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Steam Valve Thermo-Performance Analysis

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Thank you to the Donald C. Nuclear Plant and to our company advisors Katelin Kohn and Dan Sammons for proposing this project, as well as providing information and guidance. Also, thank you to our university advisors, Dr. Springstead and Dr. Wu, for providing guidance throughout the project as well.

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1. Introduction

The goal of this project is to develop and optimize a program that can track energy lost due to aging, leaking steam valves for the Cook Nuclear Plant. The thermal energy in the reactor is used to heat steam, which is then converted into electrical energy using turbines. Any steam lost due to leaky valves results in a loss of the plant's end product. While a large amount of data is available on the valves in the system, the data is difficult to process by hand due to the number of valves in the system. As such, a computer program is needed to process the data and show plant engineers where the largest steam valve leaks are occurring.

1.1 Project Description, History, and Analysis

Steam leaks occur in aging power systems due to heat energy loss from the valves of the system. Unmanaged steam leaks not only drive up operation costs for power plants, but can create other negative implications within the plant as well. Increased emissions, loss of reliability, and unnecessary safety hazards are three additional negative outcomes steam leaks can cause in a power plant. Performing regular testing and inspections on leaking valves is vital to properly managing the leak to verify it will not cause significant damage to the system or the surrounding environment. It is to be often expected that most valves will exhibit some degree of leakage. A useful approach to maintaining and analyzing leaks is to quantify the leakage and then establish an appropriate leakage tolerance to determine the most problematic valves.

A total of 103 valves were analyzed over the course of the project with the ultimate goal of determining the top 10 valves for each unit in terms of steam leakage. There are two units within the plant that function to produce electricity through the use of heating steam through nuclear power. Additionally, the two units were built and installed by two different companies. A summary of megawatt loss in relation to the top 10 valves for each unit is displayed in Table 1.1. It should be noted that all URV valves have been excluded from this list at the request of the Donald C. Cook company representative due to uncertainties in value accuracy. The top valve for unit 1 is the 1-FMO-260 (L) with a MW loss of 47.41 and the top valve for unit 2 is the 2-T-121-6 with a MW loss of 21.22. A model was developed to determine the amount of heat energy lost in an aging power plant steam pipe valve system using PEPSE. In this project, the PEPSE model was used to determine the estimated energy that was lost due to seal leakage and general valve degradation. This energy was quantified, and an economic analysis of the valves was performed to determine the lost revenue experienced by the power plant and compared that to the cost of replacing the valves with newer, more efficient models.

Table 1.1: Top Ten Megawatt Loss for Both Units (Ignoring URV Valves)

Unit 1		Unit 2	
Valve ID	MW Loss	Valve ID	MW Loss
1-FMO-260 (L)	47.41	2-T-121-6	21.22
1-MRV-403	18.96	2-FMO-260	8.31
1-MS-239	18.12	2-T-121-5	8.01
1-CRV-224 (L)	16.37	2-CRV-224	4.63
1-DRV-423	9.19	2-MS-239	3.75
1-CRV-224 (H)	6.01	2-HRV-461	2.16
1-MSD-219L	2.11	2-HRV-462	1.73
1-HRV-562	1.52	2-DRV-406	1.67
1-HRV-561	1.48	2-HRV-557	1.62
1-MRV-409	0.95	2-B-431	1.57

2. Market Survey

Nuclear fission, or the splitting of uranium atoms, produces heat used in the process of creating steam. Steam is a widely used resource in varying industries and facilities throughout the world. Steam is an odorless, colorless high energy source that is often used to generate power. In a nuclear power plant, the steam that is generated is utilized for spinning large turbines that ultimately help produce electricity. The Donald C. Cook Nuclear plant provides a clean, non-greenhouse gas emitting source of energy employed to help meet electricity demands, as all nuclear plants are able to do. It is estimated that 20% of electricity used in America originates from nuclear energy (U.S. Energy Information Administration, 2020).

2.1 Pricing History and Analysis for Electricity in the Midwest Area

Wholesale electricity market data was pulled from the U.S. Energy Information Administration database to assess market trends for the Midwest and Mid-Atlantic areas. The data available from the U.S. Energy Information Administration was originally collected by the Intercontinental Exchange. The different zones outlined for the U.S. are displayed in a map in Figure 2.1. There are two zones that are associated with Michigan for Electricity pricing, the Midwest zone and the Mid-Atlantic Zone. Both of these zones were evaluated for pricing of electricity in units of $/MWh from 2014 to 2020.

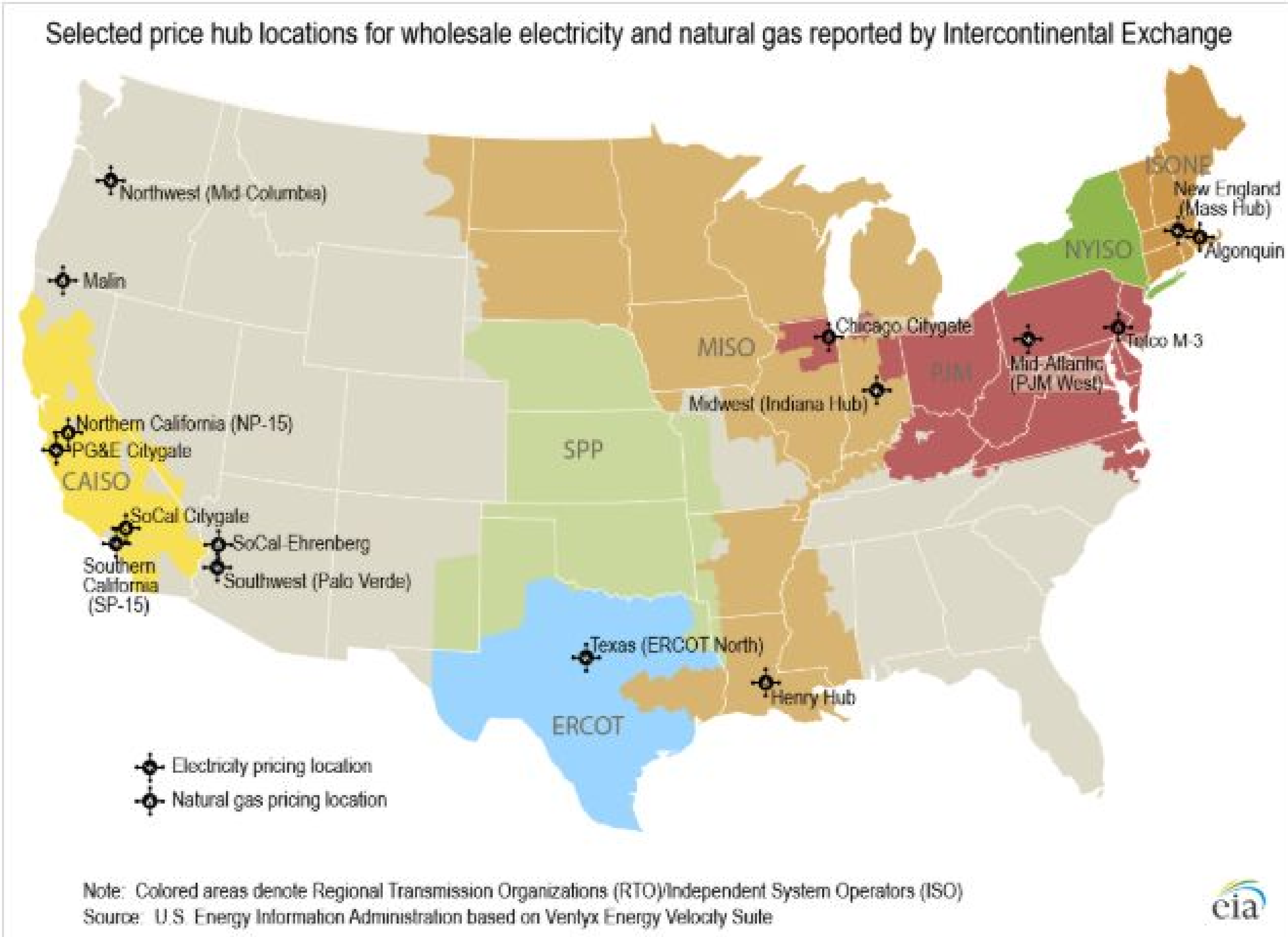


Figure 2.1: Map of Zones in the U.S. for Electricity and Natural Gas Pricing (U.S. Energy Information Administration, 2020)

The price comparison for the Mid-Atlantic electricity zone is shown in figure 2.2. The price comparison for the Midwest electricity zone is shown in Figure 2.3. Price high points and price low points for multiple days for each month are included in the price comparison graphs for the Mid-Atlantic and Midwest zones. There were notable price spikes for electricity in the Mid-Atlantic zone in 2014, 2015, and 2017. In the Midwest zone, most of the notable price spikes have been in more recent years including 2017 and 2018, but also back in 2015 as well.

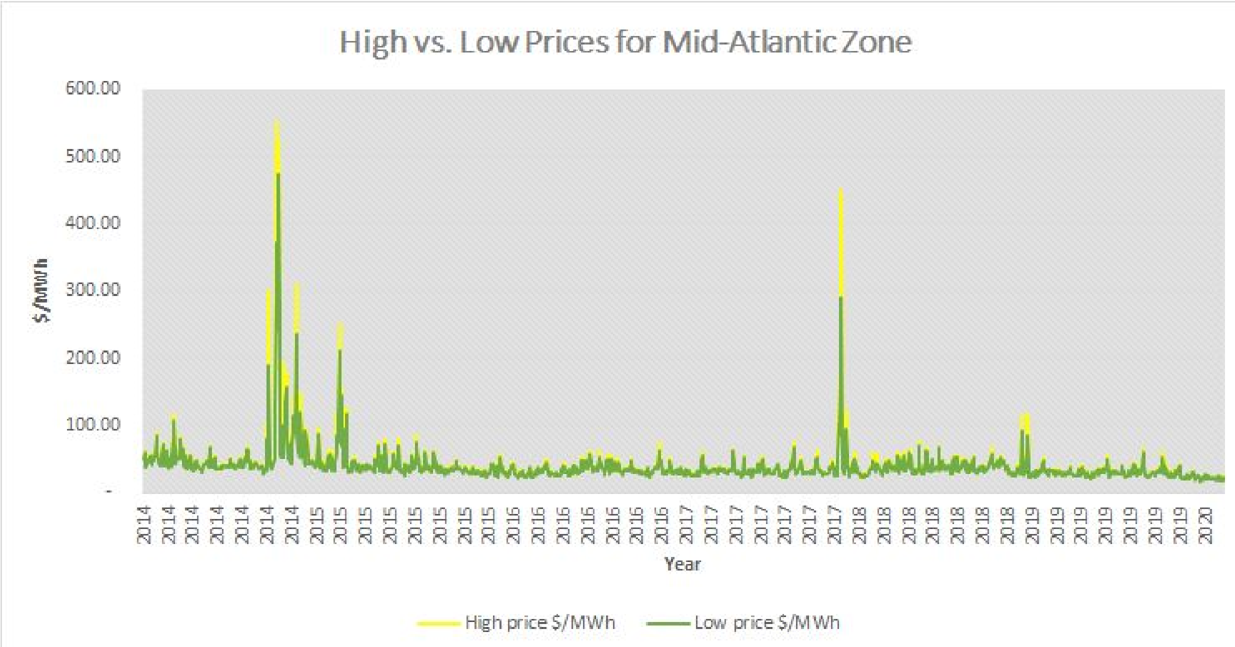


Figure 2.2: Price Comparison for Mid-Atlantic Zone (U.S. Energy Information Administration, 2020)

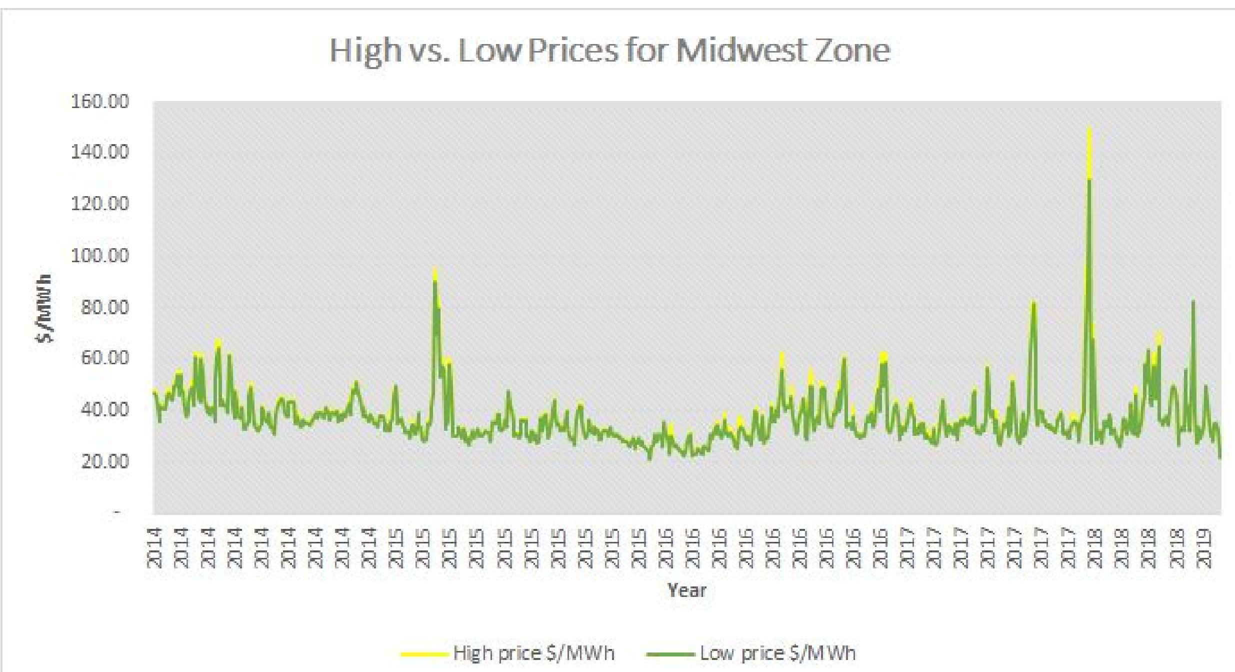


Figure 2.3: Price Comparison for Midwest Zone (U.S. Energy Information Administration, 2020)

Figure 2.4 displays historical trends as well as projected trends in terms of energy consumption for each fuel type. The trend in relation to nuclear fuel is expected to flatline starting a few years after 2020 and continuing through to the year 2050. While nuclear fuel is not the most popular fuel type for electricity generation, its contributions to electricity to supply are still somewhat significant and will not experience any sort of sharp decline within the next 30 years or so if the projection is correct.

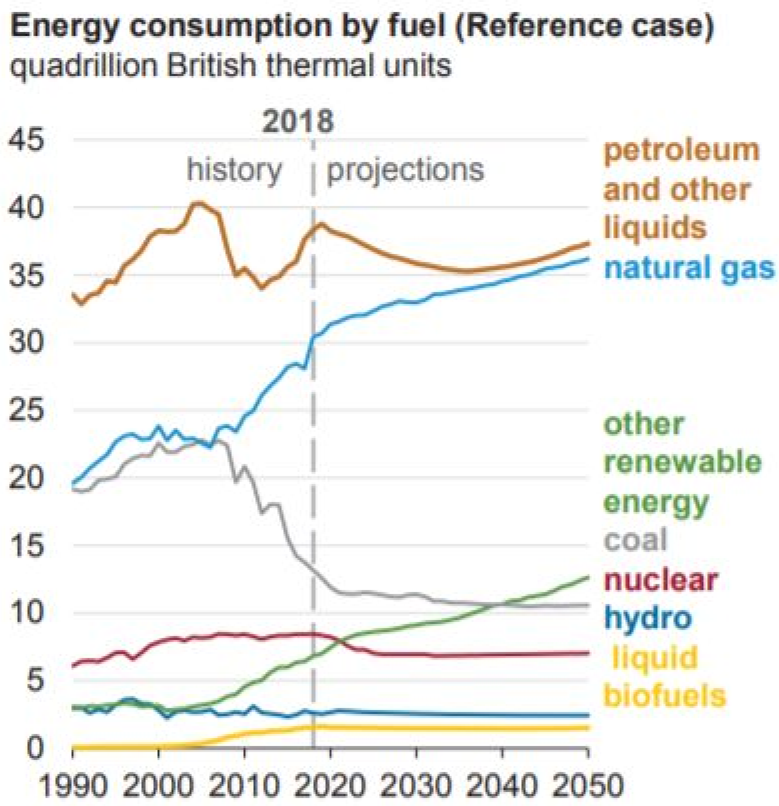


Figure 2.4: History and Projections for Energy Consumption by Fuel Type (U.S. Energy Information Administration, 2020)

3. Material and Energy Balances

A few sample material and energy balances were conducted and analyzed to show the effect of valves on the system. Figure 3.1 and Figure 3.2 show a mass and energy balance around the 5A Feedwater Heater that is included in Unit 1. The 5A feedwater heater shell side receives flow from three different locations including the High Pressure Turbine Exhaust steam, the shell drains from the Moisture Separator section of the Moisture Separator Reheater, and from the drain of the upstream Feedwater Heater 6A. Figure 3.1 displays normal flow into the shell side of the 5A FWH. This is considered the normal alignment at the plant. In Figure 3.2, the Moisture Separator shell drains are not flowing to the 5A heater, however, they are being returned to the

Main Condenser now that 1-MRV-403 is open. The cycle isolation calculations that were completed using Grashof's and ASME Figure 14 for 1-MRV-403 estimated an average of approximately 510,000 lbm/hr going through the open valve, while the PEPSE estimated just over 490,000 lbm/hr. The general impact on the plant that this valve has when it is open is estimated by PEPSE at 9 MWe. With the valve successfully closed, the approximation for the valve improves to 8 MWe.

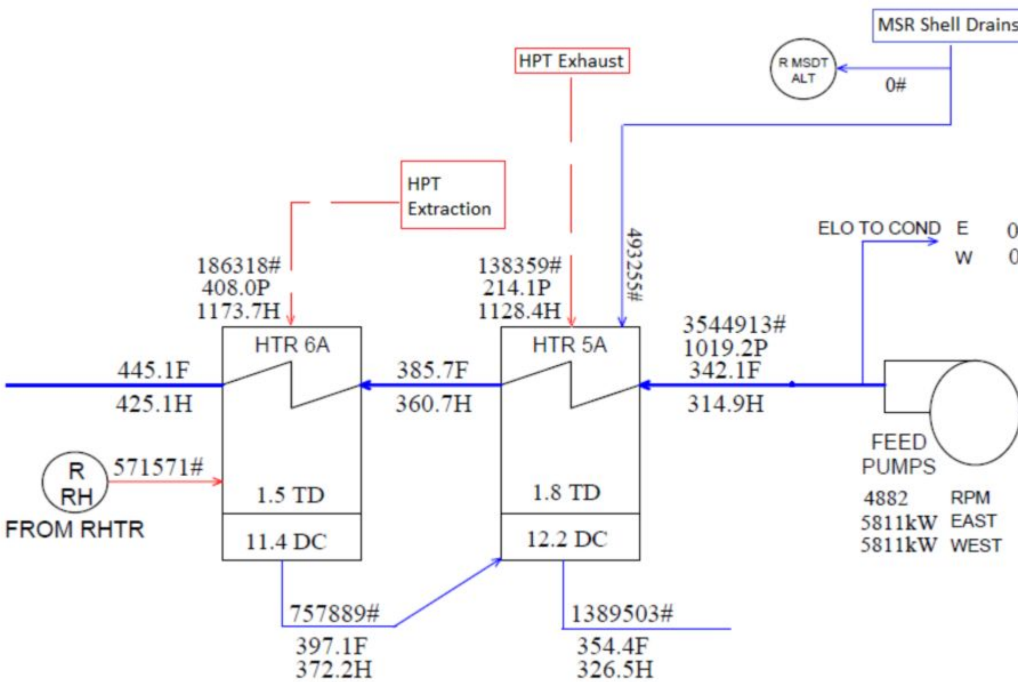


Figure 3.1: Unit 1 Heat Balance on 5A FWH Before 1-MRV-403 is Open

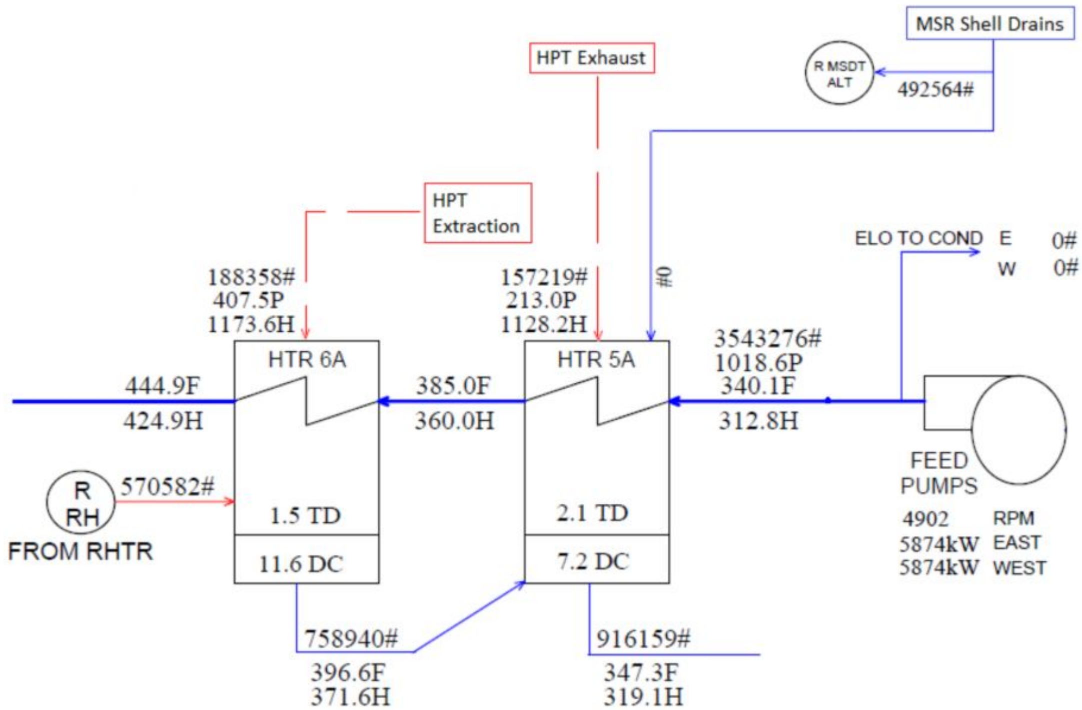


Figure 3.2: Unit 1 Heat Balance on 5A FWH After 1-MRV-403 is Open

3.1 Unit 1 Energy Losses

The energy lost by the top 10 valves in unit 1 can be seen on Table 9.2 - Unit 1 Valve Information. The second column shows the electrical energy lost per valve in MWe. These energy losses are calculated in megawatts instead of a quantity of steam so that the lost energy can be quantified and converted into a monetary value in Table 9.3 - Unit 1 Total Costs later in section 9.

3.2 Unit 2 Energy Losses

The energy lost by the top 10 valves in unit 2 can be seen on Table 9.4 - Unit 2 Valve Information. The second column shows the electrical energy lost per valve in MWe. These energy losses are calculated in megawatts instead of a quantity of steam so that the lost energy can be quantified and converted into a monetary value in Table 9.5 - Unit 2 Total Costs later in section 9.

4. List of Equipment and Specifications

For the unit 1 valves being replaced by this project, see Table 9.2 - Unit 1 Valve Information. For the unit 2 valves being replaced by this project, see Table 9.4 - Unit 2 Valve Information. These tables show the identifying code, manufacturer, and model number. This information is necessary for getting vendor quotes used in finding replacement costs.

4.1 Costing of Valves and Replacement Labor Costs

Katelin Kohn provided most of the valve material and maintenance replacement costs for the top 10 leakiest valves for each unit based on the vendors that the company typically works with for replacement valves. The costs for replacing each valve in unit 1 can be seen in Table 9.2 - Unit 1 Valve Information. Likewise, the costs for replacing each valve in unit 2 can be seen in Table 9.4 - Unit 2 Valve Information. Any holes in the monetary data received were filled with the averages from the other valves to give a more accurate representation of the total costs.

5. Utility Costs

There are no utility costs associated with operating valves. As such, this project does not calculate a utility cost for the valves being replaced. That said, there is heat energy that is lost by the leaking steam valves currently in place. This energy is quantified later in this document. Steam leak losses are not a utility cost for the operation of the valves themselves.

