ABSTRACT

Expert System for Preventive Maintenance
The Aluminum Extrusion Press and Related Equipment

by
E - Ping Lin

ESPM is an Expert System for Preventive Maintenance that provides the framework for application-specific equipment maintenance tools. The expert system for preventive maintenance and diagnosis was developed for the Aluminum Extrusion Press and Related Equipment. The system is built in VP-Expert and is implemented on a personal computer.

The expert system includes many characteristics of an expert system cell because it can be expanded easily by adding new information to its knowledge base or by changing the existing information. The expert system can be connected directly with a PC system through a VP-Expert software package and can interact with C language, dBASE III plus and VP-Planner worksheet.

The basic ideas behind this expert system are to provide a non-expert with the necessary information and correct machine parts location. The system then leads the non-expert through periodical maintenance in a very friendly enviroment.

The main task of the expert system is to replace human expertise in maintenance processing and the preventive maintenance manuals of machine equipment with a very user-friendly personal computer enviroment. In addition, the system can take advantage of the user's accumulated experience to expand and modify the knowledge base of the expert system itself.

EXPERT SYSTEM FOR PREVENTIVE MAINTENANCE
THE ALUMINUM EXTRUSION PRESS AND RELATED EQUIPMENT

by
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This thesis is dedicated to
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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

CHAPTER 1
INTRODUCTION

One of the important problems in industry is the machine maintenance. Maintenance costs can significantly affect a company's profit and loss statement (1). That is why the mechanical engineer and maintenance manager must have accurate, timely information relating to labor, materials, and inventory costs involved in keeping the machine operating.

In many plants, a carefully structured and monitored preventive maintenance (PM) program has yet to become standard practice, although more than likely PM exits in some form. Keeping a piece of equipment operating at the lowest total maintenance cost while simultaneously prolonging its life is the objective of PM. Even plants without a formal program have someone who cleans, greases, oils, and adjusts critical machinery components, perhaps on a part-time basis (2).

Because PM is performed on a schedule without specific knowledge of any defect in the equipment, breakdown repairs are not part of PM. To maintain and operate a plant at the lowest cost with optimum efficiency, and to extend its life, a careful blend of preventive and breakdown maintenance is needed. Preventive maintenance is defined as routine, recurring work required to keep a facility and its equipment in such a condition that they can be used at original or design capacity or efficiency. Repair or breakdown maintenance, on the other hand, is the restoration of a facility and its equipment to a condition equal to original or design capacity and efficiency by replacing parts or materials after they have deteriorated.

The entire maintenance effort, then, can be divided into three types of work: Scheduled PM, which entails cleaning, making minor adjustments, lubricating, testing, measuring, and replacing minor parts; scheduled corrective maintenance, which includes overhauls, alterations, replacements, and correction of problems found by

PM inspections; and unscheduled breakdown maintenance (3).

To qualify as PM, a task must consist of prevoiusly defined work, such as lubrication, filter change, cleaning, etc., it must cost less than a predetermined budgetory limit for PM work and it must be suited to scheduling.

In recent years, expert systems have become the most visible and the fastest growing branch of Artificial Intelligence. The objective of these systems is to capture the knowledge of an expert in a particular problem domain, represent it in a modular, expandable structure, and transfer it to other users in the same problem domain. Current construction of expert systems begins with the knowledge engineer entering knowledge acquired from a human expert. The knowledge engineer tests the system on a set of test case and modifies the knowledge until the system achieves a desired level of performance.

Expert systems (ES) for diagnosis and maintenance of different classes of mechanical systems appeared fairly recent, so that they represent a new generation software for this domain. The present state in the application and development of expert system in this field is characterized by: first, incubation process in research institutions is coming to its end; second, fields of application are being widened (for instance, from computers and process facilities to FMS work stations); and third, intensified research aimed at the application of new techniques and artificial intelligence tools(4).

The Expert System for Preventive Maintenance (ESPM) can be invoked to initiate the diagnosis during periodic checking or at fault occurrence. This is done by selecting the corresponding entry of the MAIN MENU. Then the program asks the user to indicate the specific sections or parts that have to be maintained . In this way the program interacts with the user in order to arrive at correct diagnosis as regards the consequenses of the fault (analyzing possible damage to equipment) and to recommend actions which should be undertaken for repair. It is very easy to accumulate expertise in the expert system by continuously expanding the existing knowledge base of the system.

The main idea for the analysis of the method and building techniques of expert system for maintenance are presented in here and the following chapters. Chapter two is specific on the Preventive Maintenance and Expert System of the artificial intelligence field. Chapter three describes ESPM application examples. Chapter four contains the detailed explanation of the aluminum extrusion expert system design and implementation to ESPM . The last chapter contains conclusions and future work.

CHAPTER 2
EXPERT SYSTEM AND PREVENTIVE MAINTENANCE

2.1 Introduction of Preventive Maintenance

Preventive maintenance means all actions intended to keep durable equipment in good operating condition and to avoid failures. A good preventive maintenance (PM) program is the heart of effective maintenance. Success is often a matter of degree. The proper balance that achieves minimal downtime and costs can be reduced between preventive maintenance and corrective maintenance. Everything is going to fail at some time. PM can prevent those failures from happening at a bad time, can sense when a failure is about to occur and fix it before it causes damage, and can often preserve capital investments by keeping equipment operating as well as it did on the day it was installed

Inept PM, however, can also cause problems. Whenever any epuipment is touched, it is exposed to potential damage. It is excessively costly to replace components prematurely. Customers may perceive the PM activity as, "that machine is broken again." A PM program requires an initial investment of time, parts, people, and money. Payoff comes months later. While there is little question that a good PM program will have a high return on investment, many people are reluctant to pay now if the return is not immediate. PM supports a commitment to long-term lifecycle cost of ownership.

Emotions play a prominent role in preventive maintenance. We all realize that perceptions often receive more attention than facts. A good data system, either manual or computerized, is necessary to provide the facts that must guide PM. PM is a dynamic process. It must support variations in equipment, wear, environment, use, personnel, schedules, and material. Changes are taking place both in technology and in management. These changes both require and support preventive maintenance. Technology provides the tools, and management provides the direction for their use. Both are necessary for success. These concepts are equally applicable to equipment and facility maintenance and field service in commerce and industry.

2.2 Major Types of Maintenance

There are three main types of maintenance and three major divisions of preventive maintenance, as illustrated in Figure 2.1 (6).

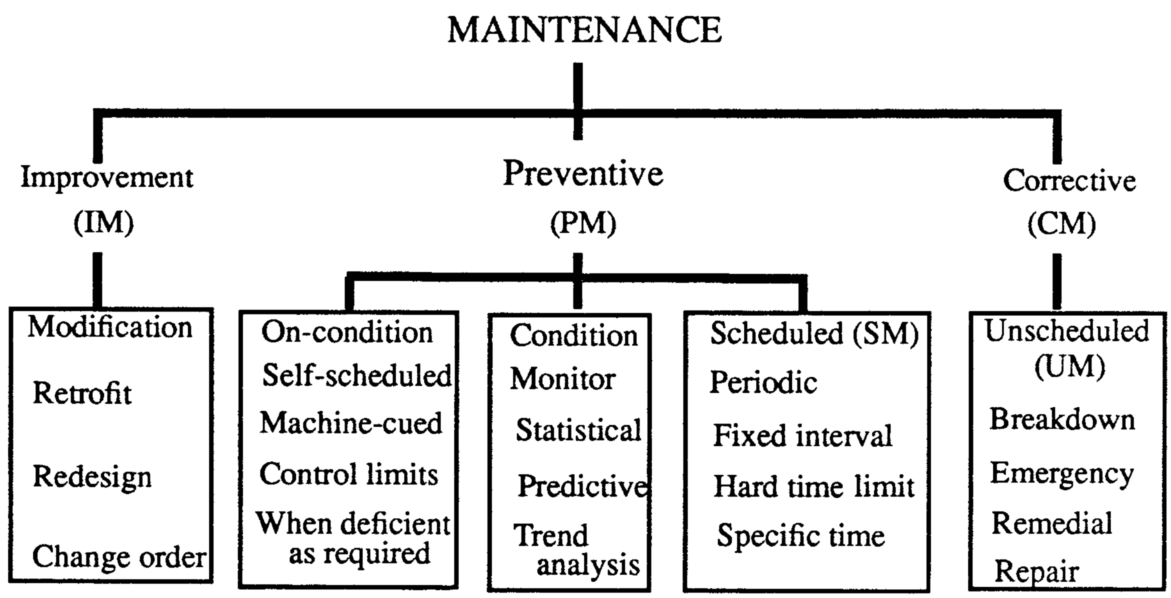

Figure 2.1

Structure of Maintenance

2.2.1 Improvement Maintenance

The figure 2-1 looks like five fingers on our hand. Improvement maintenance efforts to reduce or eliminate entirely the need for maintenance are like the thumb, the first and most valuable digit. We are often so involved in maintaining that we forget to plan ahead and eliminate the need at its source. Reliability engineering efforts should emphasize elimination of failures that require maintenance (7). This is an opportunity to preact instead of react. For example, many equipment failures occur at inboard bearings that are relocated in dark, dirty, inaccessible locations. The oiler does not lubricate those bearings as often as he lubricates those that are easy to reach. That is a natural tendency. One can consider reducing the need for lubrication by using permanently lubricated, long-life bearings. If that is not practical, at least an automatic oiler could be installed. A major selling point of new automobiles is the elimination of ignition points that require replacement and adjustment, introduction of self-adjusting brake shoes and clutches, and extension of oil-change intervals.

2.2.2 Corrective Maintenance

The little finger in the analogy to a human hand represents corrective (emergency, repair, remendial, unscheduled). At present, most maintenance is corrective. Repairs will always be needed. Better improvement maintenance and preventive maintenance, however, can reduce the need for emergency corrections. A shaft that is obviously broken into pieces is relatively easy to maintain because human decision is involved. Troubleshooting and diagnostic fault detection and isolation are major time consumers in maintenance (8). When the problem is obvious, it can usually be corrected easily. Intermittent failures and hidden defects are more time-consuming but with diagnostics the causes can be isolated and then corrected. From a preventive maintenance perspective, the problems and causes that result in failures provide the targets for elimination by PM. The challenge is to detect insipient problems before they lead to total failures and to correct the defects at the lowest possible cost. That leads us th the middle three fingers the branches of preventive maintenance.

2.2.3 Preventive Maintenance

2.2.3.1 On-Condition

On-condition maintenance is done when equipment needs it. Inspection through human senses or instrumentation is necessary, with thresholds established to indicate when potential problems start. Human decisions are required to establish those standards in advance so that inspection or automatic detection can determine when the threshold limit has been exceeded. Obviously, a relatively slow deterioration before failure is detectable by condition minitoring, whereas repid, catastrophic modes of failure may not be detected. Great advances in electronics and sensor technology are being made (9).

Also needed is a change in human thought process. Inspection and monitoring should disassemble equipment only when a problem is detected. The following are general rules for on condition maintenance (10):

-- Inspect critical components.

