# COURSE OVERVIEW PE0531
# Flare, Blowdown & Pressure Relief Systems

## Course Title
Flare, Blowdown & Pressure Relief Systems

## Course Date/Venue
December 08-12, 2024/Abu Dhabi
Meeting Room, The Tower Plaza Hotel, Dubai, UAE

3.0 CEUs (30 PDHs) AWARD

## Course Reference
PE0531

H-STK© INCLUDED

## 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 flare, blowdown and pressure relief systems are the most important elements for emergency and operational discharge of flammable substances in the process facilities. Safety relief and flare systems control vapors and liquids that are released by pressure-relieving devices and blow-downs. Pressure relief is an automatic, planned release when operating pressure reaches a predetermined level. Blowdown normally refers to the intentional release of material, such as blowdowns from process unit start-ups, furnace blowdowns, shutdowns, and emergencies. Vapor depressuring is the rapid removal of vapors from pressure vessels in case of fire. This may be accomplished by the use of a rupture disc, usually set at a higher pressure than the relief valve.

The principal elements of the safety relief and flare systems are the individual pressure relief devices, the flare piping system, the flare separator drum, and the flare (including igniters, tips, sealing devices, purge and steam injection for smokeless burning). Application of relief devices must comply with appropriate ASME Vessel Codes and API 520/521 standards.

Design of relief devices must comply with applicable national codes and laws as well as the requirements of the insurance covering the plant or installation. National regulations not only cover safety but also environmental considerations such as air and water pollution and noise abatement.

This course presents a convenient overview of relief system details based on the full scope of API, ASME, and other code and specification requirements. It covers all aspects of relief flare systems from the emergency relief sources through the valving and flare network right to the stack and flare tip. Descriptions and design criteria will be outlined for flare tips, seals, stacks, knockout drums, header systems, relief valves, depressurization systems and basic hazard analysis. Alternative design methods will be also described with reference to the specific nature of relief and flare systems worldwide.

## Course Objectives

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

- Apply an in-depth knowledge and skills in the design, operation and maintenance of flare, blowdown and pressure relief systems
- Discuss product specification and identify the different types of flow measurement
- Review the various instrumentation and sensing devices used in flare, blowdown and pressure relief systems
- Carryout installation, troubleshooting and calibration of the control systems used in plant
- Determine the components and function of the relief systems and practice the sizing and installation of the relieving devices
- Identify the types, features and application of flare systems
- Determine the applicable codes, standards and recommended practices for flare, blowdown and pressure relief systems
- Acquire knowledge on product storage and tanks and recognize the importance of product recovery
- Evaluate the scope of waste heat recovery and explain its role in flare and pressure relief systems
- Operate, maintain and troubleshoot flare, blowdown and pressure relief system in a professional manner

## 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 systematic techniques on the design, operation and maintenance of flare, blowdown and pressure relief systems. Operations personnel, supervisors, engineers, maintenance personnel, senior plant supervisors, operations process support engineers, design engineers and process engineers will gain an outstanding knowledge from the practical and operational aspects of the course.

## 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, PgDip, BSc, is a **Senior Process & Petroleum Engineer** with **40 years** of integrated experience within the **Oil & Gas** industries. His specialization widely covers in the areas of **Artificial Lift** System, **Artificial Lift** Methods, **Petroleum Economics**, **Petroleum Refinery Processing**, **Refinery** Material Balance Calculation, **Refinery** Gas Treating, **Asset Operational Integrity**, **Drilling** Operations, **Drilling Rig**, **Bits & BHA**, **Mud Pumps, Mud logging** Services, **Wireline & LWD Sensors**, **Casing & Cementing** Operation, **Completion & Workover** Operations, **Petroleum** Engineering, **Production Optimization**, **Well Completion**, **Rig & Rigless Workover**, Advanced **PVT & EOS Characterization**, **PVT/Fluid Characterization/EOS**, Advanced **Phase Behaviour & EOS Fluid Characterization**, **PVT Properties of Reservoir Fluids**, **Directional Drilling** Fundamentals, Application & Limitation, **Horizontal & Multilateral Wells** (Analysis & Design), **Directional**, **Horizontal & Multilateral Drilling**, Root Cause Analysis (**RCA**), Root Cause Failure Analysis (**RCFA**), **Root Cause Analysis** Study, **Root Cause Analysis** Techniques & Methodologies, Process Hazard Analysis (**PHA**), **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** from Agiba Petroleum Company and **Engineering Consultant/Instructor** for various Oil & Gas companies as well as a **Senior Instructor/Lecturer** for **PhD, Master & BSc degree students** from **various universities** such as the Cairo University, Helwan University, British University in Egypt, Banha University.

Dr. Hesham has **PhD** and **Master** degrees as well as **Post Graduate Diploma** 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 an active 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.

