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Operations Manual for the Plasma Source Ion Implantation Economics Program

by

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How to Use This Manual

To learn how to run PSIICOSTMODEL95 quickly, go to Section 1: Quick Steps. A design variable set and step-by-step procedure are presented in Section 1 to allow the user to immediately start using the program.

Within PSIICOSTMODEL95 data appearing in bold type are values that may be modified by the user. Quantities appearing as straight text are either calculated or referenced data and should not be directly modified by the user.

IMPORTANT

The program is sensitive about the following items so please remember to follow these instructions while running PSIICOSTMODEL95.

- Macro buttons are placed in many of the modules so the user can easily add or subtract chambers, components, dimensions, sizes, valves, chillers, power, time, and processes. You must use these buttons instead of directly entering data from the keyboard. Entering data from the keyboard erases the formulas in the cells and then the program will not run correctly.

- The macro buttons must be clicked slow enough for the macro to input the data. Clicking too fast may run the data past the end marker and cause the program to crash or give incorrect results.

- PSIICOSTMODEL95 was written in EXCEL 4.0. You can run the program in EXCEL 5.0 and save it in 5.0 but you must not save it as an EXCEL 4.0 document after starting it in the 5.0 version. EXCEL will not save the macro links correctly and the program will always be wrong. This problem was reported to the technical support personnel at Microsoft. Unfortunately they were unable to fix the problem so when running PSIICOSTMODEL95 please remember this important information.

To gain a thorough understanding of how PSIICOSTMODEL95 works, it is recommended that you read through Section 2: Details. This section reviews the program layout, gives the definition of all user input variables, the formulas of all calculated variables, and locations of all referenced variables. Because Section 2 is laid out according to modules found within the program, it may be used as a quick reference guide for questions you may have as you use the program. Please remember that the numbers shown in the modules are examples only. When the user inputs data into the program the numbers will change and not be the same as the numbers shown in this manual.

Included with this operations manual is a disk containing two versions of PSIICOSTMODEL95--a locked version and an unlocked version. The unlocked version allows the user to modify all the cells in the program whereas the locked version contains certain protected cells which are not modifiable by the user. Use the locked version to avoid inadvertent mistakes like erasing parts of the code. It is recommended that the user make a backup copy before attempting to run or modify PSIICOSTMODEL95. The PSIICOSTMODEL95 EXCEL program is available in either Macintosh or IBM format.

Macintosh locked version:	**PSIICostModel95.L**
Macintosh unlocked version:	**PSIICostModel95.UL**
IBM locked version:	**PSII95L.xls**
IBM unlocked version:	**PSII95.xls**

Abbreviations

The following abbreviations are used throughout this manual as well as in the EXCEL program.

ampere .... A
cubic foot .... ft^3
cubic foot per minute .... ft^3/min
cubic meter .... m^3
dollars .... $
foot .... ft
hertz .... Hz
horsepower .... hp
kilovolt .... kV
kilowatt .... kW
kilowatt-hour .... kW h
lead .... Pb
liters per second .... liter/s
percent .... %
square foot .... ft^2
thousands .... k
thousands of dollars .... $k
volt V
watt .... W

Introduction

Plasma Source Ion Implantation (PSII) is a surface modification technique for metal. PSIICOSTMODEL95 is an EXCEL-based program that estimates the cost for implementing a PSII system in a manufacturing setting where the number of parts to be processed is over 5,000 parts per day and the shape of each part does not change from day to day. Overall, the manufacturing process must be very well defined and should not change. This document is a self-contained manual for PSIICOSTMODEL95. It assumes the reader has some general knowledge of the technical requirements for PSII.

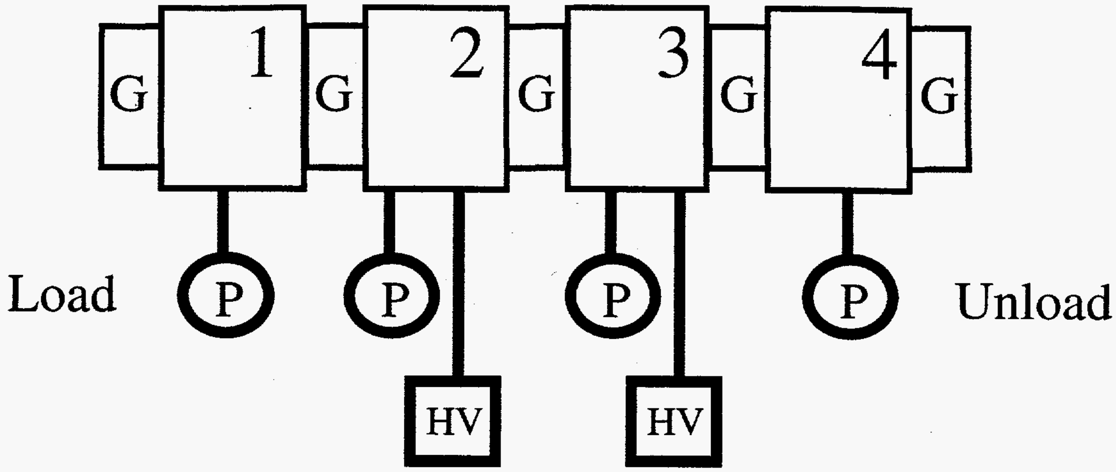
Configuration of the PSII process versus design is used as the methodology in PSIICOSTMODEL95. The reason behind this is twofold. First, the design process cannot be programmed into a computer when the relationships between design variables are not understood. Second, the configuration methodology reduces the number of assumptions that must be programmed into our software. Misuse of results are less likely to occur if the user has fewer assumptions to understand.

In configuration, the user specifies a minimum number of design variables, such as location, number, and size of major components used in the PSII process. These design variables were brought about by a design process performed separate from the program. The configuration information is then multiplied by the appropriate unit cost data in each component to arrive at an estimated total system cost. In essence PSIICOSTMODEL95 has many characteristics of a pricing program.

PSIICOSTMODEL95 was developed with a philosophy that it would be used by a team of engineers who are designing the nuts and bolts of an entire PSII system. With PSIICOSTMODEL95, the engineers may evaluate cost drivers and estimate a final system cost for a particular design. The program described in this documentation will not design a PSII system. It is a tool to help in the overall design process.

A typical PSII system layout is shown in Figure 1. This figure illustrates the general relationship of hardware used in production-line manufacturing and the types of processes occurring within the layout of hardware. Here four vacuum chambers of the same size are configured in a series with gate valves between the chambers. Chambers 1 and 4 have gate valves on their outer sides to retain a closed vacuum environment. Parts are loaded on the left side and travel through each chamber in succession before they are unloaded on the right. Parts only pass from one chamber to another once all processes in the series have been completed. The process or processes occurring within each chamber are listed. The specific process or processes occurring within each vacuum chamber determine the hardware needed for that chamber. Figure 2 illustrates the vacuum chamber dimensions. Tables 1 through 4 specify the technical requirements for each respective process. Throughout this operations manual, the terminology "chamber" and "vacuum chamber" are interchangeable and refer to the same object. Rotary vane pumps are assumed to be used as fore pumps. Also, the phrase "in the design" refers to the design that has been completed by the team of engineers separate from PSIICOSTMODEL95.

Process Design Criteria



Chamber 1:	Load, Pump down
Chamber 2:	PSII
Chamber 3:	Deposit
Chamber 4:	Vent to air, Unload

G = gate valve
P = pump system
HV = high-voltage system
1 to 4 = chambers

Figure 1. Typical system layout of the PSII process.

Process(es) within each chamber are listed. This is important because certain processes like PSII and Deposition require additional high-voltage equipment.

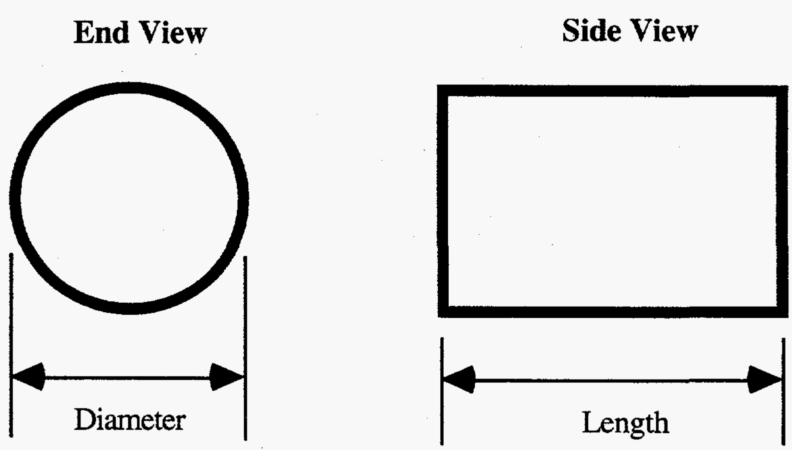


Figure 2. Cylindrical vacuum chamber dimensions.

Table 1. Pump down and vent to air.

Pump Down and Vent to Air (Chambers 1 and 4)			
Time (hours)	0.5		
Pumps	Fore	Roots	TMP
Size (ft^3/min)	677	1449	1100
Shielding	None		
Plasma	None		
High Voltage	None		

Table 2. PSII.

PSII (Chamber 2)			
Time (hours)	1.0		
Pumps	Fore	Roots	TMP
Size (ft^3/min)	495	707	850
Shielding	1 inch Pb		
Plasma	10-6 torr		
High Voltage	20 kV		
	100 A		
	1000 Hz		

Table 3. Sputter.

Sputter (Chamber 2)			
Time (hours)	1.0		
Pumps	Fore	Roots	TMP
Size (ft^3/min)	495	707	850
Shielding	1 inch Pb		
Plasma	10-6 torr		
High Voltage	1 kV		
	100 A		
	1000 Hz		

Table 4. Deposit.

Deposit (Chamber 3)			
Time (hours)	3.0		
Pumps	Fore	Roots	TMP
Size (ft^3/min)	677	1449	1100
Shielding	1 inch Pb		
Plasma	10-4 torr		
High Voltage	600 V		
	100 A		
	1000 Hz		

PSII Design Parameters

A set of PSII design parameters is presented first, followed by a straightforward process for entering data into the program. The program does no design calculations itself, so it is the responsibility of the user to enter consistent design variables.

Manufacturing Objective

Average Number of Parts per Day:	4800

Batch Layout

Maximum Process Time per Chamber:	3 hours
Number of Parts per Chamber:	1000
Number of Parts per Unit:	4
100 Percent Utilization Time:	16 hours/day
Utilization Percentage:	90%

Hardware Design Criteria

Number of Chambers:	4, cylindrical
Configuration:	All same size in series
Dimensions:	Diameter = 7 feet Length = 30 feet
Number of Gate Valves:	5, circular Diameter = 6 feet
Number of Chillers:	1, heat load rating = 400 tons

Note that the size of each part was not directly specified. Instead the vacuum chamber dimensions take into account both the number and size of parts to be processed.

