Product Catalogue

Jet Pumps
Mixers
Heaters
Vacuum Systems

GEA Wiegand GmbH

Table of contents

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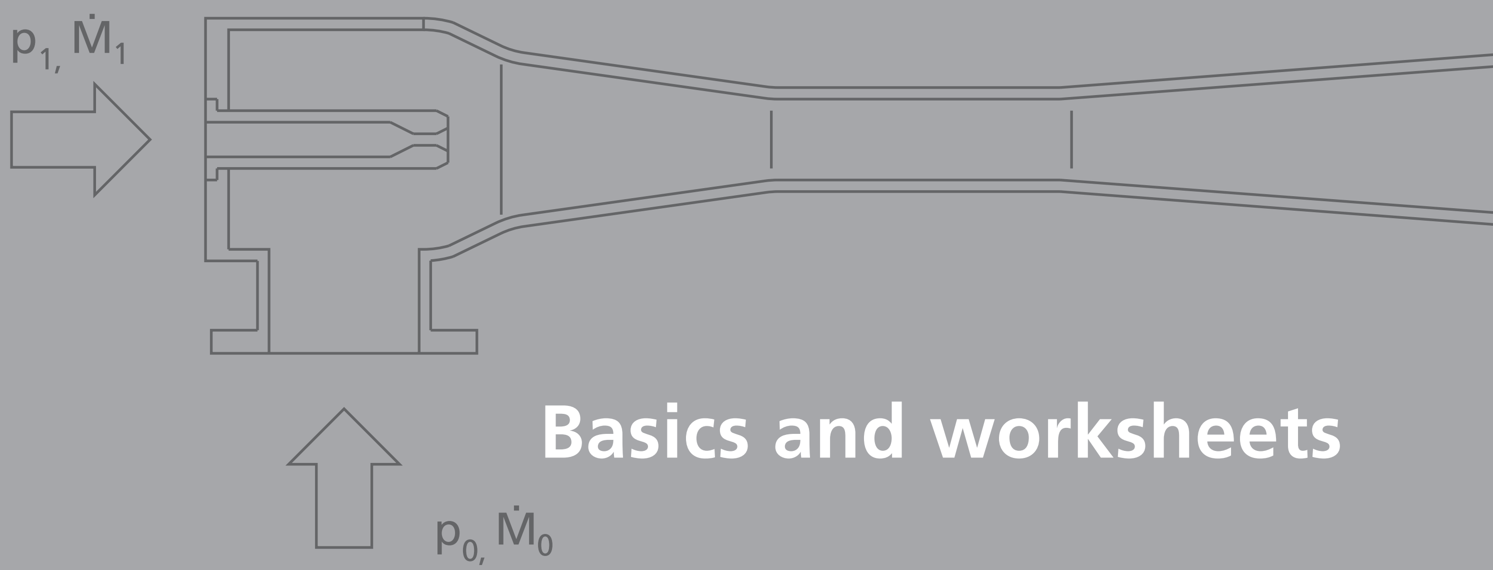
GEA



Basics and worksheets

- General information on jet pumps
- 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
- Temperature conversion table, °C in °F and vice versa
- Water vapour pressure table, vacuum range (saturated steam)
- Water vapour temperature table, vacuum range (saturated steam)
- Water vapour pressure table, pressure range 1-70 bar (saturated steam)
- Water vapour temperature table, temperature range 100-300 °C (saturated steam)
- Vapours and gases in vacuum
- Water vapour and air in vacuum
- Air leakage in vacuum vessels
- Admissible flow velocity in vacuum ducts
- Pressure loss in vacuum lines with water vapour
- Pressure loss in water pipes
- Dimensions, velocities and mass flows in steam and water pipes
- Vapour flows in pipes
- Mass flow of gases and vapours through nozzles
- Water vapour 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, vapours, 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

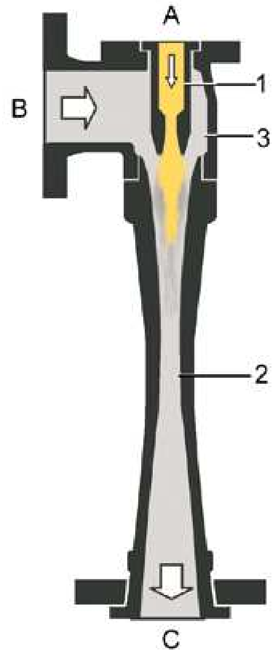
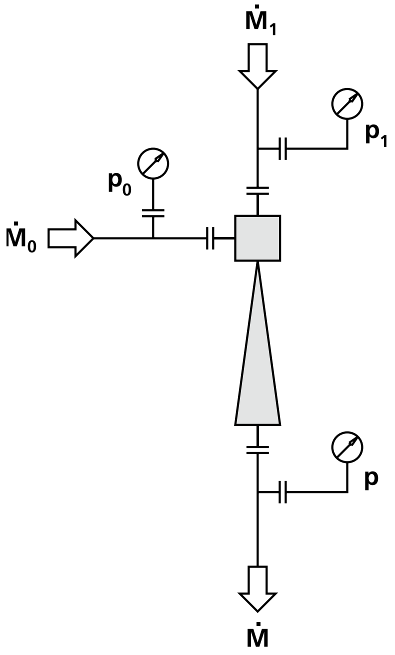


FIG. 2



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 catalogue 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 (Vapour 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 catalogue 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 CATALOGUE:

- The capacities specified in the catalogue 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 catalogue 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.

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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 catalogue, the following basic units of measurement and the corresponding abbreviations, taken from the International System of Units, shall apply.

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

THE MOST IMPORTANT OF THE DERIVED UNITS ARE:

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

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

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

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

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

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

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}
n	nano	10^{-9}
µ	mikro	10^{-6}
m	milli	10^{-3}
c	centi	10^{-2}
d	deci	10^{-1}

D	deca	10^{1}
h	hecto	10^{2}
k	kilo	10^{3}
M	mega	10^{6}
G	giga	10^{9}
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/m² = 1 mm WC 1 ata 1 Torr 1 m WC	1 kp/m² = 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 h Pa 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 $1\,W = 1\,\frac{Nm}{s} = 1\,\frac{J}{s}$
Heat transfer/ Heat transmission	$1\,\frac{kcal}{m^2 \cdot h \cdot °C}$	$1\,\frac{kcal}{m^2 \cdot h \cdot °C} = 1.163\,\frac{W}{m^2 \cdot K}$	$1\,\frac{W}{m^2 \cdot K}$
Thermal conductivity	$1\,\frac{kcal}{m \cdot h \cdot °C}$	$1\,\frac{kcal}{m \cdot h \cdot °C} = 1.163\,\frac{W}{m \cdot K}$	$1\,\frac{W}{m \cdot K}$
Specific heat capacity	$1\,\frac{kcal}{kg \cdot °C}$	$1\,\frac{kcal}{kg \cdot °C} = 4.1868\,\frac{kJ}{kg \cdot K}$	$1\,\frac{kJ}{kg \cdot K}$

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 catalogue.

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/m²	bar	at	mm WC	atm	Torr	psia
1 Pa = 1 N/m²	1	10^{-5}	$1.0197 \cdot 10^{-5}$	0.10197	$0.9869 \cdot 10^{-5}$	$0.75006 \cdot 10^{-2}$	$1.45037 \cdot 10^{-4}$
1 bar = 1000 mbar	10^{5}	1	1.0197	$1.0197 \cdot 10^{4}$	0.9869	$0.75006 \cdot 10^{3}$	14.5037
1 mbar	10^{2}	$1 \cdot 10^{-3}$	$1.0197 \cdot 10^{-3}$	10.197	$0.9869 \cdot 10^{-3}$	0.75006	$1.45037 \cdot 10^{-2}$
1 at	$0.98067 \cdot 10^{5}$	0.98067	1	$1.00003 \cdot 10^{4}$	0.96784	$0.73556 \cdot 10^{3}$	14.224
1 mm WC	9.8064	$0.98064 \cdot 10^{-4}$	$0.99997 \cdot 10^{-4}$	1	$0.96781 \cdot 10^{-4}$	$0.73554 \cdot 10^{-1}$	$1.4224 \cdot 10^{-3}$
1 atm	$1.01325 \cdot 10^{5}$	1.01325	1.03323	$1.03326 \cdot 10^{4}$	1	760	14.696
1 Torr	$1.3332 \cdot 10^{2}$	$1.3332 \cdot 10^{-3}$	$1.3595 \cdot 10^{-3}$	13.595	$1.3158 \cdot 10^{-3}$	1	$1.9336 \cdot 10^{-2}$
1 psia	$6.8948 \cdot 10^{3}$	$6.8948 \cdot 10^{-2}$	$7.0306 \cdot 10^{-2}$	$7.0306 \cdot 10^{2}$	$6.8043 \cdot 10^{-2}$	51.716	1

ENERGY UNITS

	kJ	kWh	kpm	kcal	Btu
1 kJ	1	$2.7778 \cdot 10^{-4}$	$1.0197 \cdot 10^{2}$	0.23884	0.9478
1 kWh	$3.6000 \cdot 10^{3}$	1	$3.6710 \cdot 10^{5}$	$8.598 \cdot 10^{2}$	$3.4120 \cdot 10^{3}$
1 kpm	$9.8067 \cdot 10^{-3}$	$2.7241 \cdot 10^{-6}$	1	$2.3422 \cdot 10^{-3}$	$9.2945 \cdot 10^{-3}$
1 kcal	4.1868	$1.1630 \cdot 10^{-3}$	$4.2694 \cdot 10^{2}$	1	3.96825
1 Btu	1.0551	$2.9308 \cdot 10^{-4}$	$1.0759 \cdot 10^{2}$	0.2520	1

CAPACITY UNITS

	kW	kpm/s	PS	kcal/s	kcal/h
1kW	1	$1.0197 \cdot 10^{2}$	1.3596	0.23884	859.824
1 kpm/s	$9.80665 \cdot 10^{-3}$	1	$1.3333 \cdot 10^{-2}$	$2.3422 \cdot 10^{-3}$	8.4319
1 PS	0.7355	75	1	$1.7573 \cdot 10^{-1}$	$6.3263 \cdot 10^{2}$
1 kcal/s	4.1868	$4.2694 \cdot 10^{2}$	5.692	1	$3.6 \cdot 10^{3}$
1 kcal/h	$1.163 \cdot 10^{-3}$	$1.1859 \cdot 10^{-1}$	$1.5811 \cdot 10^{-3}$	$2.7778 \cdot 10^{-4}$	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 be called the vacuum range. In vacuum technology absolute pressure is always used.

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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
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)	$6.895 \cdot 10^{-2}$ bar	1 bar	14.5 lbf/in^2
1 lbf/ft^2	$4.788 \cdot 10^{-4}$ bar	1 bar	20.88 lbf/ft^2

English-american units	Internat. system of units	Internat. system of units	English-american units
Heat / heat units		**Heat / heat units**	
1 Btu	1.055 kJ	1 kJ	0.948 Btu
Heat capacity		**Heat capacity**	
$1 \frac{Btu}{lb}$	$2.326 \frac{kJ}{kg}$	$1 \frac{kJ}{kg}$	$0.43 \frac{Btu}{lb}$
Specific heat capacity		**Specific heat capacity**	
$1 \frac{Btu}{lb \cdot °F}$	$4.1868 \frac{kJ}{kg \cdot K}$	$1 \frac{kJ}{kg \cdot K}$	$0.2388 \frac{Btu}{lb \cdot °F}$
Thermal conductivity		**Thermal conductivity**	
$1 \frac{Btu}{in \cdot h \cdot °F}$	$20.783 \frac{W}{m \cdot K}$	$1 \frac{W}{m \cdot K}$	$0.0481 \frac{Btu}{in \cdot h \cdot °F}$
$1 \frac{Btu}{ft \cdot h \cdot °F}$	$1.7308 \frac{W}{m \cdot K}$	$1 \frac{W}{m \cdot K}$	$0.5778 \frac{Btu}{ft \cdot h \cdot °F}$
Heat transfer		**Heat transfer**	
$1 \frac{Btu}{ft^2 \cdot h \cdot °F}$	$5.6785 \frac{W}{m^2 \cdot K}$	$1 \frac{W}{m^2 \cdot K}$	$0.1761 \frac{Btu}{ft^2 \cdot h \cdot °F}$
Fouling factor		**Fouling factor**	
$1 \frac{ft^2 \cdot h \cdot °F}{Btu}$	$0.1761 \frac{m^2 \cdot K}{W}$	$1 \frac{m^2 \cdot K}{W}$	$5.6785 \frac{ft^2 \cdot h \cdot °F}{Btu}$
Heat flux density		**Heat flux density**	
$1 \frac{Btu}{in^2 \cdot h}$	$454.3 \frac{W}{m^2}$	$1 \frac{W}{m^2}$	$2.202 \cdot 10^{-3} \frac{Btu}{in^2 \cdot h}$
$1 \frac{Btu}{ft^2 \cdot h}$	$3.1546 \frac{W}{m^2}$	$1 \frac{W}{m^2}$	$0.317 \frac{Btu}{ft^2 \cdot h}$

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:

$$\vartheta_{°C} = \frac{5}{9}\left(\vartheta_{°F} - 32\right) \qquad \vartheta_{°F} = \frac{9}{5}\vartheta_{°C} + 32$$

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Water vapour 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 vapour tables

Water vapour 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	2840.4	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

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Water vapour pressure table

Pressure range 1-70 bar (saturated steam)

$p_{abs.}$ bar	ϑ °C	v″ m³/kg	h″ kJ/kg	Δh_v kJ/kg
1.0	99.63	1.694	2675.4	2257.9
1.1	102.32	1.549	2679.6	2250.8
1.2	104.81	1.428	2683.4	2244.1
1.3	107.13	1.325	2687.0	2237.8
1.4	109.32	1.236	2690.3	2231.9
1.5	111.37	1.159	2693.4	2226.2
1.6	113.32	1.091	2696.2	2220.9
1.7	115.17	1.031	2699.0	2215.7
1.8	116.93	0.9772	2701.5	2210.8
1.9	118.62	0.9290	2704.0	2206.1
2.0	120.23	0.8854	2706.3	2201.6
2.1	121.78	0.8459	2708.5	2197.2
2.2	123.27	0.8098	2710.6	2193.0
2.3	124.71	0.7768	2712.6	2188.9
2.4	126.09	0.7465	2714.5	2184.9
2.5	127.43	0.7184	2716.4	2181.0
2.6	128.73	0.6925	2718.2	2177.3
2.7	129.98	0.6684	2719.9	2173.6
2.8	131.20	0.6460	2721.5	2170.1
2.9	132.39	0.6251	2723.1	2166.6
3.0	133.54	0.6056	2724.7	2163.2
3.2	135.75	0.5700	2727.6	2156.7
3.4	137.86	0.5385	2730.3	2150.4
3.6	139.86	0.5103	2732.9	2144.4
3.8	141.78	0.4851	2735.3	2138.6
4.0	143.62	0.4622	2737.6	2133.0
4.2	145.39	0.4415	2739.8	2127.5
4.4	147.09	0.4226	2741.9	2122.3
4.6	148.73	0.4053	2743.9	2117.2
4.8	150.31	0.3894	2745.7	2112.2
5.0	151.84	0.3747	2747.5	2107.4
5.5	155.46	0.3425	2751.6	2096.0
6.0	158.84	0.3155	2755.5	2085.0
6.5	161.99	0.2925	2758.8	2074.7
7.0	164.96	0.2727	2762.0	2064.9
7.5	167.76	0.2555	2764.9	2055.5
8.0	170.41	0.2403	2767.5	2046.5
8.5	172.93	0.2268	2769.9	2037.8
9.0	175.36	0.2148	2772.1	2029.5
9.5	177.66	0.2040	2774.2	2021.4
10	179.88	0.1943	2776.2	2013.6
11	184.07	0.1774	2779.7	1998.5
12	187.96	0.1632	2782.7	1984.3
13	191.61	0.1511	2785.4	1970.7
14	195.04	0.1407	2787.8	1957.7
15	198.29	0.1317	2789.9	1945.2
16	201.37	0.1237	2791.7	1933.2
17	204.31	0.1166	2793.4	1921.5
18	207.11	0.1103	2794.8	1910.3
19	209.80	0.1047	2796.1	1899.3

$p_{abs.}$ bar	ϑ °C	v″ m³/kg	h″ kJ/kg	Δh_v kJ/kg
20	212.37	0.09954	2797.2	1888.6
21	214.85	0.09489	2798.2	1878.2
22	217.24	0.09065	2799.1	1868.1
23	219.55	0.08677	2799.8	1858.2
24	221.78	0.08320	2800.4	1848.5
25	223.94	0.07991	2800.9	1839.0
26	226.04	0.07686	2801.4	1829.6
27	228.07	0.07402	2801.7	1820.5
28	230.05	0.07139	2802.0	1811.5
29	231.97	0.06893	2802.2	1802.6
30	233.84	0.06663	2802.3	1793.9
31	235.67	0.06447	2802.3	1785.4
32	237.45	0.06244	2802.3	1776.9
33	239.18	0.06053	2802.3	1768.6
34	240.88	0.05873	2802.1	1760.3
35	242.54	0.05703	2802.0	1752.2
36	244.16	0.05541	2801.7	1744.2
37	245.75	0.05389	2801.4	1736.2
38	247.31	0.05244	2801.1	1728.4
39	248.84	0.05106	2800.8	1720.6
40	250.33	0.04975	2800.3	1712.9
41	251.80	0.04850	2799.9	1705.3
42	253.24	0.04731	2799.4	1697.8
43	254.66	0.04617	2798.9	1690.3
44	256.05	0.04508	2798.3	1682.9
45	257.41	0.04404	2797.7	1675.6
46	258.75	0.04304	2797.0	1668.3
47	280.07	0.04208	2796.4	1661.1
48	261.37	0.04116	2795.7	1653.9
49	262.65	0.04028	2794.9	1646.8
50	263.91	0.03943	2794.2	1639.7
51	265.15	0.03861	2793.4	1632.7
52	266.37	0.03782	2792.6	1625.7
53	267.58	0.03707	2791.7	1618.8
54	268.76	0.03633	2790.8	1611.9
55	269.93	0.03563	2789.9	1605.0
56	271.09	0.03495	2789.0	1598.2
57	272.22	0.03429	2788.0	1591.4
58	273.35	0.03365	2787.0	1584.7
59	274.46	0.03303	2786.0	1578.0
60	275.55	0.03244	2785.0	1571.3
61	276.63	0.03186	2784.0	1564.7
62	277.70	0.03130	2782.9	1558.0
63	278.75	0.03076	2781.8	1551.5
64	279.79	0.03023	2780.6	1544.9
65	280.82	0.02972	2779.5	1538.4
66	281.84	0.02922	2778.3	1531.9
67	282.84	0.02874	2777.1	1525.4
68	283.84	0.02827	2775.9	1518.9
69	284.82	0.02782	2774.7	1512.5
70	285.79	0.02737	2773.5	1506.0

Documentation: VDI Water vapour tables

Water vapour 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	0.2681	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 vapour tables

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Vapours and gases in vacuum

If mixtures of vapours and gases are condensed under vacuum, the gases and certain portions of non-condensed vapours 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 vapours 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-vapour mixture will take place if this component is brought to a saturated steam condition (dew point) by cooling the mixture. A saturated gas-vapour mixture is, therefore, present at the condenser outlet.

