BOILER MAINTENANCE USING EXPERT SYSTEMS

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I, C.V. Gamede, submit this thesis for the degree of Master of Science in Engineering. I claim that this is my original work and that it has not been submitted in this or similar form for a degree at any university.

ABSTRACT

Maintenance management is extremely important in industry. There are machines or components of machines which are crucial to the production process, and such equipment is becoming sophisticated and costly to maintain. Boilers are machines which need careful maintenance management. In process and chemical industries, boiler breakdowns can can cost a company many thousands of rands in lost production.

There are many techniques and strategies which are used in maintenance management. Although all the traditional maintenance methods have been proved to work satisfactorily, new methods should be explored in this field. Expert systems technology is one of the promising techniques in maintenance management. The field of expert systems has been launched in South African industry, and the name expert systems is mentioned frequently at conferences and seminars.

This research explores the application of expert systems to the maintenance of boilers, and its main objectives are as follows:

[1] To explore the application of expert systems in the maintenance of boilers.

[2] To simplify the task of boiler maintenance with the help of expert systems.

[3] To improve the skills of boiler maintenance workers

through the knowledge 'captured' or 'preserved' by expert systems.

[4] To minimise errors which may cost time, money, effort and possible risk of injury to boiler maintenance personnel.

[5] To develop a prototype expert system which can advise and assist boiler maintenance personnel.

[6] To contribute to research in the application of expert systems in the field of engineering.

This thesis begins by defining expert systems. The theory of expert systems is then explored and the structure of an expert system is clearly described. Knowledge representation techniques are then explained, followed by the comparison between expert systems and conventional programs.

Problems underlying expert systems are explained clearly. They are followed by a description of how to develop an expert system. The theory of expert systems finally concludes with the selection of an expert system building tool. The tools considered are MicroExpert, EXSYS and PROLOG.

The next section is the theory of boiler maintenance. The statutory requirements of boilers are then explored. The regulations which usually cause confusion are set out in detail.

The discussion of the developed expert system software is explained clearly. The important features of the expert system development tool, EXSYS, are then discussed. This expert system software is divided into two: the first program being concerned with routine boiler maintenance; the second with shutdown boiler maintenance.

It is concluded that boiler maintenance personnel are often poorly qualified. This is due to the fact that the boiler environment is usually dirty. The expert system thus contributes towards better understanding of boiler maintenance. It is further concluded that expert systems, like experts, can also make mistakes. Therefore, results should not be necessarily accepted as correct.

Finally, the following recommendations were made:

[1] All mistakes which were not observed during the development of the expert system, should be corrected immediately when the expert system is in operation.

[2] Any company which obtains this software must modify it to any special requirements.

[3] The expert system must be expanded to the limits of personal computer memory.

[4] Feedback from the users must be sent to the Department of Mechanical Engineering of the University of Cape Town.

It is hoped that this research will contribute to the application of expert systems in the field of engineering so that the users of the expert system will benefit.

The author would like to thank the following:

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CHAPTER ONE

INTRODUCTION

Computers are becoming increasingly valuable to every facet of industry, one advantage being the fullfilment of tasks which human beings could only accomplish in a very long time. They also perform accurately and efficiently. However, computer hardware is worth nothing if not supported by its software. It is only 'a potential machine' [1].

One field which has been improved by the advent of the computer is decision techniques. Some decision techniques which have exploited the use of computers are operations research techniques, such as simulation, and expert systems. Operations research techniques are usually numerical as opposed to expert systems which are a 'symbolic ' technique.

An expert system is a computer-based system which is capable of offering advice or making intelligent decisions in a relatively narrow subject area [2]. This field has its roots in Artificial Intelligence (AI) which emerged in the late 1950's after the discovery of the digital computer [3]. Artificial Intelligence is concerned with understanding the nature of intelligent action [4]. A few examples of expert systems which have been developed in the last decade can be seen in Table 1.1. A more detailed list appears as Appendix A [6].

Field	Application	Expert System name
Medicine	Identification of bacteria in blood and urine samples, and prescription of antibiotic regime	MYCIN (Shortliffe)
	Diagnosis in internal medicine	INTERNIST (Myers and Pople)
	Intensive care ('iron lung')	VM (Fagan and others)
	Interpretation of lung cancer	PUFF (Kunz)
Chemistry	Identification of organic compounds	DENDRAL (Feigenbaum, Lederberg, Djerassi, Buchanan, Carhart and others)
	Designing organic synthesis	SECS (Wipke)
	Molecular genetics	MOLGEN Lederberg, Martin, Friedland, King, Stefik)
Other	Consultancy for structural engineers	SACON (Bennett)
	Consultancy for mineral prospecting	PROSPECTOR (Hart, Duda, Einaudi)

Table 1.1 Examples of expert systems (Source [5]).

Expert systems have recently received much attention from the engineering field. A number of engineering expert systems have been developed , especially in design and maintenance. This has been triggered by the availability of commercial, PC-based expert system shells.

1.1 OBJECTIVES OF THE RESEARCH

The objectives of this research are :

1. To explore the application of expert systems in the maintenance of boilers.

2. To simplify the task of boiler maintenance with the help of expert systems.

3. To improve the skills of boiler maintenance workers through the knowledge 'preserved' or 'captured' by expert systems.

4. To minimize errors which may cost time, money, effort and possible risk of injury to boiler maintenance personnel.

5. To develop a prototype expert system which can advise and assist to boiler maintenance personnel.

6. To contribute to research in the application of expert systems in the field of engineering.

1.2 METHOD OF INVESTIGATION

The information in this thesis has been gathered from books and journals, boiler maintenance personnel, and expert systems; published and unpublished material. Some information was gathered through structured and unstructured interviews with boiler maintenance personnel, knowledge engineers and computer scientists.

1.3 PLAN OF DEVELOPMENT

This research covers the maintenance of all types of boilers, although there is particular emphasis on economic boilers. This includes all routine and shutdown maintenance. This thesis begins with a literature review of expert systems, and then describes the theory. The procedure for building expert systems, is followed by the selection of the expert system development tool. The theory of maintenance of boilers is then covered. This leads to the development of the knowledge base which forms the core of the expert system software and this thesis. The developed expert system is then discussed, from which conclusions are drawn and recommendations made.

CHAPTER TWO

LITERATURE REVIEW

Expert systems are becoming easier to understand as more literature is becoming available in this field. Journals, books and other material are published frequently. There are many overseas companies which publish, teach and arrange conferences on expert systems, like Learned Information (Europe) [7]. Most expert system development packages give background and explanation of expert systems, and how they work. A good example of this is illustrated by a manual published by EXSYS Inc. [8].

There are many experts in this field, such as the late Dr D.A. Waterman who was the chief editor of Expert Systems, The International Journal of Knowledge Engineering. He has published many articles on this subject and also a few books one of which is "A guide to Expert Systems" [9].

Thanks to experts like Waterman, the expert system technology has been implemented in engineering with considerable success. This has been mainly in the areas of control, design and maintenance. However, this technology is very specific, hence a narrow domain should be chosen. For example, it would be meaningless to have an expert system on "maintenance". One should choose a specific topic e.g. "maintenance of four stroke engine motorcycles".

In this thesis, the maintenance of boilers is discussed Similar work, although not using expert systems, has been done on boilers. A program which simulates the operation and control of boilers was developed by the J.H.Jansen Company in the United States. This program provides an interactive simulation, complete with help, hints and tutoring facilities. This simulation is on boilers which are typical of those found in paper mills [10]. This program is supported with comprehensive graphics and can run on an IBM PC , AT with at least 512K bytes RAM , and a 20M bytes hard disk. It is known as Recovery Boiler Tutor (RBT) and it posseses 'expertise' in this field of boiler operation and control. Some of this 'expertise' can be used in the preventative maintenance of boilers.

As we have seen above, expert systems have largely been used in the First World countries North America and Europe. However, Third World countries like South Africa can benefit much from this expert system technology. Greef and Reinecke of the University of Stellenbosch [11], have written a paper on "The potential of Artificial Intelligence in South African manufacturing". This paper describes needs of expert systems in South Africa as well as their applications in this country.

Reinecke [12], has also written a paper on "Artificial Intelligence in Support of Peasant Industrial Labour". This is a valuable contribution to research and is

relevant to South Africa.

It has also been proved that expert systems can help in the mastering of engineering concepts [13]. Therefore, this expert system technology assists greatly in the advancement of technology in this country, which lacks skilled technologists. There is some kindling of interest on expert systems in South Africa. The first expert system shell to be developed commercially in South Africa appeared in 1986 . There are also firms which build expert systems like Wolf Intelligent Systems [14].

CHAPTER THREE

THE THEORY OF EXPERT SYSTEMS

3.1 DEFINITION OF AN EXPERT SYSTEM

There is no universally accepted definition of an expert system. Barr and Feigenbaum [15] describe an expert system as a "computer system that may help solve complex, real world problems in specific, engineering and medical specialties". The McGraw Hill encyclopedia describes the expert system as "Methods and techniques for constructing human machine systems with specialized problem solving expertise [16]. Another definition states that expert systems are "interactive computer programs that incopo-rate the knowledge and judgement of experts in appropriate domains" [17]. There are many other definitions, but the important thing is to get a 'summarized' definition which accomodates all other definitions.

From the above definitions, and others found in different books, it can be deduced that an expert system is a computer system / program that posseses expertise (similar to that of its human counterpart) in a specific subject area. Noting that expertise is of prime importance in expert system technology, it would be advantageous to take a closer look at the meaning of expertise. This is briefly discussed in the next section.

3.1.1 Expertise

Expertise consists of knowledge about a particular

domain, understanding of domain problems and skill at solving some of these problems. Knowledge in a specific field can be devided into two types, public and private [18]. Public knowledge consists of published definitions, facts, theories and other information contained in textbooks and references in a specific field. Expertise consists mainly of private knowledge which is not usually available to the public. This is usually in the form of heuristics or rules of thumb. Other authors divide knowledge into expertness and expertise.

Johnson [19] differentiates between expertness and expertise. He says that we usually conclude that a person is an expert if he / she performs a task correctly and with ease and efficiency. If the person was trained ahead of time to perform the task, we may say that he / she displays "expertness" in the performance of the task, but not necessarily expertise.

Concluding from the preceding paragraphs; expertness is the skill we acquire from being taught whilst expertise is the skill which we acquire through experience.

3.2 NEED FOR EXPERT SYSTEMS

In South Africa there is a shortage of managers in many areas of industry. This is not a problem of this country alone, many developing countries in the world face the

same problem. For example, South Africa and its neighbouring countries cannot produce enough engineers to cope with existing as well as developing industries.

One of the main problems of training human experts in different fields is the time and money involved. The McGraw Hill encyclopedia notes that traditionally, the transmission of knowledge from a human expert to a trainee has required education and internship periods ranging from 3 to 20 years [18]. This effort of transferring knowledge can be easily lost if the expert dies or leaves for another company. This makes many companies reluctant in spending a lot of money in training. There are many companies who have lost a lot of money in training, through trainees who say "that company is very good in training, get your three years of training and look for a better job". It then appears that there would be an advantage if the companies can 'capture' or 'store' the expertise of their trainees.

The expert system technology is the only one which offers an answer to this problem. Expert systems can 'capture and preserve' the knowledge of experts. If industry can apply this technology, it would not suffer much through the movement of experts from one company to another.

Another important fact about expert systems is that they are a conglomerate of skills of many different experts. It then follows that an expert system is theoretically

more powerful than a single expert. It is however, important to note that the power of expert systems is still limited by the state of the art of computer technology.

Some other advantages are that an expert system is available 24 hours a day; an expert system is always at the peak of its performance i.e. it never gets tired and thus reducing its reliability. Also, an expert system does not have personality. Some experts' personalities are not very favourable in a business environment, thus rendering their services useles. Expert systems overcome this limitation [20].

3.3 THE STRUCTURE OF AN EXPERT SYSTEM

An expert system is basically made up of two parts. These are the knowledge base and the inference engine. It should be noted that many authors give more detailed information of what constitute an expert system. Typical examples may be seen in Figures 3.1 and 3.2. Note that these figures can be reduced to a knowledge base and an inference engine.

3.3.1 The Knowledge Base

The knowledge base is the data base that holds expertise on a specific subject. This primarily consists of facts and heuristics (rules of thumb or experiential knowledge). There are a number of ways in which this knowledge can be represented in the knowledge base. A

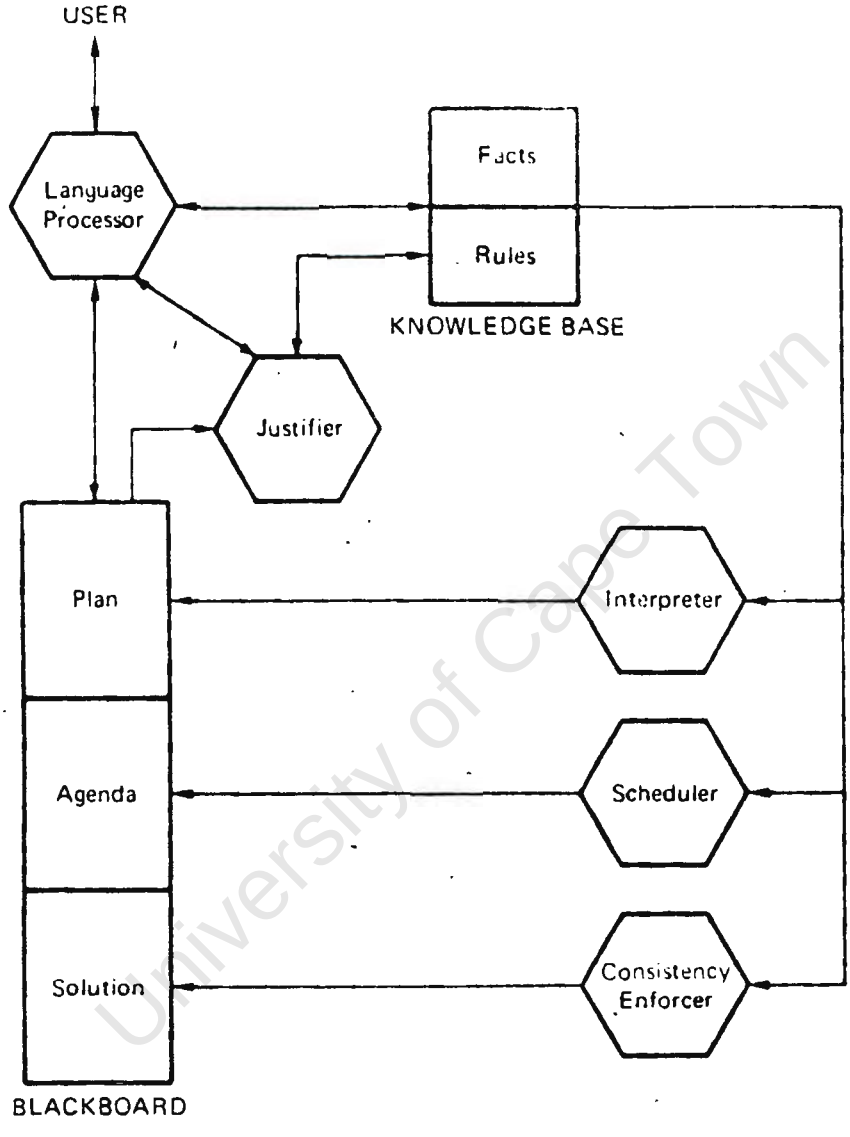

Figure 3.1 Anatomy of an ideal expert system (Source: "Expert Systems", McGraw Hill Encyclopedia, pp. 520)

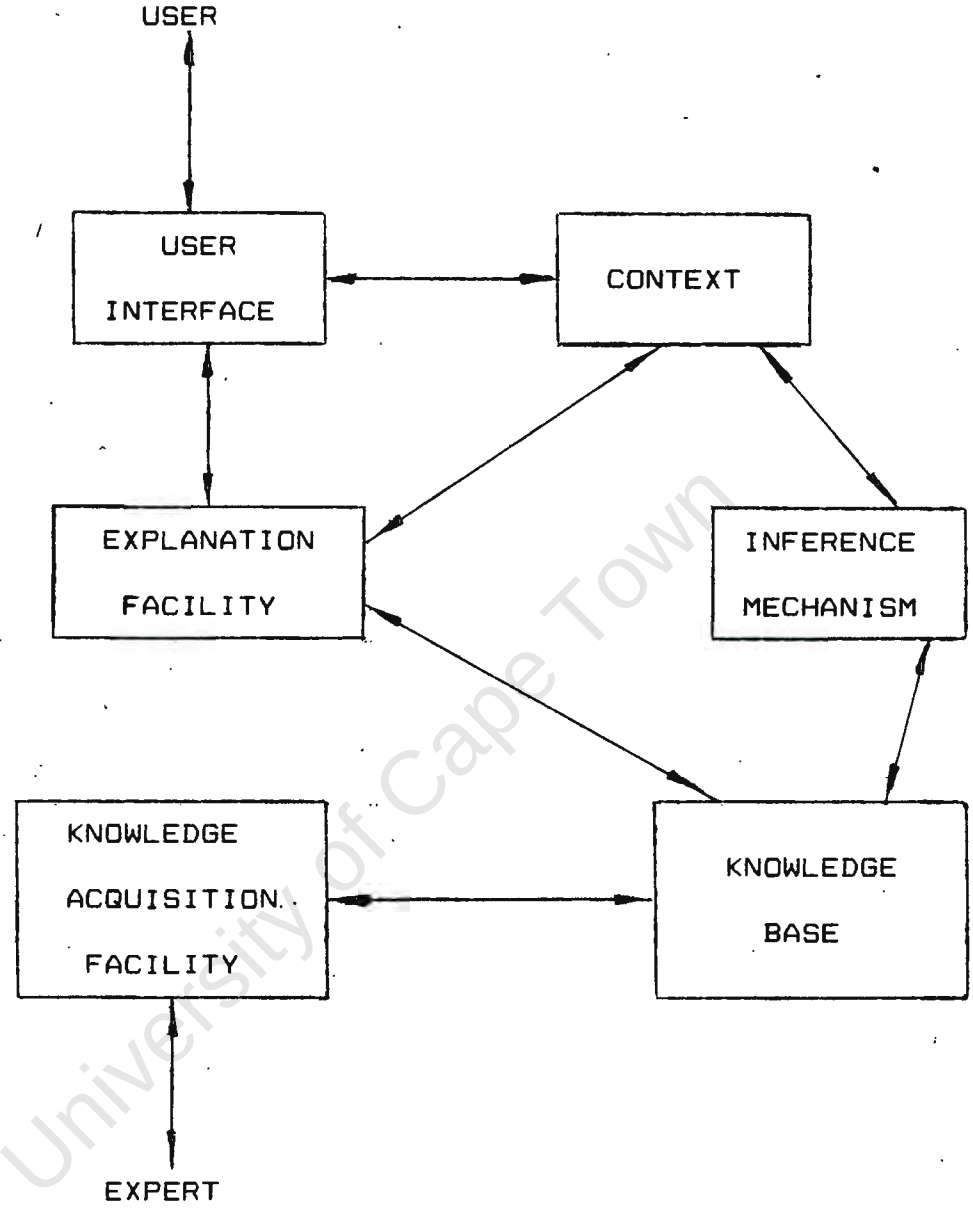

Figure 3.2 A schematic view of a complete Knowledge Based Expert System (Source: "Tools and Techniques for Knowledge Based Expert Systems for Engineering Design", Advanced Engineering Software, Vol. 6. No. 4, pp. 179)

few of these techniques are production rules, logic semantic nets and frames.

Production rules have recently gained more attention than the other techniques. Due to this, it would be advantageous if a glimpse of a rule is given before discussing it in detail in one of the following sections.

Production rules are usually structured in the IF... THEN... form. The IF part consists of a condition or conditions. Then THEN part consists of a conclusion or conclusions. A typical rule is the following in Figure 3.3.

More sophisticated expert systems have additional structures to the example in Figure 3.3. Some are in the IF... THEN... form. Some include probabilities attached to the conclusion.

3.3.2 The Inference Engine

The inference engine is that part of an expert system that manipulates supplied or deducted information to reach a goal or conclusion. Schildt [21] use the following approach in classifying inference engines. Inference engines can be classified into two types, which are:- deterministic and probabilistic inference engines.

The difference between the two lies around the idea of

IF The snake is slender and long

The snake is green or black

The snake has a small head

The snake is found only in Africa

The snake is highly poisonous

The snake is found in tropical forests

THEN The snake is a mamba

Figure 3.3 A typical example of a production rule.

certainty or uncertainty. Deterministic and probabilistic situations can be better understood by way of examples. Imagine a biologist who is trying to determine the class of an animal by using the characteristic whether it secretes milk to feed its young ones or not. The biologist can report with certainty that the animal is a mammal if it suckle its young ones. This is a deterministic situation. A public relations officer cannot say with certainty what will happen if workers are retrenched. He can only qualify his answer with a probability depending on the experience e.g. nine out of ten, the workers will strike when retrenched. This is a probabilistic situation.

Each of these two categories of inference engines use one of three ways of reasoning. These are backward chaining, forward chaining and rule value method.

(i) Backward chaining

Backward chaining is also known as goal driven, because the expert system begins with a goal and then tries to prove it. This may also be better understood by looking at an example.

Let us take the example of the rule which was verifying a mamba in the last section. Suppose we see a snake and we do not know what it is and we start by assuming that it is a mamba. If the snake happens to be yellow for instance, we would conclude that it is not a mamba

because a mamba is either black or green. If the snake is black or green, and we know for a fact that it is not poisonous, then it is not also a mamba.

We can continue like this verifying all our hypotheses and finally conclude whether the snake is a mamba or not. Backward chaining can be said to be a "bottom-up approach" of solving problems.

(ii) Forward chaining

Forward chaining is the reverse of backward chaining. This is sometimes called data-driven since this strategy uses information supplied inorder to get to a goal. In the case of inadequate information, more information is requested.

We can still use our mamba example to clarify this phenomenon. The information in the IF part will all be verified. If all the conditions in the IF part are true, then the goal or condition in the THEN part is true. However, if one or more of these conditions is not true, then the goal or conclusion is more true.

(iii) Rule-value method

Rule-value is a better strategy when compared to forward chaining or backward chaining. This is usually viewed as an improved backward chaining. The principal

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Rule-value is a better strategy when compared to forward chaining or backward chaining. This is usually viewed as an improved backward chaining. The principal

characteristic of this kind of inference engine is that it requests information which removes most uncertainty from the system.

Typically, suppose one wants to diagnose a fault in a car. Usually, one knows whether the fault is in the engine and surroundings or in the rear axle etc. Hence, to remove most uncertainty, a mechanic may ask whether the fault is in the gearbox or not. He may then ask which gears do not engage and so forth.

This is quite a good strategy since questions are selected such that the conclusion is reached rapidly. However, there are many problems underlying the construction of rule-value method. One typical problem is that in real life, the domain is so large that one cannot be certain that the question one asks removes most uncertainty. Also, the expert system builder should be very clear about the notion of certainty and uncertainty.

(iv) Which is the best inference engine?

Each of the three types of inference engines has its advantages and disadvantages. Hence, one can choose any of the three, depending on his preference and experience. However, it would be advantageous to mention a few merits of each inference engine.

The forward chaining method is good if more than one goal exists. The backward chaining method is good if only one

goal will be reached. The rule-value method is theoretically best to use, but it is difficult to implement as has been mentioned in the last section.

3.4 KNOWLEDGE REPRESENTATION

Now we have seen that an expert system has a knowledge base and an inference engine. At this point, we have not yet explored how this knowledge can be represented.

Artificial Intelligence researchers have attempted to understand how knowledge is represented in a human brain. With this hope of understanding knowledge representation in humans, they would apply a similar approach to computers. However, the human mind is more complex than psychologists used to think. This led to the emergence of other schools of thought in psychology, like the behavioral school.

With all these difficulties, some progress has been made in knowledge representation. Jackson [22] mentions and discusses three main formalisms which have found reputation with the expert system designers: production rules, structured objects and predicate logic.

3.4.1 Production rules

Kastner and Hong [23] note that by far, the most popular knowledge encoding method for expert systems is in the form of rules. These are in the IF... THEN... form as was mentioned in the earlier sections.

The rule is "fired" if all the conditions are satisfied or true i.e. if all conditions are true, then the conclusions are true.

A typical set of rules which can be found in a fault finding workshop manual of a motor car is shown in Figure 3.4.

3.4.2 Structured objects

This term "structured objects" refers to any representational scheme whose fundamental building blocks are analogical to the nodes and arcs of graph theory or the slots and fillers of record structures [25]. Since in structured objects we have predominantly graphs and record structures, it would be advisable to have an idea of these concepts.

A typical graph in Artificial Intelligence is an example by Schildt [26]. In this example, he makes an example of a person who has lost car keys in his house. The structure of the house can be seen in Figure 3.5 and the associated graph in graph in Figure 3.6.

