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Predictive modeling and risk analysis of Solar Hybrid Kiln

By

Mukul Parkhe

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Predictive modeling and risk analysis of Solar Hybrid Kiln

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Increasing population equals increase in agricultural product consumption for which continuous food production is not a viable option. Solar drying, on the other hand is a promising method to preserve agricultural products for longer durations. This thesis focuses on calculating the predictability of the independent factors and a comprehensive risk assessment to improve the performance of Solar Hybrid Kiln. Biochar samples with different moisture content were selected for 3 tests. Principal component analysis and multiple linear regression analysis were conducted on the gathered data using Minitab 18^R platform. Risk response plans associated with the kiln were provided through failure mode effects analysis. Results exhibited 3 significant principal components and reliable prediction model limits were obtained for both training and testing datasets. A total of 41 risks were identified and risk response plans were proposed for them. These results can be further used to increase the efficiency of biochar drying processes.

DEDICATION

I would like to dedicate this research to my parents, Rekha Parkhe and Mohan Parkhe, and my brother, Mayank Parkhe.

ACKNOWLEDGEMENTS

I would like to thank my advisor Dr. Ra’ed M. Jaradat, and my committee members, Dr. Richard C. Millar, Dr. Thomas Mazzuchi, and Dr. Junfeng Ma for their valuable guidance, feedback and giving me an opportunity to work under them. Dr. Usher, who always directed me in the most suited direction. A special thanks to Dr. Sita Warren for allowing me to work on this project and providing me with related literature. I would also like to thank Dr. Todd Mlsna for fulfilling all the project requirements and my colleague Joseph Soffer for his help. All my friends for helping me in settling down in United States of America.

Hail State!

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CHAPTER I

INTRODUCTION

Energy is the only source of development of humankind. As stated by (Akarslan, 2011), energy is a burning issue internationally in the areas of politics, economy, and many more. In today's era, the accumulation of energy is the measure of a country's potential to grow (Arto, Capellán-Pérez, Lago, Bueno, & Bermejo, 2016).

In fact the amount of solar energy that reaches earth is greater than the amount of total energy consumed by humans combined in a year (Vayssieres, 2010). Additionally, solar energy proved all the forms of renewable and non-renewable energy known to us (Goldemberg, J. Johansson, 2004) very small against itself. Solar energy is readily, cleanly and freely available in the environment. This makes solar energy a most promising source of energy resources options (Akarslan, 2011).

The only drawback associated with the extensive usage of solar energy is its unreliability. Solar energy is seasonal and no sunlight at night. This issue can be resolved by storing significant amount of solar energy in the excessive load periods (usually daytime) for the future energy requirements (Bal, Satya, & Naik, 2010).

Conversion from non-renewable energy to renewable such as solar energy would help in improving the quality of life on our blue planet. This energy shift will not only benefit humans but the flora and fauna (Fudholi et al., 2015) of the earth too.

1.1 Problem Statement

Earth is a home of around 7.57 billion people at present and the population growth rate is 1.09% per year(U.S. Census Bureau, 2016). Increasing population equals increase in the food consumption. In order to feed the world, either we must produce food regularly or store produced food. However, the first option is not viable, but the second option is feasible. As (Prakash & Kumar, 2014) mentioned in their work, food can be stored for a certain period by drying it.

1.2 Solar Drying

Drying can be defined as the process of reducing moisture to a desired limit (Prakash & Kumar, 2014). Solar drying is an omnipresent and oldest method of crop drying. And it is still in practice everywhere for the same purpose. It is one of the most effective way of using solar energy (Janjai, Khamvongsa, & Bala, 2007). The moisture content (MC) in the agricultural products is calculated based on dry and wet basis. This moisture content can be set to a specific limit by drying the agricultural product to a limit. The process of drying helps to reduce the activity of enzymes, bacteria, yeasts, etc. This results in the preservation of the agricultural products. Researchers have discovered multiple methods of drying. Those methods include - spray dryer, mechanical dryer, electrical dryer, solar dryer etc. (Prakash & Kumar, 2014). A case study conducted by (Negrie and Blaison, 2017) shows that the energy invested in drying operations in a sawmill is 7 to 12 times greater than the energy dedicated towards the sawing operations. Spices and herbs are regularly dried in most parts of South East Asia (Akarslan, 2011). Since in solar drying the major source of energy is solar radiation, it does not consume considerable amount of electrical energy as opposed to other drying techniques.

1.2.1 Advantages of Solar Drying

Due The world in witnessing a surge in the conventional fuel prices due to its limited availability. Due to the continuously exploitation of the limited resources they are depleting at a much higher rate. In such scenario, solar energy has emerged as a useful source of energy for fulfilling our energy requirements including agricultural product drying purposes (Prakash & Kumar, 2014). In an extensive study (Brooker, Bakker-Arkema, & Hall, 1992) affirms that for agricultural products a solar kiln consumed about 6.9 MJ of energy per kg of water extracted, considering both continuous and discontinuous application. The conversion of electrical energy to a source of heat is exorbitant in several developing countries due to very less and uncertain production of electrical energy. Another shortcoming of using a conventional dryer is the ultra-expensiveness of the dried article. In most cases, the conventional wood dryers use non-renewable source of energy. Sometimes these dryers use fossil fuels, this pollutes the environment and increases the prices of the fossil fuel. Medicinal herbs need a low temperature surrounding to carry the essential ingredients. A conventional drying process can strip off these essential ingredients from the herbs ((Kamaruzzaman Sopian, Othman, Zaidi, & Amin, 2013)**,** (Misha, Mat, Ruslan, Sopian, & Salleh, 2013)). A controlled drying chamber can employ for this purpose. After reviewing all these advantages, it can be concluded that the use of solar energy for drying process can reduce the consumption of non-renewable sources such as carbon and petroleum (Murthy, 2009). Sun drying is a has been in existence in many countries, particularly where the outdoor temperature reaches 30 °C (i.e. ~86 °F) or higher. Yet, solar energy applications are decentralized, particularly in the developing countries (Sharma, Chen, & Vu Lan, 2009). We have explored a little area of the solar drying thus far.

1.2.2 General Solar Drying

- Open Sun Drying/Natural Drying:

Products are highly dependent on the availability of sunshine under this kind of solar drying. Additionally, this requires a large amount of open area without any form of sunlight obstruction. Since the products are kept under sun in an open space, they are susceptible to contamination with alien materials (Sohif Mat Sopian, 2013) like dirt, pest infestation, and loss by birds and beast (Prakash & Kumar, 2014). For natural drying systems, the agricultural products are kept in a compact earthen floor, concrete floor and on roads during sunny days. Natural sun drying is extensively used to dry marine products. Naturally heated air is used in open sun drying for drying purposes.

- Solar Drying Systems (OSDs):

Solar drying systems offers high quality products when compared with the open sun drying. OSDs are eco-friendly, renewable and reliable. However, OSDs are expensive than open sun drying but they are economically viable everywhere (Fudholi et al., 2015). The movement of drying air can be natural or forced in the drying chambers of the OSDs.

As observed by (Muhlbauer & Muller, 1993) there is a massive increment in the demand for dried agricultural products, marine products and, medicinal plants worldwide.

1.3 Classification of Solar Dryers

Figure 1.1 represents various kinds of solar dryers. This classification was provided by (Ekechukwu & Norton, 1999).

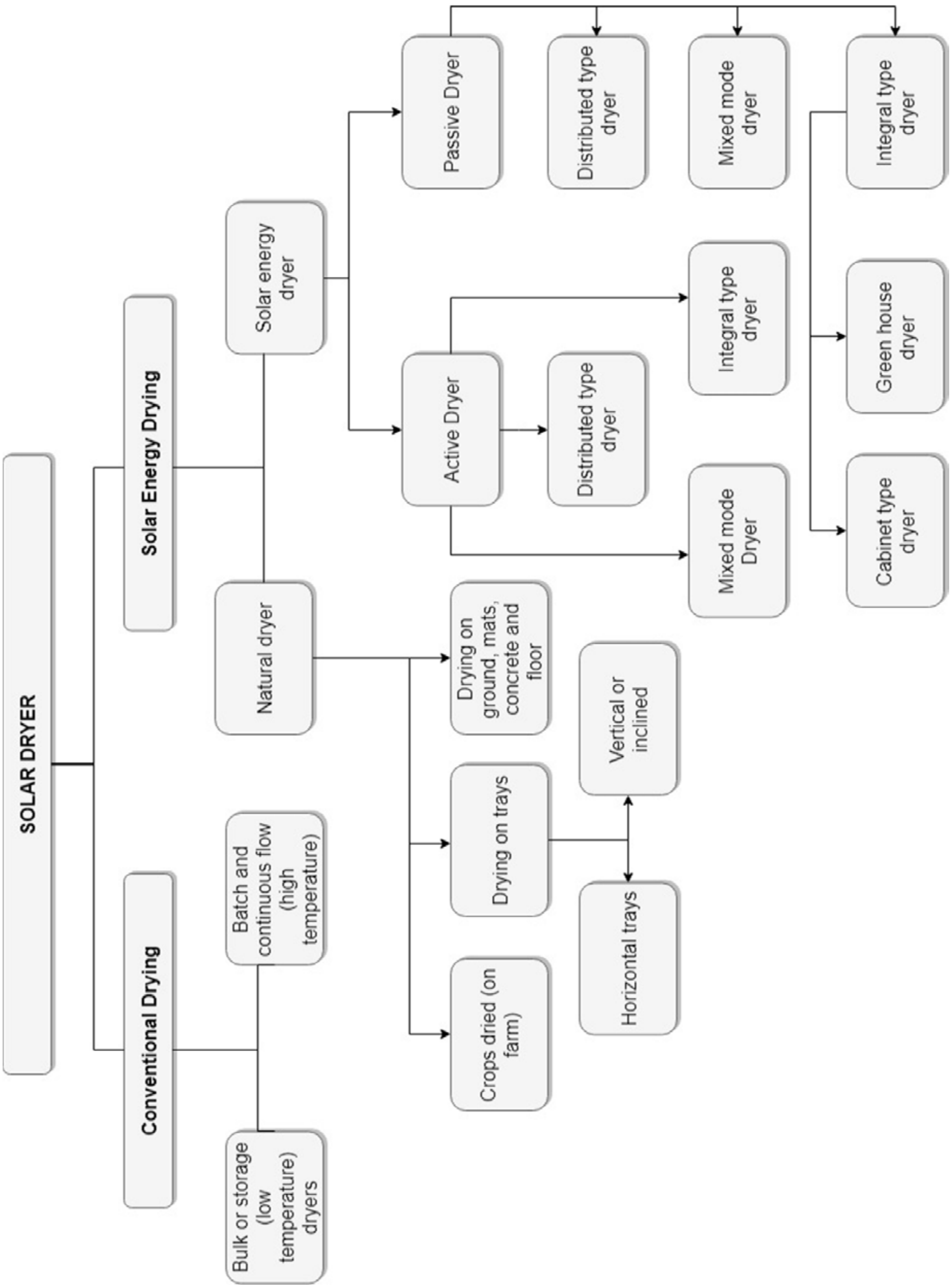


Figure 1.1 Classification of Solar Dryers (Ekechukwu & Norton, 1999)

1.4 Previous Samples

Following list represents the specimens dried using different types of solar kilns.

Table 1.1 Specimen dried using different types of solar kilns

S. No.	Reference	Specimen
1	(A. Konuralp;SAÇILIK, 2016)	Apple
2	(Smitabhindu, Janjai, & Chankong, 2008) and (Schirmer, Janjai, Esper, Smitabhindu, & Mühlbauer, 1996)	Banana
3	(Mursalim , Supratomo, 2002)	Cashew nut
4	(Forson, Nazha, Akuffo, & Rajakaruna, 2007)	Cassava
5	(Kadam & Samuel, 2006)	Cauliflower
6	(Hollick, 1999), (Hossain & Bala, 2007), and (Hossain, Woods, & Bala, 2005)	Chillies
7	(Mohanraj & Chandrasekar, 2008)	Copra
8	(McDoom, Ramsaroop, Saunders, & Tang Kai, 1999) and (Hii, Abdul Rahman, Jinap, & Che Man, 2006)	Cocoa
9	(McDoom et al., 1999)	Coconut
10	(El-Sebaii, Aboul-Enein, Ramadan, & El-Gohary, 2002) and (Gallali, Abujnah, & Bannani, 2000)	Figs
11	(D. R. Pangavhane & Sawhney, 2002), (Dilip R. Pangavhane, Sawhney, & Sarsavadia, 2002), and (Gallali et al., 2000)	Grapes
12	(El-Sebaii et al., 2002)	Green peas
13	(Madhlopa, Jones, & Kalenga Saka, 2002)and (Touré & Kibangu-Nkembo, 2004)	Mango
14	(El-Sebaii et al., 2002) and (Sarsavadia, 2007)	Onions
15	(J.C. Igbeka, 1987) and (Soponronnarit, 1995)	Paddy
16	(Madhlopa & Ngwalo, 2007) and (Bala, Mondol, Biswas, Das Chowdury, & Janjai, 2003)	Pineapple
17	(Saeed, Sopian, & Abidin, 2008)	Rosella flower
18	(El-Beltagy, Gamea, & Essa, 2007)	Strawberry
19	(Ruslan et al., 2006) and (K. Sopian, Othman, Yatim, & Ruslan, 2007)	Tea
20	(Soponronnarit, 1995)	Tobacco
21	(El-Sebaii et al., 2002)	Tomatoes
22	(Prasad, Vijay, Tiwari, & Sorayan, 2006)	Turmeric
23	(A.E. N'Jai, 1987) and (Diouf, 1986)	Fish
24	(K. Sopian, Supranto, Othman, Daud, & Yatim, 2007)	Oil palm
25	(Yahya, Othman, Sopian, & Daud, 2004)	Pegaga leaf

1.5 Solar Hybrid Kiln

1.5.1 General Discussion

The top- view of the Solar Hybrid Kiln is not plotted against the true dimensions and it should be used only as a reference diagram for the rest of study. Additionally, in order to reduce the complexity from the representation of the basic system the components such as dehumidifier, wet and dry bulbs, sensors and variable temperature controller are not included in figure 1.2.

The components such as computer system, programmable logic controllers, power grid, power distribution channel, temperature profile charts were the parts of controller chamber. Whereas, components such as the dehumidifier, wet & dry bulbs, main fan & auxiliary fans, damper, duct, sample testing bed were parts of the experimental chamber. The operations of the kiln were scheduled using the Frank Controls software. This software was pre-loaded on the computer system. This computer system was also responsible for collecting the data. This data includes, temperature profiles of wet & dry bulbs and some planted sensors, dehumidifier, fan motor speed, direction of rotation of fan motor, power consumed during the operation, and amount of water extracted from the test sample. Programmable logic controllers (PLC) was used for to maximize the performance and improve productivity. A power grid was installed to receive the electricity from an external source and to provide the constant supply of power to the kiln components. The supply of power was ensured by keeping a power distribution channel between the PLC setup and the power grid. The temperature profile charts or the temperature recording charts were obtained by the temperature recorder. These charts were used to analyze the heat distribution in the experimental chamber. Once the solar wall collected the hot air, it supplied the hot air to the experimental chamber through the regulatory action of the main fan. Where the main fan was responsible to uniformly distribute that hot air in the entire chamber. This uniform distribution of hot air was important for the consistent drying in of the sample. The auxiliary fans were planted to distribute the hot air in the experimental chamber. The sample was placed below the auxiliary fans on a bed for testing sample. The aluminium duct was used to circulate the hot air inside the experimental chamber. This air gets pushed out by the incoming hot air through the gravity exhaust damper.