The composition of such saturated gas-vapour mixtures can be calculated as follows:
For example, for a mixture of 2 components - an inert gas and a condensable vapour - 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 vapour, corresponding to the temperature of the gas-vapour 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 vapour at partial pressure p_V.

$\dot{M}_V$	Mass flow of the vapour in kg/h
$\dot{M}_I$	Mass flow of the inert gases in kg/h
$\tilde{M}_V$	Molecular mass of the vapour in kg/kmol
$\tilde{M}_I$	Molecular mass of the inert gas in kg/kmol
p_V	Partial pressure of the vapour in mbar
p_I	Partial pressure of the inert gas in mbar

The following formula applies:

$$p_I \cdot V = M_I \cdot R_I \cdot T = M_I \cdot \frac{\tilde{R}}{\tilde{M}_I} \cdot T \qquad 1)$$

$$p_V \cdot V = M_V \cdot R_V \cdot T = M_V \cdot \frac{\tilde{R}}{\tilde{M}_V} \cdot T \qquad 2)$$

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

$$\frac{p_I}{p_V} = \frac{\dot{M}_I}{\dot{M}_V} \cdot \frac{\tilde{M}_V}{\tilde{M}_I} \quad \text{or} \quad \dot{M}_{Vj} = \dot{M}_I \cdot \frac{\tilde{M}_{Vj}}{\tilde{M}_I} \cdot \frac{p_{Vj}}{p_I} \qquad 3)$$

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

$$\dot{M}_{Vj} = \dot{M}_I \cdot \frac{\tilde{M}_{Vj}}{\tilde{M}_I} \cdot \frac{p_{Vj}}{p_I} \qquad 4)$$

for j from 1 to n

For example, if a saturated mixture of air, water vapour, and benzene vapour 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 $\dot{M}_I = 100 \frac{kg}{h}$ saturation quantities of water vapour and benzene vapours can be found as follows:

At 30 °C we read from the steam tables:

p_V water vapour	=	42.4 mbar
p_V benzene vapour	=	160 mbar
Total	=	202.4 mbar

Hence

$p_I = 250 - 202.4 = 47.6$ mbar

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

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

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

and with equation 4) we have:

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

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

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

As one can see, the vapour 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 vapour and air in vacuum

Condensers in which water vapour 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 vapour as described on page “Vapours and gases in vacuum”.

In addition to the air (and other inert gases) we have to know the quantity of water vapour 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 “Vapours and gases in vacuum” and allows easier calculation.

$$\frac{\dot M_V}{\dot M_I} = \frac{\tilde M_V}{\tilde M_I} \cdot \frac{p_V}{p_I}$$

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

and $\tilde M_I = \tilde M_A = 29 \frac{kg}{kmol}$ 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:

$$\frac{\dot M_V + \dot M_A}{\dot M_A} = 1 + 0.622 \cdot \frac{p_V}{p - p_V} \ \frac{\text{kg Mixture}}{\text{kg Air}}$$

Fig. 1 shows the relation between the temperature and the vapour content in vapour/air mixtures at constant total pressures p. For easier use, the water vapour 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 vapour/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 vapour content is approximately 65 % or mathematically:

In the water vapour table (see “Water vapour temperature table”, ↗ | abl 5) 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:
$p_A = 42.4 - 31.7 = 10.7$ mbar

With the formula

$$\dot M_V = \dot M_A \cdot 0.622 \cdot \frac{p_V}{p_A}$$

you will find:

$$\dot M_V = 2 \cdot 0.622 \cdot \frac{31.7}{10.7} = 3.7 \ \frac{\text{kg Vapour}}{\text{h}}$$

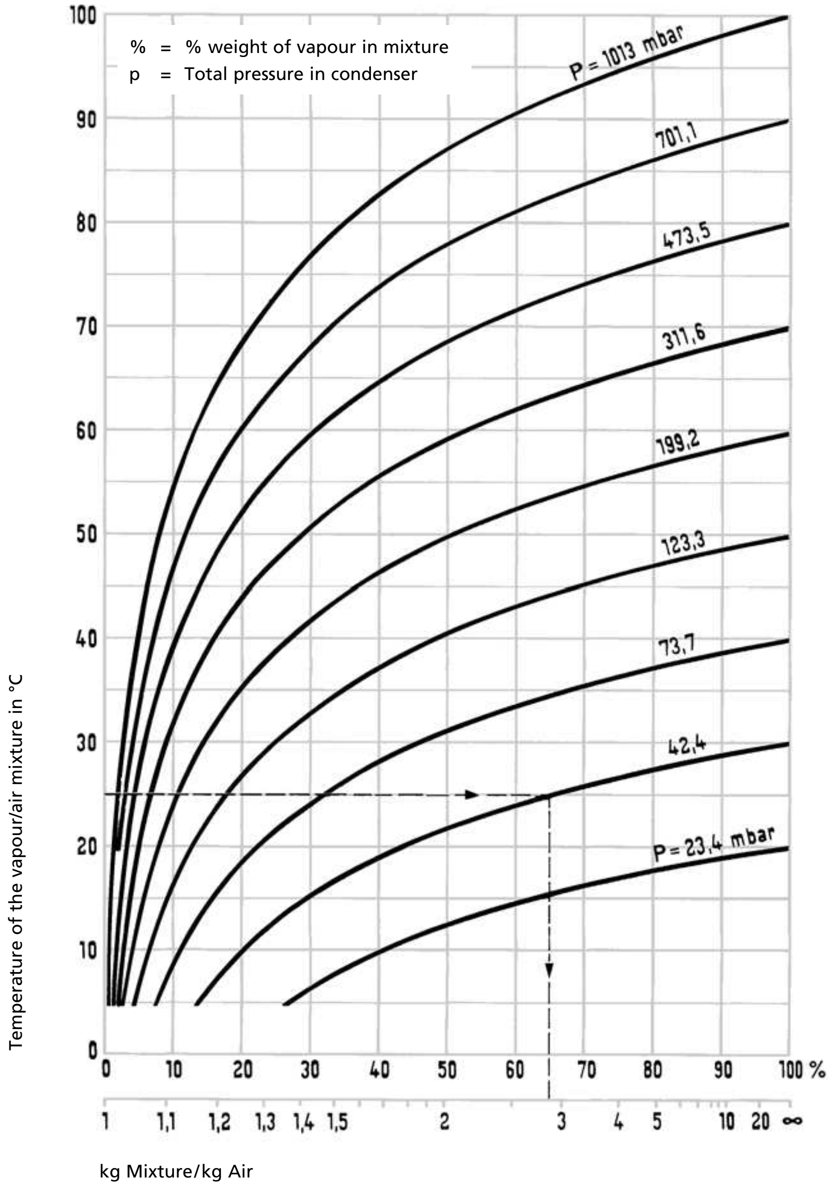
Therefore, 2 + 3.7 = 5.7 kg/h of vapour/air mixture has to be drawn off.

If instead of 2 kg/h air, 2 kg/h hydroge with $\dot M_A = 2 \frac{kg}{mol}$ have to be drawn off under the same conditions, the saturating quantity for water vapour is found according to the formula on page “Vapours and gases in vacuum” page 17:

$$\dot M_{Vj} = \dot M_I \cdot \frac{\tilde M_{Vj}}{\tilde M_I} \cdot \frac{p_{Vj}}{p_I} = 2 \cdot \frac{18}{2} \cdot \frac{31.7}{10.7} = 53.3 \ \frac{\text{kg Vapour}}{\text{h}}$$

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

FIG. 1



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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 $\frac{kg}{h}$
Δp	Change of pressure in mbar
t	Corresponing time in min
V	Plant volume in m^3

* The exact value is 0.071289977, based on:

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

EXAMPLE FOR AIR LEAKAGE

A vessel of 20 m³ 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

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

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

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

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

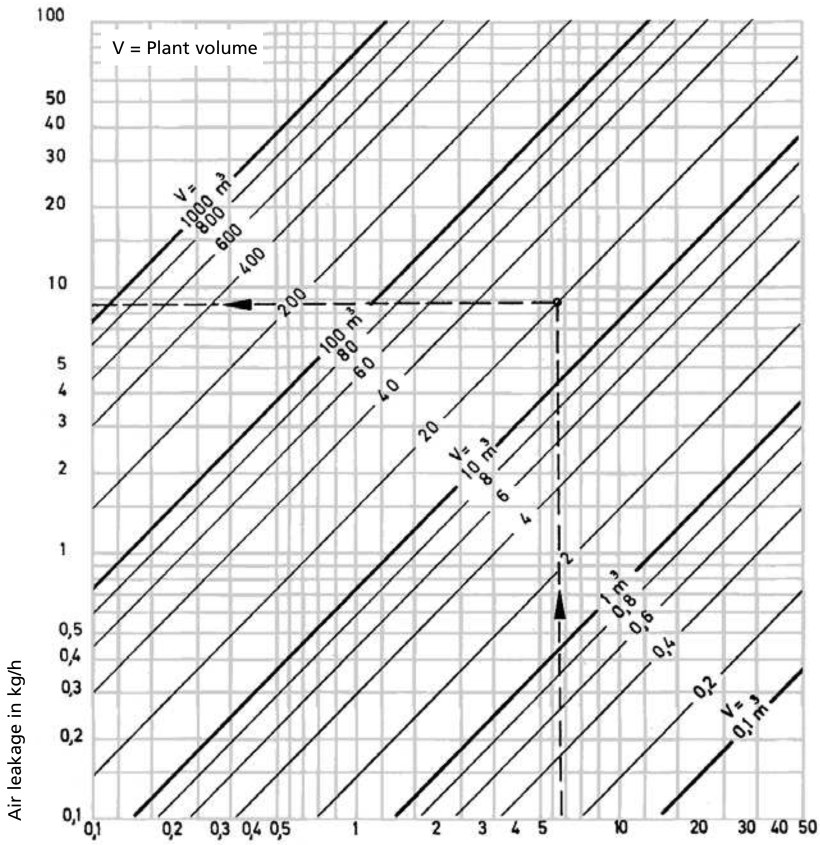
$$1\,mbar\ \frac{liter}{s} \mathrel{\hat=} 0.0043\ \frac{kg}{h} \quad \text{Air of 20 °C}$$

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 mm² approx. 0.83 kg/h of air flow into a vacuum unit, independent of the amount of vacuum, if it is only < 530 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



(The diagram is valid for pressures ≤ 500 mbar and for air of 20 °C)

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 m³	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
$R = \frac{\tilde{R}}{\tilde{M}}$	Individual gas constant in J/kg K
$\tilde{R} = 8314.3 \frac{J}{kmol} K$	Universal gas constant
$\tilde{M}$	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 ↗ I abl 9.

EXAMPLE 1

CALCULATION OF THE MASS FLOW

GIVEN:

Duct	DN 100
Duct length	l = 10 m
Flow medium	Air, 20 °C
Total pressure	p = 10 mbar
Adm. pressure loss	Δp = 1 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 $\dot{M} = \frac{\dot{V}}{v} \frac{kg}{h}$ and $v_A = \frac{840}{p} \frac{m^3}{kg}$

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:

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

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°	ζ = 0.16
	Gate valve with restriction	ζ = 1.0

GIVEN:

Duct	DN 600
Pipe length	l = 100 m
Flowing medium	air, 20 °C
Total pressure	p = 10 mbar
Adm. pressure loss	Δp = 1 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) $l_E = 100 + \frac{600}{40}(4 \cdot 0.16 + 1) = 124.6 \text{ m}$

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

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

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

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

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Pressure loss in vacuum lines with water vapour

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

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

Δp	Pressure loss in mbar
$\Delta p'$	Pressure loss in N/m²
K	Total resistance coefficient
	$= \Sigma\,\zeta$ = sum of individual resistance
w	Flow velocity in m/s
ρ	Density of the flowing Medium in kg/m³

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

FIG. 1

Pressure loss Δp in mbar and $\Delta p'$ in $\frac{N}{m^2}$

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

CALCULATION

RESISTANCE COEFFICIENTS	
(1) Acceleration from 0 → 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 → 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	$K = \Sigma\,\zeta$
(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** $\lambda = 0.024$	$\zeta = 0.024 \cdot \frac{13}{0.2} = 1.56$
	$K = \Sigma\,\zeta = 3.64$

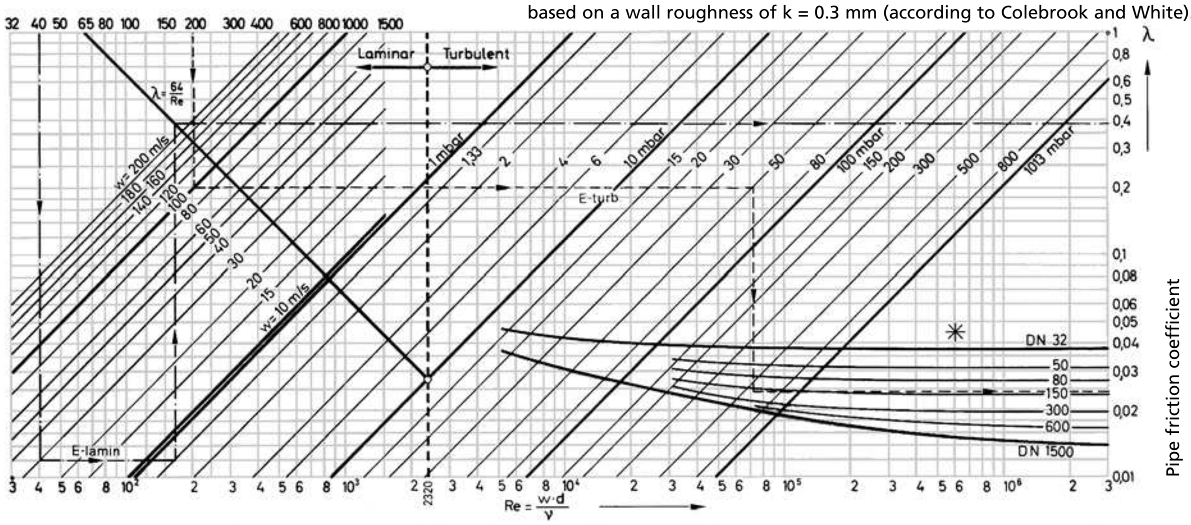
Pressure loss from diagram, **fig. 1**

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

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:

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

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

Δp	Pressure loss in mbar
Δp_{100}	Pressure loss for 100 m pipeline in mbar
l	Pipe length in m
d	Pipe diameter in m
ρ	Density of the flowing medium in kg/m³
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

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

EXAMPLE

GIVEN:

Water flow $\dot{V} = 40\,\frac{m^3}{h}$

Piping DN 80 $d = 0.08$ m
Pipe length $l = 70$ m

The following is installed in the pipe:
3 tube bends 90°
1 diaphragm valve

PARAMETERS TO BE FOUND:
1) Pressure loss in the pipeline
2) Water velocity

SOLUTION:

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

l_E Equivalent pipe length in m for shaped pieces and valves

From diagram **fig. 1**:

$\Delta p_{100} = 770$ mbar

From table:

