

DUVHA BOILER PERFORMANCE
COMPUTER MODEL

DJ VAN AARDE

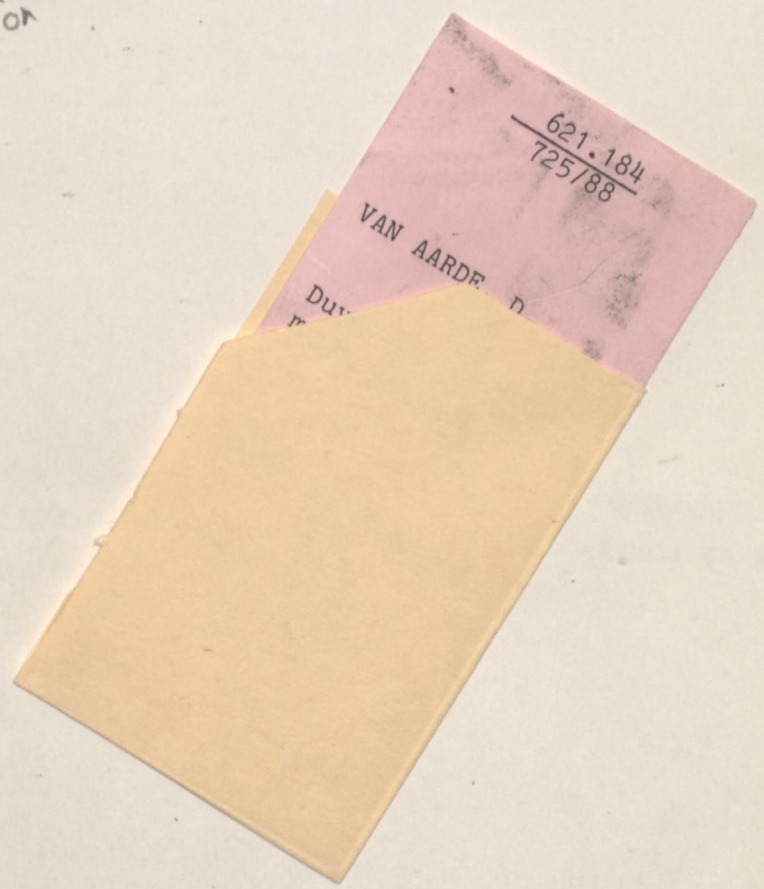
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DUVHA BOILER PERFORMANCE COMPUTER MODEL

DIRK J VAN AARDE

A RESEARCH PROJECT SUBMITTED IN PARTIAL COMPLIANCE WITH THE
REQUIREMENTS FOR THE NATIONAL DIPLOMA IN TECHNOLOGY OF THE SCHOOL
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ABSTRACT

This report investigates the possibility of constructing and developing a Performance-Boiler-Computer-Model of the Duvha Power Station Boiler from the PEPSE* computer software.

This model is to act as a "tool" in investigations into certain as-designed and off design changes on the boiler's thermodynamic behaviour.

It is evident from the results of the performance boiler model that, with further development to a model in design mode, this will be a very useful and versatile tool. This fact is evident from the results of the superheater 3 design mode model.

* See discussion on PEPSE software in Chapter 3

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CONTENTS	PAGE
TITLE PAGE	
ABSTRACT	(i)
ACKNOWLEDGEMENTS	(ii)
CONTENTS	(iii)
LIST OF FIGURES	(vi)
LIST OF TABLES	(vii)
LIST OF SYMBOLS	(viii)
1. INTRODUCTION	1
2. DUVHA BOILER DESCRIPTION	2
2.1 General	2
2.2 Boiler layout and construction	4
2.2.1 Economiser	6
2.2.2 Evaporator	7
2.2.3 Superheaters	8
2.3 Water/steam flow cycle	8
2.3.1 High pressure circuit	8
2.3.2 Reheating circuit	12
2.4 Air flow cycle	13
2.4.1 Secondary air	13
2.4.2 Primary air	14
2.4.3 Flue gas	15
2.5 Summary diagram of fuel, air and water/steam flow	17
3. THE PERFORMANCE COMPUTER MODEL OF THE DUVHA BOILER USING PEPSE SOFTWARE	19
3.1 The software - PEPSE	19
3.1.1 General remarks	19
3.1.2 Modes of operation - design and performance	20

3.1.3	Solution scheme	21
3.2	Simplifications and assumptions on practical boiler cycle	23
3.2.1	The air flow cycle	24
3.2.1.1	The rotary air heaters	24
3.2.1.2	Primary air and furnace-combustor	25
3.2.2	Water/steam flow cycle	25
3.3	The Duvha boiler computer flow chart	27
3.4	Boiler flow chart description	31
3.4.1	Air flow cycle	31
3.4.2	Flue gas flow	32
3.4.3	The water/steam flow	33
3.5	The performance mode input file	34
3.6	The performance mode output file	35
3.6.1	Discussion of results	35
4.	THE DESIGN MODE MODEL OF SUPERHEATER 3	42
4.1	General	42
4.2	The Superheater 3 design mode flow chart	42
4.2.1	Description of flue gas and steam flow on flow chart	43
4.3	Superheater 3 design mode input file	44
4.3.1	Format and type of data for the input file	44
4.3.2	Discussion on design input data and simplifications	49
4.4	Discussion of superheater 3 design results	50
4.4.1	Comparison of PEPSE computer results with actual performance results	50
4.5	Problem simulating and solving with the superheater 3 computer model	52
4.5.1	General	52
4.5.2	Simulation of tube fouling and results	53

5.	CONCLUSIONS	57
APPENDIX A	Short description on PEPSE* related component symbols	58
APPENDIX B	Heat exchanger pressure change calculations	64
APPENDIX C	Steinmüller reference Plant performance results	66
APPENDIX D	Performance model input file	72
APPENDIX E	Performance model output results	80
APPENDIX F	Design model input file	93
APPENDIX G	Design model output results	97

LIST OF FIGURES

FIGURE		PAGE
2.1	Change-of-state diagram for subcritical range	2
2.2	Cross section - once through boiler	4
2.3	Construction of the economiser	6
2.4	Parralel finned tubes and studded tube walls	7
2.5	Flow scheme for once through boiler	9
2.6	The de-superheater	10
2.7	Superheater construction	12
2.8	The rotary air heater	14
2.9	The primary air and fuel flow	15
2.10	The induced draught fan	16
2.11	Duvha power station flow diagram	17
3.1	The performance mode computer model flow chart	27
4.1	Computer flow chart - superheater 3	43
4.2	Convective stage nomenclature	44
4.3	The effect of fouling on outlet steam temperature	54
4.4	The effect of fouling on the heat transfer coefficient	54
4.5	The effect of fouling on the flue gas outlet temperature	55
4.6	The effect of fouling on the heat exchanger (superheater 3) efficiency	56

LIST OF TABLES

TABLE		PAGE
3.1	Computer flow chart related symbols and identification	28
3.2	Comparison of PEPSE* calculated Water/steam temperature output results with performance results	36
3.3	Comparison of PEPSE* calculated flue gas temperature output results to the Steinmüller performance results	37
3.4	Comparison of PEPSE* calculated tube (waterside) pressure drops with the Steinmüller performance results	40
4.1	Convective stage input design data description	45
4.2	The effect of fouling on superheater 3	53
C.1	Steinmüller reference plant performance results	67
E.1	Component properties	81
E.2	Heat exchanger performance output	89
E.3	Second law of thermodynamics performance - components	90
E.4	Detailed furnace/combustor performance output	92
G.1	Component properties	98
G.2	Detailed heat exchanger performance output	98
G.3	Detailed heat exchanger design output	99
G.4	Second law of thermodynamics performance - components	99

LIST OF SYMBOLS

PEPSE ELEMENT - PORT RELATED SYMBOLS

QUANTITY	SYMBOL
1. HEAT EXCHANGERS	
Tube side water inlet	S
Tube side water outlet	D
Shell side inlet and outlet	T
Heat input by furnace	Q
2. SOURCES AND SINKS	
Fluid input port	I
Fluid outlet port	U
3. MIXERS	
Main inlet port for fluid	IA
Secondary inlet port for fluid	IB
Total "mixed" fluid	U
4. FLOW SPLITTERS	
Incoming fluid port	I
Secondary outlet port	U
Bleed or primary outlet port	B
5. FURNACE COMBUSTOR	
Air inlet port	IA
Fuel inlet port	If
Refuse or bleed port	B
Flue gas outlet port	U

1. INTRODUCTION

The purpose of this research project is to investigate the possibility into constructing a useful Duvha Boiler Performance Computer Programme, using the PEPSE* computer software.

This knowledge is needed in the prediction of certain off-design manipulations on the boiler's performance behaviour, thus cutting the time of physically changing these input parameters on the actual boiler, a venture which might prove both catastrophic and expensive.

The computer performance input data like pressure, temperature and mass flow is obtained from the manufacturer's (Steinmüller) schedules and acceptance tests. The complete design mode programme for this boiler proved to be too lengthy and time consuming for inclusion in this undertaking and might form the basis for further research in this field. For that reason only superheater 3 is modelled in design mode to act as an example of what the latter statement involves.

A literature survey, including use of the international data base system, proved to be unsuccessful in the context of this project, thus references on input data and text is limited to Steinmüller schedules, PEPSE software manuals, as-is plant performance and design data.

2. DUVHA BOILER DESCRIPTION

The following chapter covers the boiler layout, water/steam flow cycle, air flow cycle and general information on the Duvha Power Station boiler.

2.1 General

The Duvha steam generator is a once through Benson type boiler, arranged for opposed pulverized fuel firing.

In the Benson mode, the feedwater (i.e. main water supply to the boiler) makes one fast uninterrupted circuit through the boiler's tube system. On its path through the boiler the feedwater absorbs heat from the combustion zone, which changes the state of the feedwater from liquid into vapour and then from vapour into superheated steam, as is illustrated in figure 2.1.

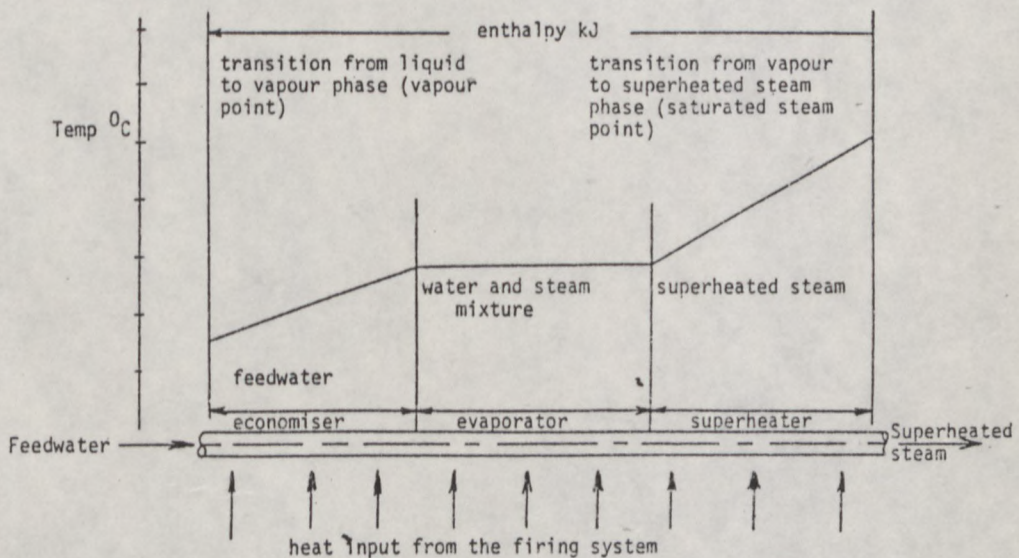


FIGURE 2.1 Change-of-state diagram for subcritical range

The Benson type of boiler depends on forced circulation through the tube system and includes no steam drum as in most of the other steam generators. At loads below 45 % of the maximum continuous rating of the boiler (especially during start-up and shut-down), the circulation system comes into operation to ensure adequate cooling of economizer and evaporator tubes. This is generally known as the non-Benson mode of operation.

The water is now circulated via the economizer, division wall tubes and the collecting vessel. At this point the circulation pump removes the water from the collecting vessel, where upon the water is returned to the feedline and thence to the economiser as is illustrated in Figure 2.5.

In the non-Benson mode there is no circulation of vapour through the superheater section of the boiler.

2.2 Boiler layout and construction (see Figure 2.2)

The once through Duvha boiler can be subdivided in three main steam heat transfer regions namely the economiser, evaporator and superheater. For clarity, every region is discussed separately below.

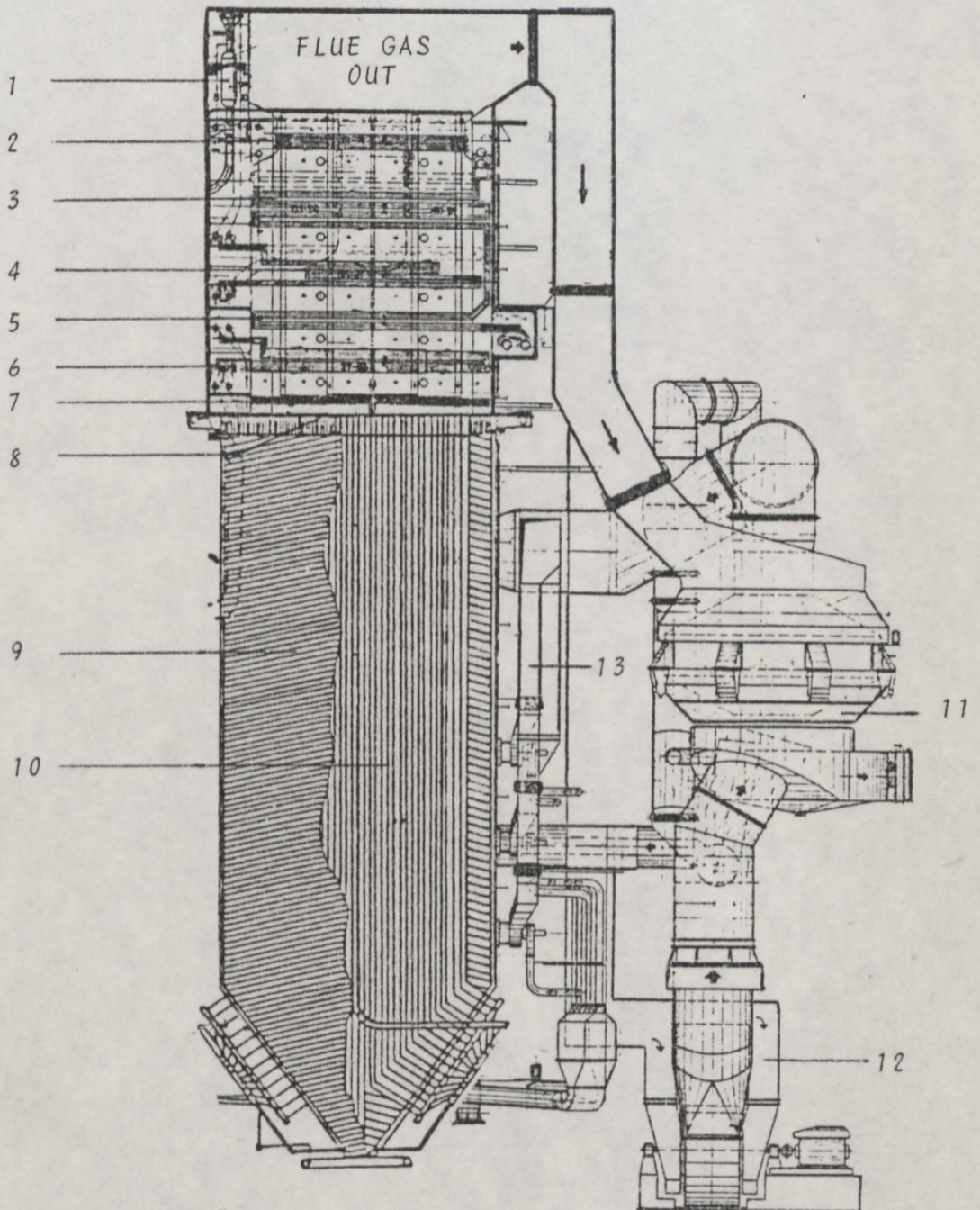


Figure 2.2 Cross section - once through boiler

Figure 2.2. Key

1. Seperation vessel
2. Economizer
3. Reheater 1 (Cold)
4. Superheater 2
5. Reheater 2 (Hot)
6. Superheater 4
7. Superheater 3
8. Superheater 1
9. Screw wall
10. Division wall
11. Air heater
12. Force draft fan
13. Burner piping

2.2.1 Economiser

This element is located at statically the highest level in the steam generator, thus coming in contact with the "coldest" flue gasses before the latter leaves the boiler. The economiser can also be considered as a type of feedwater heater.

The 160 parallel finned tubes are arranged in such a manner that the water passes through the element in a counterflow direction to flue gas i.e. top to bottom. The economiser tubes starts and terminates in separate common headers which doubles as mixing vessels.

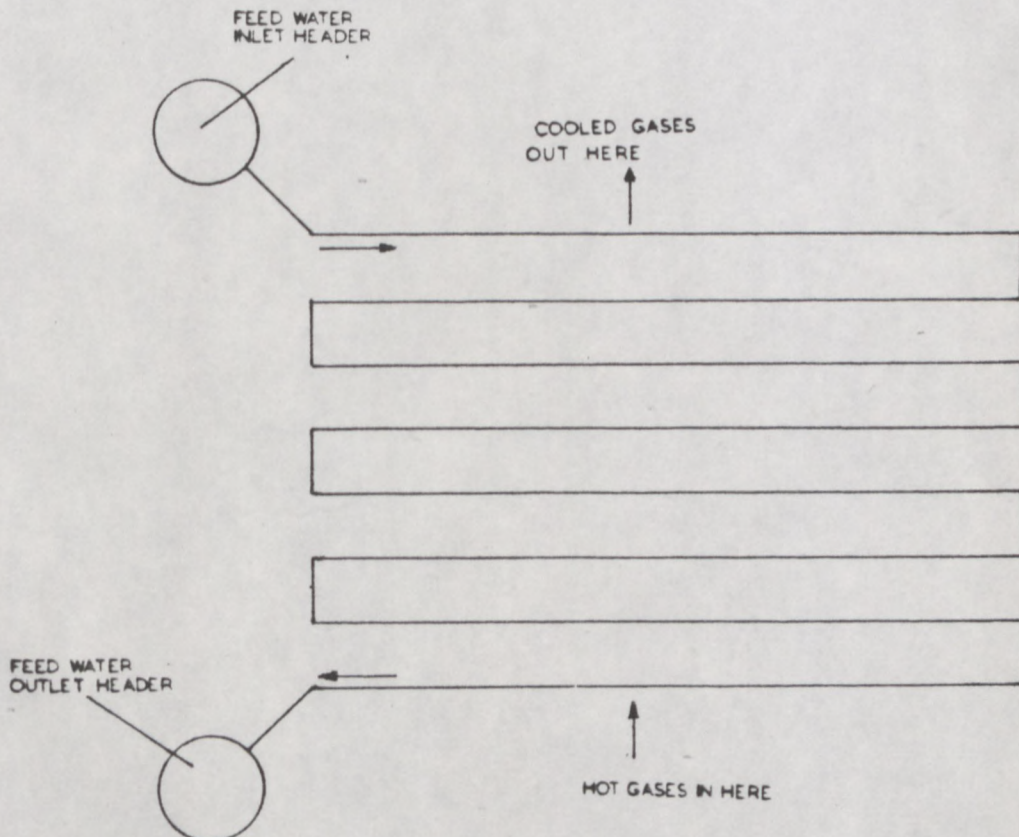


Figure 2.3 Construction of the economiser

2.2.2 Evaporator

The evaporator consists of the division wall and the furnace screw and straight walls.