Miscellaneous

Installation Cost:	$260,000
Start-Up Cost:	$260,000
Robotics Cost:	$1,000,000
Term:	5 years
Interest Rate:	12%

Section 1: Quick Steps

A. Entering Data Into the Program

This section presents a step-by-step method to enter a design variable set into the program. This is a quick-reference version.

IMPORTANT
The user **must** use the macro buttons to input or change data in the modules otherwise the program will not work correctly. Always check to make sure you are in the correct cell before making changes. Also, whenever adding vacuum chambers please check the data entered for pumps, shielding, etc. for the vacuum chamber system components and the high-voltage system components because the program automatically inputs random numbers in these cells whenever a vacuum chamber is added.

Step 1: In the Batch Layout module, manually enter values for the following:

- Maximum Process Time per Chamber
- Number of Parts per Chamber
- Number of Parts per Unit
- 100 Percent Utilization Time
- Utilization Percentage

Step 2: In the Capital Equipment Configuration module, use the Add/Sub Chamber buttons to specify the Number of Chambers. Whenever you add chambers please notice that the program automatically inputs random numbers for the Vacuum Chamber System components and High-Voltage System components. These numbers should be checked and changed if necessary.
Note: For data changes, select cell location and use add/sub chamber buttons.

Step 3: In the Capital Equipment Configuration module, under the Process Description column, manually enter text to describe the Process or Processes associated with each chamber.

Step 4: In the Capital Equipment Configuration module, use the Increase/Decrease Dimension buttons to specify the Diameter and Length for each vacuum chamber.
Note: For data changes, select cell location and use increase/decrease dimension buttons.

Step 5: In the Capital Equipment Configuration module, use the Add/Sub Component buttons to specify the quantity of pumps, plasma generators, and high-voltage equipment. Use the same buttons to specify the use of shielding on each chamber.
Note: For data changes, select cell location and use add/sub component buttons.

Step 6: In the Capital Equipment Configuration module, use the Add/Sub Valve buttons to specify the quantity of Gate Valves.
Note: For data changes, select cell location and use add/sub valve buttons.

Step 7: In the Capital Equipment Configuration module, use the Add/Sub Chiller button to specify the quantity of Chillers.
Note: For data changes, select cell location and use add/sub chiller buttons.

Step 8: In the Capital Equipment Configuration module, use the Increase/Decrease Size buttons to specify the size of Gate Valves and Chillers.
Note: For data changes, select cell location and use increase/decrease size buttons.

Step 9: In the Capital Equipment Size module, use the Increase/Decrease Size buttons to specify the size of each pump, plasma generator, and shielding area. The sizes chosen will apply to each quantity of component specified.
Note: For data changes, select cell location and use increase/decrease size buttons.

Step 10: In the Installation Cost module, select the Default Value button and then manually enter a value for the Default Installation Cost.

Step 11: In the Start-Up Cost module, select the Default Value button and then manually enter a value for the Default Start-Up Cost.

Step 12: In the Robotics Cost module, select the Default Value button and then manually enter a value for the Default Robotics Cost.

Step 13: In the Capital Amortization module, enter the Term and Interest Rate applicable for amortizing a loan for capital equipment.

Step 14: In the Operations & Maintenance module, manually enter values for the following:

- Annual Rate
- Area Multiplier
- Office Area
- Periodic Maintenance Cost
- Pump Oil Cost
- Plasma Gas Cost
- Waste Treatment Cost

Step 15: In the Electrical Cost module, manually enter values for the following:

- Electrical Rate
- Process Cooling Percentage
- Workspace Lighting Factor
- Climate Control Factor

Step 16: In the Electrical Cost module, use the Add/Sub Process buttons to specify the quantity of processes.
Note: For data changes, select cell location and use add/sub process buttons.

Step 17: In the Electrical Cost module, under the Process Name(s) column, manually enter a text description for each process specified.

Step 18: In the Electrical Cost module, use the Higher/Lower Chamber buttons to specify a chamber location for each process.
Note: For data changes, select cell location and use higher/lower chamber buttons.

Step 19: In the Electrical Cost module, use the Add/Sub Power buttons to specify the Process Average Power for each process.
Note: For data changes, select cell location and use add/sub power buttons.

Step 20: In the Electrical Cost module, use the Add/Sub Time buttons to specify the time each process takes for completion.
Note: For data changes, select cell location and use add/sub time buttons.

Step 21: In the Labor Cost module, manually enter values for the Overtime Differential and Holiday Differential. The following values require manual entry for both the hourly and salaried employees:

- Type of Worker
- Pay Rate
- Quantity of Workers
- Number of Regular Days
- Number of Holidays (Number of holidays worked not the number of holidays allocated to the employee.)
- Regular Hours per Day
- Overtime Hours per Week (The program assumes 50 weeks per year.)

Section 2: Details

A. PSIICOSTMODEL95 Structure

The economics program runs in the Macintosh software application EXCEL and is constructed in a workbook format. A workbook in EXCEL has a page called 'Workbook Contents' that shows an indexed listing of worksheets to allow the user to easily select the worksheet of their choice. Each individual worksheet is considered to be a module and is named according to its function within the program. Table 5 lists the modules as they appear in the workbook contents of the EXCEL program, PSIICOSTMODEL95. There are two types of modules in PSIICOSTMODEL95, straightforward modules and macro modules. For information on how to construct or use workbooks, consult the *EXCEL User's Guide 1* manual.

Table 5. List of modules in the PSIICOSTMODEL95 workbook.

PSIICOSTMODEL95 Workbook

Module Name	
1)	Introduction
2)	Batch Layout
3)	Capital Equipment Configuration
4)	Capital Equipment Size
5)	Installation Cost
6)	Start-Up Cost
7)	Robotics Cost
8)	Capital Cost
9)	Capital Amortization
10)	Operations & Maintenance
11)	Electrical Cost
12)	Labor Cost
13)	Hard Copy
14)	Summary
15)	Unit Cost
16)	Chamber Number (Macro)
17)	Change If Link Ref (Macro)
18)	Select (Macro)
19)	Process Number (Macro)
20)	Valve Number (Macro)
21)	Chiller Number (Macro)

The location of modules shown in Table 5 follows a top-down design approach where modules appearing higher up on the index list are more likely to require inputs by the user, and lower indexed modules are more likely to show results. However, worksheet modules may contain a mix of input variables and results. Macro modules only contain a set of commands.

As mentioned previously, **within PSIICOSTMODEL95 data appearing in bold type are values that may be modified by the user.** Quantities appearing as straight text are either calculated or referenced data and should not be directly modified by the user.

The following text gives a detailed description of each module's structure. Structure refers to the particular input values, calculated values, referenced values, and/or any macro functions present in a particular module. An input value can be altered or changed by the user unlike a calculated or referenced value. All input values do not need to be changed each time the user runs the program. A calculated value performs a mathematical calculation and a referenced value is referenced from some other location in the program. A macro is a set of commands that performs a function. The macro buttons are used in PSIICostModel95 to help the user input data and **must** be used rather than inputting data from the keyboard. Remember that inputting data from the keyboard will erase formulas in the cells that are needed for the program to run correctly.

B. Worksheet Modules

Module 1: Introduction

This module displays information describing the purpose and function of the program.

Introduction

Plasma Source Ion Implantation Economic Workbook
Version 7.0 (October 1995)
Not For Release

This program is an economic model for Plasma Source Ion Implantation.

It is intended to be used as a design tool for engineers designing a PSII system.

The user inputs certain design variables and the program estimates the cost to implement and operate a PSII system.

The program is broken into modules, each one pertaining to a particular subsystem.

Modules are arranged in top-down design.

Hard copy printouts of a particular case run may be printed from the 'Hard Copy' module.

Module 2: Batch Layout

The Batch Layout module defines the number of parts to be processed and the amount of time to process the parts.

Batch Layout

Maximum Process Time per Chamber =	**3**	**hours**
Number of Parts per Chamber =	**1000**	
Number of Parts per Unit =	**4**	
100 Percent Utilization Time =	**16**	**hours/day**
Utilization Percentage =	**90**	**%**
Average Number of Parts per Day =	4800	
Number of Units per Day =	1200	
Total Number of Parts per Year =	1224000	

User Inputs:	Definition:
Max Process Time per Chamber:	Longest time for process or processes to be completed within any one chamber. (Unit: hours)
Number of Parts per Chamber:	Quantity of parts that fit into the smallest chamber.
Number of Parts per Unit:	Quantity of parts assigned together as a unit. In many instances, a number of similar parts will be assembled in one unit later in the production process.
100 Percent Utilization Time:	Length of time that the overall PSII process is expected to run in continuous operation for one day without any dead time. (Unit: hours per day)
Utilization Percentage:	Percentage of the 100% utilization time that the overall PSII process is expected to run. Accounts for downtime due to unexpected hardware failure and maintenance. (Unit: percentage)

Referenced Values: None

From Module:

Calculated Values:

Equations:

Total Number of Parts per Day:

$$\left(\frac{\text{Utilization Percentage}}{100}\right)\left(\frac{\text{100 Percent Utilization Time}}{\text{Maximum Process Time per Chamber}}\right) * (\text{Number of Parts per Chamber})$$

Number of Units per Day:

$$\left(\frac{\text{Average Number of Parts per Day}}{\text{Number of Parts per Unit}}\right)$$

Total Number of Parts per Year:

$$(\text{Number of Regular Days} + \text{Number of Holidays}) * \text{Average Number of Parts per Day}$$

Buttons: None

Corresponding Macros:

Module 3: Capital Equipment Configuration

In this module the user specifies the chamber and number of components for a particular design. To help make this module more user friendly, all component hardware used in a PSII system has been categorized into two subsystems:

1) Vacuum Chamber System: includes all the hardware necessary to produce and maintain a plasma gas state within an enclosed environment. The hardware includes fore pumps, roots blowers, turbo-molecular pumps, shielding, plasma generators, gate valves, a rack system to hold the parts, and vacuum chambers. The plasma generators assumed in the module are the radio-frequency variety.

2) High-Voltage System: includes all the hardware necessary to regulate the voltage of the work pieces. The hardware includes transformers, phase controllers, rectifiers, pulse modulators, and relay-breakers. Chillers are also included in the high-voltage system.