## 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 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, 08th of December 2024*** |
|---|---|
| *0730 – 0800* | *Registration & Coffee* |
| *0800 – 0815* | *Welcome & Introduction* |
| *0815 – 0830* | ***PRE-TEST*** |
| *0830 – 0930* | ***Product Specification***<br>*LP-Gas Specification Parameters • Vapor Pressure • Moisture Content • Sulfur Content • Volatile Residue • Non-Volatile Residue • Non-Specification Contaminants • Odorization* |
| *0930 – 0945* | *Break* |
| *0945 – 1100* | ***Flow Measurement***<br>*Flow Calculation Guide • Gas Measurement & Pipe Rupture • Liquid Measurement • Mass Measurement • Steam Measurement • Miscellaneous Measurement Devices • Auxiliary Equipment and Common Terms* |
| *1100 – 1230* | ***Instrumentation & Sensing Devices***<br>*General Instrumentation Considerations • Identification • Pneumatic Power Supplies • Electronic Power Supplies • Pressure Sensors • Level Sensors • Temperature Sensors • Flow Sensors • Signal Transmitters • Pneumatic Transmitters • Electronic Transmitters • Signal Converters • Recorders and Indicators* |
| *1230 – 1245* | *Break* |

| | |
|---|---|
| 1245 – 1420 | ***Control Systems***<br>*Control Concepts ● Control Modes and Controllers ● Controller Tuning ● Control Valves ● Liquid Service ● Sizing Calculation Procedure ● Installation, Troubleshooting, and Calibration ● Digital Computers ● Digital First-Level Control Systems ● Analytical Instruments* |
| 1420 – 1430 | ***Recap***<br>*Using this Course Overview, the Instructor(s) will Brief Participants about the Topics that were Discussed Today and Advise Them of the Topics to be Discussed Tomorrow* |
| 1430 | *Lunch & End of Day One* |

**Day 2** **Monday, 09th of December 2024**

| | |
|---|---|
| 0730 – 0930 | ***Relief Systems***<br>*Relief Device Design ● Blocked Discharge ● Fire Exposure ● Tube Rupture* |
| 0930 – 0945 | *Break* |
| 0945 – 1115 | ***Relief Systems (cont'd)***<br>*Control Valve Failure ● Thermal Expansion ● Utility Failure* |
| 1115 – 1230 | ***Relieving Devices***<br>*Safety Relief Valves ● Rupture Disk ● Sizing of Relief Devices* |
| 1230 – 1245 | *Break* |
| 1245 – 1420 | ***Relieving Devices (cont'd)***<br>*Relief Valve Installation ● Relief System Piping Design ● Knockout Drums* |
| 1420 – 1430 | ***Recap*** |
| 1430 | *Lunch & End of Day Two* |

**Day 3** **Tuesday, 10th of December 2024**

| | |
|---|---|
| 0730 – 0930 | ***Flare Systems***<br>*Types of Flare Systems ● Thermal Radiation ● Smokeless Operation ● Pilots and Ignition* |
| 0930 – 0945 | *Break* |
| 0945 – 1115 | ***Flare Systems (cont'd)***<br>*Seals ● Location and Regulations ● Special Relief System Considerations ● Low Temperature Flaring* |
| 1115 – 1230 | ***Applicable Codes, Standards & Recommended Practices***<br>*ASME Codes ● ANSI Codes ● API Publications* |
| 1230 – 1245 | *Break* |
| 1245 – 1420 | ***Applicable Codes, Standards & Recommended Practices (cont'd)***<br>*NFPA Publications ● OSHA Publications ● CGA (Compressed Gas Association) Publications* |
| 1420 – 1430 | ***Recap*** |
| 1430 | *Lunch & End of Day Three* |

**Day 4** **Wednesday, 11th of December 2024**

| | |
|---|---|
| 0730 – 0930 | ***Product Storage & Tanks***<br>*Storage Classification ● Working Pressures ● Types of Storage ● Materials of Construction ● Protective Coatings ● Insulation ● Appurtenances ● Site Preparation and Installation ● Cathodic Protection* |
| 0930 – 0945 | *Break* |
| 0945 – 1100 | ***Product Recovery***<br>*Product Losses ● Vapor Recovery Systems ● Separators and Filters ● Fired Equipment ● Hot Oil System* |

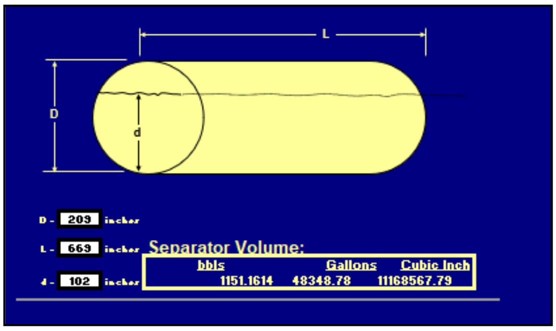
| | |
|---|---|
| 1100 – 1230 | ***Waste Heat Recovery***<br>*Heat Exchangers Overview ● Heat Balances ● Shell and Tube Exchangers ● Fouling Resistances ● Film Resistances ● Performance Evaluation with Sensible Heat Transfer ● Condensers* |
| 1230 – 1245 | *Break* |
| 1245 – 1420 | ***Waste Heat Recovery***<br>*Reboilers and Vaporizers ● Selection of Exchanger Components ● Nomenclature ● Shell Size and Tube Count Estimation ● Operating Characteristics ● Inlet Gas Exchanger ● Hairpin Heat Exchangers* |
| 1420 – 1430 | ***Recap*** |
| 1430 | *Lunch & End of Day Four* |