Graph structures have a few problems, hence alternative representations have been sought out. "Recording structures" have been seen as a more promising alterntive. These are usually known as frame systems. A typical example of a frame system representing a person can be seen in Figure 3.7.

```
IF      the engine won't turn over and
        there is no current at the starter motor
THEN    check the battery

IF      the engine turns over and
        the engine won't start and
        there is no spark at the plug
THEN    check the distributor cap for dampness

IF      the engine turns over and
        the engine won't start and
        there is no fuel at the jets
THEN    check there is petrol in the tank

IF      the engine starts and
        the engine misfires and
        the spark at the plugs is intermittent
THEN    check the ignition leads for looseness
```

Figure 3.4 A typical set of production rules. (Source: [25])

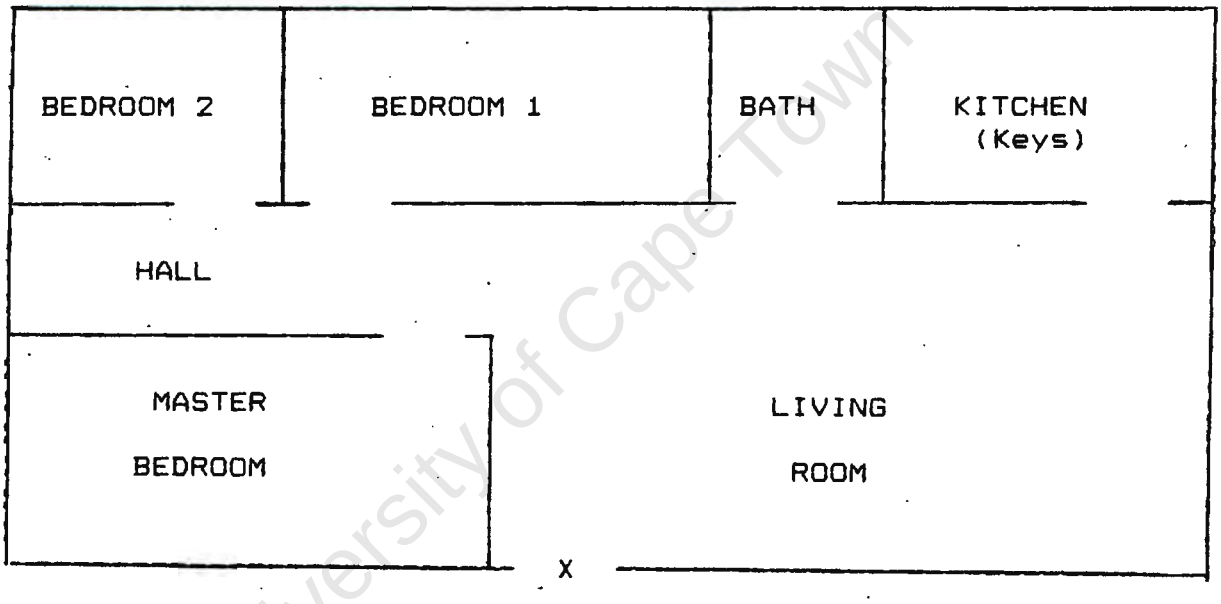


Figure 3.5 The structure of the house in which keys are lost (Source: [27])

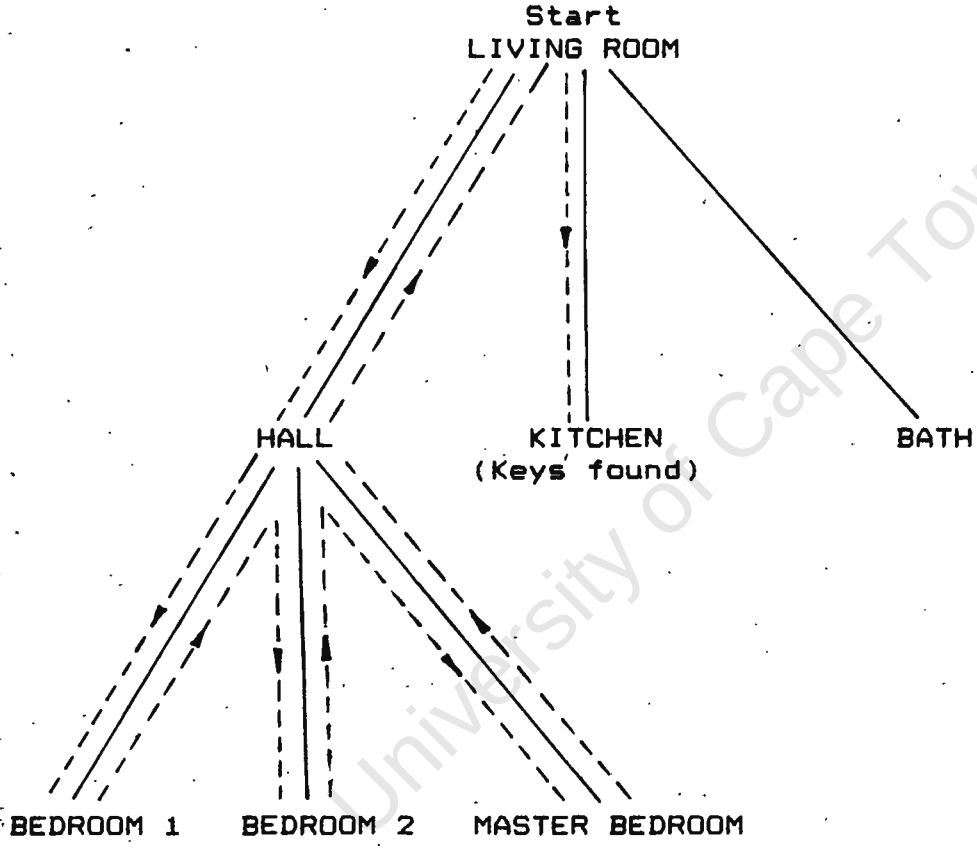


Figure 3.6 The graph of the solution path to find the missing keys (Source: [27])

```
[PERSON is a kind of a THING with
     AGE
     HEIGHT
     WEIGHT]
[PROPERTY is a kind of a THING with
     UNITS
     RANGE]
[AGE is a kind of PROPERTY with
     UNITS : YEARS
     RANGE : 0 - 120]
[HEIGHT is a PROPERTY with
     UNITS : FEET
     RANGE : 0 - 7]
[WEIGHT is a PROPERTY with
     UNITS : POUNDS
     RANGE : 0 - 300]
[PETER is a PERSON with
     AGE : 36
     HEIGHT : 6
     WEIGHT : 150]
```

Figure 3.7 A typical frame system (Source: [28]).

3.4.3 Predicate logic

Predicate logic is sometimes known as predicate calculus. However, it should not be confused with the branch of mathematics called calculus. Predicate calculus can be said to be a method for analysing propositions in a predicate-argument style. In other words, a proposition is divided into a predicate and an argument, from which we can analyse the truthfulness or falseness of the proposition.

A typical predicate might be: is-transparent. Now, associating this predicate with different arguments, we can get a false or a true statement. Typically, using the argument water, we can say that: water is-transparent, which is of course true. But, if we say milk is-transparent, we obviously get a false statement. In predicate calculus, these can be written as follows:-

is-transparent (water) ⟶ true

is-transparent (milk) ⟶ false

There is also what we call propositional calculus. This differs with predicate calculus that we do not have a predicate and an argument in propositional calculus. We just have a proposition, hence the above statements in propositional calculus can be written as:-

water is transparent

milk is not transparent

There are few variations of syntax used in predicate logic, however, they are similar to each. Hence, a person familiar with predicate logic should be able to quickly understand these variations in syntax.

3.5 EXPERT SYSTEMS vs CONVENTIONAL PROGRAMS

It is essential to note that expert systems are not the same as conventional programs. Waterman [28] has contrasted the two as follows in Table 3.1 and Figure 3.8.

Data Processing	Knowledge Engineering
Representation and use of data	Representation and use of knowledge
Algorithmic	Heuristic
Repetitive process	Inferential process
Effective manipulation of large data bases	Effective manipulation of large knowledge bases

Table 3.1 Comparison of data processing and knowledge engineering.

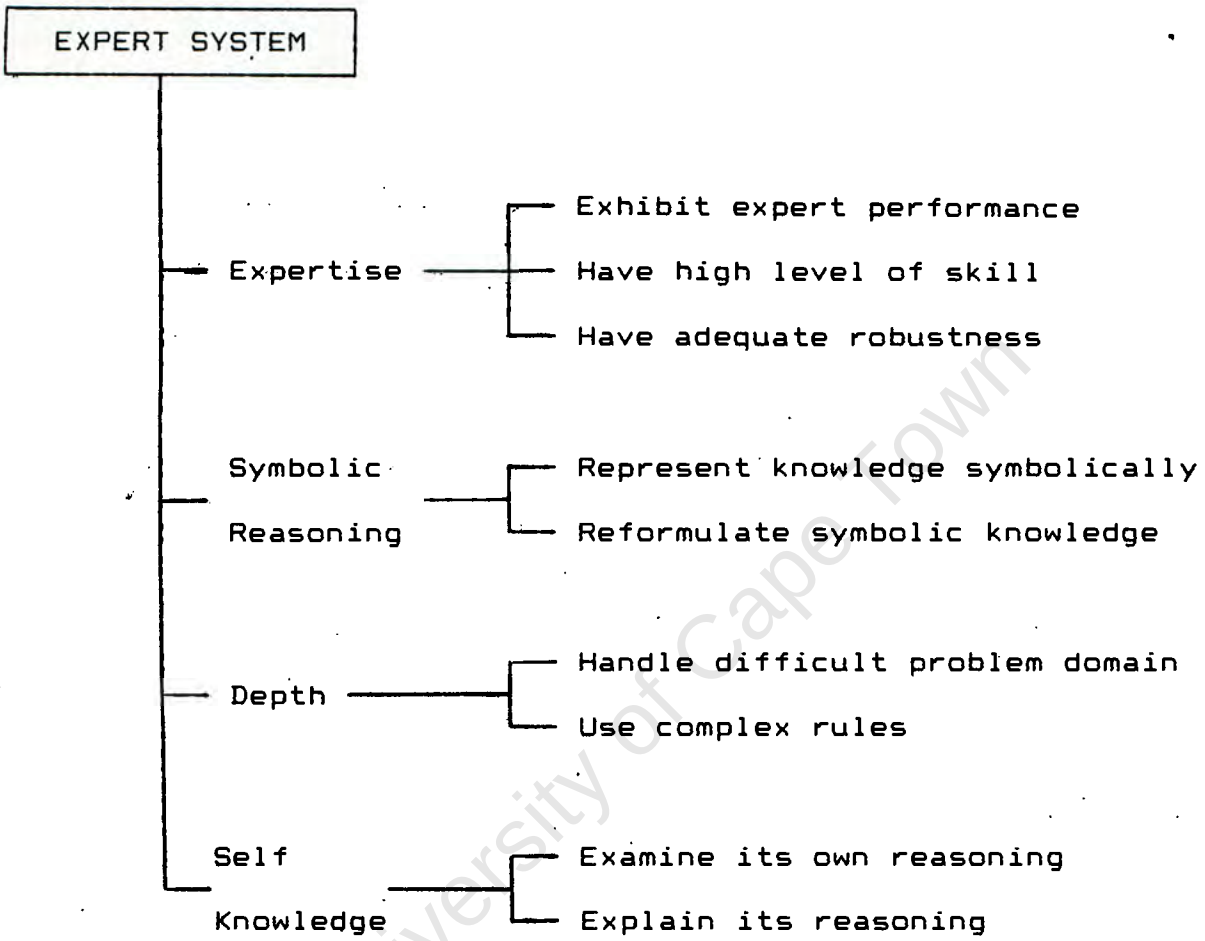


Figure 3.8 Characteristics of an expert system that distinguish it from a conventional program.

CHAPTER FOUR

PROBLEMS OF EXPERT SYSTEMS

4.1 KNOWLEDGE ACQUISITION

Intelligent Ware Inc. [29] notes that to date, knowledge acquisition and expertise transfer have been widely regarded as the major bottleneck in expert system construction. With this major bottleneck, there arises disappointing estimates of expert systems which might be built in the next decade. This was discovered when Intelligence Ware Inc. announced their first automatic knowledge acquisition system. This system can both capture expertise and automatically generate an expert system by asking systematic questions from an expert. Figures 4.1 and 4.2 show this automatic knowledge acquisition system as compared to a conventional knowledge acquisition system respectively.

This automatic knowledge acquisition system throws some hope in the expert system field. However, it is still too early to judge its success because it has been developed late last year (1987). It must still stand the test of times with very large expert systems, comparable to the size of MYCIN for example. If it stands the test of times, the time for developing an expert system will be grossly reduced, hence creating more chances for more expert systems to be developed in the near future.

The knowledge acquisition bottleneck does not take the form of time only, it can also take the form of

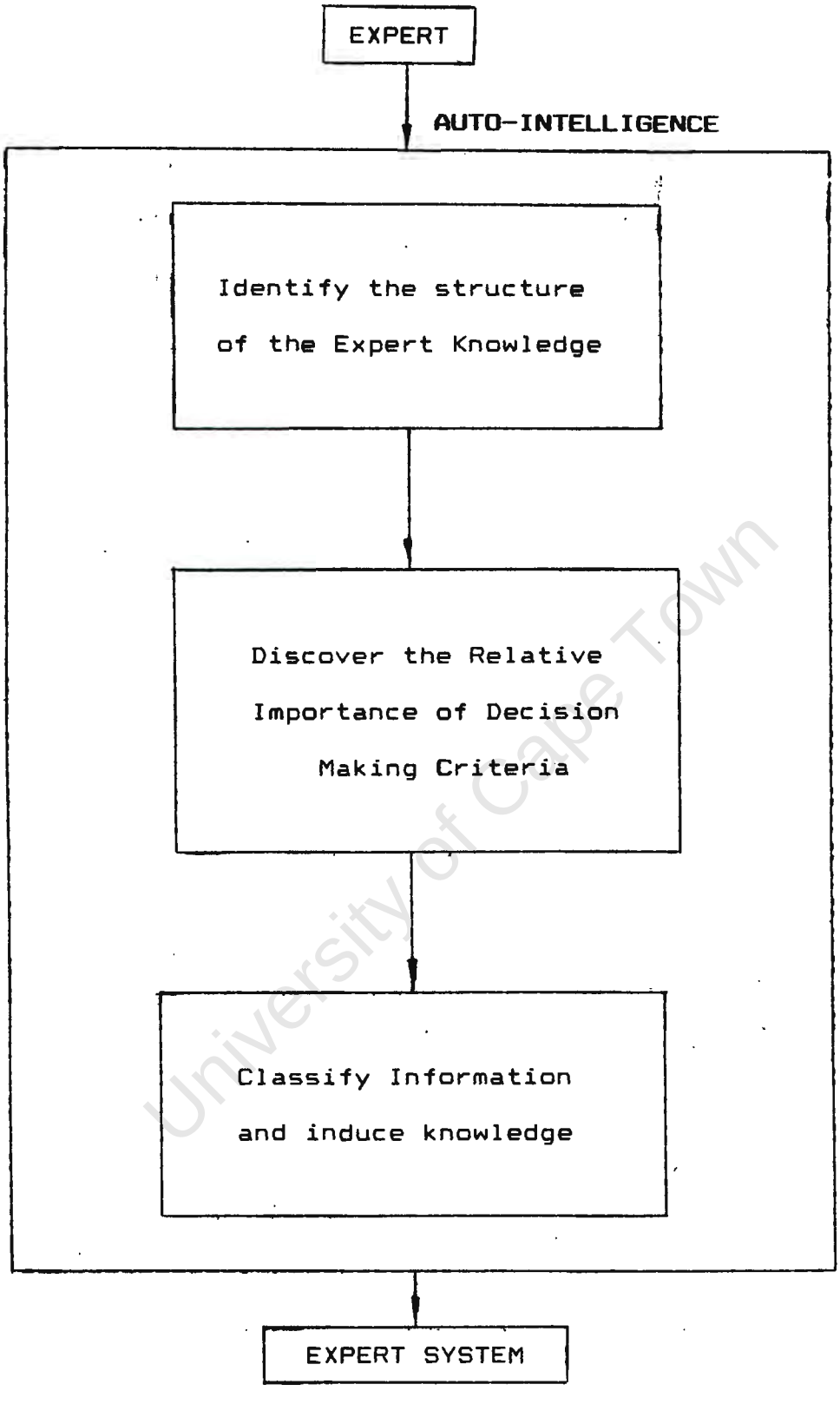


Figure 4.1 An Automatic Knowledge Acquisition System (Source: [30])

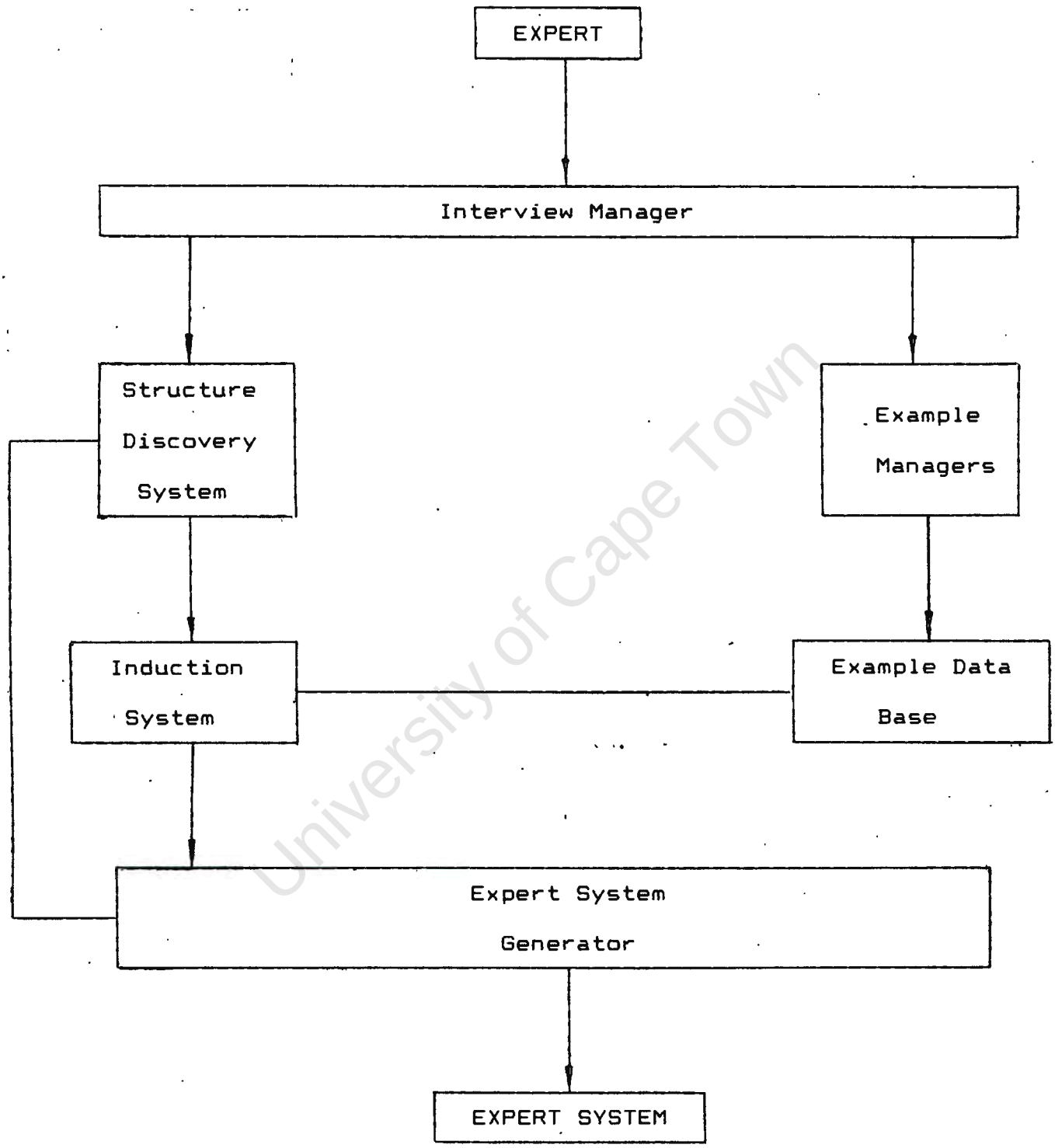


Figure 4.2 A conventional knowledge acquisition system (Source: [30]).

inaccurate information. The English language, like many others, is full of many ambiguities. Hence, a knowledge engineer interviewing an expert is susceptible to those ambiguities. These ambiguities can lead to very unreliable expert sytems.

4.2 REAL TIME EXPERT SYSTEMS

In maintenance and industrial control, a real time system is more useful than an ordinary expert system which cannot be classified as real time. Most maintenance expert systems nowadays still require operator input which is susceptible to human errors. Human errors should not be underestimated, many fatal accidents like Three Mile Island have been attributed to human error. Moreover, human operators can be asked to carry out tasks which affect the state of the plant, such as adjusting valve settings or temporarily switching the flows on and off. This might create other complications if the flow problem was not the only one [30].

This can be remedied by having sensors connected to the computer with the expert system. It is important to stress that very good and highly reliable sensors must be used in this case. Poor and unreliable sensors will increase the uncertainty of conclusions or results reached by the expert system, thus rendering it useless. Regular maintenance and calibration of sensors is recommended for on-line expert systems.

4.3 CLASHING RULES IN AN EXPERT SYSTEM

When an expert system is very large and just entering commissioning stage, it is unlikely that all the solutions it gives will be acceptible. This is usually caused by clashing rules or rules which are in conflict and sometimes by a rule with an unacceptible conclusion. This may be remedied by continually testing the expert system and modifying the rules until the expert system gives satisfactory answers.

In an expert system seminar at the University of Cape Town (U.C.T.) [31], it was mentioned that a large expert system can be in operation for a long time with a rule or rules with unacceptable solutions. This may happen if that particular rule was not "fired" during the test or if the clashing rules were also not "fired". It then follows that an expert system should be thoroughly tested before using it in practice.

4.4 DEBUGGING

Debugging an expert system can be very time consuming. Sometimes, when a rule is changed, it may happen that some rules should be reordered. Reordering the rules does not mean that one has cured the ailment. Sometimes one has to reorder the conclusions as well, depending on the kind of problem and package used.

4.5 UPDATING

When a rule is added in a knowledge base, it must be

checked whether it is not clashing with the existing rules. This is not very easy, particularly with a large expert system involving a complicated subject area. The problems discussed in section 4.3 and 4.4 may crop up again at this stage. Hence, great care should be taken when adding or deleting a rule.

CHAPTER FIVE

BUILDING AN EXPERT SYSTEM

There are many methods of developing an expert system. Sagalowicz [32] breaks his approach into four parts which are:-

1. Problem identification
2. Problem assessment
3. Knowledge architecture
4. System life cycle

Greef and Reinecke [33] divide strategies for building expert systems into three. These are separated according to their size. Hence, we have small systems, large systems and very large systems. These strategies have different kind of steps which are not very dissimilar. Since the expert system in this thesis can be classified as a small to a medium system, then we will follow steps for a small system.

5.1 STEPS TO BE FOLLOWED

The following steps are listed by Greef and Reinecke. It should be noted that these steps are not a rigid prescription. Some variations are possible. Even the order of these steps is by no means a rigid prescription. These are as follows:-

1. Select a tool and implicitly commit yourself to a consultation paradigm.

2. Identify a problem and then analyse the knowledge to be included in the system.
3. Design the system. Initially this involves making flow diagrams and matrices and drafting a few rules.
4. Develop a prototype of the system using the tool. This involves actually creating the knowledge base and testing it by running a number of consultations.
5. Expand, test and revise the system until it does what you want it to do.
6. Maintain and update the system as needed.

5.2 OTHER STRATEGIES

Any person who has ever built an expert system will agree that the larger the expert system, the more complicated it becomes to build. These complications can lead to problems described in the last chapter, Hence, it is advisable to have an expert system of a smaller size. A question now arises: How do we then build expert systems which are covering a complicated domain, needing a large number of rules ?

The above question can be answered in a straight foward manner. A large expert system may be constructed in a modular form i.e. It may be constructed in modules which can be regarded as small independant expert systems. How can this be achieved in practice ?

One can achieve this by having one module (or more if necessary) which can be called a "general" module. The "general" module can solve general problems, but specific or detailed problems are referred to "detail" modules. This are referenced from the "general" module by way of conclusions in the rules of the "general" module. See the following example for further clarification.

GENERAL MODULE

IF the bird is black
the wings are short
the beak is curved
THEN see module A

Module A is therefore a detailed expert system which can identify hawks, say. With this method, the overall expert system can be kept simple and more reliable.