-- Regard safety as paramount.

-- Repair defects.

-- If it works, don't fix it.

2.2.3.2 Condition Monitor

Statistics and probability theory are the basis for condition monitor maintenance (11). Trend detection through data analysis often rewards the analyist with insight into the causes of failure and preventive actions that will help avoid future failures. For example, stadium lights burn out within a narrow range of time. If 10 percent of the lights have burned out, it may be accurately assumed that the rest will fail soon and should, most effectively, be replaced as a group rather than individually.

2.2.3.3 Scheduled

Scheduled, fixed interval PM should generally be used only if there is opportunity for reducing failures that cannot be detected in advance, or if dictated by production requirements. The distinction should be drawn between fixed interval maintenance and fixed interval inspection that may detect a threshold condition and initiate condition monitor PM (12). Examples of fixed interval PM include 7,500-mile oil changes and 12,000-mile spark plug changes on a car, whether it needs the changes or not. This may be very swateful since all equipment and their operating environments are not alike. What is right for one situation may not be right for another.

2.3 Advantages and Disadvantages

On balance, preventive maintenance (PM) has many advantages. It is beneficial, however, to overview the advantages and disadvantages so that the good may be improved and the negative reduced. Note that in most cases the advantages and disadvantages vary with the type of PM used. Use of on-condition or condition monitor techniques is usually better than fixed intervals.

2.3.1 Advantages

2.3.1.1 Management Control

Unlike repair maintenance, which must react to failures, PM can be planned ahead. This means "preactive" instead of "reactive" management. Work loads may be scheduled so that equipment is available for PM at reasonable times.

2.3.1.2 Overtime

Overtime can be reduced or eliminated. Surprises are reduces. Work can be performed when convenient.

2.3.1.3 Work Load

Work loads can be balanced to either spread the demand over the available resources, or to hire additional personnel and equipment to meet the demand (13).

2.3.1.4 Equipment Uptime

While PM may require an investment of as many maintenance hours as were required previously for corrective maintenance, equipment should certainly perform better and with much higher availability when it is needed. It is a truism that failures are rarely found until equipment is put to use. PM, done properly, will often detect failures that have occurred but that would not otherwise be found until that equipment is needed a rush jub.

2.3.1.5 Production

Naturally, production will be happy because downtime, shutdowns, scheduling, and personnel problems will be reduced. Access to equipment is often restricted to specific times dictated by production requirement. PM helps assure best possible use of revenue producing functions.

2.3.1.6 Standardization

The "one best way" to do PM tasks should be determined. Because of the repetitious nature of PM, the procedures may be improved upon and skills may be finely honed. Maximum learning should be established early if the same persons are consistently used to conduct PM. Like any task done frequently with proper guidance, PM can reach a high level of productivity. This also permits more accurate planning because the times will evolve into a relatively narrow target range. Costs, like most insurance policies, are predetermined within small limits (14).

2.3.1.7 Parts Inventories

Since PM permits planning of which parts are going to be required and when, those material requirements may be anticipated to be sure they are on hand for the event. A smaller stock of parts is required in organizations that emphasize PM compared to the stocks necessary to cover breakdowns that would occur when PM is not emphasized.

2.3.1.8 Standby Equipment

With high demand for production and low equipment availability, reserve, standby equipment is often required in case of breakdowns (15). Some backup may still be required with PM, but the need and investment will certainly be reduced.

2.3.1.9 Safety and Pollution

If there are no PM inspections or built-in detection devices, equipment can deteriorate to a point where it is unsafe or may spew forth pollutants. Performance will generally follow a saw-tooth pattern as shown in figure 2.2, which does well after maintenance and then degrades until the failure is noticed and it is brought back up to a high level (16). A good detection system catches degrading performance before it ever reaches too low a level.

2.3.1.10 Quality

For the same general reasons discussed above, good preventive maintenance helps to assure quality output. Tolerances are maintained within control limits. Naturally, productivity is improved and the investment in PM pays off with increased revenues.

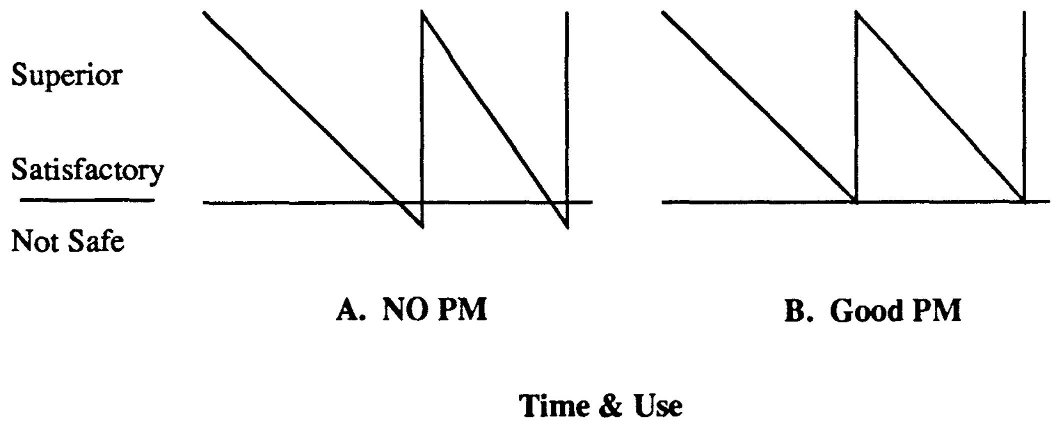

Figure 2.2 PM to keep acceptable performance

2.3.1.11 Support to Users

If properly publicized, PM helps show equipment operators, production managers, and other equipment users that the maintenance function is striving to provide a high level of support. Note here that a PM program must be published so that everyone involved understands the value of PM, the investment required, and their own roles in the PM system.

2.3.1.12 Benefit/Cost

Too often, organizations consider only costs without recognizing the benefit and profits that are the real goal. PM allows a three-way balance between corrective maintenance, preventive maintenance, and production revenues (17).

2.3.2 Disadvantages

In spite of all the good reasons for doing preventive maintenance, there are several potential problems that must be recognized and minimized.

2.3.2.1 Potential Damage

Every time a person touches a piece of equipment, there is potential for damage to occur through neglect, ignorance, abuse, or wrong procedures. Unfortunately, mush high reliability equipment is served by low reliability people. The DC-10 engine pylon failure, the Three Mile Island nuclear power plant disaster, and many less-publicized accidents have been affected by inept preventive maintenance. Most of us have experienced case or home appliance problems that were caused by something that was done or not done at a previous service call. This situation gives rise to the slogan: if it works, don't fix it.

2.3.2.2 Infant Mortality

New parts and consumables have a higher probability of being defective, or failing, than exists with the materials that are already in use (18). Replacement parts are too often not subjected to the same quality assurance and reliability tests as parts that are put into new equipment.

2.3.2.3 Parts Use

Replacing parts at PM, rather than waiting until a failure occurs, will obviously terminate that part's useful life before failure and therefore requires more parts. This is part of the tradeoff between parts and labor and downtime, of which the cost of parts will usually be the smallest component. It must, however, be controlled.

2.3.2.4 Initial Costs

Given the time value of money and inflation that causes a dollar spent today to be worth more than a dollar spent or received tomorrow, it should be recognized that the investment in PM is made earlier than when those costs would be incurred if equipment were run until failure. Even though the cost will be incurred earlier, and may even be larger than corrective maintenance costs would be, the benefits in terms of equipment availability should be substantially greater from doing PM.

2.3.2.5 Access to Equipment

One of the major challenges when production is at a high rate is for maintenance to gain aces to equipment in order to perform PM. This access will be required more frequently than it is with breakdown-driven maintenance. A good PM program requires the support of production, with immediate notification of any potential problems and willingness to coordinate equipment availability for inspections and necessary PMs.

2.4 Establishing a PM system

The necessary items for establishing a PM system are:

1. Every equipment uniquely identified by prominent ID number or serial number and product type
2. Accurate equipment history records
3. Failure information by problem/cause/action
4. Experience data from similar equipment
5. Maunfacturer's interval and procedure recommendations
6. Service manuals
7. Consumables and replaceable parts
8. Skilled personnel
9. Proper test instruments and tools
10. Clear instructions with a checklist to be signed off
11. User coorperation

12. Management

A typical initial challenge is to get proper documentation for all equipment. When a new building or plant is constructed, the architects and construction engineers should be required to provide complete documentation on all facilities and the equipment installed in them. Any major equipment that is installed after that should have complete documentation. Figure 2-4 is a checklist that should be given to anyone who purchases facilities and equipment that must be maintained. As can be seen, one of the items on this list is assuring availability of complete documentation and PM recommendations. Purchasing agents and facilities engineers are usually pleased to have such a checklist and will be cooperative if reminded occasionally about their major influence on life-cycle costs. This brings us back again to the principle of avoiding or minimizing the need or maintenance. Buying the right equipment in the beginning is the way to start. The best maintanability is eliminating the need for maintenance.

If you are in the captive service business or concerned with designing equipment that can be well maintained, you should recognize that the preceding has been aimed more at facotry maintenance; but after all, that is an environment in which your equipment will often be used. It helps to view the PM system from the operator's and service person's eyes to assure that everyone's needs are satisfied.

2.5 Scheduled Preventive Maintenance

Scheduling is, of course, one of the advantages to doing preventive maintenance over waiting until equipment fails and then doing emergency repairs. Like many other activities, the watchword should be "PADA", which stands for "Plant a Day Ahead" (19). In fact, the planning for inspections and PM can be done days, weeks, and even months in advance in order to assure that the most convenient time for production is chosen, that maintenance parts and materials are available, and that the maintenance workload is relatively uniform.

When most people think of PM, they visualize scheduled, fixed interval maintenance that is done every month, every quarter, every season, or at some other predetermined intervals. That timing may be based on days, or on intervals such as miles, gallons, activation, or hours of use. The use of performance intervals is itself a step toward basing PM on actual need, instead of just on a generality.

The two main elements of fixed interval PM are procedure and discipline. Procedure means that the correct tasks are done and the right lubricants applied and consumables replaced at the best interval. Discipline requires that all the tasks are planned and controled so that everything is done when it should be done. Both these areas deserve attention.

Discipline is a major problem in many organizations. This is obvious when one considers the fact that many organizations do not have an established PM program. Further, organizations that do claim to have a program often fail to establish a good planning and control procedure to assure accomplishment. Elements of such a procedure include:

1. Listing of all equipment and the intervals at which it must receive PM.

2. A master schedule for the year that breaks down tasks by month, week, and possibly even to the day.

3. Assignment of responsible persons to do the work.

4. Inspection by the responsible supervisor to make sure that quality work is done on time.

5. Updating of records to show when the work was done and when the next PM is due.

6. Follow-up as necessary to correct any discrepancies.

Note that there are variations within the general topic of scheduled fixed interval maintenance. Some tasks will be done every Monday whether or not they are necessary. Inspection may be done every Monday and PM tasks done if a need is indicated. Seasonal maintenance may be directed by environmental changes rather than by strict calendar date (20). Use meters, such as an automobile odometer, allow quantitative measure of use that can be related to the parameters that will need to be maintained. One must consider the relationship of components to the meter readings: for example, a struck's need for maintenance will vary greatly depending on whether it is used for long hauls or for local deliveries. A struck that is started every few miles and driven in stop-and-go, dusty city conditions will need more frequent mileage maintenance than the same truck used for long trips of continuous driving.