Under the Chamber No. column, a -1 indicates that no chamber is present. When a Chamber No. possesses a -1, the entire row becomes -1s. This is to reinforce the notion that no chamber is present and therefore no components may be specified. There can be only 6 vacuum chambers unlike gate valves and chillers where 15 may be specified. In the Electrical Cost module, the user will be able to specify up to 8 unique processes for the 6 vacuum chambers.

IMPORTANT

The user **must** use the macro buttons to input or change data otherwise the program will not work correctly. Always check to make sure you are in the correct cell before making changes. Also, whenever adding vacuum chambers please check the data entered for pumps, shielding, etc. for the vacuum chamber system components and the high-voltage system components because the program automatically inputs random numbers in these cells whenever a vacuum chamber is added.

Capital Equipment Configuration

Add Chamber | Sub Chamber | Increase Dimension | Decrease Dimension

No. of Chambers = 4

Chamber No.	Process Description	Diameter (ft)	Length (ft)	Volume (ft^3)	Volume (m^3)
1	Load/Pump down	7	30	1155	33
2	PSII/Sputter	7	30	1155	33
3	Deposition	7	30	1155	33
4	Vent/Unload	7	30	1155	33
-1		-1	-1	-1	-1
-1		-1	-1	-1	-1

Add Component | Vacuum Chamber System | Sub Component

Chamber No.	Fore Pump	Roots Blower	Turbo-Molecular	Shielding (1 = Y/0 = N)	Plasma Generator
1	2	2	2	0	0
2	2	2	2	1	4
3	2	2	2	1	4
4	2	2	2	0	0
-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1

Add Component | High-Voltage System | Sub Component

Chamber No.	13.8 kV to 480 V	Phase Controller	480 V to 480 V	Rectifier	1.5 kV Pulse Modulator	Relay-Breaker
1	0	0	0	0	0	0
2	1	1	1	1	20	1
3	1	1	1	1	1	1
4	0	0	0	0	0	0
-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1

Increase Size | Decrease Size | Add Valve | Sub Valve

No. of Gate Valves = 5

Valve No.	Diameter (ft)	Cost ($k)
1	6	120
2	6	120
3	6	120
4	6	120
5	6	120
-1	-1	-1
-1	-1	-1
-1	-1	-1
-1	-1	-1
Etc.	Etc.	Etc.

Increase Size | Decrease Size | Add Chiller | Sub Chiller

No. of Chillers = 1

Chiller No.	Size (ton)	Cost ($k)
1	400	300
-1	-1	-1
-1	-1	-1
-1	-1	-1
-1	-1	-1
-1	-1	-1
-1	-1	-1
-1	-1	-1
-1	-1	-1
Etc.	Etc.	Etc.

User Inputs:	Definition:
No. of Vacuum Chambers:	Quantity of vacuum chambers specified in design. Maximum of 6 chambers.
Process Description:	Short phrase describing the process or processes occurring within a vacuum chamber--has no effect on the outcome of the results.
Vacuum Chamber Diameter:	Diameter of cylindrical vacuum chamber. (Unit: feet)
Vacuum Chamber Length:	Length of cylindrical vacuum chamber. (Unit: feet)
Vacuum Chamber System (Number of Components):	User specifies the number of components desired. Components in this system include fore pumps, roots blowers, turbo-molecular pumps, and plasma generators. Shielding is specified as either 1=yes or 0=no.
High-Voltage System (Number of Components):	User specifies the number of components desired. Components in this system include 13.8 kV to 480 V transformers, phase controllers, 480 V to 480 V transformers, rectifiers, 1.5 kV pulse modulators, and relay-breakers.
No. of Gate Valves:	Quantity of gate valves specified in the design. Maximum of 15 gate valves.
Gate Valve Diameter:	Diameter of circular gate valves. (Unit: feet)
No. of Chillers:	Quantity of chillers specified in the design. Maximum of 15 chillers.
Chiller Size:	Size of chiller needed to cool the heat load produced by all the processes occurring within each chamber. (Unit: tons of heat load)

Referenced Values:	From Module:
Cost of Gate Valve:	Unit Cost
Cost of Chiller:	Unit Cost

Calculated Values:	Equations:
Volume (ft^2):	$\pi\left(\frac{\text{Chamber Length}}{1}\right)\left(\frac{\text{Chamber Diameter}}{2}\right)^2$ Note: Volume for one cylindrical vacuum chamber.

Buttons:	Corresponding Macros:
Add Chamber	Chamber Number!Increase
Sub Chamber	Chamber Number!Decrease
Increase Dimension	Change If Link Ref!Increase
Decrease Dimension	Change If Link Ref!Decrease
Add Component	Change If Link Ref!Increase
Sub Component	Change If Link Ref!Decrease
Increase Size	Change If Link Ref!Increase
Decrease Size	Change If Link Ref!Decrease
Add Valve	Valve Number!Increase
Sub Valve	Valve Number!Decrease
Add Chiller	Chiller Number!Increase
Sub Chiller	Chiller Number!Decrease

Module 4: Capital Equipment Size

In this module the user specifies the size of the components used in the design.

IMPORTANT
The user **must** use the macro buttons to input or change data otherwise the program will not work correctly. Always check to make sure you are in the correct cell before making changes.

Capital Equipment Size

Chamber No.	Process Description	Volume (m^3)
1	Load/Pump down	33
2	PSII/Sputter	33
3	Deposition	33
4	Vent/Unload	33
-1		-1
-1		-1

Increase Size

Decrease Size

Vacuum Chamber System Sizes					
	Pumps				Plasma
Chamber No.	Fore Pump (ft^3/min)	Roots Blower (ft^3/min)	TMP (liter/s)	Shielding (ft^2)	Generator (W)
1	677	1449	1100	-1	-1
2	495	707	850	300	600
3	677	1449	1100	300	600
4	677	1449	1100	-1	-1
-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1

Vacuum Chamber System Associated Unit Costs					
	Pumps				Plasma
Chamber No.	Fore Pump ($)	Roots Blower ($)	TMP ($)	Shielding ($)	Generator ($)
1	34000	16000	19000	0	0
2	20000	11000	19000	3900	4600
3	34000	16000	19000	3900	4600
4	34000	16000	19000	0	0
-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1

Vacuum Chamber System Associated Power and Energy				
	Pump Power			Total Pump
Chamber No.	Fore Pump (hp)	Roots Blower (hp)	TMP (hp)	Energy per Hour (kW h)
1	30.00	10.00	0.25	60.05
2	25.00	5.40	0.25	45.73
3	30.00	10.00	0.25	60.05
4	30.00	10.00	0.25	60.05
-1	-1.00	-1.00	-1.00	-1.00
-1	-1.00	-1.00	-1.00	-1.00

User Inputs:
Vacuum Chamber System: (Size of Components)

Definition:
User specifies the size of each specific component using the increase and decrease size buttons.
Components in this system include fore pumps, roots blowers, turbo-molecular pumps, shielding, and plasma generators. Sizes for the first two pumps are given in cubic feet per minute of air through the pump (ft^3/min), and the last pump in liters per second (liter/s). Size for shielding is given in square feet of surface area to be covered (ft^2). Size for the plasma generator is given in watts (W).

Referenced Values:	From Module:
Chamber Number:	Capital Equipment Configuration
Process Description:	Capital Equipment Configuration
Chamber Volume:	Capital Equipment Configuration
Vacuum Chamber System: (Unit Cost of Components)	Unit Cost
Pump Power:	Unit Cost

Calculated Values:

Pump Energy:

Equations:

$$\sum_{i=1}^{3}\left(\text{Number of Pumps}_i\right)\left(\text{Pump Power}_i\right) * .746$$

where: i = 1 refers to a Fore Pump
i = 2 refers to a Roots Blower
i = 3 refers to a Turbo-Molecular Pump

Note: Energy calculated is per vacuum chamber (Unit: kilowatt-hours)

Buttons:	Corresponding Macros:
Increase Size	Change If Link Ref!Increase
Decrease Size	Change If Link Ref!Decrease

Module 5: Installation Cost

Module 5 is where the user specifies the installation cost for implementing PSII in a manufacturing environment.

<u>**IMPORTANT**</u>
The user <u>**must**</u> use the macro buttons to input the default or calculated value otherwise the program will not work correctly. Always check to make sure you are in the correct cell before making changes.

Installation Cost

Default Value		CalculatedValue
>>>>>>>>>	Use Default Value	1
	Use Calculated Value	0

Default Installation Cost =	260	$k

Labor			
Worker	Hours	Rate ($/hour)	$k
Craft Labor	1000	25	25
Engineering-Design	200	100	20
Manufacturing-Design	150	100	15
		Subtotal Labor Cost =	60 $k
		Equipment Rental =	100 $k
		Consumables =	50 $k
		Calculated Installation Cost =	210 $k

User Inputs:	Definition:
Use Default Value:	Indicates user's choice to use the single default value in final analysis.
Default Installation Cost:	Lump sum entry of installation cost.
Use Calculated Value:	Indicates user's choice to use the calculated value in final analysis, which requires the information below.
Worker:	Type of worker employed during the installation process.
Hours:	Number of hours a particular type of worker will be needed during the installation process.

Rate: Pay rate for workers employed during the installation process. (Unit: dollars per hour).

Equipment Rental: Lump sum dollar amount needed to pay for equipment rented during the installation process. (Unit: thousands of dollars)

Consumables: Lump sum dollar amount needed to pay for consumables used during the installation process. (Unit: thousands of dollars)

Referenced Values:	From Module:
None	

Calculated Values:	Equations:
Cost of Worker:	(Rate)(Hours), for each particular worker.
Subtotal Labor Cost:	$\sum_{j=1}^{3} (\text{Cost of worker})_j$ where: j = 1 refers to Craft labor j = 2 refers to Engineering Design Labor j = 3 refers to Manufacturing Design Labor
Calculated Installation Cost:	Subtotal Labor Cost + Equipment Rental + Consumables

Buttons:	Corresponding Macros:
Default Value:	Select!Default
Calculated Value:	Select!Calculated

Module 6: Start-Up Cost

In Module 6 the user specifies the start-up cost for implementing PSII in a manufacturing environment.

> **IMPORTANT**
> The user **must** use the macro buttons to input the default or calculated value otherwise the program will not work correctly. Always check to make sure you are in the correct cell before making changes.