The division wall splits the furnace and the space accommodating the convection banks into two parallel sections on the gas side. The parallel finned tubes (see figure 2.4) which form the division wall terminate in two axial inlet headers, also acting as mixing vessels. The water mixture in the tubes flow in a co-flow direction (ie bottom to top) to the flue gas.

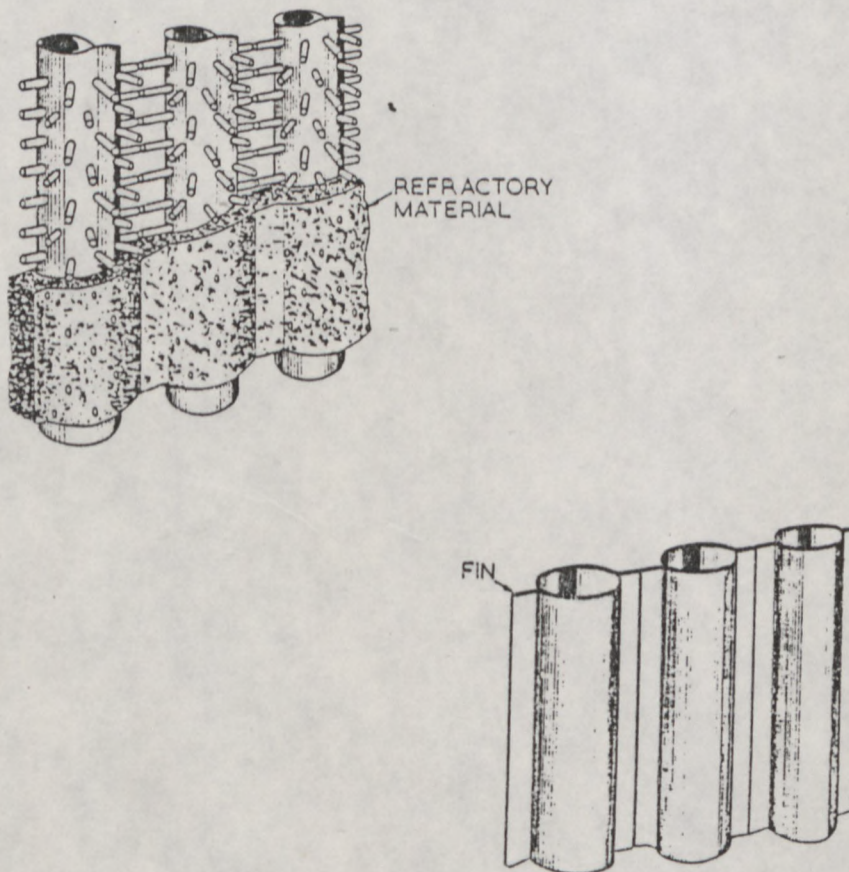


Figure 2.4 Parallel finned tubes and studded tube walls

The furnace walls form a gastight enclosure around the boiler heat transfer surfaces. The walls can be split in two sections namely the furnace screw walls, which form the radiant zone, and the straight walls which are the convection parts. The latter also forms the top part of the boiler enclosure. The flow of water is in the same direction as flue gas and the tubes terminate in four outlet headers at the top of the boiler.

The steam in this part of the boiler is usually wet, reaching saturation point in the top half of the boiler enclosure walls.

2.2.3 Superheaters

This boiler consists of four superheaters which are arranged in a specific configuration as can be seen from figure 2.2.

Superheaters 1 and 2 are arranged in counter-flow and 3 and 4 in co-flow direction (ie steam side flow direction to flue gas side flow direction).

Superheater 1 consists of a radiant part and a convective part as can be seen from its location in the boiler section (figure 2.2). Superheaters 2, 3 and 4 are convection elements, receiving the bulk of their heat from convection, because these elements are "shadowed" from the direct flames.

2.3 Water/steam flow cycle

The water/steam cycle can be sub-divided into three distinctive circuits ie the high pressure circuit, which is the main water/steam route, the reheater circuit and a secondary circuit which consist of the circulation system (refer to discussion in Section 2.1). See figure 2.5 for the flow scheme.

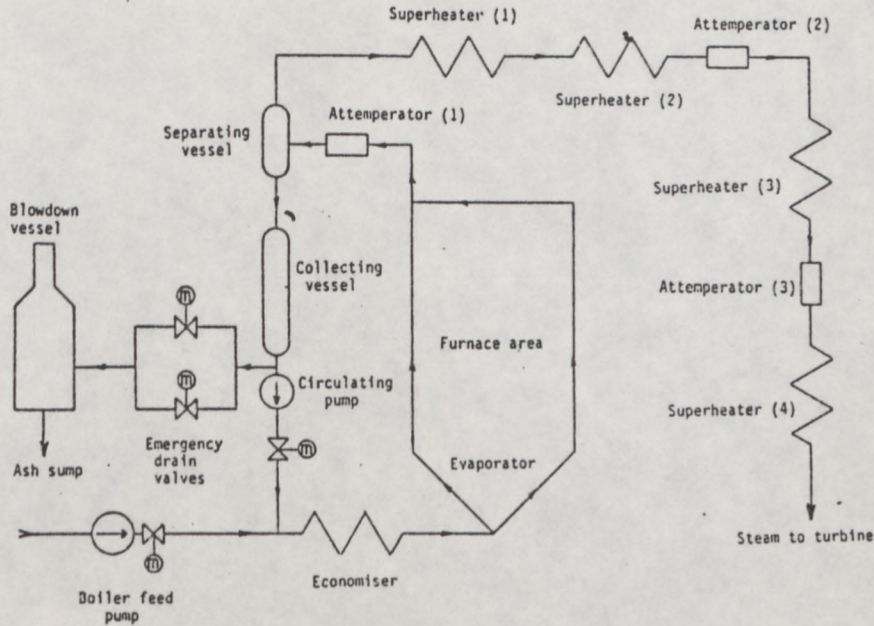


Figure 2.5 Flow scheme for once through boiler

2.3.1 High pressure circuit

The once-through system is a single line from the economiser to the separators from where it follows a four line pattern from superheater 1 inlet to superheater 4 outlet.

The main storage area of feedwater is the feedwater tank from where the water goes through either the feed pumps or the electric feed pumps after which it is heated up by the high pressure heaters. At this point the feedwater is ready for use in the boiler, which it enters through the economiser. The water now absorbs heat by passing through the economiser in a counter flow direction. The heated water from the economiser is then taken via a downcomer to a distributor system upstream (below) of the furnace floor.

The water is then distributed by two headers into the furnace division wall, where the water flow is parallel to the flue gas, ie from the bottom to top of the boiler. The water leaving the division wall is taken to the lower part of the boiler via a downcomer where it is distributed into a ring header. Said ring header delivers the water evenly among the front and rear walls. Onward flow is to the radiant part of the furnace, which is arranged in a helical pattern for heat distribution purposes. The water now flows into the furnace straight walls after collection in four mixing headers. The vertical walls terminate in four headers at the top of the boiler.

Flow is now taken past two downstream spray attemperators "1" (de-superheaters) (See figure 2.5) from where it follows a four line pattern into the moisture separators where water and steam is split into two separate circuits.

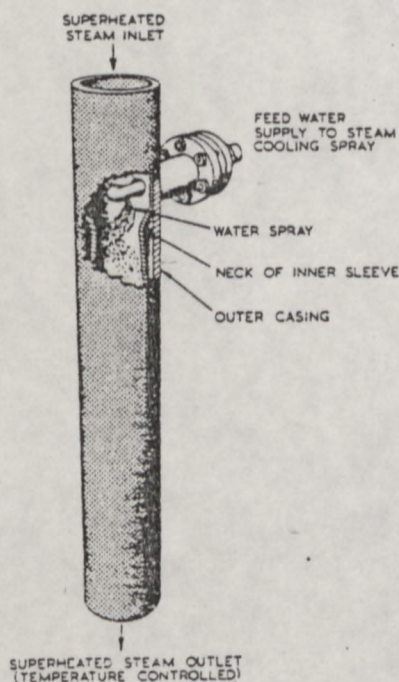


Figure 2.6 The de-superheater

In the Benson mode of operation the abovementioned separators act as mixing vessels and in conjunction with the downstream collecting vessel assumes the function of a drum while the system is on circulation (below 45 % MCR). This warrants a good temperature balance - an important criterion for uniform temperature conditions in the following four superheater lines.

Steam leaving the four separators and collecting vessel is taken via a four line system to the superheater 1 inlet.

The superheater consists of four in line banks, with superheaters 1 and 2 arranged in counterflow while superheaters 3 and 4 is arranged in co-flow to the flue gases. (See figure 2.7 for superheater construction)

From superheater 1 outlet header the flow is taken by four connecting pipes to superheater 2 inlet header. From superheater 2 outlet header the flow is taken past four spray attemperators "2" to the inlet headers of superheater 3 and then through the heating tubes of superheater 3. On leaving superheater 3 flow is taken past four spray attemperators "3" and is then taken directly into the heating tubes of Superheater 4. The exit flow from superheater 4 is collected in a common header from where it splits in a four line system to reach the high pressure part of the turbine.

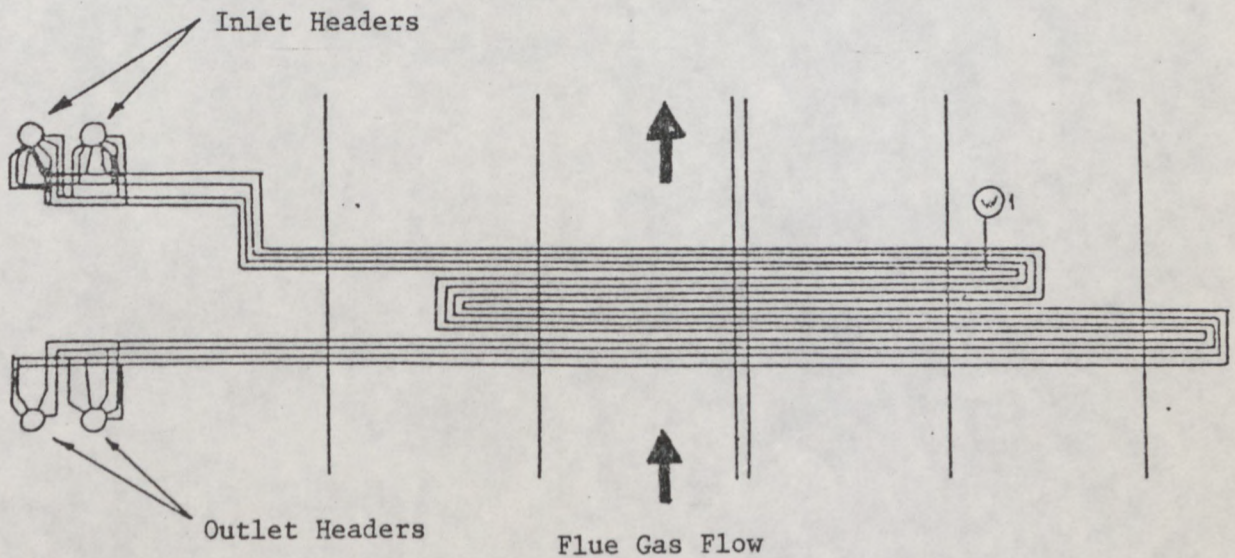


Figure 2.7 Superheater construction

2.3.2 Reheating section

Steam flow through the reheater is opposite (counterflow) to the direction of the flue gas flow.

The steam returning from the high pressure cylinder of the turbine enters the reheater inlet header where the flow is distributed among the parallel reheater coils and is collected in the outlet header.

The steam flow from reheater 1 outlet header leaves the system via a two line system passing four spray attemperators on its way to the reheater 2 inlet header. The steam leaving reheater 2 is taken via a four line system to the intermediate pressure cylinder of the turbine.

The steam entering reheater 1 is called cold reheat and the steam leaving the reheater 2 outlet header, hot reheat.

2.4 Air flow cycle

The total air flow to the boiler consists of two main streams namely the primary air and the secondary air and a combination stream called flue gas.

2.4.1 Secondary air

The secondary air is also commonly called the combustion air. The latter is drawn from a location at the boiler top by two forced draught (FD) fans, from where it is passed through the rotary air heaters, (See Figure 2.8) absorbing the desired heat on contact with the hot plates of the rotating part of the air heater.

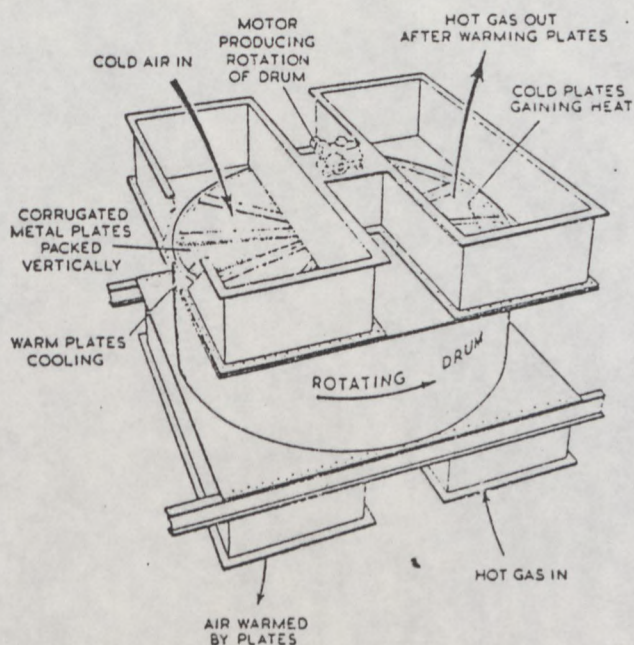


Figure 2.8 The rotary air heater

The hot secondary air is then supplied to each burner separately through a hot air-ring duct, whereafter it combines with the pulverised fuel in a combustion process.

2.4.2 Primary air

Primary air (also called transport air) is branched off the main air flow, down stream (after) of the forced draught fans, but before the air heaters (see figure 2.11). The primary air is then pressure-boosted across two primary air fans and delivered separate of the secondary air through the air heaters where the desired temperature increase is aquired.

The hot primary air is now delivered to the mill hot air duct. The primary air has two main functions, namely to dry the surface moisture of the coal and secondly to transport the fine coal to the burner nozzle. The combination of fine coal and primary air is commonly called pulverised fuel. Figure 2.9 illustrates the flow of the primary air and the fuel.

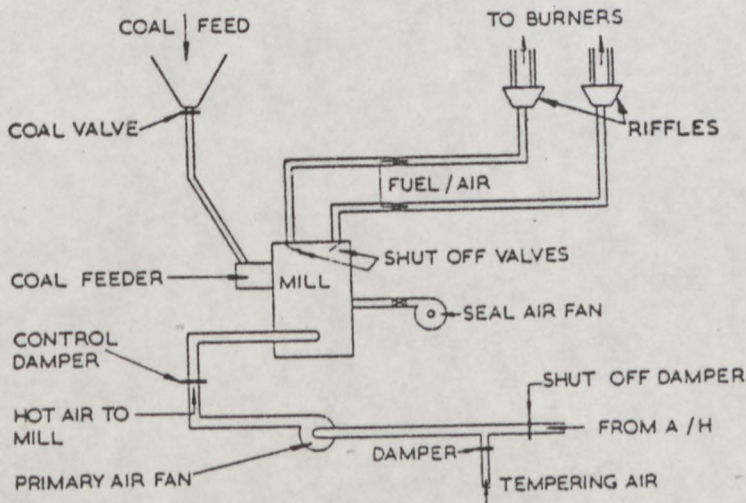


Figure 2.9 The primary air and fuel flow

2.4.3 Flue gas

The flue gas produced in the combustion process in the furnace, releases heat on contact with the boiler heating surfaces, thus becoming colder up through to the economiser level. The flue gas is then taken via a blank pass to the two air heaters, where the latter element heats up the secondary and primary air, giving up some heat in the process.

The flue gas is extracted by two induced draft fans (See Figure 2.10) to give the desired flue gas flow through the precipitator and flue stack (chimney).

