

“Saya akui bahawa saya telah membaca karya ini dan pada pandangan saya karya ini adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal (Termal-Bendalir)

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**RULE BASED EXPERT SYSTEM  
FOR INDUSTRIAL BOILER SELECTION**


**KESAVAN A/L MANOHAR**

Laporan ini diserahkan kepada Fakulti Kejuruteraan Mekanikal  
sebagai memenuhi sebahagian daripada syarat penganugerahan  
Ijazah Sarjana Muda Kejuruteraan Mekanikal (Termal Bendalir)

**Fakulti Kejuruteraan Mekanikal  
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“Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya jelaskan sumbernya”

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## ABSTRAK

Projek ini adalah berkaitan dengan “Rule Based Expert System for Industrial Boiler Selection” dimana ia berkait rapat dengan ‘Expert System’. Terdapat banyak panduan dan ‘rule’ dapat dihasilkan untuk program ini dimana ia senang dan mudah digunakan untuk pemilihan boiler dan dapat mengetahui tentang butir-butir boiler yang dipilih. Sebelum menghasilkan program ini, pemerikassan terperinci dan pencarian butir-butir tentang boiler yang kini dalam pasaran telah dibuat untuk membantu menghasilkan program ini dengan berjaya. Segala butir-butir yang penting tentang boiler diambil kira untuk menghasilkan program ini. Rangkaian ‘Kappa-PC’ digunakan untuk menghasilkan program ini adalah untuk memudahkan pengguna-pengguna yang tidak berpengalaman dapat menggunakan dengan mudah untuk mendapat maklumat dan pengetahuan tentang pemilihan boiler. Projek ini merangkumi tentang cara-cara yang digunakan untuk menghasilkan program ini. Cara-cara penghasilan *Session Window*, *Object Browser*, *Rules*, *Goal*, *Functions* dan *Class and Slot* dalam Kappa-PC ini juga diterangkan secara teliti dalam tesis ini serta penghuraian tentang program ini juga diterangkan.

## ABSTRACT

This thesis is on “Rule Based Expert System for Industrial Boiler Selection” where a set of rules and guidelines is created for boiler selection for industries. Before the rules are created, an in depth study and analysis is done on the various types of boiler that is available in today's market. The types and specification of the boiler is also determined. The rules for selection is created using Kappa-Pc software to make it easier for an un experienced user to easily gain information and knowledge on the selection of a boiler. This thesis covers the methods used in executing the Kappa-PC software and how a set of rules is created. The steps and criteria that is needed to create the rules is also explained. The problems faced during the execution of the Kappa-PC software is also explained with suggestion and improvements.

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## LIST OF ABBREVIATIONS

<b>SYMBOL</b>	<b>DEFINITION</b>
mm	Millimeter
Btu	British thermal unit.
hr	Hour
%	Percentage
°F	Fahrenheit
psig	Pressure square inches
hp	Horsepower
V	Volume
Mpa	Mega Pascal
m/s	Meter per second
ft	Feet
ABMA	Fire Tube Engineering Guide
ASME	American Society of Mechanical Engineers
CRN	Canadian Registration Number
PTC	Power Test Code
CO	Carbon monoxide
AI	Artificial Intelligence
ANN	Artificial Neural Network
NN	Neural Network
GA	Genetic Algorithms
kappa	Kappa-PC
IES	Input Expert System
OES	Output Expert System

ES	Expert System
CE	Concurrent Engineering
KM	Knowledge Management
DM	Data Mining
ICT	Communication Technology
DT	Database Technology
VPN	Virtual Private Network
Tsat	Saturation Temperature
DDE	Dynamic Data Exchange
MS	Windows applications

## **CHAPTER 1**

### **INTRODUCTION**

#### **THE RULES BASED EXPERT SYSTEM FOR INDUSTRIAL BOILER SELECTION**

Boiler is a device used for generating the steam for power generation, process use or heating, and hot water for heating purposes. Steam boiler consists of the containing vessel and convection heating surfaces only, whereas a steam generator covers the whole unit, encompassing water wall tubes, super heaters, air heaters and economizers. The selection of the boiler is very important to the industry for conducting the operation system successfully. There are many criteria which can be considered when selecting a boiler to meet its application needs. Some of the criteria are:

- a) Codes and Standards
- b) Steam or Hot Water
- c) System Load
- d) Number of Boilers
- e) Performance Considerations
- f) Special Considerations



These considerations are important because it determine that the boiler in the company uses it is full capability and perform well within the requirements of the company or industry. Boilers can be classified in many ways. Some of the ways are as follows:

**a) By Uses**

The use of boiler is mainly used as utility boiler where it produces steam for electric power generation and industrial boiler where it produce heat for heating purpose. Utility boiler is usually used for large capacity where else industrial boiler is used for smaller capacity. Large capacity is for high steam parameters with high efficiency rate where else small capacity is for lower steam parameters, furnace beds with no reheater.

