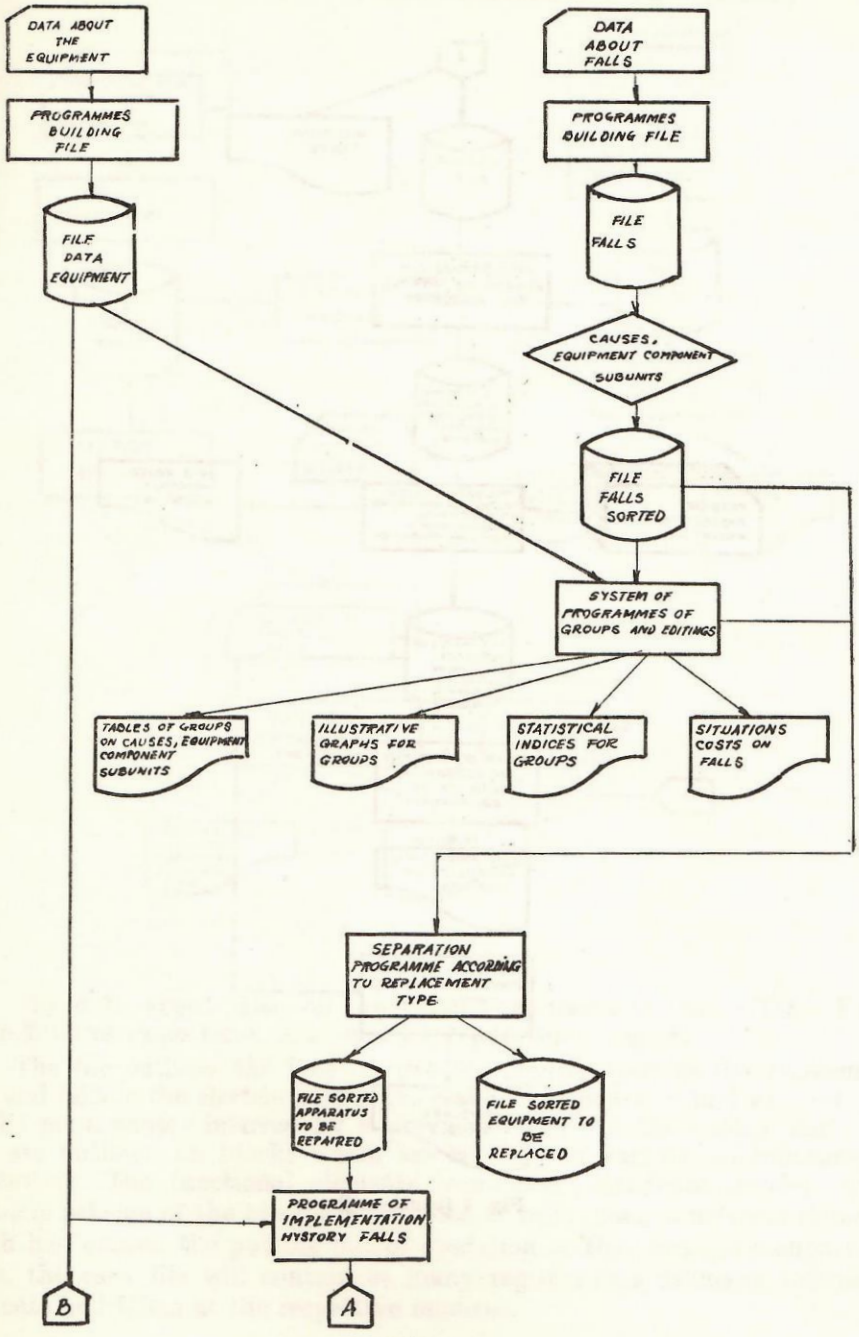


Fig. 4

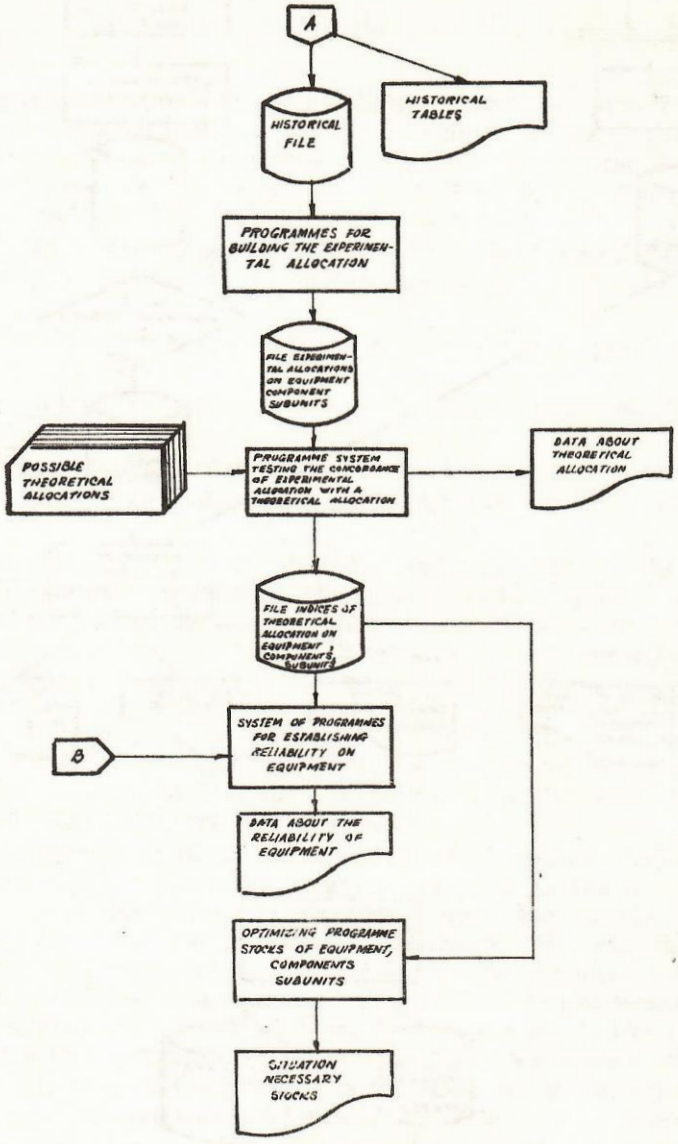


Fig. 4 (continued)

BLOCK SCHEME OF THE PROCESSING SYSTEM FOR