Start-Up Cost

Default Value		CalculatedValue
>>>>>>>>>	Use Default Value	1
	Use Calculated Value	0

Default Start-Up Cost =	260	$k

Training =	60	$k
Parts Scrapped =	30	$k
Testing =	200	$k
Calculated Start-Up Cost =	290	$k

User Inputs:	Definition:
Use Default Value:	Indicates user's choice to use the single default value in final analysis.
Default Start-Up Cost:	Lump sum start-up cost.
Use Calculated Value:	Indicates user's choice to use the calculated value in final analysis, which requires the information below.
Training:	Cost associated with training personnel who will eventually run the PSII manufacturing process full time. (Unit: thousands of dollars)
Parts Scrapped:	Cost associated with the parts scrapped during the start-up process. (Unit: thousands of dollars)
Testing:	Cost associated with testing the PSII hardware during the start-up process. (Unit: thousands of dollars)

Referenced Values:	From Module:
None	

Calculated Values:	Equations:
Calculated Start-Up Cost:	Training + Parts Scrapped + Testing

Buttons:	Corresponding Macros:
Default Value:	Select!Default
Calculated Value:	Select!Calculated

Module 7: Robotics Cost

In this module the user specifies the robotics cost for implementing PSII in a manufacturing environment.

IMPORTANT
The user **must** use the macro buttons to input the default or calculated value otherwise the program will not work correctly. Always check to make sure you are in the correct cell before making changes.

Robotics Cost

Default Value		CalculatedValue
>>>>>>>>>	Use Default Value	1
	Use Calculated Value	0

Default Robotics Cost =	1000	$k
Controls =	50	$k
Rack System =	750	$k
Calculated Robotics Cost =	800	$k

User Inputs:	Definition:
Use Default Value:	Indicates user's choice to use the single default value in the final analysis.
Default Robotics Cost:	Lump sum robotics cost. Robotics include the rack system to hold the parts and the control hardware necessary to move the parts through each successive chamber. (Unit: thousands of dollars)
Use Calculated Value:	Indicates user's choice to use the calculated value in the final analysis, which requires the information below.
Controls:	Cost associated with control system used to operate the rack system. (Unit: thousands of dollars)
Rack System:	Cost associated with the hardware assembly used to hold the parts to be processed as they pass from vacuum chamber to vacuum chamber. (Unit: thousands of dollars)

Referenced Values:	From Module:
None	

Calculated Values:	Equations:
Calculated Robotics Cost:	Controls + Rack System

Buttons:	Corresponding Macros:
Default Value:	Select!Default
Calculated Value:	Select!Calculated

Module 8: Capital Cost

In this Capital Cost module all final costs of capital equipment are displayed.

Capital Cost

Vacuum Chambers		
Cost =	164	$k

Valve System		
Cost =	600	$k

High-Voltage System ($k)	
13.8 kV to 480 V	40
Phase Controller	8
480 V to 480 V	40
Rectifier	10
Pulse Modulator	31.5
Relay-Breaker	10
Controls	20
Subtotal =	160

Pump System ($k)	
Fore Pump	244
Roots Blower	118
Turbo-Molecular	152
Controls	20
Subtotal =	534

Other ($k)	
Plasma Generator	37
Shielding	8
Chiller	300
Subtotal =	345

Robotics ($k)	
Rack System	1000
Subtotal =	1000

Installation		
Cost =	260	$k

Start Up		
Cost =	260	$k

User Inputs:
None

Definition:

Referenced Values:
Controls, High-Voltage System:
Controls, Pump System:

From Module:
Unit Cost
Unit Cost

Calculated Values:	Equations:
Vacuum Chamber System Cost:	$\sum_{q=1}^{6}$ (Chamber Unit Cost)$_q$ + (6 – Number of Vacuum Chambers) where: the letter 'q' refers to vacuum chamber number, $q_{max} = 6$
High-Voltage Equipment except controls:	((Number of particular component specified) + (6 – Number of Vacuum Chambers)) * (Corresponding Unit Cost)
Gate Valves System Cost:	$\sum_{n=1}^{15}$ (Unit Cost Gate Valve)$_n$ + (15 – Number of Gate Valves)
Pump Equipment except controls:	$\sum_{q=1}^{6}\sum_{i=1}^{3}$ (Quantity of Pumps)$_{iq}$(Pump Unit Cost)$_{iq}$ - (6 – Number of Vacuum Chambers) where: the letter 'q' refers to vacuum chamber number, $q_{max} = 6$ i = 1 refers to a Fore Pump i = 2 refers to a Roots Blower i = 3 refers to a Turbo-molecular Pump
Plasma Generator Cost:	$\sum_{q=1}^{6}$ (Quantity of Plasma Generators)$_q$ (Unit Cost)$_q$ - (6 – Number of Vacuum Chambers)
Shielding Cost:	$\sum_{q=1}^{6}$ (Shielding Cost per Chamber)$_q$ + (6 - Number of Vacuum Chambers)
Chiller Cost:	$\sum_{n=1}^{15}$ (Chiller Unit Cost)$_n$ + (15 – Number of Chillers)
Robotics Cost:	(Calculated Value Switch)(Calculated Robotics Cost) + (Default Value Switch)(Default Robotics Cost) Note: A switch is a value that may only have a value of 0 or 1. When the default value switch is 0, the calculated value switch is 1, and vice versa.
Installation Cost:	(Calculated Value Switch)(Calculated Installation Cost) + (Default Value Switch)(Default Installation Cost)
Start-Up Cost:	(Calculated Value Switch)(Calculated Start-Up Cost) + (Default Value Switch)(Default Start-Up Cost)

Buttons:	Corresponding Macros:
None	

Module 9: Capital Amortization

Module 9 is where the final capital cost is amortized over several years as defined by the user.

Capital Amortization

Term	**5**	**years**
Interest Rate	**12**	**%**
Plasma Generator + Shielding + Chiller	345	$k
Installation	260	$k
Start Up	260	$k
Robotics	1000	$k
Pumps	534	$k
High-Voltage Equipment	160	$k
Vacuum Chambers	164	$k
Gate Valves	600	$k
Total Capital Cost =	3322	$k

Annual Capital Cost =	921	$k/year

User Inputs:	Definition:
Term:	Number of years over which the user wants to amortize total capital cost. (Unit: years)
Interest Rate:	Rate of constant interest applied for the term period. (Unit: percent)

Referenced Values:	From Module:
Plasma Generator, Shielding, Chiller Cost:	Capital Cost
Installation Cost:	Capital Cost
Start-Up Cost:	Capital Cost
Robotics Cost:	Capital Cost
Pumps Cost:	Capital Cost
High-Voltage Equipment Cost:	Capital Cost
Vacuum Chambers Cost:	Capital Cost
Gate Valves Cost:	Capital Cost

Calculated Values:	Equations:
Total Capital Cost:	Plasma Generator + Shielding + Chillers + Installation + Start Up + Robotics + Pumps + HV Equipment + Vacuum Chambers + Gate Valves
Annual Capital Cost:	EXCEL Function PMT, see Page 23(3+4) of *Function Reference Manual.*

Buttons:	Corresponding Macros:
None	

Module 10: Operations & Maintenance

Operation and maintenance costs for operating PSII are defined in this module. This includes rental or use of existing facilities, periodic maintenance, consumables, and waste treatment.

Operations & Maintenance

Building Space:		
Annual Rate =	**3**	**$/ft^2**
Area Multiplier =	**30**	
Office Area =	**0**	**ft^2**
1 Vacuum Chamber Footprint =	840	ft^2
Process Footprint =	25,200	ft^2
Total Footprint =	25,200	ft^2
Subtotal Building Space Cost =	76	$k/year
Periodic Maintenance:	**25**	**$k/year**
Consumables:		
Pump Oil =	**150**	**$k/year**
Plasma Gas =	**100**	**$k/year**
Subtotal Consumables Cost =	250	$k/year
Waste Treatment:	**100**	**$k/year**
Annual O & M Cost =	451	$k/year

User Inputs:	Definition:
Annual Rate:	Dollars per square foot to rent the needed space for a production process. If an existing manufacturing facility is to be used, the corresponding dollars per square foot value is entered. (Unit: dollars per square foot)
Area Multiplier:	Factor multiplied by the process footprint area to account for the space needed to load and unload parts.
Office Area:	Amount of area designated for office support of the production process. (Unit: building area square footage)
Periodic Maintenance:	Cost associated with annual maintenance of facilities and capital equipment used in the PSII manufacturing process. (Unit: thousands of dollars per year)
Pump Oil Consumable:	Total cost associated with the annual use of oil in vacuum pumps. (Unit: thousands of dollars per year)

Plasma Gas Consumable: Total cost associated with the annual use of gasses in vacuum chambers. The gasses are used in sputtering, deposition, and implantation processes. (Unit: thousands of dollars per year)

Waste Treatment: Total cost associated with the annual treatment and disposal of waste products from the overall PSII manufacturing process. (Unit: thousands of dollars per year)

Referenced Values:
None

From Module:

Calculated Values:

Equations:

1 Vacuum Chamber Footprint:

$$\sum_{q=1}^{6} (\text{Chamber Diameter})_q (\text{Chamber Length})_q - (6 - \text{Number of Vacuum Chambers})$$

where: the letter 'q' refers to vacuum chamber number, $q_{max} = 6$

Process Footprint:	(Area Multiplier)(Vacuum Chamber Footprint)
Total Footprint:	Process Footprint + Office Area
Subtotal Building Cost:	(Annual Rate)(Total Footprint)
Subtotal Consumables Cost:	Pump Oil + Plasma Gas
Annual O & M Cost:	Building + Periodic Maintenance + Consumables + Waste Treatment

Buttons:
None

Corresponding Macros:

Module 11: Electrical Cost

In this module the user specifies the electrical power needs of each process used in the PSII manufacturing process. The corresponding electrical cost is calculated.

> **IMPORTANT**
> The user **must** use the macro buttons to input or change data otherwise the program will not work correctly. Always check to make sure you are in the correct cell before making changes.