CHAPTER SIX

SELECTING THE EXPERT SYSTEM DEVELOPMENT TOOL

There are many expert system development tools on the market today. However, each has its advantages and disadvantages. Therefore, it is necessary to examine criteria which we can use in selecting an expert system development tool.

6.1 CRITERIA FOR TOOL SELECTION

The developers of Compass, an expert system for telephone switch maintenance [34], provide a few questions which should be answered when selecting an expert system development tool. These are listed as follows:-

1. Can the tool be easily obtained and installed ? This includes cost factors, legal arrangements and compatibility with the existing hardware.
2. How well is the tool supported ? Will later upgrades to the tool be backward-compatible ? Is the current version of the system fairly stable ?
3. Has the tool been used succesfully in a variety of application domains ?
4. How difficult will it be to expand, modify or add a front or back end to the tool ? Is source code availabe or is the system sold only as a black box ?
5. Is it simple to incorporate Lisp (or other language) functions to compensate for necessary features that are not built in ?
6. What kind of knowledge representation schemes does

the tool provide ? Rules ? Networks ? Frames ? Other ? How well do these match the intended application (for example production rules are particularly attractive when expert knowledge is in the form of empirical associations; networks are attractive for representing complex inter-relations among concepts).

7. Can the tool handle the expected form of application data: continuous, error-filled, inconsistent, uncertain, time-varying etc. ?
8. Do the inference mechanisms provided match the problem ?
9. Does the tool provide the blackboard paradigm of separate specialist, and is this necessary for the problem ?
10. Does the allowable granularity of the knowledge match what is needed by the problem ?
11. Does the expected speed of the developed system match the problem if real time use is required?
12. Is there a delivery vehicle available if many copies of the application will be needed ?

Also, Waterman [35] lists some criteria of selecting an expert system development tool. However, this can be seen as a summarized version of the "Compass" criteria.

6.2 EXPERT SYSTEMS ON PC's

The package which has been developed in this thesis is intended for use in industry and should be accessible to

most industries using boilers. The hardware used should be able to meet the above requirements in section 6.1. Personal computers are now available even to very small industries. Mainframes are usually used in large companies only. Hence, mainframes would not be suitable for our purpose. This thesis will therefore be tailored for PC based expert systems. However, advantages and disadvantages of using PC's in implementing expert systems should be noted.

Lehner and Barth [36] highlight some advantages of using microcomputers in the implementation of expert systems, which can be summarized as follows:-

Advantages

1. Microcomputers cost far less than mainframes.
2. They are easily obtainable on the market.
3. They can be transported very easily.
4. They are appropriate for applications where physical space is limited.
5. They can also be used in harsh environment.

Another added advantage is that microcomputer based expert systems can be used even when the mainframe is down. It should also be noted that mainframes need regular maintenance and are not available in that period.

The main disadvantage of the microcomputer is that of speed. They usually execute at speed which are far less than that of mainframes if the program is too large.

6.3 TOOLS CONSIDERED

Three expert system development tools were considered in this thesis. These are MicroExpert, EXSYS and PROLOG (which is essentially a symbolic programming language). MicroExpert and EXSYS are regarded as shells. A shell can be taken as an empty inference engine where one can put a knowledge base, hence creating a full expert system. These shells will be discussed and a better one selected from the two. PROLOG will then be discussed to see whether it is suitable for our purpose. The choice of a shell or PROLOG for this expert system will be made.

6.3.1 MicroExpert

Although MicroExpert can be tailored to suit any need of an expert system builder, it is considered here as a shell. This has a backward inference mechanism.

The knowledge base part of the expert system is created by a text editor. The text editor should not leave any control characters e.g. when using Word Star, a non document file should be opened. The knowledge is represented in the form of production rules.

After creating the knowledge base, this can be run using the MicroExpert shell. This is an interactive expert system which initially prompt the user for a goal. After selecting the goal, a user is asked different questions. This continues until the rule with a goal is verified to be true or false. The expert system then gives a list of

facts supplied by the user as well as those which were derived during the consultation. It should be noted that this inference engine deals with "yes" or "no" answers i.e. it deals with certain information.

Only one predicate "IS" is allowed to link the attribute and the value part of a statement. A typical example is:-

Dog is black

One cannot say, for example

Dogs are black

This shell is written in Turbo-Pascal which facilitates fast execution. It allows a programmer to include his own functions and procedures written in Pascal. Thompson and Thompson [37] have written a booklet on MicroExpert which can be consulted for more features.

6.3.2 EXSYS

EXSYS is an expert system shell which represents knowledge in the form of production rules. The rules are in the IF... THEN... ELSE... format.

This package comes with runtime disk and its own editor. The runtime disk is called EXSYS and the editor is known as EDITXS.

The knowledge base is then created by using EDITXS and

can also be tested by running it with EDITXS. The only disadvantage in practically running the expert system with EDITXS is that the user can change or delete or add any information in the knowledge base. This can be remedied by using the runtime disk, EXSYS.

The inference engine is of a backward chaining type. It initially tries to derive information from other rules. If it cannot find this information, it then asks the user to supply it. The inference engine can be told to stop after the first successful rule or to evaluate all possible rules.

EXSYS, like most other expert systems, has its own terminology, although similar to others in principle. In the IF part of a rule we have condition(s) which can be either text or mathematical. The text condition has two parts: a qualifier and a value. The qualifier is the first part of a condition ending with a verb and the value is the remaining portion.

The THEN part consists of conclusion(s) known as choices. The choices have probabilities associated with them. These probabilities can either be 0 and 1, or 1 - 10, or 0 - 100. 0 and 1 is similar to "yes" and "no" like in Micro-expert. 0 - 10 and 0 - 100 allows for uncertainties, which are typical of the real world.

The choices appear in the solution listing in the order

of their probability, beginning from the largest to the smallest. When the solution listing appears, one can change the information supplied and run the expert system again. The expert system will not start from the beginning if the changed information is not in the beginning i.e. it will not ask the information which it asked in the first consultation. The new solution can be listed simultaneously with the old one for the purpose of comparison.

EXSYS Inc. [8] has written a booklet on EXSYS which can be consulted for further information. These two shells can now be compared.

6.3.3 Advantages of MicroExpert

The following advantages of MicroExpert over EXSYS can be listed:-

1. MicroExpert can be tailored to suit any need of an expert system builder.
2. MicroExpert supports graphics.
3. MicroExpert allows a programmer to include funtions and procedures written in Pascal.

6.3.4 Advantages of EXSYS

The following advantages of EXSYS over MicroExpert can be listed:-

1. EXSYS can handle unreliable information and data.

However, PROLOG has some disadvantages when compared to a good shell. Some of the problems are listed below:-

1. Extensive programming is required.
2. Large memory is required.
3. Slow execution, thus cannot be used in real time control and maintenance.
4. Only reliable data is required if rules are not to be used.
5. It needs a rule intepreter if going to deal with unreliable data.
6. The programmer / knowledge engineer has to learn and know the language.
7. One has to choose between Micro-PROLOG and Turbo-PROLOG if going to use a personal computer. These have their advantages and disadvantages. Moreover, it is impossible to implement Micro-PROLOG programs in Turbo-PROLOG.

6.4 SUITABLE TOOL

From the advantages and disadvantages cited in the description of our chosen tools, it is clear that EXSYS supercedes the other tools for our purpose. Hence, EXSYS will be used for any sofware development in this thesis.

CHAPTER SEVEN

BOILER MAINTENANCE THEORY : Part 1

Having covered the important aspects of the theory of expert systems, it is now necessary to look at the theory and practice of boiler maintenance. The knowledge base of the expert system will be developed from this theory, heuristics and case studies.

All types of boilers will be taken into account when developing the maintenance expert system software. This is because boiler inspection and maintenance is similar, irrespective of the type of the boiler. However, it should be noted that different types of boilers have different controls and methods of operation, although there are many similarities. Due to this diversity, a typical description of controls and operation procedures contained in this thesis will be similar to the Mk series boilers manufactured by John Thomson Africa. John Thompson holds 98 per cent share of the boiler manufacturing industry in South Africa, hence these boilers represent the majority of South African boilers.

These boilers are coal fired, but can be converted to fire gas or oil. At present, the majority of these are coal fired due to the lower price of coal. However, they will be versatile in future when the Mossel Bay Gas Project is complete, and gas available at lower, competitive prices. The boilers will be viewed in the broad categories of water tube and fire tube boilers in

the expert system. It should be noted that boilers can be classified according to methods of firing, size, shape, type, or according to other distinct characteristics [38 - 40]. Using the terminology of the Department of Manpower, the Mk series can be classified as economic, Cylindrically Multitubular Internally Fired boiler or simply CIMF [41].

A cutaway view of this range of boilers can be seen in Figure 7.1. Diagrams showing component location can be seen in Figures 7.2 and 7.3. These show all views of the single and double chain grate stoker boilers respictively. Component lists are also given in Tables 7.1 and 7.2 respectively.

7.1 BOILER MAINTENANCE AND CONTROL

A boiler is a very expensive piece of equipment. A boiler with a steam capacity of 20 tonnes / hour costs in the region of R 800 000, excluding transportation, installation and commissioning costs. Hence, a boiler should be controlled and operated with care in order to avoid or reduce the number of possible breakdowns.

This will also ensure a longer life for the boiler. Hence, boiler operation and control is a fundamental prerequisite for boiler maintenance. For this reason, major boiler controls and operations will be described briefly. Most control strategies will be used as preventative maintenance techniques in the expert system.

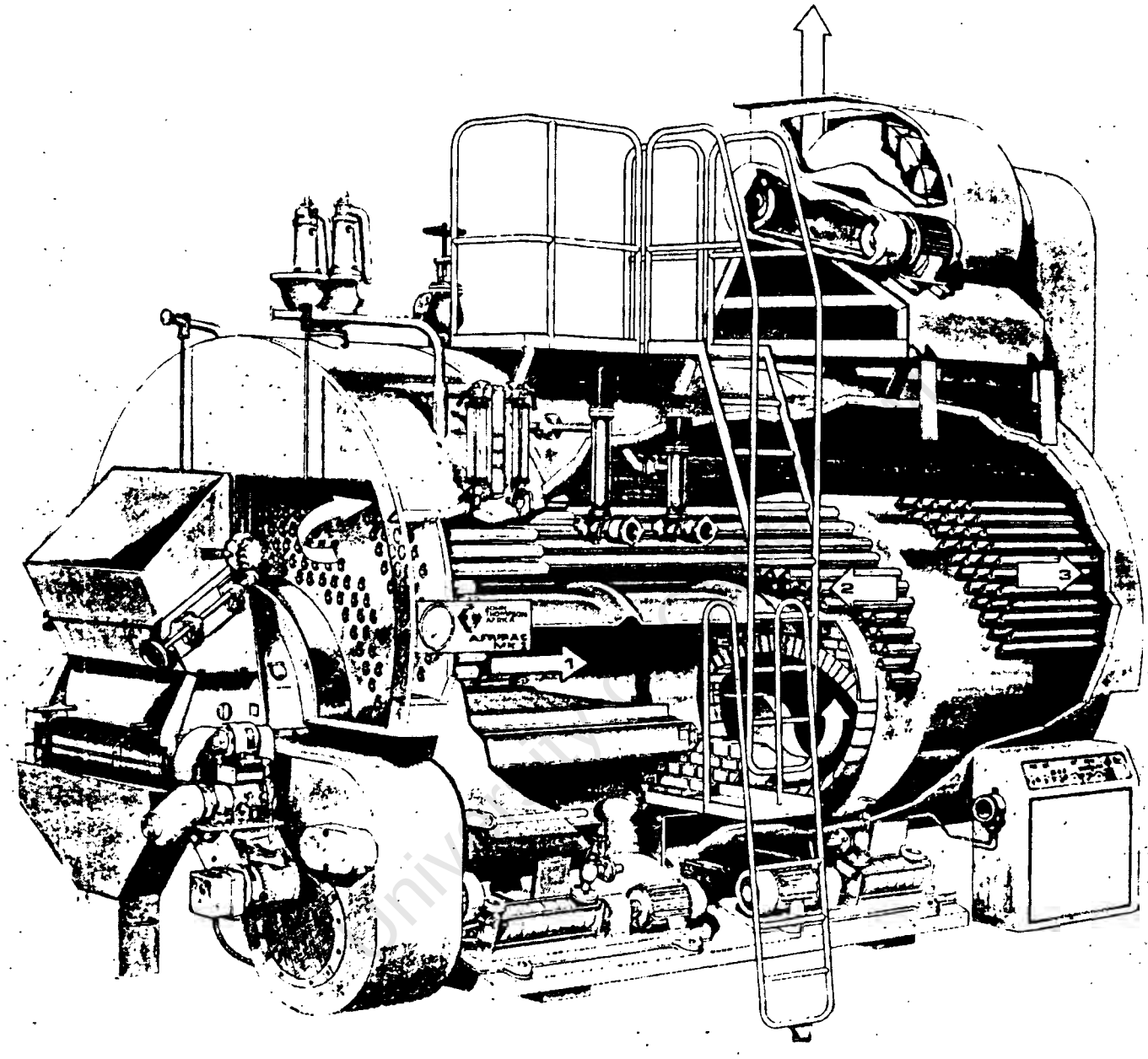
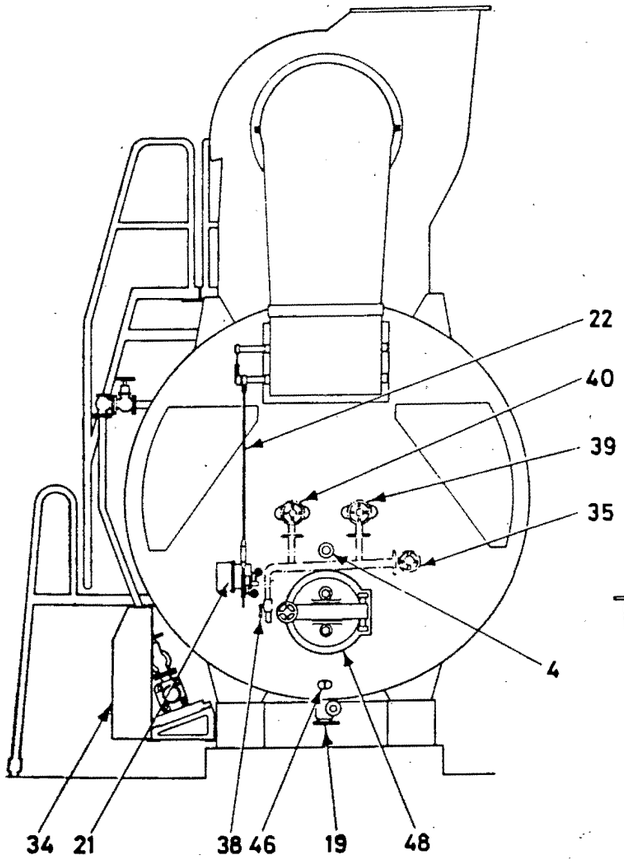
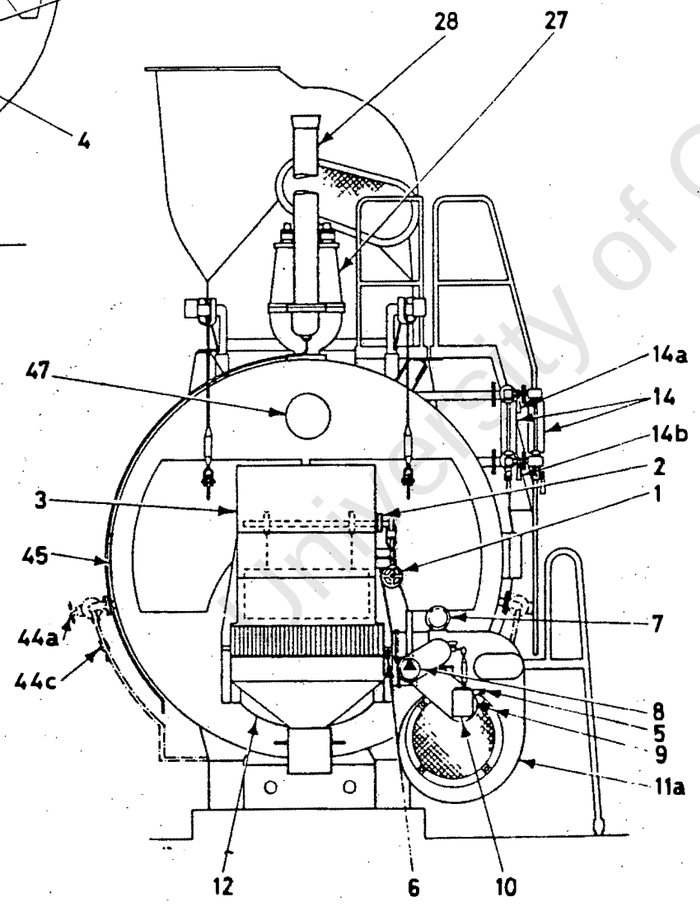
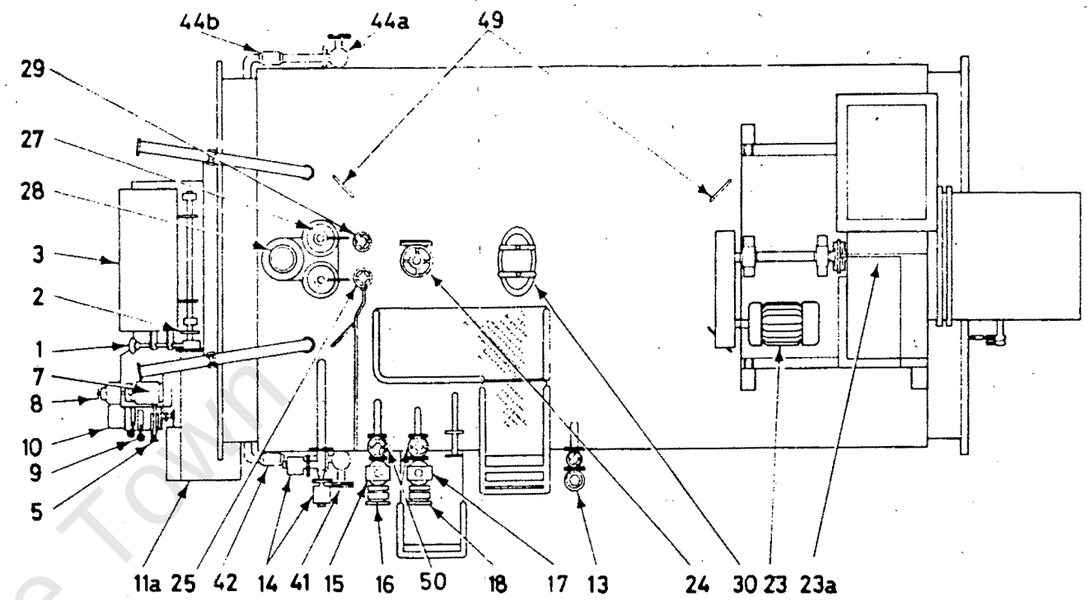


Figure 7.1 Afripac Mk 2 boiler cut-away view







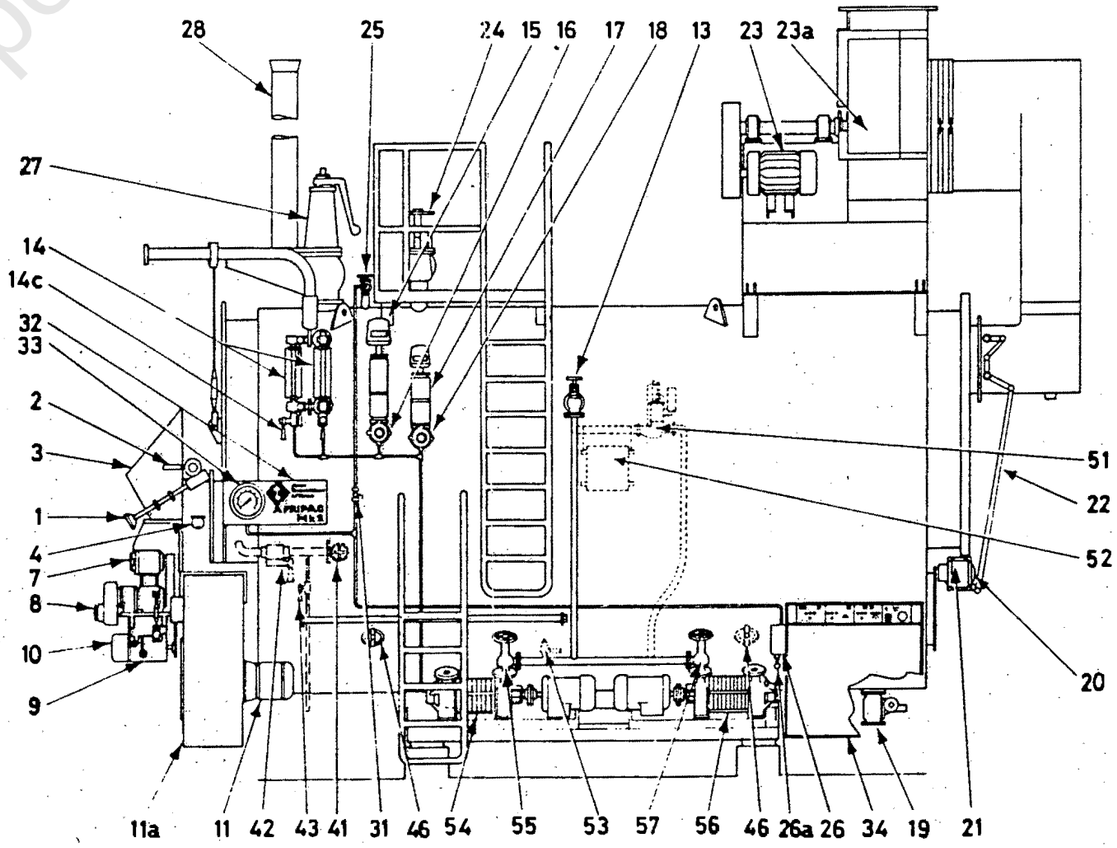
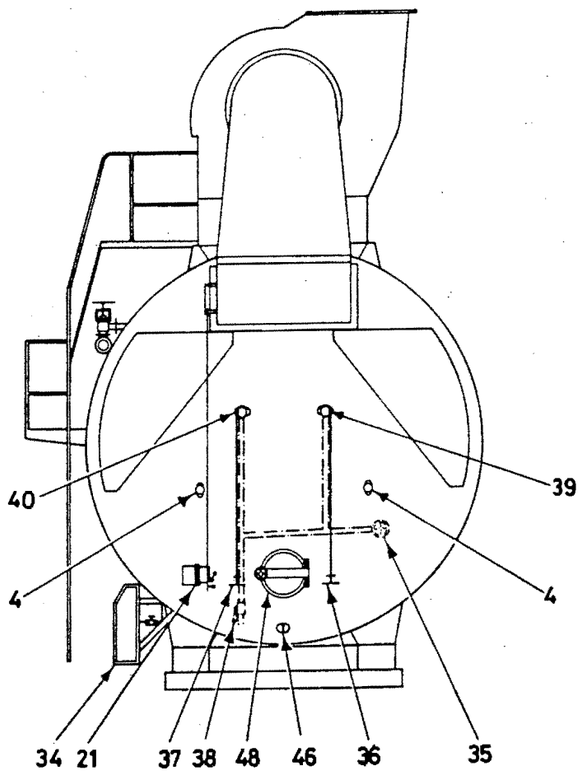
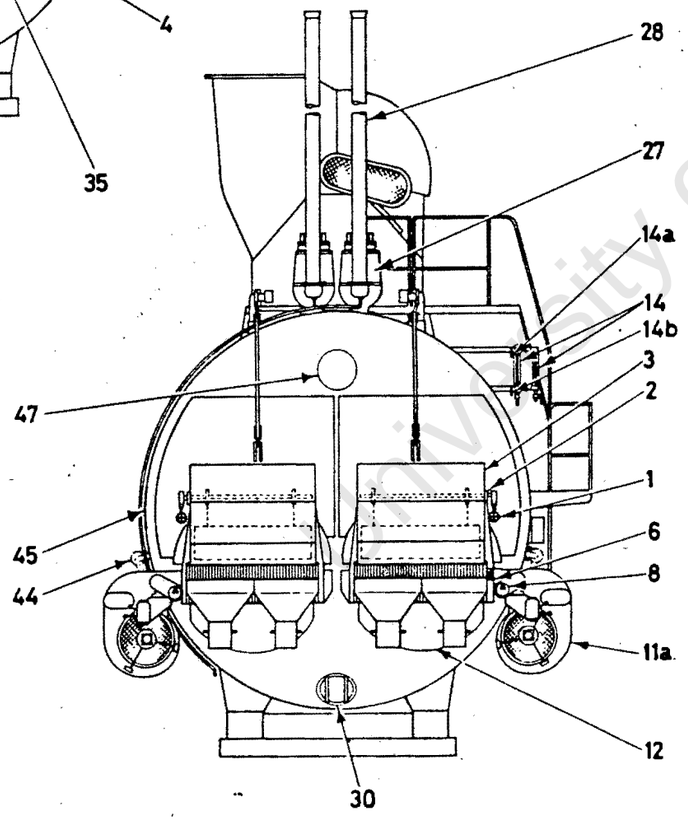


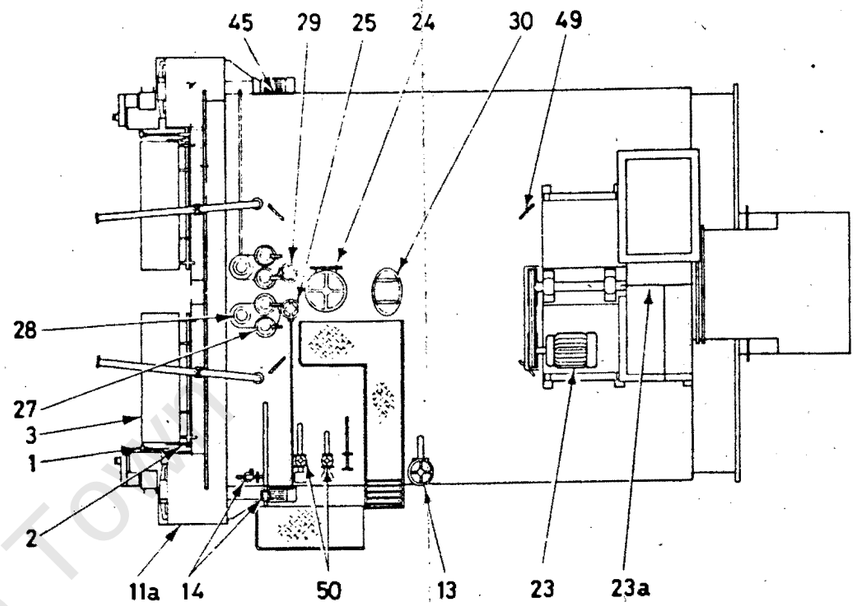
Figure 7.2 Component location for the single stoker boilers.

