

**GENERAL SOLUTION FOR ONLINE
COMPUTER BASED EXPERT SYSTEM
FOR POTABLE WATER PURIFICATION PLANT**

M. A. Rayan
Prof., Mansoura University
El-Mansoura, Egypt

N. H. Mostafa
Assoc. Prof., Zagazig University
Zagazig, Egypt

N. Gad El-Hak
Suez Canal Authority
Egypt

ABSTRACT

At the present time, the maintenance of the equipment becomes an essential task for any production system. This task is becoming more important from both the quantity and the quality points of view, particularly in developing countries. Initiating a maintenance system controlled by the computer will be valuable and effective.

The developed expert system is a combination of an intelligent inference engine matched with a database of information. This system will enable the operator to spot instantaneously the parameters of interest. The expert maintenance system will be designed to perform preventive maintenance tasks and detects faults/failure during the operating cycle. Predictive maintenance enables the operator to minimize the shut down time of faulty equipment and hence increases the productivity. Furthermore, the system will minimize the probable human faults and reduce production costs. This research work is to present a complete hard ware software package for monitoring water purification plants in view of developing an expert system for this application.

KEYWORDS

Water treatment, Water purification, Artificial intelligence, Expert systems, Knowledge representation, Fault diagnosis, Predictive and Preventive maintenance

INTRODUCTION

Rationalization of machine service and maintenance depend mainly on the adapted system of measurements, machine history records, performance, and the available spare parts. It can therefore be expected that a good linkage of these parameters will improve the maintenance process. The existence of this smart maintenance system will result not only in a smooth running operation but also in continuously recording various faults and minimizing the dependence on workers of exceptionally high skills

[1]. The last factor is of great influence, especially in Egypt, because of the very high rate of immigration of clever and well trained employees and technicians, a phenomenon which has been going on for the recent two decades with its negative impact mainly on the industrial sector.

An advantage of the proposed system is that it will achieve the correct level of operational reliability and optimize personal safety at minimum cost. It also provides up to date information about special tools, safety requirements, and parts incorporated from the plant and unit file.

Therefore, the main goal of this research is to provide a database expert system for ideal operation and develop a computer based preventive and predictive maintenance system. The design of this system will be based upon the data from measuring equipment linked with the information system. This system has some advantages as follows:

1. Continuous monitor conditions and makes necessary changes to assure that the process operates in the most efficient effective manner.
2. Rapid speed response based on measuring and anticipating changes in operating conditions.
3. Easy maintenance diagnostics which will cut the shut-down periods.
4. Ensuring the stability of the automated process.
5. Optimizing the performance of the automated process.
6. Avoid human faults allowing the use expert systems.
7. Suppressing the influence of the external effects.

LITERATURE REVIEW

Fault diagnosis is an important area of application for expert systems. Expert systems is a rich area of research in applied artificial intelligence [2,3,4]. Most of the recent research in expert systems, especially with respect to diagnosis and repair, has emphasized the use of deep knowledge. Most researchers are concerned with developing a "causal model" of the device. These systems contain a very deep understanding of how the device works. Davis' research was concerned with electronic trouble shooting using structural and causal models [5]. Chandrasekaran and Mittal worked on envisioning and qualitative physics as means of providing causal explanations of a device's behavior [6]. Genesereth worked on fault diagnosis of

electronics circuits based on their design [7]. Other research has emphasized the study of diagnostic processes itself, such as the work on ARBY by McDermott, et al [8] who used shallow models.

ANALYSIS OF WATER PURIFICATION PLANT

The plant can be easily divided into main parts as following:

- Intake, coagulation and flocculation basins.
- Filter (rapid filters).
- Chlorine units.
- The under ground reservoirs.

Intake, Coagulation and Flocculation Is the first part in the plant where water is discharged from the water channel to the plant. Coagulation is the first stage in the formation of a precipitate. Flocculation is the building up of the foci particles to a large size which can be removed either by sedimentation or by filtration or by the two processes in series.