Electrical Cost

Electrical Rate =	**0.025**	**$/kW h**
Process Cooling Percentage =	**30.00**	**%**
Workspace Lighting Factor =	**3.00**	**W/ft^2**
Climate Control Factor =	**5.00**	**W/ft^2**
Utilization Percentage =	90	%
100 Percent Utilization Time =	16	hours/day

Process Utility Energy

Add Power | Sub Power | Add Time | Sub Time
Add Process | Sub Process | Higher Chamber | Lower Chamber

Number of Processes = 3

Assigned to Chamber	Process Name(s)	Process Avg. Power (kW)	Process Time (hour)	Process Energy (kW h)	Cooling Energy (kW h)
2	Sputter	100	1.00	100	30
2	PSII	2000	1.00	2000	600
3	Deposit	60	3.00	180	54
-1		-1	-1.00	-1	-1
-1		-1	-1.00	-1	-1
-1		-1	-1.00	-1	-1
-1		-1	-1.00	-1	-1
-1		-1	-1.00	-1	-1

Subtotal Process Energy =	2280	kW h
Subtotal Cooling Energy =	684	kW h
Total Process Utility Energy per Batch =	2964	kW h

Auxiliary Utility Energy		
Daily Lighting Energy =	1814	kW h
Daily Climate Control Energy =	3024	kW h
Daily Pump Energy =	3614	kW h
Auxiliary Energy per Batch =	1585	kW h

Totals		
Total Energy per Batch =	4,549	kW h
Average Energy Use per Day =	22,318	kW h
Total Energy per Year =	5,691,192	kW h

Annual Electrical Cost =	142	$k/year

User Inputs:	Definition:
Electrical Rate:	Cost for electrical energy usage. (Unit: dollars per kilowatt-hour)
Process Cooling Percentage:	Estimated percentage of energy of the total energy process needed to cool the apparatus during the process. (Unit: percent of total energy)
Workspace Lighting Factor:	Electrical energy per square foot of process area required for lighting. (Unit: watts per square foot of process area)
Climate Control Factor:	Electrical energy per square foot of process area required for climate control. (Unit: watts per square foot of process area)
Number of Processes:	Number of total processes. More than one process may occur in the same chamber.
Assigned to Chamber:	Number that specifies the vacuum chamber in which a particular process takes place.
Process Name:	Name assigned to a process. The user enters text.
Process Avg. Power:	Average power for each individual process. (Unit: kilowatts)
Process Time:	Amount of time a process takes within a vacuum chamber. Applies only to the process itself and does not include pump downtime. (Unit: hours)

Referenced Values:

Referenced Values	From Module
Utilization Percentage:	Batch Layout
100 Percent Utilization Time:	Batch Layout

Calculated Values:

Equations:

Process Energy:

$$(\text{Process Average Power})(\text{Process Time})$$

Cooling Energy:

$$\left(\frac{\text{Process Cooling Percentage}}{100}\right)(\text{Process Energy})$$

Subtotal Process Energy:

$$\sum_{p=1}^{8} (\text{Process Energy})_p + (8 - \text{Number of Processes})$$

Subtotal Cooling Energy:

$$\sum_{p=1}^{8} (\text{Cooling Energy})_p + (8 - \text{Number of Processes})$$

Total Process Utility Energy per Batch:

$$\text{Subtotal Process Energy} + \text{Subtotal Cooling Energy}$$

Daily Lighting Energy:

$$\left(\frac{\text{Workspace Lighting Factor} * \text{Total Footprint}}{1000}\right) * 24 \text{ hours}$$

Climate Control Energy:

$$\left(\frac{\text{Climate Control Factor} * \text{Total Footprint}}{1000}\right) * 24 \text{ hours}$$

Pump Energy:

$$\sum_{q=1}^{6} (\text{Pump Energy per Chamber})_q + (6 - \text{Number of Chambers}) * 100\% \text{ Utilization Time}$$

Auxiliary Energy per Batch:

$$\text{Lighting Energy} + \text{Climate Control Energy} + \text{Pump Energy} \Big/ \left(\frac{100\% \text{ Utilization Time}}{\text{Maximum Process Time per Chamber}}\right)$$

Total Energy per Batch:

$$\text{Total Process Utility Energy per Batch} + \text{Auxiliary Energy per Batch}$$

Average Energy Use per Day:

$$\left(\frac{100\% \text{ Utilization Time}}{\text{Maximum Process Time per Chamber}}\right) * \text{Total Process Utility Energy per Batch} * \left(\frac{\text{Utilization Percentage}}{100}\right) + \text{Daily Lighting Energy} + \text{Daily Climate Control Energy} + \left(\text{Daily Pump Energy} * \left(\frac{\text{Utilization Percentage}}{100}\right)\right)$$

Total Energy per Year:

$$(\text{Average Energy Use per Day}) * (\text{Number Regular Days} + \text{Number Holidays})$$

Annual Electrical Cost:

$$(\text{Total Energy per Year})(\text{Electrical Rate}) / 1000$$

Buttons:

Buttons	Corresponding Macros
Add Power:	Change If Link Ref!Increase
Sub Power:	Change If Link Ref!Decrease
Add Time:	Change If Link Ref!Increase
Sub Time:	Change If Link Ref!Decrease
Add Process:	Process Number!Add
Sub Process:	Process Number!Sub
Higher Chamber:	Change If Link Ref!Increase
Lower Chamber:	Change If Link Ref!Decrease

Module 12: Labor Cost

In this module the user specifies the personnel needed to run the manufacturing process. The corresponding labor cost is calculated.

Labor Cost

Overtime Differential = 1.5
Holiday Differential = 2

Hourly Employees							
Worker	**Pay Rate ($/hour)**	**Quantity of Workers**	**Number Reg. Days**	**Number Holidays**	**Reg. Hours per Day**	**OT Hours per Week**	Cost per Year ($)
Operator	17	6	250	5	8	0	212160
							0
							0
							0
				Subtotal Hourly Employees =		212	$k

Salaried Employees							
Worker	**Pay Rate ($/hour)**	**Quantity of Workers**	**Number Reg. Days**	**Number Holidays**	**Reg. Hours per Day**	**OT Hours per Week**	Cost per Year ($)
Manager	37.5	0	250	0	8	0	0
Mfg. Eng.	27.5	1	250	0	4	0	27500
							0
							0
				Subtotal Salaried Employees =		28	$k

Annual Labor Cost = 240 $k/year

User Inputs:	Definition:
Overtime Differential:	Factor multiplied by Pay Rate to calculate the overtime pay rate.
Holiday Differential:	Factor multiplied by Pay Rate to calculate the holiday pay rate.
Worker:	Worker type employed to operate the PSII manufacturing process.
Pay Rate:	Regular rate of pay for a job. (Unit: dollars per hour)
Quantity of Workers:	Number of workers employed.
Number of Regular Days:	Number of days a worker performs work on weekdays and weekends, excluding holidays.

Number of Holidays: Number of days a worker performs work on holidays. (This is the number of holidays worked not the number of holidays allocated to the employee.)

Regular Hours per Day: Number of hours per day that a worker is present on regular work days.

Overtime Hours per Week: Number of hours per week that a worker is present on overtime pay. (The program assumes 50 weeks per year.)

Referenced Values: From Module:

None

Calculated Values: Equations:

Cost per Year: (Quantity of Workers * Number Reg. Days * Pay Rate * Reg Hours per Day)
+ (Quantity of Workers * Number Holidays * Pay Rate * Holiday Differential * Reg Hours per Day)
+ (Quantity of Workers * 50 weeks per Year * Pay Rate * Overtime Differential * Overtime Hours per Week)

Note: Calculation applies for both hourly and salaried employees.

Subtotal Hourly Employees: $\sum_{l=1}^{4}(\text{Cost per Year for Hourly Employees})_l$

where: l refers to type of employee

Subtotal Salaried Employees: $\sum_{l=1}^{4}(\text{Cost per Year for Salaried Employees})_l$

Annual Labor Cost: Subtotal Hourly Employees + Subtotal Salaried Employees

Buttons: Corresponding Macros:

None

Module 13: Hard Copy

Module 13 summarizes all the inputs and calculations performed in the program in a format suitable for hard copy output.

PSII Systems Summary

Batch Layout

Maximum Process Time per Chamber =	3	hours
Number of Parts per Chamber =	1000	
Number of Parts per Unit =	4	
Total Number of Parts per Day =	4800	
Number of Units per Day =	1200	

Capital Equipment Configuration

Vacuum Chambers

Number of Vacuum Chambers =	4	
Subtotal Vacuum Chambers Cost =	164	$k

Gate Valves

Number of Gate Valves =	5	
Subtotal Gate Valves Cost =	600	$k

High-Voltage Hardware

13.8 kV to 480 V Transformer =	40	$k
Phase Controller =	8	$k
480 V to 480 V Transformer =	40	$k
Rectifier =	10	$k
Pulse Modulator =	32	$k
Relay-Breaker =	10	$k
Controls =	20	$k
Subtotal High-Voltage Hardware Cost =	160	$k

Pumping Hardware

Fore Pump =	244	$k
Roots Blower =	118	$k
Turbo-Molecular Pump =	152	$k
Controls =	20	$k
Subtotal Pump Hardware Cost =	534	$k

Capital

Chiller =	300	$k
Installation =	260	$k
Start Up =	260	$k
Plasma Generator =	37	$k
Shielding =	8	$k
Rack/Robotics System =	1000	$k
Subtotal Capital Cost =	1865	$k

Capital Amortization

Total Capital Equipment Configuration Cost =	3322	$k
Term =	5	years
Interest Rate =	12	%

Annual Capital Cost =	921	$k/year

Operations & Maintenance

Building Space

Annual Rate =	3	$/ft^2
Area Multiplier =	30	
Office Area =	0	ft^2
1 Vacuum Chamber Footprint =	840	ft^2
Process Footprint =	25,200	ft^2
Total Footprint =	25,200	ft^2
Subtotal Building Space Cost =	76	$k/year
Periodic Maintenance =	25	$k/year
Consumables =	250	$k/year
Waste Treatment =	100	$k/year

Annual O & M Cost =	451	$k/year

Labor Cost

Worker	Quantity	No. Reg. Days	Cost ($k)
Operator	6	250	212
0	0	0	0
0	0	0	0
0	0	0	0
Manager	0	250	0
Mfg. Eng.	1	250	28
0	0	0	0
0	0	0	0

Annual Labor Cost =	240	$k/year

Electrical Cost

Electrical Rate =	0.025	$/kW h
Process Cooling Percentage =	30.00	%
Workspace Lighting Factor =	3.00	W/ft^2
Climate Control Factor =	5.00	W/ft^2
Utilization Percentage =	90	%
100 Percent Utilization Time =	16	hours/day

Process	Process Avg. Power (kW)	Process Time (hour)	Process Energy (kW h)
Sputter	100	1.00	100.00
PSII	2000	1.00	2000.00
Deposit	60	3.00	180.00
0	-1	-1.00	-1.00
0	-1	-1.00	-1.00
0	-1	-1.00	-1.00
0	-1	-1.00	-1.00
0	-1	-1.00	-1.00

Energy Component

Total Process Utility Energy per Batch =	2,964	kW h
Auxiliary Energy per Batch =	1,585	kW h
Total Energy per Batch =	4,549	kW h
Average Energy Use per Day =	22,318	kW h
Total Energy per Year =	5,691,192	kW h
Annual Electrical Cost =	142	$k/year

Final Numbers

Category	Cost per Part ($/part)	Annual Cost ($k/year)
O & M	0.37	451
Labor	0.20	240
Capital	0.75	921
Electricity	0.12	142

Annual Total System Cost =	1754	$k/year
Parts per Year =	1224	k
Total System Cost per Part =	1.43	$/part

