

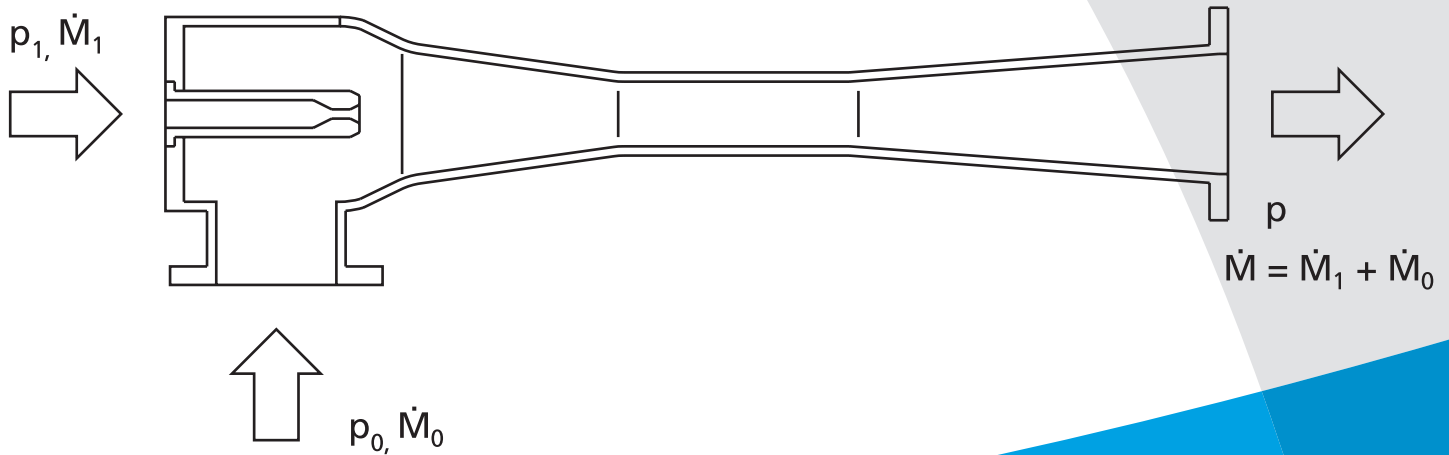


Product Catalog

Jet Pumps
Mixers, Heaters
Vacuum Systems

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Basics and worksheets

- General information on jet pumps
- Materials table (excerpt)
- International System of Units
- Conversion tables for different units of measurement
- Measurement conversion table, conversion of english-american units in the International System of Units (SI) and vice versa
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- Vapors and gases in vacuum
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- Admissible flow velocity in vacuum ducts
- Pressure loss in vacuum lines with water vapor
- Pressure loss in water pipes
- Dimensions, velocities and mass flows in steam and water pipes
- Vapor flows in pipes
- Mass flow of gases and vapors through nozzles
- Water vapor flow through motive nozzles at critical pressure ratio
- Equivalent suction flows for steam jet vacuum pumps
- Steam consumption of jet pumps

General information on jet pumps

Jet pumps, also referred to as ejectors, are devices for the conveyance, compression or mixing of gases, vapors, liquids or solids in which a gaseous or liquid medium serves as the motive force. They operate by the conversion of pressure energy into velocity in suitable nozzles. They are “pumps without moving parts”.

The basic principle of jet pumps consists in the liquid or gas jet being emitted by a nozzle at high speed entraining and accelerating the surrounding liquid, gas or solid matter. The result of this action is a mixture of the driving and entrained (sucked) fluids, the velocity of which is reduced and the pressure increased in a second nozzle.

The practical application of this principle requires a simple apparatus which essentially consists of only 3 main parts (figure 1):

- motive nozzle (1)
- diffuser (2)
- head (3)

The flow channel of the diffuser consists of a part converging in the direction of the flow (the inlet cone), a cylindrical piece (the throat) and a diverging part (the outlet cone).

The pressures at the connections and the corresponding mass flows determine the functional effect of a jet pump.

A jet pump is provided with at least 3 connections (figure 1):

- motive medium inlet connection (A)
- suction manifold (B)
- pressure manifold (C)

The pressures prevailing there are as follows (figure 2):

p_1 pressure upstream of the motive nozzle = motive medium pressure

p_0 pressure at the suction manifold = suction pressure

p pressure at the outlet manifold = discharge pressure

The mass flows \dot{M}_1 , \dot{M}_0 and \dot{M} for the entering and exiting fluids are measured in kg/h. For this purpose, the following equation shall apply: $\dot{M}_1 + \dot{M}_0 = \dot{M}$.

For the relationship between the various pressures, no simple rule can be applied. The internal processes in jet pumps are complex and only in a limited way accessible by calculation.

FIG. 1

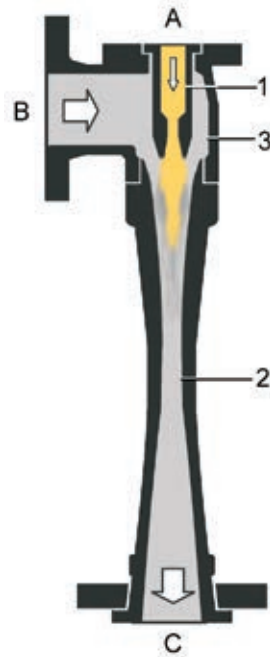
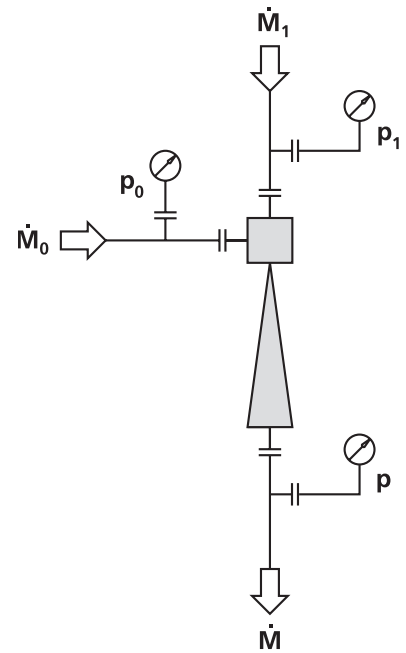


FIG. 2



DESIGNATIONS OF JET PUMPS

The terms of jet pumps (ejectors) are defined in DIN 24290. According to DIN 24290, jet pumps are named according to the motive side and to the suction side. The designations in this catalog follow this standard.

| ACCORDING TO THE SUCTION SIDE | ACCORDING TO THE MOTIVE SIDE | | |
|-------------------------------|------------------------------|---|------------------------|
| | GAS JET PUMP | STEAM JET PUMP | LIQUID JET PUMP |
| Jet ventilator | Gas jet ventilator | Steam jet ventilator | Liquid jet ventilator |
| Jet compressor | Gas jet compressor | Steam jet compressor (Vapor recompressor) | Liquid jet compressor |
| Jet vacuum pump | Gas jet vacuum pump | Steam jet vacuum pump | Liquid jet vacuum pump |
| Jet liquid pump | Gas jet liquid pump | Steam jet liquid pump | Liquid jet liquid pump |
| Jet solids pump | Gas jet solids pump | Steam jet solids pump | Liquid jet solids pump |

The designation of the individual parts of a jet pumps is standardized according to DIN 24 291.

SCOPE OF DELIVERY

The scope of delivery of the jet pumps department of GEA Wiegand is divided into two main fields.

1) DELIVERY OF STANDARD APPARATUSES

This catalog gives a wide selection. The types and sizes are selected such that for usual tasks a suitable unit can always be found. Description and capacity curves and the corresponding sheets allow the correct choice.

2) DESIGN, CONSTRUCTION AND DELIVERY OF SPECIAL APPARATUSES AND PLANTS

For this purpose our well-trained staff of specialists in jet pumps and vacuum systems is available. In our modern Research Laboratory, the required analyses, research work and tests are carried out. Special leaflets give detailed information; they show the general principles of these plants and inform the customers which data are needed for engineering and for the preparation of a

quotation. Jet pumps can be built for very small as well as for extraordinarily large capacities. They can be constructed from most different materials and stand out for the following features:

- reliability
- simplicity
- low maintenance costs
- low acquisition costs

WHAT HAS TO BE BORNE IN MIND?

WHEN PURCHASING JET PUMPS ACCORDING TO THE CATALOG:

- The capacities specified in the catalog sheets are only approximate values. They will be different if operating conditions change.
- For the design in individual cases, our order confirmation is binding and not the catalog sheet.
- Where necessary, installation and operating instructions are made available.
- Normally, cast apparatuses are supplied with flanges bored to DIN PN 10, unless otherwise agreed. If specified, flanges according to ASME, BS or other special flanges can be supplied, if the casting model is available or if it is a question of welded (fabricated) apparatus. Counter flanges together with seals and screws are only supplied on request.
- Our General Sales Conditions are valid for all supplies.

WHEN INSTALLING JET PUMPS:

- Do not mix up connections.
- Connecting pipe lines must be of equal or larger diameter than the corresponding connections on the plant.
- Valves, fittings, seals etc. must have the full cross sectional area and not restrict the line.
- For longer pipe lines, the cross sectional area must be larger to obtain the lowest possible pressure loss. In all cases, care must be taken to ensure that the pipe line be constructed with the most favourable flow characteristics.
- Steam lines should be well insulated. Dry motive steam is particularly important for the good operation of steam jet vacuum pumps.
- Before the first start-up the lines should be blasted and cleaned with steam or compressed air. Otherwise, rust, dirt and welding beads can easily block the nozzles of the pumps.
- Furthermore, we recommend the installation of a dirt trap in the supply lines for motive fluids.
- For further details on the assembly and operation of jet pumps please refer to the respective operation instructions.

Materials table (excerpt)

| Material no. | Short name acc. to EN 10088-2 | AISI/ASTM/UNS-Type | UNS |
|--------------|-------------------------------|--------------------|---------------|
| 1.0038 | S235JRG2 (RSt 37.2) | A570 Gr. 36 | K03000 |
| 1.0425 | P265GH | A516 Gr. 60 | K02505 |
| 1.0566 | P355NL1 | | K02701 |
| 1.4016 | X 6 Cr 17 | 430 | S43000 |
| 1.4113 | X6CrMo17-1 | 434 | S43400 |
| 1.4301 | X5CrNi18-10 | 304 | S30400 |
| 1.4306 | X2CrNi19-11 | 304L | S30403 |
| 1.4307 | X2CrNi18-9 | 304L | S30403 |
| 1.4401 | X5CrNiMo17-12-2 | 316 | S31600/S31609 |
| 1.4404 | X2CrNiMo17-12-2 | 316L | S31603 |
| 1.4435 | X2CrNiMo18-14-3 | 316L | S31603 |
| 1.4436 | X3CrNiMo17-13-3 | 316 | S31600 |
| 1.4439 | X2CrNiMoN17-13-5 | 317LMN | S31726 |
| 1.4462 | X2CrNiMoN22-5-3 | 318LN | S31803 |
| 1.4529 | X1NiCrMoCuN25-20-7 | 926 | N08926 |
| 1.4539 | X1NiCrMoCuN25-20-5 | 904L | N08904 |
| 1.4541 | X6CrNiTi18-10 | 321 | S32100 |
| 1.4550 | X6CrNiNb18-10 | 347 | S34700 |
| 1.4571 | X6CrNiMoTi17-12-2 | 316Ti | S31635 |
| 1.4581 | GX5CrNiMoNb19-11-2 | | |
| 1.4828 | X15CrNiSi20-12 | 309 | S30900 |
| 1.5415 | 16Mo3 | A204 Gr. A / 4017 | K11820 |

Availability on request

International System of Units

The units for measurement and weight are in accordance with the International System of Units (SI) recommended by the International Organisation of Standardisation (ISO).

For the technical range which is the subject matter of this catalog, the following basic units of measurement and the corresponding abbreviations, taken from the International System of Units, shall apply.

THE MOST IMPORTANT OF THE DERIVED UNITS ARE:

| Basic parameter | Basic unit | Abbreviation |
|---------------------|------------|--------------|
| Length | meter | m |
| Mass | kilogramme | kg |
| Time | second | s |
| Temperature | kelvin | K |
| Amperage | ampere | A |
| Amount of substance | mole | mol |

| Basic parameter | Basic unit | Abbreviation | |
|-----------------|------------|--------------|--|
| Force | newton | N | $1N = 1 \frac{\text{kg} \cdot \text{m}}{\text{s}^2}$ |
| Pressure | pascal | Pa | $1Pa = 1 \frac{\text{N}}{\text{m}^2} = 1 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \cdot \frac{1}{\text{m}^2} = 1 \frac{\text{kg}}{\text{s}^2 \cdot \text{m}}$ |
| Energy | joule | J | $1J = 1 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$ |
| Power | watt | W | $1W = 1 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^3}$ |

The interdependence between derived units and basic units is as follows:

$$1Pa = 1 \frac{N}{m^2} = 1 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \cdot \frac{1}{m^2} = 1 \frac{\text{kg}}{\text{s}^2 \cdot \text{m}}$$

$$1bar = 10^5 \frac{N}{m^2} = 10^5 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \cdot \frac{1}{m^2} = 10^5 \frac{\text{kg}}{\text{s}^2 \cdot \text{m}} = 10^5 Pa$$

$$1J = 1Ws = 1Nm = 1 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \cdot \text{m} = 1 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$$

$$1W = 1 \frac{J}{s} = 1 \frac{Nm}{s} = 1 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \cdot \frac{\text{m}}{\text{s}} = 1 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^3}$$

The unit of thermodynamic temperature is the kelvin in K. The kelvin converted to the Celsius temperature scale has the special name of degree Celsius in °C. Temperature differences are indicated in K or in °C. 0 K correspond to -273.10 °C (degrees Celsius). The graduation within the two scales is equal: one kelvin step corresponds to one Celsius step.

The following attachments denote decimal multiples and fractions of the SI-Units.

| | | | | | |
|---|-------|-------------------|---|-------|------------------|
| p | pico | 10 ⁻¹² | D | deca | 10 ¹ |
| n | nano | 10 ⁻⁹ | h | hecto | 10 ² |
| μ | mikro | 10 ⁻⁶ | k | kilo | 10 ³ |
| m | milli | 10 ⁻³ | M | mega | 10 ⁶ |
| c | centi | 10 ⁻² | G | giga | 10 ⁹ |
| d | deci | 10 ⁻¹ | T | tera | 10 ¹² |

| | Technical system of units not allowed since 1.1.1978 | Conversion | International system of units (SI) newly introduced since 1.1.1978 |
|-------------------------------------|---|---|---|
| Pressure | 1 kp/m ² = 1 mm WC 1 ata 1 Torr 1 m WC | 1 kp/m ² = 0.098067 · 10 ⁻³ bar 1 ata = 0.98067 bar 1 Torr = 1.3332 · 10 ⁻³ bar 1 m WC = 0.098067 bar | 1 bar = 10 ⁵ Pa 1 mbar = 10 ² Pa = 1 hPa 10 ⁻² mbar = 1 Pa |
| Energy Work | 1 kp m 1 kcal | 1 kp m = 9.8067 J 1 kcal = 4.1868 kJ | 1 J = 10 ⁻³ kJ 1 J = 1 Nm |
| Power | 1 PS 1 kcal/h | 1 PS = 0.7355 kW 1 kcal/h = 1.163 W | 1 W = 10 ⁻³ kW 1W = 1 $\frac{\text{Nm}}{\text{s}} = 1 \frac{\text{J}}{\text{s}}$ |
| Heat transfer/ Heat transmission | 1 $\frac{\text{kcal}}{\text{m}^2 \cdot \text{h} \cdot \text{°C}}$ | 1 $\frac{\text{kcal}}{\text{m}^2 \cdot \text{h} \cdot \text{°C}} = 1.163 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$ | 1 $\frac{\text{W}}{\text{m}^2 \cdot \text{K}}$ |
| Thermal conductivity | 1 $\frac{\text{kcal}}{\text{m} \cdot \text{h} \cdot \text{°C}}$ | 1 $\frac{\text{kcal}}{\text{m} \cdot \text{h} \cdot \text{°C}} = 1.163 \frac{\text{W}}{\text{m} \cdot \text{K}}$ | 1 $\frac{\text{W}}{\text{m} \cdot \text{K}}$ |
| Specific heat capacity | 1 $\frac{\text{kcal}}{\text{kg} \cdot \text{°C}}$ | 1 $\frac{\text{kcal}}{\text{kg} \cdot \text{°C}} = 4.1868 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$ | 1 $\frac{\text{kJ}}{\text{kg} \cdot \text{K}}$ |

The table Conversion from technical system of units to international system of units shows a comparison between the earlier used Technical System of Units and the newly, legally binding, introduced International System of Units for the most important values given in this catalog.

Conversion tables for different units of measurement

The following tables show the units of measurement for pressure, energy and capacity in use ever since in comparison to the units of the international system of units (SI).

PRESSURE UNITS

| | Pa = N/m ² | bar | at | mm WC | atm | Torr | psia |
|---------------------------|---------------------------|----------------------------|----------------------------|---------------------------|----------------------------|----------------------------|----------------------------|
| 1 Pa = 1 N/m ² | 1 | 10 ⁻⁵ | 1.0197 · 10 ⁻⁵ | 0.10197 | 0.9869 · 10 ⁻⁵ | 0.75006 · 10 ⁻² | 1.45037 · 10 ⁻⁴ |
| 1 bar = 1000 mbar | 10 ⁵ | 1 | 1.0197 | 1.0197 · 10 ⁴ | 0.9869 | 0.75006 · 10 ³ | 14.5037 |
| 1 mbar | 10 ² | 1 · 10 ⁻³ | 1.0197 · 10 ⁻³ | 10.197 | 0.9869 · 10 ⁻³ | 0.75006 | 1.45037 · 10 ⁻² |
| 1 at | 0.98067 · 10 ⁵ | 0.98067 | 1 | 1.00003 · 10 ⁴ | 0.96784 | 0.73556 · 10 ³ | 14.224 |
| 1 mm WC | 9.8064 | 0.98064 · 10 ⁻⁴ | 0.99997 · 10 ⁻⁴ | 1 | 0.96781 · 10 ⁻⁴ | 0.73554 · 10 ⁻¹ | 1.4224 · 10 ⁻³ |
| 1 atm | 1.01325 · 10 ⁵ | 1.01325 | 1.03323 | 1.03326 · 10 ⁴ | 1 | 760 | 14.696 |
| 1 Torr | 1.3332 · 10 ² | 1.3332 · 10 ⁻³ | 1.3595 · 10 ⁻³ | 13.595 | 1.3158 · 10 ⁻³ | 1 | 1.9336 · 10 ⁻² |
| 1 psia | 6.8948 · 10 ³ | 6.8948 · 10 ⁻² | 7.0306 · 10 ⁻² | 7.0306 · 10 ² | 6.8043 · 10 ⁻² | 51.716 | 1 |

ENERGY UNITS

| | kJ | kWh | kpm | kcal | Btu |
|--------|---------------------------|---------------------------|--------------------------|---------------------------|---------------------------|
| 1 kJ | 1 | 2.7778 · 10 ⁻⁴ | 1.0197 · 10 ² | 0.23884 | 0.9478 |
| 1 kWh | 3.6000 · 10 ³ | 1 | 3.6710 · 10 ⁵ | 8.598 · 10 ² | 3.4120 · 10 ³ |
| 1 kpm | 9.8067 · 10 ⁻³ | 2.7241 · 10 ⁻⁶ | 1 | 2.3422 · 10 ⁻³ | 9.2945 · 10 ⁻³ |
| 1 kcal | 4.1868 | 1.1630 · 10 ⁻³ | 4.2694 · 10 ² | 1 | 3.96825 |
| 1 Btu | 1.0551 | 2.9308 · 10 ⁻⁴ | 1.0759 · 10 ² | 0.2520 | 1 |

CAPACITY UNITS

| | kW | kpm/s | PS | kcal/s | kcal/h |
|----------|----------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| 1 kW | 1 | 1.0197 · 10 ² | 1.3596 | 0.23884 | 859.824 |
| 1 kpm/s | 9.80665 · 10 ⁻³ | 1 | 1.3333 · 10 ⁻² | 2.3422 · 10 ⁻³ | 8.4319 |
| 1 PS | 0.7355 | 75 | 1 | 1.7573 · 10 ⁻¹ | 6.3263 · 10 ² |
| 1 kcal/s | 4.1868 | 4.2694 · 10 ² | 5.692 | 1 | 3.6 · 10 ³ |
| 1 kcal/h | 1.163 · 10 ⁻³ | 1.1859 · 10 ⁻¹ | 1.5811 · 10 ⁻³ | 2.7778 · 10 ⁻⁴ | 1 |

PRESSURE, DEFINITION OF TERMS AND UNITS

In technology, various units of pressure are used. A differentiation is made between absolute pressure, differential pressure and gauge pressure.

ABSOLUTE PRESSURE $p_{abs.}$ takes as its basis zero pressure of a pure vacuum.

DIFFERENTIAL PRESSURE Δp is the difference between two pressures.

GAUGE PRESSURE p_e is the difference between an absolute pressure $p_{abs.}$ and the actual (absolute) atmospheric pressure $p_{amb.}$.

$$p_e = p_{abs.} - p_{amb.}$$

Pressure gauge p_e will have a positive value if the absolute pressure is greater than atmospheric pressure and it will have a negative value if the absolute pressure is smaller than atmospheric pressure.

“Negative Pressure” may no longer be used as a designation of a parameter, but only as a qualitative term for a condition, e.g. “A negative pressure prevails in the suction line”.

The indices used are derived from the Latin words:

abs = absolutus; detached, independent
amb = ambiens; environs, ambient
e = excedens; exceed

(see also DIN 1314 “Pressure, basic definitions and units”)

The unit of pressure is the pascal in Pa. For practical purposes the bar (1 bar = 10⁵ Pa) is used as a convenient unit for calculation. The range of pressure below atmospheric pressure is also called the vacuum range. In vacuum technology absolute pressure is always used.

Measurement conversion table

Conversion of english-american units in the International System of Units (SI) and vice versa

| English-american units | Internat. system of units | Internat. system of units | English-american units | English-american units | Internat. system of units | Internat. system of units | English-american units |
|--|---|--|---|-------------------------------|---------------------------|---------------------------|------------------------|
| Length | | | | Length | | | |
| 1 in | 25.4 mm | 1 mm | 0.0394 in | | | | |
| 1 ft (12 in) | 0.305 m | 1 m | 3.28 ft | | | | |
| 1 yd (3 ft) | 0.914 m | 1 m | 1.093 yd | | | | |
| Area | | | | Area | | | |
| 1 in ² | 6.45 cm ² | 1 cm ² | 0.155 in ² | | | | |
| 1 ft ² | 9.29 dm ² | 1 dm ² | 0.1076 ft ² | | | | |
| Volume | | | | Volume | | | |
| 1 in ³ | 16.4 cm ³ | 1 cm ³ | 0.061 in ³ | | | | |
| 1 ft ³ | 28.3 dm ³ | 1 dm ³ | 0.0353 ft ³ | | | | |
| 1 Imp. gal | 4.55 ltr. | 1 ltr. | 0.22 Imp. gal | | | | |
| 1 U.S. gal | 3.785 ltr. | 1 ltr. | 0.264 U.S. gal | | | | |
| Mass | | | | Mass | | | |
| 1 oz | 28.35 g | 1 g | 0.0353 oz | | | | |
| 1 lb (16 oz) | 0.454 kg | 1 kg | 2.205 lb | | | | |
| 1 U.S. ton | 0.907 t | 1 t | 1.1023 U.S. ton | | | | |
| 1 Brit. ton | 1.016 t | 1 t | 0.984 Brit. ton | | | | |
| Density | | | | Density | | | |
| 1 lb/ft ³ | 16.02 kg/m ³ | 1 kg/m ³ | 0.0624 lb/ft ³ | | | | |
| Temperature | | | | Temperature | | | |
| 1 °F | 5/9 °C | 1 °C | 9/5 °F | | | | |
| 1 °F | 5/9 K | 1 K | 9/5 °F | | | | |
| Pressure | | | | Pressure | | | |
| 1 lbf/in ² (psi) | 6.895 · 10 ⁻² bar | 1 bar | 14.5 lbf/in ² | | | | |
| 1 lbf/ft ² | 4.788 · 10 ⁻⁴ bar | 1 bar | 20.88 lbf/ft ² | | | | |
| | | | | Heat / heat units | | | |
| 1 Btu | 1.055 kJ | 1 kJ | 0.948 Btu | | | | |
| | | | | Heat capacity | | | |
| 1 $\frac{\text{Btu}}{\text{lb}}$ | 2.326 $\frac{\text{kJ}}{\text{kg}}$ | 1 $\frac{\text{kJ}}{\text{kg}}$ | 0.43 $\frac{\text{Btu}}{\text{lb}}$ | | | | |
| | | | | Specific heat capacity | | | |
| 1 $\frac{\text{Btu}}{\text{lb} \cdot ^\circ\text{F}}$ | 4,1868 $\frac{\text{kJ}}{\text{kg} \cdot \text{K}}$ | 1 $\frac{\text{kJ}}{\text{kg} \cdot \text{K}}$ | 0,2388 $\frac{\text{Btu}}{\text{lb} \cdot ^\circ\text{F}}$ | | | | |
| | | | | Thermal conductivity | | | |
| 1 $\frac{\text{Btu}}{\text{in} \cdot \text{h} \cdot ^\circ\text{F}}$ | 20,783 $\frac{\text{W}}{\text{m} \cdot \text{K}}$ | 1 $\frac{\text{W}}{\text{m} \cdot \text{K}}$ | 0,0481 $\frac{\text{Btu}}{\text{in} \cdot \text{h} \cdot ^\circ\text{F}}$ | | | | |
| 1 $\frac{\text{Btu}}{\text{ft} \cdot \text{h} \cdot ^\circ\text{F}}$ | 1,7308 $\frac{\text{W}}{\text{m} \cdot \text{K}}$ | 1 $\frac{\text{W}}{\text{m} \cdot \text{K}}$ | 0,5778 $\frac{\text{Btu}}{\text{ft} \cdot \text{h} \cdot ^\circ\text{F}}$ | | | | |
| | | | | Heat transfer | | | |
| 1 $\frac{\text{Btu}}{\text{ft}^2 \cdot \text{h} \cdot ^\circ\text{F}}$ | 5,6785 $\frac{\text{W}}{\text{m}^2 \cdot \text{K}}$ | 1 $\frac{\text{W}}{\text{m}^2 \cdot \text{K}}$ | 0,1761 $\frac{\text{Btu}}{\text{ft}^2 \cdot \text{h} \cdot ^\circ\text{F}}$ | | | | |
| | | | | Fouling factor | | | |
| 1 $\frac{\text{ft}^2 \cdot \text{h} \cdot ^\circ\text{F}}{\text{Btu}}$ | 0,1761 $\frac{\text{m}^2 \cdot \text{K}}{\text{W}}$ | 1 $\frac{\text{m}^2 \cdot \text{K}}{\text{W}}$ | 5,6785 $\frac{\text{ft}^2 \cdot \text{h} \cdot ^\circ\text{F}}{\text{Btu}}$ | | | | |
| | | | | Heat flux density | | | |
| 1 $\frac{\text{Btu}}{\text{in}^2 \cdot \text{h}}$ | 454,3 $\frac{\text{W}}{\text{m}^2}$ | 1 $\frac{\text{W}}{\text{m}^2}$ | 2,202 · 10 ⁻³ $\frac{\text{Btu}}{\text{in}^2 \cdot \text{h}}$ | | | | |
| 1 $\frac{\text{Btu}}{\text{ft}^2 \cdot \text{h}}$ | 3,1546 $\frac{\text{W}}{\text{m}^2}$ | 1 $\frac{\text{W}}{\text{m}^2}$ | 0,317 $\frac{\text{Btu}}{\text{ft}^2 \cdot \text{h}}$ | | | | |

Temperature conversion table

°C in °F and vice versa

| °C | | °F |
|-------|-----|-------|
| -28.8 | -20 | -4.0 |
| -28.3 | -19 | -2.2 |
| -27.7 | -18 | -0.4 |
| -27.2 | -17 | 1.4 |
| -26.6 | -16 | 3.2 |
| -26.1 | -15 | 5.0 |
| -25.5 | -14 | 6.8 |
| -25.0 | -13 | 8.6 |
| -24.4 | -12 | 10.4 |
| -23.8 | -11 | 12.2 |
| -23.3 | -10 | 14.0 |
| -22.7 | -9 | 15.8 |
| -22.2 | -8 | 17.6 |
| -21.6 | -7 | 19.4 |
| -21.1 | -6 | 21.2 |
| -20.5 | -5 | 23.0 |
| -20.0 | -4 | 24.8 |
| -19.4 | -3 | 26.6 |
| -18.8 | -2 | 28.4 |
| -18.3 | -1 | 30.2 |
| -17.7 | 0 | 32.0 |
| -17.2 | 1 | 33.8 |
| -16.6 | 2 | 35.6 |
| -16.1 | 3 | 37.4 |
| -15.5 | 4 | 39.2 |
| -15.0 | 5 | 41.0 |
| -14.4 | 6 | 42.8 |
| -13.8 | 7 | 44.6 |
| -13.3 | 8 | 46.4 |
| -12.7 | 9 | 48.2 |
| -12.2 | 10 | 50.0 |
| -11.6 | 11 | 51.8 |
| -11.1 | 12 | 53.6 |
| -10.5 | 13 | 55.4 |
| -10.0 | 14 | 57.2 |
| -9.4 | 15 | 59.0 |
| -8.8 | 16 | 60.8 |
| -8.3 | 17 | 62.6 |
| -7.7 | 18 | 64.4 |
| -7.2 | 19 | 66.2 |
| -6.6 | 20 | 68.0 |
| -6.1 | 21 | 69.8 |
| -5.5 | 22 | 71.6 |
| -5.0 | 23 | 73.4 |
| -4.4 | 24 | 75.2 |
| -3.8 | 25 | 77.0 |
| -3.3 | 26 | 78.8 |
| -2.7 | 27 | 80.6 |
| -2.2 | 28 | 82.4 |
| -1.6 | 29 | 84.2 |
| -1.1 | 30 | 86.0 |
| -0.5 | 31 | 87.8 |
| 0.0 | 32 | 89.6 |
| 0.5 | 33 | 91.4 |
| 1.1 | 34 | 93.2 |
| 1.6 | 35 | 95.0 |
| 2.2 | 36 | 96.8 |
| 2.7 | 37 | 98.6 |
| 3.3 | 38 | 100.4 |
| 3.8 | 39 | 102.2 |

| °C | | °F |
|------|----|-------|
| 4.4 | 40 | 104.0 |
| 5.0 | 41 | 105.8 |
| 5.5 | 42 | 107.6 |
| 6.1 | 43 | 109.4 |
| 6.6 | 44 | 111.2 |
| 7.2 | 45 | 113.0 |
| 7.7 | 46 | 114.8 |
| 8.3 | 47 | 116.6 |
| 8.8 | 48 | 118.4 |
| 9.4 | 49 | 120.2 |
| 10.0 | 50 | 122.0 |
| 10.5 | 51 | 123.8 |
| 11.1 | 52 | 125.6 |
| 11.6 | 53 | 127.4 |
| 12.2 | 54 | 129.2 |
| 12.7 | 55 | 131.0 |
| 13.3 | 56 | 132.8 |
| 13.8 | 57 | 134.6 |
| 14.4 | 58 | 136.4 |
| 15.0 | 59 | 138.2 |
| 15.5 | 60 | 140.0 |
| 16.1 | 61 | 141.8 |
| 16.6 | 62 | 143.6 |
| 17.2 | 63 | 145.4 |
| 17.7 | 64 | 147.2 |
| 18.3 | 65 | 149.0 |
| 18.8 | 66 | 150.8 |
| 19.4 | 67 | 152.6 |
| 20.0 | 68 | 154.4 |
| 20.5 | 69 | 156.2 |
| 21.1 | 70 | 158.0 |
| 21.6 | 71 | 159.8 |
| 22.2 | 72 | 161.6 |
| 22.7 | 73 | 163.4 |
| 23.3 | 74 | 165.2 |
| 23.8 | 75 | 167.0 |
| 24.4 | 76 | 168.8 |
| 25.0 | 77 | 170.6 |
| 25.5 | 78 | 172.5 |
| 26.1 | 79 | 174.2 |
| 26.6 | 80 | 176.0 |
| 27.2 | 81 | 177.8 |
| 27.7 | 82 | 179.6 |
| 28.3 | 83 | 181.4 |
| 28.8 | 84 | 183.2 |
| 29.4 | 85 | 185.0 |
| 30.0 | 86 | 186.8 |
| 30.5 | 87 | 188.6 |
| 31.1 | 88 | 190.4 |
| 31.6 | 89 | 192.2 |
| 32.2 | 90 | 194.0 |
| 32.7 | 91 | 195.8 |
| 33.3 | 92 | 197.6 |
| 33.8 | 93 | 199.4 |
| 34.4 | 94 | 201.2 |
| 35.0 | 95 | 203.0 |
| 35.5 | 96 | 204.8 |
| 36.1 | 97 | 206.6 |
| 36.6 | 98 | 208.4 |
| 37.2 | 99 | 210.2 |

| °C | | °F |
|-------|-----|-------|
| 37.7 | 100 | 212.0 |
| 38.3 | 101 | 213.8 |
| 38.8 | 102 | 215.6 |
| 39.4 | 103 | 217.4 |
| 40.0 | 104 | 219.2 |
| 40.5 | 105 | 221.0 |
| 41.1 | 106 | 222.8 |
| 41.6 | 107 | 224.6 |
| 42.2 | 108 | 226.4 |
| 42.7 | 109 | 228.2 |
| 43.3 | 110 | 230.0 |
| 43.8 | 111 | 231.8 |
| 44.4 | 112 | 233.6 |
| 45.0 | 113 | 235.4 |
| 45.5 | 114 | 237.2 |
| 46.1 | 115 | 239.0 |
| 46.6 | 116 | 240.8 |
| 47.2 | 117 | 242.6 |
| 47.7 | 118 | 244.4 |
| 48.3 | 119 | 246.2 |
| 48.8 | 120 | 248.0 |
| 54.4 | 130 | 266.0 |
| 60.0 | 140 | 284.0 |
| 65.5 | 150 | 302.0 |
| 71.5 | 160 | 320.0 |
| 76.6 | 170 | 338.0 |
| 82.2 | 180 | 356.0 |
| 87.7 | 190 | 374.0 |
| 93.3 | 200 | 392.0 |
| 98.8 | 210 | 410.0 |
| 104.4 | 220 | 428.0 |
| 110.0 | 230 | 446.0 |
| 115.5 | 240 | 464.0 |
| 121.1 | 250 | 482.0 |
| 126.6 | 260 | 500.0 |
| 132.2 | 270 | 518.0 |
| 137.7 | 280 | 536.0 |
| 143.3 | 290 | 554.0 |
| 148.8 | 300 | 572.0 |
| 154.4 | 310 | 590.0 |
| 160.0 | 320 | 608.0 |
| 165.5 | 330 | 626.0 |
| 171.1 | 340 | 644.0 |
| 176.6 | 350 | 662.0 |
| 182.2 | 360 | 680.0 |
| 187.7 | 370 | 698.0 |
| 193.3 | 380 | 716.0 |
| 198.8 | 390 | 734.0 |
| 204.4 | 400 | 752.0 |

The temperature values to be converted are given in the coloured centre column. The corresponding values in °C are given left of the centre column, the values in °F are given right of the centre column.

- EXAMPLES:** 1. Value to be converted (centre column) 20 °C = + 68 °F (right column)
 2. Value to be converted (centre column) 20 °F = - 6.6 °C (left column)

CONVERSION EQUATION:

$$\vartheta_{\text{°C}} = \frac{5}{9} (\vartheta_{\text{°F}} - 32)$$

$$\vartheta_{\text{°F}} = \frac{9}{5} \vartheta_{\text{°C}} + 32$$

Water vapor pressure table

Vacuum range (saturated steam)

| p mbar | ϑ °C | v'' m³/kg | h'' kJ/kg | Δh _v kJ/kg |
|-----------|---------|--------------|--------------|--------------------------|
| 0.001 | -76.19 | 909000 | 2344 | 2852 |
| 0.002 | -71.74 | 465000 | 2355 | 2851 |
| 0.003 | -69.04 | 314000 | 2361 | 2850 |
| 0.004 | -67.08 | 238000 | 2365 | 2850 |
| 0.005 | -65.53 | 192000 | 2368 | 2849 |
| 0.006 | -64.25 | 160700 | 2371 | 2849 |
| 0.007 | -63.15 | 138500 | 2374 | 2849 |
| 0.008 | -62.19 | 121700 | 2376 | 2848 |
| 0.009 | -61.34 | 108600 | 2377 | 2848 |
| 0.01 | -60.57 | 98110 | 2379 | 2848 |
| 0.02 | -55.37 | 50250 | 2390 | 2847 |
| 0.03 | -52.20 | 33990 | 2397 | 2846 |
| 0.04 | -49.90 | 25760 | 2402 | 2845 |
| 0.05 | -48.08 | 20770 | 2405 | 2844 |
| 0.06 | -46.57 | 17430 | 2408 | 2844 |
| 0.07 | -45.28 | 15020 | 2411 | 2844 |
| 0.08 | -44.14 | 13210 | 2413 | 2843 |
| 0.09 | -43.14 | 11790 | 2415 | 2843 |
| 0.1 | -42.23 | 10660 | 2417 | 2843 |
| 0.2 | -36.06 | 5471 | 2430 | 2841 |
| 0.3 | -32.29 | 3705 | 2437 | 2840 |
| 0.4 | -29.55 | 2811 | 2442 | 2839 |
| 0.5 | -27.38 | 2269 | 2447 | 2838 |
| 0.6 | -25.57 | 1904 | 2450 | 2838 |
| 0.7 | -24.02 | 1643 | 2453 | 2838 |
| 0.8 | -22.67 | 1445 | 2456 | 2837 |
| 0.9 | -21.46 | 1291 | 2458 | 2837 |
| 1 | -20.36 | 1167 | 2460 | 2837 |
| 1.5 | -16.07 | 791 | 2469 | 2836 |
| 2 | -12.94 | 600 | 2475 | 2835 |
| 2.5 | -10.45 | 485 | 2479 | 2834 |
| 3 | -8.38 | 407 | 2483 | 2834 |
| 3.5 | -6.61 | 351 | 2487 | 2833 |
| 4 | -5.06 | 309 | 2490 | 2833 |
| 4.5 | -3.67 | 276 | 2492 | 2833 |
| 5 | -2.42 | 250 | 2495 | 2833 |
| 5.5 | -1.27 | 228 | 2497 | 2832 |
| 6 | -0.22 | 210 | 2499 | 2832 |
| 7 | 1.89 | 181 | 2505 | 2497 |
| 8 | 3.77 | 160 | 2509 | 2493 |
| 9 | 5.46 | 143 | 2512 | 2489 |
| 10 | 6.98 | 129 | 2515 | 2485 |
| 11 | 8.38 | 118 | 2517 | 2482 |
| 12 | 9.66 | 109 | 2519 | 2479 |
| 13 | 10.86 | 101 | 2522 | 2476 |
| 14 | 11.98 | 94.0 | 2524 | 2474 |
| 15 | 13.03 | 88.0 | 2526 | 2471 |
| 16 | 14.02 | 82.8 | 2527 | 2469 |
| 17 | 14.96 | 78.2 | 2529 | 2467 |
| 18 | 15.85 | 74.1 | 2531 | 2464 |
| 19 | 16.70 | 70.4 | 2532 | 2462 |
| 20 | 17.51 | 67.1 | 2534 | 2460 |
| 21 | 18.28 | 64.0 | 2535 | 2459 |
| 22 | 19.03 | 61.3 | 2537 | 2457 |
| 23 | 19.74 | 58.7 | 2538 | 2455 |
| 24 | 20.43 | 56.4 | 2539 | 2454 |
| 25 | 21.09 | 54.3 | 2540 | 2452 |
| 26 | 21.73 | 52.3 | 2542 | 2451 |
| 27 | 22.35 | 50.5 | 2543 | 2449 |
| 28 | 22.95 | 48.8 | 2544 | 2448 |
| 29 | 23.53 | 47.2 | 2545 | 2446 |
| 30 | 24.10 | 45.7 | 2546 | 2445 |
| 31 | 24.64 | 44.3 | 2547 | 2444 |
| 32 | 25.18 | 43.0 | 2548 | 2442 |
| 33 | 25.69 | 41.8 | 2549 | 2441 |
| 34 | 26.20 | 40.6 | 2550 | 2440 |

| p mbar | ϑ °C | v'' m³/kg | h'' kJ/kg | Δh _v kJ/kg |
|-----------|---------|--------------|--------------|--------------------------|
| 35 | 26.69 | 39.5 | 2551 | 2439 |
| 36 | 27.17 | 38.5 | 2551 | 2438 |
| 37 | 27.64 | 37.5 | 2552 | 2437 |
| 38 | 28.10 | 36.6 | 2553 | 2435 |
| 39 | 28.54 | 35.7 | 2554 | 2434 |
| 40 | 28.98 | 34.8 | 2555 | 2433 |
| 42 | 29.83 | 33.3 | 2556 | 2431 |
| 44 | 30.64 | 31.8 | 2558 | 2429 |
| 46 | 31.42 | 30.5 | 2559 | 2428 |
| 48 | 32.17 | 29.3 | 2560 | 2426 |
| 50 | 32.90 | 28.2 | 2562 | 2424 |
| 52 | 33.60 | 27.2 | 2563 | 2422 |
| 54 | 34.27 | 26.2 | 2564 | 2421 |
| 56 | 34.93 | 25.4 | 2565 | 2419 |
| 58 | 35.57 | 24.5 | 2567 | 2418 |
| 60 | 36.18 | 23.8 | 2568 | 2416 |
| 62 | 36.78 | 23.0 | 2569 | 2415 |
| 64 | 37.37 | 22.4 | 2570 | 2413 |
| 66 | 37.93 | 21.7 | 2571 | 2412 |
| 68 | 38.49 | 21.1 | 2572 | 2411 |
| 70 | 39.03 | 20.5 | 2573 | 2409 |
| 72 | 39.55 | 20.0 | 2574 | 2408 |
| 74 | 40.06 | 19.5 | 2575 | 2407 |
| 76 | 40.57 | 19.0 | 2575 | 2406 |
| 78 | 41.06 | 18.6 | 2576 | 2404 |
| 80 | 41.54 | 18.1 | 2577 | 2403 |
| 85 | 42.69 | 17.1 | 2579 | 2401 |
| 90 | 43.79 | 16.2 | 2581 | 2398 |
| 95 | 44.84 | 15.4 | 2583 | 2395 |
| 100 | 45.84 | 14.7 | 2585 | 2393 |
| 110 | 47.71 | 13.4 | 2588 | 2388 |
| 120 | 49.45 | 12.4 | 2591 | 2384 |
| 130 | 51.06 | 11.5 | 2594 | 2380 |
| 140 | 52.58 | 10.7 | 2597 | 2377 |
| 150 | 54.00 | 10.0 | 2599 | 2373 |
| 160 | 55.34 | 9.44 | 2602 | 2370 |
| 170 | 56.62 | 8.92 | 2604 | 2367 |
| 180 | 57.83 | 8.45 | 2606 | 2364 |
| 190 | 58.99 | 8.03 | 2608 | 2361 |
| 200 | 60.09 | 7.65 | 2610 | 2358 |
| 220 | 62.17 | 7.00 | 2613 | 2353 |
| 240 | 64.09 | 6.45 | 2617 | 2348 |
| 260 | 65.88 | 5.98 | 2620 | 2344 |
| 280 | 67.55 | 5.58 | 2623 | 2340 |
| 300 | 69.13 | 5.23 | 2625 | 2336 |
| 320 | 70.62 | 4.93 | 2628 | 2332 |
| 340 | 72.03 | 4.65 | 2630 | 2329 |
| 360 | 73.38 | 4.41 | 2633 | 2325 |
| 380 | 74.66 | 4.19 | 2635 | 2322 |
| 400 | 75.89 | 4.00 | 2637 | 2319 |
| 420 | 77.07 | 3.82 | 2639 | 2316 |
| 440 | 78.20 | 3.65 | 2641 | 2313 |
| 460 | 79.29 | 3.51 | 2642 | 2311 |
| 480 | 80.33 | 3.37 | 2644 | 2308 |
| 500 | 81.35 | 3.24 | 2646 | 2305 |
| 550 | 83.74 | 2.97 | 2650 | 2299 |
| 600 | 85.96 | 2.73 | 2653 | 2294 |
| 650 | 88.02 | 2.54 | 2657 | 2288 |
| 700 | 89.96 | 2.37 | 2660 | 2283 |
| 750 | 91.78 | 2.22 | 2663 | 2279 |
| 800 | 93.51 | 2.09 | 2666 | 2274 |
| 850 | 95.15 | 1.97 | 2668 | 2270 |
| 900 | 96.71 | 1.87 | 2671 | 2266 |
| 950 | 98.20 | 1.78 | 2673 | 2262 |
| 1000 | 99.63 | 1.70 | 2675 | 2258 |

Documentation:

1. "Thermodynamische Diagramme" Z. Kältetechnik, 17. (1965) S. 299-301
2. VDI Water vapor tables

Water vapor temperature table

Vacuum range (saturated steam)

| θ °C | p mbar | v'' m³/kg | h'' kJ/kg | Δh _v kJ/kg |
|---------|-----------|--------------|--------------|--------------------------|
| -74 | 0.001411 | 651700 | 2349.3 | 2851.2 |
| -73 | 0.001647 | 561000 | 2351.6 | 2851.0 |
| -72 | 0.001920 | 483600 | 2353.9 | 2850.7 |
| -71 | 0.002236 | 417500 | 2356.1 | 2850.5 |
| -70 | 0.002598 | 361100 | 2358.4 | 2850.3 |
| -69 | 0.003015 | 312600 | 2360.6 | 2850.0 |
| -68 | 0.003495 | 271100 | 2362.8 | 2849.8 |
| -67 | 0.004044 | 235400 | 2365.0 | 2849.6 |
| -66 | 0.004672 | 204700 | 2367.2 | 2849.3 |
| -65 | 0.005391 | 178300 | 2369.4 | 2849.1 |
| -64 | 0.006212 | 155500 | 2371.6 | 2848.8 |
| -63 | 0.007149 | 135800 | 2373.8 | 2848.5 |
| -62 | 0.008215 | 118700 | 2376.0 | 2848.3 |
| -61 | 0.00929 | 103900 | 2378.1 | 2848.0 |
| -60 | 0.01080 | 91100 | 2380.3 | 2847.7 |
| -59 | 0.01237 | 79900 | 2382.4 | 2847.5 |
| -58 | 0.01414 | 70300 | 2384.5 | 2847.2 |
| -57 | 0.01614 | 61600 | 2386.7 | 2846.9 |
| -56 | 0.01841 | 54500 | 2388.8 | 2846.6 |
| -55 | 0.02097 | 48000 | 2390.9 | 2846.4 |
| -54 | 0.02385 | 42400 | 2393.0 | 2846.1 |
| -53 | 0.02711 | 37500 | 2395.1 | 2845.8 |
| -52 | 0.03077 | 33200 | 2397.2 | 2845.5 |
| -51 | 0.03488 | 29400 | 2399.3 | 2845.2 |
| -50 | 0.03949 | 26100 | 2401.3 | 2844.9 |
| -49 | 0.04467 | 23200 | 2403.4 | 2844.6 |
| -48 | 0.05047 | 20600 | 2405.5 | 2844.4 |
| -47 | 0.05696 | 18300 | 2407.5 | 2844.1 |
| -46 | 0.06422 | 16300 | 2409.6 | 2843.8 |
| -45 | 0.07232 | 14600 | 2411.6 | 2843.5 |
| -44 | 0.08136 | 13000 | 2413.6 | 2843.2 |
| -43 | 0.09144 | 11600 | 2415.7 | 2842.9 |
| -42 | 0.1026 | 10400 | 2417.7 | 2842.6 |
| -41 | 0.1151 | 9312 | 2419.7 | 2842.3 |
| -40 | 0.1289 | 8347 | 2421.7 | 2842.0 |
| -39 | 0.1443 | 7489 | 2423.7 | 2841.7 |
| -38 | 0.1614 | 6726 | 2425.7 | 2841.4 |
| -37 | 0.1803 | 6046 | 2427.7 | 2841.1 |
| -36 | 0.2012 | 5441 | 2429.7 | 2840.8 |
| -35 | 0.2244 | 4900 | 2431.7 | 2840.6 |
| -34 | 0.2500 | 4416 | 2433.7 | 2840.3 |
| -33 | 0.2783 | 3985 | 2435.7 | 2840.0 |
| -32 | 0.3095 | 3598 | 2437.6 | 2839.7 |
| -31 | 0.3438 | 3252 | 2439.6 | 2839.4 |
| -30 | 0.3816 | 2942 | 2441.6 | 2839.1 |
| -29 | 0.4233 | 2663 | 2443.5 | 2838.8 |
| -28 | 0.4691 | 2413 | 2445.5 | 2838.6 |
| -27 | 0.5194 | 2188 | 2447.4 | 2838.3 |
| -26 | 0.5746 | 1986 | 2449.4 | 2838.0 |
| -25 | 0.6351 | 1804 | 2451.3 | 2837.7 |
| -24 | 0.7014 | 1840 | 2453.3 | 2837.5 |
| -23 | 0.7741 | 1492 | 2455.2 | 2837.2 |
| -22 | 0.8536 | 1358 | 2457.1 | 2836.9 |
| -21 | 0.9407 | 1237 | 2459.1 | 2836.7 |
| -20 | 1.035 | 1129 | 2461.0 | 2836.4 |
| -19 | 1.139 | 1030 | 2462.9 | 2836.2 |
| -18 | 1.252 | 940.9 | 2464.8 | 2835.9 |
| -17 | 1.375 | 859.9 | 2466.8 | 2835.7 |
| -16 | 1.509 | 786.5 | 2468.7 | 2835.4 |
| -15 | 1.656 | 719.8 | 2470.6 | 2835.2 |
| -14 | 1.815 | 659.3 | 2472.5 | 2835.0 |
| -13 | 1.968 | 604.2 | 2474.4 | 2834.7 |
| -12 | 2.176 | 554.2 | 2476.3 | 2834.5 |
| -11 | 2.380 | 508.6 | 2478.3 | 2834.3 |
| -10 | 2.601 | 467.1 | 2480.2 | 2834.1 |
| -9 | 2.841 | 429.3 | 2482.1 | 2833.9 |
| -8 | 3.101 | 394.8 | 2484.0 | 2833.7 |
| -7 | 3.363 | 363.3 | 2485.9 | 2833.5 |
| -6 | 3.688 | 334.5 | 2487.8 | 2833.3 |
| -5 | 4.017 | 308.2 | 2489.7 | 2833.1 |
| -4 | 4.373 | 284.2 | 2491.6 | 2832.9 |
| -3 | 4.758 | 262.1 | 2493.5 | 2832.7 |
| -2 | 5.173 | 242.0 | 2495.4 | 2832.5 |
| -1 | 5.622 | 223.5 | 2497.3 | 2832.4 |
| 0 | 6.105 | 206.6 | 2501.6 | 2501.6 |

| θ °C | p mbar | v'' m³/kg | h'' kJ/kg | Δh _v kJ/kg |
|---------|-----------|--------------|--------------|--------------------------|
| 1 | 6.566 | 192.6 | 2503.4 | 2499.2 |
| 2 | 7.054 | 179.9 | 2505.2 | 2496.8 |
| 3 | 7.574 | 168.2 | 2507.1 | 2494.5 |
| 4 | 8.128 | 157.3 | 2508.9 | 2492.1 |
| 5 | 8.718 | 147.2 | 2510.7 | 2489.7 |
| 6 | 9.345 | 137.8 | 2512.6 | 2487.4 |
| 7 | 10.01 | 129.1 | 2514.4 | 2485.0 |
| 8 | 10.71 | 121.0 | 2516.2 | 2482.6 |
| 9 | 11.47 | 113.4 | 2518.1 | 2480.3 |
| 10 | 12.27 | 106.4 | 2519.9 | 2477.9 |
| 11 | 13.11 | 99.91 | 2521.7 | 2475.5 |
| 12 | 14.01 | 93.84 | 2523.6 | 2473.2 |
| 13 | 14.96 | 88.18 | 2525.4 | 2470.8 |
| 14 | 15.97 | 82.90 | 2527.2 | 2468.5 |
| 15 | 17.03 | 77.98 | 2529.1 | 2466.1 |
| 16 | 18.16 | 73.38 | 2530.9 | 2463.8 |
| 17 | 19.36 | 69.09 | 2532.7 | 2461.4 |
| 18 | 20.62 | 65.09 | 2534.5 | 2459.0 |
| 19 | 21.95 | 61.34 | 2536.4 | 2456.7 |
| 20 | 23.36 | 57.84 | 2538.2 | 2454.3 |
| 21 | 24.85 | 54.56 | 2540.0 | 2452.0 |
| 22 | 26.41 | 51.49 | 2541.8 | 2449.6 |
| 23 | 28.07 | 48.62 | 2543.6 | 2447.2 |
| 24 | 29.82 | 45.93 | 2545.5 | 2444.9 |
| 25 | 31.65 | 43.40 | 2547.3 | 2442.5 |
| 26 | 33.59 | 41.03 | 2549.1 | 2440.2 |
| 27 | 35.63 | 38.81 | 2550.9 | 2437.8 |
| 28 | 37.78 | 36.73 | 2552.7 | 2435.4 |
| 29 | 40.04 | 34.77 | 2554.5 | 2433.1 |
| 30 | 42.41 | 32.93 | 2556.4 | 2430.7 |
| 31 | 44.91 | 31.20 | 2558.2 | 2428.3 |
| 32 | 47.53 | 29.57 | 2560.0 | 2425.9 |
| 33 | 50.28 | 28.04 | 2561.8 | 2423.6 |
| 34 | 53.18 | 26.60 | 2563.6 | 2421.2 |
| 35 | 56.21 | 25.24 | 2565.4 | 2418.8 |
| 36 | 59.39 | 23.97 | 2567.2 | 2416.4 |
| 37 | 62.74 | 22.76 | 2569.0 | 2414.1 |
| 38 | 66.24 | 21.63 | 2570.8 | 2411.7 |
| 39 | 69.91 | 20.56 | 2572.6 | 2409.3 |
| 40 | 73.74 | 19.55 | 2574.4 | 2406.9 |
| 41 | 77.77 | 18.59 | 2576.2 | 2404.5 |
| 42 | 81.98 | 17.69 | 2577.9 | 2402.1 |
| 43 | 86.38 | 16.84 | 2579.7 | 2399.7 |
| 44 | 90.99 | 16.04 | 2581.5 | 2397.3 |
| 45 | 95.82 | 15.28 | 2583.3 | 2394.9 |
| 46 | 100.8 | 14.56 | 2585.1 | 2392.5 |
| 47 | 106.1 | 13.68 | 2586.9 | 2390.1 |
| 48 | 111.6 | 13.23 | 2588.6 | 2387.7 |
| 49 | 117.3 | 12.62 | 2590.4 | 2385.3 |
| 50 | 123.3 | 12.05 | 2592.2 | 2382.9 |
| 52 | 136.1 | 10.98 | 2595.7 | 2378.1 |
| 54 | 150.0 | 10.02 | 2599.2 | 2373.2 |
| 56 | 165.1 | 9.159 | 2602.7 | 2368.4 |
| 58 | 181.4 | 8.381 | 2606.2 | 2363.5 |
| 60 | 199.2 | 7.679 | 2609.7 | 2358.6 |
| 62 | 218.3 | 7.044 | 2613.2 | 2353.7 |
| 64 | 239.0 | 6.469 | 2616.6 | 2348.8 |
| 66 | 261.5 | 5.948 | 2620.1 | 2343.9 |
| 68 | 285.6 | 5.476 | 2623.5 | 2338.9 |
| 70 | 311.6 | 5.046 | 2626.9 | 2334.0 |
| 72 | 339.6 | 4.656 | 2630.3 | 2329.0 |
| 74 | 369.6 | 4.300 | 2633.7 | 2324.0 |
| 76 | 401.8 | 3.976 | 2637.1 | 2318.9 |
| 78 | 436.4 | 3.660 | 2640.4 | 2313.9 |
| 80 | 473.5 | 3.409 | 2643.8 | 2308.8 |
| 82 | 513.2 | 3.162 | 2647.1 | 2303.8 |
| 84 | 555.7 | 2.935 | 2650.4 | 2298.7 |
| 86 | 601.0 | 2.727 | 2653.6 | 2293.1 |
| 88 | 649.4 | 2.536 | 2656.9 | 2288.4 |
| 90 | 701.0 | 2.361 | 2660.1 | 2283.2 |
| 92 | 756.0 | 2.200 | 2663.4 | 2278.0 |
| 94 | 814.6 | 2.052 | 2666.6 | 2272.8 |
| 96 | 876.8 | 1.915 | 2669.7 | 2267.5 |
| 98 | 943.0 | 1.789 | 2672.9 | 2262.2 |
| 100 | 1013.2 | 1.673 | 2676.0 | 2256.9 |