Seasonal equipment such as air conditioners, lawn mowers, salt spreaders, and snow blowers require special maintenance care at the end of each season in order to clean and refurbish them and store them carefully so that they will not deteriorate and will be ready for the next season. A lawn mower, for example, should have all gasoline drained from the tank and then be run until it stops because it has completely run out of fuel. This assures that gasoline is completely removed from the lines. Oil should be changed. The spark plug should be removed and the cylinder through the spark plug hole and the cylinder pulled through several strokes to ensure that it is well lubricated. The spark plug should be put back in its hole loosely. Grass, dirt and other residur should be put back in its hole cleaned from all parts of the mower. The blade whould be sharpened and checked to see that it is in good balance. The mower should be stored in a dry place until it is needed again. Then, when the grass starts growing, all one has to do is fill the tank, tighten the spark plug, and connect the ignition wire. The motor should start on the second try. Careful preparaton of equipment for storage will pay a major dividend when the equipment is needed in a hurry.

2.6 Introduction to Expert Systems

Expert systems are a specialty within the field of artifical intelligence (AI). Other specializations include robotics, natural language understanding, visual pattern recongnition, theorem proving, knowledge representation, planning, and problem solving. Sometimes the terminology may be somewhat misleading because the technical sense differs from the ordinary meaning. For instance, planning in AI refers to a class of graph search strategies and heuristics (rules of thumb). Indeed, the term artificaial intellignece itself is somewhat deceptive. Originally, AI set out to be a method for exploring aspects of problem-solving tasks and observing their behavior. However, the more recent developments in artificial intelligence have focused on making computers "smarter," whether they behave as humans do or not. This is especially true in the area that has received the most attention from a commercial standpoint, namely, expert systems. Often, in fact, it is the way an expert system differs from human behavior that makes it valuable; for instance, we would not want an expert system to panic in an emergency situation.

Within AI, the term expert system refers to a class of applications, rather than a particular representation or implementation technique. In these applications, the computer program is intended to model the performance of a human expert in his or her specialized task. Expertise in this sense is usually based on long and specialized training, tempered and refined through experience, such as that of medical doctors, engineers, and scientists. The experience to date with various prototype expert systems is that they do very well in capturing the textbook knowledge of an expert's training, but less well in solving problems in which the experienced expert's intuitions are called into play. However, such systems are nonetheless quite valuable; while they cannot replace human experts, they can complement them in an advisory fashion. For instance, in medical applications, expert systems can offer the doctor a "consulting opinion," serving to remind him or her of the standard procedures to follow for a given set of symptoms, providing information about possible emergency procedures in, say, chemical or nuclear plants, complementing the intuitions and experience of the human operators.

One technology that has become popular for implementing expert systems consists of rule-based systems. A rule-based system is a kind of computer program in which the problem domain (the facts and knowledge relating to the problem to be solved) is described not as a sequence of steps, as in conventional programming languages, rather as a set of rules. These rules are order independent, or declarative. The computer uses them as it needs them to deduce a solution to the problem. Thus, the rule base is searched by addressing a specific problem, rather than by following a fixed procedure.

Rule-based systems are most commonly used to provide advice or recommendations to the user about some problem. When this advice is comparable in quality to that of a human expert in the same subject area, we refer to the system as an "expert" system. Of course, expertise is a relative term, and people may disagree as to when it is used appropriately. However, even if the system does not perform at the level of broad expertise, it may nonetheless provide useful advice in a more specific area. A more modest term often used for these types of applications is rule-based advisory systems.

The first rule-based expert systems were developed with a specific problem domain in mind, i.e., medical diagnosis (21). Later it was recognized that other problem domains could also be modeled with the same rule structure. For example, troubleshooting automotive problems is also a diagnostic problem. This led to the concept of and expert system "shell"--a computer program that enables the user to create his or her own rule-based system. VP-Expert is an example of such a rule-based shell. More details about using VP-Expert are introduced in chapter 4.

2.7 Avoiding Mistakes on Implementing Expert System

There are a number of mistakes that should also be avoided when implementing expert systems like these. First, don't use an expert system to solve a problem taht is not appropriate for the technoloty. Even though expert system shells typically have a full range of arithmetic and trigonometric functions, trying to solve a computationally intensive porblem with an expert system shell is inefficient. Further, most expert system software is ineffective for data base management, spreadsheet analysis, graphics generation, and so on. These activities can best be performed by somehow linking the expert system to another program.

Second, don't try to solve a problem with a scope that is too large. Expert systems do not cope well with large, vaguely defined problems. Instead, identify the worst problems or bottlenecks in the production process and eliminate those first. Expert system applications have a tendency to grow and evolve. If users select a problem that initially appears too small, they wil probably find that over time it expands to a size more appropriate for solution by an expert system.

Third, don't try to solve a problem without the help of a willing expert. Attempting to implment an effective expert system in the harsh physical condition of a factory is difficult enough. If a cooperative expert is not readily available, development of a successful expert system is probably impossible.

Fourth, don't ignore the iterative nature of the development process. Include enough time in the development program for reviewing the system with both the expert and the intended users. By doing so, managers may reduce the amount of time needed for initial system construction accordingly.

Fifth, don't assume that novice and expert users will be satisfied with the same user interface. Often, after users have operated an expert system a few times, they become impatient with menu-driven "idiot-proof" user interfaces. The sheer number of keystrokes can be a barrier to effective use. Be sure to investigate short-cuts beyond those provided by help screens, diagrams, and menus.

And finally, don't forget that expert systems work best when performing routine tasks. By taking over the drudgery encountered with most jobs, expert systems allow human experts to devote most of their time to the creative and challenging tasks for which they were trained and hired.

2.8 Designing ESPM

The basic problem in the building of an expert system is how to transfer the knowledge based on experience and physical rules with the knowledge acquisition method into the ES knowledge base. The following describes the knowledge acquisition process for the building and construction of an expert system with knowledge engineering techniques with five stages. They are briefly analysed, as they were respected in the building of ESPM as well.

The identification represents the first phase which defines further work on the construction of an expert system. In this phase the following groups of questions and answers are defined: the participants and their role in the ES development, characteristics of the problem to be analysed, the resources and the goals. Here we have two groups of participants: experts for maintenance and other engineering disciplines relevant for this field and the knowledge engineers. They jointly identify the problem (maintenance domain for which ES is to be developed), determine the structure of knowledge for the knowledge base (type and form of rules), data groups (computer maintenance structure, spare parts, diagnostic procedures, maintenance technology) used as the sources of knowledge for the forming of rules with the aid of expert knowledge of maintenance engineers, construction engineers and other specialists. Computer resources have a very important role in the building of expert systems (22). The existing computer and program languages are not sufficiently suitable for the knowledge engineering process. Therefore special program languages and tools were developed for ES. A similar statement also applies to the existing hardware. The development of the fifth generation of computer as a non-Von Neumann machine should provide condition for more comfortable work, particulary in the knowledge engineering phase (23).

The conceptualisation is the second phase in the ES knowledge engineering process in which knowledge representation concepts are defined aimed at giving the answer to the following questions: the type of available data (information bases about the mechanical system, diagnostic signals, documentation, maintenance manuals), identification hypotheses in use (the planned or corrective maintenance strategy), the relationships of objects in the defined field (i.e. the structure of the mechanical system to be maintained), information flows (e.g. in condition-based maintenance) and the definition of problem-solving knowledge concept (e.g. meta knowledge used for the solution justification. Each of these questions represents an extensive work on behalf of maintenance experts and knowledge engineers although in this phase the programme domain of the expert system is already in the process of forming. On the basis of concepts defined in the preceding phase the designing of the structure for knowledge organization is taking place through the formalization phase which includes three important factors: hypotheses space, process modelling and data characteristics. The definition of hypotheses space is defined on the basis of facts and ideas of formost significance for problem solution (diagnostic results out of the set of symptoms reacting on the condition of a mechanical system or its component elements). With the discovery of the rule regularity of the process model the solution for a process may be generated, that is the establishing of resoning procedures. The understanding of the nature of data in the problem-solution domain enables confirmation of their indefiniteness, the accuracy of their logical interpretation, characteristics of data from different sources (diagnostic signals, maintenance manuals), as well as their reliability, accuracy and precision. With the completion of this phase the prototype of the knowledge base is built.

The application phase implies a developed ES prototype, which means that the knowledge base has been built. It also means that the knowledge representation has been defined (in the field of maintenance production systems are presently most frequently involved). System inconsistencies are registered and removed, with the testing of different alternatives.

The last phase relates to the testing of the developed system on a real example, going from simple towards more complex cases (e.g. diagnosis of failure on MC tool magazine, and diagnosis of the overall MC mechanical structure). In this phase particular attention is paid to the establishing of the degree of rule interconnection and the consistency of inference rules (e.g. strategic rules for scheduling of planned maintenance and pruduction control).

For each of these phases there exist back connections enabling improvements during each step.

CHAPTER 3
ESPM APPLICATION EXAMPLES

This chapter introduces examples of how the ESPM system is used throughout the VP-Expert program in the Aluminum Extrusion industry for installing, for trouble shooting and for maintaining effective machine maintenance. This ESPM system can help equipment operators, maintenance technicians and facility managers without any need of assistance from expert programmers. In this system, I divide the Aluminum Extrusion machine and related equipment into six main sections (Press, Container, Stretcher, heating, Handling, and Painting). Each section contains a different number of parts and equipment. The lifetime of each part or equipment can be reported, diagnoseed and cleared by PM or troubleshooting hints. The following sections of this chapter provide scenarios of examples which demonstrate the way this system operates.

3.1 Case Study on an Operator

Mr. Jackson, an Aluminum extrusion equipment operator, is an employee of the North American Aluminum Extrusion Company. He works from 9:00 AM to 5:00 PM every weekday. Today, Jan. 10, 1992, he works on the daily schedule as usual. At 9:10 AM, he goes to the operating manager to get the schedule which shows his working quantity for today. He has to operate and maintain equipments. The daily schedule of maintenance is shown in the table 3.1.

About half year ago, he had to read every page of the maintenance manual and to follow the directions on it step by step. The reason was that his company never used computer Integrated Manufacturing (CIM) or Preventive Maintenance concept at that time. Without them, he always had to spend more than half day to check his

Table 3.1
Schedule of Maintenance

NORTH AMERICAN

ALUMINUM EXTRUSION COMPANY

EQUIPMENT : ALUMINUM EXTRUSION MACHINE #3

USER : JOHN JACKSON

MAINTENANCE DATE : JAN. 10, 1992

Main Section	**Sub-main Section**	**Minimum check period in the section**	**Last checking date**	**Last Report**	**Today check Report**
Press	Mechanical	Weekly	01/03/92	No Prob-lem	
	Hydraulic	Monthly	12/20/92	No Prob-lem	
	Electrical	Weekly	01/03/92	No Prob-lem	
Container	Container Liner Stem	Weekly	01/03/92	Adjust #1	
.	.	.	.	.	