6. Safety and Environmental Design Constraints

As this project takes place in a nuclear power facility, it is critical that steps are taken to ensure the safety of the people working in the plant and those living in the surrounding communities. As the plant is located on the shores of lake michigan, it is also important that proper safety procedures are followed to avoid polluting one of the world's largest freshwater resources for generations to come. There are many truly unique challenges to process safety in a nuclear plant such as the Donald C. Cook Nuclear Plant.

6.1 Technical Discussion and Overall Process Safety

The plant has a simulation room that is exactly identical to the real control room of the facility. This simulation room is used to simulate catastrophes that may occur at various points along the process so that the plant operators know how to mitigate damage and save those in the plant and those in the surrounding areas from thermonuclear disasters. There are several critical scenarios that the operators are required to have memorized. These are the worst case scenarios that would result in a significant portion of southwest michigan and northern indiana being destroyed by a full nuclear meltdown. Other, less severe problems that might take place in the plant are kept in a series of books that the operators can reference to determine how to respond to specific error codes given by the machinery. The critical scenarios are also written into these books for posterity. As far as this valve replacement project is concerned, the bulk of the safety risks will take place during the valve replacement itself. Personal protective equipment (PPE) can be used to help mitigate these risks. The different types of PPE used by workers in the plant are described below.

6.2 Security Considerations

One of the first safety measures that a person experiences when they enter the Cook Nuclear Plant is the security. There are checkpoints similar to those of TSA that visitors have to pass through before entering the nuclear plant itself. This checkpoint checks for any weapons, bombs, or other potentially hazardous devices. At these checkpoints, they also do a full background check on any visitors coming into the plant to help weed out any visitors that might be there for malicious reasons.

All visitors must be accompanied by someone that works for the plant, and visitors must remain within the direct line of sight of these workers at all times. Visitors are not allowed and employees are encouraged not to enter any green painted zone within the plant, as these zones often contain valves and equipment that are absolutely critical to the safe operation of the nuclear facility. Visitors are also prohibited from entering the nuclear plant's control room for the same reason.

Anyone entering the plant for any reason must have a name badge clearly displayed at all times. Employees are provided with a name badge and lanyard with their photo and identifying information. Visitors are given a visitor badge and lanyard that is a different color from the employee version to help security and other personnel to identify them as visitors from a distance.

6.3 Radiation Hazards

Employees that enter regions of the plant where there are slightly elevated levels of radiation must wear a radiation monitor that is similar to a small Geiger counter. This device measures the dose of radiation that a person experiences over the course of their shift, and will sound an alarm if the worker has been exposed to potentially unsafe amounts of radiation over the course of their working day. When the alarm sounds, an employee is required to leave the area immediately. This device helps to ensure that workers always stay within a safe level of radiation exposure.

For employees that are performing maintenance on the primary region of the plant that houses the reactor itself, there are full body Hazmat suits with radiation protection. These employees are also provided with a Geiger counter device that is used to help ensure the radiation they experience does not get past certain doses. The amount of time that a person is allowed to spend servicing the reactor is also limited for the same reason. Visitors are not allowed to enter the part of the plant that houses the reactor itself due to radiation concerns.

This project takes place in the secondary side of the plant where the steam turbine system is located and radiation exposure is considered to be within safe levels. The hot side is generated through nuclear fission. During nuclear fission, a neutron collides with a uranium atom and splits it, releasing a large amount of energy in the form of heat and radiation. That hot water enters a heat exchanger, creating steam on the secondary side of the plant. The water used in the steam turbine system is non-contact water so there is no radiation risk.

6.4 Insulation Abatement

Insulation abatement is the safe removal and disposal of insulation materials that contain asbestos. Due to the age of the plant, much of the insulation is asbestos based. Therefore, any changes to the system (such as valve replacements for this project) should be performed by professionals trained in insulation abatement, or the insulation should be abated prior to the valve replacement (a large portion has already been replaced).

6.5 General Personal Protective Equipment

Every person entering the nuclear power plant is required to wear steel toe boots, a hard hat, safety glasses, and hearing protection. Steel toe boots can help prevent damage done to feet in the event of unanticipated falling or rolling objects. Hard hats and safety glasses likewise protect the heads and eyes of people in the plant. As there are many moving parts and frequent repair or installations of equipment, these requirements are a must in order to ensure personal safety. The power plant can also be quite noisy (especially in the turbine room), so hearing protection is used to help people avoid hearing loss from extended exposure to high decibel noises.

7. Calculations

The project included using five methods to calculate the MW loss due to the steam leaks throughout the plant: Grashof, ASME Figure 14, the sonic equation, Darcy, and the choke equation.

The Grashof number (Gr) is a dimensionless number to show the fluid dynamics and heat transfer of a fluid. It approximates the ratio of the buoyancy to the viscous force acting on the fluid. It is commonly used when dealing with natural convection. Grashof uses the diameter of the pipe, density of the fluid (steam) coefficient of thermal expansion, temperature difference, and viscosity to determine those characteristics. The equation is as follows:

Equation 7.1: Grashof number

$$Gr = \frac{D_0^3 \rho_f^2 \beta_g \Delta T_0}{\mu_f^2}$$

The equation used in this project was slightly modified to better fit the situation. In order to apply grashof to a leaking valve, the pipe must be treated as a nozzle from the point where the downstream temperature is taken to the heat sink. This leads to the issue that a length of pipe will have more resistance than a nozzle due to flow geometry and friction. Since Grashof does not account for resistance, a correction must be applied. The modified Grashof equation used is as follows:

Equation 7.2: Modified Grashof Equation for Mass Flow

$$W = 59.4 * A * P^{0.97}$$

Where W is the mass flow rate, A is the discharge flow area, and P is the reservoir pressure. This equation was used to determine the flow from ambient temperature (pressure of 1 psi) and the uncorrected flow in which the flow was calculated using a pressure found in the steam tables and then the flow from ambient temperature was subtracted. The moisture flow was calculated using the following equation:

Equation 7.3: Moisture Flow

$$W_f = W_g * \frac{h_g - h_f}{h_T - h_f} - W_g$$

Where Wg is the gas component of leakage flow (flow uncorrected for moisture), hg is the downstream gas enthalpy, hf is the downstream liquid enthalpy, and ht is the total enthalpy. This value was added to the uncorrected flow to determine the total flow. The moisture flow was then divided by the total flow to determine the moisture fraction. This is used in the following equation to determine the correction factor in which we will multiply by the total flow to determine the corrected flow rate.

Equation 7.4: Moisture Correction Factor

$$correction\ factor = \sqrt{1 - (0.9775 * moisture\ fraction)}$$

The ASME Figure 14 method is very similar to Grashof. The equation to determine the mass flow rate is as follows:

Equation 7.5: ASME Fig. 14 Flow Rate

$$W = W_{ASME} * A * P$$

Where W_{ASME} is a critical, choking, mass flow rate for isentropic process and equilibrium conditions value taken from the 1967 American Society of Mechanical Engineers Steam Tables textbook. The figure uses inlet enthalpy and pressure. The process is the same as that used in Grashof and the moisture fraction is used to correct the flow rate.

Both the Grashof and ASME Figure 14 methods are then inserted into the following equation to determine the lost generation in MWe.

Equation 7.6: Lost Generation (MWe)

$$Lost\ Generation = \frac{Q_c * h_t * 0.33}{3412140}$$

Where Q_c is the corrected flow and h_t is the upstream enthalpy.

The sonic equation method assumes choked flow in the pipe. This implies that the velocity of the fluid will be limited by the speed of sound in the fluid. The equation assumes isentropic flow of an ideal gas. The equation is as follows:

Equation 7.7: Sonic Equation

$$V_{choke} = \sqrt{\frac{k * g * 144 * P'}{\rho}}$$

Where V_{choke} is the choked fluid velocity, k is the ratio of specific heats, g is the acceleration due to gravity, P' is the absolute pressure of the system, and ρ is the density of the fluid downstream from the valve. This equation is used much like the previous two methods and must take into account moisture and use a correction factor before being used in the lost generation equation.

The Darcy equation, also known as the Darcy-Weisbach equation, is another method to determine the flow of the fluid. The general form of the equation is as follows:

Equation 7.8: Darcy Equation

$$h = K * \frac{v^2}{2g}$$

Where h is head loss in the pipe, K is the resistance coefficient equal to the Moody friction factor times the length of pipe divided by the diameter, υ is the mean velocity, and g is the acceleration due to gravity.

The Darcy equation can be solved for velocity, combined with a general equation of flow, and an expansion factor can be inserted to account for compressibility to create the more usable equation that follows.

Equation 7.9: Converted Darcy Equation

$$W = 1891 * Yd^2 \sqrt{\frac{\Delta P}{K} * \rho}$$

Where W is flow, Y is the expansion factor, d is the internal pipe diameter, ΔP is the differential pressure from downstream of the valve to the heat sink, K is the resistance coefficient, and ρ is the density of fluid downstream of the valve. The flow rate can then be corrected for moisture and used to calculate the lost generation.

The choke equation method is similar to the sonic equation method. It again assumes there will be choked flow in the pipe which means the velocity of the fluid will be limited by the speed of sound in the fluid. The ideal gas law (PV=RT) converts the sonic equation to the following:

Equation 7.10: Choke Equation

$$V_{choke} = \sqrt{kgRT}$$

This equation is then used the same way as the previous four.

For simplicity in the program four additional equations were used to bypass using charts and steam tables. Using these equations over the graphs led to an average error of 0.35% and an estimated maximum error of 0.84% (Chem-Eng-Musings,2019) (Affandi, 2013).

Downstream enthalpy was calculated using the equation: $H_{st} = 1975 + 1.914 * Z_{st} * (t + 273)$

Compressibility (needed for pressure and density calculations) was calculated using the equation: $Z_{st} = 1 - 0.024 * P^{0.654} / (220-P)^{0.08}$

Density was calculated using the equation: $D_{st} = 216.49 * P / (Z * T)$

Pressure at saturation was calculated using the equation:
$\ln(P)=a+b*\ln(Tr)+c*(\ln(Tr)^2)+d(\ln(Tr)^3)+e*(\ln(Tr)^4)$

8. Excel File Development for Valves

As per request by Donald C. Cook, a newly formatted and updatable excel file was a major focus of the project. Such a file would allow for much quicker and more concise evaluation of which valves should be replaced or looked into fixing first. This file would allow for either new valves to be placed into the file or for valve updates to be made to the file, ensuring old data would not be part of the data set being analyzed. These requests resulted in the development of the excel file which is to be discussed in the following sections.

8.1 Introduction to the File

The file created is a Microsoft Excel Macro-Enabled Worksheet (.xlsm). The .xlsm extension is automatically generated due to macros and user forms being active within the file itself. Upon opening the file, the macro content must be enabled by the user to activate the ranking system and input data forms. The following figure gives an overview of what the user can expect when opening the file.

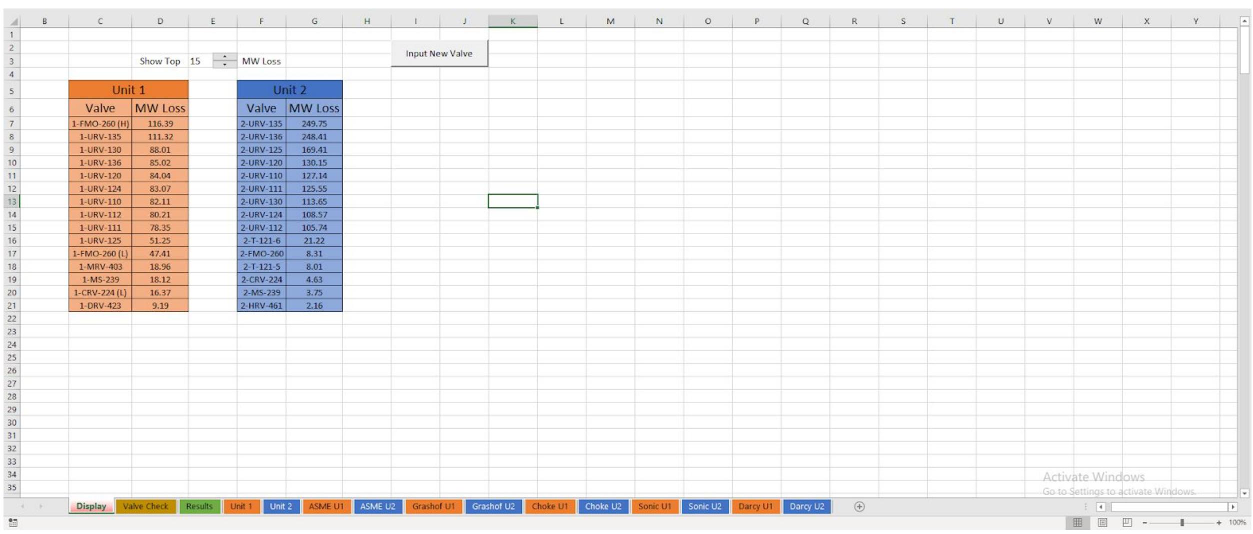
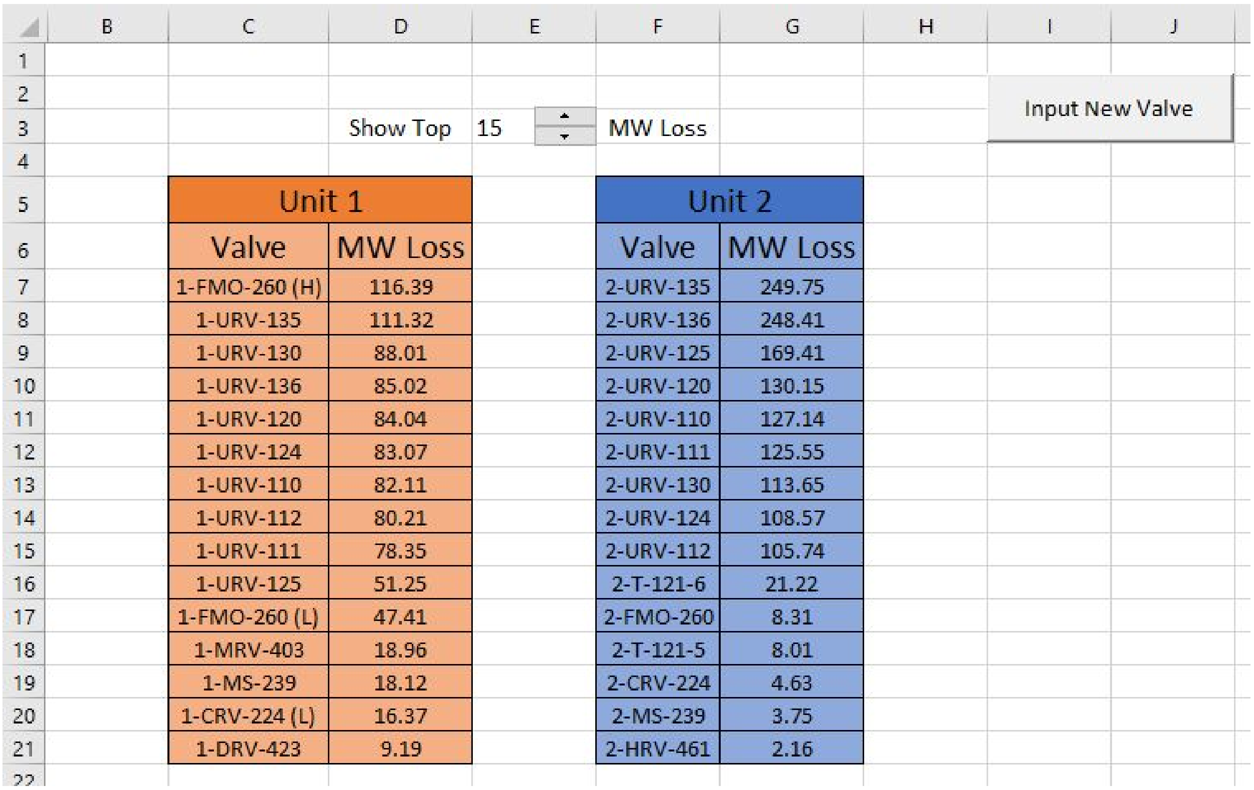


Figure 8.1: Display Sheet and Opening Visual

The goal was to create a main homepage for users to minimize any potential for confusion. The output data for megawatt loss is listed with the accompanying valve, the user has access to a button that will allow new valve data to be entered, and the user can alter the “Show Top … MW Loss” section to alter the length of the two lists present. All information (results, calculations, etc.) have been color-coded following the format used by Donald C. Cook: Unit 1 is colored orange and Unit 2 is colored blue. Additionally, all Unit 1 valves have a numeric “1” preceding the valve name and likewise for Unit 2 valves with a numeric ”2” for further clarification, as requested by Donald C. Cook representative Katelin Kohn. A closer view of the display page is given in the following figure.



Unit 1		Unit 2	
Valve	MW Loss	Valve	MW Loss
1-FMO-260 (H)	116.39	2-URV-135	249.75
1-URV-135	111.32	2-URV-136	248.41
1-URV-130	88.01	2-URV-125	169.41
1-URV-136	85.02	2-URV-120	130.15
1-URV-120	84.04	2-URV-110	127.14
1-URV-124	83.07	2-URV-111	125.55
1-URV-110	82.11	2-URV-130	113.65
1-URV-112	80.21	2-URV-124	108.57
1-URV-111	78.35	2-URV-112	105.74
1-URV-125	51.25	2-T-121-6	21.22
1-FMO-260 (L)	47.41	2-FMO-260	8.31
1-MRV-403	18.96	2-T-121-5	8.01
1-MS-239	18.12	2-CRV-224	4.63
1-CRV-224 (L)	16.37	2-MS-239	3.75
1-DRV-423	9.19	2-HRV-461	2.16

Figure 8.2: Display Sheet Main Components

As seen in the first figure of this section, Figure 8.1, there exist several tabs within this worksheet. The first five tabs contain the inputs and outputs of all valve data. These tabs include the following: “Display”, “Valve Check”, “Results”, “Unit 1”, and “Unit 2”. This layout can be seen in the following figure and each tab shall be discussed in further detail in following sections.

Figure 8.3: Main Worksheet Tabs

The final items of note within the introductory portion of the file are the remaining worksheet tabs. These ten tabs are where the calculations for the valves occur. As seen in the next figure, each tab lists the method used for calculation, as well as being color-coded to ensure the user knows which unit the calculations go with.

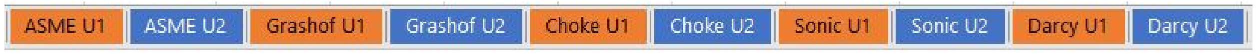


Figure 8.4: Calculation Worksheet Tabs

As calculations were discussed in the previous section, Section 8, they shall not be discussed here.

8.2 Megawatt Loss Tables

One of the main features of the display page are two lists, one orange and one blue, that showcase the MW losses at each valve in descending order. This list has been created in such a way as to allow users to alter the overall length of the list. The following figure highlights the component allowing for the alteration of this list.

Figure 8.5: Top MW Loss List Control

The spin button in Figure 8.5 is bound directly to cell E3 in the display sheet, currently displaying “15”. The user can either use the spin button to increase or decrease the value thereby changing the list length, or the user can alternatively enter in a value directly to cell E3. Several safeguards do exist to ensure only numeric values can be entered. Figure # showcases the settings for the spin button giving a minimum and maximum value for the bound cell, in addition to an allowed incremental change of 1 unit per click.

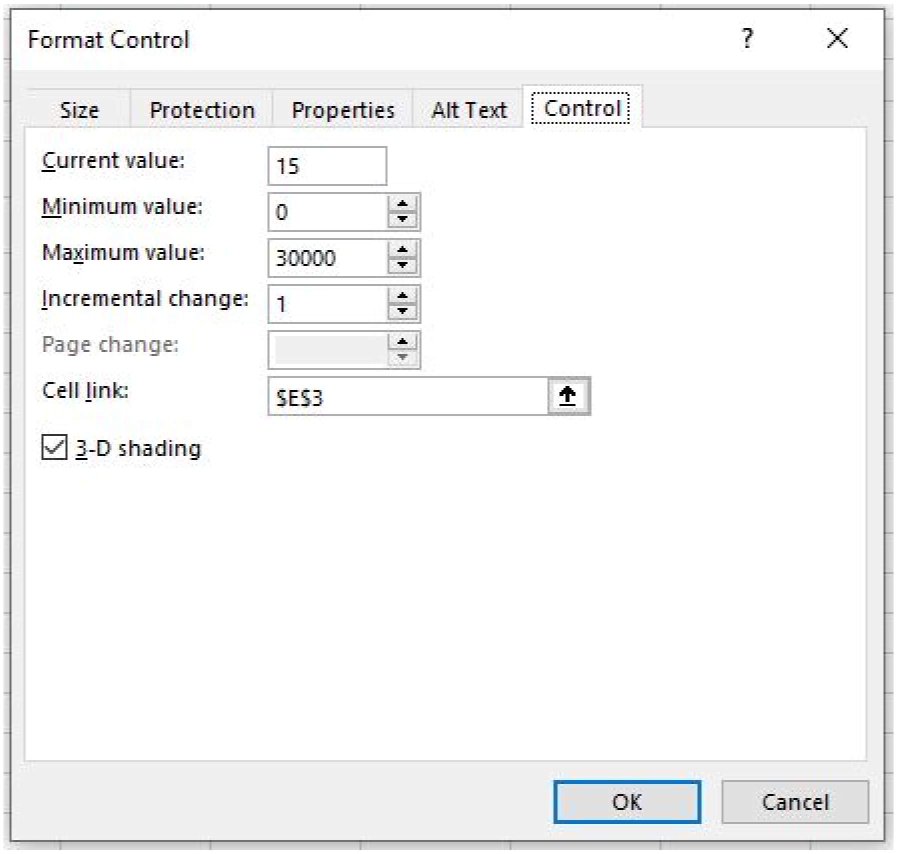


Figure 8.6: Spin Button Settings

To further safeguard the settings from potential user error, the bonded cell E3 has been further formatted to eliminate the ability of the user to enter non-numeric values into the cell. The following three figures show the settings associated with this design.

