NEURAL NET CONTROLLER FOR INDUSTRIAL BOILER SYSTEMS

A Thesis

Submitted to the Department of Electrical and Electronic Engineering, BUET, Dhaka in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

by

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APRIL 1997

DEDICATED TO MY PARENTS

CERTIFICATE

This is to certify that the work presented in this thesis was done by me under the complete supervision of Dr. Pran Kanai Saha, Associate Professor, Department of Electrical and Electronic Engineering, BUET, Dhaka, Bangladesh. It is also certified that this thesis work has not been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

Boiler is the heart of the chemical process industries like fertilizer manufacturing plant. Automatic boiler control system is desirable for safe, economic and reliable operation of the industry. Conventional three elements Proportional plus Integral plus Derivative (PID) controller are generally used in the different control loops of the boiler. Main drawback of the use of this type of the controller is the adjustment of controller's parameters such as gain, reset time and dead time due to change of operating point of the process. However, the application of Self Tuning Controller (STC) and Model Reference Adaptive Controllers (MRAC) can overcome this drawback in the case of linear process plant. The boiler plant is highly nonlinear plant. Thus a neural network based integrated control system is proposed to control an industrial boiler. A 120 ton per hour capacity boiler of the Zia Fertilizer Company Limited (ZFCL), Ashuganj, Bangladesh is taken as reference boiler for the case study.

Boiler — To produce steam →
Steam → To run turbine → EEE

The process inverse dynamic modelling technique is applied to design the proposed controller. A multilayer feedforward and diagonal recurrent neural network is trained to identify the unknown inverse dynamic model of the boiler plant by general backpropagation and dynamic back propagation training algorithm respectively. The training data was collected from the computer data bank of the reference boiler. After investigating the performance of both network, the feedforward network architecture is selected for the proposed controller. Using the weights of the network a new software controller is then developed for integrated control system of the ZFCL boiler. The developed controller is tested by using the boiler input - output data that are not used during the training. The output response of the developed controller is compared with that of the existing PID controller. Both responses are very close to each other. The developed controller output is then converted into signal using pulse width control technique. These signals can then be used for on-line regulation of the control valves through parallel port of the computer. The average value of the pulse indicates the percentage of the valve opening.

CONTENTS

CHAPTER-FIVE : REAL TIME OPERATION OF THE PROPOSED CONTROLLER

CHAPTER-SIX : CONCLUSION

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
BP	Backpropagation
DBP	Dynamic Backpropagation
DIM	Direct Inverse Modeling
DRN	Diagonal Recurrent Network
FFN	Feedforward Network
FT	Flow Transmitter
FIC	Flow Indicating Controller
GBP	General Backpropagation
LT	Level Transmitter
LIC	Level Indicating Controller
MIMO	Multi Input Multi Output
MRAC	Model Reference Adaptive Controller
NN	Neural Network
NNC	Neural Network Controller
PID	Proportional plus Integral plus Derivative
PT	Pressure Transmitter
PIC	Pressure Indicating Controller
PWC	Pulse Width Control
RSP	Remote Setpoint
STC	Self Tuning Controller
SISO	Single Input Single Output
SQRT	Square Root Extractor
TT	Temperature Transmitter
TIC	Temperature Indicating Controller
ZFCL	Zia Fertilizer Company Limited

LIST OF FIGURES

LIST OF TABLES

CHAPTER - ONE

INTRODUCTION

- INTRODUCTION
- LITERATURE REVIEW ON RECENT DEVELOPMENT IN ANN BASED CONTROL
- THE AIM AND OBJECTIVE OF THE THESIS
- THESIS LAYOUT

1.0 INTRODUCTION

A urea fertilizer manufacturing plant is an arrangement of processing units such as reformer, shift converter, absorber, desorber, methanator, ammonia converter, compressor, and urea reactor in a systematic and rational way. Steam is required for chemical process of the plant as well as for generating electricity for the plant. The valuable raw material such as natural gas and chemically treated water is being used to produce steam by an industrial boiler. Thus, one of the major production cost of the urea fertilizer depends on the cost of steam generation. This cost can be reduced by proper operation of the boiler plant which can be ensured by a sophisticated boiler control system.

Designing a control system for a boiler plant is very complicated as it involves a large number of theoretical and practical considerations such as the optimum controller response, stability, reliability, safety, operation, range of control and cost of the control system. The difficulties are aggravated by the fact that boiler plant is highly nonlinear, imprecisely known, multivariable systems with many interactions. Thus it is always desirable that an automatic control system for a boiler plant must be able to handle a wide range of unmeasurable disturbances, measurement noise, interactions from other control loops, actuators limitations and process dead time [1].

Rapid technological developments in digital computing systems coupled with significant reduction in their cost have had a profound effect on how process plants can be controlled. High speed computations along with the large information storage capacity possessed by digital computers provides virtually unlimited intelligence which allows the use of quite advance control techniques such as adaptive, inferential, multivariable and supervisory control [1],[2].

Automatic boiler control system is desirable for safe, economic and reliable operation of the industry. In the early days steam pressure, steam temperature, drum water level of boiler were controlled independently by Single Input Single Output (SISO) controller. But as boilers grew bigger in capacity, with correspondingly increased pressure levels, the SISO independent control schemes were ineffective in maximizing the boiler performance [3],[4].

Conventional three elements Proportional plus Integral plus Derivative (PID) controllers are generally used to control of the boiler plant. These types of controllers often require gain, reset time and dead time adjustment according to change of process for satisfactory performance at a particular operating condition [5]-[8].

With the progress of control theories, adaptive control system such as Model Reference Adaptive Control (MRAC) [5],[9] and Self Tuning Control (STC) [7],[9] have been developed to tune the controller's parameters automatically which is generally used in linear process plant. Boiler plant behaviors are usually non -linear [10]. Classical adaptive control systems had problems when dealing with non-linear plants or plants with unknown model. Moreover for adaptive controller, its response speed is the main determining factor for its successful application in practice. The parameter identification and optimization procedure requires a lot of computational time especially when a higher order discrete model is used to represent the control system. This problem is more often is encountered in Multi Input Multi Output (MIMO) cases like boiler plant [11]. To solve these problem a new emerging tool is the Artificial Neural Network (ANN) which tries to mimic the biological brain neural networks into mathematical model. The ANN offers more intelligent control than conventional adaptive control theories, which makes a framework for non-linear modeling, identification and control of plant by its learning, adaptation, self-organization, non-linear function approximation and massively parallel processing capabilities[10]-[12]. Thus, in this thesis work an attempt has been made to control a multivariable nonlinear plant like industrial boiler plant, using a ANN based integrated controller.

1.1 LITERATURE REVIEW ON RECENT DEVELOPMENT IN ANN BASED CONTROL

The application of ANN in different control systems such as supervised control [13],[14] direct inverse control (off-line) [15]-[20], indirect inverse control [21]-[24], self learning control [25]-[29], dynamic optimization [27] and backpropagation through time[30] have been reported by many researchers. The ANN based each control technique is briefly described in the following paragraphs.

In *Supervised control,* a Neural Network (NN) learns the mapping from sensor inputs to desired actions by adapting to a training set of examples of what it should do [14]. In this system, the more difficult task is to build a correct database of proper action, which usually comes from an expert operator. This type of control is feasible for complex and poorly defined processes for which no suitable conventional controller is available.

In Self learning control, a NN trains to find and optimise a control strategy, without guidance of exemplar training patterns[25],[26]. In most cases, the training is carried out on a model of the process. Moreover, the training involves assuming a set parameters for a given controller network and evaluating a performance measure for the set. A performance measure is used as the training signal. The network inputs are, generally, current and past value of the plant inputs and outputs. Thus, the accuracy of this type of control system is determined by the accuracy of the model used for training.

In *direct inverse control,* a NN is trained by using process input-output data so that it is able to extract the inverse mapping between the output and the control input. A multi layered Neural Network Controller proposed by D.Psaltis *et al.*[18], was trained by plant input-output data to get the inverse dynamics of the control plant. The training data was obtained from the plant input output relationship through time. The off-line learning of the NN was carried out to minimize the overall squared error (E^2) which is the difference between desired and network predicted input. Controller was then designed by using the connection weights between the layers obtained from the learning process. This type of control was employed by J. L. Dirion *etal.* [19] for temperature control of an experimental semi-batch pilot reactor. The same technique was also used by J.Savkovic-Stevanovic [20] to control the product composition of an industrial distillation plant. The use of Neural Net Controller (NNC) proposed by the researcher [21] for controlling a complex system requires a long training time because of the use of large amount of off-line input/output data of the plant.

In order to overcome the off-line learning problems as described in the previous paragraph, P. Rasiskila *etal.* [23] developed the on-line specialized learning structure. In this method, the NN was trained in region of interest only. The reference value was the input signal for the NN. The network was then trained to find out the plant output that drived the system output to the reference value. The weights of the NN were adjusted so that the error between the actual system output and the reference value could be decreased in every iteration. However, this method of control may be initially unstable during learning because the network controls the system directly by itself. Thus in order to avoid the instability, it is necessary to prepare the initial value of the weights for the NN, which may be acquired by prior off-line learning.

The comprehensive review shows that Direct Inverse Modeling (DIM) technique is very easier and fast to design a controller[24]. In this thesis work this design technique is chosen to develop a NNC for industrial boiler.

1.2 THE AIM AND OBJECTIVE OF THE THESIS

Boiler plant is the heart of the process industries like fertilizer, refinery and steam power plant. The Boiler plant is highly nonlinear, imprecisely known, multivariable systems with many interactions. The conventional single input single output controller is ineffective in maximizing the performance of multivariable nonlinear boiler plant[2][3]. A single architecture multi input multi output nonlinear controller may be capable of maximizing the performance of a boiler. Thus this thesis was aimed at developing a NN based integrated control systems for the 120 ton per hour capacity boiler (which is presently controlled by nine conventional PID controllers) of Zia Fertilizer Company Limited at Ashuganj, Bangladesh.

To fulfill the aim the following objectives were envisaged.

- Identification of unknown inverse dynamic of the boiler plant from the training of a multilayer neural network.

- Implementation of general backpropogation and dynamic backpropagation training algorithm for feedforward network and diagonal recurrent networks respectively to investigate the convergence rate, minimum error and neural net controller output response.

- Selection of the best ANN architecture which provides the fastest convergence with minimum error and desired output response.

- Development of software controller for ZFCL boiler using weights of the selected trained ANN.

- Conversion of the controller output into signals which can be used for on-line regulation of the control valves.

1.3 THESIS LAYOUT

Chapter 2 describes the existing conventional boiler control system of ZFCL. The theory and training algorithm of ANN is briefly described in chapter 3. In chapter 4, the ANN based control system of boiler plant is presented. Test results, comparison and performance of the controller are also given in chapter 4. On-line operation of the neural network based controller is described in chapter 5. Chapter 6 contains the conclusion and recommendation for further research.

CHAPTER - TWO

BOILER CONTROL SYSTEM OF ZFCL

- INTRODUCTION
- COMBUSTION CONTROL
- DRUM LEVEL CONTROL
- TEMPERATURE CONTROL

2.0 INTRODUCTION

Two high pressure boilers are being used to generate steam at ZFCL. One of the boilers known as BABCOCK boiler generates steam 195 ton/hr at 100% load. Another boiler known as SD Boiler generates 120 ton per hour steam at 100% load. A single line diagram of steam generation and distribution system of ZFCL is shown in Fig. 2.1.

To supply constant thermal energy to the process, it requires to maintain a constant pressure and temperature at common header from where the steam is distributed at various units of the plant. Thus it is desirable a boiler control system to provide steam at the desired pressure, temperature and quantity as demanded by the process.

Boiler control system of ZFCL consists of three control loops : (i) Combustion control (ii) Drum level control and (iii) Temperature control. In the case of BABCOCK boiler, combustion control and temperature control are performed manually whereas the drum level control is done automatically. Thus this boiler generates steam at a fixed rate. On the other hand, in the case of SD boiler, all controls are performed automatically except temperature control which is done manually.

The plant common steam header pressure and temperature are being maintained at a desired set point by only controlling the SD boiler. Nine microprocessor based PID controller are being used for automatic combustion and drum level control of the SD boiler. Combustion control, drum level control and temperature control system of SD boiler at ZFCL are described in the following sections.

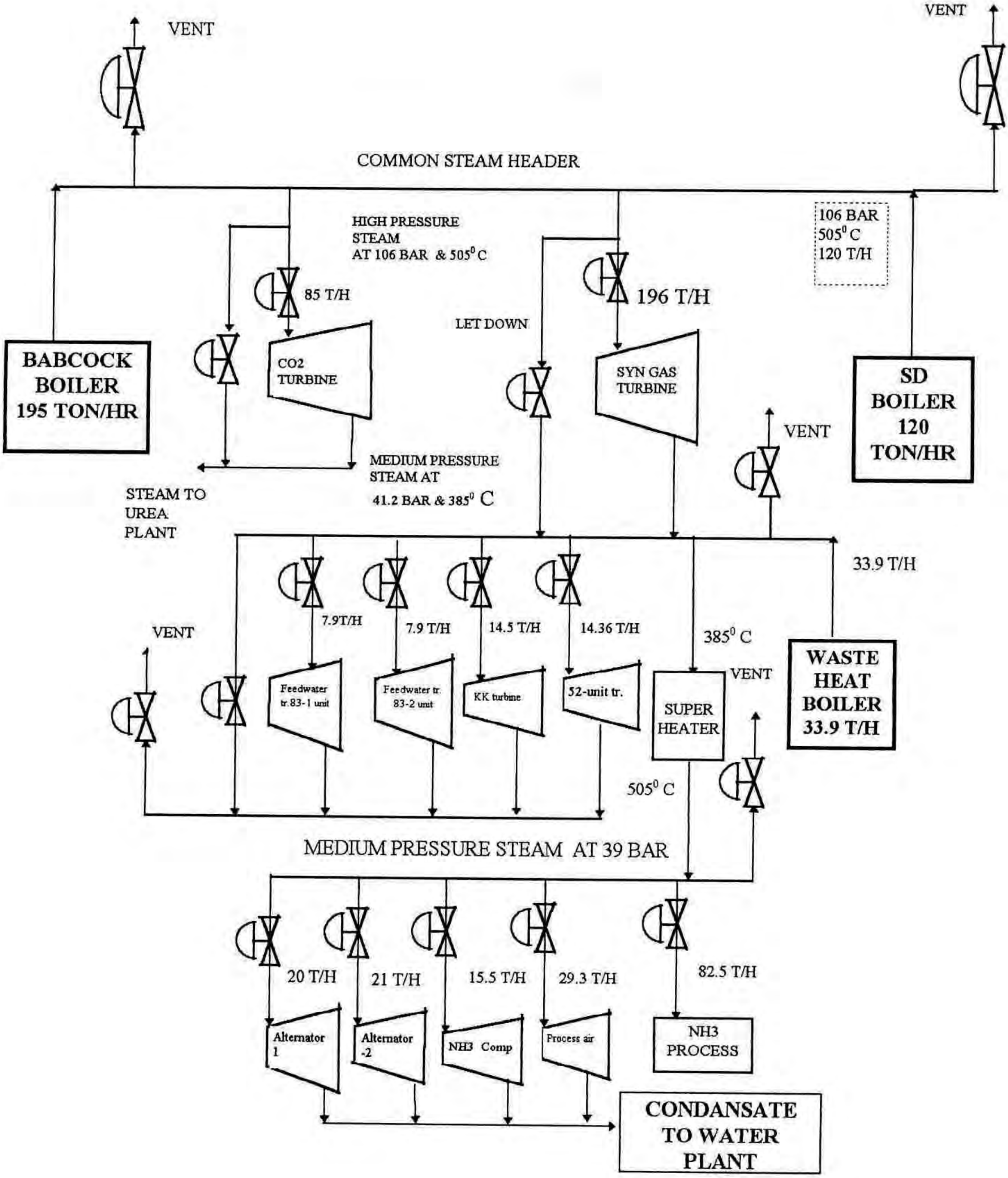


Fig.2.1. Steam generation and distribution of Zia Fertilizer Company Ltd.

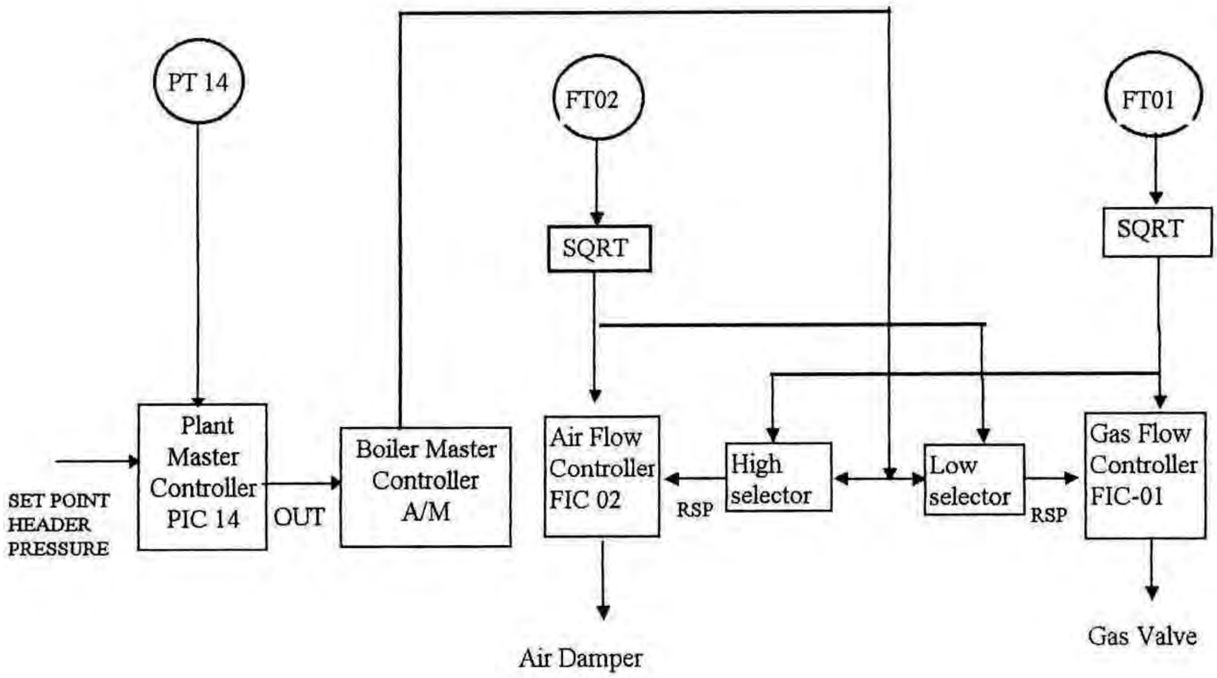
2.1 COMBUSTION CONTROL

The combustion control loop regulates the heat input to the boiler. This means that the control loop must regulates both fuel and air in order to maintain the best combustion efficiency under varying load conditions [31],[32].

Basically there are two methods of combustion control: (i) direct positioning control and (ii) metering control. In the direct positioning combustion control, the firing rate demand signal from plant master controller of the combustion control loop is transmitted directly to the fuel control valve and the combustion air fan damper. Thus this technique is referred to as open loop control as the fuel and air are not measured.

In a metering combustion control system, close loop control is used instead of open loop control. There are three types of metering combustion controls: (i) series metering control (ii) parallel metering control and (iii) parallel metering with high-low selector. The first two methods are well described in the literature [31], [32]. The third method of control is used for combustion control of SD boiler of ZFCL. A schematic block diagram of the third method is shown in Fig 2.2.

The pressure transmitter PT14 transmits common steam header pressure to plant master controller. The Master controller computes the error between the actual steam header pressure and its desired set point. The output of master controller is fed as firing rate demand signal to auto/manual station which is used in the combustion loop to modulate the fuel and air to the boiler in order to maintain the steam header pressure at its desired set point.



PT 14 = Plant steam header pressure transmitter, FT 01 = Gas flow transmitter
FT 02 = Air flow transmitter, RSP = Remote set point, SQRT= Square root extractor
A/M = Auto/ Manual station

Fig. 2.2. Combustion control system of boiler.

The firing rate demand signal from auto/manual station is fed to both fuel and air controller. A low signal selector is positioned in set point signal line to the fuel flow controller while a high signal selector is positioned in the set point signal line to the air flow controller. The low signal selector and high signal selector is also fed by measured air flow signal and measured fuel flow signal respectively. Both high and low selectors ensure the immediate increasing of the air flow for high steam demand and decreasing of fuel flow for the low steam demand. Finally gas and air control valve operates according to the deviation between above remote set point signal and measured flow signal of gas and air which are measured by FT-01 and FT-02 flow transmitter respectively.

2.2 DRUM LEVEL CONTROL

The drum level control system is designed to provide continuous mass balance i.e. for every pound of steam produced a pound of water is added to the drum. In the drum, boiler water is a combination of steam bubbles and water which depends on drum pressure. Increasing in steam demand causes a temporary drop of pressure in the drum. Thus steam bubbles and water will be increased, tending to make water swell and raising the water level. At the same time the increasing in load requires the increased flow of feed water. This feed water is comparatively cool in comparison with the near saturation temperature of water available in the drum. Increase in feed water flow cools the water in the drum and causes the level to shrink or fall [31][32].

There are three types of drum level control system such as

(i) Single element type control where only drum level is measured and is controlled by adding feedwater to compensate for water losses.

(ii) Two element type control where the feedwater flow for controlling the drum level is influenced by the steam flow and drum level.

(iii) Three element type control system where the feedwater valve position is influenced by three variables such steam flow, feedwater flow and drum level.

The third method is used to control the drum level at ZFCL. A schematic diagram of the drum level control system is shown in Fig 2.3. This type of control system is designed to regulate the flow of feed water and steam in such a manner as to hold the level of water at desired limit and can be compensated for swell and shrink effects. The steam flow can be measured by using the orifice or nozzle. Load changes in the form of steam flow change is measured by the FT-05 whose signal is transmitted to feed water flow calculator (FY-03). The level transmitter LT-06 transmits the drum level signal to the drum level controller which produces the necessary corrective signal to maintain drum level at its set point. The controller output is then transmitted to the feed water flow calculator which computes the signal A as given in equation (2.1). The signal A is known as remote set point of feedwater flow controller.

$$A = L + S - B \tag{2.1}$$

Where,

L = Level controller output (%)

S = Steam flow

B = Bias is selected as level controller output signal for 50% drum level.

Finally feed water control valve operates according to deviation between remote set point signal and measured feed water flow signal.

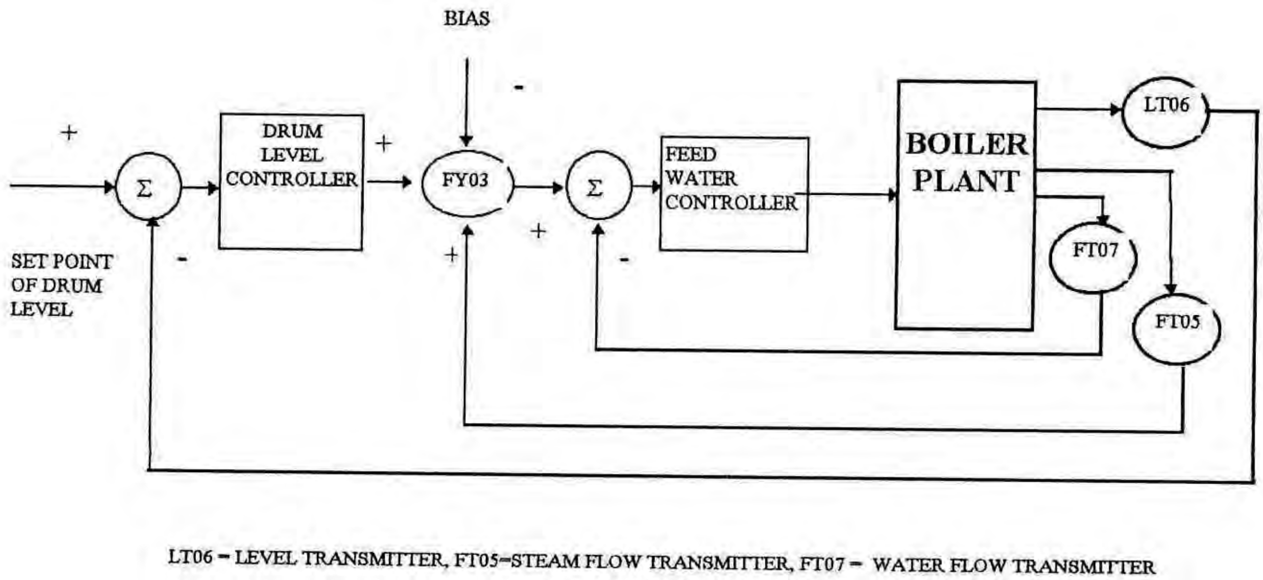
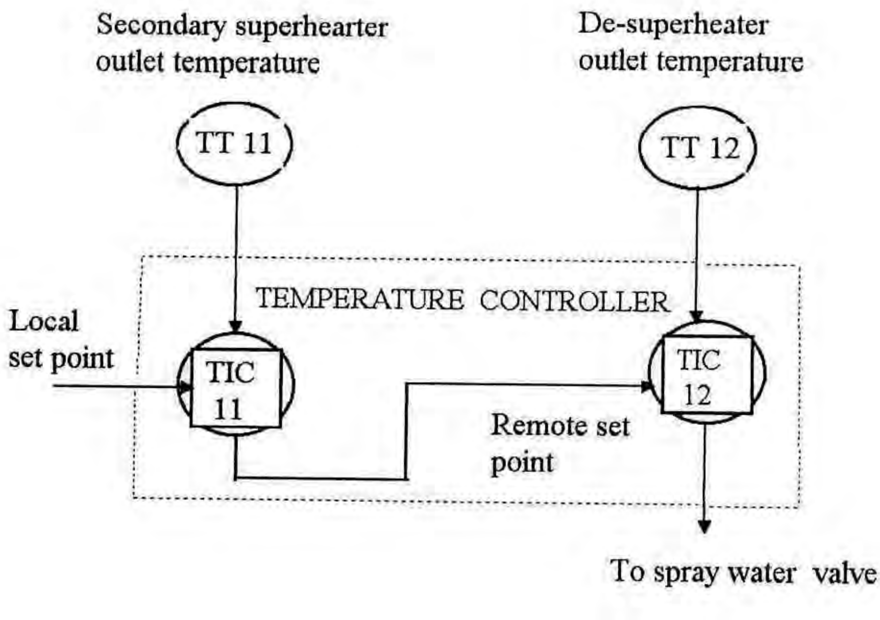


Fig. 2.3 Three elements drum level control.

2.3 TEMPERATURE CONTROL

Two element steam temperature control loop shown in Fig.2.4 uses a cascade control to maintain the final superheated outlet temperature at desired value. The primary controller TIC11 receives a final steam temperature signal from temperature transmitter TT11. The received signal is compared with the local set point of TIC11. An error which is the difference between the measured temperature and the local set point causes a change in the control output which acts as a set point of the secondary controller TIC12. This controller also receives a signal from temperature transmitter TT12 which measures the steam temperature at the outlet of the desuperheater of the boiler. Increase in the final steam temperature will cause a decrease in the set point signal of the secondary controller. The controller output then adjusts the spray water flow in order to reduce the desuperheater outlet steam temperature for maintaining the desired temperature.



TT = Temperature transmitter and TIC = Temperature indicating controller

Fig.2.4 Steam temperature control system of boiler.

CHAPTER - THREE

ARTIFICIAL NEURAL NETWORKS

- INTRODUCTION
- ARTIFICIAL NEURAL NETWORKS
- GENERAL BACKPROPAGATION WITH MULTI LAYER FEEDFORWARD NETWORK
- DYNAMIC BACKPROPAGATION WITH MULTI LAYER DIAGONAL RECURRENT NETWORK

3.0 INTRODUCTION

Among the various intelligent system ANN is one of the potential tools. It has attracted significant attention in several disciplines such as signal processing, pattern recognition, and control [13]. The success of this tool is mainly attributed due to the unique feature of the Neural Networks, such as:

(i) Learning ability by adjusting their network interconnection weights and biases based on a learning algorithm.

(ii) Parallel structure with distributed storage and processing of information.

Challenges in modern control system design are characterized by large dimentionality, computational complexity, nonlinearity, and uncertainty. Neural networks can be a very powerful tool in dealing with such requirements[13]. The following sections describe the basic theory of ANN and learning algorithms.

3.1 ARTIFICIAL NEURAL NETWORKS

The ANN is an information-processing system that has certain performance characteristics in common with biological neural networks of human brain.The basic element of biological model of the human brain is called neuron and shown in Fig. 3.1. A biological neuron has three types of components such as dendrites, soma and axon. Many inputs enter the neuron with different synaptic weights through dendrites. Soma or cell body of the neuron process these information. The output of the cell body is transmitted through axon to another neuron. Humans are born with as many as 100 billion neurons. Each neuron has an average 10,000 connections to its neighbors, so that the human neocotrex has about 10^{15} connections[33]. The massive parallelism in human brain serves a strong motivation for the idea of building an intelligent machine modelled after biological neurons, which is known as artificial neural networks[33],[34].

To simulate artificial neural networks, a simplified mathematical model can be extracted from biological is neuron which is shown in Fig. 3.2. The model is based on the following assumptions:

(i) Information processing occurs at many simple elements called neurons.

(ii) Signals are passed between neurons over connection links.

(iii) Each connection link has associated weight, which in a typical neural net, multiplies the signal transmitted.

(iv) Each neuron applies an activation function (usually nonlinear) to its net input (sum of the weighted input signals) to determine its output signal.

Generally, a neural network is characterized by

(i) The connection between the neurons known as architecture,

(ii) Activation function and

(iii) Learning algorithm.

Existing neural network architecture can be divided into three basic categories: feedforward, recurrent, and self-organizing neural networks[34]. In feedforward networks the signals flow from the input units to the output units in a forward direction. But in recurrent network the output signal of a neuron is fed back to its input. In a self - organizing neural network, neighboring units compete in their activation by means of mutual lateral interactions, and develop adaptively into specific

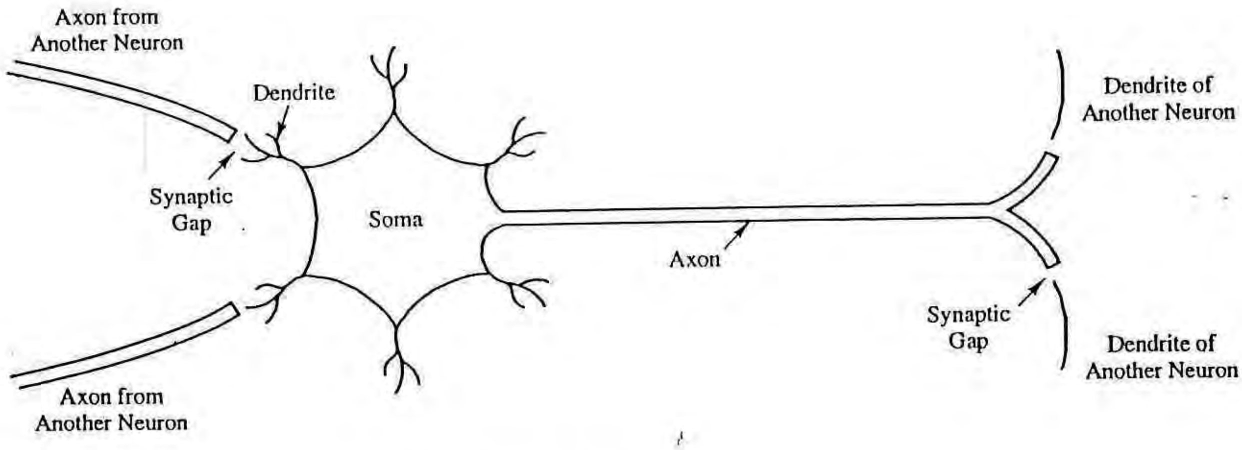
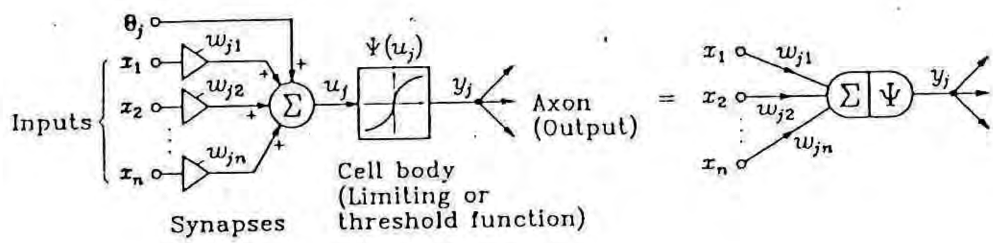
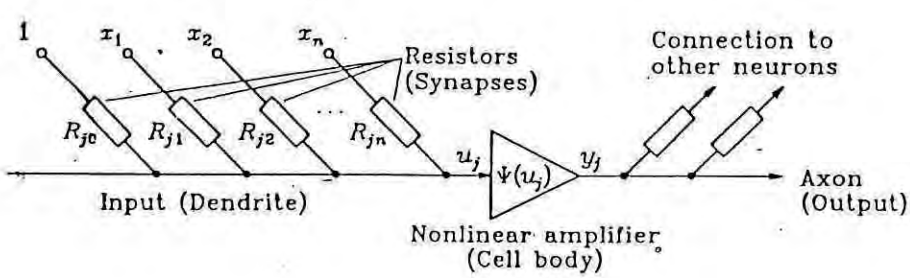


Fig. 3.1 Biological neuron.