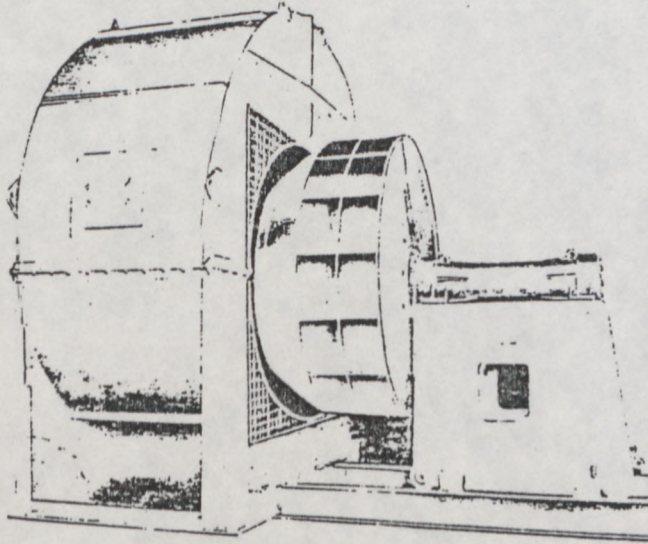


Figure 2.10 The induced draught fan

2.5 Summary diagram of fuel, air and water/steam flow

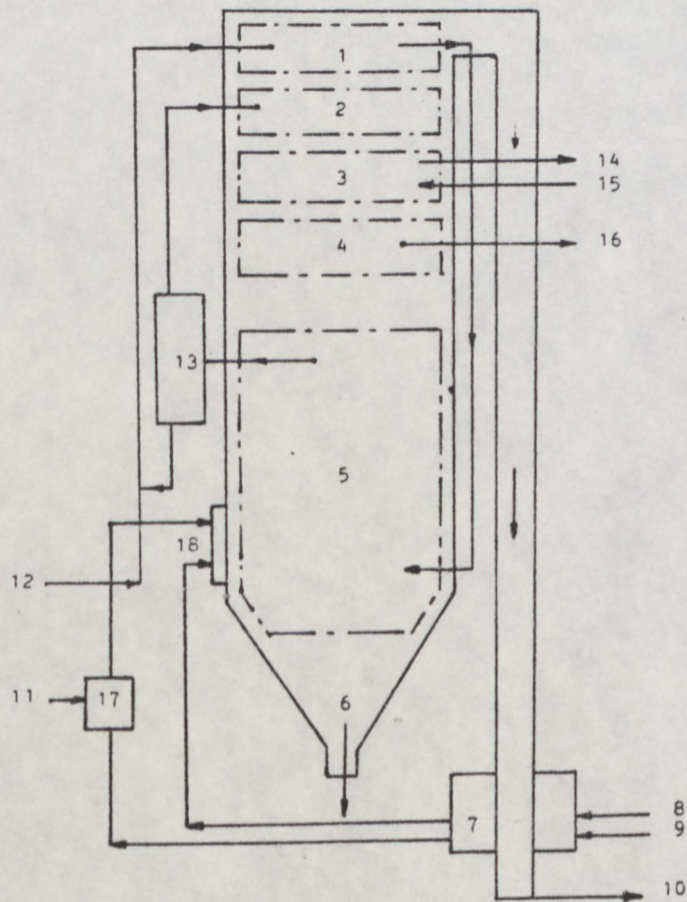


Figure 2.11 Duvha power station flow diagram

Key (Figure 2.11)

1. Boiler economizer
2. Superheater
3. Reheater
4. Superheater 1
5. Boiler combustion chamber
6. Ash disposal
7. Regenerating air heater
8. From force draft fan
9. From primary air fan
10. To precipitator
11. From coal bunker
12. Water from HP heaters
13. Separator vessel
14. From IP turbine
15. From HP turbine
16. To HP turbine
17. Tube mill
18. Boiler burners

3. THE PERFORMANCE COMPUTER MODEL OF THE DUVHA BOILER USING PEPSE SOFTWARE

3.1 The software - PEPSE

In this section an overall picture of the scope of the PEPSE software is given. It will be discussed in general, the performance mode, the design mode and a short description on the solution scheme. It is not the object of this section to describe the software in detail, only to give the reader a "feel" for the complexity of PEPSE.

3.1.1 General remarks

PEPSE stands for : Performance Evaluation Power Systems Efficiencies and is a product of Energy Incorporated of the USA. The PEPSE code is a computer programme to analyse thermodynamic cycles and is built up from independent modules. A module may represent for instance a superheater, which can be considered as a "black box" with certain parameters fixed and some set by the user.

The uses of PEPSE can be numerous and as a computational tool this programme can be used for the following operations:

- *Assessment of the performance of a plant and the isolation of controllable parameters which can affect performance (optimisation studies).

- *Study of off-design hydraulic or equipment conditions and evaluation of the impact on efficiency (sensitivity studies).

- *Determination of plant cycle heat rates for fossil-fired units as a design tool (power plant design).

The user is required to model a cycle in sufficient detail to obtain the desired accuracy, complexity and flexibility. The user can manipulate modules and define relations between them. The code also provides the user with the facility to build his own modules (write "software" into the software) and intergrate these modules into the system.

The solution principle of the PEPSE programme is based on the first law of thermodynamics (steady state condition), mainly using an itterative procedure. The model supplies the user with first and second law (entropy balance) thermodynamic analysis of each individual model, sub-systems and the total system. The second law analysis gives valuable information as to how the available energy transforms into unavailable energy.

3.1.2 Modes of operation - design and performance

PEPSE provides two modes of operation in the form of user input and calculational format, namely performance mode and design mode. In the design mode, the user may wish to design a plant theoretically, or investigate the effects of plant modifications. In this mode it is assumed that the analyst has information available describing the mechanical features of the system (ie pipe diameters, elevations, heater designs, etc). Output from the design mode provides detailed thermal design analyses of various plant components.

The performance mode assumes that the analyst is concerned with the performance of the operating power plant in a search for lost plant output, malfunctioning hardware, or the effects of plant modifications.

A few mechanical descriptions of components are required, but the emphasis is placed on measured quantities (pressures, mass flows and temperatures) associated with each type of component.

In addition, the code may be operated by combining the design and performance modes as specified by individual input cards (the following boiler program is an example). Here the user may wish to supplement design information with performance test data when test data are incomplete or minimal. The code uses, for the most part, the design information, but updates the results based on test data where such test data are available.

To characterise the steady-state behaviour of a cycle, PEPSE models the physical hardware as a network of "components" interconnected by "streams". Streams are used to model lengths of piping, or act as connections between components in a model.

3.1.3 Solution scheme

Fundamentally, the way in which a building block's behaviour is solved is by application of the basic principles of conservation of mass and energy together with equations for pressure changes and heat transfer effects. The basic principle of conservation of energy is the first law of thermodynamics for a steady flow process in the absence of magnetic and electrical effects.

$$\left[\left(h + \frac{V^2}{2} + z \right) w \right]_{1-z} = Q - W_s$$

where

h = fluid enthalpy

V = fluid velocity

z = elevation

w = mass flow rate

Q = rate of net heat added in the process

W_s = rate of shaft work produced by the process

The terms

$$\frac{V^2}{2} \text{ and } z$$

account for the kinetic and potential energies, respectively, of the flowing stream. Within PEPSE, these two terms are often ignored.

Solving for the behaviour of any building block requires a knowledge of the boundary conditions of the block, as well as a description of the block itself. For most blocks, knowledge of the boundary conditions means that the flows and the thermodynamic state at the inlet(s) to the block must be known in order for the output(s) from the block to be calculated. This requirement places a constraint on the order in which the blocks of a system can be solved. The solution approach taken by PEPSE, then, is to proceed through the user's specified model solving blocks one at a time as the boundary condition information required for solution becomes available. Because system interconnections can be complex and because solutions of some blocks require knowledge of downstream boundary conditions, analysis of some systems requires special treatment to proceed past computational impasses.

The details of these special treatments are inappropriate for discussion in this section. However, frequently the boundary conditions must initially be guessed and such guessing leads to an iterative solution of the system as a whole and of some subsystems as well.

The internal ordering of components and streams for calculational resolution proceeds, for the most part, from the highest thermodynamic state to the lowest. This ordering proceeds from the cycle inlet to the outlet.

Convergence of the iteration process occurs when the energy imbalance on any component or stream is less than or equal to 2.93×10^{-1} kW, or to a value set by the user. An additional convergence restriction is that the entire system mass flow imbalance be less than some user-specified value (defaults to 1.25998×10^{-4} kg/sec). For most problems, convergence occurs within 20 iterations.

3.2 Simplifications and assumptions on practical boiler cycle

It is obvious that in a complex arrangement of components, like a boiler, that certain simplifications and assumptions must be incorporated to be able to keep close control over simulation complexity.

The air and water/steam flow cycles as it is adapted for PEPSE Modelling of the Duvha boiler is covered in this section.

3.2.1 The air flow cycle

3.2.1.1 The rotary air heaters

The Duvha boiler's secondary and primary air supply is preheated by two rotary regenerative air pre-heaters which attain it's heat supply from the flue gas exiting from the top of the boiler.

Several simplifications are made to the air heater configuration in order to adapt it to PEPSE modelling specifications. The first assumption made was to combine the two air heaters to act as one double-capacity air heater, thus taking the total air at inlet and the total flue gas at the top of the boiler into account. Because the secondary air and primary air are flowing in concentric pipes through the air heaters, a further problem was encountered in that the PEPSE input format permits only one air input and one air output. In order to overcome this problem it was decided to split the abovementioned "combined" air heater into two air heaters namely a secondary air heater and a primary air heater. In doing so a heat transfer imbalance was encountered on the flue gas side of either air heater. This occurrence called for splitting of the flue gas in a ratio of 0.82 : 0.18, Secondary Air : Primary Air (based on heat transfer area) PA which restored the mass balance and produced the correct amount of heat transfer.

3.2.1.2 Primary air and furnace - combustor

In the practical cycle the primary air is used to transport the pulverized fuel (fine coal) and to dry the surface moisture off the "wet" coal. Limitations in PEPSE however only permit a separate input of air and fuel, thus primary air plus fuel (called pulverized fuel) had to be separated and the primary air and secondary air combined as one input (Port IA) for the furnace combustor.

Another problem on the primary air side is the fact that the latter, on its way to the furnace combustor, gives up a considerable amount of heat, especially in the mills. This heat loss is accounted for by installing a "fake" heat exchanger in the primary air line, before the primary and secondary air mix again.

3.2.2 Water/steam flow cycle

The Duvha boiler is a once-through design, thus water makes one uninterrupted cycle through the different heat stages, be it radiant or convective.

The biggest problem in modelling the water/steam side of the Duvha boiler was the lack of performance data for the furnace walls, the division wall and to a lesser extent, the economizer.

The construction side presented a few major problems in the conversion and adaption for PEPSE modelling. When one looks at the physical layout of the Duvha boiler it can be seen that, if a horizontal section is taken at any level between the 58 m and 81,25 m, four heat transfer elements are exposed, namely : The main element (eg a superheater), the vertical water walls, division wall and the hanger tubes.

To model each horizontal section through the boiler with four heat transfer elements would have been virtually impossible because of the lack of performance input data and the modelling complexity involved. The logical alternative was then to take the division wall and the furnace enclosure walls respectively as a radiant part and a convective part, for heat transfer purposes.

The location of the superheater 1 inside the boiler is such that the bottom part is located in the radiant region and the top part in the convective region. The hangers, which are water filled, are taken as a simplification as an integral part of the superheater 1.

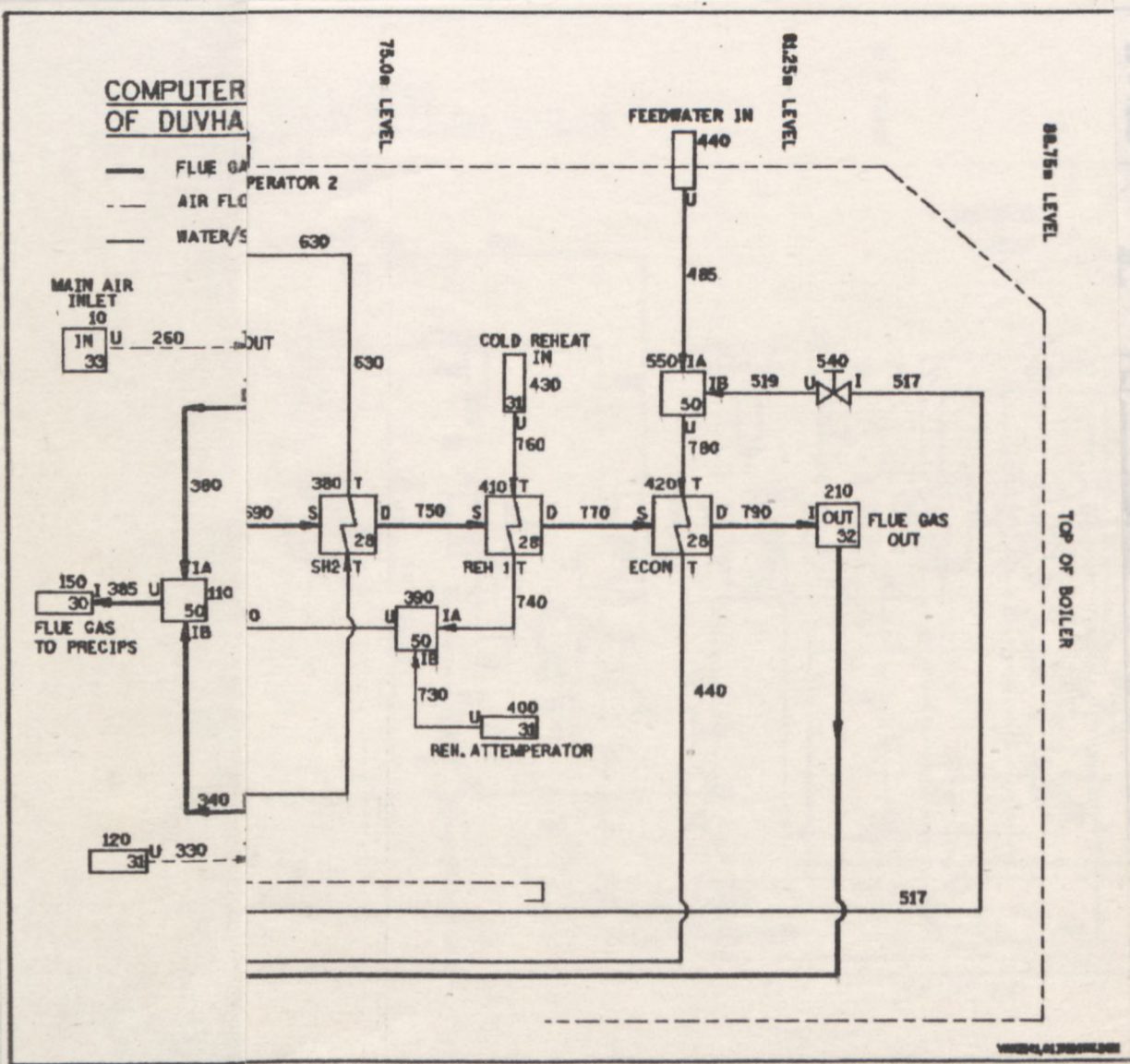
(See Figure 2.2 for more clarity on location of the different radiant and convective elements).

In order to cut down on modelling complexity the four moisture separators are combined as one element and the recirculating pump deleted. This is done because at 100% MCR (Maximum Continuous Rating), the recirculating system is not in operation as there is no water and steam to separate. (Superheated region).

The spray attemperators on the superheater and reheater steam lines are included in the model as combination elements. (ie combining the water flow of the attemperators in one location).

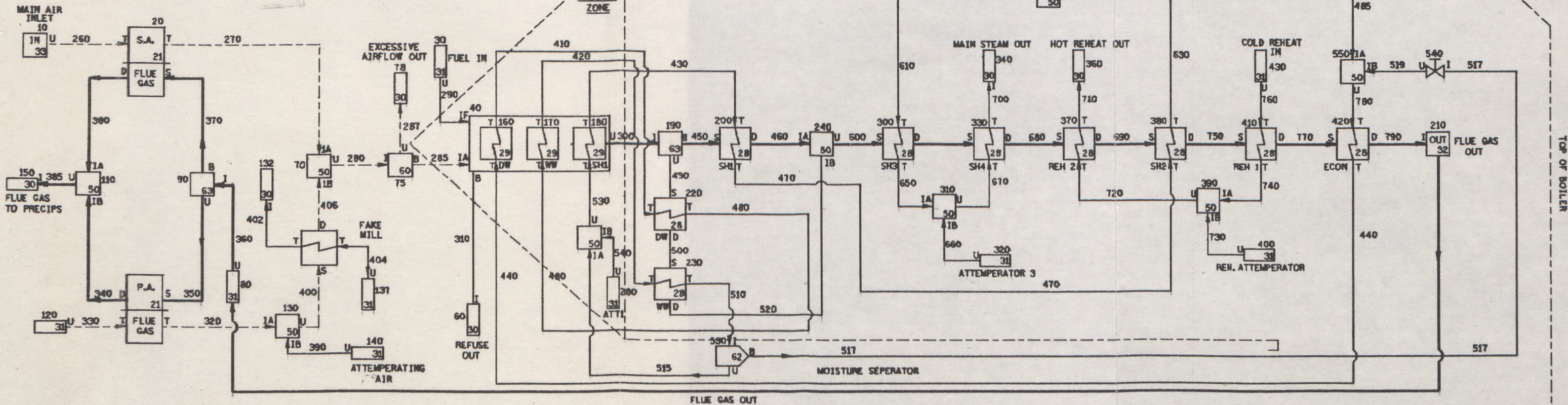
3.3 The Duvha boiler computer flow chart

(For port symbols see page viii)



COMPUTER FLOW CHART OF DUVHA POWER STATION BOILER

- FLUE GAS FLOW
- - - AIR FLOW
- WATER/STEAM FLOW



Read the preceeding flow chart in conjunction with the list of symbols and Table 3.1

TABLE 3.1

Computer flow chart related symbols and identification

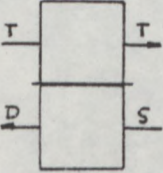
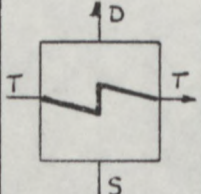
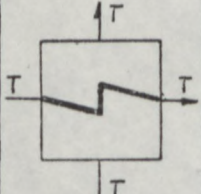
SYMBOL	TYPE PEPSE	ELEMENT OF THIS TYPE	UNIQUE NO ON CHART FLOW	CLASS
 AIR HEATER	21	S A Heater, P A Heater	20 100	I
 CONVECTIVE STAGE	28	Superheater 1 Superheater 2 Superheater 3 Superheater 4 Division wall Straight walls Reheater 1 Reheater 2 Economiser	200 380 300 330 220 230 410 370 420	II
 RADIANT STAGE	28	Superheater 1 Screw water walls Division wall	180 170 160	III

Table 3.1 (cont.)

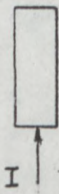
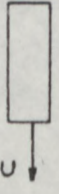
	30	Hot reheat	360	IV		
		Main steam	340			
		Refuse port	60			
		Flue gas	150			
		Excess air	78			
SINK OUTLETS						
	31	Primary air inlet	120	II		
		Flue gas source	80			
		Attemperating air	140			
		Fuel inlet	30			
		Attemperator 1 inlet	280			
		Attemperator inlet	500			
		Attemperator 3 inlet	320			
		Attemperator for reheater	400			
		Cold reheat	430			
		Feedwater inlet	440			
		SOURCE IN				

Table 3.1 (cont.)