Figure 1.2	Solar Hybrid Kiln Exterior. Source: Courtesy of Dr. Sita Warren

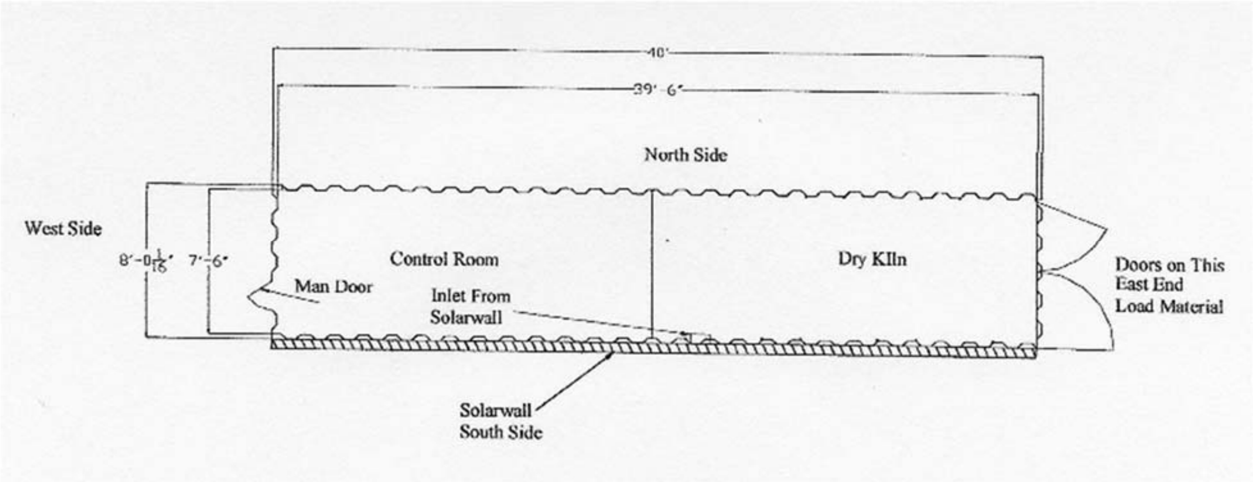


Figure 1.3 Solar Hybrid Kiln Design (Top View). Source: Courtesy Dr. Richard C. Millar

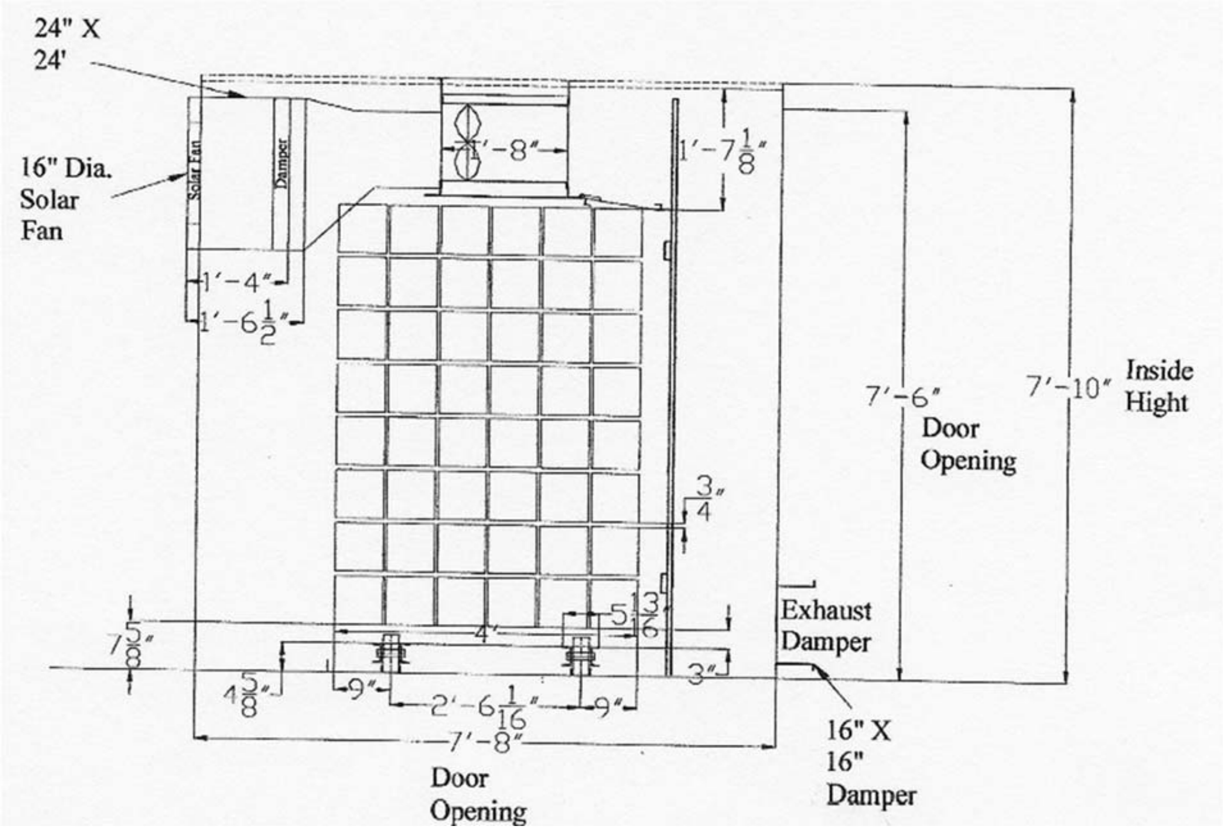


Figure 1.4 Dryer Section Interior (Top View). Source: Courtesy Dr. Richard C. Millar

1.5.2 Test Sample – Biochar

Biochar is a proven carbon rich substance (Downie, Crosky, & Munroe, 2012). The addition of this product to soil improves the endurance of soil and increases soil fertility. Different kind of soils possess different set of physical properties due to different composition of nature of minerals and organic matter (Brady & Weil, 2008). Biochar has significant effects on the texture, surface area, particle-size distribution, structure, density, porosity, and consistency of the soil mixture.

The response of soil changes, towards the water aggregation, water penetration, swelling – shrinking dynamics and permeability, cation retention capacity and reaction towards ambient temperature changes, when biochar is added to it.

1.6 Solar Insolation

Solar Insolation is the measure of direct solar radiation received per unit of a horizontal surface in a given time period. This is commonly known as average irradiance in watts per square meter (W/m2) or kilowatt-hours per square meter per day (kWh/ (m2/day)).

The state of Mississippi was chosen for the study for its hot climate during summertime. The data obtained from Prediction of World Energy Resources (POWER) (NASA, 2018) project dataset Modern Era Retrospective-Analysis for Research and Applications (MERRA-2) shows an average solar insolation of 4.36 kWh/m2/day since the last 22 years. As per National Renewable Energy Labs (NREL) the solar insolation for the months of May, June, July and, August 2018 was found to be 4 to 5 kWh/m2/day, which is congruous to the data presented by POWER project of NASA. Due to this consistency of the solar insolation Starkville, Mississippi was chosen to be the Solar Hybrid Kiln setup location. Figure 1.3 is plotted by using dataset obtained through the

POWER project. Figure 1.3 represents the solar insolation daily from the month of May to August 2018.

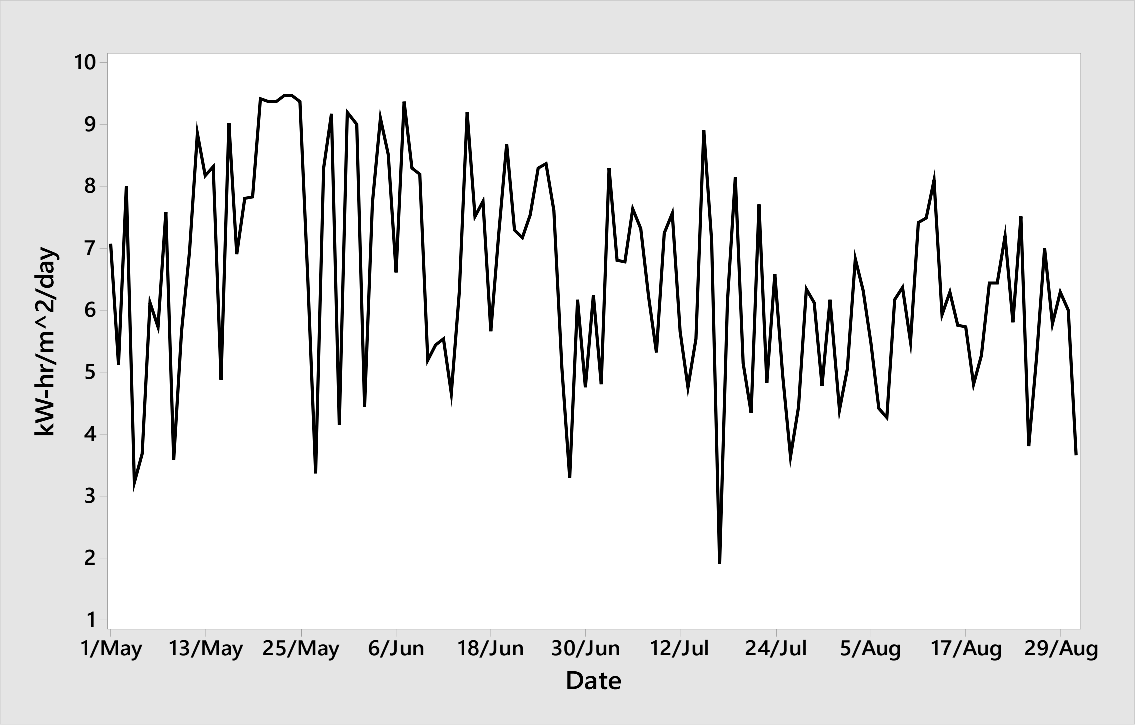


Figure 1.5 Solar Insolation. Source: POWER Data NASA

Chapter 2 entails the implementation of Principal Component Analysis (PCA) and Multiple Linear Regression Analysis (MLRA). Principal Component Analysis (PCA) was conducted on all the recorded variables to obtain the number of principal variables present in the dataset. Multiple Linear Regression Analysis (MLRA) is used in this analysis to formulate the relationships between all the responsible variables and the predictor variables. These relationships were then validated against the testing dataset.

A detailed study of risk analysis is provided in Chapter 3 of the thesis. This chapter also deals with the risk assessment and risk management plans for all the observed risks. Failure mode and effects analysis (FEMA) is used for the identification of all the possible failures. Risk matrix was drawn based on the outputs of FEMA.

CHAPTER II

PERFORMANCE OF SOLAR HYBRID KILN

2.1 Solar Panel by Solar Wall

The air heating system was the supreme for the functioning of the kiln. This was made possible by the using the solar air heating system developed by the Solar Wall. For the maximum sun exposure, this system was mounted on the north facing wall of the kiln. The amount of hot air fed to the kiln is inversely proportional to the drying time. The more hot air sent to the experimental chamber the less would be the drying time i.e. efficient drying process. Air heating system efficiently trapped hot air through the profiled sheets as shown in the image. This entrapment of the hot air helped in raising the overall efficiency of the drying operation/process. The unique geometry and the negative pressure inside the air heating system enclosure prevented the reverse flow of the hot air. This hot air was later passed into the experimental chamber via the main fan unit. The entire system was composed of various sub-systems. Either directly or indirectly all the sub-systems interacted with each other in some way.

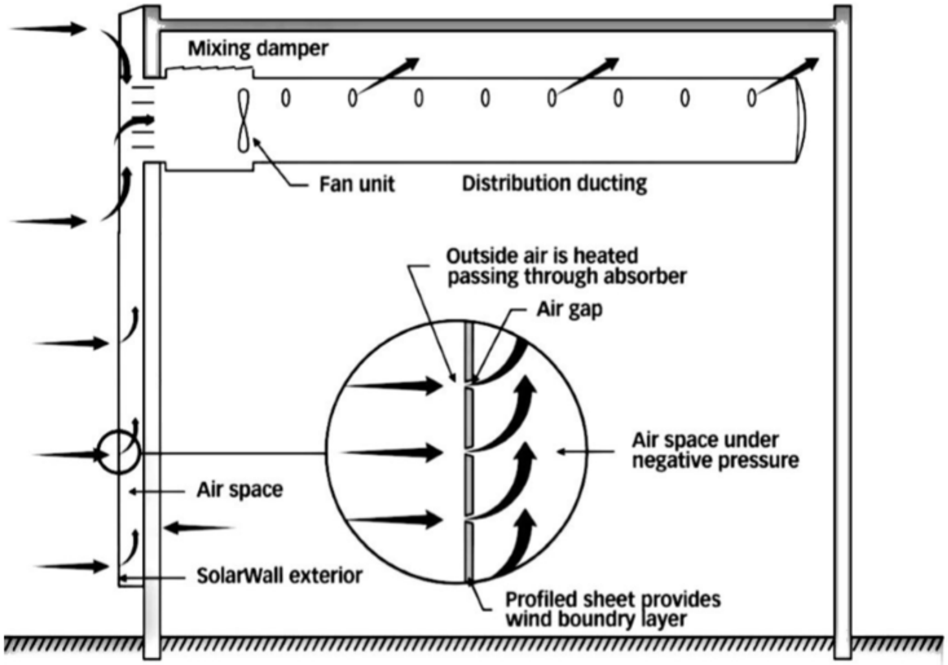


Figure 2.1 Solar Air Heating System. Source: Courtesy of SolarWall by Conserval

2.2 Solar Hybrid Kiln: Major Component Discussion

2.2.1 Container

The container was provided by Steinecker Containerhandel. Following are the dimensions of the container:

Table 2.1 Dimensions of the container

Container	External Dimensions	Internal Dimensions
Length	12,192 (0, -10) mm	12,032 (0, -10) mm
Width	2,438 (0, -5) mm	2,352 (0, -5) mm
Height	2,896 (0, -5) mm	2,698 (0, -5) mm

The entry/exit doors of the container had the width of 2,340 (0, - 5) mm and height of 2,585 (0, -5) mm. The overall internal cubic capacity of the container was 76.4 m^3 (2,700 ft^3). The gross weight of the container was 30,480 kg (67,200 lbs.). The floor of the container was made from hardwood. The thickness of the floor was 28 mm, and moisture content was less than 14%.

2.2.2 Industrial Dehumidifier

Both dehumidifiers were provided by the Ebac (Model: 10264GR-US BD80XE). The height being 34 inches, width 17 inches, depth 26 inches, and the weight 97 lbs. Power required to run one dehumidifier was 0.88 kW. The operating temperature range was 33°F to 95°F. The dehumidifier used R407c type refrigerant with a rotary compressor.

2.2.3 Variable Temperature Controller

Phason's Variable Temperature Controller (Model: VTC – 1D) was installed in the controller chamber the kiln. The temperature of the experimental chamber was adjusted using this device.

2.2.4 Main Fan

A total of four fans were installed at appropriate locations inside the kiln. Out of four, three fans were placed at the near the mixing damper. These three fans were responsible for the uniform distribution of the hot air, passed along by the fourth fan. This fourth fan unit was mounted on the north facing wall of the kiln (refer figure 2.1). The fourth fan was the only passage through which air can travel through the kiln, which made this fan the most critical section of this solar hybrid kiln. This ebmpapst fan had M4E074 – GA motor. This main fan had continuous S1 mode of operation and variable frequency drive. The maximum volt carrying capacity of this fan was 230VAC. Maximum power consumption was 245W. This fan was able to permit 5,800 cubic meter of air flow per hour at 1400 revolutions per minute. The minimum lowest ambient temperature that this fan can handle was -14.08°F.

2.2.5 Temperature measuring device

Infrared thermometer (commonly known as IR thermometer/gun) was used to measure the temperatures of the internal and external wall, and the test sample. Cheerman's DT520 model was used to serve this purpose. This IR gun can detect temperature as low as -58°F and as high as 968°F with the distance spot ratio of 8:1. This gun had 0.95 emissivity.

Components such as mixing baffle, wet & dry bulbs, and gravity exhaust damper were also mounted on the kiln, but without proper identification. It was difficult to get their details. Hence along with these components, some other adjoining components were excluded from this study.

The dehumidifier was responsible for extracting the moisture from the hot air; hence it was an important factor. Insufficient dehumidifier related data gathered due to the short duration of the project. This resulted in lack of thermal energy dataset. This issue will be investigated in further studies over the solar hybrid kiln. Figure 3 represents the relationship between every single component of the kiln. The dehumidifier worked on a constant electrical energy consumption of 0.88kW throughout the study. Solar wall did not require any form of energy to perform its function. Majorly, the total cost of energy was generated by electrical energy consumption of main fan and dehumidifier. Various electrical loads and thermal loads were provided to the solar hybrid kiln especially main fan to obtain the optimum moisture content in the test sample.