**Day 5 Thursday, 12th of December 2024**

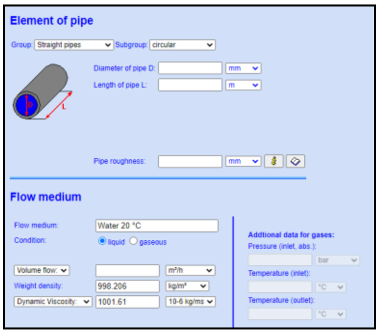
| | |
|---|---|
| 0730 – 0930 | ***Operation, Maintenance & Troubleshooting*** |
| 0930 – 0945 | *Break* |
| 0945 – 1100 | ***Operation, Maintenance & Troubleshooting (cont'd)*** |
| 1100 – 1230 | ***Operation, Maintenance & Troubleshooting (cont'd)*** |
| 1230 – 1245 | *Break* |
| 1245 – 1345 | ***Operation, Maintenance & Troubleshooting (cont'd)*** |
| 1345 – 1400 | ***Course Conclusion*** |
| 1400 – 1415 | ***POST-TEST*** |
| 1415 – 1430 | *Presentation of Course Certificates* |
| 1430 | *Lunch & End of Course* |

**Simulator (Hands-on Practical Sessions)**

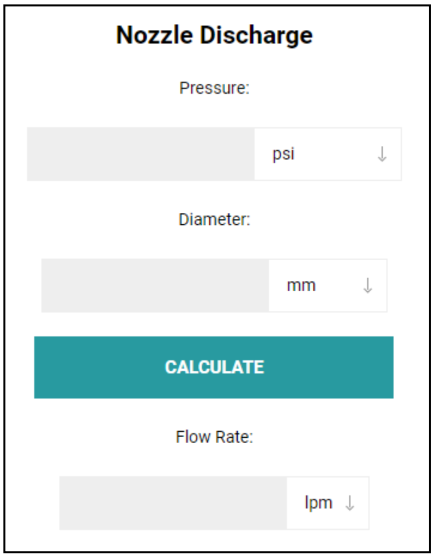
Practical sessions will be organized during the course for delegates to practice the theory learnt. Delegates will be provided with an opportunity to carryout various exercises using various online system calculator.



