## COURSE OVERVIEW ME0398
# Pumps, Compressors, Turbines & Troubleshooting

**Course Title**
Pumps, Compressors, Turbines & Troubleshooting

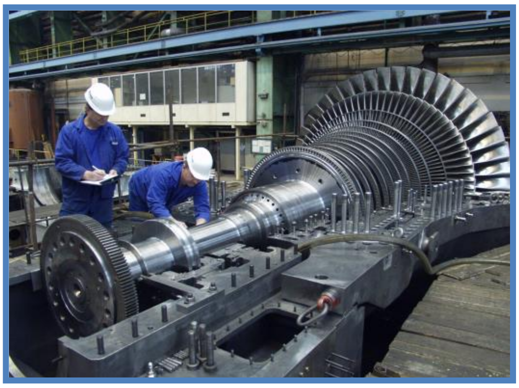
**Course Date/Venue**
October 20-24, 2024/Meeting Room No. 04, Four Seasons Hotel, Cairo at Nile Plaza, Cairo, Egypt

**Course Reference**
ME0398

3.0 CEUs (30 PDHs) AWARD

**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.***

This course is designed to provide delegates with a detailed and up-to-date overview of the fluid mechanic fundamentals and operating practice of pumps, compressors and turbines. It will address aspects of both axial and centrifugal compressors. Upon the successful completion of this course, participants will have acquired the practical knowledge to enable them not only to choose the correct device for a particular application but also be in a position to resolve many commonly occurring operating problems.

The course is ideal for those personnel in the oil, gas, petrochemical, chemical, power and other process industries who require a wider and deeper appreciation of pumps, compressors and turbines, including their design, performance and operation. No prior knowledge of the topic is required. Participants will be taken through an intensive primer of turbo-machinery principles, using the minimum of mathematics, and will learn how to solve the many and varied practical industrial problems that are encountered. The course makes use of an extensive collection of VIDEO material.

## Course Objectives

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

- Apply a comprehensive knowledge in pumps, compressors & turbines and troubleshoot rotating equipment in a professional manner
- Identify the different types of turbomachinery including basic design aspects and highlighted problem areas
- Minimize the compressor work by understanding the processes involved and identifying their efficiency
- Discuss the axial flow compressor and the corresponding velocity triangles including torque and power calculations
- List the different types of centrifugal machines including their design, installation, operation, maintenance, re-rate/retrofit and troubleshooting
- Recognize the various beneficial design aspects of turbomachines and understand the crucial process of cavitation in pumps
- Carryout the proper methods of centrifugal pumps installation, operation, maintenance and troubleshooting

## Who Should Attend

This course provides an overview of all significant aspects and considerations of pumps, compressors and turbines for those who are involved in the design, selection, maintenance or troubleshooting of such equipment. This includes maintenance, reliability, integrity, engineering, production and operations managers, engineers and other technical staff. Project managers and engineers will also benefit from this program.

## 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.

## 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 Fee**

**US$ 5,500** per Delegate + **VAT.** This rate includes Participants Pack (Folder, Manual, Hand-outs, etc.), buffet lunch, coffee/tea on arrival, morning & afternoon of each day

**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 **Pipelines**, **Pumps**, **Turbines**, **Heat Exchangers**, **Diesel Engine** Maintenance, **District Cooling** System, **Separators**, **Heaters**, **Compressors**, **Storage Tanks**, **Valves** Selection, **Compressors**, **Tank & Tank Farms** Operations & Performance, **Piping & Pumping** Operations, **Pump** Performance Monitoring, **Rotor Bearing** Modelling, **Hydraulic** Repairs & Cylinders, **Root Cause Analysis**, **Vibration & Condition** Monitoring, **Piping Stress** Analysis, **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, **Oil & Gas Transportation**, **Oil & Gas Production** Strategies, **Artificial Lift** Methods, Oil & Water Source Wells Restoration, **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**, **District Cooling Plant Maintenance 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's** degree in **Mechanical Power Engineering** and a **Bachelor's** 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, 20th of October 2024**

| | |
|---|---|
| 0730 – 0800 | *Registration & Coffee* |
| 0800 – 0815 | *Welcome & Introduction* |
| 0815 – 0830 | ***PRE-TEST*** |
| 0830 – 0930 | ***Introduction to Turbomachinery***<br>*Highlighted Problem Areas* |
| 0930 – 0945 | *Break* |
| 0945 – 1000 | ***Ideal Gas Equation & Practical Application***<br>*Isentropic Processes • Property Diagrams Involving Entropy* |
| 1000 – 1100 | ***Isentropic Processes of Ideal Gases***<br>*Constant Specific Heats • Relative Pressure and Relative Specific Volume* |
| 1100 – 1230 | ***Minimizing Compressor Work***<br>*Polytropic Processes • Multi-Stage Compression with Inter-Cooling • Isentropic Efficiency of Turbines • Isentropic Efficiency of Compressors and Pumps* |
| 1230 – 1245 | *Break* |
| 1245 – 1330 | ***Momentum & Bernoulli's Relations***<br>*General Relationship • Relationships for Incompressible Fluids* |
| 1330 – 1420 | ***VIDEO: Basic Pump Types & Technology*** |
| 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, 21st of October 2024**