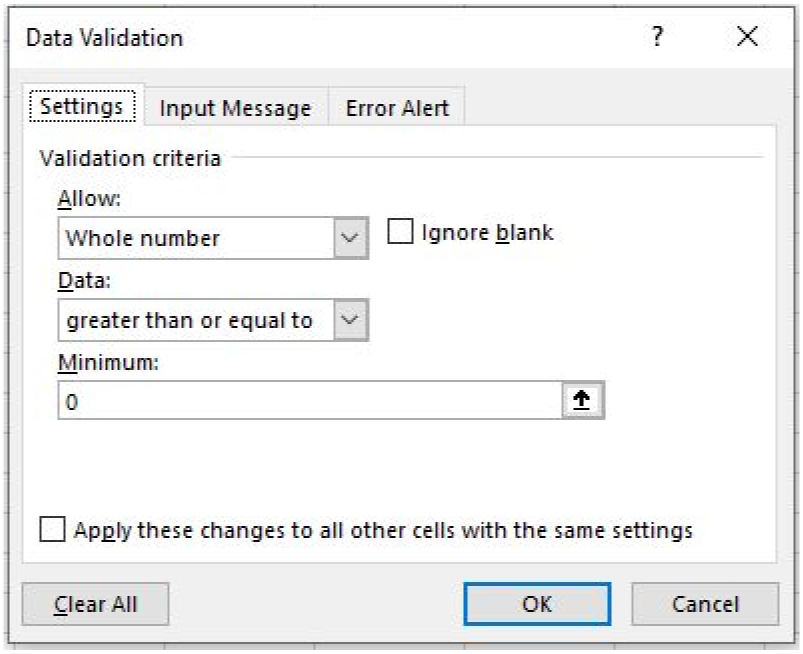


Figure 8.7: Restrictive Settings on Cell E3

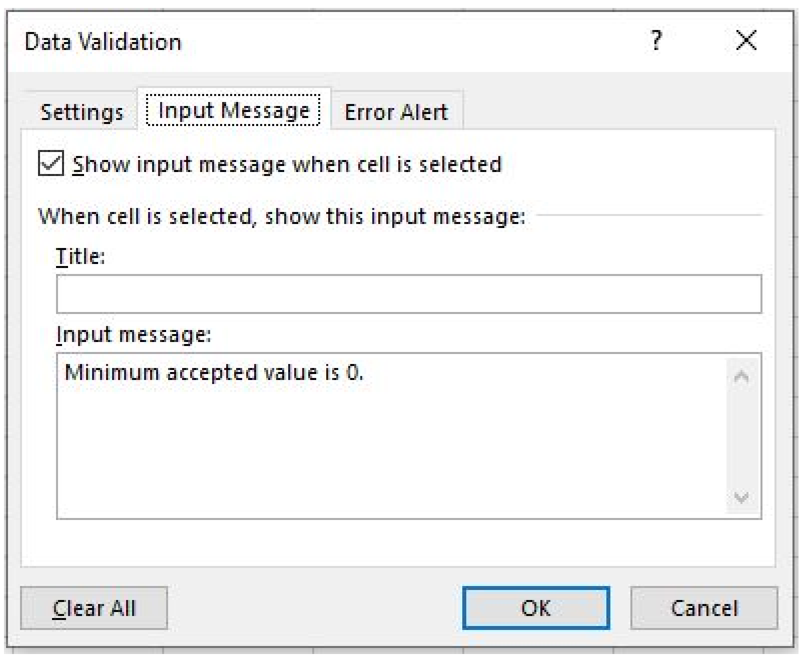


Figure 8.8: Input Message to User on Cell E3

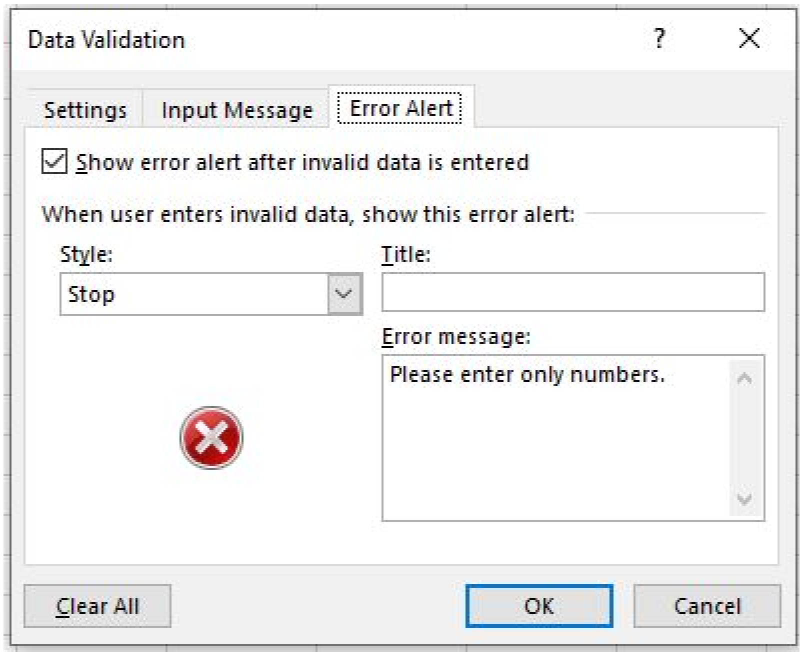


Figure 8.9: Error Notification for Invalid User Entry

The previous three figures give the overview of the data validation settings applied to cell E3 on the "Display" worksheet. In the first figure, the general settings are displayed. For an entry into the cell to be allowed, all of the shown criteria must be met; the entry must be a whole number, the entry must be greater than or equal to a value of 0, and the cell cannot be left blank. The second figure gives the settings for when the user selects the cell itself. Upon doing so, a small message box will appear informing the user of the basic constraints placed on the cell. The final figure gives the error settings that are active. If the user attempts to use any input other than accepted numeric values, they will receive an error message informing them to only enter numeric values and the cell will reset to the previous value.

The last portion of the MW loss list is a hidden column of code within the display sheet. Upon a close inspection, it can be seen that column "A" has been hidden from the user. Column "A" contains a series of cells with a recursive code. The cell A6 contains the numeric value "0" as the starting point for the column code. The remainder of the column contains the code shown in the following figure.

```
=IF(A6<$E$3,A6+1,"")
```

Figure 8.10: Recursive Code for Altering Length of MW Loss Tables

The purpose of this code is to take the numeric value in the cell directly above and compare it to the user determined value entered into cell E3. If the value in the cell above is less than the value the user has designated, the value will be increased by one and the next cell in the column will activate. This process continues until the final value in column “A” is equal to the user designated value in E3 for the length of the table. From here, new code will pull valve names and corresponding MW loss values. The following figure showcases the cells and the code used for this process.

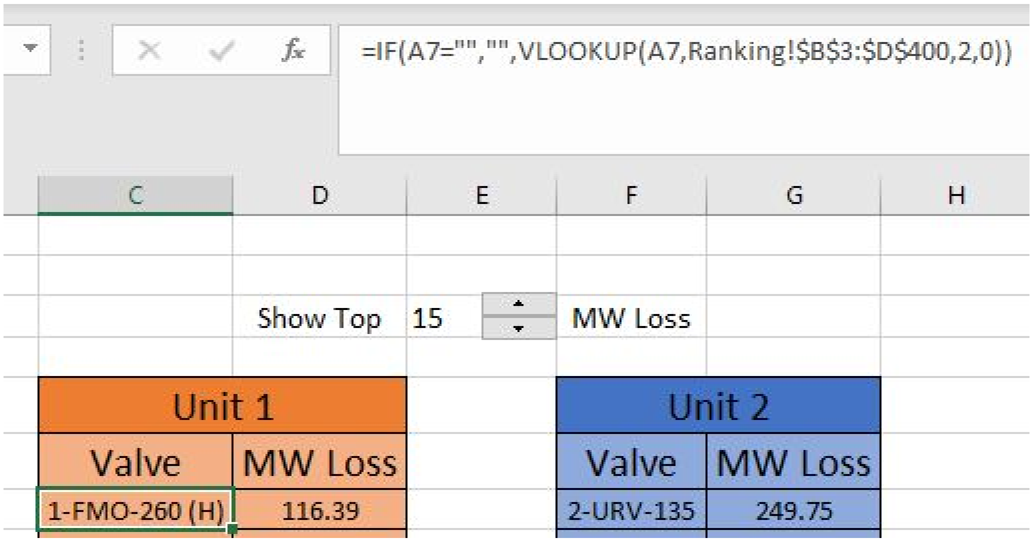


Figure 8.11: MW Loss Table Code for Length

This code looks at the cell in column “A” within the same row and enters the value into an IF statement. If the corresponding cell in column “A” is blank (shown as “”) then the cell output is blank, signaling the cease of table development. However, if the corresponding cell in column “A” has a numeric value, the code then takes that numeric value and compares it to a hidden sheet named “Ranking” to find the reference value. This hidden sheet shall be discussed in Section 8.3.4. The code finds the reference value listed within the first column of a specified range. In Figure 8.11, this specified range includes cells B3:D400 within the notation $B$3:$D$400 ensuring the range is fixed and unchanging within the code. Once the referenced value is found, the code then takes the value in the second column of the range and outputs it into the cell. In the example in Figure 8.11, this results in the output of “1-FMO-260 (H)”. This code repeats between both tables and references the appropriate valve names and megawatt values using the VLOOKUP function to ensure the proper values are selected.

8.3 “Unit 1”, “Unit 2”, “Results”, “Valve Check”, and Hidden “Ranking” Tabs

Five other tabs exist within the worksheet if the calculation tabs are not counted. “Unit 1”, “Unit 2”, “Results”, and “Ranking” tabs require no user activity or editing. It is recommended that users avoid altering these sheets and safeguards can be implemented to ensure only users with a specific password can edit these sheets. The "Valve Check" sheet is set up to allow for user interaction and the purpose shall be discussed in a following subsection.

8.3.1 "Unit 1" and "Unit 2" Tabs

The worksheets labelled "Unit 1" and "Unit 2" contain all of the input data for the Unit 1 and Unit 2 calculations. This data includes valve names, measured temperatures, upstream enthalpy values, the inner pipe diameters, and the flow values from ASME Figure 14 as shown in the following figures.

	A	B	C	D	E	F
1	Valve #	DI (in)	Temp (°F)	Upstream Enthalpy (BTU/lbm)	ASME Flow (lbm/hr*in2*psi)	
2	1-URV-110	9.750	374	1201.2	50	
3	1-URV-111	9.750	370	1201.2	50	
4	1-URV-112	9.750	372	1201.2	50	
5	1-URV-120	9.750	376	1201.2	50	
6	1-URV-124	9.750	375	1201.2	50	
7	1-URV-125	9.750	335	1201.2	50.5	
8	1-URV-130	9.750	380	1201.2	50	
9	1-URV-135	9.750	401	1201.2	50	
10	1-URV-136	9.750	377	1201.2	50	
11	1-HRV-561	15.000	108	323.98	60	
12	1-HRV-562	15.000	109	323.98	60	
13	1-CRV-224 (H)	17.000	165	150.31	56.5	
14	1-CRV-224 (L)	17.000	221	150.31	54	
15	1-FMO-260 (H)	11.750	420	314.24	50.25	
16	1-FMO-260 (L)	11.750	340	314.24	52	
17	1-MRV-404	7.625	121	360.02	59	
18	1-MRV-403	7.625	333	360	51.5	
19	1-B-360	4.026	140	1163.34	59	
20	1-B-361	4.026	139	1163.34	59	
21	1-DRV-220	4.026	118	1163.34	58.5	
22	1-DRV-222	4.026	140	1163.34	57.5	
23	1-HRV-563	6.065	116	323.23	58.5	
24	1-HRV-564	6.065	99	323.23	59	
25	1-HRV-257	7.981	106	160.39	59	
26	1-HRV-258	7.981	125	160.38	58	
27	1-HRV-357	6.065	93	216.95	59.5	
28	1-HRV-358	6.065	135	216.95	57.5	
29	1-DRV-403	2.323	172	1207.88	56.25	
30	1-DRV-404	2.323	193	1207.88	55	
31	1-MS-234	2.323	172	1207.88	56.25	
32	1-MS-239	2.323	510	1207.88	50.25	
33	1-DRV-422	4.026	140	420.15	57.5	
34	1-DRV-423	4.026	375	420.15	50.5	
35	1-MSD-219L	4.026	262	420.15	53	
36	1-MSD-219R	4.026	203	420.15	54.5	

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2 | Grashof U1

Ready

Figure 8.12: "Unit 1" Input Value Storage

	A	B	C	D	E	F
1	**Valve #**	**DI (in)**	**Temp (°F)**	**Upstream Enthalpy (BTU/lbm)**	**ASME Flow (lbm/hr*in2*psi)**	
2	**2-URV-112**	9.562	400.0	1196.3	50	
3	**2-URV-111**	9.562	415.8	1196.3	50.25	
4	**2-URV-110**	9.562	417.0	1196.3	50.25	
5	**2-URV-135**	9.562	486.8	1196.3	50	
6	**2-URV-130**	9.562	406.2	1196.3	50.5	
7	**2-URV-136**	9.562	486.2	1196.3	50	
8	**2-URV-125**	9.562	445.0	1196.3	50.5	
9	**2-URV-124**	9.562	402.2	1196.3	50.25	
10	**2-URV-120**	9.562	419.0	1196.3	50.5	
11	**2-CRV-224**	16.876	153.0	265.19	52	
12	**2-HRV-558**	15.000	95.8	323.98	59.5	
13	**2-HRV-557**	15.000	111.0	323.98	59	
14	**2-HRV-257**	7.981	86.0	1196.3	59.75	
15	**2-HRV-462**	16.876	107.8	234.98	59	
16	**2-HRV-461**	16.876	116.8	234.98	59	
17	**2-RCD-294**	11.750	93.0	519.34	59.5	
18	**2-DRV-427**	11.750	94.0	519.34	59.5	
19	**2-DRV-426**	11.750	97.0	519.34	59	
20	**2-RCD-292**	11.750	110.0	519.34	57.8	
21	**2-DRV-428**	11.750	120.0	519.34	59	
22	**2-RCD-296**	11.750	110.8	519.34	59	
23	**2-RCD-290**	11.750	93.0	519.34	59.5	
24	**2-DRV-425**	11.750	103.8	519.34	59	
25	**2-FMO-260**	11.374	225.0	292.14	54	
26	**2-DRV-224**	6.065	99.0	1147.12	58	
27	**2-MRV-427**	10.020	120.0	400.85	59	
28	**2-MRV-425**	10.020	92.0	400.85	59	
29	**2-DRV-306**	4.026	203.2	1167.52	54.5	
30	**2-B-349**	4.026	138.2	1167.52	57.5	
31	**2-DRV-305**	4.026	110.0	1167.52	57.8	
32	**2-B-348**	4.026	116.0	1167.52	58.5	
33	**2-HRV-563**	6.065	100.8	323.98	59	
34	**2-HRV-564**	6.065	82.4	323.98	60	
35	**2-MS-239**	2.900	319.6	1199.12	51.5	
36	**2-DRV-406**	2.900	261.0	1199.12	54	

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2 | Grasho

Ready

Figure 8.13: "Unit 2" Input Value Storage

All of this data is stored continually within the file and can be manually updated by the user if desired. However, the file is set up in such a way that the user should never have to access these sheets. After being entered , data from these sheets is then pulled into cells within the calculation tabs and the resulting megawatt loss estimations are stored within the “Results” tab.

8.3.2 “Results” Tab

After the calculations are performed, the resulting megawatt loss values are stored within the “Results” tab in the same valve order as the “Unit 1” and “Unit 2” tabs. The following figure shows the layout of the “Results” tab.

	A	B	C	D	E	F	G
1	Unit 1						
2	Valve	Grashof	Choke	Sonic	ASME	Darcy	Avg.1
3	1-URV-110	82.46936809			81.74717641		82.10827225
4	1-URV-111	78.74000171			77.9635835		78.3517926
5	1-URV-112	80.58762117			79.83740123		80.2125112
6	1-URV-120	84.38566685			83.69338425		84.03952555
7	1-URV-124	83.42317191			82.71569647		83.06943419
8	1-URV-125	51.49310586			51.00982063		51.25146325
9	1-URV-130	88.32362397			87.69700873		88.01031635
10	1-URV-135	111.3847778			111.2469357		111.3158567
11	1-URV-136	85.35690615			84.68029946		85.01860281
12	1-HRV-561	1.100672083			1.861038174		1.480855128
13	1-HRV-562	1.138241125			1.901501828		1.519871476
14	1-CRV-224 (H)	5.55933825			6.457332504		6.008335377
15	1-CRV-224 (L)	15.98054689			16.76861657		16.37458173
16	1-FMO-260 (H)	115.8677061			116.920149		116.3939276
17	1-FMO-260 (L)	46.90382652			47.90627464		47.40505058
18	1-MRV-404	0.44034508			0.644407717		0.542376398
19	1-MRV-403	18.87335008			19.05659583		18.96497296
20	1-B-360	0.320713464			0.419947824		0.370330644
21	1-B-361	0.312900696			0.41151547		0.362208083
22	1-DRV-220	0.177340722			0.263726547		0.220533634
23	1-DRV-222	0.320713464			0.409271184		0.364992324
24	1-HRV-563	0.232283392			0.351643942		0.291963667
25	1-HRV-564	0.129512814			0.245837591		0.187675202
26	1-HRV-257	0.260673343			0.444605525		0.352639434
27	1-HRV-258	0.468103005			0.654029222		0.561066113
28	1-HRV-357	0.091407048			0.197499977		0.144453513
29	1-HRV-358	0.357027044			0.466335803		0.411681424
30	1-DRV-403	0.217867034			0.248623893		0.233245464
31	1-DRV-404	0.329431049			0.357895444		0.343663247
32	1-MS-234	0.217867034			0.248623893		0.233245464
33	1-MS-239	17.82256554			18.41682411		18.11969483
34	1-DRV-422	0.213625401			0.272613191		0.243119296
35	1-DRV-423	9.184512499			9.197688891		9.191100695
36	1-MSD-219L	2.080318398			2.133412622		2.10686551

	I	J	K	L	M	N	O
1	Unit 2						
2	Valve	Grashof	Choke	Sonic	ASME	Darcy	Avg.2
3	2-URV-112	105.8627504			105.6253296		105.74404
4	2-URV-111	125.090143			126.001759		125.545951
5	2-URV-110	126.6547149			127.6212203		127.1379676
6	2-URV-135	247.0498918			252.4528836		249.7513877
7	2-URV-130	113.1094091			114.1873371		113.6483731
8	2-URV-136	245.7407302			251.0759382		248.4083342
9	2-URV-125	167.6841174			171.1395478		169.4118326
10	2-URV-124	108.3911461			108.7575493		108.5743477
11	2-URV-120	129.2961728			131.0052907		130.1507318
12	2-CRV-224	4.472413699			4.785932206		4.629172952
13	2-HRV-558	0.793349659			1.398601998		1.095975828
14	2-HRV-557	1.307983059			1.930063718		1.619023388
15	2-HRV-257	0.247065215			0.522819074		0.384942144
16	2-HRV-462	1.372981751			2.084291837		1.728636794
17	2-HRV-461	1.78900356			2.525632576		2.157318068
18	2-RCD-294	0.520918493			0.959165568		0.740042031
19	2-DRV-427	0.541265886			0.98069631		0.760981098
20	2-DRV-426	0.604739089			1.03913151		0.8219353
21	2-RCD-292	0.926175382			1.350346753		1.138261067
22	2-DRV-428	1.232597595			1.703896452		1.468247023
23	2-RCD-296	0.948654723			1.402196805		1.175425764
24	2-RCD-290	0.520918493			0.959165568		0.740042031
25	2-DRV-425	0.762958174			1.205804991		0.984381582
26	2-FMO-260	8.147584109			8.475849685		8.311716897
27	2-DRV-224	0.239209686			0.393350277		0.316279982
28	2-MRV-427	0.811468767			1.121743835		0.966606301
29	2-MRV-425	0.329773692			0.612316486		0.471045089
30	2-DRV-306	1.211319007			1.279846366		1.245582687
31	2-B-349	0.319475041			0.394605876		0.357040459
32	2-DRV-305	0.150562531			0.219517414		0.185039973
33	2-B-348	0.179554576			0.252752398		0.216153487
34	2-HRV-563	0.154733172			0.253070482		0.203901827
35	2-HRV-564	0.073521336			0.17075531		0.122138323
36	2-MS-239	3.74202972			3.758704297		3.750367009

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2 | Grashof U1 | Grashof U2 | Choke U1 | Choke U2 | Sonic U1 | Sonic U

Ready

Figure 8.14: “Results” Tab

The “Results” tab is set up in such a way that the user could see the megawatt loss value estimations from each calculation method. At the time of this report, only two methods have been confirmed to give accurate megawatt loss estimations (Grashof and ASME Figure 14). Once the other three methods have been determined to give proper estimations of megawatt loss, they can be added to the appropriate columns within the “Results” tab. This sheet takes all of the estimated values within each unit and calculates an average megawatt loss value for each valve.

8.3.3 “Valve Check” Tab

The “Valve Check” tab has only one purpose for the user, being a dynamic sheet that allows the user to change which valves are counted for the megawatt loss display table on the “Display” tab. The following figure gives the layout of the “Valve Check” tab.

	Unit 1			Unit 2		
	Valve	MW Loss	Count?	Valve	MW Loss	Count?
3	1-URV-110	82.11		2-URV-112	105.74	
4	1-URV-111	78.35		11	125.55	
5	1-URV-112	80.21		10	127.14	
6	1-URV-120	84.04		35	249.75	
7	1-URV-124	83.07		30	113.65	
8	1-URV-125	51.25		36	248.41	
9	1-URV-130	88.01		2-URV-125	169.41	
10	1-URV-135	111.32		2-URV-124	108.57	
11	1-URV-136	85.02		2-URV-120	130.15	
12	1-HRV-561	1.48		2-CRV-224	4.63	
13	1-HRV-562	1.52		2-HRV-558	1.10	
14	1-CRV-224 (H)	6.01		2-HRV-557	1.62	
15	1-CRV-224 (L)	16.37		2-HRV-257	0.38	
16	1-FMO-260 (H)	116.39		2-HRV-462	1.73	
17	1-FMO-260 (L)	47.41		2-HRV-461	2.16	
18	1-MRV-404	0.54		2-RCD-294	0.74	
19	1-MRV-403	18.96		2-DRV-427	0.76	
20	1-B-360	0.37		2-DRV-426	0.82	
21	1-B-361	0.36		2-RCD-292	1.14	
22	1-DRV-220	0.22		2-DRV-428	1.47	
23	1-DRV-222	0.36		2-RCD-296	1.18	
24	1-HRV-563	0.29		2-RCD-290	0.74	
25	1-HRV-564	0.19		2-DRV-425	0.98	
26	1-HRV-257	0.35		2-FMO-260	8.31	
27	1-HRV-258	0.56		2-DRV-224	0.32	
28	1-HRV-357	0.14		2-MRV-427	0.97	
29	1-HRV-358	0.41		2-MRV-425	0.47	
30	1-DRV-403	0.23		2-DRV-306	1.25	
31	1-DRV-404	0.34		2-B-349	0.36	
32	1-MS-234	0.23		2-DRV-305	0.19	
33	1-MS-239	18.12		2-B-348	0.22	
34	1-DRV-422	0.24		2-HRV-563	0.20	
35	1-DRV-423	9.19		2-HRV-564	0.12	
36	1-MSD-219L	2.11		2-MS-239	3.	

If you want the valve to be counted, leave blank. If you want the valve to be ignored from the Display list, select "No".

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2

Figure 8.15: "Valve Check" Tab for User Preference

Within this sheet, a new column is placed under each unit named “Count?”. This column allows for the user to determine if the valve in the corresponding row is to be counted towards the megawatt loss table. Why is this important? There are several valves (specifically URV type valves) where the temperature measurement could not be taken at the recommended distance of 10*L/D away from the valve location. Therefore, the corresponding calculations cannot be considered to be wholly accurate. This sheet allows the user to remove these valves before reporting the top losses within each unit. In similar fashion to the safeguards placed upon the megawatt loss list length alteration, safeguards have been placed upon the “Count?” column cells to prevent file breakdown from user error. As can be seen in Figure 8.15, when the user selects a cell within the “Count?” column, they are immediately given a message describing the purpose of the cell. The following figures give the data validation settings that are repeated within every cell in the “Count?” column.

