CERTIFICATION OF APPROVAL

Inferential Development of MLNG Depropanizer Bottom Product

By

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Approved by,

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CERTIFICATION OF ORGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledges, and that the original work contained herein have not been undertaken or done unspecified sources or persons.

(KHAIRUL AZLAN B KHAIRIANUAR)

ABSTRACT

This is an individual Final Year Project titled as 'Inferential Development for MLNG Depropanizer Bottom Product' which carries four credits hours.

The main objective of this research project is to develop an appropriate inferential model to predict the quality of a Depropanizer bottom product that consists of butane and propane. In this research project, neural network technique was employed to predict the property of the Depropanizer bottom product. There were twenty seven inputs and one output used to develop the neural network model. This research project was carried out in conjunction with MLNG whereby data were collected from the plant to construct the network and training it to perform the property prediction. The software used for this project is Matlab 6.1 especially neural network toolbox and Microsoft Excel.

The neural network used was of 'Feed Forward Backpropagation' type and suitable configuration was tested and analyzed to achieve a minimum number of prediction error. For this project, the error calculation used was Root Mean Square (RMS). The network model were developed with the configuration of 3 layers which consist of 36 neurons in the first layer, 27 neurons in the second layer and 1 neuron in the third layer. The training function used for this network is 'Trainrp' and the adaptation learning function is 'Learngdm'. This network was trained with 100 times iteration. The model can be considered accurate to predict the concentration of the propane at the Depropanizer bottom product with RMSE obtained at 5.36%.

ACKNOWLEDGEMENT

First and foremost I would like to take this opportunity to thanks to god because give me opportunity to finish this project. I also like to express and acknowledge my gratitude to those that had contributed either directly or indirectly towards the success of my final year research project (FYRP). I would like to give credit to my supervisor Professor Dr. V. R. Radhakrishnan and my co-supervisor Pn Haslinda Zabiri for the technical advice, assistance and support that they had provided to me from the beginning until to the completion of this project. Without the direct and close monitor of the progress of the project from them it would not be feasibility to complete it on time. Beside that their knowledge and experience related to the topic has provided much assistant when the project face the unsolved condition.

Next I would like to acknowledge University Teknologi PETRONAS (UTP) specifically the final year research project committee for proper organization and management of this course.

Lastly I would like to acknowledge my parents for their endless support and confidence in me throughout the semester especially during conducting this project. I also apologize to those tat had contributed towards the project whom I had neglected to mention in this report. I appreciate all the effort of those in making this project success. Without all that support this project would not be successful.

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CHAPTER 1
INTRODUCTION

The Chemical Engineering Final Year Project is a four hour credit course which involved in modeling works. The project is entitle 'Neural Network Model and Advanced Process Control for MLNG Debutaniser distillate Product'. The supervisor of the project is Prof. Dr. V.R. Radhakrishnan and Co-supervisor is Pn. Haslinda Zabiri.

1.1 BACKGROUND OF THE STUDY

This final year research work was based on previous work by Sujendren. Based on his work, further development on the model was done and the appropriate control strategy will be devised.

Neural Network (NN) is a new age technology in the information processing that was developed based on the neuron in the human brain. Neural network consist of large number of interconnecting processing elements that normally operates in parallel. The system behaves as human brain where it has the ability to learn, recall and generalize from training patterns or sets of data.

For this work, Malaysia Liquefied Natural Gas (MLNG) debutanizer column was chosen and the necessary data was obtained. Based on the previous model done by Sujendren, further work will be done to improve the Neural Network system.

1.2 PROBLEM STATEMENT

Debutanizer is very common and crucial equipment in oil and gas industries. It serves the purpose to separate butane and other higher key components from the feed. The most common problem encountered with the Debutanizer overhead product is the impurity which might be due to the column feed quality. The column receives it feed from Depropanizer bottom which splits propane and butane plus higher hydrocarbon component. If the propane content in the feed is high, it will result in off-specification of the butane produce from Debutanizer overhead product since propane which is lighter than butane could not be removed at the column bottom. This condition may happen particularly in the improper Depropanizer operating parameter coupled with higher propane in the Depropanizer feed.

As such, an inferential model is desired for the Depropanizer column bottom to predict the propane concentration so that proper column adjustment can be done to prevent propane carryover into the Debutanizer column.

1.3 OBJECTIVE AND SCOPE OF STUDY

1.3.1 Objective

This Final Year Project will be an open ended project where the availability of the time will decide on the development of the project. As of the problem statement, the objectives of project are:

i. To develop the NN model MLNG Debutanizer distilled product
ii. To construct and develop a Feed Forward Backpropagation (BP) NN architecture using MATLAB's "Network/Data Manager"
iii. To train, make necessary amendment and develop a suitable NN configuration using training set of data.
iv. To test the network using testing set of data to compute the tolerance and estimated error of the network via RMSE.
v. To develop dynamic model
vi. To integrate the NN ability in the internal model control strategies.

1.3.2 Scope

The scope of this research work is to study the characteristic of NN model and make the necessary modification on the NN model developed by Sujendren which was based on a Malaysia Liquefied Natural Gas (MLNG) Debutanizer column. Further study will be conducted to determine the compatibility and accuracy of the NN model based on the data obtained from MLNG. The NN model training, validation and testing phase will be conducted in MATLAB NN TOOL.

The Debutanizer column used for this research work belongs to MLNG. It is a distillation column used to separate the butane from other heavy component such as n-pentane. The data obtained from the equipment is limited to 16 hours (July 12 2003

23:00 to July 14 2003 14:51) on which the data is recorded every minute. This data will be used in developing the NN model.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 DISTILLATION COLUMN

The purpose of the distillation column is to separate between light key and heavy key component. Distillation column is a common separation process used in industry. From the Christie J. Giankoplis, "Transport Process and Unit Operation", Distillation used to separate te component of a liquid solution, which depends upon the distribution of these various components between a vapour and liquid phase. All components are present in both phases. The vapour phases is created from the liquid phase vaporization at the boiling point.

The basic requirement for the separation of the components by distillation is that the composition of the vapour be different from the composition of the liquid with which it is in equilibrium at the boiling point of the liquid. Distillation is concern with solutions where all components are appreciably volatile, where both components will be in the vapour phase.

For this study research, two distillation column from industry was used that is depropanizer and debutanizer column. Depropanizer used to separate propane (overhead product) from the other heavy component (bottom product). The Debutanizer column used to separate butane (overhead product) from the other heavy component (bottom product). The feed to the debutanizer column is the botom stream of the depropanizer column. That stream consist of propane, n-butane, iso-butane, iso-pentane and n-pentane. Since the feed to the debutanizer have propane component, that is lighter than butane, separation of that feed at the debutanizer column will result with the offset of debutanizer distilled product because propane exist in that product. In order to control the composition of the propane at the bottom product, the operating parameter of the deporpanizer column should be control. Because of that, the study of neural network model at the depropanizer bottom product is applicable to control the quality of the butane at the debutanizer distilled product. All the inputs and output for this research were taken from the depropanizer column. It consist of twenty seven inputs that consist of the operating parameters at that column such as pressure recoder controller alarm (PRCA) and the output is the propane concentartion at the bottom product stream. The diagrams of Depropaniser column and detailed about the inputs and output can refer to appendix 1.

2.2 NEURAL NETWORK

2.2.1 Biological Analogy

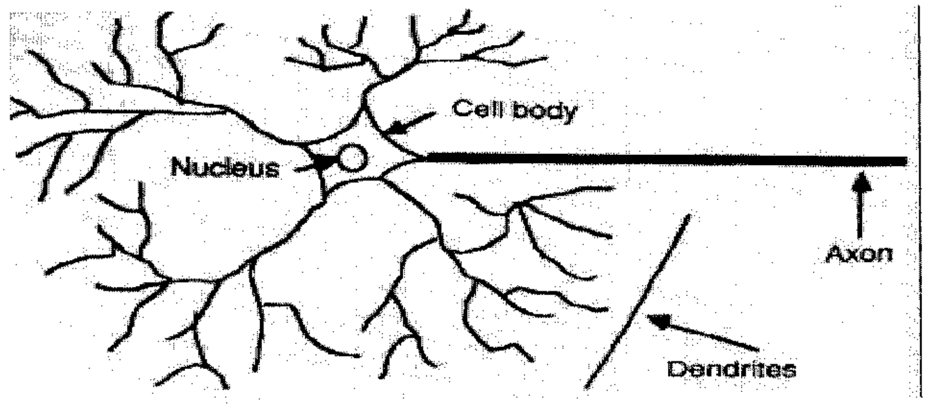
Works related on Artificial Neural Network (ANN) are commonly referred to as Neural Network (NN) was originated from the biological NN in the human brain. It comprises of a large number of interconnected neurons. Each neuron has a branching input structure (dendrites), a cell body, and a branching output structure (axon). The synapse connects axon of each cell to dendrites of another as shown in figure. ANN is used to distinguish them from real NN inside the human brain.

To maintain the characteristic of biological neural systems, ANN is defined as follow:

I. A number of inputs (either from original data or from output of other neurons) are received. Each input originates by a connection that has weight and each neuron had a single threshold value.

II. It is passed through a transfer function to produce the output of the neuron.

Figure 2.1: Component of neurons



2.2.2 Artificial Neural Network

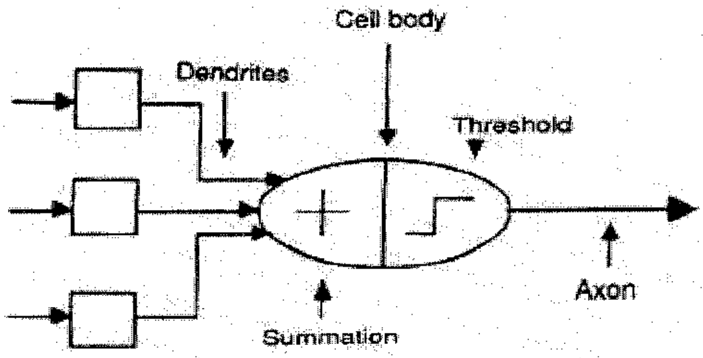
NN is identified as a form of nonlinear mapping between the inputs and outputs. The connectivity between inputs and outputs are by nodes arranged in several layers as shown in figure 2.2. The complexity of these connections often connections often contributes to excellent accuracy for nonlinear prediction from process data.

According to Radhakrishan and Mohamed (2000)

> A feed forward neural network essentially consists of a number of nodes interconnected as shown in figure. The inputs x_i are connected to the nodes in the inputs layer. The output y_p are taken from the output layer. There are no limitation on the number of inputs and outputs. Between the input layer and the output layer there exists one or more hidden layers. The transformation or mapping takes place in the hidden layers. All the nodes in one layer are connected to all the nodes in the next layer. The connection strength between the outputs of node i with node j am given by weight W_{ij}. The weights can take values between 0 and 1, 0 signifying no transmission of the signal and 1 signifying the transmission of the full signal strength to the node j. at the node all

the incoming signals are summed and the bias subtracted from the sum to give the total activation. The output is calculated as a nonlinear function of the total activation. A nonlinear function which is commonly used for the transformation is the sigmoid function.

Figure 2.2: The neuron model



Total activation of node j, $zj = \sum x_i W_{ij} - bj$

Output of node j, $x_j = \dfrac{1}{1+e^{zj}}$

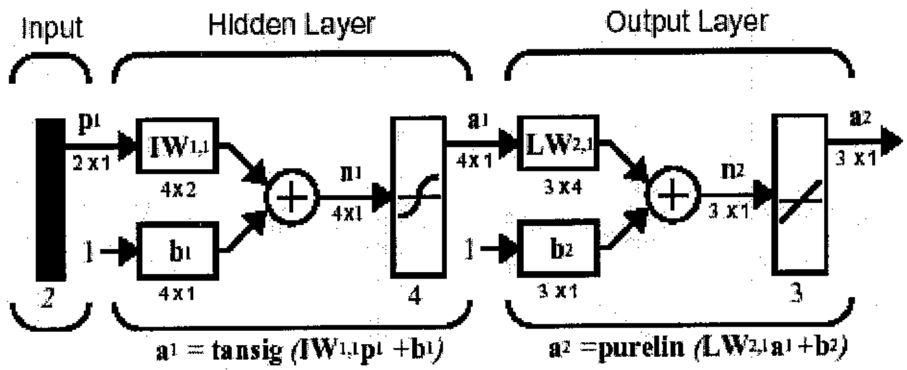
Where x_i, i	= 1,2…j…n	= output of node
z_i, i	= 1,2…j…n	= activation of node
W_{ij}, i,j	= 1,2…n, i=/ j	= weight of signal from *i*th node to *j*th node
bi, i	= 1,2…j…n	= bias of the *i*th node

Hence if activation is zero or negative the output x_j of the *i*th node is zero. The mathematical operation at the node is shown above.

2.2.3 Backpropagation Network

According to the book 'Neural Network Toolbox' by Howard Demuth and Mark Beale, the Backpropagation was created by generalizing the Window-Hoff learning rule to multiple-layer networks and nonlinear differentiable transfer functions. This rule utilizes the inputs and outputs or the targets to train the network and is known as the Delta Rule which uses the difference between the inputs and the targets to change the weights to the nodes. Training proceeds until an approximation of the function, which relate the inputs and outputs, is generated. Once trained, the network is able to approximate a set of inputs without the outputs provided to certain accuracy. This network is identified as loop free or feed forward where the inputs undergo "no past state of the network feeding back to any of its units" (Ng, 1997, [.16) through the network layer that its from the inputs layer through the hidden layers and to the output layer. Backpropagation posses a gradient descending algorithm where weights are moved along the negative gradient of the performance function. It is referred to the manner in which the gradient is generated for nonlinear multilayer networks.

Figure 2.3: Basic backpropagation network

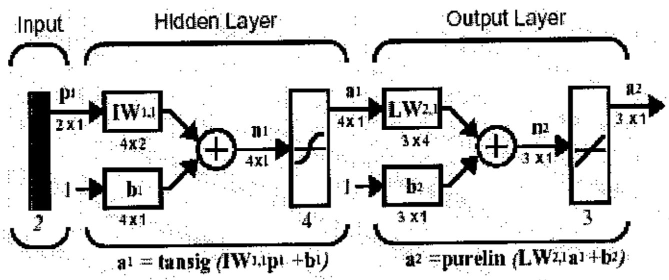


Basic Backpropagation network architecture is shown in figure 2.3. The number of hidden layers in a Feed Forward network is often one or more layers. Multiple layers of neurons with nonlinear transfer functions allow the network to adapt and learn nonlinear relationships between inputs and outputs. Linear output layer allows the network to produce values outside the range -1 to +1. Multiple layers of Backpropagation network is shown in figure 2.4. For detailed explanation the book by Howard Demuth and Mark Beale (1996) should be referred.

There are no rules governing the amount of layers and number of neurons. Usually trial and error approach is used for determining the best configuration that able to be specified before training the network such as:

I. Training function
II. Adoption learning function
III. Performance function
IV. Number of layers (including hidden layers)
V. Number of neurons in each layer
VI. Transfer function of each layer.

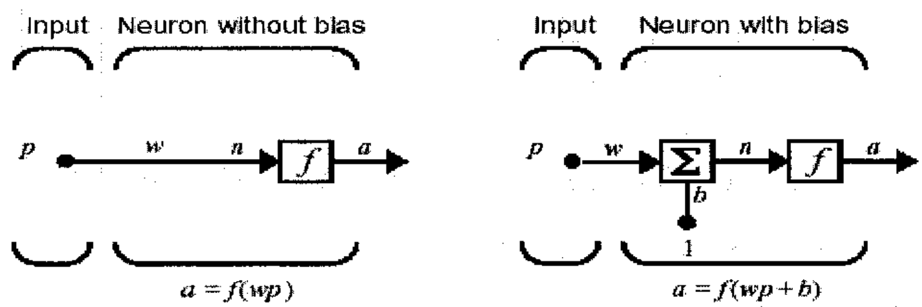
Figure 2.4: Multiple layer of backpropagation network



Single Input Neuron

A neuron with single input and no bias is shown in figure 2.5. The scalar input **p** multiplied with its strength by the scalar weight **w**, to form the product **w*p**. The product then will be the argument for of the transfer function F, which produces the scalar output **a**. The neuron also contains a bias scalar, **b**. The bias has a constant output of 1. The transfer function net input, **n** is the sum of the weighted input **w*p** and the bias **b**. This sum becomes the argument for the transfer function **F**. The transfer function which is typically a step function or sigmoid function, takes the argument and produces the output **a**.

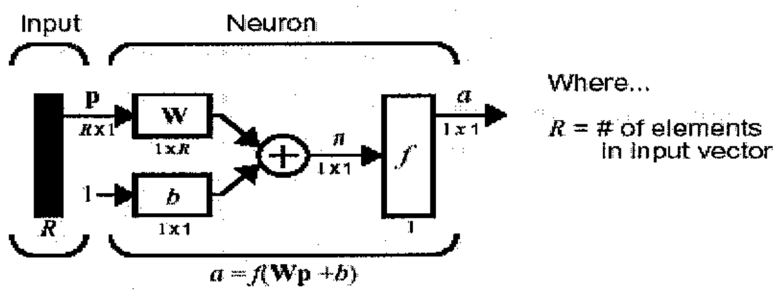
Figure 2.5: Neuron without bias and Neuron with bias



Multiple Input Neurons

A single neuron with R inputs is shown as figure 2.6. The individual inputs p(1), p(2)..p(R) are weighted by elements w(1,1), w(1,2)..w (1,R) and the weighted values are inputs to the summing junction.

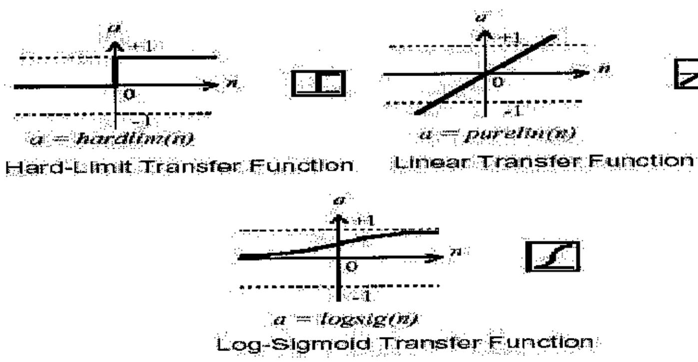
Figure 2.6: Multiple Input Neurons



Transfer function

The commonly used transfer functions for neuron are; hard limit transfer function, linear transfer function and log-sigmoid transfer function. Hard limit transfer function take argument value between 0 and 1 and mostly used for making decision such as classification. Linear transfer function used as linear approximators. The sigmoid transfer function log-sig takes the input of any finite value and gives the output into the range 0 to 1.