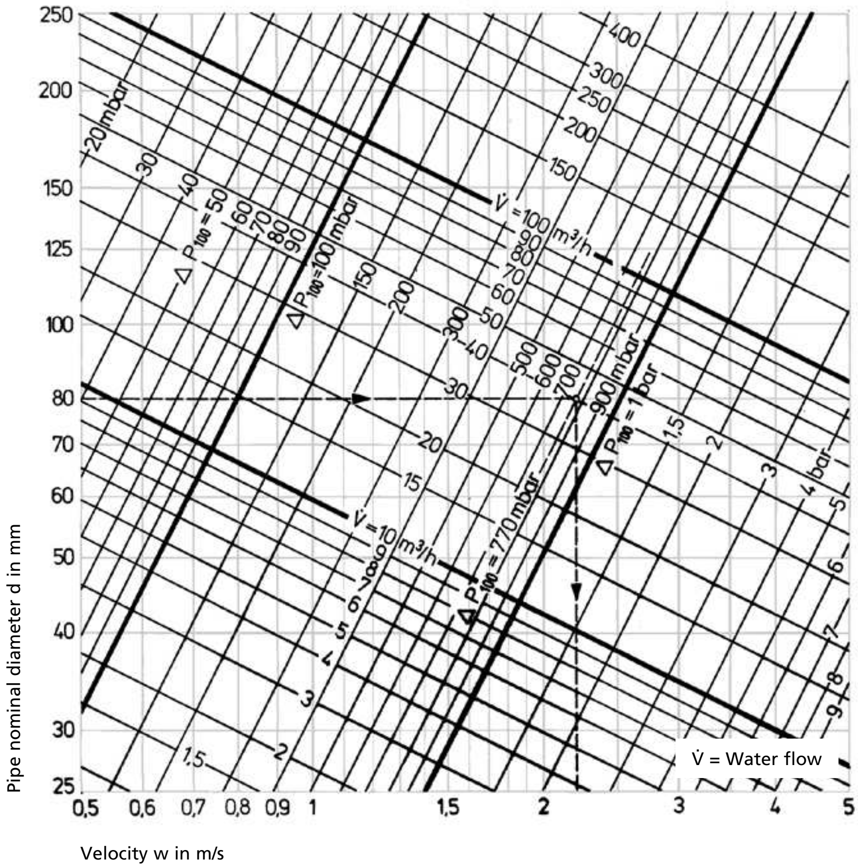
$l_E = 3 \cdot 1.2 + 10 = 13.6$ m

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

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

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

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	–

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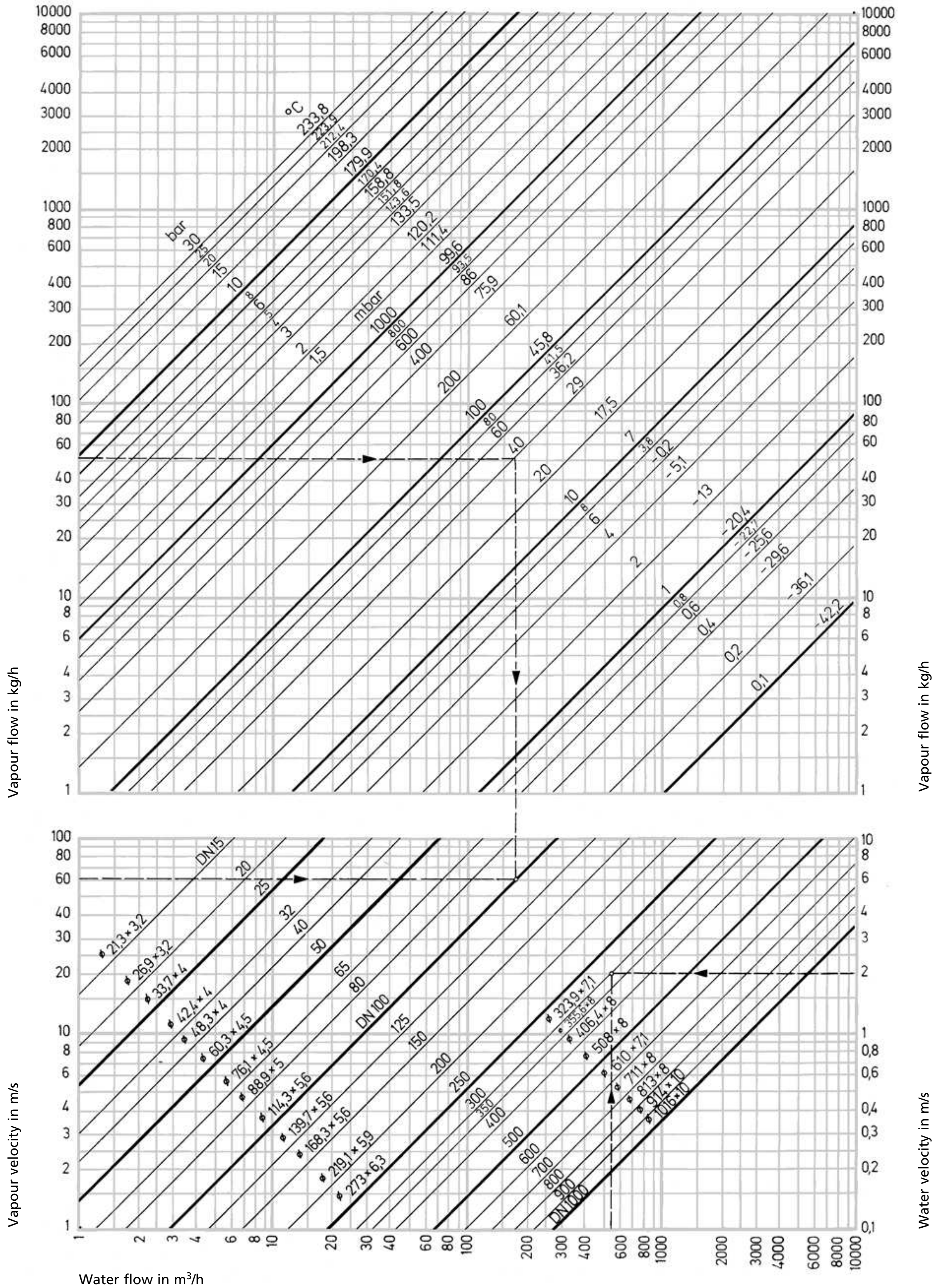
FIG. 1



Vapour flow in kg/h
Vapour velocity in m/s
Water velocity in m/s
Water flow in m³/h
bar
°C
mbar
DN15
DN100
DN1000

Vapour flows in pipes

VACUUM

Vapour 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

Vapour 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

Vapour 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

Vapour 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 vapour 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.

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Mass flow of gases and vapours through nozzles

According to the Law of Continuity the following shall apply:

$\dot{M} = a \cdot w \cdot \rho$ (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
φ	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:
a) critical or supercritical pressure drops,
b) 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:

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

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 vapour 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:

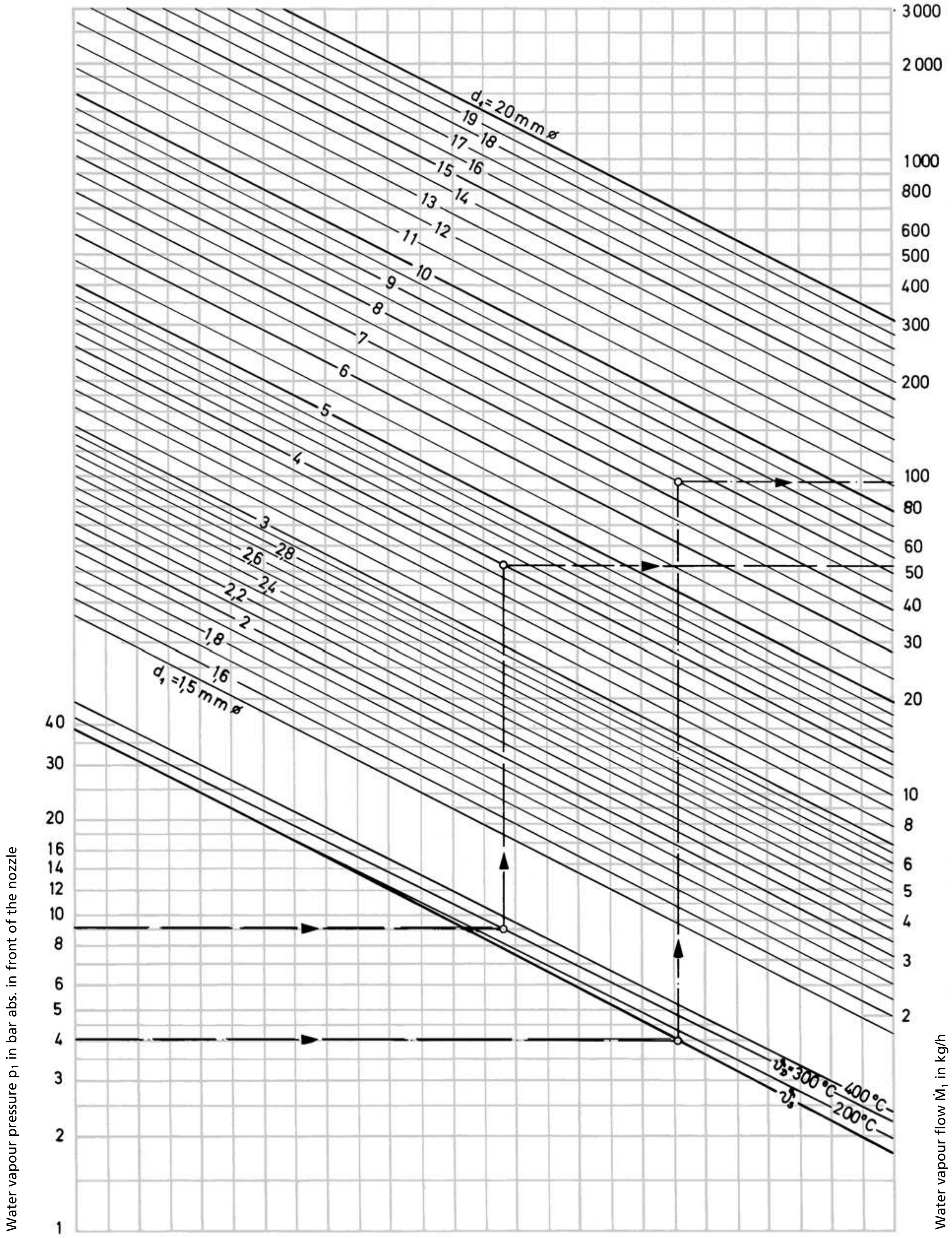
1. 96 kg/h steam pass through the nozzle at saturated steam of $p_1 = 4$ bar absolute pressure and a nozzle diameter of 7.5 mm.
2. Approx. 53 kg/h steam pass through a nozzle with a diameter of 4 mm at superheated steam ($\vartheta_D = 300$ °C) with an absolute pressure of $p_1 = 9$ bar.

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

Literature:
1) VDMA information sheet no. 24294, sheet 1 and 2
2) DIN sheet 28430

Water vapour flow through motive nozzles at critical pressure ratio

FIG. 1



Water vapour flow through motive nozzles at critical pressure ratio

ϑ_S = Saturated steam temperature
ϑ_D = Steam temperature
d_1 = Motive nozzle diameter

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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 vapours, and partly of inert gases.
For more detailed indications for determining the suction flows please refer to "Planning a steam jet vacuum pumps", ↗ | 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 vapour 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 vapour 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 vapour)
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 vapour, whereas for all other gases and vapours the temperature should be read from the top scale.

EXAMPLE 1

OPERATING AND DESIGN DATA:

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

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

Gas temperature $\vartheta_G = 240\,°C$

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 $\tilde{M} \approx 29\,kg/kmol$ and $\vartheta_G = 20\,°C$.
From **fig. 1** graph line "b" gives the equivalent flow factor
Thereby the equivalent air suction flow is calculated: $\dot{M}_{02} = 100 \cdot \frac{1}{0.179} \approx 560 \frac{kg}{h}$

EXAMPLE 2

OPERATING AND DESIGN DATA:

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

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

Temperature of the mixture $\vartheta_G = 300\,°C$

From **fig. 1** the graph line "c" gives a suction flow factor $f_1 = 1.22$.
The test should be conducted using water vapour (mol mass $\tilde{M}_{02} = 18$ kg/kmol) $\vartheta_{H20} = 150\,°C$.
From **fig. 1** graph line "d" gives the equivalent flow factor $f_2 = 0.73$.
Thereby the equivalent steam suction flow is calculated: $\dot{M}_{02} = 100 \cdot \frac{0.73}{1.22} \approx 60\,kg/h$

EXAMPLE 3

OPERATING AND DESIGN DATA:

Mixed suction flow

	100	kg/h Water vapour
+	200	kg/h Hydrocarbon vapour $\tilde{M}$ = 100 kg/kmol
+	22	kg/h Inert gases $\tilde{M}$ = 29 kg/kmol
=	322	kg/h

Temperature of the mixture $\vartheta_G = 300\,°C$

For mixtures of water vapour, other vapour and inert gases, the water vapour portion on the one hand and the vapour/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 vapour/inert gas portion (without water vapour):

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

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

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

The conversion shall be done in an equivalent water vapour flow of $\vartheta_{H20} = 150\,°C$:
For the water vapour portion you will find in diagram **fig. 1**
at $\vartheta_{H20} = 300\,°C$ and $\tilde{M} = 18$ kg/kmol
$f_1 = 0.65$ (continuous line "e")
at $\vartheta_{H20} = 150\,°C$ and $\tilde{M} = 18$ kg/kmol
$f_2 = 0.73$ (continuous line "d")

Hence results:

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

For the vapour/inert gas portion you will find in diagram **fig. 1**
at $\vartheta_G = 300\,°C$ and $\tilde{M} = 80$ kg/kmol
$f_1 = 1.22$ (continuous line "c")
and at $\vartheta_{H20} = 150\,°C$ and $\tilde{M} = 18$ kg/kmol
$f_2 = 0.73$ (continuous line "d")

Hence results:

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

Thus, the total equivalent water vapour suction flow results with

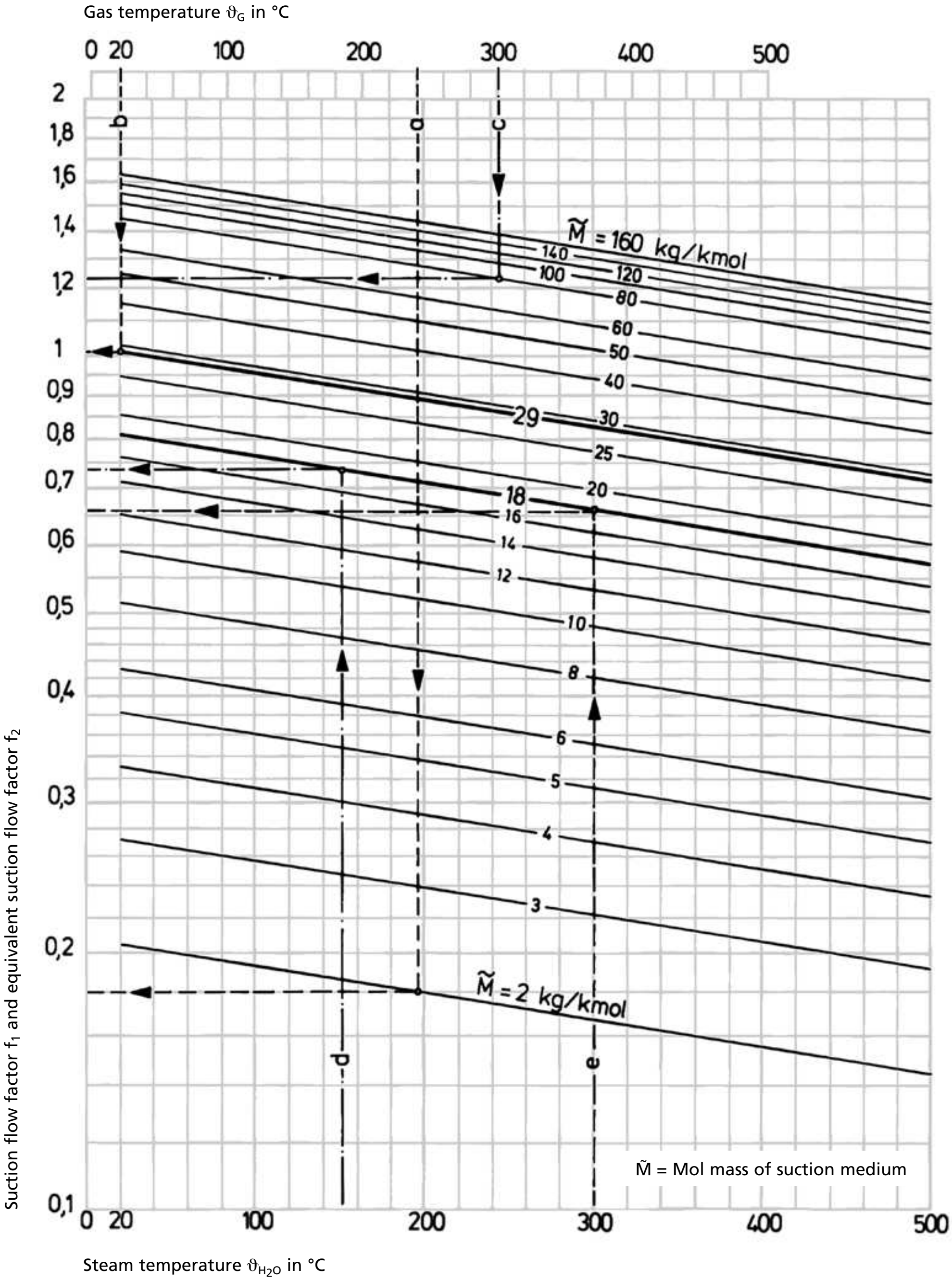
$$\dot{M}_{02}{}' + \dot{M}_{02}{}'' = 245.15 \frac{kg}{h}$$

MOLECULAR MASS OF SEVERAL SUCTION MEDIA

M̃ – Mol mass of suction medium

Gas	M̃ [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 Dampfstrahl-vakuumpumpen und Dampfstrahlkompressoren."
2) "HEI-Standards for Steam Jet Ejectors", Heat Exchange Institute, New York, USA

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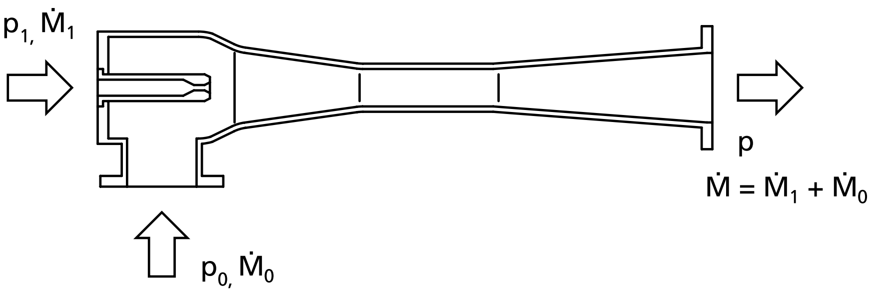
Steam consumption of jet pumps

FIG. 1



p_1	Motive pressure in bar	$\dot{M}_1$	Motive flow in kg/h
p_0	Suction pressure in mbar	$\dot{M}_0$	Suction flow in kg/h
p	Discharge pressure in mbar	$\dot{M}$	Mixed flow in kg/h

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 catalogue sheet cannot be considered.) Since the steam consumption diagram **fig. 2** applies for the removal of water vapour at $\vartheta = 150\ °C$, the operating/design suction flow must first be converted into an equivalent water vapour 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:

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

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-vapour mixture (without water vapour) with a mean molecular mass of $\tilde{M} = 18$ kg/kmol and $\vartheta_G = 300\ °C$ shall be removed (see example in catalogue sheet ↗ | abl 12).
The conversion into an equivalent water vapour suction flow of $\vartheta_{H20} = 150\ °C$ results in $\dot{M}_{0WE} = 60$ kg/h.