| | |
|---|---|
| 0730 – 0800 | ***General Description of Turbomachines***<br>*Centrifugal Pump • Centrifugal Turbine • Centrifugal Air Compressor* |
| 0800 – 0830 | ***Impulse Turbine***<br>*Velocity Triangles* |
| 0830 – 0900 | ***Axial Flow Compressor***<br>*Velocity Triangles • Torque Calculation and Torque Coefficient • Power Calculation and Power Coefficient* |
| 0900 – 0930 | ***Centrifugal Machines***<br>*Torque Calculation • Head Coefficient • Flow Coefficient • Torque Coefficient* |
| 0930 – 0945 | *Break* |
| 0945 – 1015 | ***Performance Curves*** |
| 1015 – 1100 | ***Centrifugal Pump***<br>*Centrifugal Multistage Pump • Mixed Flow Machines • Centrifugal Air Compressor* |
| 1100 – 1130 | ***Affinity Laws***<br>*Effect of Impeller Speed •Effect of Impeller Diameter* |
| 1130 – 1200 | ***Specific Speed*** |
| 1200 – 1230 | ***Specific Radius*** |
| 1230 – 1245 | *Break* |
| 1245 – 1315 | ***Hydraulic Turbines*** |
| 1315 – 1330 | ***VIDEO: Fundamentals of Pump Performance 1*** |

| | |
|---|---|
| 1330 – 1400 | ***Design Aspects of Turbomachines***<br>*Linear Cascades • Radial Cascades • Three- Dimensional Aspects of Axial- Flow Machines •Elementary Design Considerations* |
| 1400 – 1420 | ***Cavitation*** |
| 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 Two* |

**Day 3:** **Tuesday, 22nd of October 2024**

| | |
|---|---|
| 0730 – 0930 | ***Centrifugal Pumps Basics***<br>*Types of Centrifugal Pumps • Self- Priming Pumps • Specific Speeds • Suction Specific Speed • Best Efficiency Point • Affinity Laws* |
| 0930 – 0945 | *Break* |
| 0945 – 1100 | ***Centrifugal Pump Design***<br>*Balancing Disc • Impeller NPSHR • Impeller Centre-Rib • Mechanical Seals • Velocity Head* |
| 1100 – 1230 | ***Pump Sales***<br>*Affinity Laws •Pump Software • Suction Lift • Viscosity • Re-Rate/Retrofit • Head-Rise • Radial/Horizontal Split Case* |
| 1230 – 1245 | *Break* |
| 1245 – 1330 | ***Centrifugal Pump Installation***<br>*Foundation • Soft Foot • Suction Pipe • Suction Strainer* |
| 1330 – 1420 | ***VIDEO: Fundamentals of Pump Performance 2***<br>*Discussion Forum* |
| 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 Three* |

**Day 4:** **Wednesday, 23rd of October 2024**

| | |
|---|---|
| 0730 – 0930 | ***Centrifugal Pump Operation***<br>*Start-Up • Minimum Flow • Maximum Pump RPM • Motor Amps/Specific Gravity • Entrained Gas* |
| 0930 – 0945 | *Break* |
| 0945 – 1100 | ***Centrifugal Pump Operation (cont'd)***<br>*Operation at Shut Off • Temperature-Rise • Thermal Shock* |
| 1100 – 1230 | ***Centrifugal Pump Maintenance***<br>*Case Gasket • Checking for Wear Clearance • Oil Change • Storage* |
| 1230 – 1245 | *Break* |
| 1245 – 1315 | ***Centrifugal Pump Re-Rate/Retrofit***<br>*Impeller Cut • NPSH • De-Staging • Electric Motor Sizing • Viscosity Changes* |
| 1315 – 1420 | ***VIDEO: Hydraulic Loads, Critical Speed & Torque***<br>*Discussion Forum* |
| 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 Four* |

**Day 5:** **Thursday, 24th of October 2024**

| | |
|---|---|
| *0730 – 0830* | ***Centrifugal Pump Troubleshooting***<br>*Bearing Failures • Bearing Housing Oil Leakage • Cavitation Noise and Damage* |
| *0830 – 0930* | ***VIDEO: Bearings, Seals & Couplings*** |
| *0930 – 0945* | *Break* |
| *0945 – 1100* | ***Centrifugal Pump Troubleshooting (cont'd)***<br>*Impeller Cavitation/Erosion • Vibration • Cracked Volute Tongues • NPSH • Viscosity Effects* |
| *1100 – 1230* | ***Group Discussions*** |
| *1230 – 1245* | *Break* |
| *1245 – 1345* | ***VIDEO: Special Pump Topics & Final Discussion*** |
| *1345 – 1400* | ***Course Conclusion***<br>*Using this Course Overview, the Instructor(s) will Brief Participants about the Course Topics that were Covered During the Course* |
| *1400 – 1415* | ***POST-TEST*** |
| *1415 – 1430* | *Presentation of Course Certificates* |
| *1430* | *Lunch & End of Course* |

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

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."

## Compressor Power Calculator Software

https://www.engineeringtoolbox.com/horsepower-compressed-air-d_1363.html
http://yrsp.elliott-turbo.com/public/comp_perf/index.jsp
https://intech-gmbh.com/compr_calc_and_selec_examples/

