COURSE OVERVIEW PE0390
Distillation Design, Operation, Control & Troubleshooting

Course Title
Distillation Design, Operation, Control & Troubleshooting

Course Date/Venue
January 28-February 01, 2024/Royal Club Meeting Room, Radisson Blu Hotel, Dubai Deira Creek, Dubai, UAE

3.0 CEUs (30 PDHs) AWARD

Course Reference
PE0390

Course Duration/Credits
Five days/3.0 CEUs/30 PDHs

Course Description

This practical and highly-interactive course includes various practical sessions and exercises. Theory learnt will be applied using our state-of-the-art simulators.

The Distillation Process is used in many industries to separate mixtures into components. It is defined as a process in which a liquid or vapor mixture of two or more substances is separated into its component fractions of desired purity by the application and removal of heat. The application and removal of heat makes the distillation process energy intensive as it consuming up to 50 percent of a refinery's operating costs due to intense heating and cooling cycles. Having accurate measurements to feed the control system is critical for energy efficient, safe and reliable operation.

Improving distillation columns has always been challenging as problems can occur when operators and engineers have insufficient information about operating conditions. Failing to properly monitors and control process variables can result in decreased product quality and throughput, increased energy costs and unsafe operations that put employees and capital equipment at risk.

This course is designed to provide delegates with a detailed and up-to-date knowledge on the operation, design and troubleshooting of distillation process. It covers distillation technology; different distillation methods; and distillation process that involve normal operation of bubble plate, vapor velocity and velocity distribution.

The course will also discuss the factors influencing plate efficiency; the scope of distillation column including flash stages, process design basic and reflux ratio; how tray works; the various types and function of reboilers; features and use of condensers in the operation of distillation columns; instrumentation and control application; the importance of steam stripper and its efficiency; the purpose of pumparound; as well as pumparound heat removal, vapor flow and fractionation.

At the completion of the course, participants will be able to operate the vacuum system; explain the functional and structural efficiency of packed towers; employ distillation column packing as well as tray columns; recognize the guidelines and methods on how to determine the column diameter; and troubleshoot various distillation column problems.

Course Objectives

Upon the successful completion of this course, each participant will be able to:-

- Operate, control and troubleshoot distillation process in a professional manner
- Apply and gain an in-depth knowledge on distillation technology
- Identify the different distillation methods and implement distillation process involving the normal operation of bubble plate, vapor velocity and velocity distribution
- Determine the factors influencing plate efficiency and explain the scope of distillation column including flash stages, process design basic and reflux ratio
- Demonstrate how tray works and explain the types & function of reboilers
- Discuss the features & use of condensers in the operation of distillation columns and apply instrumentation & control
- Enumerate the importance of steam stripper and emphasize its efficiency
- Discuss the purpose of pump around and become familiar with pump around heat removal, vapor flow and fractionation
- Demonstrate the operation of the vacuum system and explain the functional and structural efficiency of packed towers
- Employ distillation column packing as well as tray columns and recognize the guidelines & methods on how to determine the column diameter
- Troubleshoot various distillation column problems

Exclusive Smart Training Kit - H-STK®

*Participants of this course will receive the exclusive "Haward Smart Training Kit" (**H-STK®**). The **H-STK®** consists of a comprehensive set of technical content which includes **electronic version** of the course materials, sample video clips of the instructor's actual lectures & practical sessions during the course conveniently saved in a **Tablet PC**.*

Who Should Attend

This course provides an overview of all significant aspects and considerations of distillation process for those who are involved in the operation, control and troubleshooting of such system. Process engineers, production engineers, operations engineers, maintenance engineers and other technical staff will definitely benefit from the technical and operational aspects of the course.

Training Methodology

All our Courses are including **Hands-on Practical Sessions** using equipment, State-of-the-Art Simulators, Drawings, Case Studies, Videos and Exercises. The courses include the following training methodologies as a percentage of the total tuition hours:-

30% Lectures
20% Practical Workshops & Work Presentations
30% Hands-on Practical Exercises & Case Studies
20% Simulators (Hardware & Software) & Videos

In an unlikely event, the course instructor may modify the above training methodology before or during the course for technical reasons.

Course Fee

US$ 5,500 per Delegate + **VAT**. This rate includes H-STK® (Haward Smart Training Kit), buffet lunch, coffee/tea on arrival, morning & afternoon of each day.

Accommodation

Accommodation is not included in the course fees. However, any accommodation required can be arranged at the time of booking.

Course Certificate(s)
Internationally recognized certificates will be issued to all participants of the course who completed a minimum of 80% of the total tuition hours.

Certificate Accreditations
Certificates are accredited by the following international accreditation organizations:-

- The International Accreditors for Continuing Education and Training (IACET - USA)

Haward Technology is an Authorized Training Provider by the International Accreditors for Continuing Education and Training (IACET), 2201 Cooperative Way, Suite 600, Herndon, VA 20171, USA. In obtaining this authority, Haward Technology has demonstrated that it complies with the **ANSI/IACET 2018-1 Standard** which is widely recognized as the standard of good practice internationally. As a result of our Authorized Provider membership status, Haward Technology is authorized to offer IACET CEUs for its programs that qualify under the **ANSI/IACET 2018-1 Standard**.

Haward Technology's courses meet the professional certification and continuing education requirements for participants seeking **Continuing Education Units** (CEUs) in accordance with the rules & regulations of the International Accreditors for Continuing Education & Training (IACET). IACET is an international authority that evaluates programs according to strict, research-based criteria and guidelines. The CEU is an internationally accepted uniform unit of measurement in qualified courses of continuing education.

Haward Technology Middle East will award **3.0 CEUs** (Continuing Education Units) or **30 PDHs** (Professional Development Hours) for participants who completed the total tuition hours of this program. One CEU is equivalent to ten Professional Development Hours (PDHs) or ten contact hours of the participation in and completion of Haward Technology programs. A permanent record of a participant's involvement and awarding of CEU will be maintained by Haward Technology. Haward Technology will provide a copy of the participant's CEU and PDH Transcript of Records upon request.

- British Accreditation Council (BAC)

Haward Technology is accredited by the **British Accreditation Council** for **Independent Further and Higher Education** as an **International Centre**. BAC is the British accrediting body responsible for setting standards within independent further and higher education sector in the UK and overseas. As a BAC-accredited international centre, Haward Technology meets all of the international higher education criteria and standards set by BAC.

