

VACworks II

What's New in Vacworks II

Vacuum System Design:

- Input data file handling is "Windows" like.
- Suction pressure capability is as low as 1 mmHgA.
- Vapor pressure data for condensible vapors maybe added.
- Process Flow Diagram is an available output.
- Tube side condensing is now an available option.
- Lower suction pressure allowed for stand-alone liquid ring vacuum pumps.
- Motive steam pressure may be as low as 50psig.
- Maximum water outlet temperature may be specified.
- Low capital or low utility design may be selected.
- Channels or bonnets can be selected for condensers.
- Option to selectively print output pages.

Thermo Compressor Design:

- Input data file handling is "Windows" like.
- Motive steam pressure may be as low as 50psig.

Mollier:

- Metric units are now available.

Added Calculation Sections:

User Defined Vapors:

- Allows users to build their own data base of condensible vapors for use in the vacuum system design calculations.

Tail Leg Height:

- A simple program to calculate the required condenser elevation above a condensate receiver to avoid flooding a condensing operating under vacuum.

Gas Volume & Mass:

- A program to calculate gas volumetric flow when given the mass flow and visa versa.

Gas Pressure Loss:

- Pressure drop estimation for gases with both HEI calculation method and a generic gas method.

"Go Figure":

- A calculator type tool that can "evalulate expressions" like a calculator, but can also hold variables and can save the calculations to be recalled later.

Vacworks

Welcome to **Vacworks II**, a comprehensive vacuum system design and technical support information program from the engineers at Graham Corporation. Vacworks will assist in the design of:

- Multistage Ejector Systems
- Liquid Ring Pump Systems
- Hybrid Vacuum Systems
- Thermo Compressors

Vacworks may be used as a tool for estimating vacuum system design and associated utility consumption. Preliminary dimensional information is also determined for each system designed.

To complete an analysis of a preliminary design, simply e-mail or fax the summary output sheet included for each selection. The engineers at Graham will verify the selection or finalize an optimization and then forward to you a price for the system. It is as simple as 1 .. 2.. 3.

The heart of the design software are correlations derived from substantial archival data on ejectors and liquid ring pumps acquired and continually updated by Graham during its 60 years as a designer and manufacturer of engineered vacuum systems. **Vacworks** has undergone extensive in-house evaluation by Graham engineers to ensure each selection is reliable and accurate for estimating purposes.

The software is designed to handle suction pressures as low as 1 mmHgA (.133 KpaA). This is the suction pressure to the vacuum system. As a user of a vacuum system, it is appropriate to analyze piping between your vacuum vessel and the suction to the vacuum system. Any pressure drop as a result of that piping should be accounted for and considered when specifying a suction pressure to the vacuum system.

Vacworks will specify a four-stage, three-stage, two-stage or single-stage vacuum system and describe the required utilities, equipment size/nomenclature, along with dimensional information for each component. **Vacworks** is capable of designing a vacuum system to operate against a discharge pressure ranging from 760 mmHgA (101.3 KpaA) to 900 mmHgA (120 KpaA).

Suction pressure below 1 mmHgA (.133 KpaA) or a discharge pressure greater than 900 mmHgA (120 KpaA) is possible, however, such conditions are beyond the range of **Vacworks** and a detailed design by Graham is necessary.

Vacworks contains additional useful information such as:

- Mollier program for steam properties
- Conversion program for common units of measure
- Thermo Compressor design program for preliminary design of steam-to-steam thermo compressors
- Tail leg height calculation
- Gas volumetric & mass flow calculation
- Gas pressure loss calculation
- "Go Figure" expression evaluator (similar to a calculator)
- Technical library of articles authored by engineers at Graham

- The Graham Advantage
- Vapor pressure data for over 1200 components
- User definable vapor data component to enable vapors not contained in the supplied database to be used in the vacuum system design
- Link to the Graham website @ <http://www.graham-mfg.com>
- Sales force directory

Getting Started

This program is based on a “Windows” format which allows the user to interact via the mouse and keyboard. It is assumed that the user has a basic working knowledge of “Windows”. Some of the basic "Windows" methods include:

- The mouse is used to initiate most actions within the program. This is done by moving the cursor over the desired action key and then pressing the left mouse button. The keyboard can also be used for many of the same actions, provided an underlined character is contained in the command name.
- The "F1" key can be used at any time to get "Help".
- The command buttons that have a letter underlined (Print) can be activated by holding the "ALT" key and then typing the underlined letter.

When the program is started, the main screen appears. The screen includes a number of “command buttons” on the bottom and left sides of the screen which are used to control access to various parts of Vacworks.

The bottom buttons include:



The first time the program is run, the user registration information is requested. The **User Registration** command can be used to modify this information. The user registration form should be sent to Graham. User information will be retained so program updates or assistance instructions may be issued when applicable.

The left side button actions include:

S ystem D esign	Activates the multistage Ejector design program
T hermo C ompressor	Activates the Thermo Compressor design program
V apor P ressures	Activates the Vapor Pressure calculation program
M ollier	Activates the Mollier (steam property) program
C onversions	Activates the common Conversions program
U ser Defined V apors	Activates the User Defined Vapor program
T ail Leg Height	Activates the Tail Leg Height program
G as Volume & M ass	Activates the Gas Volumetric & Mass Flow program
G as Pressure L oss	Activates the Gas Pressure Loss program
"G o F igure"	Activates the "Go Figure" program.
E xit	Terminates the program

Vacuum System Design Program

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Overview

This program will allow the design of one-stage to four-stage vacuum systems with suction pressures ranging from 1mmHgA (.133 KpaA) to 500 mmHgA (66.7 KpaA). The program can handle a maximum of 10 condensible loads and 10 non-condensable gases. The program includes a built-in condensible vapor database of 1200 fluids. Optionally, users can define other condensible vapors in the "User Defined Vapors" section for use in the vacuum system design. It should be noted that all condensing calculations are based on non-miscible condensates, which are sufficiently accurate for most applications. Should selections warrant consideration of miscible condensates, both ideal and non-ideal, forward design criteria to engineers at Graham, who will then optimize a vacuum system and forward the results to you.

The program will determine the number of stages to be utilized automatically but will allow the user to modify the number of stages in order to compare different systems. Shell and tube condensers are provided by default although the user can opt for direct contact condensers or no condensers at all. In addition, the user can choose a liquid ring vacuum pump to replace the "C" or last stage ejector.

Vacworks permits inputting specific costs for steam, electricity, and cooling water consumption. The program will indicate annual utility cost based on estimated steam, power and water consumption. It will be beneficial to review operating costs as a function of cooling water temperature, motive steam pressure, system suction pressure, or system discharge pressure. Vacworks will design a vacuum system based on minimum steam consumption because often that yields the lowest operating cost. Should a detailed economic analysis of both operating and capital cost be required, please refer specific details regarding pay back period and cost of utilities to Graham. Graham will then conduct a detailed optimization of the vacuum system to minimize evaluated cost. The program does allow a comparison of a low capital cost design approach versus a low operating cost design basis.

This program is similar to the program used internally by engineers at Graham. The program is intended to provide accurate sizing and utility requirements. An output summary sheet may be e-mailed or faxed to Graham for design verification or further optimization, followed by a price for the required system.

DISCLAIMER

Vacworks comprehensive vacuum system design software was developed to assist in preliminary design of an ejector, liquid ring pump, or hybrid vacuum system as well as thermo compressors. The software has, as its basis, correlations developed by Graham through continued testing and development work in the field of vacuum and heat transfer. As this software is intended for estimating purposes, final design and system analysis should be referred to Graham prior to procurement.