. . . . .

. . . . .

equipments and problem shootings. Additionally at the occurence of the trouble event, he had to stop operation and call maintenance technicians. The company was loosing lots of dollars from profit on such events.

Now, with CIM and PM concept, his work is much more simplified. He has to get daily worksheet from computer printout and to use ESPM systemthrough VP-Expert software package and Personal Computer (PC). Now he finishes the daily maintenance within a few minutes and reports checking results.

WELCOME TO THE ESPM SYSTEM

THIS PROGRAM WAS MADE BY **** E - PING LIN ****
THE PROGRAM IS SPECIAL FOR ALUMINUM EXTRUSION
MACHINE VERSION 1.0

THE FOLLOWING WILL SHOW YOU PICTURES OF THIS
MACHINE

AFTER YOU SEE EACH PICTURE, TYPE N TO GO TO NEXT PIC-
TURE AND QUIT THE VIEW . . .

DO YOU WANT TO SEE THE PICTURE?
YES NO

Figure 3.1

First Screen of the Equipment Maintenance System

At 9:20 AM, he invokes the ESPM equipment maintenance system to examine and report the machine maintenance. Figure 3.1 shows the first screen of the equipment maintenance system. This screen is called the Picture Decision Controller (PDC). It controls the system by either showing equipment drawing or not showing them, and then goes to examine each sections directly.

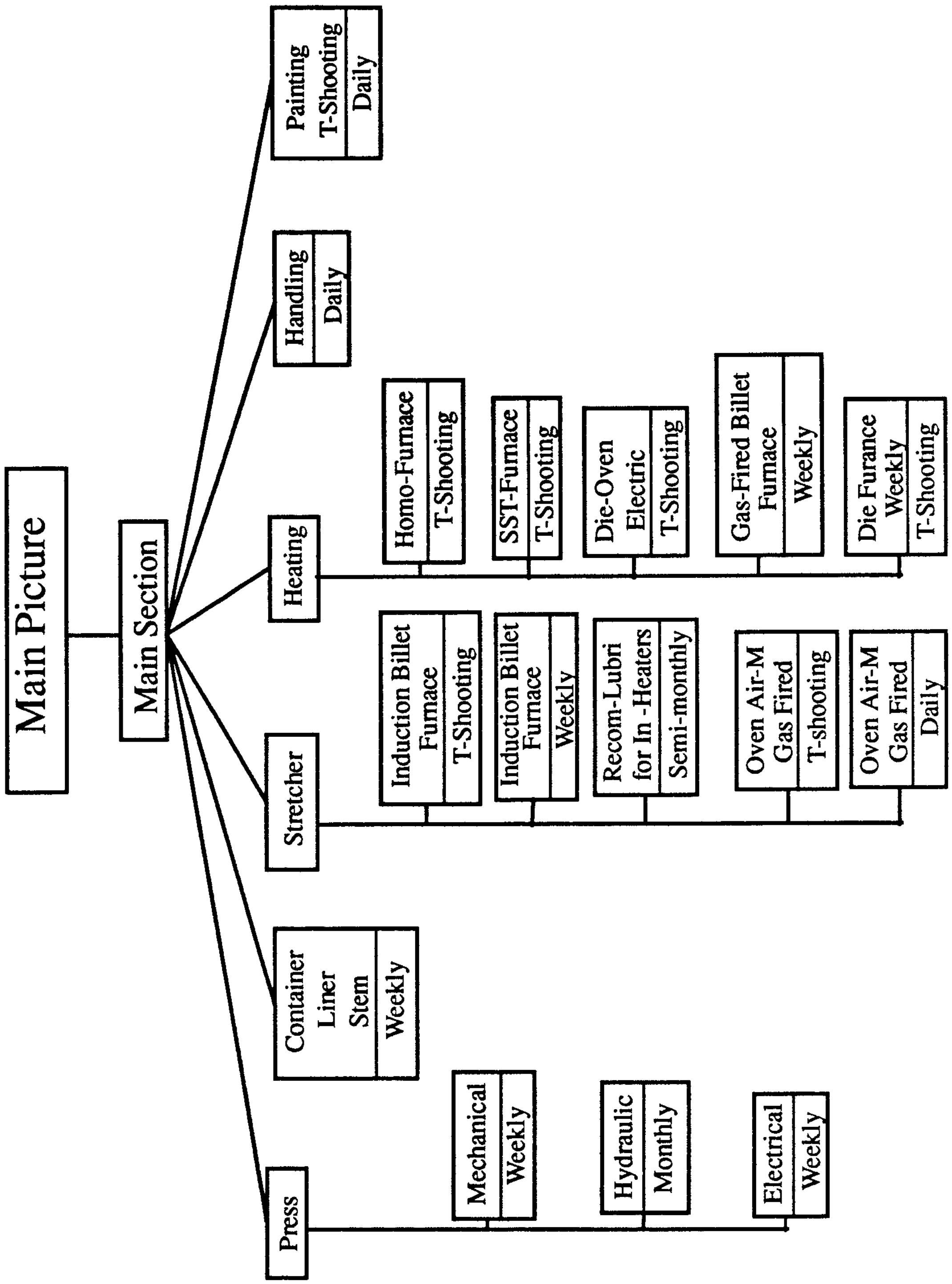

Figure 3.2

Structure of System

Mr. Jackson needs to check all equipments today. Therefore he chooses YES for his response screen shown in figure 3.1. From this response, he is able to view the diagram of all the equipment on the screen. Figure 3.2 shows one of these diagrams. He can select today's maintenance by marking the parts that need to be checked. The system then continues to show the six main sections on the screen. He checks each section by moving the cursor and then pressing the enter key. He decides to check the Press section and the system shows the Display Decision Control (DDC). He chooses NO from the screen in order to skip the display of all checking

Table 3.2

List of Examine Parts

NORTH AMERICAN
ALUMINUM EXTRUSION COMPANY

EQUIPMENT : ALUMINUM EXTRUSION MACHINE # 3
USER : JOHN JACKSON
MAINTENANCE DATE : JAN. 10, 1992
MAIN SECTION CHECK : THE PRESS
SUB-MAIN SECTION CHECK : MECHANICAL

#	PARTS	Last Checking Date	Checking Period	Last time Diagnosis	Today's Diagnosis
1	Stem	01/03/92	Weekly	No Problem	No Problem
2	Billet	01/03/92	Weekly	No Problem	No Problem
3	Container	01/03/92	Weekly	No Problem	Readjust
4	Tooling Pressure Plate	01/01/92	Monthly	Adjust Parallel	X
5	Stem Pressure Plate	01/01/92	Monthly	No Problem	X
6	Tie Rod Nuts	01/01/92	Monthly	No Problem	X
.	.	.	.	.	.
.	.		.	.	.

periods and parts because he knows all the previous data and parts from the worksheet. The Table 3.2 shows the worksheet that lists some part to be examined.

There are three main fields of examination in the Press seciton: Mechanical, Hydraulic and Electrical. While reading the display of the screen, users can press M for mechanical, press H for hydraulic, press E for electrical or press Q for quit and go back to the main menu. If they make a mistake on pressing the key, the system will bring them back to the re-press screen. Mr. Jackson presses M to begin the mechanical examination. The system prompt will show him the colorful screen. The series of labels are on the bottom of the screen. Figure 3.3 shows the sample of the screen.

Welcome to the Expert System consultant center.

This Expert System is only for the Aluminum extrusion

press and relate equipment

This Example menu is only for the PRESS periodic Mechnanical preventive maintenance check list (include check for wear and fatigue).

You will see a series of labels on the bottom of the screen. Pointing and clicking on these with the mouse will cause the corresponding hypertext the **INDEX & INDEX1** to be displayed or the program to end.

Previous	**Index**	**Help**	**Edit Area**	**Exit**

Figure 3.3
Sample of Hypertext Screen

Users only need to point and click using a mouse on these lables to selecte them. These lables are areas for Index, Help, Previews, Exit, and Edit. The Edit area is specially for PC systems which lack the coumputer mouse. Users can type comments in the Edit area and then press enter key to get the same result as using the mouse. The screen will cause the corresponding hypertext. When users click Index button on the buttom of screen or click the color Index text on the screen, they will get a list of parts and parts' checking periods on the screen. Each part and funtion key shows the color that differs from the common text. Users can click the color text to know a more detailed description and checking method. Figure 3.4 shows a example of this screen.

TOOLING PRESSURE PLATE :

CHECK PERIOD = EVERY MONTH

CHECK = STRAIGHTEDGE AND FEELER.

CHECK METHOD = Check for dishing or coining.

REMEDY = Remove from press and grind. Add shim when required.

Previous	**Index**	**Help**	**Edit Area**	**Exit**

Figure 3.4
Sample of Parts Checking

Mr. Jackson follows the screen description and does the necessary checkings for today's part maintenance. For instance, when he wants to check the Main Cylinder Packings, he first checks whether it is worn or not. The checking method for finding the wear is to check for sudden increase in leakage and scores on ram. Mr. Jackson finds the material has a little wear, therefore he asks the maintenance technician to come. The technician can find the solution under the name 'Remedy'.

Remedy introduces the method to deal with the problem. Figure 3.5 shows the remedy for the occurance of wear on the Main Cylinder Packings from the ESPM maintenance system. Every person who needs any information can use the user friendly screen to find it. Finally, Mr. Jackson puts the reports and diagnosis results into the worksheets and finishes today's maintenance task.

MAIN CYLINDER PACKINGS :

CHECK PERIOD = EVERY WEEK

CHECK = WEAR

CHECK METHOD = Check for sudden increase in leakage and scores on ram.

REMEDY = Stone smooth immediately; make sure to wash off. Repeat when convenient

Previous	**Index**	**Help**	**Edit Area**	**Exit**

Figure 3.5
Sample of Remedy

3.2 Case study on maintenance manager

Mr. Brown is a facility maintenance manager and supervisor of the North American company. He works from 9:00 AM to 5:00 PM every weekday, same as Mr. Jackson. On October 15, 1991, he had to do the sample survey. From the schedule of computer system, he found he had to survey the Aluminum extrusion equipments. The schedule of computer system also told him that he should do the survey on the Press section of the Aluminum extrusion machine.

Mr. Brown invoked the ESPM equipment maintenance system on the

Aluminum extrusion equipment. At the beginning, the system showed him the Picture Decision Controller (PDC). It asked him to make a decision whether he wanted to view the equipments' pictures or not. When he had chosen YES, the ESPM equipment maintenance system would display the Aluminum extrusion equipment pictures on the screen. Figure 3.6 shows the first picture on the screen. This picture divides every different section into a different color. From the screen Mr. Brown could easily find where the Press section is. Then the system could continue by bringing him into the Press section.