Figure 2.7: Transfer function



2.2.4 Training Algorithm

Network is trained for purposes like function approximation (nonlinear regression), pattern association or pattern classification. The training process requires a set of inputs and its targets. Weights and biases are iteratively adjusted to minimize the network performance function (minimize error). In backpropagation weights are moved in the direction of negative gradient. Gradient descent algorithm can be implemented by incremental mode and batch mode.

In incremental mode, the gradient is computed and the weights are updated after each input is applied to the network. However in batch mode all the inputs are applied to the network before the weights are updated. Examples of batch mode are such as batch training (*train*), batch gradient descent (*traingd*) and batch gradient descent with momentum (*traingdm*).

The training algorithm traingd and traingdm are often too slow for practical problems. Fast algorithm can be generalized as those which use heuristic techniques and those that use standard numerical optimization techniques. Heuristic is based on the analysis of the performance of the standard steepest descent algorithm. Variable Learning Rate backpropagation (*traingda*) and resilient backpropagation (*trainrp*) are example of fast heuristic training algorithm. Example of algorithm uses the standard numerical optimization techniques are Conjugate Gradient (*traincgf, traincgp, traincgb, trainscg*), Quasi-Newton (*trainbfg, trainoss*), and Levenberg-Marquardt problems. However, it does not perform well on fuction approximation problems. Its performance also degrades as the error goal is reduces. The memory requirements for this algorithm are relatively small in comparison to the other algorithms considered. '*trainrp*' is expressed here because the suitable network uses this training function. Detailed explanation of each algorithm and its comparison can be referred to Matlab's Neural Network Toolbox Helps Files version 6.1 Release 12.1 of the software.

2.3 STATISTICAL ANALYSIS

2.3.1 Data processing

The purpose of processing data is to normalize the data so that it can be used successfully for training the NN. By doing so, some of the inherent characteristics can be incorporated in to the model. The approach for the processing data is according to journal referred to Radhakrishan and Mohamed (2000). The procedures involved are data segmentation, normalization and testing for normal distribution. Random numbers are used for specifying the inlet parameters so that the study is without bias. Microsoft® Excel's 'Random Number Generation" is used for this purpose. 'Sampling' is used for data segmentation using random numbers and randomly performed. The set of three hundred thirty four data obtained from the experiments is divided into training set of 147 data, validation set of 144 data and testing set of 43 data. The test data are used only once for testing the model accuracy. 'ANOVA: Single Factor' was used to verify tat three segmented sets and the original set are from the same population by their means and standard deviations. The following equations are used in ANOVA testing.

$$SS_T = SS_{Treatment} + SS_E$$

$$MS_{Treatments} = \frac{SS_{Treament}}{a-1}$$

$$MS_E = \frac{SS_E}{a(n-1)}$$

$$F_o = \frac{MS_{Treatments}}{MS_E}$$

Where SS_T is the total sum of squares

$SS_{Treatments}$ is the treatment sum of squares

SS_E is the error sum of squares

$MS_{Treatment}$ is the mean square for treatment

MS_E is the error mean square

Normalization on the data was done based on this formula:

$$x_n = \frac{(x - x_{\min})}{(x_{\max} - x_{\min})}$$

Where x_n is the normalized value

x_{min} is the minimum value

x_{max} is the maximum value

Information about distribution of data is important to the NN architecture. Hence statistical distributions of the variables are analyzed accordingly. 'Descriptive Statistic' is used for generating a set of information that some of the information's are for testing segmented sets for normal distribution. This method was used in the journal referred to the Radhakrishan and Mohamed (2000), which was suggested by 'Modern Data Analysis-A first Course in Applied Statistics' by L.C. Hamilton (1990).

I. Test for symmetry is based on the skewness of the data.
II. Normality can be tested for symmetric data by comparing the standard deviation with the pseudo standard deviation.
III. Relative Peakness or Flatness of the data is tested by the Kurtosis.

2.3.2 Percentage Error

The error is identified by using Root Means Square Error method (RMSE). RMSE determined the error between the predicted and calculated values, square them, sum them, divide by the number of the data point and determined the square root of them.

RMSE = sqrt (sum ((predicted value-actual value) ^2)/number of data)

The best RMSE required for this modeling to consider as a good modeling is less than 5% because the chromatograph in the MLNG plant can be only give the reading with 5% accuracy. For this research project, trial and error method was used to develop the Neural Network models that enable to achieve the error less than 5%. The RMSE were calculated by using Microsoft® Excel's.

CHAPTER 3
METHODOLOGY OR PROJECT WORK

3.1 PROJECT OVERVIEW

The study of modeling debutanizer column with NN was conducted via research and modeling approaches. To model a neural network to control the debutanizer column distilled product using NN the potential process variable must be identified. Generally twenty-seven inputs operating parameter such as temperature indicator (TI), flow recorder controller (FRC) and pressure recorder controller alarm (PRCA) are the basic parameters related to the debutanizer column distilled product. The study uses the NN to predict the propane composition at the debutanizer feed stream with inlet parameter specified. The NN needs to be trained with sufficient amount of inputs and targets for it to be able predict.

The input parameters and corresponding outlets conditions are needed. These sets of data were taken from the MLNG. The three hundred thirty four set of inputs and one output of data is segmented to three separate sets (training sets, validation sets and testing sets). The NN trained with different configuration until a minimal error in prediction could be achieved. Then it is validated and tested so that a performance study of the NN for corresponding outlet conditions of the butane product quality could be conducted and the RMSE can be calculated.

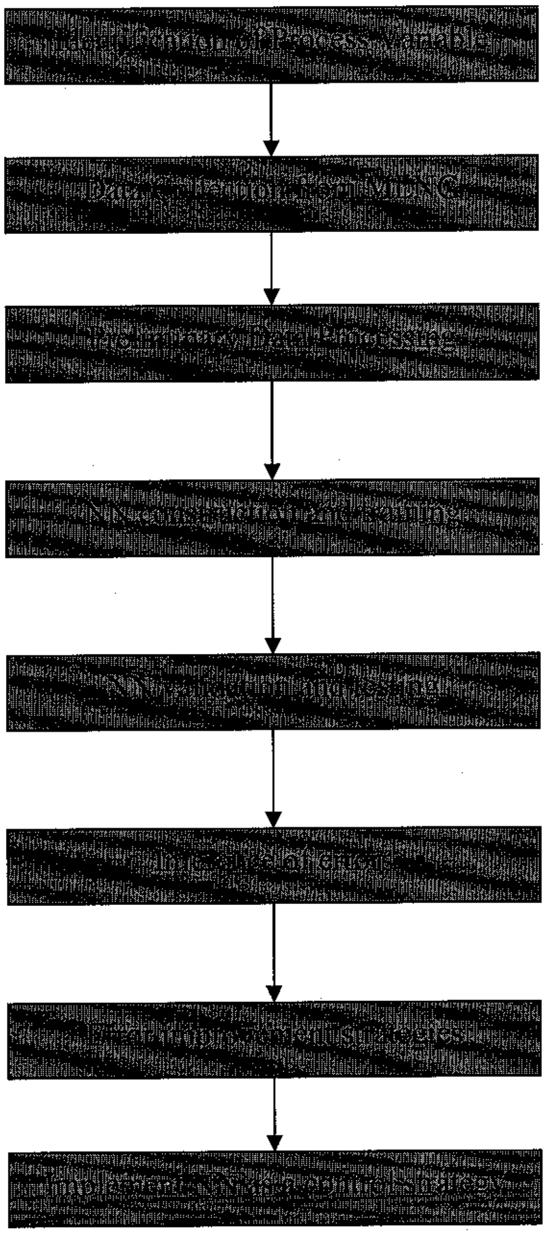
3.1.2 Tools Required

The study approaches utilized software only. The software aspects utilized are Matlab version 6.1 releases 12.1 and Microsoft® Excel 2000. The Neural Network Toolbox's 'Network Data/Manager' is an extension in Matlab, used is matter related to NN. The process of construction, training, validation, testing and enhancement of the NN is done using this software. Microsoft® Excel is used for tabulation and auxiliary purposes. The 'Spreadsheet' is used for tabulation and performing calculation for set of data with the equation specified. Calculation such normalization and RMSE used 'Spreadsheet' for those purpose. 'Random Number Generation' used for generating sets of random number so that the inlet parameters can be specified. 'Sampling' is used for selecting randomly a set of data of specified sample size from its original set. The 'ANOVA: Single Factor' data analysis is used for verifying segmented sets and the original sets are from the same population. 'Descriptive Statistics' is used in testing for normal distribution of the inlet and outlet conditions.

3.2 METHODOLOGY

They study to develop the NN model for the Debutanizer distilled product could be summarized to series of steps which are interrelated to each other as shown in figure 3.1. The succeeding steps are highly dependent on the completion of its predecessors. The results would be affected if at one particular stage the work were not completed. The steps shown here is a briefing and concise of a work involved however in each steps the work related are explained in details as in the following subchapter. The steps in figure 3.1 must proceed accordingly. There are additional works conducted such research, familiarization session with the NN toolbox software and familiarization with the Microsoft® Excel software.

Figure 3.1: Methodology in developing the NN



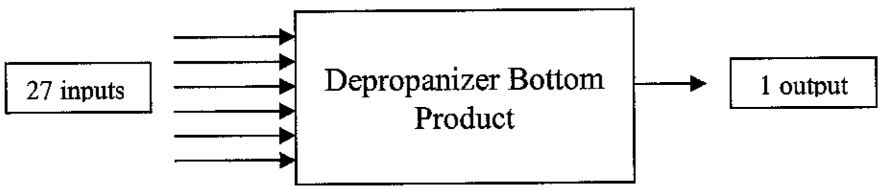
The last steps are not specified as on of the objectives. This is the following stage of any NN project that is to develop a control strategy suitable for application in industry. However this project will provide the fundamentals for developing a predictive control strategy, which may be used by other study related to this matter.

3.3 PROJECT WORK

3.3.1 Identification of the Process Variables

Process variable related to this study are operating parameters for the Depropanizer column (inlet) and the reading from analyzer at the bottom product of Depropanizer column (outlet). Three hundred and thirty four sets of data are collected from the MLNG that consists of 27 inputs and 1 output. Detail about the inputs and output were attached in appendix 1. Three sets of data that is training, validation and testing are generated using Microsoft® Excel's 'Random Number Generation'. The following figure illustrates the inlet and outlet process variables.

Figure 3.2: Depropanizer bottom product process variables



3.3.2 Preliminary Processing of Data

Processing of data is done on set of inputs with its corresponding output. These work needed to be done before attempting to train the network. Three steps involved that is:

I. Data segmentation
II. Normalization
III. Testing for normal distribution

Data segmentation

The sets of three hundred thirty four inputs and output data are needed to be divided to three sets that are training, validation and testing. These sets are needed for different stages of work in NN. The ratio between each set is according to the journal by Radhakrishnan and Mohamed (2000) that is 43% for the training, 43% for the validation and 14% for the testing. From that ratio, the training set has 147 of data, validation 144 of data and testing 43 sets of data. Segmentation is conducted randomly using Microsoft® Excel's 'Sampling'. The software required user to specify the set of data for sampling and amount of sample size required. Sampling is done in all data sets. Performing sampling using random numbers rather than absolute values will have similar result because absolute values are generated from random number by an equation. Generally the relation is constant and the random numbers could be used in segmentation. The specified size for sampling must be larger than the desired size because the software replaces the number after selection. If sampling has repetition, the following sampled number is selected. The sets should not have repeated values.

After the segmentation, an ANOVA test is required to verify the original and the three segmented sets are from the same population by comparing their means and standard deviations. The Microsoft® Excel's 'ANOVA: Single Factor' is used for this purpose. Test is conducted on the random number of the all data, training data, testing data and validation data. The means and standard deviation are compared.

Normalization

The study had numerous process variable of each different in units and ranges. Due to inconsistency in units, the absolute values must be normalized. Normalization is done using equation and the normalized values are all in the range of 0 to 1. Normalized values are used so that all inputs to the NN are all within 0 to 1 and the output is within these normalized ranges. Microsoft® Excel Spreadsheet Calculation is used to tabulate and performing normalization calculation with the equation specified.

Testing for Normal Distribution

The test for normal distribution is based on three criteria as follow:

I. Test for symmetry is based on the skewness of the data. Skew = 0, symmetric; Skew < 0 assymmetric tail extending to positive values; Skew > 0 assymmetric tail extending to negative values.

II. Normality can be tested for symmetric data by comparing the standard deviation with the pseudo standard deviation. SD = PSD Normal; SD > PSD Heavy tailed; SD < PSD Light tailed.

III. Relative Peakness or Flatness of the data is tested by the Kurtosis. Kurt = 0, Normal; Kurt > 0, Peaked distribution; Kurt < 0 Flat distribution.

The Microsoft® Excel's 'Descriptive Statistic' is used to generate a set of statistical information each for the inlets and outlet variables. However three information's that required is the skewness, standard deviation and Kurtosis. For each variable, the information is compared with the above criteria and conclusion about the distribution of the variable can be generated. The suggested test was journal referred to Radhakrishnan and Mohamed (2000). A sample of what in information obtained from the software is at figure 3.3.

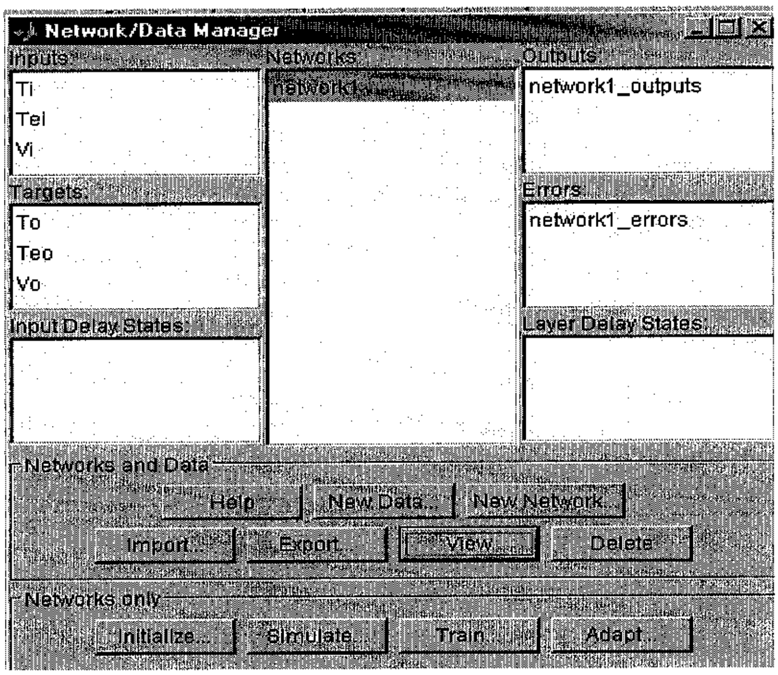
Figure 3.3: Information from The Microsoft® Excel's 'Descriptive Statistic'

Mean
Standard Error
Median
Mode
Standard Deviation
Sample Variance
Kurtosis
Skewness
Range
Minimum
Maximum
Sum
Count
Confidence Level(95.0%)

3.3.3 NN construction and Training

There are three sets of inputs and output that arranged in a matrix form. For the training sets the matrix arrangement is 27X147 for the inputs and 1X147 for the output. For the validation sets the matrix arrangement is 27X144 for the inputs and 1X144, and for the testing sets the matrix arrangement is 27X43 for the inputs and 1X43 for the output. All this data has been corrected to ensure that it can be used to construct the NN. Matlab Neural Network Toolbox's 'Network/ Data Manager' is used for constructing and training the NN. Figure 3.4 shows the network manager. This is used for managing the NN with multiple inputs and output.

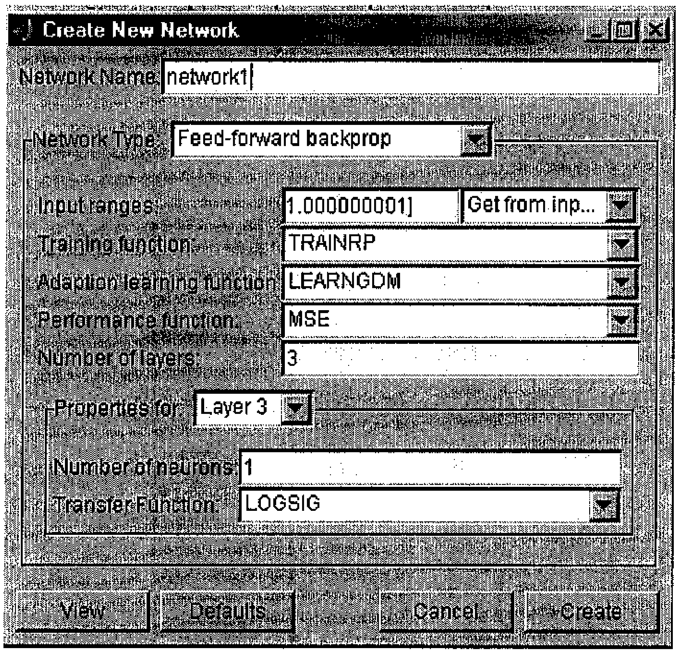
Figure 3.4: Neural Network Data/Manager



The rearranged matrixes of all data sets are specified in the Matlab's workspace before importing to the Network Data/ Manager as inputs and targets using the 'Import' button.