Water vapor pressure table

Pressure range 1-70 bar (saturated steam)

| $p_{\text{abs.}}$ bar | ϑ °C | v'' m ³ /kg | h'' kJ/kg | Δh_v kJ/kg | $p_{\text{abs.}}$ bar | ϑ °C | v'' m ³ /kg | h'' kJ/kg | Δh_v kJ/kg |
|--------------------------|-------------------|-----------------------------|----------------|-----------------------|--------------------------|-------------------|-----------------------------|----------------|-----------------------|
| 1.0 | 99.63 | 1.694 | 2675.4 | 2257.9 | 20 | 212.37 | 0.09954 | 2797.2 | 1888.6 |
| 1.1 | 102.32 | 1.549 | 2679.6 | 2250.8 | 21 | 214.85 | 0.09489 | 2798.2 | 1878.2 |
| 1.2 | 104.81 | 1.428 | 2683.4 | 2244.1 | 22 | 217.24 | 0.09065 | 2799.1 | 1868.1 |
| 1.3 | 107.13 | 1.325 | 2687.0 | 2237.8 | 23 | 219.55 | 0.08677 | 2799.8 | 1858.2 |
| 1.4 | 109.32 | 1.236 | 2690.3 | 2231.9 | 24 | 221.78 | 0.08320 | 2800.4 | 1848.5 |
| 1.5 | 111.37 | 1.159 | 2693.4 | 2226.2 | 25 | 223.94 | 0.07991 | 2800.9 | 1839.0 |
| 1.6 | 113.32 | 1.091 | 2696.2 | 2220.9 | 26 | 226.04 | 0.07686 | 2801.4 | 1829.6 |
| 1.7 | 115.17 | 1.031 | 2699.0 | 2215.7 | 27 | 228.07 | 0.07402 | 2801.7 | 1820.5 |
| 1.8 | 116.93 | 0.9772 | 2701.5 | 2210.8 | 28 | 230.05 | 0.07139 | 2802.0 | 1811.5 |
| 1.9 | 118.62 | 0.9290 | 2704.0 | 2206.1 | 29 | 231.97 | 0.06893 | 2802.2 | 1802.6 |
| 2.0 | 120.23 | 0.8854 | 2706.3 | 2201.6 | 30 | 233.84 | 0.06663 | 2802.3 | 1793.9 |
| 2.1 | 121.78 | 0.8459 | 2708.5 | 2197.2 | 31 | 235.67 | 0.06447 | 2802.3 | 1785.4 |
| 2.2 | 123.27 | 0.8098 | 2710.6 | 2193.0 | 32 | 237.45 | 0.06244 | 2802.3 | 1776.9 |
| 2.3 | 124.71 | 0.7768 | 2712.6 | 2188.9 | 33 | 239.18 | 0.06053 | 2802.3 | 1768.6 |
| 2.4 | 126.09 | 0.7465 | 2714.5 | 2184.9 | 34 | 240.88 | 0.05873 | 2802.1 | 1760.3 |
| 2.5 | 127.43 | 0.7184 | 2716.4 | 2181.0 | 35 | 242.54 | 0.05703 | 2802.0 | 1752.2 |
| 2.6 | 128.73 | 0.6925 | 2718.2 | 2177.3 | 36 | 244.16 | 0.05541 | 2801.7 | 1744.2 |
| 2.7 | 129.98 | 0.6684 | 2719.9 | 2173.6 | 37 | 245.75 | 0.05389 | 2801.4 | 1736.2 |
| 2.8 | 131.20 | 0.6460 | 2721.5 | 2170.1 | 38 | 247.31 | 0.05244 | 2801.1 | 1728.4 |
| 2.9 | 132.39 | 0.6251 | 2723.1 | 2166.6 | 39 | 248.84 | 0.05106 | 2800.8 | 1720.6 |
| 3.0 | 133.54 | 0.6056 | 2724.7 | 2163.2 | 40 | 250.33 | 0.04975 | 2800.3 | 1712.9 |
| 3.2 | 135.75 | 0.5700 | 2727.6 | 2156.7 | 41 | 251.80 | 0.04850 | 2799.9 | 1705.3 |
| 3.4 | 137.86 | 0.5385 | 2730.3 | 2150.4 | 42 | 253.24 | 0.04731 | 2799.4 | 1697.8 |
| 3.6 | 139.86 | 0.5103 | 2732.9 | 2144.4 | 43 | 254.66 | 0.04617 | 2798.9 | 1690.3 |
| 3.8 | 141.78 | 0.4851 | 2735.3 | 2138.6 | 44 | 256.05 | 0.04508 | 2798.3 | 1682.9 |
| 4.0 | 143.62 | 0.4622 | 2737.6 | 2133.0 | 45 | 257.41 | 0.04404 | 2797.7 | 1675.6 |
| 4.2 | 145.39 | 0.4415 | 2739.8 | 2127.5 | 46 | 258.75 | 0.04304 | 2797.0 | 1668.3 |
| 4.4 | 147.09 | 0.4226 | 2741.9 | 2122.3 | 47 | 260.07 | 0.04208 | 2796.4 | 1661.1 |
| 4.6 | 148.73 | 0.4053 | 2743.9 | 2117.2 | 48 | 261.37 | 0.04116 | 2795.7 | 1653.9 |
| 4.8 | 150.31 | 0.3894 | 2745.7 | 2112.2 | 49 | 262.65 | 0.04028 | 2794.9 | 1646.8 |
| 5.0 | 151.84 | 0.3747 | 2747.5 | 2107.4 | 50 | 263.91 | 0.03943 | 2794.2 | 1639.7 |
| 5.5 | 155.46 | 0.3425 | 2751.6 | 2096.0 | 51 | 265.15 | 0.03861 | 2793.4 | 1632.7 |
| 6.0 | 158.84 | 0.3155 | 2755.5 | 2085.0 | 52 | 266.37 | 0.03782 | 2792.6 | 1625.7 |
| 6.5 | 161.99 | 0.2925 | 2758.8 | 2074.7 | 53 | 267.58 | 0.03707 | 2791.7 | 1618.8 |
| 7.0 | 164.96 | 0.2727 | 2762.0 | 2064.9 | 54 | 268.76 | 0.03633 | 2790.8 | 1611.9 |
| 7.5 | 167.76 | 0.2555 | 2764.9 | 2055.5 | 55 | 269.93 | 0.03563 | 2789.9 | 1605.0 |
| 8.0 | 170.41 | 0.2403 | 2767.5 | 2046.5 | 56 | 271.09 | 0.03495 | 2789.0 | 1598.2 |
| 8.5 | 172.93 | 0.2268 | 2769.9 | 2037.8 | 57 | 272.22 | 0.03429 | 2788.0 | 1591.4 |
| 9.0 | 175.36 | 0.2148 | 2772.1 | 2029.5 | 58 | 273.35 | 0.03365 | 2787.0 | 1584.7 |
| 9.5 | 177.66 | 0.2040 | 2774.2 | 2021.4 | 59 | 274.46 | 0.03303 | 2786.0 | 1578.0 |
| 10 | 179.88 | 0.1943 | 2776.2 | 2013.6 | 60 | 275.55 | 0.03244 | 2785.0 | 1571.3 |
| 11 | 184.07 | 0.1774 | 2779.7 | 1998.5 | 61 | 276.63 | 0.03186 | 2784.0 | 1564.7 |
| 12 | 187.96 | 0.1632 | 2782.7 | 1984.3 | 62 | 277.70 | 0.03130 | 2782.9 | 1558.0 |
| 13 | 191.61 | 0.1511 | 2785.4 | 1970.7 | 63 | 278.75 | 0.03076 | 2781.8 | 1551.5 |
| 14 | 195.04 | 0.1407 | 2787.8 | 1957.7 | 64 | 279.79 | 0.03023 | 2780.6 | 1544.9 |
| 15 | 198.29 | 0.1317 | 2789.9 | 1945.2 | 65 | 280.82 | 0.02972 | 2779.5 | 1538.4 |
| 16 | 201.37 | 0.1237 | 2791.7 | 1933.2 | 66 | 281.84 | 0.02922 | 2778.3 | 1531.9 |
| 17 | 204.31 | 0.1166 | 2793.4 | 1921.5 | 67 | 282.84 | 0.02874 | 2777.1 | 1525.4 |
| 18 | 207.11 | 0.1103 | 2794.8 | 1910.3 | 68 | 283.84 | 0.02827 | 2775.9 | 1518.9 |
| 19 | 209.80 | 0.1047 | 2796.1 | 1899.3 | 69 | 284.82 | 0.02782 | 2774.7 | 1512.5 |
| | | | | | 70 | 285.79 | 0.02737 | 2773.5 | 1506.0 |

Documentation: VDI Water vapor tables

Water vapor temperature table

Temperature range 100-300 °C (saturated steam)

| θ °C | T K | p bar | v'' m³/kg | h'' kJ/kg | Δh _v kJ/kg |
|---------|--------|----------|--------------|--------------|--------------------------|
| 100 | 373.15 | 1.0133 | 1.673 | 2676.0 | 2256.9 |
| 101 | 374.15 | 1.0500 | 1.618 | 2677.6 | 2254.3 |
| 102 | 375.15 | 1.0878 | 1.566 | 2679.1 | 2251.6 |
| 103 | 376.15 | 1.1267 | 1.515 | 2680.7 | 2248.9 |
| 104 | 377.15 | 1.1668 | 1.466 | 2682.2 | 2246.3 |
| 105 | 378.15 | 1.2080 | 1.419 | 2683.7 | 2243.6 |
| 106 | 379.15 | 1.2504 | 1.374 | 2685.3 | 2240.9 |
| 107 | 380.15 | 1.2941 | 1.331 | 2686.8 | 2238.2 |
| 108 | 381.15 | 1.3390 | 1.289 | 2688.3 | 2235.4 |
| 109 | 382.15 | 1.3852 | 1.249 | 2689.8 | 2232.7 |
| 110 | 383.15 | 1.4327 | 1.210 | 2691.3 | 2230.0 |
| 111 | 384.15 | 1.4815 | 1.173 | 2692.8 | 2227.3 |
| 112 | 385.15 | 1.5316 | 1.137 | 2694.3 | 2224.5 |
| 113 | 386.15 | 1.5832 | 1.102 | 2695.8 | 2221.8 |
| 114 | 387.15 | 1.6362 | 1.069 | 2697.2 | 2219.0 |
| 115 | 388.15 | 1.6906 | 1.036 | 2698.7 | 2216.2 |
| 116 | 389.15 | 1.7465 | 1.005 | 2700.2 | 2213.4 |
| 117 | 390.15 | 1.8039 | 0.9753 | 2701.6 | 2210.7 |
| 118 | 391.15 | 1.8628 | 0.9463 | 2703.1 | 2207.9 |
| 119 | 392.15 | 1.9233 | 0.9184 | 2704.5 | 2205.1 |
| 120 | 393.15 | 1.9854 | 0.8915 | 2706.0 | 2202.2 |
| 121 | 394.15 | 2.0492 | 0.8655 | 2707.4 | 2199.4 |
| 122 | 395.15 | 2.1145 | 0.8405 | 2708.8 | 2196.6 |
| 123 | 396.15 | 2.1816 | 0.8162 | 2710.2 | 2193.7 |
| 124 | 397.15 | 2.2504 | 0.7928 | 2711.6 | 2190.9 |
| 125 | 398.15 | 2.3210 | 0.7702 | 2713.0 | 2188.0 |
| 126 | 399.15 | 2.3933 | 0.7484 | 2714.4 | 2185.2 |
| 127 | 400.15 | 2.4675 | 0.7273 | 2715.8 | 2182.3 |
| 128 | 401.15 | 2.5435 | 0.7069 | 2717.2 | 2179.4 |
| 129 | 402.15 | 2.6215 | 0.6872 | 2718.5 | 2176.5 |
| 130 | 403.15 | 2.7013 | 0.6681 | 2719.9 | 2173.6 |
| 131 | 404.15 | 2.7831 | 0.6497 | 2721.3 | 2170.7 |
| 132 | 405.15 | 2.8670 | 0.6319 | 2722.6 | 2167.8 |
| 133 | 406.15 | 2.9528 | 0.6146 | 2723.9 | 2164.8 |
| 134 | 407.15 | 3.041 | 0.5980 | 2725.3 | 2161.9 |
| 135 | 408.15 | 3.131 | 0.5818 | 2726.6 | 2158.9 |
| 136 | 409.15 | 3.223 | 0.5662 | 2727.9 | 2155.9 |
| 137 | 410.15 | 3.317 | 0.5511 | 2729.2 | 2153.0 |
| 138 | 411.15 | 3.414 | 0.5364 | 2730.5 | 2150.0 |
| 139 | 412.15 | 3.513 | 0.5222 | 2731.8 | 2147.0 |
| 140 | 413.15 | 3.614 | 0.5085 | 2733.1 | 2144.0 |
| 142 | 415.15 | 3.823 | 0.4823 | 2735.6 | 2137.9 |
| 144 | 417.15 | 4.042 | 0.4577 | 2738.1 | 2131.8 |
| 146 | 419.15 | 4.271 | 0.4346 | 2740.6 | 2125.7 |
| 148 | 421.15 | 4.510 | 0.4129 | 2743.0 | 2119.5 |
| 150 | 423.15 | 4.760 | 0.3924 | 2745.4 | 2113.2 |
| 152 | 425.15 | 5.021 | 0.3732 | 2747.7 | 2106.9 |
| 154 | 427.15 | 5.293 | 0.3551 | 2750.0 | 2100.6 |
| 156 | 429.15 | 5.577 | 0.3380 | 2752.3 | 2094.2 |
| 158 | 431.15 | 5.872 | 0.3219 | 2754.5 | 2087.7 |
| 160 | 433.15 | 6.181 | 0.3068 | 2756.7 | 2081.3 |
| 162 | 435.15 | 6.502 | 0.2924 | 2758.9 | 2074.7 |
| 164 | 437.15 | 6.836 | 0.2789 | 2761.0 | 2068.1 |
| 166 | 439.15 | 7.183 | 0.2661 | 2763.1 | 2061.4 |
| 168 | 441.15 | 7.545 | 0.2540 | 2765.1 | 2054.7 |

| θ °C | T K | p bar | v'' m³/kg | h'' kJ/kg | Δh _v kJ/kg |
|---------|--------|----------|--------------|--------------|--------------------------|
| 170 | 443.15 | 7.920 | 0.2426 | 2767.1 | 2047.9 |
| 172 | 445.15 | 8.311 | 0.2317 | 2769.0 | 2041.1 |
| 174 | 447.15 | 8.716 | 0.2215 | 2770.9 | 2034.2 |
| 176 | 449.15 | 9.137 | 0.2117 | 2772.7 | 2027.3 |
| 178 | 451.15 | 9.574 | 0.2025 | 2774.5 | 2020.2 |
| 180 | 453.15 | 10.027 | 0.1938 | 2776.3 | 2013.1 |
| 182 | 455.15 | 10.496 | 0.1855 | 2778.0 | 2006.0 |
| 184 | 457.15 | 10.983 | 0.1776 | 2779.6 | 1998.8 |
| 186 | 459.15 | 11.488 | 0.1702 | 2781.2 | 1991.5 |
| 188 | 461.15 | 12.010 | 0.1631 | 2782.8 | 1984.2 |
| 190 | 463.15 | 12.551 | 0.1563 | 2784.3 | 1976.7 |
| 192 | 465.15 | 13.111 | 0.1499 | 2785.7 | 1969.3 |
| 194 | 467.15 | 13.690 | 0.1438 | 2787.1 | 1961.7 |
| 196 | 469.15 | 14.289 | 0.1380 | 2788.4 | 1954.1 |
| 198 | 471.15 | 14.909 | 0.1324 | 2789.7 | 1946.4 |
| 200 | 473.15 | 15.549 | 0.1272 | 2790.9 | 1938.6 |
| 202 | 475.15 | 16.210 | 0.1221 | 2792.1 | 1930.7 |
| 204 | 477.15 | 16.893 | 0.1173 | 2793.2 | 1922.8 |
| 206 | 479.15 | 17.598 | 0.1128 | 2794.3 | 1914.7 |
| 208 | 481.15 | 18.326 | 0.1084 | 2795.3 | 1906.6 |
| 210 | 483.15 | 19.077 | 0.1042 | 2796.2 | 1898.5 |
| 212 | 485.15 | 19.852 | 0.1003 | 2797.1 | 1890.2 |
| 214 | 487.15 | 20.651 | 0.09646 | 2797.9 | 1881.8 |
| 216 | 489.15 | 21.475 | 0.09283 | 2798.6 | 1873.4 |
| 218 | 491.15 | 22.324 | 0.08936 | 2799.3 | 1864.9 |
| 220 | 493.15 | 23.198 | 0.08604 | 2799.9 | 1856.2 |
| 222 | 495.15 | 24.099 | 0.08286 | 2800.5 | 1847.5 |
| 224 | 497.15 | 25.027 | 0.07982 | 2800.9 | 1838.7 |
| 226 | 499.15 | 25.982 | 0.07691 | 2801.4 | 1829.8 |
| 228 | 501.15 | 26.965 | 0.07412 | 2801.7 | 1820.8 |
| 230 | 503.15 | 27.976 | 0.07145 | 2802.0 | 1811.7 |
| 232 | 505.15 | 29.016 | 0.06889 | 2802.2 | 1802.5 |
| 234 | 507.15 | 30.086 | 0.06643 | 2802.3 | 1793.2 |
| 236 | 509.15 | 31.186 | 0.06408 | 2802.3 | 1783.8 |
| 238 | 511.15 | 32.317 | 0.06182 | 2802.3 | 1774.2 |
| 240 | 513.15 | 33.478 | 0.05965 | 2802.2 | 1764.6 |
| 242 | 515.15 | 34.672 | 0.05757 | 2802.0 | 1754.9 |
| 244 | 517.15 | 35.898 | 0.05558 | 2801.8 | 1745.0 |
| 246 | 519.15 | 37.157 | 0.05366 | 2801.4 | 1735.0 |
| 248 | 521.15 | 38.449 | 0.05181 | 2801.0 | 1724.9 |
| 250 | 523.15 | 39.776 | 0.05004 | 2800.4 | 1714.6 |
| 252 | 525.15 | 41.137 | 0.04833 | 2799.8 | 1704.3 |
| 254 | 527.15 | 42.534 | 0.04669 | 2799.1 | 1693.8 |
| 256 | 529.15 | 43.967 | 0.04511 | 2798.3 | 1683.2 |
| 258 | 531.15 | 45.437 | 0.04360 | 2797.4 | 1672.4 |
| 260 | 533.15 | 46.943 | 0.04213 | 2796.4 | 1661.5 |
| 265 | 538.15 | 50.877 | 0.03871 | 2793.5 | 1633.6 |
| 270 | 543.15 | 55.058 | 0.03559 | 2789.9 | 1604.6 |
| 275 | 548.15 | 59.496 | 0.03274 | 2785.5 | 1574.7 |
| 280 | 553.15 | 64.202 | 0.03013 | 2780.4 | 1543.6 |
| 285 | 558.15 | 69.186 | 0.02773 | 2774.5 | 1511.3 |
| 290 | 563.15 | 74.461 | 0.02554 | 2767.6 | 1477.6 |
| 295 | 568.15 | 80.037 | 0.02351 | 2759.8 | 1443.6 |
| 300 | 573.15 | 85.927 | 0.02165 | 2751.0 | 1406.0 |

Documentation: VDI Water vapor tables

Vapors and gases in vacuum

If mixtures of vapors and gases are condensed under vacuum, the gases and certain portions of non-condensed vapors will have to be drawn off by means of a vacuum pump in order to maintain the required vacuum in the condenser.

The drawn-off gases (e.g. air) are saturated with the vapors of the partly condensed components.

In the following it is assumed that these components are insoluble in each other in the liquid phase.

Condensation of a component of such a gas-vapor mixture will take place if this component is brought to a saturated steam condition (dew point) by cooling the mixture. A saturated gas-vapor mixture is, therefore, present at the condenser outlet.

The composition of such saturated gas-vapor mixtures can be calculated as follows:

For example, for a mixture of 2 components - an inert gas and a condensable vapor - the following formula applies:

$$p = p_i + p_v$$

i.e. the total pressure = the sum of the partial pressures. p_v is the saturated steam pressure of the vapor, corresponding to the temperature of the gas-vapor mixture at the condenser outlet. With p_v and p , the partial pressure of the inert gas

$$p_i = p - p_v$$

can then be found. Now the general Gas Law can be applied; imagine a space with the volume of the mixture to be drawn off. On the one hand, volume V is filled with the inert gas at the partial pressure p_i and on the other hand, the same volume V is filled with the vapor at partial pressure p_v .

| | |
|---------------|--|
| \dot{M}_v | Mass flow of the vapor in kg/h |
| \dot{M}_i | Mass flow of the inert gases in kg/h |
| \tilde{M}_v | Molecular mass of the vapor in kg/kmol |
| \tilde{M}_i | Molecular mass of the inert gas in kg/kmol |
| p_v | Partial pressure of the vapor in mbar |
| p_i | Partial pressure of the inert gas in mbar |

The following formula applies:

$$p_i \cdot V = \dot{M}_i \cdot R_i \cdot T = \dot{M}_i \cdot \frac{\tilde{R}}{\tilde{M}_i} \cdot T \quad 1)$$

$$p_v \cdot V = \dot{M}_v \cdot R_v \cdot T = \dot{M}_v \cdot \frac{\tilde{R}}{\tilde{M}_v} \cdot T \quad 2)$$

If equation 1) is divided by equation 2), and if the mass is displaced by the mass flow, the following results:

$$\frac{p_i}{p_v} = \frac{\dot{M}_i}{\dot{M}_v} \cdot \frac{\tilde{M}_v}{\tilde{M}_i} \quad \text{or} \quad \dot{M}_{v_j} = \dot{M}_i \cdot \frac{\tilde{M}_{v_j}}{\tilde{M}_i} \cdot \frac{p_{v_j}}{p_i} \quad 3)$$

Equation 3) also applies quite generally where "n" different condensable components are insoluble in each other in the liquid phase.

$$\dot{M}_{v_j} = \dot{M}_i \cdot \frac{\tilde{M}_{v_j}}{\tilde{M}_i} \cdot \frac{p_{v_j}}{p_i} \quad 4)$$

for j from 1 to n

For example, if a saturated mixture of air, water vapor, and benzene vapor at a temperature of 30 °C is to be drawn from a condenser at a total pressure of $p = 250$ mbar and if it is known that the mass flow

of the air $\dot{M}_i = 100 \frac{\text{kg}}{\text{h}}$ saturation quantities

of water vapor and benzene vapors can be found as follows:

At 30 °C we read from the steam tables:

| | | |
|---------------------|---|------------|
| p_v water vapor | = | 42.4 mbar |
| p_v benzene vapor | = | 160 mbar |
| Total | = | 202.4 mbar |

Hence

$$p_i = 250 - 202.4 = 47.6 \text{ mbar}$$

$$\text{With } \tilde{M}_v \text{ water vapour} = 18 \frac{\text{kg}}{\text{kmol}}$$

$$\text{With } \tilde{M}_v \text{ benzene} = 78 \frac{\text{kg}}{\text{kmol}}$$

$$\text{With } \tilde{M}_i \text{ air} = 29 \frac{\text{kg}}{\text{kmol}}$$

and with equation 4) we have:

$$\dot{M}_v \text{ water vapour} = 100 \cdot \frac{18}{29} \cdot \frac{42.4}{47.6} = 55.3 \frac{\text{kg}}{\text{h}}$$

$$\dot{M}_v \text{ benzene vapour} = 100 \cdot \frac{78}{29} \cdot \frac{160}{47.6} = 904 \frac{\text{kg}}{\text{h}}$$

Only if more than 904 kg/h benzene vapor flow into a condenser benzene can condense under the above conditions.

As one can see, the vapor quantities saturating such mixtures may be very large. This means that very often individual components cannot be condensed at all and have then to be drawn off by the vacuum pump.

Equation 4) and the example show how important it is to seal a vacuum plant properly i.e. to keep air leakage as low as possible so that the saturation portion and, therefore, the suction flow for the vacuum pump is as small as possible.

Water vapor and air in vacuum

Condensers in which water vapor is condensed under vacuum are built in large numbers. Here the vacuum is maintained by a vacuum pump extracting air or gases saturated with water vapor as described on page "Vapors and gases in vacuum".

In addition to the air (and other inert gases) we have to know the quantity of water vapor with which it is saturated when it leaves the condenser. This saturated quantity is higher the closer the temperature of the mixture approaches the saturated steam temperature at the total pressure.

The graph in fig. 1 is calculated on the basis of the formulas indicated on page "Vapors and gases in vacuum" and allows easier calculation.

$$\frac{\dot{M}_V}{\dot{M}_A} = \frac{\dot{M}_V}{\dot{M}_A} \cdot \frac{p_V}{p_A}$$

with $\dot{M} = 18 \frac{\text{kg}}{\text{mol}}$ for water vapour and

and $\dot{M}_A = \dot{M}_A = 29 \frac{\text{kg}}{\text{kmol}}$ for air, we have:

(Index A = Air)

$$\frac{\dot{M}_V}{\dot{M}_A} = 0,622 \cdot \frac{p_V}{p_A} \frac{\text{kg Vapour}}{\text{kg Air}}$$

$$\frac{\dot{M}_V + \dot{M}_A}{\dot{M}_A} = 1 + 0,622 \cdot \frac{p_V}{p_A}$$

and with $p_L = p - p_0$ we have:

$$\frac{\dot{M}_V + \dot{M}_A}{\dot{M}_A} = 1 + 0,622 \cdot \frac{p_V}{p - p_0} \frac{\text{kg Mixture}}{\text{kg Air}}$$

Fig. 1 shows the relation between the temperature and the vapor content in vapor/air mixtures at constant total pressures p. For easier use, the water vapor pressures corresponding to the temperatures shown on the left hand scale of the graph have been chosen as values for p.

APPLICATION EXAMPLE

GIVEN: Every hour 2 kg of air have to be drawn off from a condenser working at 42.4 mbar at a condensation temperature of 30 °C.

PARAMETERS TO BE FOUND: Which quantity in kg/h of vapor/air mixture has to be drawn if the temperature at the evacuation connection is 25 °C.

SOLUTION: From the graph it is 2.85 kg mixture/kg air. The suction capacity must, therefore, be approximately 5.7 kg/h. The

vapor content is approximately 65 % or mathematically:

In the water vapor table (see "Water vapor temperature table", 7 | abl5) we find p_v for 25 °C = 31.7 mbar.

At a total pressure of $p = 42.4$ mbar, the partial pressure of air is:

$$p_A = 42.4 - 31.7 = 10.7 \text{ mbar}$$

With the formula

$$\dot{M}_V = \dot{M}_A \cdot 0,622 \cdot \frac{p_V}{p_A}$$

you will find:

$$\dot{M}_V = 2 \cdot 0,622 \cdot \frac{31,7}{10,7} = 3,7 \frac{\text{kg Vapour}}{\text{h}}$$

Therefore, 2 + 3.7 = 5.7 kg/h of vapor/air mixture has to be drawn off.

If instead of 2 kg/h air, 2 kg/h hydrogen

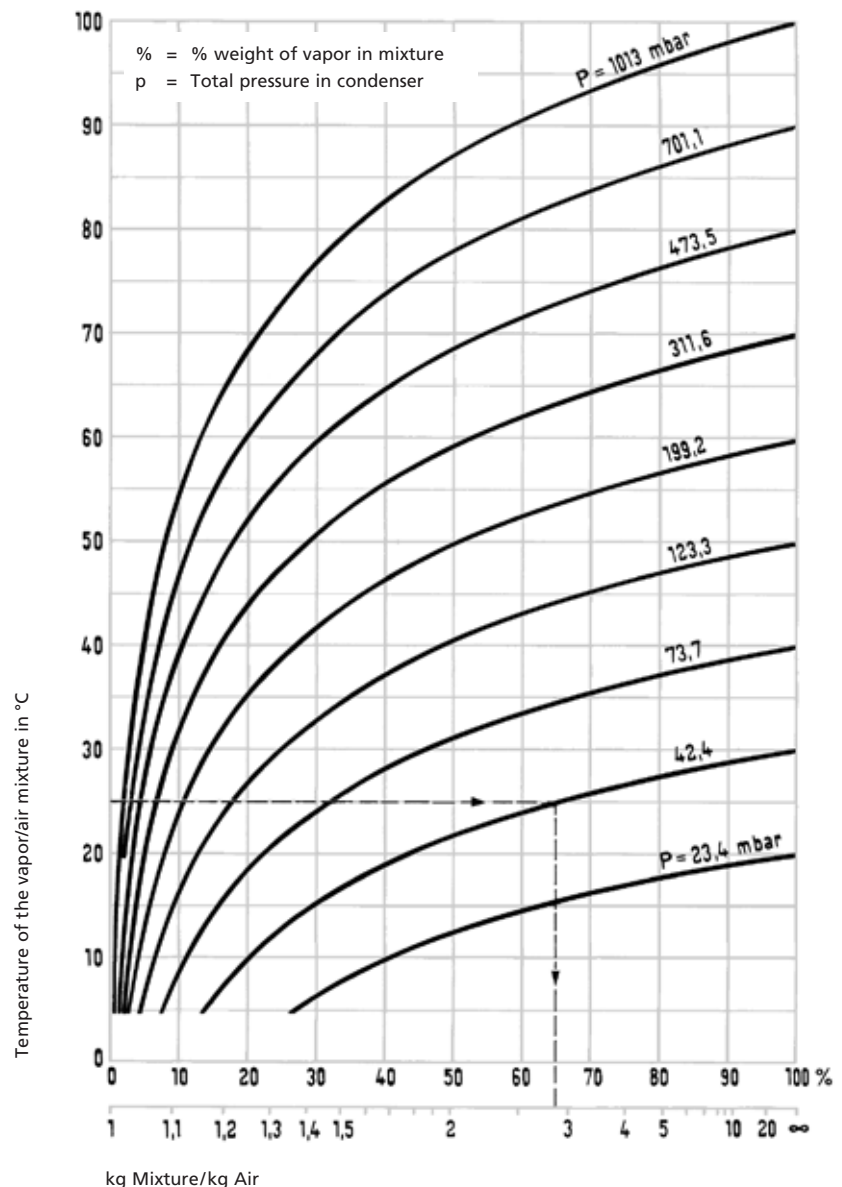
with $\dot{M}_A = 2 \frac{\text{kg}}{\text{mol}}$ have to be drawn off under

the same conditions, the saturating quantity for water vapor is found according to the formula on page "Vapors and gases in vacuum" page 17:

$$\dot{M}_{Vj} = \dot{M}_I \cdot \frac{\dot{M}_{Vj}}{\dot{M}_I} \cdot \frac{p_{Vj}}{p_I} = 2 \cdot \frac{18}{2} \cdot \frac{31,7}{10,7} = 53,3 \frac{\text{kg Vapour}}{\text{h}}$$

In this case, 2 + 53.3 = 55.3 kg/h of vapor/hydrogen mixture has to be drawn off.

FIG. 1



Air leakage in vacuum vessels

- How airtight is a vacuum plant?
- Is the suction capacity of the vacuum pump large enough?
- Why does it take so long for the plant to reach the vacuum?
- Must the vacuum pump extract leak air as well as gases from the product?

You can answer all these questions if you know the air leakage in the vacuum tank.

It is determined as follows:

- Evacuate the vessel to a vacuum under 500 mbar, e.g. 60 mbar.
- Isolate the vacuum pump from the vessel and completely seal off the vessel.
- Measure the pressure increase in the vessel and determine the corresponding time.
- The pressure increase in mbar divided by the time in minutes gives the vacuum loss in mbar/minute.

With this value and the volume of the vessel under vacuum the air leakage rate in kg/h can be found in the chart, **fig. 1**.

The chart, **fig. 1**, is calculated from the formula:

$$\dot{M}_A = 0.071 \cdot \frac{\Delta p}{t} \cdot V$$

Whereby:

| | |
|-------------|---|
| \dot{M}_A | Air leakage in $\frac{\text{kg}}{\text{h}}$ |
| Δp | Change of pressure in mbar |
| t | Corresponding time in min |
| V | Plant volume in m^3 |

* The exact value is 0.071289977, based on:

| | |
|------------------------|---|
| Universal gas constant | $8.31441 \frac{\text{J}}{\text{mol K}}$ |
| Absolute temperature | 293.15 K |
| Mol mass for air | $28.96 \frac{\text{kg}}{\text{kmol}}$ |

EXAMPLE FOR AIR LEAKAGE

A vessel of 20 m^3 volume is evacuated to 60 mbar and isolated. Within 10 minutes there is a vacuum loss to 120 mbar. The pressure change thus amounts to 60 mbar. Therefore, the vacuum loss is

$$60 : 10 = 6 \frac{\text{mbar}}{\text{min}}$$

With this value, the formula results in an air leakage of

$$0.071 \cdot 6 \cdot 20 = 8.5 \frac{\text{kg}}{\text{h}}$$

In the high-vacuum range the air leakage rate or the quantities of gases and vapors are measured in mbar · liter/s.

$$1 \text{ mbar} \frac{\text{liter}}{\text{s}} \cong 0.0043 \frac{\text{kg}}{\text{h}} \text{ Air of } 20^\circ \text{C}$$

BUDGET VALUES REGARDING AIR LEAKAGE IN VACUUM UNITS AND PLANTS

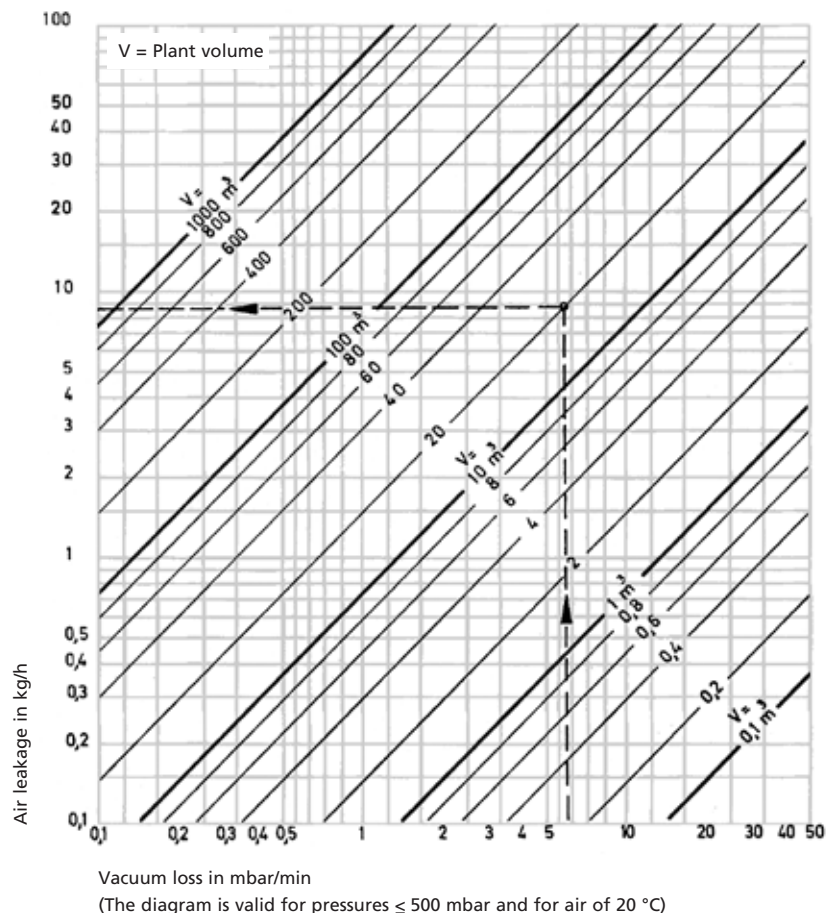
The following shall apply regarding the requirement to the tightness of a plant under vacuum: The lower the pressure to be maintained in the plant, the higher the requirement to the tightness of the plant, because the expenditure for generating and maintaining vacuum increases with decreasing pressure.

Through an opening of 1 mm^2 approx. 0.83 kg/h of air flow into a vacuum unit, independent of the amount of vacuum, if it is only $< 530 \text{ mbar}$. In this case, just critical conditions are prevailing.

In case of normal flanged connections with large nominal diameter the assumed air leakage amounts to 200 to 400 g per hour and meter of seal length. With specially designed flanged connections, e.g. with groove and tongue or fine machined sealing surfaces and with the use of special seals the value can be reduced to 50 to 100 g/hm.

The tightness of vacuum plant can vary, depending on whether mainly welded units are concerned or whether units are concerned in which flanged connections, sight glasses, valves, gate valves, glands etc. have to be taken into consideration. The table on page 20 shows values which are based on experience. Depending on the overall volume of the unit and of the type of connections of units and ducts it shows the leakage air flow to be expected in kg/h.

FIG. 1



Some measurements were compared with recommended values according to "HEI standards for steam jet ejectors", and it was

determined that the measurements are according to those standards. Shaft throughputs are not considered in the table values.

Mark-ups of 1 to 2 kg/h of air leakage per shaft throughput are required with normal gland seals.

| Unit volume to be maintained under vacuum in m ³ | 0.2 | 1 | 3 | 5 | 10 | 25 | 50 | 100 | 200 | 500 |
|---|----------|-----------|----------|----------|---------|-----|-------|-------|-------|-------|
| Leakage air flow in kg/h | | | | | | | | | | |
| Unit and duct connections | | | | | | | | | | |
| with normal seals, mainly flanged | 0.15-0.3 | 0.5-1 | 1-2 | 1.5-3 | 2-4 | 4-8 | 6-12 | 10-20 | 16-32 | 30-60 |
| partly flanged, partly welded | 0.1-0.2 | 0.25-0.5 | 0.5-1 | 0.7-1.5 | 1-2 | 2-4 | 3-6 | 5-10 | 8-16 | 15-30 |
| mainly welded or designed with special seals | < 0.1 | 0.15-0.25 | 0.25-0.5 | 0.35-0.7 | 0.6-1.2 | 1-2 | 1.5-3 | 2.5-5 | 4-8 | 8-15 |

Admissible flow velocity in vacuum ducts

The admissible velocity of flow in a vacuum pipeline depends on how high the pressure loss of this pipeline is allowed to be. Higher pressure loss implies increased energy requirements for the vacuum pump. A pressure loss of up to 10% of the total pressure can generally be accepted. This is shown in graph Fig. 1 and valid for air at 20 °C. It is calculated according to the formula:

$$w_{adm.} = \sqrt{\frac{2 \left(\frac{\Delta p}{p}\right)_{adm.} \cdot R \cdot T}{1 + 40 \cdot \frac{l}{d}}}$$

$w_{adm.}$ Admissible flow velocity in m/s
 $\left(\frac{\Delta p}{p}\right)_{adm.}$ Admissible pressure loss as portion of the total pressure
 $R = \frac{\bar{R}}{\bar{M}}$ Individual gas constant in J/kg K
 $\bar{R} = 8314.3 \frac{J}{kmol \cdot K}$ Universal gas constant
 \bar{M} Molecular mass in kg/mol
 T Temperature in K
 l Duct length in m
 d Duct diameter in mm

For reasons of simplification, the calculation is based on an average pipe friction coefficient of $\lambda = 0.04$ (this is max.) and on a free-of-loss acceleration from 0 to w m/s, i.e. with a well rounded duct inlet.

Range of application:

$$2 \text{ mbar} \leq p \leq 1000 \text{ mbar}$$

Furthermore, the graph contains lines for constant volume flow in m³/h. The graph is meant for rapid, rough dimensioning of a vacuum duct. An exact pressure loss calculation can be made with the help of sheet 7 | ab19.

EXAMPLE 1

CALCULATION OF THE MASS FLOW

GIVEN:

| | |
|--------------------|-----------------------------|
| Duct | DN 100 |
| Duct length | $l = 10 \text{ m}$ |
| Flow medium | Air, 20 °C |
| Total pressure | $p = 10 \text{ mbar}$ |
| Adm. pressure loss | $\Delta p = 1 \text{ mbar}$ |

PARAMETERS TO BE FOUND:

- 1) Admissible velocity $w_{adm.}$ in $\frac{m}{s}$
- 2) Volume flow \dot{V} in $\frac{m^3}{h}$
- 3) Mass flow \dot{M} in $\frac{kg}{h}$

SOLUTION:

With $\frac{\Delta p}{p} = 0.1$ the equation results in:

- 1) $w_{adm.} \approx 58 \frac{m}{s}$
- 2) $\dot{V} \approx 1650 \frac{m^3}{h}$
- 3) Formula $\dot{M} = \frac{\dot{V} \cdot \rho}{v_A}$ and $v_A = \frac{840 \text{ m}^3}{p \text{ kg}}$

with $v_A =$ Spec. volume of air at 20°C and $p =$ Pressure in mbar:

$$\dot{M} = \frac{1650 \cdot 10}{840} \approx 20 \frac{kg}{h}$$

EXAMPLE 2

EQUIVALENT DUCT LENGTH IF PIPE BENDS AND GATE VALVES ARE INSTALLED IN THE DUCT:

$$l_E = l + \frac{d}{40} \cdot \sum \zeta$$

- l_E Equivalent duct length in m
 l Duct length in m
 d Pipe diameter in mm
 ζ Resistance coefficients:
 Pipe bend $D/d = 3.90^\circ$ $\zeta = 0.16$
 Gate valve with restriction $\zeta = 1.0$

GIVEN:

| | |
|--------------------------------|-----------------------------|
| Duct | DN 600 |
| Pipe length | $l = 100 \text{ m}$ |
| Flowing medium | air, 20 °C |
| Total pressure | $p = 10 \text{ mbar}$ |
| Adm. pressure loss | $\Delta p = 1 \text{ mbar}$ |
| 4 tube bends 90°, 1 gate valve | |

PARAMETERS TO BE FOUND:

- 1) Equivalent pipe length l_E in m
- 2) Admissible flow velocity $w_{adm.}$ in $\frac{m}{s}$
- 3) Volume flow \dot{V} in $\frac{m^3}{h}$
- 4) Mass flow \dot{M} in $\frac{kg}{h}$

SOLUTION: The following results by way of calculation:

$$1) \quad l_E = 100 + \frac{600}{40} (4 \cdot 0.16 + 1) = 124.6 \text{ m}$$

With $\frac{\Delta p}{p} = 0.1$ the equation results in:

$$2) \quad w_{adm.} \approx 44 \frac{m}{s}$$

$$3) \quad \dot{V} \approx 45000 \frac{m^3}{s}$$

$$4) \quad \dot{M} = \frac{45000 \cdot 10}{840} \approx 535 \frac{kg}{h}$$

Pressure loss in vacuum lines with water vapor

The diagram in fig. 1, is calculated from the formula:

$$\Delta p = K \cdot \frac{\rho \cdot w^2}{2} \cdot 0.01 \quad \Delta p' = K \cdot \frac{\rho \cdot w^2}{2}$$

- Δp Pressure loss in mbar
- $\Delta p'$ Pressure loss in $\frac{N}{m^2}$
- K Total resistance coefficient
= $\sum \zeta$ = sum of individual resistance
- w Flow velocity in m/s
- ρ Density of the flowing Medium in kg/m^3

Error $\leq 10\%$ of Δp , if $\Delta p \cdot 6 \leq p_1$

CALCULATION

RESISTANCE COEFFICIENTS

- | | |
|--|-----------------------------|
| (1) Acceleration from 0 \rightarrow w | 1.0 |
| (2) Inlet contraction in the case of angular inlet | 0.4 |
| (3) Gate valve with full cross section | 0.1 - 0.2 |
| Gate valve with constriction | 1 |
| DIN straight-way valve DN 200 | 4.5 |
| (4) Pipe bend D/d = 3; 90° | 0.16 |
| (5) for pipe friction losses | $\lambda \cdot \frac{l}{d}$ |

λ = Pipe friction coefficient according to fig. 2

l = Pipe length in m

d = Pipe diameter in m

EXAMPLE

- | | |
|------------------|-----------------------|
| Piping DN 200 | $d = 0.2$ m |
| Velocity | $w = 100 \frac{m}{s}$ |
| Pressure (inlet) | $p_1 = 50$ mbar |

- (1) Acceleration from 0 \rightarrow w
- (2) Angular inlet
- (3) 1 gate valve with full passage
- (4) 3 pipe bends 90°
- (5) Pipe length $l = 13$ m

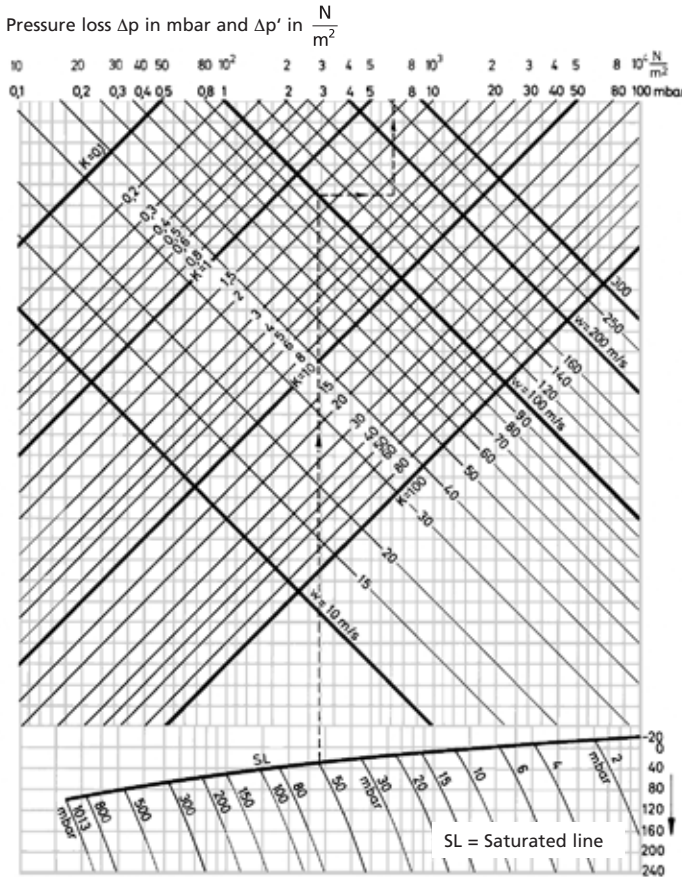
CALCULATION

- | | |
|-----------------------------------|---|
| Total resistance coefficient | $K = \sum \zeta$ |
| (1) for acceleration | $\zeta = 1.0$ |
| (2) for inlet contraction | $\zeta = 0.4$ |
| (3) 1 gate valve | $\zeta = 1 \cdot 0.2 = 0.2$ |
| (4) 3 pipe bends | $\zeta = 3 \cdot 0.16 = 0.48$ |
| (5) for pipe friction from fig. 2 | $\zeta = 0.024 \cdot \frac{13}{0.2} = 1.56$ |
| | $\lambda = 0.024$ |
| | $K = \sum \zeta = 3.64$ |

Pressure loss from diagram, fig. 1

for: $p = 50$ mbar, $w = 100 \frac{m}{s}$, $K = 3.64$, $\Delta p = 6.5$ mbar bzw. $650 \frac{N}{m^2}$

FIG. 1

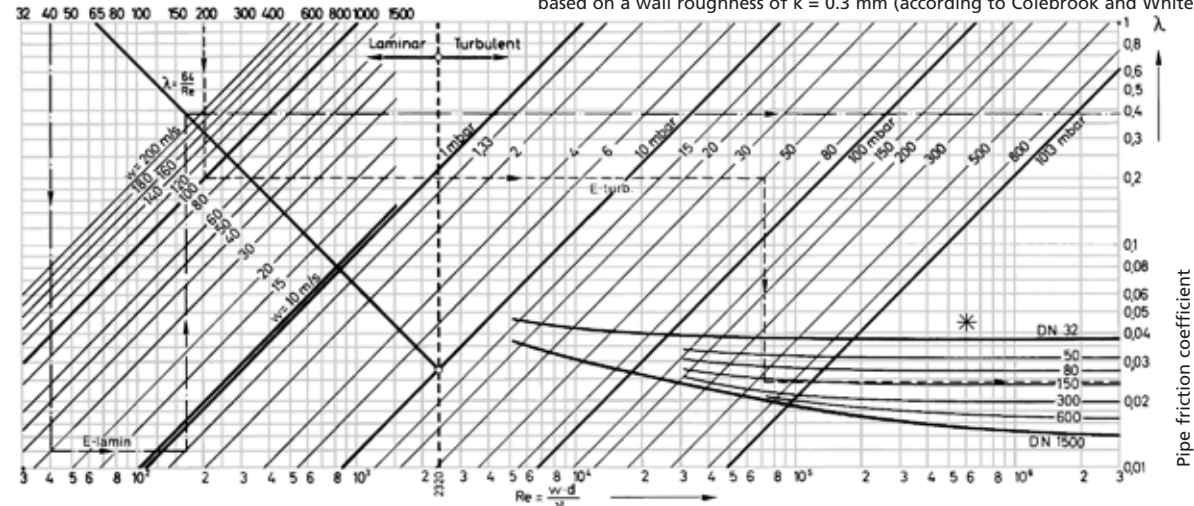


Determination of the pressure loss
The pressure loss with air at the same temperature is 1.6 times greater.

FIG. 2

Nominal diameter in mm

*) The characteristics for the determination of the pipe friction coefficient λ are based on a wall roughness of $k = 0.3$ mm (according to Colebrook and White).



Determination of the pipe friction coefficient λ .

Pressure loss in water pipes

The chart, **fig. 1**, is calculated from the following formula:

$$\Delta p = 0.025 \frac{\rho \cdot w^2}{d} \cdot 0.01$$

$$\Delta p_{100} = 0.025 \frac{l}{d} \cdot \frac{\rho \cdot w^2}{2} \cdot 0.01$$

| | |
|------------------|--|
| Δp | Pressure loss in mbar |
| Δp_{100} | Pressure loss for 100 m pipeline in mbar |
| l | Pipe length in m |
| d | Pipe diameter in mm |
| ρ | Density of the flowing medium in kg/m ³ |
| w | Flow velocity in m/s |

The chart is valid for water at 15 °C in steel and cast iron pipes.

The formula is sufficiently accurate for

$$25 \leq d \leq 250 \text{ mm} \quad \text{and} \quad 0.5 \leq w \leq 5 \frac{\text{m}}{\text{s}}$$

EXAMPLE

GIVEN:

| | |
|--------------|--|
| Water flow | $\dot{V} = 40 \frac{\text{m}^3}{\text{h}}$ |
| Piping DN 80 | $d = 0.08 \text{ m}$ |
| Pipe length | $l = 70 \text{ m}$ |

The following is installed in the pipe:

- 3 tube bends 90°
- 1 diaphragm valve

PARAMETERS TO BE FOUND:

- Pressure loss in the pipeline
- Water velocity

SOLUTION:

$$1) \Delta p = \Delta p_{100} \cdot \frac{l + l_E}{100} \text{ mbar}$$

l_E Equivalent pipe length in m for shaped pieces and valves

From diagram **fig. 1**:

$$\Delta p_{100} = 770 \text{ mbar}$$

From table:

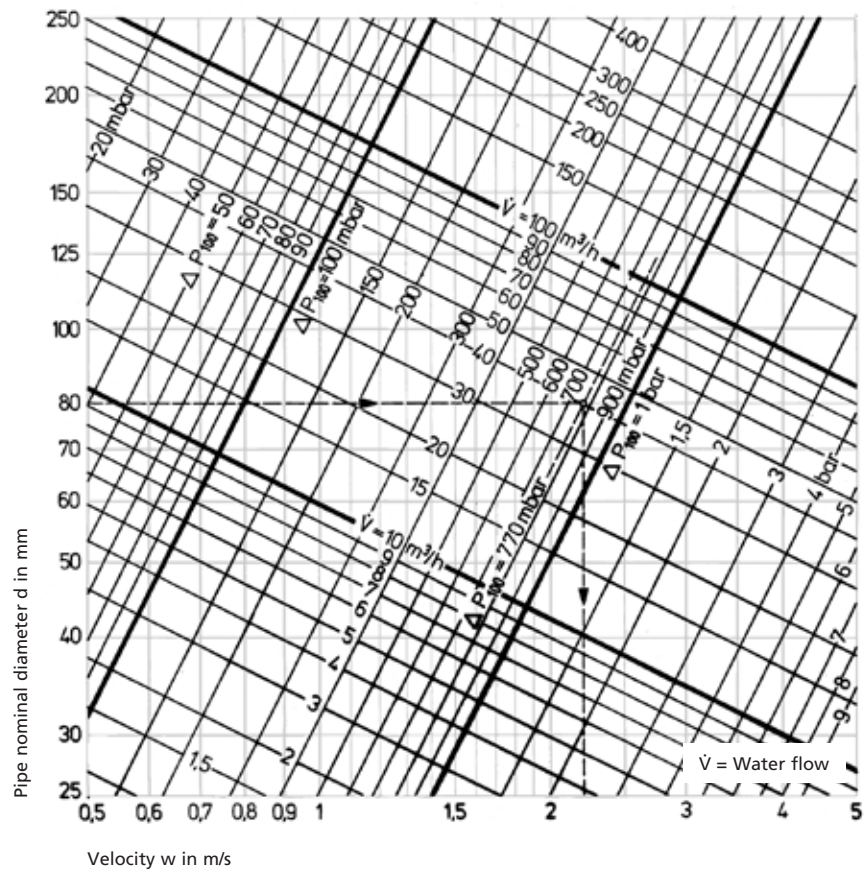
$$l_E = 3 \cdot 1.2 + 10 = 13.6 \text{ m}$$

$$\Delta p = 770 \cdot \frac{70 + 13.6}{100} = 644 \text{ mbar}$$

2) From diagram **fig. 1**:

$$w = 2.2 \frac{\text{m}}{\text{s}}$$

FIG. 1



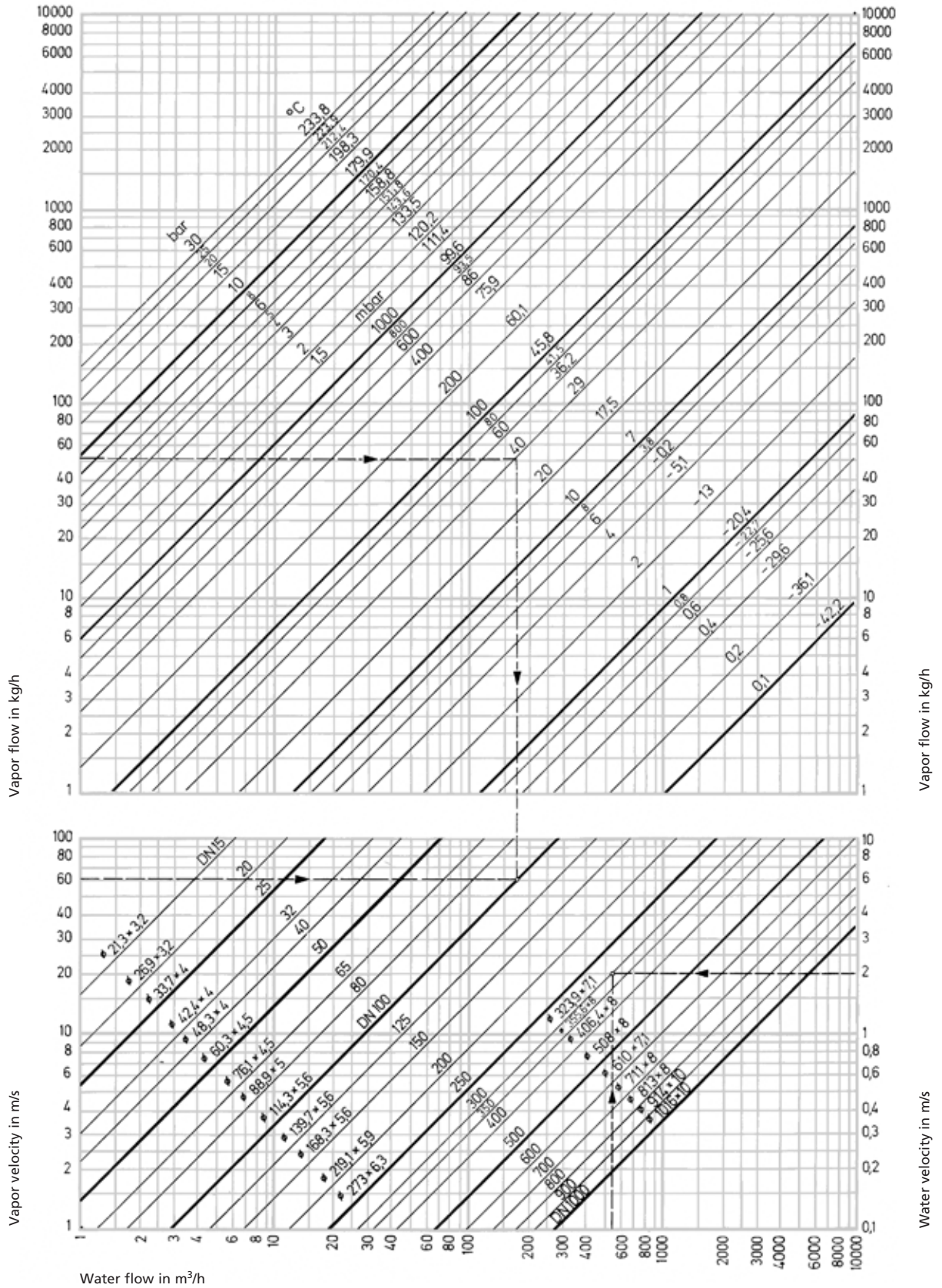
EQUIVALENT PIPE LENGTH IN m FOR SHAPED PIECES AND VALVES

| Nominal diameter (mm) | 25 | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 | 250 |
|---------------------------------|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|
| Pipe bend 90° $\frac{D}{d} = 3$ | 0.4 | 0.5 | 0.6 | 0.8 | 1.1 | 1.2 | 1.6 | 2.0 | 2.4 | 3.2 | 4.0 |
| Free-flow valves | 1.7 | 1.8 | 1.9 | 2.0 | 2.5 | 2.6 | 2.8 | 3.0 | 3.6 | 4.8 | 6.0 |
| Diaphragm valves | 1.9 | 2.0 | 4.3 | 5.0 | 9.5 | 10 | 13.6 | 15 | 24 | 29 | - |

Dimensions, velocities and mass flows

in steam and water pipes

FIG. 1



Vapor flows in pipes

VACUUM

Vapor flows in kg/h at velocity $w = 80 \frac{m}{s}$

| abs. pressure in mbar | Internal pipe diameter | | | | | | | | | | | | | |
|--------------------------|------------------------|------|------|------|------|------|------|------|------|-----|------|-----|------|-----|
| | 32 | 40 | 50 | 70 | 80 | 100 | 125 | 150 | 200 | 250 | 300 | 350 | 400 | 500 |
| 0.1 | 0.02 | 0.04 | 0.05 | 0.11 | 0.14 | 0.22 | 0.34 | 0.49 | 0.87 | 1.4 | 2 | 2.7 | 3.5 | 5.4 |
| 0.2 | 0.04 | 0.07 | 0.1 | 0.2 | 0.26 | 0.41 | 0.64 | 0.93 | 1.6 | 2.6 | -3.7 | 5 | 16.6 | 10 |
| 0.3 | 0.06 | 0.1 | 0.15 | 0.3 | 0.39 | 0.6 | 0.94 | 1.4 | 2.4 | 3.8 | 5.4 | 7.4 | 9.7 | 15 |
| 0.4 | 0.08 | 0.13 | 0.2 | 0.39 | 0.51 | 0.8 | 1.3 | 1.8 | 3.2 | 5 | 7.2 | 9.7 | 13 | 20 |
| 0.5 | 0.1 | 0.16 | 0.25 | 0.49 | 0.64 | 1 | 1.6 | 2.3 | 4 | 6.3 | 9 | 12 | 16 | 25 |
| 0.6 | 0.12 | 0.19 | 0.3 | 0.58 | 0.76 | 1.2 | 1.9 | 2.7 | 4.8 | 7.4 | 11 | 15 | 19 | 29 |
| 0.7 | 0.14 | 0.22 | 0.35 | 0.68 | 0.88 | 1.4 | 2.2 | 3.1 | 5.5 | 8.6 | 12 | 17 | 22 | 35 |
| 0.8 | 0.16 | 0.25 | 0.39 | 0.77 | 1 | 1.6 | 2.4 | 3.5 | 6.3 | 9.8 | 14 | 19 | 25 | 39 |
| 0.9 | 0.18 | 0.28 | 0.44 | 0.85 | 1.1 | 1.7 | 2.7 | 3.9 | 7 | 11 | 16 | 21 | 28 | 44 |

Vapor flows in kg/h at velocity $w = 60 \frac{m}{s}$

| abs. pressure in mbar | Internal pipe diameter | | | | | | | | | | | | | |
|--------------------------|------------------------|------|------|------|------|-----|-----|-----|------|------|------|------|------|-------|
| | 32 | 40 | 50 | 70 | 80 | 100 | 125 | 150 | 200 | 250 | 300 | 350 | 400 | 500 |
| 1 | 0.15 | 0.23 | 0.36 | 0.71 | 0.93 | 1.5 | 2.3 | 3.3 | 5.8 | 9.1 | 13 | 18 | 23 | 36 |
| 2 | 0.29 | 0.45 | 0.71 | 1.4 | 1.8 | 2.8 | 4.4 | 6.4 | 11 | 18 | 26 | 35 | 45 | 70 |
| 3 | 0.43 | 0.67 | 1 | 2 | 2.7 | 4.2 | 6.5 | 9.4 | 17 | 26 | 37 | 51 | 67 | 104 |
| 5 | 0.7 | 1.1 | 1.7 | 3.3 | 4.3 | 6.8 | 11 | 15 | 27 | 42 | 61 | 83 | 108 | 170 |
| 10 | 1.4 | 2.1 | 3.3 | 6.4 | 8.4 | 13 | 21 | 30 | 52 | 82 | 120 | 160 | 210 | 330 |
| 20 | 2.6 | 4 | 6.3 | 12 | 16 | 25 | 40 | 57 | 100 | 160 | 230 | 310 | 400 | 630 |
| 30 | 3.8 | 5.9 | 9.3 | 18 | 24 | 37 | 58 | 83 | 150 | 230 | 335 | 455 | 595 | 925 |
| 50 | 6.2 | 9.7 | 15 | 30 | 39 | 61 | 95 | 136 | 240 | 380 | 545 | 740 | 970 | 1515 |
| 75 | 9 | 14 | 22 | 43 | 56 | 88 | 137 | 200 | 350 | 550 | 790 | 1075 | 1405 | 2200 |
| 100 | 12 | 19 | 29 | 57 | 74 | 120 | 180 | 260 | 465 | 725 | 1040 | 1420 | 1850 | 2900 |
| 150 | 17 | 27 | 42 | 83 | 108 | 170 | 265 | 380 | 670 | 1060 | 1525 | 2075 | 2710 | 4230 |
| 200 | 23 | 35 | 55 | 109 | 140 | 220 | 345 | 500 | 885 | 1390 | 1990 | 2720 | 3520 | 5520 |
| 300 | 33 | 52 | 80 | 160 | 205 | 325 | 505 | 725 | 1290 | 2015 | 2900 | 3950 | 5160 | 8065 |
| 400 | 44 | 68 | 106 | 210 | 270 | 425 | 690 | 955 | 1700 | 2670 | 3820 | 5200 | 6800 | 10600 |

Vapor flows in kg/h at velocity $w = 40 \frac{m}{s}$

| abs. pressure in mbar | Internal pipe diameter | | | | | | | | | | | | | |
|--------------------------|------------------------|-----|-----|-----|-----|-----|------|------|------|------|------|------|-------|-------|
| | 32 | 40 | 50 | 70 | 80 | 100 | 125 | 150 | 200 | 250 | 300 | 350 | 400 | 500 |
| 500 | 35 | 55 | 86 | 170 | 220 | 345 | 540 | 780 | 1380 | 2160 | 3110 | 4240 | 5530 | 8650 |
| 600 | 42 | 66 | 105 | 200 | 265 | 415 | 645 | 930 | 1660 | 2590 | 3730 | 5070 | 6630 | 10400 |
| 700 | 49 | 77 | 120 | 235 | 310 | 480 | 750 | 1080 | 1920 | 3000 | 4310 | 5870 | 7670 | 12000 |
| 800 | 55 | 87 | 135 | 270 | 350 | 540 | 850 | 1220 | 2200 | 3400 | 4900 | 6600 | 8600 | 13600 |
| 900 | 61 | 95 | 150 | 290 | 380 | 600 | 930 | 1340 | 2380 | 3720 | 5360 | 7300 | 9530 | 14900 |
| 1000 | 70 | 110 | 160 | 330 | 435 | 680 | 1060 | 1500 | 2700 | 4250 | 6100 | 8300 | 10850 | 17000 |

OVERPRESSURE

Vapor flows in kg/h at velocity $w = 30 \frac{m}{s}$

| Pressure bar | Internal pipe diameter | | | | | | | |
|-----------------|------------------------|-----|------|------|------|------|------|-------|
| | 20 | 25 | 32 | 40 | 50 | 70 | 80 | 100 |
| 1 | 38 | 60 | 98 | 153 | 240 | 470 | 615 | 960 |
| 1,5 | 47 | 74 | 121 | 189 | 296 | 580 | 755 | 1180 |
| 2 | 56 | 88 | 144 | 224 | 350 | 690 | 900 | 1400 |
| 2,5 | 65 | 101 | 166 | 259 | 405 | 795 | 1035 | 1620 |
| 3 | 74 | 115 | 188 | 294 | 460 | 900 | 1175 | 1840 |
| 4 | 90 | 141 | 232 | 360 | 565 | 1110 | 1450 | 2260 |
| 5 | 108 | 168 | 275 | 430 | 675 | 1320 | 1720 | 2700 |
| 6 | 124 | 194 | 320 | 500 | 775 | 1520 | 1990 | 3110 |
| 8 | 158 | 245 | 405 | 630 | 985 | 1935 | 2530 | 3950 |
| 10 | 192 | 300 | 490 | 765 | 1200 | 2350 | 3070 | 4790 |
| 12 | 225 | 350 | 575 | 900 | 1405 | 2750 | 3600 | 5620 |
| 15 | 275 | 430 | 700 | 1095 | 1710 | 3350 | 4380 | 6840 |
| 18 | 325 | 505 | 830 | 1290 | 2020 | 3960 | 5170 | 8080 |
| 20 | 355 | 550 | 905 | 1415 | 2210 | 4330 | 5660 | 8840 |
| 25 | 440 | 685 | 1120 | 1750 | 2740 | 5370 | 7010 | 10960 |

The tables on this sheet show the vapor flows in kg/h in relation to pressure and pipe diameter, for the usual flow velocities. In the case of air the throughput is very roughly double.