Vacuum System Design Considerations

The design of a vacuum system is dependent on a number of parameters, primarily:

- Vapors and gases handled
- Required suction and discharge pressure
- Motive steam pressure
- Motive steam cost
- Cooling water availability, temperature, and cost
- Electric power availability and cost

Commonly, vacuum systems are comprised of multiple stages of ejectors (in series) with intermediate condensers and usually an after condenser. The inter condensers are located between ejector stages to condense vapors, thereby reducing the load to the next ejector. The after condenser is used to extract condensible components and to eliminate excessive vent streams.

Running The Program

When the Vacuum System Design Program is selected from the start-up screen, the Vacuum System Design Program input screen appears. This screen includes four tabbed pages for input data and several menu selections which include input file functions.

The screenshot shows the 'Vacworks - Vacuum System Design Input' window. It has a menu bar with 'File', 'Design System', and 'Help'. Below the menu bar are four tabs: 'Main Input' (selected), 'Condensible Loads', 'Non-condensible Loads', and 'Material / Design Data'. The 'Main Input' tab contains several sections:

- Units:** Radio buttons for 'Standard Units' (selected) and 'Metric Units'.
- Design Data:** A table with two columns: 'Standard Units' and 'Metric Units'.

	Standard Units	Metric Units
Suction Pressure	mmHgA	KpaA
Suction Temperature	°F	°C
Discharge Pressure	mmHgA	KpaA
Motive Pressure	psig	Bar (g)
Motive Temperature (0=D&S)	°F	°C
Cooling/Seal Water Inlet Temp.	°F	°C
Maximum Water Outlet Temp.	°F	°C
Overall S&T Fouling Factor	0.002 hr-ft ² -F/Btu	0.0004 hr-m ² -C/Kcal
- Utility Costs:** Three input fields: 'Cost of steam (\$/1000 lbs.)' with value 5, 'Cost of electricity (\$/KW hr)' with value 0.03, and 'Cost of water (\$/1000 gallons)' with value 0.1.
- Optimize:** Radio buttons for 'Minimize Utility Costs' (selected) and 'Minimize Capital Costs'.
- Number of Stages:** Radio buttons for 'Automatic' (selected), '4 Stages', '3 Stages', '2 Stages', and '1 Stage'.
- Condenser Type:** Radio buttons for 'Shell & Tube (SS condensing)' (selected), 'Shell & Tube (TS condensing)', 'Direct Contact', and 'No Condensers'.
- Pre-Condenser Option:** A checkbox 'Use precondenser (< 3 stages only)' which is unchecked.
- Liquid Ring Vacuum Pump:** A checkbox 'Use LRVF for last stage' which is unchecked, and radio buttons for '60 Cycles' (selected) and '50 Cycles'.

At the bottom, there is a text box with the following information: 'The suction pressure can range from 1 mmHgA (.133 KpaA) to 500 mmHgA (66.67KpaA). Typically, pressures below 5 mmHgA (.67 KpaA) require a four stage system, between 5 mmHgA (.67 KpaA) and 25 mmHgA (3.33 KpaA) require a three stage system, between 25 mmHgA (3.33 KpaA) and 100 mmHgA (13.33 KpaA)'.

The program allows users to store and retrieve input data files using typical Windows format file menus. The use of input data files is recommended since it allows a design to be repeated at a later time without having to re-enter the data.

Input

The input is comprised of four separate sections accessed via the tabs. These include:

- Main Input
- Condensible Loads
- Non-condensable loads
- Material / Design Data

Once all input data is complete, the **Design System** menu is used to initiate the design process. The program is highly iterative during the design phase while it works to optimize utilities. Depending on the input data, and especially when a vacuum pump is used, the calculations may take several minutes. Actual computation time is dependent upon the capabilities of a user's computer.

[Main Input](#)

[Condensible Loads](#)

[Non-condensible Loads](#)

[Material / Design Data](#)

Main Input

The main input section has three categories, two for numerical input and one for selecting design options.

[Units](#)

[Suction Pressure](#)

[Suction Temperature](#)

[Discharge Pressure](#)

[Motive Pressure](#)

[Motive Temperature](#)

[Cooling Water Temperature](#)

[Maximum Water Outlet Temperature](#)

[Overall Fouling Factor](#)

[Cost of Steam](#)

[Cost of Electricity](#)

[Cost of Water](#)

[Condenser Type](#)

[Number of Stages](#)

[Precondenser Option](#)

[Liquid Ring Pump Option](#)

[Optimize Option](#)

Units-



The main input screen allows the user to select either standard or metric units. Once units of measure are selected, all subsequent input and output will be consistent with that selection. It should be noted that for many of the numeric values, both unit values are shown on the input screens. During input only the unit type selected (standard or metric) is enabled or allowed to be modified. The units not enabled are automatically calculated and shown on the

screen. The program uses the standard units for all calculations and simply converts the values to metric as needed.

Suction Pressure-

Suction Pressure is at the inlet to the vacuum system and may range from 1 mmHgA (.133 KpaA) to 500 mmHgA (66.67 KpaA). Suction pressures outside this range are possible but require design by Graham. Often there is discharge piping between a vacuum vessel and the inlet to a vacuum system. It is important to calculate pressure drop due to piping and prior to setting design suction pressure to a vacuum system.

Suction Temperature-

This program will allow suction temperature in the range of 35°F (1.67°C) to 500 °F (260°C).

Discharge Pressure-

Vacuum system discharge pressure should be between 760 mmHgA (101.33 KpaA) and 900 mmHgA (120 KpaA). Other discharge pressures are possible, however, a detailed design by Graham is necessary. Often there is discharge piping downstream that must be considered when establishing design discharge pressure. A pressure drop calculation should be performed for the discharge piping downstream of the vacuum system to insure that the design discharge pressure at the vacuum system outlet is adequate.

Motive Pressure-

This software uses steam exclusively as a motive fluid. Other motive fluids are available and may be considered, however, a detailed design by Graham is required. The motive steam pressure may range between 50 psig (3.45 bar(g)) and 250 psig (17.24 bar(g)).

Motive Temperature-

It is not necessary to input a motive temperature and if left blank, the program will assume dry and saturated steam conditions. If there is superheat in the motive steam, then motive steam temperature should be entered as input.

Cooling Water Temperature-

Cooling water for condensers or seal water for a liquid ring pump may range from 35°F (1.67°C) to 125°F (51.67°C). When entering a value for water temperature, be certain to use the maximum anticipated cooling water supply temperature.

Maximum Water Outlet Temperature-

The program automatically limits the maximum cooling water temperature rise to 30°F (16.67 °C). If the resulting outlet water temperature exceeds the required limits, the maximum outlet can be specified here. It should be noted that a maximum outlet specified here will only be used if it results in a lower outlet water temperature than the program default.

Overall Fouling Factor-

Shell and tube condensers require a fouling allowance to account for scaling. Typical fouling factors range from 0.001 hr-ft²-F/Btu (.0002 hr-m²-C/Kcal) to 0.004 hr-ft²-F/Btu (.0008 hr-m²-C/Kcal). The default is 0.002 hr-ft²-F/Btu (.0004 hr-m²-C/Kcal).

Cost of Steam-

This software will evaluate operating utilities based on specified costs for utilities. Enter a cost per 1000 pounds of steam consumed.

Cost of Electricity-

This software will evaluate operating utilities based on specified costs for utilities. Enter a cost per kW-hr for electricity.

Cost of Water-

This software will evaluate operating utilities based on specified costs for utilities. Enter a cost per 1000 gallons of water consumed.

Condenser Type-

The system designer has the option of specifying shell and tube type inter and after condensers or direct contact type. Furthermore, it is possible to select an option without condensers.

Number of Stages-

The program will automatically select the appropriate number of stages based on the input conditions. The program will use typical configurations as automatic number of stages. The user has an option to specify the number of stages as 3, 2 or 1. Note that the greater the number of stages, the lower the utility consumption will be, but the higher the capital cost.