**Horsepower of Motor Compressor**

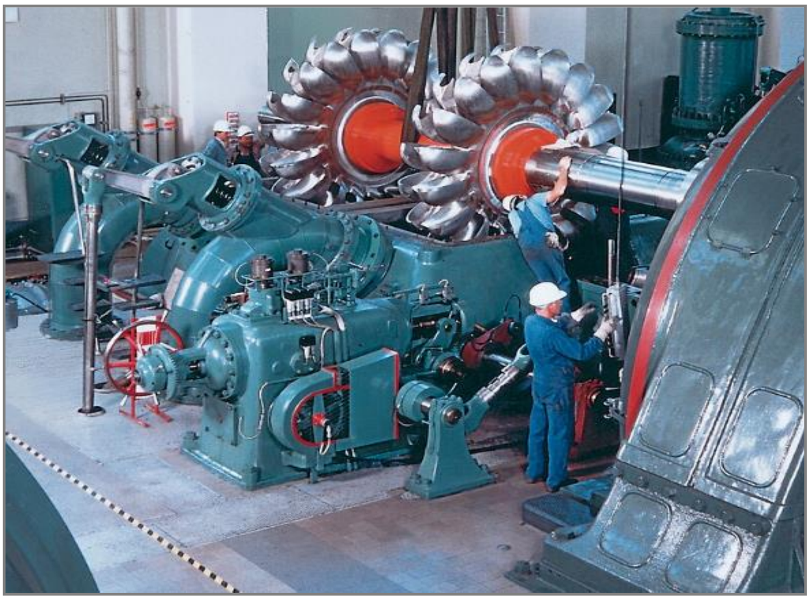
**Input Data**

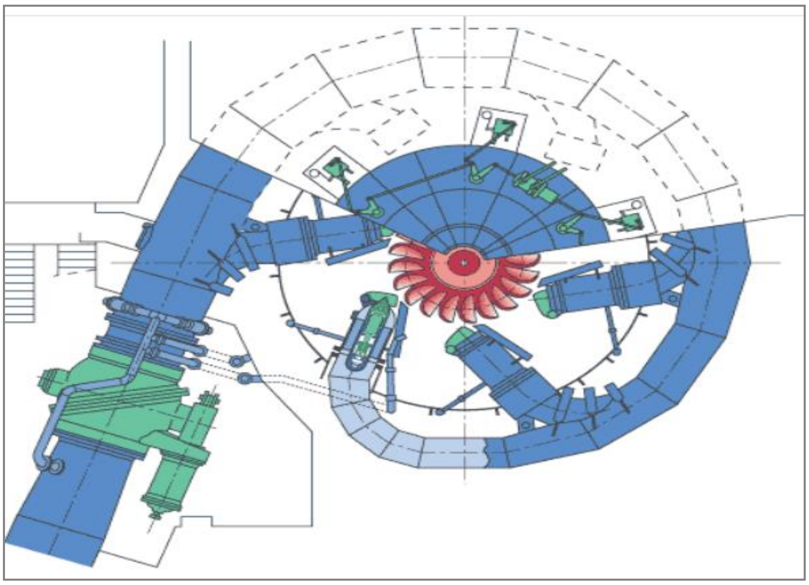
| | |
|---|---|
| K | 1.3 |
| Compressor Stages | 1 |
| CFM | 35 |
| T1, C | 27.000 |
| P1, psi | 14.06888 |
| P2, psi | 100.00508 |
| Compressor Eff., % | 68 |

**Output Results**

| | |
|---|---|
| HP (as per software) | 5.327 |
| Total HP | 7.8 |

# Turbines





# Section of Pelton Turbine

## *Design rules*

The specific speed $\eta_s$ parameter is independent of a particular turbine's size.

Compared to other turbine designs, the relatively low specific speed of the Pelton wheel implies that the geometry is inherently a "low gear" design. Thus it is most suitable to being fed by a hydro source with a low ratio of flow to pressure (meaning relatively low flow and/or relatively high pressure).

The specific speed is the main criterion for matching a specific hydro-electric site with the optimal turbine type. It also allows a new turbine design to be scaled from an existing design of known performance.

$\eta_s = n\sqrt{P}/\sqrt{\rho}(gH)^{5/4}$ (dimensionless parameter), [9]

where:

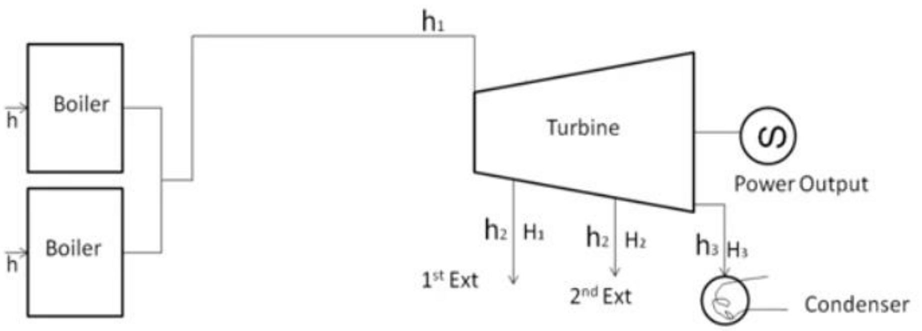
- $n$ = Frequency of rotation (rpm)
- $P$ = Power (W)
- $H$ = Water head (m)
- $\rho$ = Density (kg/m$^3$)

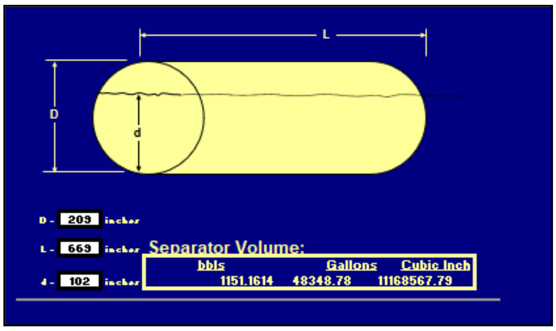
The formula implies that the Pelton turbine is *geared* most suitably for applications with relatively hig exponent being greater than unity, and given the characteristically low specific speed of the Pelton.[1

***https://www.youtube.com/watch?v=3nnFIqUDIzY***

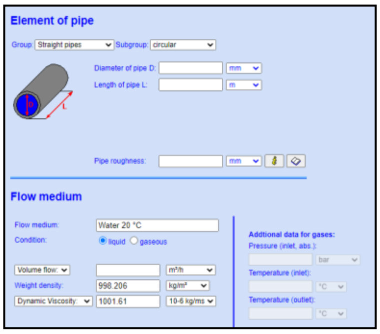
**Calculations for Steam Turbine**

The process flow diagram for cogeneration plant is shown in this figure . The following calculation procedures have been provided in this section.