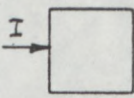
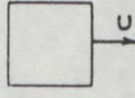
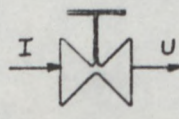
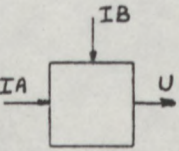
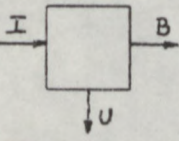
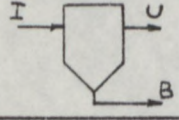
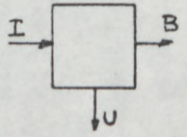
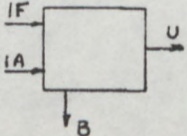
 OUTPUT	32	Flue gas outlet	210	VI
 INPUT	33	Secondary air inlet	10	VII
 VALVE	34	Circulating system stop valve	540	VIII
 MIXER	50	Flue gas	110	X
		Circulating system	550	
		Steam mixing	240	
		Attemperator 1	270	
		Attemperator 2	350	
		Attemperator 3	310	
		Reheat attemperator	390	
 DEMAND SPLITTER	60	Excess air	5	IX
	62	Moisture separator	530	XI

Table 3.1 (cont.)

 FIXED PERCENT SPLITTER	63	Flue gas for air heater Flue gas for convective stages	9 190	XII
 FURNACE COMBUSTOR	70	Furnace combustor (Bottom part of boiler)	40	XIII

3.4 Boiler flow chart description

To make it easier for the reader, a brief description of the flow logic of the flow chart is given below. The air and Water/Steam flow cycles are discussed separately. The numbers in brackets in the text are the user defined unique designation of the different components on the flow chart and also correspond with the numbers in Table 3.1.

3.4.1 Air flow cycle

For reasons mentioned in the previous section the incoming air flow is split through two different air heaters. The secondary air enters the system at the main air inlet (10), from where it follows an air duct (260) to the secondary air heater, (20) to attain the desired increase in heat. From the secondary air heater the hot secondary air flows through a duct (270), to be combined with primary air in an air mixer (70).

The primary air is introduced into the system through a source (120) from where it flows through a duct (330) to the primary air heater (100) where it is heated by the flue gas. The hot primary air is transported through a duct (320) to the mill (135), where it performs the two functions as discussed before. The primary air is cooled, along the way, by an attemperator (130). After the mill, the secondary air and primary air are mixed to form the combined combustion air, which is transported through a duct (280, 285) to the furnace combustor (40).

The fuel (30) flows through a pipe (290) to the furnace combustor (40), to combine with the total air in a stoichiometric process, producing the desired heat of combustion.

3.4.2 Flue gas flow

Flue gas produced in the combustion process gives up heat in the radiation zone (40) and in the convection zone, before being utilised in the air heaters (20, 100).

In the radiation zone (40), heat is transferred to the division wall (160), screw walls (170) and the superheater 1 (180), after which the flue gas is available for the heat transfer process in the convection zone (Port U, Element 40). A refuse outlet (Port B, Element 40) is present, for ash disposal purposes.

The flue gas exiting from the furnace combustor (40) is split (Element 190) into two streams, one (450) for the primary heat transfer components and a second (490) for the secondary heat transfer elements. On the secondary element circuit the flue gas flow is from the division wall (220) to the water walls (230) (Sequence 490, 500 and 520), where after it joins the main flue gas stream through a mixer (Element 240).

On the primary circuit the flue gas flow is from superheater 1 (200) to superheater 3 (300), superheater 4 (330), on to reheater 2 (370), superheater 2 (380), reheater 1 (410) and then the economizer (420), from where the flue gas leaves the furnace (210) on its way to the air heaters (flue gas sequence - streams 450, 460, 600, 640, 680, 690, 750, 770 and 790).

The air-heater-flue-gas-source (80) introduces the heating medium to the two air heaters (Streams 370, 350). The "cold" flue gas is combined after the air heater in a mixer (110), before it is transported to the precipitators.

3.4.3 The water/steam flow

The water/steam flow cycle, like the flue gas cycle, consists of a primary and a secondary system (The latter used only for loads under 45% of maximum continuous rating, as discussed in a previous section).

The primary system inlet (440) is taken downstream of the feedwater heaters, from where the water flows through the economizer (420), division wall (160, 220), water walls (170, 230), superheater 1 (180, 200), superheater 2 (380), superheater 3 (300), superheater 4 (330) and then out as main steam to the HP turbine (element 340) (stream sequence - 485, 780, 440, 410, 480, 420, 510, 515, 530, 430, 470, 630, 610, 650, 670 and 760).

There are three superheater attemperators (270, 360, 310) situated in the main water/steam line, acting as injection vessels for attemperating (cooling) steam.

The reheating system is part of the primary system. The cold reheat inlet (430) is taken from the high pressure turbine outlet, via a piping system (710) to the reheater 1 (410), after which it passes an attemperator (390), before the water/steam mixture is introduced into the reheater 2 (370). Through a piping system (710), the hot reheat (360) returns to the intermediate pressure part of the turbine.

The secondary flow system, as discussed before, is only used at low - loads, thus in the context of this model the latter system is not in use.

After the water wall (230), the water/steam mixture is taken through a piping system (510) to a moisture separator (530), the function of which is to separate water (Stream 517) and steam (Stream 515). The water being introduced through a valve (540) and a mixer (550) into the primary water system (780), downstream of the economizer (420). The steam is taken via a piping system (515) to superheater 1 (180) to join up with the main steam stream.

3.5 The performance mode input file (See Appendix D)

As was stated in section 3.1.2, the performance mode model comprises of data derived from the manufacturer's heat balance diagrams and performance tests.

It is possible to input a large amount of thermodynamic data to fix the thermodynamic conditions of the required data points. The input data into the performance programme comprises only of temperatures, pressures, pressure drop curves, mass flows and some component's inlet and outlet elevations. This specific PEPSE boiler model is designed for use only under 100% load conditions. Thus the performance mode model must be seen as a step towards the development of the design mode model, the latter will be discussed in Chapter 4.

The details of the compilation of the input file require an in-depth study of the PEPSE software, and falls outside scope of this undertaking.

3.6 The performance mode output file

This file is structured by the PEPSE software for the feasibility of finding output results. See Appendix E for performance output tables.

The output tables included in this output listing are:

- Component properties (temperatures, pressures, mass flows, enthalpy, entropy and specific volume).
- Detailed heat exchanger performance output (Heat dissipated, pressure drops, heat exchanger efficiency).
- Detailed mixer performance data (pressures).
- Detailed furnace combustor output data (Excess air, flame temperature, energy in, energy out and net heat to radiant stages).
- Second law of thermodynamics performance (Availability accounting, irreversability).

3.6.1 Discussion of results *

The following discussion is based on a comparison between PEPSE* calculated results and Steinmüller performance results (See Appendix C for Steinmüller performance data). The aspects involved in this discussion concern the comparison of water/steam temperatures, flue gas temperatures and pressure drops over the various boiler elements.

* Based on the first law of Thermodynamics

TABLE 3.2

Comparison of PEPSE calculated water/steam temperature output results with performance results

WATER/STEAM TEMPERATURES				
COMPONENT	PEPSE* (SEE APPENDIX E)		PERFORMANCE	
	INPUT (T) (°C)	OUTPUT (T) (°C)	INLET (°C)	OUTLET (°C)
ECONOMIZER	256.446	333.0	246.00	333.0
DIVISION (RAD)*	333.0	362.0	-	-
(CON)*	362.0	365.0	-	-
WATERWALLS (RAD)*	365.0	365.0	-	-
(CON)*	364.0	362.0	-	409.0
SH 1 (RAD)*	362.761	403.0	403.0	-
SH 1 (CON)*	403.0	423.0	-	423.0
SUPERHEATER 2	423.0	455.0	423.0	455.0
ATTEMPERATORS 2	455.0	436.53	455.0	435.0
SUPERHEATER 3	436.0	498.00	435.0	498.0
ATTEMPERATORS 3	498.0	479.435	498.0	472.0
SUPERHEATER 4	479.435	540.00	472.0	540.0
REHEATER 1	332.0	476.00	332.0	476.0
ATTEMPERATORS	476.00	471.289	476.0	446.0
REHEATER 2	471.289	540.00	446.0	540.0

* RAD - Radiant part

* CON - Convective part

From the water/steam - comparison - Table 3.6 it is evident that there is a shortage of performance input data describing the division wall and furnace walls. This situation called for some guess work, which complicated the modelling aspect considerably, as there are no figures to verify the PEPSE results (results in this region may thus be inaccurate). Looking at the PEPSE calculated temperature results in this region, it can be seen that this is the transition region for water into water/steam, because the temperature stays constant at around 364 °C.

This fact can also be verified by looking at the performance mode output listing (Appendix E), where it can be seen that there is an increase in enthalpy and entropy while the temperature stays constant, a fact that strenghtens the above statement. The results in the superheater and reheater region are fairly accurate, as can be seen from Table 3.2.

TABLE 3.3 Comparison of PEPSE calculated flue gas temperature output results to the Steinmüller performance results

FLUE GAS TEMPERATURES				
COMPONENT	PEPSE (SEE APPENDIX E)		PERFORMANCE	
	INPUT (S)	OUTPUT (D)	INPUT	OUTPUT
FURNACE COMBUSTOR	-	1307.0	-	1300.0
SUPERHEATER 1	1307.0	753.905	1300	1230
SUPERHEATER 3	1156.0	1033.031	1230	1116.0
SUPERHEATER 4	1033.031	922.017	1116.0	1001.0

Table 3.3 (cont.)

REHEATER 2	922.017	837.96	1001.0	851.0
SUPERHEATER 2	837.959	756.178	851.0	720.0
REHEATER 1	756.178	580.28	720	517.0
ECONOMIZER	580.28	344.302	517.0	341.0

It is evident from the flue gas comparison Table 3.3 that there is quite a distinct deviation from the practical temperature results. This deviation can be accounted for by the following assumptions:

The boiler is divided in two main heat transfer regions, namely the radiant and convective zones. Some elements, as they appear in the physical layout, span the radiant and convective zone and had to be broken up in two heat transfer elements, for ease of modelling. Examples of these elements are the division wall, the furnace water walls and superheater 1.

In the case of the division wall and the water walls, the PEPSE results in the radiant zone of either element are fairly accurate. This is mainly because the radiant heat transfer elements are taken to reside inside the furnace combustor (No interconnecting streams between the radiant elements). The complete lower part of the furnace can thus be seen as a "box" with the latter elements residing within the boundaries.

The actual deviation in results, as can be seen from the comparison table, is in the convective heat transfer region. If a horizontal section is now taken through the boiler at any level between 58.0 meters and 81.25 meters, it can be seen that there are actually four heat transfer elements residing in this section ie. the main element (SH or RH), part of the division wall, part of the water wall and part of the downcomer. Because of the modelling complexity involved it was decided to model the division wall and water walls as a convective stage and radiant stage respectively, while the downcomers were included in the superheater 1 configuration. The above thus means that in the practical case there is a bigger effective heat transfer area per section as is the case with the model. The above mentioned is also evident from the comparison table on flue gas temperatures.

At first glance the above statement might seem like a contradiction, but looking at the computer flow chart, it will be observed that all the heat needed for the radiant water walls and division wall is split off from the flue gas upstream from the superheater 1 convective stage. This explains the fact the endpoint temperature on the latter element is so low, (753,905 °C, Table 3.3).

It will be noted however, that from superheater 1 level and upwards, the theoretical flue gas temperatures are higher than those of the Steinmüller performance figures. This phenomena can be clarified by the fact that the heat transfer effect of the division wall and water walls are very low in the upper region of the furnace, thus adding no significant drop in flue gas temperature.

When one however compares the PEPSE calculated furnace outlet temperature of 344.302 °C with the performance figure of 341.0 °C, bearing in mind the fact that this is the figure after the total heat transfer process has taken place through the furnace, it is realised that this is a very accurate figure. (0.96% Deviation from practice).

The abovementioned temperature deviation also verifies the correctness of the assumptions and simplifications made in the initial stages of "Building the Model".

TABLE 3.4 Comparison of PEPSE* calculated tube (waterside) pressure drops with the Steinmüller performance results

COMPONENTS	PEPSE (SEE APPENDIX E)	PERFORMANCE	
	PRESSURE DROPS [KPA]	PRESSURE DROPS [KPA]	% DEVIATION
DIVISION WALL (RAD)*	401.494	400.00	+ 0.37
WATER WALL (RAD)*	399.988	400.00	0
SUPERHEATER 1 (RAD)*	238.705	160.00	+49.19
SUPERHEATER 1 (CON)*	160.0	160.0	0
DIVISION WALL (CON)*	401.906	400.00	+ 0.47
WATER WALL (CON)*	303.007	300.00	+ 1.0

Table 3.4 (cont.)

SUPERHEATER 3	666.897	650.00	+ 2.59
SUPERHEATER 4	801.08	790.00	+ 1.4
REHEATER 2	162.458	120.0	+35.38
SUPERHEATER 2	290.00	290.00	0
REHEATER 1	120.0	120.0	0
ECONOMIZER	689.917	750.00	+ 8.01

*RAD - Radiant

*CON - Convective

It is evident from Table 3.8 that most of the pressure drops calculated by PEPSE*, with the exception of superheater 1 (radiant) and reheater 2, are very accurate.

The main reason for the deviation in pressure drop on superheater 1 is the lack of input data, as is the case with the reheater 2. All performance data on superheater 1 takes the latter as one physical element, which it actually is in practice, but for modelling purposes, it was split into a radiant and convective zone. This called for some guess work on the input and output side of either zone, which inevitably led to inaccurate pressure drops results.

For information on enthalpy, entropy, efficiencies and wetness fractions on the above elements, refer to the performance output.

4. THE DESIGN MODE MODEL OF SUPERHEATER 3

This chapter covers the superheater 3 design mode model input file, output file, (results) and a general discussion on the input data needed.

4.1 General

As mentioned before, a complete design mode programme for the Duvha boiler falls out the scope of this undertaking mainly because of the time factor and complexity involved.

To support the fact that a design mode boiler programme is possible, superheater 3 was chosen, and modelled in complete design mode, as is required by the PEPSE computer code. This element was chosen because it is, as a convective stage element, representative of the type of element which has the widest use in this specific boiler model.

The design input information for this model is found from the Steinmüller schedules and some design layout drawings of superheater 3.

4.2 The superheater 3 design mode flow chart

The following flow chart must seen as a part of the main flow chart in section 3.3 (component 50 below will correspond to component 300 on the main flow chart).

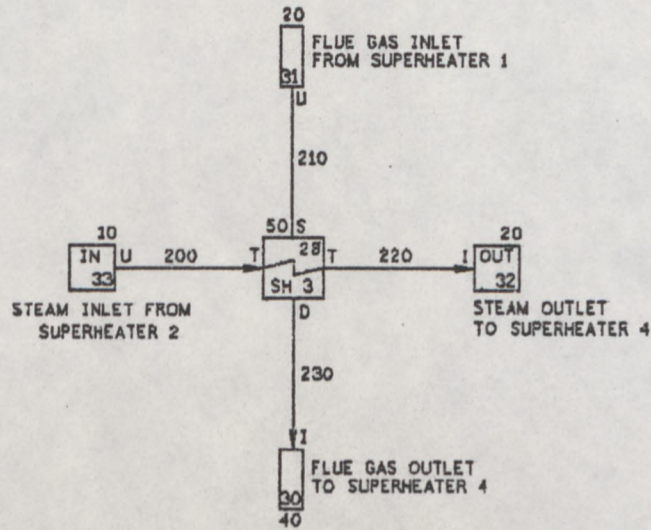


FIGURE 4.1 Computer flow chart superheater 3

4.2.1 Description of flue gas and steam flow on flow chart

On the tube side, superheated steam from superheater 2 flows through the tube system of superheater 3 (50) where it absorbs heat through a heat transfer process with the flue gas. Superheated steam then leaves superheater 3 on its way to superheater 4 (coupling element 30).

On the shell side (flue gas) of the element, outlet flue gas (20) from superheater 1 supply heat to the tube side fluid, where after the flue gas leaves superheater 3 (outlet 40) on its way to superheater 4.

4.3 Superheater 3 design mode input file

4.3.1 Format and type of data for the input file

In order to give the reader a "feel" for the complexity of the design mode input to PEPSE, a complete list of the data required for modelling superheater 3 (or any convective stage) is given below.

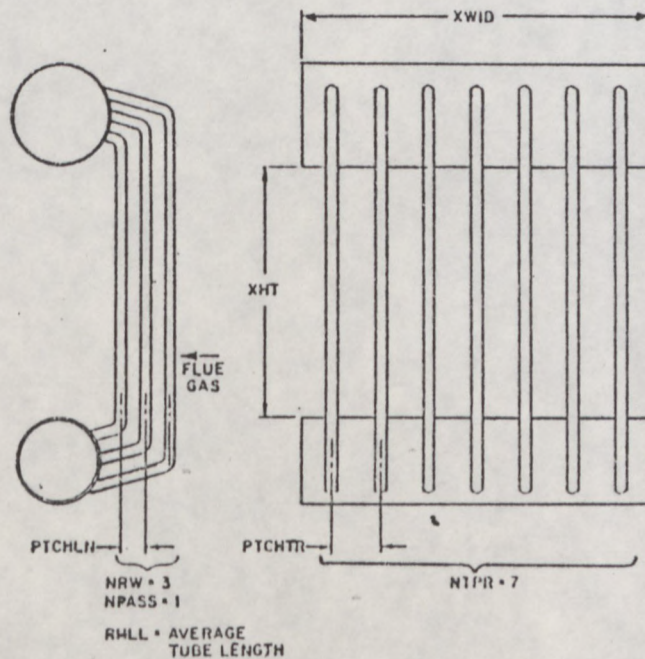


FIGURE 4.2 Convective stage nomenclature

TABLE 4.1 Convective stage input design data description

SYMBOL	DESCRIPTION
NMODHX	Calculational mode flag = 1, Design mode = 2, Performance mode Input MNODHX = 1 only if Design Card is input
WGUESS	Initial guess of mass flow rate at tube side inlet port, (kg/s)
PGUESS	Initial guess of pressure at tube side inlet port, kPa
TGUESS	Initial guess of temperature at tube side inlet port, [F ([C) If a value ~ 10.00 is input, code interprets value as quality (wet or dry steam)
NNFUEL	Flag for fuel type associated with the flue gas passing through the convective stage = 1, Oil = 2, Natural gas = 3, Coal or other fuel
NCONV	First convective stage flag = 0, Not the first convective stage = 1, First convective stage downstream of furnace exit

Table 4.1 (cont.)