With a suction pressure of $p_0 = 10$ mbar,

discharge pressure of $p = 50$ mbar and a

motive steam pressure of $p_1 = 5$ bar abs.

the following results:

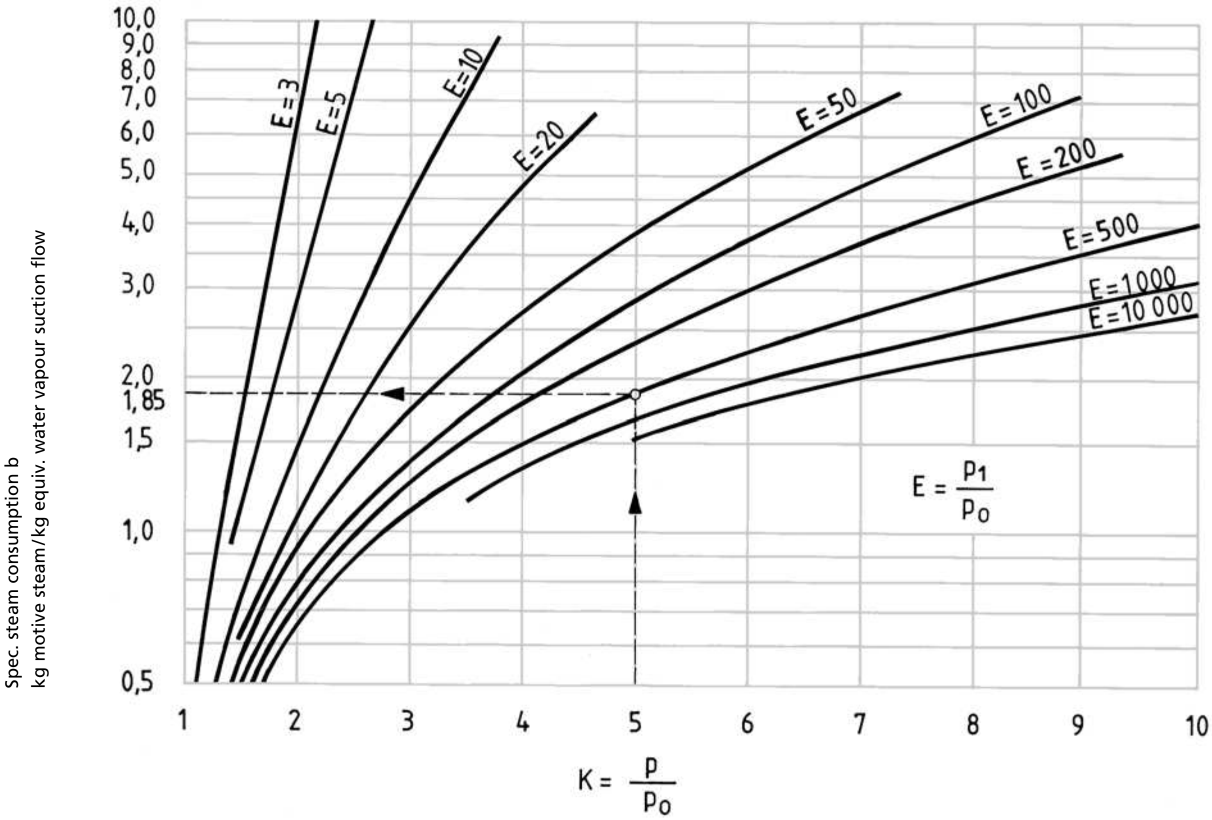
$$K = \frac{50}{10} = 5$$

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

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

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

FIG. 2



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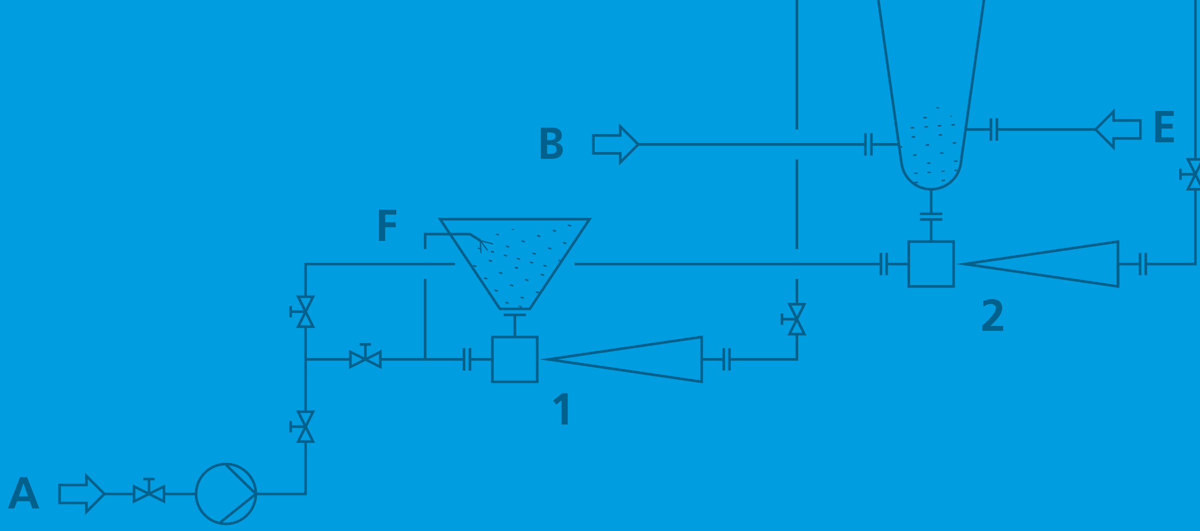


Liquid jet pumps

- 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 porcelain
- Liquid jet gas compressors
- Liquid jet liquid pumps, general information
- Liquid jet liquid pumps of cast iron or cast stainless steel
- Standard liquid jet liquid pumps of PVC/PP (plastic construction)
- Standard liquid jet liquid pumps of porcelain, armoured
- Liquid jet solids pumps
- Liquid jet mixers
- Liquid jet ventilators

Liquid jet vacuum pumps

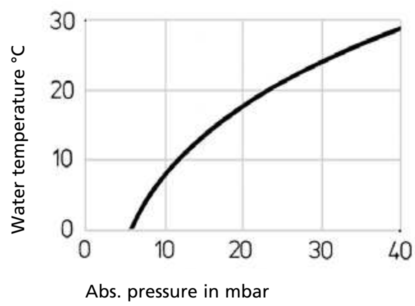
General information

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”, ↗ | abl 1.

MODE OF OPERATION

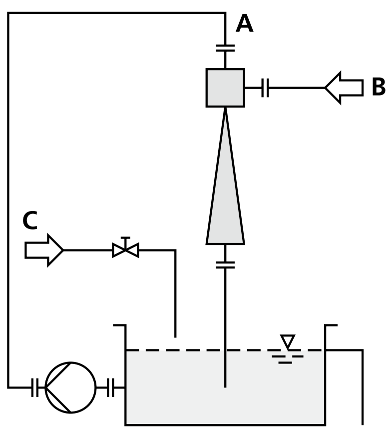
Liquid jet vacuum pumps, when water is used as the motive medium, can be directly coupled to the water line. If, however, the water consumption has to be as economical as possible, the operating water may be circulated. This is also the case when other liquids are used as the motive medium, instead of water.
The temperature of the operating liquid may be kept low by the constant addition of a small quantity of fresh liquid. Higher 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 vapour 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**.

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**).

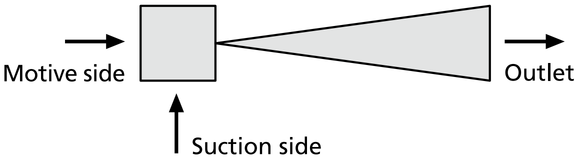
Liquid jet vacuum pump with threaded connections

Liquid jet vacuum pump with flanged connections

Liquid jet vacuum pump of porcelain

Questionnaire

for liquid jet vacuum pumps
fvp1, fvp2, fvp3



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:

DIN PN ☐
ASME lbs ☐
Others ☐

DESIGN CODE (if required):

AD ☐
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 . . . .
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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

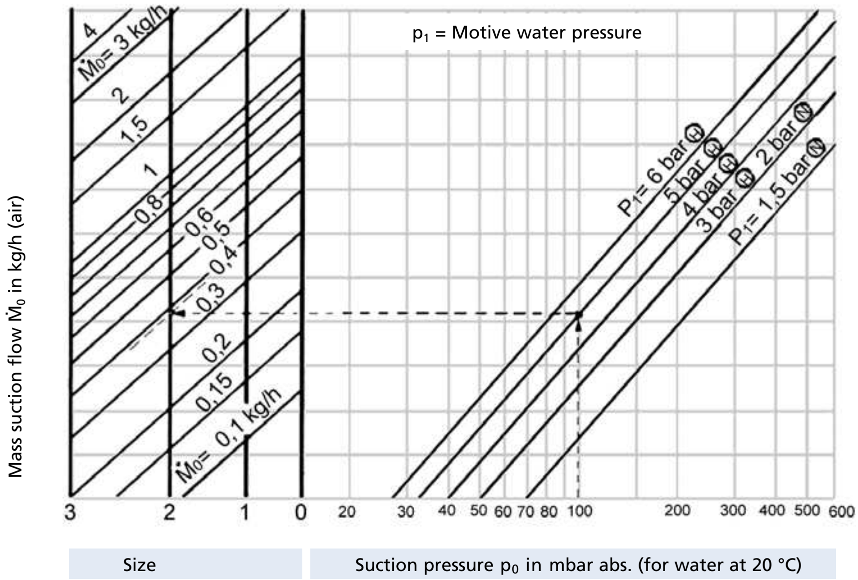
Diagram **fig. 3** gives the mass suction flow in kg/h of air in relation to the suction pressure at various operating water pressures for 4 pump sizes. The curves are based on an operating water temperature of 20 °C.
The motive liquid consumption or the motive liquid flow (circulating water operation)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

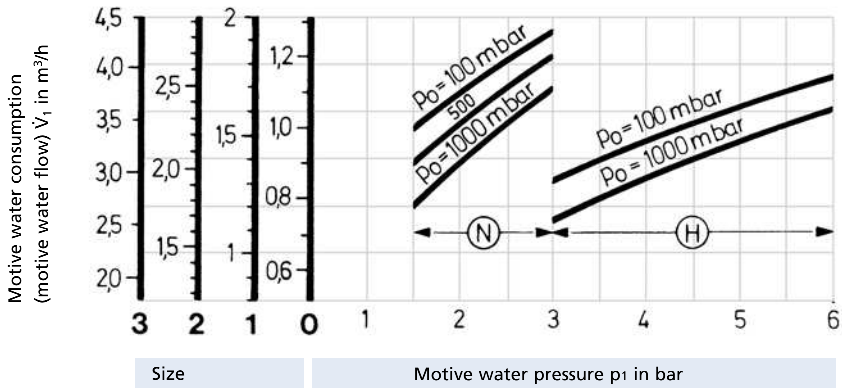
PARAMETERS TO BE FOUND: Size of pump and motive water consumption.
SOLUTION: From diagram **fig. 3**, for a suction pressure of 100 mbar and a motive water pressure of 5 bar g, pump size 2 with a mass suction flow of 0.38 kg/h is closest to the required suction volume.
From diagram **fig. 4**, for a 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



Ⓝ = Low pressure construction (1.5 – 2 bar)
Ⓗ = High pressure construction (3 – 6 bar)
Pressure indications in bar = bar g

FIG. 4



Ⓝ = Low pressure construction (1.5 – 2 bar)
Ⓗ = High pressure construction (3 – 6 bar)
Pressure indications in bar = bar g
p_0 = Suction pressure in mbar abs.

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:

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

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 x 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

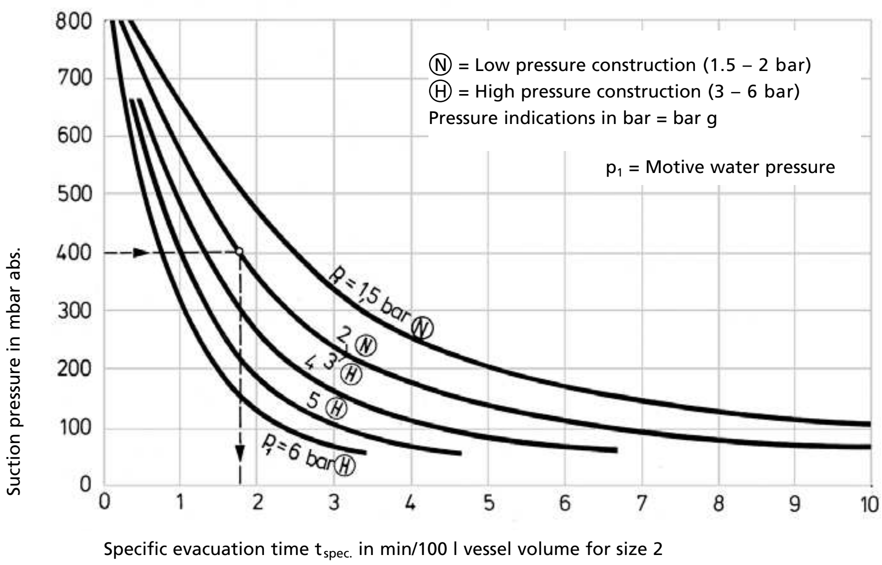
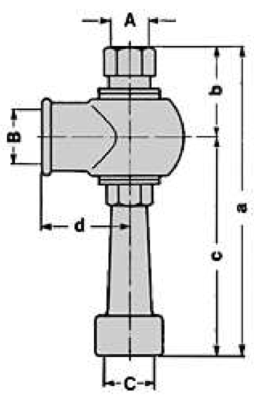


FIG. 6



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: cast iron EN-GJL-200 (GG20), motive nozzle: brass
II Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel
III Completely stainless steel

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

For standard pumps of porcelain, please see “Liquid jet vacuum pumps of porcelain”, ↗ | fvp3.
Motive pressure has to be given with inquiry/order.
For inquiries please use our questionnaire.

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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**.

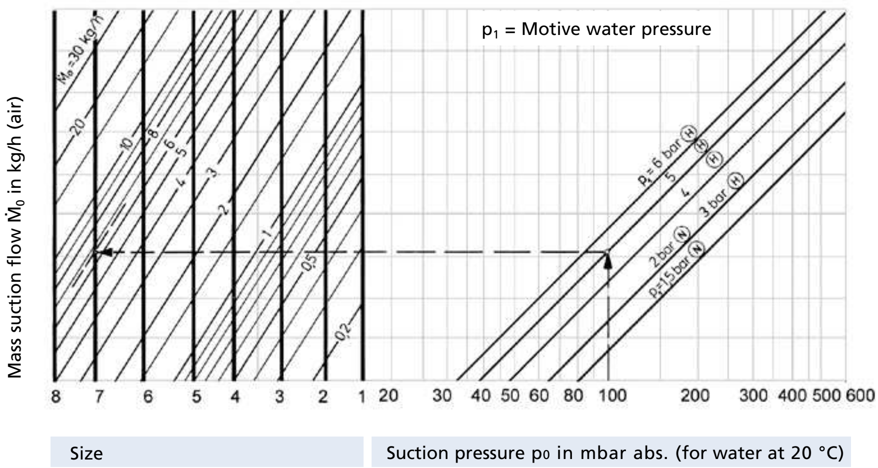
EXAMPLE

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.

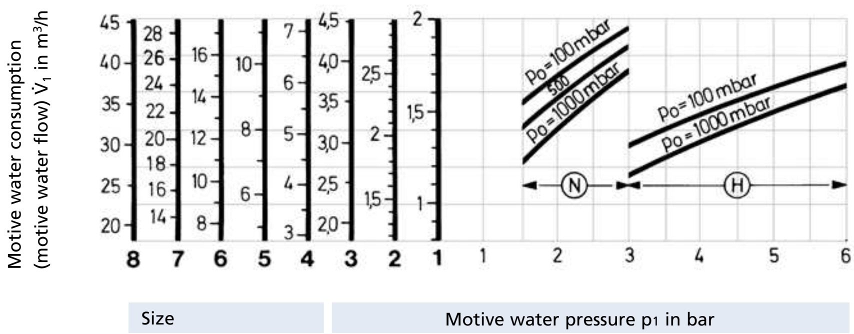
SOLUTION: From diagram **fig. 7**, for a suction pressure of 100 mbar and a motive water pressure of 5 bar g, pump size 7 with a mass suction flow of 6.8 kg/h is closest to the required suction volume.
From diagram **fig. 8**, for a motive water pressure of 5 bar g and a suction pressure of 100 mbar a motive water consumption of 23.5 m³/h for the chosen size 7 can be found.