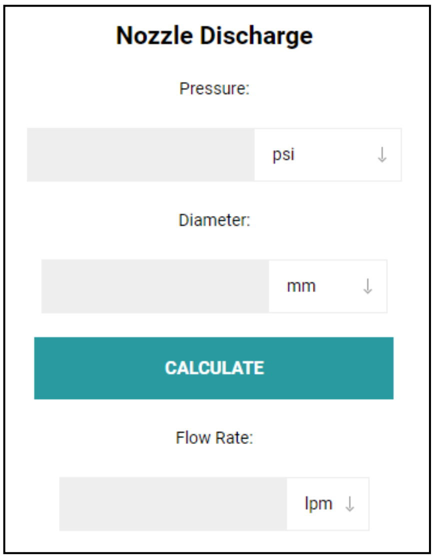




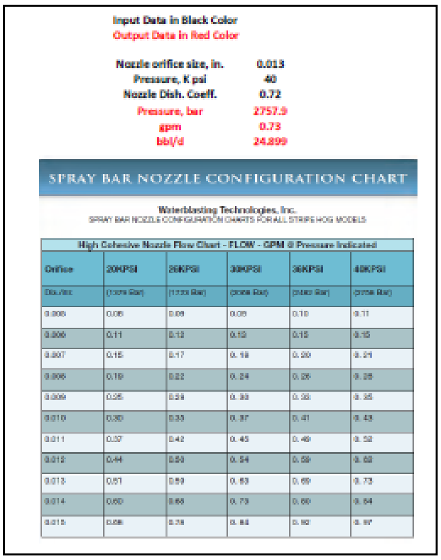

**Tank Volume Calculator**



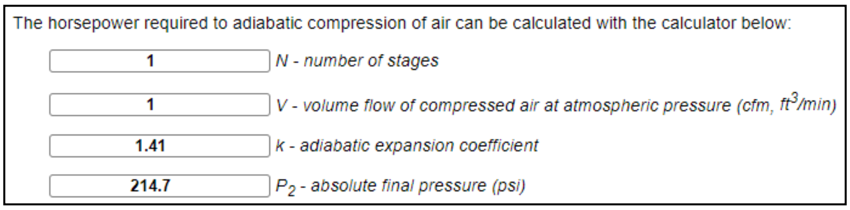

**Pressure Drop Online-Calculator**




**Nozzle Discharge**

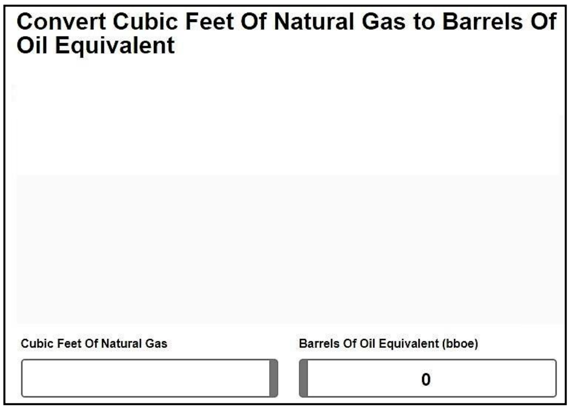



**Nozzle Calculator**

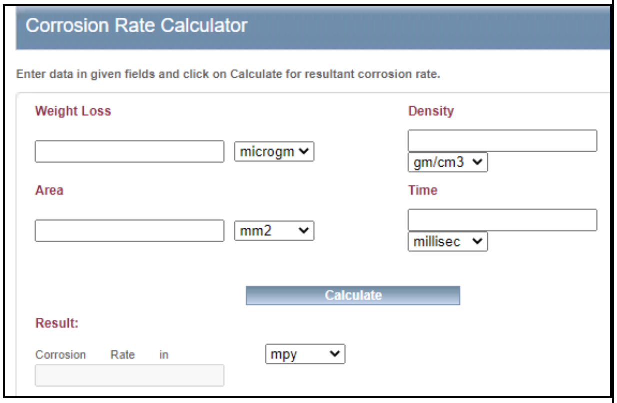



**Horsepower Calculator**

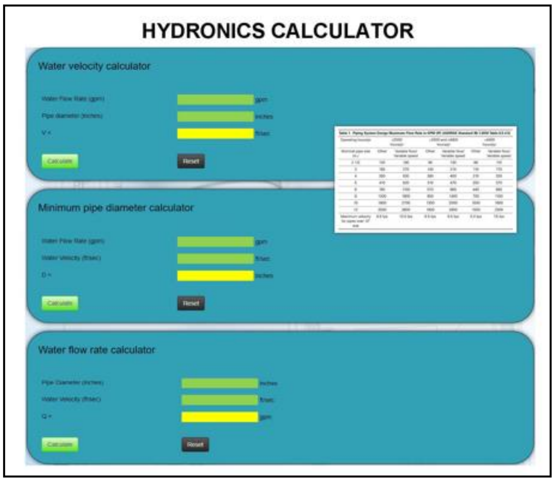

**Water Flow Rate through an Orifice Calculator**



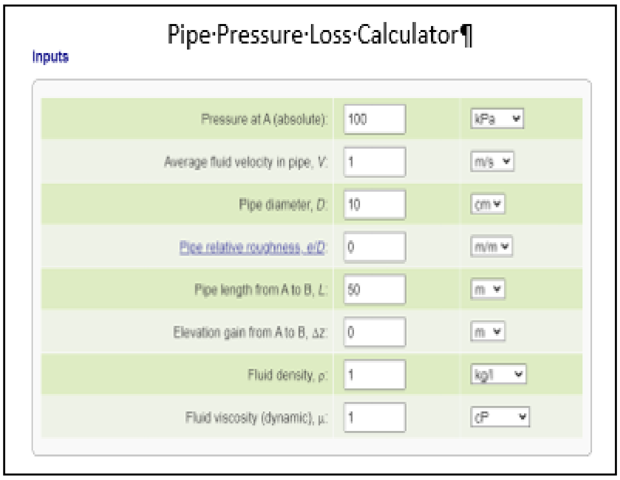

**Cubic Feet Calculator**



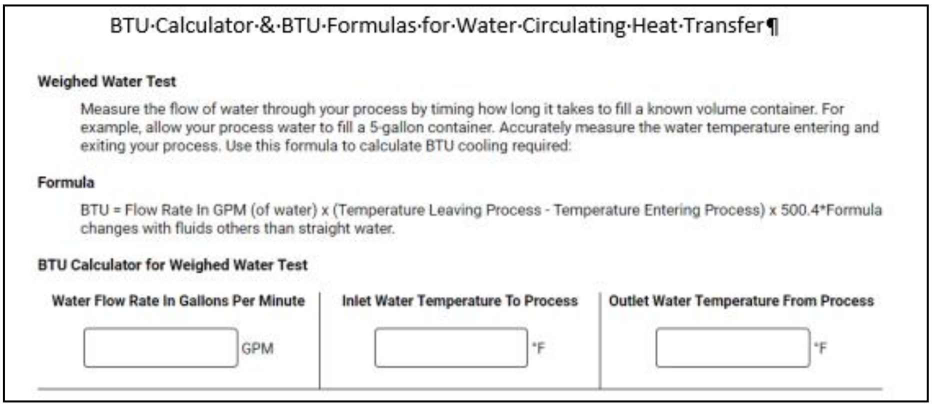

**Corrosion Rate Calculator**



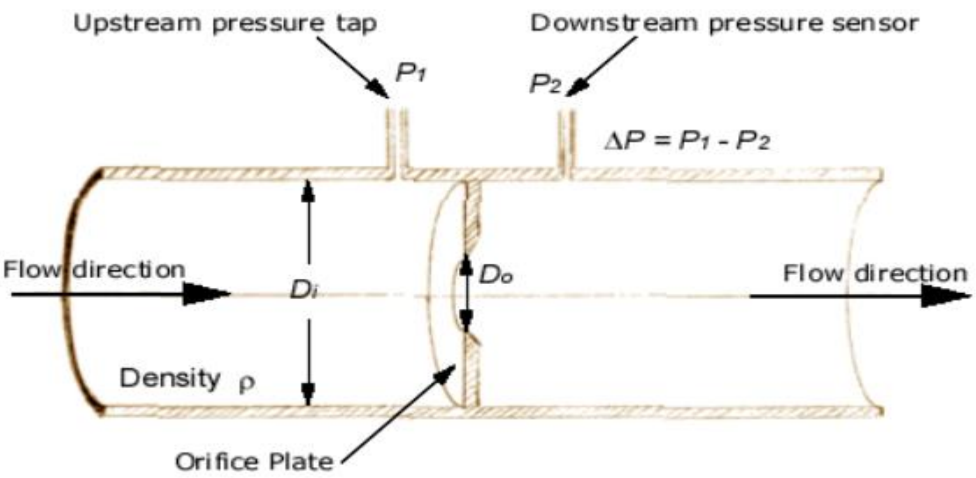

**Hydronics Calculator**




**Pipe Pressure Loss Calculator**




**BTU Calculator**




**Inputs**

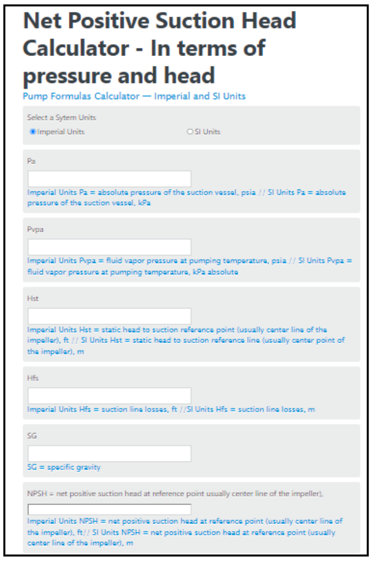