The program will automatically select the number of stages to be used based on suction pressure as follows:

Suction pressure range (mmHgA)	Suction pressure range (KpaA)	Automatic number of stages
1-5	.133-.67	4
>5 - 25	>.67 - 3.33	3
>25 - 100	>3.33 - 13.33	2
> 100	> 13.33	1

Should the user decide to override the automatic selection of stages, the suction pressure must fall within the prescribed range limit as follows:

Suction pressure range (mmHgA)	Suction pressure range (KpaA)	Allowable number of stages
1-5	.133-.67	4
5 - 50	.67 - 6.67	3
10 - 200	1.33 - 26.67	2
> 80 (*)	> 10.67	1

* Note: Minimum suction pressure for a stand-alone liquid ring vacuum pump is 25 mmHgA (3.33 KpaA).

Precondenser Option-

It is possible to specify a precondenser for either single-stage or two-stage systems. A precondenser may be appropriate when a suction load to a vacuum system consists of a large amount of condensable vapors that will condense at the inlet operating pressure based on the temperature of the cooling water available. The software performs an assessment of inlet conditions and may provide a message suggesting the use of a precondenser.

Liquid Ring Pump Option-

A liquid ring pump may be used to replace the last ejector stage. Often a liquid ring pump is considered when the cost of steam or steam usage is important.

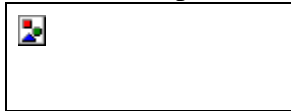
To run a stand alone LRVP:

- Check the "Use LRVP for last stage" option.
- Under number of stages, choose 1 stage.

The available power (60 cycle or 50 cycle) can be set within the liquid ring vacuum pump option section.

Optimize Option-

Vacworks allows the user to choose the way the program optimizes the design of a vacuum system. By default, Vacworks attempts to minimize utility costs. To reduce capital cost, simply choose the "minimize capital cost" option. (This option is applicable for three and four stage systems only).



Condensible Loads-

The program will allow the use of up to 10 condensible vapors. Condensible vapors, with the exception of water vapor, are selected via a Vapor ID number. (Water vapor is, by default, always the first vapor.) The Vapor ID number is based on a database contained within the program or optionally, from a user defined vapor database.

The Vapor ID number can be found via a [search](#) option.

Vapor ID #	lbs/hr	kg/hr
WATER	125	56.6996
107	15	6.8040

Once the desired fluid is found, the ID number can be typed in the appropriate Vapor ID box on the left or by double clicking the vapor name, the Vapor ID number will be automatically placed in the next available (empty) Vapor ID box on the left. For each fluid code, enter the load (quantity) in #/hr (or kg/hr) in the appropriate box adjacent to the ID box.

The name of an ID already entered can be determined by double clicking on the ID number which will highlight the vapor data in the database box.

Vapor Data Base Search-

The ID for a desired vapor can be obtained by scrolling through the database list or by searching using a search string. To search, type a search string (or number) in the search string box and, using the mouse, hit either the forward or backward search buttons. It should be noted that only a portion of the name is necessary and that a molecular weight, or ID number can be used to search. For a molecular weight, including a decimal in the number will avoid finding a vapor based on the ID number.

ID#	Name	Formula	MW
1	acenaphthene	C12H10	154.21
2	acetaldehyde	C2H4O	44.05
3	acetic acid	C2H4O2	60.05
4	acetone	C3H6O	58.08
5	acetonitrile	C2H3N	41.05
6	acrylic acid	C3H4O2	72.06

* indicates estimated vapor properties

Search Backward Search String Search Forward

User Defined Vapors

ID#	Name	MW
-1	Sample Vapor	56

Vapors other than those contained in the built-in database can be used. They must first be defined in the "User Defined Vapors" section of Vacworks. User defined vapors use a negative ID number to distinguish them from the built-in database fluids.

Non-Condensable Loads-

The program will allow the use of up to 10 non-condensable vapors.

lbs/hr	kg/hr	MW
22	9.9791	29

For each non-condensable load, the quantity in #/hr (or kg/hr) and molecular weight are required inputs. Sources of non-condensable gases would be air leakage, low molecular weight gases such as nitrogen, oxygen, carbon dioxide or hydrogen, or C₅ and lighter hydrocarbons.

It should be noted that the program requires, as a minimum, a small quantity of a non-condensable.

Heat Exchange Institute Standard for Steam Jet Ejectors, 4th Edition may be used to estimate air in-leakage by referring to Figure 42.

Material / Design Data-

This input screen includes the heading information, material selection, design pressure / temperature for condensers, and construction code selection. Heading information should be entered in order to identify printed output later.

The unit selection on the main input screen dictates the units used to input the design pressure and temperature information.

Tube Side		Standard Units	Metric Units
Design Pressure	75	psig	5.1711 Bar (g)
Design Temperature	200	°F	93.3333 °C

Shell Side		Standard Units	Metric Units
Design Pressure	20	psig	1.3789 Bar (g)
Design Temperature	300	°F	148.8889 °C

The materials and construction codes are selected from a list of available choices for each component via drop-down lists. The materials offered within this program are the materials most commonly used, although many other materials are available. For materials other than those included with this program, contact Graham Corporation.

Materials	
Tube Material	304SS
Tube Sheet Material	ADMIRALTY
Process Side (Shell) Material	304SS
Water Side Material	316SS
Construction Code	70/30 CUNI
Graham Standard	90/10 CUNI

To select a material or construction code, left mouse click on the arrow next to the component name to view the list of available selections. Then, simply click the desired selection.

Results

When the program completes the design process, the results of a design are displayed on the screen. The results are broken down into four sections.

Utilities		
	Quantity	Annual Cost (\$)
Total Motive Steam (#/hr)	531	21243
Total Water (gpm)	84	4033
Total Electric (Kw/hr)	0	0
Total Annual Utility Cost (\$)		25276

1) Utilities usage: steam, water, and electricity. If utility costs have been entered, the utility costs are also shown.

2) System components breakdown (shown with text and icons). The icons representing each component can be used to access a [preliminary drawing](#) for each component.

System Components			
1420AA	18x12BEM	10x8BEM	8x8BEM
790A	16B	3C	

3) Ejector / vacuum pump data.

Ejector Data	
Model	1st Stage 1420AA
Motive (#/hr)	291
Suction Dia. (in.)	22.00
Discharge Dia. (in.)	16.00
Motive Dia. (in.)	0.75

4) Condenser data.

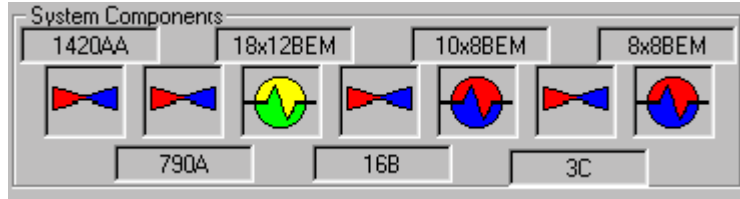
Condenser Data	
Model	1st Condenser 18x12BEM
Surface (sq.ft.)	381.7
Water Flow (gpm)	275.8
Water Inlet / Outlet (degF)	80.0 / 90.0
Water Pressure Drop (psi)	4.1

It should be noted that the connection sizes are always expressed in inches, while other data units will vary based on the units (standard or metric) selected on the main input screen.