THE RELIABILITY OF THE MEASUREMENT AND CONTROL APPARATUS (TOTAL FALLS)

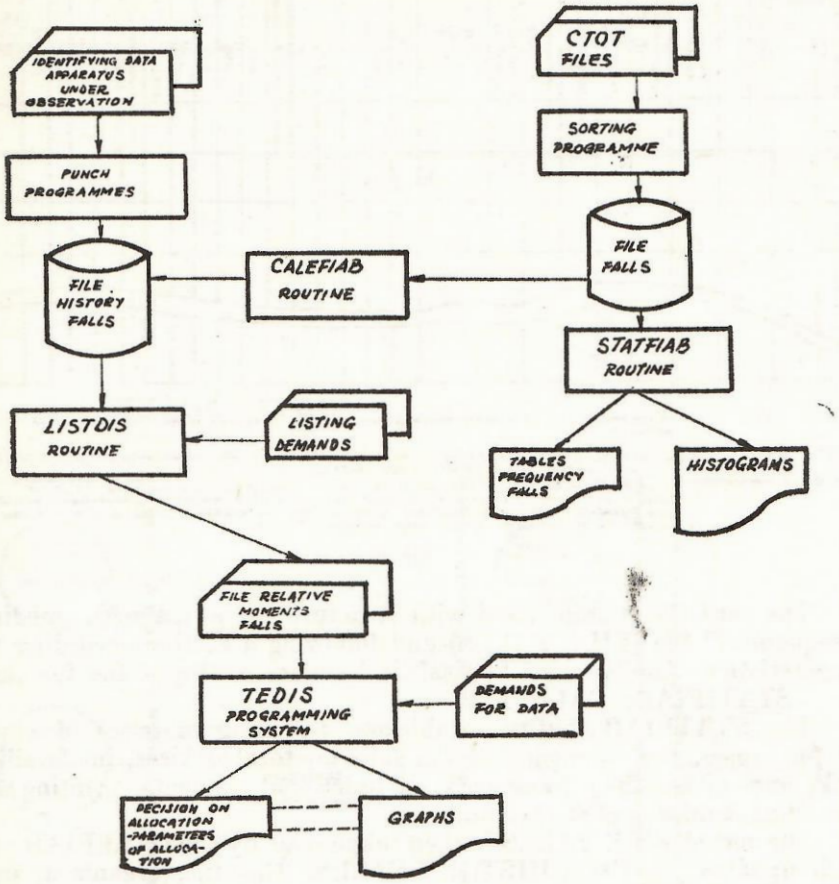
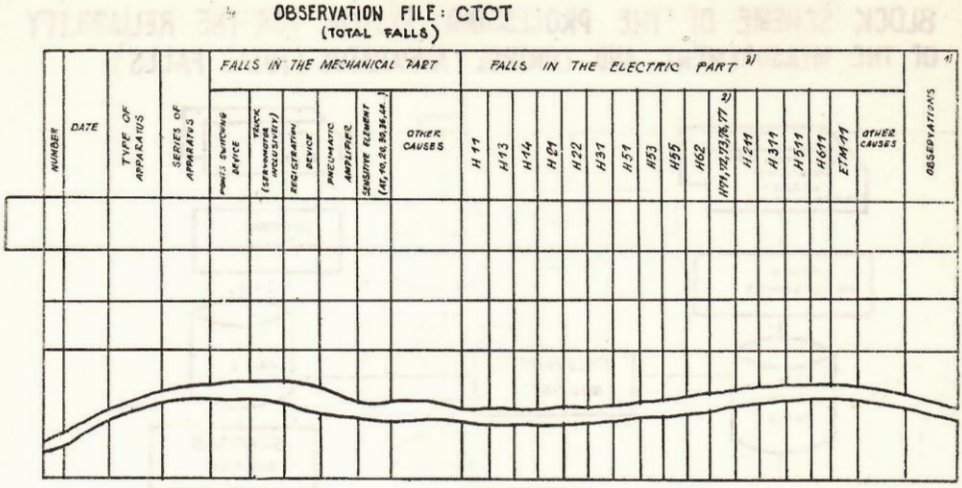