| | | |
|---|---|---|
| Pipe (inlet) diameter upstream of orifice, $D_i$: | 8 | in |
| Orifice diameter (less than the inlet diameter), $D_o$: | 3 | in |
| Pressure difference across the orifice, $\Delta p$: | 20 | psi |
| Fluid density, $\rho$: | 835 | kg/m^3 |
| Flow Coefficient, $C_f$: | 0.82 | |

## Answers

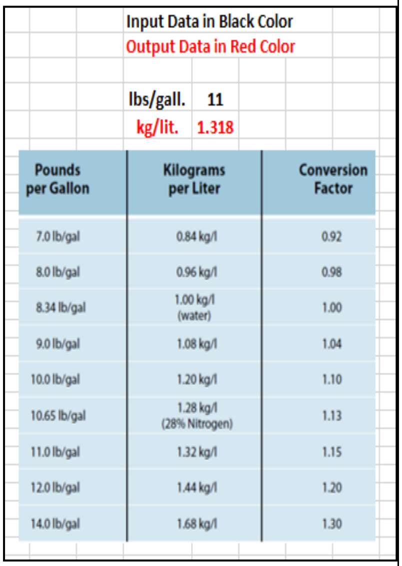
| | | |
|---|---|---|
| Velocity at the inlet, $V_i$: | 2.10 m/s | m/s |
| Volumetric Flowrate, $Q$: | 1080 gpm | gpm |
| Mass Flowrate: | 56.7 kg/s | kg/s |

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


[Net Positive Suction Head Calculator](#)




[Net Positive Suction Head Calculator](#)