2.3 Relationship chart

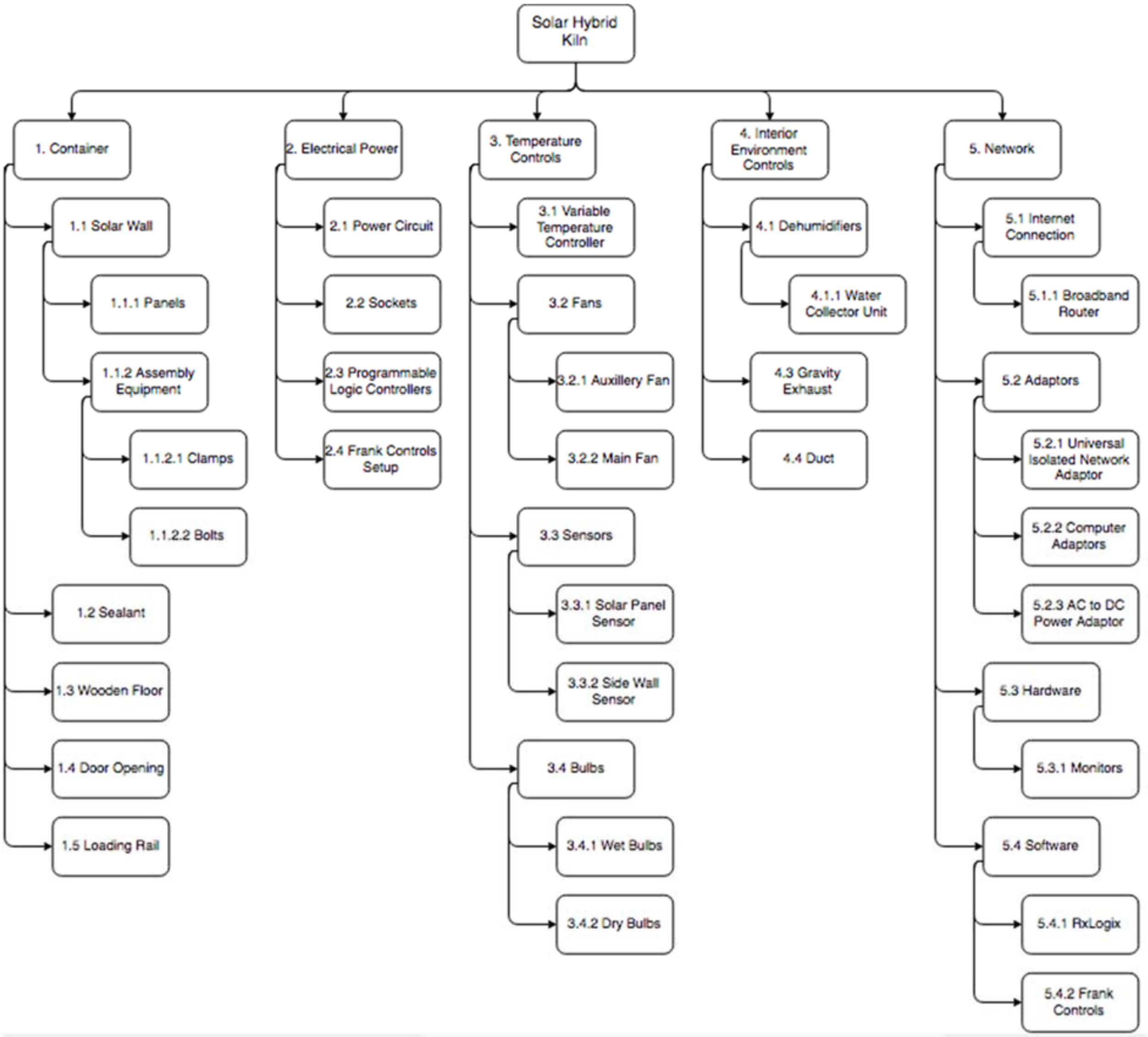


Figure 2.2 Functional Decomposition

2.4 Performance testing/Functioning of Solar Hybrid Kiln

Biochar is a carbon rich substance produced during slow exothermic decomposition of biomass under zero oxygen or low oxygen conditions at temperatures less than or equal to 700°C (Lehmann & Joseph, 2012). Biochar was used as the test sample for all the three tests. The applications of biochar are very diverse, ranging from heat and power production, flue gas cleaning, metallurgical applications, use in agriculture and animal husbandry, building material, to medical use. Biochar can be used for multifaceted applications such as heat and power production, flue gas cleaning, mechanical applications, agricultural applications, medical use and many more. Biochar has been replacing fossil fuels in several of these applications (Weber & Quicker, 2018).

The test sample, i.e. biochar, was directly obtained from the Department of Forest Resources and Environmental Conservation by the courtesy of Dr. Sita Warren and Dr. Todd Mlsna. Following steps were involved on conducting experiment over biochar in the kiln:

- Step 1: Pre-processing of test sample (biochar)

Mississippi State University Department of Chemistry processed the raw biochar test sample. This pre-processing made the biochar rich in chemical properties. Pre-processing of biochar included soaking itself in the specific amount of water (H_2O), depending upon the quantity of biochar. The processed biochar was then sent to the Department of Forestry for further research in the solar hybrid Kiln.

- Step 2: Scheduling (Setting up) the kiln

A drying schedule is a set of temperatures, relative humidity, corresponding equilibrium quantity of the test sample, and water content of test sample. The water content of the test sample changes with the time from the start of drying. Hence a time-based drying schedule was employed to dry the test sample.

- Step 3: Loading the test sample /Settling the test sample over the dedicated space

Once the kiln was set up for drying the test sample, biochar in this case, the test sample was kept over the settling platform. The test sample was laid out in a consistent manner. The thickness of the entire film was also maintained to be consistent. This dedicated platform was placed below the auxiliary fans. The auxiliary fans were used to spread the hot air, coming in from the main fan, over the test sample. Due to this orientation maximum amount of hot air was directly used up by the test sample.

- Step 4: Ensuring experimental standards

Keeping airtight conditions was a necessity to avoid the leakage of hot air into the ambience. This ensured by the solar panels. The panels were mounted on the kiln to create a cavity between itself and the main fan. This is the place where regular ambient air gets heated using the sun rays. Solar panels allowed the ambient air to enter this cavity. Due to no back pressure the ambient air remained trapped into the cavity. Later, this heated air was supplied to the experimental chamber through the main fan.

- Step 5: Checking/regulating/calibrating all the components

The components such as fan motor speed, direction of fan motor rotation, water collecting device, and a few more was required to match the drying schedule. Such calibrations made the drying schedule more effective.

- Step 6: Powering the kiln

After calibrating or regulating all the necessary components, the kiln was powered through an external power source. The power required to run the kiln was 110VAC. The container was oriented with the solar wall side facing due south with no obstruction of the sunlight, which was efficiently adsorbed by the specially coated perforated metal skin of the solar panels. Ambient air is drawn through the hot metal skin by a variable speed fan to adsorb the solar heat.

- Step 7: Regular-interval data and sample collection

The computer system's monitor failed, due to the excessive heat production inside the solar wall cavity. A moderate amount of hot air went into the controller chamber through the temperature sensor mounting holes. This was caused due to the inappropriate dimensions of those holes. The monitor of the computer system was not able to display the temperature profiles of the temperature sensors, wet & dry bulbs, dehumidifier readings, test sample temperature, ambient temperature, water collected and other relevant readings. The entire dataset was gathered manually using an infrared thermometer at equal distance in terms of length. A weighing machine was used to collect same amount of test sample. Both the temperature profiles and the test sample quantity were collected at regular time intervals.

- Step 8: Sample testing

The collected sample was then sent to the Hand Laboratory situated in Mississippi State University Department of Chemistry for further studies. Various tests were performed by lab assistants on the sample in the laboratory to accumulate multiple test results for their studies.

- Step 9: Unloading the test sample

The complete drying of the test sample was followed by unloading the entire batch of test sample. In other words, once the test sample was found to have the minimum moisture content or after complete drying, it was taken out of the drying chamber and sent to the laboratory for further testing.

- Step 10: Shutting off the operation/kiln/schedule

Right after evacuating the kiln, all the electricity driven components were brought to a complete cessation. The functioning of the kiln was stopped for acquiring the maintenance data and recording the changes in the system after a long run of the drying experiment. This helped in identification of the risks associated with all the components.

As per above discussion, it can be inferred that the fan is the only source of hot air supply in the experimental chamber of the kiln. This fan system which was a critical subsystem of the solar hybrid kiln. It is the only sub-system which had greatest impact over the performance of parent system compared to any other sub-system. Hence an intensive study was required to find the optimum fan motor speed and direction of fan motor rotation for predicting the required speed and direction of fan motor rotation given the predictor variables.

2.5 Fan design requirements and the specifications

The fan system serves the most to the entire kiln set-up by allows the hot air through itself into the experimental chamber. This hot air is responsible for fulfilling the sole purpose of the kiln. This fan system design had following specifications:

2.5.1 The Main Fan

- It would adjust the speed of motor rotation and direction of rotation of fan motor because of the variable frequency drive system.
- It was able to control the flow of hot air inside the drying chamber.

- It was mounted 8 ft. above the ground level for better compatibility with the rest of the kiln design system.
- It was able to function on 115V – 60 Hz.

2.5.2 Auxiliary Fans

- All three fans were axial.
- These fans were able to circulate air at a constant rate in the same direction at the same speed.
- They were thermally protected as well as they had moisture protection.

Figure 2.3 represents the schematic diagram of the main fan. This fan was obtained from ebmpapst with a M4E074 – GA motor and variable frequency drive.

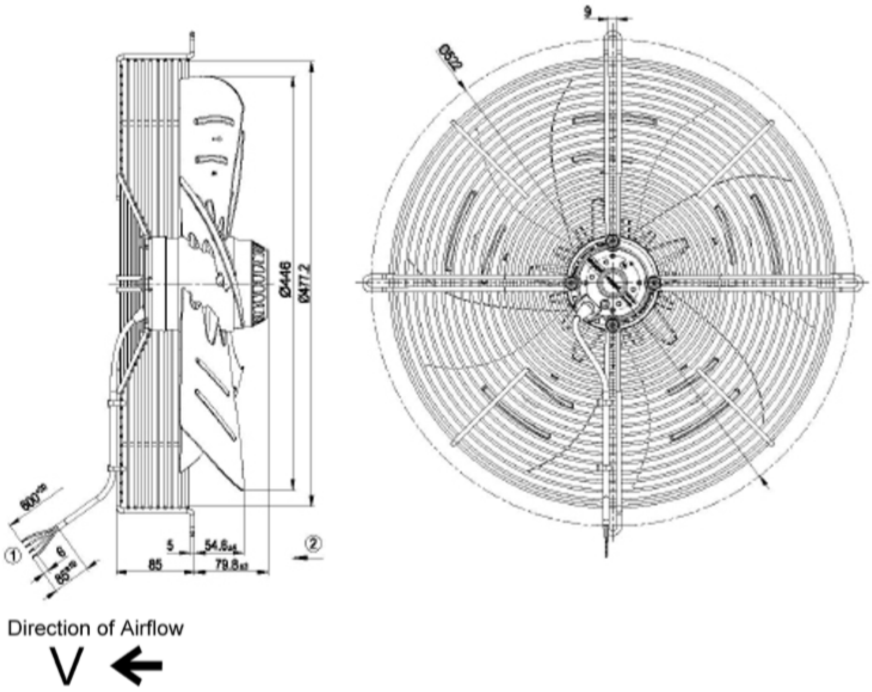


Figure 2.3 Fan Schematic Diagram. Source: Courtesy of ebmpapst

2.5.3 Analysis of Fan System

Choosing the most suitable fan motor speed and direction of fan motor rotation was significant. The fan motor rotation decided the amount of hot air that must be sent into the experimental chamber, whereas the direction of fan motor rotation decided the direction of hot air flow. The two settings for fan motor rotation were either clockwise or anticlockwise. In the clockwise direction, the fan pushed the hot air forward into the experimental chamber at a regulated fan motor speed and vice versa. The entire fan system required 245W (i.e. 0.3284 hp_E), and 230VAC, to function at 1400 RPM. There were a few risk factors associated with this fan system. The functional failure with high potential risk were detected to be electric shock due to wiring failures, fan motor shaft imbalance due to physical impact & sudden changes in operation and overheating due to motor malfunction.

These risks could be eliminated or minimized by turning off and checking the wirings in case of electric shock, turning off and readjusting/calibrating the fan in case of imbalance, and gradually reducing the fan speed/directional changes in case of overheating.

2.5.4 Airflow Data

Solar Hybrid Kiln was a control volume system (i.e. open system). It pulled the air using a fan from solar panel cavity and ejected the utilized air through the gravity exhaust damper channel. This damper was located at the bottom of the north facing wall. The fan was able to permit an air flow of 5,800 m^3/h through itself. That is the fan sent in 1.62 m^3/s whereas, the internal cubic capacity of the container was 76.3 m^3.

2.5.5 Variable Frequency Drive

A type of motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor. The variable frequency drive allows the fan to have several graduations in its speed and bidirectional flow of air. This versatility of VFDs help in the reduction electrical energy consumption, energy costs, improves motor performance, and improves motor life. VFD have multiple names some of them are adjustable speed drive, adjustable frequency drive, variable speed drive, AC drive, and inverter.

Frequency (or hertz) is directly proportional to the speed of the motor i.e. revolutions per minutes (RPMs). VFDs can ramp up or ramp down the frequency and the voltage to meet the requirements of the load on the electric motor.

Benefits of having VFD

- Reduce Energy Consumption and Energy Costs
- Increase Production Through Tighter Process Control
- Extend Equipment Life and Reduce Maintenance.

2.6 Data Acquisition

Three experiments were conducted on biochar with different under different environmental conditions. The entire dataset was collected at regular time intervals. All wall temperature readings were taken at equal distance. The entire dataset is comprised of following factors:

- Temperature profiles
    - Interior and exterior wall of solar hybrid kiln
    - Test Sample (biochar)
    - Ambience

- Fan data
  - Speed of fan
  - Rotation of fan motor
- Power consumption
- Specifications of test sample
  - Water retention capacity and/or water extraction rate
  - The quantity/bulkiness of sample.

It was found that the biochar which was used for this study was stored for a long time. This means it had higher burning point temperature as compared to freshly prepared ones (Zhao, Enders, & Lehmann, 2014). Apparently, paper also has the higher ignition temperature of 451degree Fahrenheit (Lewis, 2003). The Solar Hybrid Kiln was designed and manufactured to generate a maximum of 200-degree Fahrenheit heat inside its experimental chamber. It was concluded that both test samples will be chemically stable at 200-degree Fahrenheit (maximum capacity of the kiln). For these reasons more focus was provided on the physical properties of the test samples rather than chemical properties.

Above-mentioned factors such as fan data, power consumption, and specifications of the test sample could serve as constraints/criteria to predict the drying possibilities of future test samples, considering the similar specifications.

Following variables were used in both the analysis:

- DT1: The absolute temperature differences between internal and external Solar Panel Wall Temperature of the kiln.
- DT2: The absolute temperature differences between internal and external Front Wall Temperature of the kiln.

- DT3: The absolute temperature differences between internal and external Side Wall Temperature of the kiln.
- DT4: The absolute temperature differences between internal and external Rear Wall Temperature of the kiln.
- Sample: The temperature of the test sample.
- Amb: The ambient temperature.
- WE: The amount of water extracted from the test sample.
- Quantity: The amount of test sample quantity.
- FS: The speed of the fan motor.
- FD: The direction of rotation of the fan motor shaft.
- Power: The amount of power supplied to/consumed by the fan.

All the temperature readings were considered in degree Fahrenheit. The temperatures of all the exterior walls are taken from left to right and the temperatures of all the interior walls are taken from right to left. The sample quantity was in pounds (lbs.), power in voltage (VAC), fan motor speed in revolutions per minute (RPMs), water extracted in liters.

Fan motor shaft direction was a binary categorical variable with 0 meaning clockwise rotation of fan motor shaft and 1 meaning anticlockwise rotation of fan motor shaft (from non-drive end).

2.7 Mathematical Analysis

Conventional statistical analysis such as Principle Component Analysis (PCA) and Multiple- Linear Regression Analysis (MLRA) were implemented. PCA was used here as a means of identifying the variable contributing most towards the major principle components. Whereas, MLRA was performed over the recorded data to form a statistically correct prediction model.

2.7.1 Principal Component Analysis

The reduction in the dimensions (variable) of the feature space is called as dimensionality reduction. Dimensionality reduction is performed to find the minimum number of principal variables in a dataset/feature space.

One of the methods of achieving dimensionality reduction is Principal Component Analysis. Principal Component Analysis falls under the feature extraction class of dimensionality reduction. It combines the input variables in a specific way, then drops the "least important" variables while still retaining the most valuable parts of all the variables.

As an added benefit, each of the "new" variables after PCA are all independent of one another. This is a benefit because the assumptions of a linear model require all independent variables to be independent of one another. These "new" variables can now be used to fit a linear regression model.