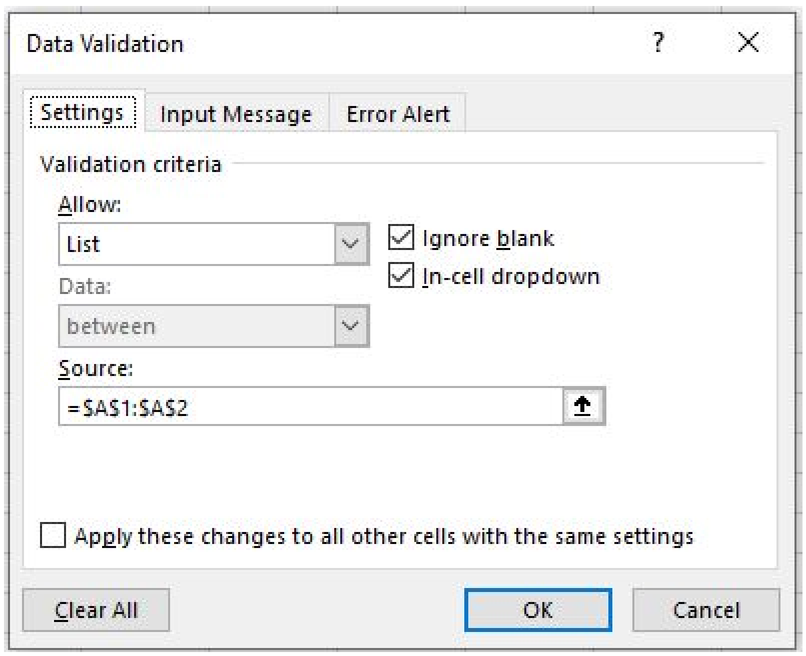


Figure 8.16: “Valve Check” Setting

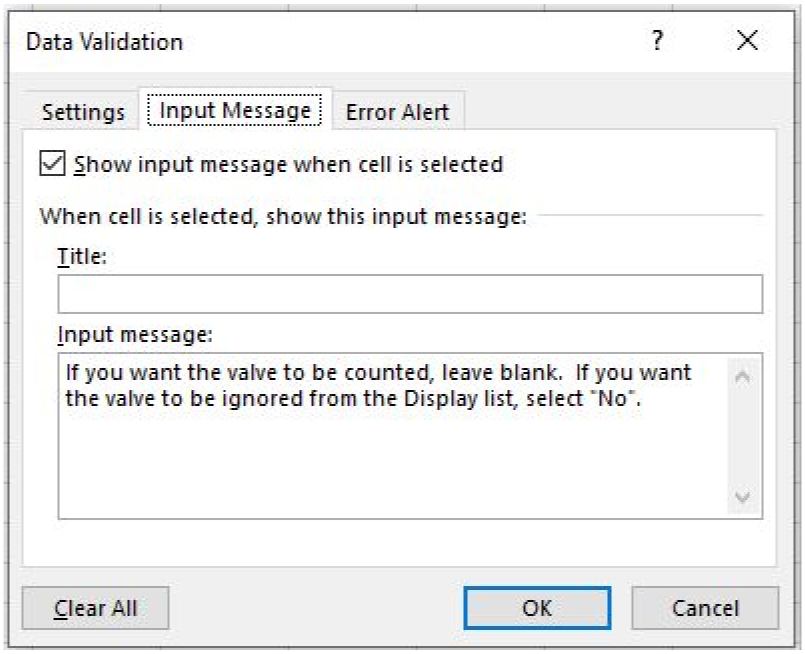


Figure 8.17: "Valve Check" User Input Message

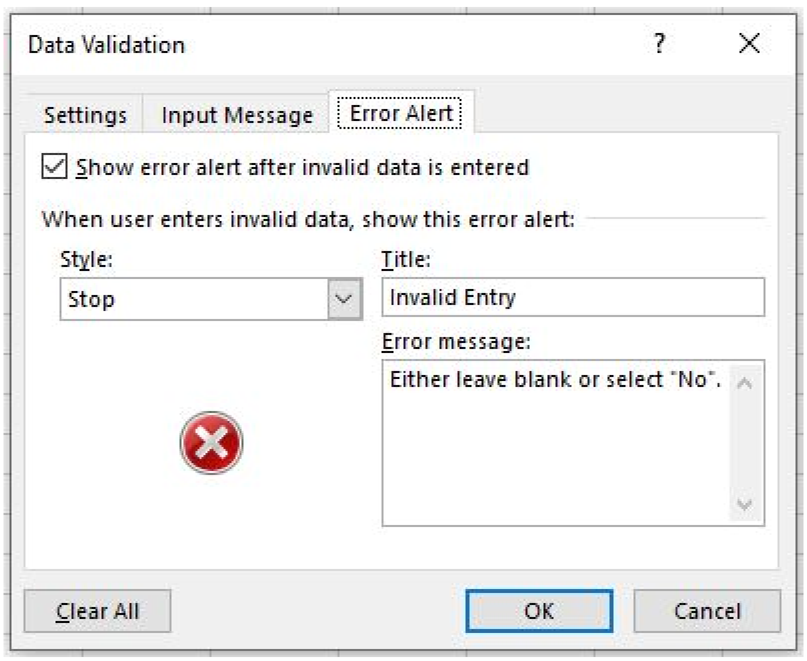


Figure 8.18: "Check Valve" User Error Notification

In Figure 8.16, the cells in the "Count?" column are set as list cells. This change produces a dropdown option within every cell in that column for the user to have access to. In similar fashion as the "Display" sheet, the "Check Valve" sheet also has a hidden column "A". With this column exists two cells that give the criteria for the list setting. This criteria gives the user the option to either select "No" or to leave the cell blank. Figure 8.17 gives the user the brief description when selecting the cell as mentioned before and Figure 8.18 specifies the error type and error messages given to the user upon improper data entry. Any entry besides “No” or leaving the cell blank results in the user receiving the predetermined error message and the cell returning to the previous entered value.

8.3.4 Hidden “Ranking” Tab

The final tab to be discussed is the hidden “Ranking” tab within the worksheet. This tab has the role of assigning values beginning at one and increasing based upon the highest to lowest megawatt loss values. Furthermore, this valve takes into account the user options from the “Check Valve” tab. If the user has assigned “No” to any valves, they are not added to the ranking process. The following figure shows the layout of the hidden “Ranking” tab if it is reentered into the file.

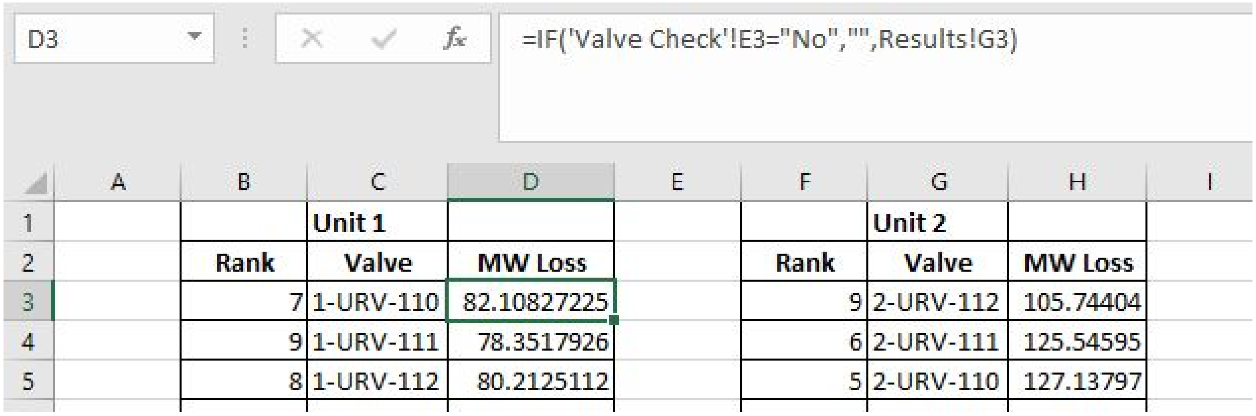
1		Unit 1				Unit 2	
2	Rank	Valve	MW Loss		Rank	Valve	MW Loss
3	7	1-URV-110	82.10827225		9	2-URV-112	105.74404
4	9	1-URV-111	78.3517926		6	2-URV-111	125.54595
5	8	1-URV-112	80.2125112		5	2-URV-110	127.13797
6	5	1-URV-120	84.03952555		1	2-URV-135	249.75139
7	6	1-URV-124	83.06943419		7	2-URV-130	113.64837
8	10	1-URV-125	51.25146325		2	2-URV-136	248.40833
9	3	1-URV-130	88.01031635		3	2-URV-125	169.41183
10	2	1-URV-135	111.3158567		8	2-URV-124	108.57435
11	4	1-URV-136	85.01860281		4	2-URV-120	130.15073
12	19	1-HRV-561	1.480855128		13	2-CRV-224	4.629173
13	18	1-HRV-562	1.519871476		24	2-HRV-558	1.0959758
14	16	1-CRV-224 (	6.008335377		18	2-HRV-557	1.6190234
15	14	1-CRV-224 (	16.37458173		34	2-HRV-257	0.3849421
16	1	1-FMO-260	116.3939276		16	2-HRV-462	1.7286368
17	11	1-FMO-260	47.40505058		15	2-HRV-461	2.1573181
18	25	1-MRV-404	0.542376398		31	2-RCD-294	0.740042
19	12	1-MRV-403	18.96497296		30	2-DRV-427	0.7609811
20	30	1-B-360	0.370330644		29	2-DRV-426	0.8219353
21	32	1-B-361	0.362208083		23	2-RCD-292	1.1382611
22	40	1-DRV-220	0.220533634		20	2-DRV-428	1.468247
23	31	1-DRV-222	0.364992324		22	2-RCD-296	1.1754258
24	35	1-HRV-563	0.291963667		32	2-RCD-290	0.740042
25	41	1-HRV-564	0.187675202		26	2-DRV-425	0.9843816
26	33	1-HRV-257	0.352639434		11	2-FMO-260	8.3117169
27	24	1-HRV-258	0.561066113		37	2-DRV-224	0.31628
28	44	1-HRV-357	0.144453513		27	2-MRV-427	0.9666063
29	28	1-HRV-358	0.411681424		33	2-MRV-425	0.4710451
30	38	1-DRV-403	0.233245464		21	2-DRV-306	1.2455827
31	34	1-DRV-404	0.343663247		36	2-B-349	0.3570405
32	39	1-MS-234	0.233245464		47	2-DRV-305	0.18504
33	13	1-MS-239	18.11969483		44	2-B-348	0.2161535
34	37	1-DRV-422	0.243119296		46	2-HRV-563	0.2039018
35	15	1-DRV-423	9.191100695		49	2-HRV-564	0.1221383
36	17	1-MSD-219	2.10686551		14	2-MS-239	3.750367

Display | Ranking | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U

Figure 8.19: Hidden "Ranking" Tab for Valve Order Determination

The "Ranking" tab is once again split into Unit 1 and Unit 2 valves, with a new column at the beginning of each unit section titled "Rank". However, the column "MW Loss" should be looked at first. As seen in Figure 8.19, the cells in this column reference the cells in the "Valve

Check" tab where the user is able to specify which valves should be included and which should be removed from the megawatt loss list.



D3 =IF('Valve Check'!E3="No","",Results!G3)

	A	B	C	D	E	F	G	H	I
1			Unit 1				Unit 2		
2		Rank	Valve	MW Loss		Rank	Valve	MW Loss	
3		7	1-URV-110	82.10827225		9	2-URV-112	105.74404	
4		9	1-URV-111	78.3517926		6	2-URV-111	125.54595	
5		8	1-URV-112	80.2125112		5	2-URV-110	127.13797	

Figure 8.20: "Valve Check" "Count?" Reference Code

The code within these cells will reference the dropdown cell in the "Valve Check" tab. If a "No" is present, then the corresponding "MW Loss" cell will be blank (shown as ""). If "No" is not present, then the appropriate value from the "Results" tab is brought into the cell. From here, the "Rank" column code needs to be examined.

```
{=IF(D3="","",COUNTIF($D$3:$D$697,">"&D3)+SUM(IF(D3=$D$3:D3,1,0)))}
```

Figure 8.21: "Rank" Column Code

The code within the cells in the "Rank" column is unique in the sense that it has been altered into an array equation format through the use of Ctrl+Shift+Enter. This allows the basic mathematical calculations in the code to be applied to an entire set of data. Why was this method used instead of the built in ranking function for excel? The latest version of Excel at the time of this report has two main ranking functions: RANK.EQ and RANK.AVG. However, both functions are incapable of distinguishing very small differences between values. This resulted in repeating ranking values which gave errors within the megawatt loss lists in the "Display" tab. The array code used instead takes first looks to see if a value is present in the "MW Loss" column. If no value exists, the array code does not take the corresponding cells in the row into account during the ranking process. If a value does exist, the value is counted in the ranking process. How does the process work? Essentially the array code used acts as a tie-breaker mechanism using the summation of values throughout as a basis in order. From here, a rank is assigned to each valve and shown in the "Rank" column.

8.4 New Valve Data Input Through Userform and VBA

The entirety of the function of this developed file lies within the userform that has been created to allow for simplified and streamlined valve data input. As shown in the "Display" tab, one of the main components is a single button with the label "Input New Valve". This button triggers the userform and allows the user to begin the process of adding new valves to the file.

8.4.1 Userform Design

The creation of any userform within Excel begins with the design stage. For this specific project, the number of required inputs was minimized and the form layout was set in such a way to ensure all appropriate data was collected before being entered into the file. Figure 8.22 is the userform the user can expect to see when initializing the program.

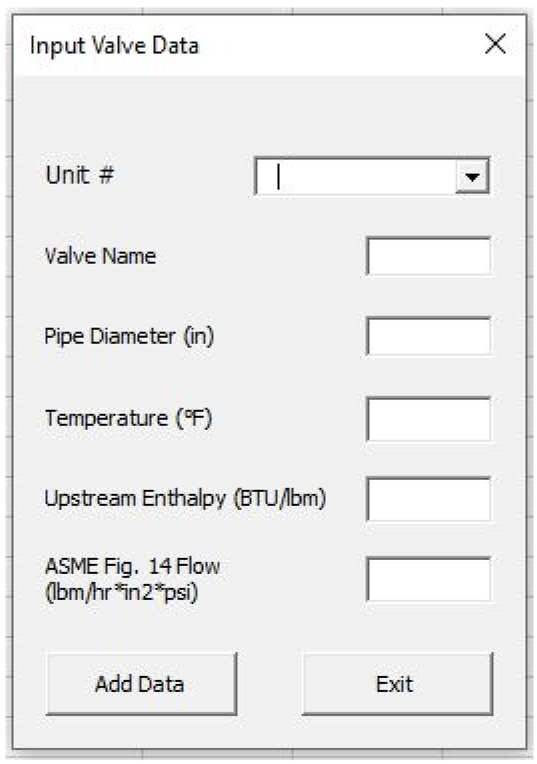


Figure 8.22: Userform to Input New Valve Data

In order to develop this form, the developer package with Excel must be made active along with VBA and macro related packages. Once this has occurred, Microsoft Visual Basic for Applications can be activated and will open in a new window. At this point a new, blank userform was inserted and the required textboxes, input spaces, and function buttons were added to the form resulting in the following figures.

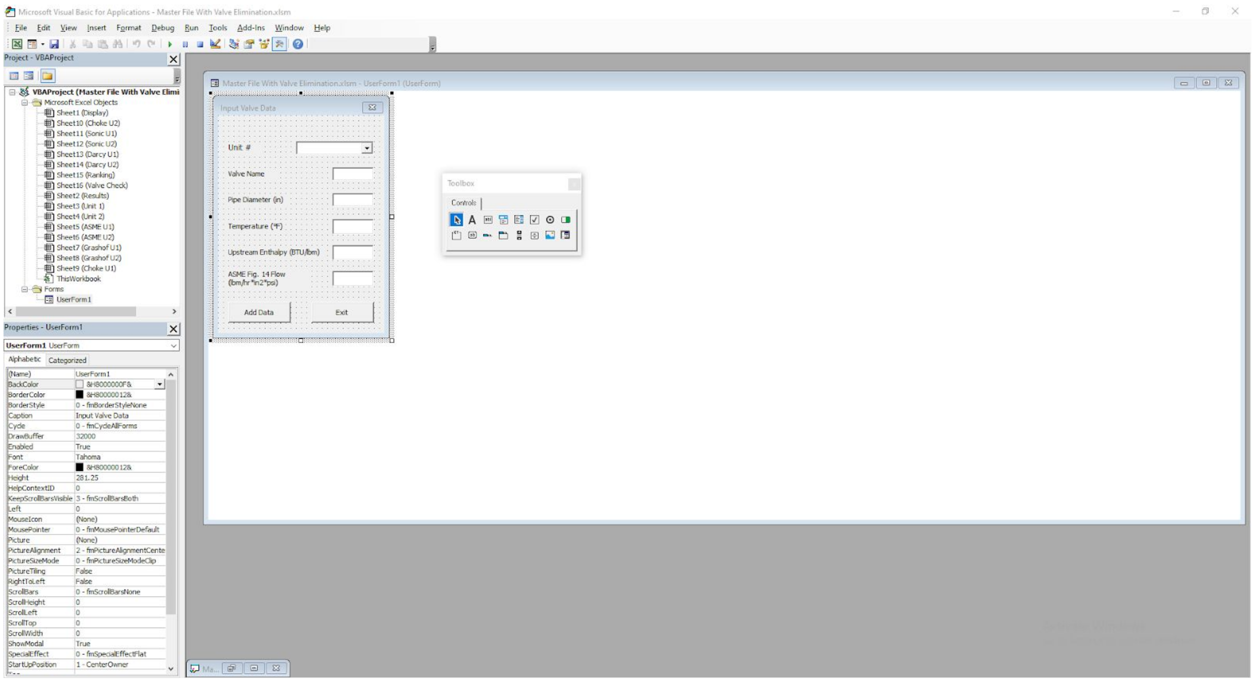


Figure 8.23: Microsoft Visual Basic for Applications Userform Design

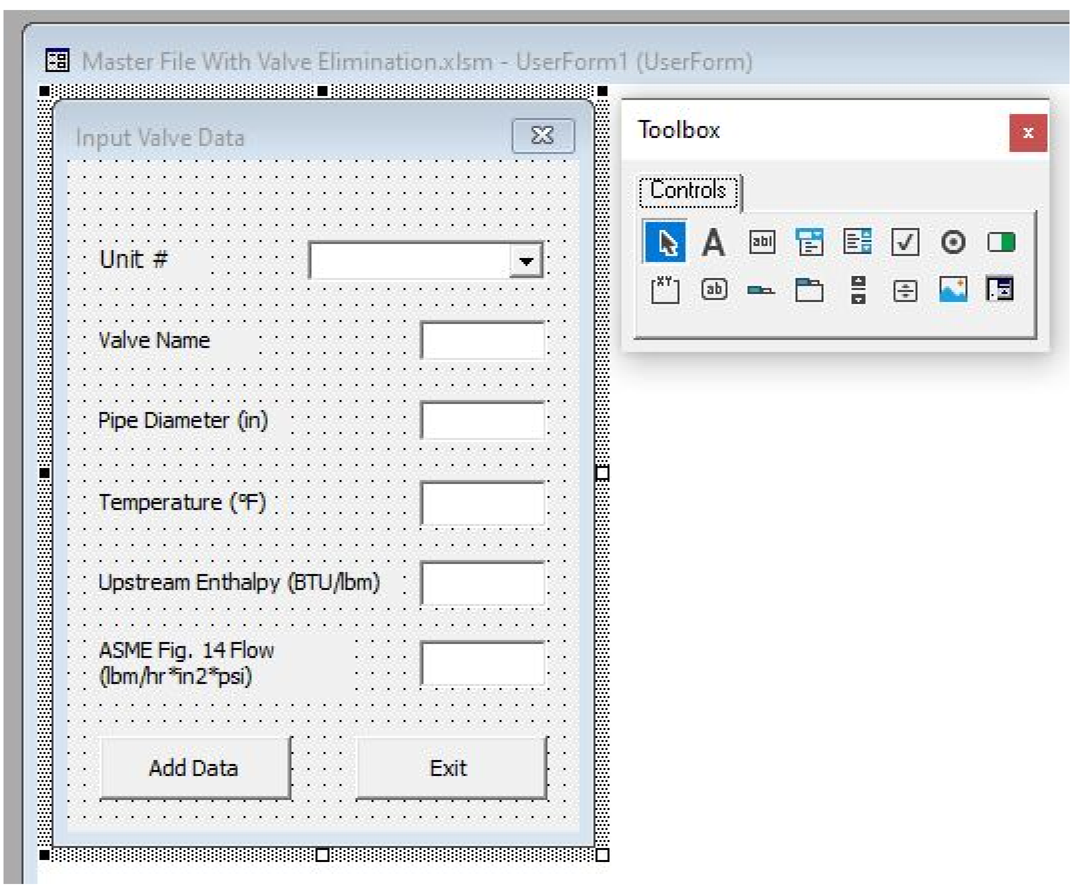


Figure 8.24: Final Userform Design

Once the final design was determined as shown in Figure 8.24, the necessary code could be developed and applied with the appropriate functions and input boxes.

8.4.2 Userform Code

The most important portion of the entire file is the coding within the userform itself. The code must be highly specific and all potential bugs must be removed. Several tests were performed throughout the coding process attempting to (and several times succeeding at) breaking the file and causing errors. This process of troubleshooting is necessary to ensure minimal future issues for the company and users once the file is transferred over for use. Due to the need for extensive explanation, the coding description shall be set throughout several subsections.

8.4.2.1 Initialization of Userform

As soon as the user presses the "Input New Valve" button, the userform has been initialized and code has already been activated. The following figure shows the code in reference.

```
Private Sub UserForm_Initialize()

    ComboBox1.AddItem "Unit 1"
    ComboBox1.AddItem "Unit 2"

End Sub
```

Figure 8.25: Userform Initialization

This private sub has been named "Userform_Initialize()" to prevent any confusion as to its purpose. When the userform is first opened, it does not contain any data. This lack of data is included in the combobox for Unit 1 or Unit 2 selection. The two lines of code prevent an error found where the user could not select a unit for valve destination. Using the .AddItem code addon to the combobox named "ComboBox1", this bug could be bypassed ensuring the user always has the "Unit 1" and "Unit 2" options.

8.4.2.2 Exiting Userform

When closing the userform either before or after inputting any data values, it is very important to clear and and all data that has been previously stored. This includes data within the combobox and within the five textboxes in the userform. To accomplish this there is a very short line of code required with another private sub being developed.

```
Private Sub Cancel_Click()

    Unload Me

End Sub
```

Figure 8.26: Exiting Userform and Data Removal

The decision was made to link this code directly to the "Exit" button on the userform. Within the VBA, this button was named "Cancel" due to potential repetition that could occur in other sections of the code. "Cancel_Click()" ensured this sub would only activate if the button was clicked by the user. The command "Unload" causes the form to eliminate any entries within the combobox and the five textboxes. The reference term "Me" tells the userform to perform this operation on itself ensuring complete data elimination. Without this section of code, old entries could possibly exist between consecutive existences of the userform leading to incorrect and inaccurate data being entered into the file.

8.4.2.3 Data Entry Check

Troubleshooting revealed a potential issue where the user could enter in data without the combobox and five textboxes all having data entries. To eliminate this potential issue, code was added to the "Add Data" button on the userform. This code would run before the data input code, functioning as a safeguard against missing data entries.

```
Private Sub AddData_Click()

TargetSheet = ComboBox1.Value

If TargetSheet = "" Then
MsgBox ("No Unit selected.")
Exit Sub
End If

If txtVN.Value = "" Then
MsgBox ("Please input the valve name.")
Exit Sub
End If

If txtPD.Value = "" Then
MsgBox ("Please input the pipe diameter.")
Exit Sub
End If

If txtT.Value = "" Then
MsgBox ("Please input the measured temperature.")
Exit Sub
End If

If txtUE.Value = "" Then
MsgBox ("Please input the upstream enthalpy for the stream.")
Exit Sub
End If

If txtASME.Value = "" Then
MsgBox ("Please input the ASME Figure 14 flowrate.")
Exit Sub
End If
```

Figure 8.27: Missing Data Safeguard

First, the "Add Data" button was named "AddData" within the code format to eliminate any potential confusion. From here, each textbox was renamed from "TextBox.1", "TextBox.2", etc., to appropriate names based upon the data that would be entered. Valve name was specified as "txtVN", pipe diameter as "txtPD", temperature as "txtT", upstream enthalpy as "txtUE", and ASME Figure 14 flow rate as "txtASME". Beginning at the top of the code in Figure 8.27, the private sub was set to begin on the click of the "Add Data" button with "AddData_Click()". From here, using the function .Value, the selection in ComboBox1 was assigned as the TargetSheet. The first safeguard then checked the value of TargetSheet. If there was no value for TargetSheet (shown as "") then a message box would be triggered through the function "MsgBox ("")". Within the parentheses and internal quotations, a predetermined message was placed to inform the user of their error. "Exit Sub" then causes the userform to end its function and the user is able to make corrections. This general setup continues for each of the five textboxes to ensure there are no blank data entries. If the user satisfies the requirements and data exists in each data entry point, the userform would continue to the next section of code.

8.4.2.4 Finding Input Location

Without being told, the userform would be unable to place the data anywhere. Data would be entered and subsequently removed once the userform was closed. Instead, destination must be specified. The following figure shows the code required to begin this process.

```
Worksheets(TargetSheet).Activate

Dim FoundCell As Range
Dim Search As String
Dim eRow As Long
eRow = Worksheets(TargetSheet).Cells(Rows.Count, 1).End(xlUp).Offset(1, 0).Row
Search = txtVN.Value
Set FoundCell = Worksheets(TargetSheet).Columns(1).Find(Search, LookIn:=xlValues, Lookat:=xlWhole)
```

Figure 8.28: Determining Location of Data Destination

Beginning this code is the line "Worksheets(TargetSheet).Activate". The "Worksheets()" function is coupled with the .Activate command to change what tab is open in the file. With the ComboBox1 value being assigned to TargetSheet (either "Unit 1" or "Unit 2") the appropriate tab is opened for the new valve data to be entered. Before the userform can continue with entering data, several new variables must be set. "FoundCell" is set "As Range" to allow for multiple cells being placed within the assignment, "Search" is set "As String" to become a new variable the userform can use later, and "eRow" is set "As Long" for use in determining the proper location for data destination.

Once the new variables are set,
"eRow = Worksheets(TargetSheet).Cell(Rows.Count,1).End(xlUp).Offset(1,0).Row" occurs. This code searches the active worksheet for the first empty row in the first column for data entry. Using the "Row.Count" function in tandem with the ".End(xlUp)" and ".Offset(1,0)" commands ensures a blank row has been selected for data entry beneath a filled row with previous data.

Next, "Search = txtVN.Value" assigns the value in the valve name textbox to the newly created variable "Search". The final line shown in Figure 8.28 causes the userform to search for the assigned valve name within the first column of the active sheet (the column containing valve names).