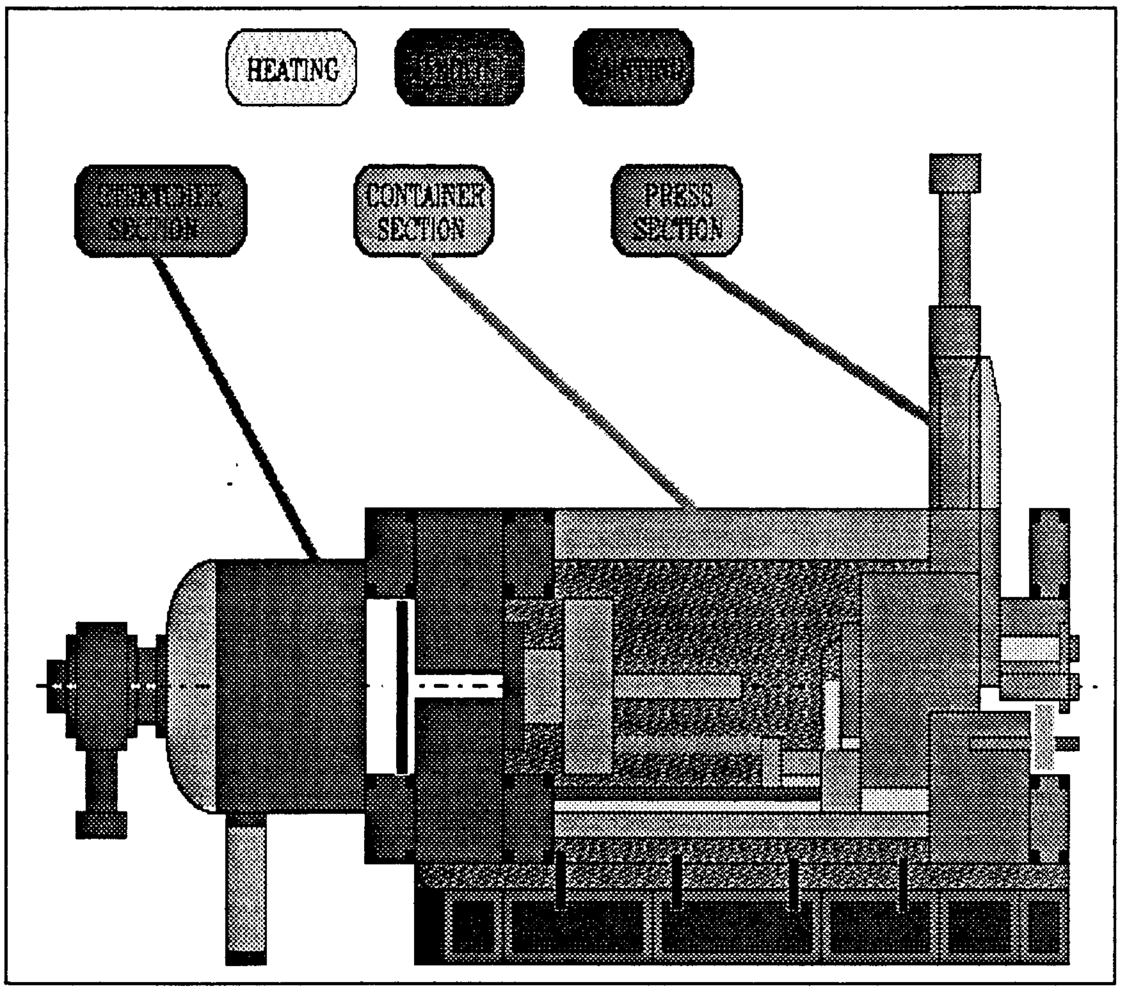

Figure 3.6

Sample of Machine Picture

In the Press section, the ESPM equipment maintenance system asked Mr. Brown if he wanted to see the display of all parts of this section. Mr. Brown selected YES on the Display Decision Controller (DDC). The system then showed a list of all parts and the parts' checking periods on the screen. Figure 3.7 shows part of the listing parts. When users click the bold face text on the screen, the expert system will show them the current optimun maintenance method.

THERE ARE THREE KINDS OF CHOICES IN PRESS SECTION:
MECHANICAL, HYDRAULIC, ELECTRICIAL CHOICES

****

THE MECHANICAL SECTION INCLUDES THE FOLLOWING PARTS:

--WEEKLY CHECK--------------------------------

1.STEM **2.BILLET** **3.CONTAINER**

--MONTHLY CHECK-----------------------------

4.TOOLING PRESSURE PLATE **5.STEM PRESSURE PLATE**
6.TIE ROD NUTS **7.ADVANCE CYLINDER LOCK NUTS**
8.CROSSHEAD TRAVEL

-------------------------------------SEMI-YEARLY CHECK---------------------------

9.PRESS BASE **10.PRESS FRAME** **11.CONDITION OF RAMS**
12.ALL WAYS AND GUIDES AND TRUNNIONS
(CROSSHEAD, CONTAINER, DIE SLIDE, SHEAR, BILLET LOADER)

---------------------------------------YEARLY CHECK---------------------------------

13.TIE RODS

--- *PLEASE PRESS ANY KEY TO CONTINUE DISPLAY THE MECHANICAL SECTION*---

Previous	**Index**	**Help**	**Edit Area**	**Exit**

Figure 3.7
Sample of Parts List on Hypertext

After Mr. Brown viewed all the parts in the Press section, he decided to survey some parts of the Hydraulic section from the previous maintenance survey data reports. Once he selected the Hydraulic section, the system displays it on the screen. The screen shows the colorful list of the parts and the parts' checking periods. The series of labels are shown on the buttom of the screen. Figure 3.8 shows the screen.

The hydraulic system covers the pumps, tank, valves, oil and piping
The following is hydraulic system maintenance check list
(1)MAIN CHECK LIST
--------------------------------EACH SHIFT------------------------------
1.OIL_LEVEL 2.OIL_LEAKS 3.OIL_TEMPERATURE
4.ERRATIC_OPERATIONS
--------------------------------EACH WEEK------------------------------
5.OIL_FILTERS 6.HEAT_EXCHANGER
7.HEAT_EXCHANGER_TEMPERATURE_--_FLOW CONTORL_VALVE
8.FLEXIBLE_HOSES_FOR_DAMAGE_AND_DETERIORATION
--------------------------------EACH MONTH----------------------------
9.AIR_BREATHERS 10.HYDRAULIC_TUBE_CONNECTIONS
11.SOLENOIDES 12.CLEAN_EQUIPMENT
---------------------- MORE INDEX IN INDEX1 -------------------------

Previous	Index	Help	Edit Area	Exit

Figure 3.8

Sample of the Listing Parts

Mr. Brown just needed to point and click on those buttons or click on the screen of the color text with a mouse. The screen would cause the corresponding hypertext. Then he could get the list of those parts' information and compared with the previous diagnosis reports. After he got all the information from the system and the printout data from the printer, Mr. Brown called the maintenance technician to go with him to survey the Aluminum extrusion equipment group. Once he found a fault from the equipment parts, he could tell the technician what to do and how to do the trouble shooting. Finally he would update the system and then update the new report into the worksheet data.

CHAPTER 4
SYSTEM DESIGN AND IMPLEMENTATION TO ESPM

4.1 System Configuration

The Expert System for Preventive Maintenance system consists of four main modules :

—— Knowledge Base for Aluminum Extrusion equipment

—— Database and Worksheet tools

—— VP-Expert software package programming

—— PC-386 with VGA monitor

The following sections explain the system's four modules.

4.1.1 Knowledge Base for Aluminum Extrusion equipment

The maintenance knowledge base has been developed from the accumulated expertise of an expert maintenance engineer.

4.1.2 Database and Worksheet tools

The main section of the PM system was installed in the database using DBase III Plus.

All parts and sections of the equipment information were entered in the worksheet tool using the VP-Planner 3D software package.

4.1.3 VP-Expert software package programming

The VP-Expert software package program using the VP-Expert 3.0 professional version connects all modules by a powerful programming chaining system.

4.1.4 PC-386 with VGA monitor

For more efficiency and economy, a PC-386 with a VGA monitor is the best choice for this ESPM system.

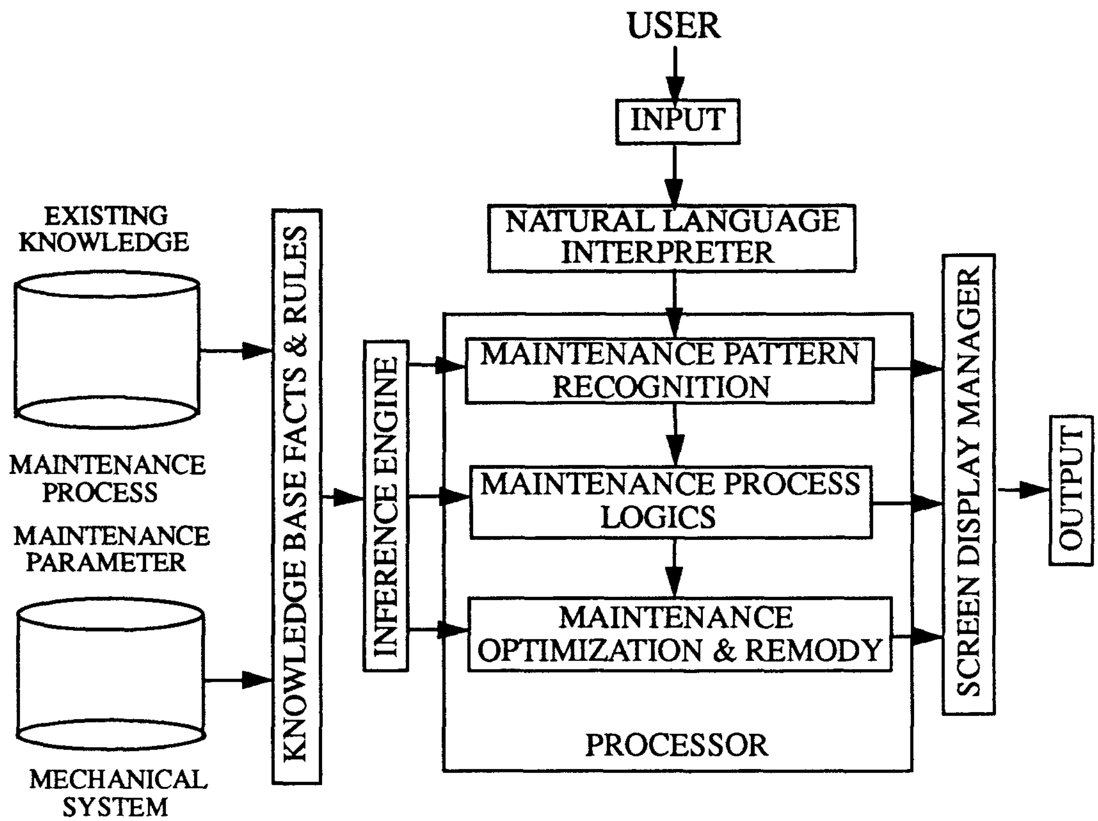

Figure 4.1

Structure development of ESPM

4.2 System Development

Figure 4.1 shows the structure development of the ESPM system and the following describe the system development.