SYMBOL	DESCRIPTION
NFLG	Flow geometry flag = 1, Parallel flow is assumed = 2, Counter-flow is assumed = 3, Cross-flow is assumed
XHT**	Cross sectional height of flue in which stage tubing resides, feet (m)
XWID**	Cross sectional width of flue in which stage tubing resides, feet (m)
RHLL**	Length of stage tubing per pass, feet (m)
NRW**	Number of stage tube rows parallel to the flue gas flow path (see figure 4.2),
NTPR**	Number of stage tubes per row perpendicular to the flue gas flow path (see figure 4.2)
NPASS**	Number of times the tube side fluid passes through the flue side stream (see Figure 4.2)
DDTIRH	Inside diameter of stage tubing, mm
DDTORH	Outside diameter of stage tubing, mm

** See Figure 4.2

Table 4.1 (cont.)

SYMBOL	DESCRIPTION
PTCHTR**	Transverse tubing pitch, mm
ZTIN	Elevation of tube side inlet port, m
ZTOUT	Elevation of tube side outlet port, m
EMISS	Emissivity of tubing material. -. Default value is 0.2 (value for steel)
CKTIRH	Thermal conductivity of tubing material w/m- °C
FOUL	Combined inner and outer tube fouling factor, $m^2 - °C/w$
EOTUB	Relative roughness inside tube, -
FRMLS	Tube side combined friction factor and form loss coefficient ($(fL/D + k, -$ If zero, PEPSE will calculate a value If negative, the absolute value will be used as a multiplier on the internally calculated combined value

** See Figure 4.2

Table 4.1 (cont.)

SYMBOL	DESCRIPTION
HTTIRH	Overall heat transfer coefficient, (W/m^2-C) . If zero, PEPSE will calculate a value. If negative, the absolute value will be used as a multiplier on the internally calculated heat transfer coefficient
AATIRH	Effective area for heat transfer, m^2
PDHXTU	The constant A^* in the equation for the tube side pressure drop description.
PDHXT2	The constant B^* in the equation for the tube side pressure drop description
PDHXT3	The constant C^* in the equation for the tube side pressure drop description
PPTORH	Measured tube side outlet pressure, kPa
PDHXSH	Pressure drop on shell side of component as given by the constant A^*
PRESHL	Measured shell side outlet pressure kPa

* See Appendix B

4.3.2 Discussion on design input data and simplifications
(See Appendix F for design mode input file)

The design mode option of a component or system is much more versatile than the performance mode option, especially looking at off-design behaviour changes. This is partly because of the fact that the element is now modelled in its physical dimensions, as it appears in practice, which also entails no user input on the steam outlet temperature and flue gas outlet temperature. The above initially unknown parameters are now calculated by PEPSE from the design data which is supplied by the user.

In order to "fine tune" a design element it might be necessary to change certain input values like pipe diameters or pipe lengths to obtain the desired output values. That is the reason why certain programme input values would be slightly different to the as-designed values. One such an example is the effective heat transfer surface, which is 14,63 % bigger than the as-designed figure. A second reason for the bigger heat transfer area in the latter element is the point raised in section 3.6.1, which takes a heat transfer "section" as one element, and by doing so ignoring the heat transfer effect of the remaining three heat transfer elements in that region. (Simulating those elements as one convective stage). In the design mode model input file this effect is taken into account when modelling an element.

A superheater element is made up from, as in the case of superheater 3, five different regions with pipe material specifications differing in every region depending on different heating applications. This fact complicated the issue considerably as PEPSE only requires one outside and inside diameter for an element input.

As a simplification on this input the wall thickness is taken as an average of the five tubes, leaving the outside diameter at 38 mm. As the longest length of tubing on superheater 3 is made up from 20 CR Mo U 121 material, the heat transfer properties of this material are used as reference.

The initial fouling factor on the superheter 3 tubing is taken as 0.0, thus simulating a new pipe. The effect of different fouling factors on the superheater 3 performance is annalized in the chapter following.

The pressure drop description over superheater 3 described by the user in the form of a second order equation, taking into account the mass flow, pressures and temperatures for three different load conditions ie 70 %, 97 % and 100 % of maximum continuous rating. (See Appendix B)

4.4 Discussion of superheater 3 design results (See Appendix G)

A study of the results reveals several points which should be highlighted as being significant to the conclusion of the report.

4.4.1 Comparison of PEPSE computed results with actual performance results.

It must be stressed, that results from the actual tests by Steinmüller and Escom can differ quite considerably and any figure taken for comparison purposes must not be taken as the only available.

Refer to Appendix G Table G.1 for component properties. Looking at component 50's T(Output) for steam which is 496.366 °C, and comparing that to the actual figure of 497 °C it can be appreciated how versatile and accurate the design mode model is. No T(Output) value is set by the user (as was done in the Performance Mode Model) and this value is calculated purely from the design layout data and input performance values of the element.

The D(Output) value for flue gas, which is calculated at 1115,443 °C compares favourably with the value of + 1116 °C from the station data. In modelling this component (consepgration) is given to the heat transfer effect of the other heat transfer areas in that region by enlarging the effective heat transfer area by 14.63 %. This is the main reason for a calculated figure on flue gas outlet temperature which is so close to 1116 °C.

The value T (Input) and S(Input) is set by the user in this case and cannot change during the course of a PEPSE run. This statement only holds true for a sub - model through because, if this component is part of a chain of components, like in a boiler, the values of T(Input) and S(Input) are set by the values of T(Output) and D(Output) of the component immediately upstream of the one in question. This means that the value of T(Input) and S(Input) will only be equal to the user input in the first iteration, where these values will be dependent on the upstream component outlet values.

The value of the fouling factor is set at 0.0, which means that all the above values from the table correspond to new or very clean Superheater tubes (See discussion on fouling). This means that the heat transfer coefficient of 58.081 (Table G.3 Appendix G) is in actual fact a bit lower in practice, because 100% clean tubes are rarely found in practice.

The pressure drop of 738.0 KPa ($T(\text{Input}) - T(\text{Output})$) on the tube side of the component (Table G.1 Appendix G) is considerably higher than the Steinmüller figure of 650 KPa.

This increase can be accounted for by the average value taken for the wall thickness in the superheater tubing.

4.5 Problem simulating and solving with the superheater 3 computer model

4.5.1 General

This section looks into sensitivity analysis on the superheater 3, simulating trends which can affect the performance and efficiency of this element as well as the boiler as a whole. To illustrate to the reader how versatile the design mode model is, the effect of inner and outer tube fouling on certain outlet parameters is simulated on the computer and represented on the graphs below.

Products of corrosion, dirt, or other foreign matter which deposit on heat transfer surfaces increase the overall thermal resistance and lower the overall heat transfer coefficient of the heat exchanger. Fouling of the boiler walls in the upper regions raises the temperature of the gasses leaving the furnace or the specific element in question (See Figure 4.4).

Outside tube fouling can be partly overcome by soot blowing and inside fouling by blow-down of the boiler. The fouling factors upon which the following computer calculations and graphs are based are a combination of the inner and outer fouling factors.

4.5.2 Simulation of tube fouling and results

It will be noted that the fouling factors chosen, are quite high (see Table 4.2), the reason for this being, rather than the calculation of 100 % realistic output values to simulate a clear and definite trend.

TABLE 4.2 The effect of fouling on superheater 3

*FOULING FACTOR ($\text{m}^2\text{-}^\circ\text{C}/\text{W}$)	OUTLET STEAM TEMPERATURE ($^\circ\text{C}$)	OUTLET FLUE TEMPERATURE ($^\circ\text{C}$)	H.T.C ($\text{W}/\text{m}^2\text{-C}$)	HEAT EXCHANGER EFFECTIVE NESS
0,00	496,366	1115,443	58,081	15,90
0,005	483,613	1139,344	45,529	12,81
0,010	475,12	1155,715	37,322	10,69
0,015	469,116	1167,543	31,574	9,16
0,02	464,669	1176,454	27,337	8,00
0,025	461,253	1185,394	24,091	7,10
0,03	458,551	1188,944	21,527	6,38

From Figure 4.3 it is clear that the outlet steam temperature decreases with an increasing fouling factor. The reason for this phenomena is that fouling on the outside of the tube and scale formation on tube inside both have the effect of lowering the heat transfer coefficient as both are very poor heat transfer mediums. From the above it is clear that the less the heat transfer to the steam side of the tube the colder the outlet steam temperature.

*For fouling factor values, note that each set of figures represents a complete run of the programme.

The effect of fouling on the heat transfer coefficient can be seen from Figure 4.4.

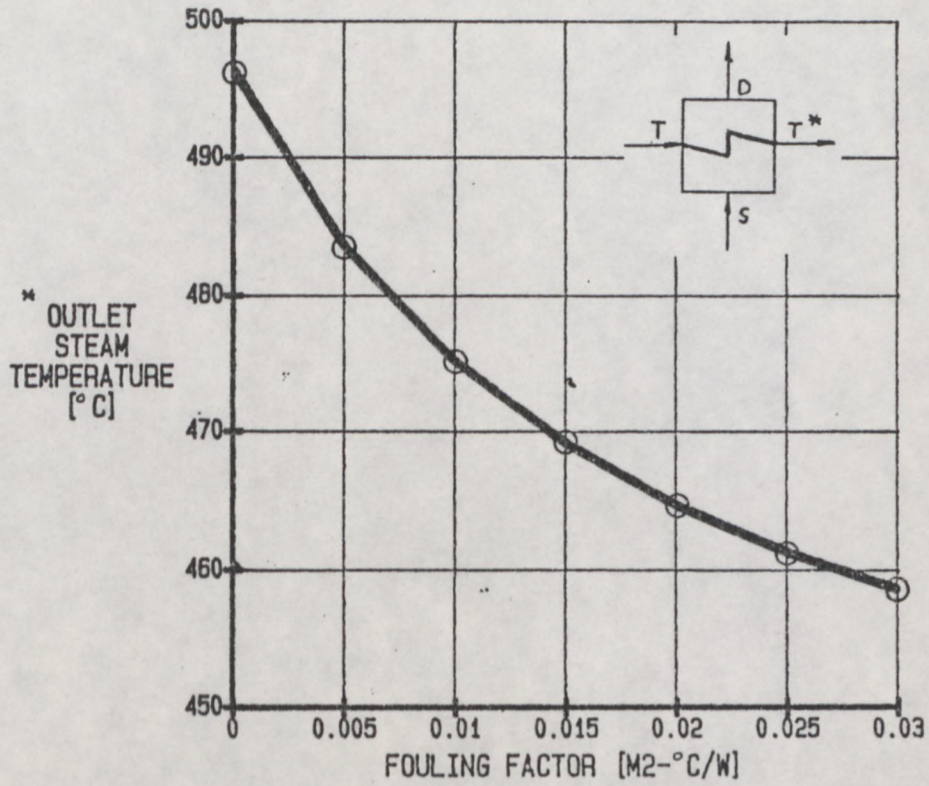


FIGURE 4.3 The effect of fouling on outlet steam temperature

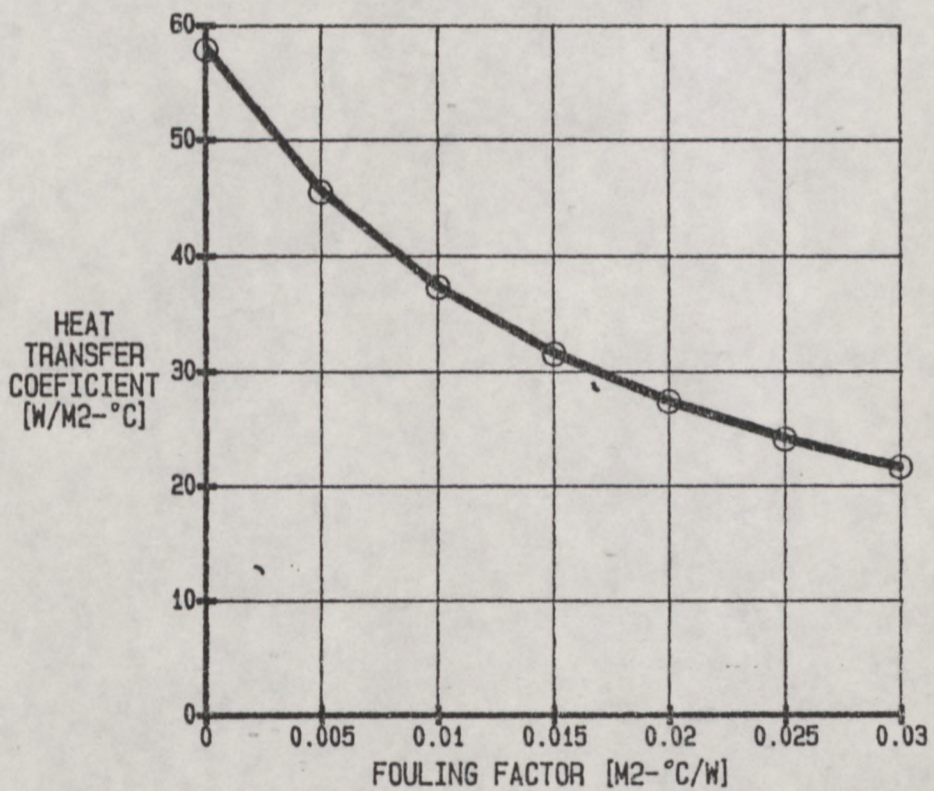


FIGURE 4.4 The effect of fouling on the heat transfer coefficient

A logical outflow of the above-mentioned facts are illustrated in Figure 4.4 which shows the effect of fouling on the flue gas outlet temperature. It is clear that the bigger the fouling factor, the higher the outlet flue gas temperature. The reason for the above trend is partly explained in the previous paragraph, with the addition that the less the heat supplied to the steam side of the tube, the higher the flue gas temperature at any specific point in the boiler. Thus, the higher the end temperature of flue gas will be at the top of the boiler.

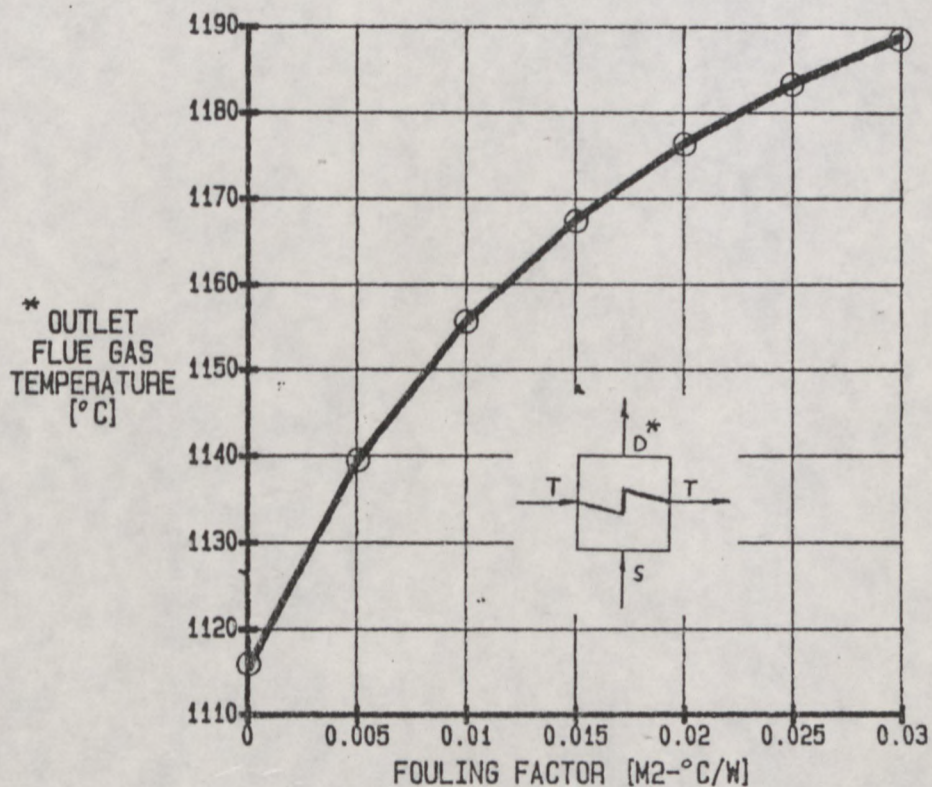


FIGURE 4.5 The effect of fouling on the flue gas outlet temperature

As was explained in the paragraphs above the effect of an increase in the fouling factor is a decreasing heat transfer coefficient which again leads to a decrease in component and boiler efficiency, as can be seen from Figure 4.6 below.

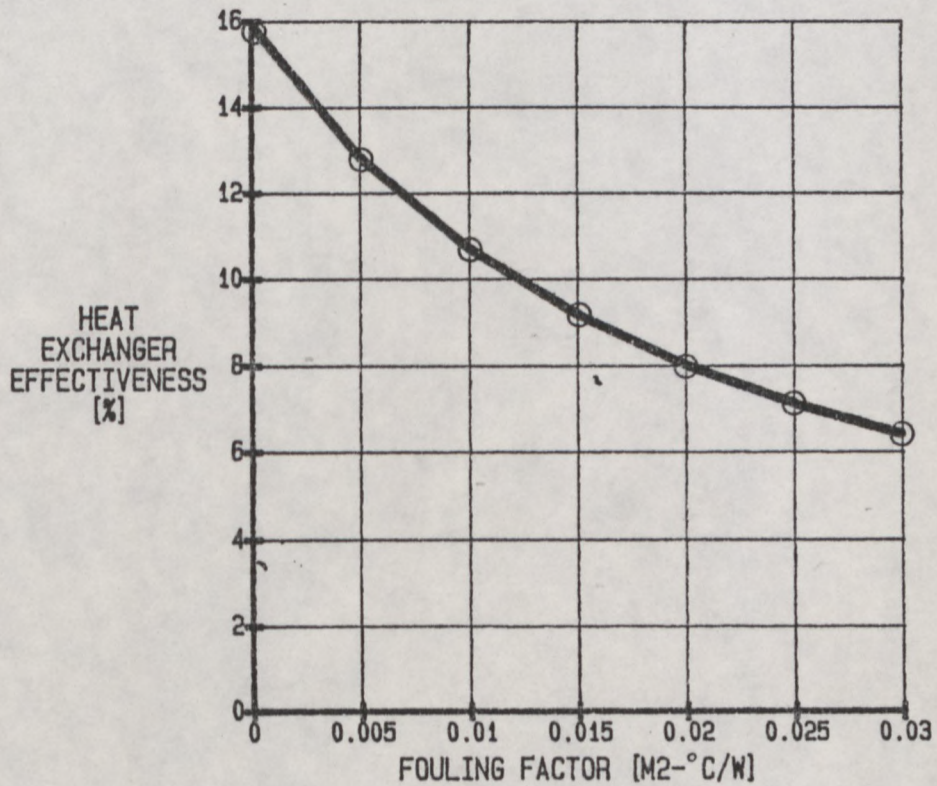


FIGURE 4.6 The effect of fouling on the heat exchanger (superheater 3) efficiency

5. CONCLUSIONS

From the preceeding results and discussion it is evident that several relevant conclusions can be drawn.