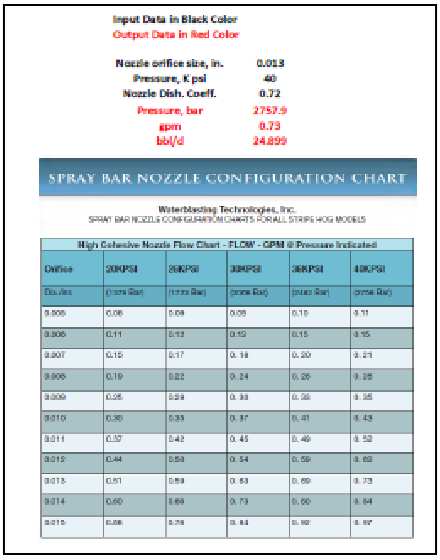

**Tank Volume Calculator**



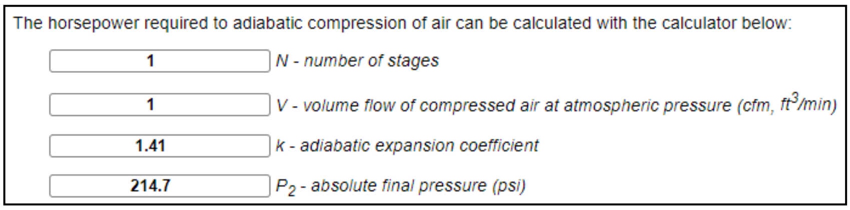

**Pressure Drop Online-Calculator**




**Nozzle Discharge**

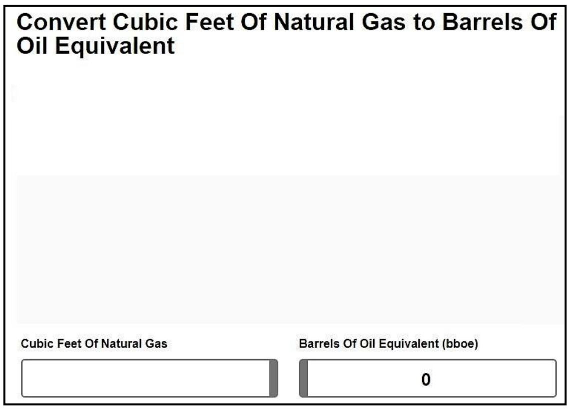



**Nozzle Calculator**

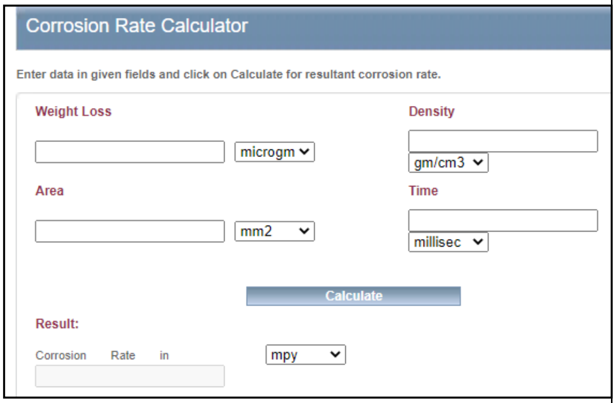



**Horsepower Calculator**

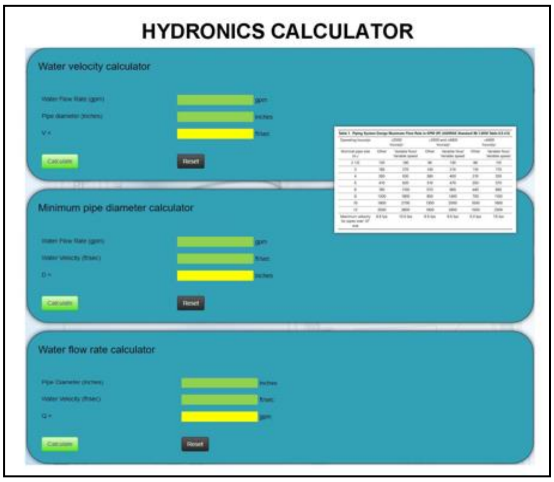

**Water Flow Rate through an Orifice Calculator**



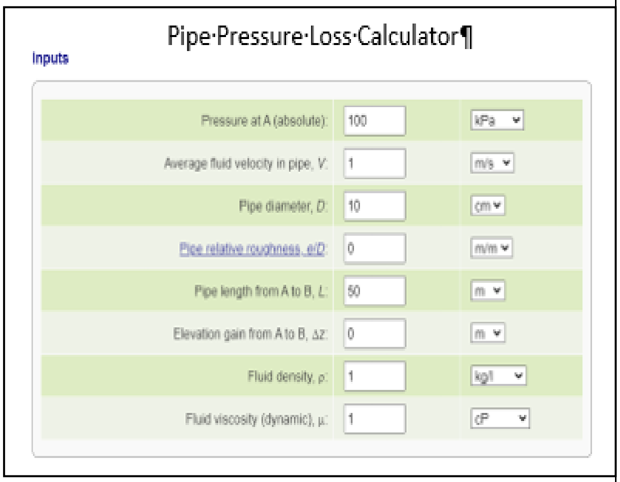

**Cubic Feet Calculator**



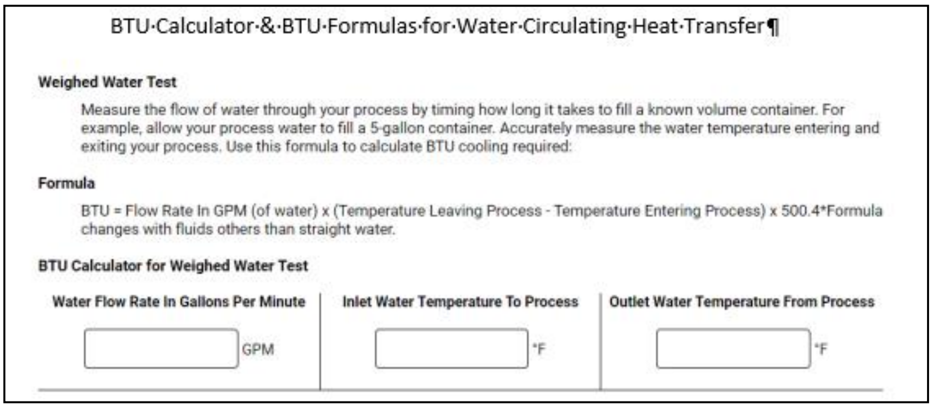

**Corrosion Rate Calculator**



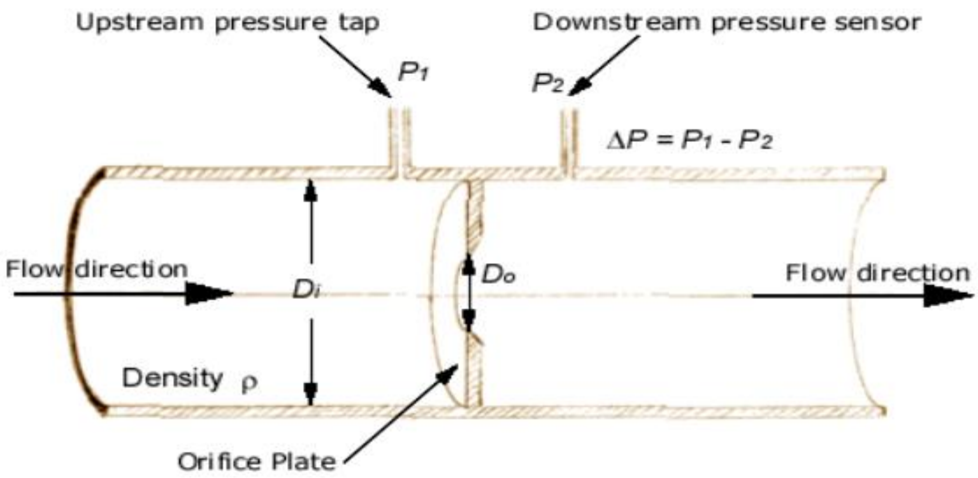

**Hydronics Calculator**




**Pipe Pressure Loss Calculator**




**BTU Calculator**




## Inputs

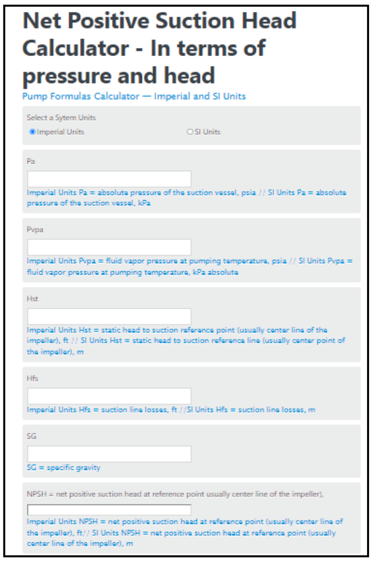
| | | |
|---|---|---|
| Pipe (inlet) diameter upstream of orifice, $D_i$: | 8 | in |
| Orifice diameter (less than the inlet diameter), $D_o$: | 3 | in |
| Pressure difference across the orifice, $\Delta p$: | 20 | psi |
| Fluid density, ρ: | 835 | kg/m^3 |
| Flow Coefficient, $C_f$: | 0.82 | |