Course Instructor(s)

This course will be conducted by the following instructor(s). However, we have the right to change the course instructor(s) prior to the course date and inform participants accordingly:

Dr. Hesham Abdou, PhD, MSc, BSc, is a **Senior Mechanical & Petroleum Engineer** with over **35 years** of integrated industrial and academic experience as a **University Professor**. His specialization widely covers in the areas of **Crude Oil Testing & Water Analysis**, **Crude Oil & Water** Sampling Procedures, **Equipment Handling** Procedures, **Crude & Vacuum Process** Technology, **Gas Conditioning & Processing**, **Cooling Towers** Operation & Troubleshooting, **Sucker Rod Pumping**, **ESP & Gas Lift**, **PCP & Jet Pump**, **Pigging** Operations, Electric Submersible Pumps (**ESP**), Progressive Cavity Pumps (**PCP**), **Natural & Artificial Flow Well Completion**, **Well Testing** Procedures & Evaluation, **Well** Performance, **Coiled Tubing** Technology, **Oil Recovery Methods** Enhancement**, Well Integrity** Management, **Well Casing & Cementing**, **Acid Gas** Removal, **Heavy Oil Production** & Treatment Techniques, **Water Flooding**, **Water Lift Pumps** Troubleshooting, **Water System Design** & Installation, **Water Networks Design** Procedures, **Water Pumping** Process, **Pipelines**, **Pumps**, **Turbines**, **Heat Exchangers**, **Separators**, **Heaters**, **Compressors**, **Storage Tanks**, **Valves** Selection, **Compressors**, **Tank & Tank Farms** Operations & Performance, **Oil & Gas Transportation**, **Oil & Gas Production** Strategies, **Artificial Lift** Methods, **Piping & Pumping** Operations, Oil & Water Source Wells Restoration, **Pump** Performance Monitoring, **Rotor Bearing** Modelling, **Hydraulic** Repairs & Cylinders, **Root Cause Analysis**, **Vibration & Condition** Monitoring, **Piping Stress** Analysis, **Amine Gas Sweetening & Sulfur Recovery**, Heat & Mass Transfer and Fluid Mechanics.

During his career life, Dr. Hesham held significant positions and dedication as the **General Manager**, **Petroleum Engineering Assistant General Manager**, **Workover Assistant General Manager**, **Workover Department Manager**, **Artificial Section Head**, **Oil & Gas Production Engineer** and **Senior Instructor/Lecturer** from various companies and universities such as the Cairo University, Helwan University, British University in Egypt, Banha University and Agiba Petroleum Company.

Dr. Hesham has a **PhD** and **Master** degree in **Mechanical Power Engineering** and a **Bachelor** degree in **Petroleum Engineering**. Further, he is a **Certified Instructor/Trainer** and a **Peer Reviewer**. Dr. Hesham is a member of Egyptian Engineering Syndicate and the Society of Petroleum Engineering. Moreover, he has published technical papers and journals and has delivered numerous trainings, workshops, courses, seminars and conferences internationally.

Course Program

The following program is planned for this course. However, the course instructor(s) may modify this program before or during the course for technical reasons with no prior notice to participants. Nevertheless, the course objectives will always be met:

Day 1: Sunday, 28th of January 2024

0730 – 0800	Registration & Coffee
0800 – 0815	Welcome & Introduction
0815 – 0830	**PRE-TEST**
0830 – 0930	**Theory of Distillation** Introduction • Boiling Point Diagram • Roault's Law • Vapor – Liquid Equilibrium • Exercise • Solution • Azeotropic Mixture
0930 – 0945	Break
0945 – 1100	**Distillation Methods & Definition** Flash Distillation • Steam Distillation • Rectification • Combination Rectification & Stripping • Exercise • Solution • Distillation Basic Definition
1100 – 1230	**Distillation Process** Normal Operation of Bubble Plate • Vapor Velocity • Velocity Distribution • Factors Influencing Plate Efficiency • Sieve-plate Towers
1230 – 1245	Break
1245 – 1330	**Distillation Column** Flash Stages • Process Design Basic • Reflux Ratio • Minimum Reflux Ratio • Minimum Number of Plates • Optimum Reflux
1330 – 1420	**How Trays Work** Down Common Backup & Flooding • Dumping and Weeping • Optimizing Tower Pressure
1420 -1430	**Recap** Using this Course Overview, the instructor(s)will Brief Participants about the Topics that were Discussed Today & Advice Them of the Topics to be Discussed Tomorrow
1430	Lunch & End of Day One

Day 2: Monday, 29th of January 2024

0730 – 0930	**Reboilers Function** Reboilers Function • The Reboiler • Heat-Balance Calculations
0930 – 0945	Break
0945 – 1100	**Types of Reboiler** Thermosyphon, Gravity Feed & Forced • Thermosyphon Reboilers • Forced Circulation Reboilers • Kettle Reboilers • Don't Forget Fouling
1100 – 1230	**Condensers** Flooded Condenser Control • Subcooling, Vapor Binding, & Condensation • Condensation and Condenser Design • Pressure Control
1230 – 1245	Break

1245 – 1330	***Instrumentation*** *Levels, Pressures, Flows & Temperatures ● Pressure Control ● Flow Control ● Level Control ● Crude Tower Kerosene Side Stream Control ● Cascade Level – Flow Control*
1330 – 1420	***Steam Stripper*** *Heat of Evaporation ● Stripper Efficiency*
1420 - 1430	***Recap*** *Using this Course Overview, the instructor(s)will Brief Participants about the Topics that were Discussed Today & Advice Them of the Topics to be Discussed Tomorrow*
1430	*Lunch & End of Day Two*

Day 3: Tuesday, 30th of January 2024

0730 - 0930	***Pumparound*** *Closing the Tower Enthalphy Balance ● Pumparound Heat Removal ● Purpose of a Pumparound ● Do Pumparounds Fractionate? ● Vapor Flow ● Fractionation*
0930 – 0945	*Break*
0945 – 1100	***Vacuum System*** *Theory of Operation ● Measuring Deep Vacuums*
1100 – 1230	***Packed Towers*** *How Packed Towers Work ● Maintaining Functional & Structural Efficiency in Packed Towers*
1230 – 1245	*Break*
1245 – 1420	***Distillation Column Packing*** *Tray Columns – Packings ● Tray Columns – Type of Packings ● Tray Columns – Packings Correlations ● Comparison Trays versus Packing ● Randomly Packed Towers Sizing ● Determine the Column Diameter ● Randomly Packed Towers Column Height ● Randomly Packed Towers Pressure Drop Correlation*
1420 - 1430	***Recap*** *Using this Course Overview, the instructor(s)will Brief Participants about the Topics that were Discussed Today & Advice Them of the Topics to be Discussed Tomorrow*
1430	*Lunch & End of Day Three*

Day 4: Wednesday, 31st of January 2024

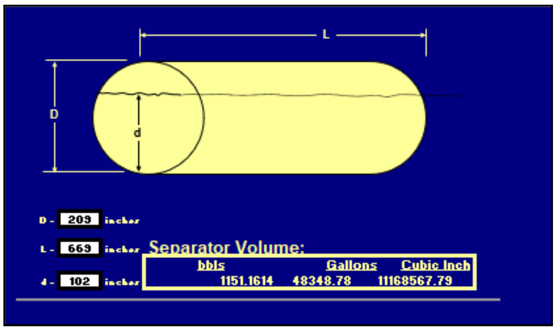
0730 – 0930	***Inspection, Troubleshooting & Case Studies*** *Tray Deck Levelness ● Loss of Downcomer Seal due to Leaks*
0930 – 0945	*Break*
0945 – 1100	***Inspection, Troubleshooting & Case Studies (cont'd)*** *Effect of Missing Caps ● Repairing Loose Tray Panels*
1100 – 1230	***Inspection, Troubleshooting & Case Studies (cont'd)*** *Improper Downcomer Clearance ● Inlet Weirs*
1230 – 1245	*Break*
1245 – 1420	***Inspection, Troubleshooting & Case Studies (cont'd)*** *Seal Pans*
1420 - 1430	***Recap***
1430	*Lunch & End of Day Four*