First, one has to get the maintenance and troubleshooting manuals of the equipment. Second, the maintenance knowledge has to be transferred and transformed into the knowledge base (VP-Expert). Third, the knowledge base program is coordinated with the database and worksheet data. Then it calculates and analyzes data. Then the program also updates new data back into the system. Finally, the system's expansion capability uses the Designer graphic tool display to show all parts and equipment when needed.

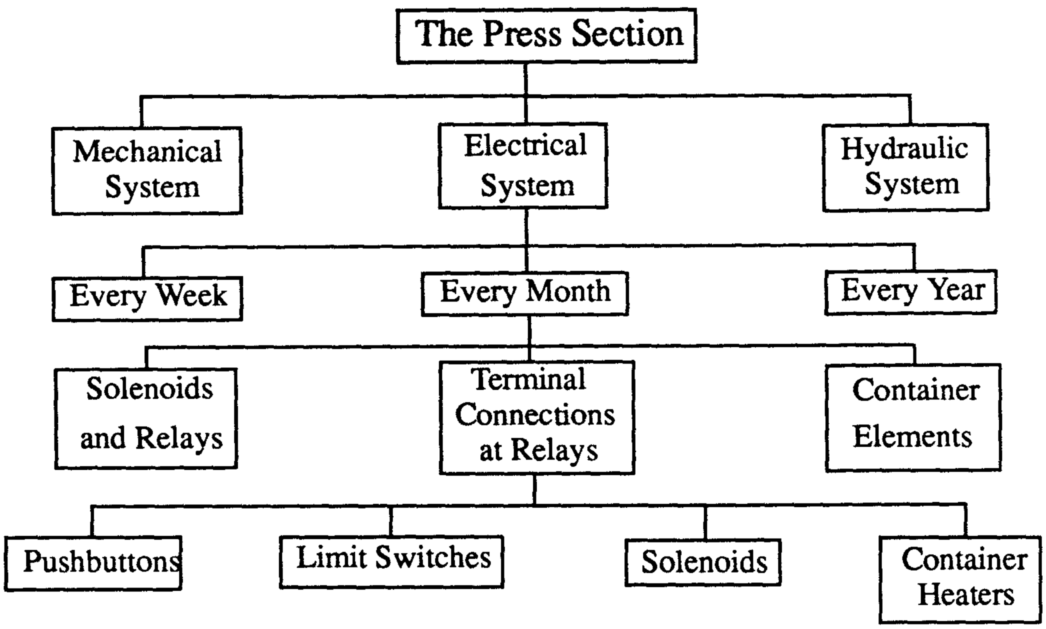

Figure 4.2

Hierarchy of Subsystem

4.3 Configuration of Knowledge Base

The reliability of an expert system relies on the quality of the Knowledge Base. A hierarchical reduction model was used to model the knowledge for the ESPM of Aluminum Extrusion equipment. The domain experts and knowledge engineer broke the system into subsystems of function buttons. Each button is called a process button and the process button indicates the name of the maintenance part or equipment. A portion of this hierarchy of subsystems can be seen in figure 4-2. All of these buttons can be seen on the computer screen, showing all the existing information and experience concerning the specific problem, and can be clicked by a mouse

Another important part of the Knowledge Base in the system is the ability to compare and update worksheet data.

4.4 Evaluation of current Hypertext System

4.4.1 Hypermedia Utilization

Once we have adequate models of hypermedia and design guidelines for how applications should be developed, we need to consider how the hypermedia will be utilized. Like many software applications, hypermedia systems will generally require a certain amount of training and they will be targeted at different types of users who may use the hypermedia in different ways for different purposes(24).

4.4.2 Strengths of hypertext

The strengths of hypertext arise from its flexibility in storing and retrieving knowledge. Any piece of information, whether it be text, graphics, or numerical data can be linked to any other piece of information. Hypertext is an extremely powerful information management tool because one is able to represent knowledge, browse, carry out structured searches, and make inferences, all within the same environment.

4.4.3 Features of current hypertext

The features of current hypertext that implement this powerful structuring capability are

1. A network of nodes.

2. A set of links that creates relations between nodes.

3. Authoring tools that allow users to build links and nodes out of new material or existing text.

4. Windowing screen facilities that allow one to view one or more nodes by using the PC mouse clicking nodes.

4.5 Expansion of the system

The system use VP-Expert to be the main connector. It has very powerful communication ability with others software packages or DOS programming languages. In this ESPM system, we have numbers of equipments (main equipment being Aluinum Extrusion machine), ability to exchange data with dBASE III Plus database files and VP-Planner 3D files, and display the graphics of equipment by using Designer graphic tool.

When new equipment is placed in the work station, a knowledge engineering team should be asked to encode the information included in the periodical maintenance manual, troubleshooting manual and accumulated experience (e.g. rules of thumb) concerning the specific new equipment. So, the ESPM system can be expanded for whole factory maintenance system by encoding all equipment informations.

CHAPTER 5
CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

This thesis successfully demonstrates how a Expert System for Preventive Maintenance (ESPM) works on Aluminum Extrusion equipment. ESPM is developed using VP-Expert, fully utilizing its features such as its rule-base programming, graphics capability and ability to execute external software package.

The construction of the hierarchical knowledge base is object-oriented hypertext programming. The graphics or tables are attached to the machine parts, sections or equipment. The yes - no decisions are requested when related support of the checking are invoked. The diagnositic solution is generated when the problems are identified. The object - oriented style of the knowledge base eases the task of adding knowledge to the system and also greatly facilitates the construction of other equipment maintenance systems.

Since ESPM considers the preventive maintenance of an equipment, it can very easily to adapted to other equipment besides Aluminum Extrusion press. ESPM has great potential to become a large - scale equipment maintenance system for all the equipment in the production line. In this way, ESPM could integrate and standardize the maintenance of all pieces of equipment in the production environment providing the advantage of central control, quick adaptation and easy maintenance.

Currently, a specific ESPM has been built for the Aluminum Extrusion press and related equipment. The knowledge-base size is more than 200 objects which include the parts in hypertext. The ESPM for Aluminum Extrusion press and related equipment will run on the manufacturing floor within half a year.

5.2 Future work

ESPM is currently designed to do off - line equipment diagnosis specific for preventive maintenance. The troubleshooting capability and PM period of the equipment could not give enough information on every part. Therefore, a complete expertise record has been investigated and will be the natural next - step for this system.

ESPM will also very likely interact with the data automation projects. The purpose is to store equipment diagnosis data into a worksheet management system (VP - Planner 3D) for both data analysis and equipment diagnosis for automatic statistical preventive maintenance control (SPMC) of the equipment.

APPENDIX A

Sample Program for Connecting Main Picture

```
*******************************************************************

!---------------------- MAIN.KBS -------------------------
!--------MAIN PROGRAM FOR CONNECTING PICTURE---------
!EXECUTE;
RUNTIME;
ENDOFF;
BKCOLOR = 3 ;
!-------------------------------------------------
ACTIONS
   DISPLAY "
--------------------------------------------------
         WELCOME TO THE ESPM SYSTEM
--------------------------------------------------
    THIS PROGRAM WAS MADE BY **** E - PING  LIN ****
--------------------------------------------------"
   DISPLAY "THIS PROGRAM IS SPECIAL FOR ALUMINUM EXTRUSION
MACHINE           VERSION 1.0
--------------------------------------------------
--------------------------------------------------
THE FOLLOWING WILL SHOW YOU THE PICTURES OF THE MACHINE
--------------------------------------------------
AFTER YOU SEE THE EACH PICTURE TYPE  N  GO TO THE NEXT
PICTURE AND QUIT THE VIEW ...
--------------------------------------------------~"

FIND ANS
FIND EEE
CHAIN THE001;

!*******************************************************
ASK RES : "DO YOU WANT TO SEE THE PICTURE ?";
CHOICES RES : YES, NO ;
!*******************************************************

RULE SHOW
   IF RES = YES
   THEN ANS = YES
   GMODE 16
   WHILETRUE ABC <> N THEN
   PCX PIC002, 0, 0
   GETCH ABC
```

```
    END
    TMODE;
!-----------------------------------------------------
RULE AAA
    IF ANS = YES
THEN
    EEE = YES
    GMODE 16
    WHILETRUE BBB <> N THEN
    PCX PIC003, 0, 0
    GETCH BBB
    END
    TMODE;
```

APPENDIX B

Sample Program for Connecting the Worksheet and Chain to the every Sections

```
*************************************************************
!------------------------THE001.KBS --------------------------
EXECUTE;
RUNTIME;
ENDOFF;
BKCOLOR = 3 ;
!------------------------------------------------
ACTIONS
   DISPLAY "
-----------------------------------------------------
----------- THIS IS A ESPM PROGRAM FOR -------------
-----------------------------------------------------
-----ALUMINUM EXTRUSION PRESS AND RELATED EQUIPMENT-----
---------------------- VERSION 1.0 --------------------
*********************************************************
---THE FOLLOWING SYSTEM WILL SHOW YOU CHECKING RESULT---
*******************************************************~"
      WHILEKNOWN SWITCH
       CCALL D:\VPX\VPP,"D:\VPX\LIN\DATA01.WKS"
       MENU  STYPE, ALL, SECTION, TYPE
       FIND  STYPE
       GET   STYPE = TYPE, SECTION, ALL
       RESET SWITCH
       FIND  SWITCH
       CLS
   END;
!@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
!STATEMENT BLOCK
!@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
ASK  STYPE : "From the picture can you tell me
which section you want to examine ?
 " ;
ASK SWITCH : "Enter ? to Exit the loop, any other character to continue. ";
!@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
!RULE BLOCK
!@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
WHENEVER 1
   IF  STYPE = THE_PRESS
   THEN
       DISPLAY "
```

```
-----------------------------------------------
      CHECK THE PRESS SECTION :
-----------------------------------------------
      PRESS ANY KEY TO CONTINUE  ~"
       SAVEFACTS PRE
       CLS
       CHAIN PRESS ;
!*****************************************
WHENEVER 2
   IF  STYPE = CONTAINER_LINER_STEM
   THEN
      DISPLAY "



-----------------------------------------------
    CHECK CONTAINER LINER STEM SECTION :
-----------------------------------------------
       PRESS ANY KEY TO CONTINUE  ~"
      SAVEFACTS CONT
      CLS
      CHAIN CONTAIN ;
!*****************************************
WHENEVER 3
   IF  STYPE = THE_STRETCHER
   THEN
      DISPLAY "



-----------------------------------------------
      CHECK THE STRETCHER SECTION :
-----------------------------------------------
      PRESS ANY KEY TO CONTINUE  ~"
       SAVEFACTS STR
       CLS
       CHAIN STRETCH ;
!*****************************************
WHENEVER 4
   IF  STYPE = HEATING_EQUIPMENT
   THEN
      DISPLAY "
```

```
--------------------------------------------------
      CHECK HEATING EQUIPMENT SECTION :
--------------------------------------------------
        PRESS ANY KEY TO CONTINUE  ~"
       SAVEFACTS HEAT
       CLS
       CHAIN HEATING ;
!*****************************************
WHENEVER 5
   IF  STYPE = HANDLING_EQUIPMENT
   THEN
       DISPLAY "



--------------------------------------------------
      CHECK HANDLING EQUIPMENT SECTION :
--------------------------------------------------
        PRESS ANY KEY TO CONTINUE  ~"
       SAVEFACTS HAND
       CLS
       CHAIN HANDLING ;
!*****************************************
WHENEVER 6
   IF  STYPE = PAINTING_FINISHING
   THEN
       DISPLAY "



-----------------------------------------------------
      CHECK PAINTING AND FINISHING SECTION :
-----------------------------------------------------
        PRESS ANY KEY TO CONTINUE  ~"
       SAVEFACTS PAIN
       CLS
       CHAIN PAINTING ;
!*****************************************
```