Mass flow of gases and vapors through nozzles

According to the Law of Continuity the following shall apply:

$$\dot{M} = a \cdot w \cdot \rho \quad (1)$$

| | |
|---------------|------------------------------------|
| \dot{M} | Mass flow |
| a | Flow cross section |
| w | Velocity |
| ρ | Density of the flowing medium |
| p_1 | Pressure upstream of the nozzle |
| ϑ_1 | Temperature upstream of the nozzle |
| c | Specific heat capacity |
| ψ | Coefficient of loss |

The aforementioned equation is valid for any point in a nozzle, when the values for a , w and ρ , present at this point, are filled in.

The mass flow through a nozzle is determined by the narrowest cross section of the nozzle.

With the diminishing cross section, the velocity $w = 0$ at the condition p_1 , ϑ_1 and ρ_1 increases up the narrowest point of the nozzle. At critical or over-critical pressure drops, sonic velocity is reached at this point. Supercritical pressure drops followed by a diverging nozzle section (Laval nozzle) further increase the velocity.

This critical pressure ratio is only dependent on the ratio of the specific heat capacities

$$\frac{c_p}{c_v} = \kappa$$

and therewith constant for a particular gas:

$$p_{crit.} / p_1 = \left(\frac{2}{\kappa + 1} \right)^{\frac{\kappa}{\kappa - 1}}$$

The mass flow through a nozzle whose inlet pressure is constant upstream of the nozzle, first increases with decreasing pressure downstream of the nozzle; the mass flow reaches its maximum at the critical pressure ratio and from then on remains constant.

For the calculation of the mass flows, two cases have to be considered:

- critical or supercritical pressure drops,
- subcritical pressure drops.

In most cases steam jet pumps are operated with nozzles operating at supercritical pressure drops. Only these nozzles will be considered in the following.

Assuming an adiabatic expansion in the nozzle, the mass flow is calculated as follows:

$$\dot{M} = \psi \cdot \psi_{crit.} \cdot a \cdot \sqrt{2 p_1 \cdot \rho_1}$$

with

$$\psi_{crit.} = \left(\frac{2}{\kappa + 1} \right)^{\frac{\kappa}{\kappa - 1}} \cdot \sqrt{\frac{\kappa}{\kappa + 1}}$$

Thus, the mass flow only depends on the condition of the gas upstream of the nozzle and its properties. The coefficients of loss of well finished nozzles are today so well known that for the purpose of calculating the mass flow, the motive nozzles of jet pumps supply far more accurate values than any other form of throughput measuring. Therefore, motive nozzles can be directly used for the exact calculation of the motive medium mass flow rate.

For water vapor the following values are used

$$\kappa = 1.3$$

This value is valid for superheated steam and for saturated steam as in spite of the expansion leading in the wet steam range, the steam remains dry due to delayed condensation.

At $\kappa = 1.3$ the critical pressure drop results with $p_1/p_{crit.} = 1.83$ and $\psi_{crit.} = 0.473$.

The diagram on page 26 was prepared with these values and with the equation for the mass flow (1).

Two examples are shown:

- 96 kg/h steam pass through the nozzle at saturated steam of $p_1 = 4$ bar absolute pressure and a nozzle diameter of 7.5 mm.
- Approx. 53 kg/h steam pass through a nozzle with a diameter of 4 mm at superheated steam ($\vartheta_D = 300$ °C) with an absolute pressure of $p_1 = 9$ bar.

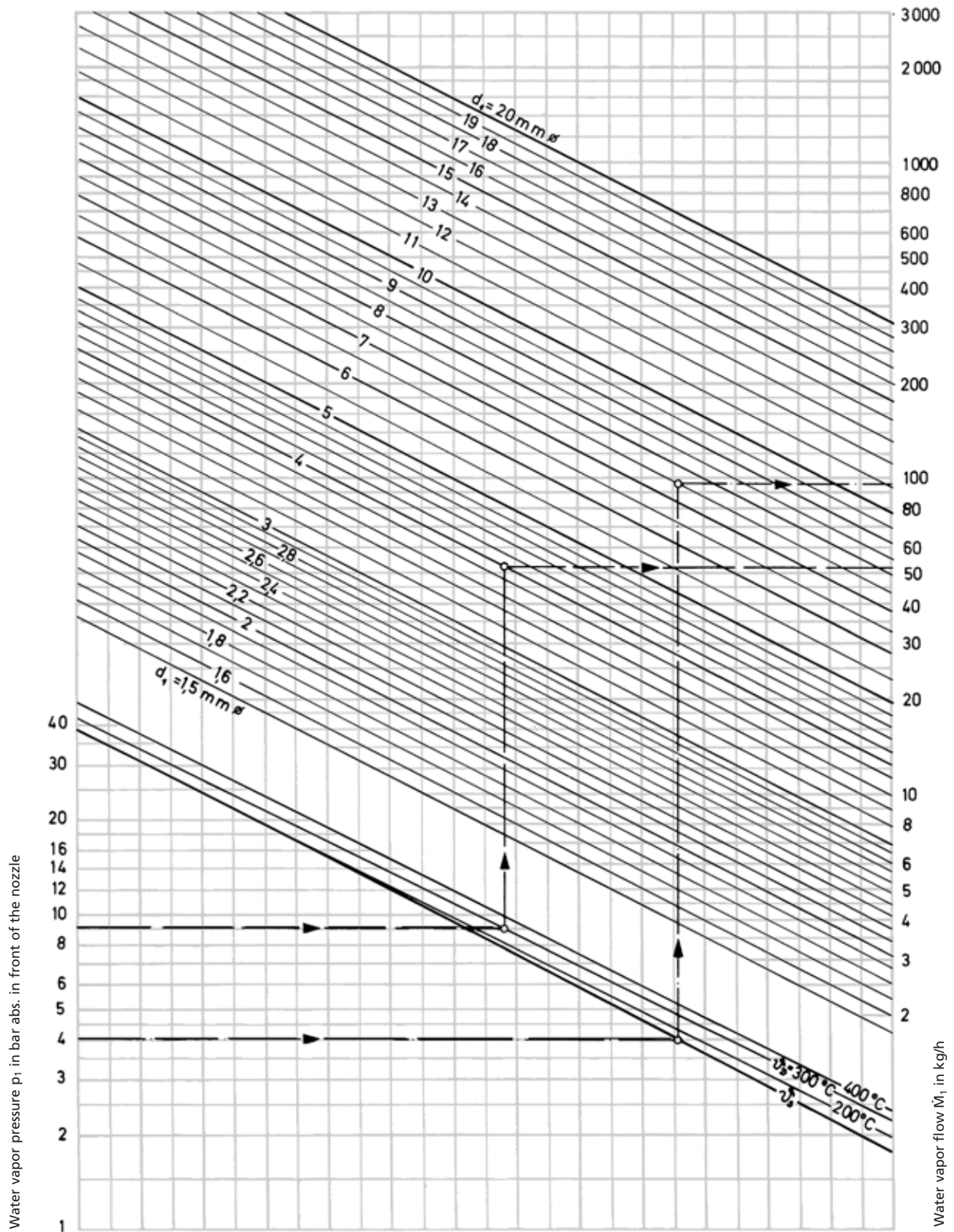
Depending on the condition of the steam ϑ_3 either the curve for saturated steam or the corresponding temperature curve for superheated steam ϑ_D should be used.

Literature:

- VDMA information sheet no. 24294, sheet 1 and 2
- DIN sheet 28430

Water vapor flow through motive nozzles at critical pressure ratio

FIG. 1



Water vapor flow through motive nozzles at critical pressure ratio

θ_s = Saturated steam temperature
 θ_o = Steam temperature
 d_1 = Motive nozzle diameter

Equivalent suction flows for steam jet vacuum pumps

In order to design a steam jet vacuum pump the suction flow must first be established.

The latter is determined by operating conditions that are to be indicated by the customer. Normally the suction flow is made up of various components, partly of condensable vapors, and partly of inert gases.

For more detailed indications for determining the suction flows please refer to "Planning a steam jet vacuum pumps", 7 | gdp3.

The suction flow of a steam jet vacuum pump depends on the suction pressure, the molecular mass and the temperature of the suction medium being conveyed. The higher the molecular mass, the more a jet pump can take in; the higher the temperature, the lower the suction flow and vice versa.

Capacity testing and acceptance tests on completed steam jet pumps should take place under exactly established and reproducible working conditions. Only in rare cases the original conditions regarding molecular mass and temperature can be reproduced. In general, only air or water vapor are at disposal as suction medium for such tests, particularly when they take place in the manufacturing works. For this reason, such measurements are taken with equivalent suction flows, i.e. suction flows which are converted to the air or water vapor equivalent.

The calculation of these equivalent suction flows is made in accordance with internationally recognized rules which are established in VDMA work sheet no. 24294 (1), in the DIN sheet 28430 (2) or in the HEI Standards (3). With correct application, these documents give same values.

This work sheet gives a simplified version of the relatively complicated methods of calculation described in the above-mentioned literature.

The calculation for equivalent suction flows is based on the equation:

$$\dot{M}_{02} = \dot{M}_{01} \cdot \frac{f_2}{f_1}$$

Where:

| | |
|-----------------|--|
| \dot{M}_{01} | Actual suction flow in kg/h |
| \dot{M}_{02} | Equivalent suction flow in kg/h (air or water vapor) |
| f_1 | Suction flow factor |
| f_2 | Equivalent suction flow factor |
| f_1 and f_2 | can be found in diagram fig. 1. |

In the application of this diagram on page 28 it is to be noted that the temperatures on the bottom scale are only valid for water vapor, whereas for all other gases and vapors the temperature should be read from the top scale.

EXAMPLE 1

OPERATING AND DESIGN DATA:

Suction flow $\dot{M}_{01} = 100 \frac{\text{kg}}{\text{h}}$ Hydrogen

Mol mass $\tilde{M}_{01} = 2 \frac{\text{kg}}{\text{kmol}}$

Gas temperature $\vartheta_G = 240^\circ\text{C}$

From fig. 1 the graph line "a" gives a suction flow factor $f_1 = 0.179$.

For the acceptance test in the manufacturing workshop, the actual suction medium (hydrogen) is substituted with air, with the molecular mass $\tilde{M} \approx 29 \text{ kg/kmol}$ and $\vartheta_G = 20^\circ\text{C}$.

From fig. 1 graph line "b" gives the equivalent flow factor

Thereby the equivalent air suction flow is

$$\text{calculated: } \dot{M}_{02} = 100 \cdot \frac{1}{0.179} \approx 560 \frac{\text{kg}}{\text{h}}$$

EXAMPLE 2

OPERATING AND DESIGN DATA:

Suction flow $\dot{M}_{01} = 100 \frac{\text{kg}}{\text{h}}$ Gas-vapour-mixture

Mol mass $\tilde{M}_{01} = 80 \frac{\text{kg}}{\text{kmol}}$

Temperature of the mixture $\vartheta_G = 300^\circ\text{C}$

From fig. 1 the graph line "c" gives a suction flow factor $f_1 = 1.22$.

The test should be conducted using water vapor (mol mass $\tilde{M}_{02} = 18 \text{ kg/kmol}$) $\vartheta_{\text{H}_2\text{O}} = 150^\circ\text{C}$.

From fig. 1 graph line "d" gives the equivalent flow factor $f_2 = 0.73$.

Thereby the equivalent steam suction flow

$$\text{is calculated: } \dot{M}_{02} = 100 \cdot \frac{0.73}{1.22} \approx 60 \text{ kg/h}$$

EXAMPLE 3

OPERATING AND DESIGN DATA:

Mixed suction flow

100 kg/h Water vapor

+ 200 kg/h Hydrocarbon vapor

$$\tilde{M} = 100 \text{ kg/kmol}$$

+ 22 kg/h Inert gases $\tilde{M} = 29 \text{ kg/kmol}$

$$= 322 \text{ kg/h}$$

Temperature of the mixture $\vartheta_G = 300^\circ\text{C}$

For mixtures of water vapor, other vapor and inert gases, the water vapor portion on the one hand and the vapor/inert gas portion on the other hand have to be converted separately.

It is therefore necessary to first determine the mean mol mass for the vapor/inert gas portion (without water vapor):

$$\frac{222 \text{ kg/h}}{\tilde{M}_{\text{mean}}} = \frac{200 \text{ kg/h}}{100 \text{ kg/kmol}} + \frac{22 \text{ kg/h}}{29 \text{ kg/kmol}} =$$

$$= (2 + 0.76) \frac{\text{kmol}}{\text{h}}$$

$$\tilde{M}_{\text{mean}} = \frac{222}{2.76} = 80 \frac{\text{kg}}{\text{kmol}}$$

The conversion shall be done in an equivalent water vapor flow of $\vartheta_{\text{H}_2\text{O}} = 150^\circ\text{C}$:

For the water vapor portion you will find in diagram fig. 1

at $\vartheta_{\text{H}_2\text{O}} = 300^\circ\text{C}$ and $\tilde{M} = 18 \text{ kg/kmol}$

$f_1 = 0.65$ (continuous line "e")

at $\vartheta_{\text{H}_2\text{O}} = 150^\circ\text{C}$ and $\tilde{M} = 18 \text{ kg/kmol}$

$f_2 = 0.73$ (continuous line "d")

Hence results:

$$\dot{M}_{02}' = 100 \cdot \frac{0.73}{0.65} = 112.3 \frac{\text{kg}}{\text{h}}$$

For the vapor/inert gas portion you will find in diagram fig. 1

at $\vartheta_G = 300^\circ\text{C}$ and $\tilde{M} = 80 \text{ kg/kmol}$

$f_1 = 1.22$ (continuous line "c")

and at $\vartheta_{\text{H}_2\text{O}} = 150^\circ\text{C}$ and $\tilde{M} = 18 \text{ kg/kmol}$

$f_2 = 0.73$ (continuous line "d")

Hence results:

$$\dot{M}_{02}'' = 222 \cdot \frac{0.73}{1.22} = 132.8 \frac{\text{kg}}{\text{h}}$$

Thus, the total equivalent water vapor suction flow results with

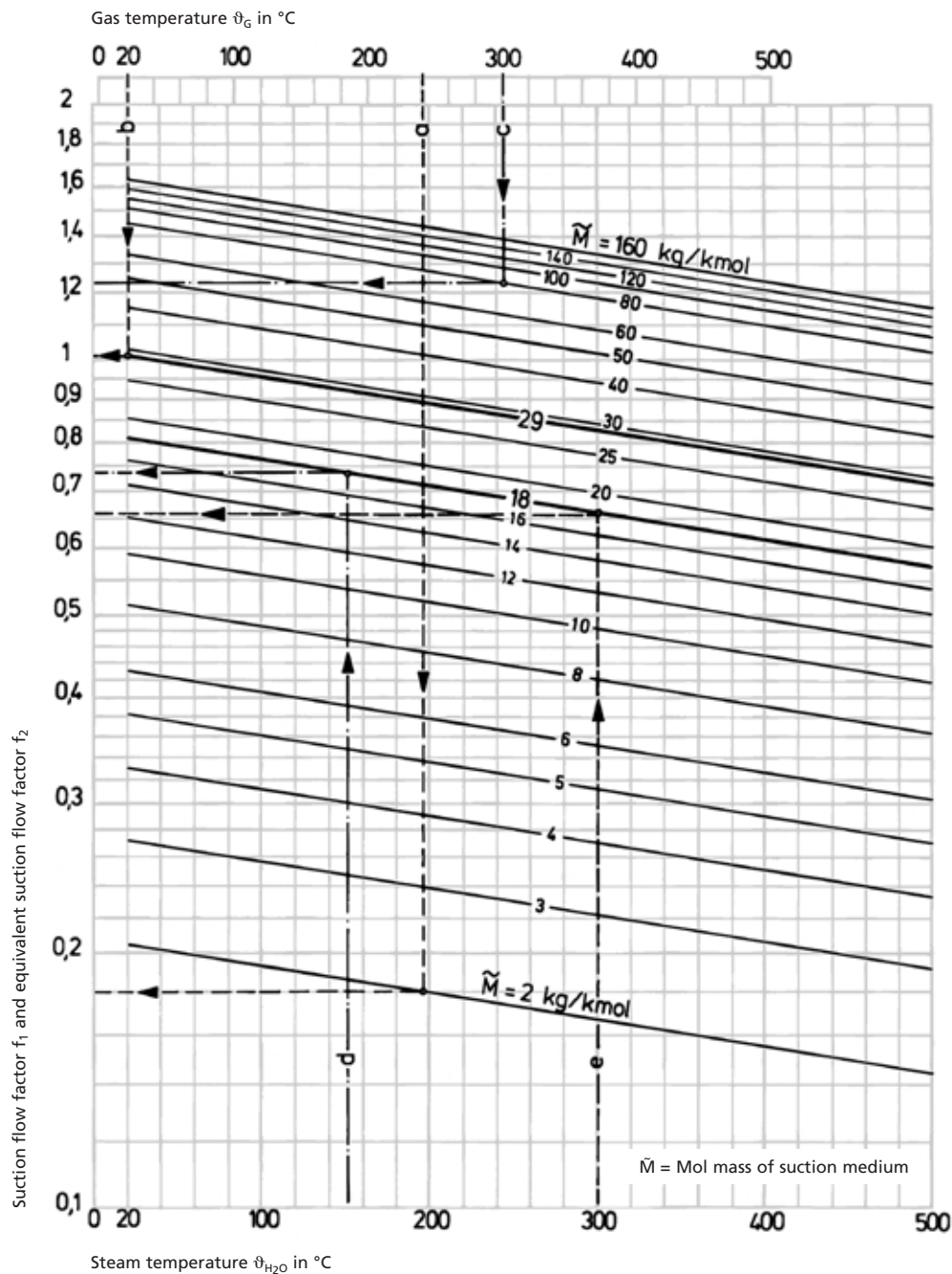
$$\dot{M}_{02}' + \dot{M}_{02}'' = 245.15 \frac{\text{kg}}{\text{h}}$$

MOLECULAR MASS OF SEVERAL SUCTION MEDIA

\bar{M} – Mol mass of suction medium

| Gas | \bar{M} [kg/kmol] |
|---------------------|---------------------|
| Acetic acid | 60.05 |
| Acetone | 58.08 |
| Acetylene | 26.04 |
| Air | 28.97 |
| Ammonia | 17.03 |
| Argon | 39.94 |
| Benzene | 78.11 |
| Butadiene | 54.09 |
| Butane | 58.12 |
| Butylene | 56.11 |
| Carbon dioxide | 44.01 |
| Carbon monoxide | 28.01 |
| Chlorine | 70.91 |
| Decane | 142.28 |
| Dinitrogen monoxide | 44.02 |
| Dodecane | 170.33 |
| Ethane | 30.07 |
| Ethyl ether | 74.12 |
| Ethyl alcohol | 46.07 |
| Ethyl chloride | 64.52 |
| Ethylene | 28.05 |
| Ethyleneglycol | 62.08 |
| Helium | 4.00 |
| Heptane | 100.20 |
| Hexane | 86.17 |
| Hydrogen | 2.02 |
| Hydrogen sulphide | 34.08 |
| Hydrogen chloride | 36.47 |
| Hydrogen cyanide | 27.03 |
| Methane | 16.04 |
| Methyl alcohol | 32.04 |
| Methyl chloride | 50.49 |
| Neon | 20.18 |
| Nitric oxide | 30.01 |
| Nitrogen | 28.02 |
| Nitrogen oxide | 60.02 |
| Nonane | 128.25 |
| Octane | 114.22 |
| Oxygen | 32.00 |
| Pentane | 72.15 |
| Propane | 44.09 |
| Propylene | 42.08 |
| Sulphur dioxide | 64.06 |
| Sulphur trioxide | 80.06 |
| Styrene | 104.14 |
| Tetradecane | 198.38 |
| Toluol | 92.13 |
| Tridecane | 184.35 |
| Undecane | 156.30 |
| Water | 18.02 |

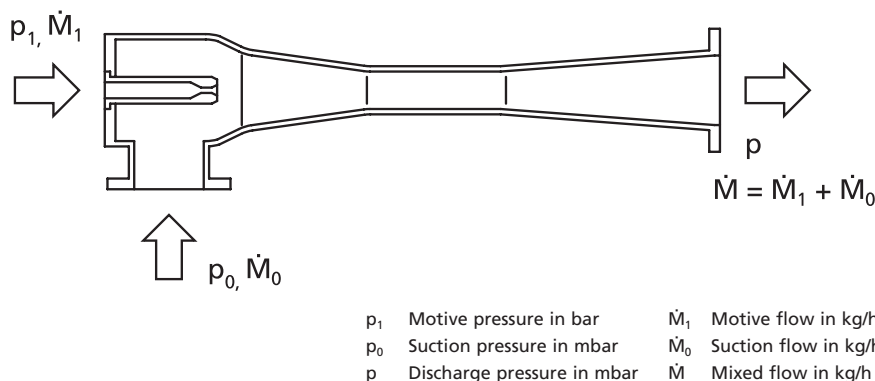
FIG. 1



- 1) DIN 28430 "Messregeln für Dampfstrahlvakuumpumpen und Dampfstrahlkompressoren."
- 2) "HEI-Standards for Steam Jet Ejectors", Heat Exchange Institute, New York, USA

Steam consumption of jet pumps

FIG. 1



The steam consumption of a steam jet pump depends on the compression ratio K , the expansion ratio E , and the composition, mean molecular mass and temperature of the suction flow. (There are, however, some other influences which within the scope of this catalog sheet cannot be considered.)

Since the steam consumption diagram **fig. 2** applies for the removal of water vapor at $\vartheta = 150\text{ °C}$, the operating/design suction flow must first be converted into an equivalent water vapor suction flow at 150 °C (\dot{M}_{0WE}) according to DIN 28430.

The expansion ratio

$$E = \frac{p_1}{p_0} = \frac{\text{Motive steam pressure}}{\text{Suction pressure}}$$

and the compression ratio

$$K = \frac{p}{p_0} = \frac{\text{Discharge pressure}}{\text{Suction pressure}}$$

are calculated on the basis of this.

The steam consumption considerably depends on both factors:

The higher E , the less motive steam is required; but the higher K the more motive steam is required.

In **fig. 2** you find the specific motive steam consumption for K and E :

$$b = \frac{\text{kg Motive steam}}{\text{kg Equiv. water vapour}} = \frac{\dot{M}_1}{\dot{M}_{0WE}}$$

The motive steam consumption of a jet pump is then:

$$\dot{M}_1 = \dot{M}_{0WE} \cdot b \frac{\text{kg}}{\text{h}}$$

The value thus determined can be used as a first approximated consumption figure.

We shall be pleased to give you exact consumption figures if you inform us about the exact application.

EXAMPLE

100 kg/h of gas-vapor mixture (without water vapor) with a mean molecular mass of $\bar{M} = 80\text{ kg/kmol}$ and $\vartheta_g = 300\text{ °C}$ shall be removed (see example in catalog sheet \nearrow | abl 12).

The conversion into an equivalent water vapor suction flow of $\vartheta_{H_2O} = 150\text{ °C}$ results in $\dot{M}_{0WE} = 60\text{ kg/h}$.

With a suction pressure of $p_0 = 10\text{ mbar}$,

discharge pressure of $p = 50\text{ mbar}$ and a

motive steam pressure of $p_1 = 5\text{ bar abs.}$

the following results:

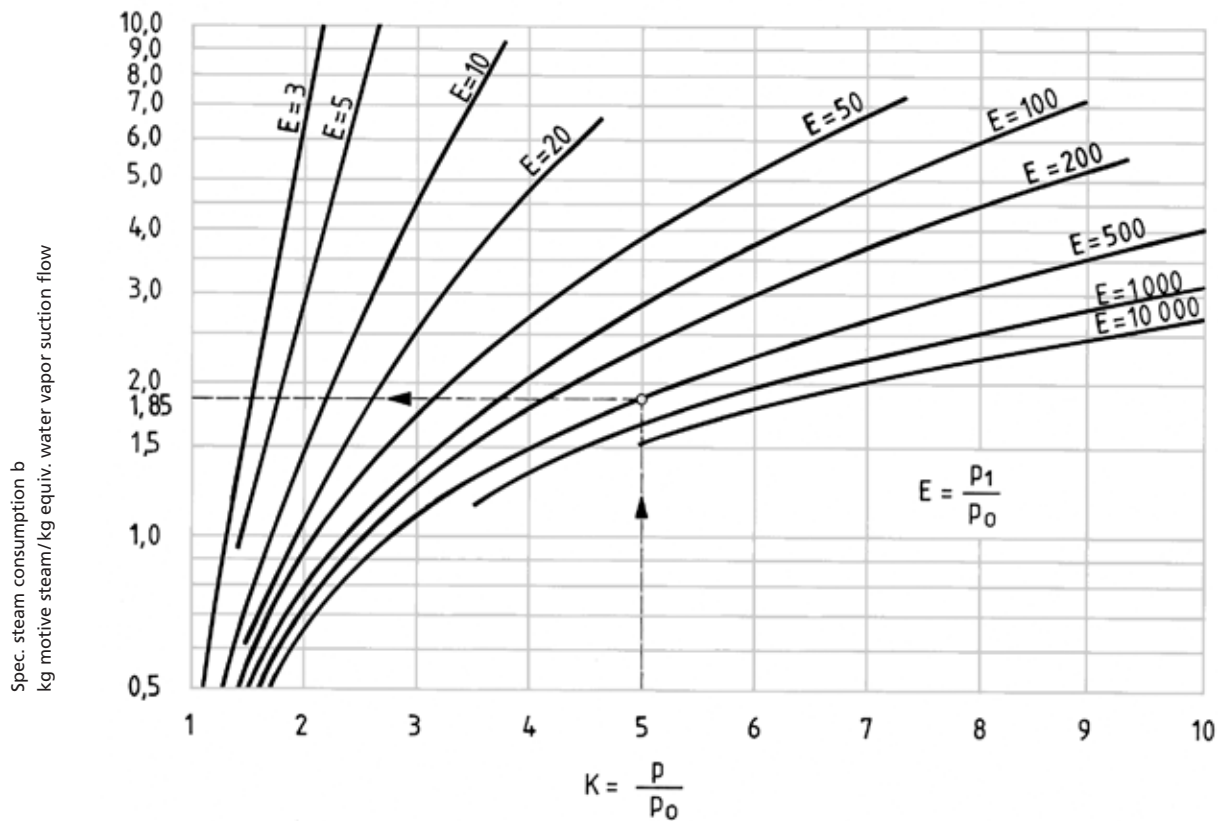
$$K = \frac{50}{10} = 5$$

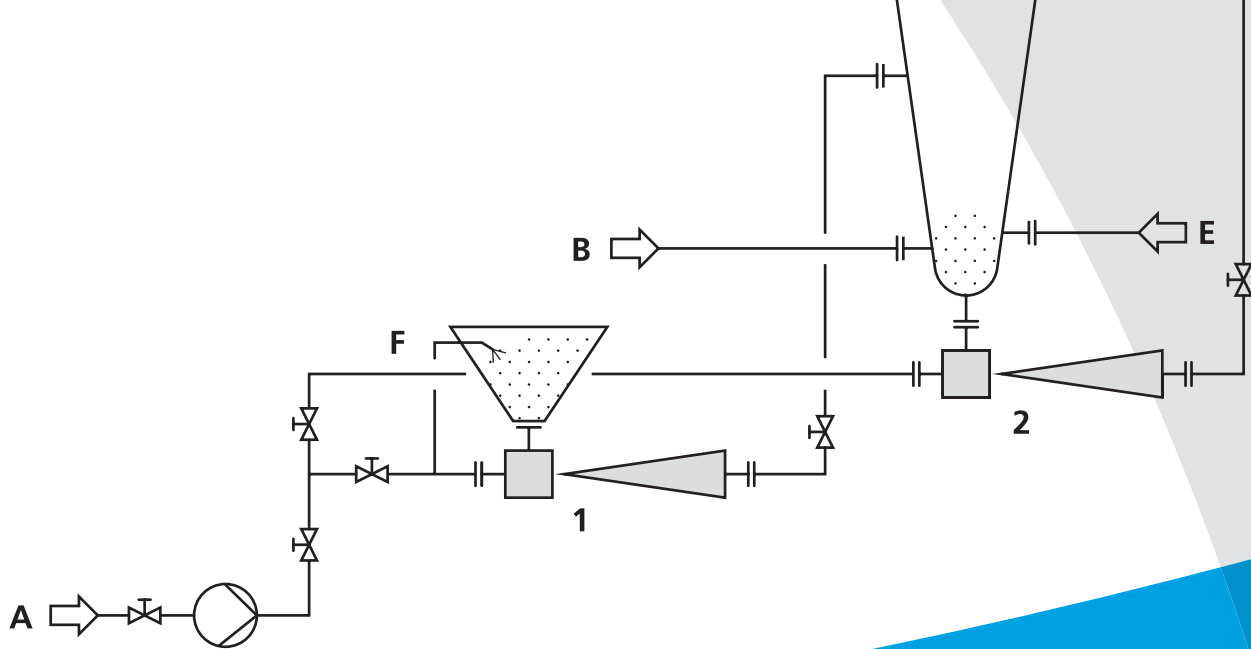
$$E = \frac{5000}{10} = 500$$

And thus, from the **fig. 2**, the following can be found: $b = 1.85\text{ kg/h}$

$$\dot{M}_1 = 60 \cdot 1.85 = 111 \frac{\text{kg}}{\text{h}}$$

FIG. 2





Liquid jet pumps

- Liquid jet vacuum pumps, general information
- Liquid jet vacuum pumps with threaded connections
- Liquid jet vacuum pumps with flanged connections
- Liquid jet vacuum pumps of PTFE
- Liquid jet gas compressors
- Liquid jet liquid pumps, general information
- Liquid jet liquid pumps of steel or stainless steel
- Standard liquid jet liquid pumps of PVC/PP
- Standard liquid jet liquid pumps of PTFE
- Liquid jet solids pumps
- Liquid jet mixers
- Liquid jet mixers for food applications/orbitally welded design
- Liquid jet ventilators

Liquid jet vacuum pumps

General information

In most cases, liquid jet pumps are operated with water as motive medium. Depending on application and material, it is also possible to use other liquids.

The action of liquid jet pumps is based on the fact that the liquid jet coming out of the motive nozzle at high speed entrains air, gas, liquid or solid matters from the head of the jet pumps and compresses them to atmospheric pressure.

For more detailed information on structure and mode of operation of jet pumps please refer to "General information on jet pumps", 7 | abt 1.

vacuum can be achieved by further cooling of the operating liquid. This is particularly expedient when the suction flow contains condensable components, e.g. solvents. In such a case the vacuum pump can be operated by using the condensate as the motive medium.

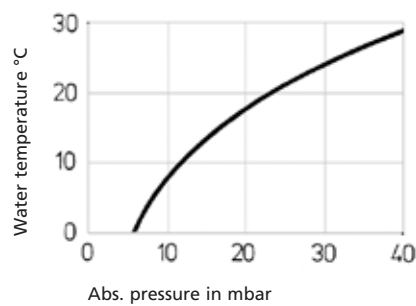
The lowest suction pressure which can be obtained with a suction capacity of zero (blind vacuum) corresponds to the vapor pressure of the motive liquid which depends on the temperature of the liquid. For the motive medium of water the relationship between water temperature and lowest suction pressure is shown in fig. 2.

MODE OF OPERATION

Liquid jet vacuum pumps, when water is used as the motive medium, can be directly coupled to the water line. If, however, the water consumption has to be as economical as possible, the operating water may be circulated. This is also the case when other liquids are used as the motive medium, instead of water.

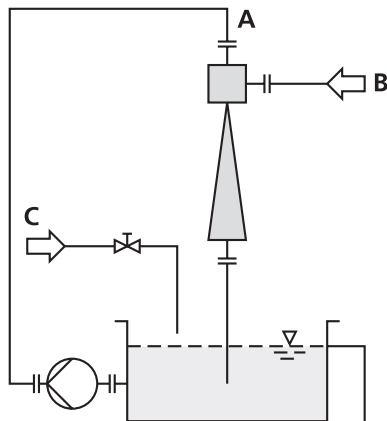
The temperature of the operating liquid may be kept low by the constant addition of a small quantity of fresh liquid. Higher

FIG. 2



Relation between water temperature and max. suction pressure

FIG. 1



- A Service liquid
- B Suction connection
- C Fresh liquid

Liquid jet vacuum pumps perform a perfect operation if the discharge pipe is below the liquid level or if a reducing piece is connected to the liquid discharge (fig. 1).



Stainless steel, with threaded connections



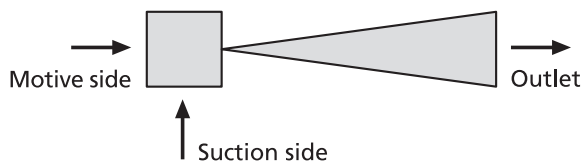
Stainless steel, with flanged connections



PTFE, with flanged connections

Questionnaire

for liquid jet vacuum pumps
fvp1, fvp2, fvp3



[Link to fillable PDF](#)

1. MOTIVE SIDE

Motive medium
 Motive flow m³/h
 Motive pressure bar abs.

Temperature °C
 Density kg/m³
 Concentration weight %
 Steam pressure bar abs.

2. SUCTION SIDE

Suction medium
 Suction flow kg/h
 Suction pressure bar abs.

Temperature °C
 Density kg/m³
 Concentration weight %

3. OUTLET

Required discharge pressure bar abs.
 Mixed flow kg/h
 Concentration weight %

4. FURTHER DATA

MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges
 Thread
 Others

FLANGES ACCORDING TO:

EN1092-1
 ASME lbs
 Others

DESIGN CODE (if required):

AD-2000
 ASME
 Others

APPLICATION:

.....

DESIGN:

Temperature °C Pressure bar g

FURTHER NOTES:

.....

Additional details, if required,
are to be stated separately.

Your inquiry no.

Offer submitted until

Requested date of delivery

YOUR ADDRESS

Company
 attn.
 Street/P.O. Box
 ZIP code/City
 Country

Telephone
 Telefax
 E-mail

Liquid jet vacuum pumps

with threaded connections



APPLICATIONS

Liquid jet vacuum pumps with threaded connections are mainly used in chemical laboratories for the production of vacuum, for example in vacuum distillation or drying.

They are also used for evacuating syphon lines, suction lines of circulating pumps and condensers; for deaeration of pressure vessels and for producing negative pressure in Nutsch filters.

PERFORMANCE CHART FOR VACUUM PUMPS

Diagram fig. 3 gives the mass suction flow in kg/h of air in relation to the suction pressure at various operating water pressures for 4 pump sizes. The curves are based on an operating water temperature of 20 °C.

The motive liquid consumption or the motive liquid flow (circulating water operation) can be taken from diagram fig 4.

EXAMPLE

0.35 kg/h of air has to be continuously exhausted out of a plant. The suction pressure amounts to 100 mbar abs. A motive water pressure of 5 bar g is available. The motive water has a temperature of 20 °C.

PARAMETERS TO BE FOUND: Size of pump and motive water consumption.

SOLUTION: From diagram fig. 3, for a suction pressure of 100 mbar and a motive water pressure of 5 bar g, pump size 2 with a mass suction flow of 0.38 kg/h is closest to the required suction volume.

From diagram fig. 4, for a motive water pressure of 5 bar g and a suction pressure of 100 mbar a motive water consumption of 2.35 m³/h for the chosen size 2 can be found.

FIG. 3

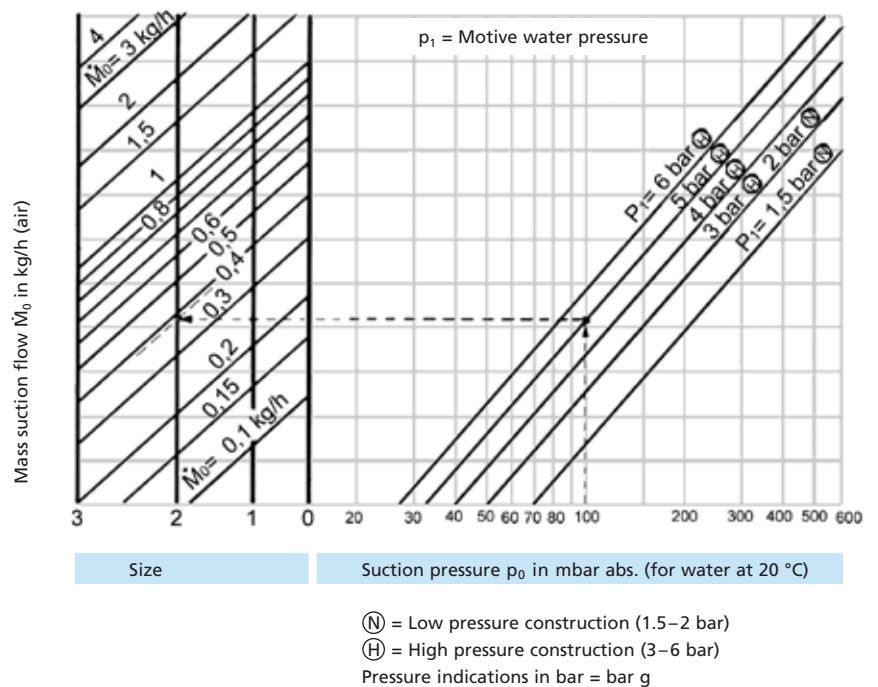
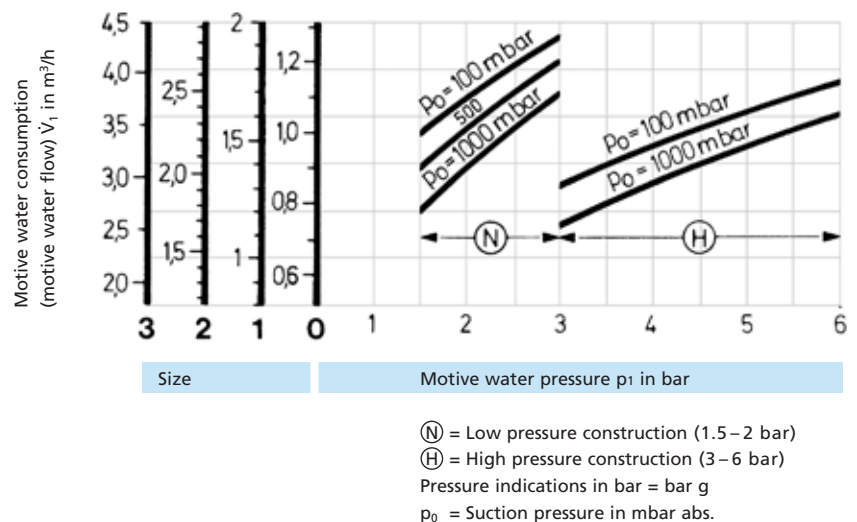


FIG. 4



PERFORMANCE CHART FOR PRE-EVACUATORS

EVACUATION TIME

Diagram fig. 5 gives the time in minutes a liquid jet vacuum pump size 2 needs to evacuate a vessel volume of 100 l to a defined suction pressure.

The selection of other sizes is achieved by the following conversion formula:

$$F = \frac{t_{spec.} \cdot V}{t_{evac.}}$$

- F Factor for the selection of the pump size
- $t_{spec.}$ Specific evacuation time in min/100 l (from diagram fig. 5)
- $t_{evac.}$ Expected evacuation time in minutes
- V Volume of vessel to be evacuated in liter

| Size | 0 | 1 | 2 | 3 |
|----------|------|------|---|-----|
| Factor F | 0.44 | 0.68 | 1 | 1.5 |

EXAMPLE

A vessel of 400 l is to be evacuated to 400 mbar in 5 minutes. The water pressure is 3 bar.

PARAMETERS TO BE FOUND: Pump size

SOLUTION: From diagram fig. 5, for 400 mbar and 3 bar, a time of 1.8 min/100 l is found. For the evacuation of a vessel volume of 400 l, a liquid jet vacuum pump size 2 requires $4 \times 1.8 = 7.2$ minutes. However,

as only 5 minutes are available the above formula is used to calculate the factor for the size of pump required:

$$F = \frac{1.8}{100 \cdot 5} \cdot 400 = 1.44$$

According to the table factor 1.5 corresponding to pump size 3 is closest to the calculated value. Pump size 3 is therefore selected.

The motive liquid consumption is influenced by the suction pressure p_0 . This is established by means of the curves in fig. 4.

FIG. 5

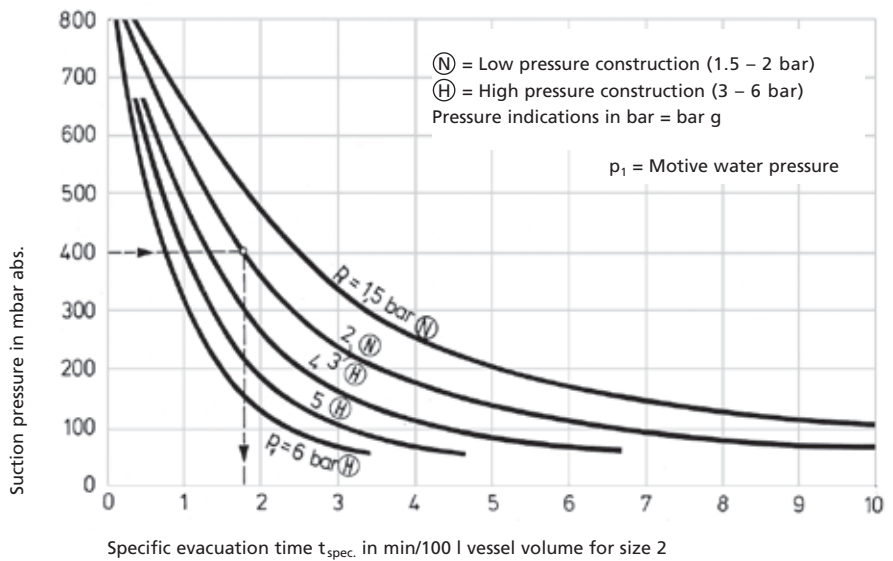
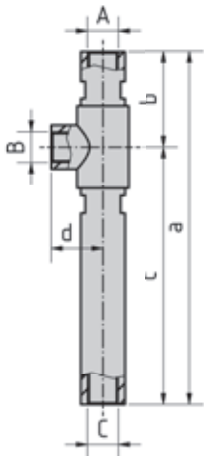


FIG. 6



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 0 | 1 | 2 | 3 |
|----------------------------|------|-------|-------|-------|---------|
| Operating water connection | A | G 1/2 | G 3/4 | G 1 | G 1 1/2 |
| Suction connection | B | G 1/2 | G 1/2 | G 3/4 | G 1 |
| Pressure connection | C | G 1/2 | G 1/2 | G 3/4 | G 1 |
| Dimensions in mm | a | 240 | 260 | 310 | 405 |
| | b | 65 | 70 | 80 | 105 |
| | c | 175 | 190 | 230 | 300 |
| | d | 35 | 40 | 45 | 50 |
| Weight in kg | | 0.9 | 1.4 | 2.3 | 3.1 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, motive nozzle: stainless steel
- II Completely stainless steel

SPECIAL CONSTRUCTIONS: Hastelloy, Titanium, plastics (PVC, PP, PVDF, PTFE) etc.

Motive pressure has to be given with inquiry/order. For inquiries please use our questionnaire.

Liquid jet vacuum pumps

with flanged connections



APPLICATIONS

Liquid jet vacuum pumps with flanged connections are mainly used for the production of vacuum in laboratories and in pilot and production plants for example for vacuum distillation and vacuum drying. They are also used for evacuating syphon lines, suction lines of circulating pumps and condensers; for the deaeration of pressure vessels and for producing negative pressure in a Nutsch filter, etc.

PERFORMANCE CHART FOR VACUUM PUMPS

Diagram **fig. 7** gives the mass suction flow in kg/h of air in relation to the suction pressure at various operating water pressures for 8 pump sizes.

The curves are based on an operating water temperature of 20 °C. The motive liquid consumption or the motive liquid flow (circulating water operation) can be taken from diagram **fig. 8**.

EXAMPLE

6 kg/h of air has to be continuously exhausted out of a plant. The suction pressure amounts to 100 mbar abs. A motive liquid pressure of 5 bar g is available. The motive water has a temperature of 20 °C.

PARAMETERS TO BE FOUND: Size of pump and motive water consumption.

SOLUTION: From diagram **fig. 7**, for a suction pressure of 100 mbar and a motive water pressure of 5 bar g, pump size 7 with a mass suction flow of 6.8 kg/h is closest to the required suction volume.

From diagram **fig. 8**, for a motive water pressure of 5 bar g and a suction pressure of 100 mbar a motive water consumption of 23.5 m³/h for the chosen size 7 can be found.

FIG. 7

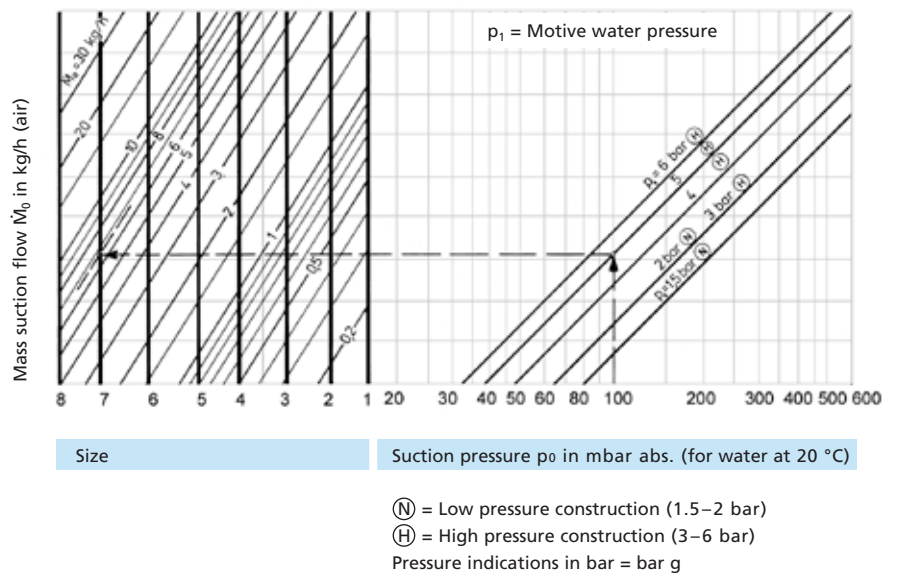
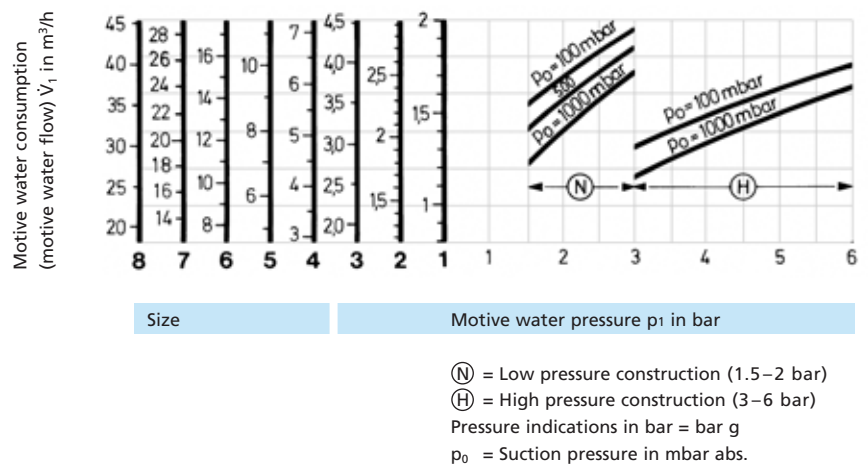


FIG. 8



PERFORMANCE CHART FOR PRE-EVACUATORS

EVACUATION TIME

Diagram fig. 9 gives the time in minutes a liquid jet vacuum pump size 4 needs to evacuate a vessel volume of 1 m³ to a defined suction pressure.

The selection of other sizes is achieved by the following conversion formula:

$$F = \frac{t_{\text{spec.}} \cdot V}{t_{\text{evac.}}}$$

- F Factor for the selection of the pump size
- t_{spec.} Specific evacuation time in min/m³ (from diagram fig. 9)
- t_{evac.} Expected evacuation time in minutes
- V Volume of vessel to be evacuated in m³

| Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----------|------|------|------|---|-----|-----|---|-----|
| Factor F | 0.28 | 0.40 | 0.63 | 1 | 1.6 | 2.5 | 4 | 6.3 |

EXAMPLE

A vessel of 3 m³ is to be evacuated to 400 mbar in 10 minutes. The water pressure is 3 bar.

PARAMETERS TO BE FOUND: Size of the pump
SOLUTION: From diagram fig. 9, for 400 mbar and 3 bar, a time of 8 min/m³ is found. For the evacuation of a vessel volume of 3 m³,

a liquid jet vacuum pump size 4 requires 3 x 8 = 24 minutes. However, as only 10 minutes are available the above formula is used to calculate the factor for the size of pump required:

$$F = \frac{8}{10} \cdot 3 = 2.4$$

According to the table factor 2.5 corresponding to pump size 6 is closest to the calculated value. Pump size 6 is therefore selected.

The motive liquid consumption is influenced by the suction pressure p₀. This is established by means of the curves in fig. 8.

FIG. 9

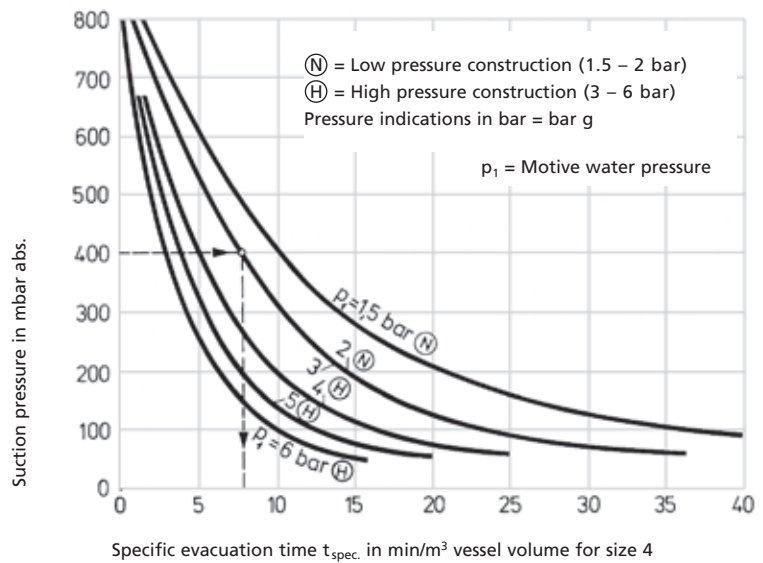
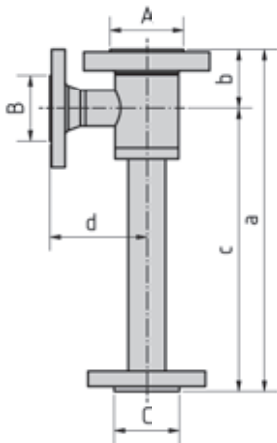


FIG. 10



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----------------------------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| Operating water connection | A | 25 | 25 | 32 | 40 | 50 | 65 | 65 | 80 |
| Suction connection | B | 20 | 20 | 25 | 32 | 40 | 40 | 50 | 65 |
| Pressure connection | C | 15 | 20 | 25 | 32 | 40 | 50 | 65 | 80 |
| Dimensions in mm | a | 207 | 267 | 347 | 407 | 478 | 608 | 778 | 963 |
| | b | 60 | 60 | 65 | 70 | 80 | 80 | 80 | 115 |
| | c | 147 | 207 | 282 | 337 | 398 | 528 | 698 | 848 |
| | d | 85 | 85 | 100 | 115 | 125 | 125 | 135 | 135 |
| Weight in kg | | 8 | 10 | 13 | 18 | 26 | 35 | 55 | 65 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, motive nozzle: stainless steel
 - II Completely stainless steel
- Flanges according to EN1092-1

SPECIAL CONSTRUCTIONS: Hastelloy, Titanium, plastics (PVC, PP, PVDF, PTFE) etc.

Motive pressure has to be given with inquiry/order.
 For inquiries please use our questionnaire.

Liquid jet vacuum pumps

of PTFE



APPLICATIONS

Liquid jet vacuum pumps of PTFE are used in laboratories and in production plants. They are used for evacuating syphon lines on acid plants, for producing vacuum, for deaerating apparatus in which solvent vapors are produced and for producing negative pressures in Nutsch filters, etc. Jet pumps are completely manufactured of PTFE. These pumps are, therefore, resistant to chemical attack. They are reliable and maintenance-free; the capital cost is low.

PERFORMANCE CHART OF VACUUM PUMPS

Diagram **fig. 11** gives the mass suction flow in kg/h of air in relation to the suction pressure at various operating water pressures for 4 pump sizes. The curves are based on an operating water temperature of 20 °C. The motive liquid consumption or the motive liquid flow (circulating water operation) can be taken from diagram **fig. 12**.

FIG. 11

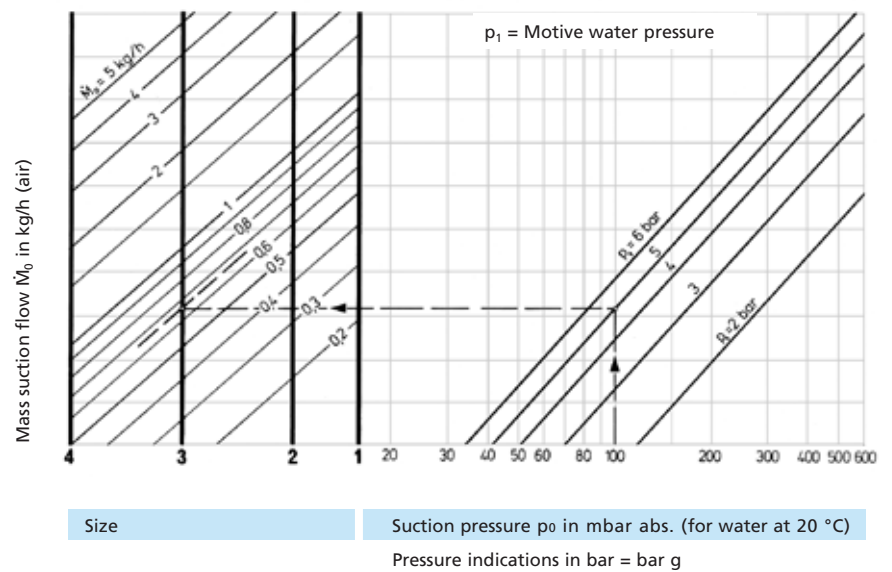
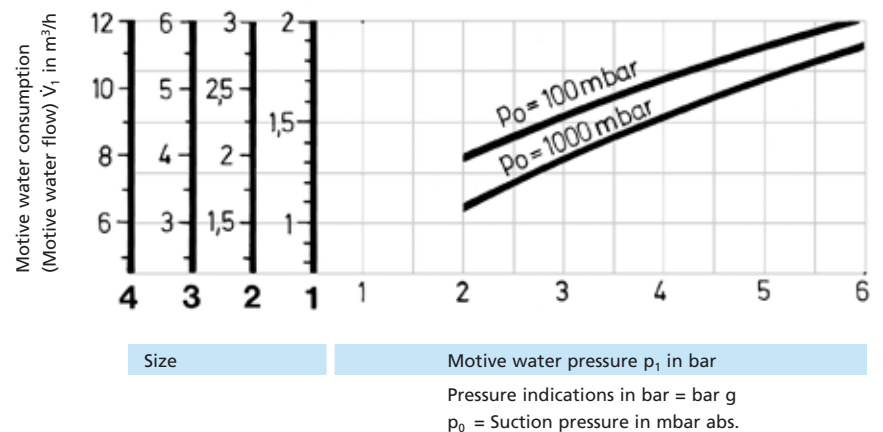


FIG. 12



EXAMPLE

0.6 kg/h of air has to be continuously exhausted out of a plant. The suction pressure amounts to 100 mbar abs. A motive liquid pressure of 5 bar g is available. The motive liquid has a temperature of 20 °C.

PARAMETERS TO BE FOUND: Size of pump and motive water consumption.

SOLUTION: From diagram **fig. 11**, for a suction pressure of 100 mbar and a motive water pressure of 5 bar g, pump size 3 with a mass suction flow of 0.67 kg/h is closest to the required suction volume.

From diagram **fig. 12**, for a motive water pressure of 5 bar g and a suction pressure of 100 mbar a motive water consumption of 5.5 m³/h for the chosen size 3 can be found.

PERFORMANCE CHART FOR PRE-EVACUATORS

EVACUATION TIME

Diagram fig. 13 gives the time in minutes a liquid jet vacuum pump size 3 needs to evacuate a vessel volume of 1 m³ to a defined suction pressure.

The selection of other sizes is achieved by the following conversion formula:

$$F = \frac{t_{\text{spec.}} \cdot V}{t_{\text{evac.}}}$$

- F Factor for the selection of the pump size
- t_{spec.} Specific evacuation time in min/m³ (from diagram fig. 13)
- t_{evac.} Expected evacuation time in minutes
- V Volume of vessel to be evacuated in m³

| Size | 1 | 2 | 3 | 4 |
|----------|------|-----|---|---|
| Factor F | 0.33 | 0.5 | 1 | 2 |

EXAMPLE

A vessel of 2 m³ is to be evacuated to 400 mbar in 15 minutes. The water pressure is 3 bar.

PARAMETERS TO BE FOUND: Size of the pump

SOLUTION: From diagram fig. 13, for 400 mbar and 3 bar, a time of 12 min/m³ is found. For the evacuation of a vessel volume of 2 m³, a liquid jet vacuum pump size 3 requires

2 x 12 = 24 minutes. However, as only 15 minutes are available the above formula is used to calculate the factor for the larger size of pump required:

$$F = \frac{12}{15} \cdot 2 = 1.6$$

According to the table factor 2 corresponding to pump size 4 is closest to the calculated value. Pump size 4 is therefore selected.

The motive liquid consumption is influenced by the suction pressure p₀. This is established by means of the curves in fig. 12.