Fig. 5

The data about falls, on causes, are registered in the CTOT FILE which, at the same time, is a model for punching (Fig. 6).

The file outlines the falls on two big groups: falls in the mechanical part and falls in the electric part of the respective apparatus and within them, on the main causes inferred by a previous study. In the electric part, the falls are outlined on blocks which are retrived in various combinations in all devices. The functional elements (condenser, resistence, diode, etc.)of the main scheme of the block are specified at each block, functional elements which had caused the putting out of operation of the respective apparatus. Thus, the card file will contain as many registrations as many functional elements had fallen at the respective moment.



NOTE: 1) FOR THE APPARATUS TO BE REPAIRED FOLLOWING THE METROLOGICAL REFUSALS, SYMBOL "R" IS NOTED IN THE "OBSERVATION" COLUMN.

2) IN ACCORDANCE WITH THE CONSTRUCTIVE VARIANT OF THE APPARATUS WE SHALL INDICATE WHICH OF THE 5 BLOCKS (H_{71}, H_{72}, H_{73}, H_{76}, H_{77}) IS IN THE SCHEME OF THE APPARATUS.

3) TO IDENTIFY THE CAUSES OF FALLS, THE SYMBOL OF THE DEFECTIVE COMPONENT WILL BE NOTED IN THE CELS OF THE BLOCKS H, ACCORDING TO THE KNOWN CODE: RESISTENCE CARBON-R, VARIABLE RESISTENCE-P, CONDENSER-C, DIODE-D DIODE ZENNGR-DZ, TRANSISTOR-T, TRANSFORMER-TR. FOR AN EXACT IDENTIFICATION, TOGETER WITH THIS SYMBOL ONE INCLUDES THE POSITION INDEX IN THE SCHEME, FOR EXAMPLE "R_2".

Fig. 6

The card file is transposed with structure on a magnetic medium as a "sequential" file (FILE FALLS) and following a sorting according to the characteristics "family" and "series" it becomes an input file for the routines: STATIFIAB, CALFFIAB.

The STATFIAB routine establishes, by using matrices of enumeration on causes, the frequency of the falls on total devices, on families, on blocks and within their framework on functional elements, printing the corresponding tables and histograms.

The sorted FILE FALLS is then taken over by the CALFFIAB routine which updates the FILE-HISTORY-FALLS. This file, organized, indexed sequentially, is pre-edited at the moment of starting the statistical observation — whose data represent the first recording into the file.

For each apparatus liable to observation, a recording is built, capable of registering the history of its falls for a five year period. The history of the falls is outlined according to the calendar and in a relative time (hours) at the moment zero (Fig. 7).