The 'New Network' button can create network. A window for creating a network shown in figure3.5:

Figure 3.5: Network Creation

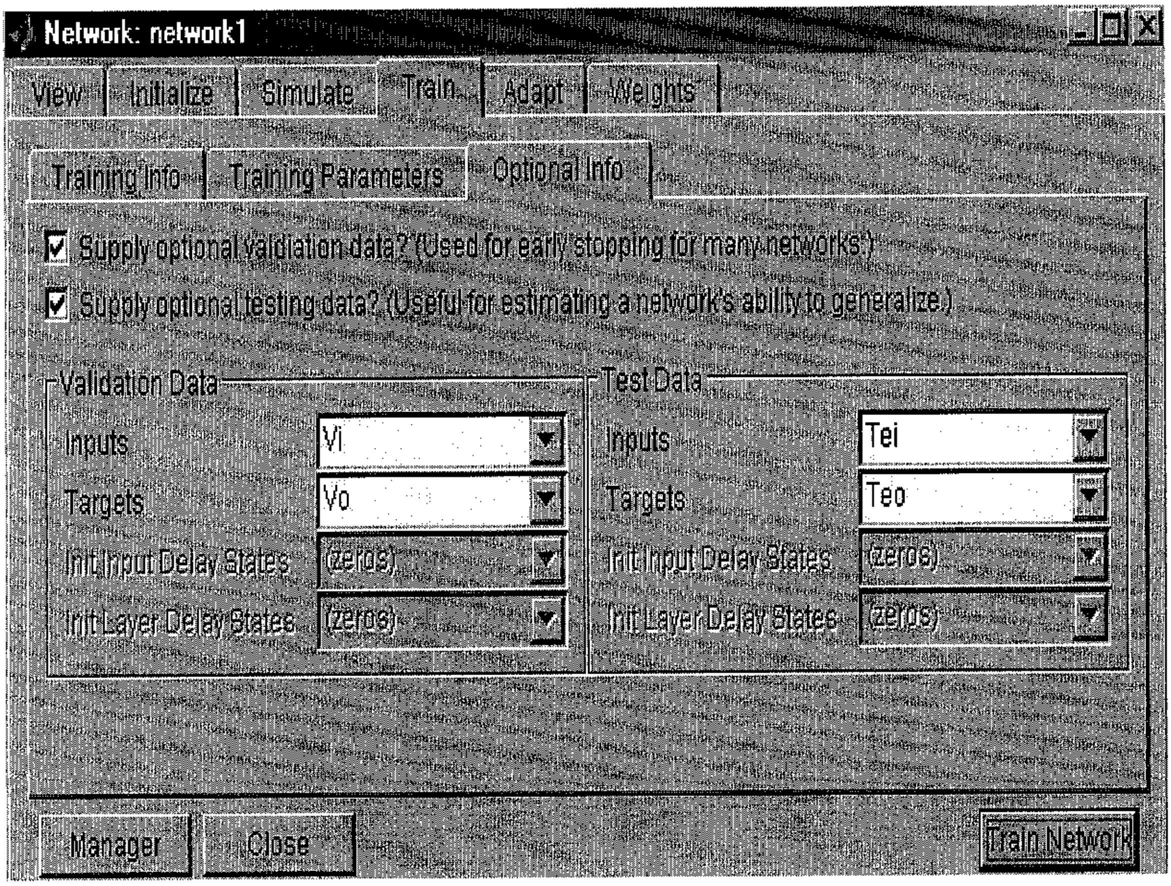


Familiarization session is conducted to determine the potential configurations. Trail and error approach is used to determine the optimum configuration that would provide the minimal error generated. The proposed network used is 'Feed Forward Backpropagation'. The input range should be specified and get from training inputs. The suitable NN configuration is determined by changing the training function, adaptation learning function, performance function number of layers, number of neurons and transfer function. The desired output in the study must be positive in value, therefore the last layer utilized the transfer function of *logsig*. For each configuration tested the output in the form of a performance curve is analyzed to identify the configuration that will produce minimum error. For each training session the same network is prohibited to be used again. The error is inconsistent for different training with the same configuration.

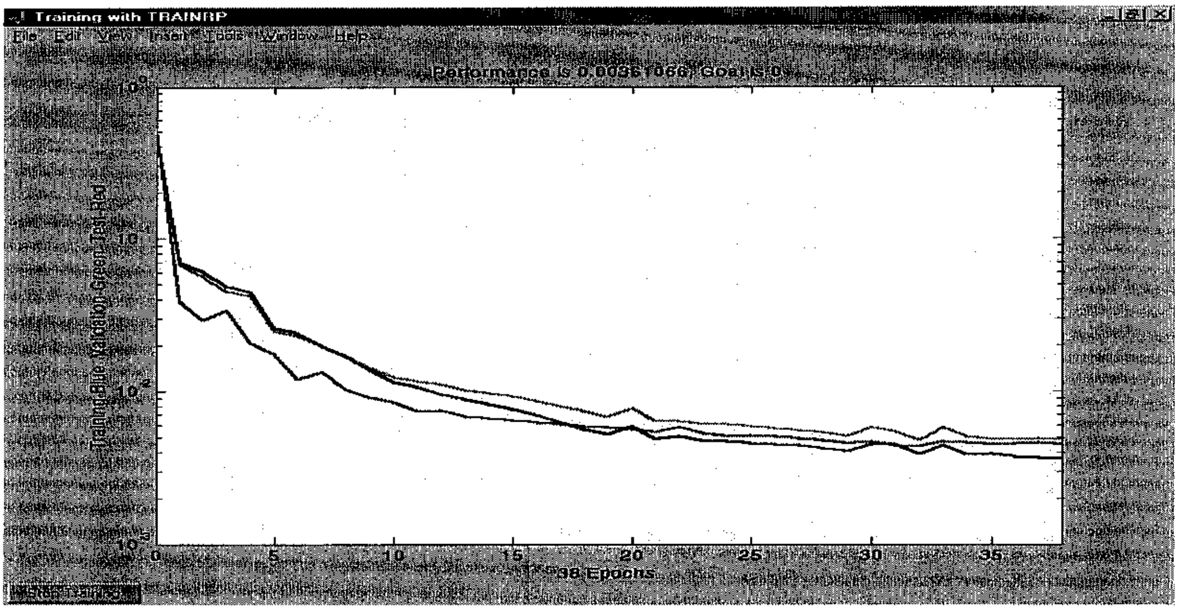
3.3.4 NN Validation and Testing

In determining a suitable network, the validation and testing set must be used with the training set so that a reasonable configuration network can be identified. It is used by supplying these sets of data before training shown in figure, so that an approximation performance curve for all sets can be generated as shown in figure 3.6(a):

Figure 3.6 (a) and (b): Consideration for construction of network



(a)



(b)

Thus additional information provided as figure 3.6(a) will generate the curve as in figure 3.6(b). This is useful for classifying a suitable NN. The testing set is not simulated to obtain the output. The reason it is useful is that the curves of the validation and testing set must be below the training set as one of the criteria for the optimum configuration. If the curves of the validation and training are higher than the training set, the error generated is much higher than the training set. Hence it is required to determine a configuration that produces validation and testing curve below the training curve. Otherwise the NN is not able to generated is robust and accurate prediction.

After a suitable configuration is identified, the validation set is used for validating the NN in its performance by simulating it using the trained network created. If the results are satisfactory, testing can be conducted using the testing set. If not the NN must be retrained with different configuration until it is successful.

3.3.5 Testing of Error

Error testing is conducted only on validation and testing set. Error is calculated on the Root Means Square Error (RMSE). RMSE determined the error between the predicted and actual plant values, square them, sum them, divide by the number of the data point and determined the square root of them.

3.3.6 Error Improvement Strategy

Potential improvement is done after suitable NN is constructed. The purpose this is to further minimize the error in prediction value. The error for the best modeling is must be less then 5%. Various improvement strategies are employed for improving the error as stated below:

I. Reduce the number of input
II. Reduce the number of data set from 2219 to 334
III. Increase the epoch number
IV. Calculate the RMSE for validation data at 500 epochs
V. Find the highest epoch number for validation set
VI. Test the testing data line by line and calculate RMSE
VII. Increase the number of inputs from 27 to 54
VIII. Using trial and error to create new NN model
IX. Calculate the RMSE at every epoch number to find the best epoch number
X. Reduce the number of inputs to 27
XI. Using trial and error and create the new NN model

CHAPTER 4
RESULS AND DISCUSSION

4.1 RESULTS

4.1.1 Preliminary Processing of Data

Data segmentation

The output of the segmentation is three sets of data with training are 147 sets, validation 144 sets and testing 43 sets. The segmentation was done using random number of inputs data. A sample of segmented data set is shown in table. The segmentation was successful and complete segmented data sets for training, validation and testing is shown in Appendix 2. In this table 4.1 it also indicates the random numbers that were generated and used.

Table 4.1: Sample of the segmentation of data from original data

Classification	random number	215_TI001_15.PNT	215_TRC005.MEAS	215_TI001_11.PNT	215_QRA3_C3.PNT
T	16.05529954	41.97441101	42.48392868	42.66430664	1.293962598
T	5.190588092	41.97576523	42.48300552	42.70524979	1.274089575
T	33.42191839	42.85163498	43.01528549	43.37582779	1.109123945
T	42.38923307	43.37921524	43.30970764	43.55733871	0.787819684
TE	91.4496292	43.40631104	44.06969452	44.54824448	0.392793477
TE	87.81798761	44.18074799	45.46683884	45.39764023	0.362660438
TE	88.48570208	42.01700974	42.45500565	42.92372131	1.361850619
TE	87.67900632	43.06742477	42.92456818	43.52058792	2.537902594
TE	88.3104648	43.30468369	45.26287079	45.00749207	0.439023405
TE	95.28067873	43.44897079	44.48462677	44.30818939	0.460583776
TE	98.29898984	42.09120178	42.4419899	42.73360062	0.814858258
V	85.10180975	42.94654083	43.4081459	43.47973251	1.984263659
V	80.5335551	43.30179214	45.83115387	45.65475464	0.432972103
V	49.87307352	43.33198166	43.27628326	43.74859238	0.392847538
V	73.21588794	42.77770996	43.01279068	43.37051773	1.766743064

ANOVA test was performed to verify the original and the three-segmented sets are from the same population. The ANOVA test was performed on the random numbers of the inputs and output variable. The results are shown in table 4.2.

Table 4.2: ANOVA test

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
All Data	334	16730.58684	50.09157737	828.4021054
Training	147	7955.579302	54.11958709	781.6106129
Validation	144	6813.751488	47.31771867	766.5647026
Testing	43	2326.704337	54.10940318	875.3401037

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3987.249751	3	1329.08325	1.645383168	0.177629502	2.61832156
Within Groups	536356.0874	664	807.7651919			
Total	540343.3371	667				

As can be seen the average of the segmented sets is almost similar to the average of the original set and because of the random number is taken from 1 to 100, the average value given large number but still acceptable. The conclusion is that the segmented sets are from the original set. The complete test is shown in appendix 3.

Normalization

The table 4.3 showed a sample of the tabulated normalized values from the inlet data. The complete normalized value of training, validation and testing set can be referred from Appendix 2. The result is calculated using equation mentioned in the literature review and theory part. All the normalized values are within the range of 0 to 1.

Table 4.3: Sample of normalized values of inlet parameters of training set

215_TI001_15.PNT	215_TRC005.MEAS	215_TI001_11.PNT	215_TI001_12.PNT	215_QRA3_C3.PNT
0.000908365	0.023140719	0.020391272	0.098900052	0.201820716
0.001226069	0.023070366	0.022906232	0.099400323	0.197848184
0.206707936	0.063634651	0.064096931	0.479517114	0.164872261
0.330479966	0.086072136	0.075246361	0.414905471	0.100644916
0.048802884	0.040122401	0.056860651	0.153300999	0.147073705
0.453532464	0.550205766	0.390491308	0.177620987	0.023300216

Testing for Normal Distribution

The test for normal distribution was conducted on all inlet and outlet properties based on the three mentioned criteria. The table 4.4 contains relevant information for the testing. The complete test result for normal distribution can be referred to Appendix 4. Overall from the test conducted it was concluded that all the inlet and outlet variables were essentially normally distributed. The values of the skewness and kurtosis were small attesting to the normality of the distribution.

Table 4.4: Information for the testing of normal distribution

215_TI001_15.PNT	
Mean	43.08958797
Standard Error	0.040577825
Median	43.06869507
Mode	42.14569092
Standard Deviation	0.741586816
Sample Variance	0.549951006
Kurtosis	0.986418761
Skewness	0.666692984
Range	4.262516022
Minimum	41.97053909
Maximum	46.23305511
Sum	14391.92238
Count	334
Confidence Level(95.0%)	0.079821219

4.1.2 NN Construction and Training

The numerous trial and errors had been performed to obtain the optimum configuration and the suitable configurations for the NN are tabulated as table 4.5.

Table 4.5: Optimum network setting

Parameters	Variable
Network	Feed-forward backprop
Training function	TRAINRP
Adaptation learning function	LEARNGDM
Performance function	MSE
Epochs	100
Number of layers	3
Layer 1: Number of Neuron Transfer function	36 LOGSIG
Layer 2: Number of Neuron Transfer function	27 LOGSIG
Layer 3: Number of Neuron Transfer function	1 LOGSIG

The curves in figure 4.1 indicate the performance of the NN in predicting all three sets. The desired error is 0 and the performance is 0.00361066. The amount of iteration (epoch), for predicting the value to this performance is 38. However the validation and testing set had not been simulated. This performance is with regards to the termination due to validation and testing set. The actual performance based on training set is 0.00121794 with termination at 100 epochs. This is the result that produces minimum error.

Figure 4.1: Performance curve of the network

4.1.3 NN Validation and Testing

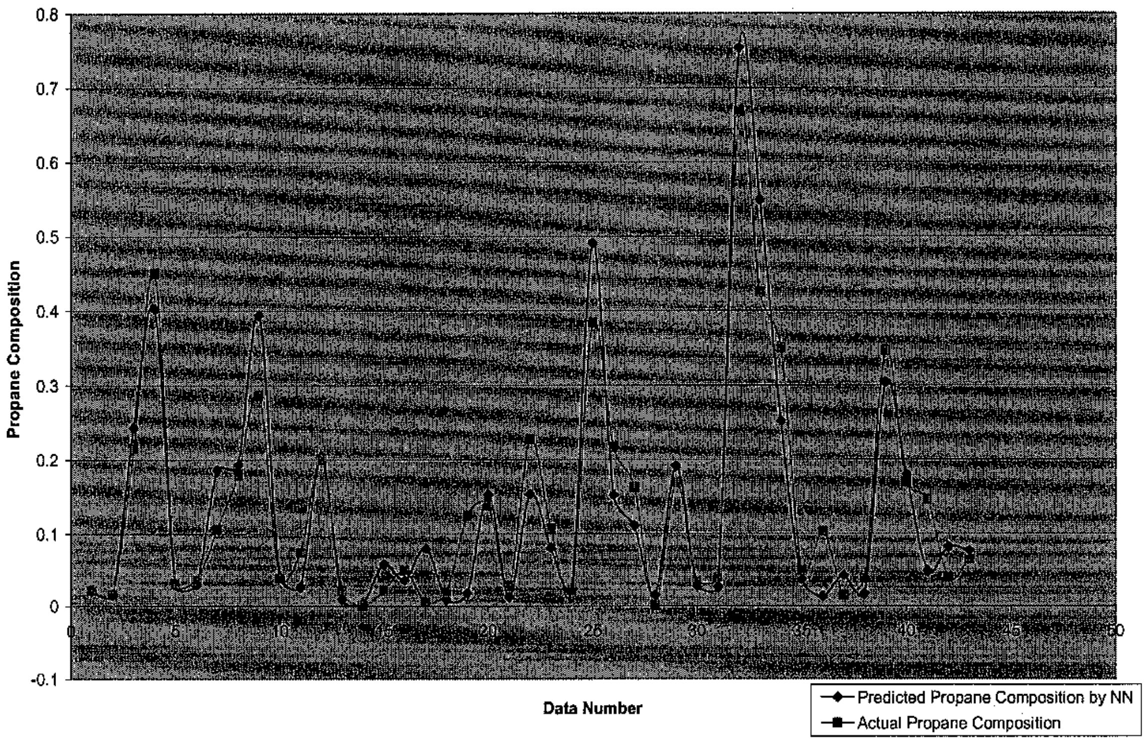
The table 4.6 is a sample of the result of testing conducted. The input of the testing set is simulated and the predicted result by NN and the error of the prediction is tabulated. The RMSE and standard deviation are calculated by using the formula given. And the result showed that the RMSE for this model is 5.36% and standard deviation of 0.00417. After that the graph of predicted output value vs. actual output value is developed. Graph in graph 4.1 show the performance of the prediction value. The complete set of the result of the simulated validation and testing sets can be referred to Appendix 5. The predicted values are quite similar as the actual value obtained from MLNG.

Table 4.6: Sample of the result predicted by Neural Network

NN value	Normalized Value	NN Error
0.0215	0.391888655	3.27139E-08
0.0163	0.365875091	4.12929E-07
0.2432	1.500966955	0.000773327
0.4026	2.298382746	0.002292398
0.0289	0.428907958	4.08862E-06
0.0293	0.430909001	3.5187E-05
0.1861	1.215318011	0.006408033

RMSE	0.053642803
Standard Deviation	0.004171314

Graph 4.1: Graph of Predicted value Vs. Actual value



4.1.4 Inference of Error

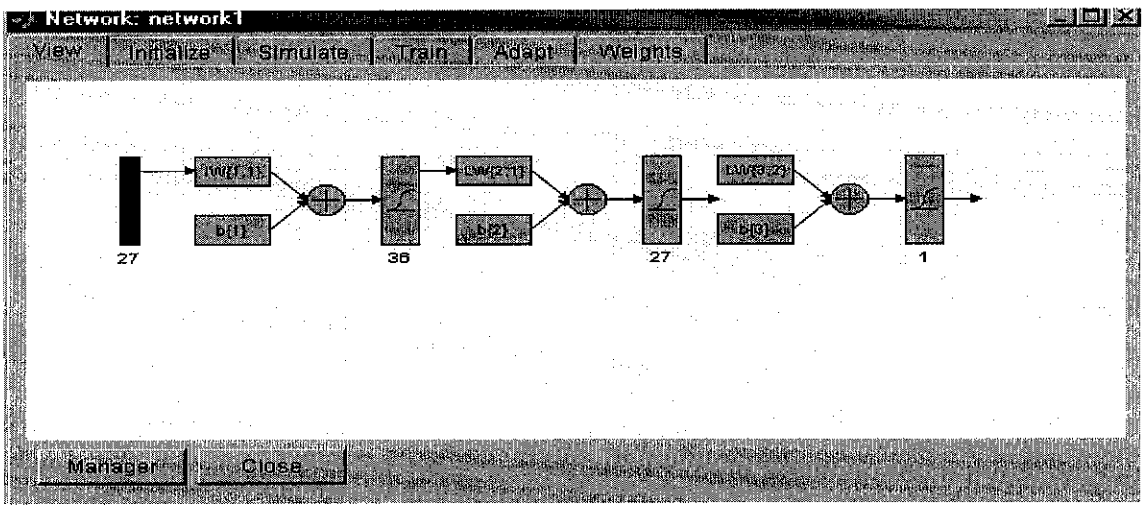
The error calculated for this project is by using Root Means Square Root Error (RMSE). RMSE can be calculated by using the equation given. The graph of predicted output value vs. actual output value was plotted to determined the point were the predicted is not accurate. The final error calculated by using RMSE is 5.36% and it can be consider good because the good modeling will produce error less than 5%. From the inference work conducted on the testing set it can be concluded that the NN is capable of predicting the outlet value of the propane concentration.

4.2 DISCUSSION

4.2.1 Neural Network

The network that was developed with configuration of table 4.5 is the optimum configuration that will provide with the minimum error in prediction. The network that is generated is shown in figure 4.2 below.