8.4.2.5 New Valve Entry or Update Old Valve Values

Once the userform has searched the active sheet for the valve name entered by the user, there are two potential outcomes. The first outcome is that no duplicate is found and the code in the following figure begins.

```
If FoundCell Is Nothing Then
Cells(eRow, 1).Value = txtVN.Value
Cells(eRow, 2).Value = txtPD.Value
Cells(eRow, 3).Value = txtT.Value
Cells(eRow, 4).Value = txtUE.Value
Cells(eRow, 5).Value = txtASME.Value

Else
answer = MsgBox("This valve already has data recorded. Would you like to overwrite?", vbYesNo + vbQuestion, "Duplicate Valve")
```

Figure 8.29: New Entry or Duplicate Discovered

If the "Search" function returns a "FoundCell" value of nothing (coded as "") then the userform continues and assigns the selected row the values input by the user. Each subsequent line of code causes the entry to occur in the following column to prevent any potential data overwriting. The userform will then continue onto the code explained in subsection 9.4.2.7. However, if "FoundCell" has been assigned a value then a duplicate has been discovered within previous entries. This will trigger a message box with a "Yes" button and a "No" button informing the user that the valve they entered already exists and asking if they wish to overwrite the data.

8.4.2.6 Handling Duplicate Valve Data

If a duplicate is discovered in the existing data, the user is given a warning and given a chance to decide whether they wish to update the old entry with the new data or to redo the data entry. The following code shows the process in detail.

```
If answer = vbYes Then
ActiveCell = FoundCell
Cells(ActiveCell.Row, 1).Value = txtVN.Value
Cells(ActiveCell.Row, 2).Value = txtPD.Value
Cells(ActiveCell.Row, 3).Value = txtT.Value
Cells(ActiveCell.Row, 4).Value = txtUE.Value
Cells(ActiveCell.Row, 5).Value = txtASME.Value
Else
MsgBox ("Data will not be added.")
ComboBox1.Clear
ComboBox1.AddItem "Unit 1"
ComboBox1.AddItem "Unit 2"
txtVN.Value = ""
txtPD.Value = ""
txtT.Value = ""
txtUE.Value = ""
txtASME.Value = ""

Worksheets("Display").Activate
Worksheets("Display").Cells(1, 1).Select
Exit Sub
End If
```

Figure 8.30: Duplicate Valve Update or Cancellation

If the user does wish to update the old data in the file, selecting "Yes" will cause the "FoundCell" to be assigned to the "ActiveCell" variable. From here the appropriate data entries are overwritten in the row of the "ActiveCell". The userform then continues on to the code described in subsection 9.4.2.7. If the user selects "No" and does not wish the valve data to be overwritten, a message box will open informing the user that their entered data will not be added to the file, all entered data will get cleared from the input points, and the "Display" tab becomes the active sheet again. The user will then begin the process of data entry at the beginning.

8.4.2.7 Resetting After New Entry

The following figure shows the code that occurs after a set of new valve data has been entered or after a valve has been updated.

```
ComboBox1.Clear
ComboBox1.AddItem "Unit 1"
ComboBox1.AddItem "Unit 2"
txtVN.Value = ""
txtPD.Value = ""
txtT.Value = ""
txtUE.Value = ""
txtASME.Value = ""

Worksheets("Display").Activate
Worksheets("Display").Cells(1, 1).Select

MsgBox ("Valve added successfully.")

answer = MsgBox("Would you like to add another valve?", vbYesNo + vbQuestion, "Another Entry")
If answer = vbNo Then
    Unload Me
End If

End Sub
```

Figure 8.31: Clearing Data and Resetting the Userform

This final section of code within the userform helps prepare for subsequent valve entries. The top paragraph begins by clearing "ComboBox1" and reloading the two user options and finished by clearing all entries within the five textboxes. The second paragraph with only two lines of code returns the user to the "Display" tab once again. Next, a message box will inform the user that the valve was added successfully. Finally, a question box will appear and ask the user if they wish to add another valve to the file. If the user selects "Yes" then the userform will begin the private sub again. If the user selects "No" then the userform will clear all loaded data and close out using the Unload command.

9. Economic Analysis

An economic analysis was performed on the 10 leakiest valves of each unit in the system to determine if replacement costs are financially feasible. The results of this analysis at different values of steam loss reduction can be seen in the subsections below. All of the economic analyses use the following tables to help calculate costs.

9.1 Data Used in All Scenarios

Table 9.1: Electricity Value and Downtime

Electricity Value:	28	USD/MWh
Estimated Downtime:	360	Hours/year

The above table shows the estimated electricity value and estimated downtime per year. These values are the same for both units, and are used in later tables to calculate the monetary value of steam energy lost. Changes to these values in the economic analysis spreadsheet will automatically update the rest of the spreadsheet. This is useful if electricity values or estimated downtimes change.

Table 9.2: Unit 1 Valve Information

Equipment	Energy Loss (MWe)	Manufacturer	Model	Material Cost (USD)	Maintenance Cost (USD)	Total Repair Cost
Steam Valve 1 **1-FMO-260 (L)**	47.41	Lunkeheimer	1469XB7MOD-12I	$13,997.67	$17,000.00	$30,997.67
Steam Valve 2 **1-MRV-403**	18.96	Copes-Vulcan	GS6	$14,042.00	$5,430.00	$19,472.00
Steam Valve 3 **1-MS-239**	18.12	Velan Valve Corp.	B09-2074C-02TY	$2,000.00	$5,430.00	$7,430.00
Steam Valve 4 **1-CRV-224 (L)**	16.37	Fisher Controls Co.	V300	$16,972.00	$5,430.00	$22,402.00
Steam Valve 5 **1-DRV-423**	9.19	Fisher Controls Co.	ED	$13,997.67	$3,880.00	$17,877.67
Steam Valve 6 **1-CRV-224 (H)**	6.01	Fisher Controls Co.	V300	$16,972.00	$5,430.00	$22,402.00
Steam Valve 7 **1-MSD-219L**	2.11	Velan Valve Corp.	B12-2064C-02TY	$13,997.67	$900.00	$14,897.67
Steam Valve 8 **1-HRV-562**	1.52	Hammel-Dahl	500THC82HBOG	$17,000.00	$1,500.00	$18,500.00
Steam Valve 9 **1-HRV-561**	1.48	Hammel-Dahl	500THC82HBOG	$17,000.00	$1,500.00	$18,500.00
Steam Valve 10 **1-MRV-409**	0.95	Fisher Controls Co.	EZ	$13,997.67	$7,800.00	$21,797.67
			Averages	$13,997.67	$5,430.00	$19,427.67

The above table shows information on the top 10 leakiest valves in unit 1 and their replacement costs. This data was provided by our plant contact Katelin Kohn. Any holes in the monetary data received were filled with the averages from the other valves. This helps to get a more accurate idea of total costs for the unit.

Table 9.3: Unit 1 Total Costs

Replacement Materials Total	116,916.68	USD
Replacement Maintenance Total	57,000.00	USD
Yearly Energy Loss	459,228	MWh
Yearly Energy Loss Cash Value	12,858,384.00	USD

Using the unit 1 valve data and the electricity value and downtime data, the total unit costs can be calculated. This is shown in the table above. The replacement materials total is used as the formal capital investment (FCI) in the different scenarios outlined in the following subsections. The replacement maintenance total is likewise used as the working capital (WC) in the different scenarios outlined in the following subsections. The yearly energy loss cash value is used to calculate income and expenses. These values are all automatically calculated using Table 9.1 - Electricity Value and Downtime and Table 9.2 - Unit 1 Valve Information tables.

Table 9.4: Unit 2 Valve Information

Equipment	Energy Loss (MWe)	Manufacturer	Model	Material Cost (USD)	Maintenance Cost (USD)	Total Repair Cost
Steam Valve 1 **2-T-121-6**	21.22	Armstrong	5133-1I	$11,691.67	$7,800.00	$19,491.67
Steam Valve 2 **2-FMO-260**	8.31	Lunkeheimer	1469XB7 MOD-12I	$11,691.67	$17,000.00	$28,691.67
Steam Valve 3 **2-T-121-5**	8.01	Armstrong	5133-1I	$11,691.67	$7,800.00	$19,491.67
Steam Valve 4 **2-CRV-224**	4.63	Fisher Controls Co.	8-U	$14,000.00	$1,800.00	$15,800.00
Steam Valve 5 **2-MS-239**	3.75	Velan Valve Corp.	B10-2074 C-02TS	$2,000.00	$5,700.00	$7,700.00
Steam Valve 6 **2-HRV-461**	2.16	Fisher Controls Co.	V100	$7,500.00	$3,000.00	$10,500.00
Steam Valve 7 **2-HRV-462**	1.73	Fisher Controls Co.	V100	$17,050.00	$4,000.00	$21,050.00
Steam Valve 8 **2-DRV-406**	1.67	Hammel-Da hl	500LFK93 HAEGZ	$5,600.00	$5,000.00	$10,600.00
Steam Valve 9 **2-HRV-557**	1.62	Hammel-Da hl	500SHC82 HAOGJ	$24,000.00	$4,000.00	$28,000.00
Steam Valve 10 **2-B-431**	1.57	Lunkeheimer		$11,691.67	$900.00	$12,591.67
			Averages	$11,691.67	$5,700.00	$17,391.67

The above table shows information on the top 10 leakiest valves in unit 2 and their replacement costs. This data was provided by the plant contact Katelin Kohn. Any holes in the monetary data received were once again filled with the averages from the other valves.

Table 9.5: Unit 2 Total Costs

Replacement Materials Total	116,916.68	USD
Replacement Maintenance Total	57,000.00	USD
Yearly Energy Loss	459,228	MWh
Yearly Energy Loss Cash Value	12,858,384.00	USD

Using the unit 2 valve data and the electricity value and downtime data, the total unit costs can be calculated. This is shown in the table above. The replacement materials total is used as the FCI in the different scenarios outlined in the following subsections. The replacement maintenance total is likewise used as the WC in the different scenarios outlined in the following subsections. The yearly energy loss cash value is used to calculate income and expenses. These values are all automatically calculated using Table 9.1 - Electricity Value and Downtime and Table 9.4 - Unit 2 Valve Information tables.

9.2 Best Case Scenario: 90% Reduction of Steam Losses

The first scenario tested was an ideal scenario. In this scenario, 90% of the steam that was lost by the leaking valves is saved by the new valves and the energy remains in the system. It is best to keep in mind that this scenario allows for 10% losses by the steam valves to account for any minor leakages that may still occur in the newly installed valves.

Table 9.6: 90% Scenario Rate Data for Both Units

MARR	5%
Tax Rate	21%
Reduction of Steam Losses	90%

The company is not looking to get any specific minimum acceptable rate of return (MARR), and is more interested in low payback periods. As such, the MARR is assumed to be 5% in order to account for the cost of inflation. Tax rates are assumed to be 21% in all cases. In this case, the reduction of steam losses is assumed to be 90%. Changing any of these values in the economic analysis spreadsheet automatically updates the rest of the spreadsheet so new scenarios can be tested easily.

9.2.1 Unit 1 Best Case Scenario Analysis

Table 9.7: Unit 1 Best Case Data Summary

NPV	78,475,242.84	USD
PBP	0.01071780251	Years
PBP	3.911997915	Days

As seen in Table 9.7, the 90% steam losses reduction best case scenario results for unit 1 in a net present value (NPV) of $78.5 million USD in today's dollars when accounting for a 5% rate of inflation over the next 5 years. This keeps in mind the time value of money. The payback period (PBP) of this scenario is also only 4 days, which is well within the company's requested 3 years or less PBP. This table was calculated using Table A.5.1.1 - Unit 1 Best Case MACRS Monetary Calculations in Appendix A.5.1.

9.2.2 Unit 2 Best Case Scenario Analysis

Table 9.8: Unit 2 Best Case Data Summary

NPV	35,055,521.64	USD
PBP	0.02147708353	Years
PBP	7.839135487	Days

As seen in Table 9.8, the 90% steam losses reduction best case scenario results for unit 2 in a net present value (NPV) of $35.1 million USD in today's dollars when accounting for a 5% rate of inflation over the next 5 years. This keeps in mind the time value of money. The payback period (PBP) of this scenario is also only 8 days, which is well within the company's requested 3 years or less PBP. This table was calculated using Table A.5.2.1 - Unit 2 Best Case MACRES Monetary Calculations in Appendix A.5.2.

9.3 Worst Case Scenario: 55% Reduction in Steam Losses

The next scenario tested was the worst case scenario. In this scenario, 55% of the steam that was lost by the leaking valves is saved by the new valves and the energy remains in the system. This scenario allows for 45% losses by the steam valves to account for any minor leakages that may still occur in the newly installed valves.

Table 9.9 - 55% Scenario Rate Data for Both Units

MARR	5%
Tax Rate	21%
Reduction of Steam Losses	55%

In Table 9.9, the MARR and tax rates are the same as in the best case scenario. The only thing that was changed was the reduction of steam losses value, which was dropped to an estimated 55%.

9.3.1 Unit 1 Worst Case Scenario Analysis

Table 9.10: Unit 1 Worst Case Data Summary

NPV	9,707,519.26	USD
PBP	0.0866173885	Years
PBP	31.6153468	Days

As seen in Table 9.10, the 55% steam losses reduction worst case scenario results for unit 1 in a net present value (NPV) of $9.7 million USD in today's dollars when accounting for a 5% rate of inflation over the next 5 years. This keeps in mind the time value of money. The payback period (PBP) of this scenario is also only 32 days, which is well within the company's requested 3 years or less PBP. This table was calculated using Table A.5.1.2 - Unit 1 Worst Case MACRS Monetary Calculations in Appendix A.5.1.

9.3.2 Unit 2 Worst Case Scenario Analysis

Table 9.11: Unit 2 Worst Case Data Summary

NPV	4,269,970.96	USD
PBP	0.1761908035	Years
PBP	64.30964328	Days

As seen in Table 9.11, the 55% steam losses reduction worst case scenario results for unit 2 in a net present value (NPV) of $4.3 million USD in today's dollars when accounting for a 5% rate of inflation over the next 5 years. This keeps in mind the time value of money. The payback period (PBP) of this scenario is also only 65 days, which is well within the company's requested 3 years or less PBP. This table was calculated using Table A.5.2.2 - Unit 1 Worst Case MACRES Monetary Calculations in Appendix A.5.2.

10. Alternative Analysis

Even in the worst case scenario depicted in Section 9.3, replacing the 10 worst performing valves in each unit results in a significant steam savings with a net present value in the millions of dollars and payback periods of less than a quarter year. In the future the financial analysis can be expanded to include replacing a larger number of valves in each unit.

11. Conclusion

The models have shown that there are extensive energy losses present in the system due to the aging valves. An economic analysis has shown that replacing the top 10 leakiest valves would keep a considerable amount of energy in the system, and therefore save the company money.

11.1 Number of Valves to Replace and Financial Feasibility

We were able to get financial information for replacing the top 10 worst valves in each unit. In the future, it would be beneficial to expand the economic analysis portion of the project to include an analysis for replacing the top 20 valves of each unit to see how this impacts the project finances. Energy loss data on the leakiest valves can be found easily using the Excel spreadsheet program outlined in section 8 of this report, and an economic analysis can be performed using the economic analysis excel spreadsheet discussed in section 9 of this report. These are living spreadsheets, so any newly audited valve data can be input into the spreadsheets and updated steam leakage results can be calculated.

11.1.1 Unit 1

Replacing the top 10 leakiest valves in unit 1 results in a net present value (NPV) monetary savings of $9.7-78.5 million USD (worst case and best case respectively). This value is shown in today's dollars accounting for a 5% inflation rate per year. The payback period for investing in these replacement valves is 4-32 days (best case - worst case). Even in the worst case scenario where the new valves recover 55% more steam than the current leaking valves, this project still pays for itself in just over one month and saves the company millions over a five year period. As such, we strongly recommend replacement of the top 10 leakiest valves in unit 1.

11.1.2 Unit 2

Replacing the top 10 leakiest valves in unit 2 results in a net present value (NPV) monetary savings of $4.3-35.1 million USD (worst case and best case respectively). This value is shown in today's dollars accounting for a 5% inflation rate per year. The payback period for investing in these replacement valves is 8-65 days (best case - worst case). Even in the worst case scenario where the new valves recover 55% more steam than the current leaking valves, this project still pays for itself in just over two months and saves the company millions over a five year period. As such, we strongly recommend replacement of the top 10 leakiest valves in unit 2.

11.2 Total Monetary Savings

In the best case scenario where the new steam valves are able to keep 90% of the leaking steam in the system, a NPV of $78.5 million USD worth of energy in unit 1 is saved over a 5 year period. In the best case scenario where the new steam valves are able to keep 90% of the leaking steam in the system, a NPV $35.1 million USD worth of energy in unit 2 is saved over a 5 year period. Therefore the total NPV in the best case scenario is $113.6 million USD worth of savings over a 5 year period.

In the worst case scenario where the new steam valves are able to keep 55% of the leaking steam in the system, a NPV of $9.7 million USD worth of energy in unit 1 is saved over a 5 year period. In the worst case scenario where the new steam valves are able to keep 55% of the leaking steam in the system, a NPV $4.3 million USD worth of energy in unit 2 is saved over a 5 year period. Therefore the total NPV in the worst case scenario is $14 million USD worth of savings over a 5 year period.

11.3 Alternative Designs and Investment Opportunities

Should valve replacement projects become commonplace after the implementation of the valve analysis code outlined in this document, we recommend the company to look into a system-wide insulation abatement procedure. This would lower the risk of individual valve replacements and make it so that the people working on the valves would not need assistance from someone trained in insulation abatement. It would also be beneficial to look into the financial feasibility of replacing more valves in the system to see if that would save the company additional money from steam energy savings.

12. Recommended Next Steps

Due to constraints that were not within the team's control, the team did not run through all five calculation methods as originally intended. Therefore, once the information required to finish the Darcy and Sonic equations can be obtained, it is recommended that these calculation methods are completed for further analysis and accuracy.

13. Table of Nomenclature

Table 13.1: Table of Nomenclature

Acronym/ID	Meaning
ASME	American Society of Mechanical Engineers
DI	Inside Diameter
FCI	Formal Capital Investment
FWH	Feedwater Heater
MARR	Minimum Acceptable Rate of Return
MACRS	Modified Accelerated Cost Recovery System
MW	Megawatt
Mwe	Megawatts Electric
MWh	Megawatt Hour
NPV	Net Present Value
PBP	Payback Period
PEPSE	Power Plant Thermal Cycle Modeling, Design, Diagnostics and Performance Analysis Software
PPE	Personal Protective Equipment
TSA	Transportation Security Administration
USD	United Stated Dollar
VBA	Visual Basic for Applications
WC	Working Capital

14. References

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Affandi, M., Mamat, N., Kanafiah, S., & Khalid, N. (2013, January 1). Simplified Equations for Saturated Steam Properties for Simulation Purpose. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877705813002142

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Appendix

A.1 Sample Calculations

A.1.1 MACRS Table Equations

Equation A.1.1.1: Yearly Energy Loss

Yearly Energy Loss = SUM(Energy Loss MWe column)*(8760 - Estimated Downtime Hours)

Equation A.1.1.2: Yearly Energy Loss Cash Value

Yearly Energy Loss Cash Value = Yearly Energy Loss * Electricity Value

Equation A.1.1.3: INC ($) Column Values

INC = Yearly Energy Loss Cash Value * Reduction of Steam Losses

Equation A.1.1.4: EXP ($) Column Values

EXP = Yearly Energy Loss Cash Value * (1 - Reduction of Steam Losses) + WC

Equation A.1.1.5: BV ($) Column Values

BC = Previous Year BV - Current Year DEP

Equation A.1.1.6: DEP ($) Column Values

DEP = FCI * DEP FRACT

Equation A.1.1.7: PROFIT ($) Column Values

PROFIT = INC - EXP - DEP

Equation A.1.1.8: TAX ($) Column Equations

TAX = Tax Rate * PROFIT

Equation A.1.1.9: CF ($) Year 0

CF0 = -(WC + FCI)

Equation A.1.1.10: CF ($) Remaining Column Values

CF = INC - EXP - TAX

Equation A.1.1.11: DF CASH Column Values

DF = 1/(1 + MARR)^Year Number

Equation A.1.1.12: DISC CF ($) Column Values

DISC CF = CF * DF CASH

A.2 Equations

Equation 7.1: Grashof number

$$Gr = \frac{D_0^3 \rho_f^2 \beta_g \Delta T_0}{\mu_f^2}$$

Equation 7.2: Modified Grashof Equation for Mass Flow

$$W = 59.4 * A * P^{0.97}$$

Equation 7.3: Moisture Flow

$$W_f = W_g * \frac{h_g - h_f}{h_T - h_f} - W_g$$

Equation 7.4: Moisture Correction Factor

$$correction\ factor = \sqrt{1 - (0.9775 * moisture\ fraction)}$$

Equation 7.5: ASME Fig. 14 Flow Rate

$$W = W_{ASME} * A * P$$

Equation 7.6: Lost Generation (MWe)

$$Lost\ Generation = \frac{Q_c * h_t * 0.33}{3412140}$$

Equation 7.7: Sonic Equation

$$V_{choke} = \sqrt{\frac{k * g * 144 * P'}{\rho}}$$

Equation 7.8: Darcy Equation

$$h = K * \frac{v^2}{2g}$$

Equation 7.9: Converted Darcy Equation

$$W = 1891 * Yd^2 \sqrt{\frac{\Delta P}{K} * \rho}$$

Equation 7.10: Choke Equation

$$V_{choke} = \sqrt{kgRT}$$

A.3 Figures

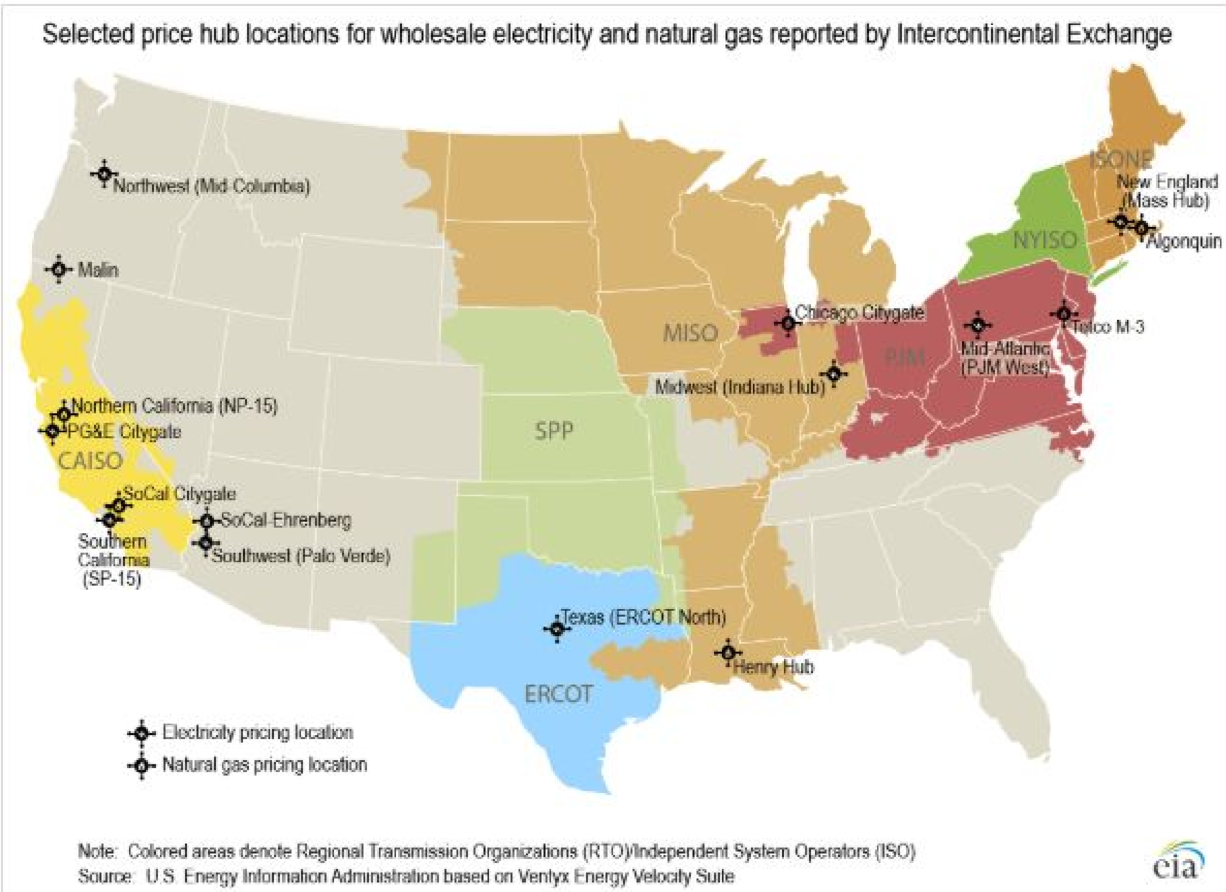


Figure 2.1: Map of Zones in the U.S. for Electricity and Natural Gas Pricing (U.S. Energy Information Administration, 2020)