Pumps are the heart of the plant, generally centrifugal or axial pumps are used. The pumps are used for pumping treated water to the network or in some cases the pump is used to bring water from the intake reservoirs.

Filters Sedimentation with or without coagulation will not give adequate treatment to water, filtration process is required. There are two types of filter slow and rapid.

The rapid filtration implies a process which includes coagulation, flocculation, clarification, filtration and disinfecting.

The essential characteristics of the rapid filter are:

Careful pretreatment of the water in preparation for filtration in sedimentation tanks.

High rat of filtration (120-240m³/day) or more.

Washing the filter unit by reversing the flow of water.

Chlorination, and chemical feedings: In order to provide soft water free from tastes and odors, the chemical additive are used. First the chlorine particularly used in water treatment in order to disinfect the water then Aluminum sulfate is used to react with water turbidity and help in the operation process.

The water reservoirs; There are two types of reservoirs; suction reservoir mainly for raw water, and treated water reservoir placed on the suction side of treated water pumps.

SYSTEM OVERVIEW

The expert system allows selective extraction and transfer of data between machine, computer and operator. In addition, the system permits the prediction of faults and gives a recommendation for operation and maintenance procedures. Computer decisions can also be sent to the machine for immediate proper control processing. These tasks are summarized in Fig. 1. The package is running under Windows 95. Different computer languages are used to assist in developing the package such as BASIC, Prolog, C and Access.

The data acquisition system consists of three stages, which are sensing & transducing, conditioning, and data representation. The measured, (which is basically a physical quantity) is detected by the first stage of the measurement system. In the first stage the quantity is detected and transduced into an electrical. In the developed data acquisition system all quantities must be in the electric form before it can be used for any further processing. This means that certain types of transducers such as must be used.

In the second stage, the signal conditioning equipment may be required to do linear processes such as amplification, attenuation, integration, differentiation, addition and subtraction. They are also required to do non-linear processes such as modulation, demodulation sampling, filtering, clipping and clamping squaring, linearizing or multiplication by another function, etc. These tasks are by no means simple. They require ingenuity, proper selection of components and the selection of the most faithful methods of reproduction of output signals for the final data presentation. The signal may be applied to analog to digital (A/D) converter. The signal is in digital form it may be applied to a variety of digital systems such as a digital computer, digital controller, digital data logger or a digital data transmitter. The sampler in Fig. 2 samples the different inputs at a specified time. The sampled value is held constant while an analog multiplexer performs the Time Division Multiplexing (TDM) operation between different data inputs. Time Division Multiplexing means that each input channel is essentially connected to the multiplexer for a certain specified time (The input signals

are not applied to the multiplexer continuously but connected in turn to the multiplexer by sharing time). The timing of the various input channels is controlled by a control unit. This unit controls the sampler and hold (S/H) circuit, the multiplexer and the analog to digital (A/D) converter. The control unit may be the controller itself.

In the third stage, the data which are derived from the conditioning circuits can be stored in a computer memory. This data can be displayed on a monitor screen in numeric or graphic forms. Also, the data can be used to initialize certain alarms according to preset values. The operation of the machine can be detected from the stored data for a long period of time. In this project, this data will be used by an expert system to give a diagnosis any faults that occurred in the machine and its preventive maintenance schedule. The developed expert system can be divided into three parts; input section, data processing section, and output section. Fig.3 shows the developed expert system layout. Also engineering machine data are considered as system inputs. The outputs of the system include monitoring and operation service, predictive maintenance reports, and preventive maintenance reports. The data processing section includes several software modules such as operating interlock, signal analysis, diagnosis and historical data. Monitoring data and operation service depend on the measuring input data with the decision of the operation limit and interlock system applied. Also, the predictive maintenance system depends on the measuring input signals with the processing through the analysis and diagnosis system. The preventive maintenance system is dependent mainly on the engineering machines data and the machine's history.