## Answers

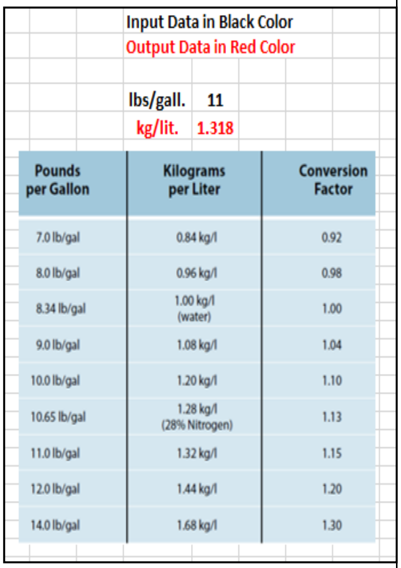
| | | |
|---|---|---|
| Velocity at the inlet, $V_i$: | 2.10 m/s | m/s |
| Volumetric Flowrate, $Q$: | 1080 gpm | gpm |
| Mass Flowrate: | 56.7 kg/s | kg/s |

**Flow Rate through an Orifice or Valve Calculator**


Net Positive Suction Head Calculator

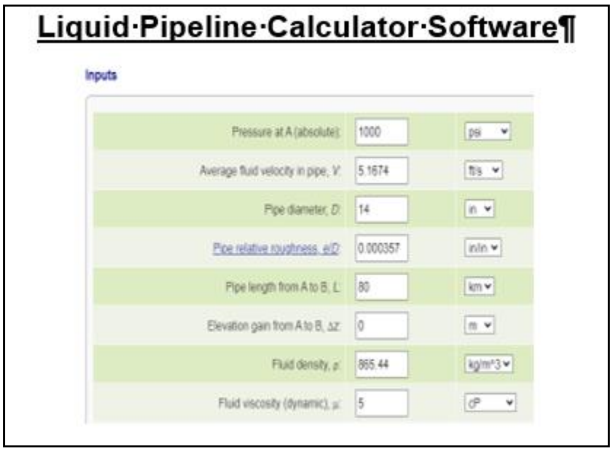



Net Positive Suction Head Calculator

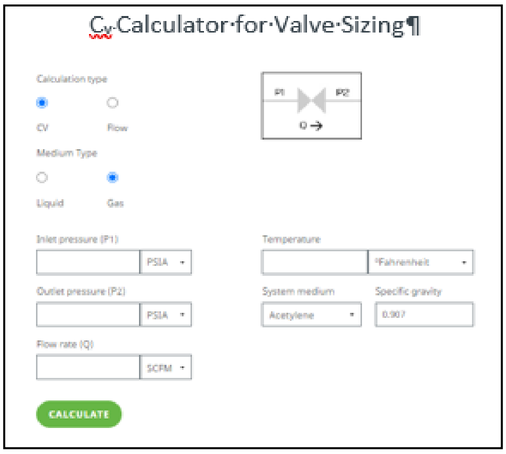



| Pounds per Gallon | Kilograms per Liter | Conversion Factor |
|---|---|---|
| 7.0 lb/gal | 0.84 kg/l | 0.92 |
| 8.0 lb/gal | 0.96 kg/l | 0.98 |
| 8.34 lb/gal | 1.00 kg/l (water) | 1.00 |
| 9.0 lb/gal | 1.08 kg/l | 1.04 |
| 10.0 lb/gal | 1.20 kg/l | 1.10 |
| 10.65 lb/gal | 1.28 kg/l (28% Nitrogen) | 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 |