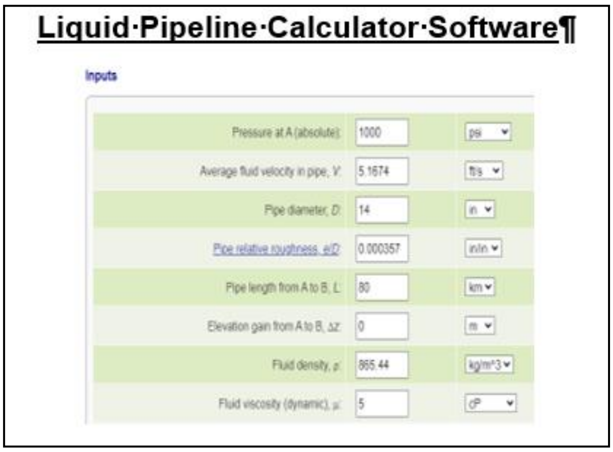


Input Data in Black Color
Output Data in Red Color

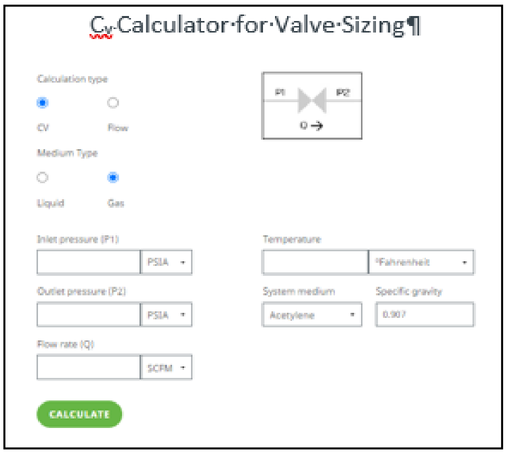
| | |
|---|---|
| lbs/gall. | 11 |
| kg/lit. | 1.318 |

| 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 |

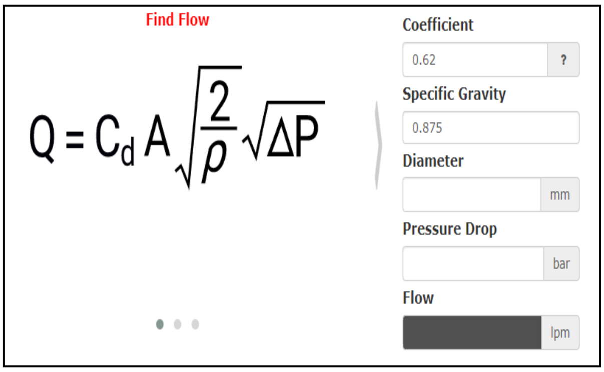
[PPG to KG Calculator](#)



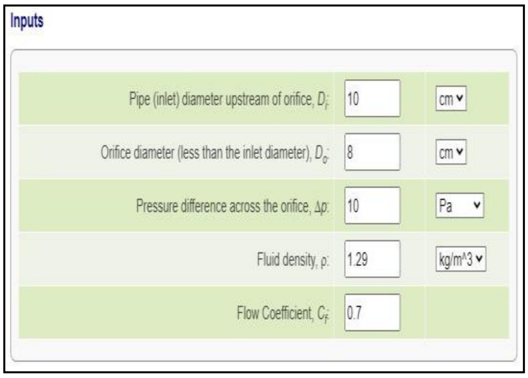

[Liquid Pipeline Calculator](#)



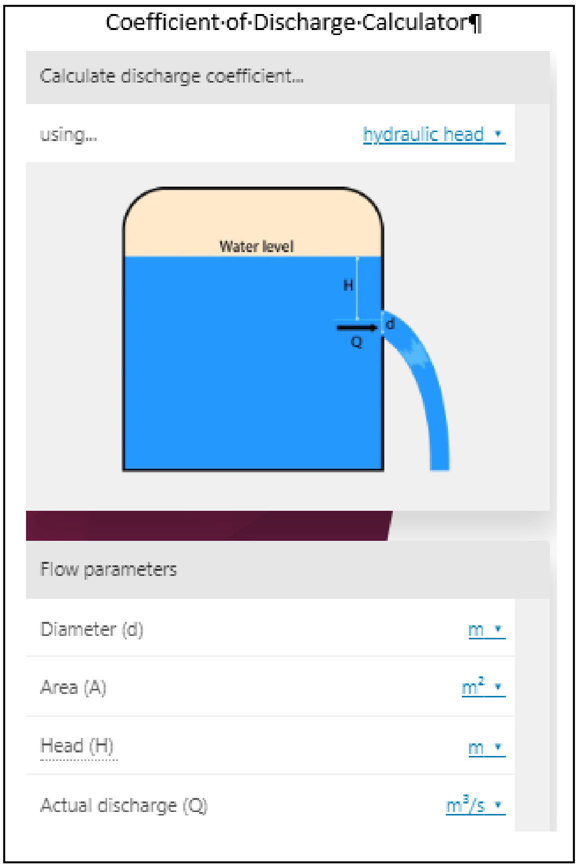

[Cv Calculator](#)



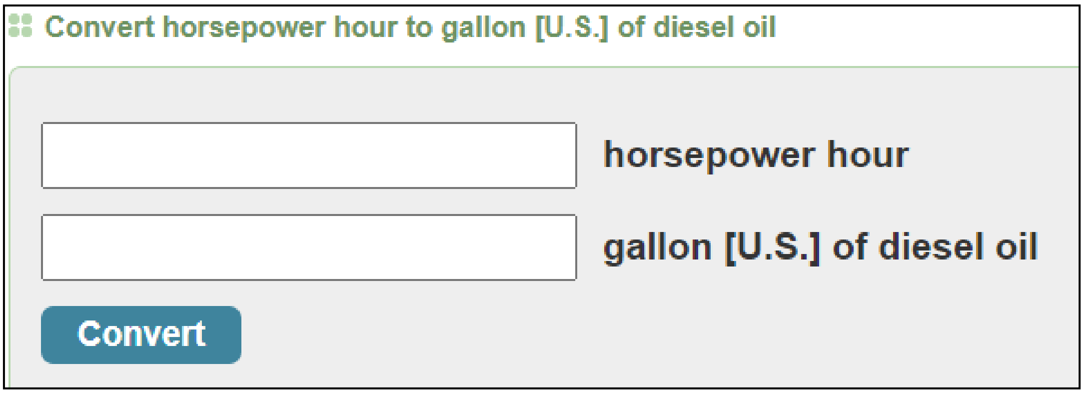

[Find Flow Calculator](#)