APPENDIX C

Sample Program for Displaying Parts and Connecting to Sub-Sections

```
*************************************************************************
!-----------------------------PRESS.KBS----------------------------
!--------------------------------(1)--------------------------------
!EXECUTE;
RUNTIME;
ENDOFF;
BKCOLOR = 5;
!----------------------------------------------
ACTIONS
   LOADFACTS PRE
   WHILEKNOWN SWITCH1
   DISPLAY "
--------------------------------------------------
     WELCOME TO EXAMINE THE PRESS SECTION
--------------------------------------------------
      THERE ARE THREE KINDS OF EXAMINE :

  (1) MECHANICAL (2) HYDRAULIC (3) ELECTRICIAL
--------------------------------------------------
   THE FOLLOWING WILL SHOW YOU ALL THE PARTS IN
   these three sections then you can decide
       which examine you want to go
--------------------------------------------------
--------------------------------------------------"
   FIND ANS
   CLS
   DISPLAY "
--------------------------------------------------------------

   PLEASE TYPE M for GO TO MECHAINCAL SECTION EXAMINE or
       TYPE H for GO TO HYDRAULIC SECTION EXAMINE or
       TYPE E for GO TO ELECTRICAL SECTION EXAMINE or
       TYPE Q for go back to MAIN MENU
--------------------------------------------------------------"
   GETCH SELECT
   FIND KINDS
   DISPLAY "THE KINDS OF EXAMINE IS {KINDS}"
   RESET SWITCH
   RESET KINDS
   FIND SWITCH
   END;
```

```
!!****************************************************
   ASK RES : "DO YOU WANT TO SEE THE PARTS ON THE PRESS SECTION

-----------------------------------------------------";
   CHOICES RES : YES, NO ;
!****************************************************
RULE SHOW
   IF  RES = YES
   THEN ANS = YES
   DISPLAY "
    THERE ARE THREE KINDS OF EXAMINES IN PRESS SECTION :
      MECHANICAL, HYDRAULIC, ELECTRICIAL EXAMINES
*****************************************************************
    THE MECHAINCAL SECTION INCLUDE THE FOLLOWING PARTS :
    ----------------------WEEKLY CHECK----------------------
    1.STEM              2.BILLET            3.CONTAINER
    ----------------------MONTHLY CHECK---------------------
    4.TOOLING_PRESSURE_PLATE      5.STEM_PRESSURE_PLATE
    6.TIE_ROD_NUTS              7.ADVANCE_CYLINDER_LOCK_NUTS
    8.CROSSHEAD_TRAVEL
    --------------------SEMI-YEARLY CHECK--------------------
    9.PRESS_BASE     10.PRESS_FRAME     11.CONDITION_OF_RAMS
    12.ALL_WAYS_AND_GUIDES_AND_TRUNNIONS
      (CROSSHEAD,_CONTAINER,_DIE_SLIDE,_SHEAR,_BILLET_LOADER)
    -----------------------YEARLY CHECK---------------------
    13.TIE_RODS
--- PLEASE PRESS ANY KEY TO CONTINUE DISPLAY THE MECHANICAL SECTION ---~"
DISPLAY "
     ---------WEAR AND FATIGUE -- PRESS AND STRETCHER---------

     14.MAIN_CYLINDER_PACKINGS       15.CONTAINER_HOLDER
     16.EXTRUSION_PLATEN  17.DIE_SLIDE       18.DUMMY_BLOCKS
     19.SHEAR_BLADE  20.PIPING_WELDS  21.MOVING_CROSSHEAD_GUIDES
     22.CONTAINER_GUIDES            23.DIE_SLIDE_GUIDES
    24.CONTAINER_HOLDER  25.RETURN_CYLINDER_PACKINGS_AND_BUSHINGS
     26.CONTAINER_CYLINDER_PACKINGS_AND_BUSHINGS
     27.MAIN_SHEAR_CYLINDER_PACKINGS_AND_BUSHINGS
     28.ALL_AUXILIARY_CYLINDER_PACKINGS_AND_BUSHINGS
     29.EXTRUSION_STEM_CENTERING_RING
     30.BILLET_LOADER (DUMMY_BLOCK_&_BUTT_HANDLING)

--------------- PLEASE PRESS ANY KEY TO CONTINUE ----------------
------------ DISPLAY PARTS OF THE HYDRAULIC SECTION -------------~"
CLS
     DISPLAY "
-------------------------------------------------------------
```

The hydraulic system covers the pumps, tank, valves, oil and piping.
The following is hydraulic system maintenance check list

-----------------------EACH SHIFT------------------------
1.OIL_LEVEL 2.OIL_LEAKS 3.OIL_TEMPERATURE
4.ERRATIC_OPERATIONS
-----------------------EACH WEEK-------------------------
5.OIL_FILTERS 6.HEAT_EXCHANGER
7.HEAT_EXCHANGER_TEMPERATURE_--_FLOW_CONTROL_VALVE
8.FLEXIBLE_HOSES_FOR_DAMAGE_AND_DETERIORATION
-----------------------EACH MONTH------------------------
9.AIR_BREATHERS 10.HYDRAULIC_TUBE_CONNECTIONS
11.SOLENOIDS 12.CLEAN_EQUIPMENT

--------------- PLEASE PRESS ANY KEY TO CONTINUE ---------------
---------- DISPLAY MORE PARTS ON HYDRAULIC SECTION ----------~"
DISPLAY "
-------------------EVERY THREE MONTHS--------------------
13.OIL_SAMPLE_FOR_ANALYSIS
14.TIGHTEN_ALL_HYDRAULIC_PIPE_CONNECTIONS_AND_PIPE_BRACES
15.RELIEF_VALVE ,_PRESSURE_SWITCHES,_TIMERS,_ETC.,_SETTINGS
16.HEAT_EXCHANGER
--------------------EVERY SIX MONTHS---------------------
17.OIL_FILTERS 18.PUMP_AND_MOTOR_ALIGNMENT
19.PUMP ,_MOTOR_&_VALVE_MOUNTING_BOLTS
11.SOLENOIDS 12.CLEAN_EQUIPMENT
13.OIL_SAMPLE_FOR_ANALYSIS
14.TIGHTEN_ALL_HYDRAULIC_PIPE_CONNECTIONS_AND_PIPE_BRACES
15.RELIEF_VALVE ,_PRESSURE_SWITCHES,_TIMERS,_ETC.,_SETTINGS
16.HEAT_EXCHANGER
17.OIL_FILTERS 18.PUMP_AND_MOTOR_ALIGNMENT
19.PUMP ,_MOTOR_&_VALVE_MOUNTING_BOLTS

--------------- PLEASE PRESS ANY KEY TO CONTINUE ----------------
------------ DISPLAY PARTS OF THE ELECTRICIAL SECTION -------------~"
CLS
DISPLAY "

The following is the parts of the electrical section
preventive maintenance check list

-----------------------EVERY MONTH-----------------------
1.TERMINAL_CONNECTIONS_AT_RELAYS ,_PUSHBUTTONS,_LIMIT
_SWITCHES,_SOLENOIDS,_CONTAINER_HEATERS
2.SOLENOIDS_AND_RELAYS 3.CONTAINER_ELEMENTS

```
    ----------------------EVERY YEAR-----------------------
    4.MAIN_MOTORS

 -------------------------------------------------------------
 -------- THIS IS THE END OF THE PRESS SECTION PARTS' LIST -------
 --------     PLEASE PRESS ANY KEY TO CONTINUE      -------
 --------------------------------------------------------------~"
   CLS;
!******************************************
RULE 1
   IF  SELECT = M
   THEN KINDS = MECHANICAL
   DISPLAY "

------------------------------------------
******************************************

   LET'S GO TO MECHANICAL EXAMINE and

    PLEASE PRESS ANY KEY TO CONTINUE

******************************************
------------------------------------------ ~"
   CHAIN P-MEC;

RULE 2
   IF  SELECT = H
   THEN KINDS = HYDRAULIC
   DISPLAY "

------------------------------------------
******************************************

   LET'S GO TO HYDRAULIC EXAMINE and

   PLEASE PRESS ANY KEY TO CONTINUE

******************************************
------------------------------------------ ~"
  CHAIN P-HYD ;

RULE 3
   IF  SELECT = E
   THEN KINDS = ELECTRICAL
   DISPLAY "
```

```
-------------------------------------------
*********************************************

   LET'S GO TO ELECTRICAL EXAMINE and

    PLEASE PRESS ANY KEY TO CONTINUE

*********************************************
------------------------------------------- ~"
   CHAIN P-ELE ;

RULE 4
   IF   SELECT = Q
   THEN KINDS = NOT_IN_PRESS_SECTION
   DISPLAY "

-----------------------------------------------------
********************************************************

       PLEASE PRESS ANY KEY TO CONTINUE

 LET'S GO BACK TO MAIN MENU and CHOOSE CORRECT SECTION

********************************************************
----------------------------------------------------- ~"
      CHAIN THE001
   ELSE KINDS = UNKNOWN
   DISPLAY "
-----------------------------------------------
*************************************************

      LET'S GO BACK TO PRESS SECTION and
    PLEASE TYPE THE CORRECT INPUT AGAIN

*************************************************
-----------------------------------------------";
!**************************************
ASK SWITCH : "ENTER ? TO EXIT THE LOOP, AND OTHER KEY TO CONTINUE.";
```