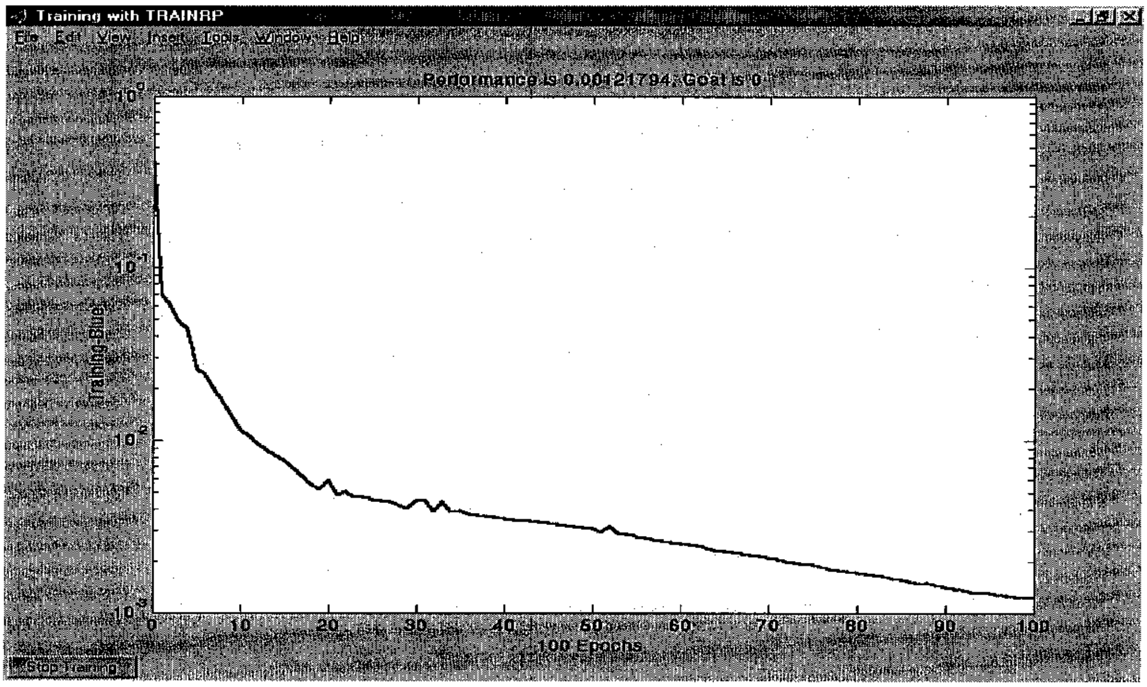
Figure 4.2: Network setting



The first block is the input to the network. The numeric '27' indicates that it is of 27 rows of data. In other words, the input has twenty seven different parameters to be used for prediction. The network developed as this, will enable that at any instance during prediction the network is able to predict any amount of set provided the twenty seven parameters are specified. There are three layers as indicated by the block with the numeric at the bottom. The numeric present the amount of neuron present at each respective layer. The first layer has 36 neurons. The inputs are connected to the nodes in the input layer. The output layer has 1 neurons and the output is taken from this layer. The layer in between is commonly known as the hidden layer with 27 neurons. All the neurons in one layer are connected to all the nodes in the layer. The weight indicated as block with notation of 'W {2, 1}'. There are three sets of weight for this network. The weights are connection strength between the neuron of the previous layer and the upcoming layer which in this case is between layer 1 and 2. The inputs are multiplied with the weights and summed with the bias which is then fed to the transfer function. The results of the weights and bias are shown in Appendix 7. The result of the multiplication and summation is then fed to the transfer function. The block with a graphical representation shows the type of transfer function. The transfer function is used to limit the output according to the limits of the transfer function. The output from the transfer function is the input for the following layer. The entire process is repeated until it completes. The output layer is indicated with a numeric value of 1 indicating 1 predicted variables are expected to be produced. The figure 4.3 shows the performance curve when training during these configurations. The performance of this configuration is 0.00121794 and is closed to the desired error of 0. The amount of iteration is 100 times.

A second testing was conducted to ensure that these configurations are suitable for prediction. The performance curve is shown in figure 4.1. This technique utilized validation and testing set without simulation them. The NN merely predict the performance using the inputs of the sets. This configuration is able to predict with error generated smaller than the error produced in training set. This is one of the characteristics of desired for an optimum configuration. However the iteration terminates at the 38th iteration compared to the training set only (100 iteration). The effect is due to failing of other sets input to converge which cause early termination. The error is higher compared to the previous due to the lower number of iterations.

Figure 4.3: Performance curve during training



If the network is trained using other training function such as *trainscg* or *traingdx*, the performance is similar to *trainrp* but it converges slowly. The prediction is also not consistent and give relatively high in error compared with *trainrp*. Other training function were tried and it had been determined that the best training function for this study is *trainrp*.

The final layer's number of neurons is 1 because the output has one process variable as mentioned previously. Other numerical values will produce an inconsistency in the matrix format. Transfer fuction *logsig* is used in the last layer to ensure that the normalized values are positive. Only this transfer function will generate positive numerical. The first two layers also used the transfer function *logsig*. This is determined through the trial and error, which stipulates that these transfer fuction produce minimum error. In this study, it had been determined that there is inconsistency between number of neuron and performance. At times when the neuron number is increased, the error is smaller. However when it is increased further, the error seems to increase. The higher the number of neuron will decrease the number of iteration to achieve the performance. However there is a limit in performance and when the limit approaches the convergence will be constant. Generally the curve is of decreasing nature due to the higher number of iteration, convergence is higher, error is smaller and offset to the desired error is smaller.

From the result obtained by prediction of the test set, the NN is capable of predicting the propane composition accurately with RMSE 5.36%. Even though the best modeling required the RMSE less than 5%, the value of error get from this study can be acceptable. The problem to achieve the RMSE less than 5% must be because of the performance of the inputs data. Since all this data is taken from industry, changes in one of the equipment is the industry will results the bad data for the study.

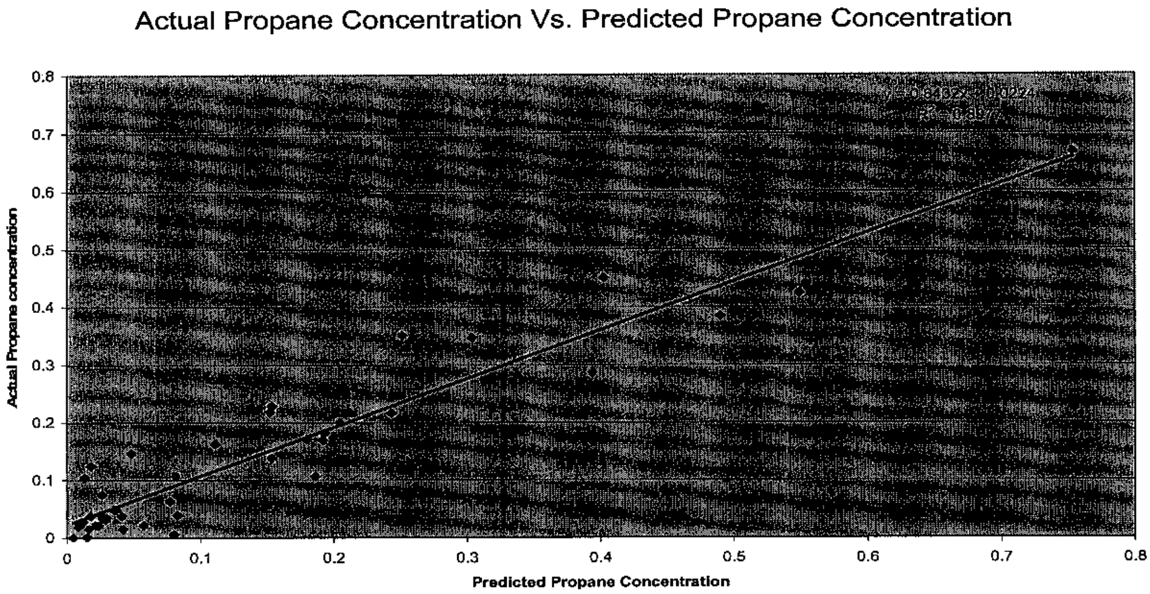
4.2.2 Statistical Analysis

A series of statistical analysis performed to conclude matters which are crucial to this study as indicated in the methodology. The ANOVA test was conducted to verify that the segmented sets are originated from the original set. From the results obtained as shown in Appendix 3, the means and standard deviations of the segmented sets are similar to the means and standard deviation of the original set. It is observed that the variances of each set to the original set are small. 'ANOVA': Single Factor' test is selected compare to others because in this project only this test applies. The natures of these sets of data violate the rules for other ANOVA test.

From all the statistical information in Appendix 4, it can be concluded that the all inlet and outlet properties are essentially symmetric except for the inlet number 215_TI001.PNT, 215_TRC005.MEAS and 215_QRA3_C3.PNT with slight asymmetric tailing to negative and inlet number 215_PRCA008.MEAS, 215_TI001_14.PNT, 215_PIC010.MEAS, 215_TI001_18.PNT and 215_TRC006.MEAS with slightly asymmetric tailing to positive. All this asymmetric value has peak distribution. Beside that, the relative Peakness of remaining properties is normal. Therefore it can be concluded that, generally the inlet and outlet properties are essentially normally distributed with small values of skewness and kurtosis attesting to the normality of distribution.

In the testing error generated for each inlet and outlet variables, the network can be consider enable to performance well because the RMSE got is slightly higher than 5% that is 5.36%. The graph below, show the performance of the predicted propane concentration by NN vs. the actual propane concentration from MLNG.

Graph 4.2: Actual Propane conc. vs. Predicted Propane conc.



From that graph in graph 4.2, the linear line is the ideal plot that is desired. In that plot, the regression value and the equation are generated. From the regression value we are able to identify the deviation of the predicted value to the actual values. Basically the regression value of unity is desired, but if the plot is approximately close to the ideal value, it indicates that the predicted values and the actual values are close. However if the predicted and the actual values deviate significantly, the generated regression value will be less than unity. The graph shows that the regression value for this study is close to unity, which is 0.8977. This is according to the result of the statistical analysis conducted on the error which concludes that the network constructed is able to predict the output of propane concentration at high accuracy.

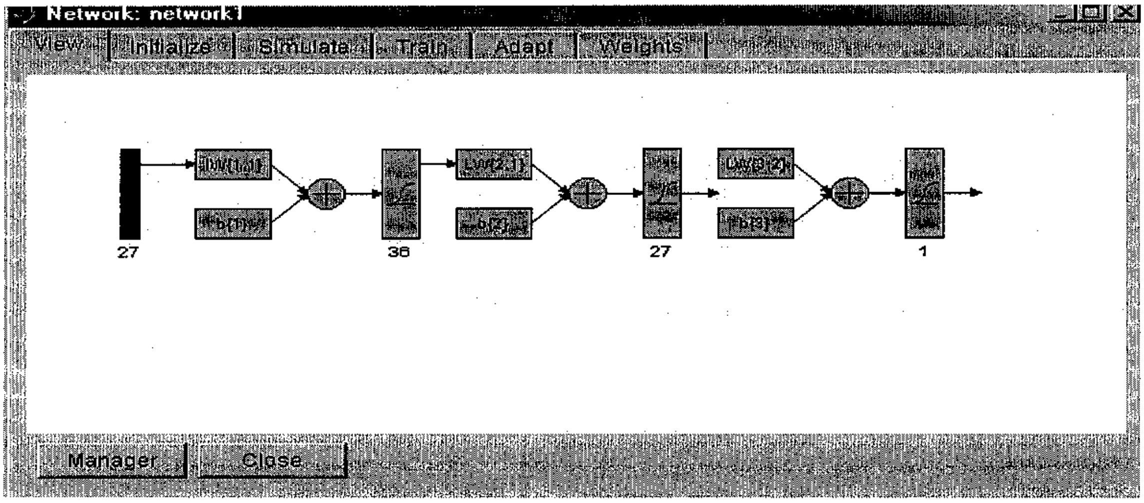
4.2.3 Improvement Strategy

There are a number of designed strategies fro improving the performance of the network developed in this study as had been mentioned earlier. The trial for improving the performance varying the epoch's number and decreasing the number of inputs had contributed large amount of changes. It is observed that once the optimal solution had been obtained, increasing or decreasing the number of iteration merely changes about 1% to 3% of the error.

For this research several steps were taken in order to improve the performance and reduce the error. As mentioned earlier, to develop the NN model, the trial and error method were used. For the first trial, the number of inputs variables was decrease from 27 to 10 and by using the existing NN model develop by previous student, the results show that the percentage of error is still high. After that the number of data sets were reduce from 2219 to 334 and the trial and error method used to develop the NN model. The results also give higher number of RMSE. In order to get the better training performance number, the validation and training sets of data was trained until it reached their limit and the RMSE calculated. From that trial, the limit for the validation sets of data is 2966 epochs while for the training sets of data is 3610 epochs number. The RMSE for both trials is quick high that is 37.2% and 29.1%.

By double the number of inputs from 27 to 54, the RMSE get is still high. To know the best iteration for these new sets of inputs data, several test has been conducted. This data were trained with the lowest epoch's number that is 25 to the highest epoch's number that will give low RMSE. From that test, the best number of iteration for these new data sets is 100 epochs that will give RMSE 11.6%. Since the number of RMSE still not reduce to less than 5%, the 27 inputs of data sets were used back. This time the new NN models were develop by using trial and error method. Results from this trial produces lower RMSE with value of 5.36% by using model developed in figure 4.4 below.

Figure 4.4: Network for training targets separately



The strategy of training the network with less number of inputs is able to help improve the performance of the network. This is because by training the network with more inputs, the error generated would be maximized and the accuracy is decreased. The network is also more robust in capable of recovering detailed ranges and minimizing the error. The study also conducted improvement test by training the network with more inputs by combining training and validation sets and simulating only the test set. Results for the improvement strategy are available in Appendix 6.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Overall the study of the 'Neural Network Model of a Debutanizer Column' was successfully completed within the period given. All the mentioned objectives had been achieved and the result is reported in this report. The Neural Network that has been constructed us shown in figure 4.6 and tested so that the best configuration for predicting purpose is able to be performed. The network type used is Feed Forward Backpropagation Network. The network was trained with *trainrp* and the model was developed with three number of layer. Layer 1 consists of 36 numbers of neuron, layer 2 consist 27 numbers of neuron and layer 3 consist of 1 number of neuron. The performance is validated using validation set. During validation the performance of the predicting output (propane concentration) is slightly accurate with the actual propane concentration from the data given by MLNG. Lastly the network is tested by using the testing data and the Root Means Square Error (RMSE) were calculated from that testing data. The neural network generated had been able to predict the output accurately with the RMSE 5.36% slightly higher than RMSE for good modeling that is 5%. Hence the network could be used for predicting any inlet parameters within the specified ranges to obtain the outlet conditions using the network constructed from this study. This study is aimed to provide a better understanding of Neural Network and its application for controlling the distilled product of the debutanizer column. This study may be a reference for any upcoming studies related to this field for the benefit in industrial controlling using predictive control method.

5.2 RECOMMENDATION

A few recommendations had been proposed for a better performance network. The first recommendation is to train and simulate the neural network by using more than one set of data. For this project only one sample of data were taken from MLNG so all the project done based on that data. The good modeling cannot be develop if only refer to one set of data. Since the condition of the plant during the time were the data were collected is not mentioned. So the accuracy of the data set given can be argued. In order to avoid that and to improve the performance of the neural network a lot set of data should be taken from MLNG.

Second recommendation is by decreasing the number of inputs parameter. Some of the inputs data get from MLNG are not highly related with the output. Data that are not highly related can be removed. The removing of inputs data is called removing the outlier. Basically it has a lot of method to remove the outlier but the easier and more practicable method is by using software called Simca-P. By using this software the inputs that didn't give highly correlated to the output can be removing and the remaining input can be used to develop the neural network model.

Last recommendation is to training using higher epochs and maximum time before failing. Naturally increasing the higher epochs and higher value of times before failing will produced better result. However this should be implemented with caution. As the epochs number approaching the limits it will produce bad results.

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APPENDICES

Appendix 1: Depropanizer Column diagram and detailed about the inputs and output

Appendix 2: Result of Data Segmentation

Appendix 3: Result of AVOVA test

Appendix 4: Result of the Normal Distribution test

Appendix 5: Result of Predicting Using Neural Network

Appendix 6: Result of Improvement strategy

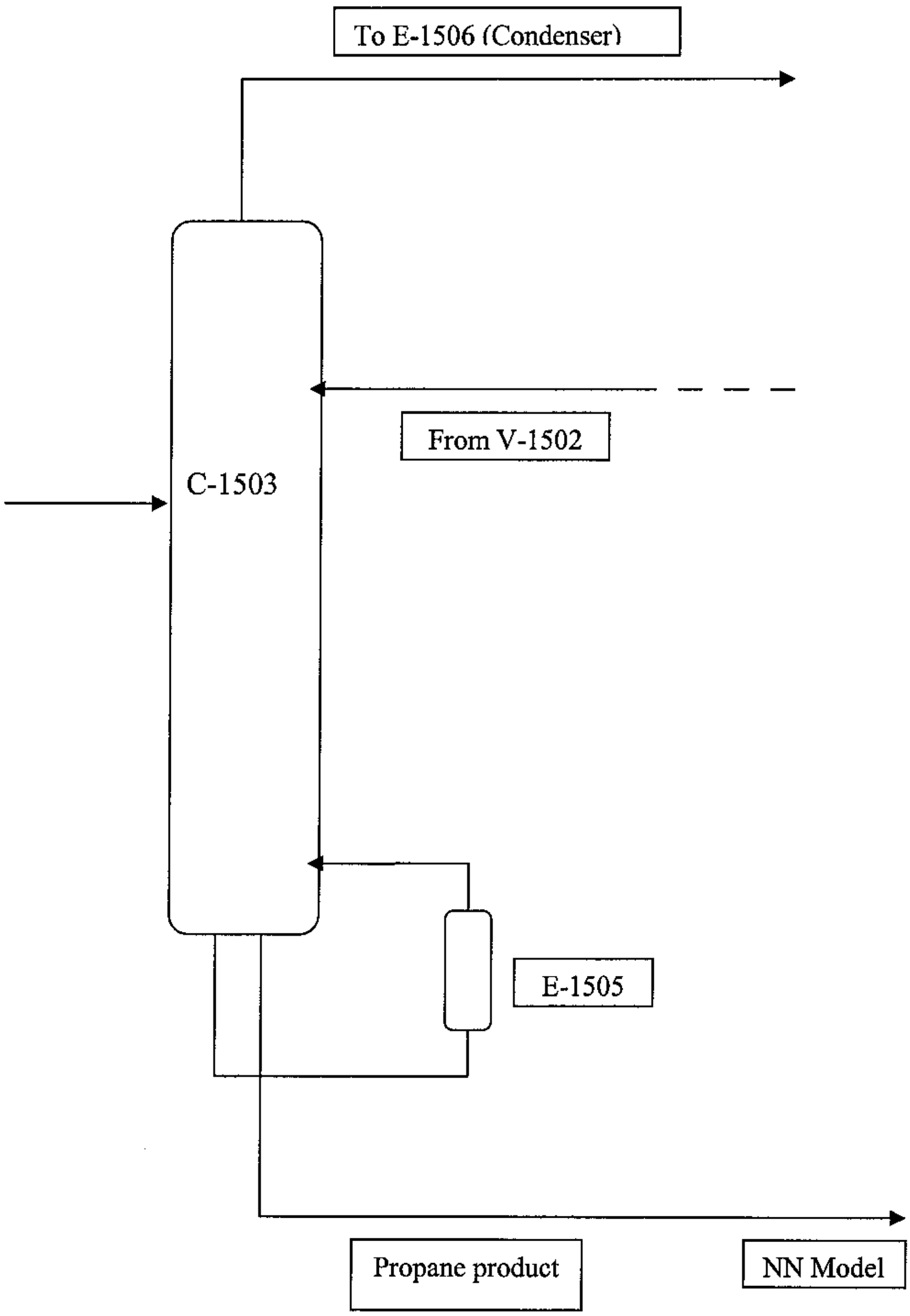
Appendix 7: Results of weight and bias

Appendix 1

Depropanizer column diagrams and detailed about the inputs and output

This show the diagrams of the Depropanizer column and explanation about the inputs and output