(a)



(b)

Fig. 3.2 (a) Mathmatical model of Biological Neuron

(b) Electronic analog model of biological Neuron.

detectors of different signal patterns. Again each categories can subdivided as single layer and multilayer connection. A single layer net has one layer of connection weight whereas a multilayer net has one or more layers of nodes (called hidden units) between the input units and the output units. Multilayer nets can solve more complicated problems than single layer nets, but training may be more difficult. However, in some cases training may be more successful, because it is possible to solve a problem that a single layer net can not be trained to perform correctly at all [34],[35].

Several types of activation functions are linear, linear with saturation, threshold, and nonlinear sigmoid function. All types of function shown in Figure 3.3. In order to achieve the advantage of multilayer nets, nonlinear activation functions are required. Because the results of feeding a signal through multilayer net with linear activation functions are no different from what can be obtained using a single layer. There are three general learning schemes in neural networks such as (i) supervised learning in which the correct output signal for each input vector to be specified , (ii) unsupervised or self organising learning in which the network self-adjusts its parameters and structure to capture the regularities of input vector, without receiving explicit information from external environment, and (iii) reinforcement or graded learning in which the network receives implicit scalar evaluations of previous inputs[34].

Among these three learning schemes, supervised learning is used for real-time learning controller function, nonlinear mappings and process parameter identification for adaptive and intelligent control of dynamic systems. The most useful learning algorithm of supervised learning is backpropagration technique.

Multi layered feedforward and diagonal recurrent network architecture has been chosen for the present work. The nonlinear sigmoid function is used as an activation function of the hidden neurons in both network. For output neurons of the feedforward network, the

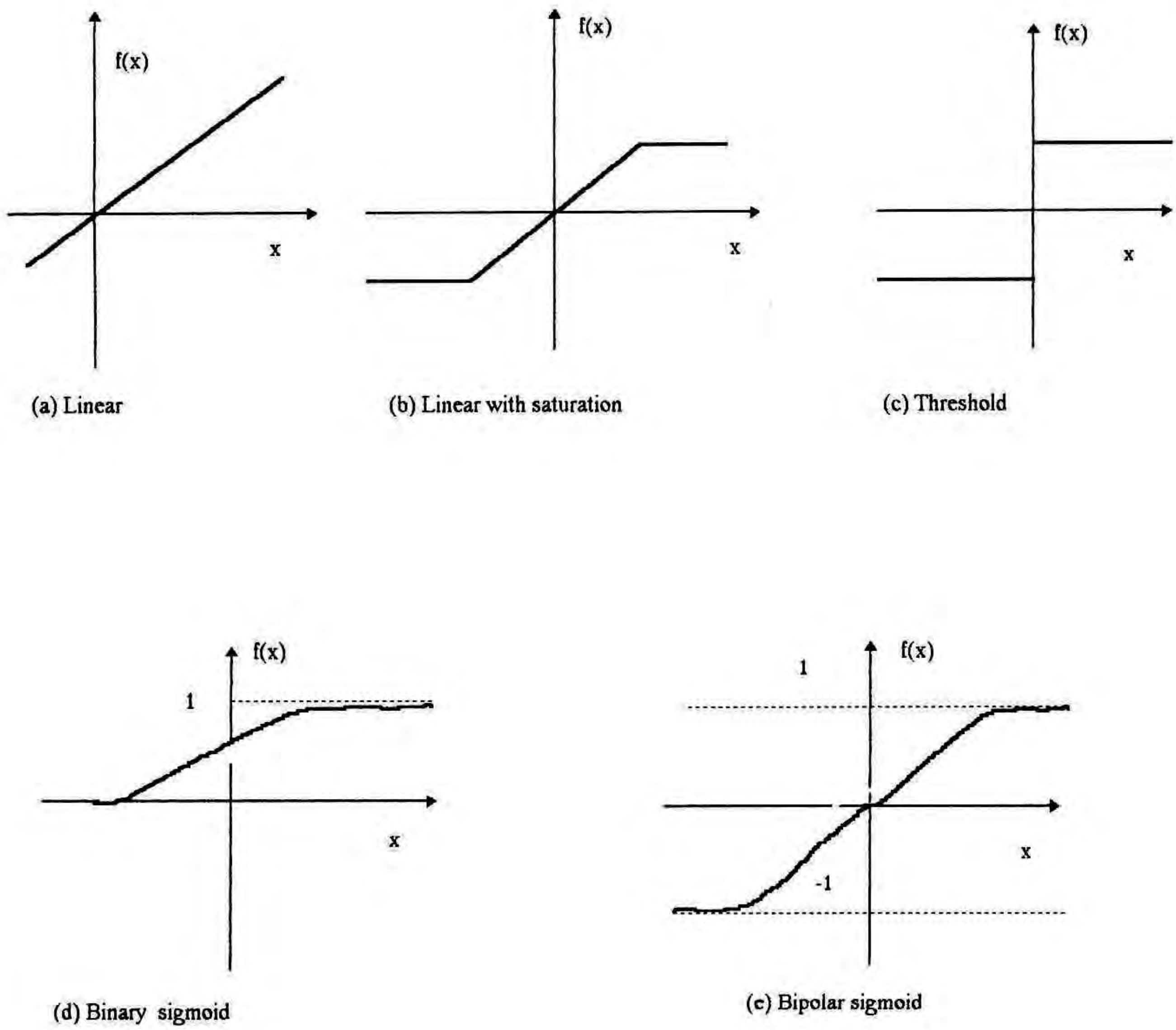


Fig. 3.3 Different activation function of a neuron.

nonlinear sigmoid function is used as an activation function whereas linear activation function is used for output neuron of diagonal recurrent network. The General Back Propagation(GBP) and Dynamic Back Propagation(DBP) algorithm has been chosen as learning algorithm for feedforward and diagonal recurrent network respectively. The mathematical background of each algorithm has been described in the following sections.

3.2 GENERAL BACK PROPAGATION ALGORITHM WITH MULTI LAYER FEEDFORWARD NETWORK

The backpropagation training algorithm is an iterative gradient algorithm designed to minimize the mean square error between the actual computed output and the desired output [32],[34]. The training of a network by backpropagation involves three stages (i) to propagate the training pattern and calculate the actual output of the network (ii) backpropagate the associate error and (iii) the adjustments of weights.

A three layer Feed Forward Network (FFN) architecture is shown in Figure 3.4. The layers are fully interconnected. When signals are applied to the input layer of the network, it propagates towards the output layer through the interconnections of the middle layer, known as hidden layer. The propagated signal will finally produce a output. This output is then compared with the desired output for each node. The error signals (which are the difference between the desired output and computed output) are transmitted backward from the output layer to each node in the intermediate layer. Each unit in the intermediate layer receives only a portion of the total error signal, based roughly on the relative contribution the unit made to the original output. This process repeats, layer by layer, until each node in the network has received an error signal that describes its relative contribution to the total error. Based on the error signal received, connection weights are then updated.

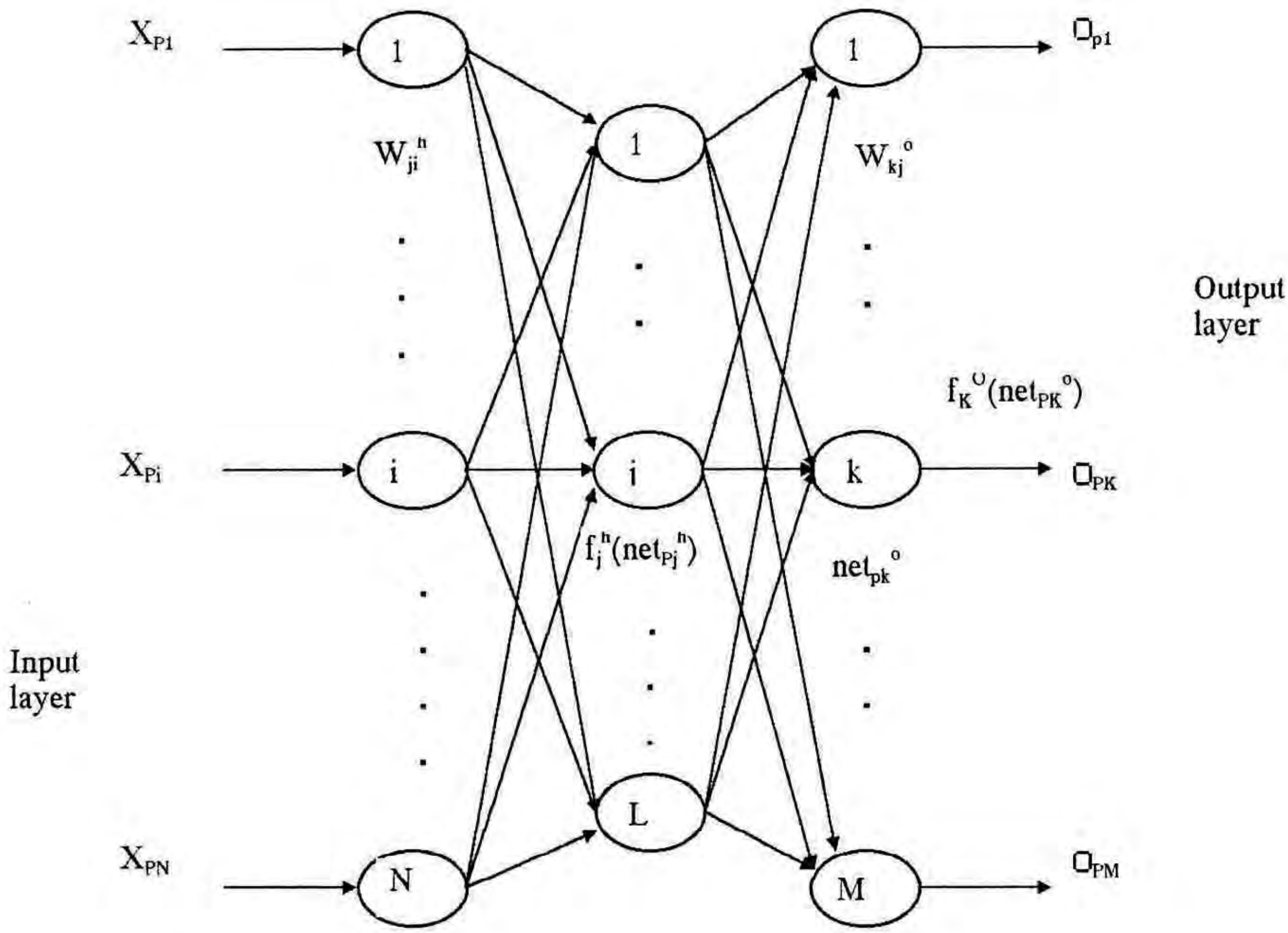


Fig. 3.4. Three layer feed forward network.

Let us consider an input vector, $\mathbf{X_P} = (x_{P1}, x_{P2}, \ldots x_{PN})$, is applied to the input layer of the network. The subscript "P" refers to the p-th training vector. The input units distribute the values to the hidden layer units.

The net input to the j-th hidden unit is given as

$$net_{Pj}^{h} = \sum_{i=1}^{L} w_{ji}^{h} \cdot x_{Pi} + \theta_j^{h} \qquad (3.1)$$

where w_{ji}^h is the weight on the connection from the i-th input unit to the j-th hidden unit, and θ_j^h is the bias term. The superscript "h" refers to quantities on the hidden layer. Assuming that the activation of this node is equal to the net input, the output of this node becomes

$$i_{Pj} = f_j^h(net_{Pj}^h) \tag{3.2}$$

Where the function $f_j^h(.)$ is refered to as an activation function. The equations for the output nodes can be written as

$$net_{Pk}^o = \sum_{j=1}^{L} w_{kj}^o . i_{Pj} \quad + \theta_k^o \tag{3.3}$$

$$O_{pk} = f_k^o(net_{Pk}^o) \tag{3.4}$$

where subscript "O"refers to quantities on the output layer.

The error value δ_{Pk} at a single output unit "k" is defined as

$$\delta_{Pk} = (y_{Pk} - O_{pk}) \tag{3.5}$$

where the subscript "k" refers to an output unit, y_{Pk} is the desired output value and O_{pk} is the actual output from the kth unit.

The error to be minimized is the sum of the squares of the errors of all the output units.

$$E_P = \frac{1}{2} \sum_{k=1}^{M} \delta_{Pk}^2 \tag{3.6}$$

The mean-square error function E_P can be reduced by changing the weights of the network. In the gradient method, the change of weight is proportional to the negative gradient of the E_P. Thus the update rule of the weights of the network becomes as

$$W(t+1) = W(t) + \eta\,(-\partial E_P / \partial W) \tag{3.7}$$

where η is learning rate.

3.2.1 Updates of Output Layer Weights

The negative gradient of E_P (ΔE_P) with respect to the weights, w_{kj} determines the direction in which to change the output layer weight.

From Eq. (3.5) and (3.6), the E_P can be written as

$$E_P = \frac{1}{2}\sum_k (y_{Pk} - O_{pk})^2 \tag{3.8}$$

The derivative of E_P with respect to w_{kj} gives

$$\frac{\partial E_P}{\partial w^o_{kj}} = -(y_{Pk} - O_{Pk}).\frac{\partial f^o_k}{\partial(net^o_{pk})}.\frac{\partial(net^o_{Pk})}{\partial w^o_{kj}} \tag{3.9}$$

The last term of Eq. (3.9) can be expressed as

$$\frac{\partial(net^o_{Pk})}{\partial w^o_{kj}} = \frac{\partial}{\partial w^o_{kj}}\sum_{j=1}^{L} w^o_{kj}.i_{pj} = i_{pj} \tag{3.10}$$

Substituting Eq(3.10) into Eq.(3.9) gives,

$$-\frac{\partial E_P}{\partial w^o_{kj}} = (y_{Pk} - O_{Pk}).f^{o\prime}_k(net^o_{Pk}).i_{Pj} \tag{3.11}$$

From Eq.(3.7) the weights of the output layer are than updated as

$$w_{kj}^o(t+1) = w_{kj}^o(t) + \Delta_P.\ w_{kj}^o(t) \tag{3.12}$$

$$\text{where } \Delta_p.w_{kj}^{o} = \eta.(y_{Pk} - O_{pk}).f_k^{o\prime}(net_{Pk}^{o}).i_{Pj} \tag{3.13}$$

Output layer error term δ_{Pk}^{0}, is defined as

$$\delta_{Pk}^{0} = (y_{Pk} - O_{Pk}).f_k^{o\prime}(net_{Pk})$$
$$= \delta_{Pk}.f_k^{o\prime}(net_{Pk}^{o}) \tag{3.14}$$

By combining the Eq. (3.13) and (3.14) the weight update equation becomes as

$$w_{kj}^{o}(t+1) = w_{kj}^{o}(t) + \eta.\delta_{Pk}^{0}.\, i_{Pj} \tag{3.15}$$

3.2.2 Updates of Hidden Layer Weights

The change of hidden layer weight can be obtained by taking the negative gradient with respect to the hidden layer weights w_{kj}. Derivative of the E_P with respect to w_{kj} gives:

$$\frac{\partial E_P}{\partial w_{ji}^{h}} = \frac{1}{2}\sum_k \frac{\partial}{\partial w_{ji}^{h}}(y_{Pk} - O_{Pk})^2 \tag{3.16}$$

$$= -\sum_k (y_{Pk} - O_{Pk}).\frac{\partial O_{Pk}}{\partial(net_{Pk}^{o})}.\frac{\partial(net_{Pk}^{o})}{\partial i_{Pj}}.\frac{\partial i_{Pj}}{\partial(net_{Pj}^{h})}.\frac{\partial(net_{Pj}^{h})}{\partial w_{ji}^{h}}$$

$$= \sum_k (y_{Pk} - O_{Pk}).\, f_k^{o\prime}(net_{Pk}^{o}).\, w_{kj}^{o}.\, f_j^{h\prime}(net_{Pj}^{h}).\, x_{Pi} \tag{3.17}$$

The hidden layer weights is updated in proportion to negative of the Eq. (3.17)

$$\Delta_P.w_{ji}^{h} = \eta.f_j^{h\prime}(net_{Pj}^{h}).x_{Pi}.\sum_k (y_{Pk} - O_{Pk}).\, f_k^{o\prime}(net_{Pk}^{o}).\, w_{kj}^{o} \tag{3.18}$$

Substituting Eq.(3.14) in the Eq.(3.18) gives

$$\Delta_P.w_{ji}^h = \eta.f_j^{h\prime}(net_{Pj}^h).x_{Pi}.\sum_k \delta_{Pk}^o.w_{kj}^o \qquad (3.19)$$

Every weight update on the hidden layer depends on all the error signal terms, δ_{Pk}^o, on the output layer. The known errors on the output layer are propagated back to the hidden layer to determine the appropriate weight changes on that layer.

By defining hidden layer error signal term δ_{Pj}^h as

$$\delta_{Pj}^h = f_j^{h\prime}(net_{Pj}^h).\sum_k \delta_{Pk}^o.w_{kj}^o \qquad (3.20)$$

The equation updating the weights of the hidden layer becomes:

$$w_{ji}^h(t+1) = w_{ji}^h(t) + \eta.\delta_{Pj}^h.x_{Pi} \qquad (3.21)$$

3.2.3 Improved Weights Updates Equations

Error convergence is sometimes faster if a momentum term is added to the weight update equation [34]. In this procedure, the weight changes in a direction that is a combination of the current gradient and previous gradient. In order to use momentum, weights from one or more previous training patterns must be saved. The simplest form of backpropagation with moment, the new weights for training step of the (t+1)th are based on the weights at the training steps of the (t)th and (t-1)th. The weight update equations (3.15) and (3.21) for general backpropagation with momentum factor can be written as :

$$w_{kj}^o(t+1) = w_{kj}^o(t) + \eta.\delta_{Pk}^0.i_{Pj} + \alpha\,(w_{kj}^o(t) - w_{kj}^o(t-1)) \qquad (3.22)$$

$$w_{ji}^h(t+1) = w_{ji}^h(t) + \eta.\delta_{Pj}^h.x_{Pi} + \alpha\,(w_{ji}^h(t) - w_{ji}^h(t-1)) \qquad (3.23)$$

where α is momentum factor.

3.2.4 Implementation of GBP for multi layer FFN

A series of equations to implement the GBP algorithm were derived in the previous sections. A flow chart of this algorithm is shown in Fig 3.5. Each step of the chart is briefly described below.

Step 1. Initialization of weights and biases :

The choice of initial weights will influence whether the net reaches a global (or only a local) minimum of error and, if so, how quickly it reaches the minimum. The update of the weight between two units depends on both the derivative of the upper unit's activation function and the output of the lower unit. For this reason, it is important to avoid choices of initial weights that would make it likely that either activation's or derivations of activations are zero. The values for the initial weights must not be too large, or the initial input signal to each hidden or output unit will likely to fall in the region where the derivative of the sigmoid function has a very small value. On the other hand, if the initial weights are too small, the net input to a hidden or output unit will be near zero, which also causes extremely slow learning. Thus all the weights and biases are initialized by random numbers between - 0.5 and 0.5.

Step 2. Choice of number of iteration, hidden layer, learning rate, momentum factor :

Number of iterations depends on error and output response. It can be chosen at any range. Both the learning rate and momentum factor are to be chosen between 0 to 1.

Step 3. Calculation of the actual output of each training pattern:

The outputs will be calculate as the Eq. (3.1) to (3.4). The sigmoid function is used as an activation function of the neurons.

Step 4. Adjustment of the weights :

In this step the error of the output layer will be calculated using Eq. (3.5). Then the weights of the output layer will be changed as using as Eq.(3.14), (3.15) and (3.22). The weight of the hidden layer will be changed according to Eq.(3.19) ,(3.20), (3.21), and (3.23).

Step 5. Change of the training pattern :

Repeat step 3 and step 4 until the end of the training data.

Step 6. Change the iteration number :

Training will be continued until the maximum number of iterations.

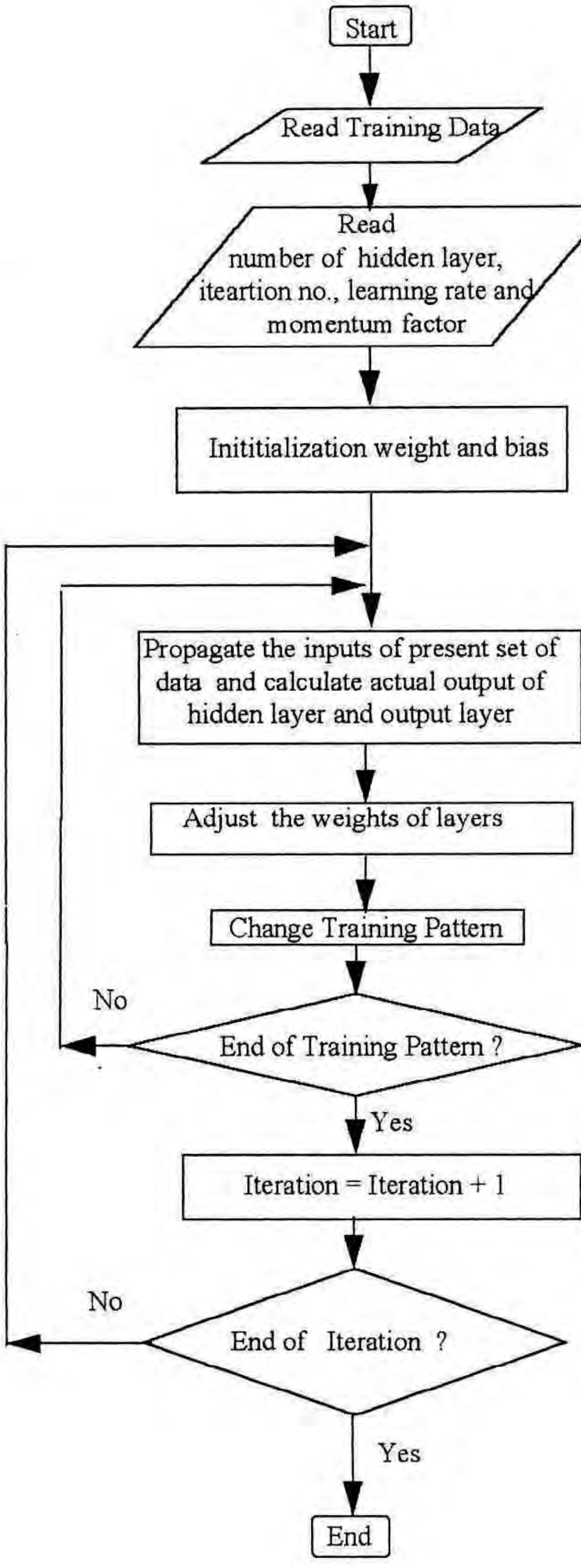


Fig3.5. Flow chart of general back propagation algorithm.

3.3 DYNAMIC BACK PROPAGATION ALGORITHM FOR DIAGONAL RECURRENT NETWORK

A three layered diagonal recurrent network is shown in Fig.3.6. Each hidden neurons output is fed back to its input .

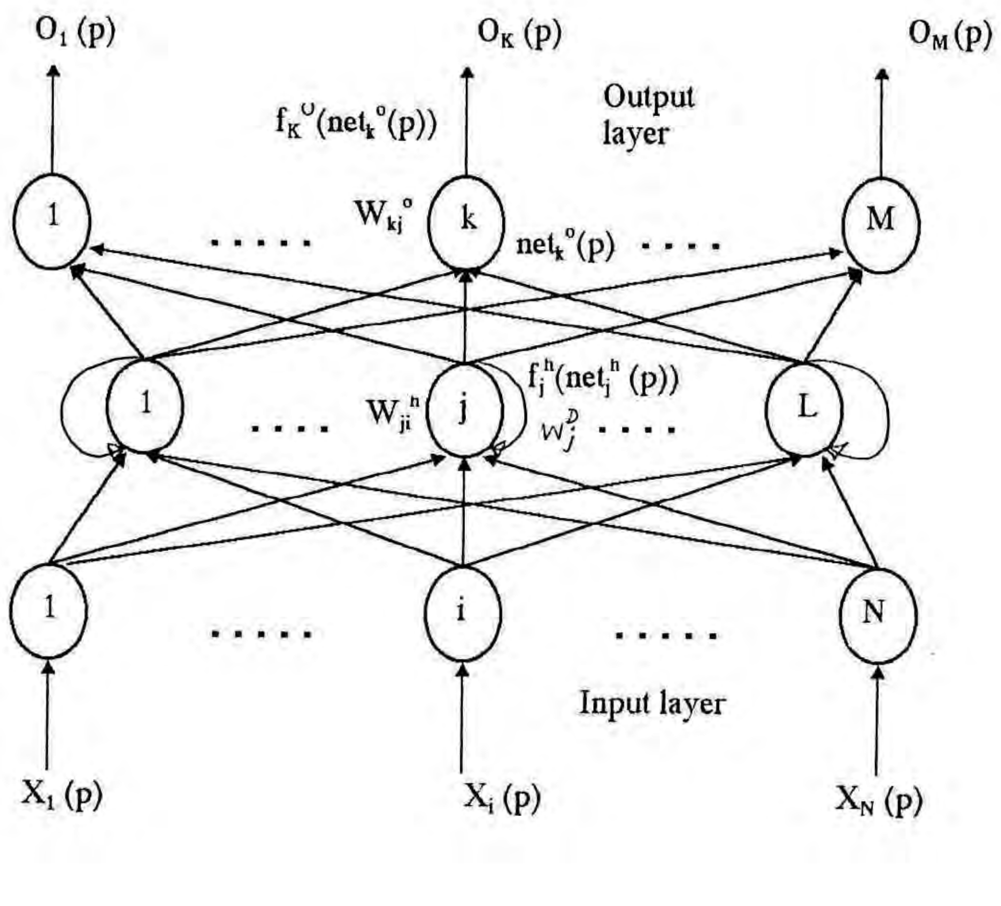


Fig. 3.6 Three -layer diagonal recurrent network.

Let us consider an input vector, $\mathbf{X(p)} = (x_{1p}, x_{2p}, \ldots x_{Np})$, which is applied to the input layer of the network. The subscript "p" refers to p-th time. The input units distribute the values to the hidden layer units.

The net input and output of the j-th hidden unit at the pth time is [36]

$$net_j^h(p) = \sum_{i=1}^{L} w_{ji}^h x_i(p) + w_j^D . i_j(p-1) \qquad (3.24)$$

$$i_j(p) = f_j^h(net_j^h(p)) \qquad (3.25)$$

where the superscript

- h refers to quantities on the hidden layer;
- w_{ji}^h is the weight on the connection from the i-th input unit;
- w_j^D is the diagonal feedback weight;
- $net_j^h(p)$ is the net input of the hidden unit;
- $i_j(p)$ is the output of the hidden unit;
- $f_j^h(net_j^h(p))$ is refered to as an activation function;

The output nodes equations are

$$net_k^o(p) = \sum_{j=1}^{L} w_{kj}^o . i_j(p) \qquad (3.26)$$

$$O_k(p) = f_k^o(net_k^o(p)) \qquad (3.27)$$

where subscript "O" refers to quantities on the output layer.

In diagonal feedback network it is assumed that the activation function of output neuron is linear. Thus the R.H.S. of the Eq.(3.27) will be $f_k^o(net_k^o(p)) = net_k^o(p)$.

The Eq.(3.27) then becomes

$$O_k(p) = net_k^o(p) = \sum_{j=1}^{L} w_{kj}^o . i_j(p) \quad (3.28)$$

The error value at a single output unit "k" is defined as $\delta_k(p) = (y_k(p) - O_k(p))$, where the $y_k(p)$ is the desired output value and $O_k(p)$ is the actual output from the kth unit at pth time. The error to be minimized by the sum of the squares of the errors of all the output units, given as.

$$E(p) = \frac{1}{2} \sum_{k=1}^{M} \delta_k^2(p) \quad (3.29)$$

Negative of the gradient of E(p), ($\nabla E(p)$) with respect to the weights determine the direction in which to change the weights. The weight at the (p+1)th time will be

$$W(p+1) = W(p) + \eta . (-\frac{\partial E_p}{\partial W}) \quad (3.30)$$

where η is a learning rate.

The values of the weights can be adjusted in such a way so that the total error is reduced.

3.3.1 Updates of Output Layer Weights

From Eq. (3.27) and the definition of $\delta_k(p)$

$$E(p) = \frac{1}{2} \sum_{k} (y_k(p) - O_k(p))^2 \quad (3.31)$$

$$\frac{\partial E(p)}{\partial w_{kj}^o} = -(y_k(p) - O_k(p)) . \frac{\partial O_k(p)}{\partial w_{kj}^o} \quad (3.32)$$

For linear activation function of output neuron, the derivative part of Eq.(3.32) can be written as $\frac{\partial O_k(p)}{\partial w^o_{kj}} = i_j(p)$. Then the Eq.(3.32) becomes

$$\frac{\partial E(p)}{\partial w^o_{kj}} = -(y_k(p) - O_k(p)).i_j(p) \tag{3.33}$$

Thus the weights of the output layer are updated as

$$w_{kj}^o(p + 1) = w_{kj}^o(p) + \eta.\ (y_k(p) - O_k(p)).\ i_j(p) \tag{3.34}$$

The output layer error signal term is $\delta_k^0(p)$, defined as

$$\delta_k^0(p) = (y_k(p) - O_k(p)) \tag{3.35}$$

By combining the Eq. (3.34) and (3.35) the weight update equation becomes

$$w_{kj}^o(p + 1) = w_{kj}^o(p) + \eta.\delta_k^0(p).\ i_j(p) \tag{3.36}$$

3.3.2 Updates of Hidden Layer Weights

The gradient of E(p) with respect to the hidden layer weights:

$$\frac{\partial E(p)}{\partial w^h_{ji}} = \frac{1}{2}\sum_k \frac{\partial}{\partial w^h_{ji}}(y_k(p) - O_k(p))^2 \tag{3.37}$$

$$= -\sum_k (y_k(p) - O_k(p)).\frac{\partial O_k(p)}{\partial w^h_{ji}} \tag{3.38}$$

$$= -\sum_k (y_k(p) - O_k(p)).w_{kj}.\frac{\partial i_j(p)}{\partial w^h_{ji}} \tag{3.39}$$

The derivative part of the Eq.(3.39) considered as,

$$Q_{ji}(p) = \frac{\partial i_j(p)}{\partial w^h_{ji}}$$

$$= \frac{\partial i_j(p)}{\partial(net^h_j(p))} \cdot \frac{\partial(net^h_j(p)}{\partial w^h_{ji}}$$

$$= f'(net^h_j(p)) \cdot \frac{\partial}{\partial w^h_{ji}} (\sum w^h_{ji}.x_i(p) + w^D_j \cdot i_j(p-1)$$

$$= f'(net^h_j(p)) \cdot (x_i(p) + w^D_j \cdot Q_{ji}(p-1)$$

$$Q_{ji}(p) = f'(net^h_j(p)) \cdot (x_i(p) + w^D_j \cdot Q_{ji}(p-1)) \qquad (3.40)$$

where $Q_{ji}(0) = 0$

The hidden layer weights is updated in proportion to the negative of the Eq. (3.39), thus

$$\Delta_P.w_{ji}^h = \eta.\ Q_{ji}(p). \sum_k (y_{Pk} - O_{Pk}).w^o_{kj} \qquad (3.41)$$

Substituting Eq.(3.35) in Eq.(3.41) rewrites as

$$\Delta_P.w_{ji}^h = \eta Q_{ji}(p). \sum_k \delta^o_k(p).\ w^o_{kj} \qquad (3.42)$$

Every weight updated on the hidden layer depends on all the error terms, $\delta_k{}^o(p)$, on the output layer. Hidden layer error signal term $\delta_j{}^h(p)$ can be defined as

$$\delta_j{}^h(p) = \sum_k \delta^o_k(p).w^o_{kj} \qquad (3.43)$$

Finally, weight update equation for the hidden layer becomes

$$w_{ji}{}^h(p+1) = w_{ji}{}^h(p) + \eta.\delta_j{}^h(p).Q_{ji}(p) \qquad (3.44)$$

3.3.2 Updates of Diagonal Recurrent Weights

The gradient of E(p) with respect to the feedback layer weights is calculate as follows,

$$\frac{\partial E(p)}{\partial w_j^D} = \frac{1}{2}\sum_k \frac{\partial}{\partial w_j^D}(y_k(p) - O_k(p))^2$$

$$= -\sum_k (y_k(p) - O_k(p)).\frac{\partial O_k(p)}{\partial w_j^D}$$

$$= -\sum_k (y_k(p) - O_k(p)).w_{kj}.\frac{\partial i_j(p)}{\partial w_j^D} \qquad (3.45)$$

The derivative term of the R.H.S of Eq. (3.45) is calculated as

$$R_j(p) = \frac{\partial i_j(p)}{\partial w_j^D}$$

$$= \frac{\partial i_j(p)}{\partial(net_j^h(p))} \cdot \frac{\partial(net_j^h(p)}{\partial w_j^D}$$

$$= f'(net_j^h(p)) \cdot \frac{\partial}{\partial w_j^D}(\sum w_{ji}^h.x_i(p) + w_j^D \cdot i_j(p-1))$$

$$= f'(net_j^h(p)) \cdot (i_j(p-1) + w_j^D \cdot \frac{\partial i_j(p-1)}{\partial w_j^D})$$

Then

$$R_j(p) = f'(net_j^h(p)) \cdot (i_i(p-1) + w_j^D \cdot R_j(p-1)) \qquad (3.46)$$

where $R_j(0) = 0$

The diagonal recurrent weights is updated in proportion to the negative of the Eq. (3.45), Thus

$$\Delta_P.w_{ji}{}^h = \eta.\ R_i(p).\sum_k (y_{Pk} - O_{Pk}).w_{kj}^{o} \qquad (3.47)$$

With the help of $\delta_{Pk}{}^{o}$ from Eq. (3.35) the Eq.(3.47) can be rewritten as.

$$\Delta_P . w_{ji}{}^{h} = \eta . R_i(p) . \sum_k \delta_k^o(p) . w_{kj}^o \tag{3.48}$$

Every weight updated on the feedback, depends on all the error terms, $\delta_k{}^{o}(p)$, on the output layer. By defining hidden layer error term $\delta_j{}^{h}(p)$ as follows

$$\delta_j{}^{h}(p) = \sum_k \delta_k^o(p) . w_{kj}^o \tag{3.49}$$

and using Eq. (3.49) in Eq. (3.48) the weight update equation for diagonal recurrent is reduced as

$$w_j{}^{D}(p+1) = w_j{}^{D}(p) + \eta . \delta_j{}^{h}(p) . R_i(p) \tag{3.50}$$

3.3.4. Adaptive Learning Rate

The convergence of a recurrent neural network is not easy to be guaranteed. It should be noted here that when a plant of unknown dynamics is combined with feedback neural network, it makes the convergence of NN based system more difficult. However it is well accepted that a small learning rate makes a network, though slow, more likely to converge, while large learning rate makes the system unstable. Thus to guarantee convergence and for faster training process an approach suggested in [36] is employed here to find the learning rate. In this approach adaptive learning rate was developed by introducing a Lyapunov function.