FIG. 13

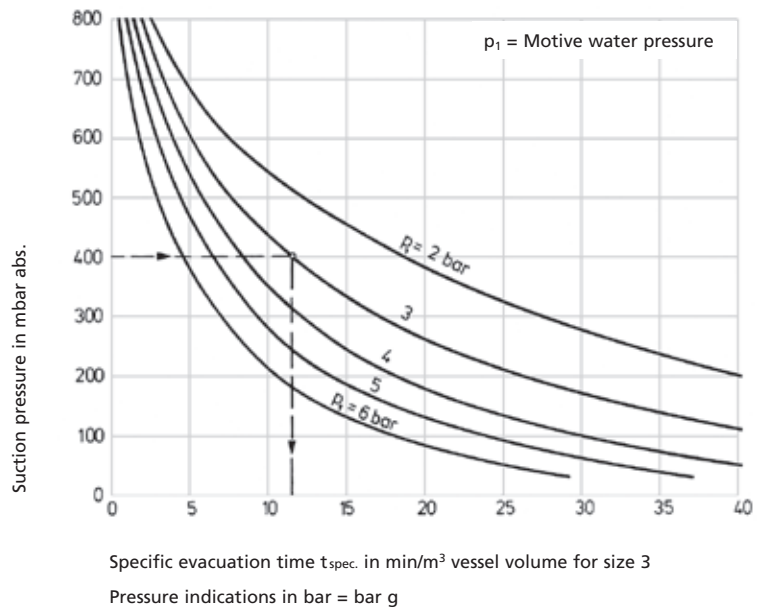
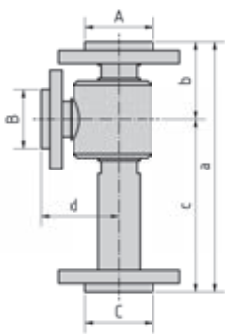


FIG. 14



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Größe | 1 | 2 | 3 | 4 |
|----------------------------|-------|-----|-----|-----|-----|
| Operating water connection | A | 32 | 32 | 40 | 50 |
| Suction connection | B | 25 | 25 | 25 | 32 |
| Pressure connection | C | 32 | 32 | 50 | 65 |
| Dimensions in mm | a | 290 | 290 | 390 | 500 |
| | b | 90 | 90 | 95 | 105 |
| | c | 200 | 200 | 295 | 395 |
| | d | 90 | 90 | 100 | 110 |
| Weight in kg | | 3 | 3 | 5 | 7 |

STANDARD CONSTRUCTION:

PTFE, loose flange made in GF-UP
Connections according to EN1092-1

METAL AND SPECIAL CONSTRUCTIONS:

Please see "Liquid jet vacuum pumps with threaded connections", ↗ | fvp 1, and "Liquid jet vacuum pumps with flanged connections", ↗ | fvp 2.

For inquiries please use our questionnaire.

Liquid jet gas compressors

APPLICATION AND MODE OF OPERATION

Liquid jet gas compressors are jet pumps for the conveyance and compression of gases at simultaneous mixing with the motive liquid.

Their operation is based on the liquid jet emerging from the motive nozzle hitting and entraining the surrounding gases and compressing them to a higher pressure (see also "General information on jet pumps", 7 | abl 1).

PERFORMANCE CHART

Fig. 1 shows the relation between the permissible suction ration

$$\varphi_{adm.} = \frac{\dot{V}_0}{\dot{V}_1} = \frac{m^3 \text{ Gas}}{m^3 \text{ Motive liquid}}$$

of the pressure difference to be overcome

$$\Delta p = p - p_0$$

and the effective motive liquid pressure

$$\Delta p_1 = p_1 - p_0$$

The suction ratio φ of sucked-in gas flow to the required motive liquid flow

- increases with increasing motive liquid pressure p_1 .
- lowers with increasing compression Δp_1 .
- is independent of type and density of the gas to be conveyed.

EXAMPLE

for the selection of a liquid jet gas compressor

GIVEN:

- $\dot{V}_0 = 13 \text{ m}^3/\text{h}$ of gas
- $p_0 = -0.2 \text{ bar}$ (= 0.8 bar abs.)
- $p_1 = 3 \text{ bar}$
- $p = 0.7 \text{ bar}$

PARAMETERS TO BE FOUND:

Motive liquid flow \dot{V}_1 and size of the compressor

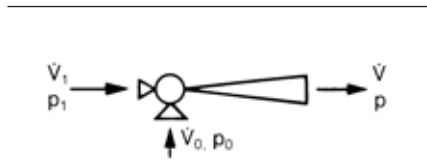
SOLUTION:

- $\Delta p = p - p_0 = 0.7 - (-0.2) = 0.9 \text{ bar}$
- $\Delta p_1 = p_1 - p_0 = 3 - (-0.2) = 3.2 \text{ bar}$
- From fig. 1 you will find for $\Delta p = 0.9 \text{ bar}$ and $\Delta p_1 = 3.2 \text{ bar}$:

$$\varphi_{adm.} = \frac{\dot{V}_0}{\dot{V}_1} = 0.85$$

This results in:

$$\dot{V}_1 = \frac{\dot{V}_0}{\varphi_{adm.}} = \frac{13}{0.85} = 15.3 \text{ m}^3/\text{h}$$



- p_1 = Motive liquid pressure in bar
- p_0 = Suction pressure in bar
- p = Discharge pressure in bar
- Δp = $p - p_0$ = Total delivery pressure in bar
- Δp_1 = $p_1 - p_0$ = Effective motive liquid pressure in bar
- \dot{V}_1 = Motive liquid flow in m^3/h
- \dot{V}_0 = Gas suction flow in m^3/h
- \dot{V} = Mixed flow in m^3/h

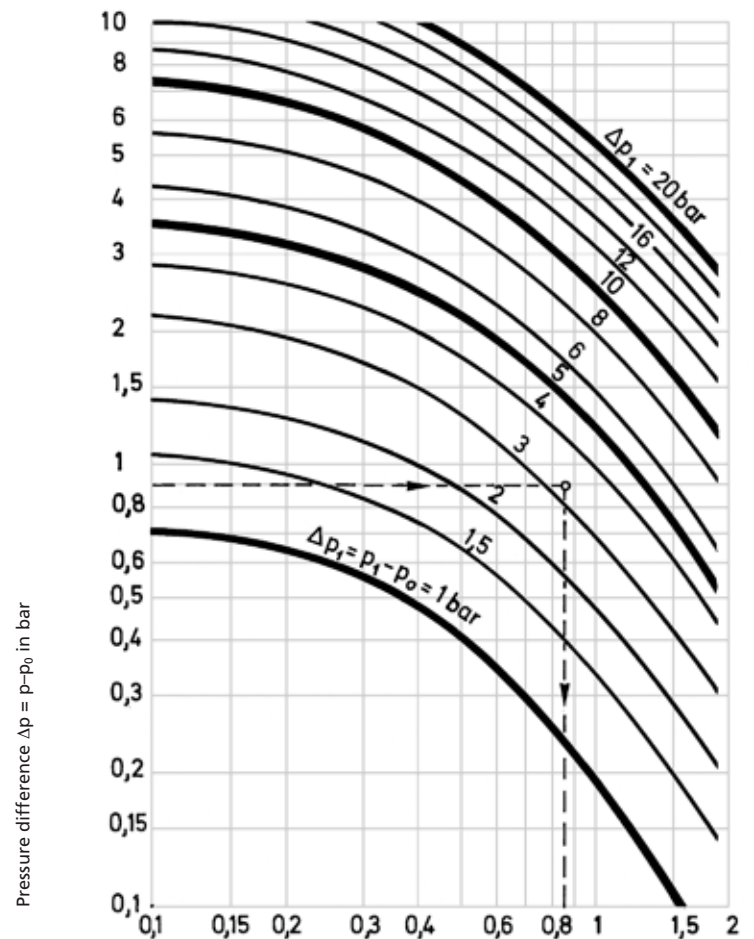
$$\varphi = \frac{\dot{V}_0}{\dot{V}_1} = \text{Suction ratio}$$

(Pressure indications in bar = bar g)



Plastic construction, PVC, type G

FIG. 1



$$\text{Suction ratio } \varphi_{adm.} = \frac{\dot{V}_0}{\dot{V}_1} \text{ in } \frac{\text{m}^3 \text{ Gas}}{\text{m}^3 \text{ Motive liquid}}$$

$$\Delta p_1 = p_1 - p_0 = \text{Effective motive liquid pressure}$$

The determination for the size of jet compressors is the motive liquid connection A (fig. 3):

For a selected pipe pressure loss Δp of approx. 1 bar for a pipe length of 100 m, according to catalog sheet "Pressure drop in water ducts" (7 | abl9), a connection diameter of DN 50 for a liquid velocity of $w = 2.2$ m/s results.

From table fig. 3 you will find
A = DN 50: size 4.

If a compressor in plastic design is selected, according to fig. 4 and fig. 5, size 5, type G will be applicable.

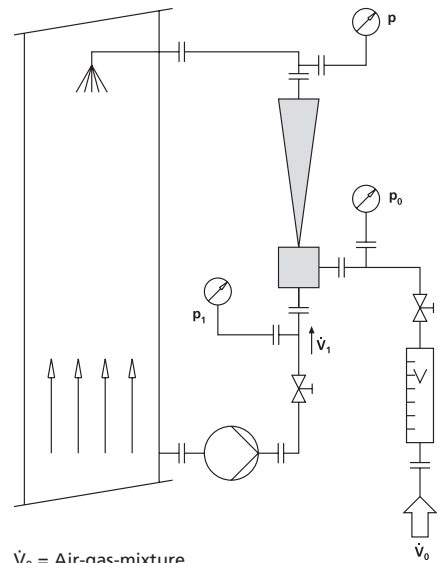
DESIGN CONDITIONS

It is necessary for the many possible operating conditions that each liquid jet gas compressor be specially designed to achieve optimum efficiency.

Gases or steams which undergo a reaction with the motive liquid or which condense are calculated with a reduced flow \dot{V}_{OR} .

The required motive liquid flow is only determined for the reduced suction flow \dot{V}_{OR} .

FIG. 2



\dot{V}_0 = Air-gas-mixture
 \dot{V}_1 = Motive liquid

Schematic view of a plant for the dosing and compression of ozone for drinking water treatment

OTHER DESIGNS



Metal construction, steel



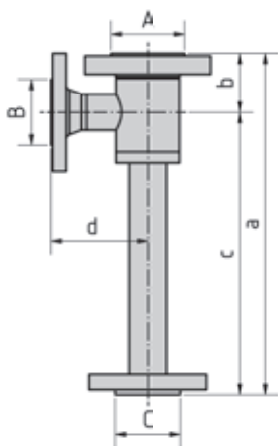
Metal construction, stainless steel



Plastic construction, "75 PVC", type F

FIG. 3

METAL CONSTRUCTION



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---------------------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| Liquid connection | A | 25 | 32 | 40 | 50 | 65 | 65 | 80 | 100 |
| Suction connection | B | 20 | 25 | 32 | 40 | 40 | 50 | 65 | 80 |
| Pressure connection | C | 32 | 40 | 50 | 65 | 65 | 80 | 100 | 125 |
| Dimensions in mm | a | 270 | 350 | 410 | 480 | 480 | 530 | 730 | 950 |
| | b | 60 | 65 | 70 | 80 | 80 | 80 | 115 | 150 |
| | c | 210 | 285 | 340 | 400 | 400 | 450 | 615 | 800 |
| | d | 85 | 100 | 115 | 125 | 125 | 135 | 135 | 165 |
| Weight in kg | | 10 | 13 | 15 | 22 | 22 | 30 | 45 | 98 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, motive nozzle: stainless steel, inlet guide vane: PVC
 - II Housing: steel, inner surfaces lined with PFA, motive/mixing nozzle: PVC, inlet guide vane: PVC
 - III Completely stainless steel
- Flanges according to EN1092-1

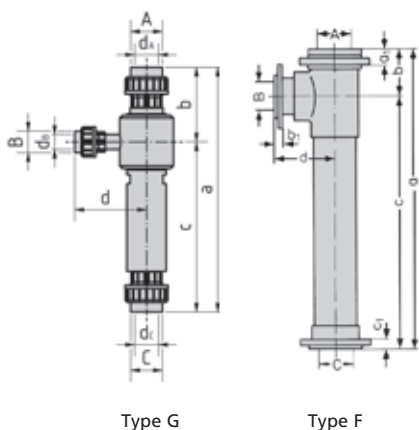
SPECIAL CONSTRUCTIONS: Hastelloy, Titanium, plastics (PP, PVDF, PTFE, PVC/GF-UP) etc.

For inquiries please use our questionnaire.

FIG. 4

FIG. 5

PLASTIC CONSTRUCTION PVC



CONNECTIONS, DIMENSIONS AND WEIGHTS

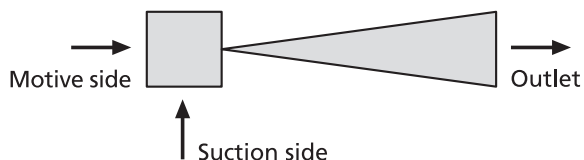
| | Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---------------------|----------------|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| Liquid connection | A | 20 | 25 | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 |
| Dimensions in mm | d _A | 25 | 32 | 40 | 50 | 63 | | | | | |
| | a ₁ | | | | | | 38 | 41 | 43 | 47 | 55 |
| Suction connection | B | 20 | 20 | 20 | 25 | 32 | 50 | 65 | 80 | 100 | 125 |
| Dimensions in mm | d _B | 25 | 25 | 25 | 32 | 40 | | | | | |
| | b ₁ | | | | | | 27 | 30 | 33 | 36 | 41 |
| Pressure connection | C | 20 | 25 | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 |
| Dimensions in mm | d _C | 25 | 32 | 40 | 50 | 63 | | | | | |
| | c ₁ | | | | | | 30 | 33 | 36 | 41 | 46 |
| Dimensions in mm | a | 280 | 320 | 410 | 530 | 610 | 600 | 675 | 825 | 1050 | 1250 |
| | b | 100 | 105 | 125 | 150 | 170 | 100 | 115 | 135 | 165 | 190 |
| | c | 180 | 215 | 285 | 380 | 440 | 500 | 560 | 690 | 885 | 1060 |
| | d | 115 | 115 | 120 | 140 | 160 | 125 | 146 | 175 | 215 | 248 |
| Weight in kg | | 0.6 | 0.8 | 1.2 | 1.9 | 2.9 | 5.5 | 8.5 | 13 | 25 | 35 |
| Type | | G | G | G | G | G | F | F | F | F | F |

TYPE G: with screw connections
 TYPE F: Connections: loose flange made in GF-UP
 Flanges according to EN1092-1

For inquiries please use our questionnaire.

Questionnaire

for liquid jet gas compressors
fgv1



[Link to fillable PDF](#)

1. MOTIVE SIDE

Motive medium
 Motive flow m³/h
 Motive pressure bar abs.

Temperature °C
 Density kg/m³
 Concentration weight %
 Steam pressure bar abs.

2. SUCTION SIDE

Suction medium
 Suction flow m³/h
 Suction pressure bar abs.

Temperature °C
 Density kg/m³
 Concentration weight %

3. OUTLET

Required discharge pressure bar abs.
 Mixed flow kg/h

Concentration weight %

4. FURTHER DATA

MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges
 Thread
 Others

FLANGES ACCORDING TO:

EN1092-1
 ASME lbs
 Others

DESIGN CODE (if required):

AD-2000
 ASME
 Others

APPLICATION:

.....

DESIGN:

Temperature °C Pressure bar g

FURTHER NOTES:

.....

Additional details, if required,
are to be stated separately.

Your inquiry no.

Offer submitted until

Requested date of delivery

YOUR ADDRESS

Company
 attn.
 Street/P.O. Box
 ZIP code/City
 Country

Telephone
 Telefax
 E-mail

Liquid jet liquid pumps

General information

CONSTRUCTION AND MODE OF OPERATION

Liquid jet liquid pumps are jet pumps which suck in a liquid \dot{M}_0 by means of a motive liquid jet \dot{M}_1 , mix the motive and suction flows and convey the mixed flow \dot{M} (fig. 1). As with all jet pumps the motive liquid has the highest pressure p_1 , the suction flow the lowest pressure p_0 , and the pressure of the mixed flow p lies between the motive pressure and suction pressure $p_1 > p > p_0$ (see also "General information on jet pumps", 7|abl1).

In order to convey the mixture, the total conveying pressure Δp must be overcome. This is determined by the geodetic height, pipeline resistance and the resistance of installed parts, such as shut-off valves or control valves etc. (see "Pressure loss in water pipelines", 7|abl9).

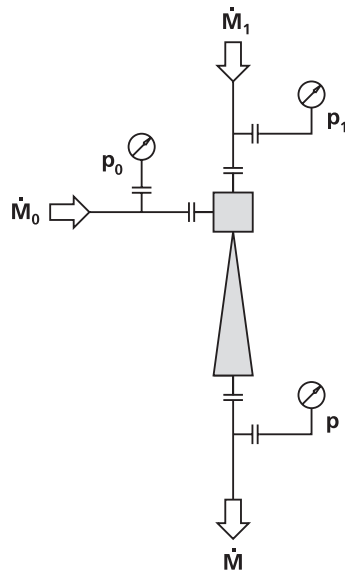
APPLICATIONS

Liquid jet liquid pumps are used for conveying and mixing liquids such as water, acids or lyes in water and waste water treatment plants.

An important range of application is for the dilution of acids or lyes to a definite final concentration such as is required in water treatment plants.

The ion exchangers at times have to be regenerated with acid (cation exchanger) or caustic (anion exchanger).

FIG. 1



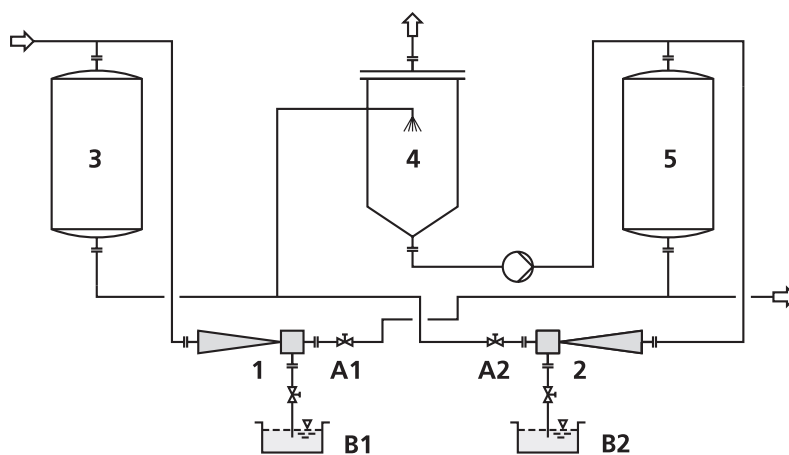
Stainless steel



PVC, construction KT, glued, form M

The liquid jet liquid pumps suck in the concentrated acid or lye and convey it into the exchangers at the respectively required mixing ratio.

FIG. 2



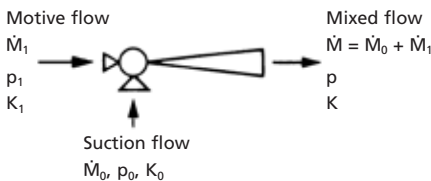
Schematic view of a demineralization plant

| | | | |
|------|--------------------------|----|-------|
| 1, 2 | Jet pumps | A1 | Water |
| 3 | Anion exchanger | A2 | Water |
| 4 | CO ₂ stripper | B1 | HCl |
| 5 | Cation exchanger | B2 | NaOH |



PVC, construction K, screwed, form M

PERFORMANCE CHART



$$\mu = \frac{\dot{M}_1}{\dot{M}_0} = \frac{K_0 - K}{K - K_1} = \frac{\text{kg Motive liquid}}{\text{kg Suction liquid}}$$

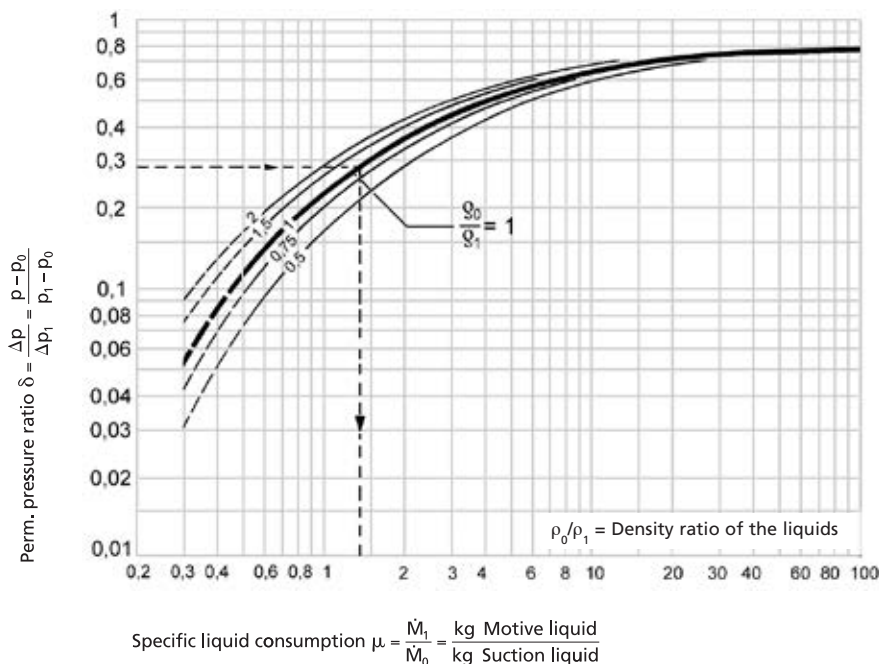
= Specific liquid consumption
= Constant mixing ratio

p_1 = Motive liquid pressure in bar g
 p_0 = Suction liquid pressure in bar g suction (-), inlet (+)
 p = Discharge pressure in bar
 Δp = $p - p_0$ = Total delivery pressure in bar g
 Δp_1 = $p_1 - p_0$ = Effective motive liquid pressure in bar g

$$\delta = \frac{\Delta p}{\Delta p_1} = \text{Permissible pressure ratio}$$

K = Concentration by weight-%
 (Pressure indications in bar = bar g)

FIG. 3



The size of a liquid jet liquid pump is principally determined by the mixed flow \dot{M} in kg/h. This can be found by the calculation as follows:

$$\dot{M} = \dot{M}_0 + \mu \cdot \dot{M}_0 = \dot{M}_0(1 + \mu)$$

| | |
|-------------|--|
| \dot{M} | Mixed flow in kg/h |
| \dot{M}_1 | Suction flow in kg/h |
| μ | Spec. liquid consumption in kg motive liquid / kg suction liquid |

The motive liquid consumption is calculated as follows:

$$\dot{M}_1 = \mu \cdot \dot{M}_0 \text{ in kg / h}$$

Fig. 3 shows the relation between the pressure ratio δ , the specific liquid consumption μ and the density ratio ρ_0/ρ_1 .

The specific liquid consumption μ in kg motive liquid/kg suction liquid is **greater** the higher the pressure ratio δ and the smaller the density ratio ρ_0/ρ_1 ;

and is **smaller** the higher the effective motive liquid pressure, that means the higher the difference between motive pressure and suction pressure $p_1 - p_0$ and the greater the density ratio ρ_0/ρ_1 .

EXAMPLE

GIVEN:

Suction flow $\dot{M}_0 = 1000$ kg/h effluent
 Suction liquid over pressure
 $p_0 = -0.2$ bar = 2 m WC suction height
 Motive liquid overpressure $p_1 = 4$ bar
 Discharge pressure $p = 1$ bar g

PARAMETERS TO BE FOUND: Required motive liquid flow \dot{M}_1 and pump size

SOLUTION:

$$\delta = \frac{\Delta p}{\Delta p_1} = \frac{p - p_0}{p_1 - p_0} = \frac{1 - (-0.2)}{4 - (-0.2)} = 0.286$$

Fig. 3 gives for a density ratio $\rho_0/\rho_1 = 1.0$ a specific liquid consumption $\mu = 1.37$.

With $\mu = \frac{\dot{M}_1}{\dot{M}_0}$ the following results:

$$\dot{M}_1 = \mu \cdot \dot{M}_0 = 1.37 \cdot 1000 = 1370 \frac{\text{kg}}{\text{h}}$$

DETERMINING THE PUMP SIZE:

$$\text{With } \dot{M} = \dot{M}_1 + \dot{M}_0 = 1370 + 1000 = 2730 \frac{\text{kg}}{\text{h}}$$

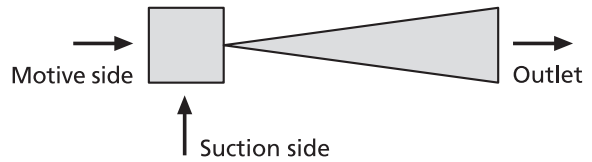
fig. 4 gives pump size 5 (max. mixed flow 3500 kg/h)

CONSTRUCTION

Depending on the application, 3 types of liquid jet liquid pumps are available.

Questionnaire

for liquid jet liquid pumps
wp1, wp2, wp3



[Link to fillable PDF](#)

1. MOTIVE SIDE

| | | |
|-----------------------|----------------------|-------------------|
| Motive medium | Temperature | °C |
| Motive flow | Density | kg/m ³ |
| Motive pressure | Concentration | weight % |
| | Steam pressure | bar abs. |

2. SUCTION SIDE

| | | |
|------------------------|----------------------|-------------------|
| Suction medium | Density | kg/m ³ |
| Suction flow | Concentration | weight % |
| Suction pressure | Dyn. viscosity | mPas |
| Temperature | | °C |

3. OUTLET

| | | | |
|-----------------------------------|----------|---------------------|----------|
| Required discharge pressure | bar abs. | Concentration | weight % |
| Mixed flow | kg/h | | |

4. FURTHER DATA

MATERIAL OF CONSTRUCTION

| | | | |
|-----------------------------------|--------------------------|------------------------------|--------------------------|
| CONNECTIONS: | | FLANGES ACCORDING TO: | |
| Flanges | <input type="checkbox"/> | EN1092-1 | <input type="checkbox"/> |
| Thread | <input type="checkbox"/> | ASME lbs | <input type="checkbox"/> |
| Others | <input type="checkbox"/> | Others | <input type="checkbox"/> |
| DESIGN CODE (if required): | | APPLICATION: | |
| AD-2000 | <input type="checkbox"/> | | |
| ASME | <input type="checkbox"/> | | |
| Others | <input type="checkbox"/> | | |
| DESIGN: | | | |
| Temperature | °C | Pressure | bar g |
| FURTHER NOTES: | | | |
| | | | |

Additional details, if required,
are to be stated separately.

Your inquiry no.

Offer submitted until

Requested date of delivery

YOUR ADDRESS

| | |
|-----------------------|-----------------|
| Company | Telephone |
| attn. | Telefax |
| Street/P.O. Box | E-mail |
| ZIP code/City | |
| Country | |

Liquid jet liquid pumps

of steel or stainless steel

DESIGN

The internal dimensions of these pumps are specially calculated and fabricated to correspond to the particular operating conditions. They are to be considered as individually purpose designed units to standard installation dimensions.

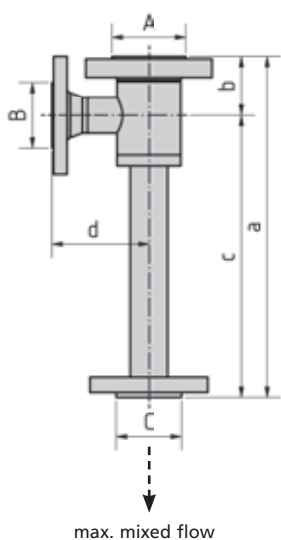


Stainless steel



Steel

FIG. 4



MAX. MIXED FLOW, CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 3 | 5 | 7 | 9 | 11 | 12 | 13 | 14 | 15 |
|-------------------------|------|-------|-------|-------|--------|--------|--------|--------|--------|---------|
| Max. mixed flow in kg/h | | 1,200 | 3,500 | 6,000 | 12,000 | 24,000 | 32,000 | 40,000 | 70,000 | 100,000 |
| Nominal diameter | A | 20 | 25 | 32 | 40 | 50 | 65 | 65 | 80 | 100 |
| | B | 20 | 20 | 25 | 32 | 40 | 40 | 50 | 65 | 80 |
| | C | 20 | 32 | 40 | 50 | 65 | 65 | 80 | 100 | 125 |
| Dimensions in mm | a | 153 | 270 | 350 | 410 | 480 | 480 | 530 | 730 | 950 |
| | b | 42 | 60 | 65 | 70 | 80 | 80 | 80 | 115 | 150 |
| | c | 111 | 210 | 285 | 340 | 400 | 400 | 450 | 615 | 800 |
| | d | 80 | 85 | 100 | 115 | 125 | 125 | 135 | 135 | 165 |
| Weight in kg | | 5 | 10 | 13 | 15 | 22 | 22 | 30 | 45 | 98 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, motive nozzle: stainless steel
 - II Housing: steel, inner surfaces lined with PFA, motive/mixing nozzle: PVC
 - III Completely stainless steel
- Flanges according to EN1092-1

SPECIAL CONSTRUCTIONS of PTFE, PVDF, Titanium, Hastelloy etc. on demand.

For inquiries please use our questionnaire.

Standard liquid jet liquid pumps

of PVC/PP

DESIGN AND PERFORMANCE CHART

EXAMPLE

$\dot{M}_0 = 100$ kg/h hydrochloric acid with $K_0 = 30\%$ is to be diluted with the motive liquid water with a concentration of $K_1 = 0$, to $K = 4\%$.

Motive liquid pressure $p_1 = 2.5$ bar g
 Suction liquid pressure $p_0 = 0$ bar g
 Discharge pressure $p = 0.8$ bar g

SOLUTION: In the performance chart fig. 5 the horizontal from $\dot{M}_0 = 100$ kg/h intersects the dilution curve $30\% \rightarrow 4\%$ giving on the abscissa $\dot{M}_1 = 650$ kg/h motive liquid flow. The intersection of the vertical $\dot{M}_1 = 650$ kg/h

with the "Type" curve 23-3 gives on the ordinate in the lower part of the chart an effective motive pressure of $\Delta p_1 = p_1 - p_0 = 2.2$ bar. By multiplying this value with the δ found on the dilution curve one can obtain the admissible total delivery pressure $\Delta p = \Delta p_1 \cdot \delta = 2.2 \cdot 0.55 = 1.21$ bar. Thereby the achievable discharge pressure is $p = 1.21 + p_0 = 1.21$ bar and the actually required motive liquid pressure is $p_1 = \Delta p_1 + p_0 = 2.2$ bar. A liquid jet liquid pump size KT2 or K2, type 23-3 is required.



PVC, construction KT, glued, form M

FIG. 5

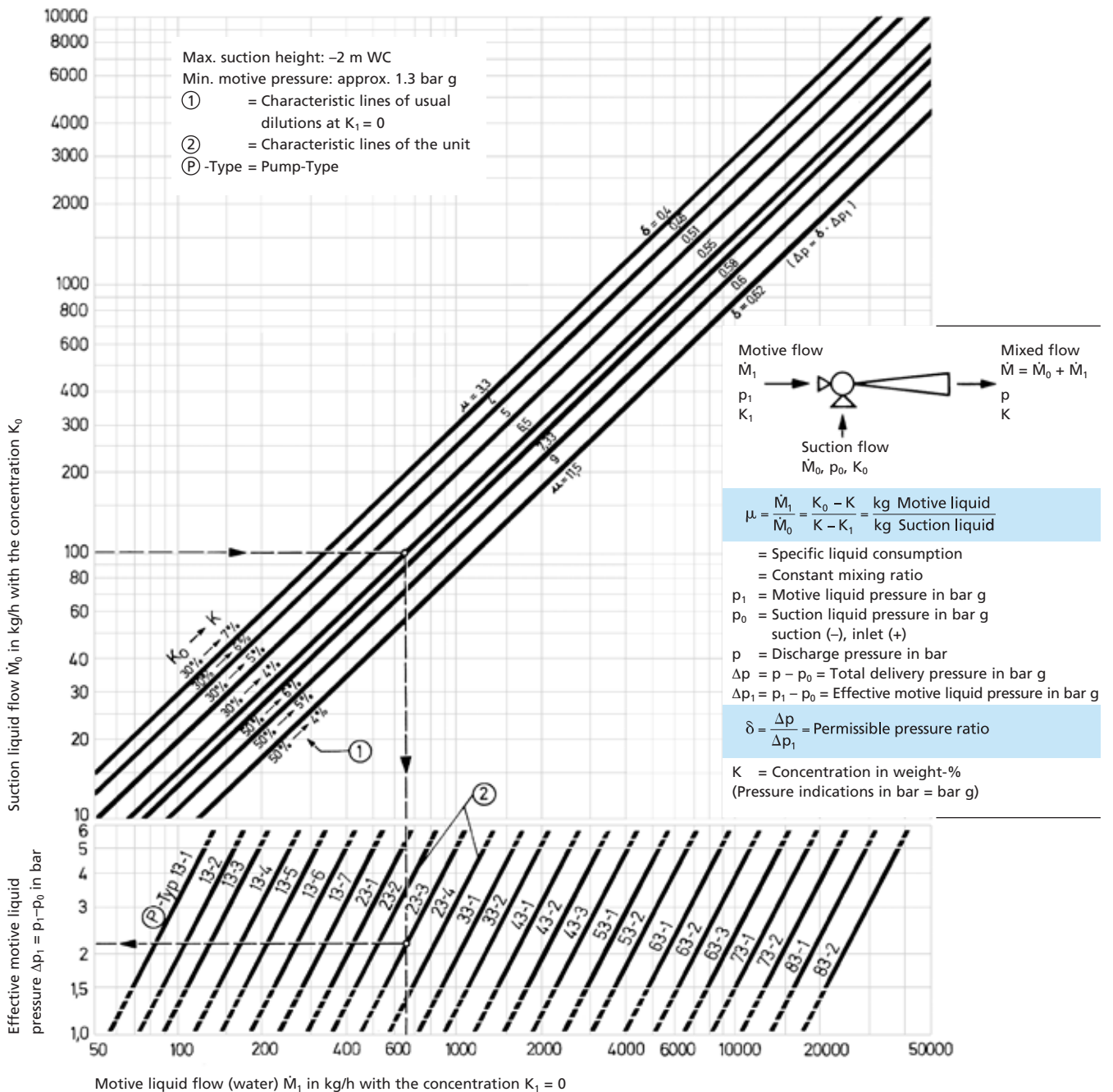


FIG. 6

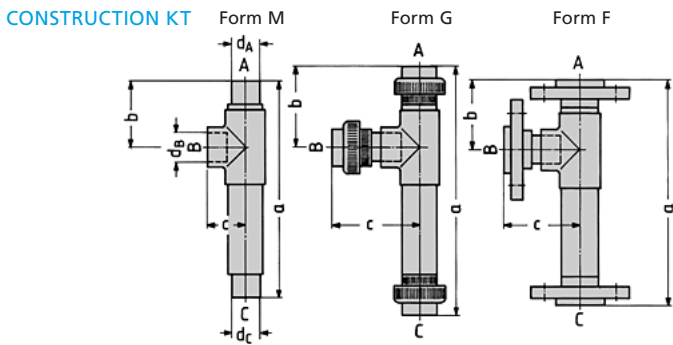
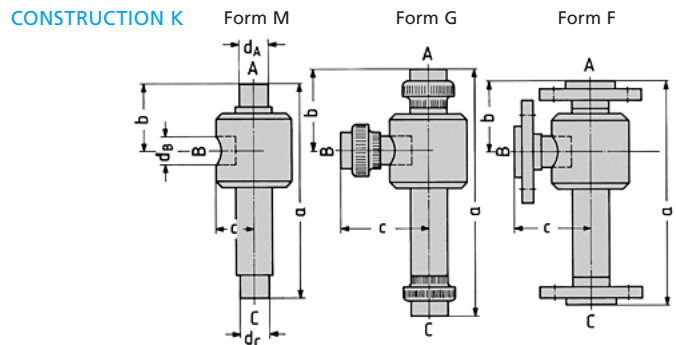


FIG. 7



MAX. MIXED FLOW, CONNECTIONS, DIMENSIONS AND WEIGHTS

Plastic construction KT, glued (PVC), welded (PP)

| Size | | KT 1 | KT 2 | KT 3 | KT 4 | KT 5 | KT 6 | KT 7 | KT 8 |
|---|----------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Type | | 13-1 ... 13-7 | 23-1 ... 23-4 | 33-1 ... 33-2 | 43-1 ... 43-3 | 53-1 ... 53-2 | 63-1 ... 63-3 | 73-1 ... 73-2 | 83-1 ... 83-2 |
| Nominal diameter | A | 15 | 20 | 25 | 32 | 40 | 50 | 65 | 80 |
| | B | 15 | 20 | 25 | 32 | 40 | 50 | 65 | 80 |
| | C | 15 | 20 | 25 | 32 | 40 | 50 | 65 | 80 |
| Dimensions in mm | d _A | 20 | 25 | 32 | 40 | 50 | 63 | 75 | 90 |
| | d _B | 20 | 25 | 32 | 40 | 50 | 63 | 75 | 90 |
| | d _C | 20 | 25 | 32 | 40 | 50 | 63 | 75 | 90 |
| Dimensions in mm | a | 150 | 190 | 220 | 280 | 385 | 480 | 570 | 650 |
| () Dimensions for PP construction only | b | 45 | 55 | 65 | 80 | 100 | 115 | 135 | 160 |
| | c | 27 | 33 | 39 | 49 | 60 | 72 | 84 | 99 |
| | (c) | (28) | (32) | (38) | (44) | (51) | (62) | (75.5) | (88) |
| Dimensions in mm | a | 208 | 254 | 290 | 362 | 481 | 598 | 680 | 782 |
| () Dimensions for PP construction only | (a) | (212) | (256) | (290) | (358) | (473) | (584) | - | - |
| | b | 74 | 87 | 100 | 121 | 148 | 174 | 190 | 226 |
| | (b) | (76) | (88) | (100) | (119) | (144) | (167) | - | - |
| | c | 100 | 115 | 130 | 150 | 180 | 210 | 215 | 245 |
| Dimensions in mm | a | 156 | 196 | 226 | 286 | 391 | 486 | 576 | 660 |
| () Dimensions for PP construction only | (a) | (160) | (200) | (230) | (290) | (395) | (490) | (580) | (664) |
| | b | 48 | 58 | 68 | 83 | 103 | 118 | 138 | 165 |
| | (b) | (50) | (60) | (70) | (85) | (105) | (120) | (140) | (167) |
| | c | 90 | 100 | 100 | 115 | 125 | 145 | 165 | 185 |
| Max. mixed flow in kg/h | | 500 | 1,200 | 2,000 | 3,500 | 6,000 | 12,000 | 25,000 | 50,000 |

MAX. MIXED FLOW, CONNECTIONS, DIMENSIONS AND WEIGHTS

Plastic construction K, screwed

| Size | | K 1 | K 2 | K 3 | K 4 | K 5 | K 6 | K 7 | K 8 |
|---|----------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Type | | 13-1 ... 13-7 | 23-1 ... 23-4 | 33-1 ... 33-2 | 43-1 ... 43-3 | 53-1 ... 53-2 | 63-1 ... 63-3 | 73-1 ... 73-2 | 83-1 ... 83-2 |
| Nominal diameter | A | 15 | 20 | 25 | 32 | 40 | 50 | 65 | 80 |
| | B | 10 | 20 | 20 | 20 | 25 | 32 | 40 | 65 |
| | C | 15 | 20 | 25 | 32 | 40 | 50 | 65 | 100 |
| Dimensions in mm | d _A | 20 | 25 | 32 | 40 | 50 | 63 | 75 | 90 |
| | d _B | 16 | 25 | 25 | 25 | 32 | 40 | 50 | 75 |
| | d _C | 20 | 25 | 32 | 40 | 50 | 63 | 75 | 110 |
| Dimensions in mm | a | 155 | 190 | 200 | 260 | 385 | 460 | 520 | 800 |
| | b | 65 | 70 | 70 | 85 | 100 | 110 | 145 | 210 |
| | c | 30 | 40 | 40 | 45 | 60 | 60 | 80 | 97.5 |
| Dimensions in mm | a | 213 | 254 | 270 | 342 | 481 | 578 | 650 | 951 |
| () Dimensions for PP construction only | (a) | (217) | (256) | (270) | (338) | (473) | (564) | - | - |
| | b | 94 | 102 | 105 | 126 | 148 | 169 | 210 | 284 |
| | (b) | (96) | (103) | (105) | (124) | (144) | (162) | - | - |
| | c | 100 | 115 | 115 | 120 | 140 | 160 | 180 | 200 |
| Dimensions in mm | a | 161 | 196 | 206 | 266 | 391 | 466 | 526 | 810 |
| () Dimensions for PP construction only | (a) | (165) | (200) | (210) | (270) | (395) | (470) | (530) | (814) |
| | b | 68 | 73 | 73 | 88 | 103 | 113 | 148 | 215 |
| | (b) | (70) | (75) | (75) | (90) | (105) | (115) | (150) | (217) |
| | c | 90 | 100 | 100 | 100 | 120 | 140 | 160 | 180 |
| Max. mixed flow in kg/h | | 500 | 1,200 | 2,000 | 3,500 | 6,000 | 12,000 | 25,000 | 50,000 |

STANDARD

Size, type, form and material must be given in all orders for standard liquid pumps, e.g. size KT1, type 13-3, form G, PP. Standard liquid jet liquid pumps of PVC/PP are available in the 6 above-mentioned constructions.

SEMI STANDARD

The inside dimensions of such pumps will be specially designed and fabricated according to the given operation conditions. These pumps are therefore tailor-made constructions with standard structural dimensions.

SPECIAL CONSTRUCTIONS

Liquid pumps for dilutions, applications and materials other than shown in diagram fig. 5 are special constructions. Design, dimensions and connection dimensions on demand.

All connections for form M and G are provided as glued or welded connections.

For inquiries please use our questionnaire.

Standard liquid jet liquid pumps

of PTFE

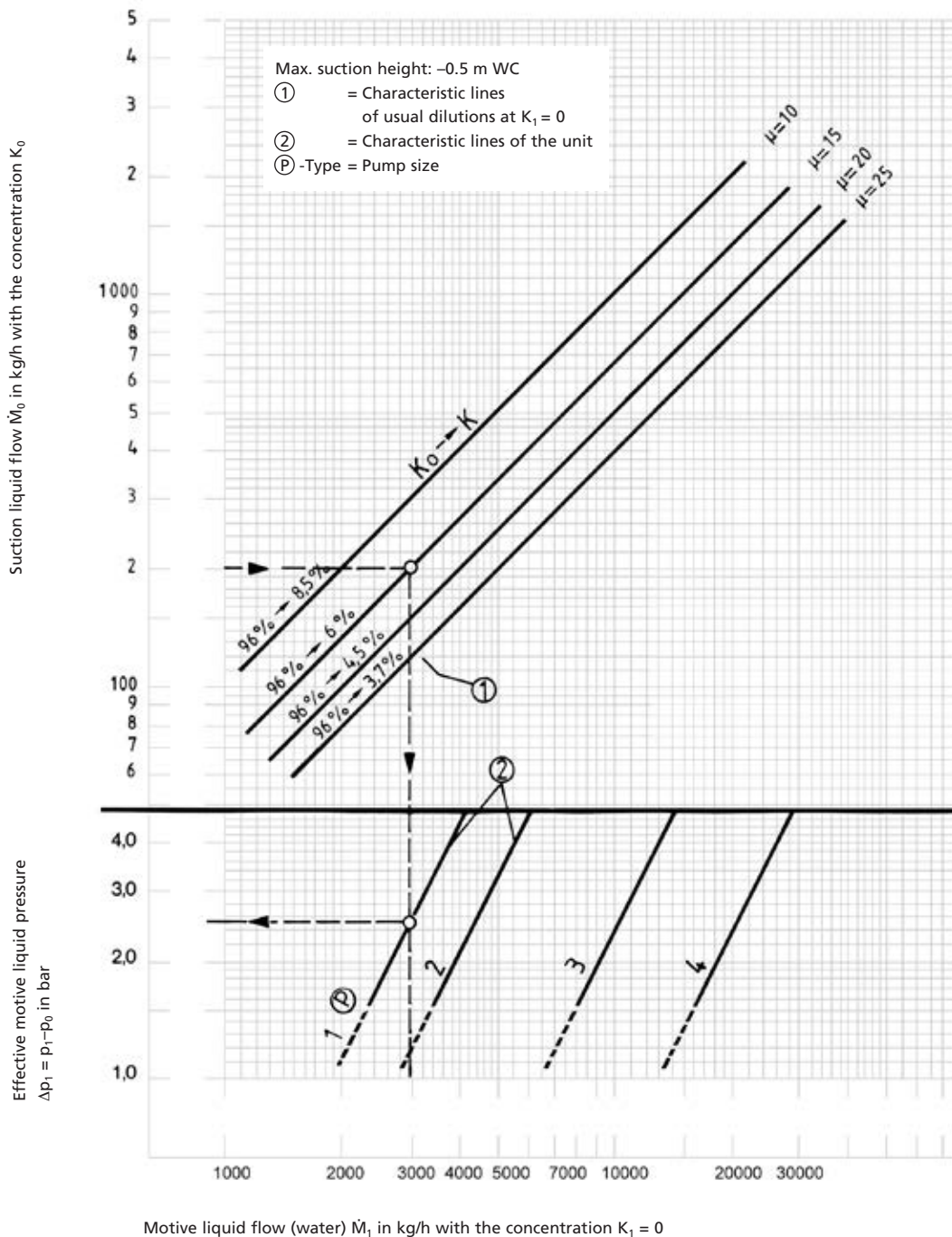
DESIGN AND PERFORMANCE CHART

The jet pumps are completely manufactured of PTFE. The pumps are, therefore, resistant to chemical attack. They are reliable and maintenance-free; the capital cost is low.

Performance chart for a suction head of max. -0.5 m liquid column



FIG. 8



EXAMPLE

GIVEN: $\dot{M}_0 = 200$ kg/h sulphuric acid with $K_0 = 96\%$ is to be diluted with motive liquid water, concentration $K_1 = 0$, to $K = 6\%$.

Motive liquid overpressure $p_1 = 3.0$ bar
 Suction liquid overpressure $p_0 = 0$ bar
 Discharge pressure $p = 0.8$ bar

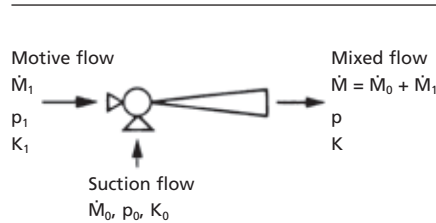
SOLUTION: (see performance chart **fig. 8**)

The horizontal from $\dot{M}_0 = 200$ kg/h intersects the $96\% \rightarrow 6\%$ dilution curve giving on the abscissa $\dot{M}_1 = 3000$ kg/h motive liquid flow.

The intersection of the vertical from $\dot{M}_1 = 3000$ kg/h with the size-line on the ordinate in the lower part of the diagram gives the effective, required motive liquid pressure of $\Delta p_1 = 2.5$ bar < 3.0 bar.

According to the performance chart, **fig. 8**, the max. permissible discharge pressure amounts to 50% of the motive pressure:
 $0.5 \cdot 2.5 = 1.25$ bar > 0.8 bar.

A liquid jet liquid pump size 1 is required.



$$\mu = \frac{\dot{M}_1}{\dot{M}_0} = \frac{K_0 - K}{K - K_1} = \frac{\text{kg Motive liquid}}{\text{kg Suction liquid}}$$

= Specific liquid consumption
 = Constant mixing ratio

p_1 = Motive liquid pressure in bar g

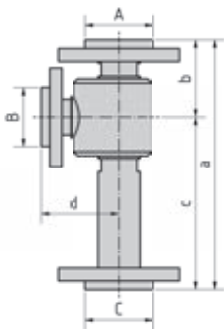
p_0 = Suction liquid pressure in bar g
 suction (-), inlet (+)

p = Discharge pressure in bar = max. $0.5 \cdot p_1$

K = Concentration by weight-%

(Pressure indications in bar = bar g)

FIG. 9



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 |
|--------------------------|------|-----|-----|-----|-----|
| Service water connection | A | 32 | 32 | 40 | 50 |
| Suction connection | B | 25 | 25 | 25 | 32 |
| Pressure connection | C | 32 | 32 | 50 | 65 |
| Dimension in mm | a | 290 | 290 | 390 | 500 |
| | b | 90 | 90 | 95 | 105 |
| | c | 200 | 200 | 295 | 395 |
| | d | 90 | 90 | 100 | 110 |
| Weight in kg | | 3 | 3 | 5 | 7 |

STANDARD CONSTRUCTION:

PTFE, loose flange made in GF-UP

Connections according to EN1092-1

For inquiries please use our questionnaire.

Liquid jet solids pumps

CONSTRUCTION AND MODE OF OPERATION

Liquid jet solids pumps are jet pumps which, with the help of a motive liquid, can convey flowable granulate material (please see also "General information on jet pumps", 7 | abl 1). The material to be conveyed flows through a hopper into the jet pump.

The motive liquid, in most cases water, emerges from the motive nozzle at a high velocity into the mixing chamber of the pump, entraining the material present in the mixing chamber. Depending upon the type of material to be conveyed, rinse water must be sprayed into the hopper in order to maintain a constant flow. The mixture of liquid and material can be conveyed directly to the point of application, by pipe or hose. Liquid jet solids pumps can also be supplied as complete units with hopper and rinse water connection. Stationary units as well as mobile units are available.

APPLICATIONS

Liquid jet solids pumps are used to convey sand, gravel, salt, activated carbon, ion exchange resin, and other types of solids; to fill and empty reactors with reactor mass or marble gravel in decarbonizing and deacidifying plants of water and effluent treatment plants; to add precipitating agents in dirty water and effluent water treatment.

Fig. 1 shows the installation of a liquid jet solids pump for filling and emptying reactors with reactor mass in a drinking water decarbonizing plant.

MOTIVE LIQUID CONSUMPTION

IN NORMAL OPERATION one needs 3 to 5 times the volume of the material to be conveyed for the motive liquid. The motive liquid pressure should be 2.5 to 3 times that of the delivery head.

The standard constructions, according to fig. 2 to 4, are designed with a water flow to material ratio of 4 : 1. The achievable discharge pressure is approx. 1–1.2 bar.

The conveyance of granular material with a smooth surface (almost spherical) and small in size (max. approx. 1–1.5 mm) can be considered a normal duty, provided the material does not have a tendency to "bridge". In these cases it is possible to operate with a relatively small quantity of rinse water, up to about 20% of the material to be conveyed.

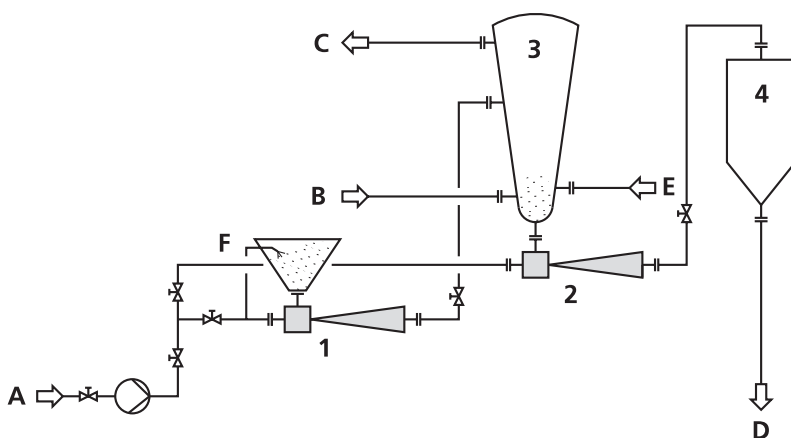
IN MORE DIFFICULT CASES, such as the conveyance of coarser materials with a rougher surface and with a relatively high specific gravity, which incline to form bridges and to bond, for instance sand or ashes, and sticky slurries, it is necessary to reckon with a motive water flow 5 to 10 times larger than the quantity of material conveyed. This includes the rinse water, which amounts to 1 to 3 times the quantity of material conveyed. With these materials the rinse water must produce a suitably flowable mixture of solid material and water; this is all the more necessary the higher the delivery head and the greater the horizontal distance to the receiving vessel.



MAX. PARTICLE SIZE OF THE FLOW RATE:

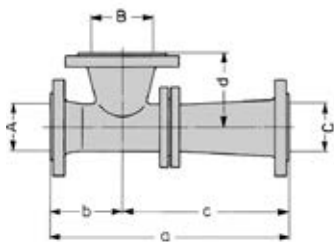
| Size | Ø |
|------|-------|
| 1 | 4 mm |
| 2 | 5 mm |
| 3 | 9 mm |
| 4 | 12 mm |

FIG. 1



- 1 Stationary liquid jet solids pump with hopper for reactor mass
- 2 Liquid jet solids pump for the batch extraction of the reactor mass load
- 3 Reactor
- 4 Silo
- A Motive water
- B Milk of lime
- C Decarbonized water
- D Discharge
- E Raw water
- F Rinse water

FIG. 2
STANDARD LIQUID JET SOLIDS PUMPS



STANDARD CONSTRUCTIONS:

I Housing: cast iron EN-GJL-200 (GG20),
motive and mixing nozzles: stainless steel
(replaceable)

II Housing: completely stainless steel
Flanges according to DIN PN 10

SPECIAL CONSTRUCTIONS on request

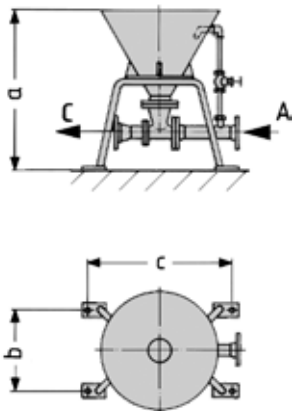
FLOW RATE, CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 |
|---|------|-----|------|------|------|
| Flow rate marble/gravel in kg/h | | 500 | 1000 | 2500 | 5000 |
| Motive water flow at 3 bar g in m ³ /h | | 2.4 | 4.8 | 12.0 | 24.0 |
| Nominal diameter | A | 25 | 32 | 50 | 80 |
| | B | 40 | 65 | 80 | 100 |
| | C | 25 | 32 | 50 | 80 |
| Dimensions in mm | a | 210 | 265 | 355 | 580 |
| | b | 50 | 65 | 80 | 90 |
| | c | 160 | 200 | 275 | 490 |
| | d | 90 | 100 | 125 | 140 |
| Weight in kg | | 8 | 11 | 15 | 30 |

Please give size, type and material with inquiry or order.
For inquiries please use our questionnaire.

FIG. 3
STATIONARY LIQUID JET SOLIDS PUMPS

inclusive standard liquid jet solids pump



FLOW RATE, CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 |
|---|------|------|------|------|------|
| Flow rate marble/gravel in kg/h | | 500 | 1000 | 2500 | 5000 |
| Rinse water in kg/h | | 100 | 200 | 500 | 1000 |
| Motive water flow at 3 bar g in m ³ /h | | 2.4 | 4.8 | 12.0 | 24.0 |
| Nominal diameter | A | 25 | 32 | 50 | 80 |
| | C | 25 | 32 | 50 | 80 |
| Storz coupling | | D | C | C | B |
| Dimensions in mm | a | 1045 | 1045 | 1035 | 1035 |
| | b | 600 | 600 | 600 | 600 |
| | c | 800 | 800 | 800 | 800 |
| Weight in kg | | 50 | 55 | 60 | 80 |
| Hopper volume in l | | 62 | 62 | 64 | 72 |

STANDARD CONSTRUCTION:

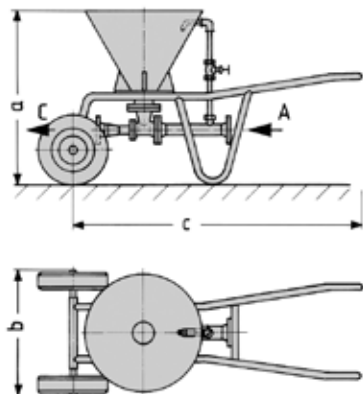
Hopper and frame: steel
Connecting pipes: steel/VA
Flanges according to EN1092-1/storz coupling

SPECIAL CONSTRUCTIONS on request

For inquiries please use our questionnaire.

FIG. 4
MOBILE LIQUID JET SOLIDS PUMPS

inclusive standard liquid jet solids pump



FLOW RATE, CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 |
|---|------|------|------|------|------|
| Flow rate marble/gravel in kg/h | | 500 | 1000 | 2500 | 5000 |
| Rinse water in kg/h | | 100 | 200 | 500 | 1000 |
| Motive water flow at 3 bar g in m ³ /h | | 2.4 | 4.8 | 12.0 | 24.0 |
| Nominal diameter | A | 25 | 32 | 50 | 80 |
| | C | 25 | 32 | 50 | 80 |
| Storz coupling | | D | C | C | B |
| Dimensions in mm | a | 990 | 990 | 990 | 990 |
| | b | 720 | 720 | 720 | 720 |
| | c | 1550 | 1550 | 1550 | 1550 |
| Weight in kg | | 60 | 65 | 70 | 90 |
| Hopper volume in l | | 62 | 62 | 64 | 72 |

STANDARD CONSTRUCTION:

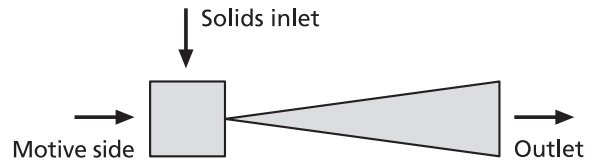
Hopper and frame: steel
Connecting pipes: steel/VA
Flanges according to EN1092-1/storz coupling

SPECIAL CONSTRUCTIONS on request

For inquiries please use our questionnaire.

Questionnaire

for liquid jet solids pumps
wfp1



[Link to fillable PDF](#)

1. MOTIVE SIDE

| | | | |
|-----------------------|-------------------|----------------------|-------------------|
| Motive medium | Temperature | °C | |
| Motive flow | m ³ /h | Density | kg/m ³ |
| Motive pressure | bar abs. | Steam pressure | bar abs. |

2. SOLIDS INLET

| | | |
|-----------------------|---------------------|-------------------|
| Solids medium | Solids feed | kg/h |
| (feed / free-flowing) | Bulk density | kg/m ³ |
| | Particle size | mm |

3. OUTLET Required discharge pressure bar abs.

4. FURTHER DATA MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges

Thread

Others

FLANGES ACCORDING TO:

EN1092-1

ASME lbs

Others

FURTHER NOTES:

.....

.....

DESIGN:

Jet pump only

Stationary

Mobile

Additional details, if required,
are to be stated separately.

Your inquiry no.

Offer submitted until

Requested date of delivery

YOUR ADDRESS

| | |
|-----------------------|-----------------|
| Company | Telephone |
| attn. | Telefax |
| Street/P.O. Box | E-mail |
| ZIP code/City | |
| Country | |

Liquid jet mixers

APPLICATIONS

Liquid jet mixers are jet pumps to **mix and circulate** liquids.

The range of applications for liquid jet mixers is only limited by the viscosity of the liquid to be mixed. As a rule, jet mixers can be used in all cases where the liquid to be mixed can still be supplied by a centrifugal pump.

Liquid jet mixers are mainly used in vessels, storage tanks and neutralization basins.

CONSTRUCTION AND MODE OF OPERATION

The liquid jet coming out of the motive nozzle generates a partial vacuum in the inlet cone of the diffuser, and therefore, a liquid flow is extracted from the tank and is entrained. The motive jet mixes with the entrained liquid and accelerates its flow. The liquid mixture emerging from the jet mixer spreads out in conical form and entrains more liquid from its surroundings (see also "General information on jet pumps", 7|abl1).

If one or several such jet mixers are correctly arranged, a three-dimensional flow is produced in the tank which mixes all of the contents homogeneously.

Jet mixers are simple and reliable, having no moving parts. Jet mixers are hardly subject to any wear.

ARRANGEMENT AND INSTALLATION

Jet mixers should be installed at the deepest possible point so that a good operation and an effective mixing is obtained even with a low liquid level.

A level of 1–2 m above the jet mixer is sufficient to avoid foaming. Fig. 1 shows an installation example in a tank. Fig. 2 shows a possible arrangement in a neutralization basin.

For the evaluation of the number of mixers, following criteria are decisive:

- geometry and size of the tank or basin
- liquid to be mixed
- mixing time
- maximal and minimal liquid level

MIXING TIME

The mixing time amongst others, depends on the liquid contents of the tank and of the total delivered flow to the jet mixers.

It amounts to:

$$t \approx 0.3 \cdot \frac{I_E}{\Sigma \dot{V}}$$

| | |
|------------------|---|
| t | Mixing time in h |
| I_E | Actual tank volume in m^3 |
| $\Sigma \dot{V}$ | Total delivered flow of the jet mixers in m^3/h |

The calculation applies to pure water. The values have to be corrected for other liquids.