**b) By Steam-Water Circulating**

Steam water circulation can be divided to natural-circulating boiler where the circulation of the working fluid in the evaporating tubes is produces by the differences in density between the steam water mixture in the risers and water in the down comer. Forced multiple circulation boiler of the other hand is where the circulation of the working fluid in the evaporating tube is produced forcedly by means of a circulating pump included in the circulating circuit.

**c) By Pressure**

There are basically two types of pressure capacity where low and middle pressure boiler is below 10mpa and high pressure boiler has pressure between 10-14mpa. Low and middle pressure boiler is used as industrial boilers with natural circulation where else high pressure boiler is used for large capacity once through or combine circulation.

**d) By Fuel or Heat Sources**

Fuel or heat source boiler can be divided to Solid Fuel Fired Boiler where cost is mainly is used, Fuel Oil Fired Boiler where it uses natural gas or blast furnace gas is mainly used, Waste Heat Boiler where it utilizes waste heat from industrial process as the heating source.

**e) By Firing Method**

Firing method can be one of the following methods, boiler with stokers which is mainly used as industrial boilers. Boilers with burners where it is mainly used as utility boiler or large capacity industrial boilers, boilers with cyclone furnace where it is applicable to coal having low slag viscosity and low iron content, and boiler with fluidized bed where it has solid-fuel particles.

**f) By Method of Removing Slag in Furnace**

Method of removing slag in furnace can be divided into boiler with Dry Ash furnace where it is applicable to coals with high-ash fusion temperature and Dofer with slag tap furnace where liquid form slag flows to the wet bottom of the furnace.

Water tube boilers are suitable for high steam pressure and temperature applications and large capacity units. In water tube boilers, the extended surfaces can be used to make the design compact if the gas stream is clean. Various types of fuels can be fired easily including solid and fuels. Compared to a fire tube boiler, a water tube boiler with extended surfaces is much smaller and will weigh less.

Fire tube boilers on the other hand usually is limited to low steam pressure and high gas pressure. Fire tube boilers can handle high gas temperature on the order of 2400 °F if the tube sheet is properly designed. High steam purity can be obtained by using an external elevated steam drum with internalys.



## 1.1 Problem Statement

There are various types of boiler with different specification, fuel base, construction and capacity. Different industries need a specific boiler in order to manufacture its products. In other words, boiler selection is based on the product that is being manufactured. There may be many criteria that can be considered when selecting a boiler to meet the application needs. Some of the criteria are as follows:

- i) Steam Capacity of Boilers
- ii) Steam Pressure of Boilers
- iii) Boiler Efficiency
- iv) Type of Fuel
- v) Weight of Boiler
- vi) Volume of Water

Currently boiler selection is done to fulfill the requirements and the need to produce the heat for a specific product. It is a time consuming and costly affair to determine the specification and requirements of a boiler for an industry, manually using thus a Rule Based Expert System to identify the criteria or rules for boiler selection and the specification of boilers needed for the various industries. Boiler specification and selection is very important to produce a good and high quality product.

In some cases, there are boilers that do not achieve the optimum efficiency because the failure to diagnose the criteria needed for boiler selection due to lack of knowledge. Boiler that does not fully utilize its capacity or has problem is detrimental to the environment. Using Kappa-PC which is related to Expert System can greatly help improve this situation by providing guidelines for the selection of an optimal boiler.

By using expert system, on an experienced person who is not familiar in determining the type of boiler that is needed for a specific industry can apply this Kappa-PC software to gain information and knowledge to correctly to select the appropriate boiler that must be used in an industry

## **1.2 Objective**

- To gather and study boiler specification.
- To determine the criteria and rules needed for Boiler Selection.
- To identify and apply the Kappa-PC software to determine solutions for the problems.
- To develop a set rules or guidelines using Kappa-PC software to select a boiler for a specific industry.

## **1.3 Scope**

- To gather and study boiler specification.
- To develop the rule based expert system using expert system shell.
- To use 'if-then' approach to develop the rules for selection.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Boiler

Broadly speaking a boiler is a device used for steam for power generating, process use or heating and hot water for heating purposes. A boiler is also a closed pressure vessel for generating steam under pressure. It includes all the mounting fitted to such vessels which remains wholly or partly under pressure when steam is shut-off.