A discrete-type Lyapunov function can be defined as

$$L(p) = \frac{1}{2} e^2(p) \tag{3.51}$$

where, e (p) represents the error in the learning process and can be written as

$$e(p) = y_k(p) - O_k(p)$$

Thus the change of Lyapunov function due to the training process is obtained by

$$\Delta L(p) = L(p+1) - L(p) = \frac{1}{2}\left[e^2(p+1) - e^2(p)\right] \tag{3.52}$$

The error difference due to the learning can be represented as

$$e\,(p+1) = e\,(p) + \Delta e\,(p) = e\,(p) + \left[\frac{\partial e(p)}{\partial w}\right]^T \nabla W \tag{3.53}$$

where ΔW represents a change in an arbitrary weight vector (normalized real vector)

The ∇W is given as

$$\nabla W = \eta.-\frac{\partial E(p)}{\partial W} = \eta.(y_k(p) - O_k(p)).\frac{\partial O(p)}{\partial W}$$

$$= \eta.\,e(p).\frac{\partial O(p)}{\partial W} \tag{3.54}$$

From Eq. (3.52 - 3.54) , $\Delta L(p)$ can be represented as

$$\Delta L(p) = \nabla e(p).\left[e(k) + \frac{1}{2}\nabla e(p)\right]$$

$$= \left[\frac{\partial e(p)}{\partial w}\right]^T.\eta.\,e(p)\frac{\partial O(p)}{\partial W}.\left\{e(p) + \frac{1}{2}\left[\frac{\partial e(p)}{\partial W}\right]^T.\eta.\,e(p)\frac{\partial O(p)}{\partial W}\right\} \tag{3.55}$$

For linear activation function of output neuron, $\frac{\partial e(p)}{\partial W} = -\frac{\partial O(p)}{\partial W}$, so that

$$\Delta L(p) = -\eta.\,e^2(p)\left\|\frac{\partial O(p)}{\partial W}\right\|^2 + \frac{1}{2}\eta^2.e^2(p).\left\|\frac{\partial O(p)}{\partial W}\right\|^4 \tag{3.56}$$

$$\equiv -\lambda e^2(p) \qquad (3.57)$$

$$\text{where,} \quad \lambda = \eta . \left\| \frac{\partial O(p)}{\partial W} \right\|^2 - \frac{1}{2}\eta^2 . \left\| \frac{\partial O(p)}{\partial W} \right\|^4$$

For simplicity, it is assumed that [36]

$$g\,(p) = \frac{\partial O(p)}{\partial W}$$

$g_{max} := \max_p \|g(p)\|$ and

$\eta_1 = \eta . g_{max}^2$ where $\|.\|$ is the usual Euclidean norm

The expression for λ becomes

$$\lambda = \frac{1}{2}.\|g(p)\|^2 \eta . \left(2 - \eta . \|g(p).\|^2\right)$$

$$= \frac{1}{2}.\|g(p)\|^2 . \eta . \left(2 - \frac{\eta_1 \|g(p)\|^2}{g_{max}^2}\right)$$

$$\lambda \geq \frac{1}{2}.\|g(p)\|^2 . \eta . (2 - \eta_1) > 0 \qquad (3.58)$$

The convergence is guaranteed if the following condition is satisfied.

$$\eta\,(2 - \eta_1) > 0$$

$$\text{or,} \quad \frac{\eta_1 (2 - \eta_1)}{g_{max}^2} > 0$$

The above condition will be valid for $0 < \eta_1 < 2$. However the maximum learning rate which guarantees the most rapid or optimal convergence is corresponding to $\eta_1 = 1$, i.e.,

$$\eta = \frac{1}{g_{max}^2} \qquad (3.59)$$

For $0 < |w_j^D| < 1$, the value of g_{max}^2 for output, hidden and diagonal feedback weight were given as [36]

For output layer weight,

$$g_{max}^2 = H = \text{No of hidden layer} \qquad (3.60)$$

For diagonal feedback weight,

$$g_{max}^2 = \frac{1}{h}\left[\frac{1}{W_{max}^O}\right]^2 \qquad (3.61)$$

$$\text{where } W_{max}^O := \max_{P}.\|w_{kj}\|$$

For hidden layer weight,

$$g_{max}^2 = \frac{1}{(N+H)}\left[\frac{1}{W_{max}^O . X_{max}}\right]^2 \qquad (3.62)$$

$$\text{where, } X_{max} = \max_p \|x_i(p)\|$$

3.3.5 Implementation of DBP for multi layer DRN

A series of equations to implement the DBP algorithm were derived in the previous sections. A flow chart of this algorithm is shown in Fig. 3.7. Each step of the chart is briefly described below.

Step 1. Initialization of weights :

The weights between output layer and hidden layer is initialized randomly. These values lies between - 0.5 and 0.5. The diagonal recurrent weights are initialized by 0.5.

Step 2. Choice of iteration no, hidden layer :

Number of number iteration depended on error and output response. It can be choice at any range.

Step 3. Calculation of the actual output of each training pattern:

The outputs will be calculate as the Eq. (3.24) to (3.28).

Step 4 : Calculation the optimum learning rate

The optimum learning rate will be calculate as the Eq.(3.60) to (3.62).

Step 5. Adjustment of the weights :

In this step the error of the output layer will be calculated using Eq. (3.31). Then the weights of the output layer will be changed by using Eq.(3.35) and (3.36). The weight of the hidden layer will be changed according to Eq.(3.40) to (3.45). The diagonal recurrent weights will be change by the Eq.(3.45) to(3.50).

Step 6. Change of the training pattern :

Repeat step 4 and step 5 until the end of the training data.

Step 7. Change the iteration number :

Training will be continued until the maximum number of iterations.

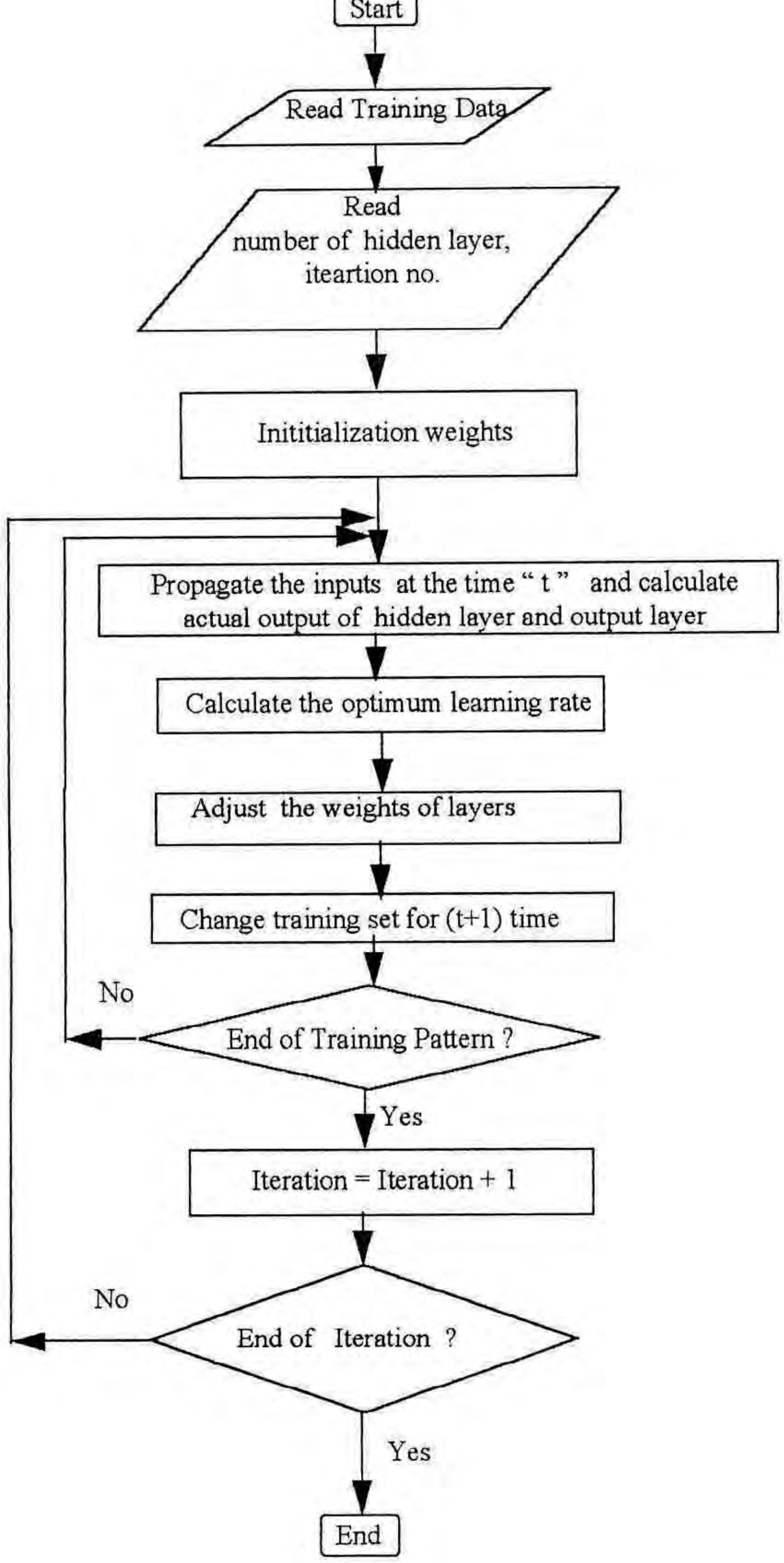


Fig3.7. Flow chart of dynamic back propagation algorithm.

CHAPTER - FOUR

PROPOSED NEURAL NET CONTROLLER

- INTRODUCTION
- ANN BASED INVERSE CONTROLLER
- BOILER CONTROL LOOPS FOR INTEGRATION
- NETWORKS INPUT- OUTPUT VECTORS
- TRAINING OF THE PROPOSED CONTROLLER
- TEST RESULT AND SELECTION OF NETWORK
- PERFORMANCE OF THE DEVELOPED CONTROLLER
- RUNNING MODE OF THE PROPOSED CONTROLLER
- NEURAL NET CONTROLLER WITH BOTH MODE.

4.0 INTRODUCTION

An adaptive gain controller has the ability to dynamically change its overall gain in response to a specific variable. Thus any change in the process gain causes a change in controller gain reciprocally to maintain the overall unity loop gain [37],[38]. The change in controller gain with change in process gain is shown in Fig 4.1. Such an adaptive controller can be designed by the inverse process dynamic technique. The inverse model of a process having an unknown transfer function is itself a process having a transfer function which is in some senses a best fit to the reciprocal of the unknown transfer function[37]. This technique can be easily implemented by neural network. A neural network can be applied as a adaptive controller of a plant after learning its inverse dynamics(input/output). Here the inverse dynamics means the boiler output quantities (controlled variables) such as steam header pressure, drum level and steam flow rate will be used as input quantities of the neural network while the three inputs of the boiler such as flow rate of gas, air and water will be used as output quantities of the neural network. In this work, this technique is implemented for developing a neural network based an integrated control system of an industrial boiler of ZFCL.

In this chapter the inverse dynamics modelling controller design methodology is presented. The training operation of the feedforward and diagonal recurrent network is briefly described. The output responses of both networks are investigated to select the best network for developing a software controller.

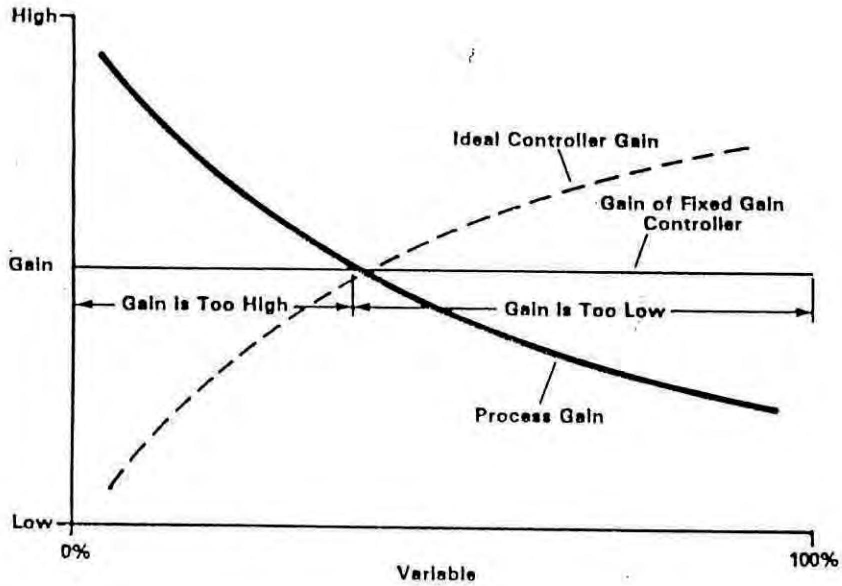


Fig. 4.1 Relationship between Process gain and Controller gain.

4.1 ANN BASED INVERSE CONTROLLER

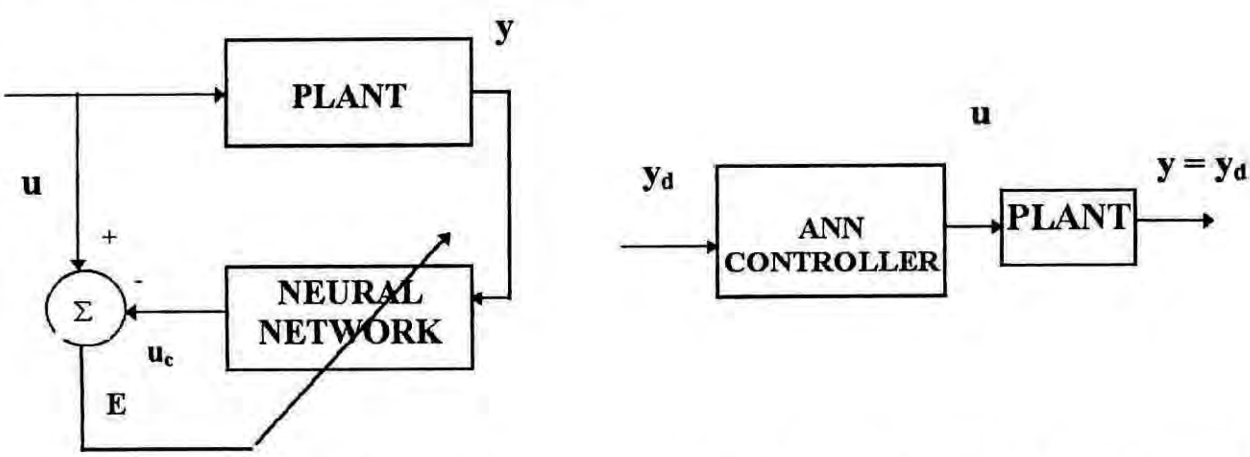
Two modes of neural net controller are: the training mode and the running mode. A general block diagram of the training mode of an ANN based controller is shown in Fig.4.2(a). The plant output (y) for the known input (u) is used as network input to obtain an output u_c. The learning process of neural network is carried out to minimize the overall squared error (E^2) which is the difference between u and u_c. After the learning process is carried out, the weights between units (i.e., input to hidden and hidden to output) of the neural network are obtained. The trained neural network can then be used as a controller of the plant. The plant output signals of the controlled plant (y) is expected to match the desired responses (y_d) which is given as the neural network input shown in fig.4.2(b). The computational function of the neural network in the training and operation phase are as follows:

Training phase: $u = f\,(y, d)$ (4.1)

where d is the plant load disturbance.

Operation phase: $u = f\,(y_d, d)$ (4.2)

where y_d is the desired set point of the plant.



(a) The training mode of the ANN Controller (b) The operation mode of the ANN controller

Fig.4.2. The training and running mode of the ANN Controller.

4.2 BOILER CONTROL LOOPS FOR INTEGRATION

There are three control loops (such as combustion, drum level and temperature control loops) for controlling the 120 ton/hr capacity boiler of the ZFCL as described in the chapter 2. Temperature is being controlled manually whereas combustion and drum level are being controlled automatically. Thus in this work these two automatic control loops have been considered for integration towards developing a single neural net controller. A schematic diagram of the present combustion and drum level control loops of the ZFCL boiler is shown in Fig. 4.3.

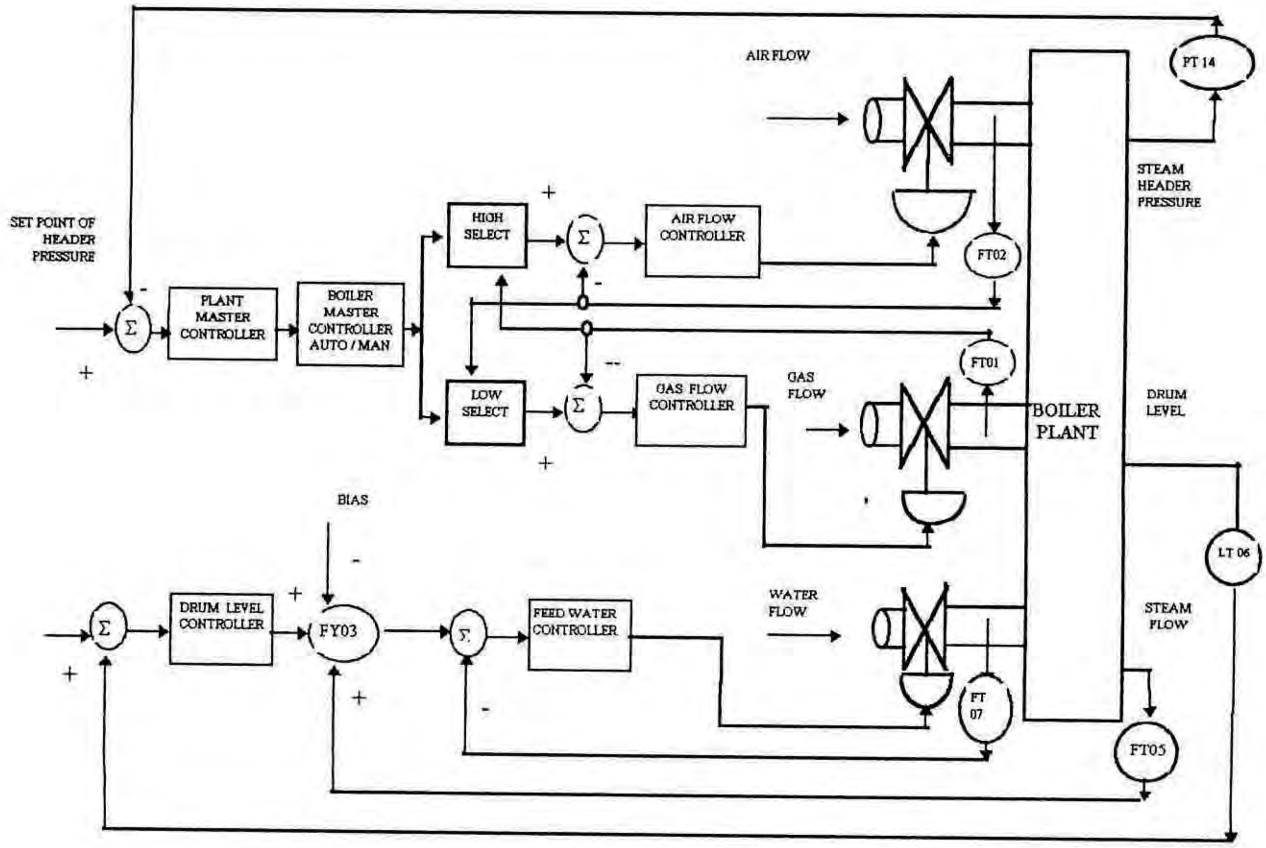
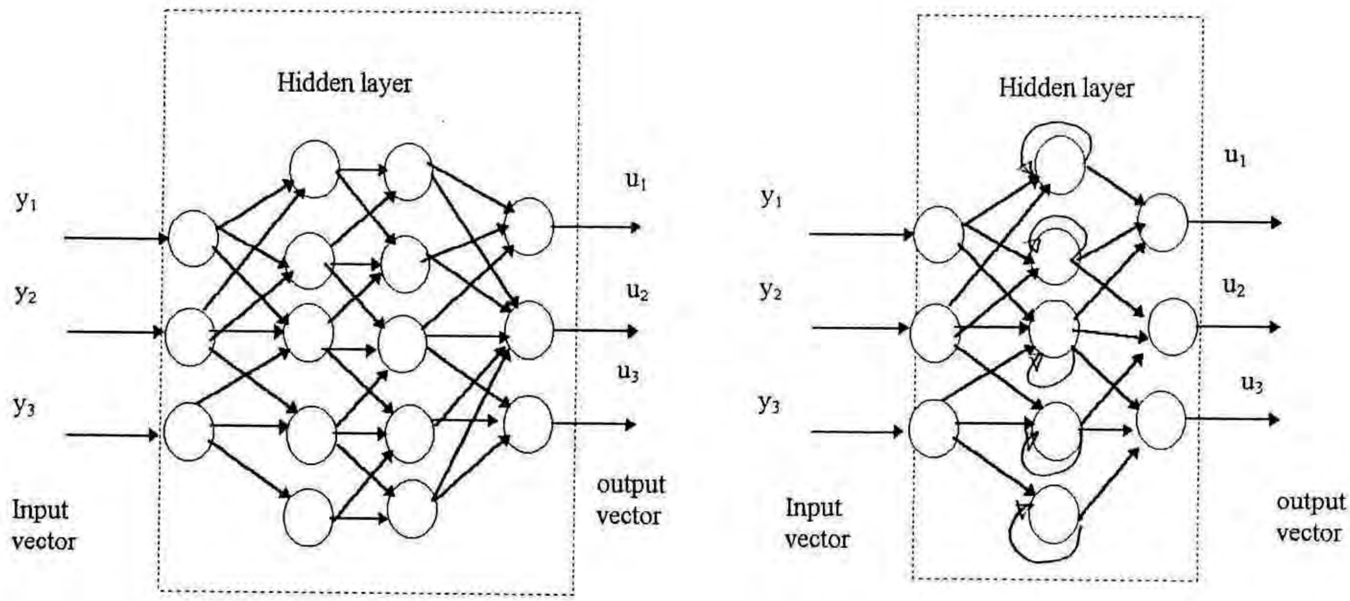


Fig. 4.3 Present PID controller controlled boiler plant of ZFCL.

4.3 NETWORKS INPUT - OUTPUT VECTORS

Two networks architecture (such as feedforward and diagonal recurrent network) has been chosen to develop the proposed controller. Since the inverse dynamic modelling technique is employed for developing the controller, the input vectors of both networks are: (i) steam header pressure (y_1) (ii) drum water level (y_2) and (iii) steam flow (y_3). The output vectors of the both networks include : (i) gas flow rate (u_1) (ii) air flow rate (u_2) and (iii) water flow rate (u_3). Both networks structure with input-output vectors are shown in Fig. 4.4. The architecture providing the fastest convergence with minimum error and desired response is to be selected.



(a) Input-output vector of feedforward network

(b) Input-output vector of diagonal recurrent network

Fig. 4.4 Input-output vector of networks.

4.4 TRAINING OF THE PROPOSED CONTROLLER

Feedforward network is trained using the general backpropagation algorithm while diagonal recurrent network is trained using dynamic backpropagation algorithm. Both training algorithms are described in the previous chapter. The training mode of the proposed controller is shown in Fig. 4.5. Input-output data of the present PID controller based 120 ton/hr capacity boiler of ZFCL are used as the training data of both the networks. The training data are collected from the data bank of process control computer of ZFCL. Data are given in appendix A. Faster convergence with minimum error and desired response depends on many training parameters. The following sub-sections discuss the selection of the training parameter in the case of both architectures.

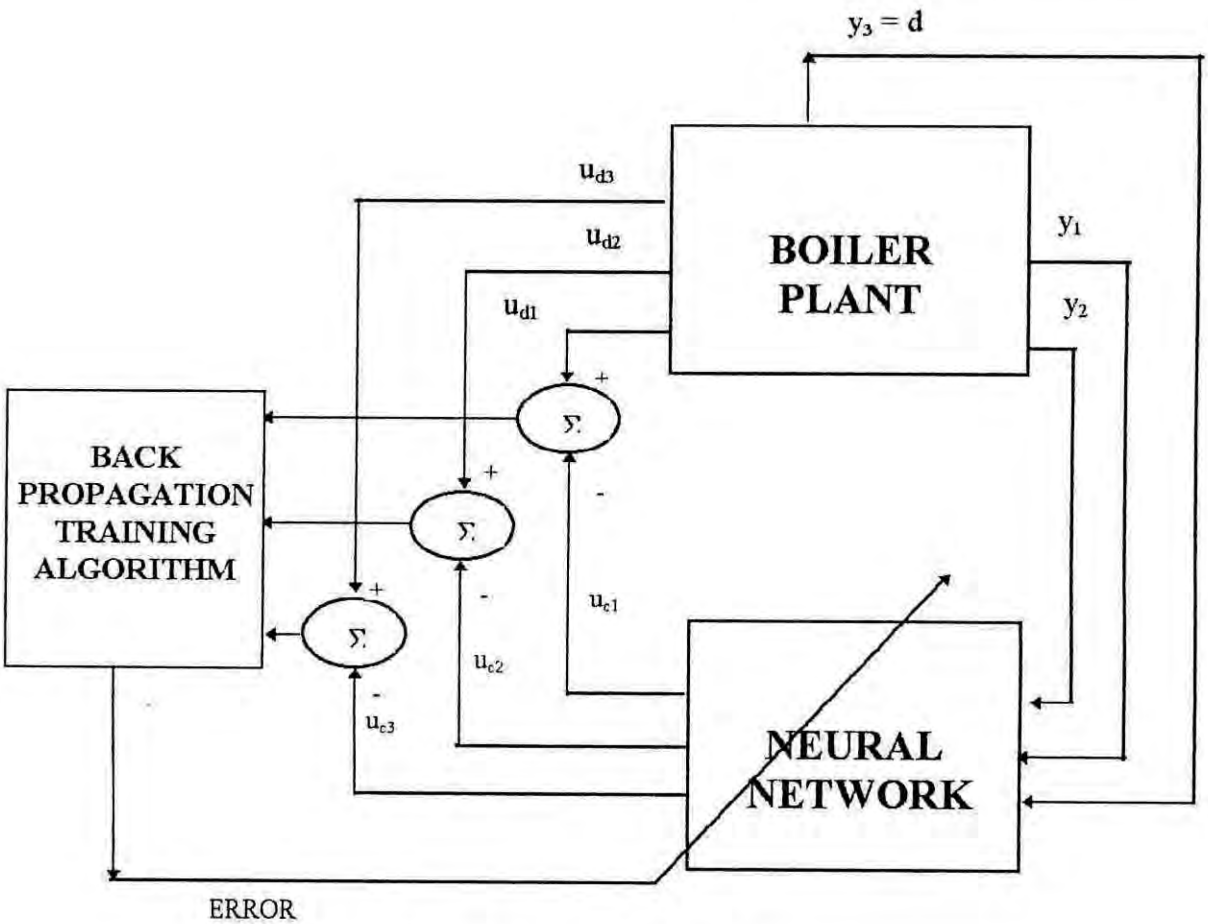


Fig. 4.5 Training mode of proposed controller.

4.4.1 Feedforward Network Training

Parameters to be selected for getting the desired response from the training of a feedforward network include: (i) learning rate, (ii) momentum factor, (iii) number of hidden layer and (iv) number of neurons in each hidden layer. In selecting the learning rate and momentum factor, nine neuron with single hidden layer is chosen for network architecture.

4.4.1.1 Learning Rate:

The learning rate (η) is used to control the amount of weight adjustment at each step of training. Generally the η has an non-negative value which is less than 1.0. For the present work the different values of learning rate such as 0.01, 0.1, 0.2, and 0.3 are chosen to train the network. The training history at different values of learning rate is shown in Fig.4.6. From the figure it is found that though at the learning rate of 0.2 and 0.3 error converges fast but initially the system becomes unstable. On the other hand at the learning rate of 0.01, convergence is very slow. However convergence with stable minimum error is achieved at the learning rate of 0.1. Thus the value of the learning rate is chosen as 0.1.

4.4.1.2 Momentum Factor

Momentum allows the net to make reasonable large weight adjustment as long as the corrections are in the same general direction for several pattern, while using a small value of learning rate to prevent a large response to the error from any one training pattern. It also reduces the likelihood that the net will find weights that a local, but not a global minimum. With momentum factor the net proceeds only in the direction of the gradient, but also in the direction of a combination of current gradient and the previous direction of weight correction[33]. Thus the use of momentum factor along with the learning rate, accelerates the training speed to achieve the convergence. Generally momentum factor lies between 0.1 to 1.0. However there is no guidelines to determine the optimum momentum factor for the learning process. Thus initially during the training process various values of momentum factor such as 0.1, 0.2, and 0.3 are taken to choose the best one. The training history at different values of momentum factor with a fixed learning rate of 0.1 is shown in Fig.4.7. From the figure it is evident that the system becomes unstable for large value of momentum factor. In this problem the faster and stable errors convergence is achieved at the momentum factor of 0.1. Thus this value is taken as the momentum factor for training the network.

4.4.1.3 Hidden layer and Neuron selection:

In this work a neural network having a single hidden layer with a various number of neurons such as 9, 12, and 15 is trained individually. A network having double hidden layer with nine neurons in the first hidden layer and six neurons in the second hidden layer is also trained. The training history of the various network is shown in fig 4.8. After 300,000 iterations for each network, the weight of the network are saved for designing the controller. Comparison between the output response of all the networks and those of the PID controller are shown in Fig.4.8 to Fig.4.10. From the figures it is evident that the output response of all the cases are close to those of the PID controller. The network with single hidden layer with nine neurons is chosen to develop the controller, because this network takes less computation time as compared to other networks. The weights obtained from the training of the selected network is given in appendix-B.

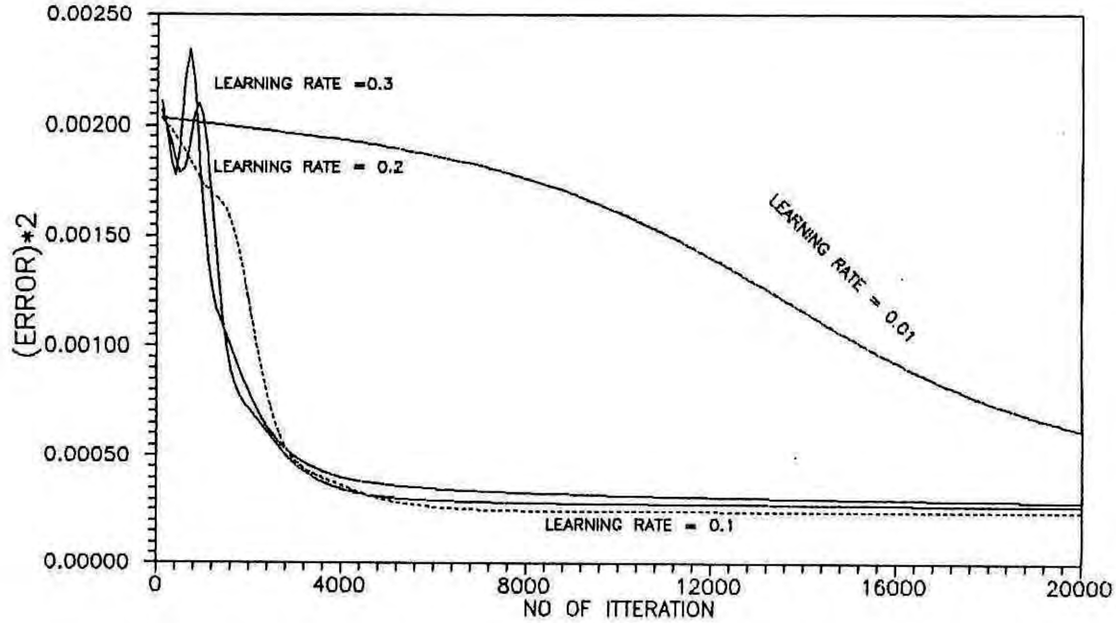


FIG.4.6 Training History of Feedforward network with different learning rate.