Day 5: **Thursday, 01st of February 2024**

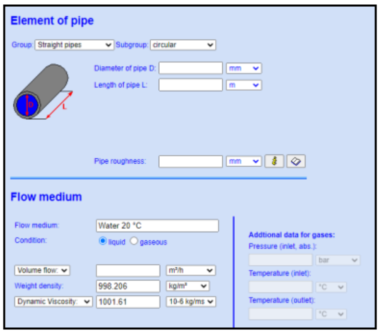
0730 – 0930	***Inspection, Troubleshooting & Case Studies (cont'd)*** *Drain Holes ● Vortex Breakers*
0930 - 0945	*Break*
0945 – 1100	***Inspection, Troubleshooting & Case Studies (cont'd)*** *Chimney Tray Leakage*
1100 – 1230	***Inspection, Troubleshooting & Case Studies (cont'd)*** *Shear Clips*
1230 – 1245	*Break*
1245 – 1345	***Inspection, Troubleshooting & Case Studies (cont'd)*** *Bubble-Cap Trays ● Final Inspection*
1345 - 1400	***Course Conclusion***
1400 – 1415	***POST-TEST***
1415 - 1430	*Presentation of Course Certificates*
1430	*Lunch & End of Course*

Simulator (Hands-on Practical Sessions)

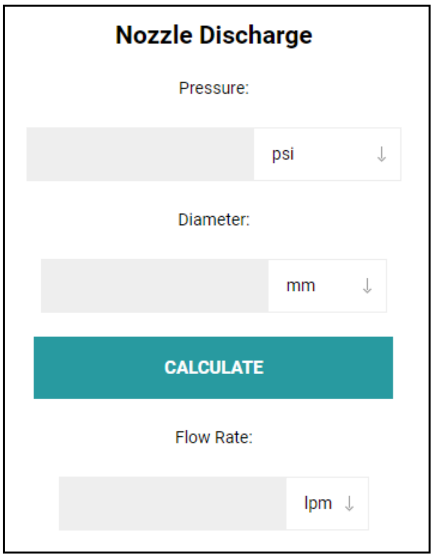
Practical sessions will be organized during the course for delegates to practice the theory learnt. Delegates will be provided with an opportunity to carryout various exercises using various online system calculator.



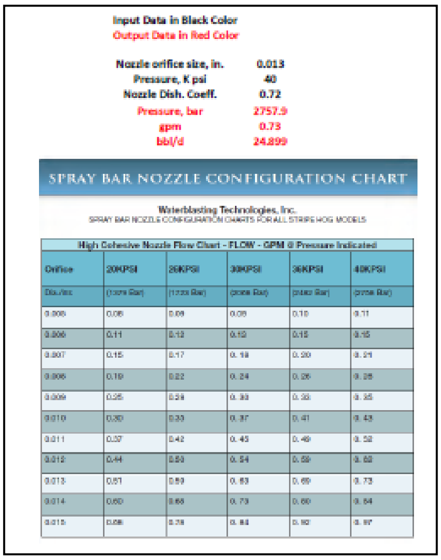
Tank Volume Calculator



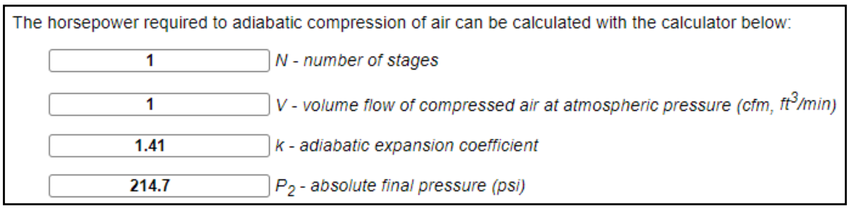
Pressure Drop Online-Calculator



Nozzle Discharge

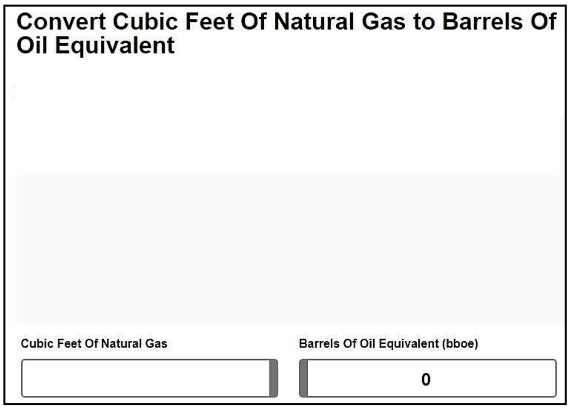


Nozzle Calculator

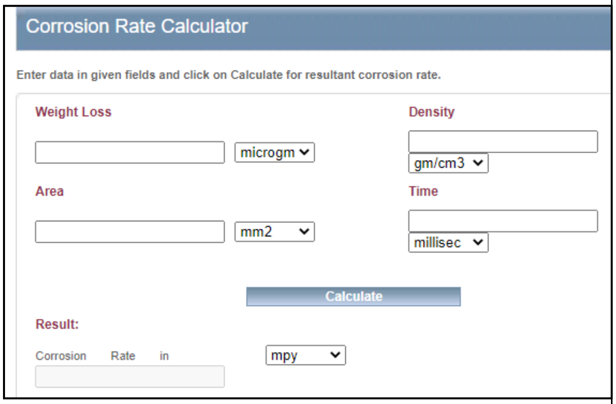


Horsepower Calculator

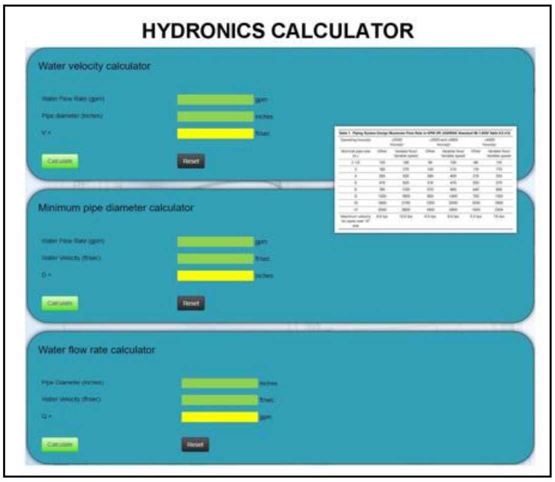
Water Flow Rate through an Orifice Calculator