User Inputs:	Definition:
None	

Referenced Values:	From Module:
Maximum Process Time per Chamber:	Batch Layout
Number of Parts per Chamber:	Batch Layout
Number of Parts per Unit:	Batch Layout
Total Number of Parts per Day:	Batch Layout
Number of Units per Day:	Batch Layout
Number of Vacuum Chambers:	Capital Equipment Configuration
Subtotal Vacuum Chambers Cost:	Capital Cost
Number of Gate Valves:	Capital Equipment Configuration
Subtotal Gate Valves Cost:	Capital Cost
13.8 kV to 480 V Transformer:	Capital Cost
Phase Controller:	Capital Cost
480 V to 480 V Transformer:	Capital Cost
Rectifier:	Capital Cost
Pulse Modulator:	Capital Cost
Relay-Breaker:	Capital Cost
High-Voltage Controls:	Capital Cost
Subtotal High-Voltage Hardware Cost:	Capital Cost
Fore Pump:	Capital Cost
Roots Blower:	Capital Cost
Turbo-molecular Pump:	Capital Cost
Pump Controls:	Capital Cost
Subtotal Pump Hardware Cost:	Capital Cost
Chiller:	Capital Cost
Installation:	Capital Cost
Start Up:	Capital Cost
Plasma Generator:	Capital Cost
Shielding:	Capital Cost
Rack/Robotics System:	Capital Cost
Total Capital Equip. Configuration Cost:	Capital Amortization
Term:	Capital Amortization
Interest Rate:	Capital Amortization
Annual Capital Cost:	Capital Amortization
Annual Rate:	Operations & Maintenance
Area Multiplier:	Operations & Maintenance
Office Area:	Operations & Maintenance
1 Vacuum Chamber Footprint:	Operations & Maintenance
Process Footprint:	Operations & Maintenance
Total Footprint:	Operations & Maintenance
Subtotal Building Space Cost:	Operations & Maintenance
Periodic Maintenance:	Operations & Maintenance
Consumables:	Operations & Maintenance
Waste Treatment:	Operations & Maintenance
Annual O & M Cost:	Operations & Maintenance
Quantity of Workers:	Labor Cost
Number Regular Days:	Labor Cost
Hourly & Salaried Employees Cost:	Labor Cost
Annual Labor Cost:	Labor Cost

Electrical Rate:	Electrical Cost
Process Cooling Percentage:	Electrical Cost
Workspace Lighting Factor:	Electrical Cost
Climate Control Factor	Electrical Cost
Utilization Percentage:	Electrical Cost
100 Percent Utilization Time:	Electrical Cost
Process:	Electrical Cost
Process Average Power:	Electrical Cost
Process Time:	Electrical Cost
Process Energy:	Electrical Cost
Total Process Utility Energy per Batch:	Electrical Cost
Auxiliary Energy per Batch:	Electrical Cost
Total Energy per Batch:	Electrical Cost
Average Energy Use per Day:	Electrical Cost
Total Energy per Year:	Electrical Cost
Annual Electrical Cost:	Electrical Cost
Category	Summary
Cost per Part, O & M:	Summary
Cost per Part, Labor:	Summary
Cost per Part, Capital:	Summary
Cost per Part, Electricity:	Summary
Annual O & M Cost:	Operations & Maintenance
Annual Labor Cost:	Labor Cost
Annual Capital Cost:	Capital Amortization
Annual Electricity Cost:	Electrical Cost
Annual Total System Cost:	Summary
Parts per Year:	Summary
Total System Cost per Part:	Summary

Calculated Values:	Equations:
Subtotal Capital Equipment Cost:	Chiller + Installation + Start Up + Plasma Generator + Shielding + Rack/Robotics System

Buttons:	Corresponding Macros:
None	

Module 14: Summary

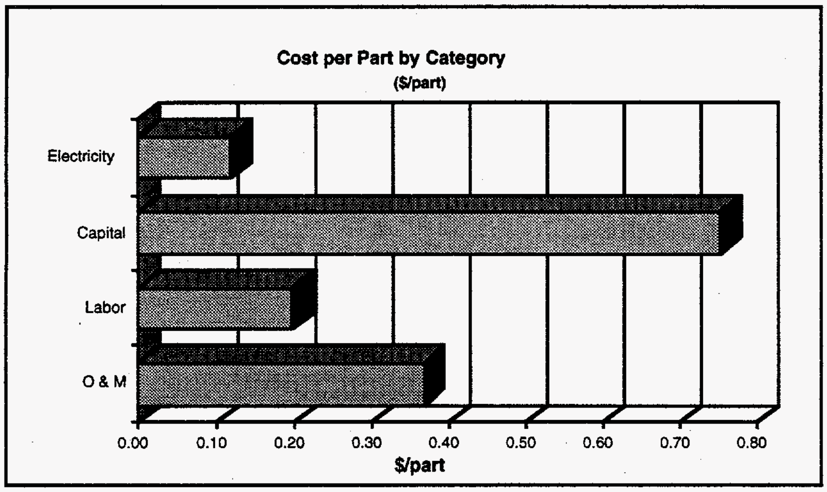
In this Summary module the final costs associated with Operations & Maintenance, Labor, Capital, and Electricity for a PSII manufacturing design are listed. A bar graph illustrates the contribution of each major category towards the cost of each part. A pie chart illustrates the percentage breakdown of each category towards the total PSII system cost.

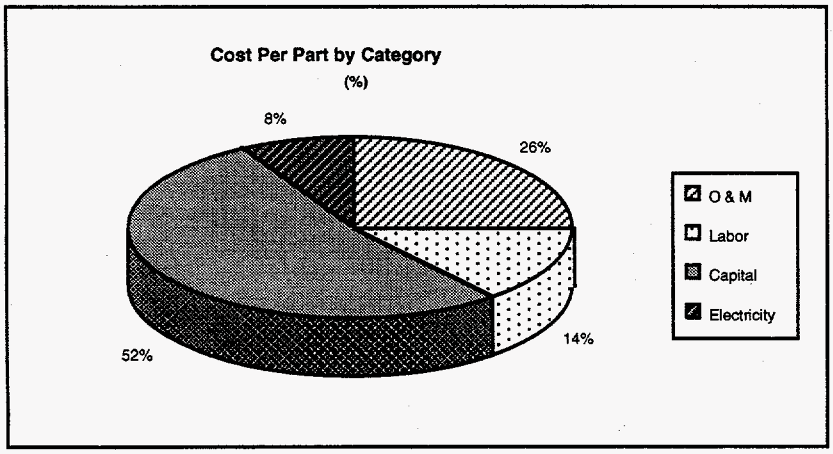
Summary

Category	Cost per Part ($/part)	Annual Cost ($k/year)
O & M	0.37	451
Labor	0.20	240
Capital	0.75	921
Electricity	0.12	142

Annual Total System Cost =	1754	$k/year
Parts per Year =	1224	k

Total System Cost per Part =	1.43	$/part





User Inputs:	Definition:
None	

Referenced Values:	From Module:
Annual O & M Cost:	Operations & Maintenance
Annual Labor Cost:	Labor Cost
Annual Capital Cost:	Capital Amortization
Annual Electricity Cost:	Electrical Cost

Calculated Values:	Equations:
Cost per Part, O & M:	$\left(\frac{\text{Annual O \& M Cost}}{\text{Annual Total System Cost}}\right)$(Total System Cost per Part)
Cost per Part, Labor:	$\left(\frac{\text{Annual Labor Cost}}{\text{Annual Total System Cost}}\right)$(Total System Cost per Part)
Cost per Part, Capital:	$\left(\frac{\text{Annual Capital Cost}}{\text{Annual Total System Cost}}\right)$(Total System Cost per Part)
Cost per Part, Electricity:	$\left(\frac{\text{Annual Electricity Cost}}{\text{Annual Total System Cost}}\right)$(Total System Cost per Part)
Annual Total System Cost:	Annual O & M Cost + Annual Labor Cost + Annual Capital Cost + Annual Electricity Cost
Parts per Year:	(Average Number of Parts per Day) * (Number Regular Days + Number Holidays)
Total System Cost per Part:	$\left(\frac{\text{Annual Total System Cost}}{\text{Parts per Year}}\right)$

Buttons:	Corresponding Macros:
None	

Module 15: Unit Cost

Module 15 stores unit cost data used to help calculate the equipment contribution to the total system cost. Most of the data is stored in a horizontal table format where cost as a function of size is listed. The Vacuum Chambers' table showing chamber number, volume, and cost is the only reference table not modifiable by the user. Note: The top line in the horizontal reference tables **must** be in ascending order (see page 222 in EXCEL's Function Reference manual).

Unit Cost

High-Voltage System ($k)	
13.8 kV to 480 V	20
Phase Controller	4
480 V to 480 V	20
Rectifier	5
Pulse Modulator	1.5
Relay-Breaker	5
Controls	20

Vacuum Chambers		
Chamber No.	Volume (m^3)	Cost ($k)
1	33	41
2	33	41
3	33	41
4	33	41
-1	-1	-1
-1	-1	-1

Fore Pump							
ft^3/min	11	17	33	46	71	127	Etc. . . .
$	2000	3000	2600	3200	4300	6600	Etc. . . .
hp	1	1.5	2	3	5	7.5	Etc. . . .

Roots Blower							
ft^3/min	108	179	357	707	1449	1907	Etc. . . .
$	6400	7500	9100	11000	16000	20000	Etc. . . .
hp	1.5	1.5	3	5.4	10	15	Etc. . . .

Turbo-Molecular Pump (TMP)							
liter/s	33	55	115	145	345	400	Etc. . . .
ft^3/min	70	117	244	307	731	848	Etc. . . .
$	3100	3400	6300	6200	11000	11000	Etc. . . .
hp	0.05	0.1	0.1	0.1	0.16	0.16	Etc. . . .

Pump Controls Cost =	20	$k

Lead Shielding Cost =	13.00	$/ft^2

Circular Gate Valves						
Diameter (ft)	6	7	8	9	10	END
$k	120	215	310	405	500	END

No. Chambers	1	2	3	4	5	6	END

No. Valves	1	2	3	4	5	6	Etc. . . .

Generic No. Components or Size	0	1	2	3	4	5	Etc. . . .

Shielding	0	1	END

Number of Processes	1	2	3	4	5	6	Etc. . . .

Average Power (kW)	10	20	30	40	50	60	Etc. . . .

Time (hour)	0.1	0.2	0.3	0.4	0.5	0.6	Etc. . . .

Chiller						
Size (ton)	100	200	300	400	500	END
$k	45	100	200	300	400	END

Lead Shielding							
Size (ft^2)	0	5	10	20	30	40	Etc. . . .