LOCATION NO	COMPONENT
1	Guillotine door operating handle.
2	Fuelbed depth indicator (mm)
3	Coal hopper incorporating. coal cut-off gate.
4	Spyhole.
5	Fuel trim knob.
6	Undergrate damper opering lever.
7	Stoker drive motor.
8	Grate movement indicator disc.
9	Single-knob Combustion Control Unit.
10	Pulling motor.
11	FD fan drive motor.
11a	FD fan and damper.
12	Emergency de-ashing door.
13	Main feedwater check valve.
14	Water gauges with test cocks.
15	Float-operated Two-switch Control or Modulating Level Controller.
16	Sequencing blowdown valve.
17	Float-operated Single-switch Control.
18	Sequencing blowdown valve.
19	Boiler blowdown valve.
20	ID damper Control Unit.
21	Pulling motor.
22	ID damper linkage.
23	ID fan drive motor.
23a	ID fan.
24	Main steam stop valve.
25	Isolating valve for steam pressure gauge.
26	Steam pressure detector.
26a	Isolating valve.
27	Safety valve.
28	Safety valve escape pipe.
29	Air relieve valve.
30	Man hole.
31	Inspector's test-cock.
32	Manufacturer's name plate.
33	Steam pressure gauge.
34	Control panel.
35	Steam isolating valve for rear sootblowers.
36	Number not used.
37	Number not used.
38	Blow cocks for rear sootblowers.
39	Rear sootblower(RHS)
40	Rear sootblower(LHS)
41	Steam isolating valve for RHS front sootblower.
42	Operating valve for RHS front sootblower
43	Drain cock for RHS front sootblower.
44a	Steam isolating valve for LHS front sootblower.
44b	Operating valve for LHS front sootblower
44c	Drain cock for LHS (obscured)
45	Manufacter's detail plate.
46	Handhole.
47	Inspection cover.
48	Rear access door.
49	Lifting lugs.
50	Isolating valves for float operated controls.
51	Modulating valve.
52	Control box for modulating valve.
53	Pressure relief valve.
54	Feedpump No. 1.
55	Isolating valve for feed pump No. 1.
56	Feedpump No. 2.
57	Isolating valve for feedpump No. 2.

Table 7.1 Component list for single stoker boilers.







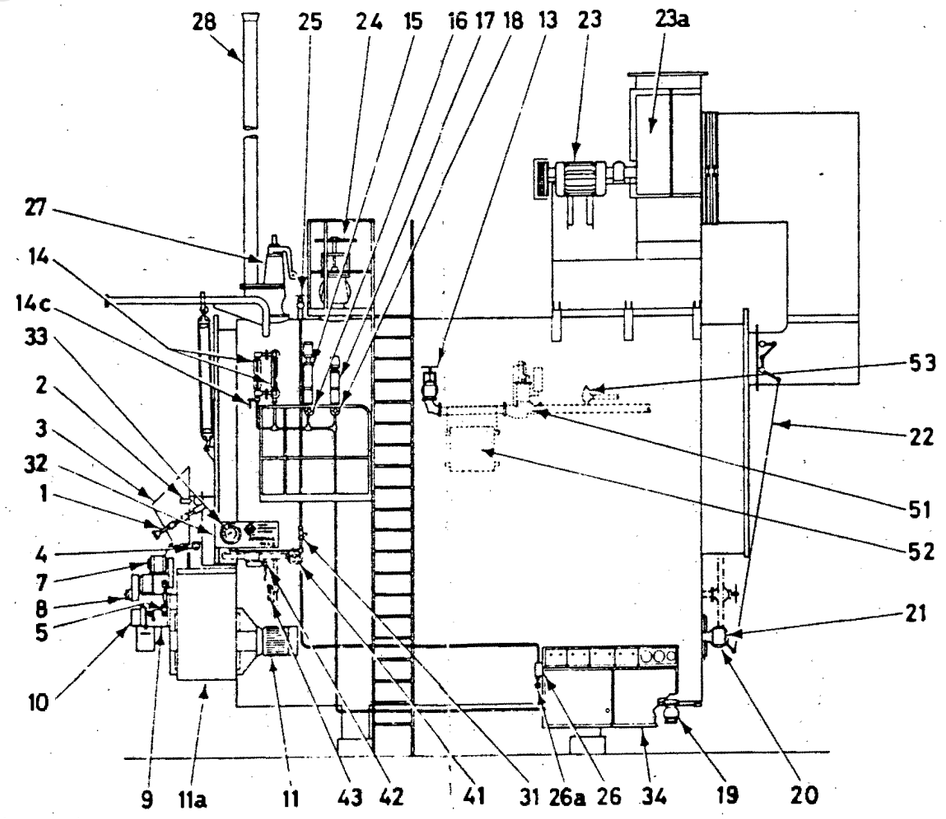


Figure 7.3 Component location for the double stoker boilers

LOCATION NO	COMPONENT
1	Guillotine door operating handle.
2	Fuelbed depth indicator (mm)
3	Coal hopper incorporating. coal cut-off gate.
4	Spyhole.
5	Fuel trim knob.
6	Undergrate damper opering lever.
7	Stoker drive motor.
8	Grate movement indicator disc.
9	Single-knob Combustion Control Unit.
10	Pulling motor.
11	FD fan drive motor.
11a	FD fan and damper.
12	Emergency de-ashing door.
13	Main feedwater check valve.
14	Water gauges with test cocks.
15	Float-operated Two-switch Control or Modulating Level Controller.
16	Sequencing blowdown valve.
17	Float-operated Single-switch Control.
18	Sequencing blowdown valve.
19	Boiler blowdown valve.
20	ID damper Control Unit.
21	Pulling motor.
22	ID damper linkage.
23	ID fan drive motor.
23a	ID fan.
24	Main steam stop valve.
25	Isolating valve for steam pressure gauge.
26	Steam pressure detector.
26a	Isolating valve.
27	Safety valve.
28	Safety valve escape pipe.
29	Air relieve valve.
30	Man hole.
31	Inspector's test-cock.
32	Manufacturer's name plate.
33	Steam pressure gauge.
34	Control panel.
35	Steam isolating valve for rear sootblowers.
36	Extension handwheel for RHS sootblower.
37	Extension handwheel for LHS sootblower.
38	Drain cock for rear sootblower.
39	Rear sootblower(RHS)
40	Rear sootblower(LHS)
41	Steam isolating valve for RHS front sootblower.
42	Operating valve for RHS front sootblower
43	Drain cock for RHS front sootblower.
44	Obscured:
(a)	Steam isolating valve for LHS front sootblower.
(b)	Operating valve for LHS front sootblower
(c)	Drain cock for LHS front sootblower.
45	Manufacturer's detail plate.
46	Handhole.
47	Inspection cover.
48	Rear access door.
49	Lifting lugs.
50	Isolating valves for float operated controls.
51	Modulating valve.
52	Control box for modulating valve.
53	Pressure relief valve.
	(Items not shown are feedpumps and their isolating valves)

Table 7.2 Component list for double stoker boilers.

installation. A job description of a boiler attendant, who is also required to carry out basic maintenance of the boiler, can be seen in Appendix B.

7.2 CONTROLS

7.2.1 Water Level Controls and Monitoring Instruments

1. Water Level Gauge Glasses

The boiler is fitted with two water level gauge glasses for visual inspection. One gauge is towards the front of the boiler, whilst the other one is situated on the side of the boiler. Each gauge glass has three divisions. There is a middle mark, which indicates the normal water level. The water level should be kept at this mark for normal operations. The top and bottom marks are the high and low water level marks indicators. An alarm sounds when the low water level mark is reached. The feed pump starts pumping when this mark is reached. The feed pump stops pumping when the highest water mark is reached. The gauges are protected by toughened glass. There is also a chevron at the back of each gauge to facilitates an accurate inspection of the water level.

2. Water Feedpump Selection Switches

These switches are situated on the control panel. Standard boilers are fitted with two control switches. One switch selects manual / automatic control of the feed pumps. The other switch selects either pump no. 1 or pump no. 2. When the operation is on the manual mode, the selected pump will operate until its off button is

depressed. When the operation is on automatic mode, the pumps are controlled by the float-operated control switches which will be described in 3.

Sometimes a modulating control unit is fitted. It controls the flow of feedwater in proportion to steam demand. The pumps operate continuously when this unit is fitted.

3. Water Level Control

In a standard boiler, the water level is controlled by two separate float-operated control switches. One is known as the two switch control unit and the other as the single switch control unit. These switch units have the following functions:-

- Control the water level in the boiler by switching a feed pump on and off.
- Cause audible and visual alarms to be invoked when the water level in the boiler falls to the low water mark.

The other float-operated switch detects an extra low water level situation. When this extra low water level is reached, all the combustion equipment is stopped. Combustion cannot be restarted until the safe water level has been re-established.

4. Alternative Water Controls

Instead of float-operated switches described in 3, a

modulating controller can perform the same function as the float operated controllers. This is an automatic controller, but the automatic function can be over-ridden if required. This can be done by opening the isolating valve to the inlet solenoid, and opening the exhaust valve.

More important, when the modulating controller is fitted, there should be a pressure relief valve on the discharge side of the pump. This pressure relief valve protects the pump from over heating and possibley more damage when the modulating valve closes completly. This is because pumps do not stop when this unit is fitted.

7.3.2 Combustion Controls and Monitoring Instruments

1. Steam Pressure Gauge

The boiler is fitted with a Bourdon tube type pressure gauge which is calibrated in kilopascals (kPa). The red mark on the gauge indicates the authorised working pressure. An isolating valve is fitted for the purpose of repairs, replacement etc.

2. Firing Rate Control

Firing rate is controlled through the Single knob Combustion Control Unit. This synchronizes the Forced Draught Damper and the chain grate speed, as well as the fuel trim assembly. This also affects the air / fuel ratio, hence varying the amount of CO_2 exhausted. Optimum results are obtained at a CO_2 content of about

12.5 per cent.

The firing rate can be controlled manually or automatically. In the manual mode, one can use the lever in the Single knob Combustion Control Unit or the panel controls to vary the firing rate. In the automatic mode, the firing rate is controlled automatically through the monitoring of the furnace pressure.

3. Furnace Pressure Control

Furnace pressure control is achieved through the Induced Draught and Forced Draught dampers. These dampers can be opened and closed by using the Induced Draught Control Unit and Single knob Combustion Control Unit respectively. Opening the Forced Draught dampers increases the furnace pressure, whilst closing the dampers decreases the furnace pressure. The furnace pressure decreases when opening the Induced Draught damper, whilst the furnace pressure increases when it is closed.

It should be noted that when increasing the firing rate, the Induced Draught dampers should be opened first. When decreasing the firing rate, the Induced Draught dampers should be closed first.

4. Furnace Pressure Gauge / Switch

Furnace pressure is monitored by a draught gauge calibrated in pascals (Pa). This gauge has three

needles. The black needle indicates the furnace pressure. The two red needles fix the range of furnace pressures when operating on automatic mode. The right hand needle should be set to - 15 Pa and the left hand needle to - 3 Pa.

7.2.3 Stoker Controls

This consists of the coal cut off gate, guillotine door and the undergrate dampers.

The coal cut off gate is in the stoker hopper. It can be closed and opened in order to allow or stop coal from reaching the grate. This gate trips and closes under dangerously low water levels.

The guillotine door controls the thickness of the fuel bed on the grate. This is controlled through a hand wheel. Whenever the hand wheel is adjusted, the fuel trim knob should also be adjusted to compensate for the change in air / fuel ratio.

The undergrate dampers are responsible for the length of the active fuel bed. Opening and closing the undergrate dampers increases and reduces the length of the active fuel bed respectively. These are closed when operating at loads less than 30 per cent or when lighting the fire.

7.2.4 Ash and Grit Removal

This basically consists of the primary de-ashing port and

the ermegency de-ashing door. The grit collector must also be fitted to reduce air pollution. Other installations are fitted with a conveyor belt for removing ash.

The primary de-ashing port is located at the end of the stoker and the emergency de-ashing door is located in the front of the stoker.

7.2.5 Sootblowers

This consists of two front and two rear sootblowers. Each end has a right and a left sootblower.

Sootblowers are recommended to be used every 12 hours on a 24 hour shift basis. Sootblowers are intended for removing soot and some loose scales from the fire tubes.

7.2.6 Valves and Mountings

These include boiler blowdown valve, safety valves, main steam valve, automatic sequencing blow down valve and the inspector's test gauge connection.

The boiler blowdown valve is used for a dual purpose. It is firstly used for blowing down water from the boiler in order to control the chemical content of water. It is also used to drain the boiler completely.

The safety valve ensures that the operating steam

pressure does not exceed the design pressure of the shell. The valve must blow the excess pressure into the atmosphere, should the operating pressure exceed the design pressure. The valve setting should not be tempered with, and should be tested at least once a week.

The main steam valve is used to isolate the boiler from the main steam line supplying user departments. The automatic sequencing blowdown valves ensures the correct operation of float-operated controls.

The main feedwater check valve isolates the boiler from the feedwater supply. The air release valve is used to vent air during filling and steam raising. It also prevents the formation of a vacuum when draining the boiler. The inspector's test gauge connection is next to the boiler pressure gauge. This is done for comparison purposes during tests.

7.3 OPERATING PROCEDURES

There are many operating procedures to be followed in order to avoid boiler breakdowns and accidents. These operations are common to most boilers employed today. Some of these operations can be done manually or automatically, depending on the type and functions of the boiler. These are outlined in the following sections.

7.3.1 Sootblowing

During the operational period, the fire tubes and the

tube plates collect soot. A regular removal of soot is then necessary. It should be noted that sootblowing should be done when the boiler is at low loads and near its maximum working pressure.

The amount of soot accumulating varies with the frequency of use and the type of coal used. Hence, each user should decide his frequency of sootblowing. It is recommended that mechanical cleaning of the tubes is done during shutdown. This helps to remove scales which can not be removed by sootblowing.

7.3.2 Blowdown Procedures

1. Blowdown of Instrumentation

The pipes connecting instruments contain varying amounts of solids and impurities. These may interfere with the correct functioning of the instruments. To alleviate this problem, instruments need some form of blowdown.

Instruments which need blowdown are: gauge glasses,float-operated switches and the modulating control unit.

2. Boiler Blowdown

Boiler blowdown is necessary for different reasons. It may be necessary under the following circumstances:-

- To control the quality of the boiler water.
- To control the boiler water under abnormal conditions.
- To empty the boiler.

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- To control the quality of the boiler water.
- To control the boiler water under abnormal conditions.
- To empty the boiler.

- To promote circulation during start up from cold.

The water in the boiler may contain varying amounts of solids and chemicals. Sludge may also be formed at the bottom of the boiler. To control the amounts of solid concentration and to remove sludge, it becomes necessary to blowdown at regular intervals. An automatic blowdown unit has proved to be more economical and accurate in boilers. It is important to observe that a boiler should never be blown down if the water level is below normal. If the blowdown valve jams, the fire should be removed from the grate immediately.

When emptying the boiler completely, the fire should be completely run off. The air release valve should be opened so as to prevent the formation of a vaccuum. The vacuum can lead to the distortion of the boiler. The pressure should be around 50 kPa before emptying it.

7.3.3 Ash and Grit Removal

The frequency of the removal of ash is dependant upon the size of the boiler and the boiler load. The ash trolley should be emptied immediately before it fills up. Ash should never be allowed to pile up. In case of an ash conveyor, one must check that the ash is leaving the boiler.

The same circumstances as above apply to the grit trolley. The frequency of grit removal is usually

constrained by the type of coal used.

7.3.4 Lighting a Fire

Certain steps should be followed when lighting a fire. Each type of boiler has its own specific procedure of lighting a fire. These are detailed in the manufacturer's manual. Many boiler attendants may ignore these steps and use their "experience". This should be avoided, since deviation from specific procedures might lead to a major breakdown, and a possible loss of the boiler. "Experience" should be checked against the rapidly changing technology.

7.3.5 Operating on Automatic Mode

Automatic control of the Forced Draught dampers should only be set when the fire is burning satisfactorily. The Induced Draught dampers should be set to automatic control only when the boiler pressure is within 50 kPa of its operating pressure.

7.3.6 Shutdown

1. Periods up to 30 minutes

It may be necessary to shut down the boiler for periods up to 30 minutes. To achieve this, the Induced Draught and the Forced Draught Fans should be closed. The Single knob Combustion Control Unit should be set to zero so that the stoker should be just moving. The furnace pressure should be kept below minus 3 kPa so that the fire will not burn back. This will also protect the

grate from over heating.

2. Periods up 18 hours

This is usually known as banking. This method keeps the coal in the grate burning extremely low. The water level and the grate should be checked regularly during banking. A blowdown should never be carried out during banking.

3. Normal Shutdown

If the boiler is to be shut down for a period of more than 18 hours, the fire should be completely run off. After shutting the boiler down, clinker should be removed and the boiler and it's sorroundings cleaned. The guillotine door should never be opened too soon. The sudden inrush of cold air may affect the grate, refractories, brickwork and tube sealings.

4. Emergency Shutdown

When there is a power failure or extra low water level, the Induced Draught Fan, the Forced Draught Fan and the stoker motors stop. It is necessary to remove all live coal when this happens. When the extra low water level is reached, and the fans and stoker do not trip, all live coals must also be removed.

CHAPTER EIGHT

BOILER MAINTENANCE THEORY : Part 2

8.1 INTRODUCTION

The boiler has major components which need different maintenance strategies. These components are the chaingrate stoker, feedwater controls and equipment, feedwater pumps, boiler valves, sootblowers, induced draught fan, forced damper, furnace draught gauge, Mobrey airbreak water level control, Mobrey thermofeed regulator, Mobrey modulating level controler and floating safetey valves.

In addition to the above, the following actions should be taken: monitoring of boiler efficiency, cleaning of the boiler, inspection of the boiler and lubrication of moving parts.

Each of the above components need some kind of maintenance policies. Coxon [42] divide maintenance policies into corrective and preventative policies. Corrective maintenance includes repair and apportunity maintenance. Preventative maintenance includes inspection, condition monitoring, replacement and shutdown maintenance. Lockyer [43] identify five types of maintenance policies as time based, work based, opportunity based, condition based and emergency based maintenance policies. It should be noted that these approaches are similar in all respects.

Hence, each component of the boiler will employ one or more of the above maintenance policies. The criteria for choosing maintenance policies will depend upon the characteristics of each component.

8.2 MAINTENANCE TOOLS AND EQUIPMENT

A boiler is usually supplied with certain tools and equipment when delivered to the customer. The following are usually supplied: manhole spanner, handhole spanner, double ended spanners, tube cleaning rod, bushes for plain tubes, manhole and handhole joints.

8.3 MAINTENANCE OF COMPONENTS

8.3.1 Feedwater Controls and Equipment

Feedwater equipment should be checked during periods when the boiler is steaming at low loads. The feedpump should be checked whether it cuts off at the correct water level. It should also be checked whether it cuts in at the correct water level.

The on / off lights for the feedwater pump should be checked at the control panel whether they light and extinguish as necessary. The water level alarm should also be checked whether it cuts in and out as necessary. Both pumps should be checked in turn.

When the boiler is fitted with a modulating valve, the modulating valve spindle should be checked whether it moves upwards when the pumps are switched off and, vice

versa when the pumps are switched on. The alarm and the panel light should also be checked.

The extra low water level switch should also be tested. Check whether the Forced Draught Fan, Induced Draught Fan and the stoker stop at the correct water level.

8.3.2 Boiler Valves

All valves should be checked to ensure that they operate with no signs of sticking or leakage. The leaks may be cured by tightening the gland nuts or repacking the glands when the boiler is shutdown.

The boiler blowdown valve is very important, hence it should be checked regularly.

8.3.3 Sootblowers

These should be checked whether the nozzles are free from blockages. All blocked nozzles should be replaced as necessary.

8.3.4 Induced Draught Fan

The fan belts of the Induced Draught Fan should be checked regularly. If there are any signs of wear, fan belts should be replaced immediately. Correct tension must be kept at all times.

The fan bearing should also be checked. It should be replaced immediately if there are any signs of defects.

8.3.5 Induced Damper

This damper consists of linkages. The linkages should operate smoothly, with no signs of sticking. If there are any signs of sticking or jamming, the linkages should be removed and cleaned.

After cleaning, the linkages should be lubricated with a suitable grease and reassembled. Recheck the damper for correct operation, and take necessary action if sticking persists.

8.3.6 Furnace Draught Gauge

The furnace draught gauge should be checked at regular intervals. This should be checked as follows:-

- Remove the rubber pipe connecting to copper pipe at the rear of the control panel.
- Blow the copper line through, preferably with compressed air. Do not blow air into the rubber pipe connected to the draught gauge.
- Check that the draught gauge reads zero. Re-zero as necessary.
- Reconnect the rubber pipe connecting to the copper pipe.

8.3.7 Forced Damper

This is controlled through the Single knob Control Unit. This can be either manually or panel controlled. On the manual mode, check that the lever operates without

any signs of sticking. On the panel mode, check that the damper light illuminates and extinguishes as necessary. Repair any signs of defect.

8.3.8 The Chain grate Stoker

The chain grate is one of the most important part of a coal fired boiler. It should be prevented from overheating at all costs. If there are any signs of overheating, it should be sent to the manufacturers for repairs.

The tension of the chain grate must be kept correct at all times. Care should be taken not to overtighten it. It should be cleaned every time the boiler is shut down.

8.3.9 Annual Services

The Mobrey Airbreak Level Controls, Mobrey Thermofeed Regulator, Mobrey Modulating Level Controller and the Floating Safety valves should be inspected and serviced at least annually. This is in accordance with the requirements of the Inspector of Factories and Machinery.

8.4 OTHER SERVICES

8.4.1 Boiler Running Efficiency

Boiler efficiency can be checked through the measurement of temperature and the carbon dioxide content of the exhaust gases. Permanent or portable equipment can be used to measure the above quantities.

The exhaust gas temperature should be approximately 250 degrees celcius at 100 per cent load. Some possible causes of high exhaust gas temperature are the following:-

- fouling of boiler tubes
- low air / fuel ratio
- overloading of the boiler

The amount of carbon dioxide in the combustion gases should normally be between 12 and 13.5 per cent. Causes of high carbon dioxide content are as follows:-

- fire moving away from guillotine door
- fire burning back into the hopper

Causes of low carbon dioxide content are as follows:-

- air infiltration through smoke box door joints and smoke box duct work
- air infiltration through ash collector flange

8.4.2 Feedpump Strainer Cleaning

If the feedpump strainer is fitted in suction pipe work, it should be cleaned during boiler shutdown.