FIG. 7



(N) = Low pressure construction (1.5 – 2 bar)
(H) = High pressure construction (3 – 6 bar)
Pressure indications in bar = bar g

FIG. 8



(N) = Low pressure construction (1.5 – 2 bar)
(H) = High pressure construction (3 – 6 bar)
Pressure indications in bar = bar g
p_0 = Suction pressure in mbar abs.

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:

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

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 p_0. This is established by means of the curves in fig. 8.

FIG. 9

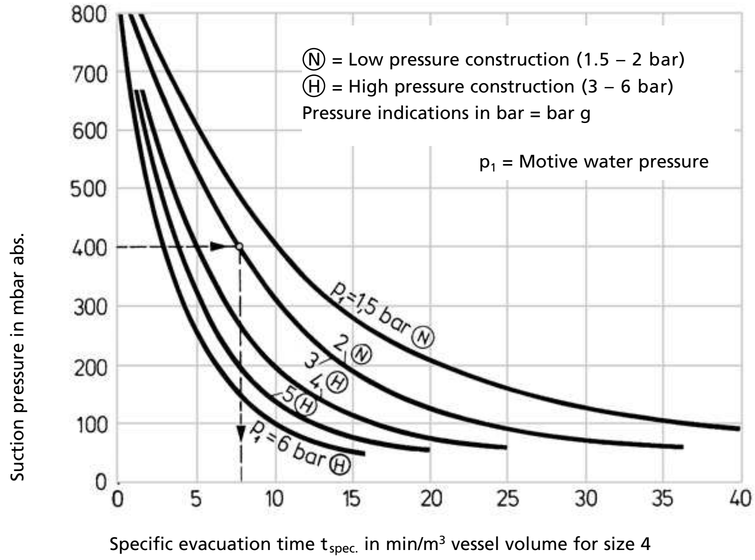
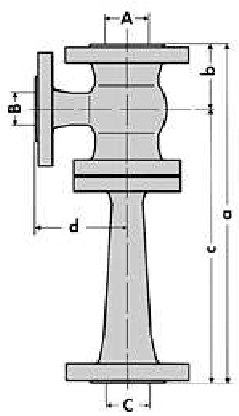


FIG. 10



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	63	68	78	78	78	113
	c	147	207	284	339	400	530	700	850
	d	85	85	100	115	125	125	125	135
Weight in kg		8	10	13	18	26	35	55	65

STANDARD CONSTRUCTIONS:

I Housing: cast iron EN-GJL-200 (GG20), motive nozzle: brass
II Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel
III Completely stainless steel, loose flanges: steel
Flanges according to DIN PN 10

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

For standard pumps of porcelain, please see “Liquid jet vacuum pumps of porcelain”, ↗ | fvp3.
Motive pressure has to be given with inquiry/order.
For inquiries please use our questionnaire.

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Liquid jet vacuum pumps

of porcelain

APPLICATIONS

Liquid jet vacuum pumps of porcelain are used in laboratories and in pilot and production plants. They are used for evacuating syphon lines on acid plants, for producing vacuum, for deaerating apparatus in which solvent vapours are produced and for producing negative pressures in Nutsch filters, etc.
Jet pumps of porcelain are encased in a protective armour of cast iron. These pumps are, therefore, well protected against mechanical and chemical aggression. They are reliable and maintenance-free; the capital cost is low.

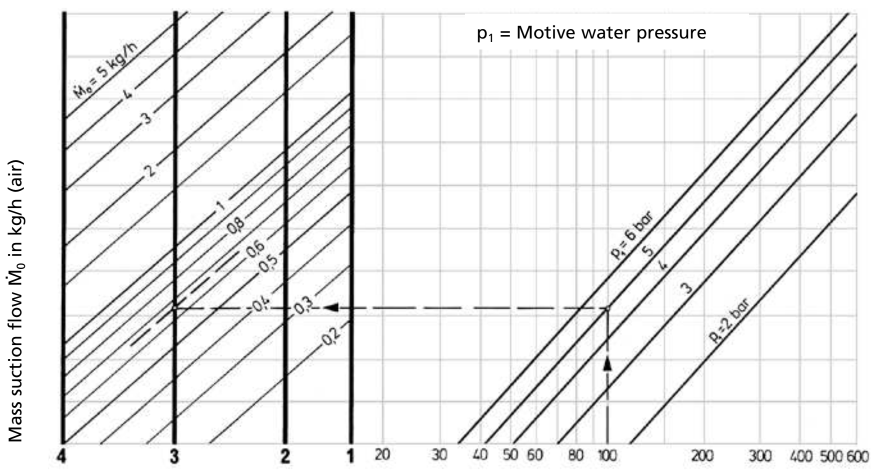
PERFORMANCE CHART OF VACUUM PUMPS

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**.

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 water 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.

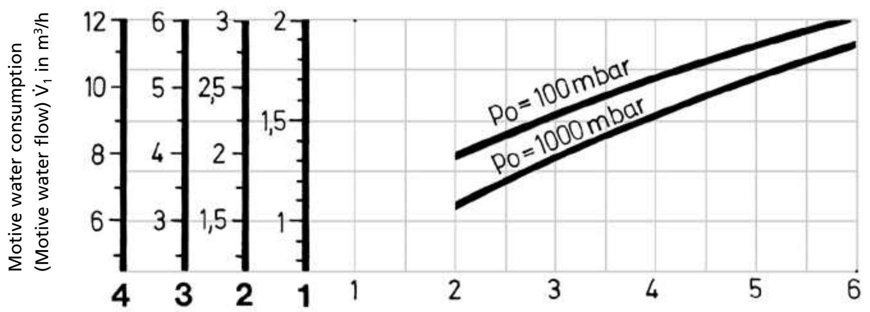
FIG. 11



Size | Suction pressure p₀ in mbar abs. (for water at 20 °C)

Pressure indications in bar = bar g

FIG. 12



Size | Motive water pressure p_1 in bar

Pressure indications in bar = bar g

p_0 = Suction pressure in mbar abs.

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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:

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

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

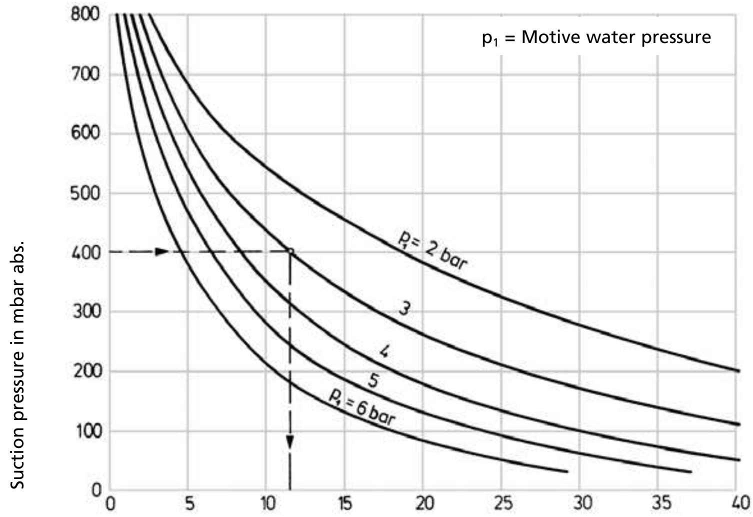
A vessel of 2 m³ is to be evacuated to 400 mbar in 15 minutes. The water pressure is 3 bar.
PARAMETERS TO BE FOUND: Size of the pump
SOLUTION: From diagram **fig. 13**, for 400 mbar and 3 bar, a time of 12 min/m³ is found. For the evacuation of a vessel volume of 2 m³, a liquid jet vacuum pump size 3 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 p_0. This is established by means of the curves in fig. 12.

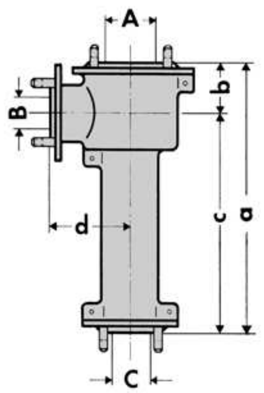
FIG. 13



Specific evacuation time $t_{spec.}$ in min/m³ vessel volume for size 3

Pressure indications in bar = bar g

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	60	60	80	100
	c	230	230	310	400
	d	90	90	100	110
Weight in kg		10	11	18	22

STANDARD CONSTRUCTION:

Pump body: porcelain with cast iron armour;
Motive nozzle: porcelain
Connections according to DIN PN 10

For inquiries please use our questionnaire.

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.

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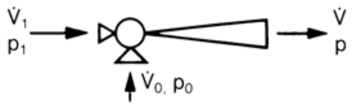
Liquid jet gas compressors

Plastic construction, "75 PVC", type R

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", ↗ Tabl 1).



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)

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

PARAMETERS TO BE FOUND:
Motive liquid flow $\dot{V}_1$ and size of the compressor

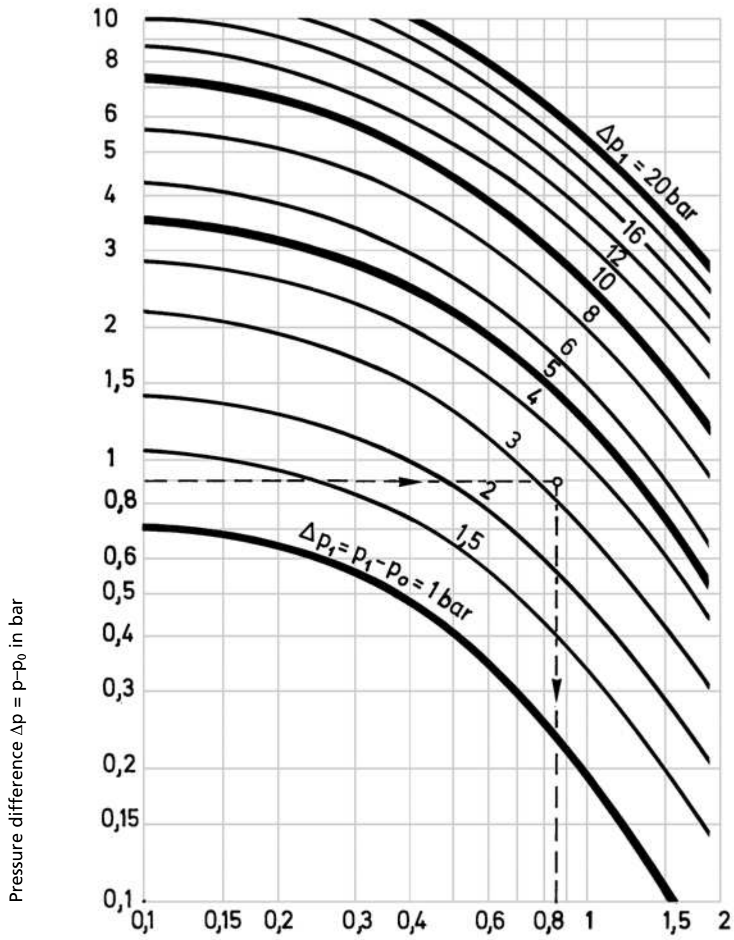
SOLUTION:
$\Delta p = p - p_0 = 0.7 - (-0.2) = 0.9$ bar
$\Delta p_1 = p_1 - p_0 = 3 - (-0.2) = 3.2$ bar
From **fig. 1** you will find for $\Delta p = 0.9$ bar and $\Delta p_1 = 3.2$ bar:

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

This results in:

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

FIG. 1



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

$\Delta p_1 = p_1 - p_0$ = Effective motive liquid pressure

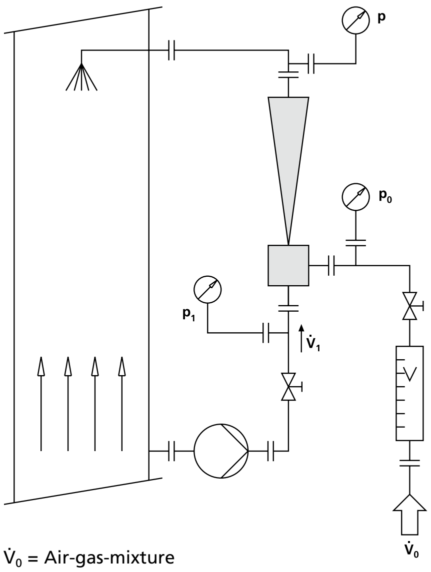
The determination for the size of jet compressors is the motive liquid connection A (**fig.** 3):
For a selected pipe pressure loss Δp of approx. 1 bar for a pipe length of 100 m, according to catalogue sheet "Pressure drop in water ducts" (↗ | abl9), a connection diameter of DN 50 for a liquid velocity 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 R 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, EN-GJL-200 (GG20) cast iron, inner surfaces lined with PFA

Metal construction, stainless steel, welded

Plastic construction, "75 PVC", type F

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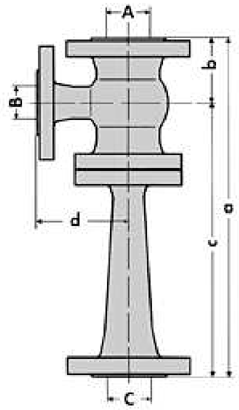
FIG. 3

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	78	78	78	115	150
	c	210	285	340	400	400	450	615	800
	d	85	100	115	125	125	125	135	165
Weight in kg		10	13	18	25	28	30	45	80

STANDARD CONSTRUCTIONS:

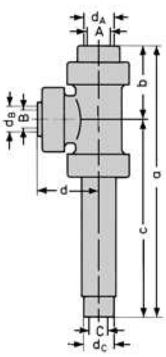
I Housing: cast iron EN-GJL-200 (GG20), motive nozzle: red brass, inlet guide vane: PVC
II Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel, inlet guide vane: PVC
III Housing: cast iron EN-GJL-200 (GG20), inner surfaces lined with PFA, motive/mixing nozzle: PVC, inlet guide vane: PVC
IV Housing: stainless steel, motive/mixing nozzle: PVC, inlet guide vane: PVC
V Completely stainless steel
VI Completely PVC
Flanges according to DIN PN 10

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

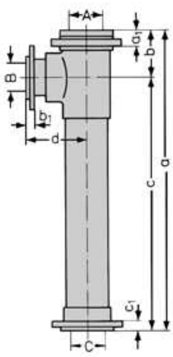
For inquiries please use our questionnaire.

FIG. 4 FIG. 5

PLASTIC CONSTRUCTION "75 PVC" (MAX. 10 BAR)



Type R



Type F

CONNECTIONS, DIMENSIONS AND WEIGHTS

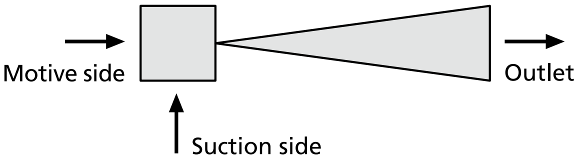
	Size	1	2	3	4	5	6	7	8	9	10
Liquid connection	A	20	25	32	40	50	65	80	100	125	150
Dimensions in mm	d_A	25	32	40	50	63					
	a_1						43	45	51	57	62
Suction connection	B	15	20	25	32	40	50	65	80	100	125
Dimensions in mm	d_B	20	25	32	40	50					
	b_1						25	26	33	40	44
Pressure connection	C	20	25	32	40	50	65	80	100	125	150
Dimensions in mm	d_C	25	32	40	50	63					
	c_1						26	33	40	44	46
Dimensions in mm	a	225	275	350	450	500	600	675	825	1050	1250
	b	75	85	95	105	130	100	115	135	165	190
	c	150	190	255	345	370	500	560	690	885	1060
	d	65	70	80	90	100	125	145	175	215	250
Weight in kg		0.6	0.8	1.2	1.9	2.9	5.5	8.5	15	25	45
Type		R	R	R	R	R	F	F	F	F	F

TYPE R: with glued connections
TYPE F: Connection A: with clamp made in aluminium cast/loose flange made in GF-UP
Connection B and C: loose flange made in GF-UP
Flanges according to DIN PN 10

For inquiries please use our questionnaire.

Questionnaire

for liquid jet gas compressors
fgv1



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:

DIN PN ☐
ASME lbs ☐
Others ☐

DESIGN CODE (if required):

AD ☐
ASME ☐
Others ☐

APPLICATION:

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

DESIGN:

Temperature . . . . °C
Pressure . . . . bar g

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

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

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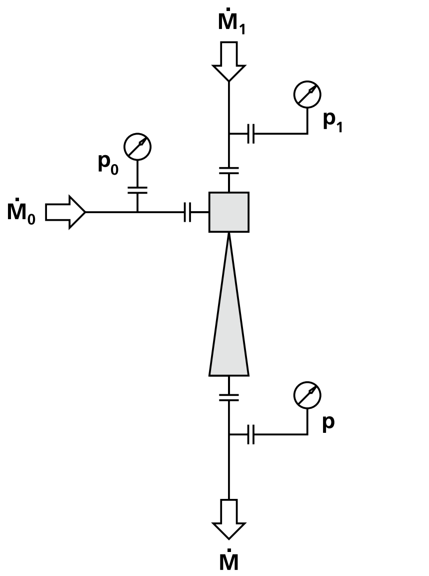
Liquid jet liquid pumps

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", ↗ | abl 1).
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", ↗ | abl 9).

FIG. 1

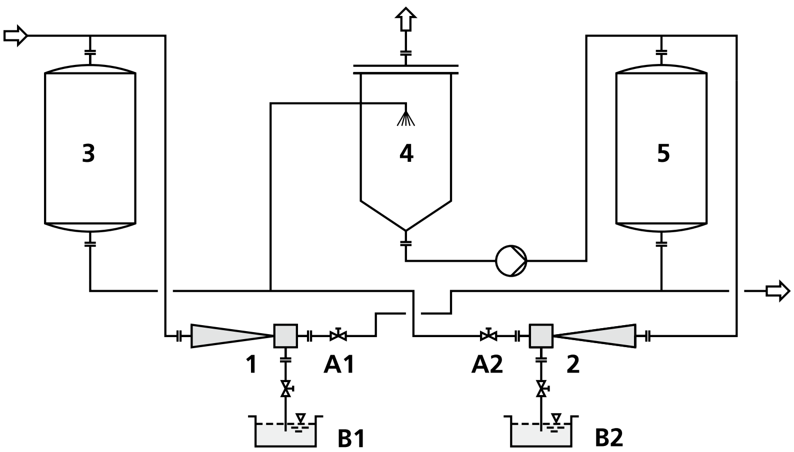


APPLICATIONS

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).