APPENDIX D

Sample Program for Sub-Section Connecting to the Hypertext

```
*******************************************************************
!----------------------------P-MEC.KBS---------------------------
!------------------------------(1)-1------------------------------
RUNTIME;
ENDOFF;
BKCOLOR = 1;

ACTIONS
   COLOR = 15
   CLS
   DISPLAY "
------------------------------------------------------------------
            WELCOME TO THE PRESS & STRETCHER
      PERIODIC MECHANICAL PREVENTIVE MAINTENANCE CHECK LIST
------------------------------------------------------------------
------------------------------------------------------------------
          THE FOLLOWING SYSTEM WILL SHOW YOU
            THE WORKSHEET CHECKING DATA
------------------------------------------------------------------~"
   CCALL D:\VPX\VPP,"D:\VPX\LIN\DATA02.WKS"
   FIND Graphics_Mode
   Topic = README_HELP
   Topic1 = INDEX
   WHILETRUE ExitButton = NO THEN END
   TMODE
   DISPLAY "
-------------------------------------------------------------------
         THE FOLLOWING SYSTEM WILL ASK YOU TO INPUT
           THE UPDATE DATA INTO A WORKSHEET
-------------------------------------------------------------------~"
   CCALL D:\VPX\VPP,"D:\VPX\LIN\DATA02.WKS"
   CHAIN PRESS;


! RULES to handle LBUTTON selection

WHENEVER Topics_Exit
IF  Topic = EXIT
THEN ExitButton = YES;


WHENEVER Previous_Selected
```

```
IF   PreviousButton = YES
THEN POP Topic, Topic1
   POP Topic, Topic1
   Topic = (Topic1)
   ResetMono = YES
   ResetColor = YES;

PLURAL: Topic;

WHENEVER Other_Selected
IF   OtherButton = YES
THEN ResetMono = YES
   ResetColor = YES
   Topic = OTHER;

WHENEVER Index_Selected
IF   MainIndexButton = YES
THEN ResetMono = YES
   ResetColor = YES
   Topic = INDEX;

WHENEVER Help_Selected
IF   HelpButton = YES
THEN ResetMono = YES
   ResetColor = YES
   Topic = README_HELP;

! Rules to display LBUTTONS in color or B&W depending on GMODE

WHENEVER ResetMono
IF   ResetMono = YES
THEN PreviousButton = NO
   OtherButton = NO
   MainIndexButton = NO
   HelpButton = NO
   ExitButton = NO;

WHENEVER ResetColor
IF   ResetColor = YES
AND  G_Mode = VGA
THEN PButton = NO
   MIButton = NO
   HButton = NO
   EButton = NO;

! Rules to select proper GMODE
```

```
RULE G1
IF   G_Mode = UNKNOWN
THEN Graphics_Mode = -1
   MOUSEON
   GMODE @Graphics_Mode
   ResetMono = YES;

RULE G2
IF   G_Mode = Hercules
THEN Graphics_Mode = 8
   MOUSEON
   GMODE @Graphics_Mode
   ResetMono = YES;

RULE G3
IF   G_Mode = CGA
THEN Graphics_Mode = 6
   MOUSEON
   GMODE @Graphics_Mode
   ResetMono = YES;

RULE G4
IF   G_Mode = VGA
THEN Graphics_Mode = 16
   MOUSEON
   GMODE @Graphics_Mode
   ResetMono = YES
   ResetColor = YES;

RULE G6
IF   G_Mode = None
THEN Graphics_Mode = -1
   GMODE @Graphics_Mode
   ResetMono = YES;

HYPERTEXT Topic: 1, 1, 78, 22, PRE-MEC, 14, 15;

!.....Color buttons.....
LBUTTON PButton: 8, 24, 0, 11, Previous;
LBUTTON MIButton: 26, 24, 0, 11, Index;
LBUTTON HButton: 41, 24, 0, 11, Help;
LBUTTON EButton: 70, 24, 0, 11, Exit;

!.....Monochrome buttons.....
LBUTTON PreviousButton: 8, 24, 11, 0, Previous;
```

```
LBUTTON MainIndexButton: 26, 24, 11, 0, Index;
LBUTTON HelpButton: 41, 24, 11, 0, Help;
FORMFIELD Topic: 52, 24, 13, 0;
LBUTTON ExitButton: 70, 24, 11, 0, Exit;


ASK G_Mode: "What Graphics Mode should be used?";
CHOICES G_Mode: VGA, None, CGA, Hercules;
```

APPENDIX E

Sample File for Sub-Section Hypertext

```
******************************************************************
*README_HELP

        Welcome to the Expert System consultant center.

      This Expert System is only for the aluminum extrusion

                press and relate equipment.

   ------------------------------------------------------------
   This Examine menu is only for the PRESS periodic MECHANICAL
   preventive maintenance check list (include check the wear and
   fatigue).
   ------------------------------------------------------------

     You will see a series of labels on the bottom of the screen.
     Pointing and clicking on these with the mouse will cause the
     corresponding hypertext the INDEX & INDEX1 to be displayed
     or the program to end.


*INDEX


INDEX :
     ---------------------WEEKLY CHECK----------------------
     1.STEM             2.BILLET            3.CONTAINER
     ---------------------MONTHLY CHECK---------------------
     4.TOOLING_PRESSURE_PLATE      5.STEM_PRESSURE_PLATE
     6.TIE_ROD_NUTS             7.ADVANCE_CYLINDER_LOCK_NUTS
     8.CROSSHEAD_TRAVEL
     -------------------SEMI-YEARLY CHECK-------------------
     9.PRESS_BASE      10.PRESS_FRAME      11.CONDITION_OF_RAMS
     12.ALL_WAYS_AND_GUIDES_AND_TRUNNIONS
       (CROSSHEAD,_CONTAINER,_DIE_SLIDE,_SHEAR,_BILLET_LOADER)
     ----------------------YEARLY CHECK---------------------
     13.TIE_RODS
          ------- MORE INDEX IN INDEX1 ---------
```

*INDEX1

INDEX (CONTINUED) :

---------WEAR AND FATIGUE -- PRESS AND STRETCHER---------

14.MAIN_CYLINDER_PACKINGS 15.CONTAINER_HOLDER
16.EXTRUSION_PLATEN 17.DIE_SLIDE 18.DUMMY_BLOCKS
19.SHEAR_BLADE 20.PIPING_WELDS 21.MOVING_CROSSHEAD_GUIDES
22.CONTAINER_GUIDES 23.DIE_SLIDE_GUIDES
24.CONTAINER_HOLDER 25.RETURN_CYLINDER_PACKINGS_AND_BUSHINGS
26.CONTAINER_CYLINDER_PACKINGS_AND_BUSHINGS
27.MAIN_SHEAR_CYLINDER_PACKINGS_AND_BUSHINGS
28.ALL_AUXILIARY_CYLINDER_PACKINGS_AND_BUSHINGS
29.EXTRUSION_STEM_CENTERING_RING
30.BILLET_LOADER (DUMMY_BLOCK_&_BUTT_HANDLING)

--------- END OF INDEX ---------

*STEM

STEM :

CHECK PERIOD = EVERY WEEK

CHECK = VISUAL AND WITH LEVEL

CHECK METHOD = Visual check for condition check with level for level.
Three position: BACK, MID, ADVANCE.

REMEDY = Clean and recondition stem if necessary. Tighten against pressure plate and centralize.

*BILLET

BILLET :

CHECK PERIOD = EVERY WEEK

CHECK = VISAUL AND WITH DUMMY BLOCK

CHECK METHOD = Visual check for condition, loose adj. screws, etc.

Try dummy on stem & into container.

REMEDY = Readjust to stem.
*CONTAINER

CONTAINER :

CHECK PERIOD = EVERY WEEK

CHECK = VISAUL AND WITH TAPE GAUGE BETWEEN LINER AND STEM.

CHECK METHOD = Visual check for nicks and scores and buildup on face.
Taper gauge for alignment.

REMEDY = Clean and deburr container Readjust if necessary.
*TOOLING_PRESSURE_PLATE

TOOLING PRESSURE PLATE :

CHECK PERIOD = EVERY MONTH

CHECK = STRAIGHTEDGE AND FEELER.

CHECK METHOD = Check for dishing or coining.

REMEDY = Remove from press and grind to parallel. Shim when replacing.
*STEM_PRESSURE_PLATE

STEM PRESSURE PLATE :

CHECK PERIOD = EVERY MONTH

CHECK = STRAIGHTEDGE AND FEELER.

CHECK METHOD = Check for dishing or coining.

REMEDY = Remove from press and grind to parallel. Shim when replacing.
*TIE_ROD_NUTS

TIE ROD NUTS :

CHECK PERIOD = EVERY MONTH

CHECK = VISUAL AND FEELER.

CHECK METHOD = Check for tightness of inside nuts under pressure.
Outside nuts when press is relaxed.

REMEDY = Tram press and restress tie rods.
*ADVANCE_CYLINDER_LOCK_NUTS

ADVANCE CYLINDER LOCK NUTS :

CHECK PERIOD = EVERY MONTH

CHECK = VISUAL AND FEELERS

CHECK METHOD = Check for tightness under load.

REMEDY = Retighten under pressure and check cylinder level.
*CROSSHEAD_TRAVEL

CROSSHEAD TRAVEL :

CHECK PERIOD = EVERY MONTH

CHECK = WITH LEVEL

CHECK METHOD = Check at three positions : full return, mid, full advance.

REMEDY = Adjust crosshead shoes if needed.
*PRESS_BASE

PRESS BASE :

CHECK PERIOD = EVERY HALF YEAR

CHECK = STRAIGHTEDGE AND LEVEL

CHECK METHOD = Check level of base both lengthwise on both ways and crosswise on both ends.

REMEDY = Proceed as in discussion portion of this chapter.
*PRESS_FRAME

PRESS FRAME :

CHECK PERIOD = EVERY HALF YEAR

CHECK = STRAIGHTEDGE, LEVEL AND TRAM

CHECK METHOD = Check tie rod level, lengthwise and crosswise, top and bottom. Tram between platens to check parallel.

REMEDY = Proceed as in discussion portion of this chapter
*CONDITION_OF_RAMS

CONDITION OF RAMS :

CHECK PERIOD = EVERY HALF YEAR

CHECK = VISUAL

CHECK METHOD = Check for nicks, scores, or other faults.

REMEDY = Clean and stone where possible. File if necessary.

*ALL_WAYS_AND_GUIDES_AND_TRUNNIONS

ALL WAYS AND GUIDES AND TRUNNIONS, CROSSHEAD, CONTAINER, DIE SLIDE, SHEAR,
BILLET LOADER :

CHECK PERIOD = EVERY HALF YEAR

CHECK = INSPECT FOR CLEARANCE, DIRT, NICKS SCORE, AND EXCESSIVE WEAR

CHECK METHOD = Remove from press all shoes and check fully. By using feelers, check excessive wear in die slide ways, shear housing and billet loader trunnion bushings.

REMEDY = Remachine or scrape shoes if needed. Scrape press ways if needed. Readjust die slide ways if needed. Remachine shear blade holder and install new bushing if needed.
*TIE_RODS

TIE RODS :

CHECK PERIOD = EVERY YEAR

CHECK = ULTRASONIC

CHECK METHOD = Have testing lab with portable ultrasonic equipment check tie rods for cracks or flaws.

REMEDY = If a flaw shows up have it checked monthly for growth. If a continued growth pattern is apparent replace the rod.
*MAIN_CYLINDER_PACKINGS

MAIN CYLINDER PACKINGS :

CHECK PERIOD = EVERY WEEK

CHECK = WEAR

CHECK MEHTOD = Check for sudden inscrease in leakage and scores on ram.

REMEDY = Stone smooth immediately; make sure to wash off. Repack when convenient or immediately if scoring persists.
GCHECK BUSHINGS-

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