The MLNG Depropanizer Column



Original Tag	Description
215_TI001_15.PNT	Temperature of top product of C-1503 depropaniser column
215_TRC005.MEAS	Temperature of the top section of the C-1503 Depropaniser column
215_TI001_11.PNT	Temperature of the top section of the column same as TRC 005
215_TI001_12.PNT	Feed temperature to C-1503 depropaniser column
215_TI001_13.PNT	Liquid boilup temperature for C-1503 depropaniser
215_TI001_14.PNT	Temperature of reflux liquid to C-1503 depropaniser column
215_LRCA008.MEAS	level of knock-out drum for C-1503 depropaniser column
215_PRCA008.MEAS	C-1503 Depropaniser column pressure
215_FRCA028.MEAS	total feed to C-1501
215_FRC006.MEAS	flow rate of feed inlet to column C-1503 depropaniser column
215_FT020.PNT	LP steam flow rate for C-1503 reboiler (E-1505)
215_PIC010.MEAS	Steam pressure for C-1503 reboiler
151_TRC008.MEAS	IJ-5140 LP STM TEMP CTR (Temperature of steam to reboiler)
215_FRC010.MEAS	flow rate of feed to column C-1504 debutaniser column
215_TI001_24.PNT	Top product temperature for column C-1504 debutaniser column
215_TI001_23.PNT	Liquid reflux temperature for C-1504 debutaniser
215_TI001_20.PNT	Boiled up vapor temperature from reboiler to column C-1504 Debutaniser column
215_TI001_21.PNT	C-1504 bottom product temperature
215_TI001_19.PNT	Feed temperature of C-1504 debutaniser
215_TI001_18.PNT	C-1504 Column temperature-middle section
215_TRC006.MEAS	C-1504 Column temperature-middle section
215_PRCA013.MEAS	pressure of feed entering C-1504 Debutaniser column
215_PIC015.MEAS	Pressure of LP steam going into C-1504 column reboiler
215_PDIC017.MEAS	Column C-1504 top product pressure
215_FT013.PNT	LP steam flow rate to C-1504 column reboiler (E-1507)
215_FIC012.MEAS	Reflux flow rate for C-1504
215_FRC029.MEAS	C3 to LPG Export Flow Cont

Appendix 2

Result of Data Segmentation

The result of the random segmentation from the original set into three sets (training set, validation set and testing set) using Microsoft® Excel's 'Sampling'.

Table of classification of training set, validation set and training set

clasification	random number	215_TI001_15.PNT	215_TRC005.MEAS	215_TI001_11.PNT	215_TI001_12.PNT
T	16.05529954	41.97441101	42.48392868	42.66430664	90.0951004
T	5.190588092	41.97576523	42.48300552	42.70524979	90.09922791
T	33.42191839	42.85163498	43.01528549	43.37582779	93.23539734
T	42.38923307	43.37921524	43.30970764	43.55733871	92.70231628
T	8.973296304	42.17856216	42.70676041	43.25802231	90.54393768
T	18.10678426	43.90372849	49.40001678	48.68947601	90.74459076
T	28.86877041	44.06997681	45.14725876	45.32014084	91.58087921
T	21.15833003	43.77100372	46.95195007	46.45788956	90.96573639
T	42.56749168	42.89976883	43.01691055	43.36001968	93.40815735
T	16.2003235	43.95920563	45.53767395	45.55353928	91.64841461
T	7.275307474	43.59327698	43.98371124	44.57313538	90.85061646
T	34.82683798	42.02243042	42.45132446	42.89260483	90.15467072
T	23.45454268	44.17292023	45.61970901	45.92420959	91.35503387
T	23.75063326	42.0156517	42.45592499	42.58903885	90.47626495
T	26.23718986	42.8017807	43.01360321	43.39220047	92.86101532
T	36.11694693	42.97197342	43.01935196	43.35414124	93.59978485
T	23.44850002	44.06178665	47.27427673	47.18490601	90.98164368
T	38.33460494	42.7505188	42.83504105	43.09783554	93.37377167
T	8.060853908	43.159935	42.93337631	43.6493988	93.82307434
T	27.12546159	42.79370499	43.47177887	43.40771103	96.46908569
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T	8.024597919	41.97305679	42.48484802	42.62336349	90.35340118
T	3.858180486	41.99648285	42.46894073	42.99247742	90.422966
T	31.391583	43.7229805	43.83165359	44.23141479	91.38314056
T	3.359660634	42.92383957	43.0177269	43.35211563	93.57049561
T	10.72869045	42.02378464	42.45040512	42.83264542	90.23165894
T	16.59913938	43.15278244	44.05174637	44.47264099	90.82649994
T	20.08575701	42.69841003	43.4924469	43.20703506	96.49929047
T	36.99313334	44.62383652	49.91522598	49.30975723	90.98212433
T	3.595324564	43.40918732	44.63751602	44.68418884	93.33533478
T	17.6445204	42.66856766	42.66135406	42.8768158	93.08092499
T	9.036744285	42.28913498	42.61045456	42.94877625	92.33433533
T	36.14111759	43.08200073	43.02306747	43.39994431	93.37110138
T	12.1487167	43.20046616	43.29832077	43.66950226	94.71951294
T	35.73323771	44.13362885	55.21386719	53.86916733	90.51911926
T	20.4755089	42.63049316	42.80589294	43.4180336	93.31342316
T	9.372112186	43.22493362	43.40274811	44.31086731	94.33531189
T	20.38789026	42.7698822	43.47694397	43.58037186	96.34562683
T	14.81655324	43.77878189	45.65834427	45.74651718	91.90744019
T	9.260322886	42.01003647	42.45973969	42.62533951	90.08080292
T	17.07046724	43.5490036	45.6049118	45.64576721	90.89762878
T	17.88018433	44.84537888	51.37614059	50.27877808	91.46993256
T	42.54634236	42.75527954	43.04855347	43.28162766	93.26172638
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T	35.61238441	42.8757019	43.01609802	43.36792374	93.55885315
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T	26.30365917	43.34292984	44.13506317	44.54310608	91.24402618
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T	37.22879727	43.26580429	43.28681946	43.58541489	93.5133667
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T	41.32572405	43.09826279	42.91413879	43.56352234	94.7218399
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T	33.63945433	43.18966675	43.21385956	43.54101944	92.74656677
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T	26.52723777	44.73432922	52.30968094	51.34700012	90.93343353
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T	38.04153569	42.99611282	43.46429825	43.52734375	96.19159698
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T	42.21097446	43.20705414	43.35648346	43.83482361	94.70661163
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T	30.63322855	43.66748047	43.81449509	44.41483688	90.44239807
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T	37.49769585	43.08939743	44.3904953	44.44211197	91.1844101
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T	22.31550035	43.045681	43.52045059	43.57495117	95.88632202
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T	28.16782128	43.41289902	44.41911316	44.14911652	90.94309235
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T	1.634479812	42.03211212	42.44475174	42.81157303	90.12748718
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T	15.89214759	43.17999268	43.18548584	43.75510788	94.83821106
TE	91.4496292	43.40631104	44.06969452	44.54824448	91.24402618
TE	87.81798761	44.18074799	45.46683884	45.39764023	91.57311249
TE	88.48570208	42.01700974	42.45500565	42.92372131	90.54866791
TE	87.67900632	43.06742477	42.92456818	43.52058792	94.44438934
TE	88.3104648	43.30468369	45.26287079	45.00749207	90.8396759
TE	95.28067873	43.44897079	44.48462677	44.30818939	90.89754486
TE	98.29898984	42.09120178	42.4419899	42.73360062	90.62759399
TE	89.29239784	43.21395493	43.41741562	44.06187439	94.59860992
TE	99.7673574	41.99222565	42.47183228	42.36899567	90.11270905
TE	90.01751762	43.59635544	43.80687332	44.35749817	90.90437317
TE	90.92391736	42.93587112	43.01813126	43.36862946	93.26290131
TE	95.22629475	41.97867203	42.48103714	42.79298782	90.10809326
TE	89.25009919	43.46969223	44.04477692	44.59421539	91.20648956
TE	95.64928129	44.63305664	47.7172699	47.42410278	91.34163666
TE	99.13589892	42.61137009	43.3053627	43.32090378	96.16597748
TE	92.10223701	43.05318069	44.77981186	44.7173996	91.0638504
TE	99.52867214	43.22932434	43.364048	44.02333069	93.74598694
TE	96.04809717	44.06700134	47.32515335	46.60293198	91.08551025
TE	91.23813593	44.59110641	50.45166016	49.9426384	92.79386902

TE	99.79152806	42.02920532	42.44672394	42.76671219	90.18654633
TE	93.27753533	43.48538971	44.90420914	44.94952393	90.97301483
TE	90.993408	42.81753159	43.46660995	43.71548462	96.25499725
TE	88.99932859	42.81729889	46.73164749	46.40558624	90.77540588
TE	90.42237617	43.91900253	47.51528549	46.95341873	91.40843964
TE	96.59495834	42.90884018	42.97820282	43.37707901	93.71636963
TE	93.87575915	43.19439316	43.50413895	44.01150131	93.67999268
TE	90.92391736	42.14569092	42.46273804	42.68366241	90.1842804
TE	92.80620746	42.35199738	43.36165237	43.81731415	90.85533142
TE	96.52244636	42.02513885	42.44948578	42.81452179	90.84324646
TE	97.91830195	43.46973419	43.86824417	44.48357773	91.04576111
TE	98.74614704	43.35771561	43.4269371	43.90708923	93.38899231
TE	90.984344	42.67865753	42.77189636	43.41360855	94.68618774
TE	98.62227241	43.03659058	42.93499756	43.47764969	94.23839569
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TE	91.63393048	43.37058258	43.50226212	44.10880661	93.41673279
TE	98.91534165	43.91303635	46.89526367	46.69910049	93.02462006
TE	94.0207831	42.62168503	43.19848633	43.27889252	97.1849823
TE	87.46449171	43.10284805	48.97848129	48.47714233	90.54281616
TE	97.27475814	42.85976791	43.24819946	43.81390381	96.23635864
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TE	92.51011689	42.74605942	43.48211288	43.50437546	96.31784058
TE	94.18997772	42.59516144	43.4211731	43.24905396	96.14405823
TE	93.23523667	43.74168015	44.39925003	44.90654755	91.6815567
V	54.58635212	42.72509003	43.46660995	43.81386566	95.36199951
V	43.12945952	42.78549957	43.01156998	43.36182022	92.88031769
V	84.74831385	42.00461578	42.46342087	42.83598328	90.08417511
V	67.55088961	42.22681808	42.32077026	42.83735657	90.31665802
V	57.72249519	43.53304291	43.79448318	44.42053986	91.0419693
V	80.12869655	43.24007034	43.3253479	43.76763153	93.55690765
V	49.7038789	42.37271118	43.51310349	43.88951874	90.53017426
V	65.03411969	43.61536026	44.38602448	44.61660767	91.3789978
V	61.97350993	43.38778305	46.06331253	45.82452774	90.93806458
V	51.55897702	42.70930481	42.7510376	42.90555573	93.29959106
V	61.48103275	43.20266342	43.31770706	43.8280983	94.70195007
V	85.10180975	42.94654083	43.4081459	43.47973251	96.18807983
V	80.5335551	43.30179214	45.83115387	45.65475464	91.29795837
V	49.87307352	43.33198166	43.27628326	43.74859238	93.60961151
V	73.21588794	42.77770996	43.01279068	43.37051773	93.23243713
V	71.7777337	43.12108994	44.13776779	44.45737457	90.86494446
V	53.82799768	43.39631653	44.22356796	44.51224136	93.61868286
V	48.5859859	43.28050995	43.27290344	43.51247406	93.51809692
V	62.4267098	42.94790649	43.01853943	43.38412857	93.26290131
V	47.67656484	41.97169876	42.48576736	42.58242035	90.6505661
V	81.87804804	42.50648499	43.02193069	43.87723923	91.05936432
V	55.78279977	43.21609497	43.4928093	43.93782043	93.84892273
V	68.63252663	42.00597	42.46249771	42.67279434	90.08248138
V	46.15381329	42.03056335	42.4458046	42.89287567	90.59233093
V	47.55873287	45.14063644	53.21250534	52.00383377	91.55514526
V	77.74788659	42.03346634	42.4438324	42.60203171	90.67152405
V	50.41389203	42.60311508	43.45639038	43.22619247	96.15551758
V	56.42030091	43.84960175	44.35086441	44.6278801	91.45649719
V	74.82927946	43.65966797	43.81926346	44.29445648	90.85494995
V	57.62581256	42.58919525	42.81267166	43.10476685	90.68251038
V	69.33649709	43.15592575	43.11883545	43.46815491	95.25019073
V	45.78823206	43.25284958	43.24580765	43.82448959	93.07342529

V	43.06903287	43.73174667	47.8027916	47.44417572	90.89361572
V	63.23340556	43.66878891	45.97119141	46.0695076	90.94006348
V	75.76287118	42.02649689	42.44856644	42.33233643	90.63944244
V	82.2103946	43.09525299	43.52679443	43.62256241	94.79759979
V	69.46641438	42.7399559	42.79841995	43.4488678	93.35076904
V	61.22724082	42.0278511	42.44764328	42.45795822	90.83382416
V	80.53053377	43.93784332	47.57894897	47.43503571	91.93753052
V	58.55336161	43.43093491	44.45186996	44.57313538	90.9203186
V	62.04904324	43.37682724	44.67341232	44.44321442	90.92167664
V	77.17685476	43.14389038	43.08551025	43.75885391	95.26901245
V	44.5253151	43.98971939	49.69126892	49.19797516	90.56407928
V	73.92892239	44.28674316	48.22639847	47.88284302	91.16152954
V	82.53065584	42.59984207	42.82860947	43.43242645	93.67092896
V	77.09225745	43.55731583	43.97950363	44.27688217	90.59962463
V	70.99520859	43.31911469	43.2363739	43.29906464	93.71992493
V	80.34925382	43.83915329	45.04546356	44.88862228	91.80169678
V	58.08505509	43.21615219	43.43680191	44.10070801	94.38182068
V	47.60405286	43.06996536	43.02266312	43.57421112	93.63261414
V	52.37171545	43.48761749	44.78935623	44.5251503	90.88870239
V	78.88995025	44.11090469	48.88344193	48.42472458	91.42851257
V	85.61845759	42.86366653	43.01569366	43.37187576	93.63420105
V	83.08658101	42.00190353	42.46525955	43.01846313	90.08755493
V	82.63942381	43.32271957	45.12150955	45.02614594	90.86017609
V	56.4656209	43.43800354	44.05723572	44.54824448	91.24402618
V	65.15799432	44.13990402	51.41306305	50.67970276	91.92897797
V	72.18561357	43.11810303	43.02428818	43.82589722	94.72505951
V	44.860683	41.98002625	42.48011398	42.83393097	90.11222076
V	78.08023316	41.98544693	42.4764328	42.70743942	90.12875366
V	80.60304575	43.50565338	45.22539902	44.53221893	90.92008209
V	71.89556566	43.84843063	46.39742279	46.41301346	91.85238647
V	82.16205329	43.04589844	43.02185059	43.69133377	93.35010529
V	55.62266915	42.89240646	43.45036697	43.45392609	96.37101746
V	60.78612629	43.27954483	43.95548248	44.11156845	91.36619568
V	46.33811457	43.41898346	44.7945137	44.76259613	90.22145844
V	44.48905911	42.00868225	42.46065903	42.64796066	90.38512421
V	73.44248787	43.00011444	43.08720398	43.41470718	93.40493774
V	47.03302103	42.00326157	42.46434021	42.55308914	90.08586884
V	78.9503769	43.78628922	43.85325623	44.16837311	91.42706299
V	59.25431074	43.02183151	43.02103424	43.63832855	92.90765381
V	69.36671041	42.80154037	42.92188263	43.42735291	93.0350647
V	82.59410382	43.55976486	46.65616989	46.41501236	90.84766388
V	83.6817835	42.89301682	43.64962387	43.77192307	96.84545135
V	48.44398328	42.70954514	42.74819946	43.08246994	92.93737793
V	67.38471633	43.25293732	43.30599976	43.80638123	93.73069
V	77.86269723	43.22054291	43.44144821	43.95856857	94.13986206
V	77.09527879	42.9118042	43.01731873	43.35606766	93.33434296
V	81.12875759	43.14482117	43.5154686	43.67016983	93.68797302
V	82.44001587	43.64575577	47.26569748	47.24001694	90.49772644
V	70.0646382	42.69398117	42.76146698	43.26866531	94.29785919
V	78.52436903	41.98409271	42.47735596	42.87942886	90.12462616
V	81.14990692	43.37461853	44.08855057	44.54824448	91.24402618
V	60.41148106	42.01274872	42.45789719	42.82948685	90.0300827
V	80.34623249	44.06294632	46.08095169	46.19817352	91.76656342
V	78.45185705	42.62694168	43.49160385	43.2205162	96.2345047
V	83.5609302	43.12909698	42.90370941	43.60646057	94.23456573
V	67.48139897	43.26862335	43.34165573	43.65148926	92.53153992

Appendix 3
Result of ANOVA test

The results of ANOVA: Single Factor tests performed using Microsoft® Excel's 'ANOVA: Single Factor' to check the segmented sets are from the original set.