Cast iron, with threaded connections



Plastic, with flanged connections



Stainless steel, with welding end

FIG. 1

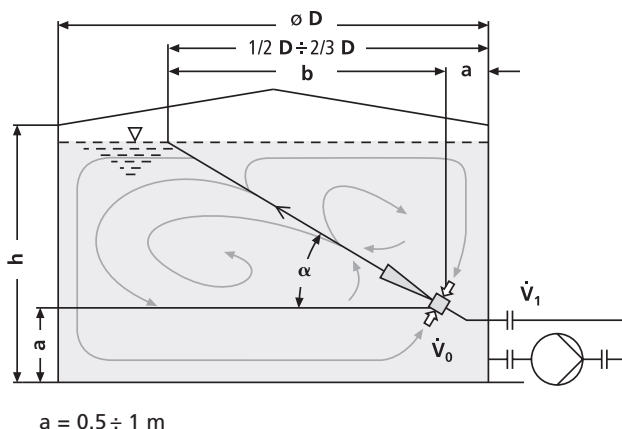
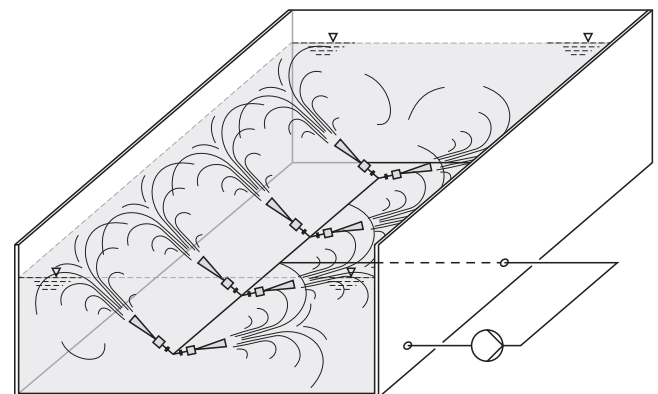


FIG. 2



SELECTION OF THE CIRCULATION PUMP

The selection of the required circulation pump is determined by the effective motive liquid pressure Δp_1 and by the motive liquid flow \dot{V}_1 .

In determining the required motive liquid pressure Δp_1 you must consider the two possible flow arrangements for the circulation pump:

1. The circulation pump **sucks** in the circulation liquid **from the tank** (fig. 3). The static liquid pressure H_{stat} in this case has no influence on the delivery head H as the inlet height at the suction connection is so arranged that $\Delta p_1 = H$.

2. The circulation pump **sucks in external liquid** and must deliver it against the static liquid pressure in the tank (fig. 4). In this case, the following shall apply:

$$\Delta p_1 = H - H_{stat}$$

H Delivery head of the pump

FIG. 3

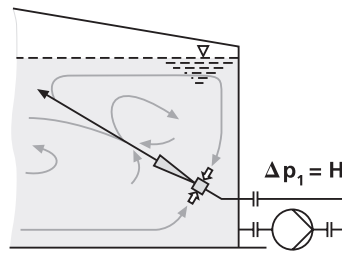
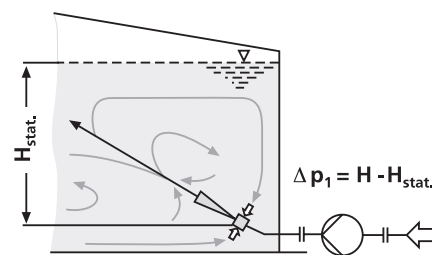


FIG. 4



EXAMPLE OF DESIGN

GIVEN:

- Tank diameter $D = 3.5 \text{ m}$
- Tank height $h = 4 \text{ m}$
- Useful volume $I_N = 38.5 \text{ m}^3$
- Actual tank volume $I_E = 30 \text{ m}^3$
- Mixing time $t = 0.5 \text{ h}$ (double circulation per hour)
- Motive liquid pressure $\Delta p_1 \leq 3 \text{ bar}$
- Pump arrangement according to fig. 3

PARAMETERS TO BE FOUND: Mixer size and parameters of the circulation pump

SOLUTION: With the help of the mixing time we calculate the total delivered flow as follows:

$$\Sigma \dot{V} = 0.3 \cdot \frac{I_E}{t} = \frac{0.3 \cdot 30}{0.5} = 18 \text{ m}^3/\text{h}$$

Taking into consideration $\Delta p_1 \leq 3 \text{ bar}$, diagram fig. 5 shows a required motive liquid pressure Δp_1 of 2.5 bar for a total delivery flow of 18 m³/h and a motive liquid flow of 4.5 m³/h.

Mixer size 3-80 is selected.

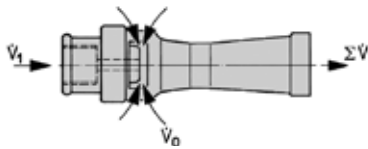
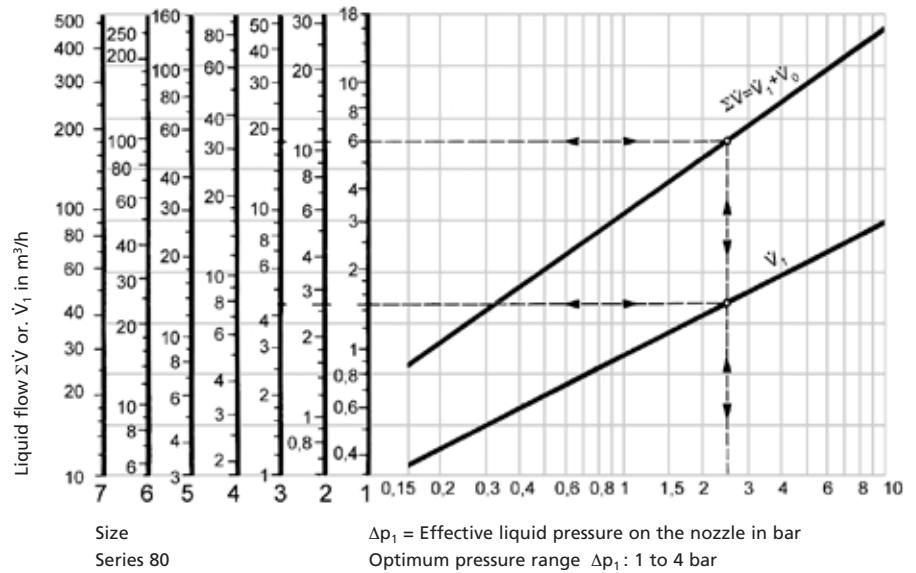


FIG. 5



Performance chart for standard sizes 1-7

CONNECTIONS, DIMENSIONS AND WEIGHTS
LIQUID JET MIXERS WITH THREADED CONNECTIONS TYPE 17.1

FIG. 6A

| CAST IRON | | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|--------------------------|---|------|-------|------|---------|---------|------|------|------|
| Motive liquid connection | A | | G 3/4 | G 1 | G 1 1/2 | G 1 1/2 | G 2 | G 3 | G 4 |
| Dimensions in mm | a | | 170 | 220 | 265 | 345 | 400 | 520 | 610 |
| | D | | 52 | 60 | 75 | 85 | 100 | 125 | 160 |
| | f | | 20 | 25 | 24 | 24 | 30 | 33 | 40 |
| Weight in kg | | | 1 | 2 | 3 | 5 | 7 | 13 | 24 |

STANDARD CONSTRUCTIONS: Housing: cast iron EN-GJL-200 (GG20), nozzles: stainless steel, threaded connections according to ISO 228, flanges according to EN1092-1

FIG. 6B

| STAINLESS STEEL | | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|--------------------------|---|------|-------|------|---------|---------|------|------|------|
| Motive liquid connection | A | | G 3/4 | G 1 | G 1 1/2 | G 1 1/2 | G 2 | G 3 | G 4 |
| Dimensions in mm | a | | 170 | 220 | 265 | 345 | 400 | 495 | 610 |
| | D | | 45 | 55 | 55 | 63 | 79 | 112 | 140 |
| | f | | 20 | 25 | 24 | 25 | 30 | 41 | 50 |
| Weight in kg | | | 1.4 | 2.8 | 2.8 | 4 | 7 | 18 | 31 |

STANDARD CONSTRUCTIONS: I Completely stainless steel 1.4571, II Completely stainless steel 1.4301, threaded connections according to ISO 228, flanges according to EN1092-1

FIG. 6C

| PLASTICS | | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|--------------------------|---|------|-------|------|---------|---------|------|------|------|
| Motive liquid connection | A | | G 3/4 | G 1 | G 1 1/2 | G 1 1/2 | G 2 | G 3 | G 4 |
| Dimensions in mm | a | | 170 | 220 | 265 | 345 | 400 | 495 | 610 |
| | D | | 50 | 60 | 70 | 80 | 90 | 120 | 150 |
| | f | | 20 | 25 | 24 | 25 | 30 | 41 | 50 |
| Weight PVC in kg | | | 0.4 | 0.7 | 1 | 1.5 | 2 | 4 | 7.5 |
| Weight PP in kg | | | 0.3 | 0.5 | 0.8 | 1 | 1.6 | 3 | 5 |
| Weight PTFE in kg | | | 0.5 | 1 | 1.5 | 2.3 | 3 | 6 | 10 |

STANDARD CONSTRUCTIONS: I Completely PVC, II Completely PP, III Completely PTFE, threaded connections according to ISO 228

LIQUID JET MIXERS WITH FLANGED CONNECTIONS TYPE 27.1

FIG. 6D

| CAST IRON | | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|--------------------------|---|------|------|------|------|------|------|------|------|
| Motive liquid connection | A | | 20 | 25 | 40 | 40 | 50 | 80 | 100 |
| Dimensions in mm | a | | 200 | 250 | 300 | 380 | 440 | 570 | 660 |
| | D | | 52 | 60 | 75 | 85 | 100 | 125 | 160 |
| Weight in kg | | | 2 | 3 | 5 | 7 | 10 | 19 | 33 |

FIG. 6E

| STAINLESS STEEL | | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|--------------------------|---|------|------|------|------|------|------|------|------|
| Motive liquid connection | A | | 20 | 25 | 40 | 40 | 50 | 80 | 100 |
| Dimensions in mm | a | | 170 | 220 | 265 | 345 | 400 | 495 | 610 |
| | D | | 45 | 55 | 55 | 63 | 79 | 112 | 140 |
| Weight in kg | | | 2.2 | 3.5 | 4.5 | 5.5 | 9 | 22 | 35 |

STANDARD CONSTRUCTIONS: I Completely stainless steel 1.4571, II Completely stainless steel 1.4301, threaded connections according to ISO 228, flanges according to EN1092-1

FIG. 6F

| PLASTICS | | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|--------------------------|---|------|------|------|------|------|------|------|------|
| Motive liquid connection | A | | 20 | 25 | 40 | 40 | 50 | 80 | 100 |
| Dimensions in mm | a | | 170 | 220 | 265 | 345 | 400 | 495 | 610 |
| | D | | 50 | 60 | 60 | 60 | 76 | 106 | 130 |
| Weight in PVC kg | | | 0.4 | 0.8 | 0.9 | 1.3 | 1.9 | 3.7 | 5 |
| Weight in PP kg | | | 0.3 | 0.6 | 0.7 | 1 | 1.5 | 3 | 4 |
| Weight in PTFE kg | | | 0.6 | 1.2 | 1.4 | 2 | 2.7 | 5 | 7 |

STANDARD CONSTRUCTIONS: I Completely PVC, loose flanges: GF-UP, II Completely PP, loose flanges: GF-UP, III Completely PTFE, flanges according to EN1092-1

SPECIAL CONSTRUCTIONS regarding material, connections and nominal diameter > DN100 on request.

For inquiries please use our questionnaire.

A numerical flow simulation (CFD) as in **fig. 7** and **fig. 8** is available on request.

FIG. 7

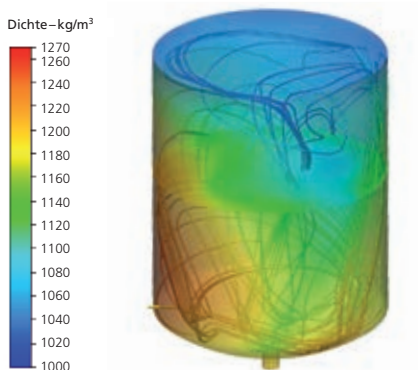
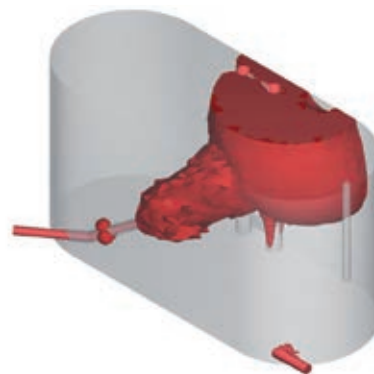


FIG. 8



Questionnaire

for liquid jet mixers
fm1, fm2

[Link to fillable PDF](#)

1. DIMENSIONS OF THE TANK OR BASIN

Volume of the tank or basin m³ Length mm
Diameter mm Width mm
Height mm

2. LIQUID TO BE MIXED

Medium Dyn. viscosity mPas
Temperature °C Solid content g/l
Density kg/m³ Particle size mm

3. CIRCULATION PUMP

Liquid flow m³/h Pressure at mixer bar g

4. MIXING REQUIREMENTS

Mixing time h
Further requirements
.....
.....

5. FURTHER DATA

MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges
Thread
Others

FLANGES ACCORDING TO:

EN1092-1
ASME lbs
Others

FURTHER NOTES:
.....
.....

Additional details, if required,
are to be stated separately.

Your inquiry no.
Offer submitted until
Requested date of delivery

YOUR ADDRESS

Company Telephone
attn. Telefax
Street/P.O. Box E-mail
ZIP code/City
Country

Liquid jet mixers

for food applications/orbitally welded design

AREAS OF APPLICATION

Mixing of food places highest demands on purity and hygiene. All tank installations must be cleaned without residue. Deposits must not be able to form even if production stops.

GEA designed a new series of jet mixers for this purpose. They are characterized by an orbitally welded design in stainless steel with particularly smooth, uninterrupted shape. They have no joints, holes, crevices, etc.

Areas of application for liquid jet mixers with welding end are for example:

- dissolving sugar for soft drinks
- mixing syrup and components
- beer fermentation
- storage of edible oils

ARRANGEMENT AND INSTALLATION

On site, the jet mixers are welded to the supply pipe of the motive fluid. Seals are not necessary. The surface roughness is $Ra < 0.8 \mu m$.

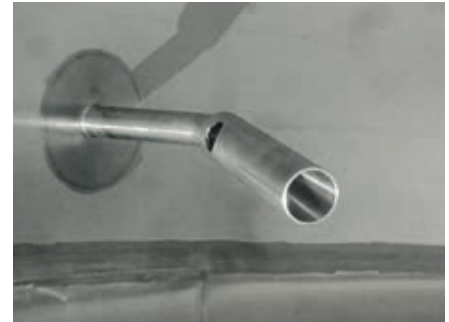
One of the three lateral openings for sucking in the secondary flow is designed such that a free drainage of residues in the housing is made possible.

LIQUID JET MIXERS IN BEER FERMENTATION TANKS

This jet mixing system (fig. 2) has been specially developed for use in fermentation tanks. A jet mixer maintains the natural bubble column caused by the formation of CO_2 during the fermentation process in the tank. In this way, more active yeast cells are kept in the suspension, conversion processes during the fermentation are accelerated and temperature differences in the fermentation tank are considerably reduced.



Stainless steel for welding on



Installation in a tank

FIG 2

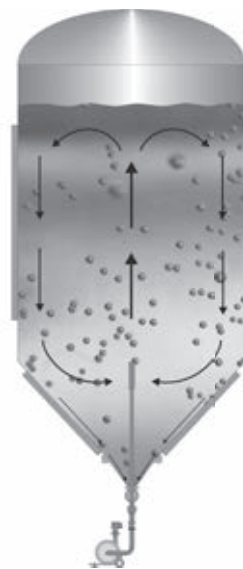
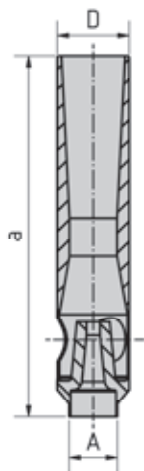


FIG. 1



CONNECTIONS, DIMENSIONS AND WEIGHTS LIQUID JET MIXER WITH WELDING END TYPE 37.1

| STAINLESS STEEL | | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|-------------------------|---|------|------|------|------|------|------|------|------|
| Motive fluid connection | A | | 20 | 25 | 40 | 40 | 50 | 80 | 100 |
| Motive fluid connection | a | | 170 | 220 | 265 | 345 | 400 | 495 | 610 |
| | D | | 40 | 50 | 50 | 60 | 79 | 112 | 140 |
| Weight in kg | | | 1 | 1.7 | 2 | 2.7 | 6 | 15 | 27 |

STANDARD CONSTRUCTION: Completely in stainless steel 1.4301

SPECIAL CONSTRUCTIONS: Other materials may be available on request.

For inquiries please use our questionnaire.

Liquid jet ventilators

APPLICATIONS

Liquid jet ventilators are used to draw off air, gases or vapor.

They are designed to suck in **gas flows** at **small pressure differences**. The pressure gain (compression) which these units can archive is in the range between **1 and 20 mbar**.

MODE OF OPERATION

Liquid jet ventilators operate on the jet pumps principle ("General information on jet pumps", 7 | abl1). Their action is based on the jet of motive liquid which emerges from the motive nozzle entraining and conveying the surrounding gas.

OPERATING CHARACTERISTICS

The specific motive liquid requirement in m^3 of liquid per m^3 of air or gas

- decreases with higher motive liquid pressure p_1
- increases with rising, required compression Δp
- is independent of nature and density off the drawn off gases

ADVANTAGES

- with correct choice of materials of manufacture an almost unlimited life
- no moving parts
- maintenance-free
- quickly and simply brought into operation
- can be fabricated from many different materials
- low capital and installation costs
- low-noise operation

EXAMPLE OF DESIGN

A liquid jet ventilator has to convey approximately $400 m^3/h$ air. The available motive water pressure is 3 bar g.

PARAMETERS TO BE FOUND:

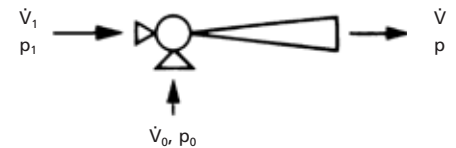
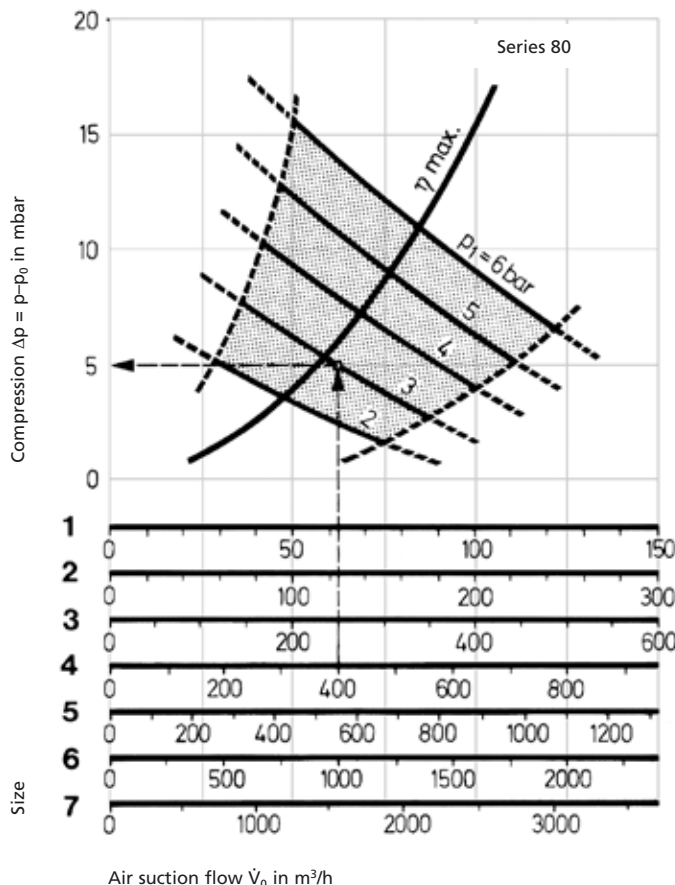
1. Maximum compression Δp in mbar
2. Size of ventilator
3. Motive liquid consumption in m^3/h

SOLUTION: Fig. 1 shows that a ventilator size 4 produces a compression of $\Delta p = 5$ mbar. The operating point lies within the area of best efficiency. Therefore the ventilator is suitable for the required duty.



From fig. 2 we find a motive liquid consumption of $4.4 m^3/h$.

FIG. 1



- p_1 = Motive liquid pressure in bar
- p_0 = Suction pressure in bar
- p = Discharge pressure in bar
- \dot{V}_1 = Motive liquid flow in m^3/h
- \dot{V}_0 = Gas suction flow in m^3/h
- \dot{V} = Mixed flow in m^3/h
- η_{max} = Optimum working efficiency

(Pressure indications in bar = bar g)

FIG. 2

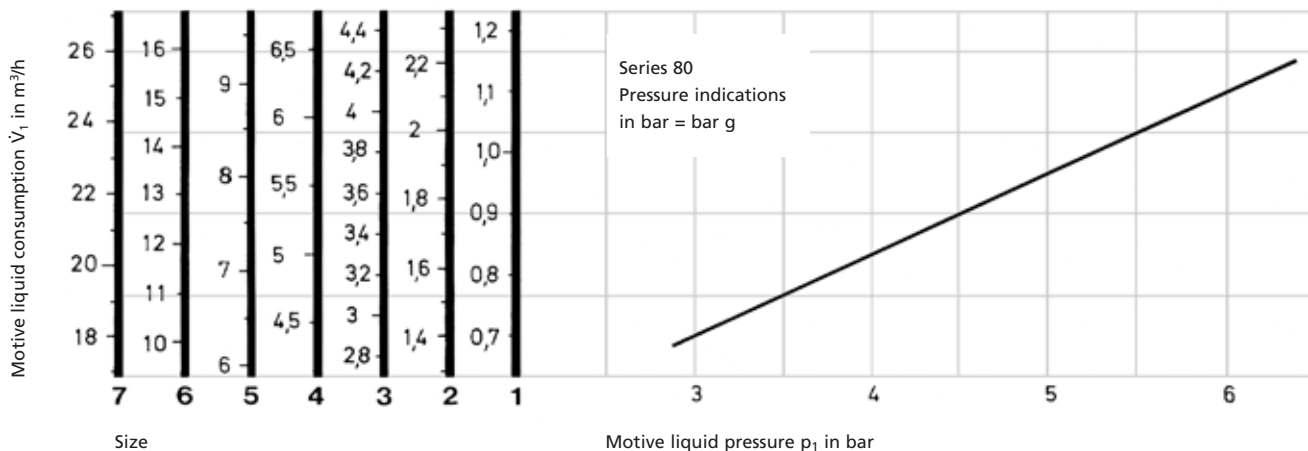
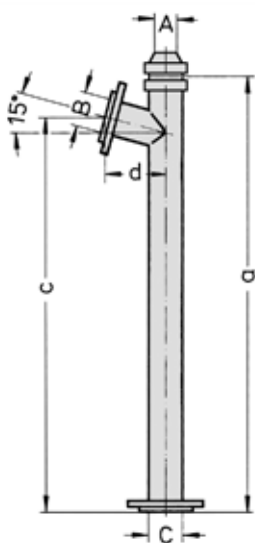


FIG. 3



CONNECTIONS, DIMENSIONS AND WEIGHTS

| SERIES 80 | | Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--------------------------|-----------------------|------|------|------|------|------|------|------|------|
| Motive liquid connection | A | | 15 | 25 | 25 | 32 | 32 | 50 | 65 |
| Suction connection | B | | 50 | 65 | 100 | 125 | 150 | 200 | 250 |
| Pressure connection | C | | 50 | 65 | 100 | 125 | 150 | 200 | 250 |
| Dimensions in mm | a | | 1025 | 1300 | 1750 | 2000 | 2350 | 2750 | 3000 |
| | c | | 925 | 1175 | 1625 | 1875 | 2125 | 2600 | 2850 |
| | d | | 150 | 175 | 200 | 225 | 250 | 300 | 325 |
| Weight in kg | Steel | | 9 | 14 | 34 | 50 | 77 | 148 | 220 |
| | Stainless steel | | 9 | 14 | 28 | 37 | 51 | 75 | 105 |
| | Plastic material (PP) | | 4 | 5 | 8 | 11 | 15 | 18 | 25 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, motive nozzle: bronze, twist piece: PVC
 - II Completely stainless steel 1.4571
 - III Completely stainless steel 1.4541
 - IV Completely PVC, loose flanges: GRP
 - V Completely PP, loose flanges: GRP
- Flanges according to EN1092-1

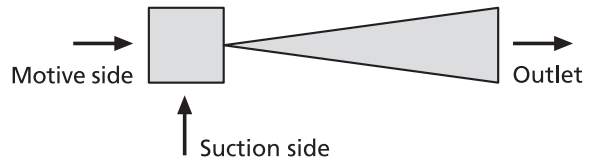
SPECIAL CONSTRUCTIONS: Titanium, Hastelloy, glass-fibre reinforced plastic (GFK) etc.

For special constructions dimensional modifications are subject to change. When ordering standard units size, type and materials of construction should be given.

For inquiries please use our questionnaire.

Questionnaire

for liquid jet ventilators
fv1



[Link to fillable PDF](#)

1. MOTIVE SIDE

| | | |
|-----------------------|----------------------|-------------------|
| Motive medium | Temperature | °C |
| Motive flow | Density | kg/m ³ |
| Motive pressure | Concentration | weight % |
| | Steam pressure | bar abs. |

2. SUCTION SIDE

| | | |
|------------------------|---------------------|-------------------|
| Suction medium | Temperature | °C |
| Suction flow | Density | kg/m ³ |
| Suction pressure | Concentration | weight % |

3. OUTLET

| | | |
|-----------------------------------|---------------------|----------|
| Required discharge pressure | Concentration | weight % |
|-----------------------------------|---------------------|----------|

4. FURTHER DATA

MATERIAL OF CONSTRUCTION

CONNECTIONS:

| | |
|---------|--------------------------|
| Flanges | <input type="checkbox"/> |
| Thread | <input type="checkbox"/> |
| Others | <input type="checkbox"/> |

FLANGES ACCORDING TO:

| | |
|----------|--------------------------|
| EN1092-1 | <input type="checkbox"/> |
| ASME lbs | <input type="checkbox"/> |
| Others | <input type="checkbox"/> |

DESIGN CODE (if required):

| | |
|---------|--------------------------|
| AD-2000 | <input type="checkbox"/> |
| ASME | <input type="checkbox"/> |
| Others | <input type="checkbox"/> |

APPLICATION:

.....

.....

.....

DESIGN:

| | | | |
|-------------------|----|----------------|-------|
| Temperature | °C | Pressure | bar g |
|-------------------|----|----------------|-------|

FURTHER NOTES:

.....

.....

Additional details, if required,
are to be stated separately.

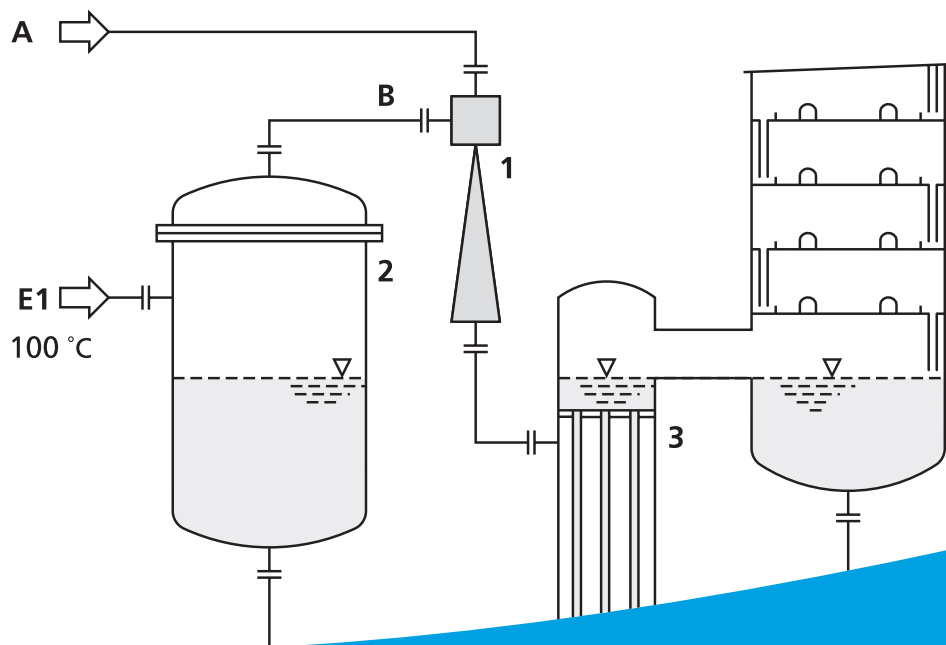
Your inquiry no.

Offer submitted until

Requested date of delivery

YOUR ADDRESS

| | |
|-----------------------|-----------------|
| Company | Telephone |
| attn. | Telefax |
| Street/P.O. Box | E-mail |
| ZIP code/City | |
| Country | |



Steam jet pumps

- Steam jet vacuum pumps
- Steam jet compressors (thermo compressors)
- Steam jet ventilators
- Steam jet liquid pumps, general information
- Steam jet liquid pumps class A
- Steam jet liquid pumps class B
- Steam jet heaters, general information
- Steam jet heaters for vessels
- Steam jet heaters "L" for installation in pipelines
- Steam jet heaters "H" for passage and circulation heating systems
- Steam jet heaters "System Ciba-Geigy" for passage and circulation heating systems

Steam jet vacuum pumps

Steam jet pumps are particularly appropriate as vacuum pumps, as they can easily handle large vacuum volumes.

Single stage jet pumps, which convey against atmospheric pressure are used for the production of vacuum down to a suction pressure of approx. 100 mbar.

For lower suction pressures multi-stage steam jet vacuum pumps are used, with or without intermediate condensation. For more details, please refer to section "Vacuum systems", 7 | gdp 1.

ADVANTAGES

- no moving parts
- easy handling of even very large suction flows
- low maintenance cost
- long life
- high reliability and safety of operation
- low priced, low operating cost
- manufacture from various materials of construction

DESIGN

Steam jet vacuum pumps have a tailor-made design depending on the individual requirements. In this way optimum efficiency is achieved.

PERFORMANCE CHART FOR VACUUM PUMPS

EXAMPLE

It is required to extract $\dot{M}_0 = 50 \text{ kg/h}$ of air at 20°C from a suction pressure of $p_0 = 200 \text{ mbar}$. A motive steam pressure of $p_1 = 10 \text{ bar g}$ is available.

From the diagrams **fig. 1** and **fig. 2**, the required motive steam flow as well as the suction connection diameter can be ascertained in relation to the suction pressure and suction flow.

The overall dimensions of the equipment are fixed in relation to the suction connection diameter.

Fig. 1 shows a specific steam consumption of

$$\mu = 3 \frac{\text{kg Steam}}{\text{kg Air}}$$

The steam consumption is, therefore,

$$\dot{M}_1 = \mu \cdot \dot{M}_0 = 3 \cdot 50 = 150 \frac{\text{kg}}{\text{h}}$$

In **fig. 2** the operating point suction flow = 50 g/h and suction pressure = 200 mbar is between the curves for DN 40 and DN 50.

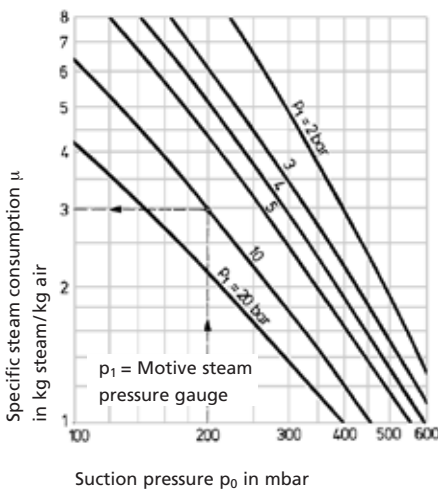


Steam jet vacuum pump in metal



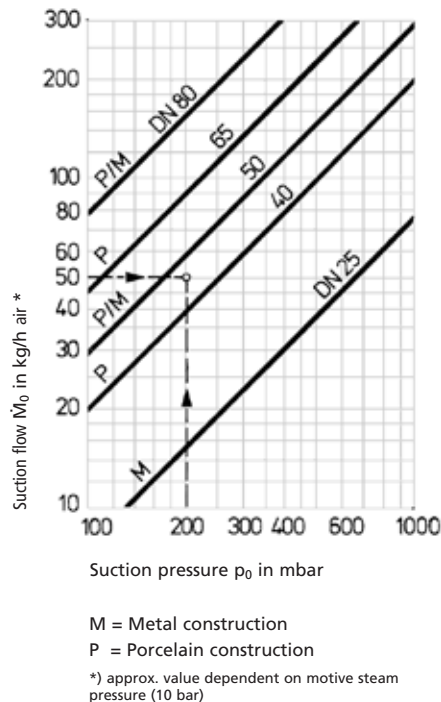
Steam jet vacuum pump in graphite

FIG. 1



Specific steam consumption of a single stage steam jet vacuum pump when compressing to atmosphere (1013 mbar)

FIG. 2



Maximum possible suction flow in kg/h for air at 20°C

DN 50 is chosen as the curves in **fig. 2** give the maximum possible suction flow for each particular size. The dimensions of the required jet pump, in various materials of construction, are given in **fig. 9** and **10**.

The diagrams **fig. 1** and **2** are valid for a suction medium of air at 20°C . At other suction temperatures, but at the same suction pressure, the suction flow is calculated according to the following equation:

$$\dot{M}_{0t} \approx \dot{M}_{020} \cdot \sqrt[4]{\frac{293}{273 + \vartheta}}$$

If water vapor, instead of air, is to be drawn off, the suction flow is approx. 80% of the values given in diagram **fig. 2**. For other gases or vapors see section "Equivalent suction flows for steam jet vacuum pumps", 7 | abl 12.

PRE-EVACUATION

If a plant is to be evacuated within a given time, for example, during start-up, and the vacuum pump which maintains the operational vacuum takes longer than the given time, a jet pump is added to speed up the evacuation. This jet pump is called pre-evacuator or start-up jet pump.

This pump is brought into operation together with the vacuum pump, but works only until the required vacuum, or a determined intermediate vacuum is reached (see also section "Vacuum systems, Planning of a steam jet vacuum pump", 7.1.3.3).

In order to determine whether a pre-evacuator is required, the evacuation time of the vacuum pump has to be calculated with the help of the following formulas:

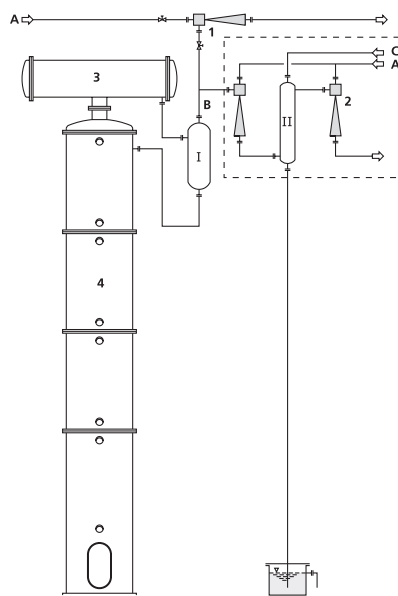
$$t_{\text{evac, DVP}} \approx \frac{V \cdot (1000 - p_0) \cdot 60}{840 \cdot \dot{M}_A \cdot 3} \approx \frac{V \cdot (1000 - p_0)}{\dot{M}_A \cdot 42}$$

in minutes.

Where:

- V Volume of the plant to be evacuated in m³
- p₀ Required operating vacuum (suction pressure) in mbar
- \dot{M}_A Air suction flow in kg/h, for which the steam jet vacuum pump is designed

FIG. 3



- 1 Steam jet vacuum pump as pre-evacuator
- 2 Two-stage steam jet vacuum pump
- 3 Column head
- 4 Column
- I Separator
- II Mixing condenser
- A Motive steam
- B Suction flow
- C Cooling water

Pre-evacuation of a vacuum plant

From the result obtained, it can be estimated whether a pre-evacuator is required. Single-stage start-up jet pumps can, according to the motive steam pressure, achieve a final pressure of approx. 80 mbar. For lower pressures a two-stage start-up jet pump must be used.

PERFORMANCE CHART FOR PRE-EVACUATORS

EXAMPLE

A vessel with a volume of 31 m³ is to be evacuated from 1000 mbar to 80 mbar in 15 minutes. Motive steam at 10 bar g is available.

From fig. 4 for 80 mbar and 10 bar g one finds a specific motive steam consumption of 2.28 kg motive steam/m³ volume to be evacuated.

The steam consumption is then calculated with the aid of the following formula:

$$\dot{M}_D = D_{\text{spec.}} \cdot V \cdot \frac{60}{t}$$

- \dot{M}_D Steam consumption in kg/h
- D_{spec.} kg motive steam/m³ volume to be evacuated
- V Volume of the plant to be evacuated in m³
- t Required evacuation time in minutes

$$\dot{M}_D = 2.28 \cdot 31 \cdot \frac{60}{15} = 283 \frac{\text{kg}}{\text{h}}$$

Fig. 5 gives the nominal diameter of the pre-evacuator required for this steam consumption. The example given requires a pre-evacuator DN 80 I.

FIG. 4

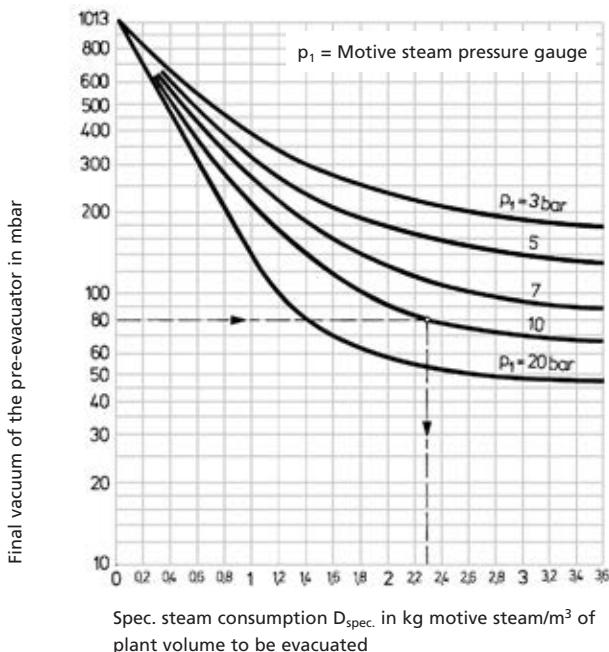


FIG. 5

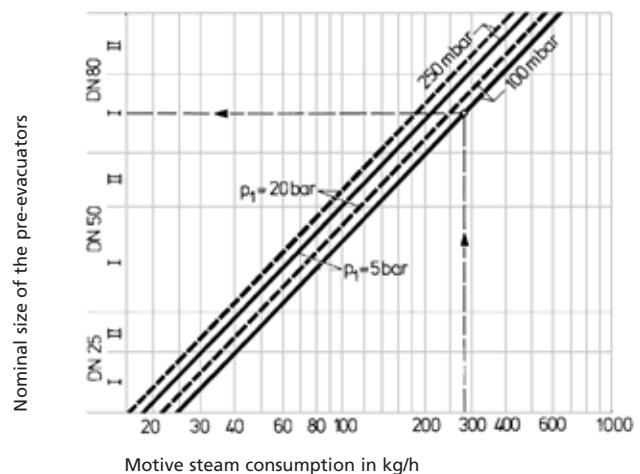


FIG. 6

EVACUATION OF A SUCTION LINE

Steam jet vacuum pump for evacuating the suction line of a non self-priming pump

- 1 Steam jet vacuum pump
- 2 Centrifugal pump
- A Motive steam
- B Suction line

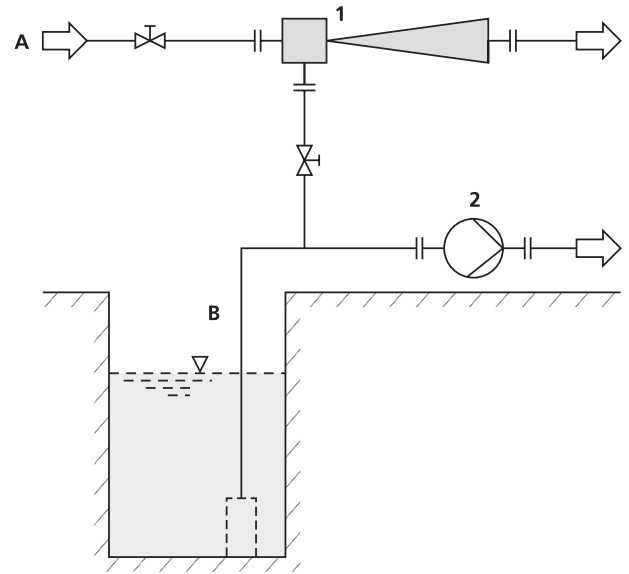


FIG. 7

VACUUM PRODUCTION

Steam jet vacuum pump for producing a negative pressure in a nutsch filter

- 1 Steam jet vacuum pump
- A Motive steam
- B Suction line

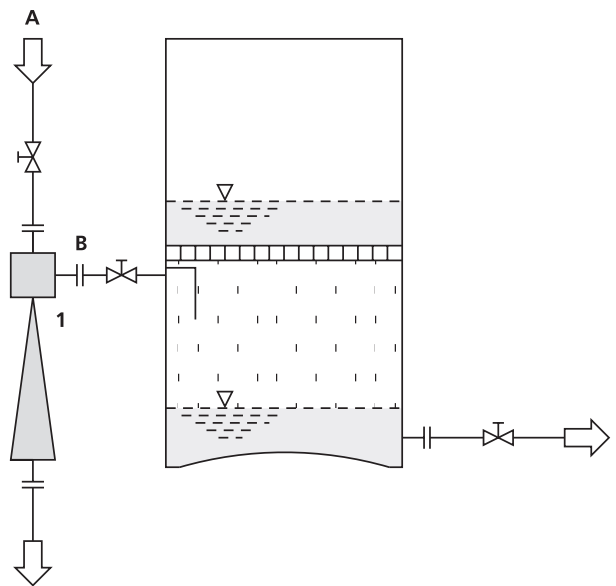


FIG. 8

LIFTING OF LIQUIDS

As long as the steam jet pump operates, vacuum is produced and liquid is drawn into the tank. When the steam valve is closed, atmospheric air returns to the tank, the vacuum is broken and lifting stops.

Steam jet vacuum pumps for the lifting of liquids

- 1 Steam jet vacuum pump
- A Motive steam
- B Suction line

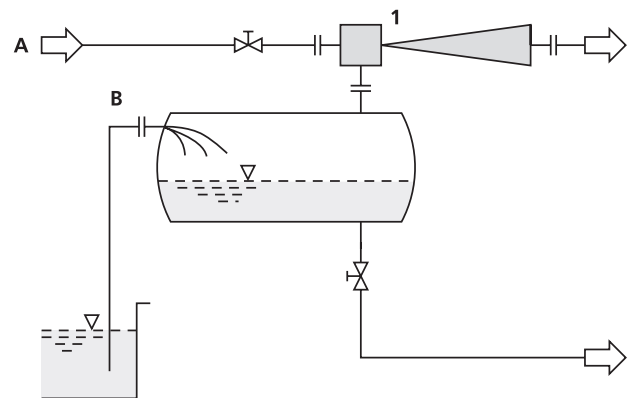
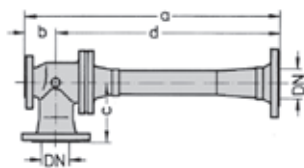


FIG. 9

STEAM JET VACUUM PUMPS, METAL CONSTRUCTION



CONNECTIONS, DIMENSIONS AND WEIGHTS

| DN | 25 | 25 | 50 | 50 | 80 | 80 | |
|------------------------|----|-----|-----|-----|-----|-----|-----|
| | I | II | I | II | I | II | |
| Steam connection DN | 25 | 25 | 25 | 25 | 40 | 40 | |
| Dimensions in mm | a | 210 | 300 | 440 | 550 | 750 | 930 |
| | b | 30 | 30 | 50 | 50 | 90 | 90 |
| | c | 100 | 100 | 110 | 110 | 175 | 175 |
| | d | 180 | 270 | 390 | 500 | 660 | 840 |
| Weight in kg (approx.) | | 6 | 7 | 18 | 21 | 43 | 46 |

REALIZED JET PUMP



Steam jet vacuum pump in stainless steel

STANDARD CONSTRUCTIONS:

- I Housing: cast iron EN-GJL-400-15 (GGG40), motive nozzle: stainless steel
 - II Housing: cast stainless steel (1.4581), motive nozzle: stainless steel
- DN 25 und 50: housing and diffusor screwed
 DN 80: housing and diffusor flanged, diffusor welded
 Flanges according to EN1092-1 or ASME 150 lbs

If necessary the steam jet vacuum pumps can also be manufactured in other sizes, constructions and materials and flanges of other nominal pressures and standards can be supplied. This, however, does not apply to pumps of porcelain.

The exact installation dimensions of the pumps depend on the operating conditions. For jet pumps according to the design given in fig. 9, two different dimensions for each size are given.

For large nominal diameters jet pumps are designed in welded construction. The dimensions are adapted to the particular conditions.

The dimensions are given in the quotation on request (see also "Steam jet compressors", 7|bv1)

SPECIAL CONSTRUCTIONS and larger nominal bores on request.

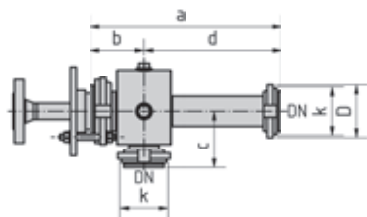
Dimensions, connection dimensions and special performance data on request.

For inquiries please use our questionnaire.

FIG. 10

STEAM JET VACUUM PUMPS, GRAPHITE CONSTRUCTION

(Replacement for porcelain construction)



CONNECTIONS, DIMENSIONS AND WEIGHTS

| DN | 32 | 40 | 50 | 65 | 80 | 100 | 125 | |
|------------------------|----|-----|-----|-----|-----|-----|------|------|
| Dimensions in mm | a | 320 | 405 | 510 | 653 | 810 | 1035 | 1270 |
| | b | 90 | 100 | 100 | 130 | 145 | 160 | 170 |
| | c | 95 | 110 | 110 | 120 | 135 | 150 | 175 |
| | d | 230 | 305 | 410 | 523 | 665 | 875 | 1100 |
| | k | 95 | 120 | 140 | 160 | 185 | 210 | 235 |
| | D | 115 | 144 | 164 | 188 | 217 | 242 | 267 |
| Weight in kg (approx.) | | 5 | 8 | 11 | 17 | 21 | 40 | 53 |

STANDARD CONSTRUCTION:

- Housing: temperature-change resistant graphite
- Motive nozzle: PTFE/GFK
- Connection clamps: aluminium cast
- Steam connections: steel galvanized

SPECIAL CONSTRUCTIONS with different connections, nominal pressure stages of the flanges: materials on request.

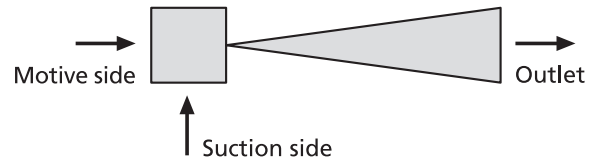
| (new construction with flanges acc. to EN1092) | DN | 25 | 50 | 80 | 100 |
|--|----|-----|-----|-----|------|
| Dimensions in mm | a | 360 | 600 | 985 | 1320 |
| | b | 90 | 100 | 145 | 160 |
| | c | 100 | 110 | 135 | 150 |
| | d | 270 | 500 | 840 | 1150 |
| Weight in kg (approx.) | | 5 | 11 | 21 | 40 |

The motive nozzle connections are not given in the above overview as they depend on the operating conditions.

For inquiries please use our questionnaire.

Questionnaire

for steam jet vacuum pumps
dvp1



[Link to fillable PDF](#)

1. MOTIVE SIDE

| | | | |
|-----------------------|------------------------|------------------------------|---------|
| Motive medium | Molecular weight | kg/kmol | |
| Motive pressure | bar abs. | Specific heat capacity | kJ/kg K |
| Temperature | °C | | |

2. SUCTION SIDE

| | | | |
|------------------------|-------------------|------------------------------|---------|
| Suction medium | Temperature | °C | |
| Suction flow | kg/h | Molecular weight | kg/kmol |
| Suction pressure | bar abs. | Specific heat capacity | kJ/kg K |

3. OUTLET

| | | | |
|-----------------------------------|----------|------------------|------|
| Required discharge pressure | bar abs. | Mixed flow | kg/h |
|-----------------------------------|----------|------------------|------|

4. FURTHER DATA **MATERIAL OF CONSTRUCTION**

CONNECTIONS:

Flanges
 Thread
 Others

FLANGES ACCORDING TO:

EN1092-1
 ASME lbs
 Others

DESIGN CODE (if required):

AD-2000
 ASME
 Others

APPLICATION:

.....

DESIGN:

Temperature

| | | |
|----------|----------------|-------|
| °C | Pressure | bar g |
|----------|----------------|-------|

FURTHER NOTES:

.....

.....

Additional details, if required,
are to be stated separately.

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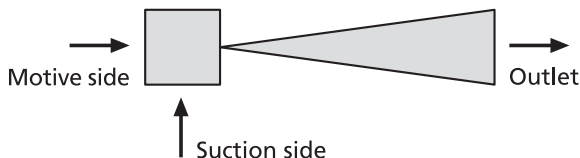
Telephone

Telefax

E-mail

Questionnaire

for steam jet compressors (thermo compressors)
bv1



[Link to fillable PDF](#)

1. MOTIVE SIDE

| | | | |
|-----------------------|------------------------|------------------------------|---------|
| Motive medium | Molecular weight | kg/kmol | |
| Motive pressure | bar abs. | Specific heat capacity | kJ/kg K |
| Temperature | °C | | |

2. SUCTION SIDE

| | | | |
|------------------------|-------------------|------------------------------|---------|
| Suction medium | Temperature | °C | |
| Suction flow | kg/h | Molecular weight | kg/kmol |
| Suction pressure | bar abs. | Specific heat capacity | kJ/kg K |

3. OUTLET

| | | | |
|-----------------------------------|----------|------------------|------|
| Required discharge pressure | bar abs. | Mixed flow | kg/h |
|-----------------------------------|----------|------------------|------|

4. FURTHER DATA

MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges

Thread

Others

FLANGES ACCORDING TO:

EN1092-1

ASME lbs

Others

DESIGN CODE (if required):

AD-2000

ASME

Others

APPLICATION:

.....

.....

.....

DESIGN:

Temperature

°C

Pressure

bar g

FURTHER NOTES:

.....

.....

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Steam jet compressors (thermo compressors)

MODE OF OPERATION

Steam jet compressors use the energy of a vapor flow \dot{M}_1 , of a high pressure level p_1 and compress a vapor flow \dot{M}_0 of low pressure level p_0 to a medium pressure level p .

Normally, such steam jet compressors are operated by water steam as motive and suction fluid.

Basically, however, steam jet compressors can be operated with any vapor.

Further information can be found in chapter "General information on jet pumps", 7 | abl 1.



Thermo compressor in steel

APPLICATIONS

Steam jet compressors are used in evaporating, distillation, cooling, crystallisation, deodorisation, degassing and drying under vacuum.

In the positive pressure range the compressed exhaust vapors are used for heating (heat pump).

OPERATIONAL BEHAVIOUR OF STEAM JET COMPRESSORS

A steam jet compressor must be constructed to unite the operating conditions accurately, otherwise the efficiency will be poor or it will not work at all. Even so, for a better understanding of the method of operation of steam jet compression, it is important to consider behaviour under varying operating conditions.

BEHAVIOUR UNDER VARYING OPERATION CONDITIONS

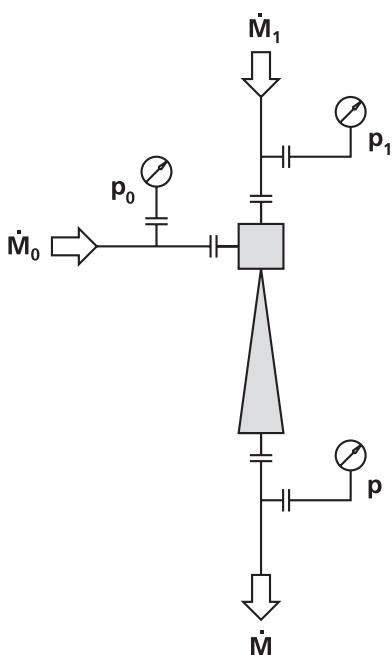
1. If the motive steam pressure changes, the steam consumption changes proportionally to the motive steam pressure. At the nominal value of the motive steam pressure, the steam consumption corresponds to the calculated figure given in the specification. Please also see "Steam consumption of jet pumps", 7 | abl 13.
2. Changes in a motive steam flow by changing the motive pressure (or by inserting steam nozzles with different hole diameters) primarily affect the discharge pressure against which the steam jet compressor is able to deliver. An increase of the motive steam flow results in an increase in the possible discharge pressure and vice versa.
3. If the discharge pressure between the suction pressure and the discharge pressure limit (dotted line) changes whilst

the suction pressure remains constant, the suction flow also remains constant as shown by the horizontal curves. If the discharge pressure is raised beyond the discharge pressure limit whilst the suction pressure remains constant, the suction flow abruptly drops to zero in case of higher compression.

4. If the suction flow is changed, the jet pump will react with a change in the suction pressure. A smaller suction flow results in a lower suction pressure (better vacuum) and vice versa.

Fig. 2 shows the relationship between suction flow \dot{M}_0 , suction pressure p_0 and discharge pressure p at a constant motive steam pressure p_1 . If two of the three variables \dot{M}_0 , p_0 and p are fixed variables on the compressor, the resulting third variable is in accordance with the graph.

FIG. 1

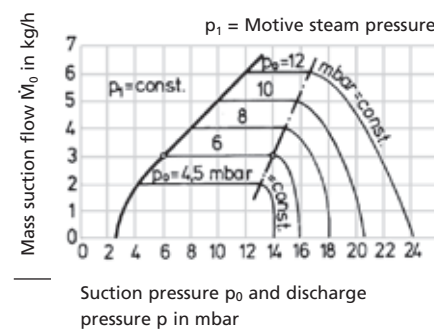


ADVANTAGES

- large vapor volumes, particularly in high vacuum ranges, are easily handled
- low investment cost due to the relatively simple construction
- long operational life expectancy as steam jet compressors can always be constructed of a suitable corrosion resistant material
- high operational safety and low maintenance as no moving parts are involved

In relation to these advantages, the efficiency does not play significant role, compared to other compressors. As a result of it being custom built for a duty, with correct design and application a high operating efficiency can be achieved.

FIG. 2



The graph has only qualitative validity. The numerical values are only inserted to give a better understanding.

ADJUSTMENT OF STEAM JET COMPRESSORS

There are various possibilities to adjust steam jet compressors to suit varying operating conditions:

1. CHANGING THE MOTIVE NOZZLE(S)

A limited adaptation of the steam consumption to a varying discharge pressure (e.g. due to a varying cooling water temperature) is possible by altering the motive steam pressure or by changing the motive nozzles.

2. THROTTLING THE MOTIVE STEAM

If a sufficiently high motive steam pressure is available, the steam consumption can be adjusted to suit a varying discharge pressure by throttling. This can be done by hand or by automatic control.

For example, the steam jet compressor delivers into a mixing condenser, operated with recycled water. A great amount of motive steam can be saved by using steam pressure control of the motive steam as the temperature of the circulating water varies considerably in the course of the year.

3. USING NOZZLE NEEDLES

The motive flow is changed by reducing the cross section of the motive nozzle by means

of a nozzle needle. This is done pneumatically or by electric positioner. Controllable steam jet compressors with spindle nozzles are used for fluctuating suction or mixing flow and constant or varying suction or discharge pressure. The economical use and satisfactory operation of a controllable jet pump is possible for an expansion ratio under 10 up to maximum 20, whereas the expansion ratio $E = p_1/p_0$. Please also see "Steam consumption of jet pumps", 7 | abl 13.

The steam jet compressor must be designed for the most unfavourable conditions. If the steam jet compressor is not controlled, its steam consumption is always that which is required for the most unfavourable condition. An automatic control takes care that only the amount of steam really required is in fact used. We can supply the required control equipment or offer consultancy for control techniques within the scope of our engineering services.

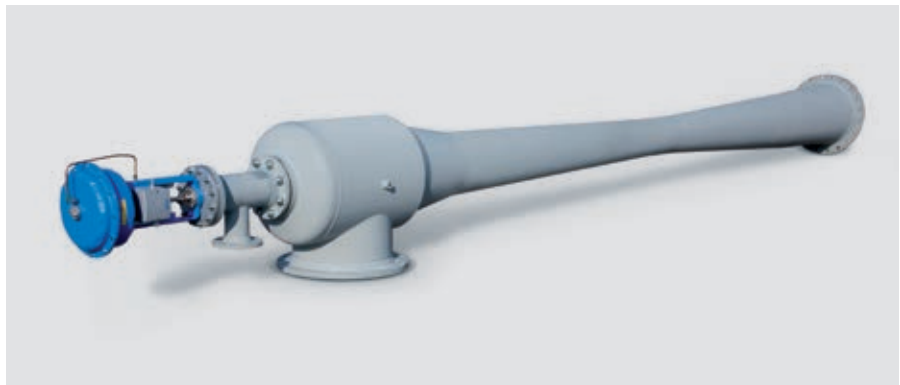


Fig. 3 Variable flow jet compressor with pneumatic positioner

FIG. 4

HEAT PUMP

A part of the drawn-off vapors are recompressed by motive steam and used to heat the evaporator. Apart from the additional saving of steam, a safer limitation in the temperature differences between the heating and boiling chambers will be achieved.

Evaporator with steam jet compressor as heat pump

- 1 Steam jet compressor
- 2 Evaporator
- A Motive steam
- B Vapor
- E Product
- H Condensate

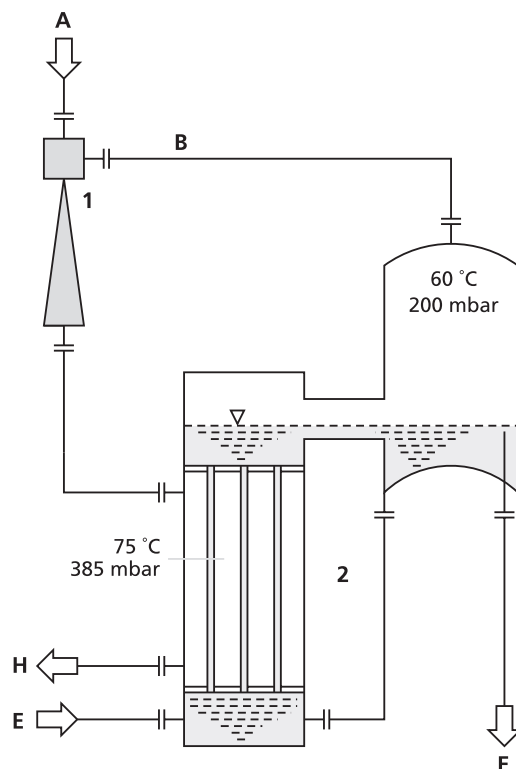


FIG. 5

REFRIGERATION

The boiling of the liquid to be cooled is achieved by using a steam jet compressor to keep a sufficiently low absolute pressure above the liquid.

The special advantage in the crystallisation and cooling of aggressive liquids by this method is that no heat exchange surfaces are required.

Agitator crystalliser with steam jet compressor for refrigeration

- | | | | |
|---|-----------------------|---|--------------------|
| 1 | Steam jet compressor | A | Motive steam |
| 2 | Agitated crystalliser | B | Vapor |
| 3 | Mixing condenser | C | Cooling water |
| | | D | To the vacuum pump |
| | | E | Product |

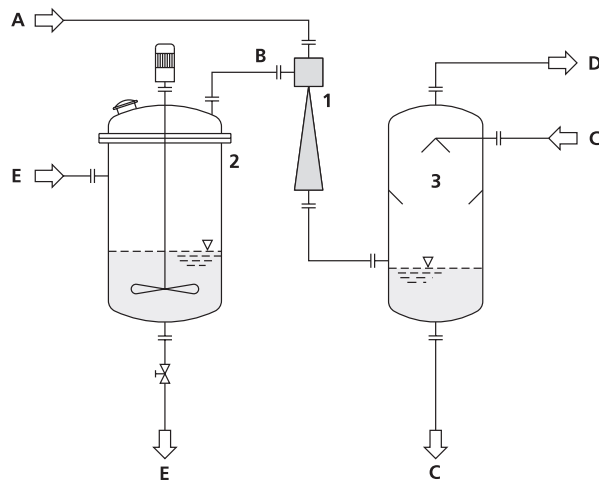


FIG. 6

VACUUM GENERATION WHEN DEODORIZING EDIBLE OIL

Normally, deodorizing is done by stripping steam at a vacuum of approx. 6 mbar. The steam jet compressor draws off the vapor and compresses it to the pressure in the condenser, e.g. 45 mbar.