[Flowrate Calculator](#)




**Coefficient Discharge Calculator**

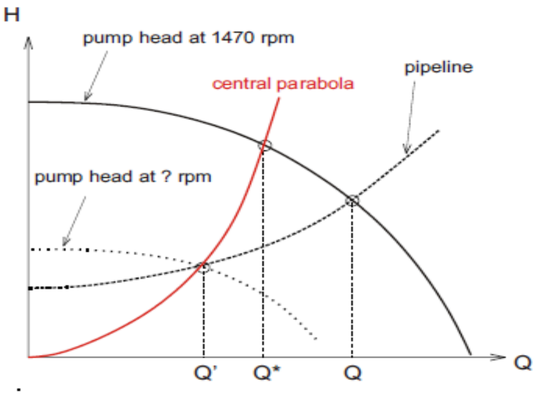



**Horsepower Hour Calculator**

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

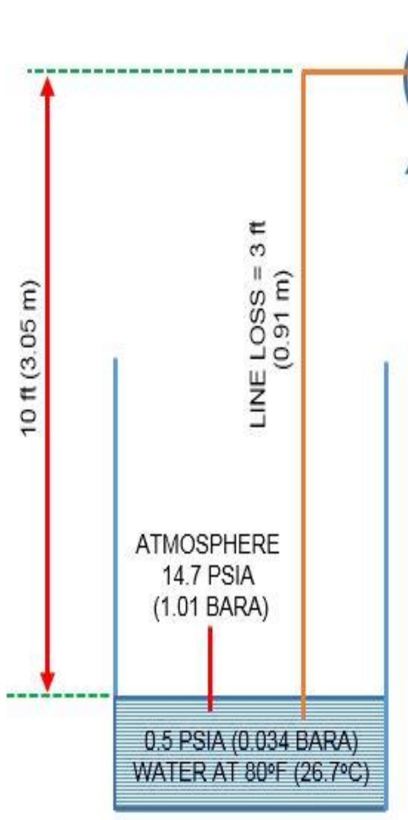
$Q^*$ is given by the intersection of the affine parabola and the original pump characteristic: $H_{ap}(Q^*) = H_{pump}(Q^*)$, which gives $Q^* = 0.06148[m^3/s]$ with $H^* = 34.5[m]$.

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

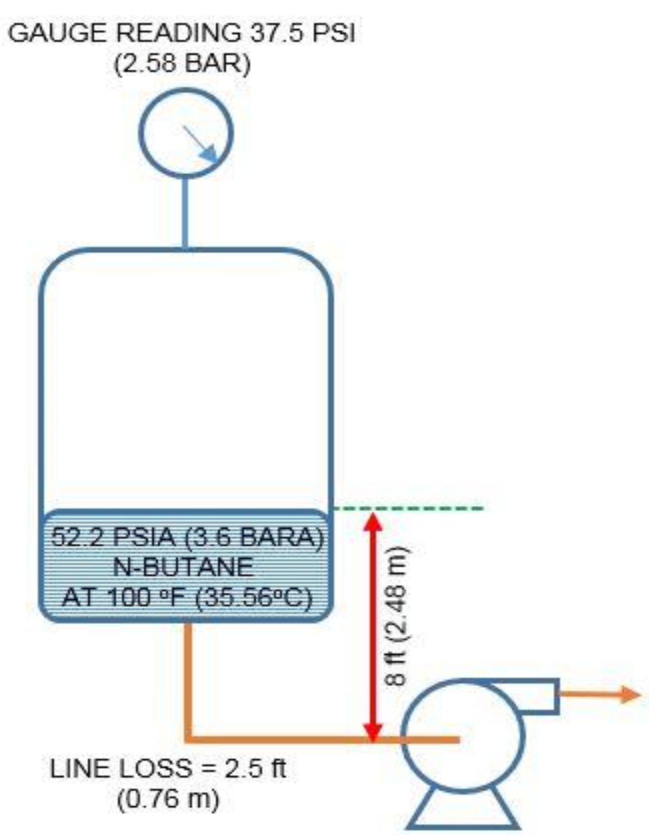
$$n' = n^* \frac{Q'}{Q^*} = 1470 \times \frac{0.05}{0.06148} = 1195.5[rpm]$$