8.4.3 Cleaning the Feedwater Tank

The feedwater tank should be inspected inside and outside and cleaned. It should also be inspected for leaks and

other defects. It will be necessary to empty the tank when cleaning it. Hence, it should be cleaned during shutdown if alternative water source cannot be sought.

When the feed water tank is drained, sediments and all other kinds of impurities should be removed. When filling the tank, the correct amount of chemicals should be added.

8.4.4 Cleaning the Boiler

The fire tubes should be cleaned at regular intervals. Failure to do so may reduce the boiler effiency drastically. Even if the sootblowers are installed, it is advisable to clean them with hand or mechanically operated tube cleaners.

It is also necessary to clean the flue, the combustion chamber and the back tube plate with a wire brush. This will help to remove grit and soot. The brick work should be inspected and repaired as required every three months.

If any tubes are found to be defective and require replacement, a qualified artisan must replace them. The manufacturers would be the best in this service.

The build up of scale on the water side must be prevented by using the correct water treatment. However, if scales build up occurs, it may be removed chemically or mechanically. A qualified chemical cleansing firm should

be called for service if chemical removal is to be used. Mechanical descaling using chipping hammers and chisels should be applied with care. The boiler shell, tubes etc. can be damaged if enough care is not taken.

The exterior of the boiler should also be kept clean by removing all coal dust and traces of oil and grease. It should be painted when necessary.

8.4.5 Boiler Inspection

Slag often collects in the combustion chamber. This can be removed using a slicing bar. Care must be taken not to damage refractories. Damaged refractories should be replaced immediately.

Brick work and insulation must be inspected during shut down periods. Brick work may be inspected by climbing into the boiler. Defective brick work should be repaired immediately. The insulation around the rear access door should be carefully inspected. All defective insulation should be replaced. Failure to do this may lower the boiler effeciency. The flap door under the stoker must be kept shut at all times when the boiler is operating.

The front and rear smoke box door joints must be checked to determine whether they are properly sealed. New asbestos rope must be installed if there are any signs of gas leaks. One sign of gas leaks is discoloured paint around the door.

Boiler foundations must also be inspected. The boiler should be shut down if there are any signs of cracks in the foundation. The boiler should never be allowed to operate until the cracks are repaired.

8.4.6 Lubrication

The grease of the Induced Draught and Forced Draught fan bearings should be changed every three months. It must be noted that the right type and amount of grease should be used. The Induced Draught Damper Unit should be also greased every three months. The central control shaft must be removed and greased. The rear sootblowers must also be greased.

8.5 MAINTENANCE SCHEDULES

The following maintenance schedule is recommended by John Thompson Africa. It was drawn from practical experience with steam boiler installations.

8.5.1 Daily Maintenance

Blowdown of gauge glasses

Checking the carbon dioxide content

Testing the two switch controller

Testing the modulating level controller

Testing the single switch controller

Inspecting the feedpumps

Inspecting boiler valves

Exterior cleaning

8.5.2 Weekly Maintenance

Testing safety valves

Checking furnace draught gauge

8.5.3 Monthly Maintenance

Cleaning feedpump suction strainer

Inspecting sootblowers

Inspecting the Induced Draught Fan belts

Inspection of brickwork and insulation

Inspection of seals in smokebox joints

8.5.4 Three to Six Months Maintenance

Inspection of boiler brickwork

Lubrication of moving parts

8.5.5 Yearly Maintenance

Cleaning the feedwater tank

Annual survey

8.5.6 Two Yearly Maintenance

Hydraulic test

Internal inspection of boiler

External inspection of boiler

(See the statutory requirements of boilers in the next chapter for more details)

8.5.7 Shutdown Maintenance

Checking the Induced Draught Fan and linkage

Checking the Forced Draught damper movement

Cleaning fire tubes

Cleaning the flue, combustion chamber and back tube plate

Removal of slag

8.6 SPARES

Spare parts are necessary to be held for prompt repairs. However, there are spare parts which must be held by all users and there are those which must be held by remote installations. This will prevent long order periods to remote installations.

8.6.1 General Boiler Spare Parts

These should be held by all users:

Manhole joint

Handhole joint

Blue Sight Glasses

Gauge Glasses

Gauge Glass Cone

Sleeve Packing for Gauge Column

Mobrey Control Float

Mobrey Control Airbreak Switch

Mobrey Control Joint

Electrically Driven Tube Cleaning Machine

Heavy Duty Flexible Shaft for tube cleaning machine

Tools for tube de-scaling

Brushes for plain tubes

Brushes for stay tubes

8.6.2 Feedpump Spares

These should be kept by remote installations only:

Drive Belt Set

Shaft

Impeller

Gland Packing Set

Gasket Set

8.6.3 Automatic Combustion Control Spare Parts

These should be kept by remote installations only:

Dwyer Photohelic Switch / Gauge

Pressure Detector

Pulling Motor

Balance Relay

Modulating Transformer

3 Pole manual / auto / off switch

220 V Filament Bulb

130 ohm Potentiometer

8.6.4 Rear Sootblower Spare Parts

These should be kept by remote installations only:

Plain Piston Ring

Gland Packing Set

Guide Pin

Guide Pin Key

Nozzle

Clydespin Grease

CHAPTER NINE

STATUTORY REQUIREMENTS OF STEAM BOILER INSTALLATIONS

In South Africa, steam boilers must be registered with the Department of Manpower, formerly the Department of Labour. These boilers must be periodically inspected by the Inspector of Machinery of the Department.

The safe operation and maintenance of a steam boiler is the legal duty of an appointed Responsible Person in the employ of the owner of the boiler. The owner and the Responsible Person must comply with regulations governing boiler installations.

Regulations governing boiler installations can be obtained from the Government Printer. These are regulations C90 to C112 of Act 22 of 1941. It should be noted that there have been amendments to these regulations as from 1987.

Relevant regulations will be summarized in this chapter. For a simplified explanation of all steam boiler regulations, one is referred to Horne [44]. This booklet has a supplement which may be obtained from the author, from the Department of Manpower. Further clarifications can be made through enquiries to the Chief Inspector of Factories from the Department of Manpower.

A clarification of one regulation which can lead to a wrong interpretation of the Act will be discussed. Examples will be made for a further simplification.

9.1 IMPORTANT REGULATIONS

Regulations which are important to the maintenance of boilers are given in this section.

9.1.1 C.94 Boiler Inspection and Log book

Every steam boiler installation is required by law to keep a log book. It is a book where maintenance, cleaning and inspection by the owner is entered. The condition of the book boiler is also kept in the log book.

Hourly readings such as steam pressure, coal thickness, hot well temperature, CO_2, water level, blowdown etc., are also recorded in the log book.

9.1.2 C.97 Inspection and Test of Boilers

This regulation may be summarized as follows:

1. The user must appoint a competent person or firm to inspect or test his boiler.
2. The inspection or test should be within 30 months of the previous inspection. The inspection and the test need not to be done simultaneously.
3. The inspector should be notified at least 90 days before the intended date of inspection or test.
4. The competent person must report all defects to the user. He must prohibit the use of a boiler if there are any defects. The competant person must submit a true report to the user.

5. The user must submit the inspection or test report to the inspector within one month after the inspection or test date.
6. The inspector may propose to conduct an inspection at any time. He may also conduct the inspection or test at the same time as the competent person.
7. The boiler must be cleaned and prepared as required by the inspector or competent person.
8. When the casing has to be removed, an opportunity can be taken to inspect or test the boiler.
9. The user is responsible for the safety of persons during work on the boiler.
10. The user shall ensure the safety of persons entering any part of the boiler by blanking off or locking shut all dangerous sources such as:
    - steam stop valve.
    - blowdown valve.
    - feedwater valve.
    - auxiliary steam line to steam feed apparatus.
    - drain valves to a common drain line.
11. Portable electric lights used should not be more than 42 volts.
12. The hydraulic test pressure is the lowest of the following:

    (a) 0.9 x Code test pressure
    (b) 1.2 x average working pressure + 400 kPa (for boilers with average working pressure greater than 500 kPa)

(c) 2 x average working pressure (for boilers with average working pressure less or equal to 500 kPa)

9.1.3 C.98 Fixing of pressure

The inspector has power to reduce the authorised pressure of a boiler whose condition has deteriorated. He can also stop the working of a boiler completely if he finds dangerous conditions.

9.1.4 C.104 Low Water Alarm

A coal fired boiler should have an audible low water alarm. This should be tested regularly to ensure the safety of the boiler.

9.2 THE "MISINTERPRETED" REGULATION C.97

The terminology used by boiler manufacturers and the one used by the Act may lead to misinterpretations. This may lead to the contravention of the Act without being aware of it. Hence, the following should be noted when interpreting this regulation.

The authorised working gauge pressure (a.w.g.p) means the authorised working pressure stamped on the copper plate by the Inspector of the Department of Manpower.

The code test pressure is the test pressure to which the boiler was tested by the manufacturer. This is usually stamped on the body of the boiler, in the vicinity of the

copper plate.

Hence, the hydraulic test pressure as stated by the regulation may be interpreted as follows:

For boilers whose a.w.g.p. > 500 kPa, use the lesser of the following:

(i) 0.9 x code test pressure i.e. 0.9 x manufacturer's test pressure.

(ii) 1.2 x a.w.g.p. + 400 kPa i.e. 1.2 x "copper plate" pressure 400 kPa.

For boilers whose a.w.g.p. < 500 kPa or a.w.g.p. = 500 kPa, the hydraulic test pressure is the lesser of the following:

(i) 0.9 x code test pressure i.e. 0.9 x manufacturer's test pressure.

(ii) 2 x a.w.g.p. i.e. "copper plate" pressure.

EXAMPLE 1

Suppose the "copper plate" plate is stamped 1 000 kPa and the manufacturer's test pressure is 1 500 kPa. The two pressures can be calculated as follows:

(i) 0.9 x 1 500 kPa = 1 350 kPa.

(ii) 1.2 x 1 000 kPa + 400 kPa = 1 600 kPa.

Hence, the hydraulic test pressure is 1 350 kPa.

EXAMPLE 2

Suppose the "copper plate" is stamped 400 kPa and the boiler was tested by the manufacturer up to 700 kPa, the two pressures can be calculated as follows:

(i) 0.9 x 700 kPa = 630 kPa.

(ii) 2 x 400 kPa = 800 kPa.

Hence, the hydraulic test pressure is 630 kPa.

9.3 A COMMENT ON BOILER USERS IN SOUTH AFRICA

Boiler users can be roughly classified into two broad categories. There are those who strive to maintain their boilers in excellent conditions. These users are like those who usually send their boiler attendants and boiler maintenance personnel to special boiler courses. They usually make sure that the statutory inspection is don on schedule. They also regard the statutory inspection as something useful and constructive.

On the other hand, we have those users who do not put much effort in maintaining their boilers. These users usually have very unskilled boiler attendants and boiler maintenance personnel. Austin [45] has expressed his dismay at the level of ignorance of many boiler attendants and maintenance personnel. These negligent users also suffer losses due to downtime caused by poor maintenance. They usually regard statutory inspections as a nuisance, not something for their own benefit.

The Department of Manpower is at the moment trying to counteract these negligent users. In its attempt, it has given the responsibility of inspection and testing of boilers to the user. The user must appoint a competent person to inspect or test the boiler. This idea may lead to many users sending their employees to boiler maintenance and inspection courses. This may help to reduce the level of ignorance of boiler personnel. It follows that boilers will be operated and maintained more safely if this idea succeeds.

CHAPTER TEN

DISCUSSION OF THE EXPERT SYSTEM

10.1 INTRODUCTION

An expert system shell, EXSYS, was used to develop this package.

The package is divided into two. One expert system is for routine boiler maintenance, the other is for shutdown maintenance. The expert system was divided because:-

- memory problems might arise as a result of too many rules.
- a set of smaller expert systems is usually more reliable than one major expert system.
- more rules may be added in smaller expert systems with less chances of rules clashing.
- it is easier to modify small expert systems.

The total expert system package has more than 200 rules. It can be run on an IBM or compatible personal computer, with at least 640 K of memory.

10.2 DISCUSSION

A more detailed description of this shell, EXSYS, may be found in the EXSYS operating manual [8]. This was also discussed in section 6.3.2.

The rule editor which will be used to run the expert system, will be included in this thesis. The runtime

program is copy-protected and needs a licence to distribute it. This runtime program can only be used in the Mechanical Engineering Department at the University of Cape Town.

10.3 THE ARCHITECTURE OF THE EXPERT SYSTEM

The expert system package was divided into two programs: routine and shutdown boiler maintenance.

10.3.1 Routine Boiler Maintenance

This expert system deals with problems which arise during the operation of the boiler. Problems which arise during the operation of a boiler can lead to heavy financial losses, and with a possible risk on human life as well.

For example, if a blowdown valve jams in an open position, the boiler may be damaged beyond repair if the boiler attendant does not know the right action to take.

The structure of the expert system can be seen in Figure 10.1. The printout of the knowledge base or rules of this expert system can be seen in Appendix C. This expert system more than 160 rules.

10.3.2 Shutdown Boiler Maintenance

This expert system deals with general shutdown boiler maintenance, hydraulic tests and internal / external inspection. The internal / external inspection and the

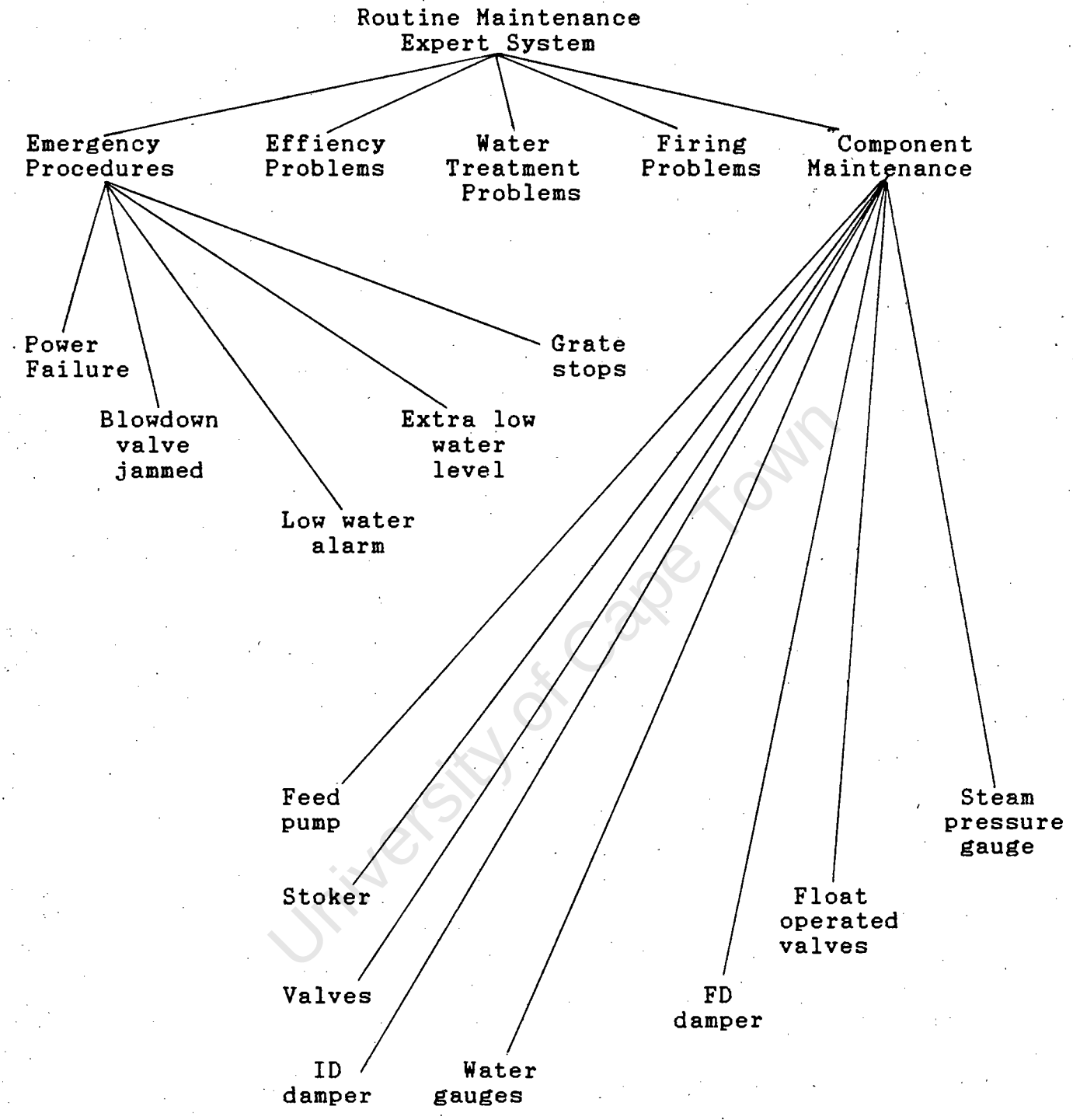

Figure 10.1 The structure of the Routine Boiler Maintenance Expert System

hydraulic test satisfy the legal requirements for steam boiler installations.

It is recommended that both the internal / external inspection and the hydraulic test be done at the same time. This ensures an effective and an accurate shutdown boiler maintenance. This will also prevent frequent shutdowns, which may affect production.

This expert system has more than 50 rules. The structure of this expert system can be seen in Figure 10.2. The printout of rules or the knowledge base can be seen in Appendix D.

10.4 HOW TO RUN THE EXPERT SYSTEMS

The routine maintenance and the shutdown maintenance expert systems are stored in files OPERATIO and SHUTDOWN respectively, in two separate floppy disks. Each floppy disk has its own EDITXS, the rule editor program which will be used to run the expert systems. The computer must be in DOS (Disk Operating System) before these programs can be run.

When the computer is in DOS (Disc Operating System), the program OPERATIO can be accessed by typing in EDITXS OPERATIO and pressing the "RETURN" key. The program will then ask the user to press any key inorder to continue. The following message will then be displayed:

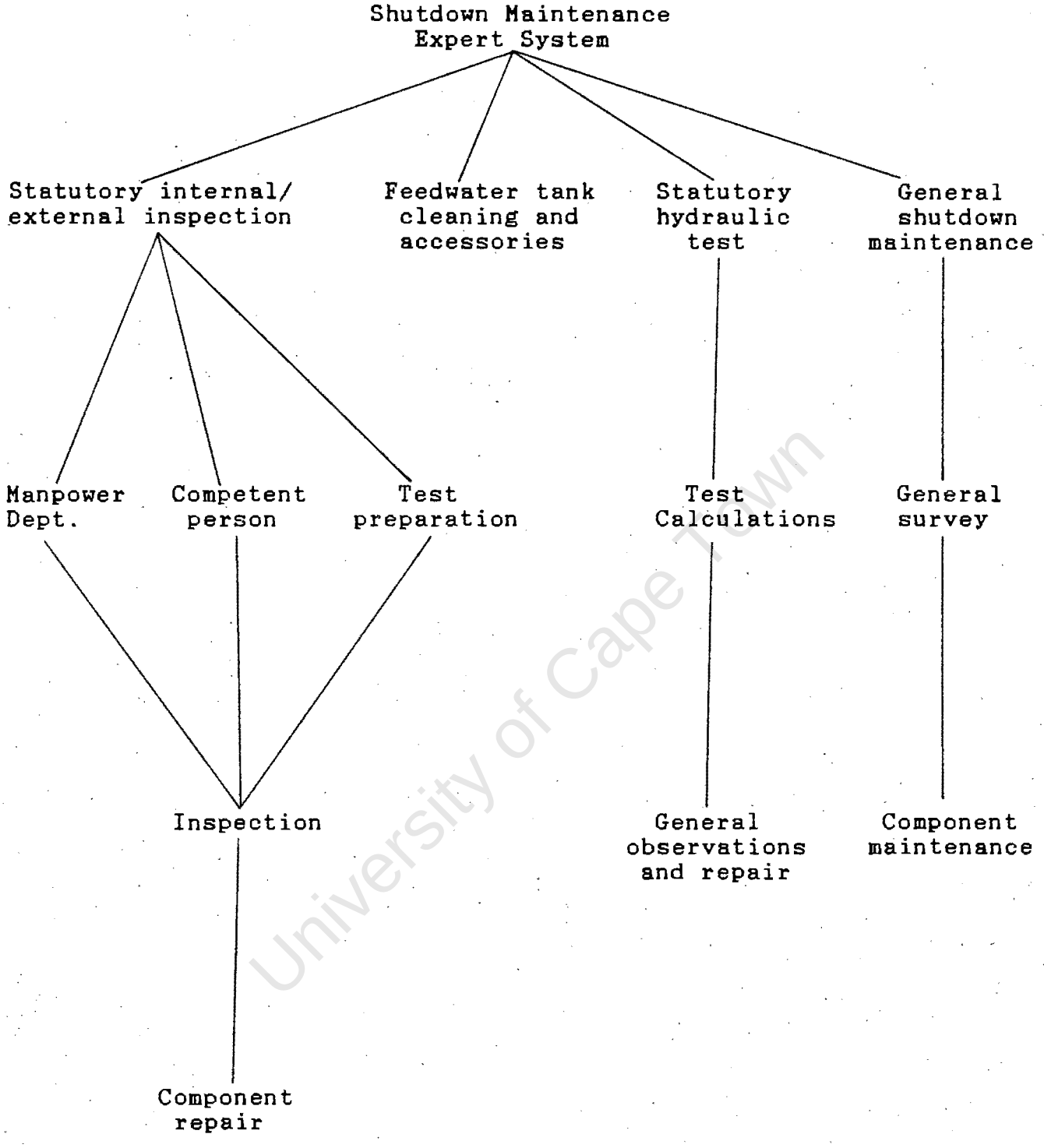

Figure 10.2 The structure of the Shutdown Boiler Maintenance Expert System

The current option chosen for rule derivation is:

Use all possible rules

Do you wish to change this option? (Y/N)

(Default = N):

Press N and the following will be further displayed:

The current option is not to display the rules as the default condition when this expert system is run.

Do you wish to change the option? (Y/N) (Default = N):

Press N and the following message will be displayed:

The function that checks new rules against the previous ones does NOT check the validity of mathematical formulas. If you predominantly use formulas it may be convenient to switch this option off.

Do you wish new rules checked against the previous rules? Y/N (Default = Y):

Pressing Y will give a menu for editing and running rules. Pressing R, the following will be displayed:

Do you wish to have the rules displayed as they are used? (Y/N) (Default = N):

Press N and the following will be displayed:

Recover previously saved input Y/N (Default = N):

Press N and the program will ask the user to press any key to start the run. Pressing a key marks the beginning of the program, and hence the first questions will be asked.

The program will ask questions, and at the end of the consultation, the program will print recommended actions and suggestions. The same procedure can be followed with the SHUTDOWN program, by first typing in EDITXS SHUTDOWN.

10.5 INTERPRETING THE SOLUTION

The solution is in the form of statements with a probability associated with each statement. A typical solutions statement is as follows:

Values based on 0 - 10 system	**Value**
The chaingrate stoker mat must be replaced	**10**

A value of 10 means that 10/10 the chain grate stoker mat must be replaced. A value of 0 means that the action must not be taken. Intermediate values 1 to 9 signify a relative likelyhood for the above action to be taken.

When the solution has been displayed, the answers supplied may be changed and the program may be rerun.

10.6 EXAMPLES

1. The routine expert system will be used for the first example and the file OPERATIO will be used in this instance.

   The problem is that there is a blowdown valve jammed in the open position, and the operator does not know what action to take. He can consult the routine maintenance expert system.

Having followed the instructions of how to run an expert system (as explained in section 10.4), the first question will be:

The required function is

1 emergency procedures

2 efficiency/CO2 problems

3 water treatment

4 routine component maintenance

5 firing problems

Since this is an emergency, the operator should press 1 and then the "RETURN" key. The following will then be displayed.

The emergency is

1 power failure

2 blowdown valve jammed

3 low water alarm

4 extra low water level(water in gauges)

5 grate stops

6 extra low water level(no water in gauges)

The operator will press 2 and then the "RETURN" key. The solution will then be displayed and will resemble the following:

Values based on 0 - 10 system	Value
Set ID damper control on hand control	10
Open ID damper to position 10	10
Press ID fan stop button	10
Set FD manual/auto to manual	10
Set panel control regulator to minimum	10
Close the coal cut-off gate	10
Lift up the shield	10
Raise the guillotine door fully	10
Push the whole fire into the ash pit	10
Immediately remove ash and coals from the boiler	10
Close the main steam valve	10
Close the ID dampers	10
Leave the boiler to cool naturally	10
Remove the object which cause jamming and overall the blowdown valve	10

2. The second example will involve running the shutdown expert system. A shutdown maintenance of the feedwater tank must be done, the SHUTDOWN file will have to be used.