- * The performance boiler model were found to be not very useful for solving practical problems, as it is too user defined.
- * The design mode model of superheater 3 proved to be most versatile and can be very useful in practice, as was illustrated by the fouling simulation of the superheater 3 steam tubing.
- * It is clear from the above, that the Duvha boiler computer model will only be really useful in the design mode. The total design mode computer model proved to be too lengthy in the context of this undertaking and could form the basis for further studies in this field.
- * Certain questions remains to be answerd

How would a change in the flow chart configuration, as presented in this project, change the accuracy of the results obtained?

Would the program converge with such a change in flow chart configuration?

APPENDIX A

A.1 Short description on PEPSE* related component symbols:

In the following section a brief description of the components used in the "building" of this computer model will be given (- related to PEPSE Computer Code). Refer to Table 3.1 for more information.

A.1.1 The rotary air heater (Type 21)

This component is used for simulating regenerative type air heaters having rotating elements, similiar to the ones found in the Duvha boiler. A single type 21 component may be used to simulate several rotary regenerators operating in parallel - two in the case of the boiler under discussion.

Performance mode input data include temperatures, pressure drops, mass flows and heat losses both on the flue gas and air side.

A.1.2 The superheaters and reheaters (Type 28)

This convective stage component is a general gas-to-water heat exchanger having both design and performance mode capabilities. It is used for modeling various fossil boiler heat transfer regions located beyond the furnace exit. Examples of these components are the superheaters and reheaters (as can be seen in the model).

The design mode heat transfer calculation, of which an example is performed, incorporates tube external and internal convection, tubing thermal conductivity and intertube radiation. The effects of fouling, inlet and outlet elevation, pressure, temperatures and non-linear pressure drop descriptions are also included in the input information. Thus a type 28 component can be simulated within very close tolerances to reality.

This component is very complex to model and a vast amount of input data is needed to describe the design mode of this element.

A.1.3 Furnace water walls (Type 29)

The radiant stage component is intended for modeling heat transfer regions within the confines of the furnace combustor (example, the bottom part of the furnace). The radiant stage is always associated with a user specified furnace/combustor component type 70 in which the radiant stage is considered to reside, ie. no component type 29 will be located outside the furnace combustor.

All radiant stages residing in the furnace combustor are to be either in design mode or in performance mode. (The latter in the case of this model.)

Input data include, amongst performance data, a non-linear pressure description which describes the components performance characteristics for different load conditions (See Appendix B for calculation).

A.1.4 Drain or sink (Type 31)

This component, as the name implies, takes any mass flow rate from any PEPSE component via the user specified plant configuration. It is used for mass balances withing the cycle. This component requires no input data from the user.

A.1.5 Fuel and flue gas source (Type 31)

The source component supplies a specified amount of fluid at the specified conditions (mass flow, temperature and pressure to any point in the cycle). Examples of which are the flue gas line and the fuel supply. The input pressure and temperature must represent a unique thermodynamic state point.

Any type of material can be supplied to a system with the addition of a special material specification card, where a specific fluid is broken down into its different chemical constituents along with teh respective mass fractions.

A.1.6 Air input and output (Type 32 and 33)

An output component may only appear once in a system, that is, at the end of the main stream fluid, in this case the air flow cycle.

The input component must always appear in a model. This element acts in exactly the same way as the source element. This component is to appear at the starting point of the computer data readings.

A.1.7 Attemperator (Type 50)

Elements like the attemperator are simulated by component type 50's. These components take the two inlet port flows and mix them according certain user specified options ie:

- * The output port pressure is based on a volume flow weighing of the two input ports. (In this case water and steam)

No user data is needed for this component as it takes already calculated data at the input port "IA" and "IB" and mixes it according to the above option.

A.1.8 Combustion air splitter (Type 60)

This component is used to feed certain components which demand a unique mass flow rate to satisfy the thermodynamic input condition of the component. As an example, one can take the air inlet to the furnace combustor where an excessive amount of combustion air is supplied to the demand splitter. This component then measures the amount of air needed for combustion. The rest of the air is split off in the "U" port of the component.

This component may only be used in certain PEPSE specified locations in the model, like the air inlet to the furnace combustor, as it is incorporated in this model.

A.1.9. The moisture separator (Type 62)

A moisture separator component is used to simulate a separating unit for water and steam in a wet mixture fluid, as in the boiler model for instance.

A moisture removal effectiveness factor is specified in the input, which can permit for some steam carry over if necessary. This component can only be used where the incoming stream carries water and/or steam with no other constituents involved.

A.1.10 The fixed precent flue gas splitter (Type 63)

This component allows a fixed fraction of the inlet port mass flow to be diverted to one of the outlet ports. This component is especially useful in splitting the flue gas in two streams to give the desired heat transfer over the secondary air and primary air heater. (See Diagram)

A.1.11 The furnace combustor (Type 70)

The furnace combustor component is one of the most important elements in this boiler model and is used in simulating the combustion process between the specified fuel and combustion air.

Any constituents entering the combustor fuel port always react in the combustion process. However any constituents entering the air port other than oxygen are not reacted. By convention any heating value associated with the combustion air is not liberated during combustion.

Refuse produced during combustion consists of ash and unburned elemental carbon. The refuse port on the furnace combustor unit takes all the refuse unless fractional carry-over is specified. (This option is not incorporated in this model)

The furnace combustor has no heat transfer surface of its own, but heat transfer from within may be modelled by the use of separate radiant stage components placed inside the boundaries of this component. Like boiler water walls and bottom port of the superheater.

User data input in this component is quite extensive and involved.

See also paragraph A.11.3

A.1.12 Pipes - steam and water (Type 0)

Streams simulate pipes in the system. Type 0 streams are also called passive streams because the thermodynamic conditions on either side of the stream is the same.

All streams used in the context of the undertaking is type 0 streams.

APPENDIX B

Heat Exchanger

Pressure Change Calculations

The performance and design mode calculation for change in pressure across either flow path through a heat exchanger is computed from the standard second order equation,

$$\frac{P}{P_i} = A + Bx + Cx^2 \dots\dots\dots (i)$$

where

$$x = \frac{W}{P_i} T_i \dots\dots\dots (ii)$$

Taking superheater 3 as an example (see Table C.1)

3 equations with 3 unknown are derived at in the following way,

$$A + Bx_1 + Cx_1^2 = \frac{P}{P_i} \quad 1 \quad \dots\dots\dots 70 \%$$

$$A + Bx_2 + Cx_2^2 = \frac{P}{P_i} \quad 2 \quad \dots\dots\dots 97 \%$$

$$A + Bx_3 + Cx_3^2 = \frac{P}{P_i} \quad 3 \quad \dots\dots\dots 100 \%$$

where (from equation (ii)),

$$X_1 = 0.4000$$

$$X_2 = 0.5384$$

$$X_3 = 0.5487$$

and

$$\frac{P}{P_{i1}} = 0,0166$$

$$\frac{P}{P_{i2}} = 0.0334$$

$$\frac{P}{P_{i3}} = 0.0351$$

Solving for A, B and C

1	0.4000	0.1600	A		0.0166
1	0.5384	0.2899	B	=	0.0334
1	0.5487	0.3011	C		0.0351

Solving the matrix gives,

$$A = 0.03126$$

$$B = -0.1540$$

$$C = 0.2934$$

The values A, B and C as calculated in the section above are the values used as inputs to the PEPSE* pressure drop description over the superheater 3 component. This same process for calculating A, B and C hold true for all the convective and radiant stage elements.

APPENDIX C

Steinmüller performance reference results as it is incorporated in the PEPSE performance and design models. (Note that the figures used PEPSE input into the models correspond to 100 % MCR* conditions as it is described by Steinmüller).

* Maximum continuous rating

TABLE C.1	Kilogrammes per second evaporation		
	228 Corresponding to 70 % M.C.R.	491.4 Corresponding to 97 % M.C.R.	507 Boiler M.C.R.
<u>Steam Temperature:</u>			
At superheater outlet °C	540	540	540
Tolerance ± K	5	5	5
Steam temperatures at 97 % M.C.R. if superheater control is not in operation °C		540	
At reheater outlet °C	540	540	540
Tolerance ± K	5	5	5
Steam temperature at 97 % M.C.R. if reheater control is not in operation *) °C		555	
<u>Evaporator and superheater:</u>			
Leaving evaporator °C	404	406	409
Leaving attemperator 1 °C	398	401	403
Leaving superheater 1 °C	420	420	423
Leaving superheater 2 °C	453	455	455
Leaving attemperator 2 °C	430	431	435
Leaving superheater 3 °C	501	498	498
Leaving attemperator 3 °C	471	471	472
Leaving superheater 4 °C	540	540	540
Quantity of steam being desuperheated %	91	91	91
<u>Reheater:</u>			
Cold reheat °C	317	330	332
Leaving reheater 1 °C	455	473	476
Leaving attemperator °C	453	447	446
Leaving reheater 2 °C	540	540	540
<u>Pressure:</u>			
Design pressure for high pressure portions of units MPa (g)		25.0 - 19.4	
Working pressure at SH outlet header MPa	16.95	17.1	17.44
Pressure at measuring point MPa	16.8	16.8	17.13

TABLE C.1 (cont)

		kilogrammes per second evaporation		
		355	491.5	507
		Corresponding to 70% M.C.R.	Corresponding to 97% M.C.R.	Boiler M.C.R.
<u>Air temperatures:</u>				
At airheater inlet	°C	43*	43*	43*
At airheater outlet	°C	257	283	285
Temperature of air/fuel mixture entering burners	°C	95	95	95
<u>Gas temperatures:</u>				
Entering superheater 1	°C	1150	1243	1250
Entering superheater 3	°C	1134	1226	1234
Entering superheater 4	°C	999	1093	1102
Entering reheater 2	°C	854	942	951
Entering superheater 2	°C	737	812	820
Entering reheater 1	°C	653	719	726
Entering economiser	°C	472	519	525
Entering airheater	°C	302	339	343
Leaving airheater (incl. airheater leakage)	°C	117	130	132
Entering electrostatic precipitator	°C	117	130	132
Leaving electrostatic precipitator	°C	114	128	130
Entering I.D. fans	°C	114	128	130
At chimney inlet	°C	114	128	130
<u>Water temperatures:</u>				
Entering economiser	°C	227	245	246
Leaving economiser	°C	287	304	306

TABLE C.1 (cont)

		Kilogrammes per second evaporation		
		355	491.5	507
		Corresponding to 70% M.C.R.	Corresponding to 97% M.C.R.	Boiler M.C.R.
<u>Flue gas pressures:</u>				
Furnace suction	kPa	0.15	0.15	0.15
Draught loss through boiler superheater and reheater	kPa	-0.042	0.054	0.068
Draught loss through economiser	kPa	0.046	0.096	0.103
Draught loss through flues betw. economiser and airheater	kPa	0.337	0.444	0.457
Draught loss through airheater	kPa	0.527	0.844	0.893
Draught loss through flues betw. airheater and electrostatic pre- cipitator	kPa	0.262	0.472	0.504
Draught loss through electrostatic precipi- tator (incl. entrance and exit losses)	kPa	0.11	0.13	0.13
Draught loss through flues between electro- static precipitator and chimney	kPa	<u>0.257</u>	<u>0.462</u>	<u>0.490</u>
Total loss through system	kPa	1.647	2.652	2.795
<u>Air pressures (secondary air):</u>				
Pressure loss through airheater Davidson	kPa	0.588	1.010	1.069
Pressure loss through ducts	kPa	0.753	1.319	1.404
Pressure required at burners	kPa	<u>1.124</u>	<u>2.178</u>	<u>2.335</u>
Total loss through system	kPa	2.465	4.507	4.808
Pressure at mill inlet*)	kPa	8.14	10.536	10.782
Pressure at mill outl.	kPa	1.74	2.336	2.382

TABLE C.1 (cont)		Kilogrammes per second evaporation		
		355	491.4	507
		Corresponding to 70 % M.C.R.	Corresponding to 97 % M.C.R.	Boiler M.C.R.
<u>Working pressure at:</u>				
Feed water inlet (terminal point)	MPa	19.68	22.34	23.04
Entering economiser	MPa	19.09	21.73	22.24
Entering SH 1	MPa	17.71	18.81	19.14
Entering SH 2	MPa	17.56	18.51	18.82
Entering SH 3	MPa	17.43	18.24	18.53
Entering SH 4	MPa	17.14	17.63	17.88
Leaving SH-steam strainer (terminal point)	MPa	16.95	17.10	17.44
Pressure drop total from feedwater inlet to steam outlet (between terminal points)	MPa	2.73	5.26	5.6
The height of highestwater level of collecting vessel above economiser inlet is	m	1.3	1.3	1.3
The height of feedwater inlet above basement level (terminal point) is	m	13.5	13.5	13.5
<u>Attemperator flow rates:</u>				
Main steam flow at attemperator 1 inlet	kg/s	322.7	447.2	461
Spray water in attemp. 1	kg/s	5.0	7.0	7.1
Spray water in attemp. 2	kg/s	13.6	18.8	19.4
Spray water in attemp. 3	kg/s	13.6	18.8	19.4
Reheater design pressure	MPa	5.39 - 5.08		
Working pressure at reheater inlet header	MPa	2.89	4.02	4.15
Working pressure at reheater outlet header	MPa	2.72	3.79	3.91
Pressure drop from inlet header to outlet header	MPa	0.17	0.23	0.24
<u>Reheater flow figures:</u>				
Cold reheat from turbine	kg/s	311.1	424.8	437.6
Hot reheat to turbine	kg/s	311.1	434.3	448.7

TABLE C.1 (cont)

Flow rates:	% MCR	70	97	100
Evaporation per kg. coal	kg	7.07	7.16	7.14
Intake air of FD-fan	kg/s	473.1	626.7	645.9
Gas flow at airheater inlet	kg/s	477.0	638.7	658.8
Water through economiser	kg/s	322.7	447.2	461.0
Primary air to furnace	kg/s	96.5	110.1	111.7
Secondary air to furnace	kg/s	339.9	473.1	489.9
Total air to furnace	kg/s	436.4	583.2	601.6

APPENDIX D

The following appendix contains the performance input file* which is written by the user to enable the computer to read the flow chart in logical order. The computer also reads all the performance data into the model through this file.

* Page over for file structure

[illegible]

* PREFERENCE DATA

* 040000	TTAIS
040000	20.00

```
# GEOMETRY INPUT DATA
# 50XXXX FROM: CPORT
```

SECURITY	* 50XXX3	FROM	GPDR	TO	IPDR
60	502600	010	U	020	T
61	502700	020	T	070	IA
62	502800	070	U	075	IA
63	502850	75	B	40	IA
64	502870	75	U	78	IA
65	502900	030	U	040	IF
66	503000	040	U	190	I
67	503100	040	B	060	I
68	503200	100	T	130	IA
69	503300	120	T	100	IA
70	503400	100	D	110	IB
71	503500	090	U	100	S
72	503600	080	U	090	I
73	503700	090	B	020	S
74	503800	020	D	110	IA
75	503850	110	U	150	IA
76	503900	140	U	130	IB
77	504000	130	U	135	S
78	504020	135	T	132	S
79	504040	137	U	135	T
80	504060	135	D	070	IB
81	504100	160	T	220	T
82	504200	170	T	230	T
83	504300	180	T	200	T
84	504400	420	T	160	T
85	504500	190	B	200	S
86	505150	530	U	270	IA
87	504600	200	D	240	IA
88	504700	200	T	380	T
89	504800	220	T	170	T
90	504950	440	U	550	IA

30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91

505000	220	L	S	230
505100	230	T	I	530
505170	530	F	I	540
505180	540	U	IE	550
505200	250	E	IE	240
505220	270	U	T	180
505400	280	U	IE	270
506000	240	U	S	300
506100	350	U	T	300
506200	560	U	IE	350
506300	380	U	IA	350
506400	300	C	S	330
506500	300	T	IA	330
506600	320	U	IE	310
506700	310	U	T	330
506800	330	E	S	370
506900	370	E	S	330
507000	330	T	I	240
507100	370	T	I	340
507200	390	I	T	370
507300	400	U	IE	390
507400	410	T	IA	390
507500	380	T	S	410
507600	430	U	T	410
507700	410	E	S	420
507800	550	U	T	420
507900	420	D	I	210

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92	505000	220	L	S	230
94	505100	230	T	I	530
95	505170	530	F	I	540
96	505180	540	U	IE	550
97	505200	250	E	IE	240
98	505220	270	U	T	180
99	505400	280	U	IE	270
100	506000	240	U	S	300
101	506100	350	U	T	300
102	506200	560	U	IE	350
103	506300	380	U	IA	350
104	506400	300	C	S	330
105	506500	300	T	IA	330
106	506600	320	U	IE	310
107	506700	310	U	T	330
108	506800	330	E	S	370
109	506900	370	E	S	330
110	507000	330	T	I	240
111	507100	370	T	I	340
112	507200	390	I	T	370
113	507300	400	U	IE	390
114	507400	410	T	IA	390
115	507500	380	T	S	410
116	507600	430	U	T	410
117	507700	410	E	S	420
118	507800	550	U	T	420
119	507900	420	D	I	210
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345	700700	50	0	
346	705500	50	0	
347	701100	50	0	
348	701300	50	0	
349	702700	50	0	
350	702400	50	0	
351	703100	50	0	
352	703500	50	0	
353	703900	50	0	
354	* FLOW SPLITTER			
355	* 70YVY0 CTYPE			
356			HHFIXR	FRSPL
357	700900	63	0.00	0.82
358	701900	63	0.00	0.10
359	* DEMAND FLOW SPLITTER			
360	* 70YVY0 CTYPE			
361			HHFIX3	WFFIXR
362	700750	60	0.00	611.6
363	*			
364				
365				

1 PEPSE CODE BY ENERGY INCORPORATED, IDAHO FALLS, ID. VERSION 49A0 CREATED 20 SEP 83 DATE 86/09/24. PAGE 1
DUVHA , 600MW ONCE THROUGH PULVERIZED FUEL,BOILER SIMULATION

APPENDIX E

This appendix contains the output* results of this performance model as it is calculated and structured by PEPSE.