random number(all data)	random number(training)	random number(validation)	random number(testing)
16.05529954	61.28586688	26.71456036	2.157170324
5.190588092	18.29410688	45.27762686	11.60487686
33.42191839	59.36005737	91.12030386	62.82825098
42.38923307	38.74652746	2.615820795	86.2746971
8.973296304	73.74462111	98.16094455	85.86318552
18.10878426	48.06329539	40.07187109	22.00732444
26.66877041	39.31653798	28.46983245	28.89252297
21.15833003	15.04919584	63.52769556	56.8100528
42.56749168	24.48481704	89.86523026	41.42542802
16.2003235	68.4041261	69.01684681	81.71187475
7.275307474	82.16083254	24.46686905	71.89526963
34.82683788	50.35950804	66.71337016	31.5970336
23.45454268	79.62856331	51.7523423	15.26673177
23.75083326	89.30207221	10.13048683	79.81749931
26.23718986	90.58250679	93.50111393	90.01751762
36.11684693	85.12900174	56.38404492	32.74211859
23.44650002	91.28847725	6.728385268	64.50840785
38.33480494	72.04361096	54.30838954	10.16087995
6.080853906	77.68745894	56.43842891	49.51957782
27.12546159	33.66060366	43.77904599	57.45681794
40.20178838	54.57728813	26.07101857	44.22922452
6.024597919	61.12753685	24.20081179	24.83831294
3.858180486	81.62123478	19.37272256	94.64922025
31.391583	96.12060915	46.98363038	99.61658681
3.358860634	76.97442549	29.04400769	30.98557512
10.72669045	46.99374371	21.21875668	87.17020173
16.59913936	95.75804926	77.99261452	26.1978515
20.08676701	42.79711296	14.83629463	38.72435682
36.99313334	81.82244331	5.767862587	23.18564409
3.595324564	53.40198881	15.77733695	89.58546709
17.6445204	5.830814539	44.2080752	90.86953337
9.036744285	97.31403546	5.081820124	42.56561968
36.14111759	41.35895871	61.62849598	65.17432173
12.1487167	2.815820796	87.36176641	30.37943683
35.73323771	36.68797876	25.34589679	33.82677694
20.4755088	55.7767571	84.50721763	84.88333781
9.372112186	59.61687063	11.56862087	71.11001923
20.38769026	30.62416456	20.50572222	59.82534257
14.81655324	18.96766401	64.54768617	95.28067873
9.280322886	60.52024903	32.69075594	7.459608753
17.07046724	41.65534632	27.5544908	95.7338786
17.86018433	48.64066591	91.32675457	71.60249641
42.54634236	19.28812625	70.6326487	29.04400769
3.377788829	61.50822474	10.24527726	
35.61238441	35.23189652	34.15308064	
25.23108615	70.04346886	77.58171331	
26.30365917	68.80776391	26.17064262	
7.819147313	97.02096622	90.35268553	
14.32105472	75.1404767	38.72435682	
37.22879727	88.1698115	10.02189866	
22.82971892	47.2445143	32.91131321	
41.32572405	10.66524247	65.26186895	
21.84719362	53.49262976	79.38544877	
33.63945433	28.63006515	93.96754845	
7.912806618	34.22257149	44.34403516	
9.30262154	43.36929411	62.61101106	
26.52723777	35.66374706	2.785607471	
11.94326609	53.21164586	51.87923826	
9.04278695	4.843134861	88.69447005	
38.04153569	26.48983245	97.39259011	
10.58668783	20.4755089	27.93820002	
41.03669747	53.94685098	67.65965758	
12.19705802	73.1192053	11.37223426	
15.87099826	99.2084109	83.20743431	
29.14371166	76.57560961	32.45811335	
14.03704947	97.77629933	19.89239174	
39.92980743	61.10940588	9.199899237	
12.90404981	83.31015961	82.37354656	
32.37351604	53.82254707	2.305215613	
36.23760023	67.66510618	75.47886563	
29.98364208	92.32863594	48.58807123	
21.05862506	41.61577197	31.19519639	
11.48402356	95.48619037	76.40339365	
21.8078165	63.91622869	23.61165197	
36.90563677	98.29886778	94.52534562	
15.47520371	44.26339518	7.59264736	
31.33115635	72.18863491	53.14819788	
12.28769799	5.189438765	26.15165654	
42.21097446	21.60489517	49.7129429	
25.6540727	85.77658821	78.92820624	
32.56858526	26.61438543	57.28440199	
32.45207068	87.60710471	64.93441572	
5.326548051	31.76822822	39.15942869	
13.65274619	57.45359861	6.402981362	
27.64513077	83.08719138	58.05774102	
32.21038409	15.0582385	69.03134251	
25.47883541	2.164362316	40.48881497	
33.43400372	25.20067283	14.88000122	
7.833957945	44.63651234	22.20673238	
13.21626638	39.65794855	61.82064272	
9.299800209	73.21588794	68.39204077	
36.24082158	24.38511307	53.42313913	
7.021515549	44.10534889	16.68863002	
13.44486831	31.46107364	74.64497618	
2.009126034	89.71236306	53.867275	
12.36825263	17.94061098	14.42982269	
30.63322855	78.06802576	8.529160436	
17.78350169	68.52081625	53.86123234	
42.76889962	75.32175865	28.49110365	
7.426374096	21.00726341	33.72707297	
37.49769585	84.50058459	91.16562395	
34.51866207	98.3231605	68.30018008	
33.7391563	72.53910947	17.41792047	
9.305642872	48.65849768	86.41811069	
30.18909268	42.0476225	21.0344554	
9.634376049	6.933868908	70.72933134	
18.46026016	7.710379345	70.35468612	
11.4507869	67.75453963	51.67017426	
32.03814814	46.94842372	25.13138218	
11.86586077	63.65337077	32.43696402	
22.31550035	91.43754387	49.18723106	
42.46476638	46.59190649	78.65718558	
25.06189154	90.49186682	21.49671926	
2.093722343	7.507950072	66.50550859	
11.3480636	37.38173589	62.53547777	
35.79064302	81.41880551	25.81118198	
19.69600513	79.69605396	89.83019501	
29.64223151	28.54548784	67.88927885	
33.5165797	84.62988983	72.8956287	
21.34263131	65.38344493	30.284626	
37.09585864	57.82219916	29.61201819	
30.62718589	72.09799493	11.87377544	
15.64741966	29.32499161	3.640644551	
19.30927458	83.94463942	29.71474349	
6.99734489	15.27277444	50.76249456	
28.16782128	66.01907407	23.02551347	
14.85280923	38.2378223	39.55220191	
29.92623676	29.6875516	21.8197058	
22.8321482	31.06225776	38.31043428	
35.44318979	59.12439344	69.20657979	
39.41018929	49.65494552	72.12620826	
9.877268762	81.02301096	6.60166034	
18.94369335	35.58519242	29.80236213	
34.54686406	1.746269112	75.76287118	
27.17984558	46.08048738	62.39649648	
31.22843104	36.94491409	47.94646476	
31.40971099	31.11966308	40.43745231	
1.634479812	37.72731712	17.48741111	
27.60585345	89.90572632	74.42744224	
14.49327067	96.64342174	37.91463973	
42.1666036	66.36954663	92.34998627	
1.057405316	46.67058321	90.4344615	
38.76665546	1.891283069	69.25492111	
12.65327921	39.62169258	79.30891546	
1.293069246	5.444360016		
14.68361461	12.62549518		
15.89214759	97.99685659		

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
All Data	334	16730.59864	50.09157737	828.4021054
Training	147	7955.679302	54.11958709	781.8106129
Validation	144	6813.751468	47.31771867	766.5647026
Testing	43	2326.704337	54.10940318	875.3401037

ANOVA

Source of Variati	SS	df	MS	F	P-value	F crit
Between Grou	3987.249751	3	1329.08325	1.645383168	0.1778295	2.618322
Within Groups	536356.0874	664	807.7651919			
Total	540343.3371	667				

91.4496292			
87.81798761			
88.48570208			
87.67900832			
88.3104848			
95.28087873			
98.29898884			
89.29239784			
89.7873574			
90.01751762			
90.92391736			
95.22628475			
89.25009919			
95.64928129			
99.13689892			
92.10223701			
99.52887214			
98.04809717			
91.23813583			
99.79152806			
93.27763533			
90.993408			
88.99932859			
90.42237617			
98.59495834			
93.87575915			
90.92391736			
92.60620746			
96.52244636			
97.91630195			
98.74614704			
90.984344			
98.62227241			
88.48570208			
91.63393046			
98.91534165			
94.0207631			
87.46449171			
97.27475814			
99.42594684			
92.51011689			
94.18997772			
93.23523667			
54.58635212			
43.12945952			
84.74831385			
67.55068961			
57.72249519			
80.12869655			
49.7038769			
65.03411969			
61.97350993			
51.55897702			
61.48103275			
85.10180975			
80.5336551			
49.87307352			
73.21588784			
71.7777337			
53.82799768			
48.5859859			
82.4267098			
47.67656484			
81.87604804			
55.78279977			
68.63252663			
46.15381329			
47.55873287			
77.74788859			
50.41389203			
56.42030091			
74.62927946			
57.62581256			
69.33649709			
45.78823206			
43.06903287			
63.23340556			
75.76287118			
82.2103946			
69.46841438			
61.22724082			
80.53053377			
58.55336161			
62.04904324			
77.17685476			
44.5263151			
73.82892239			
82.53065584			
77.09225745			
70.89620859			
80.34925362			
58.08605509			
47.80405266			
52.37171545			
78.86995025			
58.00347911			
65.61845769			
83.08658101			
82.63942381			
56.4656209			
65.15799432			
72.18561357			
44.860683			
76.08023316			
80.60304575			
71.69558566			
82.16205328			
55.62266915			
60.78812628			
48.33811457			
44.48905811			
73.44248787			
47.03302103			
76.9503769			
59.25431074			
68.36671041			
82.59410362			
83.6817835			
48.44398328			
67.36471633			
77.86269723			
77.09527879			
81.12875759			
82.44001587			
70.0646382			
78.52438903			
81.14990692			
80.41148106			
80.34623249			
78.45185705			
83.5609302			
87.48139887			
59.08698813			
59.60178397			
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76.77211828			
85.71816158			
46.4347972			
63.92226936			
49.81264887			
44.20203253			
56.64381848			
63.68358409			
79.15260618			
69.35764641			
75.87163915			
59.28150273			

82.18924526			
72.40617084			
49.59813227			
79.60902736			
50.0664386			
54.62865078			
61.20911283			
80.60484634			
78.85357219			
51.20245979			
84.69997253			
64.54164251			
82.6847438			
72.74456008			
74.72957549			
75.86316721			
78.26755577			
70.09485153			
57.21189001			
60.80786787			
45.46182816			
71.11606189			
58.17255185			
49.7038769			
57.37504196			
52.38265145			
82.814008			
69.81991028			
47.02395703			
45.31388287			
58.88860744			
48.39868329			
66.65053255			
68.56593524			
51.25888511			
44.9896843			
71.39100314			
69.71114231			
86.84605753			

Appendix 4

Result of Normal Distribution test

The result of the normal distribution test performed on the inlet and outlet properties using Microsoft® Excel's 'Descriptive Statistics'.

215_QRA3_C3.PNT	
Mean	1.114047735
Standard Error	0.053937123
Median	0.685210407
Mode	#N/A
Standard Deviation	0.985736897
Sample Variance	0.97167723
Kurtosis	5.085599701
Skewness	2.085562752
Range	5.002608478
Minimum	0.284332573
Maximum	5.286941051
Sum	372.0919435
Count	334
Confidence Level(95.0%)	0.106100484

215_TRC005.MEAS	
Mean	44.30451634
Standard Error	0.142587635
Median	43.36285019
Mode	43.46660995
Standard Deviation	2.598070363
Sample Variance	6.749969609
Kurtosis	5.428406391
Skewness	2.357251268
Range	13.12188721
Minimum	42.18027878
Maximum	55.30216599
Sum	14709.09943
Count	332
Confidence Level(95.0%)	0.280492006

215_TI001_13.PNT	
Mean	116.3845086
Standard Error	0.126244182
Median	116.3755074
Mode	113.644928
Standard Deviation	2.307196618
Sample Variance	5.323156232
Kurtosis	0.752948952
Skewness	-0.320769954
Range	15.50811768
Minimum	106.281517
Maximum	121.7896347
Sum	38872.42587
Count	334
Confidence Level(95.0%)	0.248336731

215_LRCA008.MEAS	
Mean	59.54611151
Standard Error	0.450372256
Median	60.46327591
Mode	59.98502731
Standard Deviation	8.230853331
Sample Variance	67.74694656
Kurtosis	4.133315041
Skewness	0.007358001
Range	75.44108009
Minimum	27.55696678
Maximum	102.9980469
Sum	19888.40124
Count	334
Confidence Level(95.0%)	0.885933687

215_TI001_15.PNT	
Mean	43.08959
Standard Error	0.040578
Median	43.0687
Mode	42.14569
Standard Deviation	0.741587
Sample Variance	0.549951
Kurtosis	0.986419
Skewness	0.666693
Range	4.262516
Minimum	41.97054
Maximum	46.23306
Sum	14391.92
Count	334
Confidence Level(95.0%)	0.079821

215_TI001_12.PNT	
Mean	92.4915
Standard Error	0.110807
Median	91.82704
Mode	91.24403
Standard Deviation	2.025081
Sample Variance	4.100951
Kurtosis	-0.74852
Skewness	0.599467
Range	8.250542
Minimum	89.27912
Maximum	97.52966
Sum	30892.16
Count	334
Confidence Level(95.0%)	0.217971

215_TI001_14.PNT	
Mean	44.08573
Standard Error	0.03001
Median	44.21335
Mode	44.2658
Standard Deviation	0.548447
Sample Variance	0.300794
Kurtosis	4.178698
Skewness	-1.35411
Range	4.454041
Minimum	40.64476
Maximum	45.0988
Sum	14724.63
Count	334
Confidence Level(95.0%)	0.059032

215_PRCA008.MEAS	
Mean	13.79334
Standard Error	0.009716
Median	13.81236
Mode	13.76641
Standard Deviation	0.177571
Sample Variance	0.031532
Kurtosis	3.352024
Skewness	-1.11665
Range	1.379471
Minimum	12.7722
Maximum	14.15167
Sum	4606.976
Count	334
Confidence Level(95.0%)	0.019113

215_FRCA028.MEAS	
Mean	804.6457808
Standard Error	3.457470246
Median	816.3564453
Mode	#N/A
Standard Deviation	63.18757447
Sample Variance	3992.669568
Kurtosis	-1.474959735
Skewness	-0.049977181
Range	247.0421753
Minimum	684.9434204
Maximum	931.9855957
Sum	268751.6908
Count	334
Confidence Level(95.0%)	6.801239018

215_FT020.PNT	
Mean	150.9730142
Standard Error	0.438384388
Median	148.295845
Mode	149.6151428
Standard Deviation	8.011767034
Sample Variance	64.18841101
Kurtosis	4.310064445
Skewness	-0.774529557
Range	58.02138519
Minimum	109.4191971
Maximum	167.4405823
Sum	50424.98676
Count	334
Confidence Level(95.0%)	0.862352179

151_TRC008.MEAS	
Mean	99.37920135
Standard Error	0.00013229
Median	99.38085938
Mode	99.38085938
Standard Deviation	0.002417697
Sample Variance	5.84526E-06
Kurtosis	-0.914364994
Skewness	-0.953473843
Range	0.005859375
Minimum	99.375
Maximum	99.38085938
Sum	33192.65325
Count	334
Confidence Level(95.0%)	0.00026023

215_TI001_24.PNT	
Mean	56.64508625
Standard Error	0.028808203
Median	56.62149811
Mode	#N/A
Standard Deviation	0.526489116
Sample Variance	0.277190789
Kurtosis	0.393025518
Skewness	0.393062563
Range	2.953426361
Minimum	55.5029068
Maximum	58.45633316
Sum	18919.45881
Count	334
Confidence Level(95.0%)	0.056669026

215_FRC006.MEAS	
Mean	698.4118
Standard Error	2.644569
Median	701.9258
Mode	#N/A
Standard Deviation	48.33126
Sample Variance	2335.911
Kurtosis	-1.08454
Skewness	-0.00402
Range	244.2437
Minimum	568.5394
Maximum	812.7831
Sum	233269.6
Count	334
Confidence Level(95.0%)	5.202169

215_PIC010.MEAS	
Mean	3.589054
Standard Error	0.015658
Median	3.642179
Mode	3.637402
Standard Deviation	0.286152
Sample Variance	0.081883
Kurtosis	7.430903
Skewness	-1.69482
Range	2.350117
Minimum	1.737419
Maximum	4.087536
Sum	1198.744
Count	334
Confidence Level(95.0%)	0.0308

215_FRC010.MEAS	
Mean	424.119
Standard Error	1.763895
Median	423.4997
Mode	407.6954
Standard Deviation	32.23636
Sample Variance	1039.183
Kurtosis	1.203465
Skewness	0.495663
Range	231.0518
Minimum	335.5119
Maximum	566.5637
Sum	141655.7
Count	334
Confidence Level(95.0%)	3.469783

215_TI001_23.PNT	
Mean	44.15685
Standard Error	0.038984
Median	44.11405
Mode	#N/A
Standard Deviation	0.712462
Sample Variance	0.507603
Kurtosis	1.084162
Skewness	-0.37612
Range	4.338848
Minimum	41.30321
Maximum	45.64206
Sum	14748.39
Count	334
Confidence Level(95.0%)	0.076686

215_TI001_20.PNT	
Mean	119.0583764
Standard Error	0.038706627
Median	119.1302338
Mode	118.3874893
Standard Deviation	0.707389422
Sample Variance	0.500399795
Kurtosis	-0.238579324
Skewness	-0.306326176
Range	3.941268921
Minimum	116.8643036
Maximum	120.8055725
Sum	39765.49773
Count	334
Confidence Level(95.0%)	0.076140358

215_TI001_21.PNT	
Mean	117.7384
Standard Error	0.036479
Median	117.8027
Mode	118.4
Standard Deviation	0.666682
Sample Variance	0.444465
Kurtosis	0.064694
Skewness	-0.09499
Range	4.009201
Minimum	115.8728
Maximum	119.882
Sum	39324.63
Count	334
Confidence Level(95.0%)	0.071759

215_TI001_19.PNT	
Mean	82.16961309
Standard Error	0.109365885
Median	81.52626038
Mode	#N/A
Standard Deviation	1.998734477
Sample Variance	3.994939511
Kurtosis	0.476745196
Skewness	0.219898338
Range	12.83483124
Minimum	74.86998749
Maximum	87.70481873
Sum	27444.65077
Count	334
Confidence Level(95.0%)	0.215135191

215_TI001_18.PNT	
Mean	104.6762
Standard Error	0.04619
Median	104.7788
Mode	105.1368
Standard Deviation	0.844155
Sample Variance	0.712598
Kurtosis	12.04591
Skewness	-2.36072
Range	7.743866
Minimum	98.76177
Maximum	106.5056
Sum	34961.86
Count	334
Confidence Level(95.0%)	0.090861