Deodoriser for edible oils with steam jet compressor to increase the vacuum

- | | | | |
|---|----------------------|---|--------------------|
| 1 | Steam jet compressor | C | Cooling water |
| 2 | Tank | D | To the vacuum pump |
| 3 | Mixing condenser | E | Product |
| | | F | Heating steam |
| A | Motive steam | G | Steam |
| B | Vapor | H | Condensate |

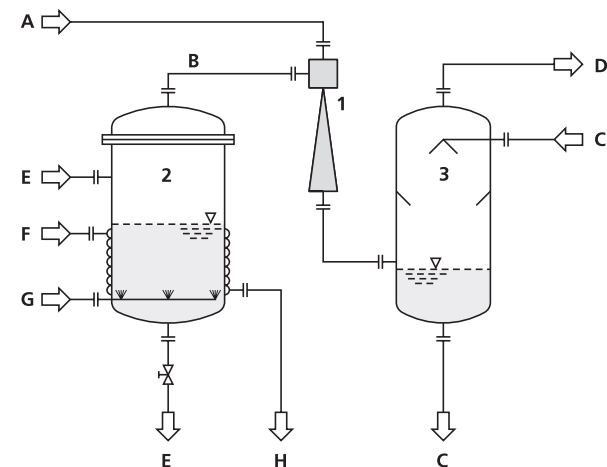


FIG. 7

HEAT RECOVERY

Flashed off vapors are recompressed by a steam jet compressor and used to heat an evaporator in a distillation plant.

Heat recovery from process effluent water by using steam jet compressors as heat pump

- | | | | |
|---|----------------------|----|--------------|
| 1 | Steam jet compressor | A | Motive steam |
| 2 | Tank | B | Vapor |
| 3 | Distillation plant | E1 | Product 1 |
| | | E2 | Product 2 |
| | | H | Condensate |

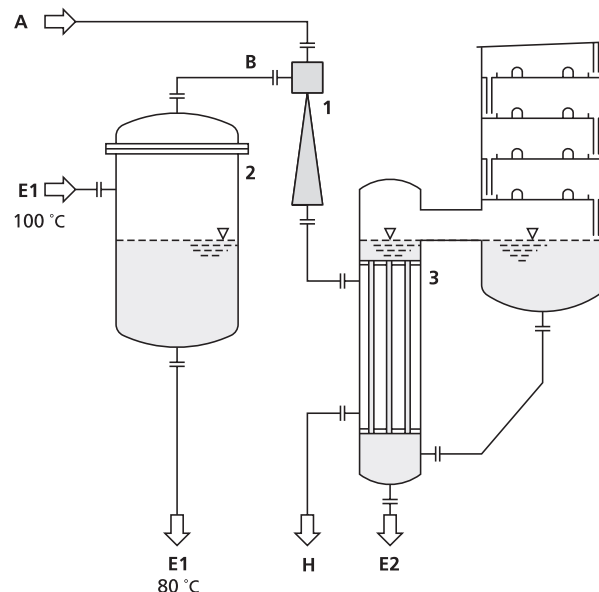
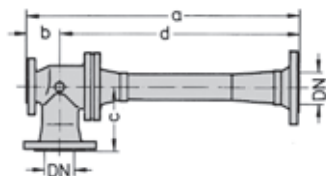


FIG. 8

**STEAM JET COMPRESSORS,
METAL CONSTRUCTION**



CONNECTIONS, DIMENSIONS AND WEIGHTS

| DN | 25 | 25 | 50 | 50 | 80 | 80 | |
|---------------------|----|-----|-----|-----|-----|-----|-----|
| | I | II | I | II | I | II | |
| Steam connection DN | 25 | 25 | 25 | 25 | 40 | 40 | |
| Dimensions in mm | a | 210 | 300 | 440 | 550 | 750 | 930 |
| | b | 30 | 30 | 50 | 50 | 90 | 90 |
| | c | 100 | 100 | 110 | 110 | 175 | 175 |
| | d | 180 | 270 | 390 | 500 | 660 | 840 |
| Weight in kg | | 6 | 7 | 18 | 21 | 43 | 46 |

STANDARD CONSTRUCTIONS:

- I Housing: cast iron EN-GJS-400-15 (GGG40), motive nozzle: stainless steel
- II Housing: cast stainless steel (1.4581), motive nozzle: stainless steel
- DN 25 and 50: housing and diffuser screwed
- DN 80: housing and diffuser flanged, diffuser welded
- Flanges according to EN1092-1 or ASME 150 lbs

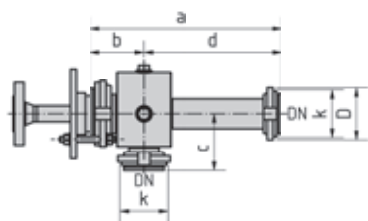
On request the steam jet compressors can be supplied in other sizes, constructions and materials. Connecting flanges with the requested nominal pressure and according to the required standards can be offered. The exact installation dimensions of the pumps depend on the operating conditions. Thus, fig. 8 gives 2 constructions for each different dimension. For large nominal diameters jet pumps are designed in welded construction. The

dimensions are adapted to the particular conditions. The dimensions are given in the quotation on request. **SPECIAL CONSTRUCTIONS** and larger nominal diameters on request. Dimensions, connection dimensions and special performance data on request. For inquiries please use our questionnaire.

FIG. 9

**STEAM JET COMPRESSORS,
GRAPHITE CONSTRUCTION**

(Replacement for porcelain construction)



CONNECTIONS, DIMENSIONS AND WEIGHTS

| DN | 32 | 40 | 50 | 65 | 80 | 100 | 125 | |
|------------------------|----|-----|-----|-----|-----|-----|------|------|
| Dimensions in mm | a | 320 | 405 | 510 | 653 | 810 | 1035 | 1270 |
| | b | 90 | 100 | 100 | 130 | 145 | 160 | 170 |
| | c | 95 | 110 | 110 | 120 | 135 | 150 | 175 |
| | d | 230 | 305 | 410 | 523 | 665 | 875 | 1100 |
| | k | 95 | 120 | 140 | 160 | 185 | 210 | 235 |
| | D | 115 | 144 | 164 | 188 | 217 | 242 | 267 |
| Weight in kg (approx.) | | 5 | 8 | 11 | 17 | 21 | 40 | 53 |

STANDARD CONSTRUCTION:

- Housing: temperature change resistant graphite
- Motive nozzle: PTFE/GFK
- Connection clamps: aluminium cast
- Steam connections: steel galvanized

SPECIAL CONSTRUCTIONS with different connections, nominal pressure stages of the flange: materials on request.

For inquiries please use our questionnaire.

| (new construction with flanges acc. to EN1092) | DN | 25 | 50 | 80 | 100 |
|--|----|-----|-----|-----|------|
| Dimensions in mm | a | 360 | 600 | 985 | 1320 |
| | b | 90 | 100 | 145 | 160 |
| | c | 100 | 110 | 135 | 150 |
| | d | 270 | 500 | 840 | 1150 |
| Weight in kg (approx.) | | 5 | 11 | 21 | 40 |

The motive nozzle connections are not given in the above overview as they depend on the operating conditions.

Steam jet ventilators

APPLICATIONS

Steam jet ventilators convey air, gases and vapors against small pressure differences up to approximately 500 mbar and are used, e.g.:

- to draw off waste air, exhaust gases and vapor
- to ventilate tanks
- as forced blast blowers, or stack ventilators for boiler burners
- to extract and mix exhaust gases from the thermal afterburning (fig. 1)

The achievable pressure difference between the suction pressure and discharge pressure is the compression of the steam jet ventilator.

ADVANTAGES

- no moving parts
- maintenance free
- can be installed in virtually all situations
- quickly and easily put into operation
- almost unlimited life, when a suitable material of construction is chosen
- can be manufactured from various materials of construction
- low acquisition costs

Instead of steam, it is also possible to use compressed air or another gas as motive fluid for jet ventilators. For more detailed information please refer to the section "Gas jet ventilators", 7|gv 1.

Apart from steam, air or gas, liquids may be used as the motive medium for jet ventilators. For further information please refer to the section "Liquid jet ventilators", 7|fv 1.

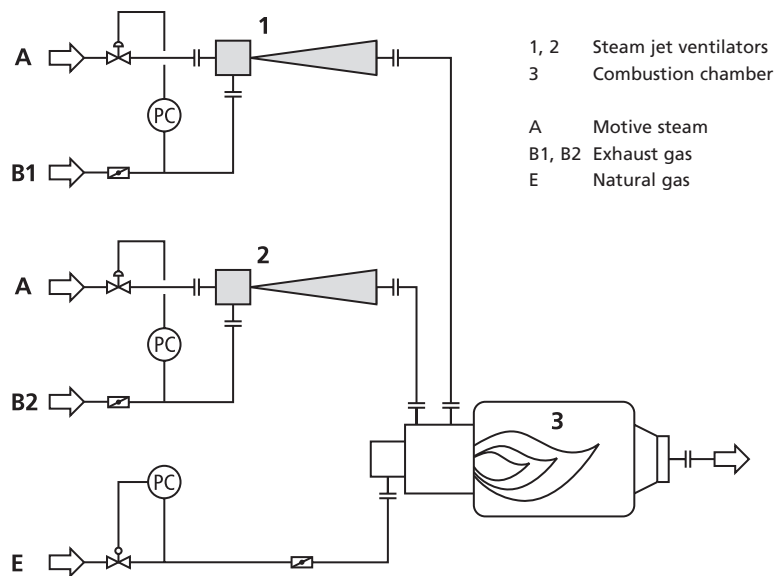
As opposed to liquid jet ventilators, steam or gas jet ventilators have the advantage that larger pressure differentials can be managed.

Steam jet ventilators operate in a range between $\Delta p = 0$ to 500 mbar. Above 500 mbar, steam jet compressors are used (see also section "Steam jet compressors", 7|bv1).



Steam jet ventilator in stainless steel

FIG. 1

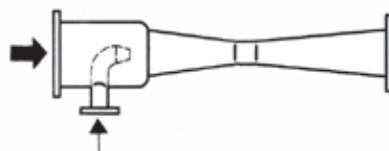


Steam jet ventilators to convey exhaust gases to thermal afterburning

CONSTRUCTIONS

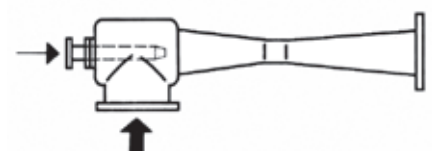
STEAM JET VENTILATORS ARE AVAILABLE IN TWO DIFFERENT CONSTRUCTIONS:

FIG. 2



Design with axial suction connection

FIG. 3



Design with lateral suction connection

DETERMINING THE MOTIVE STEAM CONSUMPTION

The diagram **fig. 4** shows the suction ratio m in kg suction medium per kg motive medium in relation to the compression Δp in mbar, at various motive steam pressures in bar.

Steam jet ventilators operate in a range between $\Delta p = 0$ to 500 mbar.

The motive liquid consumption is calculated by the following equation:

$$\dot{M}_1 = \frac{\dot{M}_0}{m} \text{ in } \frac{\text{kg}}{\text{h}}$$

- \dot{M}_0 Suction flow in kg/h
- \dot{M}_1 Motive medium in kg/h (steam)
- m Suction ratio in kg suction medium/kg motive medium

EXAMPLES FOR CALCULATION OF APPROX. MOTIVE STEAM CONSUMPTION

GIVEN:

Suction flow 1500 kg/h air

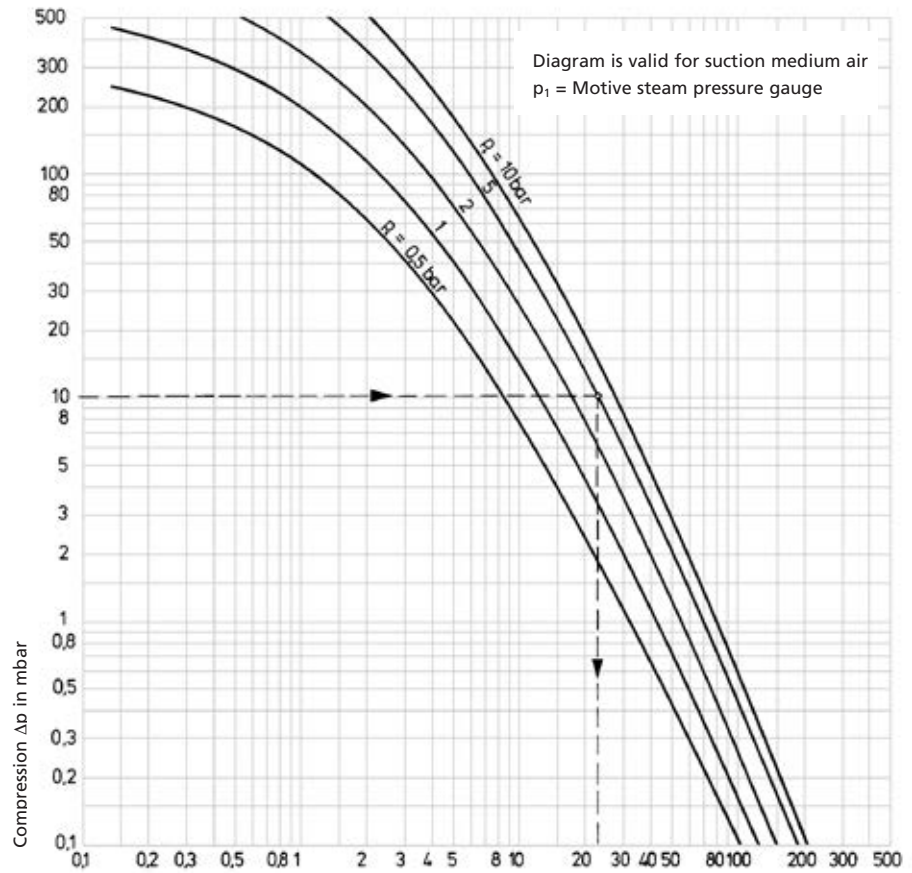
1. Required compression $\Delta p = 10$ mbar with motive steam at 5 bar, **fig. 5** shows a suction ratio of $m = 23.5$ kg/kg

$$\text{Steam consumption} = \frac{1500}{23.5} \approx 64 \frac{\text{kg}}{\text{h}}$$

2. Required compression $\Delta p \sim 0$ mbar with motive steam at 5 bar, **fig. 5** shows a suction ratio of $m = \text{ca. } 190$ kg/kg.

$$\text{Steam consumption} = \frac{1500}{190} \approx 8 \frac{\text{kg}}{\text{h}}$$

FIG. 4



$$\text{Suction ratio } m = \frac{\dot{M}_0}{\dot{M}_1} \text{ in } \frac{\text{kg Suction medium}}{\text{kg Motive medium}}$$

MATERIALS, CONSTRUCTION AND CONNECTION DIMENSIONS

Steam jet ventilators are designed according to the special requirements and are delivered in the following materials of construction:

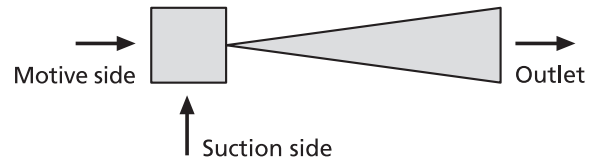
Cast iron EN-GJS-400-15 (GG40), steel, stainless steel, plastic material. Moreover, special materials of construction are possible, such as Titanium, Hastelloy.

Dimensions, connection dimensions and special capacity data on request.

For inquiries please use our questionnaire.

Questionnaire

for steam jet ventilators
dv1



[Link to fillable PDF](#)

1. MOTIVE SIDE

| | | | |
|-----------------------|------------------------|------------------------------|---------|
| Motive medium | Molecular weight | kg/kmol | |
| Motive pressure | bar abs. | Specific heat capacity | kJ/kg K |
| Temperature | °C | | |

2. SUCTION SIDE

| | | | |
|------------------------|-------------------|------------------------------|---------|
| Suction medium | Temperature | °C | |
| Suction flow | kg/h | Molecular weight | kg/kmol |
| Suction pressure | bar abs. | Specific heat capacity | kJ/kg K |

3. OUTLET

| | | | |
|-----------------------------------|----------|------------------|------|
| Required discharge pressure | bar abs. | Mixed flow | kg/h |
|-----------------------------------|----------|------------------|------|

4. FURTHER DATA **MATERIAL OF CONSTRUCTION**

CONNECTIONS:

Flanges
 Thread
 Others

DESIGN CODE (if required):

AD-2000
 ASME
 Others

DESIGN:

Temperature

FLANGES ACCORDING TO:

EN1092-1
 ASME lbs
 Others

APPLICATION:

.....

Pressure

FURTHER NOTES:

.....

.....

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Steam jet liquid pumps

General information

TYPICAL APPLICATIONS

ELEVATING AND CONVEYING of liquid chemicals such as lyes, acids, tanning liquors, lime milk, effluent water, spent wash, mash, bilge water, etc.

CIRCULATING with simultaneous heating of the liquid contents.

CONSTRUCTION AND MODE OF OPERATION

The 3 main components of steam jet liquid pumps are head, diffuser and motive nozzle. The steam jet emerging from the motive nozzle at high velocity transmits its kinetic energy to the liquid, mixes with it and condenses. In this way, the liquid is conveyed and its pressure is increased at the same time (also see "General Information about Jet Pumps", ↗ | ab11).

These pumps operate like a steam jet vacuum pump and evacuate the suction pipelines. They are, therefore, self-priming.

SPECIAL PROPERTIES

- simple erection and servicing
- no moving parts, therefore, no wear
- maintenance-free
- great reliability and safety of operation
- long life
- low cost

WORKING RANGE

In compliance with the varying demands, two different classes of standard steam liquid pumps are constructed:

1. CLASS A

for low suction heights, up to max. 1 m (where, density, $\rho = 1000 \text{ kg/m}^3$ or liquid feed) and large discharge pressures

2. CLASS B

for larger suction heights and discharge pressures up to approx. 1.1 bar g

In addition to the standard pumps, we supply special constructions for larger suction heights and discharge pressures.

SPECIAL CONSTRUCTIONS FOR THE NUCLEAR INDUSTRY

Steam jet liquid pumps are also used in nuclear plants to convey and circulate aggressive and radioactive liquids in the unapproachable "hot" zone, e.g. in a re-processing plant of nuclear fuel.

To meet the high demands in this field, they are specially constructed and made of particularly resistant stainless steel in accordance with the special tests and codes. Special quality assurance measures are ensured for manufacture and acceptance.



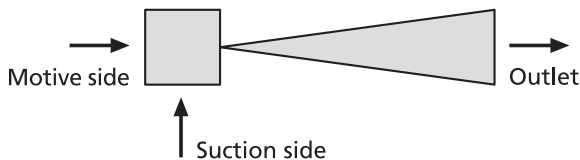
Steam jet liquid pump in steel



Special construction for the nuclear industry of a steam jet liquid pump in stainless steel

Questionnaire

for steam jet liquid pumps
dfp1, dfp2



[Link to fillable PDF](#)

1. MOTIVE SIDE Motive pressure bar abs. Temperature °C

2. SUCTION SIDE Suction medium Temperature °C
 Suction flow m³/h Density kg/m³
 Delivery head m WC Steam pressure bar abs.
 or suction pressure bar abs.

3. OUTLET Required discharge pressure bar abs.

4. FURTHER DATA MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges
 Thread
 Others

FLANGES ACCORDING TO:

EN1092-1
 ASME lbs
 Others

DESIGN CODE (if required):

AD-2000
 ASME
 Others

APPLICATION:

.....

DESIGN:

Temperature °C Pressure bar g

FURTHER NOTES:

Additional details, if required,
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Steam jet liquid pumps

Class A

PERFORMANCE CHART

Steam jet liquid pumps class A are suitable for low suction heights, up to max. 1 m (where, density, $\rho = 1000 \text{ kg/m}^3$ or for liquid feed) and large discharge pressure.

EXAMPLE

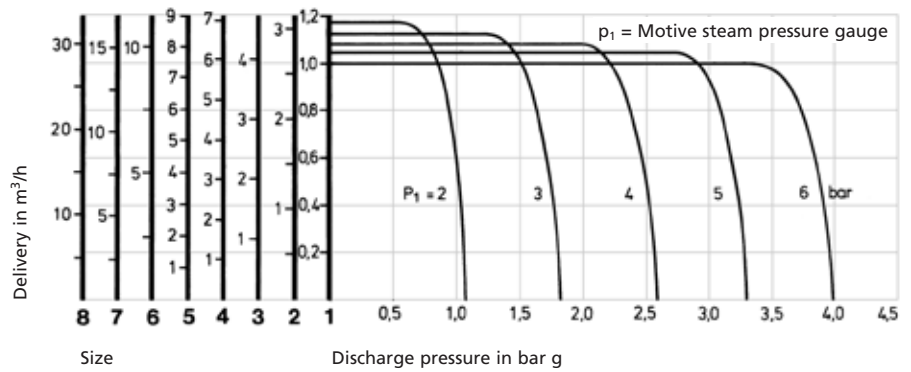
6 m³/h of water is to be drawn at a suction height of 1 m and conveyed to a discharge pressure of 1.6 bar g.

A motive steam pressure of 3 bar g is available.

PARAMETERS TO BE FOUND: Pump size and motive steam consumption.

SOLUTION: The diagram **fig. 1** shows that for a discharge pressure of 1.6 bar g and a motive steam pressure of 3 bar g in relation to the delivery of 6 m³/h, a pump size 5 has to be used.

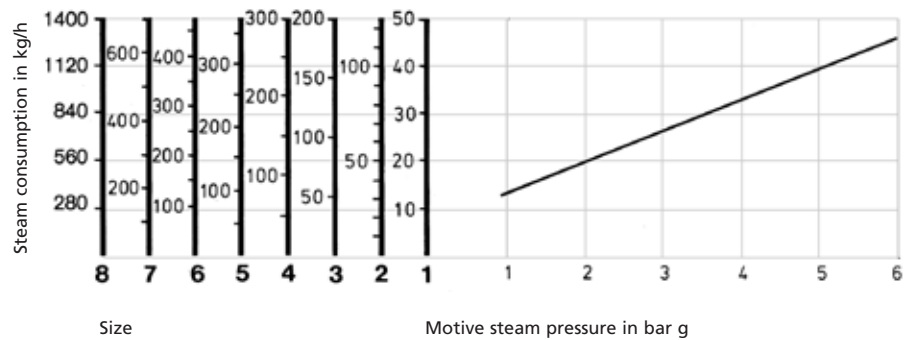
FIG. 1



Delivery in m³/h of water at a suction height of approximately 1 m in relation to the discharge pressure at varying motive steam pressures p_1 .
Size 1 achieves only 65-70% of the given discharge pressures.

Fig. 2 shows a steam consumption of approx. 190 kg/h for the chosen size.

FIG. 2

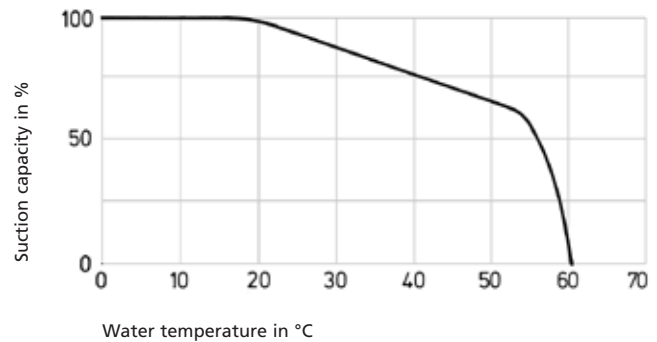


Steam consumption in kg/h of the individual sizes in relation to the motive steam pressure.

The liquid to be conveyed must not be too hot, so that the motive steam condenses in it and the total energy is available to convey the liquid (see diagram **fig. 3**).

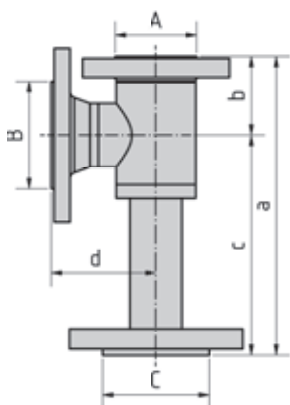
It must be taken into consideration that not only higher temperatures, but also higher specific gravities of the liquid to be conveyed reduce the performance of the pumps.

FIG. 3



The drop in % of the delivery with increasing water temperature

FIG. 4



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-------------------------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| Motive steam connection | A | 15 | 20 | 25 | 25 | 32 | 32 | 40 | 50 |
| Suction connection | B | 20 | 25 | 32 | 40 | 50 | 50 | 65 | 80 |
| Pressure connection | C | 20 | 25 | 32 | 40 | 50 | 50 | 65 | 80 |
| Dimensions in mm | a | 130 | 190 | 205 | 235 | 285 | 285 | 380 | 460 |
| | b | 50 | 60 | 60 | 70 | 75 | 75 | 95 | 110 |
| | c | 70 | 80 | 85 | 85 | 100 | 100 | 120 | 125 |
| | d | 80 | 130 | 145 | 165 | 210 | 210 | 285 | 350 |
| Weight in kg (approx.) | | 4 | 6 | 8 | 10 | 12 | 12 | 19 | 27 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, motive nozzle: brass (2.1090)
 - II Housing: steel, motive nozzle: stainless steel (1.4571)
 - III Housing: stainless steel (1.4571), motive nozzle: stainless steel (1.4571)
- Flanges according to EN1092-1/PN 16/PN 40

SPECIAL CONSTRUCTIONS for other capacity data or materials such as stainless steel, Hastelloy, Titanium, etc. on request.

SPECIAL CONSTRUCTIONS FOR THE NUCLEAR INDUSTRY are supplied in welded construction according to the special test and acceptance conditions.

Dimensions, connections and special capacity data on request.

For inquiries please use our questionnaire.

Steam jet liquid pumps

Class B

PERFORMANCE CHART

Steam jet liquid pumps class B are constructed for suction heights larger than 1 m and discharge pressure up to approximately 1.1 bar g.

EXAMPLE

5 m³/h of water is to be drawn from a manometric suction pressure of -0.6 bar and conveyed to a discharge pressure of 0.45 bar g.

PARAMETERS TO BE FOUND: Pump size, motive steam pressure and consumption required

SOLUTION: The delivery and the suction pressure determine the size of the pump whilst the discharge pressure determines the motive steam pressure required.

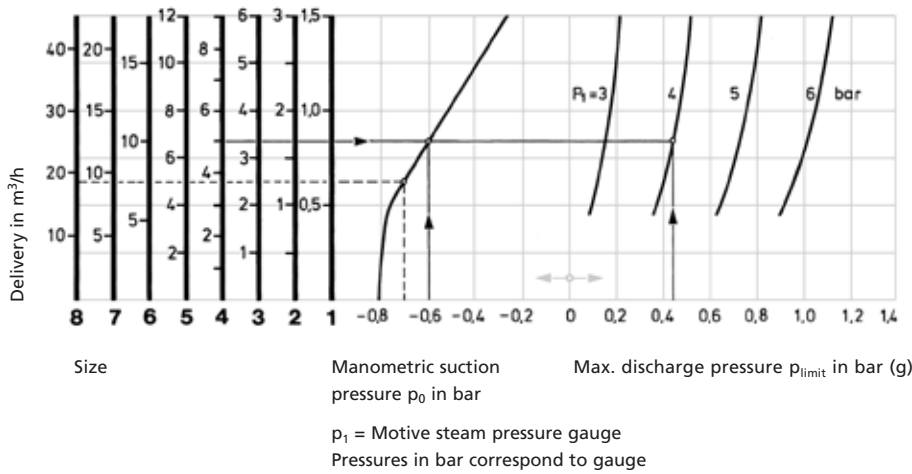
The example in fig. 5 gives a size 4 pump and a motive steam pressure of 4 bar.

The steam consumption of 110 kg/h is found in diagram fig. 6.

Steam jet liquid pumps operate like a steam jet vacuum pump and evacuate the suction pipelines (in start-up). They are, therefore, self-priming.

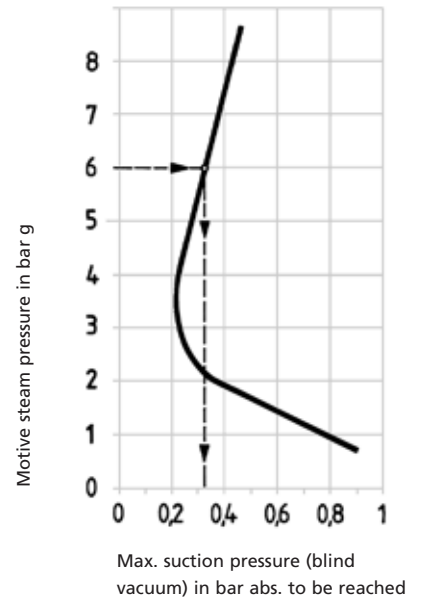
It must each time be checked by means of fig. 7 whether at the motive steam pressure determined according to fig. 5 the maximum suction pressure (blind vacuum) is lower than the necessary manometric suction pressure.

FIG. 5



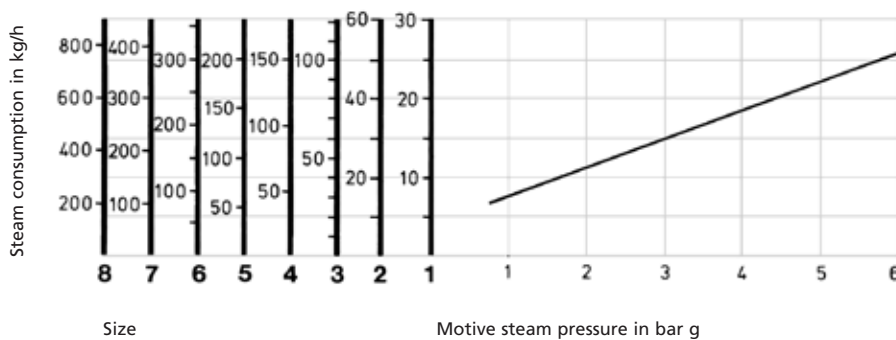
Delivery in m³/h of water at a temperature of 20 °C, depending on the suction and discharge pressure (limit discharge pressure) at different motive steam pressures p_1

FIG. 7



Suction behaviour (blind vacuum) of steam jet liquid pumps class B

FIG. 6



Steam consumption in kg/h of the individual sizes in relation to the motive steam pressure

The liquid to be conveyed must not be too hot, because only if the motive steam condenses and thereby loses its volume, can the total energy available to convey the liquid become fully effective (see diagram fig. 8).

With lower suction height or liquid feed, liquids with temperature up to 90 °C can be conveyed.

The theoretical suction pressure shown in fig. 9 with the broken line, for the same delivery, changes from -0.7 bar at 20 °C to -0.4 bar at 60 °C.

FIG. 8

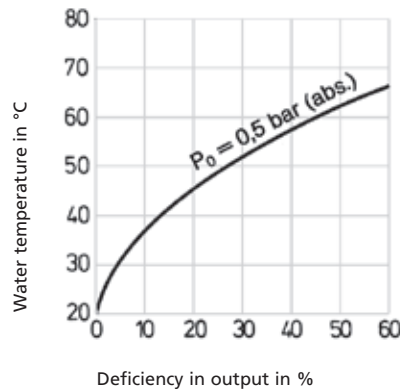
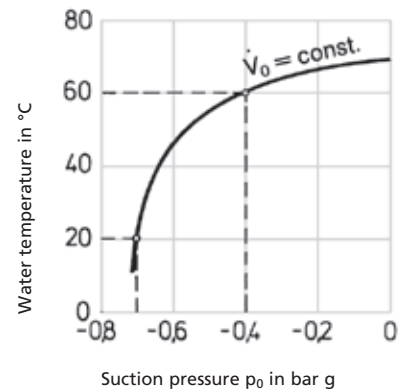


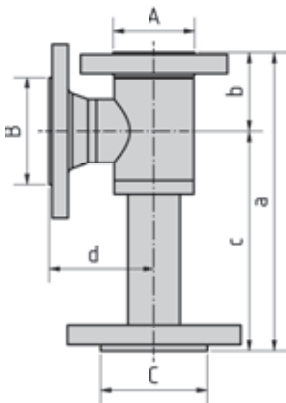
FIG. 9



Influence of the water temperature on the delivery at a constant geodetic suction height of 5 m and a constant motive steam overpressure of 5 bar.

Relation between the theoretical suction pressure (manometric suction height) and the water temperature.

FIG. 10



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-------------------------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| Motive steam connection | A | 15 | 20 | 25 | 25 | 32 | 32 | 40 | 50 |
| Suction connection | B | 20 | 25 | 32 | 40 | 50 | 50 | 65 | 80 |
| Pressure connection | C | 20 | 25 | 32 | 40 | 50 | 50 | 65 | 80 |
| Dimensions in mm | a | 130 | 190 | 205 | 235 | 285 | 285 | 380 | 460 |
| | b | 50 | 60 | 60 | 70 | 75 | 75 | 95 | 110 |
| | c | 70 | 80 | 85 | 85 | 100 | 100 | 120 | 125 |
| | d | 80 | 130 | 145 | 165 | 210 | 210 | 285 | 350 |
| Weight in kg (approx.) | | 4 | 6 | 8 | 10 | 12 | 12 | 19 | 27 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, motive nozzle: brass (2.1090)
 - II Housing: steel, motive nozzle: stainless steel (1.4571)
 - III Housing: stainless steel (1.4571), motive nozzle: stainless steel (1.4571)
- Flanges according to EN1092-1/PN 16/PN 40

SPECIAL CONSTRUCTIONS for other performance data or materials, such as for example stainless steel, Hastelloy, Titanium, etc. on request.

SPECIAL CONSTRUCTIONS FOR THE NUCLEAR INDUSTRY are supplied in welded construction according to the special test and acceptance conditions.

Dimensions, connections and special capacity data on request.

For inquiries please use our questionnaire.

Steam jet heaters

General information

Steam jet heaters are used to heat liquids by direct injection of heating steam. The heating steam condensate mixes with the liquid being heated.

Steam jet heaters are used to prepare hot water for different purposes, such as barrel rinsing water in malting plants, warm water for pickling, dyeing, and greases in tanneries, for washrooms and bathrooms and for heating sewage sludge, boiling lyes etc.

SPECIAL FEATURES

- low noise operation
- simple construction
- no moving parts
- low maintenance
- high reliability
- adjustable heating capacity

CONSTRUCTION FORMS

There are generally 2 different construction forms, according to the application

- steam jet heaters for vessels
- steam jet heaters for installation in pipes and for passage and circulation heating systems: Type "L", Type "H", "System Ciba-Geigy"



Steam jet heater for vessels with threaded connection, type 18.1 in cast stainless steel



Steam jet heater for vessels with flanged connection, type 18.1 in cast iron



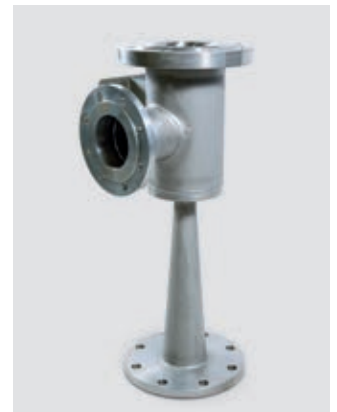
Steam jet heater, type "L" in steel



Steam jet heater, type "L" in stainless steel



Steam jet heater, type "H" in steel



Steam jet heater, type "H" in stainless steel



Steam jet heater "System Ciba-Geigy" in cast iron



Steam jet heater "System Ciba-Geigy" in stainless steel

Questionnaire

for steam jet heaters for vessels
aw1

[Link to fillable PDF](#)

1. DIMENSIONS OF THE TANK OR BASIN

Volume of the tank or basin m³ Width mm
Diameter mm Height mm
Length mm

2. REQUIREMENTS ON THE HEATING

Heating capacity kW Heating time h
Heating steam pressure bar abs. Initial temperature °C
Heating steam temperature °C Final temperature °C

MEDIUM TO BE HEATED:

Specific heat capacity kJ/kg K Dyn. viscosity mPas
Vapor pressure at final temperature bar abs. Density kg/m³

FURTHER REQUIREMENTS:

.....
.....
.....

3. FURTHER DATA

MATERIAL OF CONSTRUCTION

Installation according to catalog sheet aw1 Fig. 2 Fig. 4

CONNECTIONS:

Flanges
Thread
Others

FLANGES ACCORDING TO:

EN1092-1
ASME lbs
Others

FURTHER NOTES:

.....
.....
.....

Additional details, if required,
are to be stated separately.

Your inquiry no.
Offer submitted until
Requested date of delivery

YOUR ADDRESS

Company Telephone
attn. Telefax
Street/P.O. Box E-mail
ZIP code/City
Country

Steam jet heaters for vessels

APPLICATION

Steam jet heaters are used to heat all kinds of liquids in vessels. Heating is achieved by means of direct condensation of steam. The steam condensate mixes with the liquid.

MODE OF OPERATION

The steam jet emerging from the motive nozzle accelerates the liquid present in its vicinity and in the mixing nozzle, and condenses (see also "General information on jet pumps", 7 | ab 1).

In this way a controlled flow is produced. Furthermore, the whole content of the vessel is set in motion and the heat transferred to the liquid is evenly distributed throughout the vessel.

All the heaters are provided with a threaded connection for an air pipe. Normally it is not necessary to operate with air supply. However, the admission of air greatly intensifies the movement of the circulating liquid; it can also assist in avoiding condensation hammers and rattling that may occur when starting with a cold liquid.

If air is to be supplied, a corresponding line with installed regulation valve has to be connected (see fig. 2, 4, 6). Depending on the application, atmospheric air which is sucked in by the heater itself is sufficient.

To operate the steam jet heater, a steam overpressure of at least 1.5 bar is necessary to overcome the static pressure of the liquid and to achieve the minimum speed at which no disturbing noise is produced. The heaters described can also be used for operating with low pressure steam (special construction).

PERFORMANCE CHART

On the bottom scale, the chart in fig. 1 gives the heat flow in kW for each size. This is the heat content of the inflowing steam. However, the heat actually transferred to the liquid is less. It is reduced by the heat contained in the condensate.

The condensate flow produced by the condensation of the inflowing steam is given on the top scale. With the aid of this scale and the temperature ϑ of the heated liquid, the heat flow actually transferred is calculated as follows:

$$\dot{Q}_{tr} = \dot{Q} - \dot{M}_c \cdot c \cdot \vartheta \cdot \left(\frac{1}{3600}\right) \text{ kW}$$

Whereas:

- \dot{Q}_{tr} Transferred heat flow in kW
- \dot{Q} Heat flow in kW = Enthalpy of the inflowing steam
- \dot{M}_c Condensate flow in kg/h
- c Specific heat capacity of the condensate in kJ/kg °C (water = 4.2)
- ϑ Temperature of the heated water in °C

EXAMPLE

GIVEN: A steam quantity of approx. 70 kg/h is required to heat a vessel.

Steam at 2 bar g is available.

SOLUTION: The chart in fig. 1 shows that size 1-80 matches the example.

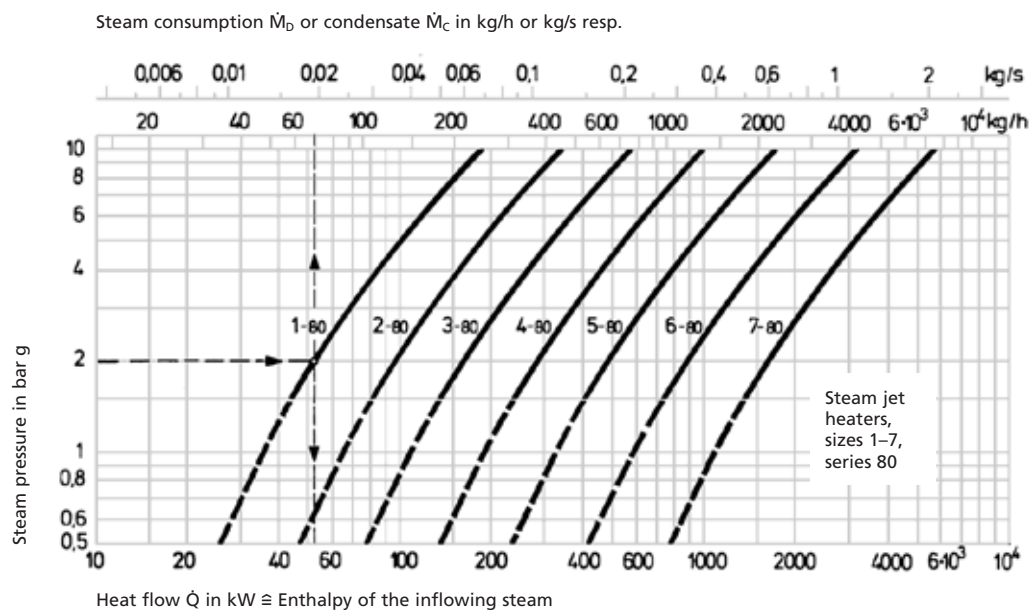


Steam jet heater type 18.1, with thread



Steam jet heater type 28.1, with flange

FIG. 1



Performance chart for steam jet heaters, size 1 to 7, construction series 80, for water

EXAMPLE OF INSTALLATION: STEAM JET HEATER TYPE 18.1, WITH THREAD



Steam jet heater type 18.1, with thread

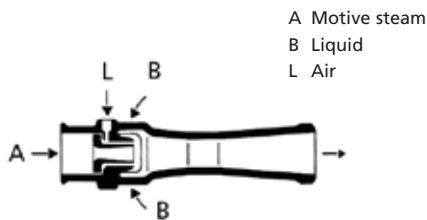


FIG. 2

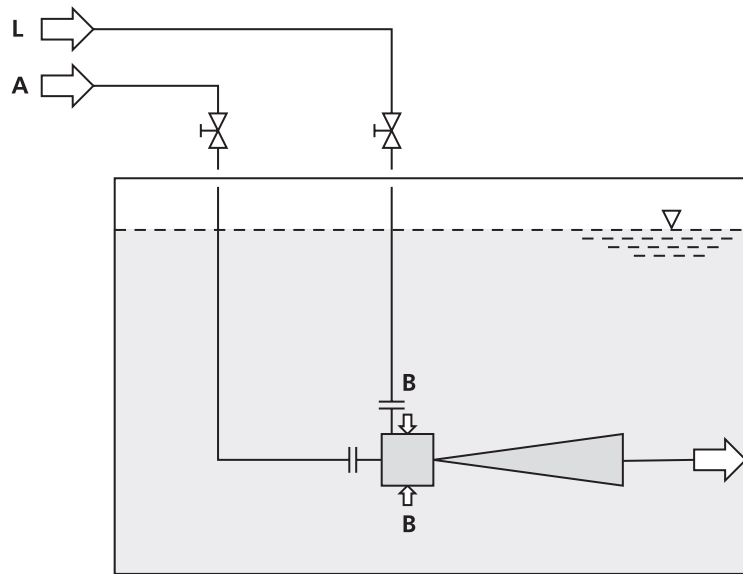
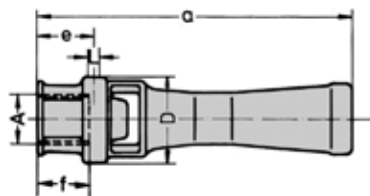


FIG. 3



CONNECTIONS, DIMENSIONS AND WEIGHTS
STEAM JET HEATER TYPE 18.1, WITH THREAD

| Size | | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|------------------------|---|-------|-------|---------|---------|-------|-------|-------|
| Nominal diameter | A | G 3/4 | G 1 | G 1 1/2 | G 1 1/2 | G 2 | G 3 | G 4 |
| | L | G 1/8 | G 1/8 | G 1/4 | G 1/4 | G 1/4 | G 3/8 | G 3/8 |
| Dimensions in mm | a | 170 | 220 | 265 | 345 | 400 | 520 | 610 |
| | D | 52 | 60 | 75 | 85 | 100 | 125 | 160 |
| | e | 35 | 40 | 40 | 40 | 50 | 75 | 80 |
| | f | 20 | 25 | 24 | 24 | 30 | 33 | 40 |
| Weight in kg (approx.) | | 1 | 2.6 | 2.8 | 4.2 | 6.4 | 13 | 23 |

STANDARD CONSTRUCTIONS:

- I Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel
 - II Housing: cast stainless steel (1.4581), motive nozzle: stainless steel
- Thread according to DIN ISO 228

SPECIAL CONSTRUCTIONS: other capacities or materials e.g. Hastelloy, Titan and more on request.

Please indicate size, type and material with your order.

For inquiries please use our questionnaire.

EXAMPLE OF INSTALLATION: STEAM JET HEATER TYPE 28.1, WITH FLANGE



Steam jet heater type 28.1, with flange

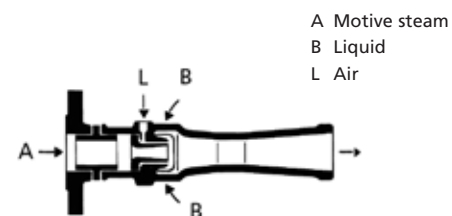


FIG. 4

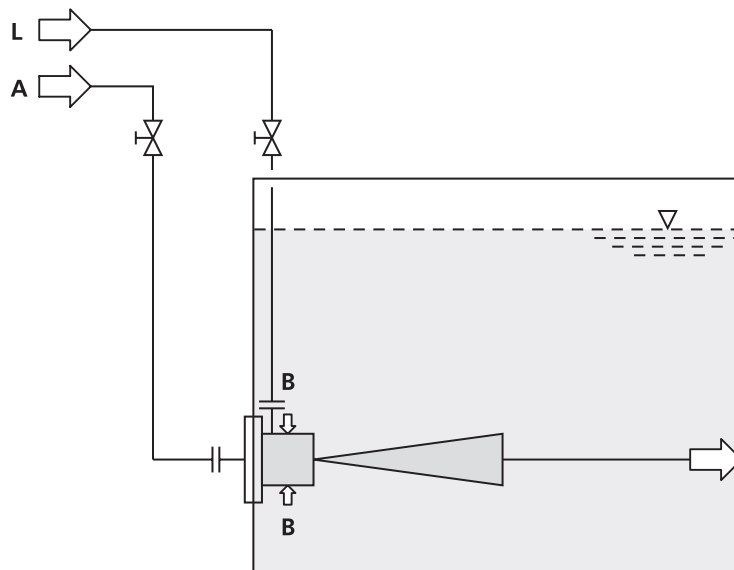
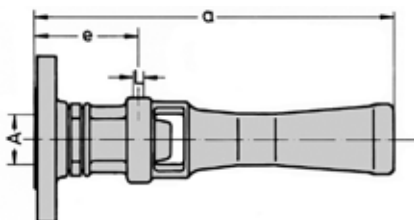


FIG. 5



CONNECTIONS, DIMENSIONS AND WEIGHTS
STEAM JET HEATER TYPE 28.1, WITH FLANGE

| | Size | 1-80 | 2-80 | 3-80 | 4-80 | 5-80 | 6-80 | 7-80 |
|------------------------|------|-------|-------|-------|-------|-------|-------|-------|
| Nominal diameter | A | 20 | 25 | 40 | 40 | 50 | 80 | 100 |
| | L | G 1/8 | G 1/8 | G 1/4 | G 1/4 | G 1/4 | G 3/8 | G 3/8 |
| Dimensions in mm | a | 205 | 255 | 300 | 380 | 440 | 570 | 665 |
| | e | 70 | 75 | 75 | 75 | 90 | 125 | 135 |
| Weight in kg (approx.) | | 2.2 | 3 | 5.2 | 6.6 | 9.3 | 18 | 30 |

STANDARD CONSTRUCTIONS:

- I Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel
 - II Housing: cast stainless steel (1.4581), motive nozzle: stainless steel
- Flanges according to EN1092-1 PN 16
Threads according to DIN ISO 228

SPECIAL CONSTRUCTIONS: other capacities or materials e.g. Hastelloy, Titan and more on request.

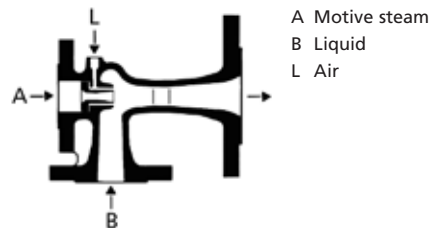
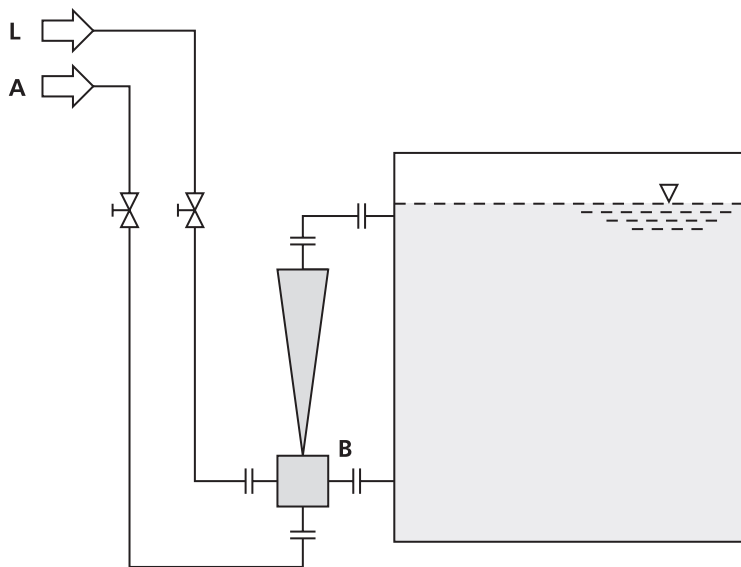
Please indicate size, type and material with your order.

For inquiries please use our questionnaire.

EXAMPLE OF INSTALLATION: STEAM JET HEATER WITH HOUSING, TYPE 38.1

SPECIAL CONSTRUCTIONS DESIGNED ACCORDING TO THE CUSTOMER'S SPECIFICATION

FIG. 6



Steam jet heaters, type 38.1 must only be used for a liquid level of min. 0.5 m above the heater.

Dimensions, connection dimensions, materials and special capacity data on request.

Steam jet heaters "L"

for installation in pipelines

APPLICATION

Steam jet heaters are used to heat liquids by means of direct condensation of steam. The steam condensate mixes with the liquid. Steam jet heaters, type "L" are used in passage and circulation heating systems. The achievable heating per pass amounts to max. 90 K.

MODE OF OPERATION

The condensation nozzle is inside the steam jet heater. It is provided with bore holes so that the steam can pass directly into the liquid to be heated and condenses (fig. 7). This takes place at the point of highest velocity of the liquid, its lowest pressure and its greatest turbulence.

The downstream arranged diffuser reduces the velocity of the liquid again at the same time increasing its pressure.

The heaters can be installed in any position. The steam valve shall be installed directly at the steam connection, if possible. A straight smoothing and slowing-down section of at least 10 x DN is to be provided for downstream of the heater.

The heaters perform a noiseless operation and can be designed even for exhaust steam. Under defined conditions, the liquid to be heated flows through the heater without pressure loss; with sufficiently high steam pressure, a pressure boost is achieved.

Fig. 8 shows the max. permissible discharge pressure p in relation to p_f and p_D ; in start-up mode, i.e. without steam, the discharge pressure p is allowed to be max. 60% of the water inlet pressure p_f .



Steam jet heater type "L"

FIG. 7

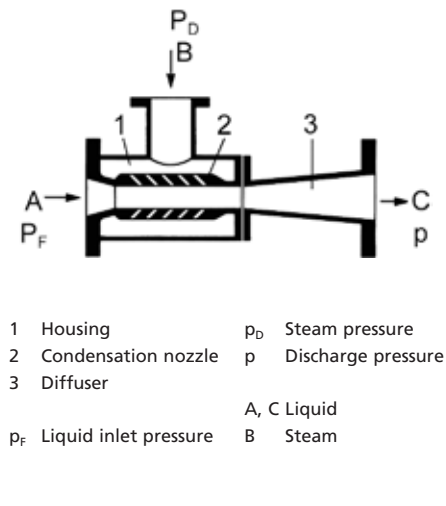


FIG. 8

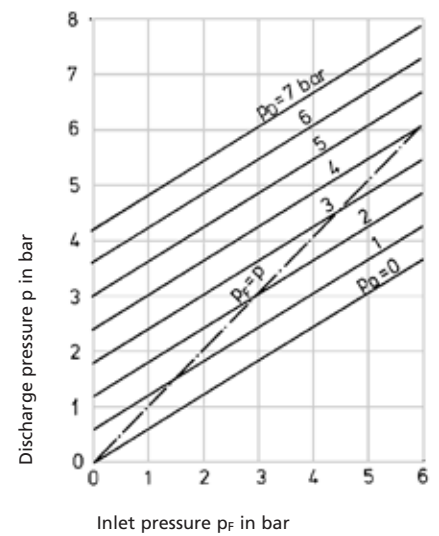
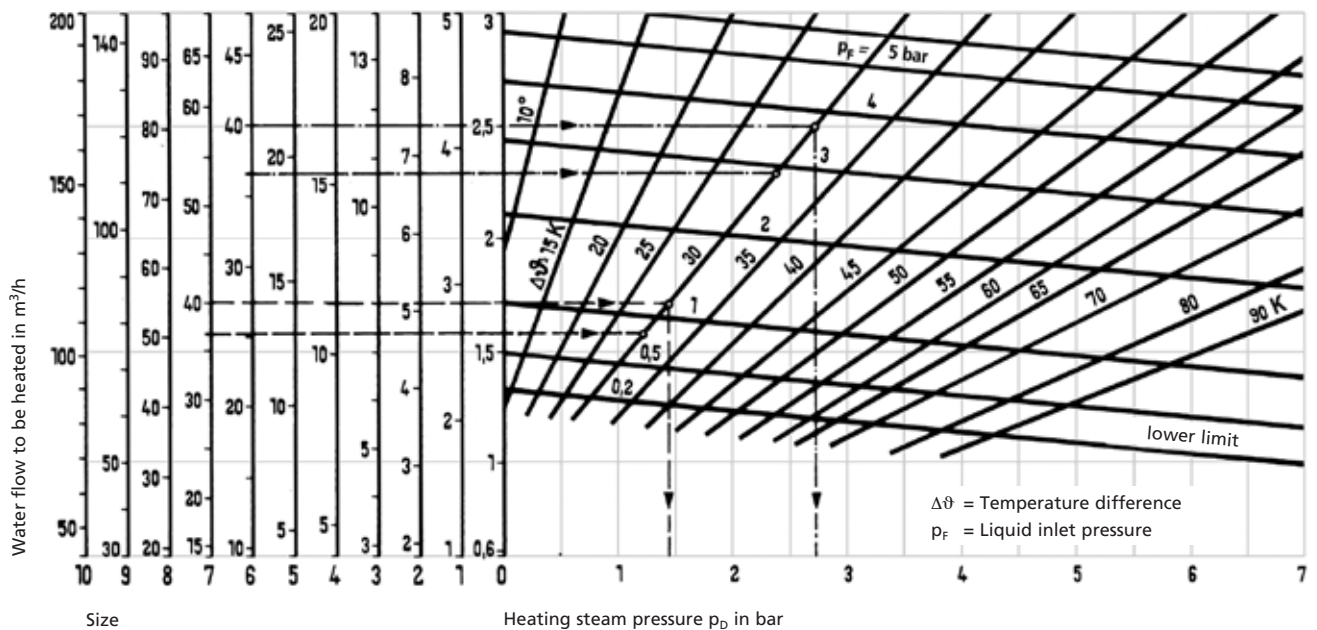


FIG. 9



The performance chart fig. 9 shows to which temperature a liquid can be heated, depending on the liquid flow and on the steam pressure at an inlet temperature of 20 °C

EXAMPLE

40 m³/h water is to be heated from 10 °C to 40 °C with steam between 1-2 bar.

PARAMETERS TO BE FOUND: Size of the heater and steam consumption.

DETERMINATION OF THE SIZE: Diagram fig. 10 shows that the liquid flow rate at an inlet temperature of 10 °C = 110%. This means that the determination of the size and of the water inlet pressure has to be based only on 36.5 m³/h instead of 40 m³/h. Thus, size 6 as well as size 7 are to be found for this in diagram fig. 9.

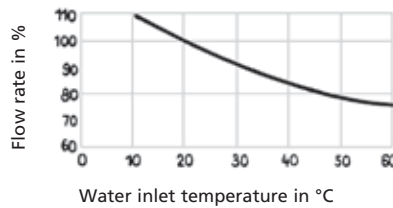
Water inlet pressure at size 6: 3.0 bar at size 7: 0.8 bar

DETERMINATION OF THE STEAM CONSUMPTION:

According to fig. 11, the steam consumption at a steam pressure of 1.4 bar and size 0 amounts to approx. 80 kg/h.

In order to determine the steam consumption of another size, the steam consumption of size 0 is multiplied by the factor of the size to be found.

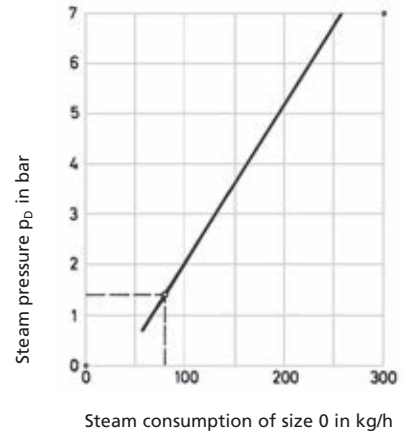
FIG. 10



Influence of the liquid inlet temperature on the liquid flow rate

According to the table, the factor for size 7 is 23. Thus, the steam consumption for size 7 is resulting with:
80 x 23 = 1840 kg/h.

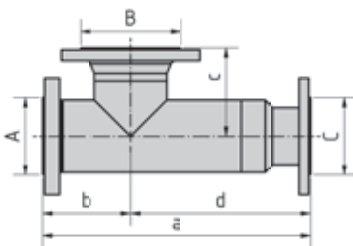
FIG. 11



Steam consumption of size 0 in function of the steam pressure

| Size | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------|---|------|---|-----|------|-----|----|----|----|----|----|
| Factor | 1 | 1.67 | 3 | 4.6 | 6.75 | 8.6 | 16 | 23 | 32 | 49 | 67 |

FIG. 12



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|------------------------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|
| Nominal diameter | A | 25 | 32 | 40 | 50 | 65 | 65 | 80 | 100 | 125 | 150 | 150 |
| | B | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 | 200 | 250 |
| | C | 25 | 32 | 40 | 50 | 65 | 65 | 80 | 100 | 125 | 150 | 150 |
| Dimensions in mm | a | 230 | 265 | 310 | 350 | 380 | 425 | 650 | 890 | 975 | 1275 | 1275 |
| | b | 70 | 85 | 100 | 110 | 125 | 140 | 200 | 345 | 365 | 515 | 515 |
| | c | 85 | 100 | 105 | 120 | 130 | 140 | 175 | 200 | 200 | 200 | 200 |
| | d | 160 | 180 | 210 | 240 | 255 | 285 | 450 | 545 | 610 | 760 | 760 |
| Weight in kg (approx.) | | 7 | 9 | 12 | 15 | 21 | 23 | 34 | 51 | 60 | 72 | 90 |

STANDARD CONSTRUCTIONS:

- I Housing: steel, condensation nozzle: red brass
 - II Housing: steel, condensation nozzle: stainless steel (1.4571)
 - III Housing: stainless steel (1.4571), condensation nozzle: stainless steel (1.4571)
- Flanges: EN1092-1 PN 16

SPECIAL CONSTRUCTIONS: other capacities or materials e.g. Hastelloy, Titan and more on request.

For inquiries please use our questionnaire.

Steam jet heaters "H"

for passage and circulation heating systems

APPLICATION

Steam jet heaters are used to heat liquids by means of direct injection of steam. Steam jet heaters, type "H", are used in passage and circulation heating systems.

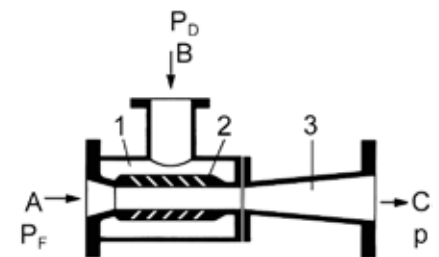
- heating to max. 30 K per pass
- steam flow control range up to max. 5:1

For greater control ranges see "Steam jet heaters, System Ciba Geigy", 71 aw6.

MODE OF OPERATION

The condensation nozzle is inside the steam jet heater. It is provided with bore holes so that the steam can pass directly into the liquid to be heated and condenses (fig. 13). This takes place at the point of highest velocity of the liquid, its lowest pressure and its greatest turbulence.

FIG. 13



- | | | |
|-----------------------------|-------|--------------------|
| 1 Housing | p_D | Steam pressure |
| 2 Condensation nozzle | p | Discharge pressure |
| 3 Diffuser | | |
| | A, C | Liquid |
| p_F Liquid inlet pressure | B | Steam |

The downstream arranged diffuser reduces the velocity of the liquid again at the same time increasing its pressure.

In order to obtain a noiseless operation, the flow should not be heated by more than approx. $\Delta\theta = 30$ K per pass.

Only rarely does this type of heating require a constant heating capacity. Normally the steam is adjusted to the required operating condition by means of a temperature control circuit.

If possible, steam jet heaters, type "H", shall only be used at low discharge pressures.

The type "H" heater's ratio of maximum steam flow to minimum steam flow, its so-called control range, depends on the discharge pressure p and the steam pressure p_D .