**Steam Boiler** : Consist only of the containing vessel and convectional heating surface.

**Steam Generator** : Covers the whole unit, encompassing waterwall tubes, super heaters, air heater and economizers.

## 2.2 Classification of Boilers

Boilers can be classified in many ways and some of the ways are as follows:

- a) By Uses
- b) By Steam-Water Circulation
- c) By Pressure
- d) By Fuel or Heat Boiler
- e) By Firing Method

### 2.2.1 By Uses

#### **Utility Boiler**

To produce steam for electric power generation. Large capacity, high steam parameters, high boiler efficiency, completely water-cooled furnace with burners when pressure is greater than or equal to 14mpa usually with reheater.

#### **Industrial Boiler**

To produce steam for heating and process, etc. smaller capacity, lower steam parameters, furnace with burners, stokers or fluidized beds, and no reheater.

#### **Marine Boiler**

As a source of motive power for ships. Compact general shape, lighter boiler weight, mostly fuel-oil fired, and no reheater.

## 2.2.2 By Steam-Water Circulation

### Natural-Circulation Boiler

The circulation of the working fluid in the evaporating tubes is produced by the difference in density between the steam-water mixture in the risers and water in the down comers. With one or two drums only operate at sub critical pressure.

### Forced Multiple Circulation Boiler

The circulation of the working fluid in the evaporating tube is produced forcedly by means of a circulating pump included in the circulating circuit. With single drum or separators, can only operate at sub critical pressure.

### Once-Through Boiler

No drum, the working fluid forcedly passes through the evaporating tubes only under the action of the feed-water pump, can operate at sub critical and supercritical pressure.

### Combined-Circulation Boiler

There are a circulating pump, a back-pressure valve, and a mixer in the circuit. At starting the back-pressure valve is opened and the boiler operates as a forced multiple-circulation boiler, on attaining the specified load, the circulating pump is switched off, the back-pressure valve is closed automatically, and the boiler operate at sub critical and supercritical pressure.



### 2.2.3 By Pressure

#### **Low and Middle Pressure Boiler (<10 Mpa)**

Used as industrial boilers, natural circulation, some with boiler bank, furnace with burners or with stockers and reheater.

#### **High Pressure Boiler (10 -14 Mpa)**

Used as utility boilers for large capacity once through or combined circulation, with reheater, the prevention of pseudo-film boiling and high temperature corrosion should be considered.

### 2.2.4 By Fuel or Heat Boiler

#### **Solid Fuel Fired Boiler**

Coal is mainly used: the component of fuel and the characteristic of boiler are important influential factors for boiler design.

#### **Fuel Oil Fired Boiler**

With higher flue gas velocity and smaller furnace volume.

#### **Gas Fired Boiler**

Natural gas or blast-furnace gas are mainly used with higher flue gas velocity and smaller furnace volume.

**Waste Heat Boiler**

Utilizing waste heat from industrial process as the heating sources.

**2.2.5 By Firing Method****Boiler with Stokers**

Mainly used as industrial boilers.

**Boiler with Burners**

Mainly used as utility boilers or large capacity industrial boilers.

**Boiler with Cyclone Furnace**

Applicable to coal having low slag viscosity and low iron content; fuel is fired in a water-cooled cylinder, and the flame is whirled by either tangential coal dust-air jets from burners or tangential high speed jets of secondary air (80-120m/s); as is removed from the furnace in liquid form.

**Boiler with Fluidized Bed**

Solid-fuel particles (1-6mm) are placed onto a grate and blown from burners with an air flow at such a speed that particles are lifted above the grate and are burned in suspending state; used as industrial boilers for burning low-grade solid fuels.

## 2.3 Specification of Boilers

### 2.3.1 Water Tube Boilers

Water tube boilers are suitable for high steam pressure and temperature applications and large capacity units, even exceeding a million pounds per hour of steam or gas flow. Extended surfaces can be used to make the design compact if the gas stream is clean. Compared to a fire tube boiler, a water tube with extended surfaces is much smaller and will weigh less, particularly if the gas flow is large, say exceeding 100,pph.

Various types of fuels can be fired with ease including solid and fuels. The water cooled membrane wall enclosure make an excellent furnace and can sized to match any firing or ash disposal equipment. If the gas stream is dirty, provisions can be made for cleaning the tubes by using rapping mechanism or soot blowers. Access lanes as required may be easily provided. Wide spacing may be provided at the front end of the boiler, where there is more chance for slagging or fouling, followed by sections with smaller spacing at the cooler end.

Due to the lower volume of water hold up compared to a fire tube boiler, the start up periods and the drum response to hold changes can be quicker in a water tube boiler. A water tube boiler is less forgiving to poor water chemis try and tube failures can occur faster compared to fire tube type. On has also to be wary of water tube boilers with extended surfaces, which operate at a much higher heat flux and tube wall temperature compared to bare tube design or designs or fire tube boilers.

A water tube boiler will be more expensive in the smaller gas flow range say 50,000 pph or less compared to fire tube type but less expensive for larger mass flows. For some situations such as gas turbine exhaust where the ration of gas to