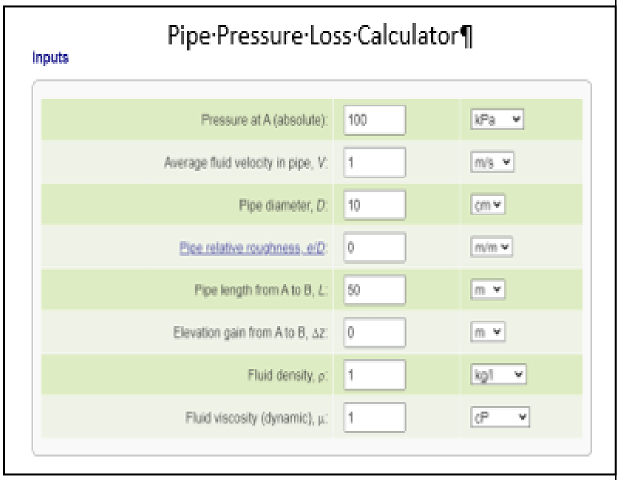
Cubic Feet Calculator



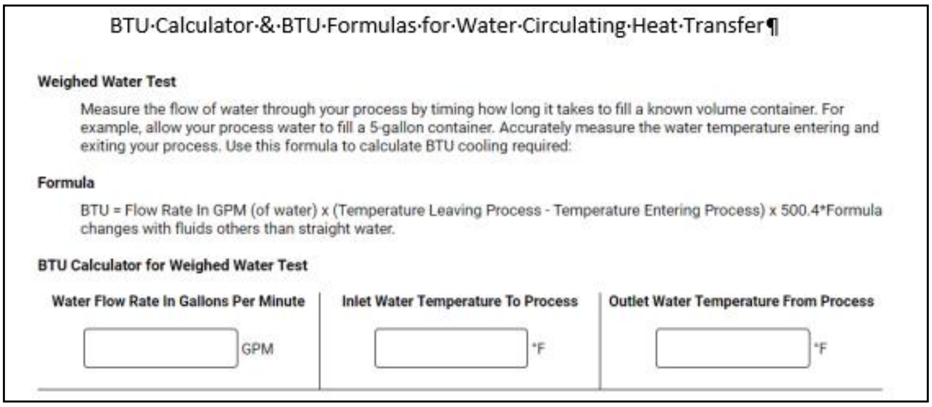
Corrosion Rate Calculator



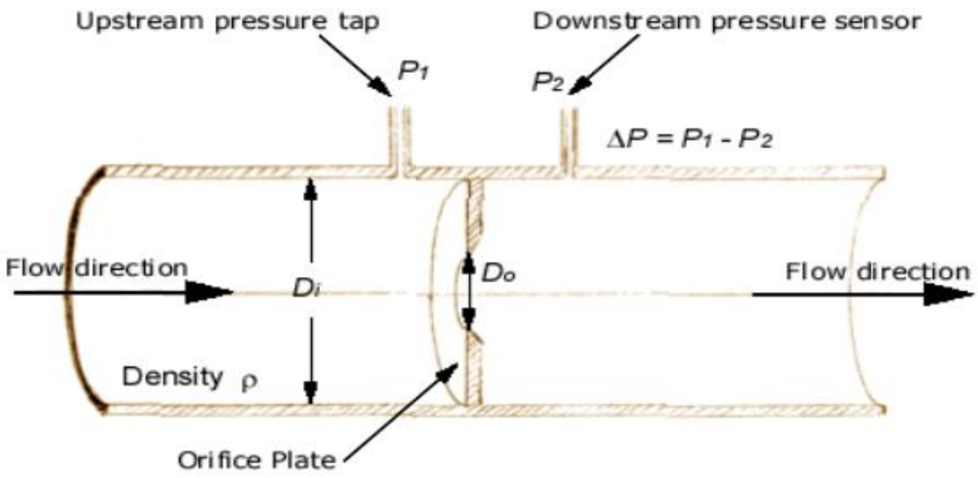
Hydronics Calculator



Pipe Pressure Loss Calculator



BTU Calculator



Inputs

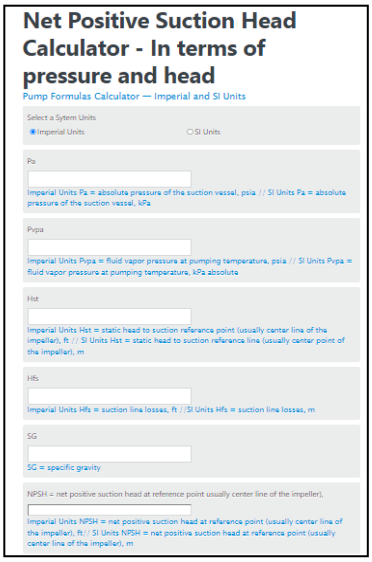
Pipe (inlet) diameter upstream of orifice, D_i:	8	in
Orifice diameter (less than the inlet diameter), D_o:	3	in
Pressure difference across the orifice, Δp:	20	psi
Fluid density, ρ:	835	kg/m^3
Flow Coefficient, C_f:	0.82	

Answers

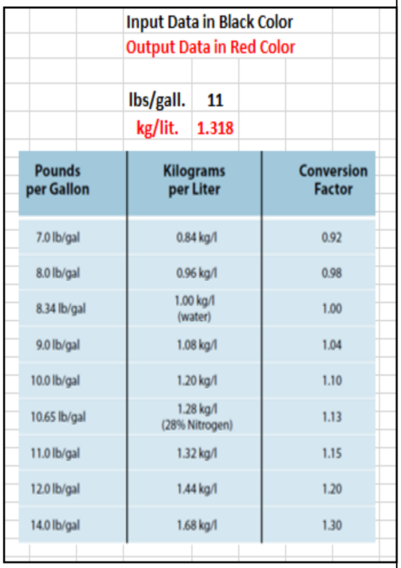
Velocity at the inlet, V_i:	2.10 m/s	m/s
Volumetric Flowrate, Q:	1080 gpm	gpm
Mass Flowrate:	56.7 kg/s	kg/s

Flow Rate through an Orifice or Valve Calculator

Net Positive Suction Head Calculator

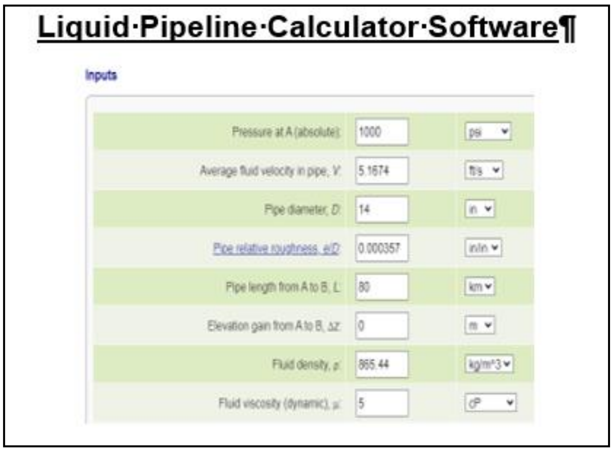


Net Positive Suction Head Calculator

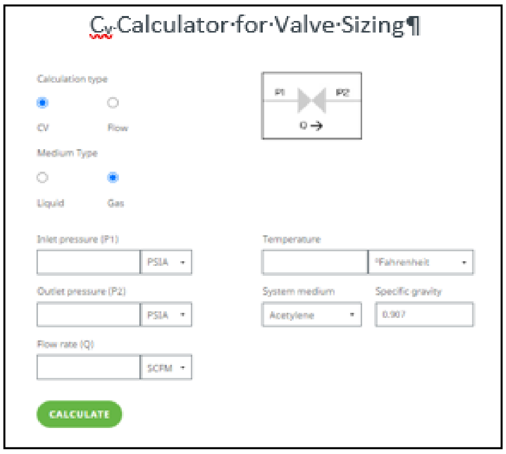


Pounds per Gallon	Kilograms per Liter	Conversion Factor
7.0 lb/gal	0.84 kg/l	0.92
8.0 lb/gal	0.96 kg/l	0.98
8.34 lb/gal	1.00 kg/l (water)	1.00
9.0 lb/gal	1.08 kg/l	1.04
10.0 lb/gal	1.20 kg/l	1.10
10.65 lb/gal	1.28 kg/l (28% Nitrogen)	1.13
11.0 lb/gal	1.32 kg/l	1.15
12.0 lb/gal	1.44 kg/l	1.20
14.0 lb/gal	1.68 kg/l	1.30