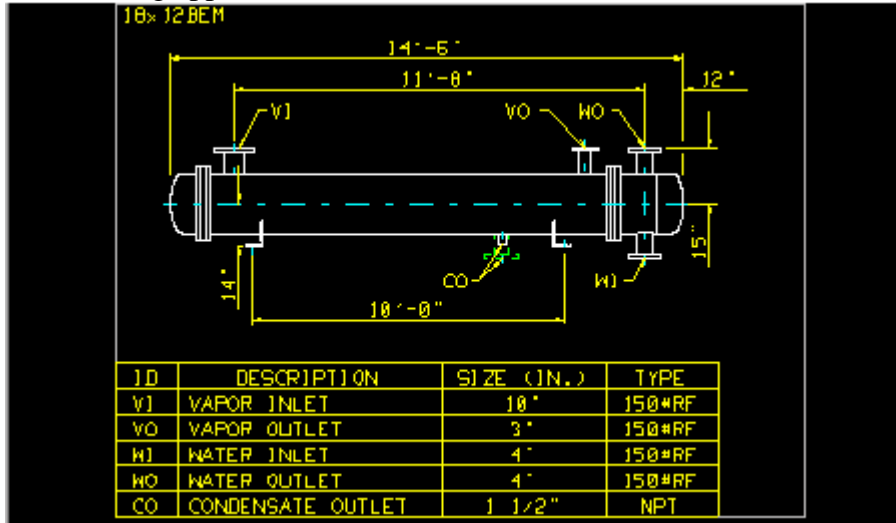
Drawings

The drawing for each component can be viewed on the screen by clicking on the icon of the desired component.

The color of the icon changes to indicate which drawing is being viewed.



The drawing appears on the screen...

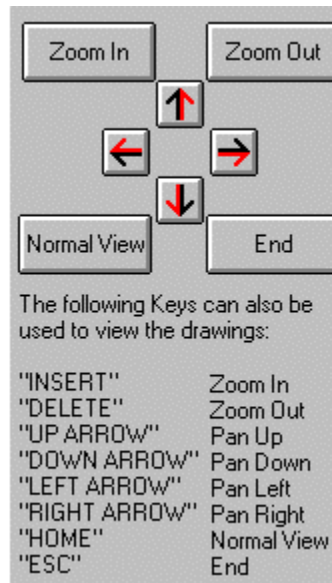


To better view the drawing, the view can be manipulated by three different methods:

- using the drawing buttons (Zoom In, Zoom Out, Normal View, or the arrow buttons).
- using the keyboard (descriptions of keys are on the screen).
- by clicking the drawing with the left or right mouse buttons. The left mouse button zooms in and pans while the right mouse button zooms out and pans.

To return to the normal output screen, simply click the "END" button or hit the "ESC" key.

Drawings can be printed via the Print command. It should be noted that the drawings offer *preliminary* dimensional data and are not to scale.



Printed Output

Printed output includes:

- Specification sheet of the design.
- Drawings (one page with up to six drawings).
- Quotation request form which can be forwarded to Graham for design verification or further optimization, followed by a price for the required system. This page contains a complete set of the input data used for the design and can be used to fully document the design parameters specified. The page is also “printed” to a “.TXT” file. This file is located in the same directory as the input data file and has the same name but with a “.TXT” extension. This file can be used to fax directly via modem or used as an E-mail attachment. For instance, if the input file name is “TEST” , the text file would be named “TEST.TXT”. It should be noted that subsequent prints using the same input file name will overwrite the list file.

The printed data is obtained via the print command.

Specification Sheet (blank sample)

GRAHAM CORPORATION VACUUM SYSTEM SPECIFICATION SHEET

Item: _____ Date: _____
Description: _____ User: _____
File: _____

Absolute pressure maintained at ejector suction inlet _____ mmHgA
Temp @ Suction Inlet _____ degF Steam Press _____ psig
Non-condensibles _____ #/hr _____ MW Steam Temp _____ degF
Condensible Vapors _____ #/hr _____ MW Water Temp _____ degF
Steam _____ #/hr Disch Press _____ mmHgA

_____ Stage Ejector. Size _____

Surface Intercondenser, Size _____ Surface _____ sqft
Water _____ gpm In/Out _____ / _____ degF Pressure Drop _____ psi

_____ Stage Ejector. Size _____

Surface Intercondenser, Size _____ Surface _____ sqft
Water _____ gpm In/Out _____ / _____ degF Pressure Drop _____ psi

_____ Stage Ejector. Size _____

Surface Aftercondenser, Size _____ Surface _____ sqft
Water _____ gpm In/Out _____ / _____ degF Pressure Drop _____ psi

*** CONDENSER MATERIALS & DESIGN ***

		PROCESS	WATER
Process Side _____	Design Press	FV& _____	_____ psig
Tube Sheets _____	Hydro Test Press	_____	_____ psig
Water Side _____	Design Temp	_____	_____ degF
Tubes _____	O.D. _____	in BWG _____	avg wall

*** EJECTOR MATERIALS ***

Suction Chamber and Diffuser _____
Steam Nozzle _____
Steam Chest _____
Nozzle Plate _____

Graham Designation: _____
Utilities: Steam _____ #/hr, Water _____ gpm, Electric _____ KWhr
Total annual utility cost: \$ _____
Construction Code Ejectors: _____
Construction Code Condensers: _____

Graham Corporation, 20 Florence Ave., Batavia, NY 14020
Telephone: (716) 343-2216, Fax: (716) 343-1097
Email: equipment@graham-mfg.com, WEBSITE: http://www.graham-mfg.com

Quotation Request (blank sample)

GRAHAM CORPORATION
VACUUM SYSTEM DESIGN PROGRAM DATA

To: Graham Corporation Fax: (716) 343-1097
Attention: Application Engineering Date:

From: Phone:
Fax:
Name:

Please provide a vacuum system quotation based on the following:

Item: User:
Description: File:

===== MAIN INPUT =====

Input Units: Standard Metric
Suction Pressure_____
Suction Temp_____
Discharge Pressure_____
Motive Pressure_____
Motive Temp (0=D&S)_____
Cooling/Seal Water Inlet Temp_____
Cost of steam (\$/1000 lbs.)_____
Cost of electricity (\$/KW hr)_____
Cost of water (\$/1000 gallons)_____
Condenser Type:_____
Number of Stages:_____
Use precondenser:_____
Use liquid ring vacuum pump for last stage:_____
Cycles:_____
Optimize:_____

===== LOAD INPUT =====

CONDENSIBLE LOADS:

ID#	#/hr	kg/h	MW	Vpr	Name	T1	P1	T2	P2	T3	P3	ALC
18					WATER							

NON-CONDENSIBLE LOAD: (#/hr) (kg/h) AV.MW

===== DESIGN REQUIREMENTS =====

	PROCESS		WATER	
Design Press	psig	Barg	psig	Barg
Hydro Test Press	psig	Barg	psig	Barg
Design Temp	degF	degC	degF	degC

===== MATERIALS =====

Suction Chamber/Diff._____
Steam Nozzle_____
Steam Chest_____
Nozzle Plate_____
LRVP_____
Code: Ejectors:_____
Code: Condensers:_____

===== RESULTS =====

Graham Designation: _____
Utilities: Steam_____ #/hr, Water_____ gpm, Electric_____ KWhr
Total annual utility cost: \$ _____

Thermo Compressor Design Program

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[Printed Output](#)

Overview

This program will allow the design of steam-to-steam thermo compressors. The suction pressure can range from 3.86 psia (.26 bar(a)) to 25 psia (1.72 bar(a)), with discharge pressures up to 45 psia (3.1 bar(a)).

This program is similar to the program used internally by Graham engineers. The program is intended to provide accurate sizing and utility requirements. An output summary sheet may be e-mailed or faxed to Graham for design verification or further optimization, followed by a price for the required thermo compressor.

DISCLAIMER

Although every effort has been made to insure this program provides reasonable thermo compressor designs, no warranty is implied or otherwise provided. This software is designed to allow the user considerable flexibility with the assumption that the user is familiar with thermo compressor design and as such, it is possible to create designs that may not be optimal for a given set of conditions. It is recommended that, should there be any doubt with a design, the necessary information should be forwarded to Graham for review.