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

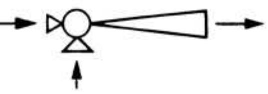
Cast stainless steel

PVC, construction KT, glued, form M

PVC, construction K, screwed, form M

PERFORMANCE CHART

Motive flow $\dot{M}_1$ p_1 K_1



Mixed flow $\dot{M} = \dot{M}_0 + \dot{M}_1$ p K

Suction flow $\dot{M}_0$, p_0, K_0

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

= Specific liquid consumption
= Constant mixing ratio

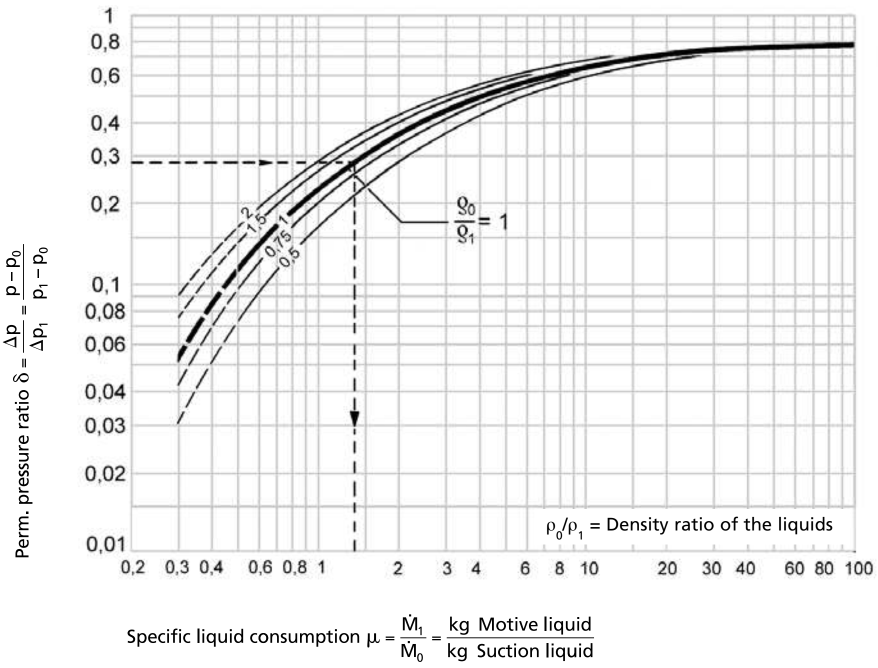
p_1 = Motive liquid pressure in bar g
p_0 = Suction liquid pressure in bar g suction (–), inlet (+)
p = Discharge pressure in bar
Δp = $p - p_0$ = Total delivery pressure in bar g
Δp_1 = $p_1 - p_0$ = Effective motive liquid pressure in bar g

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

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 ρ_0/ρ_1 = 1.0 a specific liquid consumption μ = 1.37.

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

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

DETERMINING THE PUMP SIZE:

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

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.

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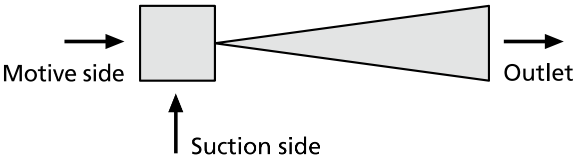
Questionnaire

for liquid jet liquid pumps
wp1, wp2, wp3



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:

DIN PN ☐
ASME lbs ☐
Others ☐

DESIGN CODE (if required):

AD ☐
ASME ☐
Others ☐

APPLICATION:

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

DESIGN:

Temperature . . . . °C
Pressure . . . . bar g

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

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

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Liquid jet liquid pumps

of cast iron or cast stainless steel

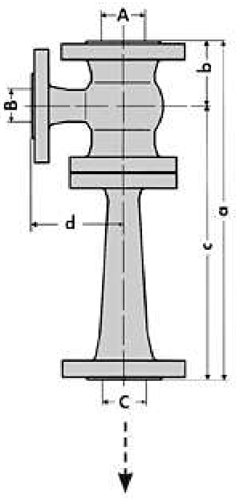
Cast stainless steel

Cast iron

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.

FIG. 4



max. mixed flow

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	78	78	78	115	150
	c	111	210	285	340	400	400	450	615	800
	d	80	85	100	115	125	125	125	135	165
Weight in kg		5	10	13	18	25	28	30	45	80

STANDARD CONSTRUCTIONS:

I Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel
II Housing: cast iron EN-GJL-200 (GG20) rubber-coated, motive nozzle/mixing nozzle: PVC
III Completely stainless steel
Flangesaccording to DIN PN 10

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

For inquiries please use our questionnaire.

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Standard liquid jet liquid pumps

of PVC/PP (plastic construction)

PVC, construction KT, glued, form M

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 % → 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 en 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.

FIG. 5

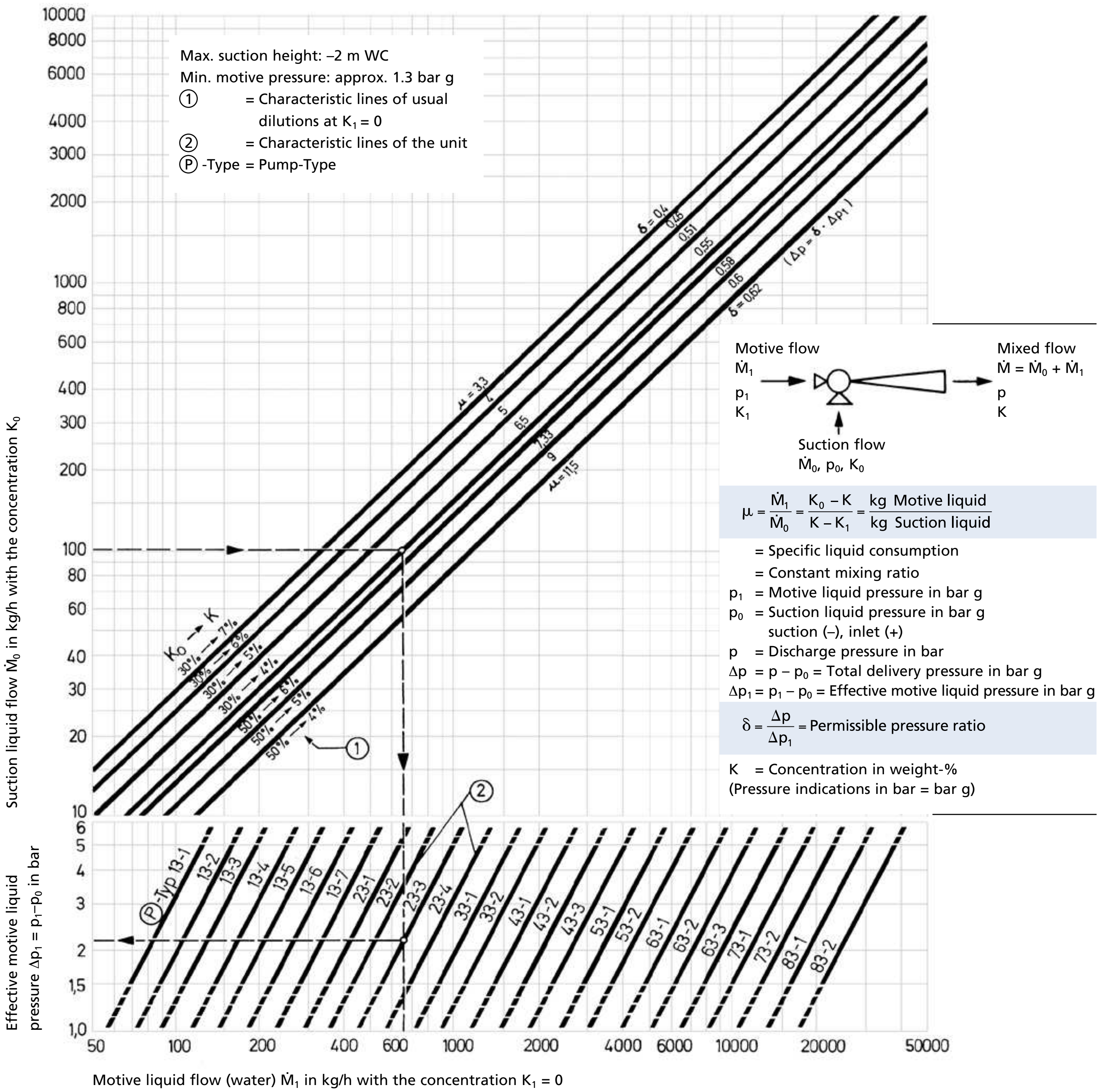


FIG. 6

CONSTRUCTION KT

Form M Form G Form F

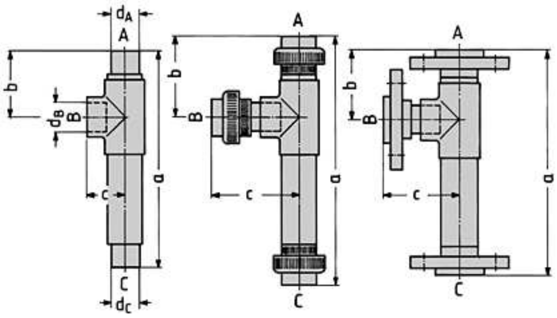
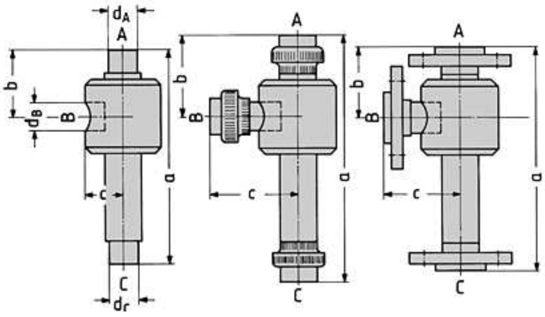


FIG. 7

CONSTRUCTION K

Form M Form G Form F



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	62-1 ... 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	Form M	150	190	220	280	385	480	570	650
( ) Dimensions for	b		45	55	65	80	100	115	135	160
PP construction	c		27	33	39	49	60	72	84	99
only	(c)		(28)	(32)	(38)	(44)	(51)	(62)	(75.5)	(88)
Dimensions in mm	a	Form G	208	254	290	362	481	598	680	782
( ) Dimensions for	(a)		(212)	(256)	(290)	(358)	(473)	(584)	-	-
PP construction	b		74	87	100	121	148	174	190	226
only	(b)		(76)	(88)	(100)	(119)	(144)	(167)	-	-
	c		100	115	130	150	180	210	215	245
Dimensions in mm	a	Form F	156	196	226	286	391	486	576	660
( ) Dimensions for	(a)		(160)	(200)	(230)	(290)	(395)	(490)	(580)	(664)
PP construction	b		48	58	68	83	103	118	138	165
only	(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
Typ			13-1 ... 13-7	23-1 ... 23-4	33-1 ... 33-2	43-1 ... 43-3	53-1 ... 53-2	62-1 ... 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	Form M	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	Form G	213	254	270	342	481	578	650	951
( ) Dimensions for	(a)		(217)	(256)	(270)	(338)	(473)	(564)	-	-
PP construction	b		94	102	105	126	148	169	210	284
only	(b)		(96)	(103)	(105)	(124)	(144)	(162)	-	-
	c		100	115	115	120	140	160	180	200
Dimensions in mm	a	Form F	161	196	206	266	391	466	526	810
( ) Dimensions for	(a)		(165)	(200)	(210)	(270)	(395)	(470)	(530)	(814)
PP construction	b		68	73	73	88	103	113	148	215
only	(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.

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Standard liquid jet liquid pumps

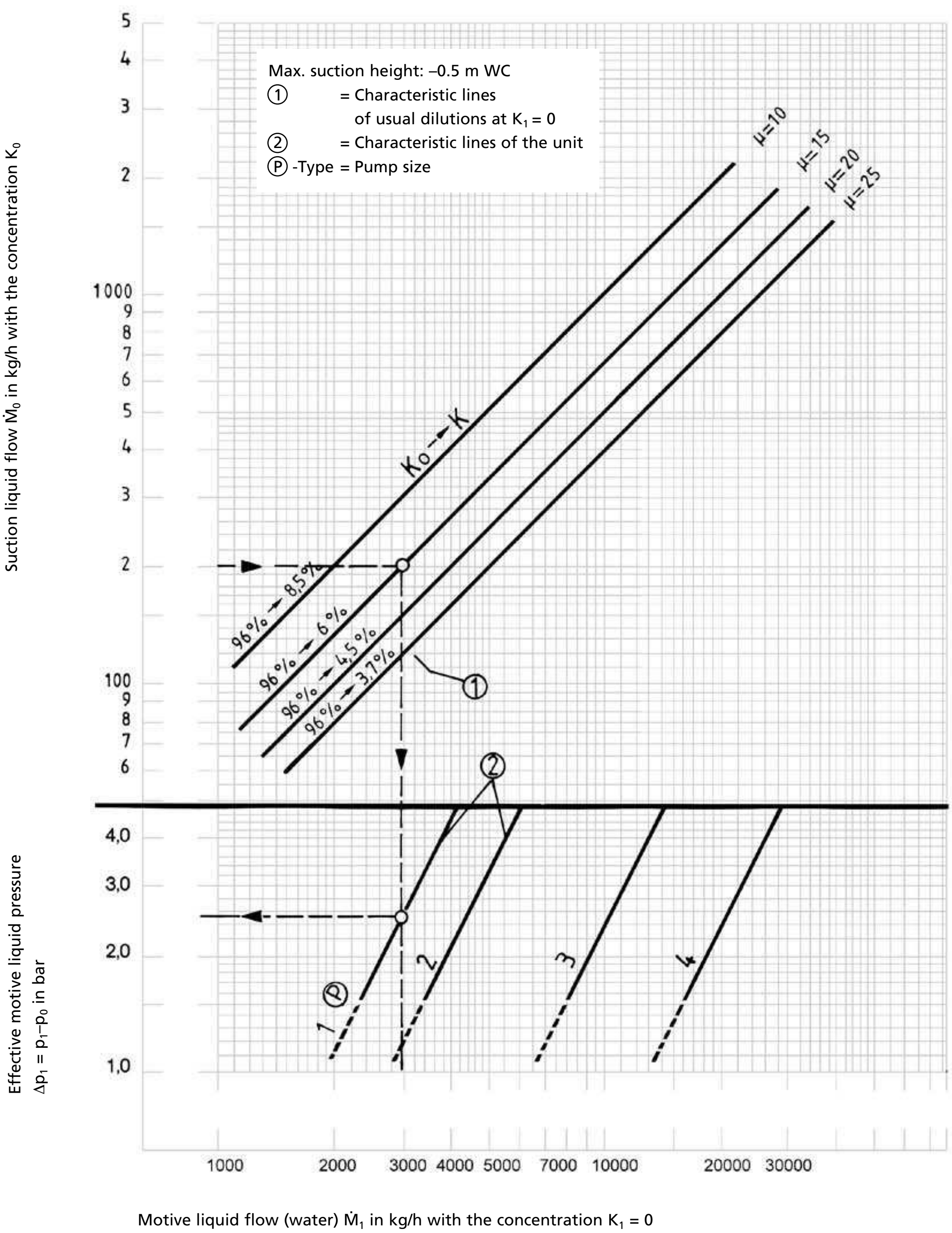
of porcelain, armoured

DESIGN AND PERFORMANCE CHART

The porcelain jet pumps are encased in a protective armour of cast iron. The pumps are, therefore, well protected against mechanical and chemical aggression. 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

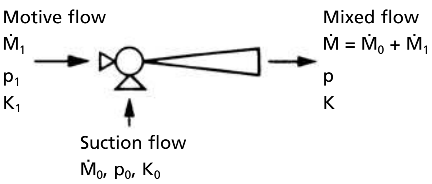


EXAMPLE

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 % → 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 Δp_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 · 2.5 = 1.25 bar > 0.8 bar.
A liquid jet liquid pump size 1 is required.

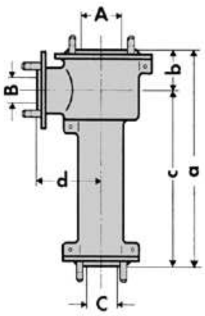


$$\mu = \frac{\dot{M}_1}{\dot{M}_0} = \frac{K_0 - K}{K - K_1} = \frac{\text{kg Motive liquid}}{\text{kg Suction liquid}}$$

= 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 · 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	60	60	80	100
	c	230	230	310	400
	d	90	90	100	110
Weight in kg		10	11	18	22

STANDARD CONSTRUCTION:

Pump body: porcelain with cast iron armour; motive nozzle: PTFE
Connections according to DIN PN 10

For inquiries please use our questionnaire.