* Page over for output results

TABLE E.1
COMPONENT PROPERTIES

COMPONENT NUMBER	COMPONENT DESCRIPTION	CONNECTING STREAM NUMBER	PORT ID	FLUID ID	MASS FLOW (KG/SEC)	TEMPERATURE (C)	PRESSURE (KPA)	THERMO. QUALITY (-)	ENTHALPY (KJ/KG)	ENTROPY (KJ/KG-C)	SPECIFIC VOLUME (M3/KG)
10	INPUT COMPONENT	250	U (OUTPUT)	1	4.700000E+02	36.580	92.000	N.A.	314.9425	6.93348	9.70840E-01
20	FOTAFY RESERVE.	260	T (INPUT)	1	4.700000E+02	36.580	92.000	N.A.	314.9425	6.93348	9.70840E-01
30	INFINITE SOURCE	260	S (INPUT)	3	5.402160E+02	322.800	87.500	N.A.	651.6554	7.63932	3.76364E+00
40	FURN./COMBUSTOR	270	T (OUTPUT)	1	4.700000E+02	295.390	90.200	N.A.	579.7804	7.55914	1.61763E+00
50	DEMAND SPLITTER	280	S (OUTPUT)	3	5.402160E+02	119.467	85.900	N.A.	621.2405	7.17285	2.52398E+00
60	INFINITE SINK	290	U (OUTPUT)	2	7.000000E+01	95.000	90.330	N.A.	434.4351	3.56167	N.A.
70	STANDARD MIXER	270	IA (INPUT)	1	6.116000E+02	249.911	91.691	N.A.	532.0421	7.46690	1.64505E+00
80	INFINITE SOURCE	290	IF (INPUT)	2	7.000000E+01	95.000	90.330	N.A.	434.4351	3.56167	N.A.
90	INFINITE SINK	300	U (OUTPUT)	4	6.776273E+02	1307.360	91.690	N.A.	1686.1701	8.39292	N.A.
100	INFINITE SOURCE	310	B (OUTPUT)	5	2.612700E+00	800.000	90.330	N.A.	648.9565	1.07245	N.A.
110	INFINITE SINK	310	T (INPUT)	5	2.612700E+00	800.000	90.330	N.A.	648.9565	1.07245	N.A.
120	STANDARD MIXER	270	IA (INPUT)	1	4.700000E+02	295.390	90.200	N.A.	579.7804	7.55914	1.61763E+00
130	DEMAND SPLITTER	280	IE (INPUT)	1	1.417700E+02	95.000	100.168	N.A.	373.7787	7.08300	1.05986E+00
140	INFINITE SINK	280	U (OUTPUT)	1	6.117700E+02	249.911	91.691	N.A.	532.0421	7.46690	1.64505E+00
150	INFINITE SOURCE	280	I (INPUT)	1	6.117700E+02	249.911	91.691	N.A.	532.0421	7.46690	1.64505E+00
160	INFINITE SINK	280	U (OUTPUT)	1	1.700000E-01	249.911	91.691	N.A.	532.0421	7.46690	1.64505E+00
170	INFINITE SOURCE	285	B (OUTPUT)	1	6.116000E+02	249.911	91.691	N.A.	532.0421	7.46690	1.64505E+00
180	INFINITE SINK	287	I (INPUT)	1	1.700000E-01	249.911	91.691	N.A.	532.0421	7.46690	1.64505E+00
190	INFINITE SOURCE	360	U (OUTPUT)	3	6.588000E+02	322.800	87.500	N.A.	851.6554	7.63932	3.76364E+00

COMPONENT PROPERTIES

TABLE E.1 (cont)

COMPONENT NUMBER		COMPONENT DESCRIPTION	CONNECTING STEAM LINE NUMBER	PORT ID	FLUID ID	MASS FLOW (KG/SEC)	TEMPERATURE (C)	PRESSURE (KPA)	THERMO. QUALITY (-)	ENTHALPY (KJ/KG)	ENTROPY (KJ/KG-C)	SPECIFIC VOLUME (M3/KG)
+	137	INFINITE SOURCE	404	U (OUTPUT)	0	2.000000E+01	30.000	120.000	-0.13974	125.7712	0.43655	1.00426E-03
+	140	INFINITE SOURCE	390	U (OUTPUT)	1	3.000000E+01	57.200	101.900	N.A.	336.3636	6.97092	9.36570E-01
+	150	INFINITE SINK	385	I (INPUT)	3	6.588000E+02	119.752	85.900	N.A.	621.5539	7.17365	2.52582E+00
+	160	RADIANT STAGE	440	T (INPUT)	0	4.515152E+02	333.000	20802.821	-0.70704	1525.3214	3.53090	1.51116E-03
+			410	T (OUTPUT)	0	4.515152E+02	362.000	20401.327	-0.16107	1760.4351	3.91001	1.85859E-03
+	170	RADIANT STAGE	480	T (INPUT)	0	4.515152E+02	365.000	19999.421	-0.02391	1812.2979	3.99268	1.99570E-03
+			420	T (OUTPUT)	0	4.515152E+02	364.014	19599.432	0.60000	2313.9087	4.78103	5.35202E-03
+	180	RADIANT STAGE	520	T (INPUT)	0	4.541000E+02	362.761	19306.705	0.97073	2436.3970	4.97613	6.30049E-03
+			430	T (OUTPUT)	0	4.541000E+02	403.000	19068.000	1.58942	2871.5752	5.64874	1.10235E-02
+	190	FIXED P.C. SPLIT	300	I (INPUT)	4	6.776873E+02	1307.360	91.600	N.A.	1686.1701	8.39292	N.A.
+			490	U (OUTPUT)	4	6.099186E+02	1307.360	91.690	N.A.	1886.1701	8.39292	N.A.
+			450	U (OUTPUT)	4	6.776873E+01	1307.360	91.690	N.A.	1686.1701	8.39292	N.A.

COMPONENT PROPERTIES

TABLE E.1 (cont)

COMPONENT NUMBER		CONNECTING STREAM NUMBER		PORT ID		FLUID ID		MASS FLOW (KG/SEC)		TEMPERATURE (C)		PRESSURE (KPA)		THERMO. QUALITY (-)		ENTHALPY. (KJ/KG)		ENTROPY (KJ/KG-C)		SPECIFIC VOLUME (M3/KG)	
200	+	CONVECTIVE STAGE		420		T (INPUT)		0		4.541000E+02		403.000		19068.000		1.58942		2871.5792		5.64874	
	+			450		S (INPUT)		4		6.776873E+01		1307.360		91.690		1886.1701		8.39292		1.10235E-02	
	+			470		T (OUTPUT)		0		4.541000E+02		423.000		18908.000		N.A.		2976.0351		N.A.	
	+			460		D (OUTPUT)		4		6.776873E+01		753.905		91.520		1.71548		1186.2393		7.84925	
210	+	OUTPUT COMPONENT		790		I (INPUT)		4		6.776873E+02		344.302		91.470		N.A.		704.6572		7.25333	
	+	CONVECTIVE STAGE		410		T (INPUT)		0		4.515152E+02		362.000		20401.327		-1.6107		1760.4351		3.91001	
	+			490		S (INPUT)		4		6.099186E+02		1307.360		91.690		1886.1701		8.39292		1.85859E-03	
	+			480		T (OUTPUT)		0		4.515152E+02		365.000		19999.421		N.A.		1812.2979		N.A.	
230	+			500		D (OUTPUT)		4		6.099186E+02		1277.699		91.690		-0.02391		1847.7768		8.36839	
	+	CONVECTIVE STAGE		420		T (INPUT)		0		4.515152E+02		364.014		19599.432		.80000		2313.9087		4.78103	
	+			500		S (INPUT)		4		6.099186E+02		1277.699		91.690		N.A.		1847.7768		8.36839	
	+			510		T (OUTPUT)		0		4.515152E+02		362.717		19296.425		.99000		2449.6805		4.99713	
240	+			520		D (OUTPUT)		4		6.099186E+02		1109.737		91.690		N.A.		1747.2666		8.30189	
	+	STANDARD MIXER		460		IA (INPUT)		4		6.776873E+01		753.905		91.520		N.A.		1186.2393		7.84925	
	+			520		IE (INPUT)		4		6.099186E+02		1109.737		91.690		N.A.		1747.2666		8.30189	
	+			500		U (OUTPUT)		4		6.776873E+02		1156.009		91.678		N.A.		1691.1439		8.26325	
270	+	STANDARD MIXER		515		IA (INPUT)		0		4.476000E+02		362.717		19296.425		1.00000		2456.3216		5.00757	
	+			540		IE (INPUT)		0		7.100000E+00		270.000		22600.000		-99.99949		1181.9913		2.92995	
	+			530		U (OUTPUT)		0		4.541000E+02		362.761		19306.705		.97073		2436.3970		4.97613	
	+																			6.44022E-03	
																				1.26557E-03	
																				6.30049E-03	

TABLE E.1 (cont)

COMPONENT PROPERTIES													
COMPONENT			CONNECTING			COMPONENT			COMPONENT				
NUMBER	DESCRIPTION	STAGE NUMBER	PORT ID	FLUID ID	MASS FLOW (KG/SEC)	TEMPERATURE (C)	PRESSURE (KPA)	THERMO. QUALITY (-)	ENTHALPY (KJ/KG)	ENTROPY (KJ/KG-C)	SPECIFIC VOLUME (M3/KG)		
+	280	INFINITE SOURCE	540	U (OUTPUT)	0	7.100000E+00	270.000	22600.000	-99.99999	2191.9913	2.92995	1.26557E-03	
+	300	CONVECTIVE STAGE	610	T (INPUT)	0	4.735000E+02	436.530	18634.897	1.76221	3039.6941	5.89937	1.33328E-02	
+			660	S (INPUT)	4	6.776873E+02	1156.009	91.678	N.A.	1691.1639	6.26325	N.A.	
+			650	T (OUTPUT)	0	4.735000E+02	408.000	17968.000	1.95773	3253.8734	6.21645	1.67406E-02	
+			640	U (OUTPUT)	4	6.776873E+02	1033.031	91.510		1534.5299	8.14914		
+	310	STANDARD MIXER	650	IA (INPUT)	0	4.735000E+02	498.000	17968.000	N.A.	3263.8734	6.21645	N.A.	
+				660	IB (INPUT)	0	1.940000E+01	365.000	22688.000	1.95773	1763.7525	3.90859	1.67406E-02
+				670	U (OUTPUT)	0	4.929000E+02	479.435	17989.080	-99.99999	3204.8303	6.13849	1.83301E-03
+										1.88526			1.59543E-02

1 PEPSE CODE BY ENERGY INCORPORATED, IDAHO FALLS, ID. VERSION 49A0 CREATED 20 SEP 83

DUVHA, 600MPH ONCE THROUGH PULVERIZED FUEL BOILER SIMULATION

DATE 86/09/24.

PAGE 4

TABLE E.1 (cont)

COMPONENT PROPERTIES											
CONNECTING					COMPONENT			FLUID			
COMPONENT NUMBER	DESCRIPTION	STREAM NUMBER	PORT ID	FLUID ID	MASS FLOW (KG/SEC)	TEMPERATURE (C)	PRESSURE (KPA)	THERMO. QUALITY (-)	ENTHALPY (KJ/KG)	ENTROPY (KJ/KG-C)	SPECIFIC VOLUME (M3/KG)
320	INFINITE SOURCE	660	U (OUTPUT)	0	1.940000E+01	365.000	22688.000	-99.99999	1763.7525	3.90859	1.83301E-03
330	CONVECTIVE STAGE	670	T (INPUT)	0	4.929000E+02	479.435	17989.080	1.89526	3204.8303	6.13849	1.59543E-02
+		640	S (INPUT)	4	6.776873E+02	1033.031	91.510	N.A.	1534.5299	8.14914	N.A.
+		700	T (OUTPUT)	0	4.929000E+02	540.000	17188.000	2.00844	3397.0050	6.40236	1.92997E-02
+		680	D (OUTPUT)	4	6.776873E+02	922.017	91.500	N.A.	1394.7561	8.03733	N.A.
340	INFINITE SINK	700	T (INPUT)	0	4.929000E+02	540.000	17188.000	2.00844	3397.0050	6.40236	1.92997E-02
350	STANDARD MIXER	630	1A (INPUT)	0	4.541000E+02	455.000	18612.000	1.85686	3110.3199	5.99796	1.42273E-02
+		620	1B (INPUT)	0	1.940000E+01	310.000	22688.000	-99.99999	1386.5412	3.29297	1.38837E-03
+		610	U (OUTPUT)	0	4.735000E+02	436.530	18634.897	1.76221	3039.6941	5.89937	1.33326E-02
360	INFINITE SINK	710	I (INPUT)	0	4.487000E+02	540.000	3998.000	1.42934	3535.8683	7.20574	9.14005E-02
370	CONVECTIVE STAGE	720	T (INPUT)	0	4.487000E+02	471.289	4160.456	1.33995	3377.7471	6.98481	7.93803E-02
+		680	S (INPUT)	4	6.776873E+02	922.017	91.500	N.A.	1394.7561	8.03733	N.A.
+		710	T (OUTPUT)	0	4.487000E+02	540.000	3998.000	1.42934	3535.8683	7.20574	9.14005E-02
+		690	D (OUTPUT)	4	6.776873E+02	837.959	91.490	N.A.	1290.0632	7.94651	N.A.
380	CONVECTIVE STAGE	470	T (INPUT)	0	4.541000E+02	423.000	18908.000	1.71548	2476.0351	5.90380	1.23641E-02
+											

TABLE E.1 (cont)

COMPONENT NUMBER		COMPONENT DESCRIPTION	CONNECTING STREAMS NUMBER		PORT ID	FLUID ID	MASS FLOW (KG/SEC)	TEMPERATURE (C)	PRESSURE (KPA)	THERMO. QUALITY (-)	ENTHALPY (KJ/KG)	ENTROPY (KJ/KC-C)	SPECIFIC VOLUME (M3/KG)
380			690		S (INPUT)	4	6.776873E+02	637.959	91.490	N.A.	1290.0632	7.94651	N.A.
+			630		T (OUTPUT)	0	4.541000E+02	455.000	18618.000	1.85686	3110.3199	5.99796	1.42273E-02
+			750		D (OUTPUT)	4	6.776873E+02	765.178	91.480	N.A.	1200.0926	7.86278	N.A.
390		STANDARD MIXER	740		IA (INPUT)	0	4.376000E+02	476.000	4118.000	1.34581	3389.0332	7.00447	8.08190E-02
+			730		IB (INPUT)	0	1.110000E+01	355.000	10388.000	1.16364	2932.8121	5.94643	2.17223E-02
+			720		U (OUTPUT)	0	4.487000E+02	471.299	4160.458	1.33995	3377.7471	6.98481	7.93803E-02
400		INFINITE SOURCE	730		U (OUTPUT)	0	1.110000E+01	355.000	10388.000	1.16364	2932.8121	5.94643	2.17223E-02
410		CONVECTIVE STAGE	760		T (INPUT)	0	4.376000E+02	332.000	4238.000	1.14376	3042.8631	6.47747	5.98509E-02
+			750		S (INPUT)	4	6.776873E+02	765.178	91.480	N.A.	1200.0826	7.86278	N.A.
+			740		T (OUTPUT)	0	4.376000E+02	476.000	4118.000	1.34581	3389.0332	7.00447	8.08190E-02
+			770		D (OUTPUT)	4	6.776873E+02	580.280	91.470	N.A.	976.5517	7.62593	N.A.
420		CONVECTIVE STAGE	780		T (INPUT)	0	4.515152E+02	256.446	21492.738	-2.20422	1117.2300	2.81178	1.23618E-03
+			770		S (INPUT)	4	6.776873E+02	580.280	91.470	N.A.	976.5517	7.62593	N.A.
+			440		T (OUTPUT)	0	4.515152E+02	333.000	20802.821	-0.70704	1525.3214	3.53090	1.51116E-03
+			790		D (OUTPUT)	4	6.776873E+02	344.302	91.470	N.A.	704.6572	7.25333	N.A.
430		INFINITE SOURCE	760		U (OUTPUT)	0	4.376000E+02	332.000	4238.000	1.14376	3042.6631	6.47747	5.98509E-02
+			485		U (OUTPUT)	0	4.470000E+02	255.000	21528.000	-2.29440	1110.4120	2.79891	1.23300E-03
500		INFINITE SOURCE	620		U (OUTPUT)	0	1.940000E+01	310.000	22688.000	-0.99999	1336.5412	3.29297	1.39837E-03
530		MOISTURE SEP.	510		I (INPUT)	0	4.515152E+02	362.717	15236.425		2449.6305	4.99713	

COMPONENT PROPERTIES

COMPONENT PROPERTIES												
COMPONENT			CONNECTING		FLUID		MASS FLOW		THERMO.		SPECIFIC	
NUMBER	DESCRIPTION	STREAM NUMBER	PORT ID	ID	TEMPERATURE (C)	PRESSURE (KPA)	QUALITY (-)	ENTHALPY (KJ/KG)	ENTROPY (KJ/KG-C)	VOLUME (M3/KG)		
+	530	515	U (OUTPUT)	0	4.470000E+02	362.717	19296.425	.99000	2456.3216	5.00757	6.39520E-03	
+		517	B (OUTPUT)	0	4.515152E+00	362.717	19296.425	1.00000	1792.2088	3.96331	6.44022E-03	
+								0.00000			1.95570E-03	
+	540	517	I (INPUT)	0	4.515152E+00	362.717	19296.425	0.00000	1792.2088	3.96331	1.95570E-03	
+		519	U (OUTPUT)	0	4.515152E+00	362.634	19277.129	.00134	1792.2088	3.96321	1.94271E-03	
+	550	485	IA (INPUT)	0	4.470000E+02	255.000	21528.000	-2.28440	1110.4120	2.79881	1.23300E-03	
+		519	IB (INPUT)	0	4.515152E+00	362.634	19277.129	.00134	1792.2088	3.96321	1.94271E-03	
+		780	U (OUTPUT)	0	4.515152E+02	256.446	21492.738	-2.20422	1117.2300	2.81178	1.23618E-03	
1	PEPSE CODE BY ENERGY INCORPORATED, IDAHO FALLS, ID.						VERSION 49A0	CREATED 20 SEP 83	DATE 86/09/24.		PAGE 6	
DUVHA , 600MW ONCE THROUGH PULVERIZED FUEL BOILER SIMULATION												