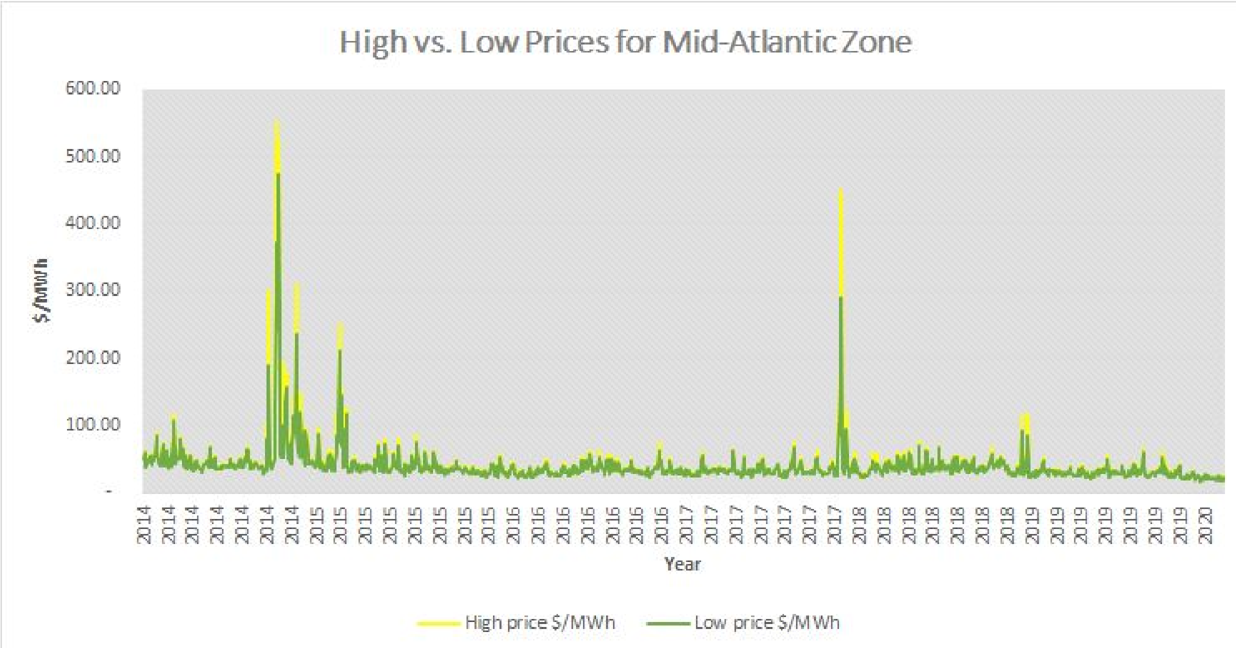


Figure 2.2: Price Comparison for Mid-Atlantic Zone (U.S. Energy Information Administration, 2020)

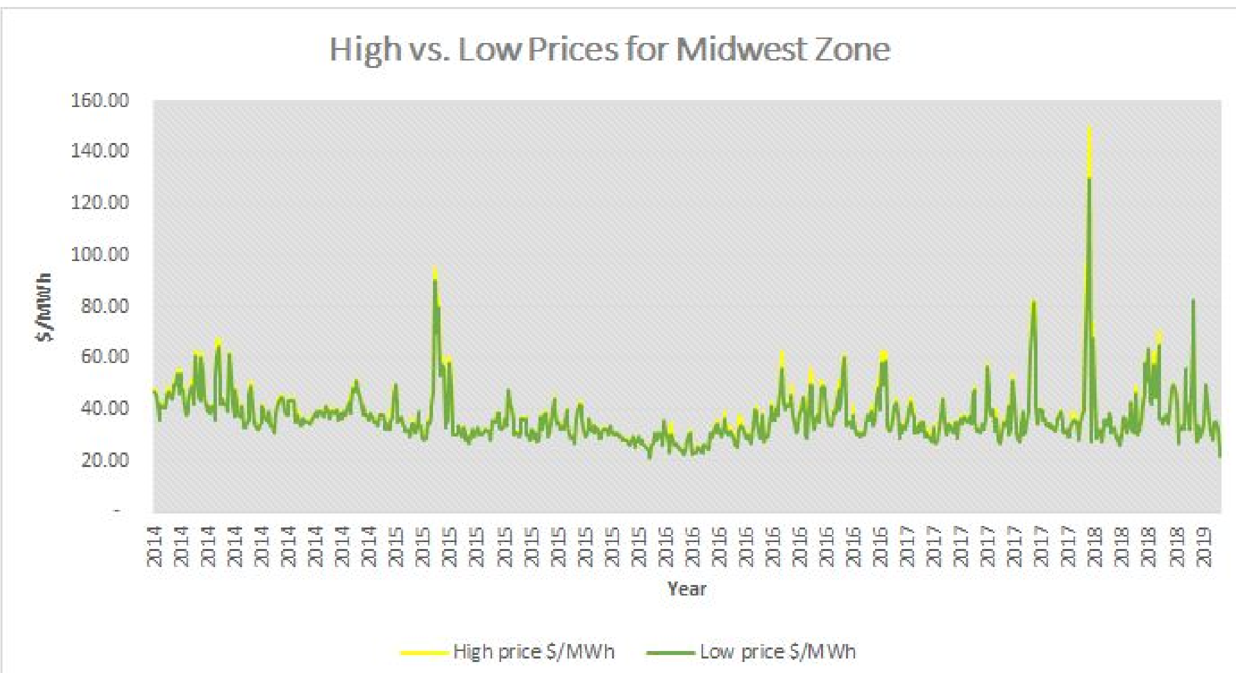


Figure 2.3: Price Comparison for Midwest Zone (U.S. Energy Information Administration, 2020)

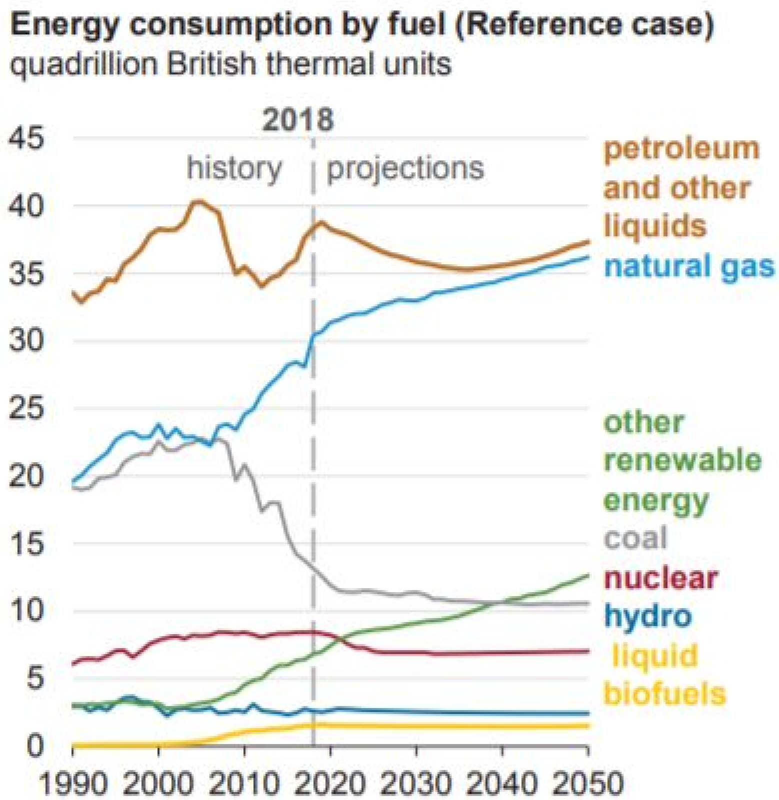


Figure 2.4: History and Projections for Energy Consumption by Fuel Type (U.S. Energy Information Administration, 2020)

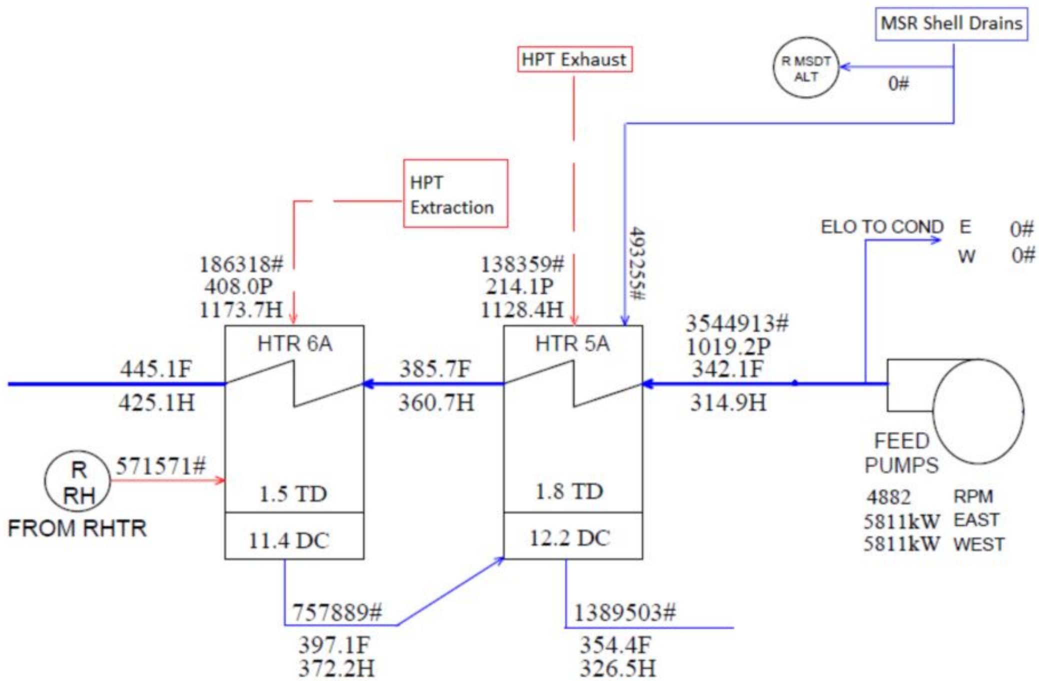


Figure 3.1: Unit 1 Heat Balance on 5A FWH Before 1-MRV-403 is Open

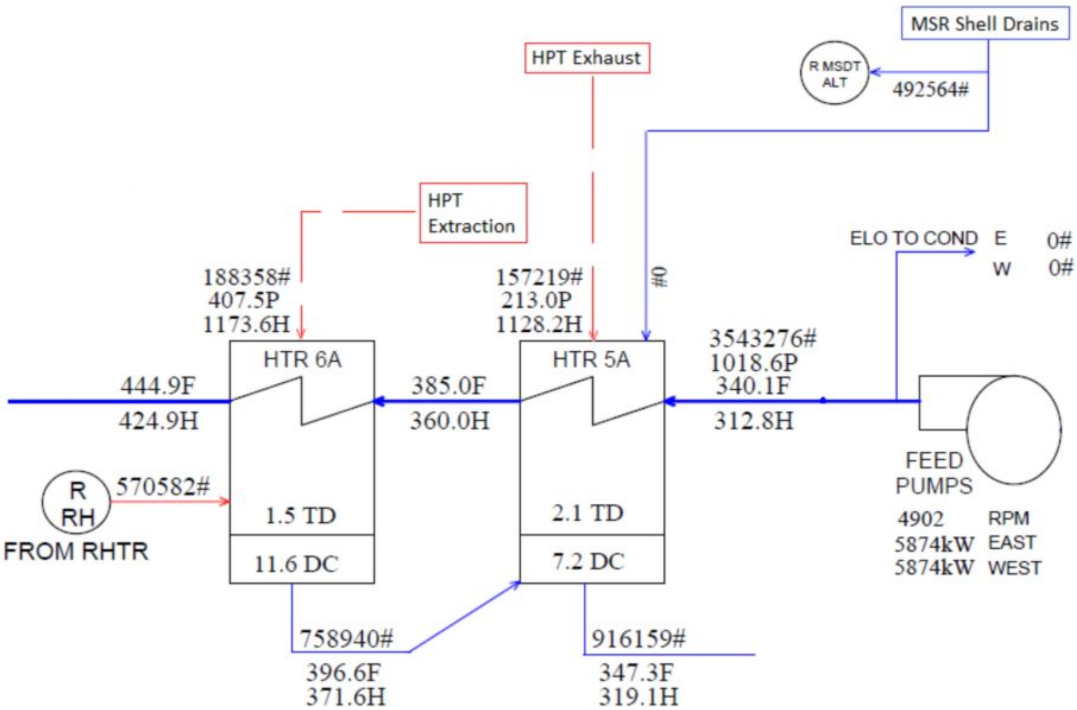
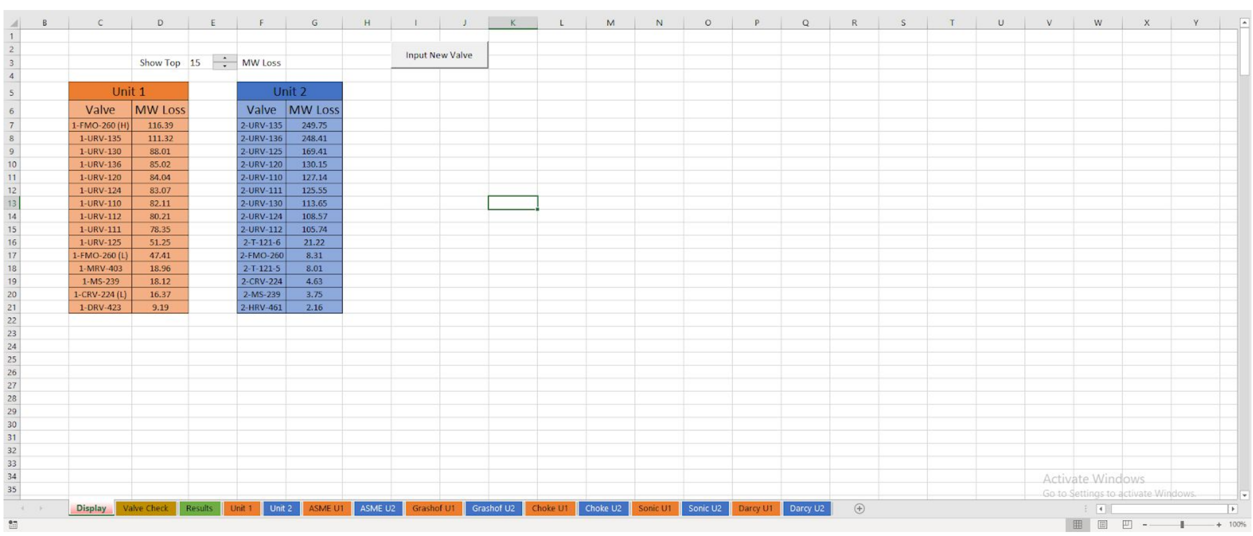
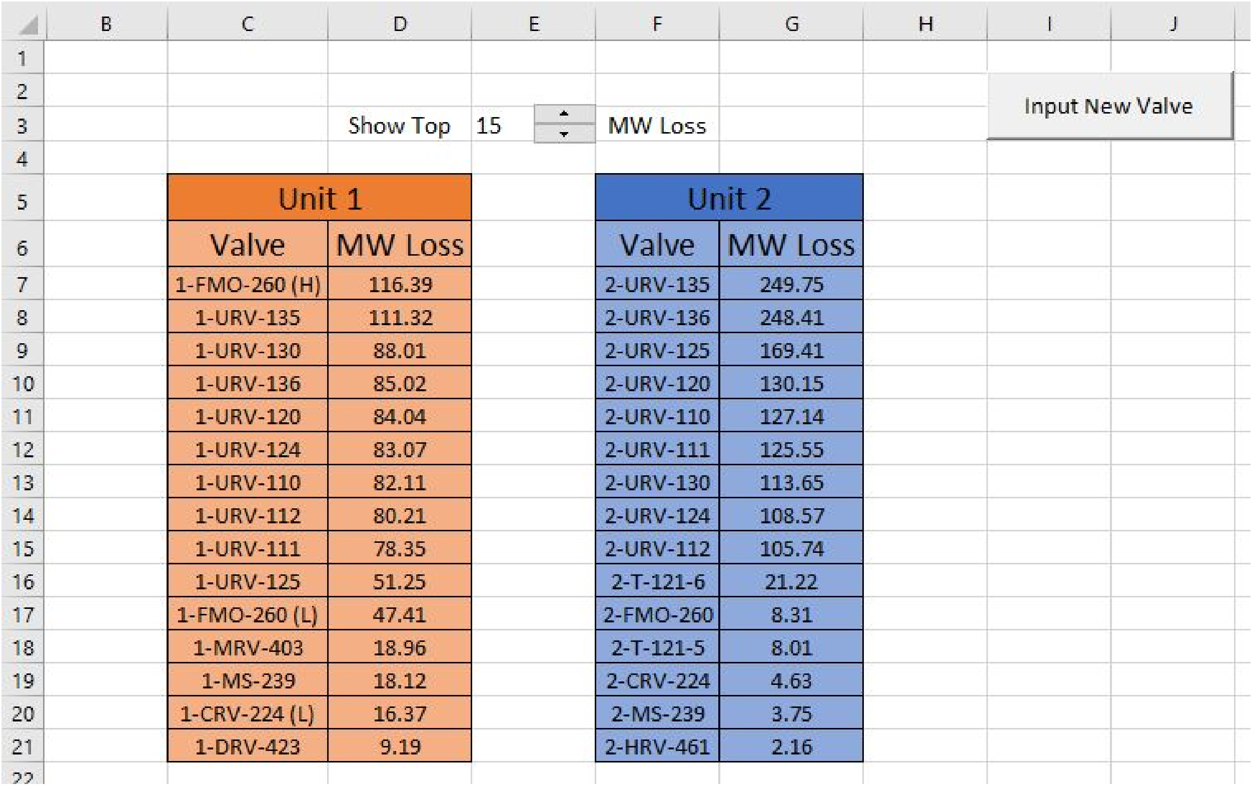


Figure 3.2: Unit 1 Heat Balance on 5A FWH After 1-MRV-403 is Open



Unit 1		Unit 2	
Valve	MW Loss	Valve	MW Loss
1-FMO-260 (H)	116.39	2-URV-135	249.75
1-URV-135	111.32	2-URV-136	248.41
1-URV-130	88.01	2-URV-125	169.41
1-URV-136	85.02	2-URV-120	130.15
1-URV-120	84.04	2-URV-110	127.14
1-URV-124	83.07	2-URV-111	125.55
1-URV-110	82.11	2-URV-130	113.65
1-URV-112	80.21	2-URV-124	108.57
1-URV-111	78.35	2-URV-112	105.74
1-URV-125	51.25	2-T-121-6	21.22
1-FMO-260 (L)	47.41	2-FMO-260	8.31
1-MRV-403	18.96	2-T-121-5	8.01
1-MS-239	18.12	2-CRV-224	4.63
1-CRV-224 (L)	16.37	2-MS-239	3.75
1-DRV-423	9.19	2-HRV-461	2.16

Figure 8.1: Display Sheet and Opening Visual



Unit 1		Unit 2	
Valve	MW Loss	Valve	MW Loss
1-FMO-260 (H)	116.39	2-URV-135	249.75
1-URV-135	111.32	2-URV-136	248.41
1-URV-130	88.01	2-URV-125	169.41
1-URV-136	85.02	2-URV-120	130.15
1-URV-120	84.04	2-URV-110	127.14
1-URV-124	83.07	2-URV-111	125.55
1-URV-110	82.11	2-URV-130	113.65
1-URV-112	80.21	2-URV-124	108.57
1-URV-111	78.35	2-URV-112	105.74
1-URV-125	51.25	2-T-121-6	21.22
1-FMO-260 (L)	47.41	2-FMO-260	8.31
1-MRV-403	18.96	2-T-121-5	8.01
1-MS-239	18.12	2-CRV-224	4.63
1-CRV-224 (L)	16.37	2-MS-239	3.75
1-DRV-423	9.19	2-HRV-461	2.16