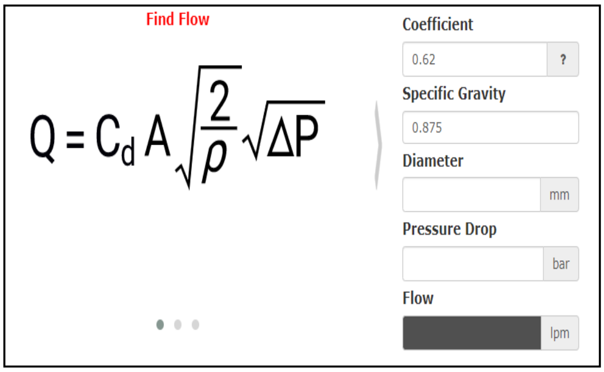
PPG to KG Calculator



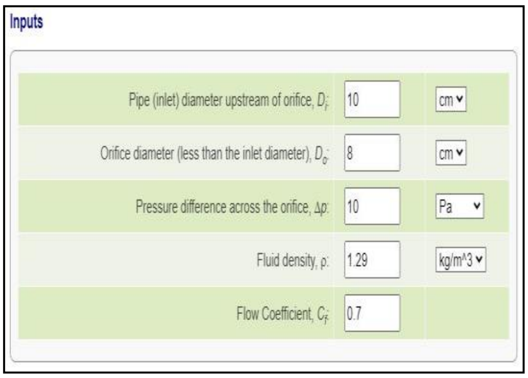

Liquid Pipeline Calculator



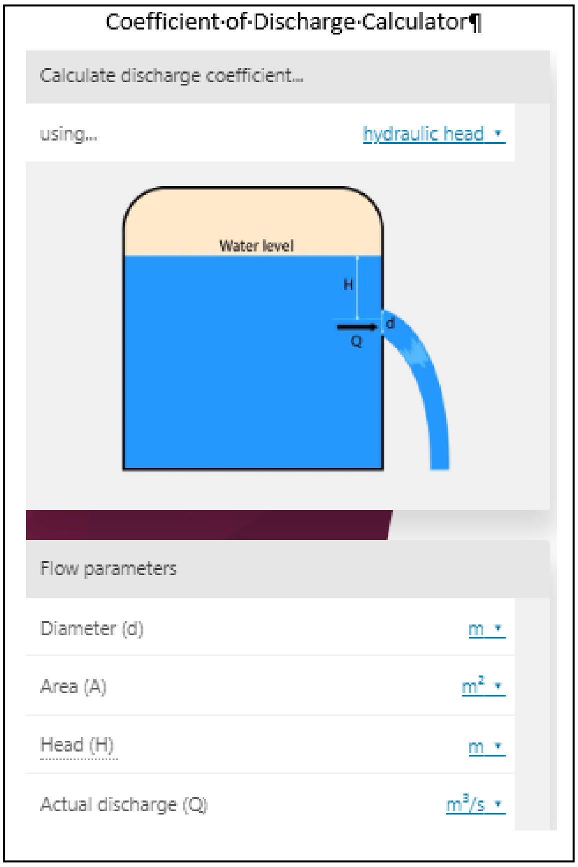

Cv Calculator



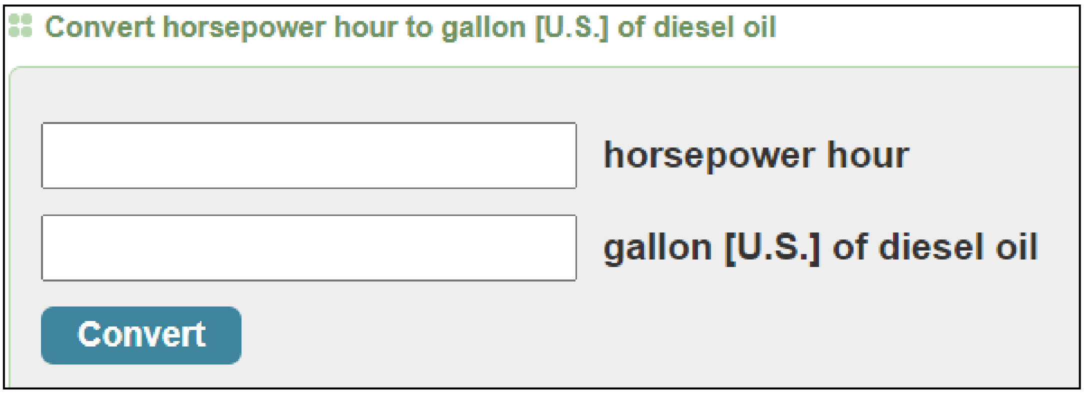

Find Flow Calculator




Flowrate Calculator




**Coefficient Discharge Calculator**

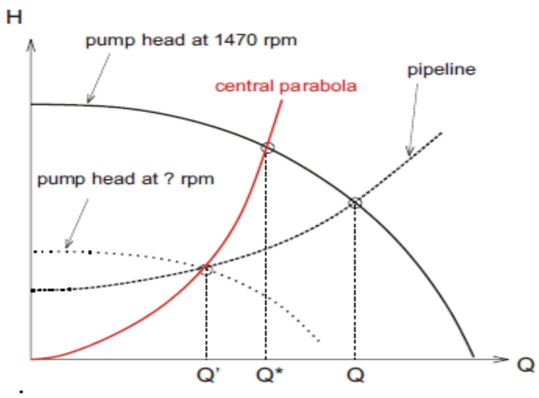



**Horsepower Hour Calculator**

| 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 $a = H'/Q'^2 = 9125$.

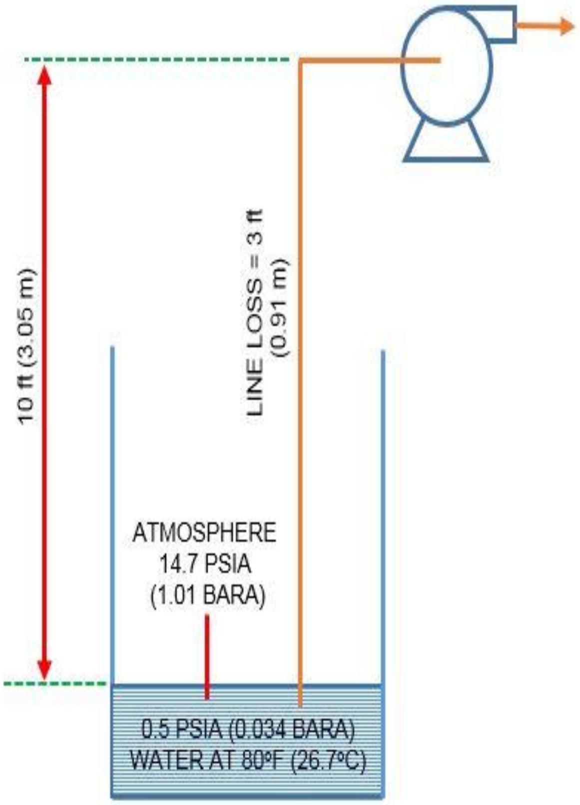
$Q^*$ is given by the intersection of the affine parabola and the original pump characteristic: $H_{ap}(Q^*) = H_{pump}(Q^*)$, which gives $Q^* = 0.06148[m^3/s]$ with $H^* = 34.5[m]$.