TABLE E.2 DETAILED HEAT EXCHANGER PERFORMANCE OUTPUT						
COMPONENT NUMBER	COMPONENT DESCRIPTION	HEAT EXCH SHELL LUSSES (W)	HEAT TO TUBE SIDE FLUID (W)	HEAT EXCH EFFECTIVENESS (-)	PRESSURE DROP TUBE (KPA)	PRESSURE DROP SHELL (KPA)
20	ROTARY REGENER.	0.0000	1.24474E+08	.9011	1.800 *	1.600 *
100	ROTARY REGENER.	0.0000	2.71171E+07	.8763	1.502 *	1.600 *
135	GEN. HT. EXCH.	0.0000	2.13229E+07	.6966	0.000	0.000
160	RADIANT STAGE	N.A.	1.06157E+08	N.A.	401.494	N.A.
170	RADIANT STAGE	N.A.	2.26485E+08	N.A.	399.988	N.A.
190	RADIANT STAGE	N.A.	1.97516E+08	N.A.	238.705	N.A.
200	CONVECTIVE STAGE	0.0000	4.74334E+07	.6274	160.000	.170
220	CONVECTIVE STAGE	0.0000	2.34168E+07	.0330	401.906	0.000
230	CONVECTIVE STAGE	0.0000	6.13030E+07	.0897	393.007	0.000
300	CONVECTIVE STAGE	0.0000	1.06149E+08	.1775	666.897	.168
330	CONVECTIVE STAGE	0.0000	9.47229E+07	.2067	801.080	.010
370	CONVECTIVE STAGE	0.0000	7.09489E+07	.1918	162.458	.010
380	CONVECTIVE STAGE	0.0000	6.09787E+07	.1812	290.000	.010
410	CONVECTIVE STAGE	0.0000	1.51484E+08	.4301	120.000	.010
420	CONVECTIVE STAGE	0.0000	1.84259E+08	.7381	689.917	0.000

+ + + + + + + + + + + + + + +

TABLE E.3

SECOND LAW OF THERMODYNAMICS PERFORMANCE - COMPONENTS

| COMPONENT
NUMBER | COMPONENT
DESCRIPTION | AVAILABILITY
CHANGE
(%) | RELATIVE
AVAILABILITY
CHANGE
(-) | MAXIMUM
POTENTIAL
FOR POWER
(W) | RELATIVE
POTENTIAL
FOR POWER
(-) | IRREVERSIBILITY
(W) | RELATIVE
IRREVERS-
IBILITY
(-) | EFFECT-
IVENESS
(-) |
|---------------------|---|--|---|--|---|------------------------|---|---------------------------|
| 20 | ROTARY REGENER.
SHELL SIDE
TUBE SIDE | -1.190936E+07
-5.312055E+07
4.121119E+07 | -.0180
-.0804
.0624 | 1.190936E+07 | .0180 | 1.190936E+07 | .0180 | .7758 |
| 40 | BURN./COMBUSTOR | -2.002805E+08 | -1.2118 | 3.297128E+03 | .5140 | 3.297128E+08 | .5140 | |
| 70 | STANDARD MIXER | -3.136304E+06 | -.0047 | 3.136304E+06 | .0047 | 3.136304E+06 | .0047 | |
| 75 | DEMAND SPLITTER | -6.987381E-03 | -.0000 | 6.987381E-08 | .0000 | 6.987381E-08 | .0000 | |
| 90 | FIXED P.C. SPLIT | 0. | 0.0000 | 0. | 0.0000 | 0. | 0.0000 | |
| 100 | ROTARY REGENER.
SHELL SIDE
TUBE SIDE | -2.257072E+06
-1.160280E+07
9.345725E+06 | -.0034
-.0176
.0141 | 2.257072E+06 | .0034 | 2.257072E+06 | .0034 | .8055 |
| 110 | STANDARD MIXER | -2.452268E+02 | -.0000 | 2.452268E+02 | .0000 | 2.452268E+02 | .0000 | |
| 130 | STANDARD MIXER | -8.851964E+05 | -.0013 | 8.851964E+05 | .0013 | 8.851964E+05 | .0013 | |
| 135 | GEN. HT. EXCH.
SHELL SIDE
TUBE SIDE | -2.730753E+06
-7.542748E+06
4.811995E+06 | -.0041
-.0114
.0073 | 2.730753E+06 | .0041 | 2.730753E+06 | .0041 | .6360 |
| 160 | RADIANT STAGE | 5.768973E+07 | .0873 | 3.462558E+07 | .0524 | 3.462558E+07 | .0524 | |
| 170 | RADIANT STAGE | 1.256964E+08 | .1902 | 7.125669E+07 | .1078 | 7.125669E+07 | .1078 | |
| 180 | RADIANT STAGE | 1.111335E+08 | .1681 | 6.071518E+07 | .0919 | 6.071518E+07 | .0919 | |
| 190 | FIXED P.C. SPLIT | 0. | 0.0000 | 0. | 0.0000 | 0. | 0.0000 | |
| 200 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -9.505187E+06
-3.700111E+07
2.749592E+07 | -.0144
-.0360
.0416 | 9.505187E+06 | .0144 | 9.505187E+06 | .0144 | .7431 |
| 220 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -6.332291E+06
-1.918111E+07
1.284783E+07 | -.0096
-.0290
.0194 | 6.332291E+06 | .0096 | 6.332291E+06 | .0096 | .6698 |

SECOND LAW OF THERMODYNAMICS PERFORMANCE - COMPONENTS

TABLE E.3 (cont)

| COMPONENT NUMBER | COMPONENT DESCRIPTION | AVAILABILITY CHANGE (B) | RELATIVE AVAILABILITY CHANGE (-) | MAXIMUM POTENTIAL FOR POWER (W) | RELATIVE POTENTIAL FOR POWER (-) | IRREVERSIBILITY (W) | RELATIVE IRREVERSIBILITY (-) | EFFECTIVENESS (-) |
|------------------|---|--|------------------------------------|---------------------------------|------------------------------------|---------------------|--------------------------------|---------------------|
| 230 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -1.614221E+07
-4.981705E+07
3.367547E+07 | -.0244
-.0754
.0510 | 1.614221E+07 | .0244 | 1.614221E+07 | .0244 | .6760 |
| 240 | STANDARD MIXER | -1.271583E+06 | -.0019 | 1.271583E+06 | .0019 | 1.271583E+06 | .0019 | |
| 270 | STANDARD MIXER | -1.347497E+05 | -.0002 | 1.347497E+05 | .0002 | 1.347497E+05 | .0002 | |
| 300 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -2.061384E+07
-8.425180E+07
6.363785E+07 | -.0312
-.1275
.0663 | 2.061384E+07 | .0312 | 2.061384E+07 | .0312 | .7553 |
| 310 | STANDARD MIXER | -1.796619E+06 | -.0027 | 1.796619E+06 | .0027 | 1.796619E+06 | .0027 | |
| 320 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -1.537251E+07
-7.326762E+07
5.789512E+07 | -.0233
-.1109
.0876 | 1.537251E+07 | .0233 | 1.537251E+07 | .0233 | .7902 |
| 350 | STANDARD MIXER | -1.640879E+06 | -.0025 | 1.640879E+06 | .0025 | 1.640879E+06 | .0025 | |
| 370 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -1.064346E+07
-5.352353E+07
4.298007E+07 | -.0161
-.0810
.0649 | 1.064346E+07 | .0161 | 1.064346E+07 | .0161 | .8011 |
| 380 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -8.897702E+06
-4.491076E+07
3.601306E+07 | -.0135
-.0680
.0545 | 8.897702E+06 | .0135 | 8.897702E+06 | .0135 | .8019 |
| 390 | STANDARD MIXER | -8.272995E+05 | -.0013 | 8.272995E+05 | .0013 | 8.272995E+05 | .0013 | |
| 410 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -1.982987E+07
-1.060155E+08
8.618558E+07 | -.0300
-.1604
.1304 | 1.982987E+07 | .0300 | 1.982987E+07 | .0300 | .8130 |
| 420 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -2.046010E+07
-1.127828E+08
9.232272E+07 | -.0310
-.1706
.1397 | 2.046010E+07 | .0310 | 2.046010E+07 | .0310 | .8186 |
| 520 | MOISTURE SEP. | -1.984766E+02 | -.0000 | 1.984766E+02 | .0000 | 1.984766E+02 | .0000 | |
| 540 | STANDARD VALVE | 1.231839E+02 | .0000 | -1.231839E+02 | -.0000 | -1.231839E+02 | -.0000 | |
| 550 | STANDARD MIXER | -1.700402E+05 | -.0003 | 1.700402E+05 | .0003 | 1.700402E+05 | .0003 | |

TABLE E.4

DETAILED FURNACE/COMBUSTOR PERFORMANCE OUTPUT

| COMPONENT
NUMBER | FUEL
FIRING RATE
(KG/S) | FRACT.
EXCESS
AIR
(-) | AD.
FLAME
TEMP.
(C) | EXIT
TEMP.
(C) | ENERGY IN
WITH AIR
(W) | ENERGY IN
WITH FUEL
(W) | ENERGY OUT
WITH REFUSE
(W) | ENERGY LOST
TO
ENVIRONMENT
(W) | ENERGY OUT
WITH
FLUE GAS
(W) | NET HEAT
TO RADIANT
STAGES
(W) |
|---------------------|-------------------------------|----------------------------------|------------------------------|----------------------|------------------------------|-------------------------------|----------------------------------|---|---------------------------------------|---|
| 40 | 7.00302E+01 | .2601 | 1898.4 | 1307.4 | 1.38966E+08 | 1.45057E+09 | 7.81775E+06 | 1.49310E+06 | 1.05096E+09 | 5.30258E+08 |

APPENDIX F

Design component input* file for the superheater 3.
Structured by the user for explaining flow logic to the
computer and input of data on design.

* Page over for input file

| LINE NO. | OUTPUT | SUPPRESSION CARDS |
|----------|--------|--------------------------|
| 14 | * | |
| 15 | * | |
| 16 | * | STATUS |
| 17 | * | NO |
| 18 | | NOPT |
| 19 | | NOPT |
| 20 | | PRINT |
| 21 | | NOPT |
| 22 | | NOPT |
| 23 | | NOPT |
| 24 | | NOPT |
| 25 | | NOPT |
| 26 | | NOPT |
| 27 | | NOPT |
| 28 | | PRINT |
| 29 | | NOPT |
| 30 | | NOPT |
| 31 | | NOPT |
| 32 | | NOPT |
| 33 | | NOPT |
| 34 | | NOPT |
| 35 | | NOPT |
| 36 | | PRINT |
| 37 | | PRINT |
| 38 | | NOPT |
| 39 | | NOPT |
| 40 | | NOPT |
| 41 | | NOPT |
| 42 | | NOPT |
| 43 | | NOPT |
| 44 | | NOPT |
| 45 | | NOPT |
| 46 | | NOPT |
| 47 | | NOPT |
| 48 | | NOPT |
| 49 | | NOPT |
| 50 | | NOPT |
| 51 | | NOPT |
| 52 | | NOPT |
| 53 | | * END OUTPUT SUPPRESSION |
| 54 | | |
| 55 | | |
| 56 | | REFERENCE DATA |
| 57 | | TTAIR |
| 58 | | 20.00 |
| 59 | | |
| 60 | | * GEOMETRY INPUT DATA |
| 61 | | FROM |
| 62 | | 50XXX0 |
| 63 | | 502000 |
| 64 | | 502100 |
| 65 | | 502200 |
| 66 | | 502300 |
| 67 | | * STEAM SPECIFICATIONS |
| 68 | | 60YYY0 |
| 69 | | 602000 |
| 70 | | 602100 |
| 71 | | 602200 |
| 72 | | 602300 |
| 73 | | |
| 74 | | * COMPONENT SPECS. |
| 75 | | |
| 76 | | |


```

77 * * * CONVECTIVE STAGE - SUPERHEATER 3
78 * * *
79 * * * 70YYS CTYPE NMGDHX WGUSS PGUSS TGUSS
80 * * * 70YYS NMFUEL XHT XWID RHL ZTIN ZTOUT
81 * * * NCONV NGLG PCHLN PCHLN FCHLN ZTIN ZTOUT
82 * * * NPASS PCHLN PCHLN PCHLN FCHLN ZTIN ZTOUT
83 * * * EMISS CICTIRH FOUL ECTUP FRMLS HTIRH AATIRH
84 * * * PCHTU PCHT2 PCHT3 PCHT4 PCHT5 PCHT6 PCHT7
85 * * * 700500 29 1 487.5 18616.0 435.0
86 * * *
87 * * * DESIGN CARD
88 * * *
89 * * * 700504 3
90 * * * 1 20.3 17.2 17.186 40.0 26.0
91 * * * 2.0 23.9 38.0 55.0 58.35 61.3
92 * * * 0.2 30.0 6.0 0.0006 0 0.00 2460.00
93 * * * 0.03126 -0.1540 0.2934 17380.0 6.0001 91.51
94 * * *
95 * * * SOURCE AND SINK DATA
96 * * *
97 * * * SINK
98 * * * 70YYS CTYPE
99 * * * 700400 30
100 * * *
101 * * * SOURCE (FLUE GAS )
102 * * * 70YYS CTYPE TVSC PVSC WWSV
103 * * * 700200 31 1238.0 91.52 605.9
104 * * *
105 * * * MATERIAL SPECS. (FLUE GAS)
106 * * * 70YYS NAME1 XMASSF NAME2 XMASSF NAME3 XMASSF NAME4 XMASSF
107 * * * 700204 CO2 0.12 H2O 0.098 O2 0.035 N2 0.747
108 * * *
109 * * * OUTPUT - STEAM
110 * * * 70YYS CTYPE
111 * * * 700300 32
112 * * *
113 * * * INPUT STEAM
114 * * * 70YYS CTYPE TVSC PVSC WWSV
115 * * * 700100 33 440.0 18618.0 487.5
116 * * *
117 * * *

```


APPENDIX G

Contained in this appendix is the design output* results file as structured by PEPSE for feasibility of reading.

* Page over for output results

TABLE G.1

COMPONENT PROPERTIES

| COMPONENT NUMBER | COMPONENT DESCRIPTION | CONNECTING STREAM NUMBER | PORT ID | FLUID ID | MASS FLOW (KG/SEC) | TEMPERATURE (C) | PRESSURE (KPA) | THERMO. QUALITY (-) | ENTHALPY (KJ/KG) | ENTROPY (KJ/KG-C) | SPECIFIC VOLUME (M3/KG) |
|------------------|-----------------------|--------------------------|------------|----------|--------------------|-----------------|----------------|-----------------------|------------------|-------------------|-------------------------|
| 10 | INPUT COMPONENT | 200 | U (OUTPUT) | 0 | 4.875000E+02 | 440.000 | 18618.000 | 1.77906 | 3053.8095 | 5.91953 | 1.35207E-02 |
| 20 | INFINITE SOURCE | 210 | V (OUTPUT) | 2 | 6.099000E+02 | 1238.000 | 91.520 | | 2028.0645 | 8.80905 | |
| 30 | OUTPUT COMPONENT | 220 | I (INPUT) | 0 | 4.875000E+02 | 496.366 | 17880.000 | | 3260.0750 | 6.21343 | |
| 40 | INFINITE SINK | 230 | I (INPUT) | 2 | 6.099000E+02 | 1115.443 | 91.510 | | 1863.1942 | 8.69531 | |
| 50 | CONVECTIVE STAGE | 200 | T (INPUT) | 0 | 4.875000E+02 | 440.000 | 18618.000 | | 3053.8095 | 5.91953 | |
| | | 210 | S (INPUT) | 2 | 6.099000E+02 | 1238.000 | 91.520 | | 2028.0645 | 8.80905 | |
| | | 220 | T (OUTPUT) | 0 | 4.875000E+02 | 496.366 | 17880.000 | | 3260.0750 | 6.21343 | |
| | | 230 | D (OUTPUT) | 2 | 6.099000E+02 | 1115.443 | 91.510 | | 1863.1942 | 8.69531 | |

1 PEPSE CODE BY ENERGY INCORPORATED, IDAHO FALLS, ID. VERSION 49A0 CREATED 20 SEP 83 DATE 86/09/24. PAGE 2
DESIGN MODE PROGRAM - SUPERHEATER 3

TABLE G.2

DETAILED HEAT EXCHANGER PERFORMANCE OUTPUT

| COMPONENT NUMBER | COMPONENT DESCRIPTION | HEAT EXCH SHELL LOSSES (W) | HEAT TO TUBE SIDE FLUID (W) | HEAT EXCH EFFECTIVENESS (-) | HEAT EXCH TUBE (KPA) | HEAT EXCH SHELL (KPA) |
|------------------|-----------------------|----------------------------|-----------------------------|-------------------------------|----------------------|-----------------------|
| 50 | CONVECTIVE STAGE | 0.0000 | 1.00554E+08 | .1500 | 738.000 | .010 |

1 PEPSE CODE BY ENERGY INCORPORATED, IDAHO FALLS, ID. VERSION 49A0 CREATED 20 SEP 83 DATE 86/09/24. PAGE 3
DESIGN MODE PROGRAM - SUPERHEATER 3

| DETAILED HEAT EXCHANGER DESIGN OUTPUT | | | | |
|---------------------------------------|-----------------------|----------------------------------|---------------------------------|--|
| TABLE G.3 | | | | |
| COMPONENT NUMBER | COMPONENT DESCRIPTION | HEAT TRANS. COEFFICIENT (W/M2-C) | EFFECTIVE HEAT TRANS. AREA (M2) | |
| 50 | CONVECTIVE STAGE | 58.081 | 2460.00 | |

1 PEPSE CODE BY ENERGY INCORPORATED, IDAHO FALLS, ID. VERSION 49AD CREATED 20 SEP 83 DATE 86/09/24. PAGE 4
DESIGN MODE PROGRAM - SUPERHEATER 3

| SECOND LAW OF THERMODYNAMICS PERFORMANCE - COMPONENTS | | | | | | | | |
|---|---|---|---|--|---|------------------------|---|-----------------------------|
| COMPONENT
NUMBER | COMPONENT
DESCRIPTION | AVAILABILITY
CHANGE
(W) | RELATIVE
AVAILABILITY
CHANGE
(-) | MAXIMUM
POTENTIAL
FOR POWER
(W) | RELATIVE
POTENTIAL
FOR POWER
(-) | IRREVERSIBILITY
(W) | RELATIVE
IRREVERS-
IBILITY
(-) | EFFECT-
IVENESS
(-) |
| 50 | CONVECTIVE STAGE
SHELL SIDE
TUBE SIDE | -2.092611E+07
-8.01191E+07
5.928581E+07 | -1.0000
-3.8656
2.8666 | 2.092611E+07 | 1.0000 | 2.092611E+07 | 1.0000 | .7414 |

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