Principal Component Analysis was conducted on all the variables i.e. on the entire dataset using the Minitab software. Following outcomes were obtained:

Table 2.2 Eigen analysis of the Correlation Matrix – Principal component analysis

	PC1	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalue	4.637	3.278	1.078	0.854	0.689
Proportion	0.422	0.298	0.098	0.078	0.063
Cumulative	0.422	0.72	0.818	0.895	0.958

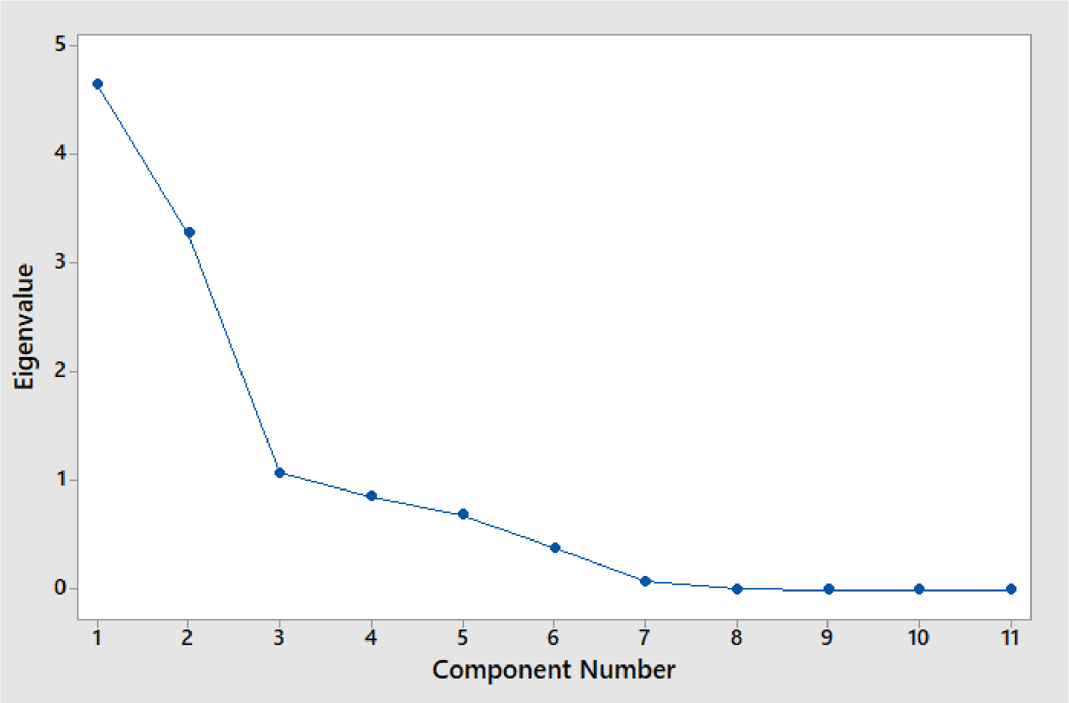


Figure 2.4 Scree Plot of Principal Component Analysis

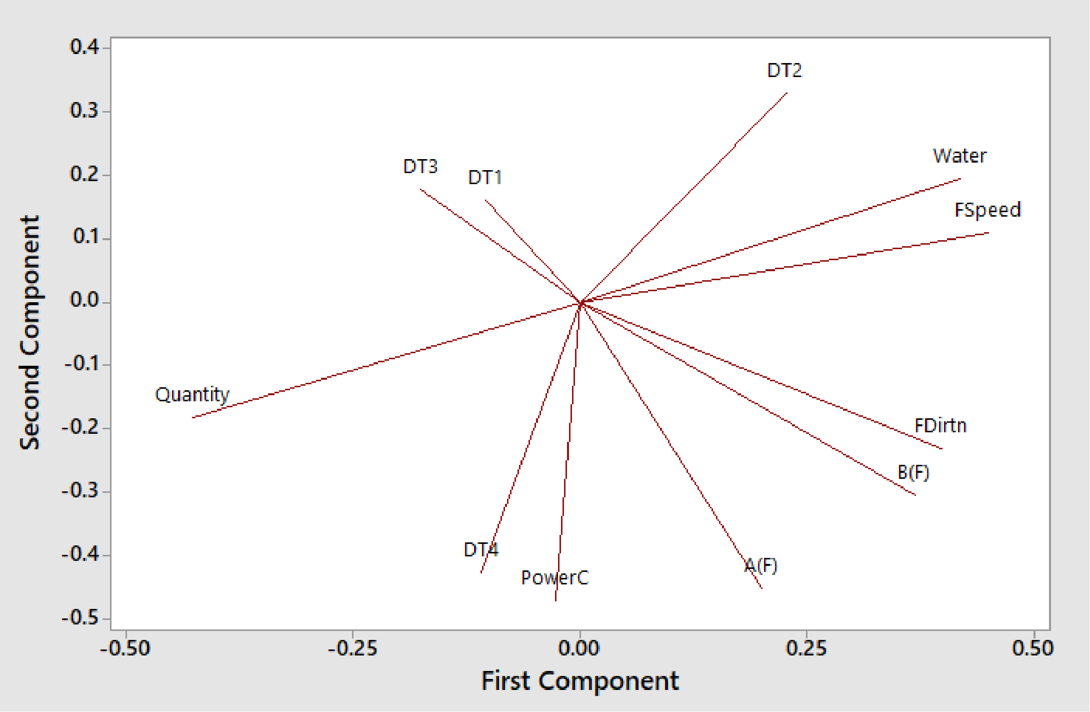


Figure 2.5 Loading Plot of Principal Component Analysis

Scree plot represents the amount of variation captured by each principal component in the dataset. Fig 2.4 has the principal component numbers on the x-axis and the respective eigenvalues on the y-axis. This scree plot has an elbow at component number 3, i.e. there are 3 principal components. These principal components can be crosschecked with Table 2.2 which shows that the eigenvalues of 3 principal components are greater than 1 and they are able to cover 81.8% variance proportion in the dataset on the new feature space.

Loading plots helps in identifying the variables that have major effect on each principal component. The range of loading is from -1 to 1. Where -1 and 1 represents strong influence and 0 indicates weak influence. Evaluation of loadings helps in characterizing the principal components with the variables involved. Fig 2.5 shows that the variables such as Quantity, FSpeed, Water, FDirtn and B(F) have high influence on the first principal component.

From the correlation matrix (refer Appendix) it can be observed that the dataset has 3 principal components.

2.7.2 Multiple - Linear Regression Analysis (MLRA)

MLRA was implemented to find a relationship between the all the above-defined. The variables such as Quantity, FS, FD, and Power were considered as response variables, whereas DT1, DT2, DT3, DT4, sample, Amb and WE were considered as the predictor variables. A response variable (also known as dependent variable) is a variable (often denoted by y) whose value depends on that of another. A predictor variable (also known as independent variable) is used to predict another variable.

The assumptions of MLRA are as follows:

- Linear relationship:

  There must be a linear relationship between the outcome variable and the independent variables. Scatterplots can represent whether a linear or curvilinear relationship exist between the outcome and the variables

- Multivariate normality:

  MLRA assumes that all the residuals are normally distributed.

- No Multi-collinearity:

  MLRA assumes there is very little, or no multi-collinearity exists between the independent variables.

- Homoscedasticity:

  The variance of error terms is similar across the values of the independent variables, this is defined by Homoscedasticity.

Around 85% of data was used to train the MLRA models and the remaining 15% was used to test the validity of the MLRA models.

General Relations

- Sample Quantity (Quantity)

The amount of test sample that can be dried give the specific conditions can be estimated by the predictor variables. The best relation between the response variable and the predictor variable can be obtained using a proper regression analysis. Following is the general relationship between the predictor variables and the response variable Quantity.

Quantity = f (DT1, DT2, DT3, DT4, sample, WE, Amb)

- Fan System

The fan system is responsible for drying the test sample. Hence, it is critical to conduct a more intensive analysis on this system to get more reliable and predictable results. Fan system was chosen to be a response function to get a prediction equation and to obtain a prediction interval. The general equation for fan system can be written as:

Fan motor Speed (FS): FS = f (DT1, DT2, DT3, DT4, sample, WE, Amb)

Fan motor Direction (FD):FD = f (DT1, DT2, DT3, DT4, sample, WE, Amb)

- Power Consumed (Power)

As the study focuses on the fan system, the amount of power required to operate the fan is considered in this analysis. The general relation between the Power response variable and the predictor variables can be defined as:

Power = f (DT1, DT2, DT3, DT4, sample, WE, Amb)

Common Terminologies

- Backward Stepwise Elimination

The method that eliminates candidate variables from the regression model which are non-significant for the model that can perfectly explain the data is a backward elimination method. This method is usually used where the predictor variables are highly intertwined. Stepwise approach effective in reducing the problem of multi-collinearity and number of predictor variables. This elimination method removes the predictor variables with p-vale greater than the accepted significant level (α). In general term, this method removes the least significant predictor variables. This accepted significant level also known as “p-to-remove”. This process continues until only significant variables remain. For this study a significance level (α) of 0.1 was fed into the program in order to remove the insignificant predictor variables.

- Analysis of variance (ANOVA)

T-test is widely used for comparing means of two predictor variables but gets complicated when there are more than two variables. And hence, ANOVA test is used for the comparison of means of more than two predictor variables. A typical ANOVA table contains source of variation in the dataset, degrees of freedom of those sources, mean sum square values produced by those sources, F-value, and P-value.

- Coefficient of Determination (R^2)

The percentage of variation present in the response data that a regression model can explain is measure by the coefficient of determination. This coefficient of determination is commonly referred as R^2- value. R^2 represents the closeness of data to the fitted regression line or R^2 indicates the accuracy of the prediction. In multiple linear regression modeling, R^2 is termed as coefficient of multiple determination for multiple regressions. The range of R^2 is from 0% to 100%. R^2 value of 0% indicates that the model is unable to explain any variability of the data, whereas 100% represents that the model can explain full variability of the data.

- F-value

The ration of two variances is known as F-statistic test. Smaller ratio value or F-value means smaller dispersion of variance in the data around its mean, and less significance of the regression model. It can be defined as:

F = Variation between sample means / Variation within the samples

- Significance Level (α)

The probability of rejecting a null hypothesis is the significance level. This significance level is denoted by alpha (α).

- P-Value

P-Value is the probability that provides evidences which are not in favor of the null hypothesis. P-value can also be termed as probability value or asymptotic significance. Larger p-value means weak evidence against the null hypothesis. Usually, a significance level (α) of 0.05 is used as a cut-off point for p-value evaluation.

2.7.3 MLRA - Training Data Set Results

All the calculations were performed using Minitab 18. Out of 400 data reading, 350 were used for training the regression equations whereas remaining 50 were used to test the viability of the trained regression equations. Following are the outcomes obtained through the training set.

Stepwise backward elimination (with significance level of 0.1) of variables was used to remove the variables. The variables that did not have the accepted P-value were removed from the regression analysis using this process.

- **Quantity**

The coefficient of determination (R^2) for this test was found to be 46.40% for following linear regression equation:

$$\text{Quantity} = 104.60 + 0.395*\text{DT4} - 0.5171*\text{sample} - 0.6581*\text{WE} + 0.695*\text{Amb}$$

Although the obtained R^2 value is not promising the regression equation gave significant results with the acceptable P-values. The plot of predicted fits, prediction intervals and sample quantity for biochar dried in the solar hybrid kiln are shown in fig. 2.6. The predicted fits and the prediction intervals were calculated using regression equation for Quantity.

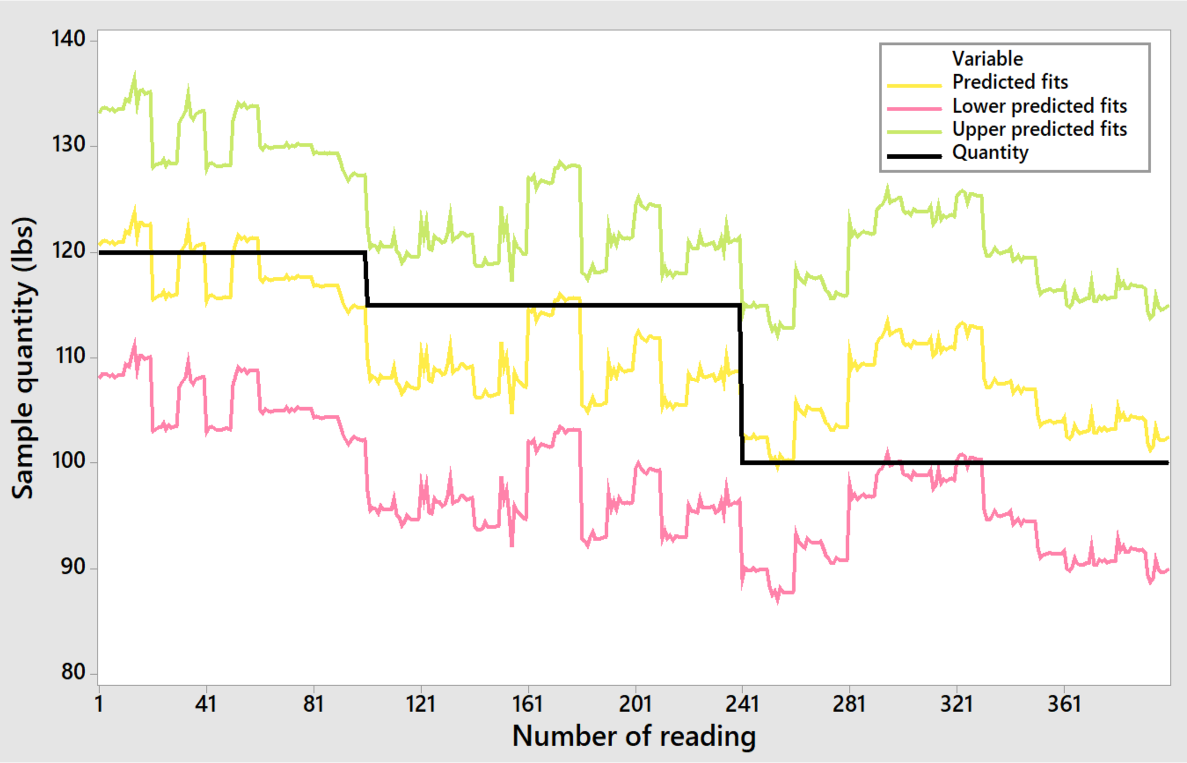


Figure 2.6 Prediction plot vs. training data for sample quantity

- **Fan motor speed**

The coefficient of determination (R^2) for this test was found to be 63.15% for following linear regression equation:

$FS = 1296.9 – 0.1878*(DT1^2) – 0.807*DT2 – 0.2144*(DT3^2) – 11.25*DT4 + 7.258*sample + 8.704*WE – 8.51*Amb$

The results obtained using this regression equation are plotted in figure 2.7. The plot of predicted fits, prediction intervals and fan motor speed are shown in fig. 2.7.

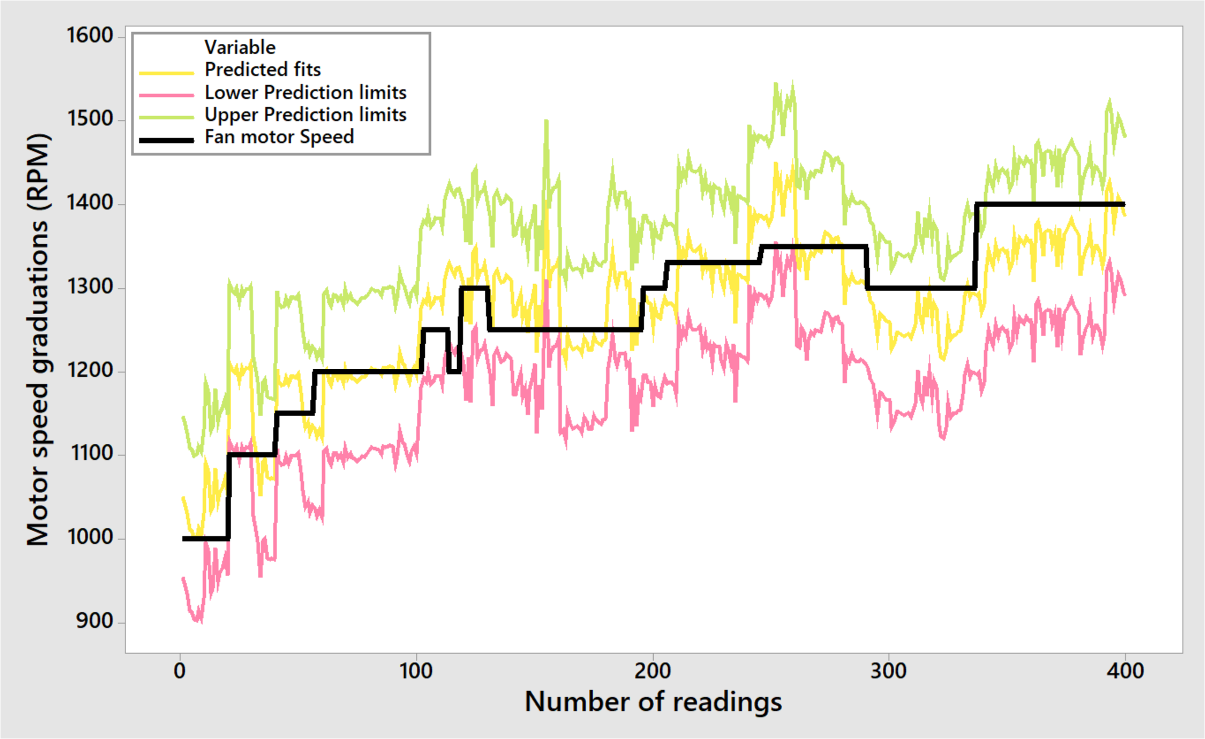


Figure 2.7 Prediction plot vs training data for Fan motor speed

- **Fan motor direction of rotation**

Fan motor direction of rotation was a binary categorical variable with 0 being clockwise and 1 as counter – clockwise direction of rotation of fan motor (from non-drive end). A range of column operations were performed on the fan motor rotation data set to a non-zero value. By taking exponential value and multiplying it with 10, the clockwise value became 10 and the counter – clockwise value became 27.18. This operation gave the best p-value and the coefficient of determination (R^2 = 70.66%). Following regression equation was obtained:

$$10*\text{Exp}\ (FD) = -30.10 - 0.1274*DT2 - 0.03658*(DT3^2) - 0.4119*\text{sample} + 1.4218*WE + 0.9592*\text{Amb}$$

The results obtained using this regression equation are plotted in figure 2.8. The plot of predicted fits, prediction intervals and fan motor direction of rotation are shown.