MONITORING AND OPERATION

The proposed monitoring system will be very helpful for operator as it will improve the visibility of the process by providing access to a much wider range of process data and more effective forms of presentation. A preliminary design of the visual data shape for running the operation loop is embodied in five main strategies as shown in Fig. 4. These strategies are:

Flow Diagram This file displays the plant flow diagram. This file can be tailored to the specific plant layout, also a continuous display of measurement at hot point may be done it is possible to indicate the plant discharge output and pressure on the flow diagram but it is recommended not to over charge the diagram.

Daily consumption This part of the program displays the reading of the flow-meters, the readings can be stored for a long period depending on the hard disk memory capabilities. The advantage of this way is, its easy access to the stored information in a friendly way.

Measurement Table This table indicates the important parameters of the plant instantaneously. It includes an alarm, the setting of the alarm can be determined by the plant operator. The main parameters are: discharge in cubic meter/hour, discharge water pressure at exit from the plant in meters of water, the salinity in part per million, and finally the residual chlorine. It is important to note that these parameters are considered as the minimum required parameter in order to judge the water quality. Certainly all the measuring devices must possess a milli volt output in order to make the necessary interface with the computer. The advantages of display is the grouping of all the important set in one screen also the impeded alarm facilitate the task of the plant operators and decision makers another advantage is the possibility to have this display telephone transmitted to another place this facility gives the decision maker an overview of what going on in the plant.

Water intake The water intake screen displays the readings of a level transmitter this screen can be controlled to give an alarm when the water level falls behind the minimum level. Also it can actuate the mechanical screen in order to be activated.

Water sump is the underground water reservoir connected to the main intake. This reservoir constitutes the raw pump suction. Usually, it must be equipped by a level transmitter. An alarm is triggered when the water level falls behind the minimum design level.

Pump Control This screen displays the necessary pump information particularly the suction and discharge pressures. The pressure gauges must be equipped by transducer and transmitter in order to transmit the pressure signal in Milli volt to the computer interface card.

Chemical Feed This screen displays the chemical feed pump it can calculate the necessary amount of chemical need to be injected according to the following equation:

$$\text{The required amount of chemical in liter/second} = X8.34XC.$$

Where C is the volumetric concentration.

Q is the water flow rate in cubic meter/hour.

Rapid Mixer The chemical mixed with water enter in the bottom of the rapid mixer reservoir. A low speed propeller is used to enhance the mixing. In this part only the R.P.M. of the propeller is transmitted to the computer.

Classifier This screen displays the reaction chamber where the mixture passes before the classifier, then the classifier. The level transmitter signal is transmitted for each basin an alarm signal is delivered.

Filter Simulation The main function of this part is to scraping the suspended solid, sludge's and floc from the water. This is an important part where the sequences of opening the air valve then activating the wash pumps can be programmed and activated according to the required time scheduled. This part is in fact vital, in all new plants this part is already automated. The sequence is as following:

- Immediately when the process receives the head loss indicator signal a washing program will be applied to the filter.
- Automation washing program will increase the system reliability and will also decrease the labor cost.

Under ground sump This screen displays the water level in the under ground water reservoir.

Chlorination Unit This unit displays the discharge of chlorine in kg/hour also a leakage detector is connected, it delivers an alarm if it detect any leak.

The above key mode strategies which form the basis of the control package may be displayed numerically, graphically or trend function of time. For example, the graphic mode is shown in Figs. 5 & 6.

PREVENTIVE AND PREDICTIVE MAINTENANCE

It is well established that the preventive maintenance (PM) is extremely important for the reduction of maintenance costs and improvement of equipment reliability. The principles of machine service and maintenance depend mainly on the adapted systems of measurement, machine history records, performance records, and the available spare parts. It can, therefore, be expected that a good linkage of these parameters will improve the maintenance process.

The existence of a smart maintenance system will result not only in a smooth running operation but will also result in continuously recording various faults and minimizing

the dependence on highly skilled workers. Another advantage of the proposed system is that it will achieve the correct level of operational reliability and best possible safety at minimum cost. It also provides up to date information about special tools, safety requirements, parts incorporated from the plant and unit file information.

Therefore the aim of this paper is to design software to carry out the required analysis for a specified variable and supply reports able to give a complete view of the system behavior. The flow chart shown in Fig. 7 represents the proposed preventive maintenance system.