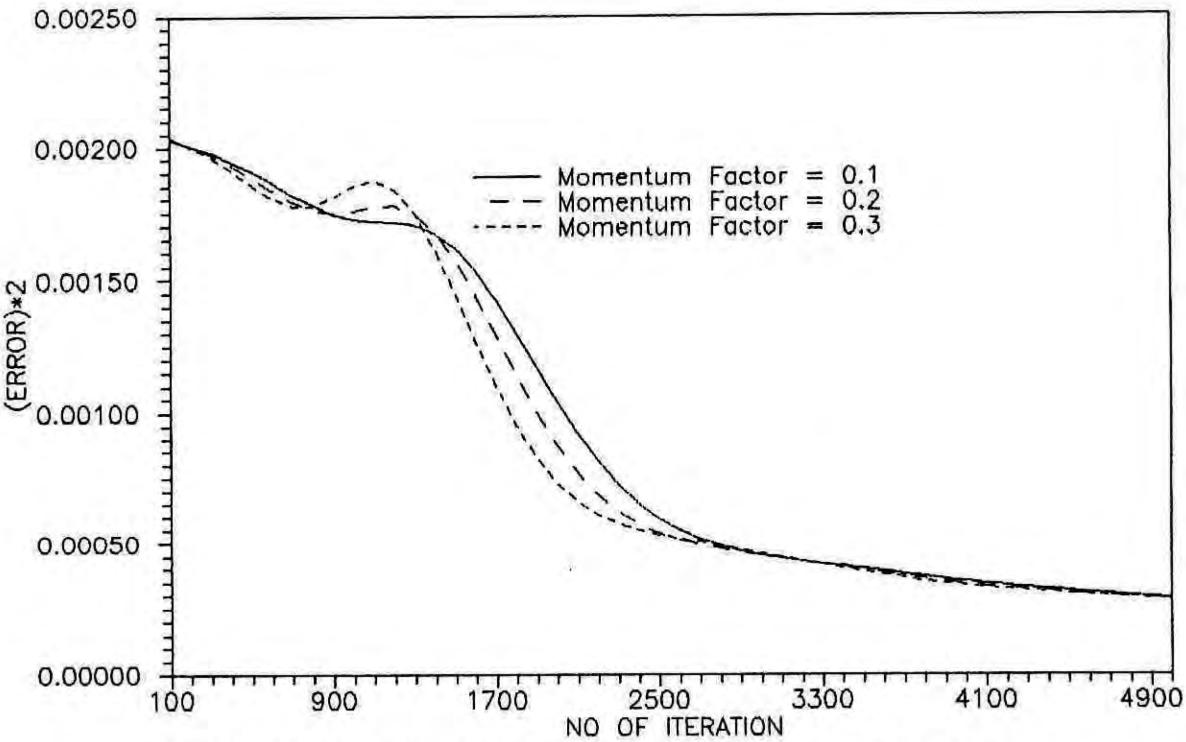
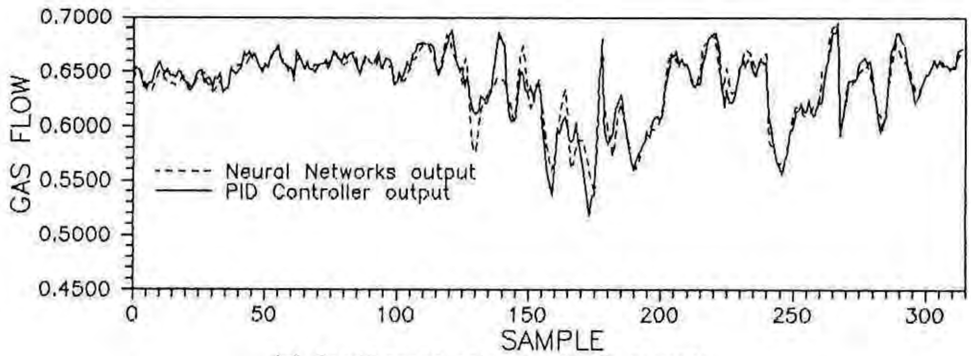
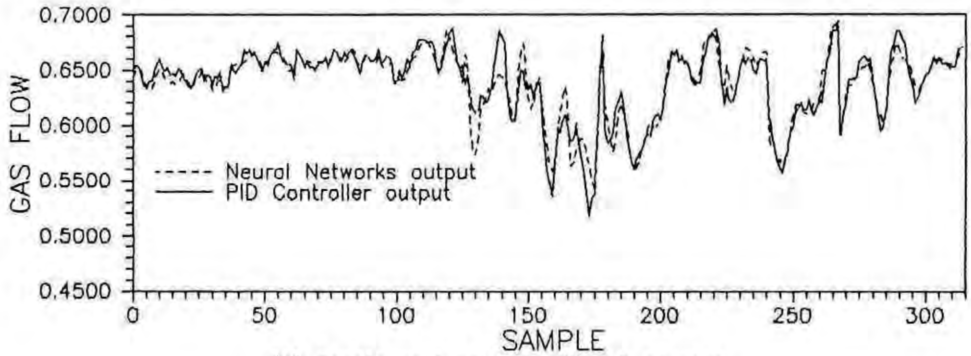


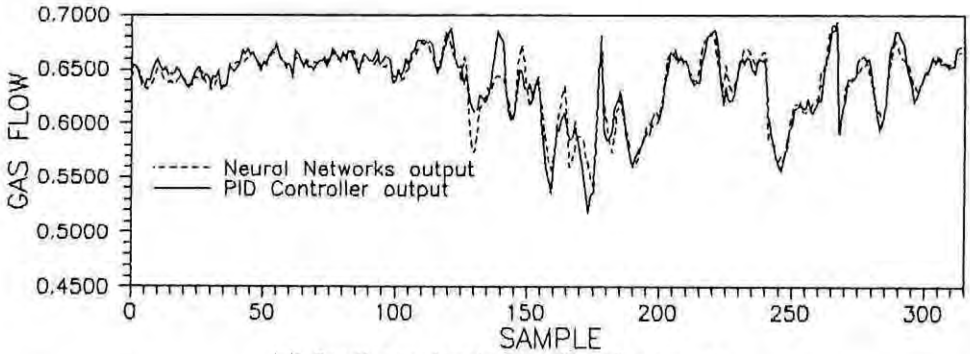
Fig.4.7. Training history of different value of Momemtum factor with fixed learning rate (0.1)



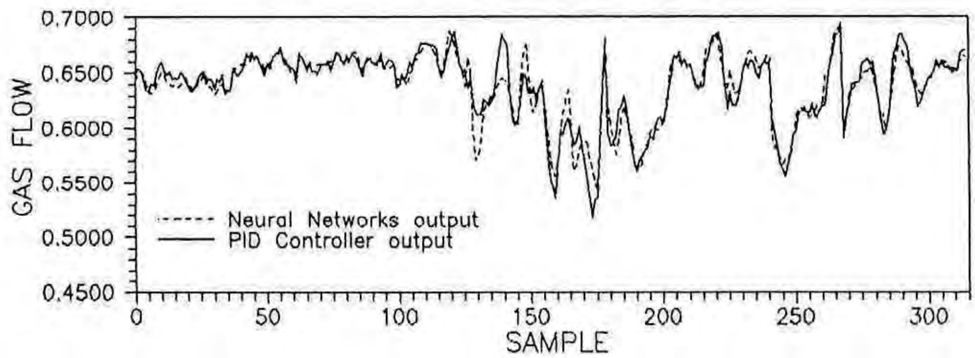
(a) Feedforward network with 9 neurons



(b) Feedforward network with 12 neurons

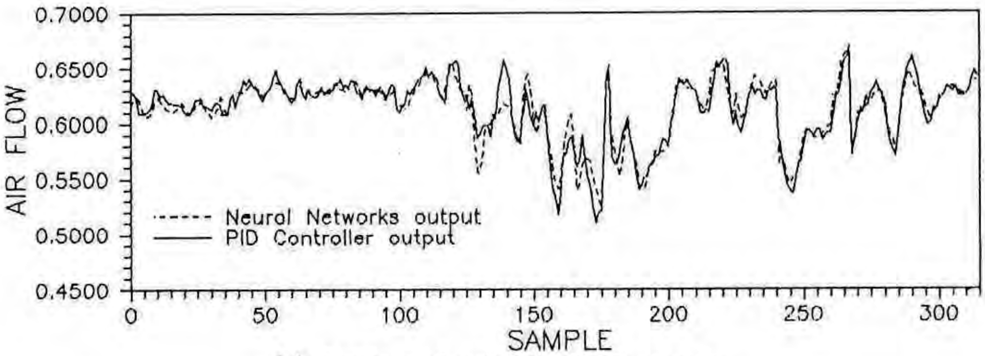


(c) Feedforward network with 15 neurons

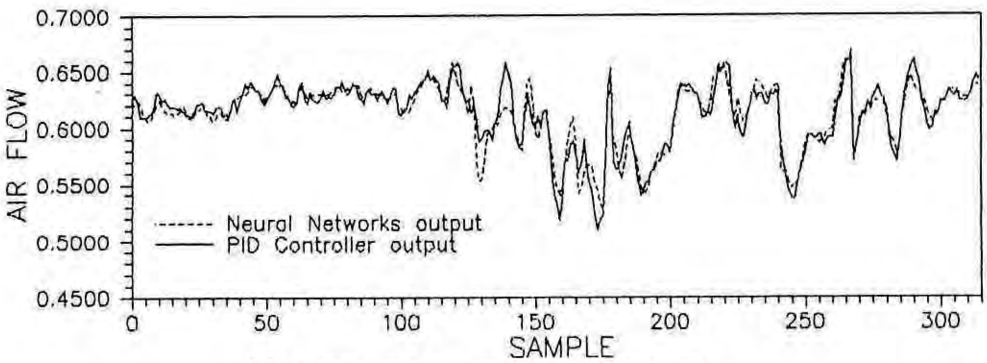


(d) Feedforward network with 2 Hidden Layer(9+6 neurons)

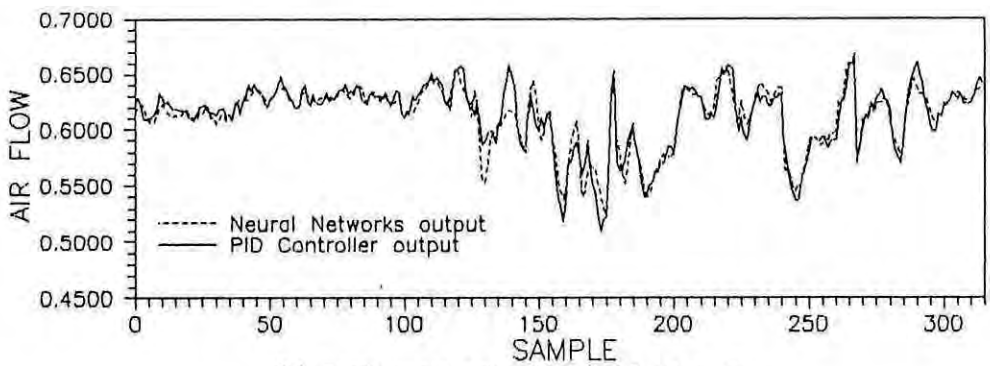
FIG.4.8.Gas Flow of different Feedforward Networks after training



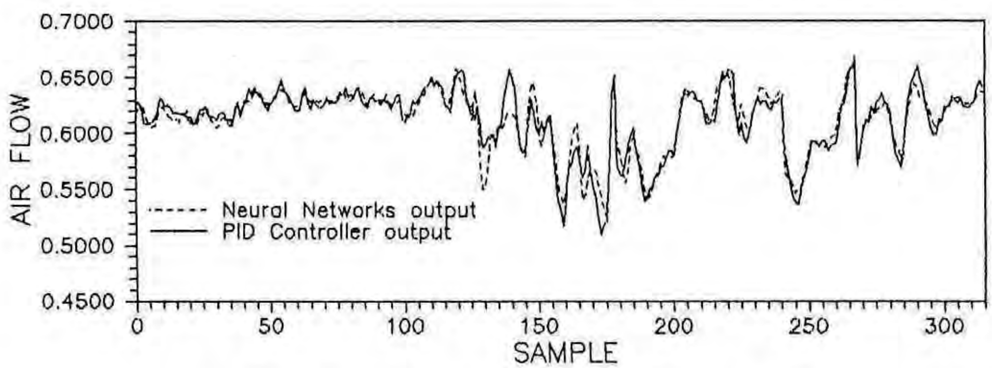
(a) Feedforward network with 9 neurons



(b) Feedforward network with 12 neurons

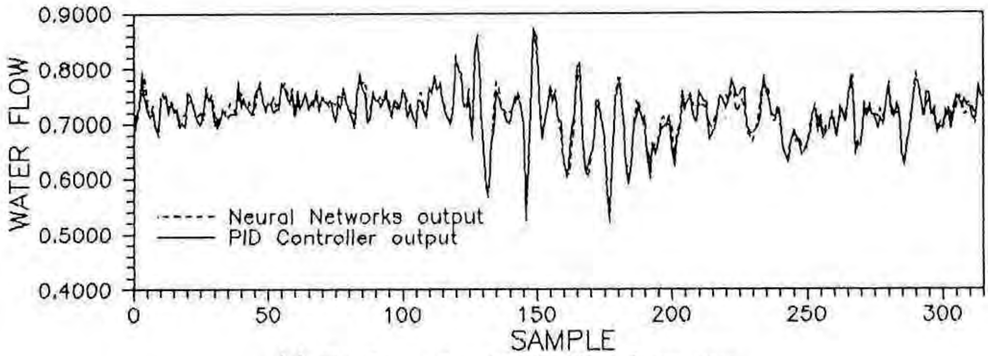


(c) Feedforward network with 15 neurons

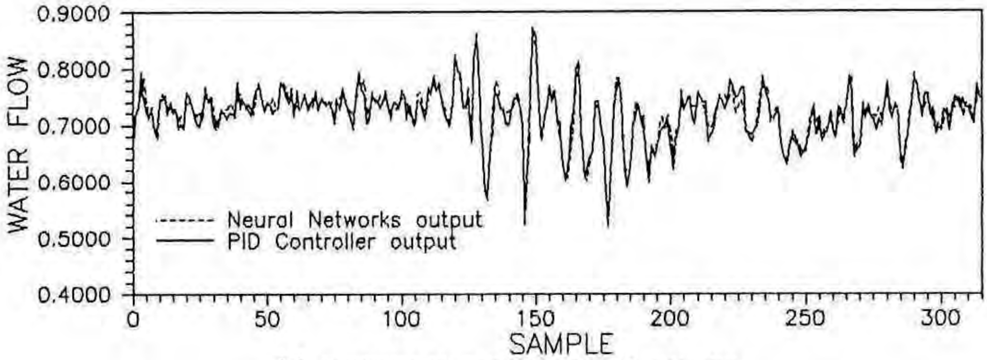


(d) Feedforward network with 2 hidden layer(9+6 neurons)

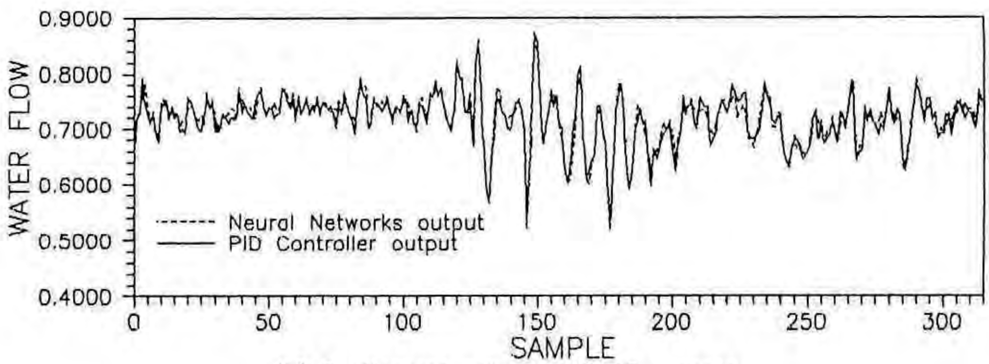
FIG.4.9.Air Flow of different Feedforward Networks after training



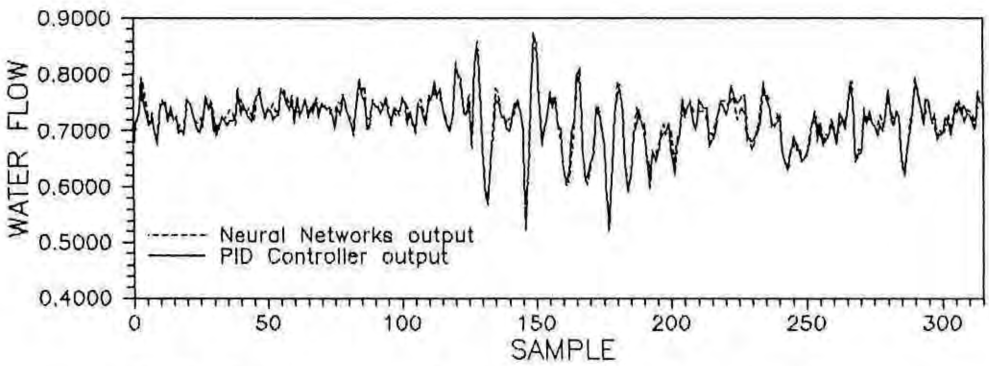
(a) Feedforward network with 9 neurons



(b) Feedforward network with 12 neurons



(c) Feedforward network with 15 neurons



(d) Feedforward network with 2 hidden layers (9+6 neurons)

FIG.4.10. Water Flow of different Feedforward Networks after training

4.4.2 Training for Diagonal Recurrent Network

A diagonal recurrent network with single hidden layer is trained by dynamic backpropagation training algorithm with adaptive learning rate. This learning scheme is described in the previous chapter. Various networks are trained with different number of neurons such as 7, 9, 12, and 15. After 50,000 iterations the training history for each case is depicted in Fig 4.11. From the figure it is evident that in the case of 7, 12, and 15 neurons, the training process becomes unstable and convergence becomes very slow, whereas in the case of 9 neurons, fast convergence and stable minimum error is found. Thus the network with nine neuron in hidden layer is selected for further training. After 300,000 iteration the error convergence rate is very low and the error square is 0.00023. Thus weights of the network are then saved to design the controller. The weights are given in appendix- C.

4.5 TEST RESULTS AND SELECTION OF NETWORK

Initially two neural net controller are developed to choose the better one. The first N
controller is designed using the weights of the feedforward network. While the sec
NN controller is designed using the weights of the recurrent network. To test these
controllers, four sets of test data are taken from the history file of the ZFCL whi
not used during the training. These sets of test data are given in Appendix D. Both
developed NN controllers are tested individually by using each set of test da

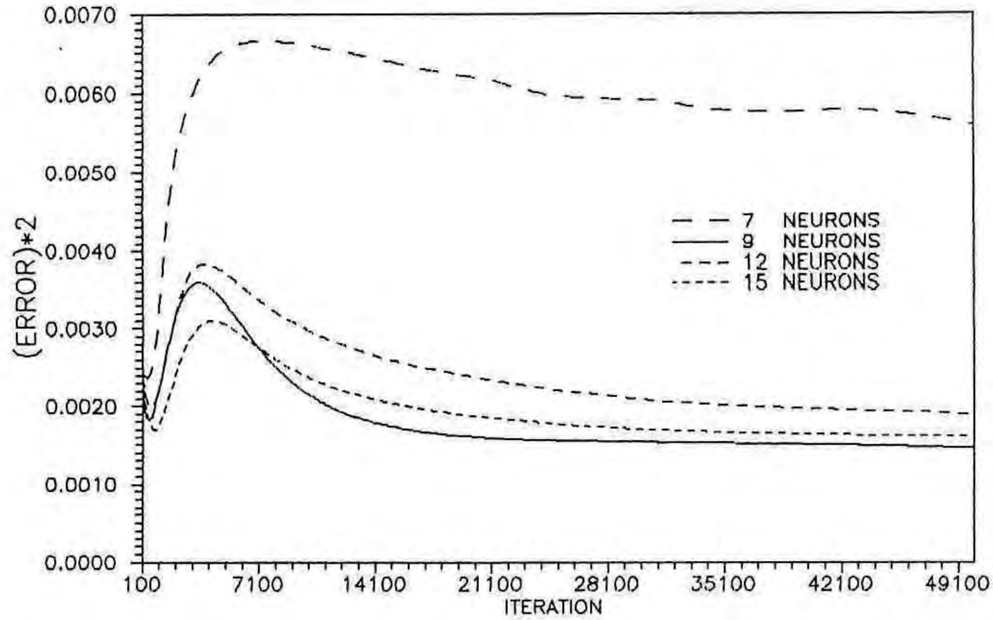


Fig.4.11. Training history of diagonal feedback network with different hidden neurons.

developed NN controller predicts the plant inputs such as air flow, gas flow and water flow for a particular plant output. Predicted plant inputs of both NN controller are then compared with the actual plant inputs which are controlled by the conventional PID controller. These comparisons for each set of test data are shown in Figs. 4.12 to 4.15. Results in the figures show that the actual plant inputs and the predicted inputs from the NN controllers are in well agreement except for a few cases. This may be due to the use of short range of the training data. Both the NN controllers predicted gas flow rate , air flow rate and water flow rate in an hour and those predicted by conventional PID controller are also given in Table-4.1 to 4.4. From the tables it is evident that the total flow rate of gas, air, and water of the developed NN controller based plant are very close to those of the existing PID controller based plant. The comparison tables also shows that in most cases the percentage of error in the case of first NN controller based plant less than that of the second NN controller based plant. Thus the output response of the feedforward network based controller is more better than that of the recurrent network based controller. Moreover, in the case of the first NN controller based plant, the variation in flow (i.e., the difference between the maximum and minimum flow of gas, air and water) is smaller than that of the second NN controller based plant (refer to Figs 4.12 to 4.15. So the first NN controller based plant is more stable than the second NN controller based plant. From Figs. 4.12 to 4.15, it can also be noted here that in the case of the first NN controller (i.e., feedforward network based controller) based plant the variation in flow is smaller than that of the PID controller based plant. Thus the three layered feedforward network architecture with nine neurons in the hidden layer is chosen to design the proposed software controller.

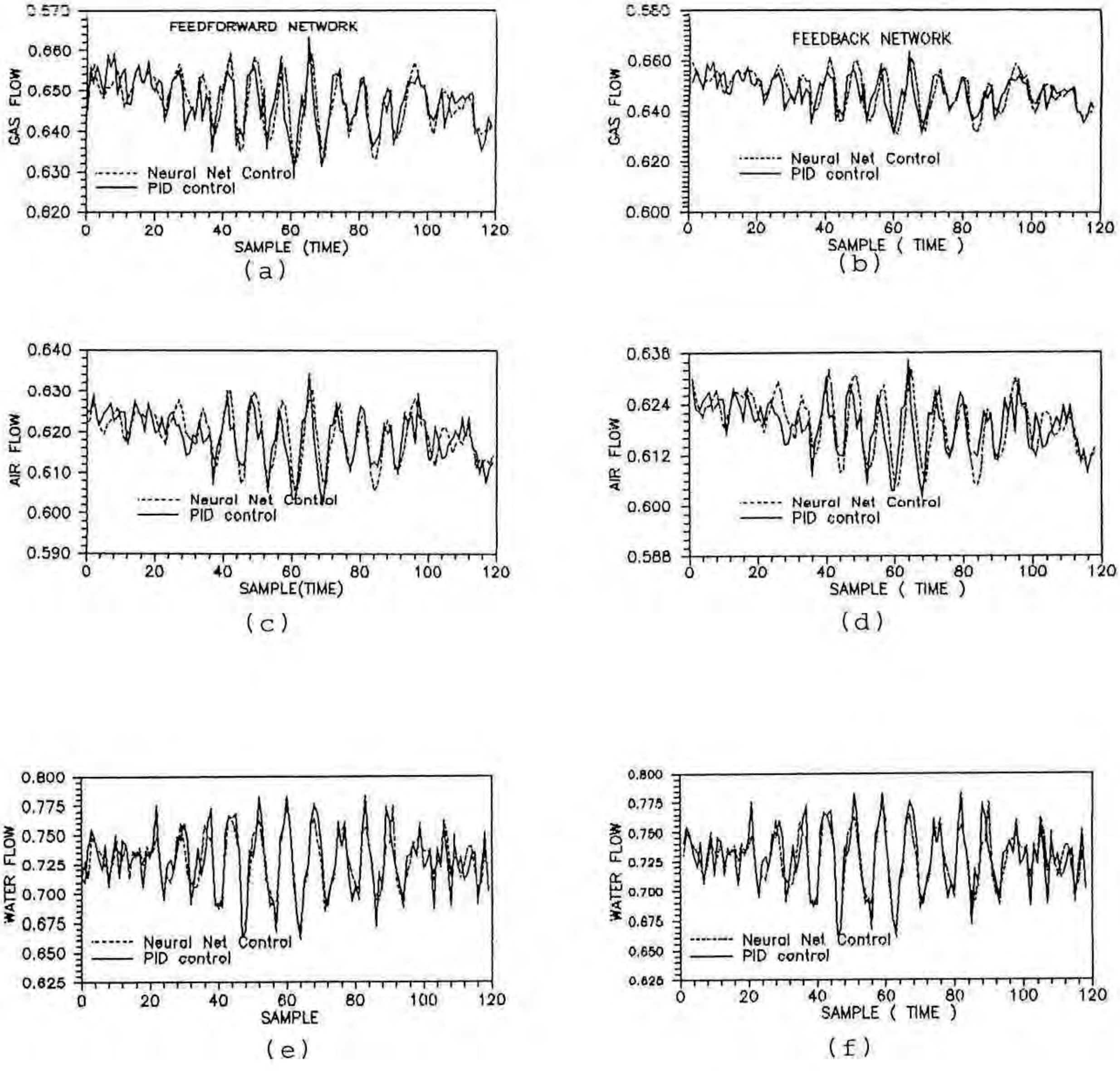


Fig.4.12 : Gas, Air, and Water Flow variation with time
for 1st set of test data.

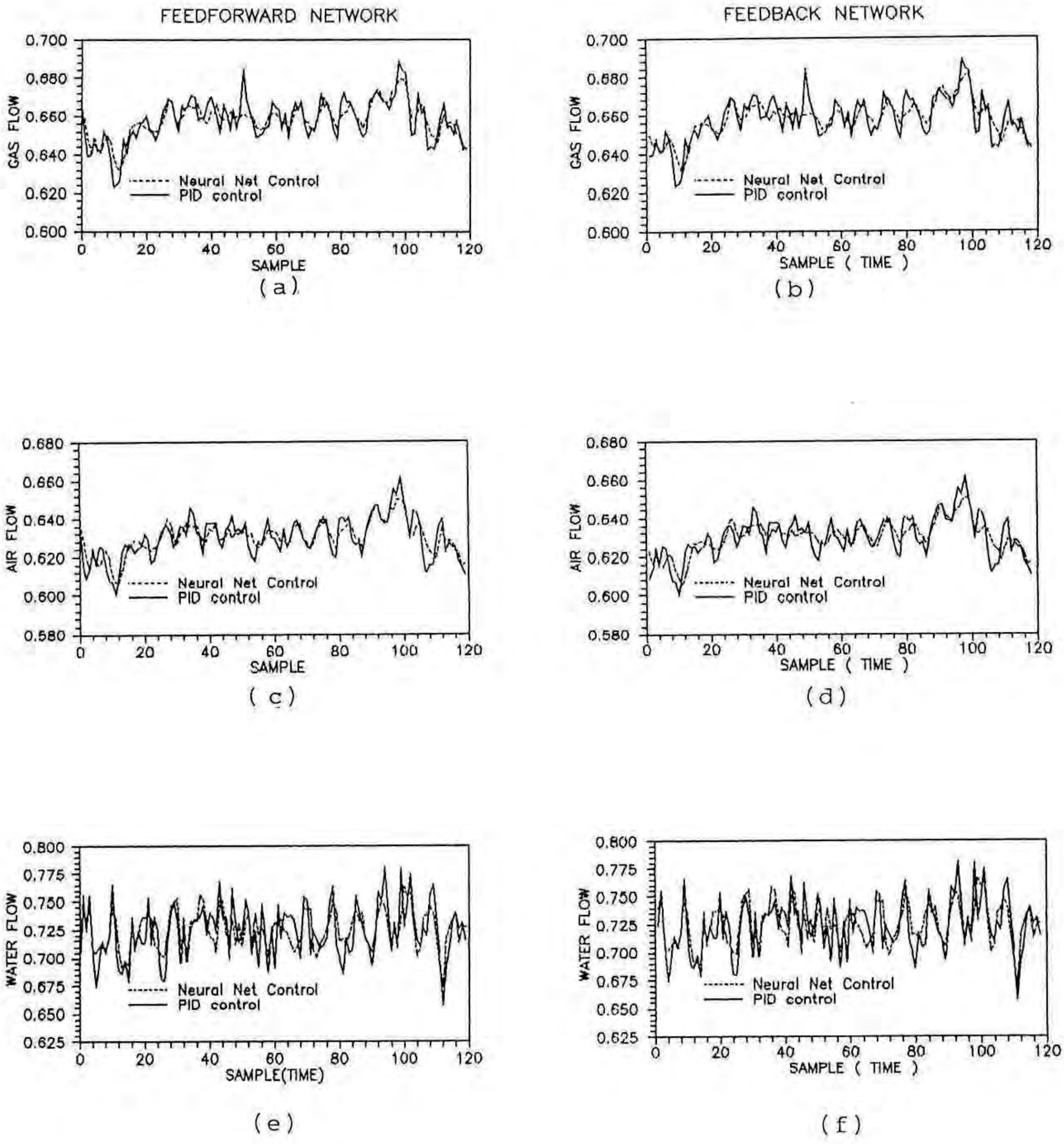


Fig.4.13 : Gas, Air, and Water Flow variation with time for 2nd set of test. data

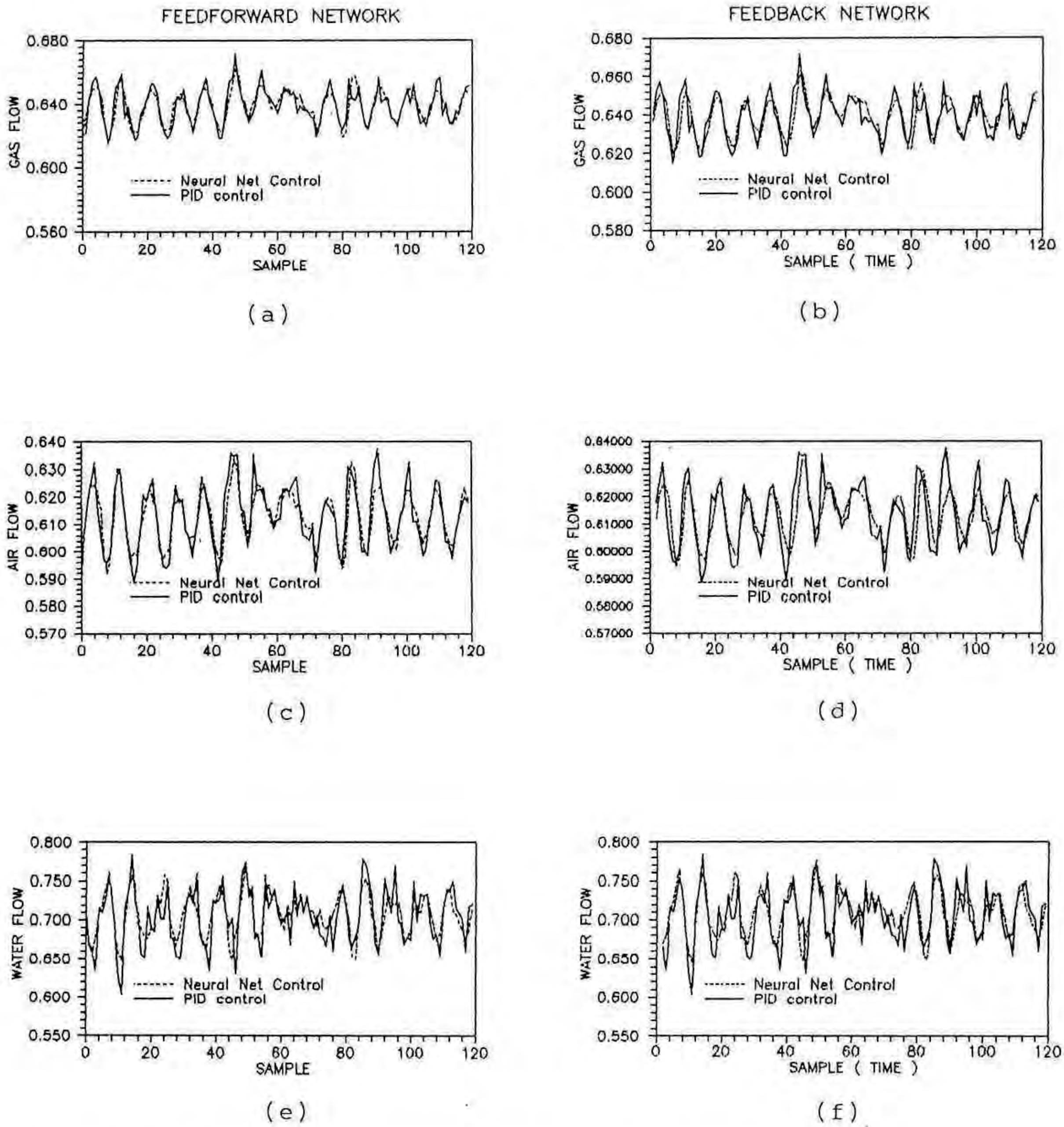


Fig.4.14 : Gas, Air, and Water Flow variation with time for 3rd set of test. data

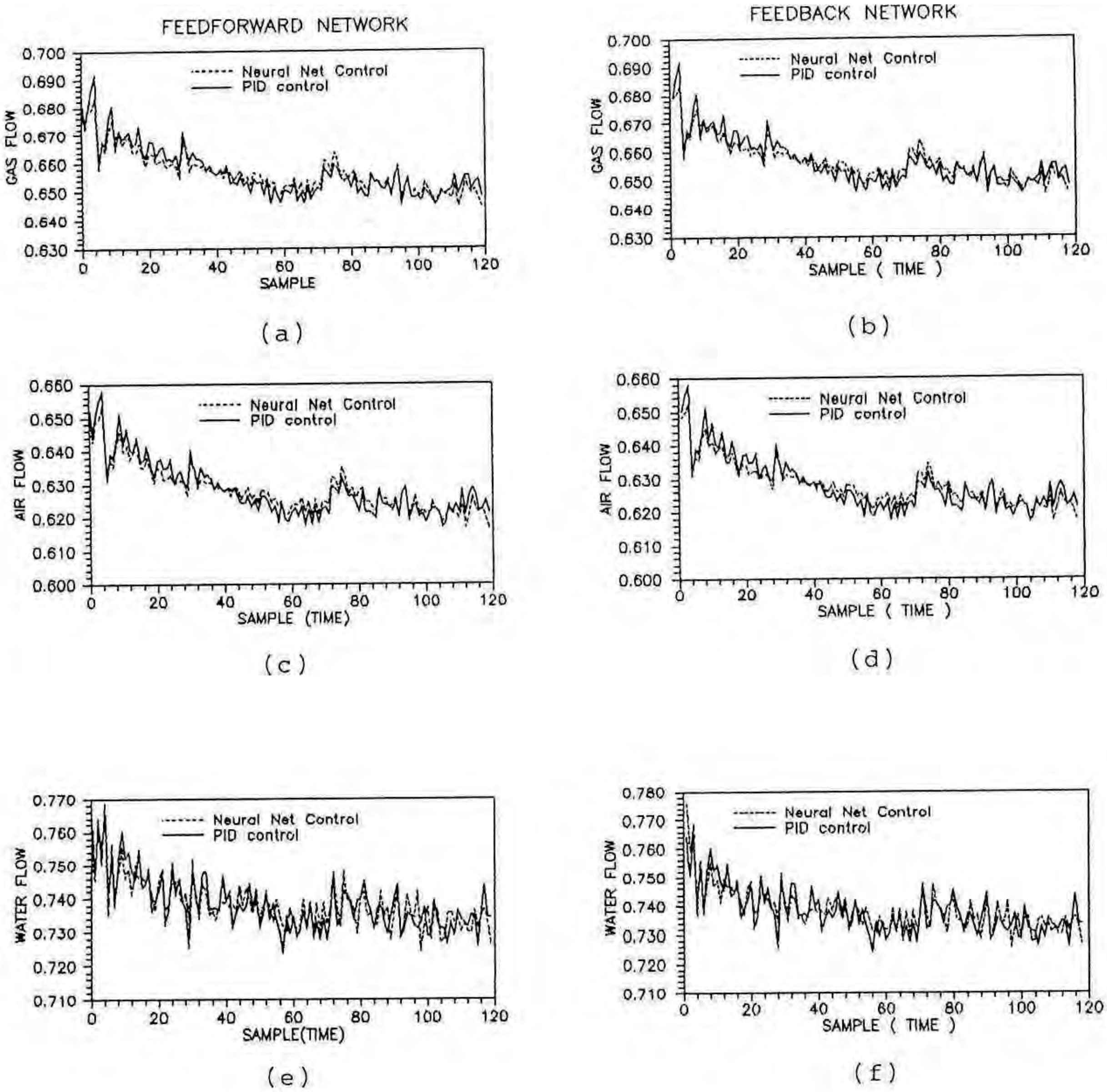


Fig.4.15 : Gas, Air, and Water Flow variation with time
for 4th set of test data

Table-4.1

Flow rate variation of different controller based plant for 1st set of test data.