In order to prevent the backing up of the liquid, through the holes into the steam chamber of the heater, the total control range must always remain at: $p_D \geq p$

The available steam pressure should be indicated to us for the design.

Steam jet heaters type "H" can be installed in any position. The free cross-sections of the connecting pipes of the liquid must be at least as large as the corresponding connections of the heater.

A straight smoothing and slowing-down section of at least $10 \times DN$ is to be provided for downstream of the heater. The steam valve shall be provided for directly at the steam connection, if possible.

PERFORMANCE CHART

The flow rate and the pressure loss determine the size of the steam jet heater. In circulation systems, the circulation pump must not only overcome the pressure loss of the heater, but also the flow resistance in the heating jacket and in the pipeline system.

The flow rate and the required heating determine the steam consumption. This is calculated according to the following formula:

$$\dot{M}_D = \dot{V} \cdot \rho \cdot \frac{c_L \cdot \Delta\theta}{h - c_C \cdot \vartheta}$$

- \dot{M}_D Steam consumption in kg/h
- \dot{V} Flow rate in m³/h
- ρ Density of the liquid in kg/m³
- c_L Specific heat capacity of the liquid in kJ/kg °C (water = 4.2)
- c_C Specific heat capacity of the condensate in kJ/kg °C (for water steam as heating medium = 4.2)
- $\Delta\theta$ Temperature difference per pass in K
- h Specific enthalpy of the steam in kJ/kg
- ϑ Temperature of the liquid at the discharge of the heater in °C



Steam jet heater type "H"

EXAMPLE

50 m³/h water is to be heated from 20 °C to 50 °C using steam at 3 bar. The liquid inlet pressure shall be $0.5 \leq p_F \leq 1$ bar g.

PARAMETER TO BE FOUND: Required steam quantity, size of the steam jet heater and required liquid inlet pressure p_F .

SOLUTION: Determination of the steam consumption:

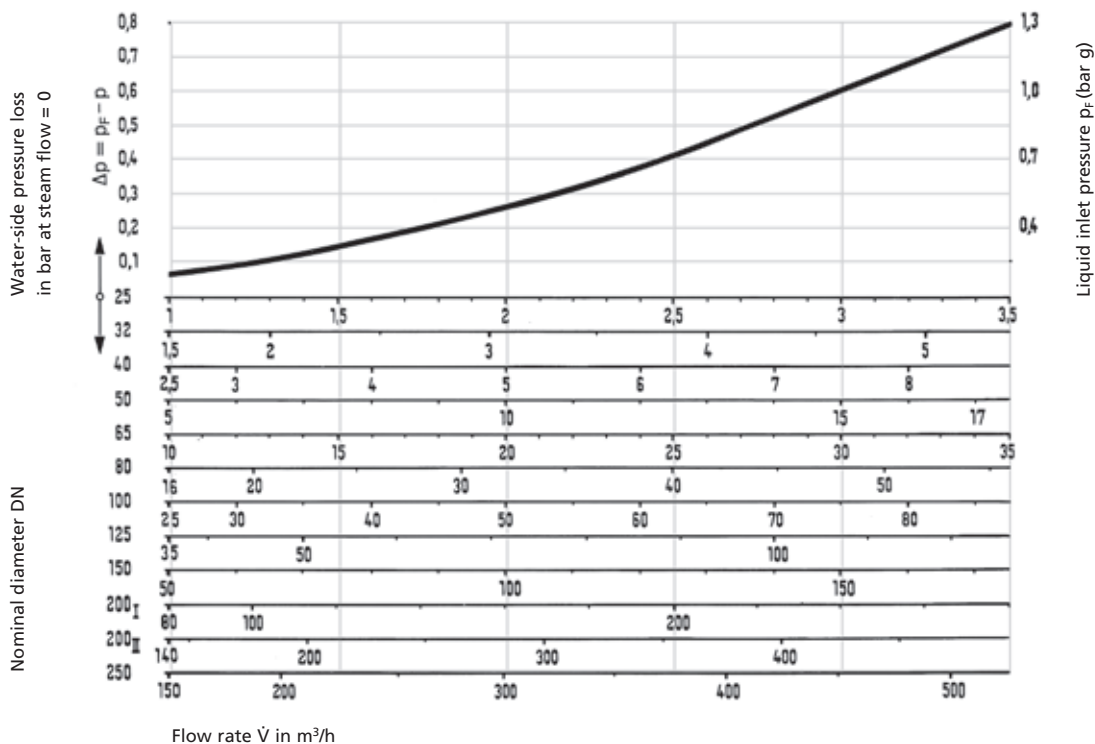
$$\dot{M}_D = 50 \cdot 1000 \cdot \frac{4.2 \cdot (50 - 20)}{2736 - 4.2 \cdot 50} \approx 2500 \frac{\text{kg}}{\text{h}}$$

The diagram in fig. 15 shows the following possibilities for a flow rate of 50 m³/h:

- Liquid inlet pressure for size DN 80: 1.1 bar
- Liquid inlet pressure for size DN 100: 0.5 bar
- Liquid inlet pressure for size DN 125: < 0.4 bar

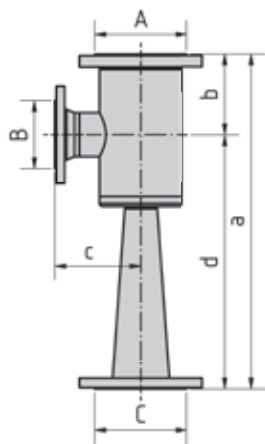
Due to the condition that liquid inlet pressure $0.5 \leq p_F \leq 1$ bar g, size DN 100 is selected.

FIG. 14



Relation between flow rate, heating and steam consumption

FIG. 15



CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 25 | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 I | 200 II | 250 |
|------------------------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|--------|------|
| Nominal diameter | A | 25 | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 | 200 | 250 |
| | B | 32 | 40 | 32 | 40 | 50 | 65 | 65 | 80 | 100 | 150 | 150 | 200 |
| | C | 25 | 32 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 | 200 | 250 |
| Dimensions in mm | a | 230 | 265 | 260 | 280 | 350 | 450 | 500 | 685 | 750 | 1000 | 1050 | 1400 |
| | b | 70 | 85 | 70 | 80 | 80 | 115 | 100 | 165 | 165 | 200 | 200 | 250 |
| | c | 85 | 100 | 115 | 125 | 125 | 135 | 135 | 175 | 200 | 200 | 200 | 250 |
| | d | 160 | 180 | 190 | 200 | 270 | 335 | 400 | 520 | 585 | 800 | 850 | 1150 |
| Weight in kg (approx.) | | 7 | 9 | 10 | 14 | 23 | 24 | 30 | 38 | 44 | 71 | 77 | 112 |

STANDARD CONSTRUCTIONS:

DN 125 TO DN 250:

- I Housing: steel, condensation nozzle: red brass
 - II Housing: steel, condensation nozzle: stainless steel (1.4571)
 - III Housing: stainless steel (1.4571), condensation nozzle: stainless steel (1.4571)
- Flanges according to EN1092-1 PN 16

SPECIAL CONSTRUCTIONS are possible in most of the usual materials.

For inquiries please use our questionnaire.

Steam jet heaters "System Ciba-Geigy"

for passage and circulation heating systems

APPLICATION

Steam jet heaters are used to directly heat a liquid with heating steam.

Steam jet heaters, "System Ciba Geigy", are used in passage and circulating heating systems and for batch processes:

- flow rates of 2–700 m³/h
- heating per pass up to approx. 30 K
- control range of heating capacity up to 200:1
- heating up to approx. 5 °C below the saturated steam temperature of the heating steam

MODE OF OPERATION

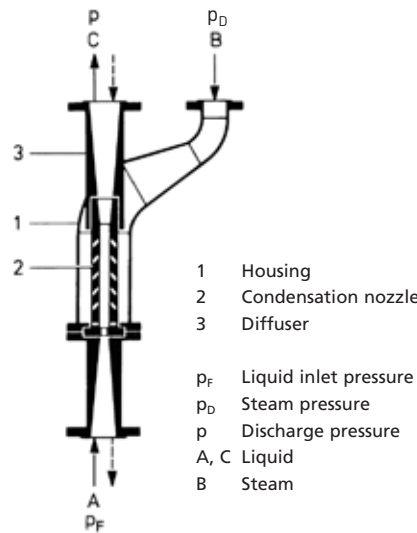
Inside the heater there is a condensation nozzle, which is, in principle, a cylinder with holes bored through. The steam passes into the liquid to be heated and condenses (fig. 16).

This occurs at the point of the highest velocity of the liquid, its lowest pressure and maximum turbulence.

In the downstream-arranged diffuser the velocity of the liquid is reduced, at the same time increasing its pressure.

Heating processes rarely require a constant heating capacity. Normally the steam flow is adjusted to the required operating conditions, by means of a temperature control circuit (fig. 17).

FIG. 16



Steam jet heater "System Ciba-Geigy"

In many cases in process technology, a large control range is required.

The steam jet heater "System Ciba-Geigy" by GEA allows a control range of up to 200:1 with a noiseless operation.

This exceptionally large control range is not achieved by a mechanical process, but hydraulically by the liquid to be heated itself, by freeing more or fewer holes, thereby increasing or decreasing the free open area for the steam flow.

INSTALLATION INFORMATION

- vertical installation only
- steam supply from top to bottom only
- direction of flow of the liquid optionally from top to bottom or vice versa. By replacing the condensation nozzle you can change the sense of flow even afterwards
- steam control valve installed directly on the steam connection
- system layout possible according to fig. 18

FIG. 18

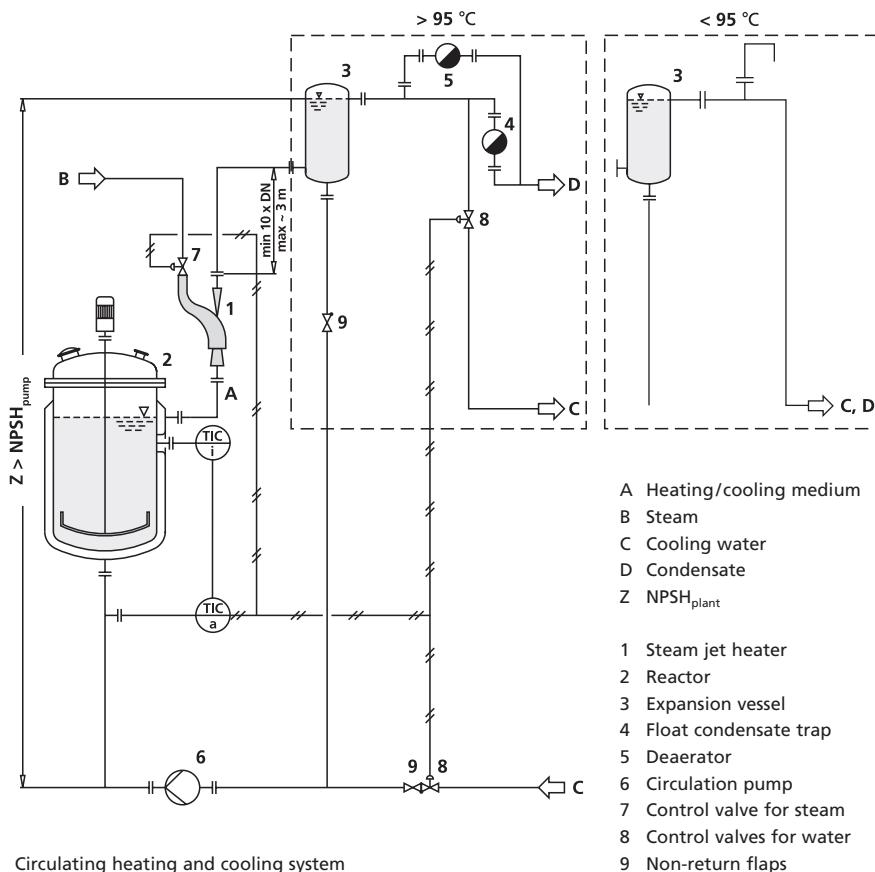
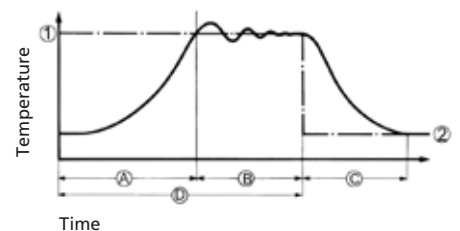


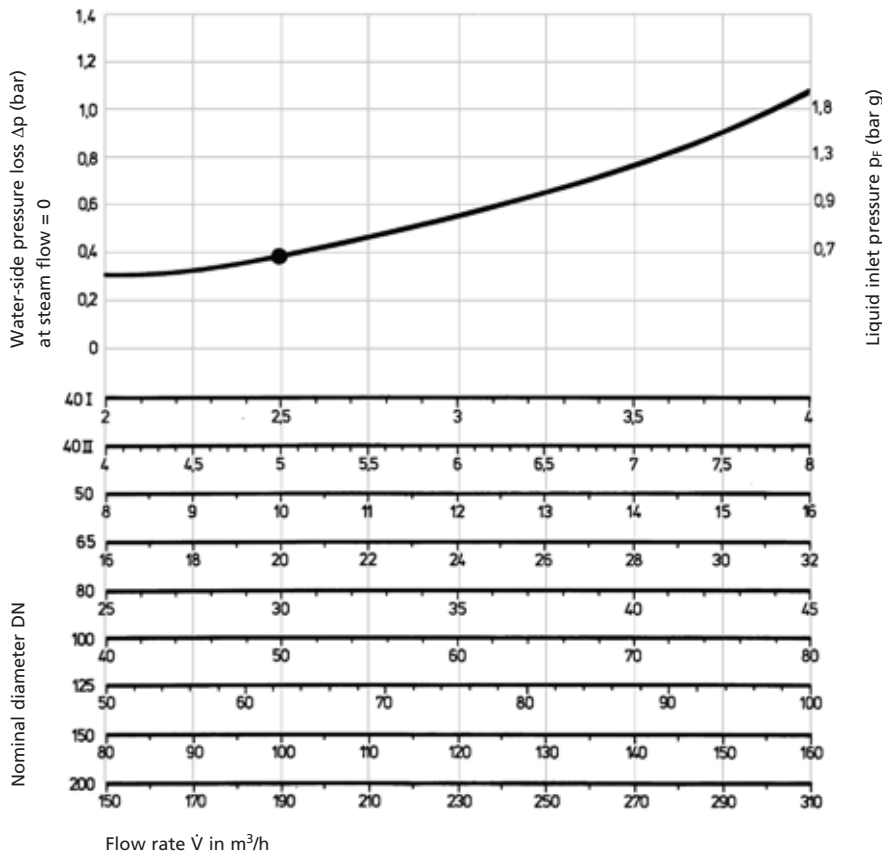
FIG. 17

Temperature/time profile for a batch process



1–2 = Required temperature
A = Heating
B = Temperature maintaining
C = Cooling
D = Working range of the steam jet heater

FIG. 19



PERFORMANCE CHART

The flow rate and the pressure loss determine the size of the steam jet heater. In fig. 19, the pressure loss at steam flow = 0 is in relation to the circulated flow rate. At temperature differences greater than 10 °C between inlet and outlet, the pressure loss will reduce due to the conveying effect of the steam. This has the advantage that, during the heating phase the circulation pump is relieved, the circulated flow rises and a better heat transfer is achieved.

The flow rate and the required heating determine the steam flow. This is calculated according to the following formula:

$$\dot{M}_D = \dot{V} \cdot \rho \cdot \frac{c_L \cdot \Delta \vartheta}{h - c_C \cdot \vartheta}$$

- \dot{M}_D Steam consumption in kg/h
- \dot{V} Flow rate in m³/h
- ρ Density of the liquid in kg/m³
- c_L Special heat capacity of the liquid in kJ/kg °C (water = 4.2)
- c_C Special heat capacity of the condensate in kJ/kg °C (for water steam as heating medium= 4.2)
- $\Delta \vartheta$ Temperature difference per pass in K
- h Special enthalpy of the steam in kJ/kg
- ϑ Temperature of the liquid at the outlet of the heater in °C

FIG. 20

CONNECTIONS, DIMENSIONS AND WEIGHTS

| | Size | 40 I | 40 II | 50 | 65 | 80 | 100 | 125 | 150 | 200 |
|------------------------|------|------|-------|-----|-----|-----|-----|------|------|------|
| Nominal diameter | A | 40 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 |
| | B | 40 | 40 | 40 | 50 | 65 | 65 | 80 | 100 | 150 |
| | C | 40 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 |
| Dimensions in mm | a | 450 | 450 | 500 | 630 | 800 | 900 | 1120 | 1300 | 1700 |
| | b | 158 | 158 | 188 | 205 | 217 | 250 | 305 | 400 | 535 |
| Weight in kg (approx.) | | 23 | 23 | 30 | 42 | 35 | 46 | 66 | 104 | 186 |

STANDARD CONSTRUCTION:

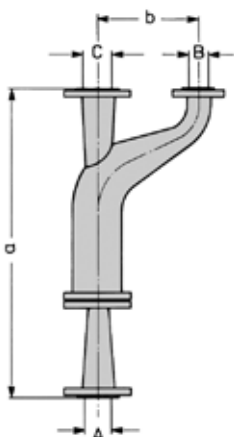
DN 40 TO 65:

- I Housing: cast iron EN-GJS-400-18-LT (GGG40.3), condensation nozzle: brass
- II Housing: cast iron EN-GJS-400-18-LT (GGG40.3), condensation nozzle: stainless steel (1.4571)

DN 40 TO 200:

- III Housing: steel, condensation nozzle: brass
 - IV Housing: steel, condensation nozzle: stainless steel (1.4571)
 - V Housing: stainless steel (1.4571), condensation nozzle: stainless steel (1.4571)
- Flanges EN1092-1 PN 16

SPECIAL CONSTRUCTIONS: other capacities or materials e. g. Hastelloy, Titan and more on request.



EXAMPLE

A circulating flow of 50 m³/h is to be heated from 40 °C to 80 °C by means of steam at 3 bar. The heating per pass is to amount to 20 K.

PARAMETERS TO BE FOUND: Required steam flow, size of the steam jet heater and liquid inlet pressure.

SOLUTION: Determination of the steam consumption:

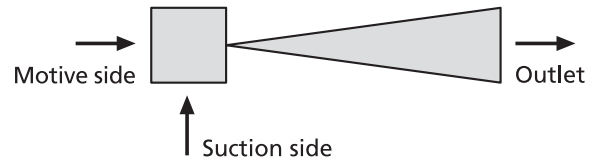
$$\dot{M}_D = 50 \cdot 1000 \cdot \frac{4.2 \cdot 20}{2736 - 4.2 \cdot 80} \approx 1750 \frac{\text{kg}}{\text{h}}$$

The diagram, fig. 20, shows a steam jet heater DN 100 for a circulating flow of 50 m³/h. The required liquid inlet pressure amounts to 0.7 bar g.

For inquiries please use our questionnaire.

Questionnaire

for steam jet heaters, type "L", aw4
 steam jet heaters, type "H", aw5
 steam jet heaters "System Ciba-Geigy", aw6



[Link to fillable PDF](#)

1. LIQUID INLET

| | | |
|-----------------------------|------------------------------|-------------------|
| Medium | Specific heat capacity | kJ/kg K |
| Rate of liquid flow | Dyn. viscosity | mPas |
| Temperature | Density | kg/m ³ |
| Liquid inlet pressure | | bar abs. |

2. OUTLET

| | |
|---|----------|
| Requested final temperature | °C |
| Required discharge pressure | bar abs. |
| FOR CIRCULATION SYSTEMS: | |
| Heating per pass | °C |
| Vapor pressure of the liquid at final temperature | bar abs. |

3. HEATING STEAM

| | | | |
|----------------|----------|-------------------|----|
| Pressure | bar abs. | Temperature | °C |
|----------------|----------|-------------------|----|

4. FURTHER DATA

MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges
 Thread
 Others

FLANGES ACCORDING TO:

EN1092-1
 ASME lbs
 Others

DESIGN CODE (if required):

AD-2000
 ASME
 Others

APPLICATION:

.....

DESIGN:

| | | | |
|-------------------|----|----------------|-------|
| Temperature | °C | Pressure | bar g |
|-------------------|----|----------------|-------|

FURTHER NOTES:

.....

.....

Additional details, if required,
 are to be stated separately.

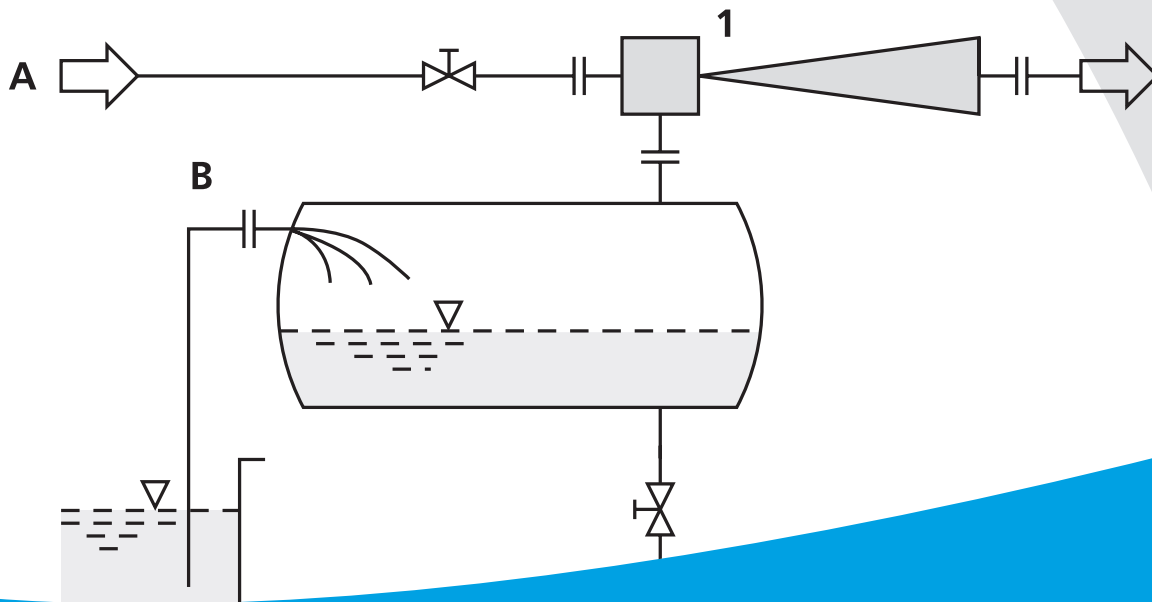
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| Street/P.O. Box | E-mail |
| ZIP code/City | |
| Country | |



Gas/air jet pumps

- Gas jet vacuum pumps and gas jet compressors
- Air jet vacuum pumps for connections to the suction side of liquid ring vacuum pumps
- Gas jet ventilators

Gas jet vacuum pumps and gas jet compressors

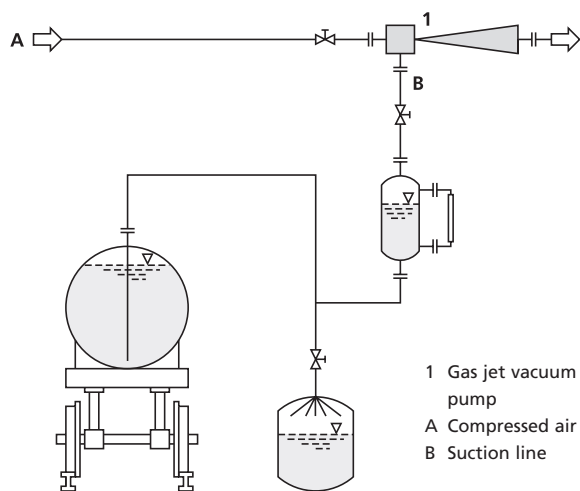
Gas jet vacuum pumps and air jet vacuum pumps operate on the same principle as all jet pumps: The pressure energy of the motive medium is converted into speed energy in the motive nozzle.

For more detailed information on structure and operating mode of jet pumps please refer to "General information on jet pumps", 7 | ab1.

Instead of liquid or steam, gas or compressed air is used as the motive medium. This is particularly suitable where no steam is available or where compressed air or gas as motive medium offer advantages over steam.

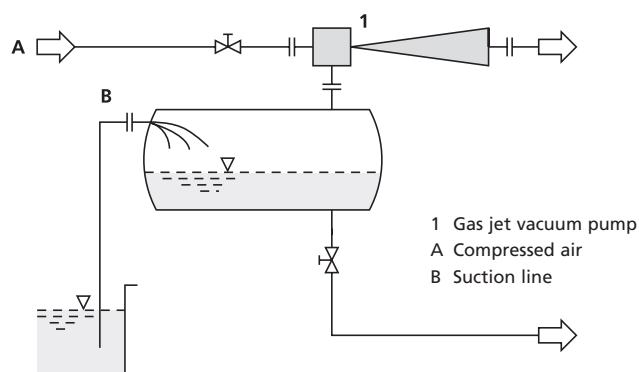
TYPICAL APPLICATIONS FOR GAS JET VACUUM PUMPS

FIG. 1



EXAMPLE 1: EVACUATION OF A SIPHONING INSTALLATION

FIG. 2



EXAMPLE 2: ELEVATION OF LIQUIDS WITH GAS/AIR

As long as the compressed air valve is open, a vacuum is produced and liquid is drawn into the vessel. When the compressed air is turned off, atmospheric pressure returns to the vessel, the vacuum is broken and elevation of the liquid stops. Typical application: suction of leak oil or petrol. Canal cleaning and emergency vehicles can be equipped with compressed air pumps for this purpose.



Gas jet vacuum pump



Gas jet vacuum pump for the nuclear industry

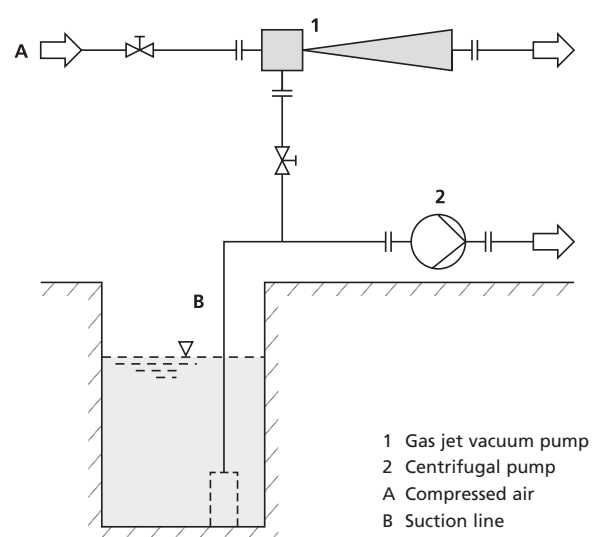


Gas jet compressor for the natural gas industry

GAS JET VACUUM PUMPS are used in many cases to evacuate pipelines, vessels and plants.

GAS JET COMPRESSORS are mainly used to mix and compress gases.

FIG. 3



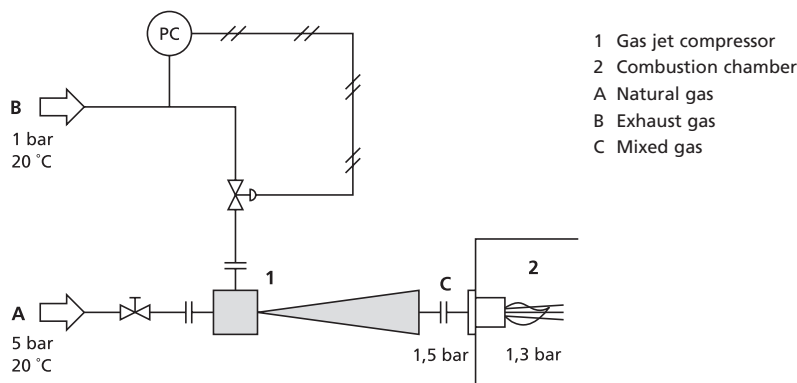
EXAMPLE 3: EVACUATION OF THE SUCTION LINE OF A CENTRIFUGAL PUMP

TYPICAL APPLICATION FOR GAS JET COMPRESSORS

EXAMPLE 1: TO SUCK IN AND MIX NATURAL GAS WITH OTHER GASES

If, for example, natural gas shall be mixed with an exhaust gas and then be burned off in a boiler plant, a gas jet compressor can be used. In this case the natural gas has a higher pressure and serves as motive medium. The exhaust gas, which predominantly is occurring at atmospheric pressure, is sucked in by the compressor and is compressed to the burner inlet pressure.

FIG. 4



Gas jet compressor to convey exhaust gas at atmospheric pressure into the steam boiler combustion chamber

DETERMINING THE COMPRESSED AIR CONSUMPTION

The compressed air consumption required is found in relation to the evacuating apparatus volume according to the following formula:

$$\dot{M}_A \approx A_{spec} \cdot V \cdot \frac{60}{t}$$

- \dot{M}_A Compressed air consumption in kg/h
- A_{spec} Specific compressed air consumption in kg compressed air/m³ of volume to be evacuated (Fig. 5)
- V Vessel volume to be evacuated
- t Evacuation time in minutes

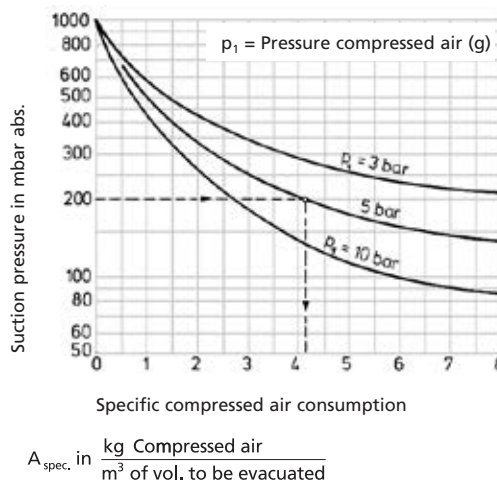
EXAMPLE

A vessel of 2 m³ is to be evacuated from atmospheric pressure to 200 mbar in 10 minutes. A compressed air pressure of 5 bar is available.

From fig. 5, you will find a specific air consumption of 4.15 kg of compressed air/m³ of volume to be evacuated. The compressed air consumption is, therefore:

$$\dot{M}_A \approx 4.15 \cdot 2 \cdot \frac{60}{10} \approx 50 \frac{kg}{h}$$

FIG. 5



MATERIALS, MEASUREMENTS AND CONNECTING DIMENSIONS

Gas jet vacuum pumps and gas jet compressors are specially calculated and fabricated to correspond to the particular operating conditions and can be supplied in the following materials for example:

Cast iron EN-GJS-400-15 (GGG40), steel, stainless steel, plastics. Moreover, there is the possibility to use special materials such as Titanium, Hastelloy and others.

SPECIAL CONSTRUCTIONS FOR THE NUCLEAR INDUSTRY are supplied in construction according to the special tests and inspection conditions.

Measurements, connecting dimensions and special capacity data on request.

For inquiries please use our questionnaire.

Air jet vacuum pumps

for connections to the suction side of liquid ring vacuum pumps

Air jet vacuum pumps use atmospheric air as motive medium. Backed by a liquid ring vacuum pump which produces an intermediate vacuum of 50 to 100 mbar, the air jet vacuum pump can reach a suction pressure of 5 mbar, depending on design and operating conditions.

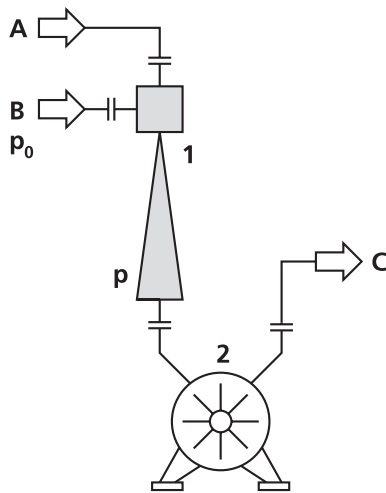
APPLICATIONS

- When no steam is available as motive medium for a steam jet vacuum pump required to produce a vacuum of 40 to 5 mbar.
- When a liquid ring pump is available with a suction capacity sufficient to handle the motive air of the air jet pump and when a suction pressure below 40 mbar is to be produced.
- When a vacuum of 40 to 5 mbar is to be produced and simple installation with low capital cost is important.
- When only a small suction capacity at a suction pressure of 40 to 50 mbar is required and cooling water at low temperature is available, because under these circumstances, the power consumption of the liquid ring vacuum pump is relatively low.



Air jet vacuum pump in stainless steel

FIG. 1



- 1 Air jet vacuum pump
- 2 Liquid ring vacuum pump
- A Atmospheric air as motive medium
- B Suction medium
- C Atmosphere
- p_0 Suction pressure
- p Discharge pressure of the air jet vacuum pump = Suction pressure of the liquid ring vacuum pump

Whenever it is a question of low energy consumption, it is better to connect a steam jet pump with condenser to the suction side of the liquid ring vacuum pump, whereby the motive medium (steam) of the jet pump is condensed and does not load the liquid ring vacuum pump as is the case with an air jet pump.

Method of operation of an air jet vacuum pump for connection to the suction side of a liquid ring vacuum pump

MATERIALS, CONSTRUCTION AND CONNECTING DIMENSIONS

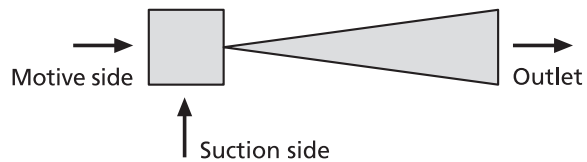
Air jet vacuum pumps are specially calculated and fabricated to correspond to the particular operating conditions and can be supplied in the following materials: Cast iron EN-GJS-400-15 (GGG40), steel, stainless steel, plastics, porcelain. Further, special materials of construction are possible, such as Titanium, Hastelloy etc.

Dimensions, connecting dimensions and special capacity data on request.

For inquiries please use our questionnaire.

Questionnaire

for gas jet vacuum pumps and
gas jet compressors, gp1
air jet vacuum pumps , lvp1
gas jet ventilators, gv1



[Link to fillable PDF](#)

1. MOTIVE SIDE

| | | | |
|-----------------------|------------------------|------------------------------|---------|
| Motive medium | Molecular weight | kg/kmol | |
| Motive pressure | bar abs. | Specific heat capacity | kJ/kg K |
| Temperature | °C | | |

2. SUCTION SIDE

| | | | |
|------------------------|-------------------|------------------------------|---------|
| Suction medium | Temperature | °C | |
| Suction flow | kg/h | Molecular weight | kg/kmol |
| Suction pressure | bar abs. | Specific heat capacity | kJ/kg K |

3. OUTLET

| | | | |
|-----------------------------------|----------|------------------|------|
| Required discharge pressure | bar abs. | Mixed flow | kg/h |
|-----------------------------------|----------|------------------|------|

4. FURTHER DATA

MATERIAL OF CONSTRUCTION

CONNECTIONS:

Flanges

Thread

Others

FLANGES ACCORDING TO:

EN1092-1

ASME lbs

Others

DESIGN CODE (if required):

AD-2000

ASME

Others

APPLICATION:

.....

.....

.....

DESIGN:

Temperature

°C

Pressure

bar g

FURTHER NOTES:

.....

.....

Additional details, if required,
are to be stated separately.

Your inquiry no.

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Gas jet ventilators

APPLICATIONS

Gas jet ventilators convey air, gases and vapors against pressure differences up to approximately 500 mbar.

Gas jet ventilators are used:

- to draw off stale air, ill-smelling gases and vapors from working and storage areas
- to ventilate tanks, e.g. on ships
- as forced blast blowers or stack ventilators for boiler burners
- for the circulation of air, in particular in the textile, leather and tobacco industries
- to deaerate reaction vessels, agitator vessels and other items of equipment in chemical factories

The achievable pressure difference between the suction and discharge pressure is the compression of a gas jet ventilator.

ADVANTAGES

- no moving parts
- maintenance free
- installed in virtually all situations
- immediately ready for operation
- almost unlimited life, when a suitable material of construction is chosen
- manufactured from various materials of construction
- low acquisition costs

Steam or liquid may be used, instead of compressed air or gas, as the motive medium for jet ventilators; in this case, one would speak of steam jet ventilators ($\nabla | dv1$) or liquid jet ventilators ($\nabla | fv1$).

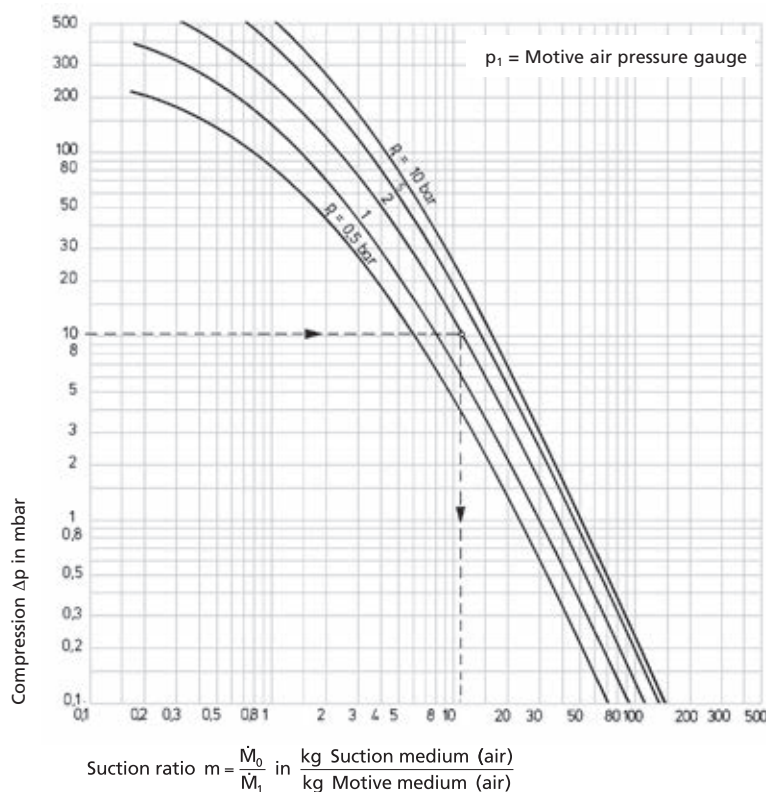
As opposed to liquid jet ventilators, gas or steam jet ventilators have the advantage that they can be installed in any installation



Gas jet ventilator in stainless steel

position and that larger pressure differentials can be obtained.

FIG. 1



The characteristic lines apply to air as motive medium.

In case the motive medium used is a gas other than air, the corresponding correction factors have to be considered.

Gas jet ventilators operate in a range between $\Delta p = 0$ to 500 mbar. Above 500 mbar, gas jet compressors are used, $\nabla | gp1$.

The motive medium consumption is calculated as follows:

$$\dot{M}_1 = \frac{\dot{M}_0}{m} \text{ in kg/h}$$

| | |
|-------------|---|
| \dot{M}_0 | Suction flow in kg/h |
| \dot{M}_1 | Motive steam consumption in kg/h (compressed air) |
| m | Suction ratio in kg suction medium/kg motive medium |

EXAMPLES

Suction flow: 1500 kg/h air \cong 1250 m³/h

Compressed air pressure: 2 bar (g)

1. Required compression $\Delta p = 10$ mbar

According to fig. 1, with compressed air at 2 bar, there is a suction ratio

$m = \text{approx. } 12.7 \text{ kg/kg.}$

$$\text{Compressed air consumption} = \frac{1500}{12.7} = 118 \frac{\text{kg}}{\text{h}}$$

2. Required compression $\Delta p \sim 0$ mbar

According to fig. 1, with compressed air at 2 bar, there is a suction ratio

$m = \text{approx. } 120 \text{ kg/kg.}$

$$\text{Compressed air consumption} = \frac{1500}{120} = 12.5 \frac{\text{kg}}{\text{h}}$$

DETERMINING THE MOTIVE MEDIUM CONSUMPTION

Diagram fig. 1 serves to roughly estimate the motive medium consumption. It shows the

suction ratio m in kg of suction medium per kg of motive medium in relation to the compression Δp in mbar, at various motive pressures in bar gauge.

APPLICATION SUCTION PLANT

An example for the deaeration of reaction vessels with a low-pressure gas jet ventilator. Here, air is fed into the gas jet ventilator as motive medium by a blower with low compression.

As the blower is only in contact with atmospheric air, a standard design without special corrosion proofing is sufficient.

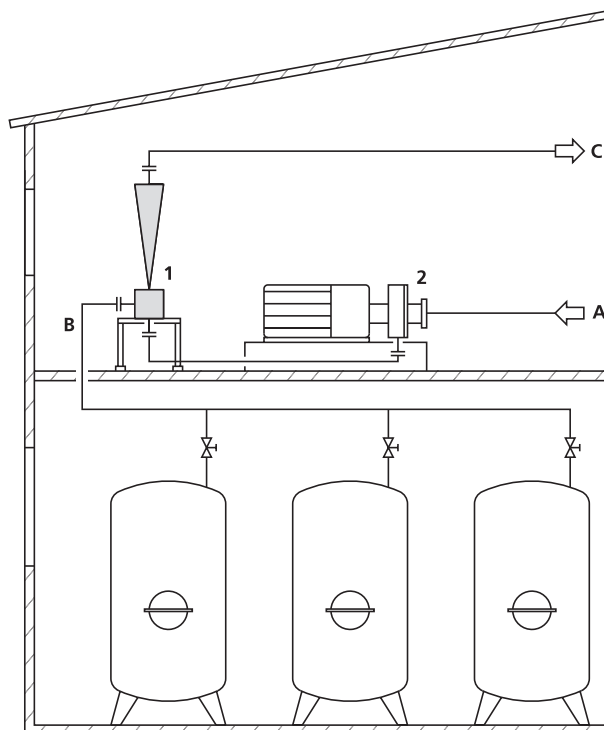
The drawn off exhaust gases are heavily rarefied by the motive air.

For reasons of air pollution control the exhaust gas air mixture is usually supplied to an exhaust gas cleaning plant.

FIG. 2

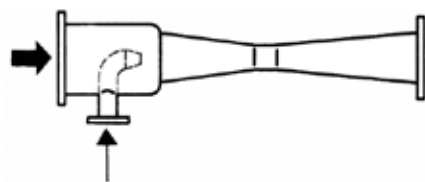
Suction plant with a low-pressure gas jet ventilator

- 1 Gas jet ventilator
- 2 Compressor
- A Air
- B Exhaust gas
- C To exhaust gas cleaning plant



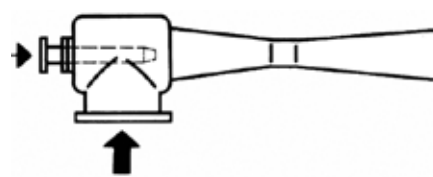
CONSTRUCTIONS OF GAS JET VENTILATORS

FIG. 3



Design with axial suction connection

FIG. 4



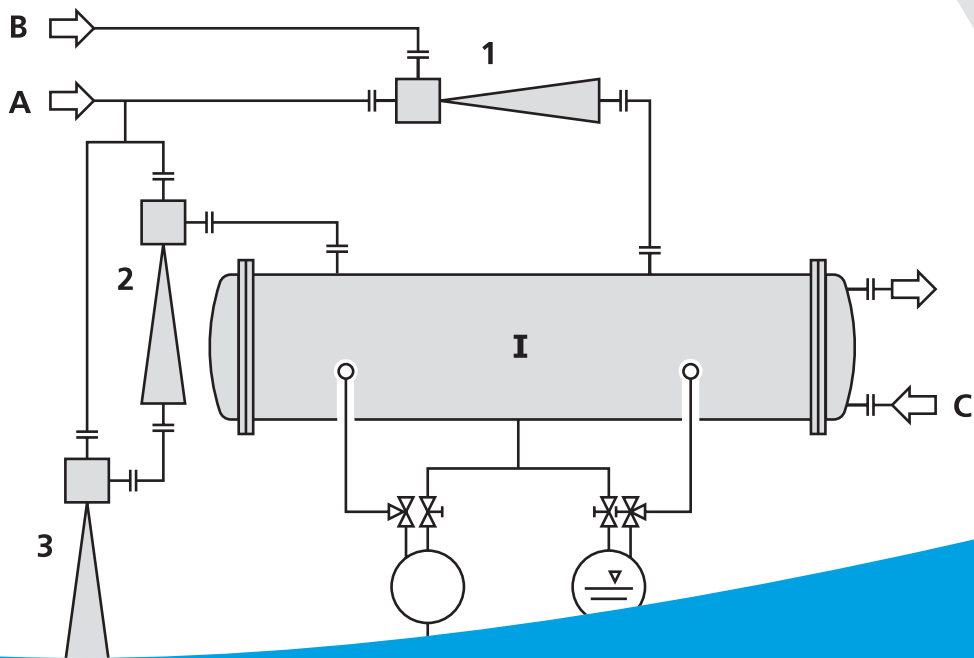
Design with lateral suction connection

MATERIALS, MEASUREMENTS AND CONNECTING DIMENSIONS

Gas jet ventilators are specially calculated and fabricated to correspond to the particular operating conditions and can be supplied in the following materials of construction: Cast iron EN-GJS-400-15 (GGG40), steel, stainless steel, plastics. Further, special materials of construction are possible, such as Titanium, Hastelloy etc.

Measurements, connecting dimensions and special capacity data on request.

For inquiries please use our questionnaire.



Vacuum systems

- Vacuum systems
- Multi-stage steam jet vacuum pumps
- Multi-stage steam jet vacuum pumps in metal construction with mixing condensers
- Multi-stage steam jet vacuum pumps in metal construction with surface condensers
- Multi-stage steam jet vacuum pumps in metal construction with liquid ring vacuum pumps (hybrid system)
- Multi-stage steam jet vacuum pumps in graphite
- Arrangements of steam jet vacuum pumps
- Laboratory steam jet vacuum pumps
- Planning a steam jet vacuum pump

Vacuum systems

ADVANTAGES AND OPERATION OF A STEAM JET VACUUM PUMP

Steam jet vacuum pumps are pumps without moving parts. They consist of the main components head, motive nozzle and diffuser which again consists of the inlet cone, the mixing nozzle and the discharge cone. Structure and mode of operation can be divided into three main processes:

- flashing the motive steam in the motive nozzle and formation of a directed steam jet
- mixing of the steam jet with the medium to be sucked in (air, gases and steam)
- conversion of the velocity of the mixture into pressure in the mixing nozzle and discharge cone

ADVANTAGES:

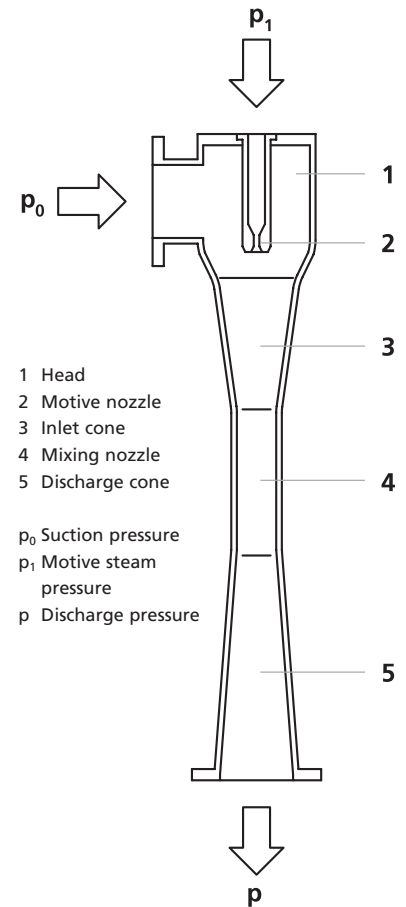
- no moving parts
- almost any vacuum duty can be accommodated including large suction flows
- low maintenance costs
- long equipment life
- reliable operation
- low operating costs if operated correctly
- manufacture possible in different materials

For further details on the mode of operation of jet pumps please refer to section "General information on jet pumps", 7.1.1.

Steam jet pumps are particularly suited as vacuum pumps as the large volumes can be easily handled in the vacuum due to the very high gas velocities.

When selecting steam jet vacuum pumps, their special performance characteristics must be taken into account to ensure proper and most effective operation. This document is designed to provide general information regarding the operation of steam jet vacuum pumps. It is not intended as a substitute for the assistance of our experienced engineers who are at your disposal to ensure the best equipment selection for meeting your requirements.

BILD 1



Cross section of a steam jet vacuum pump

Multi-stage steam jet vacuum pumps

Multi-stage steam jet vacuum pumps are used to produce vacuum in evaporators, driers, distillation plants, rectifying, freeze drying, poly-condensation, degassing, deodorizing plants etc.

The compression ratio of a single stage steam jet vacuum pump is limited (1:10, max. 1:20). Therefore, for low suction pressures, several jet vacuum pumps are arranged in series. A condenser is arranged between two jet pumps in order to condense the motive steam as far as possible. In this way, the volume of the complete gas mixture and thus the energy requirement of the next stage is reduced. Such multi-stage steam jet vacuum pumps are constructed for suction pressures up to approx. 0.01 mbar.

To compress process gases from a pressure of 0.3 mbar to a condenser pressure of 56 mbar (i.e. a compression ratio of $56:0.3 \approx 187$), two jet stages are just sufficient, each handling a compression ratio of approx. 14. For a suction pressure of 0.1 mbar, the pressure gradient is $56:0.1 \approx 560$, and therefore, 3 jet pumps must be arranged in series, each handling a compression ratio of 8.25 per stage. The maximum compression ratio for a steam jet vacuum pump depends on the suction pressure and the pressure of the available motive steam.

The condensers used are water-cooled mixing condensers or surface condensers, in some individual cases, even air-cooled condensers are used.

Steam jet vacuum pumps with mixing condensers are used where the extracted medium is allowed to get in contact with the cooling water and where the recovery of condensate is not required.

If, however, the contact with cooling water is not allowed, such as for example, if there is ammonia and chalky water, or if condensed product or motive steam condensate has to be recovered, surface condensers have to be used instead of mixing condensers.

For steam jet pumps for suction pressure of less than 6 mbar the head and the mixing nozzle are heated, depending on the installation position. In this way, the formation of ice inside the pump is avoided which otherwise could lead to trouble.

If steam jet vacuum pumps are required for the extraction of steams which contain any constituents with a high melting point (e.g. caprolactam, oligomers, low polymers in poly-condensation plants, etc.), heat jacketing is recommended even for higher suction pressure levels. For processes involving fluids with very high melting points, the ejectors are heated by means of vaporous or liquid diphyll, high temperature resistant oils or any other heat carrier fluid.

Steam jet vacuum pumps are mainly operated with water steam. Water steam is easily available in industry and proved well as motive fluid for jet pumps. In special cases in which the product condensate must not be diluted by or mixed with water steam condensate, steam jet pumps are operated on product steam.

Steam jet vacuum pumps can be manufactured of different materials, mainly:

- for jet pumps: cast iron, steel, stainless steel
- for condensers: steel, rubberized or enamelled steel, stainless steel, bronze or other special alloys

For applications in which metallic materials are not resistant, steam jet vacuum pumps in graphite are used.

For more detailed information on the discussed topics please refer to section "Planning a steam jet vacuum pump", 7.1 gdp3.

Multi-stage steam jet vacuum pumps

in metal construction with mixing condensers

DESIGN AND MODE OF OPERATION

FIVE-STAGE STEAM JET VACUUM PUMP WITH MIXING CONDENSERS FOR 1 mbar (FIG. 1)

STAGE 1: extracts the vapors and gases from the process to be kept under vacuum; final vacuum e.g. 2 mbar

STAGE 2: compresses both the motive steam and the extracted vapors and gases of the 1st stage to a pressure of approx. 55 mbar

MIXING CONDENSER I: is designed for a condensation pressure level which is as low as possible to keep the steam consumption as low as possible. The suction flow load of the downstream-arranged stages and their steam requirements are thereby reduced.

STAGE 3: extracts all gases and vapors which were not condensed in the upstream mixing condenser I for compression to a pressure of 160 mbar

MIXING CONDENSER II: reduces the suction flow in order to relieve the downstream arranged stages

STAGE 4: compresses to a pressure of 400 mbar

MIXING CONDENSER III: condenses the remaining suction flow and the motive steam of the upstream arranged stage

STAGE 5: compresses to atmospheric pressure for discharge to the ambient air via a scrubber or a mixing condenser

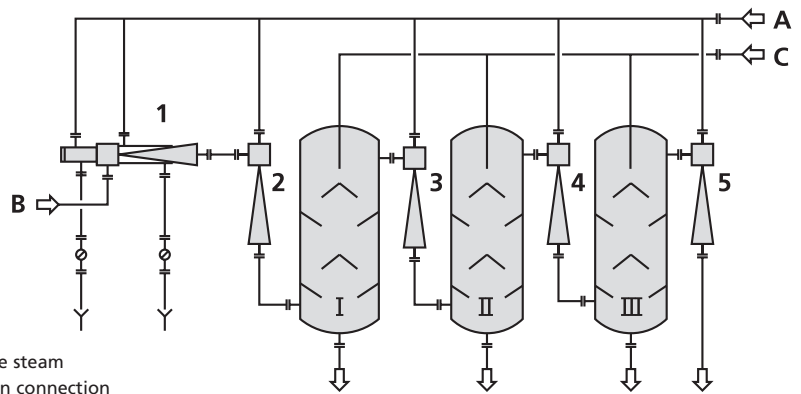
Mixing condensers are internally fitted with baffles or nozzles to enhance water distribution. They are shaped such that fouling problems are minimized. The cooling water is best drained off through barometric legs.

See also "Planning a steam jet vacuum pump", 7 | gdp3.



Suction capacity: 17 kg/h from 1 mbar, corresponding to 7230 m³/h and 3.6 kg/h from 2 mbar, corresponding to 1500 m³/h

FIG. 1



- A Motive steam
- B Suction connection
- C Cooling water

1–5 Steam jet vacuum pumps, stages 1 to 5
I–III Mixing condensers

5-stage steam jet vacuum pump with mixing condenser



Fig. 2
3-stage steam jet vacuum pump with mixing condensers
Suction capacity: 3380 kg/h steam and 225 kg/h of inert gas from 60 mbar



Fig. 3
3-stage steam jet vacuum pump with mixing condenser and liquid jet vacuum pump in a polyester production plant



Fig. 4
Vacuum unit for a MED plant for sea water desalination with a capacity of 800 t/h of distillate

Multi-stage steam jet vacuum pumps

in metal construction with surface condensers

DESIGN AND MODE OF OPERATION

FOUR-STAGE STEAM JET VACUUM PUMP WITH SURFACE CONDENSER FOR 1 mbar (FIG. 1)

STAGE 1: extracts the vapors and gases from the process to be kept under vacuum; final vacuum e.g. 2 mbar

STAGE 2: compresses both the motive steam and the extracted vapors and gases discharged by the 1st pump stage to a pressure of 80 mbar

SURFACE CONDENSER I: is designed for a condensation pressure level which is as low as possible to keep the steam consumption as low as possible. The suction flow load of the downstream-arranged stages and their steam requirements are thereby reduced.

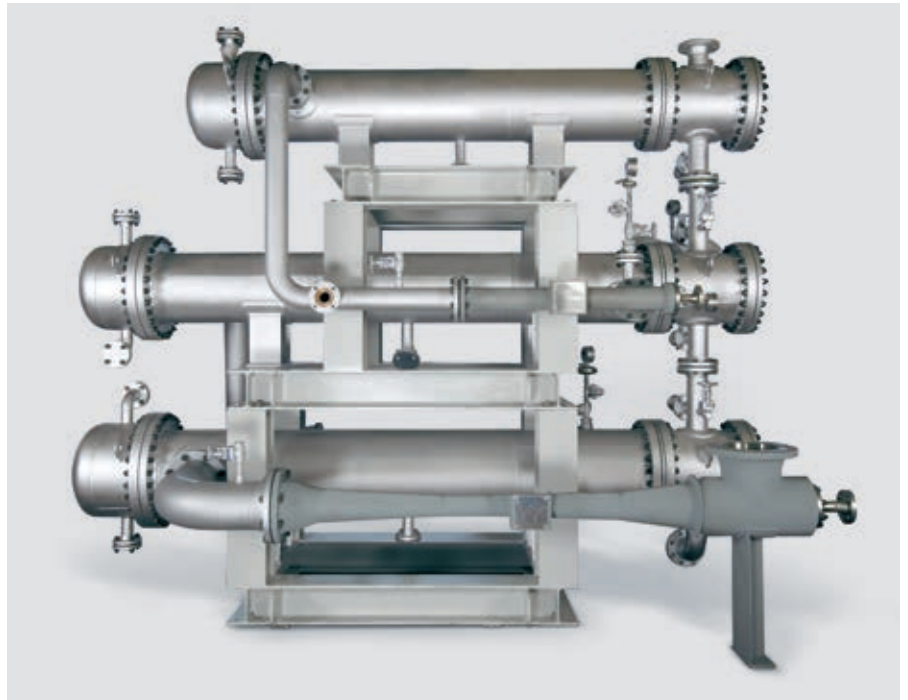
STAGE 3: stage extracts all gases and vapors which were not condensed in the surface condenser I for compression to a pressure of 320 mbar

SURFACE CONDENSER II: reduces the suction flow in order to relieve the downstream arranged stages

STAGE 4: compresses to atmospheric pressure for discharge to the ambient air via a scrubber or a surface condenser

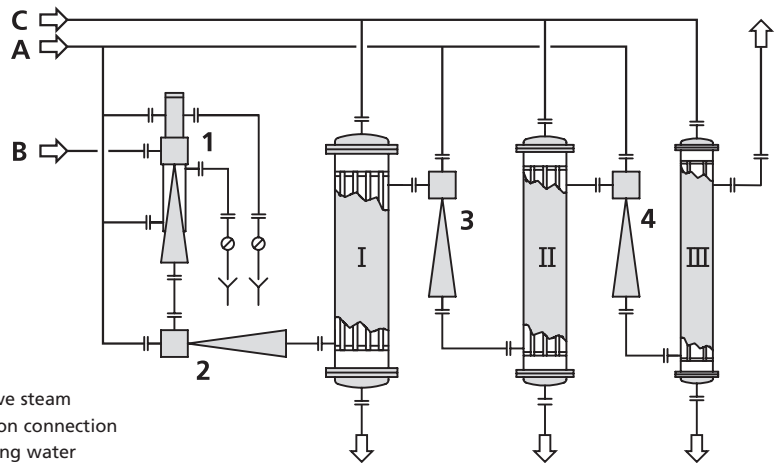
SURFACE CONDENSER III: condenses the remaining suction flow and the motive steam of the upstream arranged stage

See also "Planning a steam jet vacuum pump", 71 gdp3.



3-stage steam jet vacuum pump downstream of the 1st stage (pre-stage, heated), suction capacity: 3462 kg/h from 26.7 mbar abs.

FIG. 1



- A Motive steam
- B Suction connection
- C Cooling water

- 1-4 Steam jet vacuum pumps, stages 1 to 4
- I-III Surface condenser

4-stage steam jet vacuum pump with surface condensers

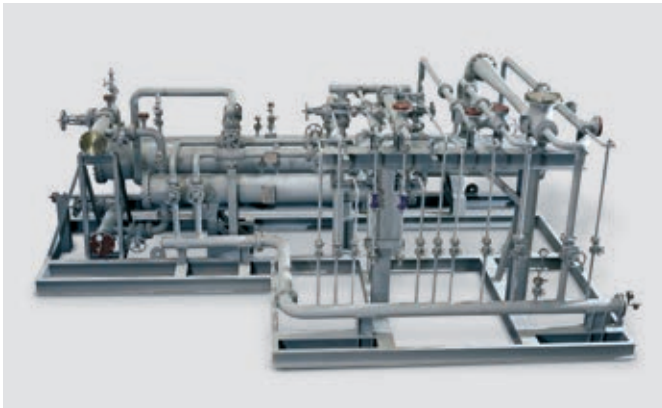


Fig. 2
3-stage steam jet vacuum pump with several lateral flows (10 jet pumps in total) for the production of mono-ethylene glycole (plastics industries)
Total suction flow: approx. 1050 kg from different pressure levels

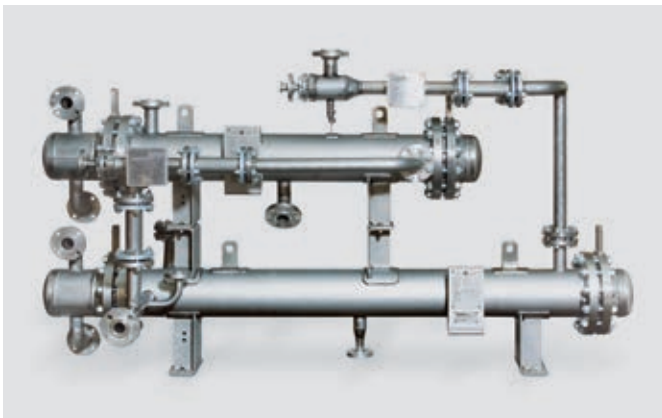


Fig. 3
2-stage steam jet vacuum pump with surface condenser, completely in Hastelloy
Suction capacity: 110 kg/h from 35 mbar



Fig. 4
3-stage steam jet vacuum pump with surface condenser for the vacuum column of a refinery
Suction flow: 13 180 kg/h (436 000 m³/h)
Suction pressure abs.: 4.5 kPa abs.
Discharge pressure abs.: 110 kPa abs.