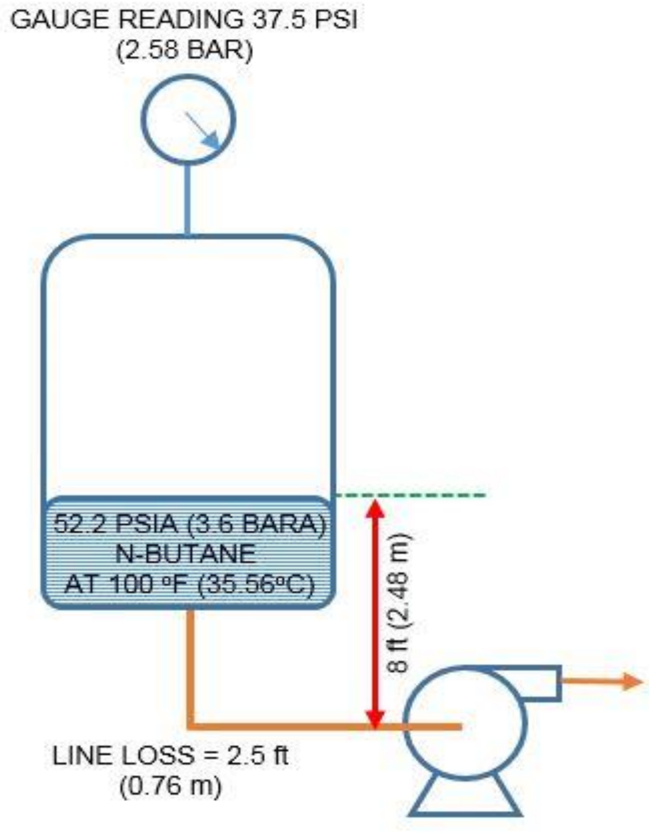
Now we can employ affinity between $Q^*$ and $Q'$:

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

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.**

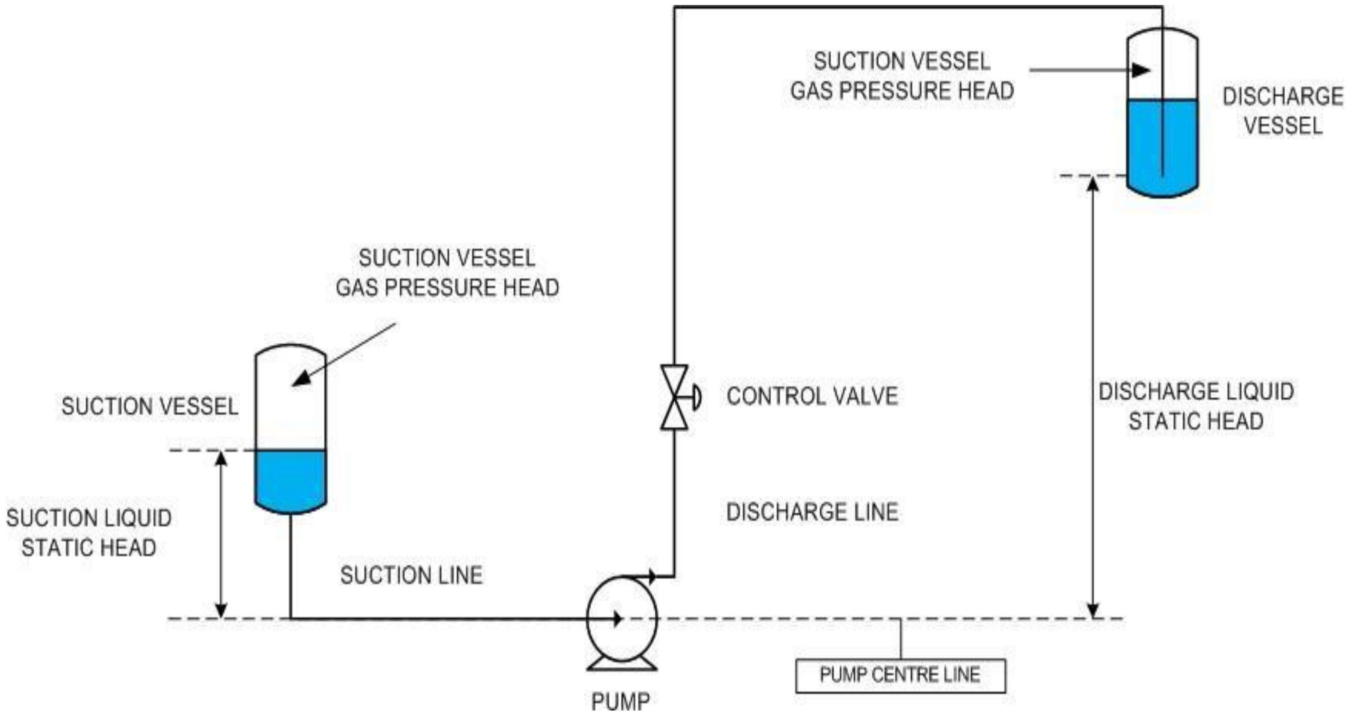
https://engineeringunits.com/net-positive-suction-head-calculator/?utm_content=cmp-true