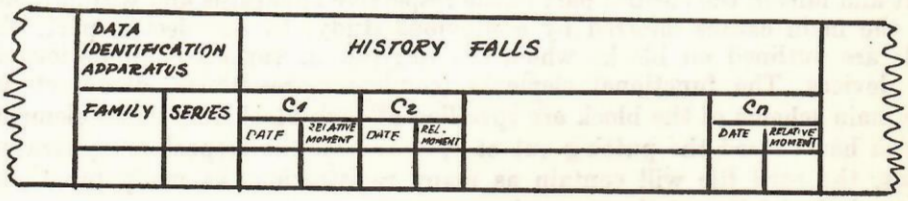


Fig. 7

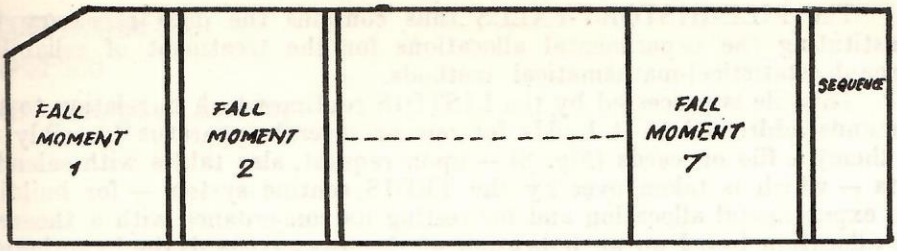

FALL MOMENT 1
FALL MOMENT 2
FALL MOMENT 7
SEQUENCE

Fig. 8

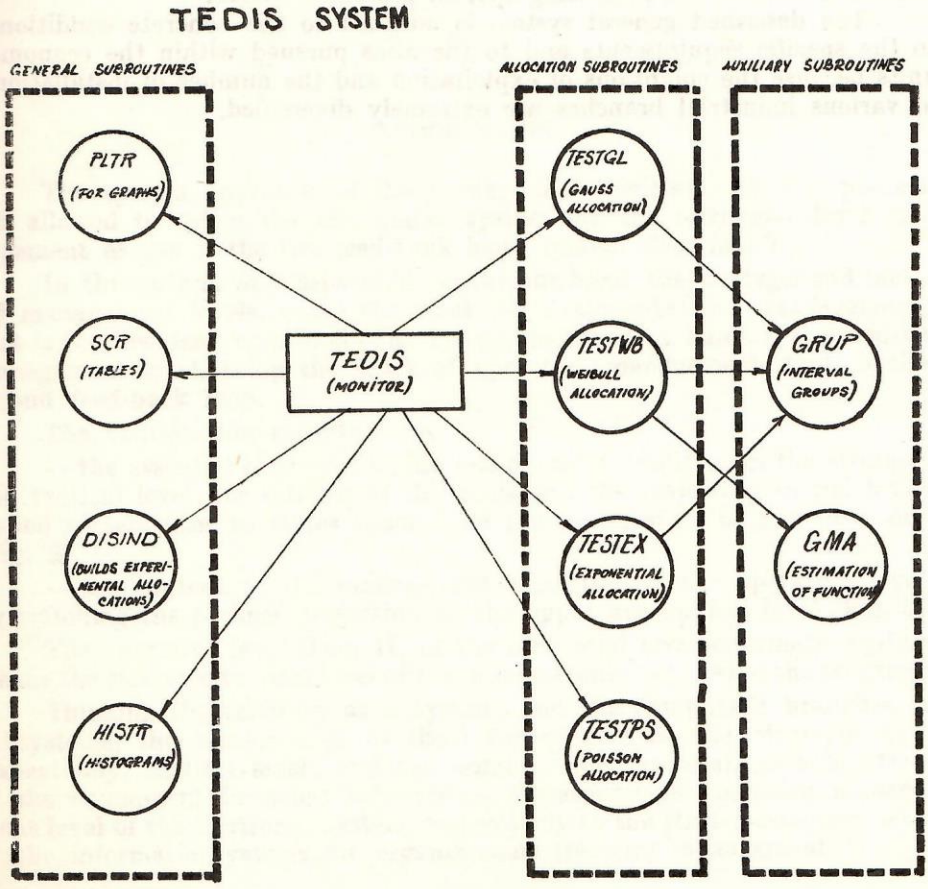

TEDIS SYSTEM
GENERAL SUBROUTINES
ALLOCATION SUBROUTINES
AUXILIARY SUBROUTINES
PLTR (FOR GRAPHS)
SCR (TABLES)
DISIND (BUILDS EXPERIMENTAL ALLOCATIONS)
HISTR (HISTOGRAMS)
TEDIS (MONITOR)
TESTGL (GAUSS ALLOCATION)
TESTWB (WEIBULL ALLOCATION)
TESTEX (EXPONENTIAL ALLOCATION)
TESTPS (POISSON ALLOCATION)
GRUP (INTERVAL GROUPS)
GMA (ESTIMATION OF FUNCTION)

Fig. 9

The FILE-HISTORY-FALLS thus contains the data necessary for constituting the experimental allocations for the treatment of reliability through statistical-mathematical methods.

This file is processed by the LISTDIS routine which in relation to the demands addressed to it builds for one or several apparatus (possibly all of them) a file on cards (Fig. 8) — upon request, also tables with calendar data — which is taken over by the TEDIS routine system — for building the experimental allocation and for testing its concordance with a theoretical allocation based on an indication of the user as regards the hypothetical theoretical allocation.

Concurrantly, the TEDIS system provides a series of parameters of allocation, histograms, graphs, tables, etc. necessary for the analysis. In the present variant, tests can be carried out on allocations of a Gauss, Poisson, Exponential, Weibull type and in the future, of an Alfa and Raleygh type.

The system has a modular structure (Fig. 9), being made up of several subroutines, coordinated by a monitor. It was conceived so that it can be used also outside the processing system presented above.

The described general system is adapted to the concrete conditions, to the specific requirements and to the aims pursued within the economic units because the conditions of exploitation and the number of installations in various industrial branches are extremely diversified.