CONCLUSION

The main objective of a system is to develop computer based models for problem solving that are different from physical modeling. An expert system attempts to model the knowledge and procedures used by a human expert in solving problems within a well-defined domain. Knowledge representation is a key issue in expert systems.

- The developed expert system is a combination of an intelligent inference engine coupled with a database. This system will enable the operator to spot instantaneously the parameters of interest and operational instructions.
- The expert system will be designed to perform preventive maintenance tasks and detect faults/failure during the operating cycle.
- Predictive maintenance enables the operator to minimize the shut down time of the faulty equipment and hence increases the productivity. Furthermore, the system will minimize the probable human faults and reduce production costs.
- The computer based monitoring system can increase the profitability of water purification plant operation this will result certainly in an improved efficiency.
- The real gain is the improved productivity through a precise control of the process a good example is the filters where a pressure control system can decrease water loss used in washing.
- The system will enable the decision maker to control what is going in the plant from any place using a simple note book computer connected to the telephone line.

The presented system package has partially tested using a laboratory circuit shows a good response and reliability. It should be applied on a full scale unit, (water plant) in order to evaluate its real benefits.

REFERENCES

- [1] El-Mitwally, E. S., Rayan, M. A., Mostafa, N. H., Enab, Yehia M., 1992, "Computer Based Expert System For Rotating Machinery Preventive and Predictive Maintenance" Computer in Engineering, San Francisco California. Vol. 1, pp. 99-104.
- [2] Jackson, P. (1986) Introduction to expert systems, Addison-Wesley, Reading, Masis.
- [3] Steels, L. (1986) Second generation Expert Systems, In M.A. Bramer, (ed) Research and Development in Expert Systems III, Cambridge University Press, Cambridge, pp. 175-183.
- [4] P. Hart, "Directions for AI in eighties," SIGART Newslett., No. 79, Jan. 1982.
- [5] R. Daviis, "Expert systems: where are we? and where do we go from here?" AI Magazine, Vol. 3, No. 2, pp. 3-22, spring 1982
- [6] B. Chandrasekaran and S. Mittal, "Deep Versus Compiled knowledge approaches to diagnostic problem solving," Int. J. Man-Machine Studies, Vol. 19, No. 5, pp. 425-436, Nov. 1983.
- [7] M. Genesereth, "Diagnosis using hierarchical design models," in Pro. Nat. Conf. Artificial intelligence, Aug. 1982, pp. 278-283.
- [8] D. Mc Dermatt and R. Brooks, "ARBY: Diagnosis with Shallow Causal models," in Proceeding. Nat. Conf. AI, Aug., 1982, pp. 370-372.