Thermo Compressor Design Considerations

The design of a thermo compressor is dependent on a number of parameters, primarily:

- Required suction and discharge pressure
- Motive steam pressure
- Required load (steam mass flow)

Running The Program

When the Thermo Compressor Design Program is selected from the start-up screen, the Thermo Compressor Design Program input screen appears. This screen includes two tabbed pages for input data and several menu selections which include input file functions.

Thermo Compressor Input

File Design Thermo Compressor Help

Main Input Material / Design

Thermo Compressor Input

Units

☒ Standard Units ☐ Metric Units

Design Data

	Standard Units		Metric Units
Suction Pressure	psia		Bar (a)
Suction Temperature (0=D&S)	°F		°C
Discharge Pressure	psia		Bar (a)
Motive Pressure	psig		Bar (g)
Motive Temperature (0=D&S)	°F		°C
Load (mass flow rate of steam)	#/hr		kg/hr

This program will design steam to steam thermo-compressors. For other fluids, contact Graham Corporation.

The suction pressure can range from 3.86 psia (200mmHgA)(.26 bar(a)) to 25 psia (1.72 bar(a)).

The program allows users to store and retrieve input data files using typical Windows format file menus. The use of input data files is recommended since it allows a design to be repeated at a later time without having to re-enter the data.

Input

The input is comprised of two separate categories:

- Main input
- Material / Design

Once all input data is complete, the **Design Thermo Compressor** menu is used to initiate the design process.

Main Input

Material / Design Data

Main Input

The main input section has three sections, two for numerical input and one for selecting design options.

Units

Suction Pressure

Suction Temperature

Discharge Pressure

Motive Pressure

Motive Temperature

Load (steam mass flow)

Units-



The main input screen allows the user to select either standard or metric units. This sets the units for all subsequent input and output. It should be noted that for many of the numeric values, both unit values are shown on the input screens. During input only the unit type selected (standard or metric) is enabled or allowed to be modified. The units not enabled are automatically calculated and shown on the screen. The program uses the standard units for all calculations and simply converts the values to metric as needed.

Suction Pressure-

Suction Pressure is at the inlet to the thermo compressor and may range from 3.86 psia (.26 bar(a)) to 25 psia (1.72 bar(a)). Suction pressures outside this range are possible but require design by Graham.

Suction Temperature-

The suction temperature must be greater than or equal to the load (steam) saturation temperature at the inlet pressure. There is an upper limit of 500 °F (260 °F).

Discharge Pressure-

The discharge pressure must be greater than the suction pressure and may not exceed 45 psia (3.1 bar(a)). Other discharge pressures are possible, however, a detailed design by Graham is necessary.

Motive Pressure-

This software exclusively uses steam as a motive fluid. Other motive fluids are available and may be considered, however, a detailed design by Graham is required. The motive steam pressure may range between 50 psig (3.45 bar(g)) and 250 psig (17.2 bar(g)).

Motive Temperature-

It is not necessary to input a motive temperature and if left blank, the program will assume dry and saturated steam conditions. If there is superheat in the motive steam, then motive steam temperature should be included as an inputted value.

Load (steam mass flow)-

This program will only handle a steam load. The load is expressed as a mass flow rate.

Material / Design Data-

This input screen includes the heading information, material selection, and construction code selection. Heading information should be entered in order to identify printed output later.

The materials and construction codes are selected from a list of available choices for each component via drop-down lists. The materials offered within this program are the materials most commonly used, although many other materials are available. For materials other than those included with this program, contact Graham.

Ejector Parameters

Materials

Suction Chamber / Diffuser	CAST IRON
Steam Nozzle	304SS
Steam Chest	STEEL
Nozzle Plate	STEEL
Construction Code	STEEL
Graham Standard	304SS
	316SS

To select a material or construction code, left mouse click on the arrow next to the component name to view the list of available selections. Then, simply click the desired selection.

Results

When the program completes the design process, the results of a design are displayed on the screen.

Ejector Data

Model	6x6TC
Motive (#/hr)	963
Suction Dia. (in.)	6.00
Discharge Dia. (in.)	6.00
Motive Dia. (in.)	1.25

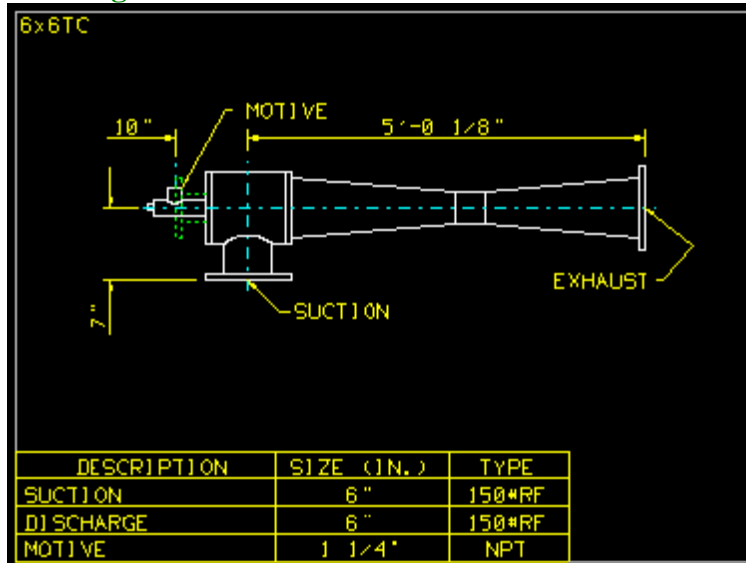
Click ejector icon for dimensional information



The ejector icon can be used (click with mouse) to access a [preliminary drawing](#).

It should be noted that the connection sizes are always expressed in inches while other data units will vary based on the units (standard or metric) selected on the main input screen.

Drawings

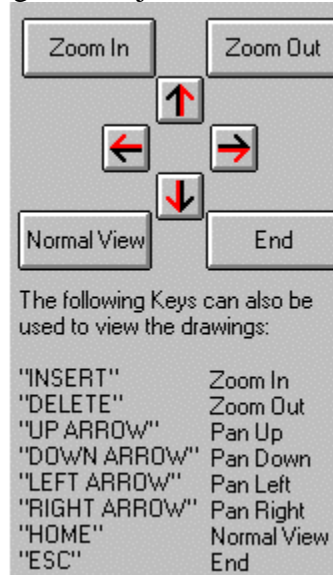


The drawing can be viewed on the screen by clicking on the ejector icon.

To better view the drawing, the view can be manipulated by three different methods:

- using the drawing buttons (Zoom In, Zoom Out, Normal View, or the arrow buttons).
- using the keyboard (descriptions of keys are on the screen).
- by clicking the drawing with the left or right mouse buttons. The left mouse button zooms in and pans while the right mouse button zooms out and pans.

To return to the normal output screen, simply click the "END" button or hit the "ESC" key. Drawings can be printed via the Print command. It should be noted that the drawings offer *preliminary* dimensional data and are not to scale.



Printed Output

Printed output includes:

- Specification sheet of the design.
- Quotation request form which can be forwarded to Graham for design verification or further optimization, followed by a price for the required system. This page contains a complete set of the input data used for the design and can be used to fully document the design parameters specified. The page is also "printed" to a ".TXT" file. This file is located in the same directory as the input data file and has the same name but with a ".TXT" extension. This file can be used to fax directly via modem or used as an E-mail attachment. For instance, if the input file name is "TEST", the text file would be named "TEST.TXT". It should be noted that subsequent prints using the same input file name will overwrite the list file.

The printed data is obtained via the print command.