215_TRC006.MEAS	
Mean	103.9891241
Standard Error	0.043207564
Median	104.059391
Mode	104.3359375
Standard Deviation	0.78964705
Sample Variance	0.623542464
Kurtosis	18.46535534
Skewness	-3.054368694
Range	8.043838501
Minimum	97.57608795
Maximum	105.6199265
Sum	34732.36744
Count	334
Confidence Level(95.0%)	0.084994216

215_PIC015.MEAS	
Mean	2.709607
Standard Error	0.005968
Median	2.7049
Mode	#N/A
Standard Deviation	0.109062
Sample Variance	0.011895
Kurtosis	-0.19583
Skewness	0.373101
Range	0.568135
Minimum	2.485991
Maximum	3.054126
Sum	905.0088
Count	334
Confidence Level(95.0%)	0.011739

215_PDIC017.MEAS	
Mean	1.5795615
Standard Error	0.006586559
Median	1.592441678
Mode	#N/A
Standard Deviation	0.120373756
Sample Variance	0.014489841
Kurtosis	0.7679511
Skewness	-0.585414084
Range	0.80371511
Minimum	1.085399508
Maximum	1.889114618
Sum	527.5735412
Count	334
Confidence Level(95.0%)	0.012956514

215_FT013.PNT	
Mean	136.9427
Standard Error	0.298023
Median	136.9532
Mode	#N/A
Standard Deviation	5.446568
Sample Variance	29.66511
Kurtosis	1.016637
Skewness	0.415006
Range	40.01726
Minimum	123.4863
Maximum	163.5036
Sum	45738.86
Count	334
Confidence Level(95.0%)	0.586245

215_FIC012.MEAS	
Mean	700.8709552
Standard Error	0.204104646
Median	700.8557739
Mode	698.7125854
Standard Deviation	3.730148518
Sample Variance	13.91400796
Kurtosis	0.228121906
Skewness	0.258619333
Range	22.34326172
Minimum	691.4464722
Maximum	713.7897339
Sum	234090.899
Count	334
Confidence Level(95.0%)	0.401497159

215_PRCA013.MEAS	
Mean	6.042531
Standard Error	0.005002
Median	6.072143
Mode	5.916102
Standard Deviation	0.091412
Sample Variance	0.008356
Kurtosis	0.292932
Skewness	-0.65589
Range	0.532927
Minimum	5.768587
Maximum	6.301514
Sum	2018.205
Count	334
Confidence Level(95.0%)	0.009839

215_FRC029.MEAS	
Mean	257.0517177
Standard Error	3.490088447
Median	253.6997986
Mode	322.6694641
Standard Deviation	63.78369385
Sample Variance	4068.359602
Kurtosis	-1.618978734
Skewness	-0.167450239
Range	218.6078033
Minimum	110.0694733
Maximum	328.6772766
Sum	85855.2737
Count	334
Confidence Level(95.0%)	6.865402747

215_TI001_11.PNT	
Mean	44.53851
Standard Error	0.134635
Median	43.67047
Mode	44.54824
Standard Deviation	2.460541
Sample Variance	6.054262
Kurtosis	8.448763
Skewness	2.683561
Range	16.28015
Minimum	42.33234
Maximum	58.61248
Sum	14875.86
Count	334
Confidence Level(95.0%)	0.264842

Appendix 5

Result of Predicting Validation and Testing Set Using Neural Network

The result obtained from predicting the outlet conditions of validation and testing set using the developed Neural Network

215_TI001_15.PNT	215_TRC005.MEAS	215_TI001_11.PNT	215_TI001_12.PNT
0.336836727	0.143989634	0.136113406	0.23815464
0.518522132	0.250463977	0.188288105	0.27804127
0.010902163	0.020936536	0.036325991	0.153874322
0.257332918	0.056721216	0.072988919	0.626051978
0.312994623	0.234919868	0.164322995	0.189145702
0.346844844	0.175611019	0.121367863	0.196159661
0.028307857	0.019944625	0.0246477	0.163440492
0.291709364	0.094280405	0.1062378	0.644744154
0.005087736	0.022218869	0.002251599	0.101034293
0.381421757	0.123960412	0.124396687	0.19698728
0.226470007	0.063851522	0.063654769	0.482850709
0.001908013	0.022920359	0.028295599	0.100474841
0.35170616	0.1420907	0.1389372	0.233605045
0.624635201	0.421966065	0.312764916	0.249985436
0.150341018	0.085741014	0.060723188	0.834715627
0.253991211	0.198106647	0.146503872	0.216316585
0.295315078	0.090213336	0.103870228	0.541402699
0.491836803	0.392083432	0.262323953	0.218941849
0.614793543	0.630349983	0.467467641	0.426002043
0.013763287	0.020305399	0.026681601	0.109983679
0.355388839	0.207586783	0.160762263	0.205306936
0.19870717	0.098029434	0.084960578	0.845505194
0.198652579	0.346853211	0.25020186	0.181355908
0.457115805	0.406573127	0.283852835	0.258082235
0.220128461	0.060808634	0.064173789	0.537812958
0.28712011	0.100889464	0.1031436	0.53340392
0.041091184	0.02152581	0.021580213	0.109709038
0.089491344	0.090030769	0.091215525	0.191043216
0.012809281	0.020515875	0.029618337	0.189578469
0.351716004	0.128637395	0.132141208	0.214124087
0.325436083	0.095006023	0.096730019	0.498133464
0.166126869	0.045086318	0.06641764	0.655358951
0.250099115	0.057516024	0.070351409	0.60108469
0.238629561	0.102986955	0.088576141	0.832176361
0.328454716	0.100746433	0.109120643	0.501495725
0.455716119	0.359322163	0.268231168	0.45397003
0.152760936	0.077596121	0.058142618	0.958223253
0.265643333	0.518081157	0.37744857	0.153165066
0.208615949	0.081384687	0.091006042	0.843246117
0.041091184	0.00731113	0.024119308	0.180727103
0.181939569	0.09921089	0.071993058	0.853122066
0.146538417	0.094566757	0.056309764	0.832058922
0.415515401	0.169104582	0.158122411	0.29118516

215_TI001_13.PNT	215_TI001_14.PNT	215_LRCA008.MEAS	215_PRCA008.MEAS
0.558006672	0.789719082	0.283742895	0.806475721
0.567279651	0.890095923	0.224896267	0.913743018
0.474810104	0.569212915	0.478494509	0.589191694
0.778733495	0.724570915	0.43921982	0.694044163
0.65184338	0.78360483	0.329567857	0.862438472
0.604894524	0.892279034	0.297050759	0.893135059
0.482087196	0.616495375	0.459079627	0.585618883
0.720586123	0.895379411	0.431339125	0.835506195
0.466957417	0.61725334	0.500109992	0.593811184
0.596883426	0.807595067	0.32690059	0.886351695
0.740422497	0.81297876	0.438809635	0.720715116
0.482805952	0.632975334	0.450816607	0.596338008
0.585519119	0.864940904	0.195361457	0.83094132
0.478710866	0.998037855	0.185893872	0.937211714
0.783800697	0.797340699	0.438530616	0.784879847
0.490799832	0.678890887	0.573260518	0.637746807
0.746639905	0.88826653	0.432920553	0.800642249
0.609153434	0.920675745	0.272899176	0.921152729
0.660825118	0.706251285	0.44338488	0.409806567
0.492363285	0.605656047	0.468138746	0.586917898
0.699850445	0.886488523	0.286498246	0.901962004
0.930384025	0.815747687	0.434316407	0.826410321
0.835776414	0.57038198	0.817685364	0.602727312
0.622216976	0.83080507	0.327354312	0.874643272
0.761962041	0.771282117	0.428647486	0.703534789
0.747049217	0.853165468	0.439157726	0.857514795
0.577206448	0.580981501	0.367551918	0.573669184
0.092385916	0.570121617	0.204548961	0.416226289
0.492544819	0.541535629	0.486196659	0.587676291
0.650988843	0.820676601	0.175361889	0.892595819
0.748904403	0.745463344	0.456846665	0.743450308
0.950049197	0.788741007	0.473151937	0.642472071
0.745574808	0.80125471	0.446661357	0.695889332
0.861664896	0.806103974	0.439137601	0.841042393
0.688432022	0.782699555	0.532782426	0.749566535
0.605035717	0.737165981	0.287013202	0.613944197
0.766783754	0.789403049	0.411614985	0.754768819
0.675480647	0.747046934	0.610944778	0.551833418
0.84694984	0.82555841	0.372492497	0.789242852
0.59316469	0.485387975	0.433409064	0.522698552
0.919975599	0.865360569	0.424015658	0.831264864
0.852212351	0.809812436	0.428379085	0.808770256
0.684822501	0.836315519	0.671740595	0.895173801

215_FRCA028.MEAS	215_FRC006.MEAS	215_FT020.PNT	215_PIC010.MEAS
0.653490183	0.653602766	0.813303363	0.760369626
0.695605651	0.6165774	0.896642712	0.830456424
0.645921633	0.64291303	0.685445022	0.673510562
0.072541117	0.314155348	0.658764869	0.819232744
0.844347392	0.82910491	0.899498736	0.882352893
0.77651951	0.829763132	0.913651043	0.867247141
0.649320735	0.555205065	0.66560644	0.667623844
0.192903144	0.316800981	0.65000666	0.799570888
0.652333677	0.717969087	0.659713984	0.661827011
0.714639686	0.839110935	0.91314164	0.856686537
0.252568536	0.397803277	0.641435696	0.807632281
0.702379149	0.61465896	0.656466112	0.677350837
0.662837344	0.738523158	0.812945703	0.766585548
0.778661305	0.759130207	0.847230347	0.740222942
0.217327369	0.386324374	0.578308631	0.83702468
0.699500857	0.65851869	0.872361777	0.730044498
0.124000535	0.281053325	0.682464869	0.811018975
0.778095282	0.764619639	0.889389306	0.882214415
0.296120433	0.421326345	0.821674721	0.81638627
0.599336782	0.63497788	0.667607234	0.677620287
0.76865226	0.724117991	0.860727557	0.90181256
0.240672666	0.42398972	0.624658003	0.939530933
0.569239975	0.551155524	0.892584318	0.9986913
0.7777909	0.734917181	0.870219234	0.864177782
0.167825931	0.146156285	0.632771109	0.807881644
0.24991606	0.312645485	0.630410024	0.810492552
0.646028611	0.768727655	0.636896827	0.653428603
0.525387402	0.287461869	0.208843311	0.147238956
0.70872671	0.677036121	0.666019327	0.663529032
0.840012412	0.734360166	0.883236758	0.877194686
0.249422921	0.303993639	0.692778112	0.804737415
0.168579969	0.322507821	0.70018405	0.98804497
0.072614248	0.292186124	0.613455342	0.807064467
0.333555032	0.43976206	0.613470333	0.868522465
0.233031973	0.312555273	0.732254356	0.821421825
0.226368418	0.345416648	0.828893413	0.818276987
4.11113E-11	0.07765596	0.428608547	0.713533769
0.702882912	0.704020977	0.588351	0.706857469
0.225498507	0.378941992	0.560344874	0.803681324
0.58931489	0.580954692	0.625796731	0.651090898
0.343532206	0.268115538	0.598175353	0.922383101
0.319386916	0.403980919	0.600765498	0.857084828
0.734028752	0.591984284	0.973704595	0.95154521

151_TRC008.MEAS	215_FRC010.MEAS	215_TI001_24.PNT	215_TI001_23.PNT
0.287760171	0.499738743	0.650700121	0.522633578
0.999999147	0.528962743	0.555103633	0.738719698
0	0.422222196	0.338487748	0.798854935
0.999999147	0.231223681	0.322288281	0.577409238
0.999999147	0.541066787	0.325193129	0.565776598
0.908853391	0.609635369	0.409072063	0.616847327
0	0.397632129	0.517428441	0.844323428
0.999999147	0.247068394	0.392341741	0.78698755
0	0.508734919	0.260515381	0.797895733
0.59765574	0.542464998	0.413268528	0.594009335
0.999999147	0.309918788	0.283561713	0.669752058
0	0.365784999	0.395962145	0.620355318
0.31640598	0.552830722	0.677479228	0.589624786
0.507812067	0.582215597	0.699015658	0.683653024
0.999999147	0.337086814	0.107413497	0.546418464
0.124999893	0.492197309	0.355214195	0.206188132
0.999999147	0.278839974	0.272998865	0.507611638
0.746093113	0.479085618	0.612473409	0.716088317
0.999999147	0.405995372	0.384896858	0.807886035
0	0.4324705	0.558234514	0.591802554
0.670572344	0.467548334	0.403397987	0.542649351
0.999999147	0.345273729	0.286143656	0.992413419
0.080729098	0.196838612	0.156257306	0.028632771
0.774738922	0.487436182	0.707985942	0.875670277
0.999999147	0.099099392	0.41414037	0.96201786
0.999999147	0.240607119	0.533314045	0.883096845
0.007812493	0.466503045	0.454345841	0.638011329
0.999999147	0.695887761	0.927203144	0.680164375
0	0.420505009	0.525910493	0.582388124
0.627603631	0.48607601	0.395276296	0.664084762
0.999999147	0.311801869	0.242511524	0.420555423
0.999999147	0.126695624	0.380465318	0.787984558
0.999999147	0.242779721	0.300410863	0.516790443
0.999999147	0.297399085	0.268279294	0.497936967
0.999999147	0.287593649	0.187972974	0.470231747
0.999999147	0.381069291	0.563434566	0.867506064
0.999999147	0.24988991	0.007953781	0.515729253
0	0.39591283	0.24560624	0.443378468
0.999999147	0.452030919	0.409490547	0.898811591
0.037760384	0.332250136	0.336360454	0.3343828
0.999999147	0.218439419	0.037664859	0.631453407
0.999999147	0.377718922	0.263726342	0.955423891
0.999999147	0.314793109	0.508485281	0.446140022

215_TI001_20.PNT	215_TI001_21.PNT	215_TI001_19.PNT	215_TI001_18.PNT
0.588729941	0.483012181	0.443386295	0.805105204
0.626442634	0.630366858	0.410205274	0.83455829
0.76203953	0.49888867	0.459552977	0.824664733
0.503757332	0.430964013	0.754128754	0.825933693
0.710772567	0.600193346	0.504607121	0.776645217
0.701895121	0.72831279	0.456566567	0.831881453
0.791025766	0.451046069	0.478385079	0.762923104
0.57409164	0.425346442	0.675199297	0.70038936
0.745533209	0.577957127	0.453286508	0.784768338
0.747834841	0.682285624	0.454878983	0.943341113
0.353522135	0.271015472	0.685946571	0.809610605
0.791258059	0.601961206	0.489818919	0.784904298
0.495774211	0.502770731	0.437815902	0.794170271
0.357513695	0.37822697	0.323655833	0.554144616
0.389440368	0.29635734	0.71106357	0.641829985
0.134191523	0.223380295	0.312966218	0.685563803
0.387769797	0.38555341	0.60596438	0.759754643
0.475363441	0.392019706	0.470089824	0.646781689
0.386470895	0.37961043	0.767133075	0.848759219
0.660754177	0.532575068	0.469645191	0.765514227
0.479672467	0.422334039	0.518741451	0.80567466
0.270448517	0.285401935	0.833154509	0.576877531
0.392001393	0.352620589	0.663764863	0.798922962
0.638401828	0.475421228	0.492468883	0.692403184
0.599705763	0.457748334	0.788322682	0.61238281
0.256491607	0.10428474	0.686865558	0.543633327
0.894663081	0.743028467	0.454448616	0.942347028
0.178123849	0.335823061	0.21811201	0.22050258
0.831390466	0.511216118	0.466281318	0.817193826
0.596052963	0.639339368	0.479863424	0.887363008
0.291904604	0.154977992	0.557466116	0.761393061
0.587721404	0.476974053	0.948975412	0.76978219
0.568768269	0.414588946	0.757663228	0.806984014
0.510398962	0.408413804	0.732426155	0.754865008
0.267076403	0.154977992	0.540832807	0.827793784
0.131313031	0.220071028	0.555008152	0.746426617
0.567662944	0.38301104	0.676826843	0.694639629
0.371298321	0.426364532	0.548278623	0.850954284
0.619560968	0.483583072	0.8148033	0.814123887
0.674500088	0.649208177	0.50258844	0.889864476
0.334410266	0.387054854	0.772923407	0.720432631
0.451481832	0.258421608	0.78629984	0.689173641
0.629423721	0.49145947	0.489652479	0.839862702

215_TRC006.MEAS	215_PRCA013.MEAS	215_PIC015.MEAS	215_PDIC017.MEAS
0.803313404	0.689956766	0.594413272	0.865727655
0.865408286	0.639489168	0.555329084	0.761475403
0.846757437	0.609559711	0.543706433	0.589827933
0.853317103	0.435960803	0.2319633	0.566320546
0.787223443	0.581315071	0.52692837	0.798650886
0.856411983	0.603939773	0.632362723	0.732362452
0.835099708	0.630254432	0.590670405	0.472048046
0.71996126	0.596873915	0.308197923	0.643517381
0.791726811	0.598143569	0.520615561	0.42382637
0.921280211	0.603304499	0.627168284	0.671504265
0.788156744	0.286023615	0.146345701	0.626036647
0.785297087	0.643191652	0.516299452	0.716987902
0.816234504	0.665641877	0.512597711	0.841777525
0.588410368	0.645573483	0.484082432	0.854306057
0.76043087	0.213053897	0.283494753	0.63022736
0.751434567	0.29759097	0.230409752	0.898566624
0.814671414	0.375435297	0.262434991	0.703427934
0.751952435	0.611754537	0.446743153	0.661062784
0.887522023	0.220418601	0.068074932	0.39653601
0.793569702	0.598922898	0.450933787	0.758121824
0.812316346	0.52115015	0.448412944	0.772589232
0.710674723	0.422135988	0.187236906	0.445419354
0.881971537	0.042067665	0.272329101	0.702666444
0.722795309	0.694189838	0.613321483	0.67355913
0.706102117	0.678680205	0.376171718	0.401023665
0.543254335	0.665119342	0.248114404	0.488740296
0.989704278	0.626446367	0.702057087	0.636448464
0.316551299	0.836254997	0.486553336	1
0.808327053	0.644141879	0.563406945	0.715853974
0.896776312	0.545779097	0.411145005	0.706732863
0.796704418	0.216963069	0.199426925	0.723538579
0.756552548	0.546108365	0.194886302	0.470103979
0.830301364	0.521791688	0.394764352	0.586450029
0.836463618	0.431368935	0.275238541	0.57165379
0.791881413	0.241169692	0.155322874	0.713088495
0.782405181	0.325355128	0.170094166	0.455636572
0.801700994	0.101472047	0.222961368	0.563026889
0.816550347	0.222032734	0.24025686	0.707623986
0.793028122	0.637313131	0.329925768	0.442060287
0.964209221	0.462545677	0.514599446	0.731499955
0.814105174	0.144043457	0.087627307	0.488464861
0.736233329	0.351953423	0.23281645	0.474121748
0.857718036	0.486987621	0.387401996	0.769127674