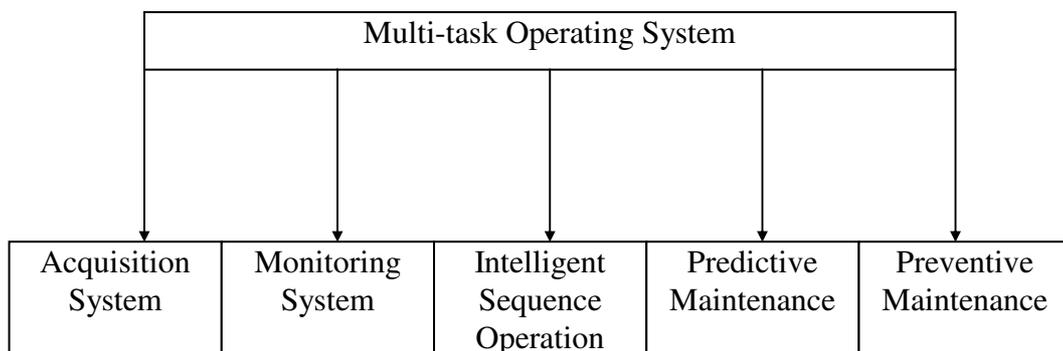


Fig. (1) Schematic drawing for chart of the proposed multi-tasking system

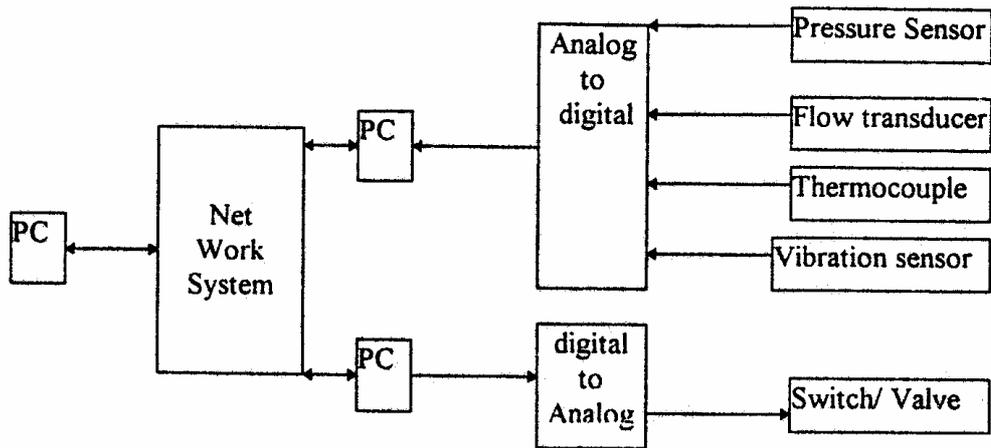


Fig. (2) Computer system configuration