Specification Sheet (blank sample)

GRAHAM CORPORATION
THERMO COMPRESSOR SPECIFICATION SHEET

Item: _____ Date: _____
Description: _____ User: _____
File: _____

Size: _____

Motive Steam Pressure	_____	psig
Motive Steam Temperature	_____	degF
Motive Flow Rate	_____	#/hr
Suction Pressure	_____	psia
Suction Temperature	_____	degF
Load (steam)	_____	#/hr
Discharge Pressure	_____	psia
Discharge Temperature	_____	degF

*** MATERIALS ***

Suction Chamber and Diffuser _____
Steam Nozzle _____
Steam Chest _____
Nozzle Plate _____

Construction Code Ejectors: _____

*** PRELIMINARY DRAWING ***

Drawing is shown here.

Graham Corporation, 20 Florence Ave., Batavia, NY 14020
Telephone: (716) 343-2216, Fax: (716) 343-1097
Email: equipment@graham-mfg.com, WEBSITE: <http://www.graham-mfg.com>

Quotation Request (blank sample)

GRAHAM CORPORATION THERMO COMPRESSOR DESIGN PROGRAM DATA

To: Graham Corporation
Attention: Application Engineering
From:
Fax: (716) 343-1097
Date:
Phone:
Fax:
Name:

Please provide a thermo compressor quotation based on the following:
Item: User:
Description: File:

===== MAIN INPUT =====
Input Units: Standard Standard Metric
Suction Pressure _____
Suction Temperature (0=D&S) _____
Discharge Pressure _____
Motive Pressure _____
Motive Temp (0=D&S) _____
Load (steam) _____

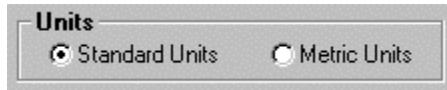
===== MATERIALS =====
Suction Chamber/Diff. _____
Steam Nozzle _____
Steam Chest _____
Nozzle Plate _____
Code of Construction: _____

===== RESULTS =====
Size: _____
Motive Steam Flow _____ #/hr

Graham Corporation, 20 Florence Ave., Batavia, NY 14020
Telephone: (716) 343-2216, Fax: (716) 343-1097
Email: equipment@graham-mfg.com, WEBSITE: <http://www.graham-mfg.com>

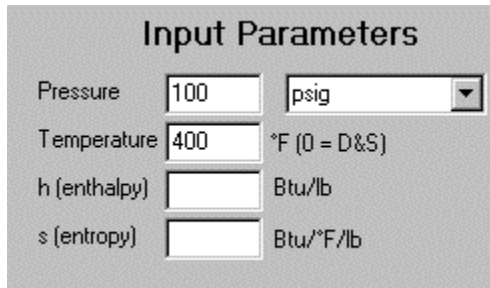
Mollier Program (steam properties)

The Mollier Program allows access to the steam database. The program will show properties ranging from wet conditions to highly superheated based on the input provided.



A dialog box titled "Units" with two radio buttons. The first radio button is selected and labeled "Standard Units". The second radio button is labeled "Metric Units".

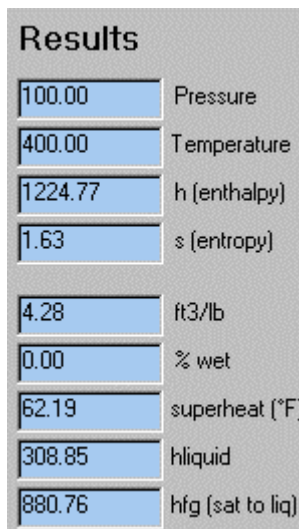
Steam data is shown in either standard or metric units.



A dialog box titled "Input Parameters" with four input fields. The first field is "Pressure" with the value "100" and a unit dropdown menu set to "psig". The second field is "Temperature" with the value "400" and a unit dropdown menu set to "°F (0 = D&S)". The third field is "h (enthalpy)" with a unit dropdown menu set to "Btu/lb". The fourth field is "s (entropy)" with a unit dropdown menu set to "Btu/°F/lb".

The input values include pressure, temperature, enthalpy, and entropy. The pressure units are selected via a drop-down list. Pressure must be entered while temperature, enthalpy, and entropy are optional. If more than one of the optional values is input, the program will use the optional values based on the order of priority, which is temperature, enthalpy, and entropy. If more than one optional value is input, a warning message is displayed.

The "Calculate" button initiates the calculation of the steam properties based on the input parameters. The results are shown in the blue shaded boxes to the right of the input data. The exit button is used to return to the Vacworks main screen.



A dialog box titled "Results" with ten blue shaded boxes containing numerical values and their corresponding units. The values are: 100.00 (Pressure), 400.00 (Temperature), 1224.77 (h (enthalpy)), 1.63 (s (entropy)), 4.28 (ft³/lb), 0.00 (% wet), 62.19 (superheat (°F)), 308.85 (hliquid), and 880.76 (hfg (sat to liq)).

The Result boxes include pressure, temperature, enthalpy, entropy, specific volume, percent moisture, degrees superheat, enthalpy of saturated liquid, and the latent heat (hfg). The resulting values are dependent on the input data supplied. The expected results based on the possible input values are listed below.

Pressure only:

Saturated conditions.

Pressure and Temperature:

Saturated to superheated conditions. If the temperature is less than the saturation temperature, you have subcooled water and an error message is shown.

Pressure and Enthalpy:

Wet to superheated conditions. If the enthalpy is less than h-liquid, you have subcooled water and an error message is shown.

Pressure and Entropy:

Wet to superheated conditions. If the entropy is less than s-liquid, you have subcooled water and an error message is shown.

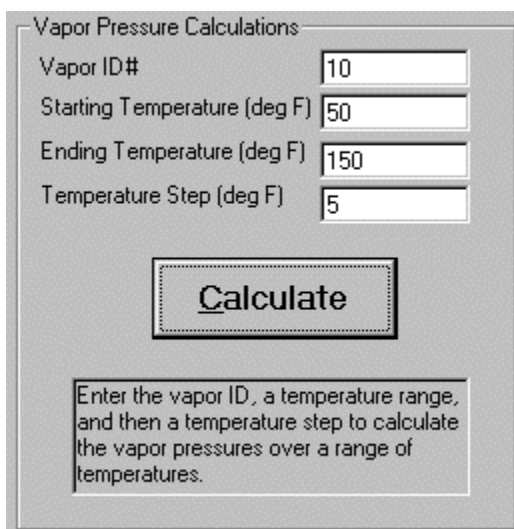
Vapor Pressures Of Common Fluids

This program allows the calculation of vapor pressures for vapors contained in the database for a range of temperatures. The vapor pressure database contains in excess of 1200 fluids.

The program requires four inputs:

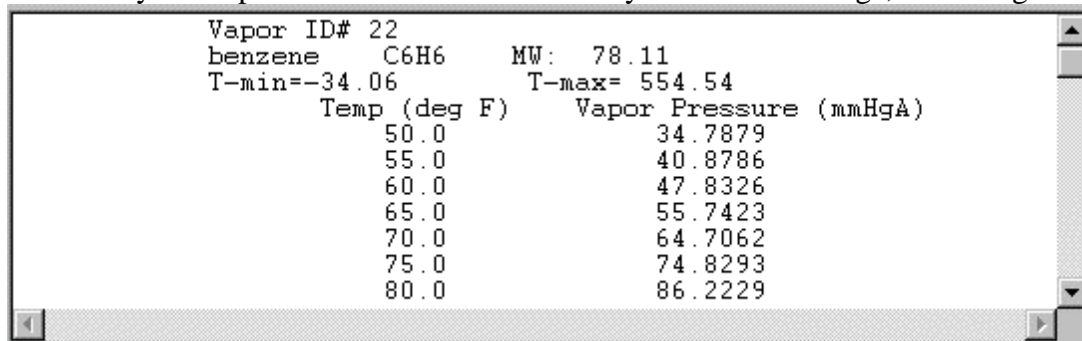
- Vapor ID. (The ID can be found via a [search](#) option.)
- Starting Temperature (°F).
- Ending Temperature (°F).
- Temperature Step (°F).