215_FT013.PNT	215_FIC012.MEAS	215_FRC029.MEAS	215_QRA3_C3.PNT
0.468645463	0.390204658	0.981108116	0.02168087
0.422040052	0.234172511	0.703591502	0.015657405
0.416812358	0.111125679	0.981792573	0.215391241
0.172955852	0.383353547	0.973626271	0.450478991
0.369920967	0.460185427	0.97898983	0.030922035
0.424352287	0.504370724	0.973232461	0.03523186
0.439480571	0.466869904	0.307759697	0.106049811
0.212917401	0.333374308	0.971986394	0.180609739
0.447717908	0.658643654	0.508801166	0.286699321
0.48482615	0.573775103	0.823264439	0.038582528
0.207247011	0.421072903	0.956008932	0.074637754
0.430413133	0.323570225	0.960637778	0.20043258
0.443739369	0.486054655	0.388764641	0.020759654
0.498470776	0.265229243	0.404443011	8.27266E-11
0.350239517	0.260145544	0.218276116	0.021194416
0.529719501	0.248128782	0.978072521	0.049146035
0.298235587	0.404791952	0.954101302	0.005895281
0.385030949	0.632457548	0.790482108	0.019129376
0.161827841	0.5793669	0.337303944	0.124613053
0.412966513	0.404035271	0.506086371	0.13915844
0.349735051	0.624650341	0.370985646	0.027671558
0.18866372	0.164601498	0.974818034	0.2278857
0.394417921	0.500095609	0.95757175	0.107015606
0.424182225	0.237614457	0.473274445	0.021293993
0.290499667	0.520170894	0.414511847	0.384241717
0.27667087	0.198171397	0.968937258	0.217364675
0.437555361	0.206765335	0.152532886	0.162969672
0.563721631	0.043313882	0.972713429	0.00091471
0.423442111	0.336174303	0.446823099	0.169172639
0.326701546	0.349218185	0.35143848	0.033486909
0.339721594	0.290052229	0.337847056	0.039352731
0.139423109	0.161501015	0.963720278	0.667356842
0.226855251	0.411170479	0.476192637	0.424802499
0.220782202	0.569289647	0.441244905	0.350387919
0.198928457	0.222374286	0.329039713	0.048741114
0.329040854	0.325203784	0.95900851	0.103340429
0.169127166	0.474570575	0.959765559	0.015409144
0.355557963	0.339673615	0.91205751	0.038009394
0.213848167	0.40971175	0.502511014	0.346611956
0.419778912	0.314768678	0.146500924	0.170297674
0.072445894	0.524926789	0.965363227	0.146656262
0.171752071	0.149481521	0.298191535	0.039372867
0.309241581	0.481831442	0.435232487	0.063514011

NN value	Error	Data Number
0.0215	3.27139E-08	1
0.0163	4.12929E-07	2
0.2432	0.000773327	3
0.4026	0.002292398	4
0.0289	4.08862E-06	5
0.0293	3.5187E-05	6
0.1861	0.006408033	7
0.1929	0.000151051	8
0.3941	0.011534906	9
0.0407	4.48369E-06	10
0.026	0.002365631	11
0.2046	1.73674E-05	12
0.0092	0.000133626	13
0.0045	2.025E-05	14
0.0571	0.001289211	15
0.0353	0.000191713	16
0.08	0.005491509	17
0.0083	0.000117275	18
0.0178	0.011409028	19
0.1533	0.000199984	20
0.012	0.000245598	21
0.1535	0.005533232	22
0.0812	0.000666446	23
0.0238	6.28007E-06	24
0.49	0.011184814	25
0.1522	0.004246435	26
0.1108	0.002721675	27
0.0151	0.000201222	28
0.1916	0.000502987	29
0.0268	4.47148E-05	30
0.0261	0.000175635	31
0.7535	0.007420644	32
0.5489	0.01540019	33
0.2516	0.009759053	34
0.0367	0.000144988	35
0.013	0.008161393	36
0.042	0.000707074	37
0.0174	0.000424747	38
0.3037	0.001841436	39
0.1799	9.22047E-05	40
0.0478	0.00977256	41
0.0825	0.00185995	42
0.077	0.000181872	43

RMSE	0.053642803
Standard Deviation	0.004171314

Appendix 6

Result of Improvement strategy

The conclusion of the step taken and the result to improve the Neural Network performance and reduce the number of Root Means Square Error (RMSE)

First trial (Reduce the number of input)

Inputs	RMSE
26	0.428149
25	0.442515
24	0.391788
23	0.371951
22	0.371961
21	0.417685
20	0.520335
19	0.386998
10	0.394454

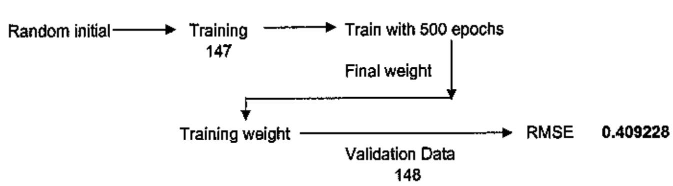
Second trial (Reduce the number of data set from 2219 to 334)

Inputs	RMSE
27	0.353117
26	0.428149
25	0.442515
24	0.391788
23	0.377276
22	0.371961
21	0.417685
20	0.520335
19	0.386998
10	0.394454

Forth trial (Increase the epochs number)

Inputs	Epochs	RMSE
27	1500	0.5065
	1000	0.4566
	500	0.2815
	250	0.4505
	200	0.366
	100	0.353117
10	1000	0.32026
	500	0.296907
	100	0.394454

Fifth trial (Calculate RMSE for Validation data at 500 epochs)



Sixth trial (Find the highest epochs number for validation data and calculate the RMSE)

Data types	Epochs	RMSE
Validation	2966	0.372
Training	3610	0.29152

Seven trial (Test the testing data line by line and calculate the RMSE)

Epochs	RMSE
500	0.113
100	0.085

Eight trial (Increase the number of inputs from 27 to 54 inputs)

Nine trial (using trial & erors, create the new NN model and calculate the RMSE by using 54 inputs)

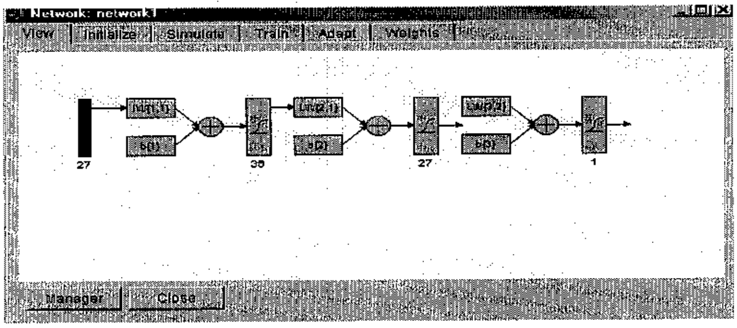
Ten trial (Calculate the RMSE for validation data set at every epochs number to find the best epoch number that will give less RMSE)

Epoch	RMSE
25	0.162
50	0.1409
75	0.1197
100	0.116
125	0.117
150	0.131

since 100 epoch give less RMSE, all trial should using 100 epochs

Eleven trial (Using trial&erors, create new NN model and calculate RMSE)

Twelve trial (Using 27 inputs data, create new NN model and calculate RMSE)



RMSE **5.36%**

Appendix 7

Results of weight and biases

Columns 1 through 6

2.0909	-1.5942	-1.2532	-0.6709	-12.3181	-0.5894
-3.8060	1.3199	0.5737	0.8054	0.0686	-1.7828
-0.5461	1.7701	-0.3404	2.7498	0.3368	-1.6207
0.4931	-1.2836	-1.7103	0.8482	2.0056	1.6044
-1.7343	2.5631	2.4874	-2.7411	1.3749	2.5655
0.3895	1.4214	-0.2481	-0.2510	-1.4754	-1.5285
1.7170	0.5860	0.7487	1.4917	-1.8909	-2.2738
-1.8077	1.5527	-1.3798	-0.5680	-2.1129	-0.7631
0.4913	0.8890	-0.4279	0.1995	-0.2340	-0.1719
1.7098	0.7685	-1.5138	3.1782	0.6218	-1.4769
-0.1798	2.3576	-0.5742	0.2814	-1.4058	-0.0347
-2.3897	-1.8682	-0.6938	-1.1842	1.4170	-0.9997
-2.1407	1.5473	0.5736	0.3093	4.7902	1.2331
-0.8069	-2.6235	-1.8092	-20.1352	0.1306	-2.5867
1.2678	1.2195	1.8044	0.5738	-2.1843	0.0136
-0.7064	-0.1950	-0.8405	-0.3757	-0.8155	-0.3966
1.9919	0.4894	1.0042	-2.0017	-0.4437	-0.6722
2.3618	-0.7715	1.6231	-0.6020	0.6741	-2.0582
0.6921	-0.0216	-1.6343	0.9181	-0.6385	-1.4877
-0.3456	1.2315	1.3156	2.0321	1.3334	-0.5105
1.8400	0.8138	1.6287	-2.1037	-1.6168	1.4249
-1.3691	-0.3414	1.0518	2.1391	-0.6348	-1.2389
-1.0664	-1.6238	0.4177	0.8016	-0.6417	0.2082
-0.0128	0.6930	-1.4266	-0.3082	1.1029	0.7770
1.3488	0.5866	-0.7007	1.5929	0.1084	-0.2975
1.3632	-0.1773	-1.2887	0.6831	1.3299	-1.9927
2.1916	-1.4803	0.5561	0.2147	1.6863	1.2722

Columns 7 through 12

3.8746	-2.5583	1.1815	2.0993	-9.2268	1.0490
-0.7551	-0.8997	-3.1603	0.0831	-57.2018	-1.4535
2.6035	-48.0850	1.2020	0.8857	-11.9522	-1.9724
2.7029	-0.6920	-0.2304	0.1622	-11.4458	-1.3033
2.2641	2.2565	-1.5623	0.4019	-52.9142	-0.8220
-1.5153	-1.3998	-1.5259	-1.9760	-54.2132	-0.8548
0.2469	-1.7045	-0.1998	-1.0728	-8.1705	0.5250
2.0629	1.0089	-0.6977	-0.5187	-55.6181	0.2503
0.6715	-0.6290	-2.3992	1.8482	-1.7872	-1.2813
1.2538	1.1058	-1.9525	-2.1975	-11.1299	-1.8727
-0.4239	-0.5275	0.7876	1.9961	-56.8568	-1.5138
1.0028	2.7446	0.0553	1.6137	-53.4787	2.1840
-1.2581	-0.1833	0.8510	-1.0733	-9.3690	0.4335
0.5353	-1.3799	1.5750	-2.6317	-317.4082	-2.3393
1.7727	1.6353	-1.1794	0.6038	-55.8108	1.6193
0.0302	0.4214	-0.8141	-1.8165	-319.6912	-0.0988
-2.0574	1.4499	1.6357	-0.5294	0.3312	-1.5561
-0.8315	0.2094	-0.3083	0.2789	-1.4324	-1.5683
0.3632	1.4027	0.7977	-0.0524	-53.3533	-1.7460
0.6629	1.0645	-1.3038	1.7451	-55.1394	0.5430
-0.3809	1.6519	1.0537	0.3191	-56.1547	-1.2985
2.1723	-0.9915	1.4645	1.7982	-3.4232	-1.1457
-0.2679	1.1005	-2.0648	-1.0530	-4.1912	-0.5729
-0.0998	1.0019	1.3790	12.7122	-318.9893	-1.9347
1.1664	0.9747	1.5438	0.0804	-55.2392	1.3601
0.9925	-5.6036	1.6009	-0.2139	-54.4449	-0.2534
-0.2387	-2.0083	1.7101	-2.3180	-9.0662	1.3275

Columns 13 through 18

-2.5714	-0.8975	-0.6556	1.4240	1.9444	0.2453
1.4126	0.0855	0.6564	-1.1286	-1.4191	-1.6536
-1.3401	2.3998	2.0566	-0.7774	2.0531	0.8895
-0.9030	-1.0342	-2.2645	-1.1155	0.3746	-1.9240
0.8700	0.6288	-2.5150	2.6060	1.8571	1.1490
-0.8984	1.6477	-1.8928	0.5631	0.1820	0.6910
-1.4694	1.6812	1.1380	1.6933	0.9882	-0.4291
0.6565	0.6805	0.5183	0.9590	0.0628	0.9707
-2.1905	-0.6614	-0.3165	0.0934	-1.7673	2.3636
-2.8302	1.9806	-1.4805	-1.8679	1.1077	0.2850
0.4804	1.8822	-1.8312	1.7157	-1.7331	-0.4191
-1.7873	1.6619	2.1881	-1.8059	-1.8324	1.5956
0.8338	-1.2213	0.5990	-1.1028	0.0895	0.1173
-0.2066	2.5838	-1.0032	2.9662	-1.8433	-2.5746
-0.0009	-0.7604	-0.1059	0.1376	1.8005	-0.7186
-2.6752	0.6653	0.8992	-0.0221	-0.8793	1.2384
2.2575	1.1477	-0.3003	-0.6046	1.7971	0.1990
2.2605	1.0250	1.1542	1.3626	0.6110	-2.0370
-0.1741	0.1902	-0.9812	0.2460	-1.9483	0.3051
-0.6131	0.2081	1.7279	-1.1880	0.5354	-0.5285
-1.1225	-1.1854	-0.2856	0.9492	-0.0735	1.4483
-1.3451	-1.8717	0.5591	-1.6756	1.3494	-2.2048
1.1985	-1.5753	-1.8250	0.5905	0.3526	-3.7376
-1.0358	-0.5068	1.6476	-1.4302	1.1102	2.6219
-1.6066	2.1420	-0.9556	0.5096	1.5516	1.2405
-0.3982	-1.2456	-1.2354	0.8741	-0.7628	0.8408
1.2995	1.0762	-1.4701	-0.2721	1.9611	1.4589

Columns 19 through 24

1.0244	1.3716	1.2281	1.6293	0.6758	2.1365
2.5546	0.2006	-1.4979	3.3299	0.5129	1.4961
-1.1709	0.1534	-0.5796	-0.4523	-1.7226	-1.6150
-2.4696	1.7687	2.2744	-1.1773	-2.1533	3.6368
-0.6466	1.1476	0.5301	-1.1937	1.9363	-0.2470
-0.8387	-1.1740	-0.4756	-0.8695	0.7066	1.8577
-0.9325	0.0264	0.2246	1.0774	1.2613	-0.0712
-0.0439	0.4055	1.9593	1.2273	-0.7856	0.5092
-1.6790	-2.4278	-1.0412	-1.7482	1.7870	-1.1469
-1.1885	-0.8257	-2.7038	1.9008	1.7905	-1.3047
-1.4625	0.9915	-1.1884	1.6364	-1.5475	0.2529
1.1369	0.8439	1.4000	0.7562	2.1139	-1.1135
-0.5113	0.9648	1.5794	-1.3491	-0.8165	3.1526
-1.4876	1.9915	-2.3996	-1.3291	2.6815	-1.7732
-1.9102	0.5515	1.6362	-0.2760	-1.1048	1.9650
1.2270	2.0508	-0.2248	1.8661	-0.2236	1.5898
-1.3582	-0.7265	-1.6167	-0.2896	-0.4461	-0.2014
-1.0579	0.1376	0.4910	-2.1105	-1.8090	-1.0456
0.5481	2.5884	1.0214	0.8478	-0.3059	1.4192
0.5083	0.8607	-0.5592	-0.4521	0.6330	1.3792
-0.2984	-0.1774	-0.3222	-0.4579	1.6688	-2.1344
-1.7047	2.3364	0.0302	-0.9775	-0.8849	-0.4744
-2.0974	-2.7951	0.2979	-2.0514	-0.6573	0.6663
2.2998	1.1177	-0.4477	-0.0562	-1.3073	-1.3322
-1.7073	-2.6846	1.8114	-1.4186	-1.0361	0.6457
-1.6401	0.6718	-0.4976	1.3601	1.4672	-3.4137
-0.5252	1.8978	-2.4410	-0.8779	1.5586	-3.9798

Columns 25 through 30

4.0836	0.0449	1.2438	0.9130	-0.7879	-4.0618
11.1212	0.2749	-1.1970	-3.9387	-2.2038	-2.2088
3.0015	1.4447	-2.0977	2.4016	-0.3854	1.0563
-16.0593	1.8731	-1.4189	0.9794	-1.1934	-1.8862
-2.5919	-2.1164	-0.2952	-1.0158	2.6882	2.4088
-0.3123	0.2724	-1.5586	-1.4695	-0.9591	0.3078
0.5788	-0.1584	-1.0924	0.4872	0.8476	1.0439
-0.8192	-0.9793	1.3042	0.8107	-2.1654	0.3335
2.3013	-0.3116	-0.5355	1.7240	-1.5902	0.1480
0.3920	-1.6413	0.4980	-1.0242	0.9831	2.4597
1.7330	1.8108	-0.4464	-0.2170	-0.0837	-1.9174
-0.6509	-1.5233	-2.3022	-2.4843	2.1582	-1.1573
-0.9624	1.7283	-0.4133	-1.9374	-1.9305	1.3725
0.2919	-1.0215	0.8799	2.7811	1.6764	1.1816
0.2930	2.3050	0.6327	1.8215	-1.2564	-0.3400
1.3948	-1.3343	-0.4207	0.1016	1.0155	0.3746
-0.0292	-1.9732	-0.5665	0.6022	-1.6527	0.7303
-0.8290	-0.1386	1.7549	0.4533	-0.8085	-0.1259
-0.4286	-1.7183	2.1181	1.6362	0.4849	-1.3482
-1.1401	-0.3017	0.3826	0.3172	1.0082	0.0591
-0.6493	-1.8303	0.7841	0.7010	2.2204	0.2849
-0.5739	0.3803	-2.0477	-2.2239	-0.2161	2.2253
1.7315	0.7405	-1.6926	-0.1895	-0.2772	-0.8042
-0.5721	2.0333	0.9166	-0.2933	1.2616	-1.3339
-1.1401	-0.0939	-1.9559	2.5294	0.4593	-0.4594
-0.2635	1.5907	1.7008	0.4725	1.4487	0.8722
-1.1961	-1.3723	-1.6772	0.6655	-1.1921	-1.9720