		PID controller based plant	Feedforward network based plant	Diagonal Recurrent network based plant
GAS	Total flow (NM^3/HR)	8682.99	8682.73	8688.82
	Percentage of Error	-	0.003	0.067
AIR	Total Flow (NM^3/HR	105540.6	105566.1	105625.5
	Percentage of Error	-	0.024	0.080
WATER	Total Flow (TON/HR)	120.92	120.72	120.60
	Percentage of Error	-	0.165	0.266

Table-4.2

Flow rate variation of different controller based plant for 2nd set of test data.

		PID controller based plant	Feedforward network based plant	Diagonal Recurrent network based plant
GAS	Total flow (NM^3/HR)	8827.08	8829.00	8827.89
	Percentage of Error	-	0.022	0.009
AIR	Total Flow (NM^3/HR	107419.1	107439.5	07427.8
	Percentage of Error	-	0.019	0.008
WATER	Total Flow (TON/HR)	120.21	120.34	120.38
	Percentage of Error	-	0.110	0.141

Table-4.3

Flow rate variation of different controller based plant for 3rd set of test data .

		PID controller based plant	Feedforward network based plant	Diagonal Recurrent network based plant
GAS	Total flow (NM^3/HR)	8572.73	8572.12	8574.11
	Percentage of Error	-	0.007	0.0161
AIR	Total Flow (NM^3/HR	104561.1	104523.0	104524.4
	Percentage of Error	-	0.0365	0.0352
WATER	Total Flow (TON/HR)	117.02	117.42	117.69
	Percentage of Error	-	0.3344	0.5725

Table-4.4

Flow rate variation of different controller based plant for 4th set of test data.

		PID controller based plant	Feedforward network based plant	Diagonal Recurrent network based plant
GAS	Total flow (NM^3/HR)	8809.59	8808.00	8810.66
	Percentage of Error	-	0.018	0.012
AIR	Total Flow (NM^3/HR	107123.6	107113.5	107137.3
	Percentage of Error	-	0.009	0.013
WATER	Total Flow (TON/HR)	122.53	122.54	122.58
	Percentage of Error	-	0.007	0.041

4.5 PERFORMANCE OF THE DEVELOPED CONTROLLER

The performance of the developed controller can be determined from the characteristics of the boiler such as average air/gas ratio, steam/gas ratio as well as gas and air flow due to change in steam load. Average air/gas ratio and steam/gas ratio are computed from the developed controller predicted inputs (such as gas, air and water flow). These ratios are given in Table-4.5. From the table it can be found that the predicted ratios of of developed controller are very close to the ratios obtained from the history file of the PID controller based boiler plant. The air flow and gas flow due to steam load change are shown in Figs.4.16 and 4.17, respectively. From the figures it is evident that the characteristics of air and gas flow due to steam load change are similar for both PID and NN controller. Thus it can be concluded here that the developed NN controller has the ability to control the reference boiler (i.e. 120 ton/hour capacity boiler of ZFCL) having the non-linear process dynamics.

Table - 4.5
Comparison of air/gas and steam/gas ratios

Average Ratio	Proposed NN controller based plant	Actual PID controller based plant
Air / Gas	12.168	12.167
Steam / Gas	13.556	13.553

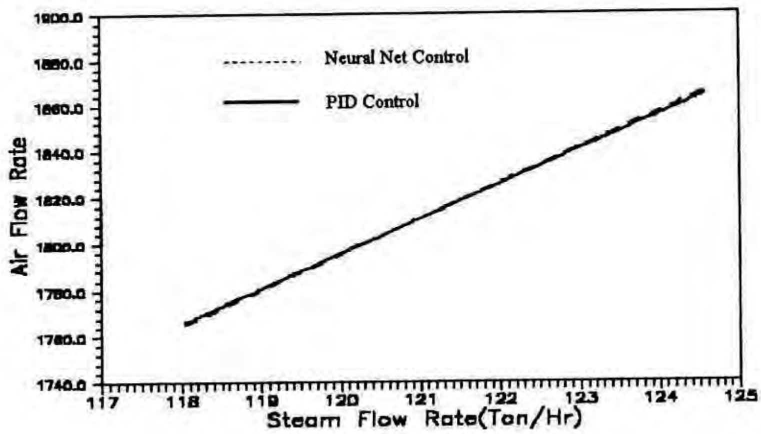


Fig. 4.16. Variation of air flow with load (steam flow).

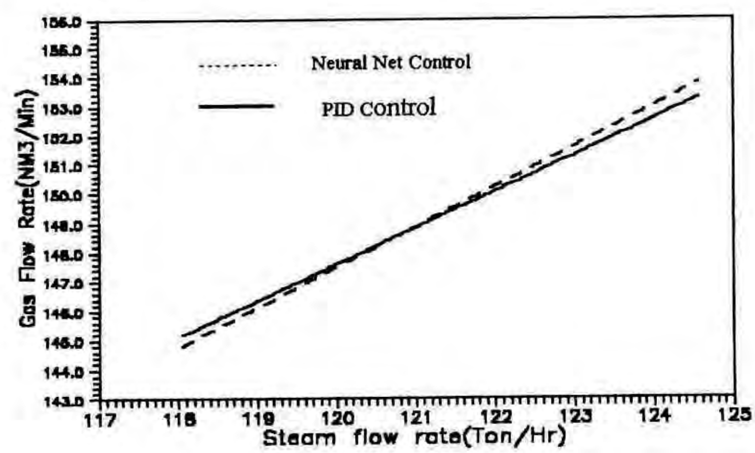
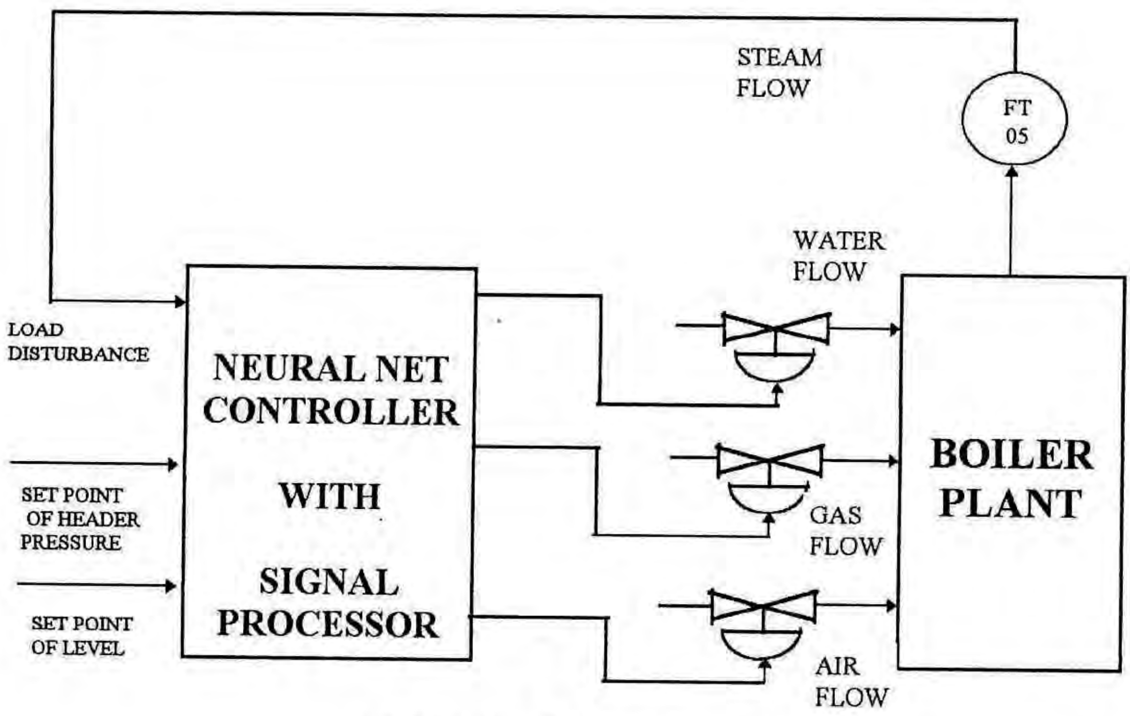


Fig. 4.17. Variation of gas flow with load (steam flow).

4.6 RUNNING MODE OF THE PROPOSED CONTROLLER

The running mode of the developed controller is shown in Fig. 4.18. During the normal operation of the proposed controller, the desired set points of the steam header pressure and the drum level can be changed by the operator through the keyboard. The load disturbance is sensed continuously by steam flow transmitter. Thus if any change in steam flow is occurred then the control inputs of the plant such as gas, air and water will be changed automatically by the proposed controller.

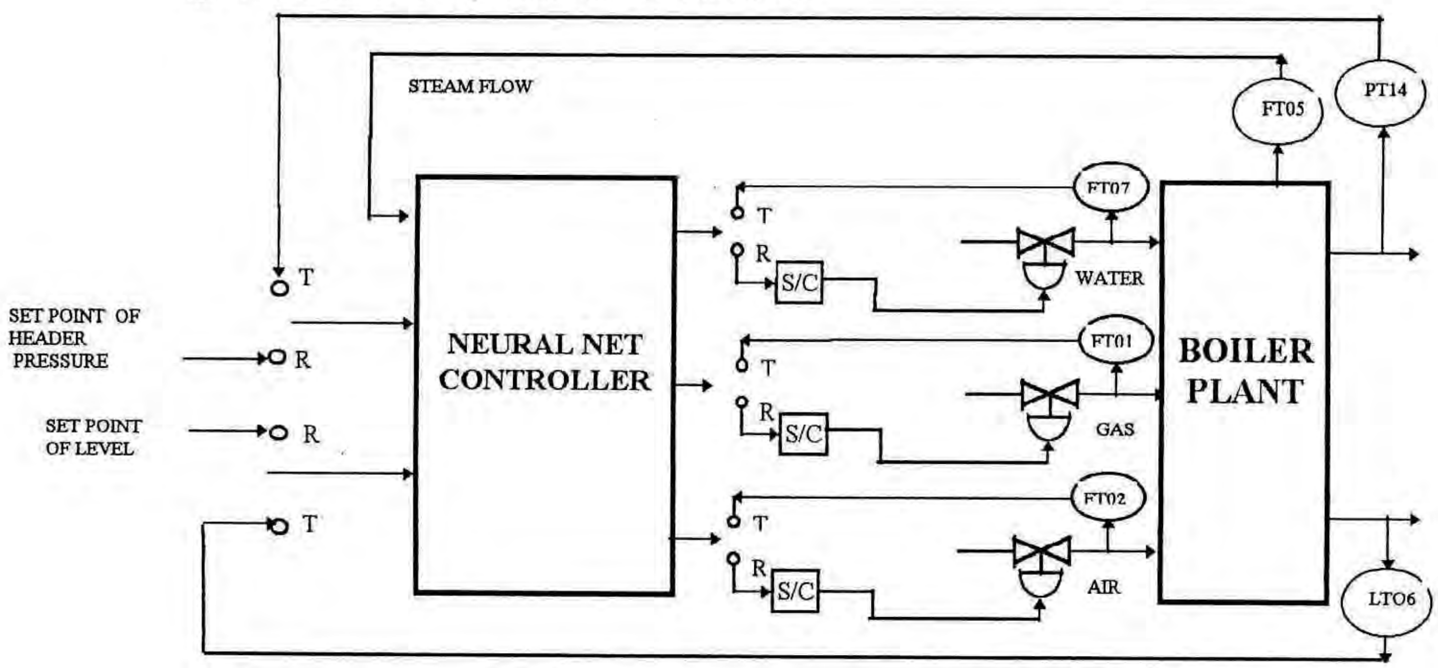


FT 05 = Steam flow transmitter

Fig. 4.18 Running mode of the proposed Neural Net Controller.

4.7 NEURAL NET CONTROLLER WITH BOTH MODE

Training and running mode of the proposed neural net controller is shown in Fig. 4.19. The user can select either the training mode or the running mode through keyboard by pressing "T" for training and "R" for running . During the training mode the boiler plant output-input such as steam header pressure, drum level , steam flow, gas flow, air flow and water flow are used as training data of the NN controller as mentioned in section 4.4. The input output data can be obtained from the output of the transmitters such as PT14 for steam header pressure, LT06 for drum level, FT05 for steam flow, FT01 for gas flow, FT02 for air flow and FT07 for water flow. The training operation must be done during the plant shut down(i.e., off-line training). At running mode (i.e. at the normal operation of the plant) the desired set points such as steam header pressure and drum level is changed by operators through computer keyboard as mentioned in the previous section. The NN controller output will change due to steam load disturbance which is measured by FT05. The controller output is than converted into in electronic signal which is used to postion the control valves.



FT01 = Gas flow transmitter, FT02 = Air flow transmitter, FT07=Water flow transmitter, FT05 = Steam flow transmitter, LT06=Drum level transmitter, PT14= Header pressure transmitter, T = Training mode, R=Running mode, S/C= Signal converter.

Fig. 4.6 Proposed Neural Net controller for 120 ton/hour capacity boiler of ZFCL.

CHAPTER - FIVE

REAL TIME OPERATION OF THE PROPOSED CONTROLLER

- INTRODUCTION
- CONTROL VALVE MODEL
- ON-LINE REAL TIME PULSE GENERATION
- RESULTS

5.0 INTRODUCTION

A schematic diagram for real time operation of the developed controller for boiler is shown in Fig.5.1. Each block of the diagram except the controller is described in the following sections. The operation of the control valves is investigated for different sets of test data as mentioned in the previous chapter. For the simulation the valves characteristics (e.g., flow vs. percentage of valve opening) model is developed by the best fit analysis of the data obtained from the history file of the boiler plant of ZFCL. Control valve model gets inputs (such as gas flow, air flow, and water flow) from the neural net controller for a desired plant output. The control valve model calculates the percentage valve opening for each input. A computer software is developed to generate pulse signals for the operation of control valves according to the desired percentage valve opening. The generated pulse signal is then sent to an external circuit through the parallel port of the computer. The average voltage of the pulse is measured by a voltmeter which is calibrated in terms of percentage of valve opening. The measured valve opening is then compared with actual valves opening.

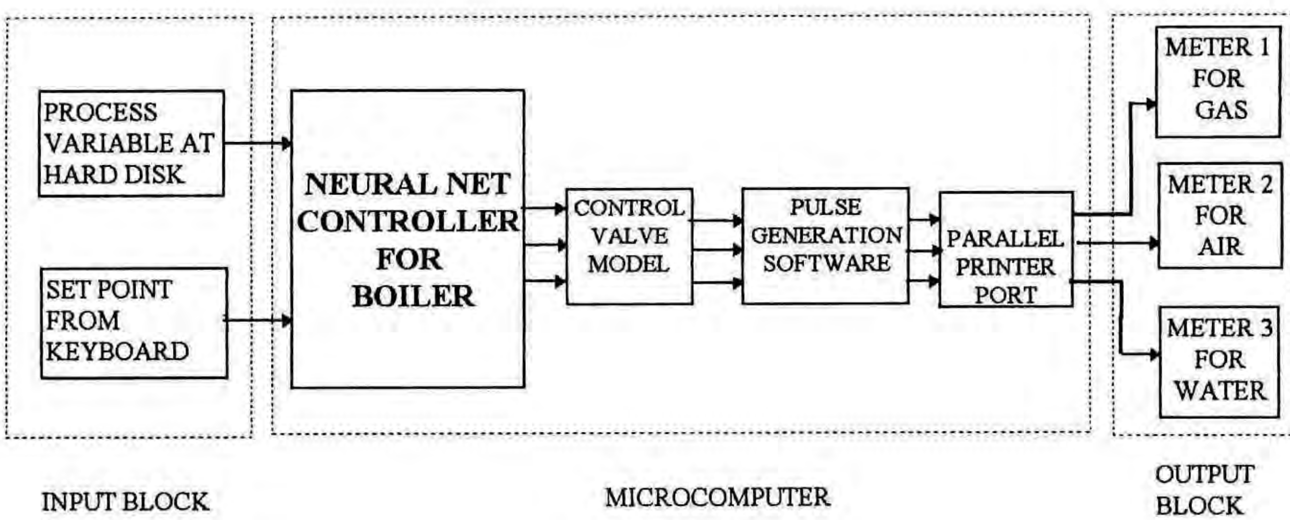


Fig 5.1. Block diagram of simulation setup of Neural Net Controller for Boiler plant

5.1 CONTROL VALVE MODEL

The neural network controller predicts the value of plants control inputs such as gas, air, and water flow according to the desired set point of steam header pressure and drum level. To determine the control valves opening from the predicted control inputs an equation is developed by the best fit analysis of the normalized training data. It is assumed that the relationship between the control input flow and valve opening is linear. The equations for different control inputs are as follows :

For Gas $\quad y = 0.4275x + 0.279 \quad$ (5.1)

For Air $\quad y = 2.1x - 0.582 \quad$ (5.2)

For Water $\quad y= 0.2545x +0.072 \quad$ (5.3)

where, x= NN controller output

y = Control valve opening.

From the above equation the control valve opening is determined. A corresponding electronic pulse signal is then generated whose average value of the voltage is used to position the control valve.

5.2 ON-LINE REAL-TIME PULSE GENERATION

The average voltage of the generated pulse is proportional to the control valve opening. This voltage can be controlled by the Pulse Width Control (PWC) technique. In this technique average voltage of the pulse is controlled by changing the pulse width. The waveform of the pulse is shown in Fig.5.2 where pulse period T represents the maximum valve opening (100%) . The generated signal becomes available at the parallel port of the computer and it sustains until the next data is available.

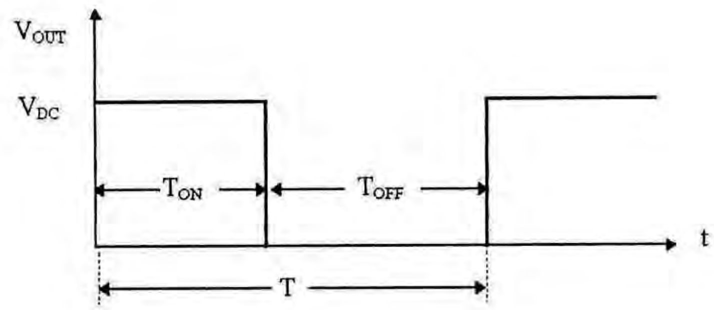


Fig.5.2. Waveform of the generated pulse.

The average voltage of the pulse is given as [39],

$$V_a = \frac{1}{T}\int_0^{T_{ON}} V_{OUT}.dt$$

$$V_a = \frac{T_{ON}}{T}.V_{DC}$$

$$V_a = D.V_{DC} \qquad (5.4)$$

where D = Duty cycle = $\frac{T_{ON}}{T}$

The period T and V_{DC} are constant. So the average voltage varies with the time T_{ON} which represents the actual valve opening.

An algorithm of PWC technique is described in the following paragraphs. This algorithm is implemented by a computer program[40][41]. A flow chart of the program shown in Fig.5.3. Brief description of each step of the flow chart is given below.

STEP- 1 :

Get the values of gas, air, and water valves opening as the variables tg, ta, and tw respectively from the output of valve model. Also set the total number of time segments to be scanned for generation of the pulse pattern as *num_seg* = 100.

STEP- 2 :

This step creates an array deci[r] of decimal numbers and initializes it with binary values '0'. Here r is the segment number , r=0, 1, 2, ... *num_seg*.

STEP- 3 TO 5 :

These steps create three arrays g[r], a[r], and w[r] for the value of gas, air and water valve respectively. Binary values '1' (high) will be stored in the array positions ranging from [0] to [tg*num_seg], [ta*num_seg], and [tw*num_seg] for gas, air, and water valve respectively. While binary values '0' (low) will be stored in the array positions starting from [tg*num_seg] or [ta*num_seg] or [tw*num_seg] to [num_seg] respectively.

STEP - 6 :

This step creates an array deci[r] of decimal numbers, which incorporates each of the above three arrays (i.e., g[r], a[r], and w[r]) as $deci[r]= g[r]*2^0 + a[r]*2^1 + w[r]*2^2$. This expression represents the respective time segment of three pulses to be generated.

STEP- 7 :

In this step pulses are generated as a composite byte. This byte will sent at the data pin (pin 2 for gas valve, pin 3 for air valve and pin 4 for water valve) of the parallel port which is addressed as 0x378. Each and every decimal numbers of the array deci[r] will be sustained for a time of 1 ms sequentially.

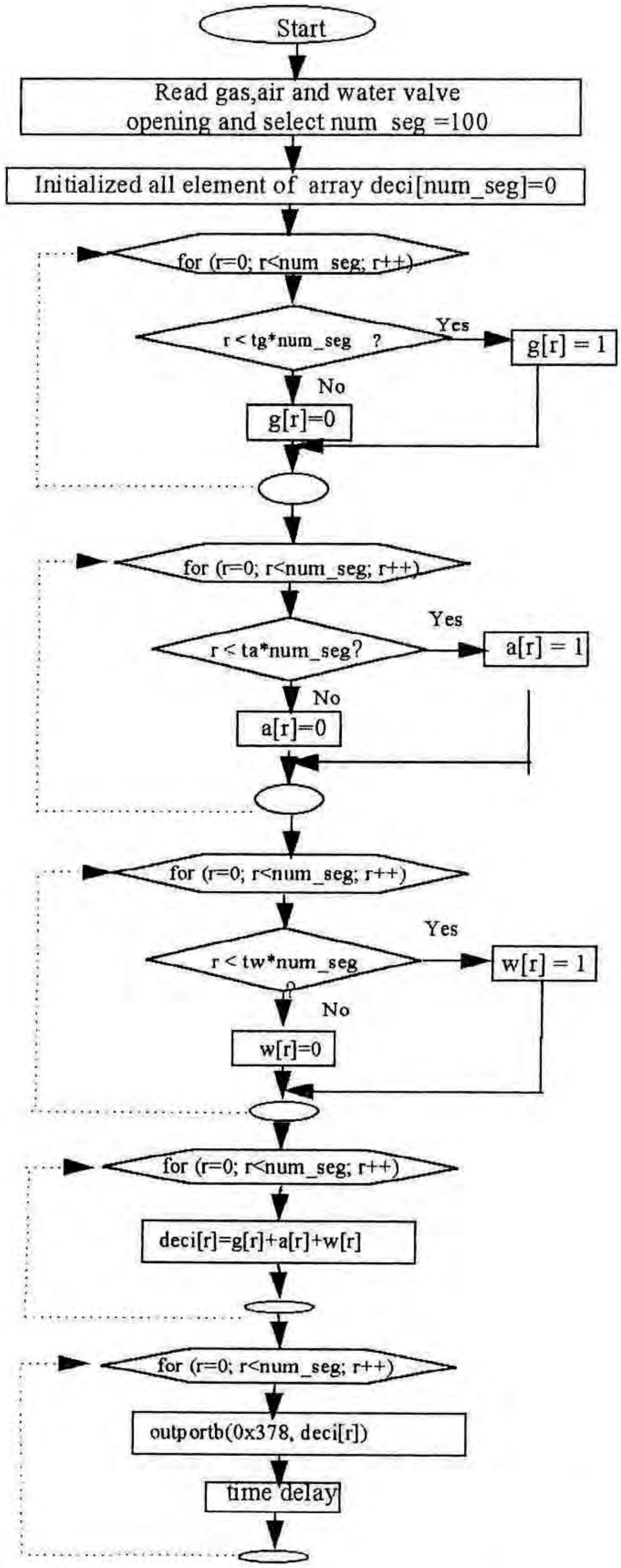


Fig. 5.3 Flow chart for on-line signal generation by PWC technique.

5.3 RESULT

The average voltages of the pulses at pin number 2, 3, and 4 of the parallel port of the computer are measured by voltmeters for investigating the operation of control valves for the gas, air, and water flow respectively. In all cases it is found that the percentage of valve opening corresponding to the measured voltage follows the valve characteristics. It is also found that the pulses at the port are sustained until the next set of data is available. The simulation result (i.e. the measured average voltage of the pulse corresponding to percentage of valve opening) is given in table-5.1.

Table-5.1 : Simulation result

Measured average voltage vs. percentage of valve opening

Average voltage of pulse (Volt) From simulation	Percentage of valve opening in (%)
0.0	0
1.25	25
2.50	50
3.75	75
5.00	100

CHAPTER - SIX

CONCLUSION

- CONCLUSION
- RECOMMENDATION FOR FUTURE WORKS

6.1 CONCLUSION

In this thesis, a multi-layered neural network based an integrated controller has been developed to control a nonlinear MIMO boiler plant. Drum level control and combustion control of the boiler is performed by the integrated controller. The process inverse dynamic methodology has been applied to design the integrated NN controller. The real time input output data of 120 ton/hour capacity boiler of ZFCL, Ashuganj, Bangladesh has been used for training of the networks. Nonlinear activation function has been considered because of nonlinear process of boiler plant.

Two neural networks such as feedforward and diagonal recurrent networks have been trained over the full working range of the boiler to memorize the reverse input/output mapping of the boiler plant. General backpropagation and dynamic backpropagation training algorithm is implemented for feedforward and diagonal recurrent network respectively to obtain the network weights which produce minimum difference between networks predicted output and desired input. The proposed software controller is then developed using the weights of the feedforwrd networks. Because feedforward network based controller has been shown better output response and performance than those of the feedback network based controller.

The developed controller has been tested by using different sets of boiler plant input-output data which were not used during the training. The output response and performance of the developed controller has also been compared with that of the existing six single input single output PID controller. Comparison shows that the developed controller has the learning capability and ability to control a boiler plant having the non-linear process dynamics. It can be noted that the integrated controller has also the ability to solve the loop interaction problem in MIMO plant by its parallel operation.

A real time operation of the developed controller has been implemented. The valves characteristics model has been developed by the best fit analysis. The control valve model calculates the percentage valve opening for each input. A computer software has been developed to generate pulse signals for the operation of control valves. The generated pulse signal is then sent to an external circuit through the parallel port of the computer is sustained until any disturbance is occurred.

The main drawback of the neuro control approach is it prior training. The success of the NN based controller depends on the proper choice of training data and the learning parameters. Once the neural networks is trained, the NN controller is self-tuned and does not consist any requirement for tuning. Whereas the conventional controller requires tuning which is very difficult task especially in the case of nonlinear plant.

The advantage of the developed controller over the traditional adaptive and conventional controller is that the developed controller can be used to highly nonlinear plants. The non-linear sigmoid functions in the hidden neurons allow the network to learn and solve nonlinear control problems where to this end traditional controllers have no solution yet. Moreover, the parallel operation of the proposed controller are more robust even some of the synaptic connections failed. The benefits of the use of the proposed NN based integrated controller include faster response, adaptive control, simplicity and reliability. This technique can also be implemented in real time control of other process industries such as refinery plant and distillation plant.

6.2 RECOMMENDATION FOR FUTURE WORKS

The following recommendations have been made to extend the proposed controller.

1. The temperature control loop has not been considered for integration because of the nonavailability of loop input data (i.e., the quantity of spray water). If this data is available, the present work can be extended by considering the temperature control loop in addition to the drum level control loop and combustion control loop for integration.

2. The on-line operation of the developed NN controller performance has been investigated by observing the operation of the control valves which are simulated by voltmeters. If the mathematical model of the boiler process is known, further investigation of the performance of the NN controller can be carried out by observing the plant output.

3. The developed NN based controller is a direct inverse controller. It does not have the error correction capabilities. This can be introduced by using errors (which is the difference between desired plant output and actual measured output) as NN inputs instead of direct plant outputs.

4. The developed controller is based on the feedforward network which is trained by GBP algorithm. Further work can be carried out by training the feedforward network by backpropagation through time training algorithm to improve the controller performance.