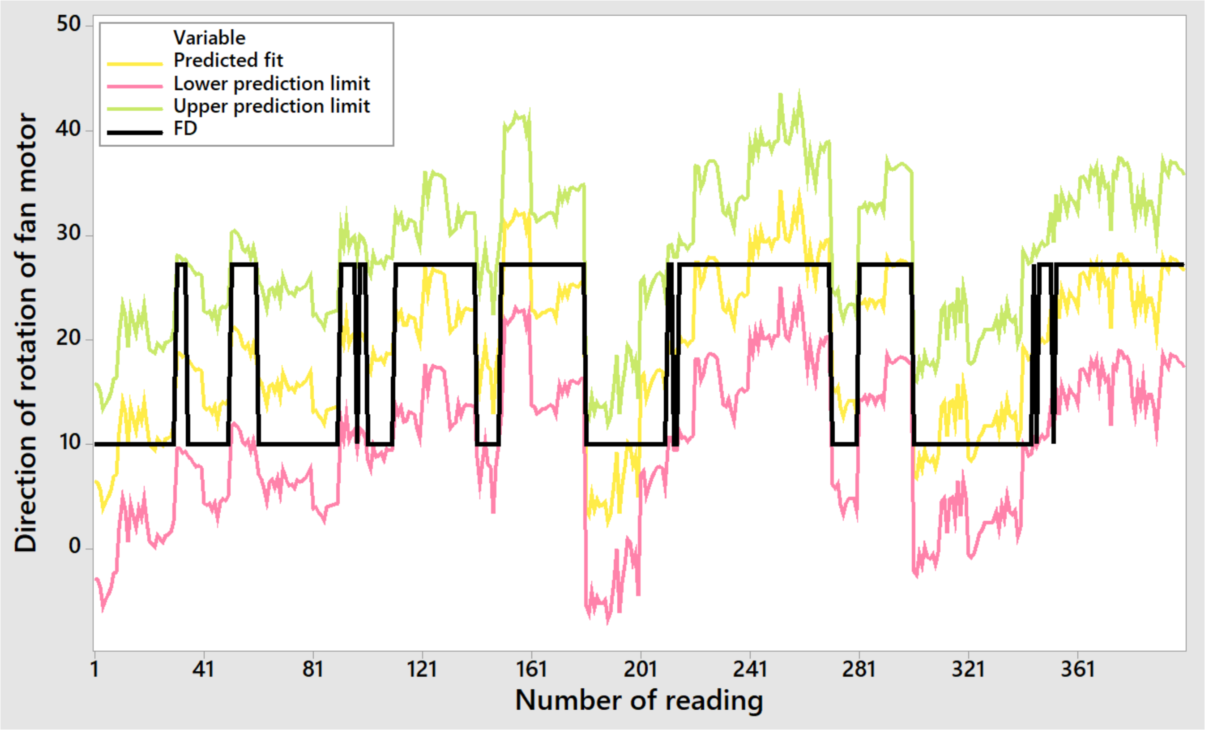


Figure 2.8 Prediction plot vs. training data for direction of rotation of fan motor

- **Power consumption**

The regression equation for power consumption is given below. The R^2 in this is found to be 60.82%.

Power = 215.319 + 0.05056*DT2 + 0.00601*($DT3^2$) + 0.0923*DT4 + 0.07789*sample – 0.3242*WE

The results obtained using this regression equation are plotted in figure 2.9. The plot of predicted fits, prediction intervals and fan motor direction of rotation are shown.

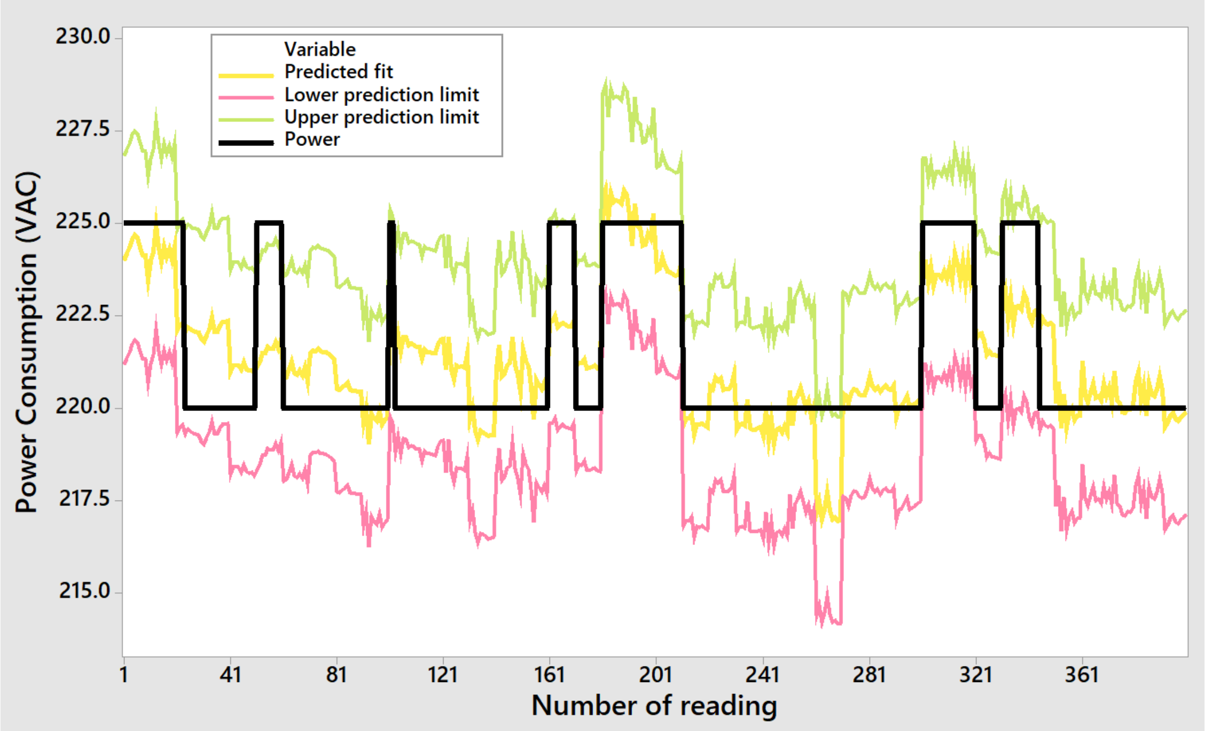


Figure 2.9 Prediction plot vs. training data for power consumption

2.7.4 MLRA - Test Data Set Results

The dataset for 50 data readings was fed to the pre-obtained regression equations. All the outcomes are plotted against the actual data reading.

On all the plots, the predicted values and the original dataset are having closely similar trends, but the exact values. Following are the prediction plots for test sample quantity, fan motor speed, fan motor direction of rotation, and power consumption.

- **Quantity:**

  There are three graduation in the sample quantity data readings which are 120 lbs., 115 lbs. and 100 lbs. The predicted sample quantity is showing the similar trend as expected for all the three test sample quantities.

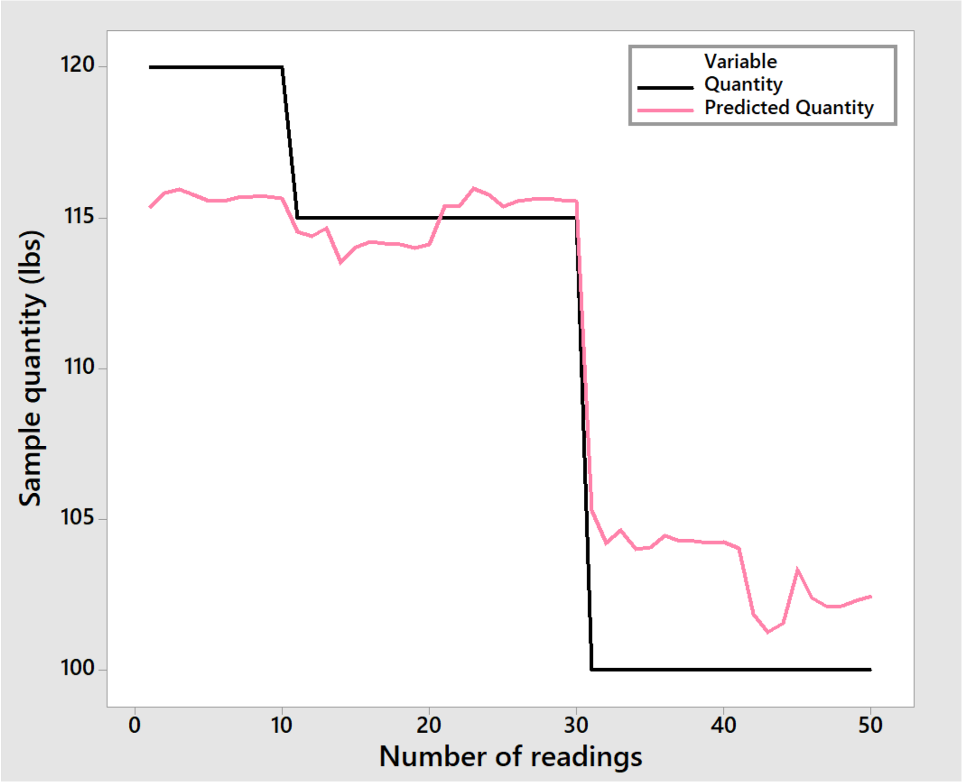


Figure 2.10 Predicted Quantity vs. Quantity

- **Fan motor speed:**

  The fan motor also has three graduation in the dataset at 1150 RPM, 1250 RPM, and 1400 RPM. From the figure it can be inferred that the expected values of the fan speed are quiet close to the actual values.

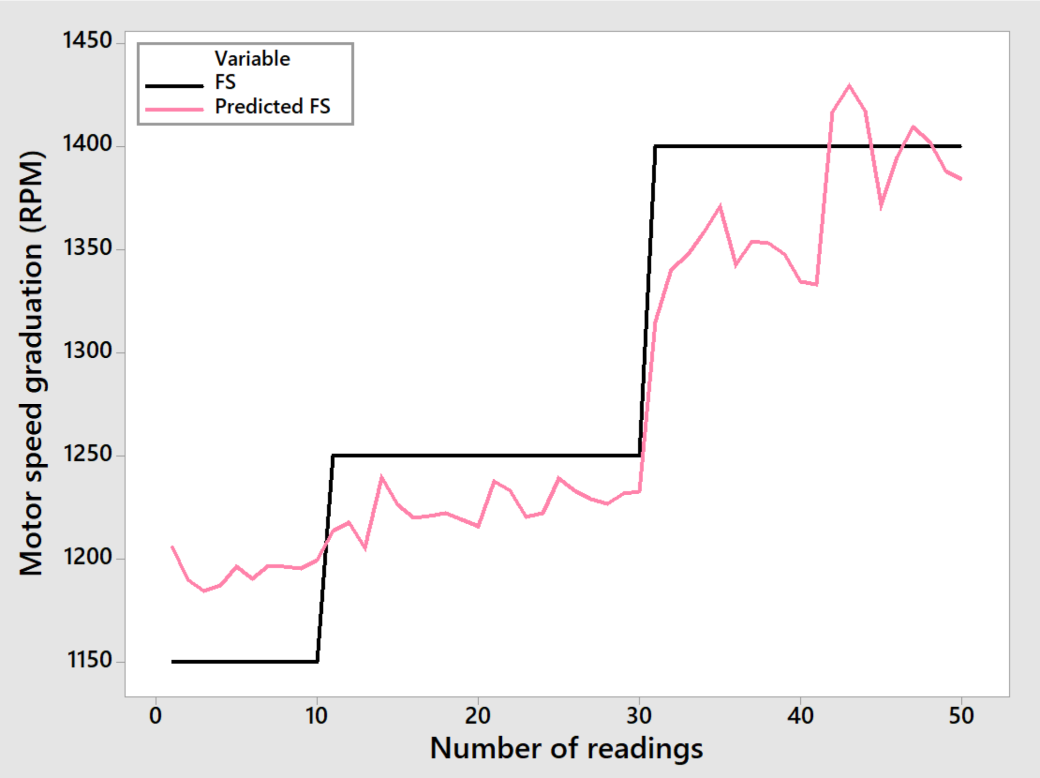


Figure 2.11 Predicted Fan motor speed vs Fan motor speed

- **Fan motor direction of rotation:**

In order to have consistency between the training and the test dataset, the test dataset was also remodeled as per the training dataset. The same column operations were performed to convert the 0 value to 10 and 1 to 27.18. From the following graph it can be observed that the predicted data is wavering around the actual dataset.

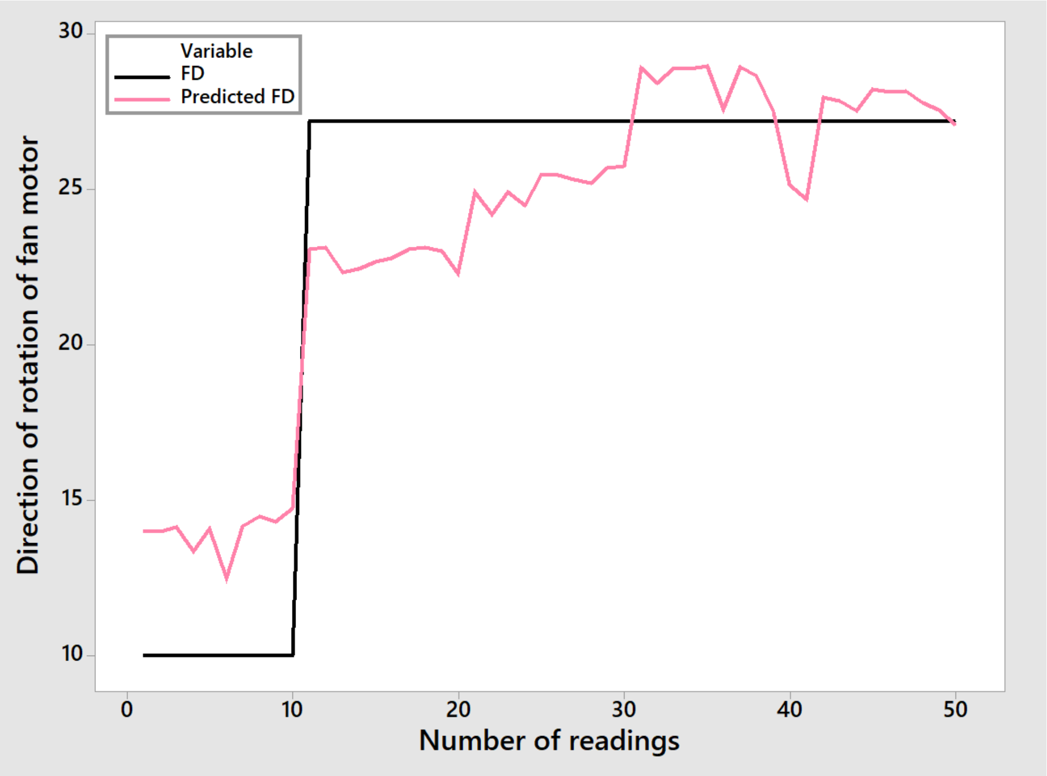


Figure 2.12 Predicted Fan motor direction of rotation vs Fan motor direction of rotation

Since Fan motor direction is a categorical variable, meaning it can either be clockwise or anti – clockwise. Hence, the sensitivity analysis was performed in order to verify the hypothesis. The following ROC curve is plotted between sensitivity (true positive rate) and specificity (false positive rate). The formula used for calculating the sensitivity:

Sensitivity or True Positive Rate = True Positive (TP)/Condition Positive (P)

Specificity of True Negative Rate = True Negative (TN)/Condition Negative (N)

From the plot it can be observed that approximately 84% area is covered by the curve. This area indicates the predictive probability of the direction of rotation of fan motor which is 0.84.

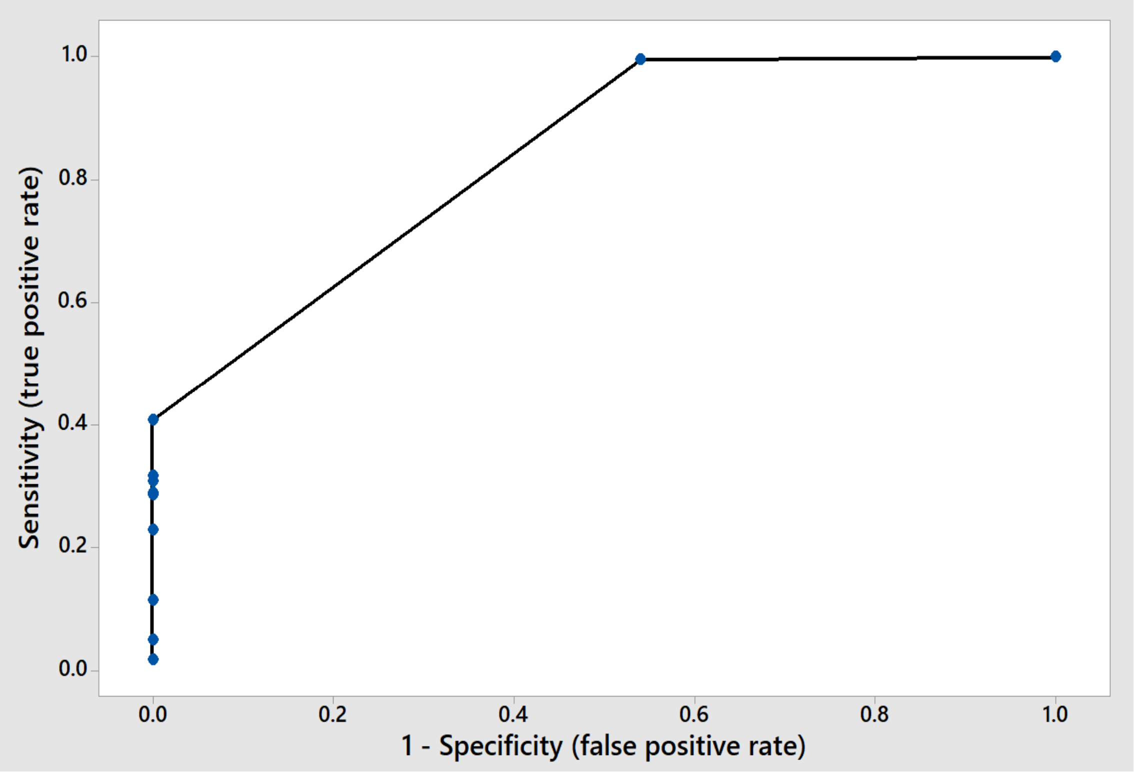


Figure 2.13 Receiver operating characteristic (ROC) curve

- **Power Consumption:**

The power consumed by the fan system have two different values on the graph which are 220 VAC and 225 VAC. The prediction model gave significantly close predicted values for the expected power consumption.