Having followed the instructions on how to run the expert system, the first question will be the following:

Required function is

1 internal/external inspection

2 hydraulic test

3 feedwater tank and accessories cleaning

4 general shutdown maintenance

Pressing 3 and the "RETURN" key, the following will be displayed:

Procedure for cleaning is

1 known

2 not known

Pressing 2 and the "RETURN" key, the following will displayed:

Feedwater tank calcium hardness is

1 approximately 50 mg/l

2 not approximately 50 mg/l

Pressing 2 and the "RETURN" key, the following will be displayed:

Feedwater pH is

1 approximately 8.5

2 not approximately 8.5

Pressing 2 and the "RETURN" key, the following will be displayed:

The feedwater pipe is

1 corroded

2 not corroded

Pressing 1 and the "RETURN" key, the computer will be ready to give solutions. Pressing any key, the solutions will be displayed and will resemble the following:

Values based on 0 - 10 system	Value
Close fresh water inlet isolating valve	10
Close feedwater outlet isolating valve	10
Check feedwater tank for leakage signs	10
Drain feedwater tank	10
Remove mud and sediments from interior	10
Wash down with clean water	10
Carry out repairs immediately if there is any leakage	10
Open inlet isolating valve to fill tank	10
Add correct amount of chemicals	10
Verify samples for correct chemical content	10
Allow feedwater to circulate in the boiler	10
Start feedpump no. 1	10
Run feedpump no. 1 for 3 to 5 minutes	10
Switch to feedpump no. 2	10
Run feedpump no. 2 for 3 to 5 minutes	10
Close inlet and outlet isolating valves for	

both pumps	10
Remove strainers from suction side	10
Clean strainers thoroughly in clean water	10
Fit back the strainers	10
Open inlet isolating valves on both pumps	10
Check the water level in the boiler	10
Ensure the water level is correct	10
Reduce or increase feedwater tank calcium hardness to approximately 50 mg/l	10
Reduce or increase pH until it is approximately 8.5	10
Use sodium sulphide oxygen scavenger	10
Use hydrazine oxygen scavenger	10
Check whether having copper and steel pipe together	10

CHAPTER ELEVEN

CONCLUSIONS

This research project has shown that expert systems have great potential, not only in boiler maintenance, but in maintenance management as a whole. Boiler maintenance is usually carried out by unqualified personnel, since very few people like the dirty boiler room. This problem should be given more attention by senior management because poor boiler maintenance can result in heavy financial losses.

The expert system helps boiler maintenance personnel to maintain their boilers effectively and profitably. The expert system also gives maintenance personnel more 'feel' and understanding of their job.

The expert system is simple to operate. No previous computer background is necessary to operate it. Few mistakes can be made by the maintenance personnel since the typing of long words is unnecessary. One simply types in a number corresponding to the answer.

The expert system also helps to educate boiler attendants in the basic maintenance of boilers. This is necessary since boiler attendants are usually the first to observe problems in their early stages.

However, it is important to note that expert systems, like experts, can make mistakes. Results should

therefore be treated with care.

It is also important to note that expert systems should be applied in a specific domain. They are not useful if a domain is too general.

CHAPTER TWELVE

RECOMMENDATIONS

The following recommendations were made concerning this research project:

1. All mistakes which were not observed during the development of the expert system, should be corrected immediately when the expert system is in operation.

2. Any company which obtains this software must modify it to any special requirements.

3. The expert system must be expanded to the limits of the personal computer memory.

4. Feedback from the users must be sent to the Department of Mechanical Engineering of the University of Cape Town.

CHAPTER THIRTEEN

FUTURE STUDY

It was mentioned in chapter four that knowledge acquisition is one of the major bottlenecks in developing expert systems. This is a time consuming process which may take up to eighty percent of the time for developing an expert system.

Automatic knowledge acquisition systems have already been launched in the United States of America. It will be interesting to see the effect of such systems in boiler maintenance. The benefits might not only be the reduced time for developing an expert system of this magnitude, but also the accuracy of the expert system developed using these automatic packages.

The main problem of acquiring automatic knowledge acquisition systems in South Africa would be the high cost of such systems due to the disadvantageous exchange rate. Although these automatic packages are expensive, they may contribute a lot to the study of expert systems.

At this time, John Thompson Africa, Bellville, is developing a system which diagnoses faults during the operation of a boiler. This system is still in the experimental stages. The company believes that this system will contribute greatly to the operation and maintenance of boilers.

Using the expert systems, together with the John Thompson fault diagnosis system, may prove to be worthwile. However, an interface must be developed to link this system with expert systems.

The above combination system will reduce the risk of operators or any other personnel supplying the expert system with wrong information. The system will extract information directly from the boiler and supply it to the expert system. The success of this combined system will depend on both the availability of knowledge engineers and funds for supporting further research.

This expert system will also be given to John Thompson Africa. It would be an interesting idea if this is also distributed to more companies. Each company could offer suggestions and its specific problems. In this way the knowledge base can be expanded and modified according to the company's needs. A survey to evaluate the impact of the expert system would then be necessary, say after a year or two.

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APPENDIX A

This appendix contains a list of expert systems which are already in operation.

EXPERT SYSTEMS IN OPERATION

AGRICULTURE

NAME	DESCRIPTION
WHEAT COUNCELLOR	Advise on control of disease in winter wheat crops.
POMME	Advise farmers on management of apple orchards, including pest management, drought control, pesticide selection, treatment of winter injuries.

CHEMISTRY

TQMSTUNE	Tune triple quadruple mass spectrometer.
DENDRAL	Search chemical structure libraries for substructures.
SYNCHEM	Plan chemical synthesis steps.

COMPUTERS AND ELECTRONICS

XCON, XSEL, XSITE	Configure VAX orders, Check orders for accuracy, Plan site layout.
AI-SPEAR	Diagnose failures in tape drives and suggest preventive actions.
CALLISTO	Help manage resources for chip designers.

COMPUTERS AND ELECTRONICS (continued)

NAME	DESCRIPTION
CDx	Analyse VMS dump files after system crashes.
DAS-LOGIC	Assist circuit designers with logic design.
NTC	Troubleshoot problems related to Ethernet and DECnet networks.
PIES	Diagnose problems on circuit fabrication line.
COMPASS	Analysis and maintenance records for telephone switching system and suggest maintenance actions.
PHOTOLITHOGRAPHY ADVISOR	Troubleshoot photolithography steps in circuit fabrication.
HICLASS	Sequences steps in pc board assembly.
CSS	Aid in planning, relocation, reinstallation and rearrangement of IBM main frames.
PINE	Guide people writing reports on analysis of software problems.
YES/MVS	Monitor MVS operation system.
BDS	Troubleshoot baseband distributions subsystem of communi-

	cation hardware.
DIGVOLTAGETESTER	Aid troubleshooting digital voltage sources in testing lab.
OCEAN	Check orders for computer systems, configure orders.
FAULTFINDER	Diagnose faults in disk-drives.
CONAD	Check order entry and configure computer systems.
ACE	Troubleshoot telephone lines.
DIAG8100	Diagnose failures in DP equipment.

CONSUMER SERVICES

INFORMATADVISOR	Advise shoppers on computer purchases.

EDUCATION

TVX	Tutor users of VMS operating system.
DECGUIDE	Tutor designers in design checking.
BUGGY	Debug students' subtraction errors [field tested, now dormant]

FINANCIAL

NAME	DESCRIPTION
APEX System	Aid professional financial planners manage clients' accounts.

GEOLOGY

SECOFOR	Advise on drill-bit sticking problems in oil wells [training tool]
GEOX	Identify earth surface minerals from remotely sensed hyperspectral image data.
MUDMAN	Diagnose problems in composition of drilling mud during oil well drilling.
DIAMETERADVISOR	Analyse oil well logging data.

INFORMATION MANAGEMENT

EDDAS	Advise on disclosure of confidential business information.

MANUFACTURING AND ENGINEERING

ICLX	Aid technicians diagnose faults in rod milling process.

MANUFACTURING AND ENGINEERING (continued)

NAME	DESCRIPTION
ENGINECOOLINGADVISOR	Diagnose cause of noise in automatic engine cooling system.
MOTORBRUSHDESIGNER	Construct design of brushes and springs for small electrical motors.
ISA	Schedule orders for manufacturing and delivery.
DISPATCHER	Schedule dispatching of parts for robots.
CATS	Diagnose problems in diesel electric motors.
STOWAGEPLANNER	Develop cargo storage plans for warehouse.
VT	Configure orders for new elevator systems.
ISIS	Shedule manufacturing steps in job shop.
PRIDE	Create and analyse new designs for copies.

MEDICINE

PUFF	Interpret pulmonary function tests.
ONCOCIN	Management of therapy for patients with cancer.

MILITARY

NAME	DESCRIPTION
AALPS	Plan optimal loading of equipment and cargo on aircraft.

These expert systems are derived from [6]

APPENDIX B

This appendix contains a job description of a boiler attendant.

THE BOILER ATTENDANT : JOB DESCRIPTION

(This job description was obtained from John Thompson Africa, Bellville)

At all times

- Watch boiler pressure.
- Watch water level in the boiler.
- Keep floor area around boiler clean and clear.

Every 15 minutes

- Check ignition of the coal through the stoker peephole.
- Check the length of the fire through the rear peephole and adjust the undergrate dampers.
- Open the ash valve to allow ash to drop into the ash trolley.

Every 30 minutes

- Check the water level and the water temperature in the hotwell.
- Check that coal is flowing correctly in the stoker hopper.

Every 60 minutes

- Inspect boiler plant for defects.
- Take log of boiler.
- Check the ash built-up under the stoker.

Every 4 hours

- Remove the ash built-up under the stoker.
- Empty the grit trolley.

- Operate the grit screw.

Every 8 hours (or once per shift)

- Blow down water gauges.
- Blow down both Mobrey controls.
- Operate sootblowers.
- Check and log level of chemicals in chemical dosing pump tank.
- Check brine tank of water softener.

Once per day

- Check ignition arch for clinker and remove any built-up.
- Carry out hardness test on water softener.

Once per week

- Top up grease nipples on stoker and sootblowers.
- Ease safety valve.
- Change over to the other feedpump.

APPENDIX C

This appendix contains a printout of rules or knowlegde base of the Routine Boiler Maintenance Expert System.

Subject:
ROUTINE BOILER MAINTENANCE

Author:
C.V. GAMEDE

John Thompson Africa, Bellville.

Starting text:
SUPPLY THE REQUIRED INFORMATION BY PUNCHING IN THE NUMBER CORRESPONDING TO THE CORRECT ANSWER

Ending text:
THE FOLLOWING ACTIONS AND SUGGESTIONS ARE RECOMMENDED:

Uses all applicable rules in data derivations.

RULE NUMBER: 1

IF:
The required function is emergency procedures
and The emergency is power failure
and The power is restored within 30 minutes

THEN:
Close the main steam valve - Probability=10/10
and Close automatic blowdown valve, if any - Probability=10/10
and Set FD Combustion Control Unit to manual and close position - Probability=10/10
and Open both undergrate dampers fully - Probability=10/10
and Remove the grate movement indicator disc and cover - Probability=10/
and Fit the grate crank handle - Probability=10/10
and Turn the handle to relieve pressure off shear pin - Probability=10/1
and Remove the shear pin - Probability=10/10
and Wind the grate foward 10 turns clockwise - Probability=10/10
and At panel, set FD manual/auto switch to manual - Probability=10/10
and Set ID manual/auto switch to manual - Probability=10/10
and Set panel control regulator to minimum - Probability=10/10
and Set ID damper control unit to manual - Probability=10/10
and Close ID damper till furnace pressure between -5 to -10 kPa - Probability=10/10
and Wind grate foward if fire burns into guillotine door - Probability=10/10
and Open the ash valve from time to time - Probability=10/10

RULE NUMBER: 2

IF:
The required function is emergency procedures
and The emergency is power failure
and The power is not restored within 30 minutes

THEN:
Bank the fire - Probability=10/10

RULE NUMBER: 3

IF:
The required function is emergency procedures
and The emergency is blowdown valve jammed

THEN:
Set ID damper control on hand control - Probability=10/10
and Open ID damper to position 10 - Probability=10/10
and Press ID fan stop button - Probability=10/10
and Set FD manual/auto to manual - Probability=10/10
and Set panel control regulator to minimum - Probability=10/10
and Close the coal cut-off gate - Probability=10/10
and Lift up the shield - Probability=10/10
and Raise the guillotine door fully - Probability=10/10
and Push the whole fire to the ash pit - Probability=10/10
and Immediately remove ash and coals from the boiler - Probability=10/10
and Close the main steam valve - Probability=10/10
and Close the ID dampers - Probability=10/10
and Leave the boiler to cool naturally - Probability=10/10
and Remove the object causing the jamming and overall the blowdown valve
Probability=10/10

RULE NUMBER: 4

IF:
The required function is emergency procedures
and The emergency is low water alarm

THEN:
Switch over to the other feedpump - Probability=10/10
and Check water level in the feedpump - Probability=10/10

RULE NUMBER: 5

IF:
The required function is emergency procedures
and The emergency is extra low water level(water in gauges)
and The water level does not disappear

THEN:
Switch over to the other feedpump - Probability=10/10
and Set ID manual/auto switch to manual - Probability=10/10
and Set ID panel control regulator to minimum - Probability=10/10
and Set FD manual/auto switch to manual - Probability=10/10
and Set FD panel control regulator to minimum - Probability=10/10
and Open both undergrate dampers fully - Probability=10/10
and Remove grate movement indicator disc and cover - Probability=10/10
and Fit grate crank handle - Probability=10/10
and Turn handle to remove pressure off shear pin - Probability=10/10
and Remove the shear pin - Probability=10/10
and Wind grate foward 10 turns clockwise - Probability=10/10
and Remember to remove the ash - Probability=10/10
and Open ID damper on panel control - Probability=10/10
and Keep furnace pressure between -5 to -10 kPa - Probability=10/10
and Watch water level carefully - Probability=10/10
and Check water level in the feed tank - Probability=10/10

RULE NUMBER: 6

IF:
The required function is emergency procedures
and The emergency is extra low water level(water in gauges)
and The water level disappears or does not rise after 10 minutes

THEN:
Close the main steam valve - Probability=10/10
and Set ID fan damper control on hand - Probability=10/10
and Open ID fully to position 10 - Probability=10/10
and Close coal cut-off gate - Probability=10/10
and Lift up the shield - Probability=10/10
and Raise guillotine door fully - Probability=10/10
and Push fire into the ash pit - Probability=10/10
and Remove ash and coal immediately from the boiler - Probability=10/10
and Switch off the feedpump - Probability=10/10
and Close the feed check valve - Probability=10/10
and Close the feed check valve - Probability=10/10

RULE NUMBER: 7

IF:
The required function is emergency procedures
and The emergency is extra low water level(water in gauges)
and The water level rises before 10 minutes

THEN:
Continually try to start the stoker - Probability=10/10
and Replace the shear pin when the stoker starts - Probability=10/10
and Replace the stoker cover and disc - Probability=10/10
and Restart the boiler - Probability=10/10

RULE NUMBER: 8

IF:
The required function is emergency procedures
and The emergency is extra low water level(no water in gauges)

THEN:
Set the ID fan damper on hand - Probability=10/10
and Open the ID damper to position 10 - Probability=10/10
and Switch off the feed pump - Probability=10/10
and Close the coal cut-off gate - Probability=10/10
and Lift up the shield - Probability=10/10
and Raise the guillitine door carefully - Probability=10/10
and Push the whole fire into the ash pit - Probability=10/10
and Close the mainsteam valve - Probability=10/10
and Close the feed check valve - Probability=10/10
and Close the ID damper - Probability=10/10
and Leave the boiler to coal naturally for four hours - Probability=10/1(
and Examine tube plates, tubes and the flue for damage - Probability=10/1
and Refire the boiler if no damage is detected - Probability=10/10

RULE NUMBER: 9

IF:
The required function is emergency procedures
and The emergency is grate stops
and The motor is running
and The shear pin failed
and The grate is not jammed

THEN:
Remove grate movement indicator disc and cover - Probability=10/10
and Remove the broken shear pin - Probability=10/10
and Fit the grate crank handle - Probability=10/10
and Move the grate foward - Probability=10/10
and If the grate moves foward, wind it 10 turns clockwise - Probability=10/10
and Fit the new shear pin - Probability=10/10

RULE NUMBER: 10

IF:

The required function is emergency procedures
and The emergency is grate stops
and The motor is running
and The shear pin failed
and The grate is jammed

THEN:

Set FD manual/auto switch to manual - Probability=10/10
and Set FD panel control regulator to minimum - Probability=10/10
and Set ID manual/auto switch to manual - Probability=10/10
and Close the ID damper on panel control - Probability=10/10
and Close the coal cut-off gate - Probability=10/10
and Lift up the shield - Probability=10/10
and Clear away fresh coal in front of the guillotine door - Probability=10/10
and Lower the guillotine door to 120 mm - Probability=10/10
and Push burning coal away from the guillotine door - Probability=10/10
and Leave 100 mm between coal and guillotine door - Probability=10/10
and Trim coal under arch to 80-100 mm thick layer - Probability=10/10
and Lower guillotine door fully - Probability=10/10
and Drop down a small quantity of coal - Probability=10/10
and Seal the guillotine door with this coal - Probability=10/10
and Drop down the shield - Probability=10/10
and Set FD manual/auto switch to automatic - Probability=10/10
and Open ID damper to position 5 on panel control - Probability=10/10
and Inform your supervisor - Probability=10/10
and Leave ID damper on panel control - Probability=10/10
and Wait till fire is no longer than arch - Probability=10/10
and Switch FD dampers to panel and to minimum - Probability=10/10
and Set ID damper to panel and minimum - Probability=10/10
and Stop the FD fan - Probability=10/10
and Wait for 3 - 5 minutes - Probability=10/10
and Stop the ID fan - Probability=10/10
and Open both undergrate dampers fully - Probability=10/10
and Open ID damper on panel control - Probability=10/10
and Keep furnace pressure between -5 and -10 Pa - Probability=10/10
and Close the main steam valve - Probability=10/10
and Switch feedpump control to manual - Probability=10/10
and Raise the water level to the highest level in the gauge - Probability=10/10
and Switch the feedpump to automatic - Probability=10/10
and Close the feed check valve - Probability=10/10
and Allow the arch to cool for 10 - 15 minutes - Probability=10/10
and Remove the fire from the grate - Probability=10/10

RULE NUMBER: 11

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide is greater than 13.5 %
and The fire is moving away from guillotine door
and Ignition is poor
and Fire is long

THEN:
Reduce grate speed - Probability=10/10
and Increase the fuel bed - Probability=10/10
and Maintain same quantity of fuel - Probability=10/10

RULE NUMBER: 12

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide is greater than 13.5 %
and Ignition is good
and Fire is long

THEN:
Reduce grate speed - Probability=10/10

RULE NUMBER: 13

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide is greater than 13.5 %
and Fire is burning back into the hopper
and Ignition is poor
and Fire is long

THEN:
Reduce the fuel bed thickness - Probability=10/10

RULE NUMBER: 14

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide content is less than 12 %
and Fire is short

THEN:
Increase the grate speed - Probability=10/10

RULE NUMBER: 15

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide content is less than 12 %
and The smokebox joint is infiltrating air
and The smokebox ductwork is infiltrating air

THEN:
Renew jointing and tighten securing nuts - Probability=10/10

RULE NUMBER: 16

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide content is less than 12 %
and Ash collector trolley is inflitrating air

THEN:
Adjust packing pieces on trolley for better seal - Probability=10/10

RULE NUMBER: 17

IF:
The required function is efficiency/CO2 problems
and Flue gas temperature is known
and Ambient boiler house temperature is known

THEN:
[DFGL] IS GIVEN THE VALUE 0.63 * ([T1] - [T2]) / [CO2]
and [RADIATION] IS GIVEN THE VALUE 160 / [BOILER OUTPUT]
and [EFFICIENCY] IS GIVEN THE VALUE 100 - ([RADIATION] + [DFGL] + 7)

RULE NUMBER: 18

IF:
The required function is efficiency/CO2 problems
and Flue gas temperature is known
and Ambient boiler house temperature is known
and [EFFICIENCY] < 75

THEN:
The boiler has poor efficiency - Probability=10/10
and Control carbon dioxide between 12 and 13.5 % - Probability=10/10

RULE NUMBER: 19

IF:
The required function is efficiency/CO2 problems
and The fire in the grate is big
and Ignition is good
and Steam ouput is low

THEN:
Check blocked tubes during shutdown - Probability=10/10
and Check scaling of tubes during shutdown - Probability=10/10

RULE NUMBER: 20

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide content is greater than 12 %
and Carbon dioxide is less than 13.5 %

THEN:
The corbon dioxide content is very good - Probability=10/10

RULE NUMBER: 21

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide content is less than 12 %

THEN:
The carbon dioxide content is too low - Probability=10/10

RULE NUMBER: 22

IF:
The required function is efficiency/CO2 problems
and Carbon dioxide content is greater than 13.5 %

THEN:
The carbon dioxide content is too high - Probability=10/10

RULE NUMBER: 23

IF:
The required function is water treatment
and There is carry over

THEN:
There is foaming due to high boiler TDS - Probability=10/10
and There is foaming due to organic contamination of feedwater - Probability=10/10
and There is priming due to surges in steam demands - Probability=10/10
and There is misting due to poor water treatment - Probability=10/10
and There is high water level due to faulty level controllers - Probability=10/10

RULE NUMBER: 24

IF:
The required function is water treatment
and Blowdown is manual
and TDS is greater than 3500 mg/l

THEN:
Make sure that the water level is correct - Probability=10/10
and Blowdown till the TDS is approximately 3500 mg/l - Probability=10/10

RULE NUMBER: 25

IF:
The required function is water treatment
and Blowdown is automatic
and The TDS is not kept at required level

THEN:
Service and calibrate TDS automatic control mechanism - Probability=10/10

RULE NUMBER: 26

IF:
The required function is water treatment
and Total alkalinity is not within 350 - 700 mg/l

THEN:
Keep total alkanity within 350 - 700 mg/l - Probability=10/10

RULE NUMBER: 27

IF:
The required function is water treatment
and Caustic alkalinity is not within 150 - 350 mg/l

THEN:
Keep caustic alkalinity within 150 - 350 mg/l - Probability=10/10

RULE NUMBER: 28

IF:
The required function is water treatment
and Phosphate residual is not within 30 - 60 mg/l

THEN:
Keep phosphate residual within 30 - 60 mg/l - Probability=10/10

RULE NUMBER: 29

IF:
The required function is water treatment
and Sulphite residual is not within 30 - 60 mg/l

THEN:
Keep sulphite residual within 30 - 60 mg/l - Probability=10/10

RULE NUMBER: 30

IF:
The required function is water treatment
and Calcium hardness is far greater than zero

THEN:
Reduce calcium hardness to approximately zero - Probability=10/10

RULE NUMBER: 31

IF:
The required function is water treatment
and pH is not within 10.5 and 11

THEN:
Keep the pH between 10.5 and 11 - Probability=10/10

RULE NUMBER: 32

IF:
The required function is water treatment
and The condensate system is corroded

THEN:
There is oxygen in the condensate system - Probability=10/10
and There is carbon dioxide in the condensate system - Probability=10/10
and Use volatile neutralising amines for water treatment -
Probability=10/10
and Use volatile filming inhibitors for water treatment - Probability=10

RULE NUMBER: 33

IF:
The required function is water treatment
and The TDS in one shift is frequently high

THEN:
Use phosphate type chemical treatment - Probability=10/10
and Use chelate type chemical treatment - Probability=10/10
and Use polymer type chemical treatment - Probability=10/10

RULE NUMBER: 34

IF:
The required function is water treatment
and Feedwater pipe system is corroded

THEN:
Use sodium sulphite oxygen scavenger - Probability=10/10
and Use hydrazine oxygene scavenger - Probability=10/10

RULE NUMBER: 35

IF:
The required function is routine component maintenance
and The component is the feedpump
and The boiler is steaming
and The feedpump mode is panel control
and The water level is at the normal mark or below normal mark
and The feedpump is not pumping

THEN:
Switch on the other pump immediately - Probability=10/10
and Check the pump electrical connections - Probability=10/10
and Check the two switch controller for correct operation -
Probability=10/10

RULE NUMBER: 36

IF:
The required function is routine component maintenance
and The component is the feedpump
and The feedpump mode is automatic control
and The water level is at the normal mark or below normal mark
and The feedpump is not pumping

THEN:
At panel, set FD manual/auto switch to manual - Probability=10/10
and Check the pump electrical connections - Probability=10/10
and Check the pump auto/manual switch - Probability=10/10

RULE NUMBER: 37

IF:
The required function is routine component maintenance
and The component is the feedpump
and The boiler is steaming
and The feedpump mode is automatic control
and The water level is at the normal mark or below normal mark
and The auxilliary pump does not pump also