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APPENDIX - A

TRAINING DATA

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
Min	0.0	-250.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	140.0	250.0	166.0	225.50	2866.0	166.0	100.0	100.0	100.0
TIME									
16:00:30	90.008	53.344	116.587	135.765	1657.920	120.184	52.163	47.856	27.577
16:01:00	89.906	54.990	116.698	134.097	1650.630	115.785	52.819	49.200	27.096
16:01:30	89.819	58.635	117.203	135.723	1657.800	113.783	53.129	50.227	26.231
16:02:00	89.965	56.219	116.573	135.610	1647.290	114.374	52.981	50.117	27.465
16:03:00	90.008	58.042	116.515	133.792	1669.740	113.468	53.540	48.162	28.067
16:03:30	90.037	58.938	116.501	133.040	1642.630	123.193	53.137	48.952	26.204
16:04:00	90.037	57.500	116.871	134.919	1625.140	109.311	52.006	49.519	27.594
16:05:00	90.037	56.969	117.632	134.187	1665.560	123.082	52.917	48.465	26.442
16:06:00	89.862	57.115	118.216	134.736	1650.930	111.469	52.821	49.788	27.858
16:06:30	89.731	59.240	119.565	136.705	1703.710	111.116	54.283	49.769	28.031
16:07:00	89.775	57.802	119.191	138.302	1703.890	115.432	54.369	50.340	27.125
16:07:30	89.965	61.969	118.669	136.940	1639.590	111.715	52.973	51.502	27.698
16:08:00	89.965	52.813	118.974	136.897	1648.010	115.861	53.142	51.102	28.619
16:08:30	89.994	55.531	118.316	135.991	1647.530	113.011	53.171	51.029	28.010
16:09:00	89.950	56.896	118.406	135.831	1684.610	106.776	54.377	49.925	28.581
16:09:30	89.979	56.896	118.206	136.230	1664.430	114.042	53.519	50.123	27.029
16:10:00	90.023	59.771	118.666	133.956	1684.430	120.602	53.979	48.881	26.694
16:10:30	89.877	61.292	119.831	136.258	1640.720	116.159	52.831	52.529	26.494
16:11:00	89.965	52.125	118.289	137.330	1684.670	126.215	53.675	50.350	27.085
16:11:30	90.052	52.427	117.836	136.517	1645.980	114.021	52.015	50.388	27.650
16:12:00	89.965	55.156	118.866	135.234	1618.870	122.079	52.690	52.356	27.008
16:12:30	89.921	56.208	118.026	136.460	1636.360	113.440	52.950	51.990	27.858
16:13:00	89.892	60.448	119.032	136.676	1702.460	112.603	54.181	50.135	26.650
16:14:00	90.125	56.740	118.493	135.807	1638.690	113.222	52.706	49.944	28.019
16:14:30	89.965	55.083	119.046	135.352	1676.310	117.742	53.587	49.531	27.458
16:15:00	89.848	57.427	119.769	136.723	1700.430	114.253	53.604	50.208	27.442
16:15:30	89.935	54.094	119.378	137.019	1703.590	118.604	53.952	50.737	27.171
16:16:00	90.081	54.385	118.725	136.169	1645.140	118.576	53.281	51.487	27.852
16:16:30	89.862	63.188	120.257	137.005	1678.580	103.138	53.800	51.813	28.171
16:17:00	90.183	47.958	116.833	135.972	1643.470	130.085	52.642	51.165	27.954
16:17:30	90.213	56.292	116.923	131.311	1621.910	111.791	53.460	50.260	27.556
16:19:00	89.994	61.958	118.355	132.895	1681.800	115.142	54.177	49.354	26.610
16:20:00	89.979	52.646	118.614	136.597	1662.870	116.456	53.267	50.485	28.631

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
16:20:30	90.140	48.104	116.567	134.652	1629.970	126.122	52.385	50.152	28.058
16:21:30	90.008	62.042	115.750	132.326	1619.940	106.434	52.967	50.823	27.246
16:22:00	89.833	65.979	117.054	136.846	1672.250	97.318	52.885	50.987	27.496
16:23:30	90.140	59.167	116.712	129.296	1636.780	111.884	53.006	47.133	26.879
16:24:00	90.008	56.813	116.708	131.894	1648.600	118.313	53.013	48.125	27.425
16:25:00	89.819	62.646	117.601	132.571	1642.030	107.174	53.025	50.325	25.960
16:26:00	90.227	46.073	113.551	133.820	1594.450	116.076	52.240	48.967	29.500
16:26:30	90.125	54.917	114.509	131.246	1600.960	113.302	52.225	48.388	26.210
16:28:00	89.673	64.625	121.069	138.960	1700.970	109.992	54.254	51.169	27.042
16:28:30	89.950	53.708	120.599	136.536	1659.410	117.874	53.540	50.273	29.915
16:29:00	89.965	48.406	119.140	136.597	1668.190	127.740	53.027	49.360	28.073
16:30:00	89.760	57.427	119.354	141.074	1709.980	115.567	53.925	52.700	27.560
16:30:30	89.921	59.167	119.918	139.744	1690.880	111.469	53.477	51.354	27.496
16:31:30	89.965	60.375	119.997	135.915	1659.110	111.587	53.150	50.979	27.156
16:32:00	89.790	62.802	121.315	137.250	1689.260	112.797	53.671	52.156	27.573
16:32:30	89.469	63.396	124.749	140.975	1761.390	114.180	55.385	53.550	26.590
16:38:00	90.490	64.844	110.860	123.804	1541.600	100.873	51.265	45.408	25.892
16:39:30	90.533	47.354	109.197	123.771	1555.040	121.363	51.683	42.915	26.644
16:40:00	90.227	56.063	111.241	122.461	1499.870	107.457	50.506	46.413	26.248
16:41:00	89.892	55.156	110.947	130.170	1571.220	115.598	51.273	46.423	26.604
16:41:30	90.271	50.833	108.595	126.228	1505.000	118.562	50.975	46.550	25.575
16:43:00	89.921	58.417	113.375	128.154	1555.820	104.241	51.400	47.165	26.960
16:43:30	90.154	46.656	110.068	126.614	1533.720	115.999	50.917	46.063	27.704
16:44:00	89.921	57.510	112.026	125.820	1573.790	106.230	51.633	45.573	26.013
16:45:00	89.804	59.010	113.409	131.941	1590.740	106.748	51.933	47.727	26.396
16:45:30	89.848	56.594	114.312	130.240	1576.300	104.808	52.385	48.592	28.029
16:46:00	89.921	55.156	114.519	129.691	1593.070	116.726	52.433	47.490	26.335
16:47:30	89.877	58.417	115.211	131.387	1593.130	114.063	51.798	48.677	27.479
16:48:00	89.863	58.938	114.779	130.696	1634.750	114.786	53.054	47.321	26.040
16:51:00	89.979	54.615	113.568	127.633	1572.950	113.838	51.742	47.233	27.223
16:52:00	89.979	57.271	114.094	131.471	1587.820	109.878	51.704	46.792	28.844
16:52:30	89.950	52.125	113.527	129.348	1593.730	117.071	52.496	47.287	27.335
16:53:00	89.979	59.250	113.316	129.118	1595.520	112.219	52.056	47.556	27.173
16:54:00	89.673	61.146	115.785	135.197	1625.550	107.955	53.260	50.856	27.863
16:54:30	89.877	60.229	116.148	134.746	1632.120	110.933	52.969	49.587	27.425
16:55:00	90.227	53.865	113.918	129.639	1596.180	107.533	52.906	47.354	28.915
16:56:00	90.329	50.979	111.877	127.854	1550.260	116.466	51.940	47.104	27.092
16:56:30	90.256	58.563	111.638	125.401	1553.190	103.698	51.915	46.071	26.685
16:57:00	90.154	57.583	110.943	127.638	1548.710	107.869	50.658	46.700	25.992
16:57:30	90.344	52.427	107.876	124.157	1541.960	110.266	51.623	45.031	27.160
16:58:00	90.183	60.823	110.376	123.137	1538.440	103.792	51.452	45.421	26.256
16:58:30	89.819	71.063	112.790	126.637	1608.120	100.797	53.060	46.325	24.865

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
22:00:30	90.227	46.927	120.845	137.865	1674.400	127.191	53.946	50.446	29.831
22:01:00	90.300	50.844	118.050	134.844	1650.930	115.287	53.073	48.694	29.754
22:02:30	90.213	57.188	118.064	135.619	1654.930	118.648	53.671	49.415	28.375
22:03:00	89.892	64.094	120.087	135.676	1674.690	111.611	53.444	51.123	28.058
22:03:30	89.877	60.719	120.689	139.345	1686.760	104.148	54.017	52.448	29.212
22:04:00	90.169	51.375	119.420	136.747	1671.950	122.653	53.454	50.092	28.571
22:04:30	90.008	55.385	119.717	135.385	1650.100	120.008	53.098	51.525	28.369
22:05:00	90.154	49.448	117.255	136.972	1672.130	124.877	53.388	50.215	28.552
22:05:30	89.994	60.604	117.410	136.705	1660.130	110.947	52.269	51.071	27.042
22:06:00	90.096	62.073	117.251	135.901	1642.510	112.835	53.142	51.665	26.860
22:06:30	90.198	55.677	115.782	134.266	1636.720	113.236	52.056	49.631	28.917
22:07:30	90.344	53.365	115.328	132.599	1613.370	112.794	51.987	48.242	28.117
22:09:00	89.906	56.510	118.323	137.785	1674.690	113.534	53.619	51.350	27.765
22:09:30	90.037	55.531	117.158	135.977	1660.250	116.200	53.108	50.575	28.475
22:10:00	90.110	50.146	116.563	134.520	1653.140	118.043	52.821	49.525	28.885
22:11:30	89.921	59.781	115.771	137.799	1666.100	111.462	53.979	51.971	27.383
22:12:00	90.140	60.990	115.795	136.723	1641.080	107.226	52.810	50.990	27.942
22:12:30	89.935	60.604	116.919	135.211	1644.780	104.563	52.925	51.454	27.550
22:13:00	89.775	60.156	117.770	138.429	1727.600	111.455	54.242	50.671	27.329
22:13:30	90.008	50.542	116.470	138.269	1696.070	121.896	53.960	50.175	28.515
22:14:00	90.067	50.688	116.418	135.093	1675.710	121.885	53.385	49.106	27.454
22:15:00	89.717	58.708	116.577	140.557	1723.180	110.404	54.362	52.431	27.573
22:15:30	89.833	58.333	116.380	142.262	1708.730	112.233	53.663	52.729	27.788
22:16:00	89.585	67.125	119.306	141.811	1720.190	108.073	54.527	54.450	26.629
22:16:30	89.615	61.656	119.672	145.152	1790.170	114.488	55.763	53.206	26.954
22:17:00	90.183	51.063	118.064	141.290	1711.530	126.928	53.548	51.452	28.265
22:17:30	90.023	39.823	115.515	130.020	1625.730	129.113	52.121	46.323	29.917
22:18:00	89.352	54.698	115.411	130.306	1611.220	109.408	52.654	47.398	28.942
22:19:00	88.346	60.531	116.736	135.370	1643.170	119.129	52.069	49.273	26.544
22:19:30	88.069	59.396	116.625	132.885	1632.120	116.795	53.154	49.660	27.358
22:20:00	87.704	57.438	116.525	134.966	1628.180	106.977	52.600	50.998	28.650
22:23:30	84.729	57.917	118.714	143.061	1737.150	114.001	54.900	52.925	27.846
22:24:00	85.065	58.552	118.278	139.350	1694.580	111.555	53.767	50.646	27.887
22:24:30	85.035	57.646	118.057	137.480	1680.790	113.859	53.296	49.948	27.352
22:25:00	84.860	62.688	118.936	137.964	1700.430	117.704	54.071	49.846	25.781
22:25:30	84.656	64.198	120.295	140.346	1717.680	106.738	54.431	52.075	26.044
22:26:00	84.904	59.302	119.731	140.308	1711.360	117.877	54.381	51.777	26.100
22:26:30	85.473	42.948	115.920	135.873	1660.780	130.597	53.404	48.362	26.671
22:27:00	85.429	48.354	115.619	133.609	1618.690	119.420	51.088	47.769	26.431
22:29:00	85.021	58.260	116.881	135.709	1662.510	109.899	53.321	49.929	25.788
22:29:30	85.021	59.990	117.144	135.572	1632.420	103.252	52.608	50.821	26.531
22:30:30	84.846	58.563	118.593	136.921	1683.350	114.004	54.340	50.848	26.829

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
22:31:30	84.904	58.708	117.884	137.997	1704.130	106.814	53.775	49.160	26.754
22:32:30	84.933	56.906	118.541	137.945	1667.530	114.661	53.490	51.290	25.363
22:33:00	84.700	63.521	120.260	140.378	1721.330	107.900	53.773	51.623	25.473
22:33:30	84.729	60.281	120.336	141.722	1765.210	107.748	55.121	50.913	26.385
22:34:00	84.919	54.427	120.602	139.453	1736.430	118.655	55.019	50.619	26.623
22:35:00	84.671	58.417	121.630	140.942	1768.020	118.016	55.727	52.342	25.377
22:35:30	84.744	57.656	122.038	144.964	1757.330	112.261	55.246	53.479	26.721
22:36:00	85.065	53.969	121.294	142.234	1712.430	116.480	54.067	52.298	27.252
22:36:30	85.167	53.531	120.326	140.674	1719.420	115.159	54.108	50.050	27.417
22:37:00	85.006	59.146	119.814	138.852	1691.050	106.226	52.335	51.538	26.577
22:37:30	84.977	56.604	119.520	138.166	1681.920	114.229	54.096	52.827	26.381
22:38:00	84.919	57.969	119.102	139.129	1707.300	110.930	54.115	52.306	26.077
22:38:30	85.137	60.667	118.206	139.054	1687.230	107.094	54.181	51.727	26.165
22:40:00	85.590	53.979	112.842	127.412	1533.480	109.674	52.015	48.065	26.017
22:41:00	84.817	70.281	116.501	137.292	1675.230	103.695	54.177	51.554	24.994
22:41:30	85.210	54.281	116.968	136.169	1662.450	119.243	53.779	48.462	26.415
22:42:00	85.400	46.990	115.833	132.881	1599.100	120.419	50.950	47.777	26.325
22:47:00	84.773	65.833	115.826	136.893	1673.680	103.259	53.733	51.052	24.400
22:47:30	84.919	66.594	116.791	137.113	1711.000	105.330	54.804	49.550	24.246
22:48:00	85.138	60.740	117.608	136.366	1656.480	115.958	53.587	49.429	25.410
22:48:30	85.210	57.802	118.050	132.420	1625.260	117.262	52.773	49.048	25.350
22:49:00	84.875	55.479	118.731	135.065	1675.350	110.414	53.190	49.060	26.698
22:49:30	84.846	52.708	118.645	136.752	1716.550	107.444	54.277	49.165	27.854
22:50:00	84.904	55.250	119.254	138.805	1687.770	103.785	54.094	50.446	29.031
22:50:30	84.846	52.927	118.804	138.955	1691.410	117.573	53.579	51.237	26.785
22:51:00	84.919	61.948	118.725	138.415	1712.070	114.139	54.290	50.008	27.427
22:52:00	84.831	56.302	118.538	142.788	1731.840	112.966	54.856	52.694	28.200
22:53:00	85.852	43.771	112.852	130.973	1615.880	104.379	52.798	47.146	30.017
22:53:30	85.998	48.354	110.193	124.481	1527.330	125.340	51.085	45.808	25.521
22:54:00	85.269	62.990	112.845	124.406	1533.660	105.977	51.765	47.796	23.313
22:54:30	84.744	74.635	115.235	131.969	1613.490	83.387	51.806	50.335	26.098
22:55:00	84.700	69.823	118.068	134.910	1668.370	115.954	53.885	50.869	23.608
22:58:00	87.252	53.000	111.351	138.711	1697.860	110.594	54.158	50.813	27.627
22:58:30	87.617	64.708	111.434	136.103	1681.380	101.471	54.117	52.477	25.773
22:59:00	88.054	77.583	112.717	138.358	1709.270	84.529	54.415	51.085	24.079
22:59:30	88.944	66.740	111.773	137.982	1657.740	96.128	52.535	50.333	26.931
23:00:00	90.081	45.760	108.640	130.922	1578.030	117.289	51.575	49.965	26.727
23:00:30	90.840	41.531	104.860	128.267	1613.430	113.976	52.502	46.560	26.627
23:01:30	91.510	73.854	108.685	137.442	1701.500	81.254	54.735	51.402	23.627
23:03:00	93.115	37.354	106.818	121.089	1474.910	122.449	49.733	44.996	26.940
23:04:00	92.750	38.073	99.275	116.226	1423.200	111.746	48.315	42.700	26.794
23:18:30	92.138	46.104	118.787	149.431	1825.700	115.470	56.073	53.685	31.310

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
23:19:00	92.867	44.063	113.132	140.491	1692.970	109.059	53.694	52.094	29.896
23:19:30	92.998	45.479	107.751	133.463	1624.960	126.250	51.679	48.702	27.646
23:20:00	93.188	41.281	102.692	125.552	1587.460	109.996	52.069	43.752	28.790
23:21:00	92.852	63.073	99.451	120.821	1473.300	103.536	49.442	43.702	25.302
23:21:30	92.823	63.917	98.438	120.234	1471.270	93.461	49.498	42.769	25.306
23:22:30	92.196	69.573	104.134	122.193	1520.710	113.053	50.490	45.242	21.979
23:23:00	92.254	62.229	104.421	122.165	1525.070	89.394	51.160	44.254	27.633
23:23:30	92.269	54.135	104.763	121.559	1503.210	101.319	50.123	44.998	27.077
23:24:00	91.787	60.552	108.028	122.874	1552.110	106.178	52.604	46.583	25.340
23:25:00	91.321	58.490	110.698	133.787	1645.740	103.273	53.283	51.031	26.400
23:28:30	92.575	44.490	115.228	140.496	1691.230	121.087	53.848	52.040	29.523
23:29:00	92.604	48.771	112.005	133.750	1679.230	102.993	54.444	49.996	30.567
23:30:00	92.838	71.865	111.711	140.980	1713.680	103.747	53.921	52.475	24.979
23:30:30	93.188	68.052	112.679	138.856	1680.010	105.842	54.415	50.106	25.413
23:31:00	93.435	54.865	112.631	133.909	1611.940	113.703	52.496	50.406	27.525
23:32:00	93.727	53.240	111.137	140.510	1687.050	106.375	53.177	53.329	27.571
23:32:30	93.960	55.177	111.490	139.617	1683.470	105.863	53.650	51.702	26.967
23:33:00	94.179	54.094	111.338	139.406	1718.700	110.238	53.587	50.725	26.004
23:34:00	94.821	62.500	114.288	144.376	1744.250	105.123	54.952	53.383	25.631
23:34:30	95.156	60.125	115.107	140.919	1714.820	111.393	54.444	51.096	26.612
23:35:00	95.317	50.542	114.938	135.075	1633.560	117.327	54.035	51.858	28.208
23:37:30	96.483	48.604	111.998	137.682	1670.520	118.559	53.840	50.083	27.348
23:38:00	96.629	48.990	109.681	135.723	1667.950	110.615	52.513	49.598	27.246
23:40:30	98.204	52.510	105.932	136.437	1644.540	106.105	53.306	50.233	27.481
23:41:00	98.656	55.740	104.743	130.071	1582.680	104.307	52.790	47.642	27.298
23:42:30	99.269	63.042	105.860	133.989	1632.120	95.685	53.123	47.919	27.027
23:43:00	99.750	52.198	104.532	128.352	1580.770	113.824	52.104	45.800	25.602
23:43:30	99.779	46.771	102.643	124.429	1537.900	112.676	51.404	47.029	27.938
23:44:30	100.173	58.010	101.758	132.721	1607.880	98.639	51.263	46.346	26.802
23:45:30	100.465	57.917	100.503	123.494	1526.500	98.891	52.342	46.054	27.248
23:46:00	100.567	57.938	99.849	123.217	1534.980	102.491	50.429	43.369	26.148
23:46:30	100.581	50.573	98.690	120.633	1455.510	112.327	48.529	45.063	25.671
23:47:00	100.465	52.906	97.705	116.663	1461.240	100.890	51.646	45.063	27.398
23:48:00	100.348	57.635	96.636	119.055	1471.870	100.067	50.352	44.135	25.740
23:49:00	100.202	59.271	96.992	119.055	1480.700	98.922	50.763	43.144	26.225
23:49:30	100.027	59.521	97.411	119.773	1507.750	94.295	50.783	43.823	26.733
23:50:30	100.013	59.052	98.161	122.526	1514.970	106.067	50.692	44.975	25.467
23:51:30	99.983	57.708	98.998	123.565	1518.980	105.891	50.579	45.004	25.531
23:52:30	99.925	56.521	99.002	123.114	1529.070	104.746	50.865	45.394	26.406
23:53:00	99.838	56.917	99.220	122.935	1503.990	104.238	51.623	47.648	26.273
23:53:30	99.940	58.010	100.046	124.048	1512.350	100.886	50.877	46.865	25.642
23:54:00	99.940	59.583	100.319	122.447	1527.220	98.262	52.152	45.844	26.758

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
23:54:30	99.983	57.167	100.433	123.696	1554.320	101.571	50.954	44.131	27.240
23:55:00	99.969	57.240	100.644	122.902	1535.460	108.094	51.002	45.202	26.771
23:55:30	99.925	59.750	100.914	124.734	1516.950	101.032	51.167	46.119	26.056
23:56:00	99.910	58.344	100.883	125.603	1528.410	96.889	50.669	46.287	26.827
23:56:30	99.969	54.240	100.468	125.514	1558.980	107.374	51.931	44.615	26.731
23:57:00	99.881	58.573	101.378	125.726	1566.380	101.699	51.631	44.677	25.796
23:57:30	99.692	59.438	102.768	128.601	1579.340	99.638	51.494	46.635	26.058
23:59:00	99.823	55.740	103.836	127.116	1585.010	104.494	52.306	47.085	27.060
23:59:30	99.896	55.896	102.975	128.197	1577.490	106.354	52.313	47.269	27.565
00:00:00	99.925	53.844	102.740	130.278	1588.060	109.238	51.577	46.852	27.238
15:03:00	105.292	51.208	117.099	143.662	1735.000	120.724	55.400	53.300	29.719
15:03:30	105.248	46.281	115.699	142.544	1720.070	126.018	54.733	52.719	30.513
15:04:00	105.088	50.240	114.229	139.650	1689.560	119.385	54.560	54.031	30.008
15:04:30	104.810	56.635	113.686	142.798	1768.500	116.162	56.125	54.425	29.352
15:05:00	104.737	62.542	114.910	146.354	1787.840	115.467	56.042	55.056	27.188
15:05:30	104.883	65.615	116.605	147.228	1775.000	110.369	55.935	54.817	26.988
15:06:00	105.000	65.458	118.047	145.222	1769.090	117.926	56.096	54.454	27.573
15:06:30	104.971	54.292	118.171	145.043	1766.170	115.802	55.933	54.552	28.765
15:07:00	104.956	54.125	118.462	144.865	1757.930	125.935	55.538	55.027	28.846
15:07:30	104.942	49.188	118.175	144.752	1767.120	127.702	55.742	55.217	29.775
15:08:00	104.665	53.563	118.911	144.729	1794.110	121.616	56.121	56.892	30.154
15:08:30	104.300	60.604	120.312	151.766	1838.120	110.663	56.110	59.625	29.608
15:19:00	104.796	56.865	110.127	133.238	1642.930	115.301	53.615	50.742	27.767
15:19:30	104.606	56.719	111.127	137.616	1675.470	110.895	53.904	52.092	28.531
15:20:00	104.490	54.927	111.555	139.627	1699.060	118.835	54.587	53.267	27.752
15:20:30	104.490	58.219	112.548	140.970	1744.910	116.006	55.381	53.485	27.729
15:21:00	104.475	57.417	113.897	143.427	1728.730	110.971	54.902	54.931	27.890
15:21:30	104.563	57.604	114.457	144.856	1771.780	110.210	56.212	54.640	28.646
15:22:00	104.679	61.323	115.875	144.747	1763.540	112.711	55.837	54.675	28.200
15:22:30	104.825	57.448	116.082	145.043	1760.850	113.890	55.896	54.087	29.219
15:23:30	104.942	52.021	114.167	141.962	1708.730	117.338	54.769	53.765	29.381
15:24:00	104.898	54.208	114.049	141.370	1731.420	120.039	55.544	53.394	28.238
15:24:30	104.956	55.500	113.893	143.319	1747.120	111.822	54.758	52.788	29.569
15:25:00	105.015	56.552	113.610	141.868	1715.770	116.165	54.783	52.733	27.858
15:25:30	104.840	56.708	113.534	139.829	1709.680	111.604	54.981	54.198	28.623
15:26:00	104.840	60.917	114.059	143.056	1749.570	111.583	55.154	54.108	27.960
15:26:30	105.000	57.521	114.623	144.903	1725.270	114.395	54.681	53.850	28.048
15:27:00	105.131	53.719	113.769	142.685	1712.910	123.919	54.508	52.873	27.529
15:27:30	105.088	54.208	113.530	139.702	1732.910	118.130	55.112	51.781	28.350
15:28:00	105.029	53.719	113.388	139.378	1703.890	118.707	54.288	53.081	28.433
15:28:30	105.044	52.917	112.659	139.321	1716.490	115.446	54.821	53.033	29.610
15:29:00	104.985	59.385	112.448	139.960	1725.090	110.563	54.985	53.429	28.188

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
15:29:30	104.956	57.604	112.859	140.919	1729.150	118.514	55.067	53.635	27.550
15:30:00	105.058	58.417	112.669	143.225	1720.910	115.436	54.696	53.217	27.452
15:30:30	105.146	59.135	113.388	139.890	1720.490	117.352	54.846	51.954	28.423
15:31:00	105.088	57.521	113.112	138.438	1685.080	117.348	54.356	52.735	27.985
15:31:30	105.073	53.229	112.323	138.429	1694.520	115.443	54.573	52.831	28.577
15:32:00	104.985	54.125	112.043	139.166	1712.910	118.631	54.794	52.994	27.908
15:32:30	104.971	56.063	112.368	142.051	1716.670	111.078	54.656	52.837	28.694
15:33:00	104.956	61.323	112.624	140.378	1720.550	114.450	55.169	52.690	28.142
15:33:30	105.000	61.323	112.963	140.501	1696.430	108.519	54.471	52.894	28.483
15:34:00	104.985	56.969	113.762	141.976	1724.190	108.727	54.804	52.377	28.904
15:34:30	104.971	55.833	113.956	139.556	1730.040	118.624	55.500	52.156	28.612
15:35:00	104.942	55.427	113.838	138.908	1730.700	114.924	55.375	52.744	28.254
15:37:00	105.000	57.281	113.599	144.813	1766.410	112.088	55.554	53.921	28.796
15:37:30	105.073	58.979	114.602	144.048	1742.520	114.931	55.260	53.394	28.327
15:38:00	105.160	53.073	113.893	142.276	1705.270	116.321	54.085	52.975	30.098
15:38:30	105.175	55.990	112.773	140.317	1709.210	117.466	54.656	52.427	28.548
15:39:00	105.073	54.531	112.500	139.429	1694.700	113.451	53.963	52.777	28.965
15:39:30	104.971	56.156	112.956	138.828	1703.890	117.068	54.865	53.490	28.594
15:40:00	104.942	59.698	113.171	141.811	1724.430	118.140	55.152	53.827	28.052
15:40:30	105.015	54.698	113.267	141.886	1731.000	112.562	55.054	53.098	29.169
15:41:00	105.102	57.115	112.507	141.276	1707.240	118.956	54.144	52.975	28.183
15:41:30	105.088	58.177	112.880	139.772	1697.090	113.731	54.773	52.900	28.319
15:42:00	104.985	60.271	112.866	140.021	1717.920	111.780	54.915	53.294	28.254
15:42:30	104.942	60.438	113.025	140.407	1725.390	111.213	55.308	53.425	27.935
15:43:00	105.073	59.792	113.430	139.782	1720.490	107.571	54.944	53.048	28.319
15:43:30	105.088	53.958	113.516	141.506	1695.890	116.297	54.398	53.002	28.608
15:44:00	105.117	51.542	112.818	139.335	1685.260	120.115	54.725	52.544	28.462
15:44:30	105.131	52.677	111.638	138.922	1691.000	116.089	54.612	51.823	28.394
15:45:00	105.102	54.125	111.313	137.827	1671.950	118.770	54.046	52.142	28.462
15:45:30	104.942	57.198	111.638	138.119	1701.800	117.282	54.163	52.967	27.894
15:46:00	104.796	58.167	111.635	142.187	1705.210	106.243	54.300	54.015	28.200
15:46:30	104.869	63.833	112.327	141.567	1715.360	106.181	54.404	54.327	27.819
15:47:00	105.015	60.844	113.219	142.417	1728.010	109.719	54.948	53.737	28.585
15:47:30	105.131	56.073	113.492	141.727	1709.270	110.988	54.642	53.008	28.967
15:48:00	105.233	51.135	113.036	137.884	1692.310	121.374	54.492	52.208	28.248
15:48:30	105.190	53.240	112.707	137.123	1690.580	114.042	54.471	51.992	29.638
15:49:00	105.073	52.188	111.272	138.358	1673.080	119.849	54.171	52.454	28.381
15:51:00	105.044	61.333	112.313	138.814	1705.150	112.731	54.494	53.090	27.879
15:52:00	105.131	53.719	112.123	138.565	1686.880	121.564	54.331	51.527	28.525
15:52:30	105.029	53.396	112.195	137.043	1671.350	116.155	53.792	52.106	29.035
15:53:00	104.942	49.115	110.494	136.263	1664.010	114.557	54.179	53.342	28.885
15:53:30	104.942	57.208	110.099	140.642	1686.520	115.899	53.875	53.321	27.879
15:54:00	104.956	61.073	110.936	140.698	1699.710	108.951	53.969	53.131	28.102
15:54:30	105.073	60.438	111.061	138.607	1687.110	113.606	54.313	52.652	27.350

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
15:55:30	105.248	58.167	111.116	136.728	1650.270	114.803	53.398	51.417	28.477
15:56:00	105.321	54.052	110.221	134.985	1645.980	112.870	53.592	50.279	28.396
15:56:30	105.233	53.083	109.550	133.642	1624.600	117.525	53.577	50.288	27.833
15:57:00	105.000	56.156	109.221	134.290	1634.150	113.271	53.108	51.681	28.154
15:57:30	104.840	57.844	109.142	135.361	1655.890	117.078	53.852	52.835	27.877
15:58:00	104.738	61.500	110.027	139.693	1712.430	114.862	54.458	52.977	26.244
15:58:30	104.913	63.760	111.822	140.294	1711.890	111.431	54.767	52.446	27.385
15:59:00	104.971	58.573	112.033	137.588	1674.400	112.164	54.475	52.767	28.008
15:59:30	104.927	56.719	112.085	137.447	1676.960	111.140	54.388	53.256	29.035
08:00:30	105.992	56.396	114.457	143.653	1750.410	116.425	54.971	54.794	29.290
08:01:00	106.006	59.063	115.055	146.425	1783.720	118.718	55.771	54.462	27.913
08:01:30	106.021	57.281	115.557	145.316	1760.560	116.999	55.721	54.992	28.658
08:02:00	106.021	61.240	116.027	145.875	1769.270	115.031	55.885	54.831	28.831
08:02:30	106.079	53.969	115.989	145.758	1778.350	120.824	55.777	54.160	29.498
08:03:00	106.035	57.531	116.214	145.105	1764.560	117.397	55.290	53.965	29.404
08:03:30	105.919	56.385	115.723	145.081	1754.640	120.315	55.254	55.212	29.633
08:04:00	105.860	54.781	116.093	145.617	1765.270	119.430	55.640	56.219	29.306
08:04:30	105.758	58.333	116.470	147.031	1803.780	124.483	56.458	56.783	28.781
08:05:30	105.904	57.042	118.147	148.896	1822.290	116.985	57.325	56.685	29.615
08:06:00	106.006	57.521	117.895	149.342	1804.560	120.018	56.356	56.042	29.604
08:06:30	106.065	58.000	117.525	147.411	1788.680	124.130	55.621	55.954	28.669
08:07:30	106.006	55.417	117.248	147.632	1794.290	115.118	56.465	55.688	29.729
08:08:00	106.094	54.365	116.497	148.036	1799.540	123.431	55.815	54.644	29.179
08:08:30	106.065	57.927	116.414	145.992	1792.200	121.761	56.567	54.579	29.490
08:09:00	105.977	58.740	117.165	148.290	1779.360	121.111	55.385	55.219	28.379
08:09:30	105.831	58.740	118.088	146.758	1796.620	116.843	56.021	56.013	29.106
08:10:00	105.904	57.365	117.237	148.182	1818.650	122.134	56.344	56.260	29.408
08:10:30	105.977	52.344	116.985	150.906	1805.280	118.728	55.217	56.098	30.529
08:11:00	106.035	62.063	117.407	148.210	1805.870	116.740	56.319	55.650	28.548
08:12:00	106.021	56.958	116.366	147.754	1788.680	126.627	55.592	56.021	29.381
08:12:30	106.021	55.010	116.390	149.478	1785.690	113.959	55.431	56.092	29.346
08:13:30	106.313	53.000	115.723	144.686	1753.030	120.775	55.498	53.696	29.540
08:14:00	106.327	58.010	114.191	143.564	1739.900	120.730	55.315	52.825	29.585
08:14:30	106.167	55.500	114.374	142.685	1739.300	117.320	54.656	52.817	29.883
08:15:00	105.890	56.802	114.305	143.352	1771.420	112.738	55.633	53.846	28.694
08:15:30	105.904	60.833	115.176	146.025	1779.360	117.528	56.108	54.175	28.771
08:16:00	106.035	62.792	116.079	146.166	1782.470	120.893	56.469	53.642	27.102
08:18:30	105.831	56.469	116.698	147.073	1802.890	117.365	56.362	55.685	29.758
08:19:00	105.846	58.323	117.227	149.727	1807.550	114.322	55.794	56.102	28.858
08:19:30	105.919	61.000	118.064	149.234	1827.550	116.698	56.773	55.713	29.058
08:20:00	106.035	57.688	118.444	148.905	1818.650	114.976	56.679	54.544	29.748
08:20:30	106.137	54.135	118.109	148.083	1795.250	120.907	56.231	53.844	30.308
08:21:00	106.108	50.167	117.365	144.898	1770.830	126.724	56.040	53.942	29.975
08:21:30	106.079	49.104	116.556	145.170	1780.740	125.869	55.992	53.790	29.444
08:22:00	105.933	55.417	116.280	145.837	1763.000	117.652	55.610	54.919	28.860