Figure 8.2: Display Sheet Main Components

Figure 8.3: Main Worksheet Tabs

Figure 8.4: Calculation Worksheet Tabs

Figure 8.5: Top MW Loss List Control

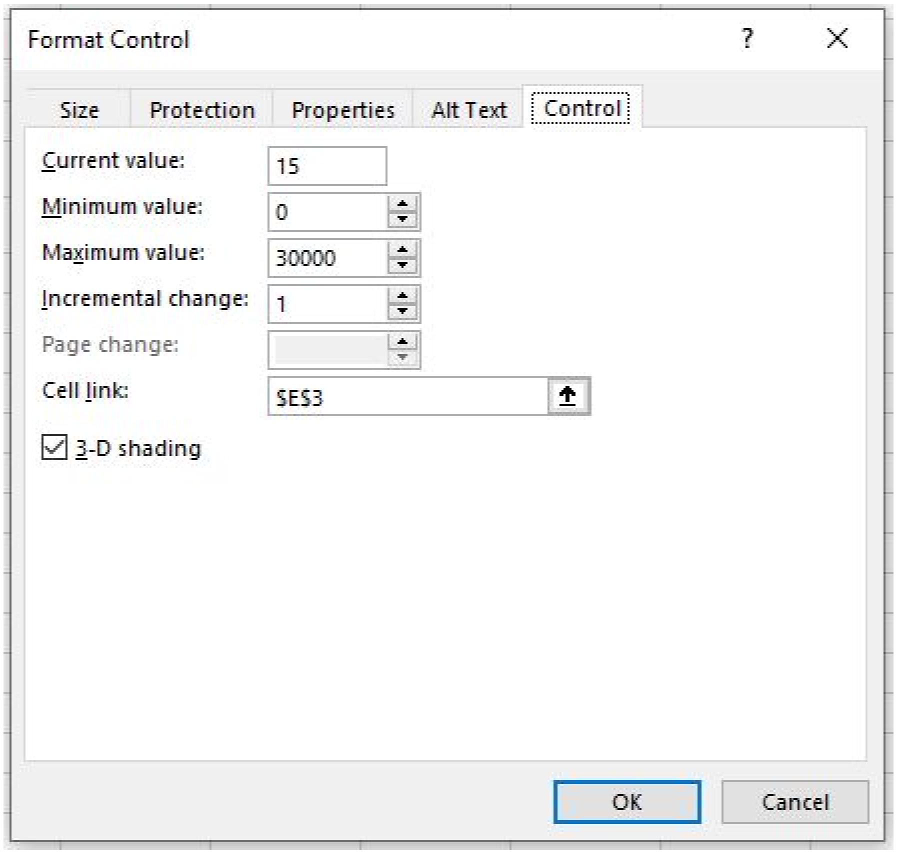


Figure 8.6: Spin Button Settings

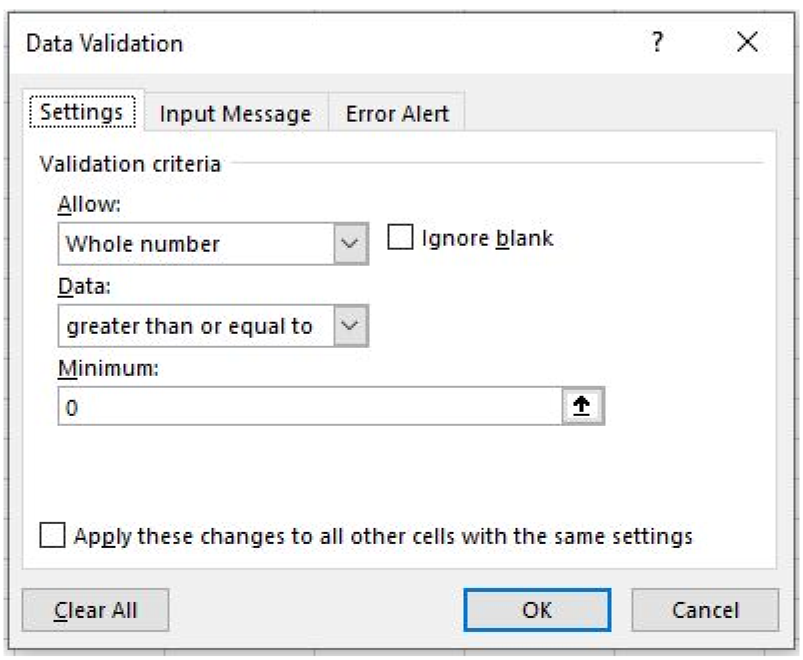


Figure 8.7: Restrictive Settings on Cell E3

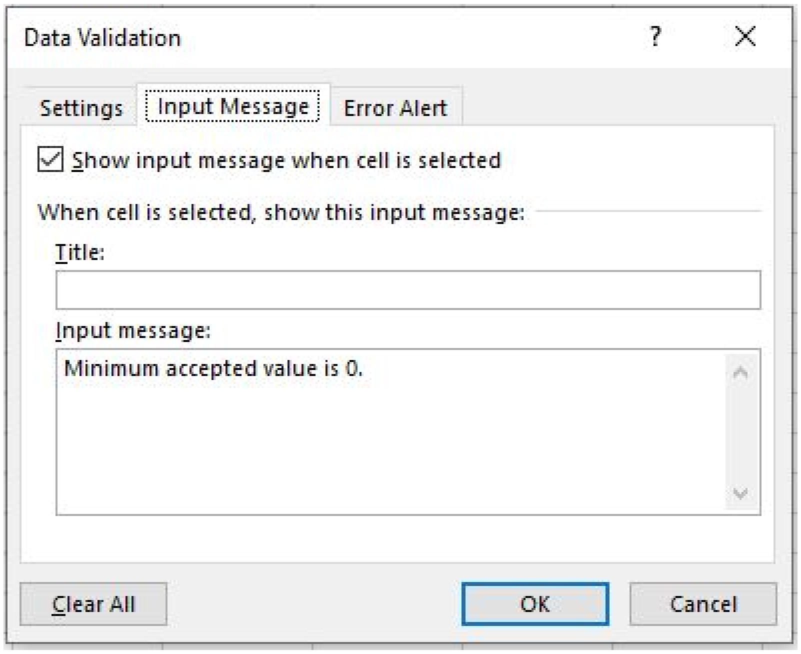


Figure 8.8: Input Message to User on Cell E3

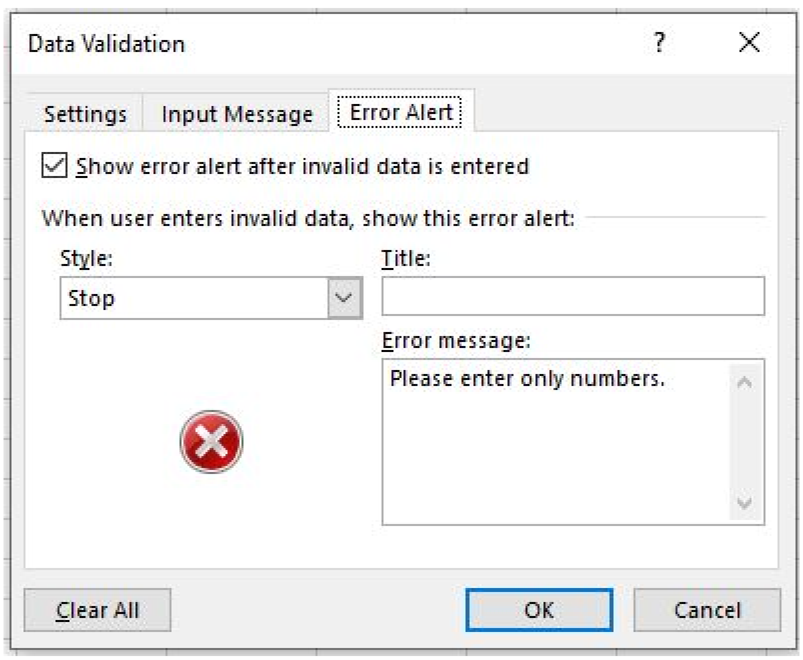


Figure 8.9: Error Notification for Invalid User Entry

```
=IF(A6<$E$3,A6+1,"")
```

Figure 8.10: Recursive Code for Altering Length of MW Loss Tables

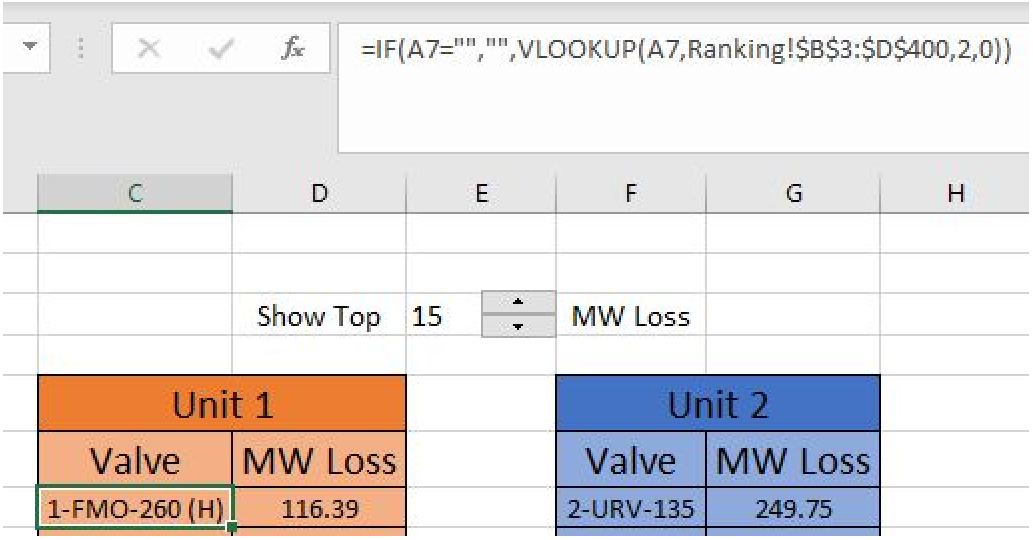


Figure 8.11: MW Loss Table Code for Length

	A	B	C	D	E	F
1	Valve #	DI (in)	Temp (°F)	Upstream Enthalpy (BTU/lbm)	ASME Flow (lbm/hr*in2*psi)	
2	1-URV-110	9.750	374	1201.2	50	
3	1-URV-111	9.750	370	1201.2	50	
4	1-URV-112	9.750	372	1201.2	50	
5	1-URV-120	9.750	376	1201.2	50	
6	1-URV-124	9.750	375	1201.2	50	
7	1-URV-125	9.750	335	1201.2	50.5	
8	1-URV-130	9.750	380	1201.2	50	
9	1-URV-135	9.750	401	1201.2	50	
10	1-URV-136	9.750	377	1201.2	50	
11	1-HRV-561	15.000	108	323.98	60	
12	1-HRV-562	15.000	109	323.98	60	
13	1-CRV-224 (H)	17.000	165	150.31	56.5	
14	1-CRV-224 (L)	17.000	221	150.31	54	
15	1-FMO-260 (H)	11.750	420	314.24	50.25	
16	1-FMO-260 (L)	11.750	340	314.24	52	
17	1-MRV-404	7.625	121	360.02	59	
18	1-MRV-403	7.625	333	360	51.5	
19	1-B-360	4.026	140	1163.34	59	
20	1-B-361	4.026	139	1163.34	59	
21	1-DRV-220	4.026	118	1163.34	58.5	
22	1-DRV-222	4.026	140	1163.34	57.5	
23	1-HRV-563	6.065	116	323.23	58.5	
24	1-HRV-564	6.065	99	323.23	59	
25	1-HRV-257	7.981	106	160.39	59	
26	1-HRV-258	7.981	125	160.38	58	
27	1-HRV-357	6.065	93	216.95	59.5	
28	1-HRV-358	6.065	135	216.95	57.5	
29	1-DRV-403	2.323	172	1207.88	56.25	
30	1-DRV-404	2.323	193	1207.88	55	
31	1-MS-234	2.323	172	1207.88	56.25	
32	1-MS-239	2.323	510	1207.88	50.25	
33	1-DRV-422	4.026	140	420.15	57.5	
34	1-DRV-423	4.026	375	420.15	50.5	
35	1-MSD-219L	4.026	262	420.15	53	
36	1-MSD-219R	4.026	203	420.15	54.5	

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2 | Grashof U1

Ready

Figure 8.12: "Unit 1" Input Value Storage

	Valve #	DI (in)	Temp (°F)	Upstream Enthalpy (BTU/lbm)	ASME Flow (lbm/hr*in2*psi)
2	2-URV-112	9.562	400.0	1196.3	50
3	2-URV-111	9.562	415.8	1196.3	50.25
4	2-URV-110	9.562	417.0	1196.3	50.25
5	2-URV-135	9.562	486.8	1196.3	50
6	2-URV-130	9.562	406.2	1196.3	50.5
7	2-URV-136	9.562	486.2	1196.3	50
8	2-URV-125	9.562	445.0	1196.3	50.5
9	2-URV-124	9.562	402.2	1196.3	50.25
10	2-URV-120	9.562	419.0	1196.3	50.5
11	2-CRV-224	16.876	153.0	265.19	52
12	2-HRV-558	15.000	95.8	323.98	59.5
13	2-HRV-557	15.000	111.0	323.98	59
14	2-HRV-257	7.981	86.0	1196.3	59.75
15	2-HRV-462	16.876	107.8	234.98	59
16	2-HRV-461	16.876	116.8	234.98	59
17	2-RCD-294	11.750	93.0	519.34	59.5
18	2-DRV-427	11.750	94.0	519.34	59.5
19	2-DRV-426	11.750	97.0	519.34	59
20	2-RCD-292	11.750	110.0	519.34	57.8
21	2-DRV-428	11.750	120.0	519.34	59
22	2-RCD-296	11.750	110.8	519.34	59
23	2-RCD-290	11.750	93.0	519.34	59.5
24	2-DRV-425	11.750	103.8	519.34	59
25	2-FMO-260	11.374	225.0	292.14	54
26	2-DRV-224	6.065	99.0	1147.12	58
27	2-MRV-427	10.020	120.0	400.85	59
28	2-MRV-425	10.020	92.0	400.85	59
29	2-DRV-306	4.026	203.2	1167.52	54.5
30	2-B-349	4.026	138.2	1167.52	57.5
31	2-DRV-305	4.026	110.0	1167.52	57.8
32	2-B-348	4.026	116.0	1167.52	58.5
33	2-HRV-563	6.065	100.8	323.98	59
34	2-HRV-564	6.065	82.4	323.98	60
35	2-MS-239	2.900	319.6	1199.12	51.5
36	2-DRV-406	2.900	261.0	1199.12	54

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2 | Grasho

Ready

Figure 8.13: "Unit 2" Input Value Storage

Unit 1								Unit 2						
Valve	Grashof	Choke	Sonic	ASME	Darcy	Avg.1		Valve	Grashof	Choke	Sonic	ASME	Darcy	Avg.2
1-URV-110	82.46936809			81.74717641		82.10827225		2-URV-112	105.8627504			105.6253296		105.74404
1-URV-111	78.74000171			77.9635835		78.3517926		2-URV-111	125.090143			126.001759		125.545951
1-URV-112	80.58762117			79.83740123		80.2125112		2-URV-110	126.6547149			127.6212203		127.1379676
1-URV-120	84.38566685			83.69338425		84.03952555		2-URV-135	247.0498918			252.4528836		249.7513877
1-URV-124	83.42317191			82.71569647		83.06943419		2-URV-130	113.1094091			114.1873371		113.6483731
1-URV-125	51.49310586			51.00982063		51.25146325		2-URV-136	245.7407302			251.0759382		248.4083342
1-URV-130	88.32362397			87.69700873		88.01031635		2-URV-125	167.6841174			171.1395478		169.4118326
1-URV-135	111.3847778			111.2469357		111.3158567		2-URV-124	108.3911461			108.7575493		108.5743477
1-URV-136	85.35690615			84.68029946		85.01860281		2-URV-120	129.2961728			131.0052907		130.1507318
1-HRV-561	1.100672083			1.861038174		1.480855128		2-CRV-224	4.472413699			4.785932206		4.629172952
1-HRV-562	1.138241125			1.901501828		1.519871476		2-HRV-558	0.793349659			1.398601998		1.095975828
1-CRV-224 (H)	5.55933825			6.457332504		6.008335377		2-HRV-557	1.307983059			1.930063718		1.619023388
1-CRV-224 (L)	15.98054689			16.76861657		16.37458173		2-HRV-257	0.247065215			0.522819074		0.384942144
1-FMO-260 (H)	115.8677061			116.920149		116.3939276		2-HRV-462	1.372981751			2.084291837		1.728636794
1-FMO-260 (L)	46.90382652			47.90627464		47.40505058		2-HRV-461	1.78900356			2.525632576		2.157318068
1-MRV-404	0.44034508			0.644407717		0.542376398		2-RCD-294	0.520918493			0.959165568		0.740042031
1-MRV-403	18.87335008			19.05659583		18.96497296		2-DRV-427	0.541265886			0.98069631		0.760981098
1-B-360	0.320713464			0.419947824		0.370330644		2-DRV-426	0.604739089			1.03913151		0.8219353
1-B-361	0.312900696			0.41151547		0.362208083		2-RCD-292	0.926175382			1.350346753		1.138261067
1-DRV-220	0.177340722			0.263726547		0.220533634		2-DRV-428	1.232597595			1.703896452		1.468247023
1-DRV-222	0.320713464			0.409271184		0.364992324		2-RCD-296	0.948654723			1.402196805		1.175425764
1-HRV-563	0.232283392			0.351643942		0.291963667		2-RCD-290	0.520918493			0.959165568		0.740042031
1-HRV-564	0.129512814			0.245837591		0.187675202		2-DRV-425	0.762958174			1.205804991		0.984381582
1-HRV-257	0.260673343			0.444605525		0.352639434		2-FMO-260	8.147584109			8.475849685		8.311716897
1-HRV-258	0.468103005			0.654029222		0.561066113		2-DRV-224	0.239209686			0.393350277		0.316279982
1-HRV-357	0.091407048			0.197499977		0.144453513		2-MRV-427	0.811468767			1.121743835		0.966606301
1-HRV-358	0.357027044			0.466335803		0.411681424		2-MRV-425	0.329773692			0.612316486		0.471045089
1-DRV-403	0.217867034			0.248623893		0.233245464		2-DRV-306	1.211319007			1.279846366		1.245582687
1-DRV-404	0.329431049			0.357895444		0.343663247		2-B-349	0.319475041			0.394605876		0.357040459
1-MS-234	0.217867034			0.248623893		0.233245464		2-DRV-305	0.150562531			0.219517414		0.185039973
1-MS-239	17.82256554			18.41682411		18.11969483		2-B-348	0.179554576			0.252752398		0.216153487
1-DRV-422	0.213625401			0.272613191		0.243119296		2-HRV-563	0.154733172			0.253070482		0.203901827
1-DRV-423	9.184512499			9.197688891		9.191100695		2-HRV-564	0.073521336			0.17075531		0.122138323
1-MSD-219L	2.080318398			2.133412622		2.10686551		2-MS-239	3.74202972			3.758704297		3.750367009

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2 | Grashof U1 | Grashof U2 | Choke U1 | Choke U2 | Sonic U1 | Sonic U

Ready

Figure 8.14: "Results" Tab

	B	C	D	E	F	G	H	I	J
1		Unit 1				Unit 2			
2		Valve	MW Loss	Count?		Valve	MW Loss	Count?	
3		1-URV-110	82.11			2-URV-112	105.74		
4		1-URV-111	78.35			11	125.55		
5		1-URV-112	80.21			10	127.14		
6		1-URV-120	84.04			35	249.75		
7		1-URV-124	83.07			30	113.65		
8		1-URV-125	51.25			36	248.41		
9		1-URV-130	88.01			2-URV-125	169.41		
10		1-URV-135	111.32			2-URV-124	108.57		
11		1-URV-136	85.02			2-URV-120	130.15		
12		1-HRV-561	1.48			2-CRV-224	4.63		
13		1-HRV-562	1.52			2-HRV-558	1.10		
14		1-CRV-224 (H)	6.01			2-HRV-557	1.62		
15		1-CRV-224 (L)	16.37			2-HRV-257	0.38		
16		1-FMO-260 (H)	116.39			2-HRV-462	1.73		
17		1-FMO-260 (L)	47.41			2-HRV-461	2.16		
18		1-MRV-404	0.54			2-RCD-294	0.74		
19		1-MRV-403	18.96			2-DRV-427	0.76		
20		1-B-360	0.37			2-DRV-426	0.82		
21		1-B-361	0.36			2-RCD-292	1.14		
22		1-DRV-220	0.22			2-DRV-428	1.47		
23		1-DRV-222	0.36			2-RCD-296	1.18		
24		1-HRV-563	0.29			2-RCD-290	0.74		
25		1-HRV-564	0.19			2-DRV-425	0.98		
26		1-HRV-257	0.35			2-FMO-260	8.31		
27		1-HRV-258	0.56			2-DRV-224	0.32		
28		1-HRV-357	0.14			2-MRV-427	0.97		
29		1-HRV-358	0.41			2-MRV-425	0.47		
30		1-DRV-403	0.23			2-DRV-306	1.25		
31		1-DRV-404	0.34			2-B-349	0.36		
32		1-MS-234	0.23			2-DRV-305	0.19		
33		1-MS-239	18.12			2-B-348	0.22		
34		1-DRV-422	0.24			2-HRV-563	0.20		
35		1-DRV-423	9.19			2-HRV-564	0.12		
36		1-MSD-219L	2.11			2-MS-239	3.		

If you want the valve to be counted, leave blank. If you want the valve to be ignored from the Display list, select "No".

Display | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U2

Figure 8.15: "Valve Check" Tab for User Preference

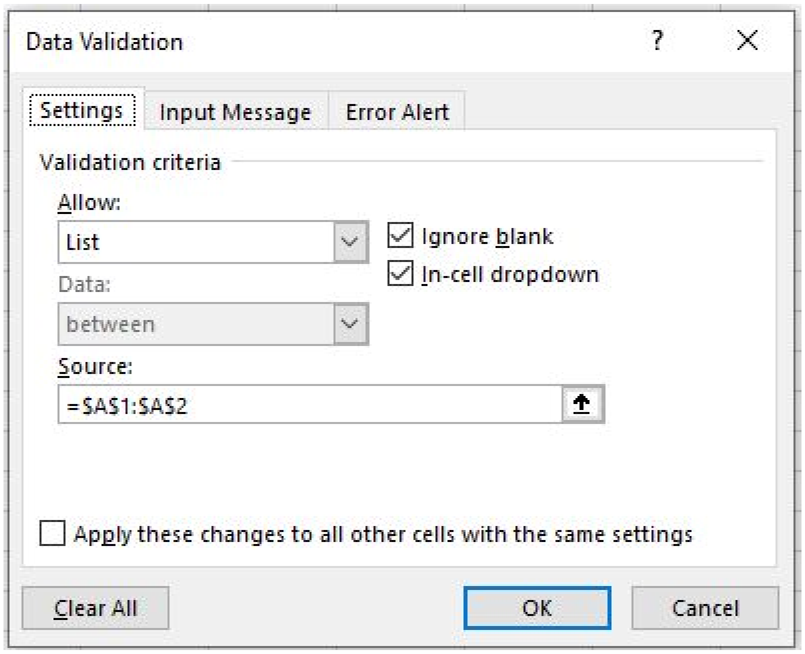


Figure 8.16: “Valve Check” Setting

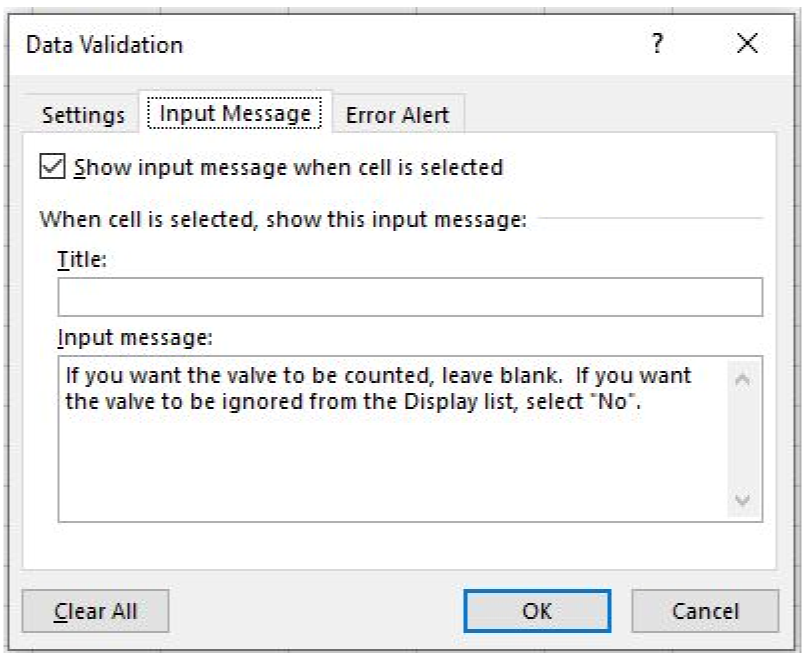


Figure 8.17: “Valve Check” User Input Message

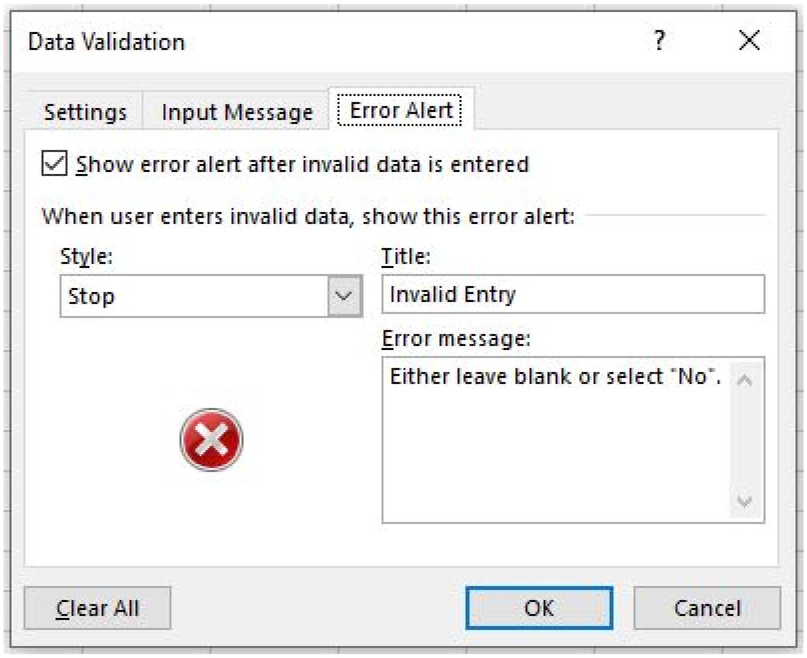
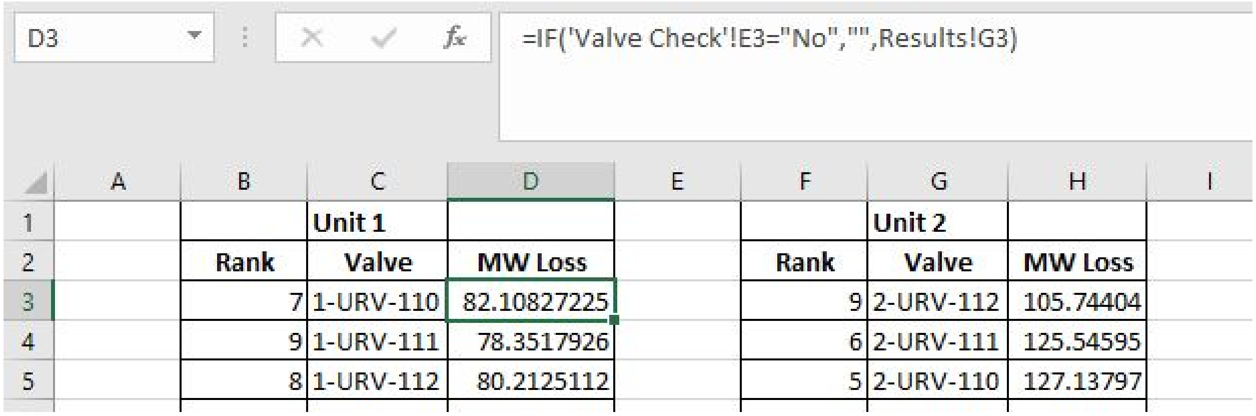