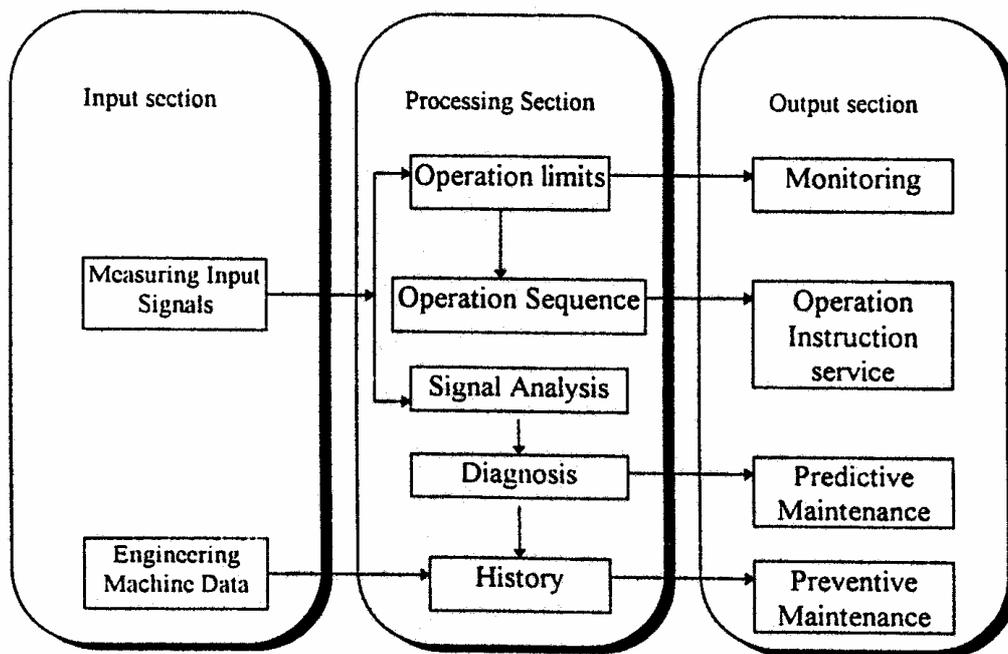


Fig. (3) Flow chart of the expert system

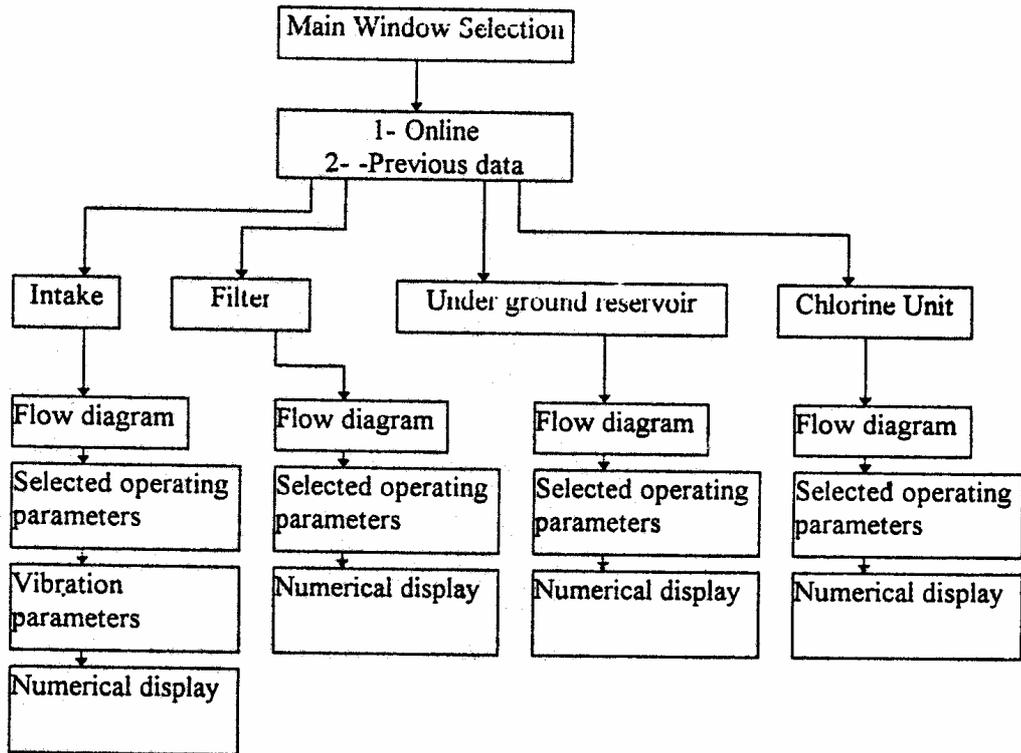


Fig. (4) Flow diagram of operation monitoring system

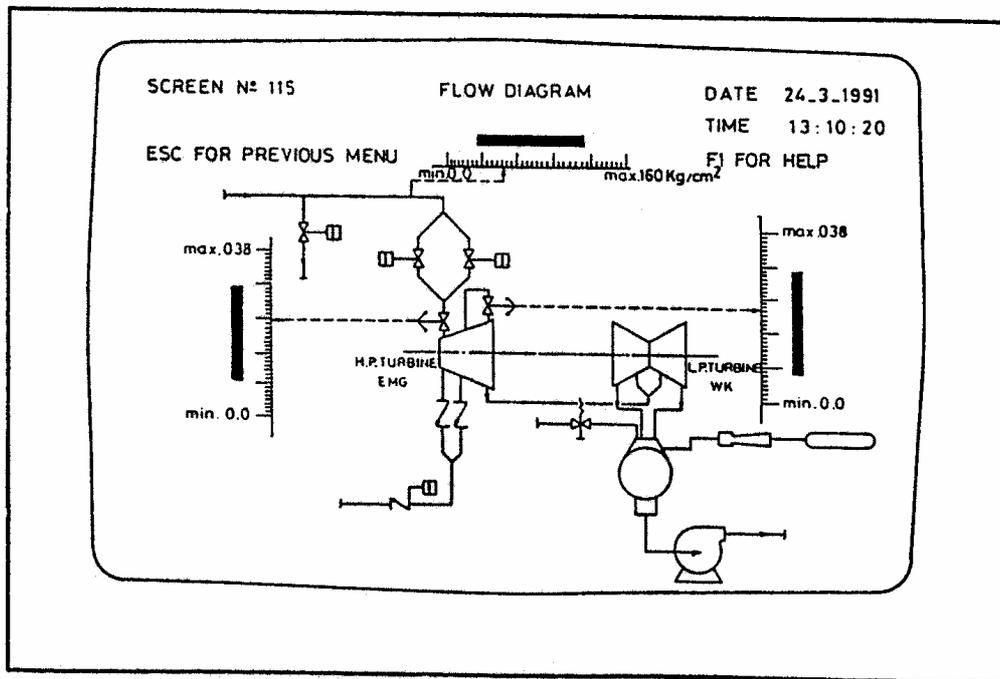