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
08:22:30	105.773	59.635	116.280	144.663	1801.340	115.920	56.704	55.802	29.479
08:23:00	105.700	59.063	117.459	149.046	1824.320	119.700	56.731	56.985	28.285
08:23:30	105.904	64.073	118.233	152.884	1832.320	117.199	56.052	56.521	28.558
08:24:00	106.050	60.677	119.261	149.770	1820.260	117.331	56.533	55.327	28.873
08:24:30	106.108	52.177	118.728	147.862	1800.080	122.411	56.429	54.625	30.190
08:25:00	106.108	53.479	118.534	147.261	1781.690	127.142	55.921	54.265	29.613
08:25:30	106.021	52.354	117.459	146.711	1794.950	120.464	56.402	54.027	30.531
08:26:00	105.860	56.469	117.320	146.237	1777.090	118.808	56.163	55.298	30.163
08:26:30	105.700	58.094	117.231	147.782	1802.530	118.514	56.556	57.119	29.025
08:27:00	105.729	61.729	118.078	149.934	1841.280	114.858	56.996	57.452	29.040
08:27:30	105.933	60.844	118.361	151.855	1846.770	120.381	56.619	56.777	28.340
08:28:00	106.021	61.083	119.762	152.029	1827.070	115.214	56.602	55.960	28.337
08:28:30	106.050	54.458	119.434	151.484	1815.130	121.910	56.335	55.167	30.206
08:29:30	106.065	54.042	117.345	147.585	1790.650	126.354	56.010	54.810	29.565
08:30:00	106.006	53.313	116.784	145.955	1809.280	124.503	57.098	54.752	29.644
08:31:00	105.963	61.250	117.545	148.182	1804.800	117.525	56.046	56.179	28.692
08:31:30	106.065	61.573	118.531	147.749	1838.650	117.410	57.167	54.981	28.658
08:32:00	106.225	57.115	118.486	147.237	1788.680	126.153	56.200	54.444	29.469
08:32:30	106.152	52.427	117.497	145.908	1791.130	122.882	55.871	53.821	29.660
08:33:00	105.963	54.125	116.677	145.635	1774.590	123.297	55.865	55.185	29.983
08:34:00	105.860	63.510	118.092	149.018	1808.740	112.047	56.002	56.260	29.423
08:35:00	105.817	58.417	119.205	151.968	1845.340	117.933	56.438	56.923	29.979
08:35:30	105.846	57.760	119.703	150.996	1838.120	120.212	56.977	57.142	29.079
08:36:00	105.963	56.469	120.149	153.190	1852.210	124.600	56.660	55.915	29.400
08:37:30	105.802	53.240	119.046	150.808	1849.100	122.868	57.010	57.002	31.046
08:38:00	105.919	59.781	118.977	152.612	1843.850	122.847	56.477	57.217	28.652
08:38:30	106.021	60.031	119.357	151.945	1851.550	121.384	56.969	56.271	29.946
08:39:00	106.108	57.521	119.752	151.024	1833.940	121.737	56.544	55.417	28.852
08:39:30	106.108	55.188	119.274	152.316	1817.100	120.495	55.652	54.960	29.663
08:40:30	105.890	60.760	118.994	149.149	1815.130	120.077	56.267	56.854	30.231
08:41:00	105.758	57.281	118.939	153.091	1855.130	119.375	56.471	57.456	29.198
08:41:30	105.890	60.521	119.568	155.501	1854.660	121.754	56.469	57.015	29.694
08:42:00	105.992	59.302	119.420	152.602	1863.310	122.581	57.310	56.294	29.337
08:42:30	106.167	60.208	119.472	152.612	1828.500	115.536	56.273	55.502	29.165
08:43:00	106.283	54.531	118.527	148.379	1793.450	128.612	55.560	55.267	29.371
08:43:30	106.298	56.146	117.694	147.674	1784.980	125.247	55.810	54.258	29.577
08:44:00	106.210	49.104	117.487	146.096	1784.860	124.248	56.300	53.813	30.779
08:44:30	106.094	54.448	116.781	146.998	1775.660	121.152	56.183	54.173	29.219
08:45:00	105.860	62.625	117.410	147.745	1774.830	110.926	55.421	56.042	29.329
08:45:30	105.744	60.760	119.008	150.127	1818.470	122.000	56.590	56.606	28.229
08:46:00	105.802	61.083	119.703	151.231	1829.100	117.663	56.546	57.510	29.302
08:46:30	105.846	59.865	119.911	152.344	1835.070	122.667	56.487	57.763	29.012
08:48:00	105.919	57.125	120.613	151.855	1867.730	123.307	57.165	56.998	29.742
08:48:30	106.123	54.938	118.974	152.344	1841.700	125.856	56.508	56.140	29.194
08:49:00	106.152	56.635	118.853	149.817	1817.700	122.747	56.373	55.958	29.185

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
08:50:30	106.094	54.854	118.002	146.476	1787.600	118.023	56.477	55.290	30.146
08:51:00	106.035	54.115	117.227	146.589	1793.280	123.324	56.038	55.925	30.050
08:51:30	106.006	56.563	117.006	148.487	1803.370	116.280	56.333	56.137	29.069
08:52:00	106.065	64.323	117.525	149.943	1820.560	116.176	56.160	55.494	28.419
08:52:30	106.298	55.656	116.698	148.440	1812.020	119.150	56.596	53.796	29.688
08:53:00	106.327	54.698	116.753	146.481	1769.870	121.495	55.560	52.958	29.340
08:53:30	106.298	55.490	115.612	144.048	1750.940	122.435	55.385	52.544	29.333
08:54:00	106.269	52.188	113.437	143.249	1742.820	115.031	55.060	52.279	29.829
08:54:30	106.167	54.781	113.292	141.534	1719.060	118.116	54.623	53.460	29.319
08:55:30	106.050	59.781	113.807	143.986	1757.690	120.025	55.192	54.381	28.410
08:56:00	106.035	64.406	114.789	145.321	1775.660	114.547	55.610	54.033	28.248
08:56:30	106.094	62.135	115.740	145.119	1779.300	108.986	55.792	53.331	29.417
08:57:00	106.196	53.635	115.104	143.601	1750.290	117.739	55.483	52.883	29.740
08:57:30	106.196	58.010	114.761	144.423	1739.540	120.554	54.898	52.475	29.204
08:58:00	106.065	50.406	114.789	141.807	1723.360	124.047	54.900	53.219	30.296
08:58:30	105.919	55.667	114.018	140.928	1747.120	122.705	55.492	54.140	28.656
08:59:00	105.817	52.354	113.485	144.339	1764.020	118.725	55.425	55.250	29.392
08:59:30	105.758	63.667	114.128	146.608	1791.480	108.395	55.888	56.038	28.300
09:00:00	105.787	61.729	115.913	148.783	1801.520	109.812	55.877	56.610	27.813
05:00:20	105.992	59.385	114.388	144.099	1739.960	113.312	55.427	55.044	27.723
05:00:50	105.787	60.927	116.183	144.367	1792.980	114.976	56.217	55.688	28.231
05:01:20	105.831	61.563	116.899	150.009	1780.560	108.305	55.469	56.552	27.215
05:01:50	105.963	58.573	118.258	145.880	1813.160	118.680	57.217	55.508	28.933
05:02:20	105.963	50.490	118.323	148.511	1780.260	118.908	55.754	55.819	30.190
05:02:50	105.919	53.729	117.307	144.212	1772.080	119.136	56.406	56.356	28.738
05:03:20	105.904	51.938	116.781	146.274	1774.290	122.038	56.000	57.042	29.054
05:03:50	105.890	58.896	116.103	149.149	1807.840	120.336	56.269	57.150	28.185
05:04:20	105.904	57.688	116.733	145.485	1799.430	118.216	56.998	57.667	28.758
05:04:50	106.021	60.917	117.020	147.444	1817.580	113.783	56.819	56.856	28.621
05:05:20	106.035	60.354	117.611	150.517	1803.960	115.660	56.202	56.706	29.175
05:05:50	106.138	55.104	117.729	149.088	1805.580	121.592	56.454	55.344	28.083
05:06:20	106.225	57.688	118.213	145.142	1775.540	117.652	56.529	54.371	28.438
05:06:50	106.196	48.781	116.795	143.766	1733.690	124.348	55.619	54.440	29.752
05:07:20	106.094	51.052	115.311	143.174	1740.910	121.432	55.396	54.408	29.596
05:07:50	105.948	57.844	114.865	143.338	1742.700	120.194	55.581	55.679	28.554
05:08:20	105.831	60.271	115.439	145.983	1791.130	111.715	56.631	56.085	28.023
05:08:50	105.773	61.969	117.448	146.636	1794.770	114.108	56.469	57.465	27.969
05:09:20	105.802	62.865	117.822	148.670	1827.550	111.002	57.219	57.104	28.215
05:09:50	105.992	65.771	118.707	148.971	1830.590	113.962	57.321	56.152	27.831
05:10:20	106.108	54.698	118.455	148.097	1796.920	126.955	56.633	55.769	28.927
05:10:50	106.283	47.979	117.576	145.908	1765.330	126.347	56.160	54.490	30.238
05:11:20	106.225	48.063	115.906	143.390	1735.960	122.591	55.515	54.485	29.560
05:11:50	106.094	52.354	115.166	143.211	1748.080	123.718	55.992	54.404	28.865
05:12:20	105.875	57.927	114.986	143.037	1748.430	114.457	56.108	56.202	28.429

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
05:12:50	105.729	65.042	116.812	147.186	1804.920	109.207	56.675	56.869	27.823
05:13:20	105.744	62.302	117.628	148.994	1817.160	112.932	56.754	57.533	28.246
05:13:50	105.948	60.604	118.109	148.609	1806.830	116.024	56.760	57.181	27.825
05:14:20	106.152	57.688	117.888	148.877	1804.620	119.797	56.921	56.031	28.598
05:14:50	106.342	54.448	117.784	145.565	1772.440	121.879	56.169	54.554	28.196
05:15:20	106.429	47.979	116.491	143.681	1721.450	125.645	55.675	53.548	29.742
05:15:50	106.327	47.740	114.288	140.665	1717.450	122.214	55.223	52.723	29.069
05:16:20	106.108	51.781	112.769	139.439	1698.160	121.114	54.758	54.046	29.073
05:16:50	105.773	62.375	113.707	142.164	1766.110	110.549	55.798	55.265	27.231
05:17:20	105.583	67.479	115.401	145.617	1799.600	113.938	56.752	56.998	27.758
05:17:50	105.758	61.010	116.964	149.211	1811.730	117.639	56.875	57.035	28.175
05:18:20	105.963	62.448	118.147	148.863	1807.780	116.176	56.892	56.065	27.775
05:18:50	106.167	55.010	117.729	146.406	1773.270	116.473	56.133	55.071	29.573
05:19:20	106.269	48.865	116.594	145.480	1750.170	123.020	55.837	53.913	30.142
05:19:50	106.269	48.792	115.270	143.268	1733.390	122.712	55.617	52.819	29.304
05:20:20	106.138	54.042	114.198	142.497	1727.540	116.065	55.204	52.860	29.231
05:20:50	105.919	57.281	113.841	141.797	1722.580	120.523	55.183	54.346	28.527
05:21:20	105.685	61.646	114.488	144.696	1765.510	108.270	56.210	55.981	28.575
05:21:50	105.613	65.292	116.252	145.866	1781.570	118.444	56.477	57.531	27.173
05:22:20	105.773	64.313	117.320	153.434	1816.680	109.155	55.465	57.221	28.000
05:22:50	105.977	59.708	118.382	149.535	1807.490	112.219	56.646	56.296	28.462
05:23:20	106.240	53.240	117.355	146.946	1772.560	122.453	56.256	54.748	29.440
05:23:50	106.313	50.000	115.723	146.256	1737.810	124.030	54.933	54.304	28.958
05:24:20	106.240	50.646	114.180	142.854	1736.790	126.592	55.754	53.004	28.596
05:24:50	105.992	52.177	114.253	143.061	1723.830	117.625	55.246	53.946	29.998
05:25:20	105.685	58.729	114.775	143.874	1771.300	116.200	56.508	55.525	28.150
05:25:50	105.656	62.219	115.118	147.890	1794.050	112.133	56.210	57.208	27.700
05:26:20	105.758	64.969	117.238	148.543	1815.370	106.952	57.200	57.517	28.204
05:26:50	105.875	63.510	118.669	150.958	1821.520	116.660	56.515	57.002	28.242
05:27:20	106.138	59.302	119.164	148.388	1808.080	115.889	56.798	55.610	29.060
05:27:50	106.313	48.698	117.659	142.878	1763.000	128.273	57.004	54.813	30.006
05:28:20	106.298	46.198	115.660	145.184	1742.400	125.641	55.298	54.596	29.760
05:28:50	106.181	52.917	114.699	144.090	1760.380	118.811	55.648	53.175	29.017
05:29:20	105.963	59.302	114.948	144.235	1761.870	116.494	56.035	53.608	28.379
05:29:50	105.860	60.281	115.380	143.860	1733.570	115.740	55.515	55.594	27.837
05:30:20	105.802	61.323	115.290	144.733	1796.080	120.537	56.685	56.325	27.852
05:30:50	105.875	62.698	116.930	150.028	1800.260	110.300	56.162	56.529	28.560
05:31:20	106.006	61.167	117.241	148.933	1800.740	115.844	56.175	55.602	28.252
05:31:50	106.138	54.448	116.961	146.495	1776.860	123.262	56.244	54.496	29.327
05:32:20	106.079	51.625	115.581	144.057	1767.660	124.009	56.354	54.602	28.733
05:32:50	106.108	52.990	115.398	145.391	1752.440	122.162	55.698	54.319	28.742
05:33:20	106.035	57.115	115.318	143.301	1739.480	115.100	55.867	54.629	28.760
05:33:50	106.021	60.271	114.744	144.005	1745.390	111.611	55.706	54.879	28.167
05:34:20	105.963	60.198	115.360	144.320	1758.410	114.810	56.288	55.129	28.837

	STEAM HEADER PRESSURE	DRUM LEVEL	STEAM FLOW	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
Unit	BAR	MMH2O	TONES PER HOUR	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
TIME									
05:34:50	105.933	58.083	116.044	143.723	1743.300	114.616	55.873	56.094	28.700
05:35:20	105.933	57.281	116.266	144.141	1752.080	117.974	56.023	56.654	28.931
05:35:50	105.890	56.469	116.079	144.696	1762.350	112.327	56.015	57.319	29.063
05:36:20	105.875	55.823	116.183	149.065	1777.870	119.894	55.460	57.825	28.033
05:36:50	106.006	61.250	116.625	146.683	1799.250	118.444	56.721	56.335	28.760
05:37:20	106.108	56.958	116.186	148.515	1785.210	114.720	56.167	55.319	28.892
05:37:50	106.167	57.438	116.325	143.390	1776.200	119.693	56.667	54.169	29.267
05:38:20	106.108	55.344	115.785	144.409	1738.700	121.270	55.419	54.073	28.517
05:38:50	105.992	56.063	114.343	143.413	1740.550	120.042	56.083	54.731	28.390
05:39:20	105.948	60.677	115.021	143.329	1740.250	115.138	55.906	55.406	27.519
05:39:50	105.773	57.125	115.768	145.607	1786.950	115.460	56.069	55.971	29.085
05:40:20	105.787	62.938	117.158	147.322	1795.780	113.814	56.640	56.783	28.456
05:40:50	105.860	58.260	117.988	149.535	1808.680	119.734	56.344	56.567	28.637
05:41:20	105.963	55.906	117.974	146.772	1806.890	122.183	56.952	56.060	29.133
05:41:50	106.050	56.625	117.009	145.894	1788.140	115.899	56.548	55.587	28.671
05:42:20	106.079	55.917	116.650	147.101	1774.350	121.671	55.788	55.417	28.798

APPENDIX-B

Weights of the Feedforward Network

Weights between Hidden units to Input units:

1.880239	2.763206	0.985821	-4.713161	3.785458	1.212157	-1.369956	-1.328609	-1.928793
3.425219	3.028979	-8.753602	-0.893967	-1.783797	4.215807	-0.621234	0.333328	-5.339055
-1.370833	-1.051854	-3.575195	-2.842655	-3.734456	-2.418285	0.731273	1.937030	-5.201807

Biases of Hidden Units:

-2.547429 -2.248640 0.799262 -1.286236 -2.043156 1.648581 1.843474 4.057236 -0.535920

Weights between Output Units to Hidden units:

1.794870	2.649074	-1.403950
2.651125	-0.542122	-1.430088
-1.838513	-3.668092	0.388256
1.507106	2.709671	-1.561927
3.310131	1.344991	-0.940774
-1.925971	-3.310776	0.626847
0.479773	0.128336	0.686039
5.840600	-2.662455	3.883122
2.181360	-0.185983	3.877370

Biases of Output Units

-0.511899 -0.970527 -0.973443

APPENDIX-C

Weights of the Diagonal Recurrent Networks

Weights Between hidden units and Input units

-1.669573	0.041340	0.216326	-0.947682	0.005933	-0.571288	-0.979237	-0.192803	-0.539198
-1.179941	0.224555	-0.640814	-1.059260	-0.446977	0.081150	-0.744381	0.072850	-0.975029
-1.156799	-0.625604	-0.621394	-0.565755	-0.499059	-0.467792	-0.445173	-0.694816	-0.490589

Diagonal Recurrent Weights of Hidden units

0.682956	0.259470	0.260337	0.259677	0.260824	0.260224	0.269923	0.262091	0.261537

Weights Between Output units and hidden units

-1.284855	8.325061	-5.022710
1.751932	3.215289	1.387959
-12.767349	1.925872	-0.693107
-1.139107	7.381287	-4.601721
1.285997	3.508275	1.681475
-12.23774	1.891842	-0.799903
-3.638592	4.312669	-0.677278
1.550705	-6.307288	7.791666
0.786624	0.720946	-1.104216

APPENDIX-D

1ST SET OF TEST DATA

TIME	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H_2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
05:00:30	105.890	118.780	60.760	144.517	1791.840	118.479	56.523	72.708	25.569
05:01:00	105.890	119.589	57.688	147.895	1791.420	117.829	55.831	73.737	26.067
05:01:30	105.992	120.371	61.323	146.927	1802.950	123.034	56.288	72.706	27.102
05:02:00	105.992	119.734	53.396	147.956	1785.630	125.257	55.760	72.471	27.290
05:02:30	106.006	119.236	53.885	147.195	1783.300	123.967	55.633	72.742	27.506
05:03:00	105.992	118.880	55.188	146.251	1790.350	121.194	56.027	73.069	26.765
05:03:30	105.948	119.406	56.469	148.586	1793.160	119.572	55.913	73.329	26.869
05:04:00	105.919	119.340	58.333	147.909	1796.560	123.099	55.923	73.498	27.298
05:04:30	105.963	119.596	61.250	148.623	1784.260	117.255	55.467	74.010	26.252
05:05:00	106.035	120.039	59.135	146.312	1787.660	121.439	56.098	73.806	26.200
05:05:30	106.108	119.416	54.771	147.364	1791.310	124.490	56.360	71.977	27.458
05:06:00	105.977	118.448	55.177	147.764	1791.370	118.462	55.677	71.596	26.198
05:06:30	105.992	118.801	56.802	145.875	1768.020	123.846	55.558	73.279	26.531
05:07:00	105.948	119.337	54.531	145.833	1783.010	123.148	56.021	74.277	27.425
05:07:30	105.977	119.700	60.833	147.449	1799.010	120.118	55.969	73.787	26.260
05:08:00	106.021	120.004	56.229	148.017	1791.900	121.367	55.635	73.010	26.452
05:08:30	106.035	119.810	57.292	147.049	1786.110	121.972	55.860	73.308	27.065
05:09:00	106.006	119.731	55.583	147.007	1776.860	121.910	55.558	73.808	26.933
05:09:30	105.992	120.142	58.740	148.215	1797.160	117.168	55.904	72.465	26.913
05:10:00	106.006	119.980	55.510	146.786	1786.590	121.903	55.917	72.240	27.085
05:10:30	106.006	119.762	56.719	146.561	1776.680	121.336	55.442	73.110	26.498
05:11:00	106.050	119.070	55.500	147.148	1777.450	123.801	55.702	73.010	27.119
05:11:30	106.035	118.766	52.823	146.937	1787.250	128.736	55.681	72.129	27.056
05:12:00	105.977	118.213	56.635	144.856	1774.890	120.094	55.990	73.683	26.375
05:12:30	105.963	118.759	62.458	145.631	1787.600	115.335	56.383	73.421	26.525
05:13:00	105.963	119.347	60.198	147.176	1790.770	120.385	56.219	73.752	26.300
05:13:30	106.006	119.876	61.646	147.219	1781.810	120.979	55.756	73.490	25.877
05:14:00	106.035	120.423	59.302	147.688	1781.570	119.164	55.496	73.208	27.533
05:14:30	106.108	119.911	56.313	146.833	1774.710	124.237	55.563	72.044	26.856
05:15:00	106.123	119.140	50.729	144.409	1760.620	123.756	56.079	71.727	27.752
05:15:30	106.094	118.662	53.802	145.260	1761.330	125.963	55.658	70.902	26.852
05:16:00	105.977	118.088	59.458	145.654	1774.650	123.767	55.548	71.540	26.663
05:16:30	105.948	117.870	59.615	144.982	1772.500	114.689	55.552	72.906	26.769
05:17:00	106.035	118.949	61.896	147.261	1784.380	117.929	55.608	71.427	26.008
05:17:30	106.021	119.731	62.063	144.879	1768.800	122.487	55.987	71.856	26.248
05:18:00	106.094	119.274	56.969	146.350	1771.480	118.683	55.608	70.721	27.427
05:18:30	106.108	119.285	51.219	145.786	1776.860	121.806	55.573	69.060	27.887
05:19:00	106.035	117.739	51.865	143.221	1739.780	126.368	55.110	71.200	27.558
05:19:30	105.948	117.345	52.427	144.959	1764.970	128.280	55.563	71.698	27.006
05:20:00	105.802	117.576	62.781	146.833	1773.450	114.502	55.427	73.715	25.535
05:20:30	105.846	119.053	65.458	146.425	1784.080	114.844	55.923	74.817	25.983

TIME	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
05:21:00	105.992	119.956	64.156	147.702	1805.750	114.253	56.115	73.640	25.360
05:21:30	106.108	120.945	58.333	147.313	1778.410	124.497	55.458	72.833	27.356
05:22:00	106.210	119.748	49.760	147.120	1780.680	126.883	55.419	69.748	27.904
05:22:30	106.152	118.130	49.115	143.503	1757.270	126.938	55.677	68.912	27.913
05:23:00	106.050	116.553	50.000	144.428	1753.990	127.453	55.348	69.329	27.415
05:23:30	105.904	116.632	53.396	143.841	1753.450	122.539	55.490	71.667	26.865
05:24:00	105.744	117.798	67.563	147.294	1791.250	110.034	55.983	72.998	24.525
05:24:30	105.802	119.686	68.438	147.543	1801.870	110.974	56.015	74.240	25.215
05:25:00	105.977	120.689	61.813	147.933	1793.690	122.214	55.815	73.052	26.981
05:25:30	106.094	120.661	53.885	146.608	1771.360	121.443	55.329	72.688	27.815
05:26:00	106.196	119.651	52.427	144.987	1781.100	125.043	55.688	70.140	27.363
05:26:30	106.167	117.528	48.708	146.664	1757.810	129.854	54.992	68.998	26.844
05:27:00	106.021	116.812	53.146	143.319	1734.640	125.257	55.069	70.848	27.348
05:27:30	105.948	116.591	58.740	145.199	1765.150	119.309	55.617	71.158	26.050
05:28:00	105.890	117.189	60.917	145.969	1771.180	114.460	55.458	72.077	25.971
05:28:30	105.860	118.555	64.646	147.294	1793.280	115.138	55.833	72.563	25.525
05:29:00	105.977	119.880	65.135	148.464	1784.980	110.795	55.358	72.454	26.333
05:29:30	106.138	120.281	56.229	145.081	1766.290	124.071	55.890	70.542	26.827
05:30:00	106.240	119.012	51.375	144.334	1754.760	125.306	55.450	69.046	27.069
05:30:30	106.225	117.345	46.438	143.127	1729.570	129.968	55.002	68.069	27.775
05:31:00	106.079	115.896	47.573	142.258	1729.510	124.884	54.777	68.229	27.833
05:31:30	105.875	115.795	59.063	143.977	1751.780	119.714	55.040	71.298	25.679
05:32:00	105.817	116.847	65.615	146.270	1784.320	112.956	55.621	72.058	25.608
05:32:30	105.817	118.648	68.688	145.152	1786.530	109.709	56.029	74.771	24.940
05:33:00	105.875	120.281	62.542	149.553	1817.580	117.974	56.104	72.760	25.900
05:33:30	106.079	120.810	61.167	146.617	1782.890	119.613	56.027	71.746	26.981
05:34:00	106.225	119.354	51.781	145.241	1761.390	125.952	55.277	69.563	27.365
05:34:30	106.196	117.943	48.625	144.052	1738.400	128.799	55.004	68.752	27.475
05:35:00	106.123	116.473	52.021	142.347	1725.450	127.498	54.985	69.075	26.917
05:35:30	105.948	116.010	54.771	143.761	1751.120	123.172	54.467	70.192	26.858
05:36:00	105.817	117.310	64.490	144.804	1781.930	115.605	56.006	71.590	25.065
05:36:30	105.787	118.123	62.385	147.303	1781.450	114.419	55.598	73.463	25.848
05:37:00	105.890	119.396	61.740	147.463	1797.400	117.746	55.854	72.969	26.081
05:37:30	106.050	120.115	60.760	147.284	1778.110	119.662	55.421	71.606	26.900
05:38:00	106.108	119.053	52.104	145.795	1775.540	126.291	55.798	70.344	27.013
05:38:30	106.108	118.195	51.292	145.809	1756.440	122.868	55.350	69.448	27.067
05:39:00	105.963	117.276	49.521	144.550	1751.900	126.343	54.950	70.623	26.925
05:39:30	105.904	117.767	56.073	144.978	1757.630	118.984	55.250	72.402	26.208

TIME	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
05:40:00	105.846	118.361	59.063	145.227	1781.810	115.176	56.165	73.565	26.471
05:40:30	105.948	119.143	61.490	147.195	1795.190	117.310	56.060	72.623	25.992
05:41:00	106.035	119.478	62.615	147.252	1792.020	115.429	55.606	70.856	25.938
05:41:30	106.152	119.281	52.917	145.354	1769.990	124.375	55.865	69.308	27.358
05:42:00	106.152	117.189	49.917	144.461	1753.510	130.023	55.304	68.440	27.271
05:42:30	106.094	116.065	51.375	143.446	1756.080	122.764	55.194	67.975	26.819
05:43:00	106.006	115.868	56.875	143.799	1752.550	120.070	55.017	68.546	26.483
05:43:30	105.890	116.470	61.896	144.287	1766.410	111.580	55.433	70.227	25.733
05:44:00	105.860	118.289	63.510	146.091	1783.180	119.205	55.913	70.794	25.919
05:44:30	105.977	119.223	60.271	145.335	1775.720	116.909	55.606	71.487	26.408
05:45:00	106.079	118.904	54.542	146.598	1781.570	128.418	55.625	69.633	26.938
05:45:30	106.108	117.414	52.760	143.582	1751.180	126.302	55.310	69.983	27.254
05:46:00	106.065	117.310	45.948	144.240	1750.170	121.823	55.277	70.665	27.860
05:46:30	105.904	117.065	58.906	145.570	1767.780	119.627	55.367	71.113	26.231
05:47:00	105.846	117.670	62.385	146.119	1791.190	117.455	55.946	71.867	26.387
05:47:30	105.817	118.974	63.115	147.040	1781.570	114.336	55.802	73.033	26.375
05:48:00	105.860	119.980	61.083	147.031	1791.130	121.360	55.854	73.575	25.973
05:48:30	105.919	120.582	58.906	146.956	1768.850	121.661	55.590	74.525	26.535
05:49:00	105.933	120.111	54.781	147.411	1803.840	123.179	56.079	73.465	26.875
05:49:30	106.094	119.351	54.292	146.796	1786.290	121.394	55.954	72.160	26.492
05:50:00	106.123	119.548	52.427	146.711	1784.920	126.029	55.819	69.996	27.771
05:50:30	106.065	118.607	55.104	145.255	1757.990	119.748	55.333	70.273	26.452
05:51:00	106.050	117.542	54.125	145.203	1757.270	120.509	55.396	70.794	27.413
05:51:30	105.948	117.182	54.542	144.865	1780.920	122.339	56.094	70.933	26.171
05:52:00	105.977	117.926	59.552	145.621	1771.480	114.090	55.823	71.552	25.983
05:52:30	106.021	119.022	57.125	146.650	1758.530	122.546	55.192	71.963	26.708
05:53:00	106.094	118.998	57.844	144.480	1759.720	119.956	55.510	70.725	25.975
05:53:30	106.006	119.102	49.927	145.264	1767.960	126.125	55.477	70.654	27.119
05:54:00	105.992	118.067	52.104	146.490	1771.840	121.270	55.477	70.438	27.125
05:54:30	105.890	118.036	58.969	145.823	1778.590	114.443	55.808	71.583	26.869
05:55:00	105.948	118.406	56.219	145.950	1772.740	124.573	55.708	72.127	26.650
05:55:30	106.006	118.230	56.469	146.213	1787.300	119.631	55.498	71.577	27.085
05:56:00	106.006	118.538	59.958	146.002	1774.410	121.287	55.294	71.612	26.358
05:56:30	106.035	118.797	57.281	146.246	1787.300	118.088	55.715	70.079	26.715
05:57:00	106.123	118.427	54.365	146.415	1765.990	118.998	55.279	69.383	26.929
05:57:30	106.094	117.148	53.323	144.442	1763.300	121.623	55.571	68.721	27.800
05:58:00	106.079	117.199	57.448	144.066	1748.080	122.027	55.100	68.960	26.758
05:58:30	106.021	116.809	60.125	143.254	1756.850	114.775	55.744	69.671	26.196
05:59:00	106.021	117.068	59.635	143.695	1741.090	119.437	54.917	70.535	26.015
05:59:30	106.079	117.224	54.125	145.034	1751.720	124.746	55.098	69.954	27.458
06:00:00	105.948	117.511	57.844	144.569	1754.940	116.411	55.271	70.827	25.633

2ND SET OF TEST DATA

	STEAM HEADER PRESSURE	STEAM FLOW	DRUM LEVEL	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
	BAR	TONES PER HOUR	MM H2O	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
Min	0.0	0.0	-250.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	140.0	166.0	250.0	225.50	2866.0	166.0	100.0	100.0	100.0
TIME									
17:00:30	89.513	115.256	63.479	132.589	1615.880	105.500	52.831	50.506	26.029
17:01:00	89.658	116.324	60.531	135.765	1602.990	102.377	52.025	50.790	27.754
17:01:30	89.950	114.360	46.365	133.195	1581.790	119.233	51.908	49.427	28.379
17:02:00	89.877	113.471	50.073	131.471	1606.330	114.201	52.473	48.471	27.265
17:02:30	89.775	114.436	59.844	134.276	1626.210	105.773	52.123	48.994	27.485
17:03:00	89.833	113.689	59.927	133.482	1635.350	110.369	52.585	48.727	26.454
17:03:30	90.169	112.638	56.063	128.610	1550.200	106.285	51.715	49.502	26.642
17:04:00	90.548	109.671	50.229	126.233	1528.650	114.945	51.198	45.894	26.733
17:04:30	90.796	106.160	42.427	119.905	1495.930	120.015	50.385	43.165	26.913
17:05:00	90.563	105.759	54.323	114.432	1453.890	107.115	51.158	43.827	25.794
17:05:30	90.315	105.998	58.406	118.002	1457.120	109.041	49.875	44.998	24.510
17:06:00	90.154	107.153	67.875	122.151	1511.630	95.744	49.450	43.723	24.242
17:06:30	90.256	107.416	61.135	122.080	1448.940	104.884	49.098	45.831	26.379
17:07:00	90.154	107.762	59.615	118.979	1494.610	108.571	50.408	43.881	25.804
17:07:30	90.008	108.498	56.448	119.844	1514.200	102.737	50.552	44.802	26.673
17:08:00	89.804	110.400	64.688	125.899	1536.770	97.259	50.165	46.123	25.877
17:08:30	89.979	110.214	56.969	124.810	1526.380	113.648	51.008	45.969	25.240
17:09:00	89.921	110.362	53.719	124.655	1546.680	112.690	51.371	44.792	25.844
17:09:30	89.790	111.531	57.354	124.781	1565.970	115.865	51.881	45.669	24.954
17:10:00	89.731	112.147	60.906	126.994	1558.620	112.590	51.873	47.675	25.500
17:10:30	89.906	111.759	53.563	127.130	1575.820	104.805	52.471	45.952	27.419
17:11:00	89.848	111.704	55.146	127.797	1572.950	118.697	51.996	46.077	26.290
17:11:30	89.760	112.399	55.448	129.587	1567.640	111.403	52.015	47.823	26.033
17:12:00	89.615	114.243	62.802	130.771	1616.000	103.612	52.765	47.796	26.829
17:12:30	89.498	116.020	62.573	134.614	1619.110	105.030	52.100	50.840	26.404
17:13:00	89.862	114.066	52.344	131.034	1619.820	125.755	53.500	48.252	26.950
17:13:30	90.037	112.949	47.885	131.936	1576.240	117.241	51.377	47.744	27.235
17:14:00	89.979	112.261	54.542	130.964	1618.090	116.079	51.906	45.887	26.215
17:14:30	89.979	111.811	61.208	128.760	1559.040	103.549	51.869	48.112	26.131
17:15:00	90.096	111.376	55.833	127.718	1542.140	110.099	51.252	48.075	26.404
17:15:30	90.169	110.739	58.865	125.838	1536.950	100.617	51.573	46.785	26.871
17:16:00	90.213	110.802	55.979	125.016	1516.470	107.807	51.433	47.094	27.063
17:16:30	90.388	109.024	53.563	123.010	1522.200	114.080	50.923	44.548	26.581
17:17:00	90.329	107.962	53.948	123.076	1510.970	112.548	50.306	44.087	25.496
17:17:30	90.140	109.027	61.979	121.530	1522.740	103.038	50.988	45.044	26.200
17:18:00	90.242	107.475	57.646	123.048	1504.230	107.222	50.706	44.925	26.385
17:18:30	90.183	108.232	55.229	121.751	1477.000	112.652	50.473	45.633	25.890