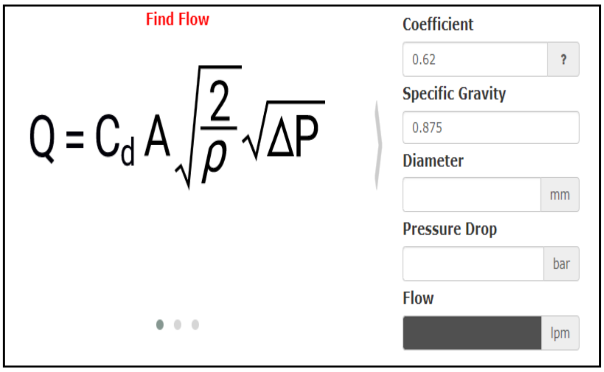
PPG to KG Calculator



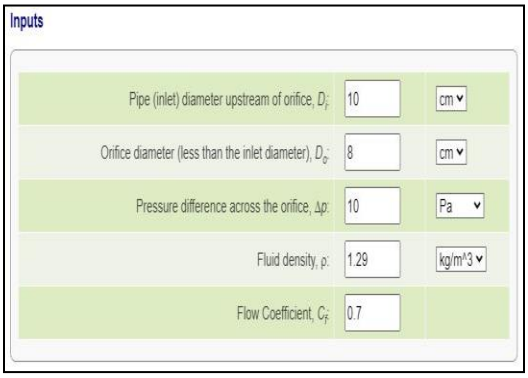
Liquid Pipeline Calculator



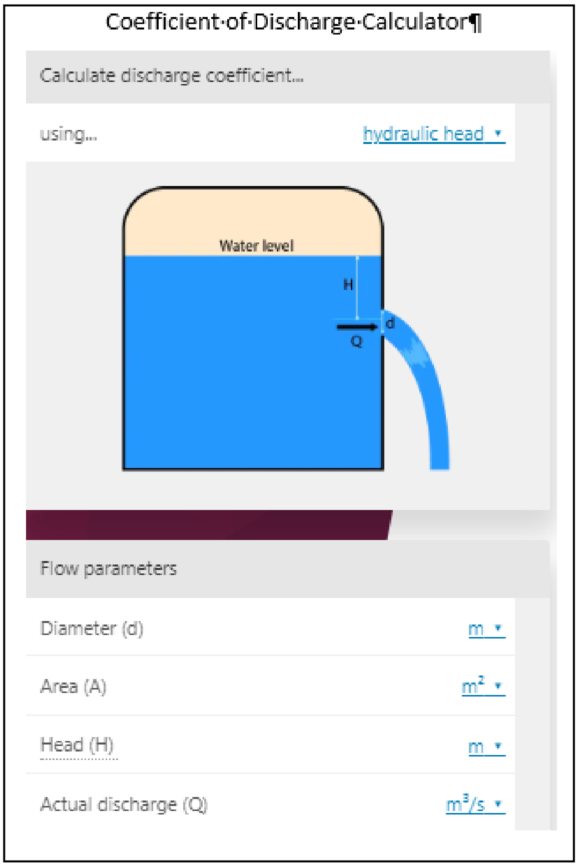
Cv Calculator



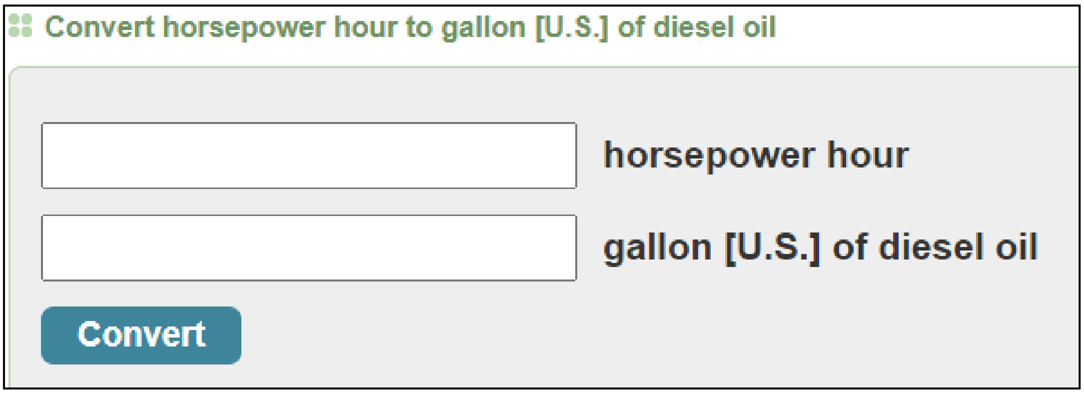
Find Flow Calculator



Flowrate Calculator



Coefficient Discharge Calculator



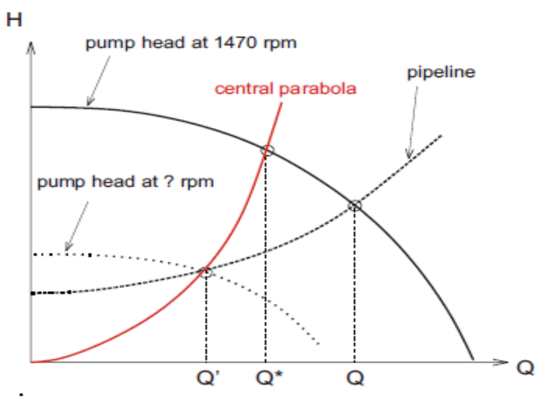
Horsepower Hour Calculator

Liquid Pumping Program

Input Data	
API	28
c.P.	5
1000 bbl/d	3.3
Length, km	2.4384
I.D., in.	2.800
Rough. (E), in.	0.005
Difference in elev., m	50
Destination press., psi	60
Pump Suc. psi	80
Overall Pump Eff., %	65
Motor Eff., %	90
Motor Loading %	80

Output Results	
Flow Velocity, ft/s	5.0154
Erosion Velocity, ft/s	13.440
E/I.D.	0.001786
sp.gr.	0.8871
Re	19290.3
F	0.02987
Hf, psi	153.67
Hf, m water	108.17
Total Pump Dich. psi	276.68
TDP, psi	196.68
Hydr. Power, HP	16.99
Hydr. Power, Kw	12.67
Shaft Power, HP	18.88
Shaft Power, Kw	14.083
Nama Plate Motor HP	23.60
Nama Plate Motor Kw	17.60

A pump running at $1470[rpm]$ with $H_{pump} = 45 - 2781Q^2$ head delivers water into a pipeline with $H_{pipe} = 20 + 1125Q^2$. Calculate the required revolution number for the reduced flow rate $Q' = 0.05[m^3/s]$.