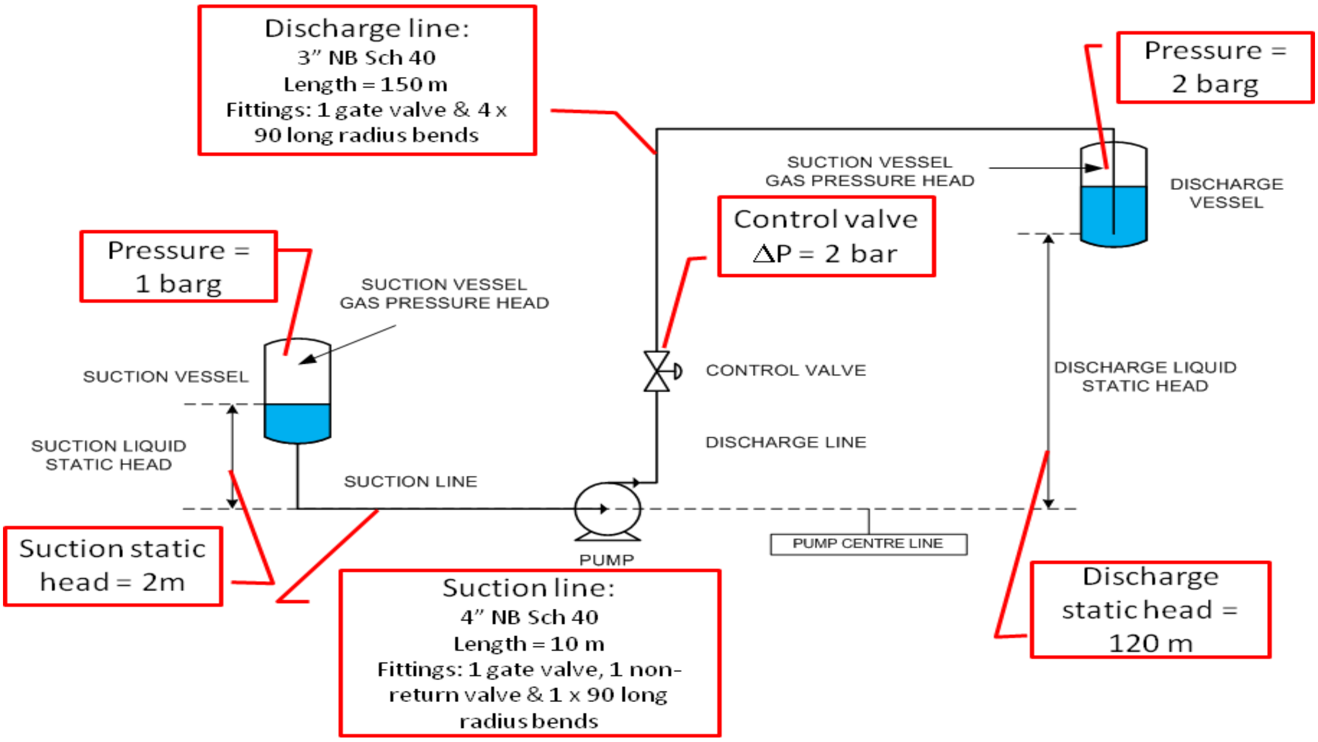
http://www.pressure-drop.com/Online-Calculator/index.html

## 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 |






## 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 | $\eta$ | 70% | |

### FLUID PROPERTIES

| | | | |
|---|---|---|---|
| Fluid | | Water | |
| Phase | | Liquid | |
| Flowrate | m | 30000 | kg/hr |
| Density | $\rho$ | 998 | kg/m3 |
| Viscosity | $\mu$ | 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** | $\Delta P_{pump}$ | **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 | | Output Results | |
|---|---|---|---|
| T1, F | 60 | Compression Ratio | 34.014 |
| K | 1.35 | Cp, J/kg/K | 1107 |
| P1, psi | 14.7 | Gas, cfm | 36791.50 |
| P2, psi | 500 | Gas, kg/s | 21.250 |
| Gas sp.gr. | 1 | Theoretical Power, HP | 9731.847 |
| No. of Comp. stages | 3 | Total Required HP | 12721.37 |
| Gas million SCMD | 1.5 | | |
| Eff. of Gas Comp., % | 85 | | |
| Eff. of Driving Motor, % | 90 | | |

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

| Input Data | | Output Results | |
|---|---|---|---|
| Million BTU/hr. | 0.75 | Delta Temp., C | 15.6 |
| API | 10.0 | Mega Watt | 0.220 |
| Specific Heat, BTU/lb/F | 1.00 | Billion Joule/hr. | 0.791 |
| Delta Temp., F | 60 | gpm | 25.0 |
| Heater Eff., % | 100 | 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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