Once the desired fluid is found, the ID number can be typed in the Vapor ID box on the left or by double clicking the vapor name, the Vapor ID number will be automatically placed in the Vapor ID box on the left.



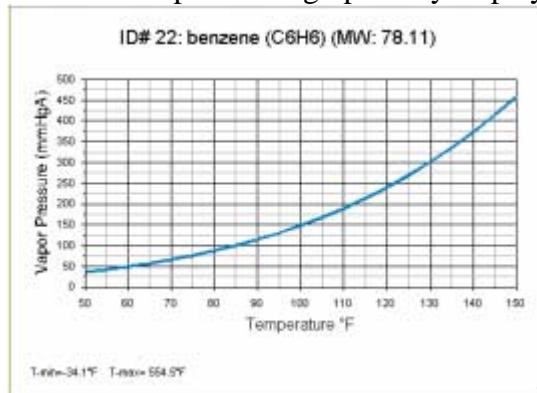
The Starting temperature, Ending temperature, and Temperature step define the range of temperatures for which to calculate the corresponding vapor pressures. To calculate the vapor pressure at a single temperature, enter the desired temperature in all the temperature input boxes.

Once the calculate command is issued, the calculated values are shown in a text box at the bottom of the screen. It should be noted that each fluid has a valid temperature range beyond which calculated values may be suspect. For values calculated beyond the valid range, a warning is issued.



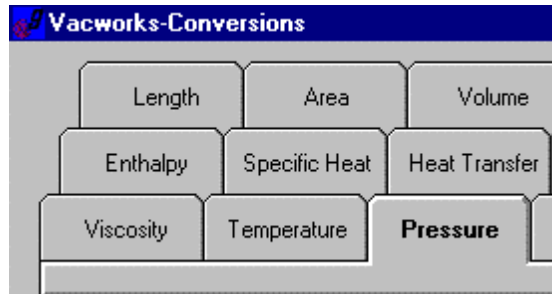
Vapor ID# 22	
benzene C6H6 MW: 78.11	
T-min=-34.06 T-max= 554.54	
Temp (deg F)	Vapor Pressure (mmHgA)
50.0	34.7879
55.0	40.8786
60.0	47.8326
65.0	55.7423
70.0	64.7062
75.0	74.8293
80.0	86.2229

There is an option that graphically displays vapor pressure as a function of temperature:



Common Conversions

The available conversions are broken down into approximately 20 categories. The first step is to select the desired category of conversion (length, volume, etc.) by clicking the appropriate tab along the top of the screen. The tabs are used to choose the type of conversion to be done based on the category of the value to be converted. For instance, to convert a pressure in psia to mmHgA, choose the pressure tab.

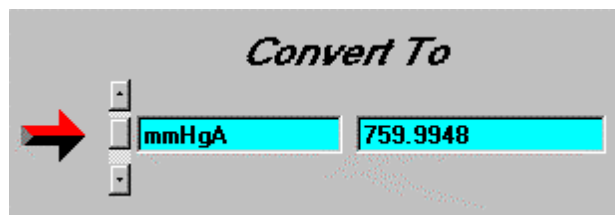


Once the category is chosen, the available units to convert “from” and “to” are loaded into the scrolling lists on the lower left and lower right screen.



The default value in the numeric input box is 1. To calculate a conversion from another value, simply click this box with a left mouse click and then type in the desired value. The “convert from” scroll bar allows the selection of various starting units. The value shown in the numeric input box (label indicates: "Enter value to convert") will be in the units defined by this selection.

The “convert to” scroll bar allows the selection of various ending units. The value shown in the numeric input box (label indicates: "Enter value to convert") will be converted to the units defined by this selection. The converted value is shown in the result box on the right side of the screen.



The exit command button returns control to the main Vacworks screen.

User Defined Vapors

The User Defined Vapor program allows users to define condensible vapors for use in the vacuum system design program.

ID#	Name	MW	T1 °C	P1	T2 °C	P2	T3 °C	P3	Alcohol=1
-1	VaporXYZ	55	37.78	50	93.33	150	148.89	500	0

The vapor pressure for a fluid is defined by three temperatures and three corresponding vapor pressures. This allows the program to calculate a curve fit (Antoine's) for the vapor. In addition, the molecular weight, fluid name, and an indication of the type of fluid (alcohol or non-alcohol) are required.

The program assigns the vapor ID numbers automatically. User Defined Vapors use negative ID numbers to distinguish them from the internal database vapors.

Vapor Data

User Defined Vapor ID# -1

Temperature #1 100 (lowest temperature)

Vapor Press. #1 (mmHgA) 50

Temperature #2 200 (middle temperature)

Vapor Press. #2 (mmHgA) 150

Temperature #3 300 (highest temperature)

Vapor Press. #3 (mmHgA) 500

Vapor Molecular Weight 55

Vapor Name VaporXYZ

Vapor Type ☒ Non-alcohol ☐ Alcohol

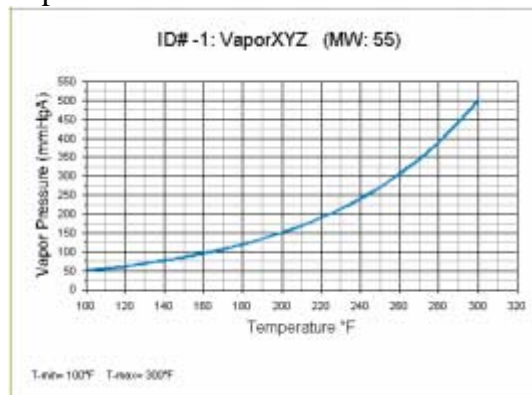
Abort Change

Update Database

The acceptable range of a given fluid is set by the lowest and highest temperatures entered for that fluid.

A warning is issued by the vacuum system design program when a fluid's vapor pressure is calculated beyond the acceptable range.

The program includes the capability to view a graph of the calculated vapor pressures. This is useful for a quick check of interpolated data.

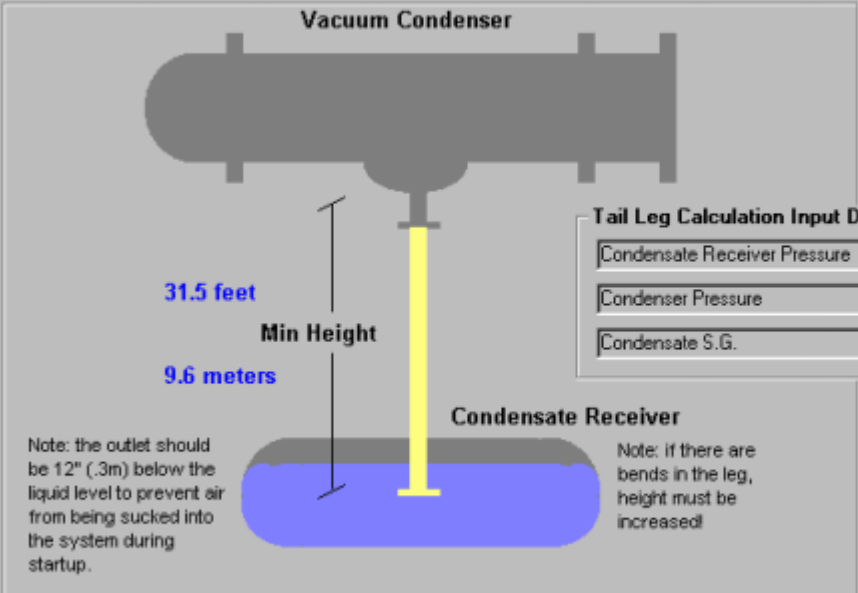


Tail Leg Height Calculation

The tail leg height calculation is used to determine the minimum height required. The calculation is based on condensate receiver and condenser operating pressure.