Solution:

- The actual working point is given by the solution of $H_{pump} = H_{pipe}$, which gives $Q = 0.08[m^3/s]$ and $H = 27.2[m]$.
- Affinity states that while varying the revolutionary speed, H/n^2 and Q/n remain constant. Thus, also H/Q^2 remains constant, let's denote this constant by a. So, while varying the revolutionary speed, the working point moves along the *central parabola* (see figure), given by $H_{ap} = a\,Q^2$.

However, as Q' is given and we also know that this point has to be located on the pipeline characteristic, we know that $H' = 20 + 1125 \times 0.05^2 = 22.81[m]$. Thus, the parameter of the affine parabola is $a = H'/Q'^2 = 9125$.

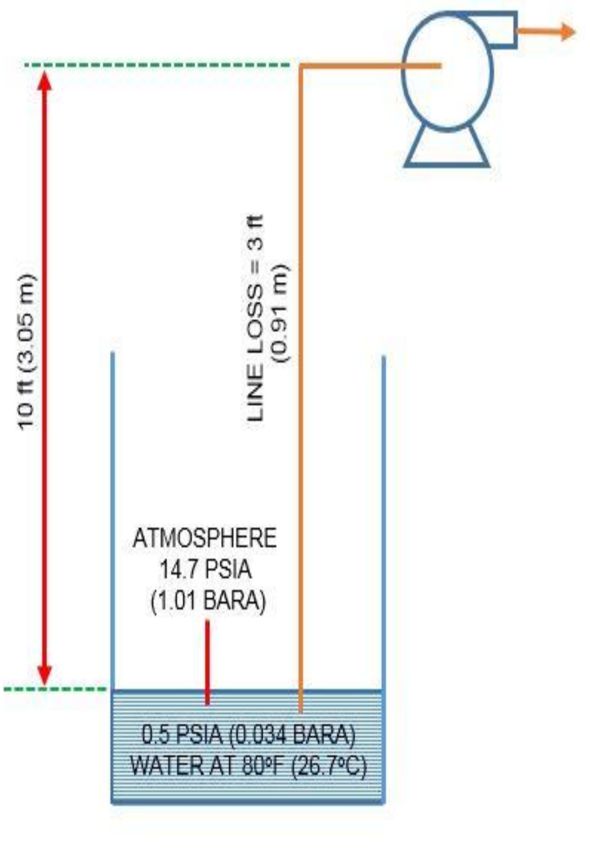
Q^* is given by the intersection of the affine parabola and the original pump characteristic: $H_{ap}(Q^*) = H_{pump}(Q^*)$, which gives $Q^* = 0.06148[m^3/s]$ with $H^* = 34.5[m]$.

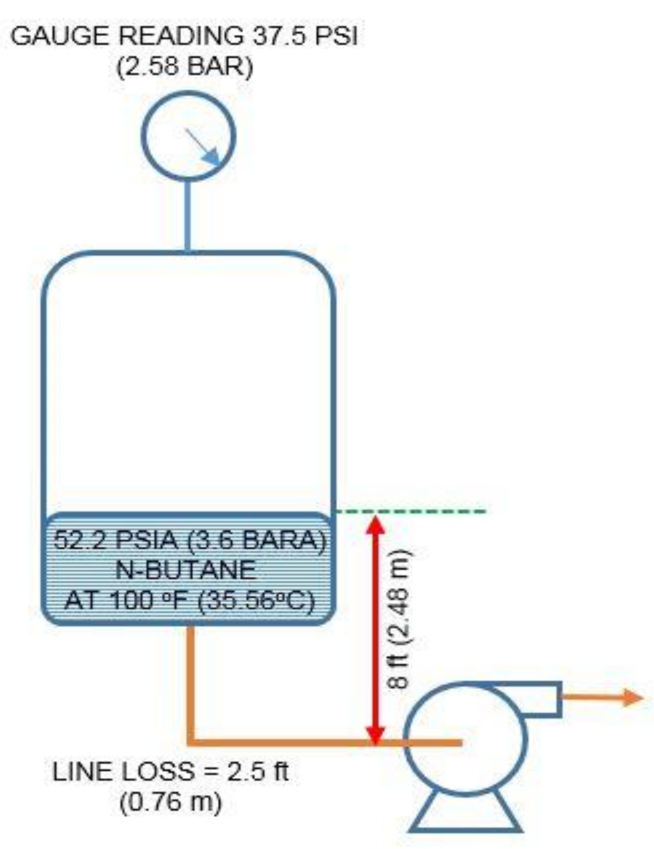
Now we can employ affinity between Q^* and Q':

$$n' = n^* \frac{Q'}{Q^*} = 1470 \times \frac{0.05}{0.06148} = 1195.5[rpm]$$

and just for checking the calculation

$$H' = H^* \left(\frac{n'}{n^*}\right)^2 = 34.5 \times \frac{1195.5^2}{1470^2} = 22.81[m].$$