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.**

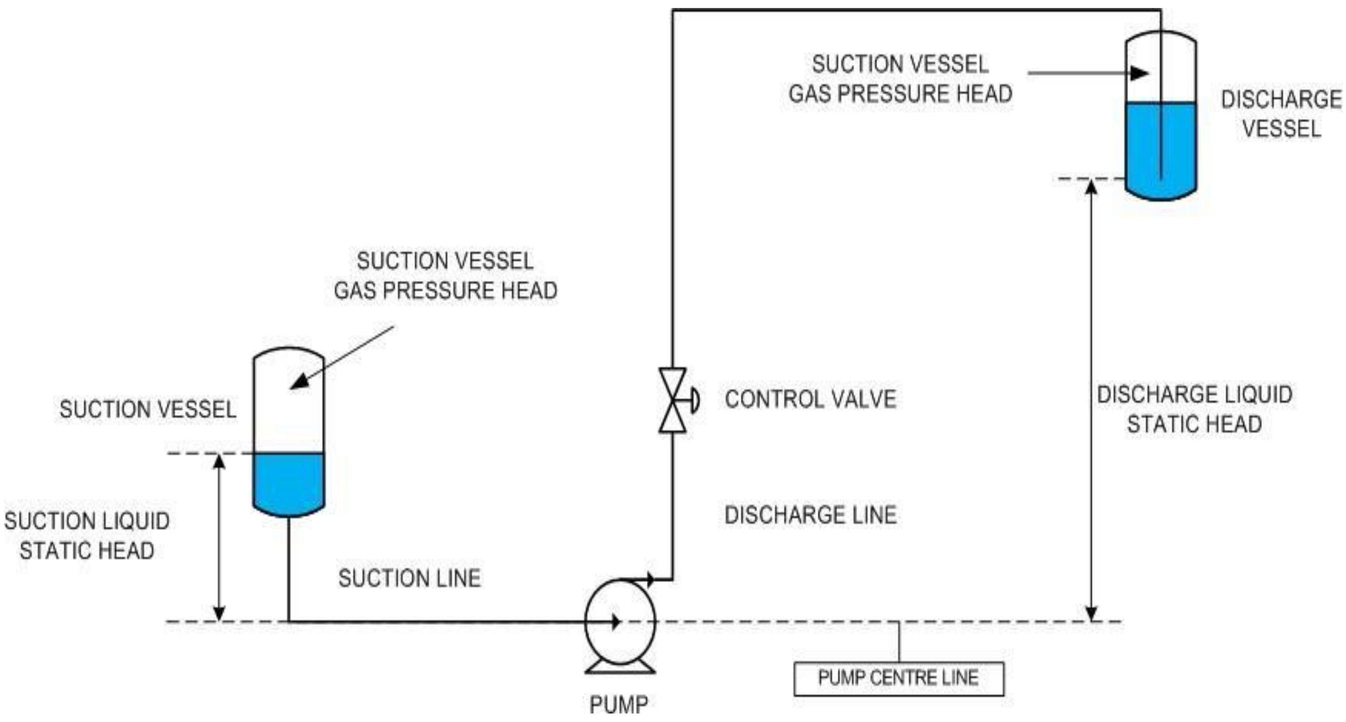
https://engineeringunits.com/net-positive-suction-head-calculator/?utm_content=cmp-true

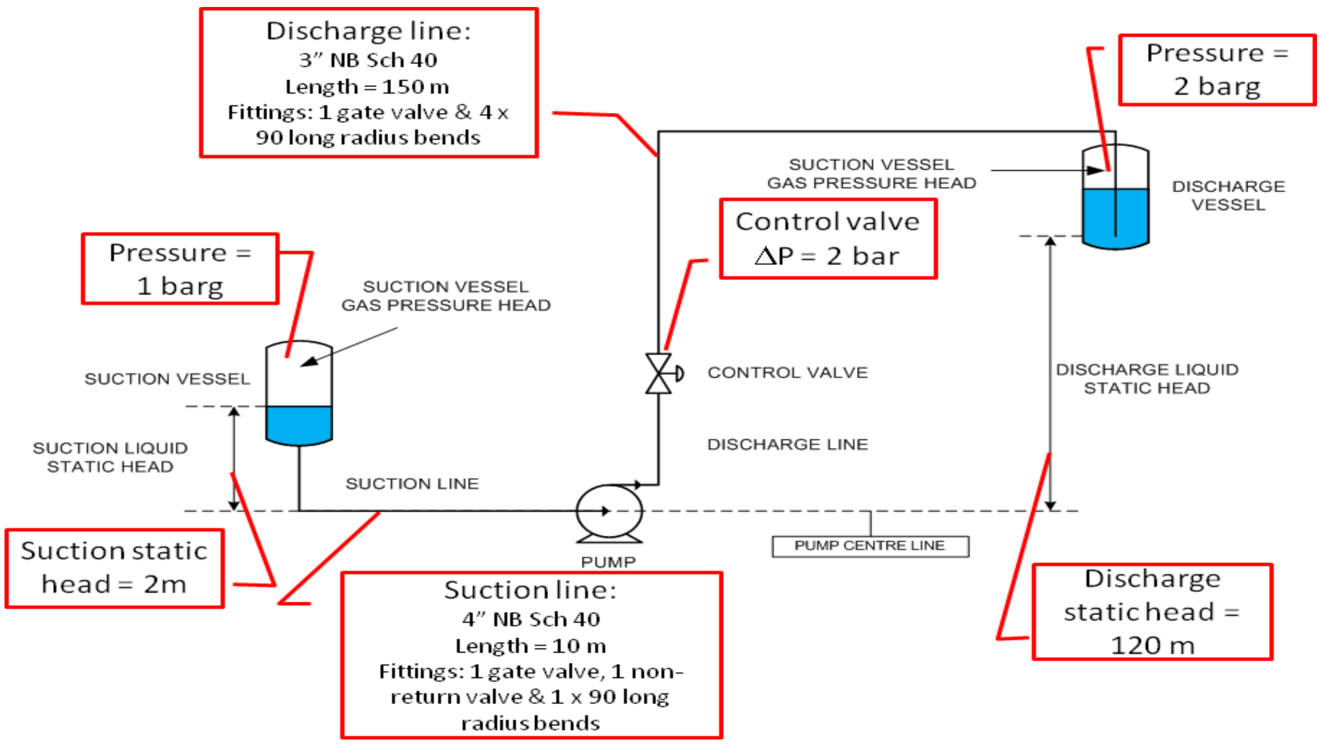
http://www.pressure-drop.com/Online-Calculator/index.html

**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
PUMP CENTRE LINE
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 | $\eta$ | 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 | |
|---|---|
| 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 = $50^0$C

Outlet temperature = $30^0$C

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 |

**<u>Course Coordinator</u>**

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