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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”, ↗ | 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 hoper 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

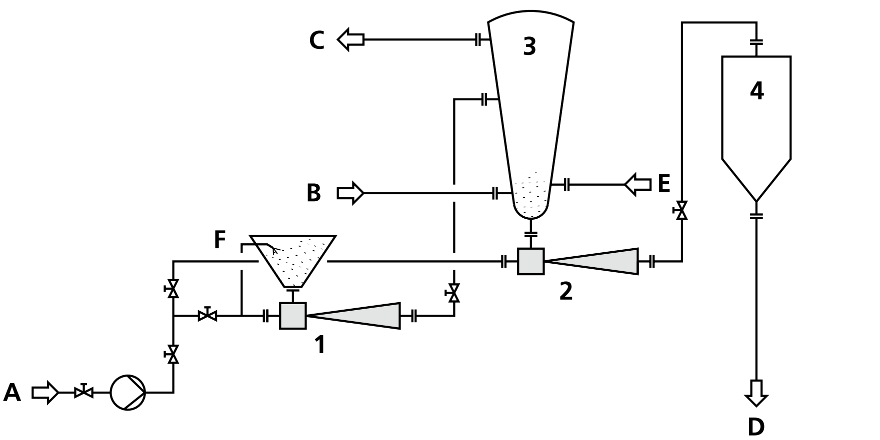
IN NORMAL OPERATION one needs 3 to 5 times the volume of the material to be conveyed for the motive liquid. The motive liquid pressure should be 2.5 to 3 times that of the delivery head.
The standard constructions, according to **fig. 2 to 4**, are designed with a water flow to material ratio of 4 : 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	∅
1	4 mm
2	5 mm
3	9 mm
4	12 mm

FIG. 1

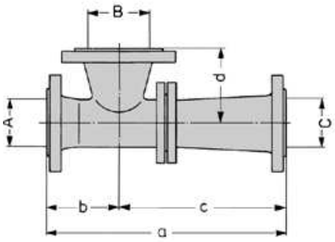


1 Stationary liquid jet solids pump with hopper for reactor mass
2 Liquid jet solids pump for the batch extraction of the reactor mass load
3 Reactor
4 Silo

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

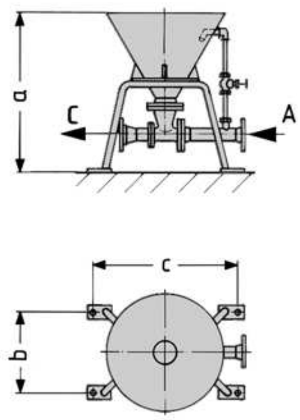
	Size	1	2	3	4
Flow rate marble/gravel in kg/h		500	1000	2500	5000
Rinse water in kg/h		100	200	500	1000
Motive water flow at 3 bar g in m³/h		2.4	4.8	12.0	24.0
Nominal diameter	A	25	32	50	80
	B	40	65	80	100
	C	25	32	50	80
Dimensions in mm	a	210	265	355	580
	b	50	65	80	90
	c	160	200	275	490
	d	90	100	125	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 m³/h		2.4	4.8	12.0	24.0
Nominal diameter	A	25	32	50	80
	C	25	32	50	80
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

STANDARD CONSTRUCTION:
Hopper and frame: steel
Connecting pipes: steel
Flanges according to DIN PN 10

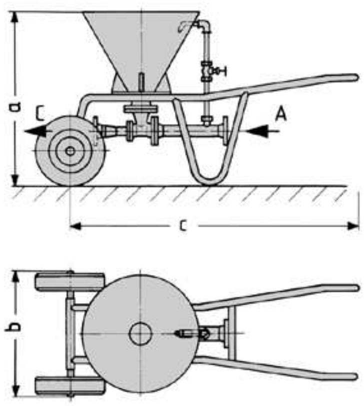
SPECIAL CONSTRUCTIONS on request

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 m³/h		2.4	4.8	12.0	24.0
Nominal diameter	A	25	32	50	80
	C	25	32	50	80
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

STANDARD CONSTRUCTION:
Hopper and frame: steel
Connecting pipes: steel
Flanges according to DIN PN 10

SPECIAL CONSTRUCTIONS on request

For inquiries please use our questionnaire.

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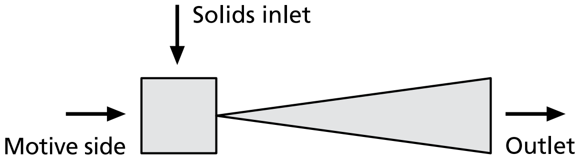
Questionnaire

for liquid jet solids pumps
wfp1



1. MOTIVE SIDE

Motive medium . . . .

Motive flow . . . . m³/h

Motive pressure . . . . bar abs.

Temperature . . . . °C

Density . . . . kg/m³

Steam pressure . . . . bar abs.

2. SOLIDS INLET

Solids medium . . . .
(feed / free-flowing)

Solids feed . . . . kg/h

Bulk density . . . . kg/m³

Particle size . . . . mm

3. OUTLET

Required discharge pressure . . . . bar abs.

4. FURTHER DATA

Material of construction . . . .

CONNECTIONS:

Flanges ☐

Thread ☐

Others ☐

FLANGES ACCORDING TO:

DIN PN ☐

ASME lbs ☐

Others ☐

FURTHER NOTES: . . . .

. . . .

CONSTRUCTION: ☐ 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 . . . .

attn. . . . .

Street/P.O. Box . . . .

ZIP code/City . . . .

Country . . . .

Telephone . . . .

Telefax . . . .

E-mail . . . .

Questionnaire

for liquid jet mixers
fm1

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 . . . . | Viscosity . . . . mPas
Temperature . . . . °C | Solid content. g/l
Density . . . . kg/m³ | Particle size . . . . mm

3. CIRCULATION PUMP

Liquid flow . . . . m³/h | Delivery head . . . . m WC

4. MIXING REQUIREMENTS

Mixing time . . . . h

Further requirements . . . .

. . . .

. . . .

5. FURTHER DATA

Material of construction . . . .

CONNECTIONS:		FLANGES ACCORDING TO:	
Flanges	☐	DIN PN	☐
Thread	☐	ASME lbs	☐
Others	☐	Others	☐

FURTHER NOTES: . . . .

. . . .

. . . .

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

Your inquiry no. . . . .
Offer submitted until . . . .
Requested date of delivery . . . .

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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”, ↗ | abl 1).
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 an 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 m³
$\Sigma\dot{V}$	Total delivered flow of the jet mixers in m³/h

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

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 $\Delta p_1 = H$.

FIG. 3

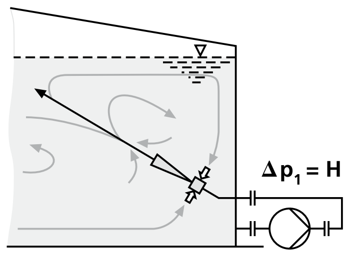
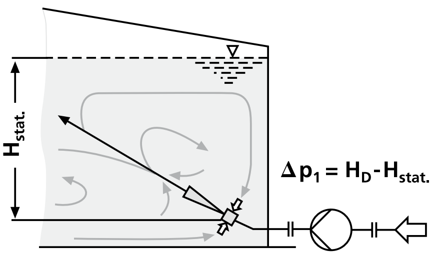


FIG. 4



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:

$\Delta p_1 = H_D - H_{stat}$
H_D Delivery head of the pump

EXAMPLE OF DESIGN

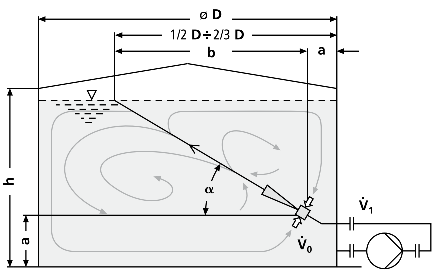
GIVEN:

Tank diameter	D = 3.5 m
Tank height	h = 4 m
Useful volume	I_N = 38.5 m³
Actual tank volume	I_E = 30 m³
Mixing time	t = 0.5 h (double circulation per hour)

Motive liquid pressure $\Delta p_1 \leq 3$ bar
Pump arrangement according to **fig. 3**

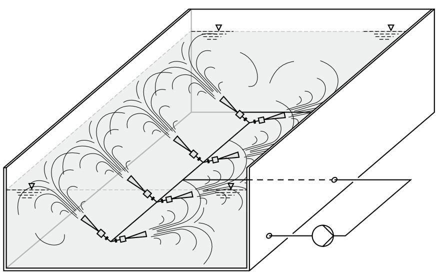
PARAMETERS TO BE FOUND: Mixer size and parameters of the circulation pump

FIG. 1



a = 0.5 ÷ 1 m

FIG. 2



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

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

Taking into consideration $\Delta p_1 \leq 3$ 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.

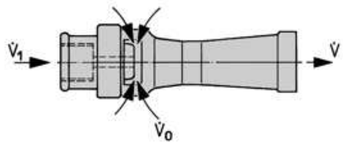
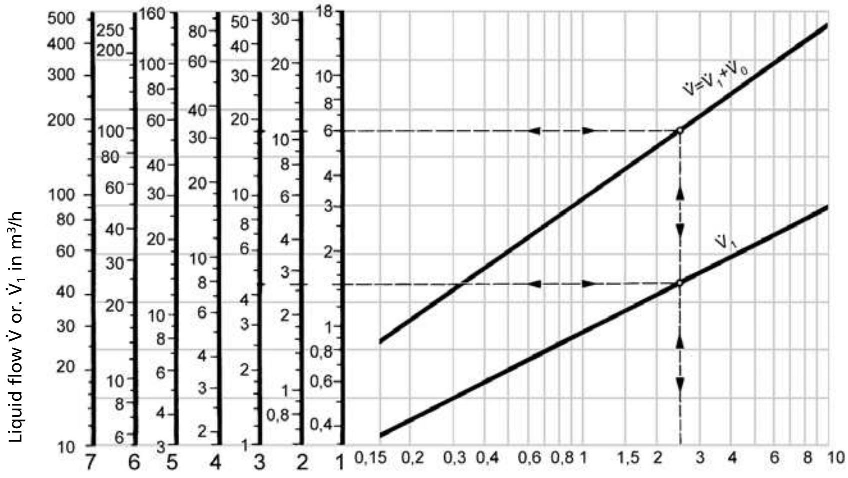


FIG. 5



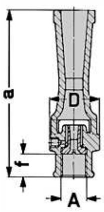
Size
Series 80

Δp_1 = Effective liquid pressure on the nozzle in bar
Optimum pressure range Δp_1: 1 to 4 bar

CONNECTIONS, DIMENSIONS AND WEIGHTS

LIQUID JET MIXERS WITH THREADED CONNECTIONS TYPE 17.1

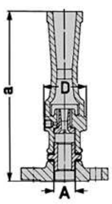
FIG. 6A



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 11/2	G 11/2	G 2	G 3	G 4
Dimensions	a	170	220	265	345	400	520	610
in mm	D	52	60	75	85	100	125	160
	f	20	25	24	24	30	33	40
Weight in kg		1	2	3	5	7	12	27

LIQUID JET MIXERS WITH FLANGED CONNECTIONS TYPE 27.1

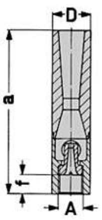
FIG. 6D



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	a	200	250	300	380	440	570	660
in mm	D	52	60	75	85	100	125	160
Weight in kg		2	3	5	7	11	19	33

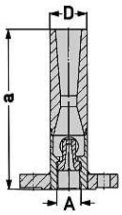
STANDARD CONSTRUCTIONS: I Housing: cast iron EN-GJL-200 (GG20), nozzles: red brass, threaded connections according to ISO 228, flanges according to DIN PN 10,
II Housing: cast iron EN-GJL-200 (GG20), nozzles: stainless steel, threaded connections according to ISO 228, flanges according to DIN PN 10

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 11/2	G 11/2	G 2	G 3	G 4
Dimensions	a	170	220	265	345	400	495	610
in mm	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

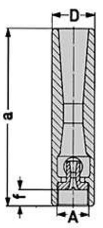
FIG. 6E



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	a	170	220	265	345	400	495	610
in mm	D	45	55	55	63	79	112	140
Weight in kg		2.2	3.5	4.0	5.5	9.5	22	35

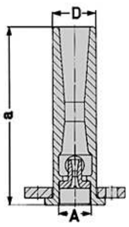
STANDARD CONSTRUCTIONS: I Completely stainless steel 1.4571, II Completely stainless steel 1.4301, threaded connections according to ISO 228, flanges according to DIN PN 10

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 11/2	G 11/2	G 2	G 3	G 4
Dimensions	a	170	220	265	345	400	495	610
in mm	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	6.5
Weight PP in kg		0.3	0.5	0.8	1.2	1.6	3	5
Weight PTFE in kg		0.5	1	1.5	2.3	3	5.8	10

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	a	170	220	265	345	400	495	610
in mm	D	50	60	60	60	76	106	130
Weight in PVC kg		0.4	0.8	0.9	1.3	1.9	3.7	7.0
Weight in PP kg		0.3	0.6	0.7	1.0	1.5	3.0	5.5
Weight in PTFE kg		0.6	1.2	1.4	2.0	2.7	5.8	10.6

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

I Completely PVC, loose flanges: GF-UP, II Completely PP, loose flanges: GF-UP, III Completely PTFE

SPECIAL CONSTRUCTIONS on request. Please indicate size, type and material in your order.
For inquiries please use our questionnaire.

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Liquid jet ventilators

APPLICATIONS

Liquid jet ventilators are used to draw off air, gases or vapour.
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", ↗ | abl 1). 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 m³ of liquid per m³ of air or gas

- decreases with higher motive liquid pressure p_1
- increases with rising, required compression Δp
- is independent of nature and density of 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 m³/h air. The available motive water pressure is 3 bar g.

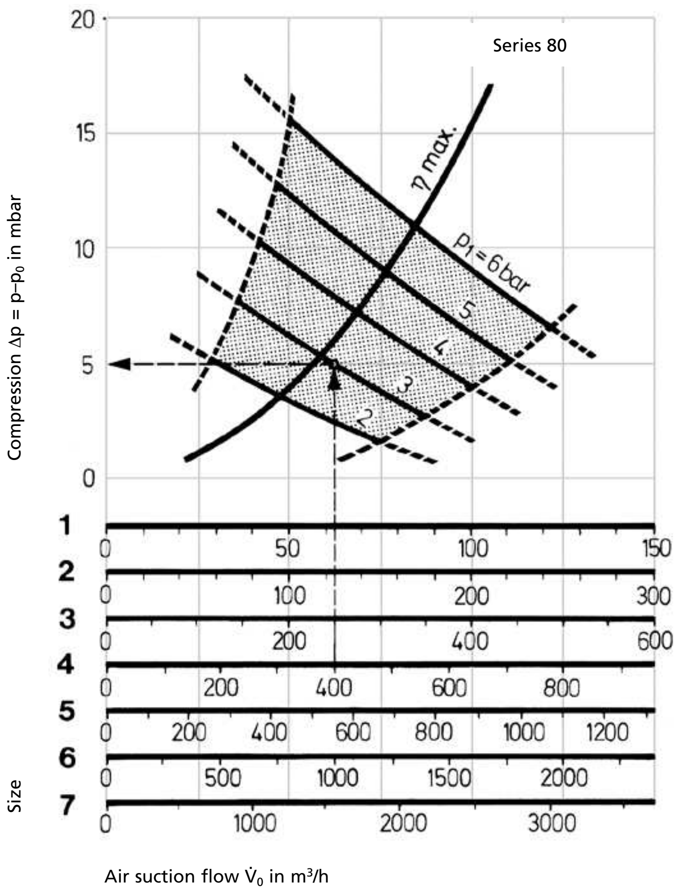
PARAMETERS TO BE FOUND:

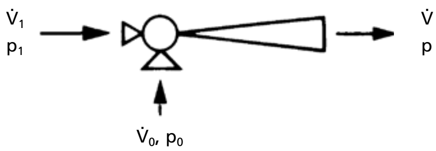
1. Maximum compression Δp in mbar
2. Size of ventilator
3. Motive liquid consumption in m³/h

SOLUTION: Fig. 1 shows that a ventilator size 4 produces a compression of Δp = 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 m³/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 m³/h
$\dot{V}_0$ = Gas suction flow in m³/h
$\dot{V}$ = Mixed flow in m³/h
$\eta_{max.}$ = Optimum working efficiency

(Pressure indications in bar = bar g)

FIG. 2

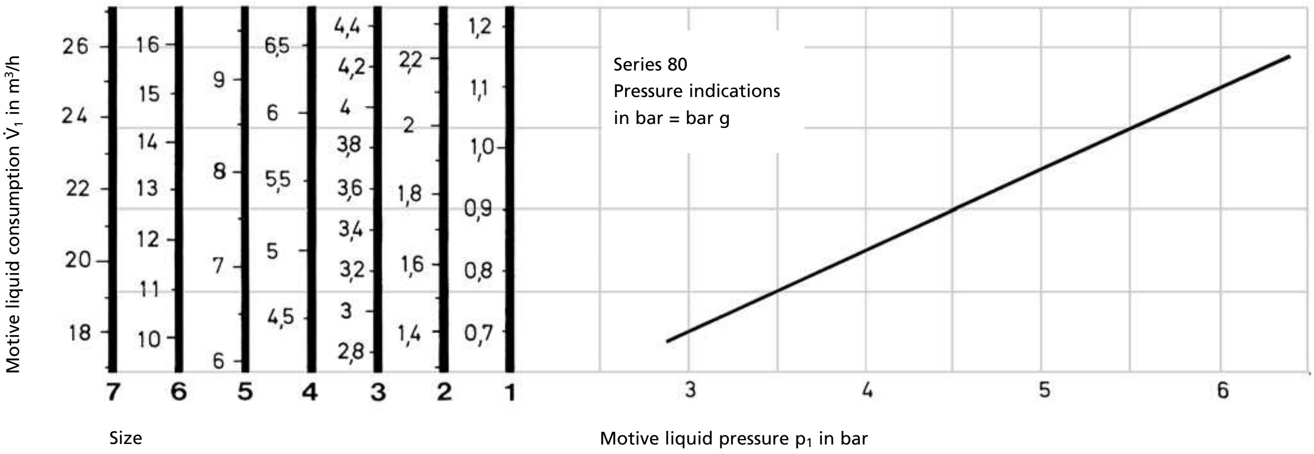
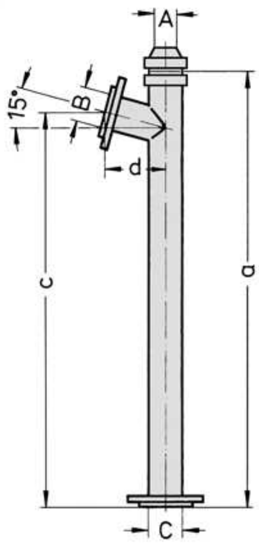


FIG. 3



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, loose flanges: steel
III Completely stainless steel 1.4541, loose flanges: steel
IV Completely PVC, loose flanges: GRP
V Completely PP, loose flanges: GRP
Flanges according to DIN PN 10

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.