NPSHA of pump – suction lift

NPSHA of pump – at boiling point
SG of n-butane at 100 deg F = 0.56

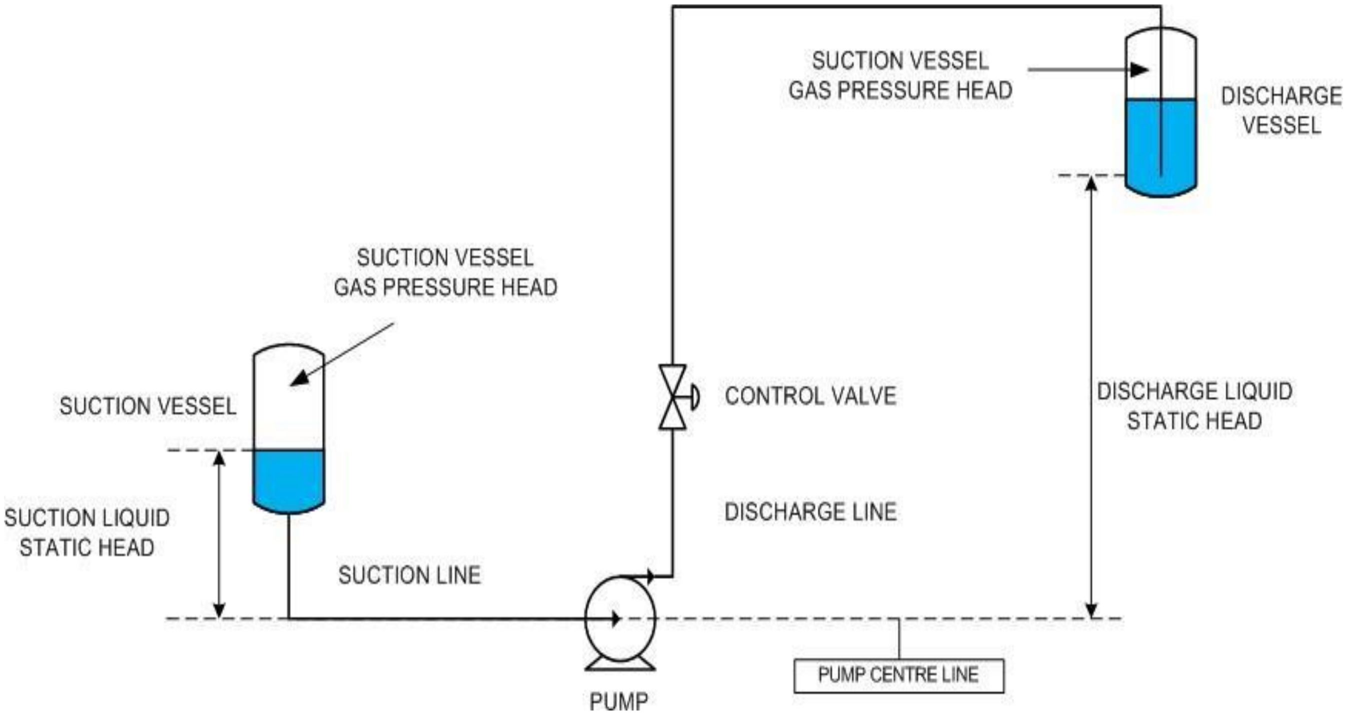
NPSHA = Hatmp.+/- Hs – Hf – Hvap.

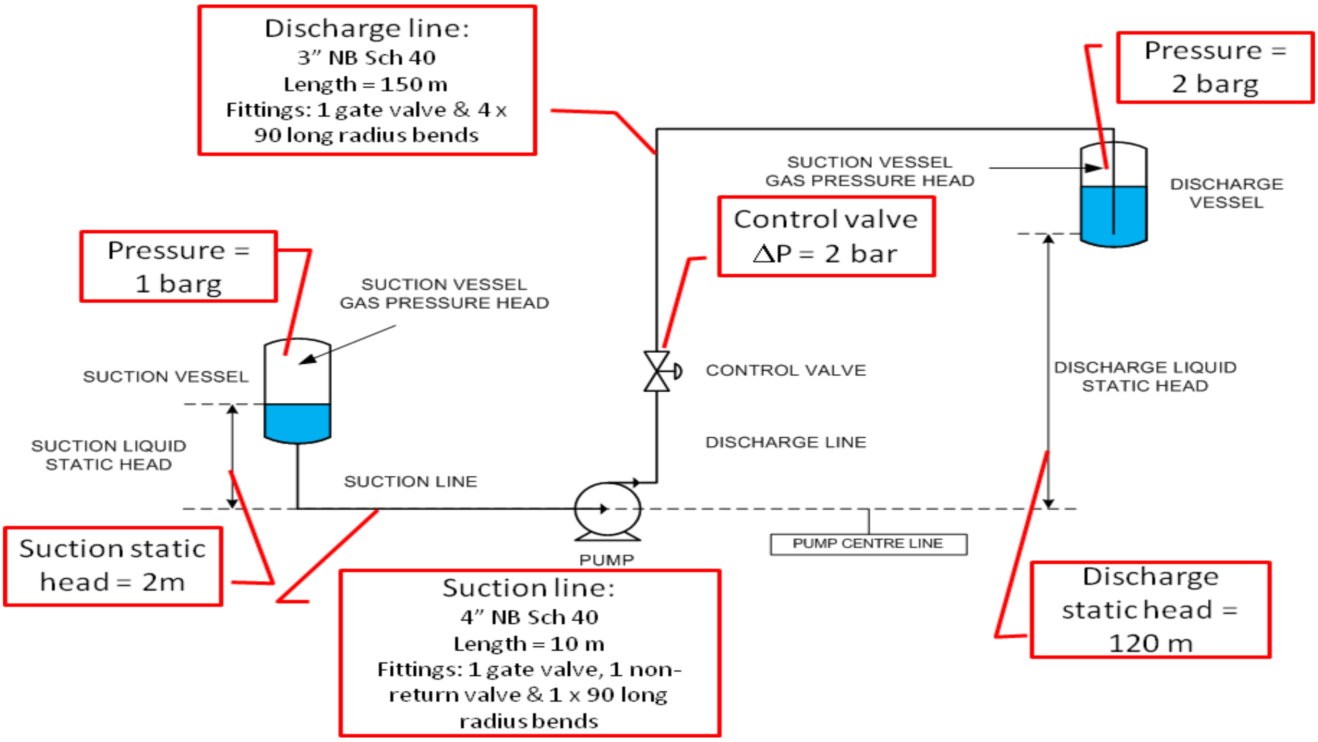
https://engineeringunits.com/net-positive-suction-head-calculator/?utm_content=cmp-true

http://www.pressure-drop.com/Online-Calculator/index.html

NPSH Calculations	
Input Data	
API	36
c.P.	3
Vapor pressure, psi	10
Atmp. Pressure, psi	14.7
Height above pump, ft	20
1000 bbl/d	2.0
Length, km	0.003
I.D., in.	2.992
Rough. (E), in.	0.005

Output Results	
Flow Velocity, ft/s	2.6620
E/I.D.	0.001671
sp.gr.	0.8448
Re	17363.9
F	0.0302
Hf, psi	0.048
Hf, ft water	0.111
NPSHA, ft oil	32.72
NPSHA, ft water	27.64


SUCTION VESSEL
GAS PRESSURE HEAD
DISCHARGE VESSEL
SUCTION VESSEL
GAS PRESSURE HEAD
SUCTION VESSEL
CONTROL VALVE
DISCHARGE LIQUID
STATIC HEAD
DISCHARGE LINE
SUCTION LIQUID
STATIC HEAD
SUCTION LINE
PUMP CENTRE LINE
PUMP


Discharge line:
3" NB Sch 40
Length = 150 m
Fittings: 1 gate valve & 4 x 90 long radius bends
Pressure = 2 barg
SUCTION VESSEL
GAS PRESSURE HEAD
DISCHARGE VESSEL
Control valve
ΔP = 2 bar
Pressure = 1 barg
SUCTION VESSEL
GAS PRESSURE HEAD
SUCTION VESSEL
CONTROL VALVE
DISCHARGE LIQUID
STATIC HEAD
DISCHARGE LINE
SUCTION LIQUID
STATIC HEAD
SUCTION LINE
PUMP CENTRE LINE
PUMP
Suction static head = 2m
Suction line:
4" NB Sch 40
Length = 10 m
Fittings: 1 gate valve, 1 non-return valve & 1 x 90 long radius bends
Discharge static head = 120 m

Calculator

PUMP DETAILS

Pump tag number		P-001	
Suction vessel tag number		V-001	
Discharge vessel tag number		V-002	
Barometric pressure	P_{atm}	1.013	bara
NPSH available margin	H_{margin}	0	m
Pump efficiency	η	70%	