Multi-stage steam jet vacuum pumps

in metal construction with liquid ring vacuum pumps (hybrid system)

DESIGN AND MODE OF OPERATION

Steam jet liquid ring vacuum pumps are especially suited if the permissible height of the installation is limited, i.e. if a barometric installation is not possible. Thanks to the combination of steam jet pumps and a liquid ring vacuum pump the steam and water consumption values are low. Compared to a steam jet vacuum pump only, the operating costs are lower.

The hybrid system is delivered as compact unit in a steel frame.

TWO-STAGE PUMP FOR A NOMINAL SUCTION PRESSURE OF 1 mbar (FIG. 1)

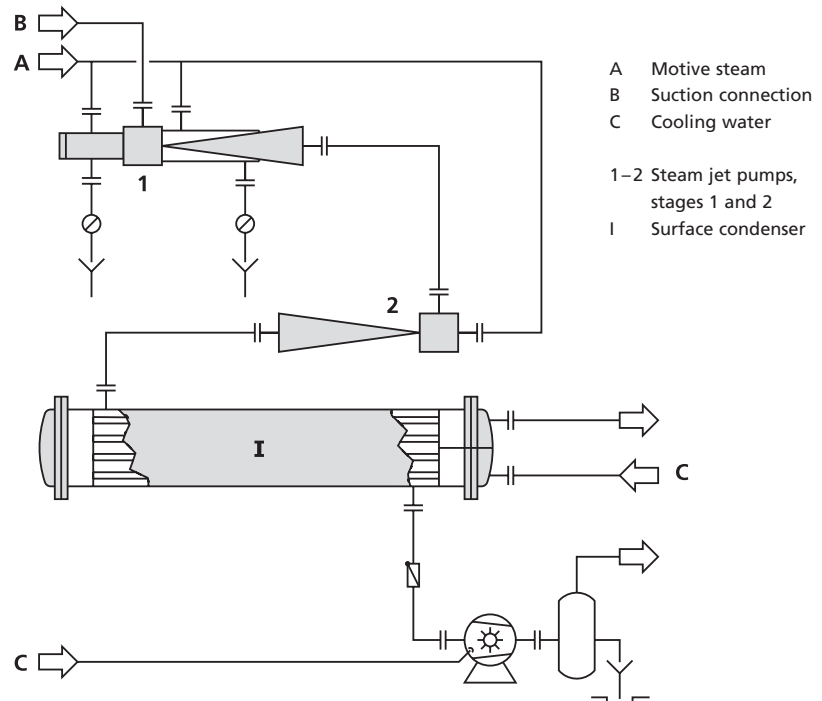
The 2nd stage is connected to the vacuum plant and extracts the vapors and gases or air and compresses it to approx. 13 mbar. The 2nd stage conveys it and compresses to approx. 90 mbar. The motive steam condenses in the surface condenser. The liquid ring vacuum pump extracts all non-condensables and the occurring condensate from the surface condenser and conveys it to atmospheric pressure.

See also "Planning a steam jet vacuum pump", 7 | gdp3.



Suction capacity: 4.5 kg/h of air/benzyl alcohol from 2 mbar

FIG. 1



2-stage steam jet liquid ring vacuum pump



Fig. 2

3-stage steam jet liquid ring vacuum pump

Suction capacity: 0.3 kg/h of air from 0.05 mbar (5725 m³/h) + 0.5 kg/h of air from 1 mbar (480 m³/h)

Special features:

- High vacuum, 0.05 mbar
- Re-cooling of the operating liquid of the liquid ring vacuum pump



Fig. 3

2-stage vacuum pump with product steam generator

Motive agent: methylene chloride

suction capacity: 120 kg/h from 4 mbar, corresponding to 7000 m³/h



Fig. 4

2-stage steam jet liquid ring vacuum pump with surface condensation for a distillation column in a refinery

Suction flow: 6198 kg/h (689,337 m³/h)

Suction pressure abs.: 8 mbar

Discharge pressure abs.: 1500 mbar

Liquid ring pumps with closed operating liquid circuit

Multi-stage steam jet vacuum pumps

in graphite

DESIGN AND MODE OF OPERATION

Multi-stage steam jet vacuum pumps in graphite are used to extract corrosive gases and vapors, particularly where halogen compounds are present, if stainless steels are not sufficiently resistant.

FOUR-STAGE STEAM JET VACUUM PUMP FOR 2 mbar, (FIG. 1)

STAGE 1: extracts the vapors and gases from the process to be kept under vacuum; final vacuum e.g. 2 mbar

STAGE 2: compresses the motive steam and the extracted vapor and gases of stage 1 to 75 mbar

SURFACE CONDENSER CHAMBER I: is designed for a condensation pressure level which is as low as possible to keep the steam consumption as low as possible. The suction flow load of the downstream-arranged stages and their steam requirements are thereby reduced.

STAGE 3: extracts all gases and vapors which were not condensed in the upstream condenser chamber I for compression to a pressure of approx. 320 mbar

SURFACE CONDENSER CHAMBER II: reduces the suction flow in order to relieve the downstream arranged stages

STAGE 4: extracts all non-condensable gases and vapor from condenser chamber II and compresses them to atmospheric pressure.

SURFACE CONDENSER CHAMBER III: will only be required if the exhaust gases are not allowed to reach the open air. The inert gases are discharged silently and without steam trailing.

The condensate lines can be made in plastic or graphite tubes.

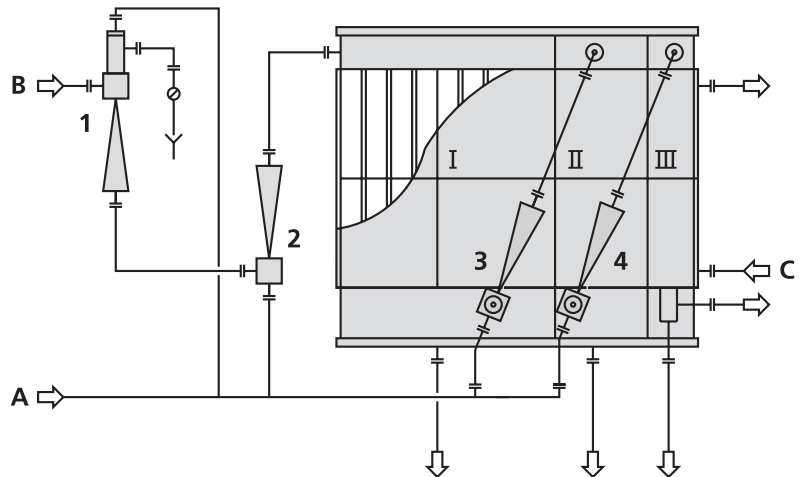
In the here described steam jet vacuum pump the extracted medium does not come into contact with the cooling water.

If the extracted medium is allowed to get into contact with the cooling water, we recommend the use of our multi-stage steam jet vacuum pumps made of graphite, where mixing condensers of temperature-change resistant enamelled steel are used for inter-condensation (Fig. 2).



Steam jet vacuum pump with jet pumps and block condenser made of graphite

FIG. 1



- | | | | |
|---|--------------------|------|---------------------------------|
| A | Motive steam | 1-4 | Jet pumps, stages 1 to 4 |
| B | Suction connection | I-II | Intermediate condenser chambers |
| C | Cooling water | III | After-condenser chamber |

4-stage steam jet vacuum pump with compact block condenser

MATERIALS AND CONSTRUCTION

GRAPHITE is used for the construction of surface condensers and jet pumps in all cases where the usual corrosion and acid proof materials are not resistant enough. On account of its excellent thermal conductivity and its high resistance to temperature change, graphite is ideal for heat exchangers and jet pumps. Gas-tightness is achieved by means of impregnation. Jet pumps made of graphite and operated in vacuum below 3 mbar can be heated to eliminate ice formation.

As surface condensers, block heat exchangers, shell-and-tube heat exchangers or also plate heat exchangers from graphite of all commercial makes are used which are suitable to condense vapors under vacuum.

STANDARD CONSTRUCTIONS are supplied for suction capacities of 1 kg/h to 10 kg/h at suction pressures from 1 to 10 mbar; thereby meeting most requirements. Pumps are

constructed as modular units from standard elements.

SPECIAL CONSTRUCTIONS can easily be built as modular units from standard parts. By using different combinations of standard parts, most intermediate duties are attainable.

SPARE PARTS for graphite jet pumps are manufactured on demand at short notice thanks to high standardization.

REVAMPING OF EXISTING PLANTS

Graphite jet pumps replace existing porcelain jet pumps without any on-site modifications. The installation dimensions remain unchanged.

By means of graphite jet pumps, existing steam jet vacuum plants can be optimized in terms of energy consumption and performance.

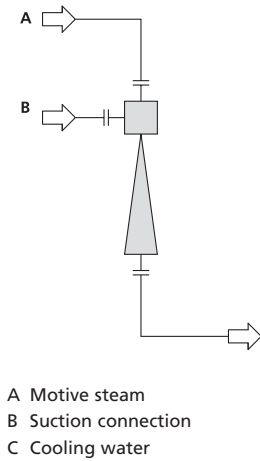


Fig. 2
5-stage steam jet vacuum pump in corrosion-resistant design
Materials: jet pumps in graphite, mixing condensers in C-steel, enamelled
Suction capacity: 5 kg/h of air from 2.5 mbar abs.

Arrangements of steam jet vacuum pumps

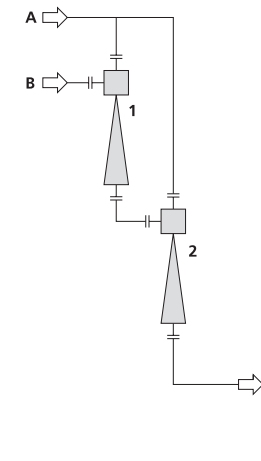
FIGURES 1-2

FIG. 1



Single-stage steam jet vacuum pump

FIG. 2



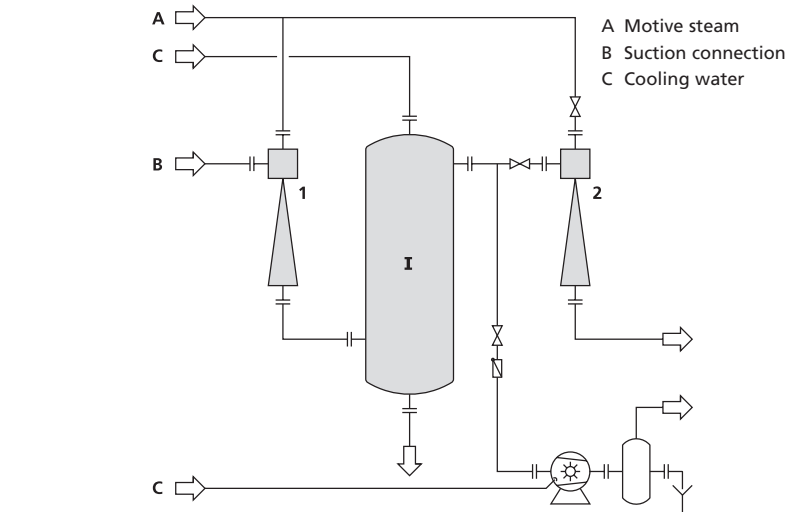
2-stage steam jet vacuum pump

Single-stage steam jet vacuum pump for suction pressures down to 100 mbar at atmospheric discharge pressure. The compression ratio p/p_0 is generally limited to $p/p_0 \leq 10$.
Typical application: pre-evacuator

Two-stage steam jet vacuum pump without inter-stage condenser, for suction pressures down to approx. 40 mbar, at atmospheric discharge pressure.
Typical applications: two-stage pre-evacuator or for small suction flow

FIGURES 3-4

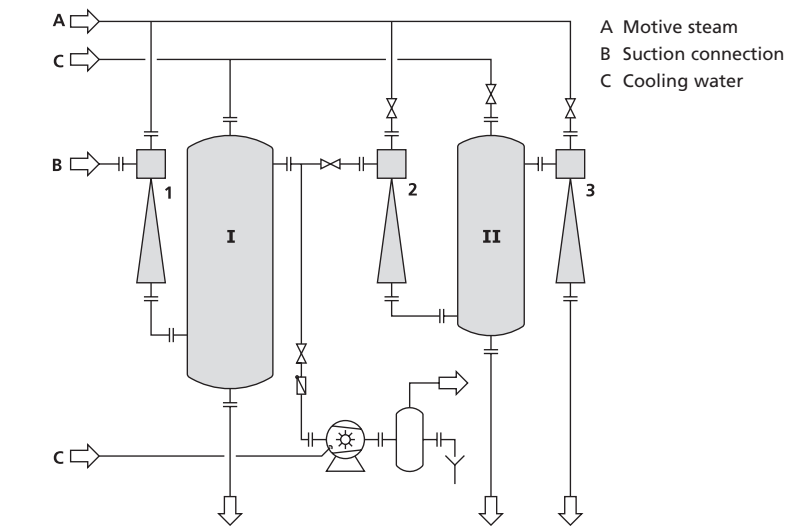
FIG. 3



2-stage steam jet vacuum pump

Two-stage steam jet vacuum pump with inter-stage condenser I (mixing condensation), for suction pressures down to approx. 40 mbar. Mainly used for the evacuation of condensers imposing low air loads.

FIG. 4

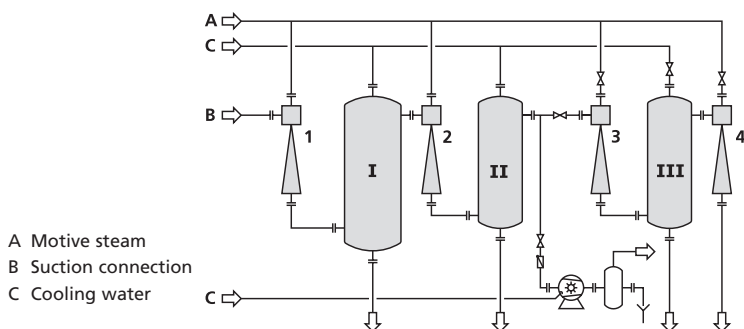


3-stage steam jet vacuum pump

Three-stage steam jet vacuum pump with 2 inter-stage condensers (I, II), for suction pressures down to approx. 10 mbar. These pumps consume less steam and water than two-stage pumps with inter-stage condensers (fig. 3) sized for the same duty.

FIGURES 5-6

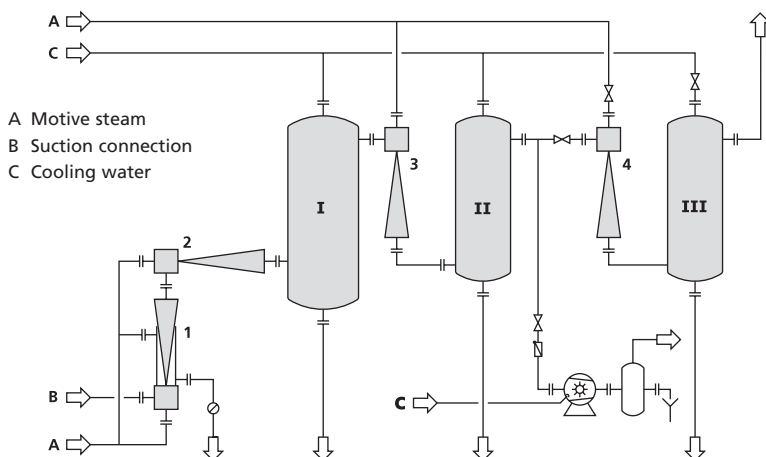
FIG. 5



4-stage steam jet vacuum pump

Four-stage steam jet vacuum pump with 3 mixing condensers (I, II, III), for suction pressures ranging from 2 to 10 mbar, used to extract air, gases, and vapors from various types of vacuum plants

FIG. 6



4-stage steam jet vacuum pump

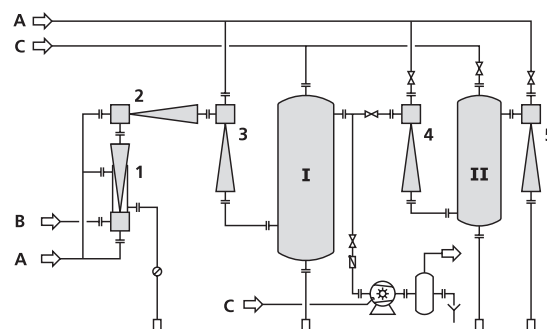
Four-stage steam jet vacuum pump utilizes 2 stages upstream of the 1st of the 3 inter-stage condensers (I, II, III), for suction pressures ranging from 0.5 to 2 mbar and suction flows of approx. 0.5 kg/h to several 1000 kg/h.

A two-stage steam jet vacuum pump according to fig. 3 to de-aerate the first condenser will be sufficient if the inert gas load is low in the suction flow is low and the motive steam pressure sufficiently high.

Typical applications: generation of vacuum for synthetic fibre production plants – especially polyester condensation, further, distillation, steel degassing, deodorizing, vacuum drying etc.

FIGURE 7

FIG. 7



A Motive steam
B Suction connection
C Cooling water

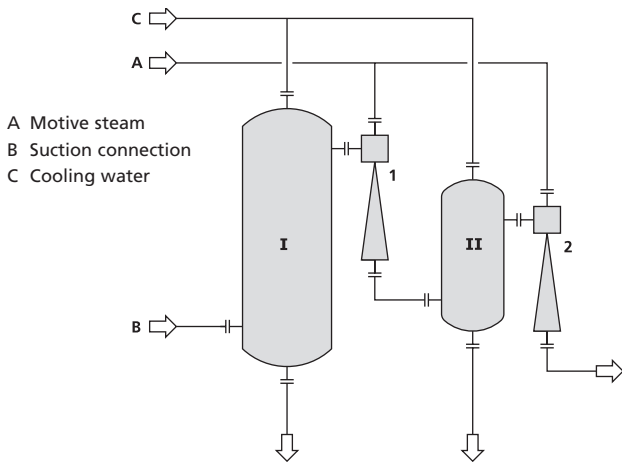
5-stage steam jet vacuum pump

Five-stage steam jet vacuum pump utilizes 3 pre-stages upstream of the 1st condenser and 2 inter-stage condensers, for suction pressure up to approx. 0.01 mbar. Typical applications: The same as fig. 6.

- Depending on the suction capacity and on the water temperature, liquid ring vacuum pumps can be used in the range of 60 up to approximately 200 mbar for the air extraction and pre-evacuation of the 1st or 2nd inter-stage condenser (fig. 3 to 7). This kind of combination is based on the fact that it offers the operational advantages over a normal steam jet pump and that there are no objections with regard to the materials. See also "Planning a steam jet vacuum pump", 7 | gdp3.
- Surface condensers can also be used in place of mixing condensers (see fig. 10) when contact between extracted process fluid and cooling water is not acceptable, or in case the condensate is to be recovered.

FIGURES 8-9

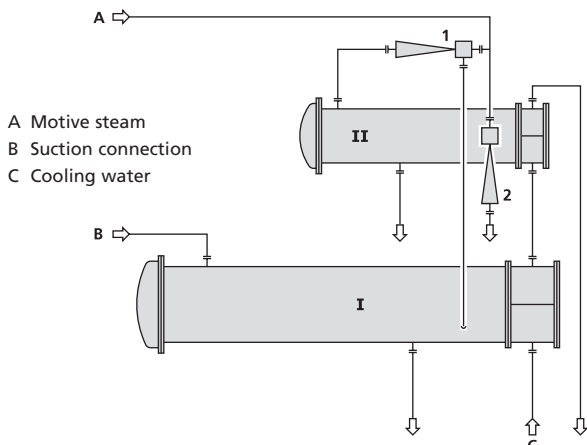
FIG. 8



Condensation system with mixing condensers and de-aeration station

Condensation system with mixing condensers and de-aeration station for the condensation of vapors, predominantly in the range of 30 to 200 mbar. They are available for steam flows of up to several 1000 kg/h of steam. Typical application: evaporation plants etc.

FIG. 9



Condensation system with surface condensers with de-aeration station

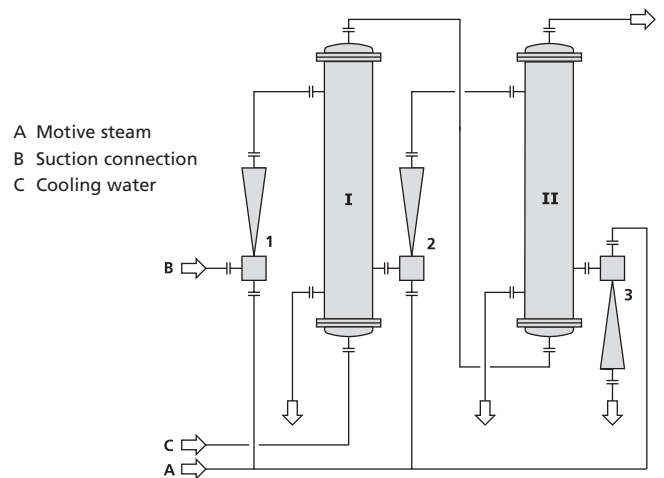
Condensation system with surface condensers with de-aeration station for the condensation of vapors, predominantly in the range of 40 to 200 mbar.

To de-aerate the 1st or 2nd condenser, a liquid ring vacuum pump can be used in place of the steam jet pump (see fig. 11).

Typical applications: in oil refineries, turbine plant exhausters, distillation plants – when contact between vapors to be condensed and cooling water is not acceptable.

FIGURES 10-11

FIG. 10

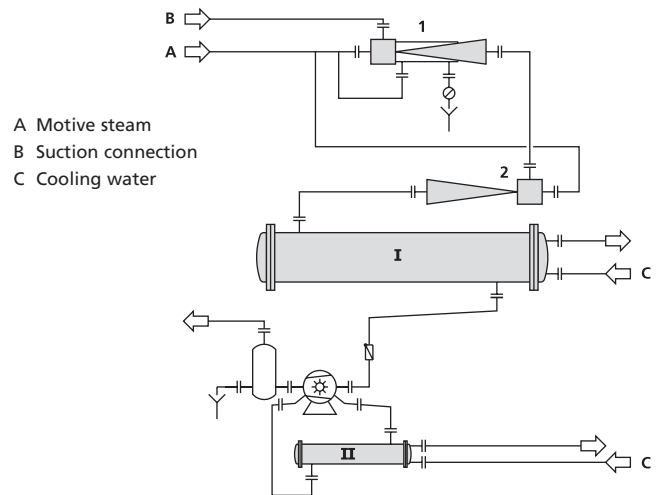


3-stage steam jet vacuum pump

Three-stage steam jet vacuum pump with surface condensers, for suction pressures down to approx. 5 mbar and for any suction flow rate.

Applications: mineral oil refineries, distillation plants etc.

FIG. 11



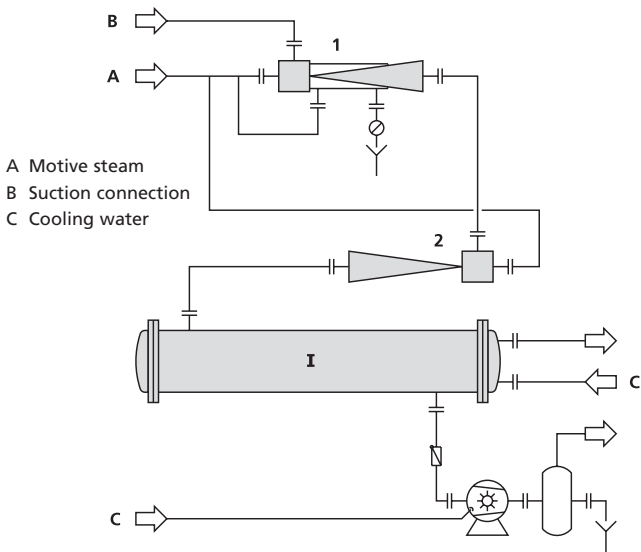
3-stage steam jet liquid ring vacuum pump with surface condensers

Three stage steam jet liquid ring vacuum pump with surface condensers and indirect cooling of the operating liquid to be circulated for the liquid ring vacuum pump. Depending on the number of pre-stages for suction pressures in the range of 0.5 to 40 mbar and any suction flow rates.

Typical applications: same as indicated under fig. 9.

FIGURE 12

FIG. 12

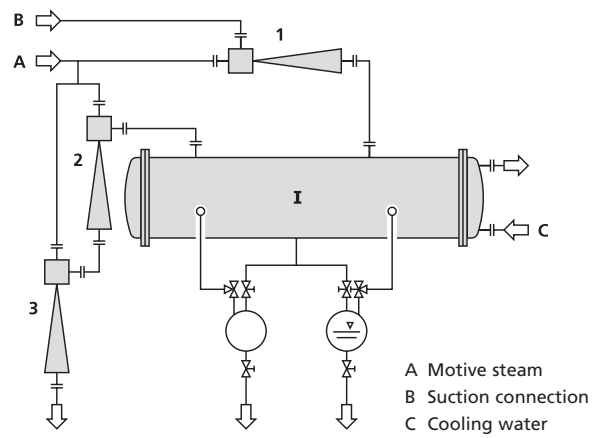


One or multi-stage steam jet liquid ring vacuum pump

One or multi-stage steam jet liquid ring vacuum pump with surface condenser, for suction pressures ranging from 0.5 to 30 mbar and small and medium suction flows (see also fig. 11).

FIGURES 13-14

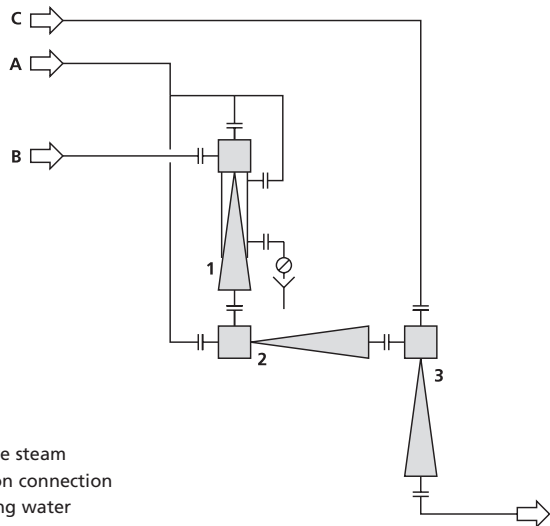
FIG. 13



Multi-stage steam jet vacuum pump

Multi-stage steam jet vacuum pump with surface condenser and discontinuous condensate trap, via alternately working condensate feed tanks. Used for suction pressures ranging from 0.1 to 10 mbar.

FIG. 14



Multi-stage laboratory steam jet vacuum pump

Multi-stage laboratory steam jet vacuum pump with a liquid jet vacuum pump, for suction pressures ranging from 0.05 to 5 mbar and small suction flows. Available with and without cooling water re-circulation.

A water jet pump (3) will be used for condensation.

Laboratory steam jet vacuum pumps

Laboratory steam jet vacuum pumps are used as vacuum producers in chemical laboratories, for pilot plants and in small production plants. Here, they are mostly required for processes operating discontinuously or needing vacuum for short operation periods.

Laboratory steam jet vacuum pumps consist of two steam jet stages connected in series and backed by a liquid jet vacuum pump. Unlike the multi-stage steam jet vacuum pumps they do not use any drain pumps or barometric legs.

The specific steam and cooling water requirements are higher in comparison to multi-stage steam jet vacuum pumps which are designed to operate continuously for longer operation periods.

Laboratory steam jet vacuum pumps are portable. The larger packages are supplied with castors unless they are required for stationary use. They can be quickly connected via short suction lines to any vacuum consumer. This is an important feature because branched suction lines incl. shut-off valves etc. are eliminated. The possibility of leakage air entering and consequently, the pull-down time are reduced. This is of increased significance for higher operation vacuum levels.

The water consumption of the laboratory steam jet vacuum pumps is relatively high as the jet vacuum pump does not only serve to condense but also to compress the air and gases to atmospheric pressure. The fresh water requirement can be reduced by utilizing water re-circulation.

When cooling water consumption is an important factor, the laboratory steam jet vacuum pumps are supplied with a complete water recirculation system. This consists of the following: water tank, pump incl. motor, water temperature controller, automatic cooling water supply valve, thermometer and interconnecting piping between pump and jet condenser. All re-circulation system parts are protected against corrosion. The automatic cooling water supply valve ensures that the water temperature is kept within permissible limits.

If required, laboratory steam jet vacuum pumps can even be delivered without water circulation system.

CAPACITY AND CONSUMPTION DATA

Laboratory steam jet vacuum pumps are available in several sizes and materials as standardized units.

The following table lists the available models. The model designations indicate the suction capacity and suction pressure, and whether they are designed for once through or re-circulated cooling water.

Model number 01.1-K denominates a laboratory steam jet vacuum pump with a suction capacity of 0.1 kg/h of air at a suction pressure of 1 mbar.

K means "with cooling water re-circulation". The table indicates the design capacity and the associated suction pressure of each pump model and the suction pressure achieved with the delivery flow = 0 (so-called ead end vacuum).

| Designation | Suction flow | | Water consumption m ³ /h | Steam consumption m ³ /h | Evacuation time for a unit volume | |
|-------------|--------------|-----------|--|--|--------------------------------------|---------|
| | kg/h air | from mbar | | | from m ³ | minutes |
| 01.1 | 0.3 | 1.50 | 3.4 | 25 | 0.2 | 10 |
| | 0.1 | 1.00 | | | | |
| | 0.0 | 0.75 | | | | |
| 01.1-K | 0.3 | 1.50 | 0.6-2.5 | 25 | 0.2 | 10 |
| | 0.1 | 1.00 | | | | |
| | 0.0 | 0.75 | | | | |
| 05.3 | 0.5 | 2.80 | 3.9 | 40 | 0.5 | 18 |
| | 0.0 | 1.40 | | | | |
| 05.3-K | 0.5 | 2.80 | 1-2.5 | 40 | 0.5 | 18 |
| | 0.0 | 1.40 | | | | |
| 1.2 | 1.0 | 2.00 | 5.5 | 75 | 1.0 | 15 |
| | 0.0 | 1.00 | | | | |
| 1.2-K | 1.0 | 2.00 | 2-4 | 75 | 1.0 | 15 |
| | 0.0 | 1.00 | | | | |

Each jet pump can be turned off individually. This permits stable operation even at higher suction pressure ranges. Alternatively, the operating suction pressures can be elevated by admitting "ballast" steam to the pump inlet.

As a rough guide to the selection of a pump model, the following "rule of thumb" can be applied:

The volume of the system to be evacuated expressed in m³ equals the required suction capacity in kg/h.

For example for an apparatus with 0.5 m³ content = suction capacity of 0.5 kg/h.

Planning a steam jet vacuum pump

Most important points to be considered when designing steam jet vacuum pumps:

- suction flow
- suction pressure (vacuum)
- type of condensation
- type of installation
- motive steam properties – water steam or product steam?
- cooling water properties
- materials of construction
- evacuation time
- steam jet vacuum pump versus steam jet pump /liquid ring vacuum pump combination

1. SUCTION FLOW

The steam consumption of a steam jet vacuum pump depends on whether the complete suction flow is to be conveyed or only a part of it. For this reason, the max. suction flow has to be determined as precisely as possible for the design of the pump.

In most of the cases, steam jet vacuum pumps are designed for and operated under a determined suction pressure. Therefore, the mass flows and the molecular weights are decisive factors for the design of a jet pump.

For mechanical pumps, however, the suction flow is frequently measured as volume flow in m^3/h .

1.1 GASES AND VAPORS RELEASED BY THE PRODUCT TO BE TREATED IN THE PLANT

Generally, the non-condensable and condensable constituents of the suction flow must be differentiated. See also “Vapors and gases in vacuum” and “Water vapor and air in vacuum”, 7|ab|7.

To determine the condensability of the vapors involved, their vapor pressure curves and molecular weights of the substances in question (boiling point depends on the pressure) are required.

Additionally, for discontinuous processes, it is important to know at which vacuum gases or vapors are released. If, for example, for a drying process a total of 200 kg of water steam has to be extracted and if already approx. 90 % have a pressure of 1000 and 50 mbar, the energy requirement is rather low.

If, however, the 200 kg of steam have to be extracted only in the range between 10 and 1 mbar, the energy requirement is much higher. Even the temperature of the gases or vapors to be extracted is very important for the design of a steam jet vacuum pump.

1.2 AIR AND GASES RELEASED FROM THE COOLING WATER

The cooling water normally contains dissolved air and gases. These are released under vacuum. The quantities of air in solution depend on the saturation. Fig 1 illustrates the relationship.

Attention should be paid to the possibility of air bubbles and CO_2 being present in the cooling water. These are released under vacuum and, hence, to be added to the steam jet vacuum pump suction flow requirement.

1.3 LOAD SPLITTING

When the actual leakage air flow cannot be accurately determined, excessive safety margins are often applied when theoretically determining the suction flow for a vacuum pump.

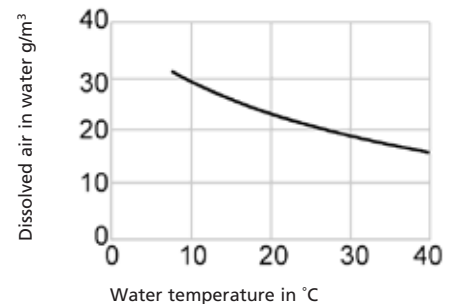
See also “Air leakage into vacuum vessels”, 7|ab|8.

This entails increased motive steam consumption rates, even if later the air leakage amount is not as high as assumed. The steam consumption depends on whether the complete suction flow is to be conveyed or only a part of it; it remains constant.

One way to avoid this is by dividing the total duty into parallel streams and the use of parallel steam jet vacuum pumps, e.g. one pump for 1/3 and the second for 2/3 of the capacity. When the real requirement is known, after plant start-up, one or the other of the jet pumps can be turned off to save motive steam and cooling water.

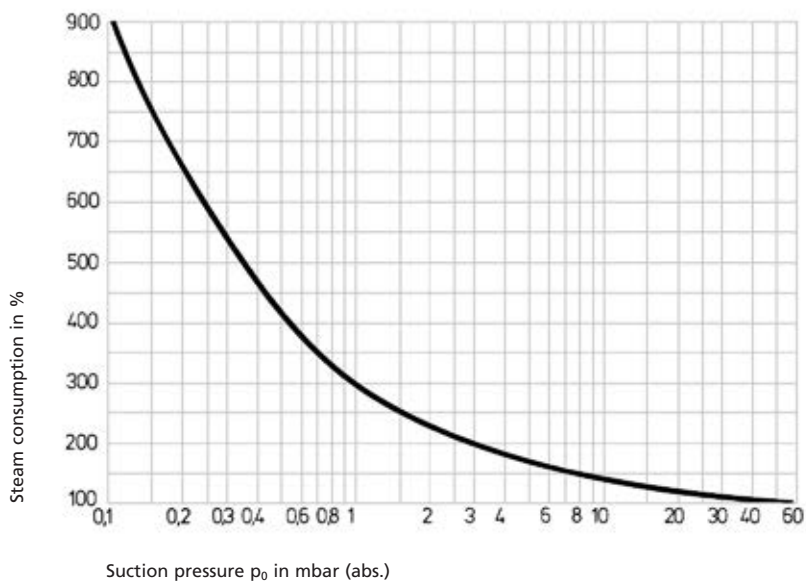
The additional investment is in a set of shut-off valves for each suction connection and motive steam supply line to the jet pumps.

FIG. 1



Solubility of air in water at saturation

FIG. 2



2. SUCTION PRESSURE

The suction pressure is determined by the process requirements. Often, a safety margin is applied, i.e. a lower pressure is specified than is really needed. This is a questionable approach as it leads to:

- excessive steam consumption
- excessive cooling water consumption
- unnecessarily large diameter of the suction pipe
- unnecessarily large and therefore expensive steam jet vacuum pump

If a safety margin is to be included in the determination of the suction conditions for a steam jet vacuum pump, this factor should be applied to the suction flow rate and never to the suction pressure.

The diagram, fig. 2, shows the increase in steam consumption within the range of 60 to 0.1 mbar taking the steam consumption at 60 mbar as 100%. The curve is based on cooling water of 25 °C and on motive steam pressure of 6 bar. As can be seen, at a suction pressure of 1 mbar, the steam consumption amounts to 300%. At 0.1 mbar, it is 900%. The chart illustrates the over-proportionally high increase in steam consumption for every 1 mbar rise in vacuum at suction pressures below 10 mbar.

When determining the suction pressure, pressure losses between vacuum unit and steam jet pump have to be taken into consideration. They should be kept as low as possible.

This is achieved by realizing short suction lines with as few tube bends as possible, eliminating points of throttling such as reduced tube diameters, shut-off valve etc. The tube bend should be laid in the same or somewhat larger nominal diameter as the suction socket of the jet pump.

At suction pressures below 6 mbar, the corresponding saturated steam temperature drops below 0 °C. Ice can then form inside the head and the mixing chamber of the steam jet pump, affecting the operation. To avoid this, for this pressure range, the steam jet pumps are equipped with heating jackets.

3. CONDENSATION

Condensation is mostly done by water-cooled mixing condensers or surface condensers, in particular cases by air-cooled condensers.

When utilizing mixing or injection condensers, the process fluid comes into direct contact with the cooling water. Mixing condensers are relatively insensitive to fouling and are, therefore, reliable in operation. It should be noted, however, that mixing condensers cannot be recommended for the extraction of soluble gases. The contact with the cooling water leads to the formation of undesirable components. In such cases, only surface condensers can be used.

Mixing condensers are simple in design and therefore considerably cheaper than surface condensers.

Mixing condensers can be designed as parallel flow or counter flow condenser.

Mixing condensers can be internally rubber lined or otherwise coated against corrosion. Smaller units are easily manufactured in porcelain or in a synthetic plastic material.

Surface condensers offer the advantage of separating the process fluid from the cooling water. They are used in all cases when environmental or other considerations do not permit the contact or mixing of the product condensate with the cooling water. When vapors can be condensed in a surface condenser (pre-condenser), the condensate can be recovered in a pure state.

When, however, gases and vapors are sucked by a steam jet vacuum pump and precipitate in a downstream arranged surface condenser, the motive vapor condensate will mix with the condensate of the suction medium. Depending on the suction medium, the condensate will not only mix with the motive steam condensate, but it will be dissolved in the latter.

In special cases in which the product condensate must not be diluted or mixed with the water steam condensate, steam jet pumps are operated with product steam and not with water steam.

In surface condensers, the condensation can take place in or around the tubes. They can be delivered with fixed or removable tube bundle. Constructions according to different design codes are possible, such as for example, internal standard, TEMA and others, with stability design according to AD-rules or ASME code etc.

Condensers with fixed tube bundles can only be mechanically cleaned inside the tubes, whereas removable tube bundles can be cleaned on both the tube and the shell side.

It remains to be mentioned that mixing condensers generally require less cooling water than surface condensers. Therefore, the cooling water requirements are lower when operating with mixing condensers.

4. TYPE OF INSTALLATION

4.1 BAROMETRIC INSTALLATION

Whenever possible, steam jet vacuum pumps are installed “barometrically” permitting the cooling water to drain out freely through the barometric legs without pumping.

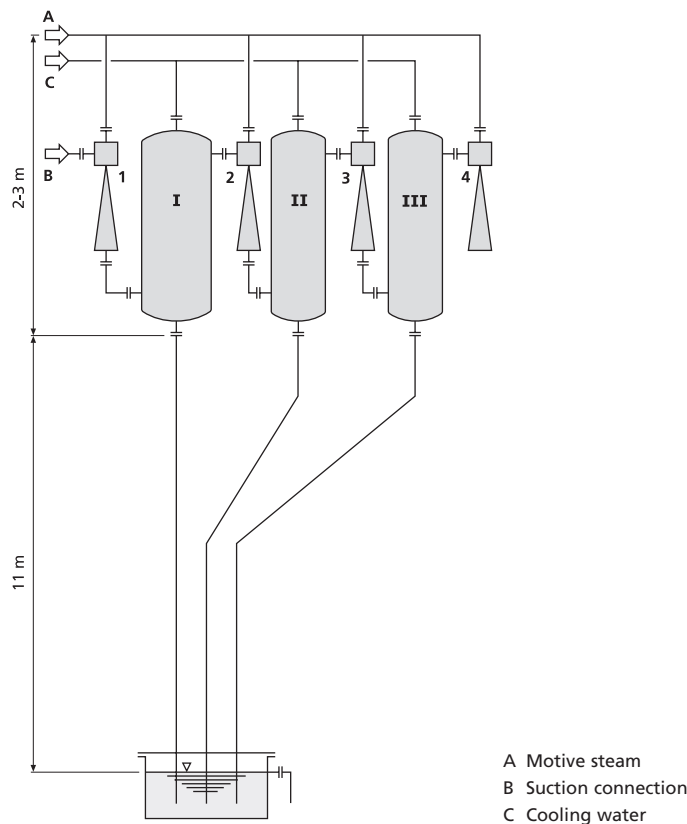
Depending upon the individual condenser pressures of a multi-stage steam jet vacuum pump, this height less the equivalent height of the actual pressures is required to ensure free drainage of the cooling water/condensate through the barometric legs. This height is referred to as “barometric height”. For water, the max. height is 10.3 m.

Because the draining water may be carrying entrained air when passing down through the barometric legs, and to overcome any pressure losses, it is recommended to add to the theoretically required height a safety margin of approximately 0.5 m.

Fig. 3 schematically shows a barometric installation. If a barometric installation is not feasible due to insufficient available room height, a semi-barometric installation should be considered.

The possible installation options shown in fig. 3 are – in analogy – also applicable to surface condensers.

FIG. 3



Barometric installation of a steam jet vacuum pump with mixing condensers

4.2 SEMI-BAROMETRIC INSTALLATION

Depending on the available height there are various alternatives of installation.

Fig. 4 illustrates a four-stage steam jet vacuum pump using a closed hotwell. The pressure difference between the 1st and the 3rd stage condenser amounts to $400 - 40 = 360$ mbar corresponding to a water column of approx. 3.6 m. The dimensions shown in the figure 2 indicate that the installation requires an overall height of 7 to 8 m.

A liquid pump with corresponding NPSH is responsible to extract the condensate from the tank.

In exceptional cases a siphon can be installed between two condensers. This

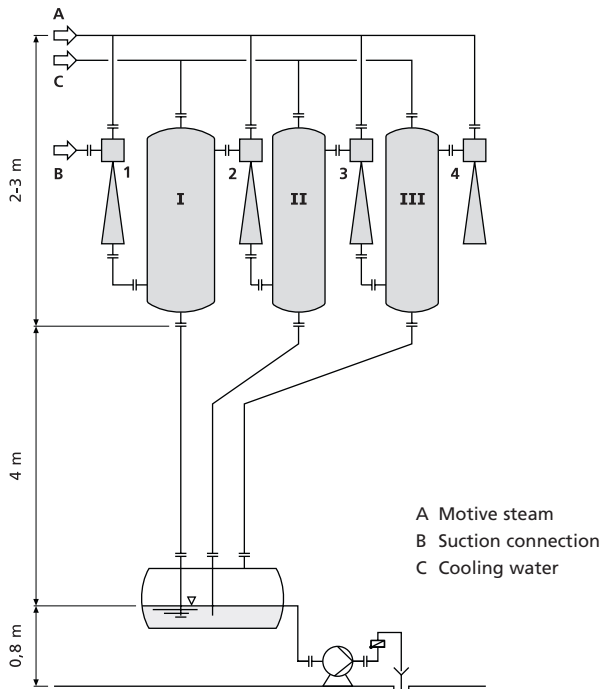
allows that cooling water is drawn from the condenser operating under higher pressure into the condenser with the lower pressure. From here, the liquid is extracted by means of a water pump.

Caution:

If for any reason, the water extraction pump fails (e.g. due to a power failure), the water level in the condensers may rise to the point of entering into the system to be evacuated. If this is to be prevented a variety of precautions, e.g. shut-off valves, are at hand.

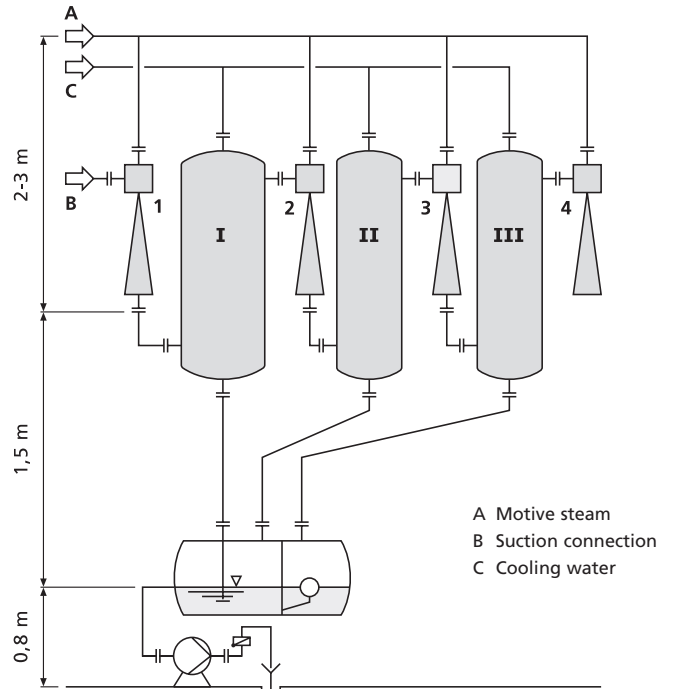
The possible installation options shown in fig. 4 and 5 are – in analogy – also applicable to surface condensers.

FIG. 4



Semi-barometric installation with intermediate tank and water extraction pump

FIG. 5



Semi-barometric installation with intermediate tank, float valve and water extraction pump

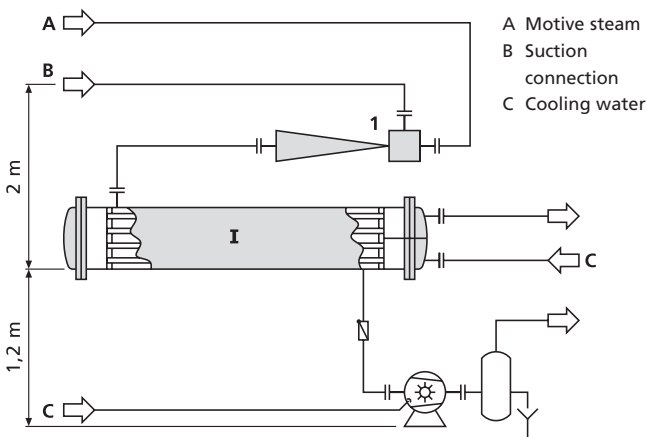
4.3 NON-BAROMETRIC INSTALLATION

Steam jet liquid ring vacuum pump combinations according to fig. 6 require a total installation height of less than 2 m and can therefore be installed in nearly any room.

A multi-stage steam jet vacuum pump (without liquid ring pump) with surface condensers has the identical low installation height, if the condensate is drained off via two alternately working collector tanks. See fig. 7.

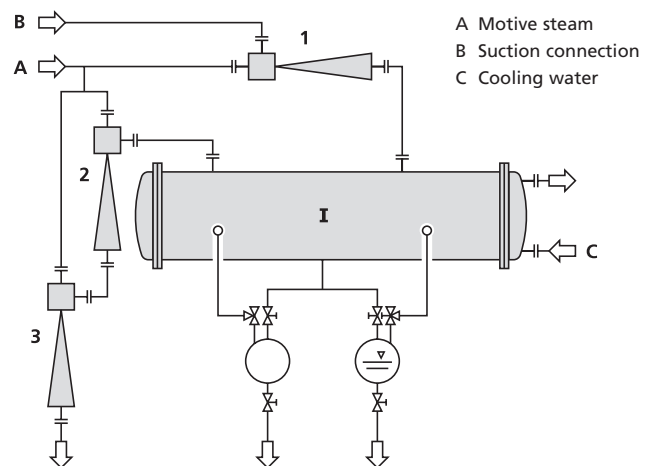
See also "Arrangement of steam jet vacuum pumps", fig. 13, 7 | gdp2).

FIG. 6



Non-barometric installation with surface condenser and liquid ring vacuum pump

FIG. 7



Non-barometric installation with surface condenser and condensate feed tank for batch operation, with alternately working feed tank for continuous operation

5. MOTIVE STEAM PROPERTIES

Steam jet vacuum pumps are available for motive steam pressures ranging from 1 to 40 bar g.

Motive steam of less than 1 bar can also be used, for instance for multi-stage jet pumps, if a liquid ring vacuum pump is used as the final stage.

If designed for a low suction pressure, a steam jet vacuum pump can even be operated with below atmospheric pressure steam, drawn, for instance, from the pressure side of a downstream stage.

If a suitable source of heat is available, a special evaporator is needed to produce motive steam, e.g. in an evaporation condenser of a distillation column. In this way the heat of condensation is recovered rather than passed onto the cooling water or the atmosphere and lost. The produce water steam can be used as motive steam for a steam jet vacuum pump.

In cases when motive steam is available at different pressure levels, the question arises which pressure is the most economical and efficient to be used.

A steam jet vacuum pump should always be operated with the steam pressure for which it is designed. If the steam pressure is lower than the design, the proper functioning cannot be ensured. A higher steam pressure results in higher steam consumption without increasing the pump performance.

In case of a fluctuation in the steam supply pressure, it is advisable to install a pressure regulator. Further, it is essential to ascertain the available steam pressure at the point of the steam jet vacuum pump installation. Often this is considerably lower than the boiler pressure.

Steam jet vacuum pumps operate most efficiently when supplied with dry saturated or slightly superheated steam. Wet steam erodes the nozzle or diffuser and must be dried by means of an effective water separator.

The steam temperature must be known for the design of a steam jet vacuum pump as a higher degree of superheating influences its geometry.

Jet vacuum pumps can be operated utilizing a motive fluid other than steam. This may be desirable for environmental reasons. In these cases, a suitable process vapor is used. The condensate of the motive vapor and product can be recycled without burdening the environment.

5.1 PRODUCT-STEAM OPERATED JET VACUUM PUMPS

Jet vacuum pumps are mainly operated with water steam. Usually, water steam is easily available in industry and is tried and tested as motive fluid for jet vacuum pumps.

As a result of condensation of the motive medium in the jet vacuum pump a condensate is produced which in some cases has to be considered as waste water.

This can be avoided by integrating the jet vacuum pump into a closed product circuit. The product vapors occurring in the process are used as motive medium for the jet pumps. The motive steam condensate from the jet vacuum pump is further used in the process, or after evaporation it is used again as motive medium. Thanks to the lower evaporation heats of organic vapors the energy requirement for the product-steam operated jet vacuum pumps is in part much lower than for the water-steam operated jet vacuum pump.

Another important application of product-steam operated jet pumps is the case when the penetration of water into the process must be absolutely avoided.

ADVANTAGES OF PRODUCT-STEAM OPERATED JET VACUUM PUMPS

The structure and function of product-steam operated jet vacuum pumps is the same as of water-steam operated vacuum pumps. Therefore, the advantages are more or less the same:

- simple structure
- high operational reliability, low maintenance
- long service life, low wear
- resisting to corrosion, in case of proper selection of material
- available in all materials used in apparatus engineering
- insusceptible against fouling and, in addition
- no waste water thanks to recycling of the condensate

Organic vapors, such as monochlorbenzole, trichlorethylene, tuluole, butanediol, ethylene glycole, furan, phenol etc., can be used as motive medium for product-steam operated jet pumps.

6. COOLING WATER

Steam jet vacuum pumps must be selected for the most unfavourable cooling water conditions, e.g. for the maximum cooling water temperature. Usually, well water temperatures remain constant throughout the year. River and sea temperatures, however, vary from approximately 3 to nearly 35 °C. The same applies to cooling tower water, which varies considerably between summer and winter. The motive steam and cooling water consumption of a steam jet vacuum pump is highly dependent on the cooling water temperature on which the selection is to be based. This is especially true if condensable vapors are to be compressed.

For example, assuming a cooling water temperature of 25 °C and supposing a temperature rise of 10 °C, the attainable condensing temperature is 35 °C. This corresponds to a condensing pressure of 56 mbar. A lower condensing pressure of, for instance, 42.5 mbar corresponding to 30 °C, would even reduce the practically possible heating and imply an increased cooling water consumption. The lowest condensing pressure therefore depends on the cooling water temperature and the pressure of the available cooling water flow.

For example: To extract 100 kg/h of water vapor from a system at 6 mbar using 3 bar motive steam and cooling water of 15 °C, the motive steam consumption is approx. 200 kg/h. When using 28 °C cooling water, the motive steam consumption becomes 400 kg/h.

It may be advisable to adjust the steam supply in relation to the changing cooling water temperatures over the year. This can be accomplished by exchanging the motive steam nozzles for new ones designed for the changed conditions or by altering the motive steam pressure. In the latter case, an automatic steam pressure control station is recommended.

The cooling water pressure should not fluctuate because this affects the suction pressure (vacuum). Mixing condensers require a relatively low supply pressure. A pressure of 0.2–0.5 bar g is sufficient. (Water jet condensers are different and require a higher water supply pressure).

When using surface condensers, the water pressure must be sufficient to overcome the pressure losses of the water boxes and the tubes.

Often the cooling water return temperature is limited to a maximum, for example to 45 °C, to avoid calcium carbonate fouling problems. The max. return temperature must be specified for the equipment selection.

7. MATERIALS OF CONSTRUCTION

It is customary to manufacture the steam jet vacuum pump from the same or an equally resistant material as the process plant which the pump is to keep under vacuum. Frequently used materials are steel and stainless steels. When sea or brackish water are used for cooling, as a minimum requirement, the mixing condensers are internally coated with a corrosion protecting coat or rubber lined. Surface condensers are manufactured in seawater-resistant bronze. If carbon steel is used, the surfaces are coated by a corrosion protecting coat.

In all cases when standard materials cannot be used, the steam jet vacuum pumps are available in materials complying with our customers' specific requirements.

The material selection does not know restrictions. Jet Pumps can be made of Hastelloy, titanium, graphite etc.

8. EVACUATION TIME

The time required to reduce the process plant's system pressure from atmospheric pressure to the required vacuum depends on following five variables: system space, kind and capacity of the vacuum pump used, the leakage air rates entering and the amount of gases and vapors released by the product and the cooling water.

In most cases (particularly when continuous processes are involved) the evacuation time as is reached by the chosen vacuum pump is sufficiently short. If, however, the required time is shorter, an auxiliary start-up pump is needed. Depending upon the required vacuum, single or two stage vacuum pumps are installed.

Normally, the utility requirements of auxiliary pumps are not of any greater importance as they operate only for a short period of time. However, care must be taken to ensure that the steam pipe lines are large enough in diameter to pass the relatively high steam flow rate needed without any excessive pressure losses.

Start-up pumps (pre-evacuators) are best operated with the highest pressure steam available on site. The motive steam requirement is considerably reduced. For example, the 10 bar steam requirement amounts to only 40% of that of 3 bar.

Start-up steam jet pumps are put into operation simultaneously with the vacuum pumps for normal operation. They can be shut off manually or automatically (using a pressure switch) by closing the suction and the motive steam supply line. To determine whether or not an auxiliary start-up pump is needed we require the following information:

- required pull-down time
- volume of the system to be evacuated
- leakage air entering the system
- gases and vapors in kg/h released during the evacuation
- kind and suction capacity of the vacuum pump used

For further information refer to section "Air leakage in vacuum vessels", 7 | ab18, and "Steam jet vacuum pumps", 7 | dvp1.

9. DESIGN CODES

In accordance with national and international safety rules, steam jet vacuum pumps and condensers for steam jet vacuum pumps do not require any acceptance procedures by official authorities, such as for instance TÜV, PED or U-Stamp, because they operate under vacuum.

Nevertheless, surface condensers are often required to be designed to a pressure vessel code to permit their later use for duties involving above atmospheric pressures. In such cases, the necessary stress calculations are carried out in accordance with the requirements of various codes such as AD-Regelwerk, ASME-Code etc.

If the condensers are to be built to any other design codes such as TEMA, HEI or any Works Standard Specifications, we need to know. If the requirements are not known to us, we will offer our own standard execution which is based on the "Allgemeinen Regeln der Technik" adjusted to the latest "Stand der Technik" (State-of-the-Art).

Flanges are supplied to DIN PN 10 or 16 as standard.

ASME or BS flanges are available on request. The equipment is also available with only the outside connecting flanges to ASME or BS or with all flanges to these standards i.e. including the flanges internal of the package.

10. STEAM JET VACUUM PUMPS VERSUS STEAM JET/LIQUID RING PUMP COMBINATION

There are applications for which steam jet liquid ring pump combinations are advantageous and economical. This especially applies when:

- The available motive steam pressure is less than 1.5 bar.
- The head room available for the installation of a steam jet vacuum pump with barometric condenser is insufficient.
- A liquid ring pump is already available and the pressure required by the process is considerably lower than can be reached by a liquid ring pump.
- It is the specific advantage of an upstream arranged steam jet pump, contrary to the motive gas/air of the gas jet pump, that motive steam is condensed upstream of the liquid ring vacuum thus considerably reducing the air load for the liquid ring pump.
- Large suction flows at suction pressures below approx. 60 mbar (abs.) are to be extracted. This is the case for example in mineral oil refineries. Here, each requirement must be examined individually especially as the suction streams contain a number of components, apart from gases or vapors, such as for example hydrocarbon vapors. If the suction flow contains several components which are partly dissolvable one in the other or in the operating liquid, such conditions can be taken into consideration by way of calculation and applying suitable measures.

To optimise the selection of a steam jet pump/liquid ring pump combination, a variety of factors have to be taken into consideration. These are:

- fractions of non-condensable gases and condensable vapors
- cooling water temperatures, min/max.
- motive steam pressure
- utility costs including costs of motive steam
- investment costs
- maintenance costs
- required pay-back time
- required materials for construction
- expected service life
- spare parts requirement

Depending on these factors, the optimum inter-stage pressure from which on it is reasonable to arrange a liquid ring pump downstream of a steam jet pumps, normally turns out to be in the range between 60 and 200 mbar. For very high capacities, the inter-stage pressure might even be 300 mbar.

To avoid or significantly reduce the costs for waste water, it is advisable to circulate the liquid ring pump operating water.

The heat (condensation/compression/loss heat) absorbed by the operating liquid in the pump is removed in an intermediately arranged separator/heat exchanger.

On the basis of our extensive experience and aided by computer programmes, we are in the position to determine the most favourable steam jet/liquid ring vacuum pump combination for the specific requirements and conditions of our customers.

Regarding the make of the liquid ring pump, we have the liberty of choice and can attend to the preferences of our customers.

Questionnaire

for the planning of a steam jet vacuum pump
or a vacuum condensation plant

[Link to fillable PDF](#)

1. SUCTION FLOW *) Several components to be stated separately.

Suction temperature °C

Air kg/h Non-condensable gases kg/h Mol weight kg/kmol

Water vapor kg/h Condensable vapors *) kg/h Mol weight kg/kmol

2. PRESSURE

Suction pressure mbar abs. Discharge pressure mbar abs.

3. CONDENSATION

MIXING CONDENSER

SURFACE CONDENSER

Installation: horizontal vertical

Cooling water: tube side shell side

Max. allowable tube length mm

External tube diameter mm

Wall thickness mm

Fouling factor $m^2K/W \cdot 10^{-4}$ (cooling water side) Fouling factor $m^2K/W \cdot 10^{-4}$ (vacuum/product side)

4. TYPE OF INSTALLATION

Barometric Semi-barometric Non-barometric

5. MOTIVE STEAM CONDITION

Temperature °C Pressure min. bar abs.

6. COOLING WATER

Temperature max °C Pressure min. mbar abs.

Permissible pressure loss mbar

7. MATERIALS

STEAM JET PUMPS Motive nozzles

MIXING CONDENSERS

SURFACE CONDENSERS: Tubes Tube sheets

Shell Water channels

8. PRE-EVACUATION

Volume of the total system m^3 to be evacuated in minutes

from atm. pressure to mbar abs.

9. COMBINATION: STEAM JET / LIQUID RING VACUUM PUMP

Cooling water temperature °C

With / without heat exchanger to recool the operating liquid Operating liquid

Motor data V Hz Ex-protection yes no Temperature of the operating liquid °C

Type of protection Temperature class

10. PARTICULARS ON OPTIMIZATION

Operating hours / year: h Amortization period

UTILITY COSTS: Motive steam Cooling water Electricity

Additional details, if required, are to be stated separately.

Your inquiry no. Offer submitted until Requested date of delivery

FURTHER NOTES:

YOUR ADDRESS

Street/P.O. Box Telephone

Company ZIP code/City Telefax

attn. Country E-mail



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