Figure 8.18: "Check Valve" User Error Notification

		Unit 1				Unit 2	
	Rank	Valve	MW Loss		Rank	Valve	MW Loss
3	7	1-URV-110	82.10827225		9	2-URV-112	105.74404
4	9	1-URV-111	78.3517926		6	2-URV-111	125.54595
5	8	1-URV-112	80.2125112		5	2-URV-110	127.13797
6	5	1-URV-120	84.03952555		1	2-URV-135	249.75139
7	6	1-URV-124	83.06943419		7	2-URV-130	113.64837
8	10	1-URV-125	51.25146325		2	2-URV-136	248.40833
9	3	1-URV-130	88.01031635		3	2-URV-125	169.41183
10	2	1-URV-135	111.3158567		8	2-URV-124	108.57435
11	4	1-URV-136	85.01860281		4	2-URV-120	130.15073
12	19	1-HRV-561	1.480855128		13	2-CRV-224	4.629173
13	18	1-HRV-562	1.519871476		24	2-HRV-558	1.0959758
14	16	1-CRV-224 (	6.008335377		18	2-HRV-557	1.6190234
15	14	1-CRV-224 (	16.37458173		34	2-HRV-257	0.3849421
16	1	1-FMO-260	116.3939276		16	2-HRV-462	1.7286368
17	11	1-FMO-260	47.40505058		15	2-HRV-461	2.1573181
18	25	1-MRV-404	0.542376398		31	2-RCD-294	0.740042
19	12	1-MRV-403	18.96497296		30	2-DRV-427	0.7609811
20	30	1-B-360	0.370330644		29	2-DRV-426	0.8219353
21	32	1-B-361	0.362208083		23	2-RCD-292	1.1382611
22	40	1-DRV-220	0.220533634		20	2-DRV-428	1.468247
23	31	1-DRV-222	0.364992324		22	2-RCD-296	1.1754258
24	35	1-HRV-563	0.291963667		32	2-RCD-290	0.740042
25	41	1-HRV-564	0.187675202		26	2-DRV-425	0.9843816
26	33	1-HRV-257	0.352639434		11	2-FMO-260	8.3117169
27	24	1-HRV-258	0.561066113		37	2-DRV-224	0.31628
28	44	1-HRV-357	0.144453513		27	2-MRV-427	0.9666063
29	28	1-HRV-358	0.411681424		33	2-MRV-425	0.4710451
30	38	1-DRV-403	0.233245464		21	2-DRV-306	1.2455827
31	34	1-DRV-404	0.343663247		36	2-B-349	0.3570405
32	39	1-MS-234	0.233245464		47	2-DRV-305	0.18504
33	13	1-MS-239	18.11969483		44	2-B-348	0.2161535
34	37	1-DRV-422	0.243119296		46	2-HRV-563	0.2039018
35	15	1-DRV-423	9.191100695		49	2-HRV-564	0.1221383
36	17	1-MSD-219I	2.10686551		14	2-MS-239	3.750367

Display | Ranking | Valve Check | Results | Unit 1 | Unit 2 | ASME U1 | ASME U

Figure 8.19: Hidden "Ranking" Tab for Valve Order Determination



D3 =IF('Valve Check'!E3="No","",Results!G3)

	A	B	C	D	E	F	G	H	I
1			Unit 1				Unit 2		
2		Rank	Valve	MW Loss		Rank	Valve	MW Loss	
3		7	1-URV-110	82.10827225		9	2-URV-112	105.74404	
4		9	1-URV-111	78.3517926		6	2-URV-111	125.54595	
5		8	1-URV-112	80.2125112		5	2-URV-110	127.13797	

Figure 8.20: "Valve Check" "Count?" Reference Code

```
{=IF(D3="","",COUNTIF($D$3:$D$697,">"&D3)+SUM(IF(D3=$D$3:D3,1,0)))}
```

Figure 8.21: "Rank" Column Code

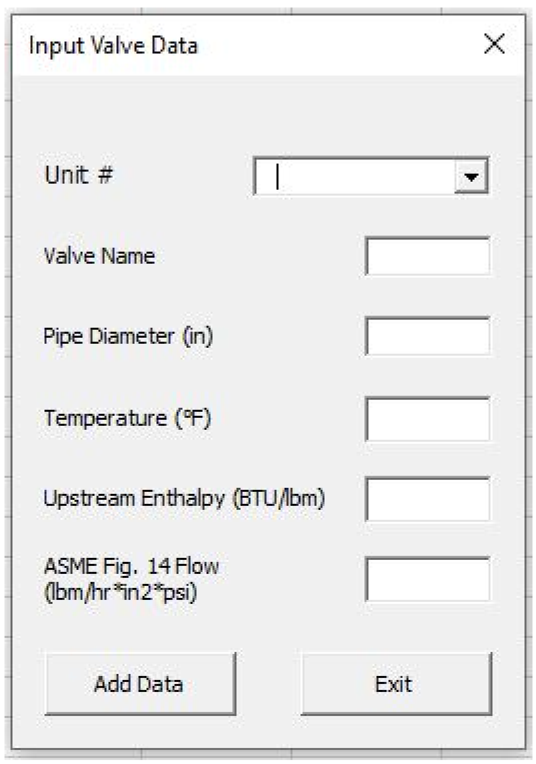


Figure 8.22: Userform to Input New Valve Data

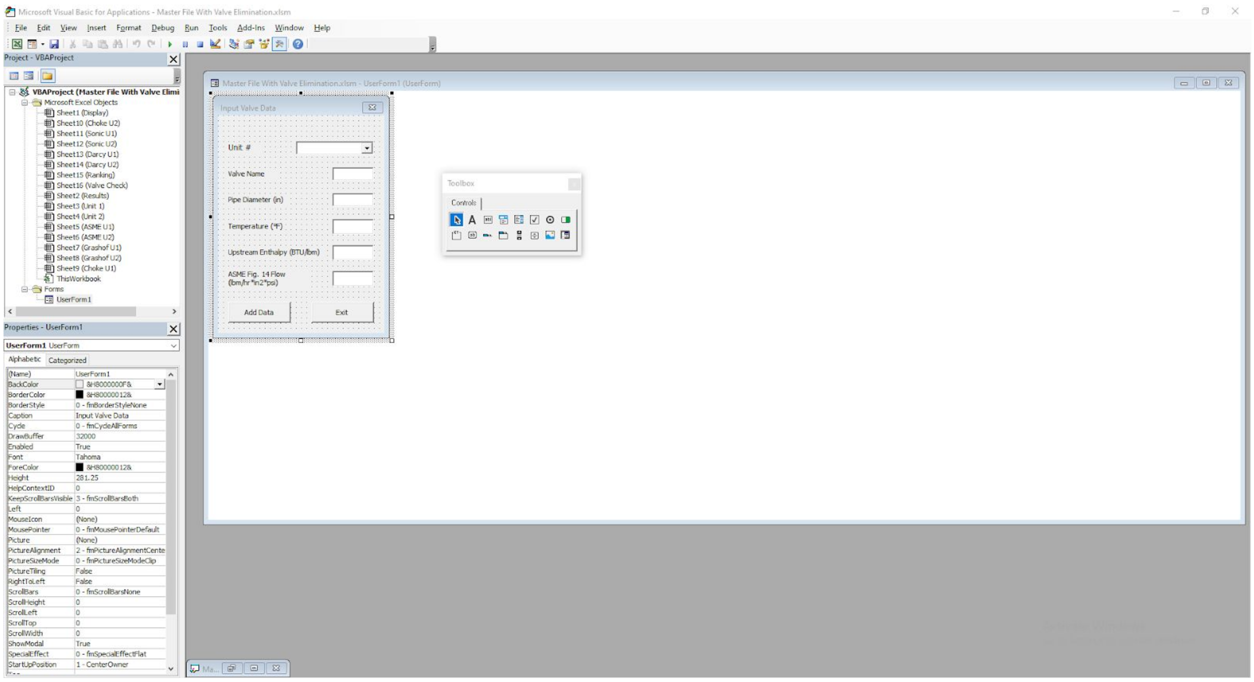


Figure 8.23: Microsoft Visual Basic for Applications Userform Design

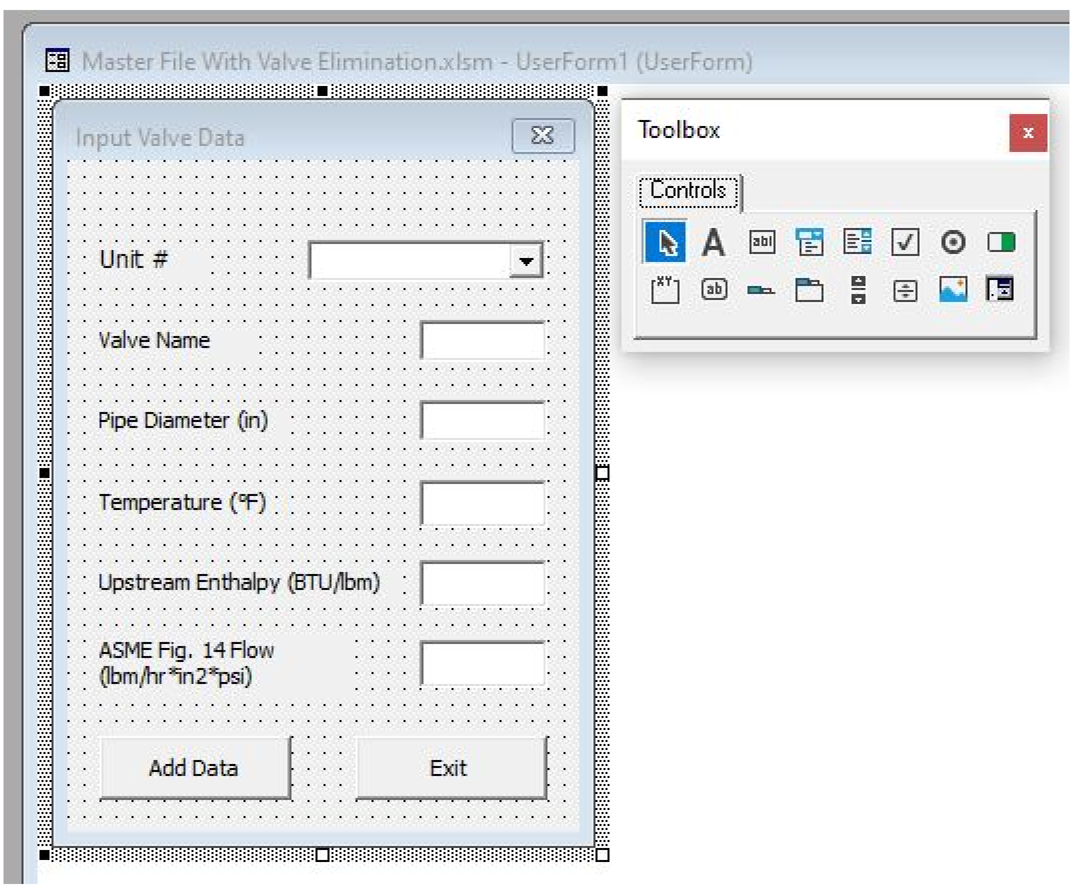


Figure 8.24: Final Userform Design

```
Private Sub UserForm_Initialize()

    ComboBox1.AddItem "Unit 1"
    ComboBox1.AddItem "Unit 2"

End Sub
```

Figure 8.25: Userform Initialization

```
Private Sub Cancel_Click()

    Unload Me

End Sub
```

Figure 8.26: Exiting Userform and Data Removal

```
Private Sub AddData_Click()

TargetSheet = ComboBox1.Value

If TargetSheet = "" Then
MsgBox ("No Unit selected.")
Exit Sub
End If

If txtVN.Value = "" Then
MsgBox ("Please input the valve name.")
Exit Sub
End If

If txtPD.Value = "" Then
MsgBox ("Please input the pipe diameter.")
Exit Sub
End If

If txtT.Value = "" Then
MsgBox ("Please input the measured temperature.")
Exit Sub
End If

If txtUE.Value = "" Then
MsgBox ("Please input the upstream enthalpy for the stream.")
Exit Sub
End If

If txtASME.Value = "" Then
MsgBox ("Please input the ASME Figure 14 flowrate.")
Exit Sub
End If
```

Figure 8.27: Missing Data Safeguard

```
Worksheets(TargetSheet).Activate

Dim FoundCell As Range
Dim Search As String
Dim eRow As Long
eRow = Worksheets(TargetSheet).Cells(Rows.Count, 1).End(xlUp).Offset(1, 0).Row
Search = txtVN.Value
Set FoundCell = Worksheets(TargetSheet).Columns(1).Find(Search, LookIn:=xlValues, Lookat:=xlWhole)
```

Figure 8.28: Determining Location of Data Destination

```
If FoundCell Is Nothing Then
Cells(eRow, 1).Value = txtVN.Value
Cells(eRow, 2).Value = txtPD.Value
Cells(eRow, 3).Value = txtT.Value
Cells(eRow, 4).Value = txtUE.Value
Cells(eRow, 5).Value = txtASME.Value

Else
answer = MsgBox("This valve already has data recorded. Would you like to overwrite?", vbYesNo + vbQuestion, "Duplicate Valve")
```

Figure 8.29: New Entry or Duplicate Discovered

```
If answer = vbYes Then
ActiveCell = FoundCell
Cells(ActiveCell.Row, 1).Value = txtVN.Value
Cells(ActiveCell.Row, 2).Value = txtPD.Value
Cells(ActiveCell.Row, 3).Value = txtT.Value
Cells(ActiveCell.Row, 4).Value = txtUE.Value
Cells(ActiveCell.Row, 5).Value = txtASME.Value
Else
MsgBox ("Data will not be added.")
ComboBox1.Clear
ComboBox1.AddItem "Unit 1"
ComboBox1.AddItem "Unit 2"
txtVN.Value = ""
txtPD.Value = ""
txtT.Value = ""
txtUE.Value = ""
txtASME.Value = ""

Worksheets("Display").Activate
Worksheets("Display").Cells(1, 1).Select
Exit Sub
End If
```

Figure 8.30: Duplicate Valve Update or Cancellation

```
ComboBox1.Clear
ComboBox1.AddItem "Unit 1"
ComboBox1.AddItem "Unit 2"
txtVN.Value = ""
txtPD.Value = ""
txtT.Value = ""
txtUE.Value = ""
txtASME.Value = ""

Worksheets("Display").Activate
Worksheets("Display").Cells(1, 1).Select

MsgBox ("Valve added successfully.")

answer = MsgBox("Would you like to add another valve?", vbYesNo + vbQuestion, "Another Entry")
If answer = vbNo Then
    Unload Me
End If

End Sub
```

Figure 8.31: Clearing Data and Resetting the Userform

A.4 Tables

Table 1.1: Top Ten Megawatt Loss for Both Units (Ignoring URV Valves)

Unit 1		Unit 2	
Valve ID	**MW Loss**	**Valve ID**	**MW Loss**
1-FMO-260 (L)	47.41	2-T-121-6	21.22
1-MRV-403	18.96	2-FMO-260	8.31
1-MS-239	18.12	2-T-121-5	8.01
1-CRV-224 (L)	16.37	2-CRV-224	4.63
1-DRV-423	9.19	2-MS-239	3.75
1-CRV-224 (H)	6.01	2-HRV-461	2.16
1-MSD-219L	2.11	2-HRV-462	1.73
1-HRV-562	1.52	2-DRV-406	1.67
1-HRV-561	1.48	2-HRV-557	1.62
1-MRV-409	0.95	2-B-431	1.57

A.4.1 Unit 1

Table A.4.1.1: Unit 1 Best Case MACRS Monetary Calculations

Year	FCI ($)	WC ($)	INC ($)	EXP ($)	DEP FRACT	BV ($)	DEP ($)	PROFIT ($)	TAX ($)	CF ($)	DF CASH	DISC CF ($)
0	139,976.68	54,300.00	0.00	0.00	0	139,976.68	0	0	0	-194,276.68	1	-194,276.68
1	0	0	25,850,361.60	2,926,562.40	0.3333	93,322.45	46,654	22,877,144.97	4,804,200.44	18,119,598.76	0.9523809524	17,256,760.72
2	0	0	25,850,361.60	2,926,562.40	0.4445	31,102.82	62,220	22,861,579.57	4,800,931.71	18,122,867.49	0.9070294785	16,437,975.05
3	0	0	25,850,361.60	2,926,562.40	0.1481	10,372.27	20,731	22,903,068.65	4,809,644.42	18,114,154.78	0.8638375985	15,647,687.97
4	0	0	25,850,361.60	2,926,562.40	0.0741	0.00	10,372	22,913,426.93	4,811,819.65	18,111,979.55	0.8227024748	14,900,770.40
5	0	-54,300.00	25,850,361.60	2,926,562.40	0	0.00	0	22,923,799.20	4,813,997.83	18,164,101.37	0.7835261665	14,232,048.71

Table A.4.1.2: Unit 1 Worst Case MACRS Monetary Calculations

Year	FCI ($)	WC ($)	INC ($)	EXP ($)	DEP FRACT	BV ($)	DEP ($)	PROFIT ($)	TAX ($)	CF ($)	DF CASH	DISC CF ($)
0	139,976.68	54,300.00	0.00	0.00	0	139,976.68	0	0	0	-194,276.68	1	-194,276.68
1	0	0	15,797,443.20	12,979,480.80	0.3333	93,322.45	46,654	2,771,308.17	581,974.72	2,235,987.68	0.9523809524	2,129,512.08
2	0	0	15,797,443.20	12,979,480.80	0.4445	31,102.82	62,220	2,755,742.77	578,705.98	2,239,256.42	0.9070294785	2,031,071.58
3	0	0	15,797,443.20	12,979,480.80	0.1481	10,372.27	20,731	2,797,231.85	587,418.69	2,230,543.71	0.8638375985	1,926,827.52
4	0	0	15,797,443.2	12,979,480.8	0.0741	0.00	10,372	2,807,590.13	589,593.93	2,228,368.47	0.822702474	1,833,284.26

			0	0							8	
5	0	-54,300.00	15,797,443.20	12,979,480.80	0	0.00	0	2,817,962.40	591,772.10	2,280,490.30	0.7835261665	1,786,823.82

A.4.2 Unit 2

Table A.4.2.1: Unit 2 Best Case MACRS Monetary Calculation

Year	FCI ($)	WC ($)	INC ($)	EXP ($)	DEP FRACT	BV ($)	DEP ($)	PROFIT ($)	TAX ($)	CF ($)	DF CASH	DISC CF ($)
0	116,916.68	57,000.00	0.00	0.00	0	116,916.68	0	0	0	-173,916.68	1	-173,916.68
1	0	0	11,572,545.60	1,342,838.40	0.3333	77,948.35	38,968	10,190,738.87	2,140,055	8,089,652.04	0.9523809524	7,704,430.51
2	0	0	11,572,545.60	1,342,838.40	0.4445	25,978.89	51,969	10,177,737.74	2,137,325	8,092,382.28	0.9070294785	7,340,029.27
3	0	0	11,572,545.60	1,342,838.40	0.1481	8,663.53	17,315	10,212,391.84	2,144,602	8,085,104.91	0.8638375985	6,984,217.61
4	0	0	11,572,545.60	1,342,838.40	0.0741	0.00	8,664	10,221,043.67	2,146,419	8,083,288.03	0.8227024748	6,650,141.07
5	0	-57,000.00	11,572,545.60	1,342,838.40	0	0.00	0	10,229,707.20	2,148,239	8,138,468.69	0.7835261665	6,376,703.17

Table A.4.2.2: Unit 2 Worst Case MACRS Monetary Calculations

Year	FCI ($)	WC ($)	INC ($)	EXP ($)	DEP FRACT	BV ($)	DEP ($)	PROFIT ($)	TAX ($)	CF ($)	DF CASH	DISC CF ($)
0	116,916.68	57,000.00	0.00	0.00	0	116,916.68	0	0	0	-173,916.68	1	-173,916.68
1	0	0	7,072,111.20	5,843,272.80	0.3333	77,948.35	38,968	1,189,870.07	249,873	978,965.69	0.9523809524	932,348.27
2	0	0	7,072,111.20	5,843,272.80	0.4445	25,978.89	51,969	1,176,868.94	247,142	981,695.92	0.9070294785	890,427.14
3	0	0	7,072,111.20	5,843,272.80	0.1481	8,663.53	17,315	1,211,523.04	254,420	974,418.56	0.8638375985	841,739.39
4	0	0	7,072,111.20	5,843,272.80	0.0741	0.00	8,664	1,220,174.87	256,237	972,601.68	0.822702474	800,161.81

											8	
5	0	-57,000.00	7,072,111.20	5,843,272.80	0	0.00	0	1,228,838.40	258,056	1,027,782.34	0.7835261665	805,294.35

A.5 Major Equipment and Costs

Major equipment material and maintenance costs were provided by Katelin Kohn. Any holes in the data for a valve's material or maintenance costs were filled using average materiel or maintenance costs for valves in that unit.

A.5.1 Unit 1

Table 9.2: Unit 1 Valve Information

Equipment	Energy Loss (MWe)	Manufacturer	Model	Material Cost (USD)	Maintenance Cost (USD)	Total Repair Cost
Steam Valve 1 **1-FMO-260 (L)**	47.41	Lunkeheimer	1469XB7MOD-12I	$13,997.67	$17,000.00	$30,997.67
Steam Valve 2 **1-MRV-403**	18.96	Copes-Vulcan	GS6	$14,042.00	$5,430.00	$19,472.00
Steam Valve 3 **1-MS-239**	18.12	Velan Valve Corp.	B09-2074C-02TY	$2,000.00	$5,430.00	$7,430.00
Steam Valve 4 **1-CRV-224 (L)**	16.37	Fisher Controls Co.	V300	$16,972.00	$5,430.00	$22,402.00
Steam Valve 5 **1-DRV-423**	9.19	Fisher Controls Co.	ED	$13,997.67	$3,880.00	$17,877.67
Steam Valve 6 **1-CRV-224 (H)**	6.01	Fisher Controls Co.	V300	$16,972.00	$5,430.00	$22,402.00
Steam Valve 7 **1-MSD-219L**	2.11	Velan Valve Corp.	B12-2064C-02TY	$13,997.67	$900.00	$14,897.67
Steam Valve 8 **1-HRV-562**	1.52	Hammel-Dahl	500THC82HBOG	$17,000.00	$1,500.00	$18,500.00
Steam Valve 9 **1-HRV-561**	1.48	Hammel-Dahl	500THC82HBOG	$17,000.00	$1,500.00	$18,500.00
Steam Valve 10 **1-MRV-409**	0.95	Fisher Controls Co.	EZ	$13,997.67	$7,800.00	$21,797.67
			Averages	$13,997.67	$5,430.00	$19,427.67

Table 9.3: Unit 1 Total Costs

Replacement Materials Total	116,916.68	USD
Replacement Maintenance Total	57,000.00	USD

Yearly Energy Loss	459,228	MWh
Yearly Energy Loss Cash Value	12,858,384.00	USD

A.5.2 Unit 2

Table 9.4: Unit 2 Valve Information

Equipment	Energy Loss (MWe)	Manufacturer	Model	Material Cost (USD)	Maintenance Cost (USD)	Total Repair Cost
Steam Valve 1 **2-T-121-6**	21.22	Armstrong	5133-1I	$11,691.67	$7,800.00	$19,491.67
Steam Valve 2 **2-FMO-260**	8.31	Lunkeheimer	1469XB7 MOD-12I	$11,691.67	$17,000.00	$28,691.67
Steam Valve 3 **2-T-121-5**	8.01	Armstrong	5133-1I	$11,691.67	$7,800.00	$19,491.67
Steam Valve 4 **2-CRV-224**	4.63	Fisher Controls Co.	8-U	$14,000.00	$1,800.00	$15,800.00
Steam Valve 5 **2-MS-239**	3.75	Velan Valve Corp.	B10-2074 C-02TS	$2,000.00	$5,700.00	$7,700.00
Steam Valve 6 **2-HRV-461**	2.16	Fisher Controls Co.	V100	$7,500.00	$3,000.00	$10,500.00
Steam Valve 7 **2-HRV-462**	1.73	Fisher Controls Co.	V100	$17,050.00	$4,000.00	$21,050.00
Steam Valve 8 **2-DRV-406**	1.67	Hammel-Da hl	500LFK93 HAEGZ	$5,600.00	$5,000.00	$10,600.00
Steam Valve 9 **2-HRV-557**	1.62	Hammel-Da hl	500SHC82 HAOGJ	$24,000.00	$4,000.00	$28,000.00
Steam Valve 10 **2-B-431**	1.57	Lunkeheimer		$11,691.67	$900.00	$12,591.67
			Averages	$11,691.67	$5,700.00	$17,391.67

Table 9.5: Unit 2 Total Costs

Replacement Materials Total	116,916.68	USD
Replacement Maintenance Total	57,000.00	USD
Yearly Energy Loss	459,228	MWh
Yearly Energy Loss Cash Value	12,858,384.00	USD