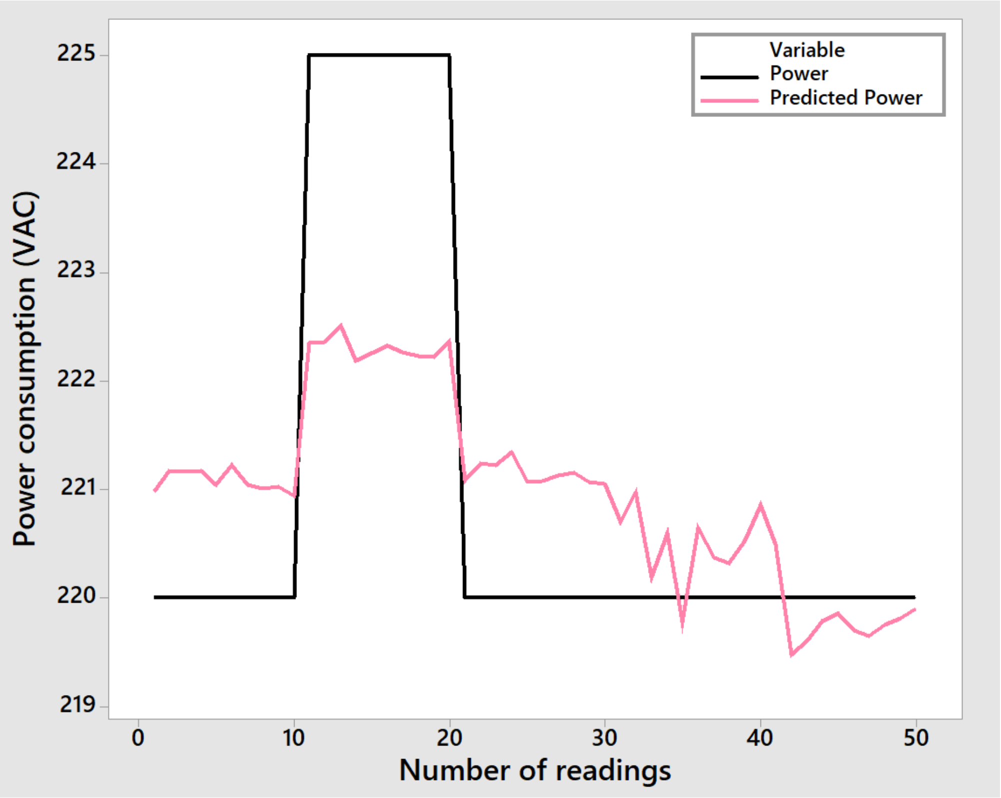


Figure 2.14 Predicted Power consumption vs Power consumption

CHAPTER III

RISK ANALYSIS

3.1 Risk

Risk is generally defined as a measure of the probability and severity of adverse effects (George & Modarres, 2006). Risk is anything that could impact the cost, time or performance of the project. Though risk management and risk assessment are different from each other, some people may indicate risk assessment as risk management ((Yakov, 2018) (Hossain and Jaradat, 2016; Hossain et al., 2019). In order to assess the risk, there is always a need to deploy a "systemic approach" (Hossain and Jaradat, 2018, Hossain et al., 2019))

3.1.1 Risk Assessment and Risk Management

Risk assessment is performed by finding answers to the triple questions which are what can go wrong? How likely is this to happen? What are the consequences? The answers to these sorts of questions greatly assist in identifying, measuring, quantifying, and evaluating risks and their related consequences and impacts.

The process of finding answers to the questions such as what can be done. What options are available and what are their associated trade-offs in terms? What are the impacts of current management decisions on upcoming options? Lead to the risk management side of the risk analysis. Apart from traditional technique, there are different kinds of techniques- namely systems thinking, simulation, optimization, financial analysis, total quality management also can be employed to assess the risk (Hossain et al., 2013; Nur et al., 2016; Quddus et al., 2017; Hossain et al., 2017; Hossain and Jaradat, 2018; Nagahisarchoghaei, 2018; Nagahi et al., 2018; 2019).

3.1.2 Failure modes and effects analysis (FMEA)

FMEA is a systematic approach developed by U.S. military in 1940s. This is used to identify all the possible failures in a design, a manufacturing or assembly process, or a product or service (Jensen, 2007).

FMEA is also known as potential failure modes and effects analysis; failure modes, effects and criticality analysis (FMECA) (Carbone & Tippett, 2004). On breaking down the term:

- **Failure modes**

Any potential or actual error or defect that affect the project/program is a failure and the ways in which something might fail are the modes of those failures.

- **Effects analysis**

Failures are always followed by the consequences or impacts. The study of consequences occurred due to those failures can be termed as effects analysis.

The purpose of the FMEA is to take suitable actions to eliminate, reduce or to shun the expected failures. Risk priority number (RPN) is calculated for each risk. This RPN is usually assigned after evaluating seriousness of the consequences, their frequency of occurrence and easiness in their detectability. Documentation in FMEA involves documents for current knowledge and actions about the risks of failures. FMEA document can also be used for continuous improvement purposes.

3.1.3 Risk Matrix

Risk matrix is a structured approach that identifies which risks are more critical to a program or a product and provides a methodology to assess the potential impacts of a risk, or a set of risks, across life of the program or the product. This approach was devised by the acquisition reengineering team at the Air Force Electronic Systems Centre (ESC) in 1995.

Steps involved in forming a risk matrix are:

- Identification of risk or set of risks
- Assessing the potential impacts of those risks on the program or the product. The impacts could be critical, serious, moderate, minor, and negligible.
- Hypothesizing the probability that the risk (s) will occur. Here, the probability range of 0 – 10% indicate very unlikely to occur, 11 – 40% indicate unlikely to occur, 41 – 60% indicate may occur about half of the time, 61 – 90% indicate likely to occur, and 91 – 100% indicate very likely to occur.
- Rating the risk. This can be done by using table 3.1
- Documenting an action plan to manage or mitigate the risk

Table 3.1 Risk rating scale

S. No.	Percentage	Negligible	Minor	Moderate	Serious	Critical
1	0 – 10%	Low	Low	Low	Medium	Medium
2	11 – 40%	Low	Low	Medium	Medium	High
3	41 – 60 %	Low	Medium	Medium	Medium	High
4	61 – 90%	Medium	Medium	Medium	Medium	High
5	91 – 100%	Medium	High	High	High	High

3.2 Risk Data Chart

Table 4 below displays the risk data chart, which details the major aspects to the risk analysis of the project. This includes the component considered, its functionality, possible functional risks or failures, a failure identification number, failure cause, and failure effect on the overall system as well as individual subsystem components. The risk data sheet also details a short risk response plan based on methods of transfer, mitigate, avoid, and accept.

Table 3.2 Component Risks, Causes, Effects and Response Plans

Component	**Comp. Function**	**Functional Failure**	**Failure ID**	**Failure Cause**	**Failure Effect**	**Risk Response Plan**
Solar Panel	Solar panel assembly foams a duct and entraps the hot air	Dents/Holes	1.1	Natural weathering, vandalism	New panels may need to be purchased	Use hammer for dents and sealant for small holes
		Improper Alignment	1.2	Misinformed or improperly trained personnel	Hot air may not be captured appropriately and efficiently	Prepare a stepwise assembly/ dismantling manual
		Inappropriate Sealing	1.3	Sealing may be inadequate strength, insufficient amount assumed	Hot air may not be captured appropriately and efficiently	Ensure double coat of sealant by overlapping
Clamps	Help secure solar panels to container exterior wall	Improper Assembly	2.1	Wrong dimensions/ components	Reassembly required postponing project	Designate easy to understand markings and codes for each component part
Bolts	Threaded fasteners used to secure solar panels on the container wall	Improper Screwing	3.1	Wrong dimensions/ components	New components needed. Additional costs/time	Clearly check hole alignment and other sub-assembly parts

Table 3.2 (continued)

Component	**Comp. Function**	**Functional Failure**	**Failure ID**	**Failure Cause**	**Failure Effect**	**Risk Response Plan**
Temp. Recorder Charts	Record all temperature data from interior and exterior walls	Misplacement	4.1	Mishandling	Redo experiment. Postponing subsequent activities	Make soft copies and store properly
Sockets	Electrical devices used to connect devices into power source	Overheating	5.1	Wiring errors	Rewire devices	Turn off main power and check wiring occasionally
Water Flow Indicator	Visual indicator of water flow through clear polystyrene housing	Indicator Error	6.1	Calibration error	Recalibration required. Possibly new indicator purchase	Remove sludge and check for proper connections
AC to DC Power Adaptor	Convert AC to DC	Electric Shock	7.1	Wiring errors	Lower electric yield	See adaptor specifications to avoid overload
		Fire/Explosion	7.2	Mishandling	New adaptor needed	Accept risk (unlikely)
Broadband Router	Provide internet to the computer for the programs required for the PLC	Slow Speed	8.1	Bad connection	Insufficient speed for program functions	Accept temporarily in case of environmental factors. Purchase higher speed device
		Router Setup Access	8.2	Improper preparation or budget	Obtain proper access	Utilize user's manual or technician
Fans	Circulate hot air inside the kiln	Electric Shock	9.1	Wiring errors	Rewiring required	Turn off and check wiring
		Imbalance	9.2	Fan shifted by physical impact	Improper cooling	Turn off and readjust
		Overheating	9.3	Physical fan malfunction	Reset fan	Reduce speed/direction changes

Table 3.2 (continued)

Component	**Comp. Function**	**Functional Failure**	**Failure ID**	**Failure Cause**	**Failure Effect**	**Risk Response Plan**
Mobile Dehumidifier	Maintain suitable warm temperature during lack of hot air from the main fan while also drying moist air present inside the kiln	Unit Inoperative	10.1	Electricity outage	New unit must be purchased	Check wiring and all connections
		Insufficient Airflow	10.2	Low quality component or blockage	Moist air can cause damage to container and other devices	Accept because airflow depends on main fan
		Insufficient Water Extraction	10.3	Unit malfunction	Material not dried sufficiently	Turn off and check air compressor for dirt or sludge
		Excessive Vibrations	10.4	Overuse or improper electrical input	Provide additional electrical input	Turn off and check orientation, dirt, sludge
		Tube Blockage	10.5	Lack of maintenance	Moist air inside kiln not properly disposed	Remove sludge, replace in case of dents
Compressor	Mechanical device that increases pressure of gas by reducing volume	Pressure Build-up	11.1	Lack of maintenance	Maintenance Required	Replace intake valve
		Lack of Lubrication	11.2	Lack of maintenance	Maintenance Required	Apply lubricant
		Obstructed Air Filters	11.3	Lack of maintenance	Maintenance Required	Clean timely
		Overheating	11.4	Fans/dehumidifier malfunction	Additional time needed for cleaning/rewiring	Turn off and check for lubrication, clogging, and wiring
Variable Temp. Controller	Automatically control the temperature of the kiln chamber by adjusting speed of fans	Wiring Issues	12.1	Excessive electrical use	Rewire devices	Utilize user's manual
		Power-up Issues	12.2	Power outage or short circuit	Repower system	Check power source and all links
		Time Consuming	12.3	Insufficient training	Project time rundown	Utilize user's manual

Table 3.2 (continued)

Component	**Comp. Function**	**Functional Failure**	**Failure ID**	**Failure Cause**	**Failure Effect**	**Risk Response Plan**
Adaptors	Adapts hardware/electronic interface to another hardware/electronic interface	Connection/ Wiring	13.1	Excessive electrical use	Rewire devices	Accept
		Time Consuming	13.2	Insufficient training	Project time rundown	Utilize user's manual
Sensors	Measure temperatures along the outside wall as well as the ambient temperature	Improper Data Reading	14.1	Sensor malfunction	Delta T measurements incorrect, causing false data analysis	Check sensor for damage, check wiring and connections to intermediate devices
Computer	Obtain information regarding controlling actions, schedules, programming, and data	Software Connection with Setup	15.1	Improper network connection	Reboot network system	Check wiring, intermediate devices, and internet
		Data Reading Display	15.2	Excessive working temperature	Repurchase display if electronics malfunction	Maintain appropriate working temperature
		Time Consuming	15.3	Wiring errors	Project time rundown	Prepare stepwise description of process
Assembly	Assemble kiln/solar panels	Broken/Damaged Parts	16.1	Mishandling	Project time rundown	Replace
Power Grid	Supply flow of electricity throughout various components of the kiln	Power-up issues	17.1	Electricity outage	Fan and other components will not receive power	Check all connections
Shipping Container	Container houses the entire system with the solar panels and main fan attached to the south wall. The interior is split into the kiln chamber and the controller chamber.	Dents	18.1	Natural weathering, vandalism	Misalignment of solar panels/clamps	Use hammer for dents
		Holes	18.2	Natural weathering, vandalism	Increased rate of entrapped heat dissipation	Use sealant for small holes
		Loss of Epoxy	18.3	Inadequate epoxy strength	Reduction of chamber's heat retaining capacity	Reapply epoxy and/or obtain higher strength epoxy
		Rusted Interior	18.4	Improper moisture outtake	Strength capacity reduction	Check dehumidifier

Table 3.2 (continued)

Component	Comp. Function	Functional Failure	Failure ID	Failure Cause	Failure Effect	Risk Response Plan
Wooden Floor	Interior base of shipping container	Physical Damage	19.1	Wood could rot or break from excessive weight	Decrease ability to roll material into chamber	Check floor for damage often and ensure proper weight distribution
		Heat Consumption	19.2	Some materials can be good conductor of heat	Wooden floor consuming heat and transmitting it to the ground	Need for additional proper insolation material

3.3 Failure modes and effects analysis

The failure modes and effects analysis (FMEA) is a quantitative representation of individual risks used to score and rank identified risks based on a 1-10 scoring system for three criteria: severity, likelihood of occurrence, and ability to detect. These scores are multiplied together to obtain a risk priority number (RPN), which are then ranked. Higher ranked risks are to be evaluated closer and in more detail because of their higher possible effects on the system (Ben-Daya, 2009). Table 5 below displays the scores and corresponding RPN's and rank for each failure mode.