RF Plasma Generator					
Size (W)	600	1250	3000	5500	END
$	4600	12000	13200	27000	END

User Inputs:	Definition:
High-Voltage System:	Includes a single numeral representing the component cost for the following equipment: 13.8 kV to 480 V transformer, phase controller, 480 V to 480 V transformer, rectifier, pulse modulator, relay-breaker, and controls. (Unit: thousands of dollars)
Fore Pump:	Reference table containing rows of pump size in cubic feet per minute (ft^3/min), cost in dollars ($), and pump power in horsepower (hp).
Roots Blower:	Reference table containing rows of pump size in cubic feet per minute (ft^3/min), cost in dollars ($), and pump power in horsepower (hp).
Turbo-Molecular Pump:	Reference table containing rows of pump size in liters per second (liter/s), cubic feet per minute (ft^3/min), cost in dollars ($), and pump power in horsepower (hp).

Pump Controls Cost:	Single numeral representing the cost of control hardware associated with the pump system. (Unit: thousands of dollars)
Lead Shielding Cost:	Single numeral representing the cost per unit area of lead acrylic shielding used around the vacuum chambers. (Unit: dollars per square foot)
Circular Gate Valves:	Reference table containing gate valve diameter in feet (ft) and cost in thousands of dollars ($k).
Number of Chambers:	Reference table the number of vacuum chambers. The maximum is 6.
Number of Gate Valves/Chillers:	Reference table containing the number of gate valves and chillers. The maximum number for both is 15.
Generic No. Components or Size:	Reference table containing the number of generic components or size of components.
Shielding:	Reference table containing a 0 and 1 (0=No, 1=Yes).
Number of Processes:	Reference table containing the number of processes. User may input up to 8 processes.
Average Power:	Reference table referring to electrical power. (Unit: kilowatts)
Time:	Reference table referring to process time. (Unit: hours)
Chiller:	Reference table containing the chiller size in tons of heat load (ton) and cost in thousands of dollars ($k).
Lead Shielding:	Reference table containing the lead shielding dimensions in square feet (ft^2).
RF Plasma Generator:	Reference table containing the generator size in watts (W) and the cost in dollars ($).

Referenced Values:	From Module:
Chamber Number:	Capital Equipment Configuration
Chamber Volume:	Capital Equipment Configuration

Calculated Values:	Equations:
Vacuum Chamber Cost:	$4(\text{Vacuum Chamber Volume in cubic meters})^{2/3}$ Note: Cost applies to one chamber.

Buttons:	Corresponding Macros:
None	

C. Macro Modules

A macro worksheet is a sheet that holds a unified set of commands called a macro. Several unique macros may be located on one macro worksheet. For more information on how to make macros consult the *EXCEL User's Guide 2* manual.

Modules 16 through 21 are macro modules. These macros were designed to assist the user in inputting data.

Module 16: Chamber Number

This macro module changes the quantity of vacuum chambers as specified in the Capital Equipment Configuration module.

Names	Commands	Comments
Notes:		This macro is for those references simply placed in a cell as an "=" equation.
"Increase" is a macro which moves a reference link over to the right one column.		The use of this macro is hard wired for the cell location $C$5 in the Configuration module.
"Decrease" is a macro which moves a reference link over to the left one column.		
	Increase	
row	=CELL("row")	Find row of active cell
col	=CELL("col")	Find Column of active cell
formula_i	=GET.FORMULA('[PSIICostModel95]Capital Equipment Configuration'!$C$5)	Get formula from cell C5.
nexttolast	=VALUE(MID(formula_i,LEN(formula_i)-1,1))	
	=IF(TYPE(nexttolast)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_i	= MID(formula_i,LEN(formula_i)-1,2)	Extract last 2 char's
number2_i	= VALUE(last2char_i)	Convert to a number
newchar2_i	= TEXT(number2_i+1,"@@@")	Add one to 'number2_i' and convert back to text.
newformula2_i	= MID(formula_i,2,LEN(formula_i)-3)&newchar2_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_i)))=2)	Check that the new Ref. Table location contains a number.
	= ALERT("You may not enter a larger value!",2)	Show a warning box if Ref. Table location contains text
	= ELSE()	
	= FORMULA.FILL("="&newformula2_i,!$C$5)	Place new text back into active cell.
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_i	= RIGHT(formula_i)	Extract last char from formula.
number_i	= VALUE(Lastchar_i)	Convert to a number
newchar_i	= TEXT(number_i+1,"@")	Add one to 'number_i' and convert back to text.
newformula_i	= MID(formula_i,2,LEN(formula_i)-2)&newchar_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_i)))=2)	Check that the new Ref. Table location contains a number.
	= ALERT("You may not enter a larger value!",2)	Show a warning box if Ref. Table location contains text
	= ELSE()	
	= FORMULA.FILL("="&newformula_i,!$C$5)	Place new text back into active cell.
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN
	Decrease	
formula_d	=GET.FORMULA(!$C$5)	Get formula from active cell.
next2last_d	=VALUE(MID(formula_d,LEN(formula_d)-1,1))	Extract second to last char from formula. Convert to a number.
	=IF(TYPE(next2last_d)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_d	= MID(formula_d,LEN(formula_d)-1,2)	Extract last 2 char's
number2_d	= VALUE(last2char_d)	Convert to a number
newchar2_d	= TEXT(number2_d-1,"@@@")	Subtract one from 'number2_d' and convert back to text.
newformula2_d	= MID(formula_d,2,LEN(formula_d)-2)&newchar2_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula2_d,!$C$5)	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_d	= RIGHT(formula_d)	Extract last char from formula.
number_d	= VALUE(Lastchar_d)	Convert to a number
newchar_d	= TEXT(number_d-1,"@@@")	Subtract one from 'number_d' and convert back to text.
newformula_d	= MID(formula_d,2,LEN(formula_d)-2)&newchar_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula_d,!$C$5)	
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN

Macro Name:	Function:
Increase	Increase the number of vacuum chambers.
Decrease	Decrease the number of vacuum chambers.

Module 17: Change If Link Ref

Macro module 17 changes the reference link embedded within an IF statement. This is a general purpose macro.

Names	Commands	Comments
Notes:		This macro is for use with those references imbedded in an IF statement and which utilize a reference table.
"Increase" is a macro which moves a reference link over to the right one column.		It has a special feature which allows for the macro to check for the beginning and ending of a reference table and not allow the user to enter values outside the reference table.
"Decrease" is a macro which moves a reference link over to the left one column.		
	Increase	
formula_i	=GET.FORMULA(ACTIVE.CELL())	Get formula from active cell.
ref_loc	=SEARCH(",",formula_i)	Search 'formula_i' for location of ",".
ref1	=MID(formula_i,ref_loc+1,50)	Extract reference from string. Reference will include an extra ")" on end.
ref	=MID(ref1,1,LEN(ref1)-1)	Subtract off last ")".
check_n2l	=VALUE(MID(ref,LEN(ref)-1,1))	Extract second to last char from 'ref'. Convert to a number.
	= IF(TYPE(check_n2l)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
check_l2c	= MID(ref,LEN(ref)-1,2)	Extract last 2 char's
check_n2	= VALUE(check_l2c)	Convert to a number
check_new_n2	= TEXT(check_n2+1,"@@@")	Add one to 'check_n2' and convert back to text.
new_ref	= MID(ref,1,LEN(ref)-2)&check_new_n2	Replace this new text in old location of formula 'ref'.
	= IF(TYPE(GET.CELL(5,TEXTREF(new_ref)))=2)	Check if NEXT reference location has text for a value.
	= ALERT("You may not enter a larger value!",2)	IF true, Show an alert box stating that end of ref table has been reached.
	= ELSE()	
	= FORMULA.FILL(MID(formula_i,1,ref_loc)&new_ref&")")	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
check_lc	= MID(ref,LEN(ref),1)	Extract last char from formula.
check_n	= VALUE(check_lc)	Convert to a number
check_new_n	= TEXT(check_n+1,"@@@")	Add one to 'check_n' and convert back to text.
new_ref2	= MID(ref,1,LEN(ref)-1)&check_new_n	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(new_ref2)))=2)	Check if NEXT reference location has text for a value.
	= ALERT("You may not enter a larger value!",2)	IF true, Show an alert box stating that end of ref table has been reached.
	= ELSE()	
new_formula	= MID(formula_i,1,ref_loc)&new_ref2&")"	=TYPE(GET.CELL(5,TEXTREF(new_ref2)))
	= FORMULA.FILL(new_formula)	=TYPE(new_ref2)
	= END.IF()	
	=END.IF()	ENDIF of inner loop
	=RETURN()	RETURN
	Decrease	
formula_d	=GET.FORMULA(ACTIVE.CELL())	Get formula from active cell.
ref_loc_d	=SEARCH(",",formula_d)	Search 'formula_d' for location of ",".
ref1_d	=MID(formula_d,ref_loc_d+1,50)	Extract reference from string. Reference will include an extra ")" on end.
ref_d	=MID(ref1_d,1,LEN(ref1_d)-1)	Subtract off last ")".
check_n2l_d	=VALUE(MID(ref_d,LEN(ref_d)-1,1))	Extract second to last char from 'ref_d'. Convert to a number.
	= IF(TYPE(check_n2l_d)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
check_l2c_d	= MID(ref_d,LEN(ref_d)-1,2)	Extract last 2 char's
check_n2_d	= VALUE(check_l2c_d)	Convert to a number
check_new_n2_d	= TEXT(check_n2_d-1,"@@@")	Subtract one from 'check_n2_d' and convert back to text.
new_ref_d	= MID(ref_d,1,LEN(ref_d)-2)&check_new_n2_d	Replace this new text in old location of formula 'ref'.
	= IF(TYPE(GET.CELL(5,TEXTREF(new_ref_d)))=2)	Check if NEXT reference location has text for a value.
	= ALERT("You may not enter a lower value!",2)	IF true, Show an alert box stating that end of ref table has been reached.
	= ELSE()	
	= FORMULA.FILL(MID(formula_d,1,ref_loc_d)&new_ref_d&")")	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
check_lc_d	= MID(ref_d,LEN(ref_d),1)	Extract last char from formula.
check_n_d	= VALUE(check_lc_d)	Convert to a number
check_new_n_d	= TEXT(check_n_d-1,"@@@")	Subtract one from 'check_n_d' and convert back to text.
new_ref2_d	= MID(ref_d,1,LEN(ref_d)-1)&check_new_n_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(new_ref2_d)))=2)	Check if NEXT reference location has a text for a value.
	= ALERT("You may not enter a lower value!",2)	IF true, Show an alert box stating that end of ref table has been reached.
	= ELSE()	
new_formula_d	= MID(formula_d,1,ref_loc_d)&new_ref2_d&")"	
	= FORMULA.FILL(new_formula_d)	
	= END.IF()	
	=END.IF()	ENDIF of outer loop
	=RETURN()	RETURN

Macro Name:	Function:
Increase:	Macro that moves a reference link over to the right one column within a reference table.
Decrease:	Macro that moves a reference link over to the left one column within the reference table.