THEN:
Check the two switch controller for correct operation -
Probability=10/10

RULE NUMBER: 38

IF:
The required function is routine component maintenance
and The component is the feedpump
and The feedpump is pumping
and The pump indication lamp is not on

THEN:
Switch on the other pump immediately - Probability=10/10
and Correct the pump electrical connections or replace the pump indicator lamp - Probability=10/10

RULE NUMBER: 39

IF:
The required function is routine component maintenance
and The component is the feedpump
and The pump gland is leaking
and The pump gland nuts have not been tightened

THEN:
Switch on the other pump immediately - Probability=10/10
and Tighten the gland nuts - Probability=10/10
and Check pump for smooth operation after tightening gland nuts - Probability=10/10

RULE NUMBER: 40

IF:
The required function is routine component maintenance
and The component is the feedpump
and The pump gland is leaking
and The pump gland nuts have been tightened

THEN:
Renew pump gland packings - Probability=10/10
and Check pump for smooth operation after renewing gland packings - Probability=10/10

RULE NUMBER: 41

IF:
The required function is routine component maintenance
and The component is the feedpump
and The pump flange are leaking

THEN:
Renew pump flange gasket - Probability=10/10
and Check pump for smooth operation after flange gasket renewal - Probability=10/10

RULE NUMBER: 42

IF:
The required function is routine component maintenance
and The component is the feedpump
and Pump isolating valve glands are leaking

THEN:
Tighten the isolating valve gland nuts - Probability=10/10
and Check the isolating valve glands for smooth operation after tightenir
gland nuts - Probability=10/10

RULE NUMBER: 43

IF:
The required function is routine component maintenance
and The component is the feedpump
and The isolating valve gland nuts have been tightened
and The isolating valve is still leaking

THEN:
Renew the isolating valve gland packings - Probability=10/10
and Tighten the isolating valve gland nuts if necessary - Probability=10,

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RULE NUMBER: 44

IF:
The required function is routine component maintenance
and The component is the feedpump
and The isolating valve flanges are leaking

THEN:
Renew isolating valve flange gasket - Probability=10/10

RULE NUMBER: 45

IF:
The required function is routine component maintenance
and The component is the feedpump
and Both pumps take longer than normal time to recover water level

THEN:
Check whether the spray pipeline nozzles are not blocked -
Probability=10/10

RULE NUMBER: 46

IF:
The required function is routine component maintenance
and The component is the feedpump
and Feedpump is fitted with a strainer

THEN:
Clean the feedpump strainer monthly - Probability=10/10

RULE NUMBER: 47

IF:
The required function is routine component maintenance
and The component is the feedpump
and The pump bearings are noisy

THEN:
Switch on the other pump immediately - Probability=10/10
and Renew the pump bearings - Probability=10/10

RULE NUMBER: 48

IF:
The required function is routine component maintenance
and The component is the feedpump
and The no.1/no.2 selection switch is faulty

THEN:
Repair the no.1/no.2 switch immediately - Probability=10/10

RULE NUMBER: 49

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and Oustside driver links are burnt

THEN:
Use a swinging chute if there is segregation of coal - Probability=10/10
and Remove clinkers on the ignition arch - Probability=10/10
and Replace chain grate burnt links - Probability=10/10

RULE NUMBER: 50

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and Burnt links are inside driver links or common links

THEN:
Avoid piling of ash under the rear of grate - Probability=10/10
and Replace chain grate burnt links - Probability=10/10

RULE NUMBER: 51

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and Rods are moving across grate

THEN:
Dimple the grate rod ends - Probability=10/10

RULE NUMBER: 52

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The shear pin is broken

THEN:
The grate drive unit must be realigned - Probability=10/10
and Correct the tension of the chain grate - Probability=10/10
and Remove any metal inclusions from the grate - Probability=10/10

RULE NUMBER: 53

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The chain grate is humping

THEN:
Increase the grate tension - Probability=10/10
and Check the grate for signs of overheating - Probability=10/10

RULE NUMBER: 54

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and Chain grate links are broken

THEN:
Remove any metal inclusions from the grate - Probability=10/10
and Replace broken grate drive links - Probability=10/10

RULE NUMBER: 55

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The grate roller shaft is bent

THEN:
Avoid piling of ash under the rear of grate - Probability=10/10
and Replace or straighten the grate roller shaft - Probability=10/10

RULE NUMBER: 56

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and Bottom dead plate has sagged

THEN:
Avoid piling of ash under the rear of grate - Probability=10/10
and Straigten or replace the bottom dead plate - Probability=10/10

RULE NUMBER: 57

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and Grate rods are bent

THEN:
Repair the inequality in length of driving chains - Probability=10/10
and Replace the bent grate rods - Probability=10/10

RULE NUMBER: 58

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The chain grate breaks frequently

THEN:
Use Mark 4 Triumph Stoker introduced by John Thompson 1984/85 -
Probability=10/10

RULE NUMBER: 59

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The stoker motor is not running
and The water level in the boiler is too low

THEN:
Fill the boiler up to the normal water level - Probability=10/10

RULE NUMBER: 60

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The stoker motor is not running
and The single switch controller is faulty

THEN:
Shut down the boiler - Probability=10/10
and Repair the single switch controller - Probability=10/10

RULE NUMBER: 61

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The stoker motor is not running
and The auto/hand switch is on auto position

THEN:
Switch the auto/hand switch for stoker to hand - Probability=10/10

RULE NUMBER: 62

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The stoker motor is not running
and The stoker motor terminal connections are loose

THEN:
Clean the stoker motor terminal connections - Probability=10/10
and Tighten the stoker motor terminal connections - Probability=10/10

RULE NUMBER: 63

IF:
The required function is routine component maintenance
and The component is chain grate stoker
and The stoker motor is not running
and Plug and socket stoker motor connection is poor

THEN:
Clean the stoker plug and socket connections - Probability=10/10
and Tighten the stoker plug and socket connections - Probability=10/10

RULE NUMBER: 64

IF:
The required function is routine component maintenance
and The component is valves
and The safety valve is leaking

THEN:
Tighten the safety valve gland nuts - Probability=10/10

RULE NUMBER: 65

IF:
The required function is routine component maintenance
and The component is valves
and The safety valve gland nuts have been tightened
and Safety valve is still leaking

THEN:
Renew the safety valve gland packings - Probability=10/10

RULE NUMBER: 66

IF:
The required function is routine component maintenance
and The component is valves
and The safety valve has not been tested this week

THEN:
Test the safety valve for correct operation - Probability=10/10

RULE NUMBER: 67

IF:
The required function is routine component maintenance
and The component is valves
and The blowdown valve is leaking

THEN:
Tighten the blowdown valve gland packing - Probability=10/10

RULE NUMBER: 68

IF:
The required function is routine component maintenance
and The component is valves
and The blowdown valve gland nuts have been tightened
and Blowdown valve is still leaking

THEN:
Renew the blowdown valve gland packings - Probability=10/10

RULE NUMBER: 69

IF:
The required function is routine component maintenance
and The component is valves
and The blowdown valve has signs of sticking

THEN:
Shut down the boiler - Probability=10/10
and Remove any foreign objects in the blowdown valve - Probability=10/10
and Renew the blowdown valve gland packings - Probability=10/10

RULE NUMBER: 70

IF:
The required function is routine component maintenance
and The component is valves
and The problem is any other valve
and The valve is leaking
and The gland nuts of the valve has not been tightened

THEN:
Tighten the gland nuts of the leaking valve - Probability=10/10

RULE NUMBER: 71

IF:
The required function is routine component maintenance
and The component is valves
and The problem is any other valve
and The valve is leaking
and The gland nuts of the valve has been tightened

THEN:
Renew the gland packings of the leaking nut - Probability=10/10

RULE NUMBER: 72

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The damper shaft sprockets are loose

THEN:
Tighten the FD damper shaft sprockets - Probability=10/10

RULE NUMBER: 73

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The FD damper shaft spring is sticking

THEN:
Replace the FD damper shaft spring - Probability=10/10

RULE NUMBER: 74

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The cam, chain and sprocket are misaligned

THEN:
Check the tightness of cam in FD damper - Probability=10/10
and Check axial movement in sprockets and cam of FD damper - Probability=10/10
and Check the tightness of sprockets in the FD damper - Probability=10/1C

RULE NUMBER: 75

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The single knob control clutch is not engaged

THEN:
Engage the single knob control clutch - Probability=10/10
and If single knob clutch cannot engage, check fault in gearbox - Probability=10/10

RULE NUMBER: 76

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The multipin plug and socket has bad connection

THEN:
Connect the multipin plug and socket correctly - Probability=10/10

RULE NUMBER: 77

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The FD auto/hand switch contacts are clean

THEN:
Clean the FD auto/hand switch contacts - Probability=10/10

RULE NUMBER: 78

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The photohelic set points are not set correclty

THEN:
Set the photohelic set points correctly - Probability=10/10

RULE NUMBER: 79

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The photohelic draught pipe is blocked or disconnected

THEN:
Connect the photohelic draught pipe correctly - Probability=10/10
and Blow dry air through the draught pipe - Probability=10/10

RULE NUMBER: 80

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The photohelic zero setting is wrongly set

THEN:
Reset the photohelic zero setting - Probability=10/10

RULE NUMBER: 81

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD damper does not open or not close
and The damper shaft sprockets are not loose
and The FD damper shaft spring is not sticking
and The cam, chain and sprocket are not misaligned
and The single knob control clutch is engaged
and The multipin plug and socket has good connection
and The FD auto/hand switch contacts are clean
and The photohelic set points are set correctly
and The photohelic draught pipe is not blocked
and The photohelic draught pipe is disconnected
and The photohelic zero setting is correctly set

THEN:
Check the panel regulator - Probability=10/10
and Check the Sauter motor - Probability=10/10
and Check RDA or EXP 10 balance relay - Probability=10/10

RULE NUMBER: 82

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD motor will not run
and The water level in the boiler is too low

THEN:
Fill up the boiler to normal water level - Probability=10/10

RULE NUMBER: 83

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD motor will not run
and Single switch controller is faulty

THEN:
Repair the single switch controller - Probability=10/10

RULE NUMBER: 84

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD motor will not run
and The FD auto/hand switch is on auto

THEN:
Switch the FD auto/hand switch to hand control - Probability=10/10

RULE NUMBER: 85

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD motor will not run
and The control fuse is blown

THEN:
Replace the control fuse - Probability=10/10

RULE NUMBER: 86

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD motor will not run
and The FD motor terminal connections are loose

THEN:
Clean the FD motor terminal connections - Probability=10/10
and Tighten FD motor terminal connections - Probability=10/10

RULE NUMBER: 87

IF:
The required function is routine component maintenance
and The component is FD damper
and The FD motor will not run
and The multipin plug and socket has bad connection

THEN:
Connect the multipin plug and socket correctly - Probability=10/10

RULE NUMBER: 88

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and Grub screws in damper shaft collars are loose

THEN:
Tighten grub screws in the ID damper shaft collar - Probability=10/10

RULE NUMBER: 89

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and The damper shaft is seized in bearings

THEN:
Replace the ID damper shaft bearings - Probability=10/10
and Grease the ID damper shaft bearings with suitable oil -
Probability=10/10

RULE NUMBER: 90

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and The ID control shaft is seized

THEN:
Remove the ID control unit shaft - Probability=10/10
and Remove all foreign material from the ID control unit shaft - Probability=10/10
and Grease the ID control unit shaft with suitable oil - Probability=10/1

RULE NUMBER: 91

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and The ID control unit clutch is not engaged

THEN:
Engage the ID control unit clutch - Probability=10/10

RULE NUMBER: 92

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and The Sauter motor gears are stripped

THEN:
Renew the Sauter motor gears - Probability=10/10
and Check the condition of the Sauter motor bearings - Probability=10/10

RULE NUMBER: 93

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and The ID terminal connections are loose

THEN:
Clean the ID terminal connections - Probability=10/10
and Tighten the ID terminal connections - Probability=10/10

RULE NUMBER: 94

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and The ID pressure line valve is not open

THEN:
Open the ID pressure line valve - Probability=10/10

RULE NUMBER: 95

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan damper does not close or not open
and Grub screws in damper shaft collars are not loose
and The damper shaft is not seized in bearings
and The ID control unit clutch is engaged
and The Sauter motor gears are not stripped
and The ID terminal connections are not loose
and The ID pressure line valve is open

THEN:
Check Sauter motor feedback port - Probability=10/10
and Check RDA or EXP 10 balance relay - Probability=10/10
and Check pressure detector - Probability=10/10
and Check panel regulator - Probability=10/10

RULE NUMBER: 96

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan motor will not run
and Water level is too low

THEN:
Fill up the boiler to normal water level - Probability=10/10

RULE NUMBER: 97

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan motor will not run
and The single switch controller is faulty

THEN:
Repair the single switch controller - Probability=10/10

RULE NUMBER: 98

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan motor will not run
and The ID auto/hand switch is on auto

THEN:
Switch the ID auto/hand switch to hand control - Probability=10/10

RULE NUMBER: 99

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan motor will not run
and The control fuse is blown

THEN:
Replace the control fuse - Probability=10/10

RULE NUMBER: 100

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan motor will not run
and The ID motor terminal connections are loose

THEN:
Tighten the ID motor terminal connections - Probability=10/10

RULE NUMBER: 101

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan motor will not run
and The ID fan motor overload relay has tripped

THEN:
Remove any source of overload on the ID fan motor - Probability=10/1C
and Switch on the overload relay - Probability=10/10

RULE NUMBER: 102

IF:
The required function is routine component maintenance
and The component is ID damper
and The ID fan motor will not run
and The ID fan V-belts are strecthed

THEN:
Replace the stretched V-belts with new ones - Probability=10/10

RULE NUMBER: 103

IF:
The required function is routine component maintenance
and The component is water gauges
and There are no chevrons in water gauges

THEN:
Install chevrons in water gauges - Probability=10/10
and Caution about water gauges without chevrons

RULE NUMBER: 104

IF:
The required function is routine component maintenance
and The component is water gauges
and The gauge glass is blown

THEN:
Replace the blown gauge glass immediately - Probability=10/10

RULE NUMBER: 105

IF:
The required function is routine component maintenance
and The component is water gauges
and The gauge has not been blown down today

THEN:
Blow down the gauge glasses - Probability=10/10

RULE NUMBER: 106

IF:
The required function is routine component maintenance
and The component is water gauges
and Blow down of gauge glasses is needed
and The procedure of blowing down is not known

THEN:
Close the water leg valve - Probability=10/10
and Open the tail cock - Probability=10/10
and Allow steam to blow through the gauge glass - Probability=10/10
and Close the tail cock - Probability=10/10
and Open the water leg valve - Probability=10/10
and Close the steam leg valve - Probability=10/10
and Open the tail cock and allow water to blow through - Probability=10/1
and Close the tail cock and open the steam leg valve - Probability=10/10

RULE NUMBER: 107

IF:
The required function is routine component maintenance
and The component is water gauges
and Gauge glass has a leaking valve

THEN:
Replace the defective valve in the gauge glass - Probability=10/10

RULE NUMBER: 108

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is the single switch controller
and The two switch controller has not been blown down today

THEN:
Blowdown the two switch controller - Probability=10/10
and Check whether the two switch controller controls the pumps correctly - Probability=10/10
and Check the water level indicator light for proper operation - Probability=10/10
and Listen to the alarm cutting in and off - Probability=10/10

RULE NUMBER: 109

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and Two switch blowdown procedure is not known
and Two switch controller blowdown is needed

THEN:
Turn sequencing blowdown valve clockwise - Probability=10/10
and Turn the sequencing valve till mid position is reached - Probability=10/10
and Keep the valve in this position for 5 to 10 seconds - Probability=10/
and Continue to turn full extent of travel - Probability=10/10
and Keep the valve in this position for 5 to 10 seconds - Probability=10/
and Check that low water level lamp illuminates - Probability=10/10
and Listen whether the bell sounds - Probability=10/10
and Check that the pump starts - Probability=10/10
and Turn the valve anticlockwise - Probability=10/10
and Stop at midposition for 5 seconds - Probability=10/10
and Turn the valve again till fully closed - Probability=10/10
and Check that the low water level light extinguishes - Probability=10/1
and Check whether the pump cuts off at this stage - Probability=10/10

RULE NUMBER: 110

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and Two switch blowdown has been done
and The low level light did not illuminate
and The light bulb is okay

THEN:
The two switch controller is faulty - Probability=10/10
and Repair the two switch controller immediately - Probability=10/10

RULE NUMBER: 111

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and Two switch blowdown has been done
and The pump did not cut in on low water level

THEN:
The two switch controller is faulty - Probability=10/10
and Repair the two switch controller immediately - Probability=10/10

RULE NUMBER: 112

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and Two switch blowdown has been done
and The alarm did not sound of low water level

THEN:
The two switch controller is faulty - Probability=10/10
and Repair the two switch controller immediately - Probability=10/10

RULE NUMBER: 113

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and Two switch blowdown has been done
and The alarm light did not extinguish at the right level

THEN:
The two switch controller is faulty - Probability=10/10
and Repair the two switch controller immediately - Probability=10/10

RULE NUMBER: 114

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and Two switch blowdown has been done
and The alarm did not stop on right level

THEN:
The two switch controller is faulty - Probability=10/10
and Repair the two switch controller immediately - Probability=10/10

RULE NUMBER: 115

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and Two switch blowdown has been done
and Pump did did not stop at the right level

THEN:
The two switch controller is faulty - Probability=10/10
and Repair the two switch controller immediately - Probability=10/10

RULE NUMBER: 116

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is two switch controller
and The sequencing blowdown valve can turn both directions at mid length

THEN:
The sequencing blowdown valve is faulty - Probability=10/10
and Repair the sequencing blowdown valve immediately - Probability=10/10

RULE NUMBER: 117

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is the single switch controller or two switch controll
and The sequencing blowdown valve flange is leaking

THEN:
Replace the flange gasket for the sequencing blowdown valve -
Probability=10/10

RULE NUMBER: 118

IF:
The required function is routine component maintenance
and The component is float operated controllers
and The controller is the single switch controller
and The single controller has not been blown down today

THEN:
Blowdown the single switch controller - Probability=10/10
and Check ID fan, FD fan and stoker motors stop during single switch
blowdown - Probability=10/10

RULE NUMBER: 119

IF:
The required function is firing problems
and The fire on grate is running away
and Furnace pressure is too low

THEN:
Move the photohelic set points closer to zero - Probability=10/10

RULE NUMBER: 120

IF:
The required function is firing problems
and The fire on grate is running away
and The undergrate damper does not match the fire length

THEN:
Set the undergrate damper correctly - Probability=10/10

RULE NUMBER: 121

IF:
The required function is firing problems
and The fire on grate is running away
and The coal bed is too thin for the load

THEN:
Close the ID damper to position 3 temporarily - Probability=10/10
and Raise the guillotine door - Probability=10/10

RULE NUMBER: 122

IF:
The required function is firing problems
and The fire on grate is running away
and The small coal is too wet

THEN:
Shut off steam moisturising - Probability=10/10
and Reduce damping of coal - Probability=10/10
and Protect the coal bunker from the weather - Probability=10/10

RULE NUMBER: 123

IF:
The required function is firing problems
and The fire on grate is running away
and Coal segregation is noticed

THEN:
Dampen coal in the bunker - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 124

IF:
The required function is firing problems
and The fire on grate is running away
and The coal size is too large

THEN:
Raise the furnace pressure temporarily - Probability=10/10
and Reduce the fuel trim - Probability=10/10
and Increase the guillotine door height - Probability=10/10

RULE NUMBER: 125

IF:
The required function is firing problems
and The fire on grate is running away
and The coal contains too much dust

THEN:
Raise the furnace pressure - Probability=10/10
and Increase the fuel trim - Probability=10/10
and Reduce the guillotine door - Probability=10/10

RULE NUMBER: 126

IF:
The required function is firing problems
and The fire on grate is running away
and The volatile content of coal is low

THEN:
Raise the furnace pressure - Probability=10/10

RULE NUMBER: 127

IF:
The required function is firing problems
and The fire on grate is burning back into the hopper
and Furnace pressure is very high

THEN:
Reduce the furnace pressure - Probability=10/10
and Move the photohelic set points closer to zero - Probability=10/10

RULE NUMBER: 128

IF:
The required function is firing problems
and The fire on grate is burning back into the hopper
and When dampers close at high pressure, the stoker stops

THEN:
Set the stoker minimum speed to 0.5 - 1.5 rpm - Probability=10/10

RULE NUMBER: 129

IF:
The required function is firing problems
and The fire on grate is burning back into the hopper
and The minimum stoker speed is too low

THEN:
Raise the minimum stoker speed to 1.5 rpm - Probability=10/10

RULE NUMBER: 130

IF:
The required function is firing problems
and The fire on grate is burning back into the hopper
and The shear pin is broken

THEN:
Replace the broken shear pin - Probability=10/10

RULE NUMBER: 131

IF:
The required function is firing problems
and The fire on grate is burning back into the hopper
and Coal segregation is noticed

THEN:
Reduce the furnace pressure - Probability=10/10
and Dampen coal in the bunker - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 132

IF:
The required function is firing problems
and The fire on grate is burning back into the hopper
and The volatile content of coal is high

THEN:
Reduce the furnace pressure - Probability=10/10

RULE NUMBER: 133

IF:
The required function is firing problems
and The chimney is smoking
and The volatile content of coal is high

THEN:
Reduce furnace pressure until photohelic needle is steadier -
Probability=10/10

RULE NUMBER: 134

IF:
The required function is firing problems
and The chimney is smoking
and The coal bed is too thick for the load

THEN:
Reduce the guillotine door - Probability=10/10

RULE NUMBER: 135

IF:
The required function is firing problems
and The chimney is smoking
and Red coal is running over the end of chaingrate

THEN:
Reduce the guillotine door - Probability=10/10

RULE NUMBER: 136

IF:
The required function is firing problems
and The chimney is smoking
and Boiler is dirty

THEN:
Clean the boiler tubes - Probability=10/10

RULE NUMBER: 137

IF:
The required function is firing problems
and The chimney is smoking
and The dampers close suddenly under auto control

THEN:
There is a wiring fault in the ID servo feedback system - Probability=10/10
and Switch the FD dampers to panel and close them fully - Probability=10/
and Stop the FD fan for 2 to 3 minutes - Probability=10/10
and Start the fan and switch back to automatic - Probability=10/10

RULE NUMBER: 138

IF:
The required function is firing problems
and The chimney is smoking
and The boiler load is flactuating quickly and widely

THEN:
Operate the ID on panel till the pressure is within 50kPa of operatin
pressure - Probability=10/10

RULE NUMBER: 139

IF:
The required function is firing problems
and The photohelic needle is flickering
and The volatile content of coal is high

THEN:
Reduce furnace pressure until photohelic needle is steadier - Probability=10/10

RULE NUMBER: 140

IF:
The required function is firing problems
and Emergency door is flaping and banging
and The volatile content of coal is high

THEN:
Reduce furnace pressure until photohelic needle is steadier - Probability=10/10

RULE NUMBER: 141

IF:
The required function is firing problems
and Smoke puffs can be noticed from the front of the boiler
and The minimum stoker speed is too low

THEN:
Reduce furnace pressure until photohelic needle is steadier - Probability=10/10

RULE NUMBER: 142

IF:
The required function is firing problems
and The flames are short
and The steam pressure is dropping
and The fuel bed is too thin

THEN:
Close the ID dampers until the fire is orange-yellow - Probability=10/10
and Raise the guillotine door - Probability=10/10
and Open ID dampers slowly, keeping orange yellow colour - Probability=10/10

RULE NUMBER: 143

IF:
The required function is firing problems
and Red coal is running over the end of chaingrate
and The chaingrate runs hot
and The fuel trim setting is too high

THEN:
Reduce the fuel trim - Probability=10/10

RULE NUMBER: 144

IF:
The required function is firing problems
and Red coal is running over the end of chaingrate
and The chaingrate runs hot
and The fuel bed is too thick

THEN:
Reduce the guillotine door - Probability=10/10

RULE NUMBER: 145

IF:
The required function is firing problems
and Red coal is running over the end of chaingrate
and The chaingrate runs hot
and Boiler is dirty

THEN:
Clean the boiler tubes - Probability=10/10

RULE NUMBER: 146

IF:
The required function is firing problems
and Red coal is running over the end of chaingrate
and The chaingrate runs hot
and Undergrate dampers shut too for

THEN:
Match undergrate dampers with the fire length - Probability=10/10

RULE NUMBER: 147

IF:
The required function is firing problems
and Red coal is running over the end of chaingrate
and The chaingrate runs hot
and The minimum stoker speed is too high

THEN:
Set the stoker minimum speed to 0.5 - 1.5 rpm - Probability=10/10

RULE NUMBER: 148

IF:
The required function is firing problems
and The fire on grate is burning back into the hopper
and The chaingrate runs hot
and The FD dampers close too far