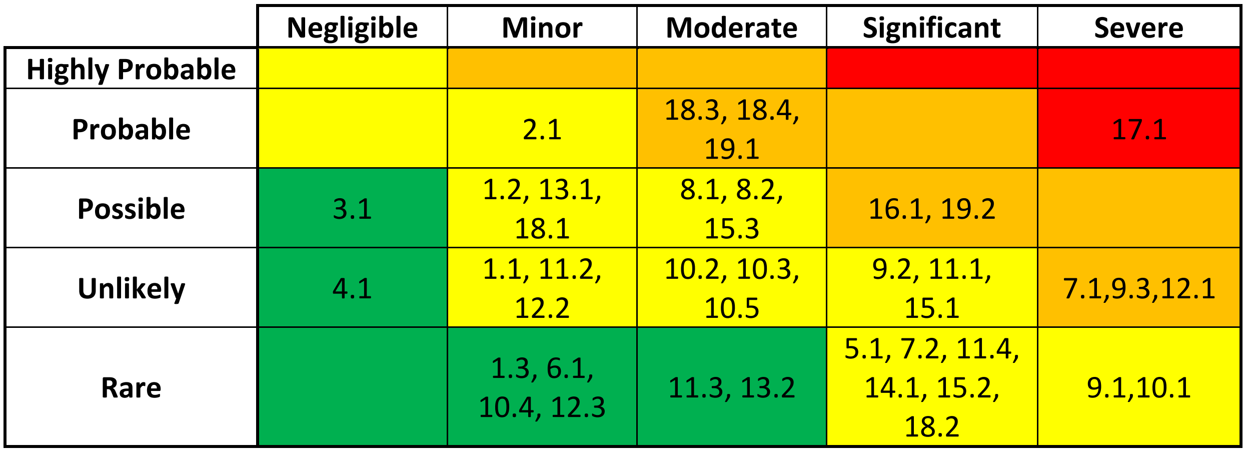
Table 3.3 Failure Modes and Effects Analysis Ranks

Failure ID	Severity	Occurrence	Detection	RPN	Rank
1.1	4	3	1	12	39
1.2	3	5	1	15	38
1.3	4	2	6	48	24
2.1	4	7	1	28	30
3.1	2	5	7	70	16
4.1	1	3	4	12	39
5.1	7	2	5	70	16
6.1	4	2	8	64	18
7.1	10	3	2	60	22
7.2	7	1	3	21	35
8.1	5	6	1	30	28
8.2	5	5	1	25	34
9.1	10	1	2	20	36
9.2	7	4	1	28	30
9.3	9	3	1	27	33
10.1	10	1	1	10	41
10.2	6	3	4	72	14
10.3	6	3	4	72	14
10.4	4	2	2	16	37
10.5	6	4	4	96	8
11.1	7	3	5	105	6
11.2	4	4	4	64	18
11.3	6	2	4	48	24
11.4	8	2	6	96	8
12.1	10	4	2	80	13
12.2	4	3	5	60	22
12.3	3	2	5	30	28
13.1	3	6	2	36	26
13.2	6	2	7	84	11
14.1	8	1	8	64	18
15.1	7	3	3	63	21
15.2	7	2	2	28	30
15.3	6	6	6	216	2
16.1	7	5	1	35	27
17.1	10	8	2	160	4
18.1	3	5	7	105	6
18.2	7	2	8	112	5
18.3	6	7	2	84	11
18.4	6	8	2	96	8
19.1	5	7	5	175	3
19.2	8	6	8	384	1

3.4 Risk Matrix

Risk matrices use the severity and likelihood scores from the FMEA to visually represent the level of hazard to the system associated to each individual risk. The cells in the matrix presented in figure 6 are color coded by the following:

Table 3.4 Risk Matrix for the observed risks



	Negligible	Minor	Moderate	Significant	Severe
Highly Probable					
Probable		2.1	18.3, 18.4, 19.1		17.1
Possible	3.1	1.2, 13.1, 18.1	8.1, 8.2, 15.3	16.1, 19.2	
Unlikely	4.1	1.1, 11.2, 12.2	10.2, 10.3, 10.5	9.2, 11.1, 15.1	7.1,9.3,12.1
Rare		1.3, 6.1, 10.4, 12.3	11.3, 13.2	5.1, 7.2, 11.4, 14.1, 15.2, 18.2	9.1,10.1

Green: Negligible

Yellow: Marginal

Orange: Critical

Red: Disastrous

CHAPTER IV

CONCLUSION AND FUTURE WORK

4.1 Conclusion

The thesis is focused on the usage of mathematical operations to obtain the optimum criterion required for drying purposes. First, the factors with significant impact on the drying operations were identified out of the observed factors.

Principal Component Analysis (PCA) was employed to find the principal components within the observed dataset. This PCA was conducted using Minitab 18^R. Multiple Linear Regression Analysis was performed to form the prediction intervals and the regression equations. The predicted intervals were plotted against the observed data in the training and testing phases of the analysis. A comprehensive risk analysis study showed the risks associated to all the 70 observed components of the system.

All the mathematical analysis was performed on the Minitab 18^R platform. PCA showcased that there are 3 significant factors which can explain the dataset. The prediction intervals, fits and analytic models obtained through MLRA gave acceptable results (refer all MLRA figures). After identifying the potential risks, risk response plans were provided (refer table 3.2).

4.2 Future Work

All the plots and the results obtained displays significance. Since only 11 factors were observed and used for the analysis, the prediction interval is broader. This prediction interval can be made thinner by exploring more variables/increasing the dataset related to dehumidifier and test sample (grain size and water retention capacity).

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APPENDIX A

MATHEMATICAL ANALYSIS TABLES WITH DATASET

A.1 Principal Component Analysis:

Table A.1 Principal component analysis, eigenvectors

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
DT1	-0.103	0.162	-0.727	0.457	-0.329	0.328	0.093	0.018	0	0	0
DT2	0.227	0.329	-0.068	0.076	0.687	0.416	-0.194	-0.384	0	0	0
DT3	-0.175	0.177	-0.252	-0.859	-0.14	0.332	0.079	-0.008	0	0	0
DT4	-0.108	-0.427	-0.473	-0.135	0.194	-0.3	-0.661	-0.017	0	0	0
B(F)	0.369	-0.303	-0.132	-0.09	-0.197	-0.139	0.27	-0.676	0.083	-0.297	0.251
A(F)	0.201	-0.451	0.167	0.016	-0.239	0.439	-0.129	-0.181	-0.137	0.489	-0.413
Water	0.42	0.195	-0.164	-0.086	-0.017	-0.244	0.043	0.112	-0.793	-0.067	-0.209
Quantity	-0.426	-0.181	0.156	0.084	0.019	0.221	-0.033	-0.128	-0.564	0.061	0.605
FSpeed	0.45	0.109	-0.114	-0.073	-0.032	-0.102	-0.016	0.206	0.158	0.617	0.554
FDirtn	0.398	-0.23	0.102	-0.004	-0.074	0.43	-0.217	0.464	0.045	-0.527	0.212

A.2 Multiple Linear Regression Analysis: Final ANOVA Tables

Table A.2 Sample quantity ANOVA table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	13676.2	3419.06	85.48	0
DT4	1	544.4	544.41	13.61	0
sample	1	3931.4	3931.41	98.29	0
WE	1	3424.2	3424.16	85.61	0
Amb	1	1797.8	1797.8	44.95	0
Error	395	15798.8	40		
Total	399	29475			

Table A.3 Fan motor speed ANOVA table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	7	3355660	479380	95.98	0
DT1	1	22845	22845	4.57	0.033
DT2	1	35692	35692	7.15	0.008
DT3	1	41319	41319	8.27	0.004
DT4	1	356763	356763	71.43	0
sample	1	700431	700431	140.24	0
WE	1	554646	554646	111.05	0
Amb	1	240239	240239	48.1	0
Error	392	1957840	4994		
Total	399	5313500			

Table A.4 Fan motor direction of rotation ANOVA table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	20728.5	4145.7	189.77	0
DT2	1	895.3	895.3	40.98	0
DT3	1	1434	1434	65.64	0
sample	1	2333.9	2333.9	106.83	0
WE	1	15248	15248	697.97	0
Amb	1	3215.3	3215.3	147.18	0
Error	394	8607.5	21.8		
Total	399	29336			

Table A.5 Power consumption ANOVA table

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Regression	5	1205.8	241.16	122.34	0
DT2	1	157.52	157.522	79.91	0
DT3	1	36.61	36.607	18.57	0
DT4	1	29.43	29.433	14.93	0
sample	1	297.08	297.083	150.71	0
WE	1	856.19	856.189	434.36	0
Error	394	776.64	1.971		
Total	399	1982.44			

A.3 Dataset:

Table A.6 Training Dataset

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
960.40	0.20	432.18	10.50	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
688.90	2.20	426.32	11.50	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
1144.90	2.80	462.08	11.60	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
1768.90	2.30	557.78	11.40	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
2310.40	10.50	468.18	11.00	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
2856.10	9.50	450.00	11.40	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
3459.60	6.20	438.08	10.90	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
3204.10	4.81	375.38	11.19	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
3648.10	5.47	364.50	11.28	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
3880.90	5.94	137.78	11.25	86.10	82.00	0.92	120.00	1000.00	10.00	225.00
52.90	16.00	137.78	8.10	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
462.40	19.60	169.28	7.70	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
462.40	18.10	353.78	10.40	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
313.60	10.70	208.08	12.70	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
547.60	10.20	273.78	6.80	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
532.90	7.50	348.48	10.10	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
624.10	7.70	250.88	10.20	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
313.60	12.83	259.92	9.43	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
240.10	12.38	165.62	9.62	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
372.10	11.34	292.82	9.89	89.80	88.00	0.92	120.00	1000.00	10.00	225.00
313.60	4.50	103.68	0.00	83.90	79.00	0.92	120.00	1000.00	10.00	225.00
336.40	6.60	103.68	0.50	83.90	79.00	0.92	120.00	1000.00	10.00	225.00
280.90	7.00	112.50	0.80	83.90	79.00	0.92	120.00	1000.00	10.00	225.00
396.90	4.30	76.88	0.80	83.90	79.00	0.92	120.00	1000.00	10.00	220.00
490.00	3.00	103.68	2.00	83.90	79.00	0.92	120.00	1000.00	10.00	220.00
476.10	4.80	106.58	0.30	83.90	79.00	0.92	120.00	1000.00	10.00	220.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
462.40	3.30	81.92	1.40	83.90	79.00	0.92	120.00	1000.00	10.00	220.00
448.90	4.79	67.28	0.83	83.90	79.00	0.92	120.00	1000.00	10.00	220.00
504.10	4.83	56.18	0.95	83.90	79.00	0.92	120.00	1000.00	10.00	220.00
608.40	4.57	1.62	1.01	83.90	79.00	0.92	120.00	1000.00	10.00	220.00
960.40	3.80	42.32	8.70	84.30	83.00	3.71	120.00	1000.00	27.18	220.00
1210.00	5.50	33.62	10.00	84.30	83.00	3.71	120.00	1000.00	27.18	220.00
1040.40	4.20	62.72	11.30	84.30	83.00	3.71	120.00	1000.00	27.18	220.00
1368.90	4.30	54.08	15.10	84.30	83.00	3.71	120.00	1000.00	27.18	220.00
1512.90	4.30	76.88	10.30	84.30	83.00	3.71	120.00	1000.00	10.00	220.00
1716.10	4.80	89.78	9.50	84.30	83.00	3.71	120.00	1000.00	10.00	220.00
2131.60	4.48	115.52	10.82	84.30	83.00	3.71	120.00	1150.00	10.00	220.00
1876.90	4.60	131.22	11.17	84.30	83.00	3.71	120.00	1150.00	10.00	220.00
1716.10	4.45	128.00	11.36	84.30	83.00	3.71	120.00	1150.00	10.00	220.00
1716.10	4.49	137.78	11.38	84.30	83.00	3.71	120.00	1150.00	10.00	220.00
144.40	0.70	12.50	1.60	82.40	85.00	2.69	120.00	1150.00	27.18	225.00
168.10	0.10	6.48	3.90	82.40	85.00	2.69	120.00	1150.00	27.18	225.00
102.40	1.10	12.50	5.90	82.40	85.00	2.69	120.00	1150.00	27.18	225.00
84.10	1.10	36.98	5.00	82.40	85.00	2.69	120.00	1150.00	27.18	225.00
115.60	0.10	98.00	5.50	82.40	85.00	2.69	120.00	1150.00	27.18	225.00
176.40	0.62	109.52	4.38	82.40	85.00	2.69	120.00	1150.00	27.18	225.00
230.40	0.60	92.48	4.94	82.40	85.00	2.69	120.00	1200.00	27.18	225.00
250.00	0.70	141.12	5.14	82.40	85.00	2.69	120.00	1200.00	27.18	225.00
291.60	0.63	89.78	4.99	82.40	85.00	2.69	120.00	1200.00	27.18	225.00
230.40	0.53	165.62	4.99	82.40	85.00	2.69	120.00	1200.00	27.18	225.00
48.40	0.90	44.18	0.70	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
62.50	2.50	56.18	0.00	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
44.10	1.00	121.68	0.80	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
28.90	3.00	169.28	0.50	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
48.40	3.00	72.00	0.30	78.30	79.00	2.69	120.00	1200.00	10.00	220.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
90.00	2.08	67.28	0.46	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
160.00	2.32	103.68	0.41	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
176.40	2.28	56.18	0.49	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
211.60	2.54	131.22	0.43	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
115.60	2.44	8.82	0.42	78.30	79.00	2.69	120.00	1200.00	10.00	220.00
176.40	1.30	79.38	1.00	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
136.90	3.90	89.78	0.10	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
184.90	2.00	98.00	0.70	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
348.10	3.60	103.68	0.30	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
435.60	3.30	64.98	1.00	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
360.00	2.82	79.38	0.62	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
313.60	3.12	69.62	0.54	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
372.10	2.97	58.32	0.63	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
313.60	3.16	33.62	0.62	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
302.50	3.08	5.78	0.68	82.90	82.00	2.10	120.00	1200.00	10.00	220.00
10.00	1.10	19.22	0.40	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
3.60	0.00	19.22	0.70	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
12.10	1.00	40.50	0.40	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
3.60	1.10	54.08	0.30	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
6.40	0.30	87.12	0.50	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
4.90	0.70	14.58	0.46	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
40.00	0.62	10.58	0.47	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
32.40	0.74	6.48	0.43	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
25.60	0.69	0.08	0.43	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
48.40	0.61	2.42	0.46	73.50	74.00	2.10	120.00	1200.00	10.00	220.00
230.40	14.80	12.50	5.10	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
260.10	25.60	23.12	3.00	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
240.10	9.30	12.50	1.80	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
608.40	28.30	13.52	0.60	72.30	75.00	8.06	120.00	1200.00	27.18	220.00

Table A.6 (continued)

10*(DT1^{2})	DT2	2*(DT3^{2})	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
448.90	24.30	5.78	1.60	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
828.10	20.46	16.82	2.42	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
921.60	21.59	106.58	1.88	72.30	75.00	8.06	120.00	1200.00	10.00	220.00
1210.00	20.79	3.92	1.66	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
688.90	23.09	3.92	1.63	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
864.90	22.05	46.08	1.84	72.30	75.00	8.06	120.00	1200.00	27.18	220.00
448.90	40.00	0.72	9.30	95.20	82.00	9.45	115.00	1200.00	10.00	225.00
184.90	45.10	2.00	4.50	95.20	82.00	9.45	115.00	1200.00	10.00	225.00
48.40	26.70	24.50	5.20	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
36.10	37.10	2.00	4.90	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
4.90	25.00	84.50	3.80	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
12.10	34.78	0.72	5.54	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
14.40	33.74	38.72	4.79	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
14.40	31.46	0.02	4.85	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
40.00	32.42	1.28	4.77	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
16.90	31.48	8.82	4.75	95.20	82.00	9.45	115.00	1200.00	10.00	220.00
84.10	8.70	6.48	9.60	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
28.90	16.00	0.18	5.80	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
40.00	11.30	0.02	5.00	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
270.40	18.50	23.12	3.10	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
270.40	13.40	56.18	4.00	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
48.40	13.58	6.48	5.50	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
32.40	14.56	6.48	4.68	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
14.40	14.27	15.68	4.46	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
230.40	14.86	87.12	4.35	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
250.00	14.13	137.78	4.60	103.50	87.00	9.45	115.00	1200.00	27.18	220.00
6.40	0.80	196.02	8.50	105.60	91.00	9.45	115.00	1200.00	27.18	220.00
409.60	1.40	1.28	5.00	105.60	91.00	9.45	115.00	1200.00	27.18	220.00
562.50	6.90	103.68	8.50	105.60	91.00	9.45	115.00	1200.00	27.18	220.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
0.10	7.60	2.00	1.90	105.60	91.00	9.45	115.00	1200.00	27.18	220.00
90.00	2.70	0.18	1.70	105.60	91.00	9.45	115.00	1200.00	27.18	220.00
230.40	3.88	1.62	5.12	105.60	91.00	9.45	115.00	1250.00	27.18	220.00
36.10	4.50	1.28	4.44	105.60	91.00	9.45	115.00	1250.00	27.18	220.00
32.40	5.12	0.18	4.33	105.60	91.00	9.45	115.00	1250.00	27.18	220.00
19.60	4.76	14.58	3.50	105.60	91.00	9.45	115.00	1250.00	27.18	220.00
16.90	4.19	141.12	3.82	105.60	91.00	9.45	115.00	1250.00	27.18	220.00
67.60	2.50	128.00	2.10	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
28.90	1.30	118.58	6.30	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
4.90	0.60	112.50	0.30	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
0.10	0.10	18.00	0.90	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
4.90	1.30	72.00	1.10	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
1.60	1.16	30.42	2.14	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
1.60	0.89	18.00	2.15	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
10.00	0.81	24.50	1.32	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
14.40	0.85	25.92	1.52	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
168.10	1.00	25.92	1.65	86.60	79.00	9.45	115.00	1250.00	27.18	220.00
846.40	37.50	237.62	3.60	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
160.00	48.80	292.82	2.80	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
184.90	30.90	302.58	2.80	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
67.60	42.60	121.68	3.20	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
14.40	34.40	292.82	4.70	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
40.00	38.84	278.48	3.42	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
14.40	39.11	512.00	3.38	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
32.40	37.17	283.22	3.50	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
57.60	38.42	165.62	3.64	89.10	79.00	12.78	115.00	1250.00	10.00	220.00
22.50	37.59	27.38	3.73	89.10	79.00	12.78	115.00	1250.00	27.18	220.00
62.50	3.80	38.72	17.70	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
67.60	10.20	15.68	11.70	108.90	93.00	12.78	115.00	1250.00	27.18	220.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
592.90	0.10	69.62	14.10	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
184.90	2.40	35.28	7.70	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
122.50	0.00	3.92	0.10	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
152.10	3.30	2.00	10.26	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
14.40	3.20	0.98	8.77	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
0.90	1.80	2.88	8.19	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
0.00	2.14	87.12	7.00	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
36.10	2.09	23.12	6.86	108.90	93.00	12.78	115.00	1250.00	27.18	220.00
960.40	35.80	3.92	4.40	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
144.40	41.30	0.72	3.90	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
62.50	25.60	4.50	2.80	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
115.60	37.80	0.50	4.60	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
48.40	30.40	0.32	6.10	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
57.60	34.18	4.50	4.36	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
62.50	33.86	5.12	4.35	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
67.60	32.37	0.50	4.44	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
52.90	33.72	89.78	4.77	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
25.60	32.90	58.32	4.81	114.40	86.00	2.30	115.00	1250.00	10.00	225.00
1716.10	1.10	432.18	4.30	114.20	92.00	2.30	115.00	1250.00	10.00	225.00
1210.00	0.30	278.48	0.70	114.20	92.00	2.30	115.00	1250.00	10.00	225.00
1188.10	1.20	598.58	2.30	114.20	92.00	2.30	115.00	1250.00	10.00	225.00
940.90	1.80	438.08	0.60	114.20	92.00	2.30	115.00	1250.00	10.00	225.00
462.40	1.40	353.78	3.10	114.20	92.00	2.30	115.00	1250.00	10.00	225.00
504.10	1.16	220.50	2.20	114.20	92.00	2.30	115.00	1300.00	10.00	225.00
608.40	1.17	242.00	1.78	114.20	92.00	2.30	115.00	1300.00	10.00	225.00
168.10	1.35	338.00	2.00	114.20	92.00	2.30	115.00	1300.00	10.00	225.00
640.00	1.38	292.82	1.94	114.20	92.00	2.30	115.00	1300.00	10.00	225.00
462.40	1.29	512.00	2.20	114.20	92.00	2.30	115.00	1300.00	10.00	225.00
102.40	0.90	54.08	3.00	111.40	94.00	2.30	115.00	1300.00	10.00	225.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
84.10	0.30	38.72	4.40	111.40	94.00	2.30	115.00	1300.00	10.00	225.00
84.10	1.70	158.42	3.00	111.40	94.00	2.30	115.00	1300.00	10.00	225.00
72.90	1.60	112.50	2.30	111.40	94.00	2.30	115.00	1300.00	10.00	225.00
36.10	1.70	67.28	1.80	111.40	94.00	2.30	115.00	1300.00	10.00	225.00
40.00	1.24	36.98	2.90	111.40	94.00	2.30	115.00	1330.00	10.00	225.00
176.40	1.31	14.58	2.88	111.40	94.00	2.30	115.00	1330.00	10.00	225.00
435.60	1.51	6.48	2.58	111.40	94.00	2.30	115.00	1330.00	10.00	225.00
640.00	1.47	16.82	2.49	111.40	94.00	2.30	115.00	1330.00	10.00	225.00
476.10	1.45	112.50	2.53	111.40	94.00	2.30	115.00	1330.00	10.00	225.00
360.00	9.40	30.42	0.50	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
184.90	9.40	27.38	2.30	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
129.60	8.00	103.68	0.60	89.40	77.00	10.27	115.00	1330.00	10.00	220.00
168.10	9.20	95.22	1.30	89.40	77.00	10.27	115.00	1330.00	10.00	220.00
160.00	4.50	28.88	0.20	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
270.40	8.10	36.98	0.98	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
409.60	7.84	35.28	1.08	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
435.60	7.53	60.50	0.83	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
409.60	7.43	40.50	0.88	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
384.40	7.08	33.62	0.79	89.40	77.00	10.27	115.00	1330.00	27.18	220.00
184.90	0.30	42.32	4.20	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
144.40	2.70	27.38	2.60	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
240.10	2.60	137.78	2.50	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
220.90	3.20	100.82	2.40	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
240.10	3.60	18.00	5.70	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
396.90	2.48	0.08	3.48	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
656.10	2.92	0.02	3.34	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
592.90	2.96	0.18	3.48	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
1254.40	3.03	20.48	3.68	103.50	90.00	10.27	115.00	1330.00	27.18	220.00
902.50	3.00	121.68	3.94	103.50	90.00	10.27	115.00	1330.00	27.18	220.00