TIME	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
17:19:00	89.965	110.376	66.750	121.789	1471.390	97.487	50.212	47.596	24.808
17:19:30	89.863	111.441	62.958	126.280	1589.370	107.748	51.919	44.340	25.756
17:20:00	90.037	110.791	50.375	125.401	1518.800	111.960	50.362	46.619	26.862
17:20:30	90.096	109.733	50.688	123.673	1509.960	122.214	50.421	45.640	25.560
17:21:00	90.008	109.439	49.396	124.828	1531.570	120.893	50.823	45.200	26.063
17:21:30	89.819	109.397	57.427	125.275	1581.910	105.794	52.233	45.021	24.967
17:22:00	89.804	110.456	63.552	127.177	1574.150	98.037	51.496	46.465	26.796
17:22:30	90.096	109.723	55.531	125.120	1544.410	111.839	51.496	45.338	25.673
17:23:00	90.169	108.944	59.167	122.991	1504.290	103.923	49.962	45.431	25.969
17:23:30	90.154	108.758	58.792	125.312	1499.150	107.890	49.108	45.004	26.733
17:24:00	90.140	108.308	54.083	121.840	1539.750	114.516	51.398	42.775	25.565
17:24:30	90.067	108.543	59.708	120.990	1499.630	103.269	50.502	45.081	25.981
17:25:00	90.008	108.332	54.542	123.828	1538.680	106.887	50.894	44.148	26.756
17:25:30	89.965	109.128	59.688	122.602	1505.000	104.044	50.565	46.042	25.325
17:26:00	90.008	109.557	59.396	124.142	1484.290	106.738	50.148	46.808	26.310
17:26:30	89.877	110.176	60.240	123.889	1517.180	100.188	50.896	46.894	26.429
17:27:00	89.935	110.182	57.729	124.739	1584.830	113.703	52.410	43.458	25.181
17:27:30	89.950	110.231	56.896	125.317	1504.290	107.668	50.837	46.931	26.329
17:28:00	90.008	109.487	54.625	124.283	1539.870	109.218	50.425	44.942	26.240
17:28:30	89.950	109.788	55.000	123.884	1540.170	107.959	51.294	45.027	25.656
17:29:00	89.892	110.082	56.135	124.565	1555.220	106.731	51.465	45.354	26.050
17:29:30	90.037	109.934	61.438	125.876	1528.890	108.941	50.898	45.642	25.212
17:30:00	89.921	109.875	55.375	126.219	1555.100	108.906	50.367	45.067	26.423
17:30:30	90.008	110.328	54.917	124.232	1527.750	112.534	50.998	45.479	25.683
17:31:00	89.950	110.549	54.396	125.124	1545.370	114.782	51.023	45.394	25.660
17:31:30	89.935	110.003	57.958	125.453	1540.950	109.411	51.165	46.290	25.879
17:32:00	89.979	110.940	57.115	125.261	1549.490	108.934	51.754	45.679	26.398
17:32:30	89.833	111.815	58.042	127.069	1571.220	97.359	52.408	45.871	26.915
17:33:00	89.790	112.583	57.500	126.971	1559.040	105.908	52.123	47.313	27.348
17:33:30	89.760	113.119	57.052	129.587	1589.310	103.522	51.523	47.246	26.352
17:34:00	89.819	114.087	56.365	132.946	1565.670	115.031	51.085	48.027	26.092
17:34:30	89.688	115.031	58.781	130.062	1616.540	110.698	52.790	47.667	25.823
17:35:00	89.702	114.741	59.094	133.891	1614.450	113.520	51.890	48.260	26.792
17:35:30	89.848	114.578	50.604	132.754	1609.970	115.757	52.442	47.902	27.006
17:36:00	89.848	114.170	52.427	131.269	1579.640	110.466	51.938	49.158	26.283
17:36:30	89.804	114.637	59.083	131.885	1599.760	108.405	52.631	48.771	26.406
17:37:00	89.819	114.277	60.302	131.645	1639.350	113.561	53.106	47.517	25.704
17:37:30	89.965	114.384	56.521	134.468	1601.790	112.901	51.271	47.869	26.692
17:38:00	90.023	114.374	52.875	130.391	1551.700	113.935	51.229	49.235	26.356
17:38:30	90.052	113.703	54.552	131.133	1585.310	116.560	51.788	47.333	26.540
17:39:00	89.833	114.198	61.292	129.244	1612.420	107.115	52.471	48.108	25.679
17:39:30	89.892	115.149	60.760	131.448	1600.840	110.286	52.202	49.163	26.740

TIME	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
17:40:00	89.906	115.031	57.656	134.130	1607.100	113.793	51.823	48.650	26.750
17:40:30	89.979	115.405	55.906	127.971	1598.390	117.725	52.927	48.013	25.704
17:41:00	89.892	115.342	58.177	133.463	1615.050	110.736	52.377	47.996	26.779
17:41:30	89.892	115.142	55.448	133.844	1584.060	115.813	51.540	49.890	26.177
17:42:00	89.892	115.356	57.417	130.832	1621.430	117.231	53.065	48.350	26.163
17:42:30	89.790	116.584	58.417	132.989	1618.810	115.304	52.796	49.894	26.169
17:43:00	89.804	116.286	58.865	134.727	1628.360	105.666	53.323	50.112	27.467
17:43:30	90.198	113.624	54.167	133.360	1616.240	114.976	52.344	47.206	27.121
17:44:00	90.256	112.565	50.760	129.019	1620.780	113.824	52.692	45.265	26.706
17:44:30	90.154	112.610	57.198	128.028	1574.090	103.584	52.554	46.696	26.740
17:45:00	90.140	112.901	60.229	128.328	1550.620	112.766	51.975	47.931	25.688
17:45:30	90.125	113.478	61.281	128.258	1572.590	110.428	52.137	46.596	25.219
17:46:00	90.154	112.213	54.094	127.295	1567.760	111.663	51.942	46.865	27.315
17:46:30	90.081	112.413	58.490	127.736	1589.910	102.979	52.660	46.263	26.402
17:47:00	89.760	114.938	65.615	132.044	1610.330	100.824	52.435	47.985	26.421
17:47:30	89.906	114.692	53.792	131.758	1563.940	115.681	51.410	50.356	26.440
17:48:00	90.008	115.384	50.833	129.846	1588.600	110.947	52.271	48.048	27.733
17:48:30	89.833	116.304	57.729	134.173	1620.840	114.377	52.677	47.865	25.494
17:49:00	89.790	115.930	59.698	133.313	1615.520	106.586	52.625	49.483	27.679
17:49:30	89.775	116.231	56.510	133.693	1650.810	115.595	53.017	48.733	26.671
17:50:00	89.746	117.262	61.052	134.891	1688.370	112.569	53.710	48.423	25.650
17:50:30	89.731	117.711	60.990	136.113	1660.720	105.310	53.383	50.325	27.715
17:51:00	89.833	118.590	57.875	136.301	1633.730	117.867	52.473	50.665	26.294
17:51:30	89.848	119.005	53.031	134.962	1621.550	112.998	53.217	51.779	27.815
17:52:00	90.125	116.093	50.990	132.148	1655.110	116.881	53.375	47.606	27.719
17:52:30	90.125	115.380	52.573	131.016	1604.060	119.254	52.671	48.648	26.771
17:53:00	89.906	116.193	55.458	134.628	1633.200	112.652	52.602	48.929	27.058
17:53:30	89.892	116.477	63.865	134.229	1625.910	106.454	52.698	49.973	26.915
17:54:00	90.067	116.055	60.688	134.093	1614.570	104.621	52.288	49.269	27.990
17:54:30	90.081	116.387	58.792	133.712	1602.690	119.534	51.767	48.962	26.363
17:55:00	89.935	116.750	55.917	133.595	1644.180	109.252	53.706	48.258	27.677
17:55:30	89.862	116.909	58.406	136.075	1665.920	114.243	52.460	48.677	25.485
17:56:00	89.994	116.691	55.677	133.510	1650.570	116.625	53.217	48.487	27.427
17:56:30	90.052	116.024	54.771	134.478	1633.020	110.030	52.260	48.813	27.569
17:57:00	90.008	116.369	53.104	132.524	1631.760	117.237	52.742	48.810	26.494
17:57:30	89.921	116.788	57.729	134.548	1619.640	114.388	52.302	50.619	26.383
17:58:00	90.081	115.875	55.156	133.383	1617.490	111.037	52.513	49.408	27.492
17:58:30	90.081	115.813	57.344	133.519	1620.240	107.495	52.104	48.896	27.319
17:59:00	89.833	117.697	61.365	131.946	1602.450	117.549	52.688	52.002	25.375
17:59:30	89.629	119.160	62.573	137.099	1684.190	113.357	53.558	51.767	25.369
18:00:00	89.921	117.497	53.333	137.499	1673.260	114.381	53.544	50.573	28.487

3RD SET OF TEST DATA

	STEAM HEADER PRESSURE	STEAM FLOW	DRUM LEVEL	GAS FLOW	AIR FLOW	WATER FLOW	GAS VALVE OPEN	AIR VALVE OPEN	WATER VALVE OPEN
	BAR	TONES PER HOUR	MM H2O	NM3 PER MIN	NM3 PER MIN	TONES PER HOUR	%	%	%
Min	0.0	0.0	-250.0	0.0	0.0	0.0	0.0	0.0	0.0
Max	140.0	166.0	250.0	225.50	2866.0	166.0	100.0	100.0	100.0
TIME									
08:00:20	105.963	112.870	51.948	139.895	1689.740	117.874	54.394	53.623	28.271
08:00:50	105.642	113.648	63.833	140.120	1748.320	110.563	56.273	55.529	28.044
08:01:20	105.554	115.038	67.958	144.499	1770.530	110.480	56.194	57.608	26.794
08:01:50	105.715	116.684	63.917	147.303	1792.200	105.683	56.563	57.662	28.704
08:02:20	106.050	117.407	58.417	148.219	1812.380	118.783	56.758	56.190	28.023
08:02:50	106.269	117.272	55.979	146.298	1759.720	117.863	55.813	54.992	28.696
08:03:20	106.371	116.470	50.802	142.807	1733.210	120.710	55.475	53.502	29.927
08:03:50	106.356	114.035	44.906	141.412	1709.740	125.257	54.996	52.285	30.033
08:04:20	106.065	112.123	51.042	138.650	1708.010	121.917	55.181	52.631	28.446
08:04:50	105.700	112.475	60.271	141.144	1719.000	113.513	54.775	55.531	27.723
08:05:20	105.467	113.935	66.177	146.537	1777.510	103.698	55.590	57.240	27.842
08:05:50	105.656	116.836	71.188	147.477	1800.140	100.236	56.673	57.590	27.438
08:06:20	105.992	117.850	61.896	148.515	1806.110	118.922	56.671	56.054	28.242
08:06:50	106.298	116.746	51.938	142.314	1767.840	122.079	56.627	54.631	29.952
08:07:20	106.400	114.882	46.615	143.907	1737.090	130.078	55.138	53.525	29.167
08:07:50	106.298	113.170	47.490	141.426	1714.520	120.118	54.833	52.410	28.481
08:08:20	106.138	112.565	58.177	139.307	1687.410	117.442	54.648	52.777	29.094
08:08:50	105.860	112.427	58.490	139.533	1700.730	109.038	54.523	54.706	28.913
08:09:20	105.715	113.561	61.896	143.084	1736.250	108.011	54.931	56.308	27.333
08:09:50	105.700	114.502	63.188	143.855	1778.950	118.974	56.212	56.933	27.517
08:10:20	105.787	115.927	61.010	145.556	1772.380	114.668	56.298	57.746	27.887
08:10:50	105.919	116.995	60.833	147.209	1785.160	113.772	56.142	57.165	28.185
08:11:20	106.035	117.020	54.135	147.031	1795.780	121.294	56.560	55.679	27.644
08:11:50	106.269	116.162	55.021	145.753	1759.780	116.363	55.737	54.885	29.219
08:12:20	106.385	114.343	45.719	142.502	1731.660	116.518	55.742	53.298	29.083
08:12:50	106.269	113.582	46.917	140.468	1704.070	124.548	54.592	52.758	28.396
08:13:20	106.079	112.714	57.521	139.495	1702.700	112.382	54.558	53.446	28.242
08:13:50	105.773	112.707	60.198	140.092	1707.120	112.199	54.956	55.346	27.940
08:14:20	105.656	114.955	65.125	141.534	1756.200	108.280	56.015	56.648	27.604
08:14:50	105.729	115.927	60.688	145.377	1788.620	107.959	56.331	56.583	27.440
08:15:20	105.890	116.826	57.115	144.865	1771.840	114.851	56.469	56.885	28.550
08:15:50	106.079	116.529	55.094	146.490	1774.050	120.758	56.054	55.250	28.560
08:16:20	106.225	115.273	49.604	143.911	1741.630	121.550	55.617	54.163	29.790
08:16:50	106.225	114.357	52.750	142.244	1735.600	119.804	55.542	53.054	29.010
08:17:20	105.977	114.284	55.021	140.346	1714.160	126.053	55.063	54.404	28.050
08:17:50	105.729	113.717	59.708	142.948	1739.120	113.205	55.548	56.346	28.919
08:18:20	105.700	115.235	64.156	145.137	1761.210	111.013	55.933	57.392	27.598
08:18:50	105.802	116.733	67.885	146.561	1783.960	111.071	56.550	57.419	26.708
08:19:20	106.035	116.708	61.240	147.980	1788.320	105.528	56.279	56.021	29.052
08:19:50	106.313	116.511	55.990	144.780	1762.290	120.326	56.104	54.450	28.281

TIME	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
08:20:20	106.444	115.481	54.125	143.592	1735.900	119.821	55.725	53.223	28.385
08:20:50	106.415	114.294	48.375	141.717	1714.520	120.782	54.788	51.873	29.529
08:21:20	106.152	113.489	49.917	139.552	1689.800	125.309	54.369	51.806	28.746
08:21:50	105.773	112.776	53.323	139.500	1725.980	117.960	54.700	53.535	29.313
08:22:20	105.510	113.471	63.833	143.766	1778.770	114.851	55.890	55.415	27.106
08:22:50	105.496	115.017	69.177	147.486	1795.720	116.480	56.244	57.365	26.431
08:23:20	105.612	117.348	64.000	147.966	1822.650	104.898	56.813	57.852	28.063
08:23:50	105.860	119.212	60.917	151.400	1818.770	116.504	56.237	56.823	28.258
08:24:20	106.079	119.036	53.875	147.228	1820.680	126.506	57.150	55.046	28.221
08:24:50	106.181	117.186	45.063	145.100	1766.290	128.546	56.154	54.954	29.788
08:25:20	106.152	115.384	49.760	144.386	1759.600	121.083	55.987	54.042	29.023
08:25:50	106.079	114.253	52.104	141.623	1725.570	123.338	55.629	55.131	28.610
08:26:20	105.919	114.810	61.406	142.577	1739.420	112.098	55.362	56.242	27.240
08:26:50	105.846	115.546	63.188	143.695	1820.800	113.292	57.554	55.694	27.558
08:27:20	105.904	116.864	63.594	146.716	1782.890	108.408	56.344	56.531	27.948
08:27:50	105.977	117.794	55.906	149.074	1784.500	125.793	55.404	55.963	28.188
08:28:20	106.079	117.528	50.646	145.950	1785.510	118.821	56.598	55.327	29.281
08:28:50	106.108	116.580	54.125	145.654	1762.530	120.364	56.046	54.535	28.598
08:29:20	106.065	115.543	53.156	144.879	1764.680	122.792	55.667	54.300	28.456
08:29:50	106.021	115.218	54.448	144.057	1743.180	117.915	55.679	54.550	28.475
08:30:20	105.919	115.481	57.688	143.037	1753.150	115.142	55.875	55.362	27.615
08:30:50	105.890	116.203	62.302	144.517	1753.750	116.515	55.552	56.523	27.679
08:31:20	105.875	116.964	55.823	146.688	1784.320	118.154	56.263	56.642	28.258
08:31:50	105.890	117.158	60.104	146.227	1783.960	111.026	56.508	56.660	28.210
08:32:20	105.904	117.151	55.104	145.518	1782.350	124.476	56.856	57.119	28.194
08:32:50	106.021	116.854	58.740	146.091	1792.020	117.760	57.054	56.569	28.929
08:33:20	106.079	116.529	52.427	143.094	1798.230	121.602	57.144	55.406	29.096
08:33:50	106.225	116.574	56.802	144.062	1771.240	117.701	56.410	54.235	28.681
08:34:20	106.196	115.560	53.792	143.366	1737.690	121.235	55.663	54.290	28.821
08:34:50	106.181	114.855	55.260	143.521	1735.120	117.082	55.602	53.456	28.748
08:35:20	106.167	114.540	56.073	142.723	1731.780	114.481	55.500	52.996	28.954
08:35:50	106.138	114.512	59.708	142.145	1745.270	117.040	55.133	52.438	27.444
08:36:20	106.021	112.922	53.958	139.641	1696.970	113.053	55.098	54.283	29.152
08:36:50	105.846	113.288	58.823	141.205	1730.880	112.572	55.454	55.598	27.600
08:37:20	105.831	115.124	60.677	144.499	1759.120	110.750	56.156	56.021	27.433
08:37:50	105.904	115.989	60.438	145.664	1773.270	117.231	55.962	55.490	27.692
08:38:20	106.006	116.670	58.177	147.712	1766.770	109.646	55.431	55.108	29.050
08:38:50	106.050	116.764	55.583	146.133	1760.440	115.702	55.969	54.517	28.448
08:39:20	106.196	115.916	51.302	144.259	1754.580	120.468	55.877	53.252	29.904
08:39:50	106.167	114.329	48.375	141.595	1712.610	123.196	55.044	53.581	29.069
08:40:20	106.006	112.548	51.135	140.703	1709.210	118.745	54.950	54.625	28.998
08:40:50	105.875	112.593	56.885	142.065	1744.550	111.863	55.438	55.381	27.819

TIME	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
08:41:20	105.656	114.308	67.719	147.853	1807.780	110.487	56.179	56.046	26.900
08:41:50	105.787	117.400	70.948	144.874	1804.080	112.538	57.625	56.208	25.862
08:42:20	105.948	118.406	60.917	144.748	1790.530	115.315	56.481	55.681	28.275
08:42:50	106.225	117.269	50.333	146.866	1762.230	129.321	55.475	54.346	28.721
08:43:20	106.298	115.671	47.813	143.597	1719.180	128.159	55.429	53.513	29.363
08:43:50	106.210	113.931	48.948	141.172	1719.540	124.908	54.971	52.883	28.142
08:44:20	105.919	113.122	56.396	140.825	1715.300	121.384	55.083	54.494	28.000
08:44:50	105.773	114.336	58.344	143.470	1774.590	111.358	55.983	55.092	27.646
08:45:20	105.715	115.622	68.198	144.311	1809.640	109.083	57.202	56.071	27.150
08:45:50	105.758	116.501	63.844	148.060	1826.530	115.934	57.323	55.742	26.977
08:46:20	106.021	117.255	59.146	144.480	1792.560	125.050	57.242	55.337	27.633
08:46:50	106.152	116.864	52.990	144.959	1774.590	120.973	56.023	54.529	28.602
08:47:20	106.210	115.927	53.979	145.227	1746.110	117.881	55.617	53.692	29.094
08:47:50	106.210	114.561	54.125	142.352	1718.160	127.616	55.010	53.098	28.017
08:48:20	106.108	114.118	52.510	142.004	1729.690	116.093	55.179	52.590	29.042
08:48:50	105.875	113.392	55.094	141.257	1731.300	115.342	55.421	54.252	28.517
08:49:20	105.773	114.557	63.823	143.150	1755.660	110.902	55.777	55.631	27.000
08:49:50	105.758	115.135	63.510	144.682	1763.420	112.527	55.990	57.123	27.867
08:50:20	105.831	116.646	61.896	146.575	1796.380	111.898	56.519	56.985	28.102
08:50:50	106.065	117.303	57.042	144.174	1813.460	124.372	57.258	55.450	28.185
08:51:20	106.210	116.255	55.750	147.059	1751.420	115.965	54.938	55.444	29.167
08:51:50	106.240	115.705	57.115	143.766	1750.760	121.654	55.888	53.748	27.919
08:52:20	106.210	115.045	52.750	141.468	1736.430	121.215	55.606	53.067	28.596
08:52:50	106.181	114.201	51.052	141.872	1715.120	121.657	54.833	53.348	28.506
08:53:20	105.860	114.512	55.104	141.201	1721.210	116.031	55.073	54.396	28.760
08:53:50	105.758	114.312	59.219	143.902	1751.060	112.074	55.542	56.071	28.467
08:54:20	105.715	115.595	64.406	144.475	1764.260	113.094	55.865	57.229	27.346
08:54:50	105.787	116.584	63.271	147.571	1794.650	108.723	56.150	57.133	28.533
08:55:20	106.021	117.002	57.198	148.008	1792.440	117.822	56.406	55.973	28.621
08:55:50	106.181	116.307	51.375	142.685	1768.970	121.823	56.827	54.662	28.521
08:56:20	106.254	115.304	49.844	144.466	1731.180	122.657	54.754	54.442	28.796
08:56:50	106.138	113.893	54.938	141.501	1728.070	124.514	54.935	54.273	27.933
08:57:20	106.065	113.499	55.823	141.356	1711.770	118.707	55.071	55.123	27.767
08:57:50	105.992	113.655	58.573	143.329	1737.510	117.538	55.008	55.190	28.379
08:58:20	105.860	114.654	60.833	142.798	1751.720	116.363	55.742	56.219	26.900
08:58:50	105.831	115.664	64.802	144.672	1765.570	109.726	56.150	56.904	27.315
08:59:20	105.963	116.774	62.052	146.580	1777.270	119.029	55.879	56.510	27.610
08:59:50	106.050	116.663	56.396	146.993	1771.600	119.693	55.767	55.708	28.215

4TH SET OF TEST DATA

	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
22:04:00	106.048	124.537	56.753	154.106	1877.160	127.332	57.171	82.728	27.524
22:08:00	105.921	123.129	57.930	151.788	1847.000	123.988	56.614	80.851	27.195
22:12:00	106.065	124.038	55.828	153.146	1863.160	126.828	57.013	79.987	27.473
22:16:00	105.840	124.397	57.120	154.847	1877.070	124.585	56.866	85.231	27.406
22:20:00	106.203	124.870	55.773	155.965	1885.460	127.569	56.898	85.216	27.643
22:24:00	106.061	121.083	58.275	148.342	1808.800	122.976	56.045	75.800	26.951
22:28:00	106.063	121.995	54.947	150.574	1831.890	125.390	56.484	77.159	27.391
22:32:00	105.917	121.805	58.172	150.168	1827.250	122.432	56.273	77.729	27.033
22:36:00	105.900	123.028	57.616	152.241	1843.240	124.886	56.398	80.676	27.183
22:40:00	105.979	123.582	56.492	153.437	1865.380	126.200	56.824	81.839	27.435
22:44:00	106.076	122.487	57.393	149.894	1838.770	124.864	56.738	78.151	27.109
22:48:00	105.968	122.826	57.112	151.431	1853.280	125.175	56.781	81.019	27.348
22:52:00	106.015	122.146	58.111	150.696	1835.770	124.259	56.433	77.971	27.166
22:56:00	106.063	122.436	56.604	150.963	1832.140	123.772	56.384	77.574	27.295
23:00:00	105.957	122.552	57.374	151.297	1846.260	125.277	56.660	78.699	27.120
23:04:00	106.061	121.682	56.542	150.269	1824.580	123.414	56.209	76.434	27.302
23:08:00	105.977	121.658	56.827	150.364	1826.130	123.567	56.299	77.762	27.230
23:12:00	106.032	122.193	57.027	151.740	1837.470	124.302	56.333	78.552	26.989
23:16:00	105.990	121.488	57.543	149.695	1825.340	122.172	56.314	77.121	27.096
23:20:00	105.995	120.881	57.746	149.240	1811.840	122.692	56.056	75.820	26.865
23:24:00	105.997	121.595	56.503	150.575	1825.390	123.169	56.136	77.121	27.224
23:28:00	106.006	121.524	56.050	150.568	1827.430	124.255	56.337	77.290	27.122
23:32:00	105.973	121.023	57.864	149.209	1818.930	121.537	56.294	76.698	26.987
23:36:00	106.017	121.120	57.663	149.836	1819.850	122.289	56.114	76.187	26.912
23:40:00	106.004	121.270	56.560	150.160	1827.740	124.635	56.259	76.470	26.967
23:44:00	106.015	120.773	56.037	149.106	1806.300	122.982	55.861	75.845	27.177
23:48:00	106.030	120.917	56.757	149.167	1814.040	123.829	56.066	75.984	26.603
23:52:00	105.966	121.026	57.478	148.992	1816.630	122.871	56.191	75.751	26.957
23:56:00	106.046	120.790	56.749	149.428	1806.590	122.285	55.891	76.321	27.018
00:00:00	105.946	120.159	57.606	148.249	1803.470	120.444	55.875	74.739	26.818
00:04:00	105.986	122.148	56.475	151.266	1834.780	124.789	56.469	77.863	27.312
00:08:00	105.964	121.738	57.393	149.753	1819.800	122.712	56.263	80.450	27.025
00:12:00	106.042	120.561	58.021	148.964	1806.240	122.299	55.888	75.206	26.827
00:16:00	105.999	121.031	56.401	149.761	1819.940	124.097	56.289	76.025	27.082
00:20:00	106.036	120.920	56.703	149.114	1812.550	124.158	56.118	76.249	27.008
00:24:00	105.992	120.855	58.020	149.158	1813.040	122.370	56.062	76.472	26.813
00:28:00	105.990	120.936	57.900	148.867	1810.330	122.360	56.191	76.823	26.633
00:32:00	106.026	120.515	57.991	148.279	1801.100	122.385	55.885	75.582	26.779
00:36:00	105.937	120.663	57.313	148.658	1807.150	122.238	56.032	75.997	26.762
00:40:00	106.085	120.463	56.999	148.062	1801.880	123.958	55.996	75.112	26.961
00:44:00	106.003	120.359	56.897	147.934	1799.320	122.711	56.033	75.077	26.925

	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
00:48:00	105.990	120.547	57.253	148.301	1803.300	123.198	55.907	75.740	26.680
00:52:00	106.025	120.111	56.755	148.083	1799.500	121.372	55.924	74.453	26.797
00:56:00	105.968	120.685	57.542	148.595	1802.580	122.108	55.928	76.512	26.697
01:00:00	106.012	120.412	55.960	147.151	1794.170	122.573	56.010	75.030	26.921
01:04:00	105.997	119.936	56.581	147.296	1789.610	122.204	55.807	74.711	26.733
01:08:00	106.035	120.195	55.885	147.096	1789.430	122.509	55.949	74.451	26.815
01:12:00	105.982	120.606	56.917	147.781	1794.900	123.628	55.906	75.178	26.932
01:16:00	106.019	119.962	57.159	147.028	1786.070	122.359	55.810	74.345	26.913
01:20:00	106.003	120.159	56.465	147.332	1791.870	123.291	55.895	74.646	26.802
01:24:00	106.037	119.730	57.514	146.429	1782.980	121.416	55.823	72.966	26.583
01:28:00	105.957	120.498	57.193	147.543	1795.350	122.054	56.031	75.481	26.884
01:32:00	105.973	120.374	56.432	147.159	1794.700	123.166	56.005	75.393	26.752
01:36:00	105.994	120.310	57.029	147.332	1790.970	121.803	55.919	76.124	26.757
01:40:00	106.043	119.758	57.449	146.255	1781.600	122.613	55.779	73.510	26.929
01:44:00	106.013	119.994	56.371	147.558	1786.690	121.712	55.685	74.587	26.807
01:48:00	106.013	119.643	56.928	145.650	1772.690	121.054	55.661	73.697	27.014
01:52:00	106.006	119.892	57.958	146.864	1790.640	120.186	55.941	74.499	26.826
01:56:00	105.950	119.139	57.521	146.367	1775.400	121.927	55.530	73.913	26.557
02:00:00	106.030	119.125	56.089	145.716	1773.900	121.101	55.615	72.723	26.764
02:04:00	105.981	119.620	57.382	146.695	1781.320	121.931	55.771	73.729	26.793
02:08:00	105.966	119.755	57.717	146.631	1785.380	120.907	55.884	74.260	26.868
02:12:00	106.010	119.667	57.604	146.395	1777.490	121.293	55.620	73.817	26.921
02:16:00	106.014	120.014	56.362	147.179	1786.760	122.188	55.790	74.310	26.881
02:20:00	105.997	119.294	57.466	145.792	1770.020	121.334	55.430	73.307	26.933
02:24:00	105.977	119.830	56.359	146.466	1783.440	122.646	55.785	74.122	26.774
02:28:00	106.043	119.061	57.385	145.646	1770.800	120.859	55.452	72.606	26.528
02:32:00	105.930	119.989	56.556	147.047	1785.860	121.638	55.756	74.479	26.812
02:36:00	106.035	119.115	57.534	145.903	1772.380	120.820	55.652	72.882	26.737
02:40:00	105.999	119.772	56.329	146.486	1783.800	121.830	55.872	73.396	26.800
02:44:00	105.946	119.907	57.695	146.874	1786.070	120.767	55.798	74.653	26.712
02:48:00	105.953	119.723	56.637	146.664	1779.570	122.068	55.633	74.010	26.518
02:52:00	106.019	121.110	55.732	148.417	1803.640	124.060	56.205	75.925	26.988
02:56:00	105.977	121.094	57.717	148.058	1802.200	121.551	56.180	76.148	26.844
03:00:00	105.986	120.529	58.359	147.586	1796.670	121.686	55.942	75.727	26.741
03:04:00	105.994	121.647	56.199	148.722	1810.790	123.196	56.263	76.960	26.996
03:08:00	106.005	121.210	57.505	148.325	1801.610	123.045	55.997	75.939	26.822
03:12:00	105.995	120.165	56.525	147.632	1794.830	122.670	55.919	74.979	26.798
03:16:00	106.027	120.575	57.507	147.315	1795.990	121.786	55.941	75.051	26.808
03:20:00	105.972	120.073	58.372	147.622	1791.170	122.723	55.865	74.956	26.594

	STEAM HEADER PRESSURE BAR	STEAM FLOW TONES PER HOUR	DRUM LEVEL MM H2O	GAS FLOW NM3 PER MIN	AIR FLOW NM3 PER MIN	WATER FLOW TONES PER HOUR	GAS VALVE OPEN %	AIR VALVE OPEN %	WATER VALVE OPEN %
03:24:00	106.065	120.282	56.455	146.881	1781.250	122.871	55.659	73.713	26.883
03:28:00	105.986	120.566	56.471	147.836	1798.380	123.758	55.998	75.308	26.559
03:32:00	106.035	119.766	57.162	146.370	1781.390	122.812	55.881	73.330	26.598
03:36:00	105.986	119.887	57.169	146.832	1782.300	122.194	55.799	73.935	26.515
03:40:00	106.013	119.566	57.353	146.194	1780.050	121.344	55.817	73.224	26.695
03:44:00	106.001	119.368	57.232	146.167	1776.220	122.398	55.712	72.878	26.577
03:48:00	105.948	120.438	56.227	147.891	1800.890	122.417	56.145	75.029	26.725
03:52:00	105.962	119.898	57.240	147.289	1790.130	121.754	55.852	74.280	26.619
03:56:00	106.050	119.993	56.865	147.321	1787.910	121.114	55.813	73.554	27.008
04:00:00	105.995	119.542	58.232	146.910	1787.200	121.975	55.857	73.874	26.376
04:04:00	105.983	119.688	56.786	146.745	1783.800	122.885	55.850	73.512	26.823
04:08:00	106.076	120.002	55.927	147.238	1791.380	123.564	55.979	74.056	26.690
04:12:00	105.979	119.043	57.575	146.328	1777.190	120.890	55.612	73.157	26.553
04:16:00	105.884	120.377	57.829	147.541	1797.800	121.337	56.062	75.551	26.694
04:20:00	105.997	120.723	56.697	148.640	1802.130	122.108	56.068	76.086	26.724
04:24:00	106.063	119.118	56.512	145.518	1774.720	121.923	55.772	72.578	26.784
04:28:00	105.977	119.654	57.088	146.933	1785.610	121.552	55.840	74.255	26.791
04:32:00	105.992	120.125	55.997	147.421	1788.700	121.367	55.851	74.599	26.825
04:36:00	106.019	119.157	58.589	146.061	1777.780	121.622	55.675	72.863	26.480
04:40:00	105.977	119.418	57.303	146.079	1779.880	122.384	55.652	73.310	26.661
04:44:00	106.076	119.094	56.038	146.160	1772.540	120.988	55.572	72.714	26.779
04:48:00	105.935	119.198	57.898	145.852	1778.250	120.995	55.763	73.304	26.405
04:52:00	105.990	119.828	56.949	146.716	1784.870	122.754	55.908	73.714	26.870
04:56:00	106.019	119.416	56.466	146.352	1785.020	121.615	55.761	72.829	26.776
05:00:00	105.995	119.190	58.145	146.064	1781.920	121.357	55.830	72.969	26.514
05:04:00	106.034	118.773	57.574	145.475	1768.630	121.354	55.544	72.027	26.601
05:08:00	106.004	118.946	56.280	145.755	1772.120	120.580	55.638	72.767	26.818
05:12:00	105.944	119.413	56.512	146.500	1788.210	121.650	55.906	73.378	26.570
05:16:00	106.030	119.123	56.929	146.394	1779.420	120.999	55.780	72.307	26.545
05:20:00	105.970	119.165	56.698	146.520	1788.790	122.209	55.949	73.089	26.741
05:24:00	106.012	118.945	57.214	146.791	1781.080	121.819	55.713	72.338	26.495
05:28:00	105.957	119.730	57.505	147.839	1800.450	121.644	56.198	73.588	26.687
05:32:00	106.061	118.398	56.797	146.321	1780.170	121.466	55.777	70.523	26.548
05:36:00	105.953	119.139	57.443	147.070	1794.670	122.033	56.068	72.564	26.409
05:40:00	105.990	120.079	57.091	147.728	1802.360	121.876	55.997	73.601	26.759
05:44:00	105.984	119.502	57.486	147.799	1795.560	120.497	56.071	73.803	26.616
05:48:00	106.004	119.233	56.688	146.642	1782.700	121.942	55.761	73.019	26.446
05:52:00	106.070	119.437	56.491	147.191	1784.150	123.495	55.727	72.462	26.453
05:56:00	105.970	118.970	56.768	147.422	1791.690	121.896	55.943	72.330	26.320
06:00:00	106.008	118.434	57.636	146.132	1780.230	121.897	55.749	72.000	26.433