THEN:
Set FD damper to drill marks on casing when fully closed -
Probability=10/10

RULE NUMBER: 149

IF:
The required function is firing problems
and The shear pin breaks often
and The chaingrate is humping

THEN:
The chaingrate tension is too slack - Probability=10/10
and Retension the chaingrate - Probability=10/10

RULE NUMBER: 150

IF:
The required function is firing problems
and Unburnt coal can be noticed in the ash
and The fuel bed is too thick

THEN:
Lower guillotine door 10 mm at a time - Probability=10/10

RULE NUMBER: 151

IF:
The required function is firing problems
and The fire burns unevenly
and The fuel bed is too thick

THEN:
Lower guillotine door 10 mm at a time - Probability=10/10

RULE NUMBER: 152

IF:
The required function is firing problems
and Dark spots can be seen in the fire
and The fuel bed is too thick

THEN:
Lower guillotine door 10 mm at a time - Probability=10/10

RULE NUMBER: 153

IF:
The required function is firing problems
and Flames are higher on one side of grate
and The fuel bed is too thick

THEN:
Lower guillotine door 10 mm at a time - Probability=10/10

RULE NUMBER: 154

IF:
The required function is firing problems
and The fire runs away from sides
and The fuel bed is too thick

THEN:
Lower guillotine door 10 mm at a time - Probability=10/10

RULE NUMBER: 155

IF:
The required function is firing problems
and Dark red mounds are falling over end of grate occationally
and The fuel bed is too thick

THEN:
Lower guillotine door 10 mm at a time - Probability=10/10

RULE NUMBER: 156

IF:
The required function is firing problems
and Unburnt coal can be noticed in the ash
and Coal segregation is noticed

THEN:
Dampen coal in the bunker - Probability=10/10
and Use swinging coal chute - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 157

IF:
The required function is firing problems
and The fire burns unevenly
and Coal segregation is noticed

THEN:
Dampen coal in the bunker - Probability=10/10
and Use swinging coal chute - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 158

IF:
The required function is firing problems
and Dark spots can be seen in the fire
and Coal segregation is noticed

THEN:
Dampen coal in the bunker - Probability=10/10
and Use swinging coal chute - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 159

IF:
The required function is firing problems
and Flames are higher on one side of grate
and Coal segregation is noticed

THEN:
Dampen coal in the bunker - Probability=10/10
and Use swinging coal chute - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 160

IF:
The required function is firing problems
and The fire runs away from sides
and Coal segregation is noticed

THEN:
Dampen coal in the bunker - Probability=10/10
and Use swinging coal chute - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 161

IF:
The required function is firing problems
and Dark red mounds are falling over end of grate occationally
and Coal segregation is noticed

THEN:
Dampen coal in the bunker - Probability=10/10
and Use swinging coal chute - Probability=10/10
and Stir coal in the hopper - Probability=10/10

RULE NUMBER: 162

IF:
The required function is firing problems
and Unburnt coal can be noticed in the ash
and The coal contains too much dust

THEN:
Mix in pea coal if available - Probability=10/10
and Lower the guillotine door by 20 mm - Probability=10/10

RULE NUMBER: 163

IF:
The required function is firing problems
and The fire burns unevenly
and The coal contains too much dust

THEN:
Mix in pea coal if available - Probability=10/10
and Lower the guillotine door by 20 mm - Probability=10/10

RULE NUMBER: 164

IF:
The required function is firing problems
and Dark spots can be seen in the fire
and The coal contains too much dust

THEN:
Mix in pea coal if available - Probability=10/10
and Lower the guillotine door by 20 mm - Probability=10/10

RULE NUMBER: 165

IF:
The required function is firing problems
and Flames are higher on one side of grate
and The coal contains too much dust

THEN:
Mix in pea coal if available - Probability=10/10
and Lower the guillotine door by 20 mm - Probability=10/10

RULE NUMBER: 166

IF:
The required function is firing problems
and The fire runs away from sides
and The coal contains too much dust

THEN:
Mix in pea coal if available - Probability=10/10
and Lower the guillotine door by 20 mm - Probability=10/10

RULE NUMBER: 167

IF:
The required function is firing problems
and Dark red mounds are falling over end of grate occationally
and The coal contains too much dust

THEN:
Mix in pea coal if available - Probability=10/10
and Lower the guillotine door by 20 mm - Probability=10/10

APPENDIX D

This appendix contains a printout of rules or knowledge base of the Shutdown Boiler Maintenance Expert System.

Subject:
SHUTDOWN BOILER MAINTENANCE

Author:
C.V.GAMEDE

Starting text:
SUPPLY THE REQUIRED INFORMATION BY PUNCHING IN THE NUMBER CORRESPONDING TO THE CORRECT ANSWER

Ending text:
THE FOLLOWING ACTIONS AND SUGGESTIONS ARE RECOMMENDED:

Uses all applicable rules in data derivations.

RULES:

RULE NUMBER: 1

IF:
Required function is internal/external inspection or hydraulic test
and Inspection/test is not within 30 months

THEN:
Notify inspector about inspection overdue date - Probability=10/10

RULE NUMBER: 2

IF:
Required function is internal/external inspection or hydraulic test
and At least 90 days to inspector are not given before inspection

THEN:
Notify inspector at least 90 days before inspection/test -
Probability=10/10

RULE NUMBER: 3

IF:
Required function is internal/external inspection or hydraulic test
and Competent person/firm particulars are not supplied

THEN:
Suply particulars of the competent person - Probability=10/10

RULE NUMBER: 4

IF:
Required function is internal/external inspection or hydraulic test
and Encasement is needed before inspection

THEN:
Do not encase before written permission from inspector -
Probability=10/10

RULE NUMBER: 5

IF:
Required function is internal/external inspection or hydraulic test
and The inspector wants to inspect the boiler

THEN:
Prepare boiler according to inspector's instructions - Probability=10/10
and Men and equipment should be provided free of charge - Probability=10/

RULE NUMBER: 6

IF:
Required function is internal/external inspection
and General preparation steps are not known by user

THEN:
Drain boiler after cooling - Probability=10/10
and Break the vacuum - Probability=10/10
and Blank or padlock all live connections - Probability=10/10
and Overhaul all fittings and renew packings - Probability=10/10
and Hammer test all studs - Probability=10/10
and Replace soft or crystaline studs - Probability=10/10
and Chip away hard scale with a blunt tool - Probability=10/10
and Use special equipment on tubes if necessary - Probability=10/10
and Brush and scrape all flue surfaces - Probability=10/10
and Clean smoke tubes - Probability=10/10
and Clear all choked connections - Probability=10/10
and Renew corroded pipes - Probability=10/10
and Pay special attention to water passages - Probability=10/10
and Do not paint surface before inspection - Probability=10/10
and Remove all loose dust - Probability=10/10
and Fill in the logbook - Probability=10/10
and Provide a 42 volt light - Probability=10/10
and Provide a chiping and a light hammer - Probability=10/10
and Do any special requirements by inspector/competent person - Probability=10/10

RULE NUMBER: 7

IF:
Required function is internal/external inspection
and The boiler particulars cannot be identified at the copper plate

THEN:
Check original data from registration certificate - Probability=10/1
and New numbers should be punched clearly - Probability=10/10

RULE NUMBER: 8

IF:
Required function is internal/external inspection
and The inspection lamp is greater than 42 volts

THEN:
Use a lamp less than 42 volts - Probability=10/10

RULE NUMBER: 9

IF:
Required function is internal/external inspection
and The front tube plate is lightly distorted

THEN:
Ask advice from boiler inspector before firing the boiler - Probability=10/10

RULE NUMBER: 10

IF:
Required function is internal/external inspection
and The front tube plate is heavily distorted

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Manufacturer recommended for repairs - Probability=10/10
and The plate front tube plate will need to be straightened - Probability=10/10

RULE NUMBER: 11

IF:
Required function is internal/external inspection
and The front tube welds are heavily corroded

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Rewelding of the corroded part will be needed - Probability=10/10

RULE NUMBER: 12

IF:
Required function is internal/external inspection
and Front tube ends are leaking
and There is no rust around tube ends

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Front tube ends will need to be re-expanded - Probability=10/10

RULE NUMBER: 13

IF:
Required function is internal/external inspection
and Front tube ends are leaking
and There is rust around tube ends

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Tube will need to be replaced or blanked - Probability=10/10

RULE NUMBER: 14

IF:
Required function is internal/external inspection
and The smoke tubes are lightly distorted

THEN:
Do not fire boiler before inspector's advice - Probability=10/10
and Ask advice from the inspector - Probability=10/10

RULE NUMBER: 15

IF:
Required function is internal/external inspection
and The smoke tubes are heavily distorted

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Tube will need to be replaced or blanked - Probability=10/10

RULE NUMBER: 16

IF:
Required function is internal/external inspection
and The furnace tube welds are cracked or heavily corroded

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Furnace tube will need to be rewelded - Probability=10/10

RULE NUMBER: 17

IF:
Required function is internal/external inspection
and The furnace tube is eccentric

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Manufacturer recommended for reshaping furnace tube - Probability=10/

RULE NUMBER: 18

IF:
Required function is internal/external inspection
and Furnace tube has signs of overheating

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Overheated parts may need cutting out and replaced - Probability=10/1

RULE NUMBER: 19

IF:
Required function is internal/external inspection
and The rear tube plate is lightly distorted

THEN:
Ask advice from boiler inspector before firing the boiler -
Probability=10/10

RULE NUMBER: 20

IF:
Required function is internal/external inspection
and The rear tube plate is heavily distorted

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Rear tube plate need to be straightened - Probability=10/10

RULE NUMBER: 21

IF:
Required function is internal/external inspection
and The rear tube plate welds are leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Rear tube plate need to be straightened - Probability=10/10
and Rewelding the rear tube welds is needed - Probability=10/10

RULE NUMBER: 22

IF:
Required function is internal/external inspection
and The rear tube ends are leaking
and There is no rust around rear tube ends

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Rear tube ends need to be re-expanded - Probability=10/10

RULE NUMBER: 23

IF:
Required function is internal/external inspection
and There is rust around rear tube ends
and The rear tube ends are leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Tube will need to be replaced or blanked - Probability=10/10

RULE NUMBER: 24

IF:
Required function is internal/external inspection
and Wet wall stays are broken

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and New wet wall stays need to be installed - Probability=10/10

RULE NUMBER: 25

IF:
Required function is internal/external inspection
and Wet wall stays have weld cracks

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Well wall stays need to be rewelded - Probability=10/10

RULE NUMBER: 26

IF:
Required function is internal/external inspection
and External back plate is heavily corroded

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and External back plate needs cutting out and replating - Probability=10/

RULE NUMBER: 27

IF:
Required function is internal/external inspection
and Hand holes and/or manholes have wastage

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Handholes and/or manholes must be replaced - Probability=10/10

RULE NUMBER: 28

IF:
Required function is internal/external inspection
and Fitting connections have flange wastage

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Fitting connection flanges need to be replaced - Probability=10/10

RULE NUMBER: 29

IF:
Required function is internal/external inspection
and Fitting connections are blocked

THEN:
Clear fitting connections blockages - Probability=10/10

RULE NUMBER: 30

IF:
Required function is internal/external inspection
and Steam space is heavily corroded or heavily pitted

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Corroded steam space needs replating - Probability=10/10

RULE NUMBER: 31

IF:
Required function is internal/external inspection
and Internal shell plate is heavily corroded or heavily pitted

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Internal shell plate need replating - Probability=10/10

RULE NUMBER: 32

IF:
Required function is internal/external inspection
and Internal shell has scale

THEN:
Remove scale from internal shell carefully - Probability=10/10
and Check for corrosion or pitting under scale - Probability=10/10
and Ask advice from inspector in case of pitting or corrosion under scale
Probability=10/10

RULE NUMBER: 33

IF:
Required function is internal/external inspection
and Front or rear tube plate has corrosion

THEN:
Check whether tube plate corrosion is active - Probability=10/10
and Monitor tube plate corrosion carefully is active - Probability=10/10

RULE NUMBER: 34

IF:
Required function is internal/external inspection
and Front or rear tube plate is layered with scale

THEN:
Remove tube plate scale carefully - Probability=10/10
and Check under tube plate scale for corrosion - Probability=10/10

RULE NUMBER: 35

IF:
Required function is internal/external inspection
and Tubes have corrosion or pitting

THEN:
Check whether corrosion is active on tubes - Probability=10/10
and Check under tube plate scale for corrosion - Probability=10/10
and Active corrosion on tubes is very dangerous - Probability=10/10
and Report active corrosion to inspector - Probability=10/10

RULE NUMBER: 36

IF:
Required function is internal/external inspection
and Tubes have a layer of scale

THEN:
Remove tube scale carefully - Probability=10/10
and Check for corrosion or pitting under tube scale - Probability=10/10
and Report to inspector if there is heavy tube corrosion or pitting -
Probability=10/10

RULE NUMBER: 37

IF:
Required function is internal/external inspection
and Feedwater pipes are blocked

THEN:
Remove obstacles from feedwater pipes - Probability=10/10
and Check scale from feedwater pipes - Probability=10/10

RULE NUMBER: 38

IF:
Required function is internal/external inspection
and Fittings are wasted

THEN:
Replace wasted fittings - Probability=10/10

RULE NUMBER: 43

IF:
Required function is internal/external inspection
and Blowdown sump baffle is heavily corroded

THEN:
Erect a new blowdown sump baffle - Probability=10/10

RULE NUMBER: 44

IF:
Required function is internal/external inspection
and Blowdown sump concrete is corroded

THEN:
Replace corroded blowdown sump concrete - Probability=10/10

RULE NUMBER: 45

IF:
Required function is feedwater tank and accessories cleaning
and Procedure for cleaning is not known

THEN:
Close fresh water inlet isolating valve - Probability=10/10
and Close feedwater outlet isolating valve - Probability=10/10
and Check feedwater tank for leakage signs - Probability=10/10
and Drain feedwater tank - Probability=10/10
and Remove mud and sediments from interior - Probability=10/10
and Wash down with clean water - Probability=10/10
and Carry out repairs immediately if there is leakage - Probability=10/10
and Open inlet isolating valve to fill tank - Probability=10/10
and Add correct amount of chemicals - Probability=10/10
and Verify samples for correct chemical content - Probability=10/10
and Allow feedwater to circulate in the boiler - Probability=10/10
and Start feedpump no. 1 - Probability=10/10
and Run feedpump no.1 for 3 to 5 minutes - Probability=10/10
and Switch to feedpump no.2 - Probability=10/10
and Run feedpump no. 2 for 3 to 5 minutes - Probability=10/10
and Close inlet and outlet isolating valves for both pumps - Probability=10/10
and Remove strainers from suction side - Probability=10/10
and Clean strainers thoroughly in clean water - Probability=10/10
and Fit back strainers - Probability=10/10
and Open inlet isolating valves on both pumps - Probability=10/10
and Check water level in the boiler - Probability=10/10
and Ensure the water level is correct - Probability=10/10

RULE NUMBER: 46

IF:
Required function is feedwater tank and accessories cleaning
and Feedwater tank calcium hardness is not approximately 50 mg/l

THEN:
Reduce or increase feedwater tank calcium hardness to approximately
mg/l - Probability=10/10

RULE NUMBER: 47

IF:
Required function is feedwater tank and accessories cleaning
and Feedwater tank pH is not approximately 8.5

THEN:
Reduce or increase pH until it is approximately 8.5 - Probability=10/

RULE NUMBER: 48

IF:
Required function is feedwater tank and accessories cleaning
and Feedwater pipe system is corroded

THEN:
Use sodium sulphide oxygen scavenger - Probability=10/10
and Use hydrazine oxygen scavenger - Probability=10/10
and Check whether having copper and steel pipe together - Probability=10/

RULE NUMBER: 49

IF:
Required function is hydraulic test
and General initial preparation are not known

THEN:
Expose all seams and rivets - Probability=10/10
and Overhaul all fittings and renew packings - Probability=10/10
and Replace all fittings - Probability=10/10
and Blank off or gag safety valves - Probability=10/10
and Fill completely with cold water - Probability=10/10
and Provide a 42 volt light - Probability=10/10

RULE NUMBER: 50

IF:
Required function is hydraulic test
and Steam stop valve discharge is coupled

THEN:
Uncouple the steam stop valve discharge - Probability=10/10

RULE NUMBER: 51

IF:
Required function is hydraulic test
and Blowdown valve discharge is coupled

THEN:
Uncouple the blowdown valve discharge - Probability=10/10

RULE NUMBER: 52

IF:
Required function is hydraulic test
and [AWGP] > 500

THEN:
[TP1] IS GIVEN THE VALUE 0.9*[MTP]
and [TP2] IS GIVEN THE VALUE 1.2*[AWGP]+400

RULE NUMBER: 53

IF:
Required function is hydraulic test
and [AWGP] > 500
and [TP1] <= [TP2]

THEN:
[TPU] IS GIVEN THE VALUE [TP1]

RULE NUMBER: 54

IF:
Required function is hydraulic test
and [AWGP] > 500
and [TP2] <= [TP1]

THEN:
[TPU] IS GIVEN THE VALUE [TP2]

RULE NUMBER: 55

IF:
Required function is hydraulic test
and [AWGP] <= 500

THEN:
[TP1] IS GIVEN THE VALUE 0.9 * [MTP]
and [TP2] IS GIVEN THE VALUE 2 * [AWGP]

RULE NUMBER: 56

IF:
Required function is hydraulic test
and [AWGP] <= 500
and [TP1] <= [TP2]

THEN:
[TPU] IS GIVEN THE VALUE [TP1]

RULE NUMBER: 57

IF:
Required function is hydraulic test
and [AWGP] <= 500
and [TP2] <= [TP1]

THEN:
[TPU] IS GIVEN THE VALUE [TP2]

RULE NUMBER: 58

IF:
Required function is hydraulic test
and Gauge glasses are not isolated

THEN:
Isolate gauge glasses - Probability=10/10

RULE NUMBER: 59

IF:
Required function is hydraulic test
and Pressure stat is not isolated

THEN:
Isolate the pressure stat - Probability=10/10

RULE NUMBER: 60

IF:
Required function is hydraulic test
and The test gauge flange has not been blown through

THEN:
Blow through the test gauge flange - Probability=10/10

RULE NUMBER: 61

IF:
Required function is hydraulic test
and The test gauge flange has been blown through

THEN:
Attach the test gauge - Probability=10/10
and Check that both gauges in circuit and equal - Probability=10/10

RULE NUMBER: 62

IF:
Required function is hydraulic test
and The boiler is not at test pressure

THEN:
Pressurise the boiler to test pressure and stop - Probability=10/10
and Wait for test pressure to become steady - Probability=10/10

RULE NUMBER: 63

IF:
Required function is hydraulic test
and External tube plate welds are leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Leaking tube plate welds need rewelding - Probability=10/10

RULE NUMBER: 64

IF:
Required function is hydraulic test
and External circumferential weld is leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and External circumferential weld needs rewelding - Probability=10/10

RULE NUMBER: 65

IF:
Required function is hydraulic test
and External longitudinal weld is leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and External longitudinal weld needs rewelding - Probability=10/10

RULE NUMBER: 66

IF:
Required function is hydraulic test
and Front tube plate tube expansions are leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Front tube ends will need to be re-expanded - Probability=10/10

RULE NUMBER: 67

IF:
Required function is hydraulic test
and Furnace tube welds are leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Furnace tube will need to be rewelded - Probability=10/10

RULE NUMBER: 68

IF:
Required function is hydraulic test
and Rear tube plate tube expansions are leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Rear tube ends need to be re-expanded - Probability=10/10

RULE NUMBER: 69

IF:
Required function is hydraulic test
and Handhole seal is leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Fit new handhole seals - Probability=10/10

RULE NUMBER: 70

IF:
Required function is hydraulic test
and Manhole seal is leaking

THEN:
Do not fire boiler before repairs - Probability=10/10
and Fit new manhole seal - Probability=10/10

RULE NUMBER: 71

IF:
Required function is hydraulic test
and The tube leaks along it's length

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and Tube will need to be replaced or blanked - Probability=10/10

RULE NUMBER: 72

IF:
Required function is hydraulic test
and Pressure in gauges is falling

THEN:
There is a leak - Probability=10/10
and Check carefully where the leak is - Probability=10/10

RULE NUMBER: 73

IF:
Required function is hydraulic test
and The lowest working level is not 75 mm above the flue

THEN:
Adjust your float operated controllers - Probability=10/10
and Make sure lowest working water level is 75 mm above the flue - Probability=10/10

RULE NUMBER: 74

IF:
Required function is hydraulic test
and Fittings glands are leaking

THEN:
Replace all leaking gland packings - Probability=10/10

RULE NUMBER: 75

IF:
Required function is hydraulic test
and All examinations have been done

THEN:
Reduce pressure slowly to zero - Probability=10/10
and Witness safety valves now or later - Probability=10/10

RULE NUMBER: 76

IF:
Required function is general shutdown maintenance
and The stoker frame is twisted

THEN:
Measure the stoker frame diagonals, top and bottom - Probability=10/1
and Give stoker diagonal measurements to the manufacturer - Probability=10/10
and Ask for advice from manufacturer whether to scrape or repair - Probability=10/10

RULE NUMBER: 77

IF:
Required function is general shutdown maintenance
and The stoker frame is having other problems

THEN:
Refer to stoker in the OPERATIONAL EXPERT SYSTEM - Probability=10/10

RULE NUMBER: 78

IF:
Required function is general shutdown maintenance
and Induced Draught fan bearings have not been greased

THEN:
Remove old grease from ID bearings - Probability=10/10
and Apply grease to the ID fan bearings - Probability=10/10

RULE NUMBER: 79

IF:
Required function is general shutdown maintenance
and Fire tubes have not been cleaned

THEN:
Clean fire tubes - Probability=10/10

RULE NUMBER: 80

IF:
Required function is general shutdown maintenance
and The flue has been cleaned

THEN:
Clean the flue - Probability=10/10

RULE NUMBER: 81

IF:
Required function is general shutdown maintenance
and The combustion chamber has not been cleaned

THEN:
Clean the combustion chamber - Probability=10/10

RULE NUMBER: 82

IF:
Required function is general shutdown maintenance
and Tube plates have not been cleaned

THEN:
Cleaned the tube plates - Probability=10/10

RULE NUMBER: 83

IF:
Required function is general shutdown maintenance
and Slag has not been removed

THEN:
Remove slag from the boiler - Probability=10/10

RULE NUMBER: 84

IF:
Required function is general shutdown maintenance
and Brickwork is damaged

THEN:
Replaced damaged brickwork - Probability=10/10

RULE NUMBER: 85

IF:
Required function is general shutdown maintenance
and Smokebox joints seals have not been changed

THEN:
Install new smokebox joint seals - Probability=10/10

RULE NUMBER: 86

IF:
Required function is general shutdown maintenance
and The boiler foundation has cracks

THEN:
Do not fire boiler before repairs - Probability=10/10
and Repair boiler foundations - Probability=10/10

RULE NUMBER: 87

IF:
Required function is general shutdown maintenance
and The boiler insulation is more than 10 years

THEN:
Renew the boiler insulation - Probability=10/10

RULE NUMBER: 88

IF:
Required function is general shutdown maintenance
and The boiler has oil/gas burner
and The oil/gas burner has not been overalled

THEN:
Overall the oil/gas burner - Probability=10/10

RULE NUMBER: 89

IF:
Required function is internal/external inspection
and Corrosion in the header is heavy

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The header needs to be replaced - Probability=10/10

RULE NUMBER: 90

IF:
Required function is internal/external inspection
and Cracks are observed in the header

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The header needs to be replaced - Probability=10/10

RULE NUMBER: 91

IF:
Required function is internal/external inspection
and Distortion in the header is observed

THEN:
Do not paint surface before inspection - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The header needs to be replaced - Probability=10/10

RULE NUMBER: 92

IF:
Required function is internal/external inspection
and Cracks in the header are observed

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The header needs to be rewelded - Probability=10/10

RULE NUMBER: 93

IF:
Required function is internal/external inspection
and Bulging in the header is observed

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The header needs to be replaced - Probability=10/10

RULE NUMBER: 94

IF:
Required function is internal/external inspection
and Pitting in the drum is heavy

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The drum needs to be replated - Probability=10/10

RULE NUMBER: 95

IF:
Required function is internal/external inspection
and Corrosion in the drum is heavy

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The drum needs to be replated - Probability=10/10

RULE NUMBER: 96

IF:
Required function is internal/external inspection
and Wastage in the drum is heavy

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The drum needs to be replated - Probability=10/10

RULE NUMBER: 97

IF:
Required function is internal/external inspection
and Cracks in the drum are observed

THEN:
Do not fire boiler before repairs - Probability=10/10
and Report the fault to the inspector - Probability=10/10
and Ask advice from inspector about repairs - Probability=10/10
and The drum needs to be rewelded - Probability=10/10