Module 18: Select

Macro that switches a pointer used to specify either a default cost value or a calculated cost value.

Names	Commands	Comments
This macro switches a pointer between a default cost value and a calculated cost value.		Macro switches binary numbers to specify default cost value.
	Default	
	= FORMULA.FILL(">>>>>>>>>>",!$B$5)	Place arrow in cell B5 of active worksheet.
	= FORMULA.FILL("",!$B$7)	Place an empty space in cell B7 of active worksheet.
first	=1	Define constants
second	=0	
	= FORMULA.FILL(first,!$E$5)	Place 1 in cell E5
	= FORMULA.FILL(second,!$E$7)	Place 0 in cell E7
	=RETURN()	RETURN
	Calculated	Macro switches binary numbers to specify calculated cost value.
	= FORMULA.FILL("",!$B$5)	Place an empty space in cell B5 of active worksheet.
	= FORMULA.FILL(">>>>>>>>>>",!$B$7)	Place arrow in cell B7 of active worksheet.
third	=0	Define constants
fourth	=1	
	= FORMULA.FILL(third,!$E$5)	Place 0 in cell E5
	= FORMULA.FILL(fourth,!$E$7)	Place 1 in cell E7
	=RETURN()	RETURN

Macro Name:	Function:
Default:	Macro switches binary numbers to specify calculated cost value.
Calculated:	Macro switches binary numbers to specify default cost value.

Module 19: Process Number

A macro that changes the numeral assigned to a particular process as specified in the Electrical Cost module. Numerals may represent a quantity or dimensional size.

Names	Commands	Comments
Notes:		This macro is for those references simply placed in a cell as an "=" equation.
"Increase" is a macro which moves a reference link over to the right one column within the reference table.		The use of this macro is hard wired for the cell location $F$17 in the Electricity module.
"Decrease" is a macro which moves a reference link over to the left one column within the reference column.		
	Add	
row	=CELL("row")	Find row of active cell
col	=CELL("col")	Find Column of active cell
formula_i	=GET.FORMULA(!$F$17)	Get formula from cell F17.
nexttolast	=VALUE(MID(formula_i,LEN(formula_i)-1,1))	
	=IF(TYPE(nexttolast)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_i	= MID(formula_i,LEN(formula_i)-1,2)	Extract last 2 char's
number2_i	= VALUE(last2char_i)	Convert to a number
newchar2_i	= TEXT(number2_i+1,"@@@")	Add one to 'number2_i' and convert back to text.
newformula2_i	= MID(formula_i,2,LEN(formula_i)-3)&newchar2_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_i)))=2)	
	= ALERT("You may not enter a larger value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula2_i,!$F$17)	Place new text back into active cell.
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_i	= RIGHT(formula_i)	Extract last char from formula.
number_i	= VALUE(Lastchar_i)	Convert to a number
newchar_i	= TEXT(number_i+1,"@")	Add one to 'number_i' and convert back to text.
newformula_i	= MID(formula_i,2,LEN(formula_i)-2)&newchar_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_i)))=2)	
	= ALERT("You may not enter a larger value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula_i,!$F$17)	
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN
	Sub	
formula_d	=GET.FORMULA(!$F$17)	Get formula from active cell.
next2last_d	=VALUE(MID(formula_d,LEN(formula_d)-1,1))	Extract second to last char from formula. Convert to a number.
	=IF(TYPE(next2last_d)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_d	= MID(formula_d,LEN(formula_d)-1,2)	Extract last 2 char's
number2_d	= VALUE(last2char_d)	Convert to a number
newchar2_d	= TEXT(number2_d-1,"@@@")	Subtract one from 'number2_d' and convert back to text.
newformula2_d	= MID(formula_d,2,LEN(formula_d)-2)&newchar2_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula2_d,!$F$17)	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_d	= RIGHT(formula_d)	Extract last char from formula.
number_d	= VALUE(Lastchar_d)	Convert to a number
newchar_d	= TEXT(number_d-1,"@@@")	Subtract one from 'number_d' and convert back to text.
newformula_d	= MID(formula_d,2,LEN(formula_d)-2)&newchar_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula_d,!$F$17)	
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN

Macro Name:	Function:
Increase:	Macro that moves a reference link over to the right one column within a reference table.
Decrease:	Macro that moves a reference link over to the left one column within the reference table.

Module 20: Valve Number

This macro module changes the quantity of gate valves as specified in the Capital Equipment Configuration module.

Names	Commands	Comments
Notes:		This macro is for those references simply placed in a cell as an "=" equation.
"Increase" is a macro which moves a reference link over to the right one column.		The use of this macro is hard wired for the cell location $D$37 in the Configuration module.
"Decrease" is a macro which moves a reference link over to the left one column.		
	Increase	
formula_i	=GET.FORMULA('[PSIICostModel95]Capital Equipment Configuration'!$D$37)	Get formula from cell $D$37.
nexttolast	=VALUE(MID(formula_i,LEN(formula_i)-1,1))	Extract second to last char from formula. Convert to a number.
	=IF(TYPE(nexttolast)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_i	= MID(formula_i,LEN(formula_i)-1,2)	Extract last 2 char's
number2_i	= VALUE(last2char_i)	Convert to a number
newchar2_i	= TEXT(number2_i+1,"@@@")	Add one to 'number2_i' and convert back to text.
newformula2_i	= MID(formula_i,2,LEN(formula_i)-3)&newchar2_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_i)))=2)	
	= ALERT("You may not enter a larger value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula2_i,!$D$37)	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_i	= RIGHT(formula_i)	Extract last char from formula.
number_i	= VALUE(Lastchar_i)	Convert to a number
newchar_i	= TEXT(number_i+1,"@@@")	Add one to 'number_i' and convert back to text.
newformula_i	= MID(formula_i,2,LEN(formula_i)-2)&newchar_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_i)))=2)	
	= ALERT("You may not enter a larger value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula_i,!$D$37)	
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN
	Decrease	
formula_d	=GET.FORMULA(!$D$37)	Get formula from active cell.
next2last_d	=VALUE(MID(formula_d,LEN(formula_d)-1,1))	Extract second to last char from formula. Convert to a number.
	=IF(TYPE(next2last_d)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_d	= MID(formula_d,LEN(formula_d)-1,2)	Extract last 2 char's
number2_d	= VALUE(last2char_d)	Convert to a number
newchar2_d	= TEXT(number2_d-1,"@@@")	Subtract one from 'number2_d' and convert back to text.
newformula2_d	= MID(formula_d,2,LEN(formula_d)-3)&newchar2_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula2_d,!$D$37)	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_d	= RIGHT(formula_d)	Extract last char from formula.
number_d	= VALUE(Lastchar_d)	Convert to a number
newchar_d	= TEXT(number_d-1,"@@@")	Subtract one from 'number_d' and convert back to text.
newformula_d	= MID(formula_d,2,LEN(formula_d)-2)&newchar_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula_d,!$D$37)	
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN

Macro Name:	Function:
Increase:	Increase the quantity of gate valves.
Decrease:	Decrease the quantity of gate valves.

Module 21: Chiller Number

Macro module 21 changes the quantity of chillers as specified in the Capital Equipment Configuration module.

Names	Commands	Comments
Notes:		This macro is for those references simply placed in a cell as an "=" equation.
"Increase" is a macro which moves a reference link over to the right one column.		The use of this macro is hard wired for the cell location $D$60 in the Configuration module.
"Decrease" is a macro which moves a reference link over to the left one column.		
	Increase	
formula_i	=GET.FORMULA('[PSIICostModel95]Capital Equipment Configuration'!$D$60)	Get formula from cell $D$60
nexttolast	=VALUE(MID(formula_i,LEN(formula_i)-1,1))	Extract second to last char from formula. Convert to a number.
	=IF(TYPE(nexttolast)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_i	= MID(formula_i,LEN(formula_i)-1,2)	Extract last 2 char's
number2_i	= VALUE(last2char_i)	Convert to a number
newchar2_i	= TEXT(number2_i+1,"@@@")	Add one to 'number2_i' and convert back to text.
newformula2_i	= MID(formula_i,2,LEN(formula_i)-3)&newchar2_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_i)))=2)	
	= ALERT("You may not enter a larger value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula2_i,!$D$60)	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_i	= RIGHT(formula_i)	Extract last char from formula.
number_i	= VALUE(Lastchar_i)	Convert to a number
newchar_i	= TEXT(number_i+1,"@@@")	Add one to 'number_i' and convert back to text.
newformula_i	= MID(formula_i,2,LEN(formula_i)-2)&newchar_i	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_i)))=2)	
	= ALERT("You may not enter a larger value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula_i,!$D$60)	
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN
	Decrease	
formula_d	=GET.FORMULA(!$D$60)	Get formula from active cell.
next2last_d	=VALUE(MID(formula_d,LEN(formula_d)-1,1))	Extract second to last char from formula. Convert to a number.
	=IF(TYPE(next2last_d)=1)	IF the "next-to-last" char is indeed a number, then column is 10 or greater.
last2char_d	= MID(formula_d,LEN(formula_d)-1,2)	Extract last 2 char's
number2_d	= VALUE(last2char_d)	Convert to a number
newchar2_d	= TEXT(number2_d-1,"@@@")	Subtract one from 'number2_d' and convert back to text.
newformula2_d	= MID(formula_d,2,LEN(formula_d)-3)&newchar2_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula2_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula2_d,!$D$60)	
	= END.IF()	
	=ELSE()	ELSE IF the "next-to-last" char is not a number, then column is 9 or less.
Lastchar_d	= RIGHT(formula_d)	Extract last char from formula.
number_d	= VALUE(Lastchar_d)	Convert to a number
newchar_d	= TEXT(number_d-1,"@@@")	Subtract one from 'number_d' and convert back to text.
newformula_d	= MID(formula_d,2,LEN(formula_d)-2)&newchar_d	Replace this new text in old location of formula.
	= IF(TYPE(GET.CELL(5,TEXTREF(newformula_d)))=2)	
	= ALERT("You may not enter a lower value!",2)	
	= ELSE()	
	= FORMULA.FILL("="&newformula_d,!$D$60)	
	= END.IF()	
	=END.IF()	ENDIF
	=RETURN()	RETURN

Macro Name:	Function:
Increase:	Increase the quantity of chillers.
Decrease:	Decrease the quantity of chillers.