Tail Leg Height

Calculate the height required to ensure condensate receiver pressure does not cause the condenser to flood.



Vacuum Condenser

Condensate Receiver

Min Height

31.5 feet

9.6 meters

Note: the outlet should be 12" (.3m) below the liquid level to prevent air from being sucked into the system during startup.

Note: if there are bends in the leg, height must be increased!

Tail Leg Calculation Input Data

Condensate Receiver Pressure	760	mmHgA
Condenser Pressure	55	mmHgA
Condensate S.G.	1	

Calculate

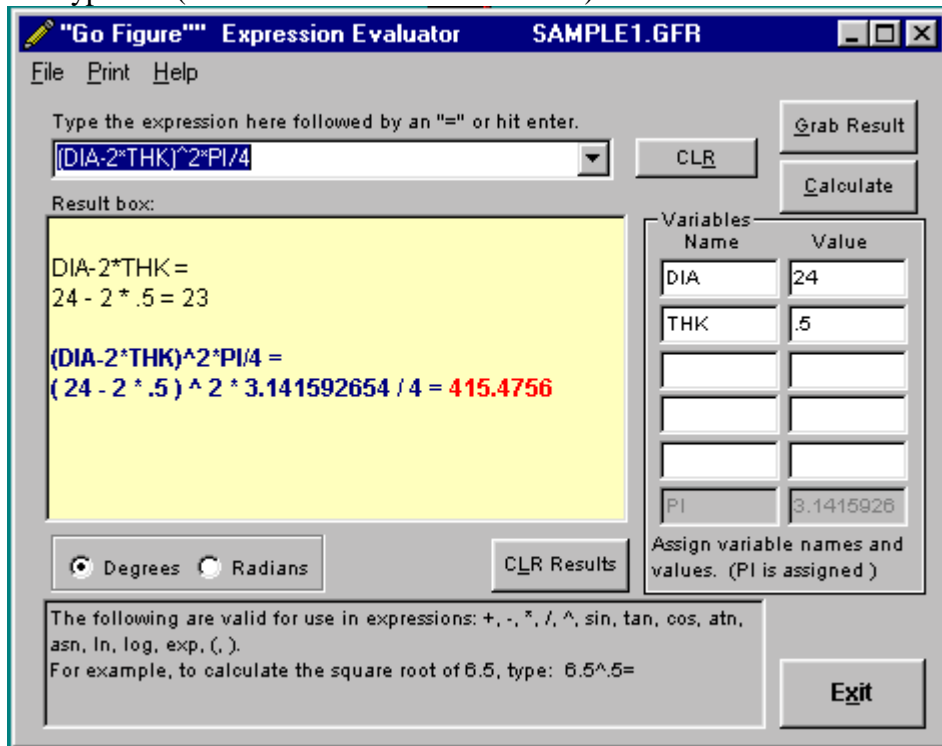
Print

Exit

"Graham recommends vacuum condenser operating pressure is full vacuum (0 psia) to be conservative. Vacuum condenser operating pressure varies based on cooling water temperature, fouling, and process loading. It is best to err on the conservative side."

"Go Figure"

"Go Figure" is an expression evaluator (something like a calculator). Simply type in the expression and type "=" (or enter or the Calculate button) to see the results.



"Go Figure" capabilities include:

- Saving input data files so the calculations can be recalled for later use.
- Define up to 5 variables.
- Can copy the results of a calculation to the expression area (and to the clipboard) by the "Grab Result" button.
- Allows printing of the input and output.
- Change a variable value and hit enter (while the cursor is in the value box) to recalculate the equation currently shown in the expression. (In the above example, change the value of 24 to 36 and hit the enter key).

Gas Mass & Volumetric Flow Calculation

This program calculates the volumetric flow when a mass flow is specified and visa versa. The units for each input are selected by clicking on the appropriate button.

The screenshot shows a software window titled "Gas Mass & Volume Calculation". Inside the window, there is a text box at the top explaining the program's function: "This program will calculate either the mass flow or volumetric flow of a gas. Simply enter the molecular weight, pressure, temperature and either the mass flow or the volumetric flow and then choose 'Calculate'. Units of the input values can be selected by clicking the button next to the appropriate unit in each category."

The interface is organized into several input sections:

- Molecular Weight:** A text box labeled "MW" with the value "29" entered.
- Pressure:** A group of radio buttons for unit selection:
 - ☒ mmHgA: 760.00
 - ☐ psig: 0.00
 - ☐ psia: 14.70
 - ☐ bar A: 1.0133
 - ☐ kPa: 101.33
- Temperature:** A group of radio buttons for unit selection:
 - ☒ °F: 70
 - ☐ °C: 21.11
- Flow Type Selection:** Two radio buttons at the top:
 - ☒ Enter Mass Flow
 - ☐ Enter Volumetric Flow
- Mass Flow:** A group of radio buttons for unit selection:
 - ☒ #/hr: 4000
 - ☐ kg/hr: 1814.39
- Volumetric Flow:** A group of radio buttons for unit selection:
 - ☒ ACFM: 888.02
 - ☐ SCFM: 871.26
 - ☐ NCFM: 824.35
 - ☐ NM3/hr: 1400.58

At the bottom center is a large "Calculate" button, and at the bottom right is an "Exit" button.

In the example shown, the volumetric flow equivalent to 4000 #/hr of air (at 760mmHgA & 70°F) is calculated.

Gas Pressure Drop Estimation

Sample input screen:

Pressure Drop Estimation Method: ☐ HEI ☒ Graham

Mass flow (#/hr)	1200
Temperature (deg.F)	272
Molecular weight	29
Viscosity (cP) (Air ~ 0.015 cP)	.015
Initial pressure (mmHgA)	42
Pipe inside diameter (in)	12
Length of Straight Pipe (ft)	120
# of Gate Valves full open.... (L/D= 8)	1
# of 90 deg Elbows (CAST).... (L/D= 30)	
# of 45 deg Elbows (CAST).... (L/D= 16)	
# of Std Tees thru flow..... (L/D= 20)	
# of Std Tees branch flow.... (L/D= 60)	1
# of Close Return Bends..... (L/D= 50)	
# of Swing Check Valves..... (L/D= *)	
# of Angle Valves..... (L/D=150)	
# of Globe Valves..... (L/D=340)	
# of 90 deg Wld Elbows r/d=1.0 (L/D= 20)	
# of 90 deg Wld Elbows r/d=1.5 (L/D= 16)	3
# of 90 deg Wld Elbows r/d=2.0 (L/D= 12)	

* L/D=100 <= 6.625"
L/D= 50 > 6.625"

The results of the calculation show the input data, calculated velocity at the inlet, the equivalent pipe lengths for each fitting, and the total calculated pressure drop.

Flow (pph).....	1200	
Temperature (deg.F).....	272.0	
Molecular Weight.....	29.00	
Viscosity (cP).....	0.01500	
Initial Pressure (mmHgA).....	42.00	
Pipe I.D. (in.).....	12.00	
Velocity (fps).....	141.5	
Description	Quantity	Equiv. lg (ft)
Length of Straight Pipe (ft.).....		120.0
# of Gate Valves full open.... (L/D= 8)	1	8.000
# of Std Tees branch flow.... (L/D= 60)	1	60.00
# of 90 deg Wld Elbows r/d=1.5 (L/D= 16)	3	48.00
Total equivalent pipe length (ft)		236.0
Total calculated pressure drop:		1.7439 mmHg

* Be sure to apply a safety margin to the calculated pressure drop!