FLUID PROPERTIES

Fluid		Water	
Phase		Liquid	
Flowrate	m	30000	kg/hr
Density	ρ	998	kg/m3
Viscosity	μ	1	cP
Vapour pressure	P_{vap}	0.023	bara

VESSEL GAS PRESSURES

Suction vessel gas pressure	$P_{suc.\_vessel}$	1	barg
Discharge vessel gas pressure	$P_{dis.\_vessel}$	2	barg

STATIC HEADS

Suction static head	$H_{suc.\_static\_head}$	2	m
Discharge static head	$H_{dis.\_static\_head}$	120	m

PIPELINES

		Suction Line	Discharge Line	
Pipe nominal diameter		4	3	inch
Pipe schedule		Sch 40	Sch 40	
Pipe internal diameter	d	102.26	77.92	mm
Pipe length	L	10	150	m
Absolute roughness	e	0.046	0.046	mm

OUTPUTS

Volumetric flow rate Q 30.060 m3/hr

		Suction Line	Discharge Line	
Relative roughness	e:d	0.00045	0.00059	
Flow area	A	0.00821	0.00477	m2
Velocity	u	1.02	1.75	m/s
Reynolds No.	Re	103758	136170	
Flow regime		turbulent	turbulent	
Friction factor	f	0.02011	0.02010	
Pipe velocity head loss	K_{pipe}	1.966	38.695	
Fittings total velocity head loss	$K_{fittings}$	1.724	2.152	
Frictional pressure loss	$\Delta P_{friction}$	0.02	0.62	bar
Frictional head loss	$H_{friction}$	0.19	6.38	m

Pump suction pressure	$P_{suction}$	2.19 bara
Pump suction head	$H_{suction}$	22.37 m
Pump discharge pressure	$P_{discharge}$	15.39 bara
Pump discharge head	$H_{discharge}$	157.16 m
Net positive suction pressure available	P_{NPSHA}	2.17 bara
Net positive suction head available	NPSHa	22.13 m
Pump total differential pressure	ΔP_{pump}	**13.20 bar**
Pump total differential head	H_{pump}	**134.79 m**
Pump absorbed power	E	**15.74 kW**

Results of above calculations may be confirmed through either of followinglinks:
https://www.swagelok.com/en/toolbox/cv-calculator

https://experttoolsonline.com/danfoss/orifice_calculator

https://www.efunda.com/formulae/fluids/calc_orifice_flowmeter.cfm

https://www.omnicalculator.com/physics/coefficient-of-discharge

Power Calculations:
https://inventory.powerzone.com/resources/centrifugal-pump-power-calculator/%3Aflu%3DGPM%3Apru%3DHEAD%20FT%3Apu%3DHP

http://irrigation.wsu.edu/Content/Calculators/General/Required-Water-Pump-HP.php

Required Compressor Horsepower
https://www.engineeringtoolbox.com/horsepower-compressed-air-d_1363.html

Input Data	
T1, F	60
K	1.35
P1, psi	14.7
P2, psi	500
Gas sp.gr.	1
No. of Comp. stages	3
Gas million SCMD	1.5
Eff. of Gas Comp., %	85
Eff. of Driving Motor, %	90

Output Results	
Compression Ratio	34.014
Cp, J/kg/K	1107
Gas, cfm	36791.50
Gas, kg/s	21.250
Theoretical Power, HP	9731.847
Total Required HP	12721.37

Heater Duty
https://www.advantageengineering.com/fyi/288/advantageFYI288.php

Input Data	
Million BTU/hr.	0.75
API	10.0
Specific Heat, BTU/lb/F	1.00
Delta Temp., F	60
Heater Eff., %	100

Output Results	
Delta Temp., C	15.6
Mega Watt	0.220
Billion Joule/hr.	0.791
gpm	25.0
gallon/hr.	1498.4
Lit./min.	94.5
m3/hr.	5.7
1000 bbl/d	0.856
Required Diesel Lit./day	502.90
Required Diesel bbl/d	3.16
Required Gas, 1000 ft3/d	16.364
Required crude oil, bbl/d	3.268

https://www.enggcyclopedia.com/2011/09/problem-solving-heat-exchanger-tubeside-pressure-drop-calculation/

Input Data		Output Results	
Mass Flow Rate, kg/hr.	2000.0	cm3/s	562.303
Fluid Density, Kg/m3	988.0	V, cm/s	110.9720
Visc., c.P.	0.53	Re	52544.59
Pipe Diameter (D), in.	1	f	0.0261
Roughness (E), mm	0.045	Total Hf, cm (per single tube)	22.5583
Tube Length, m	3.5	Total Hf, psi (per single tube)	0.3166
No. of tubes	1	Total Hf, bar (per single tube)	0.0218

Heat exchanger tube side pressure drop calculation

Calculate the tube side pressure drop for the following heat exchanger specification,

Process fluid = water

Inlet pressure = 4 barg

Inlet temperature = 50^0C

Outlet temperature = 30^0C

Tubeside flowrate = 50000 kg/hr

Number of tubes = 25

Tube ID (internal diameter) = 1 inch

Tube length = 3.5 m

Total volumetric flow = 50000 kg/hr ÷ 988.0 kg/m^3 = 50.61 m^3/hr Volumetric flow in each 1" tube = 50.61 ÷ 25 = 2.02 m^3/hr Pressure loss per unit length of the tube is then calculated using EnggCyclopedia's pressure drop calculators for pipes and tubes. This calculator is based on Darcy-Weisbach equation.

Pressure loss across a single tube (ΔP/L) = 6.17 bar/km

SINGLE PHASEFLOW INPUTS

W – Mass flow capacity	2000	kg/h
ρ – Density of fluid	988	kg/m^3
μ – Viscosity of fluid (either liquid or gas)	0.53	cP
PIPE SPECIFICATIONS		
e – Effective roughness of the pipe	0.045	mm
d – Nominal diameter of the pipe	1	inches
sch – pipe schedule	STD	
Calculate pressure loss	Reset	
RESULTS		
Fluid Velocity	1.110	m/s
Volumetric flow	2.02	m^3/hr
Reynold's No.	52557.9	
Pressure loss	6.1715	bar/km

Tube length (L) = 3.5 m

Tubeside pressure drop (ΔP) = 6.17 × 3.5 / 1000 = 0.0216 bar

Another alternative is to directly use EnggCyclopedia's Heat Exchanger Tube side Pressure Drop Calculator. All the inputs given in the sample problem statements are given to the calculator and pressure drop across the tubeside is calculated as output. This calculator uses the same basic steps discussed above and hence the answer also matches with the figure above (0.0216 bar) . The following image is a snapshot of this direct calculation of tubeside pressure drop.

Exchanger tubeside pressure drop

Tubeside inputs		
Total tubeside mass flow	50000	kg/hr
Tubeside Density	988	kg/m^3
Tubeside Viscosity	0.53	cP
Number of tubes	25	
Total tube length (accounting for all tube passes)	3.5	m
Tube nominal diameter	1	inches
Tubeside roughness	0.045	mm
Calculate pressure drop	Reset	
Results		
Tubeside pressure drop	0.0216	bar

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