Table A.6 (continued)

10*(DT1^{2})	DT2	2*(DT3^{2})	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
90.00	0.90	109.52	0.50	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
108.90	2.40	112.50	0.90	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
144.40	1.20	79.38	3.00	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
115.60	2.60	131.22	0.00	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
250.00	2.20	184.32	6.20	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
160.00	1.86	54.08	2.12	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
220.90	2.05	28.88	2.44	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
260.10	1.98	21.78	2.75	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
230.40	2.14	33.62	2.70	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
220.90	2.05	25.92	3.24	90.00	81.00	10.27	115.00	1330.00	27.18	220.00
490.00	31.40	3.38	0.20	98.00	84.00	16.43	100.00	1330.00	27.18	220.00
324.90	40.60	10.58	2.70	98.00	84.00	16.43	100.00	1330.00	27.18	220.00
230.40	25.50	10.58	2.10	98.00	84.00	16.43	100.00	1330.00	27.18	220.00
122.50	37.20	2.88	2.00	98.00	84.00	16.43	100.00	1330.00	27.18	220.00
96.10	23.20	0.32	2.80	98.00	84.00	16.43	100.00	1330.00	27.18	220.00
160.00	31.58	2.42	1.96	98.00	84.00	16.43	100.00	1350.00	27.18	220.00
152.10	31.62	5.12	2.31	98.00	84.00	16.43	100.00	1350.00	27.18	220.00
193.60	29.82	0.18	2.23	98.00	84.00	16.43	100.00	1350.00	27.18	220.00
396.90	30.68	38.72	2.26	98.00	84.00	16.43	100.00	1350.00	27.18	220.00
230.40	29.38	4.50	2.31	98.00	84.00	16.43	100.00	1350.00	27.18	220.00
6.40	1.60	312.50	4.40	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
1.60	1.30	60.50	2.50	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
57.60	6.20	184.32	3.40	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
44.10	6.70	278.48	1.40	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
980.10	3.50	312.50	4.10	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
22.50	3.86	250.88	3.16	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
136.90	4.31	151.38	2.91	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
176.40	4.91	204.02	2.99	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
0.90	4.66	76.88	2.91	116.10	94.00	16.43	100.00	1350.00	27.18	220.00

Table A.6 (continued)

10*(DT1^{2})	DT2	2*(DT3^{2})	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
0.10	4.25	165.62	3.22	116.10	94.00	16.43	100.00	1350.00	27.18	220.00
96.10	3.40	81.92	5.50	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
160.00	3.40	228.98	3.80	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
168.10	2.80	109.52	2.90	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
129.60	4.10	196.02	2.30	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
302.50	4.50	273.78	4.40	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
230.40	3.64	144.50	3.78	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
384.40	3.69	79.38	3.44	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
476.10	3.75	98.00	3.36	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
384.40	3.93	58.32	3.46	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
313.60	3.90	54.08	3.69	80.40	74.00	16.43	100.00	1350.00	27.18	220.00
10.00	1.60	19.22	6.00	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
1.60	3.30	28.88	4.20	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
0.90	0.00	27.38	3.70	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
115.60	2.30	121.68	2.30	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
25.60	2.10	169.28	2.30	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
260.10	1.86	118.58	3.70	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
102.40	1.91	92.48	3.24	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
168.10	1.63	92.48	3.05	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
722.50	1.96	92.48	2.92	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
193.60	1.89	154.88	3.04	94.00	75.00	9.07	100.00	1350.00	10.00	220.00
48.40	11.10	13.52	4.90	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
14.40	12.00	8.82	1.70	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
44.10	8.20	13.52	2.60	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
8.10	12.00	19.22	1.20	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
0.40	8.00	11.52	2.20	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
10.00	10.26	2.00	2.52	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
40.00	10.09	36.98	2.04	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
78.40	9.71	8.00	2.11	95.20	85.00	9.07	100.00	1350.00	27.18	220.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
280.90	10.01	0.72	2.02	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
102.40	9.61	42.32	2.18	95.20	85.00	9.07	100.00	1350.00	27.18	220.00
122.50	2.20	0.50	0.50	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
211.60	4.80	16.82	1.50	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
176.40	3.70	32.00	1.90	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
202.50	4.70	19.22	3.20	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
435.60	3.90	8.82	5.50	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
722.50	3.86	0.08	2.52	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
547.60	4.19	0.02	2.92	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
624.10	4.07	7.22	3.21	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
532.90	4.14	21.78	3.47	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
422.50	4.03	35.28	3.52	92.60	87.00	9.07	100.00	1350.00	27.18	220.00
360.00	34.50	81.92	2.80	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
152.10	34.70	95.22	2.30	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
144.40	26.60	46.08	2.40	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
57.60	36.60	32.00	1.70	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
57.60	24.40	25.92	3.20	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
211.60	31.36	28.88	2.48	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
90.00	30.73	42.32	2.42	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
160.00	29.94	21.78	2.44	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
72.90	30.61	72.00	2.45	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
52.90	29.41	18.00	2.60	94.10	81.00	2.89	100.00	1350.00	10.00	225.00
0.90	2.60	144.50	4.70	108.30	91.00	2.89	100.00	1350.00	10.00	225.00
230.40	6.30	98.00	0.50	108.30	91.00	2.89	100.00	1350.00	10.00	225.00
16.90	9.10	264.50	1.30	108.30	91.00	2.89	100.00	1350.00	10.00	225.00
67.60	7.30	95.22	4.70	108.30	91.00	2.89	100.00	1350.00	10.00	225.00
3.60	3.40	112.50	1.70	108.30	91.00	2.89	100.00	1350.00	10.00	225.00
102.40	5.74	208.08	2.58	108.30	91.00	2.89	100.00	1400.00	10.00	225.00
19.60	6.37	8.82	2.16	108.30	91.00	2.89	100.00	1400.00	10.00	225.00

Table A.6 (continued)

10*(DT1^{2})	DT2	2*(DT3^{2})	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
193.60	6.38	196.02	2.49	108.30	91.00	2.89	100.00	1400.00	10.00	225.00
422.50	5.84	9.68	2.72	108.30	91.00	2.89	100.00	1400.00	10.00	225.00
422.50	5.55	98.00	2.33	108.30	91.00	2.89	100.00	1400.00	10.00	225.00
25.60	0.90	216.32	1.70	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
72.90	0.90	228.98	2.70	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
78.40	2.00	204.02	3.10	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
52.90	2.50	151.38	2.60	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
136.90	2.00	98.00	0.20	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
176.40	1.66	84.50	2.06	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
202.50	1.81	42.32	2.13	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
211.60	1.99	42.32	2.02	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
168.10	1.99	42.32	1.80	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
211.60	1.89	40.50	1.64	85.30	77.00	2.89	100.00	1400.00	10.00	220.00
883.60	35.00	5.78	4.60	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
176.40	43.50	28.88	2.30	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
360.00	30.70	1.28	2.30	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
115.60	40.30	1.62	3.20	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
90.00	24.10	0.02	4.40	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
102.40	34.72	0.98	3.36	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
302.50	34.66	16.82	3.11	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
202.50	32.90	9.68	3.27	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
336.40	33.34	144.50	3.47	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
122.50	31.94	106.58	3.52	97.10	81.00	6.82	100.00	1400.00	10.00	225.00
10.00	0.60	98.00	4.60	110.90	91.00	6.82	100.00	1400.00	10.00	225.00
57.60	1.70	115.52	1.70	110.90	91.00	6.82	100.00	1400.00	10.00	225.00
184.90	6.00	128.00	2.20	110.90	91.00	6.82	100.00	1400.00	10.00	225.00
96.10	5.80	118.58	3.00	110.90	91.00	6.82	100.00	1400.00	10.00	225.00
0.40	1.10	76.88	1.70	110.90	91.00	6.82	100.00	1400.00	27.18	220.00
2.50	3.04	98.00	2.64	110.90	91.00	6.82	100.00	1400.00	10.00	220.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
40.00	3.53	60.50	2.25	110.90	91.00	6.82	100.00	1400.00	27.18	220.00
2.50	3.89	32.00	2.36	110.90	91.00	6.82	100.00	1400.00	27.18	220.00
160.00	3.47	54.08	2.39	110.90	91.00	6.82	100.00	1400.00	27.18	220.00
230.40	3.01	46.08	2.27	110.90	91.00	6.82	100.00	1400.00	27.18	220.00
921.60	34.40	76.88	2.50	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
547.60	44.50	165.62	0.20	91.90	80.00	14.00	100.00	1400.00	10.00	220.00
476.10	25.80	40.50	0.70	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
270.40	41.50	76.88	1.10	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
202.50	26.30	30.42	1.30	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
184.90	34.50	16.82	1.16	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
72.90	34.52	72.00	0.89	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
176.40	32.52	0.32	1.03	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
291.60	33.87	14.58	1.10	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
84.10	32.34	40.50	1.10	91.90	80.00	14.00	100.00	1400.00	27.18	220.00
108.90	6.60	216.32	12.20	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
19.60	7.00	40.50	7.60	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
102.40	2.60	64.98	7.20	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
250.00	6.50	60.50	8.00	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
202.50	3.50	118.58	10.50	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
28.90	5.24	4.50	9.10	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
52.90	4.97	36.98	8.48	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
324.90	4.56	0.00	8.66	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
25.60	4.95	137.78	8.95	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
72.90	4.64	27.38	9.14	107.70	86.00	14.00	100.00	1400.00	27.18	220.00
6.40	0.40	188.18	10.20	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
19.60	4.00	144.50	5.70	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
0.00	6.80	375.38	5.70	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
0.10	6.70	64.98	7.10	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
6.40	4.40	100.82	6.50	105.60	86.00	14.00	100.00	1400.00	27.18	220.00

Table A.6 (continued)

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
72.90	4.46	2.00	7.04	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
1.60	5.27	0.00	6.41	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
62.50	5.53	32.00	6.55	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
384.40	5.27	25.92	6.72	105.60	86.00	14.00	100.00	1400.00	27.18	220.00
462.40	4.99	67.28	6.64	105.60	86.00	14.00	100.00	1400.00	27.18	220.00

Table A.7 Testing Dataset

10*(DT1^2)	DT2	2*(DT3^2)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
152.10	3.50	84.50	3.10	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
240.10	5.00	84.50	4.30	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
396.90	4.80	76.88	4.60	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
336.40	3.20	118.58	4.20	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
396.90	4.00	79.38	3.60	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
280.90	2.50	165.62	3.60	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
220.90	3.83	74.42	3.90	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
250.00	3.89	58.32	4.03	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
280.90	3.70	67.28	3.99	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
280.90	3.52	44.18	3.89	79.00	76.00	3.71	120.00	1150.00	10.00	220.00
8.10	1.50	12.50	9.00	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
0.40	2.70	8.82	8.60	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
16.90	1.70	52.02	9.30	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
0.40	1.00	46.08	6.40	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
3.60	0.80	33.62	7.70	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
62.50	1.54	27.38	8.20	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
193.60	1.55	12.50	8.04	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
211.60	1.32	8.00	7.93	102.50	91.00	5.85	115.00	1250.00	27.18	225.00

Table A.7 (continued)

10*(DT1^{2})	DT2	2*(DT3^{2})	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
518.40	1.24	15.68	7.65	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
302.50	1.29	54.08	7.90	102.50	91.00	5.85	115.00	1250.00	27.18	225.00
36.10	0.00	46.08	2.00	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
22.50	0.80	84.50	2.00	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
48.40	0.10	46.08	3.50	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
44.10	1.90	69.62	3.00	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
62.50	1.60	15.68	2.00	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
102.40	0.88	15.68	2.50	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
220.90	1.06	24.50	2.60	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
211.60	1.11	30.42	2.72	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
193.60	1.31	2.88	2.56	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
220.90	1.19	0.00	2.48	94.20	90.00	5.85	115.00	1250.00	27.18	220.00
608.40	40.50	2.88	4.00	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
336.40	49.30	28.88	1.30	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
122.50	33.50	2.00	2.40	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
32.40	44.30	4.50	0.80	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
19.60	28.10	0.08	0.90	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
52.90	39.14	74.42	1.88	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
136.90	38.87	0.32	1.46	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
152.10	36.78	16.82	1.49	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
176.40	37.44	79.38	1.30	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
144.40	36.07	208.08	1.41	94.60	82.00	13.62	100.00	1400.00	27.18	220.00
176.40	0.30	196.02	8.20	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
12.10	0.90	16.82	2.70	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
0.10	5.90	23.12	1.20	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
78.40	7.20	40.50	1.90	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
202.50	2.60	2.88	6.40	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
291.60	3.38	7.22	4.08	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
6.40	4.00	5.12	3.26	105.60	86.00	13.62	100.00	1400.00	27.18	220.00

Table A.7 (continued)

10*($DT1^2$)	DT2	2*($DT3^2$)	DT4	sample	Amb	WE	Quantity	FS	10*Exp(FD)	Power
176.40	4.62	25.92	3.37	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
608.40	4.36	38.72	3.80	105.60	86.00	13.62	100.00	1400.00	27.18	220.00
476.10	3.79	64.98	4.18	105.60	86.00	13.62	100.00	1400.00	27.18	220.00