Fig. (5) Sample of Screen of flow diagram

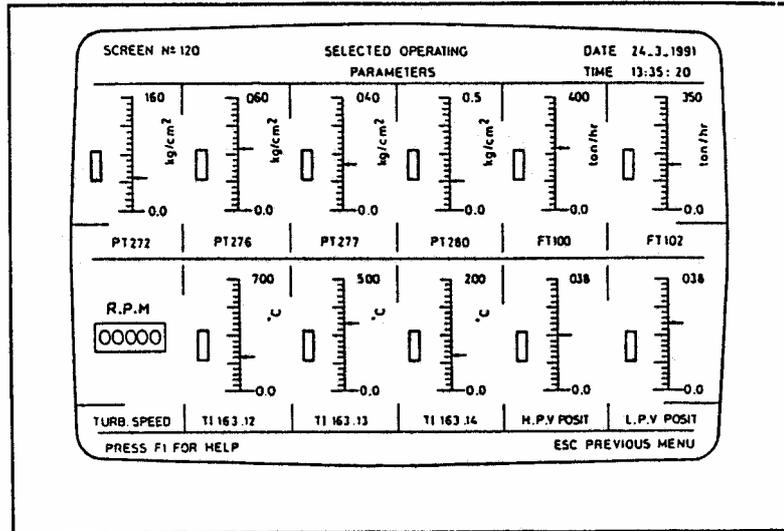


Fig. (6) Sample of selected operating parameters screen

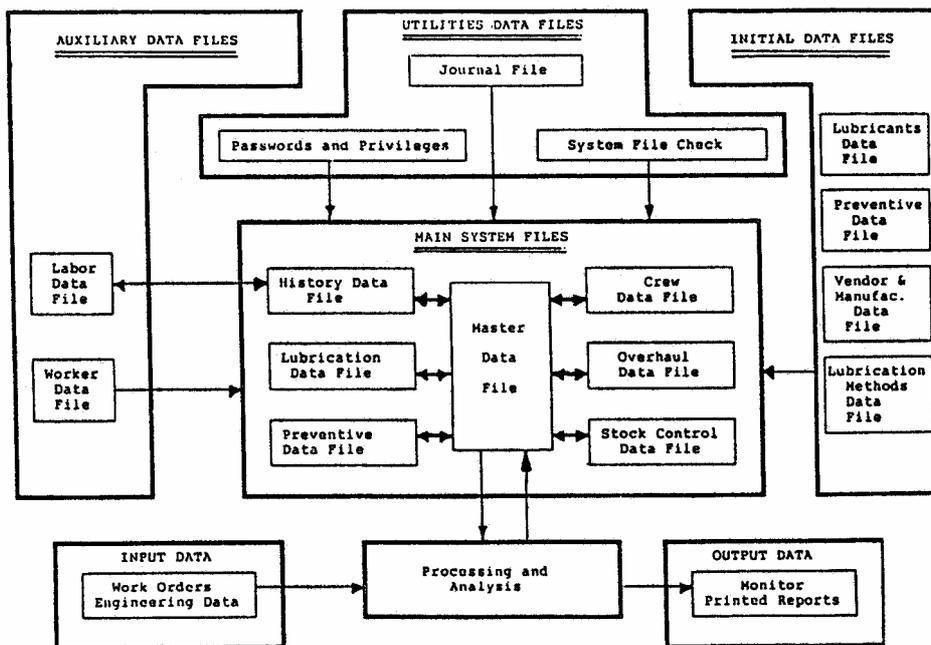


Fig. (7) Flow chart of the maintenance system