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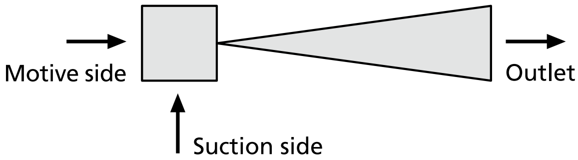
Questionnaire

for liquid jet ventilators
fv1



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:

DIN PN ☐
ASME lbs ☐
Others ☐

DESIGN CODE (if required):

AD ☐
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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Requested date of delivery . . . .

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Company . . . .
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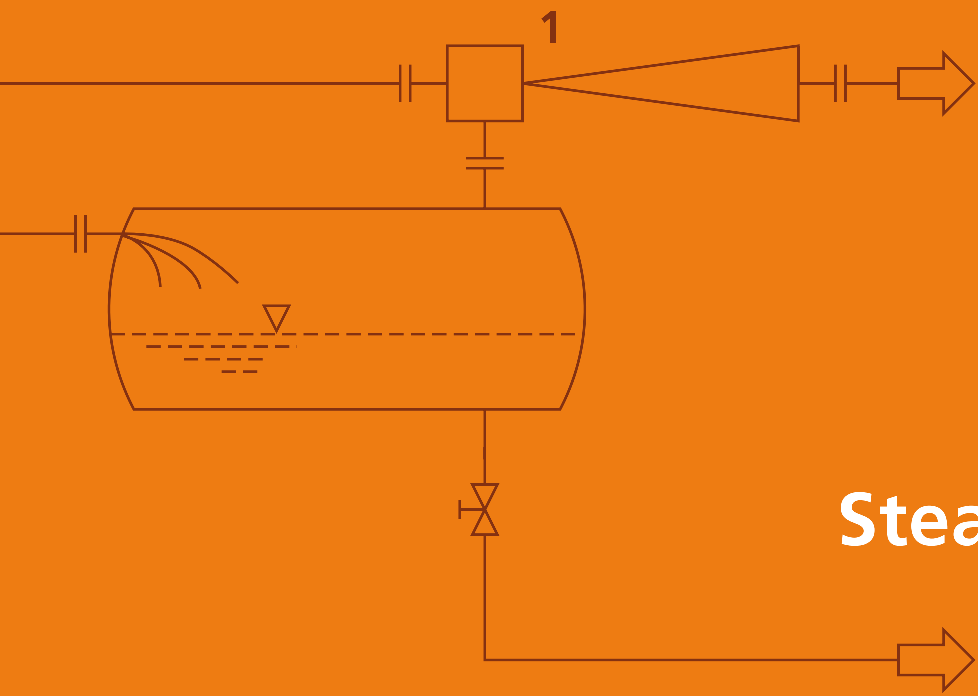


Steam jet pumps

- 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”, ↗ | gdp 1.

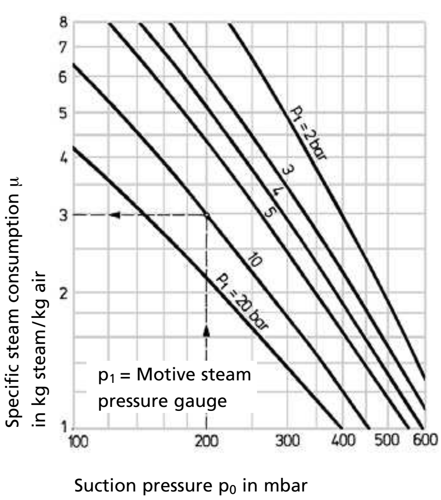
ADVANTAGES

- 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.

FIG. 1



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

PERFORMANCE CHART FOR VACUUM PUMPS

EXAMPLE

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

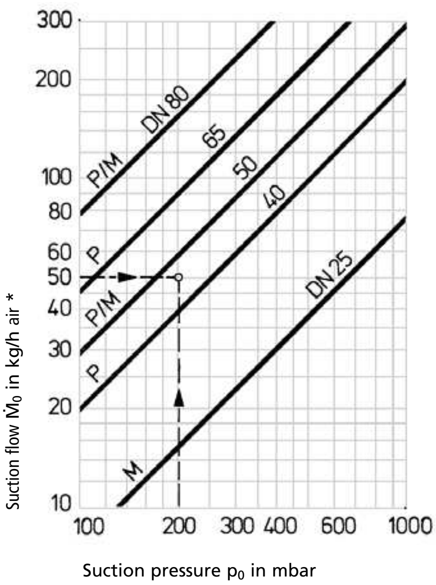
$$\mu = 3 \frac{\text{kg Steam}}{\text{kg Air}}$$

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.

FIG. 2



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

Steam jet vacuum pump in metal

Steam jet vacuum pump in porcelain

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:

$$\dot{M}_{0_t} \approx \dot{M}_{0_{20}} \cdot \sqrt[4]{\frac{293}{273 + \vartheta}}$$

If water vapour, 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 vapours see section “Equivalent suction flows for steam jet vacuum pumps”, ↗ | 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”, ↗ | gdp 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:

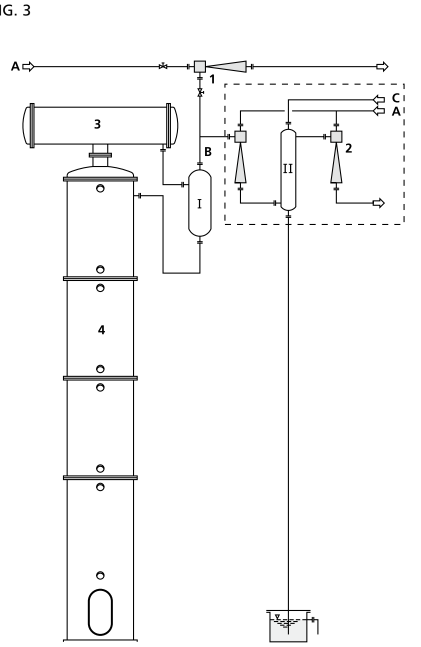
$$t_{evac.\,DVP} \approx \frac{V \cdot (1000 - p_0) \cdot 60}{840 \cdot \dot{M}_A \cdot 3} \approx \frac{V \cdot (1000 - p_0)}{\dot{M}_A \cdot 42}$$

in minutes.

Where:

V	Volume of the plant to be evacuated in m³
p_0	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:

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

$\dot{M}_D$	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

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

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

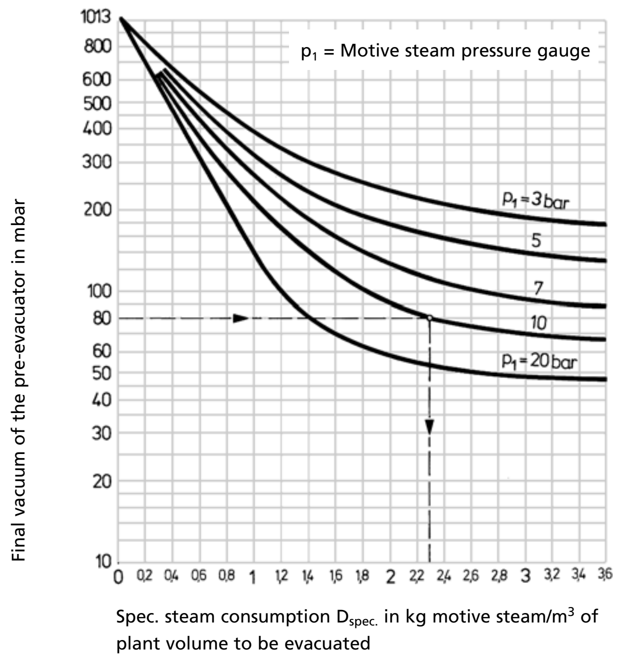


FIG. 5

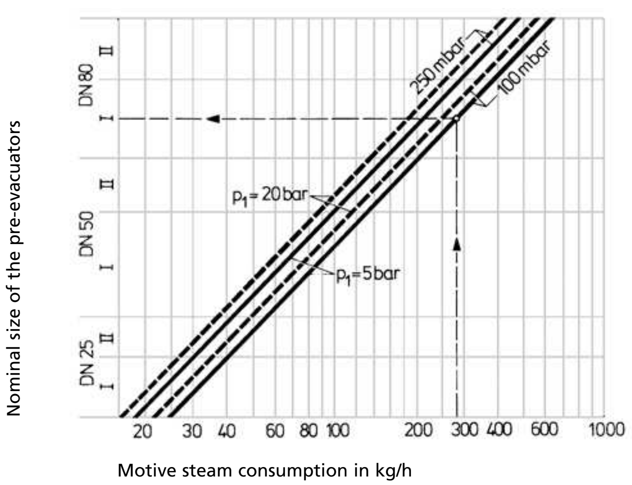


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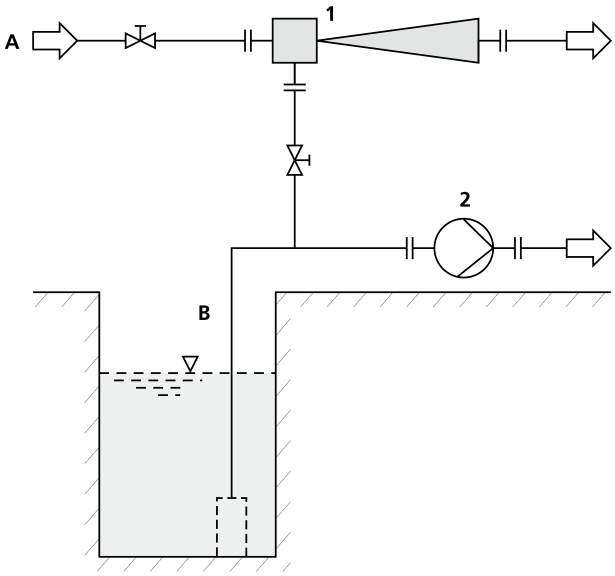
FIG. 6

EVACUATION OF A SUCTION LINE

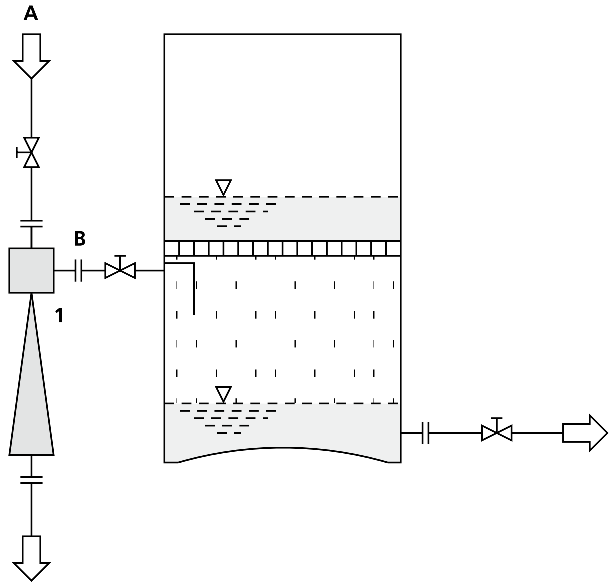


Steam jet vacuum pump for evacuating the suction line of a non self-priming pump

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

FIG. 7

VACUUM PRODUCTION



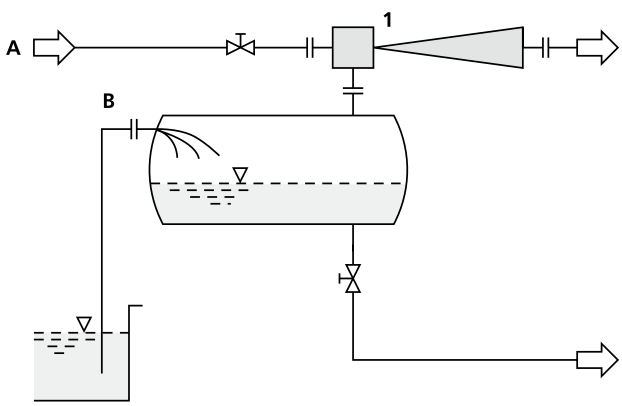
Steam jet vacuum pump for producing a negative pressure in a nutsch filter

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.

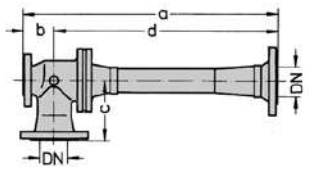


Steam jet vacuum pumps for the lifting of liquids

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		5	7	10	15	32	38

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 DIN PN 10 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.

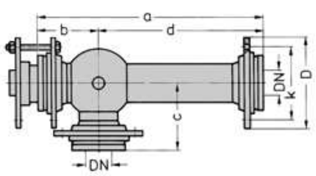
The exact installation dimensions of the pumps depend on the operating conditions. For jet pumps according to the design given in **fig. 9**, two different dimensions for each size are given.
For large nominal diameters jet pumps are designed in welded construction. The dimensions are adapted to the particular conditions.
The dimensions are given in the quotation on request (see also "Steam jet compressors", ↗ | bv 1)

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, 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	120	150	170	185	215	240	265
Weight in kg		4	5	7	10	15	22	30

STANDARD CONSTRUCTION:

Housing and motive nozzle: temperature-change resistant porcelain
Connection clamps: aluminium cast
Steam connections: aluminium cast

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

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

If needed, the heads of steam jet compressors are provided with hand hole covers for easier cleaning.
Large nominal bores on request.

For inquiries please use our questionnaire.

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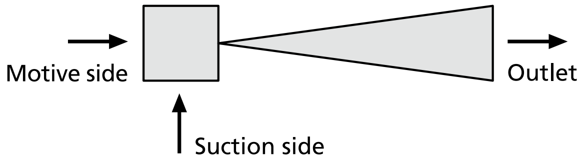
Questionnaire

for steam jet vacuum pumps
dvp1



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:

- DIN PN ☐
- ASME lbs ☐
- Others ☐

DESIGN CODE (if required):

- AD ☐
- ASME ☐
- Others ☐

APPLICATION:

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

DESIGN:

Temperature .... °C

Pressure. .... bar g

FURTHER NOTES: ....

....
....

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

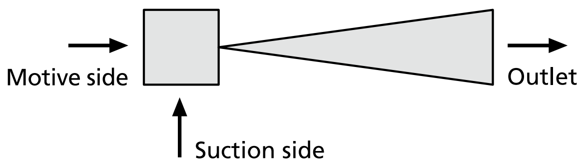
Your inquiry no. ....
Offer submitted until ....
Requested date of delivery ....

YOUR ADDRESS

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

Questionnaire

for steam jet compressors (thermo compressors)
bv1



1. MOTIVE SIDE

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

2. SUCTION SIDE

Suction medium . . . .
Suction flow . . . . kg/h
Suction pressure . . . . bar abs.
Temperature . . . . °C
Molecular weight . . . . kg/kmol
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:

DIN PN ☐
ASME lbs ☐
Others ☐

DESIGN CODE (if required):

AD ☐
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

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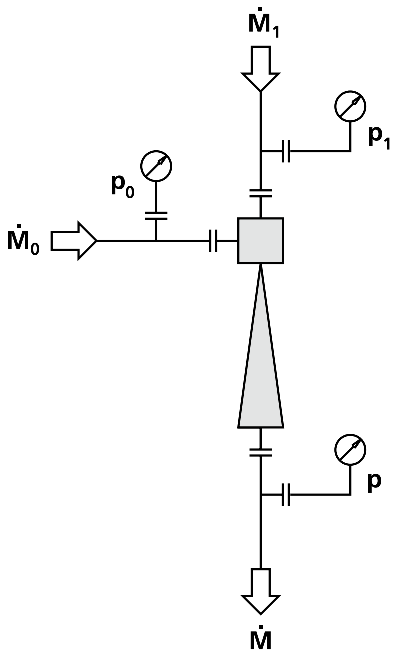
Steam jet compressors (thermo compressors)

MODE OF OPERATION

Steam jet compressors use the energy of a vapour flow $\dot{M}_1$, of a high pressure level p_1 and compress a vapour 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 vapour.
Further information can be found in chapter “General information on jet pumps”, ↗ | abl 1.

FIG. 1



ADVANTAGES

- large vapour 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.

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 vapours 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”, ↗ | abl 13.

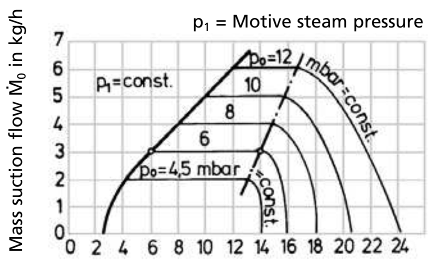
2. Changes in a motive steam flow by changing the motive pressure (or by inserting steam nozzles with different hole diameters) primarily affect the discharge pressure against which the steam jet compressor is able to deliver. An increase of the motive steam flow results in an increase in the possible discharge pressure and vice versa.
   Fig. 2 would show the increase of the motive steam pressure if the dotted line (discharge pressure limits) was moved further to the right.

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. 2



Suction pressure p_0 and discharge pressure p in mbar

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", ↗ | 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 vapours 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 Vapour
E Product
H Condensate

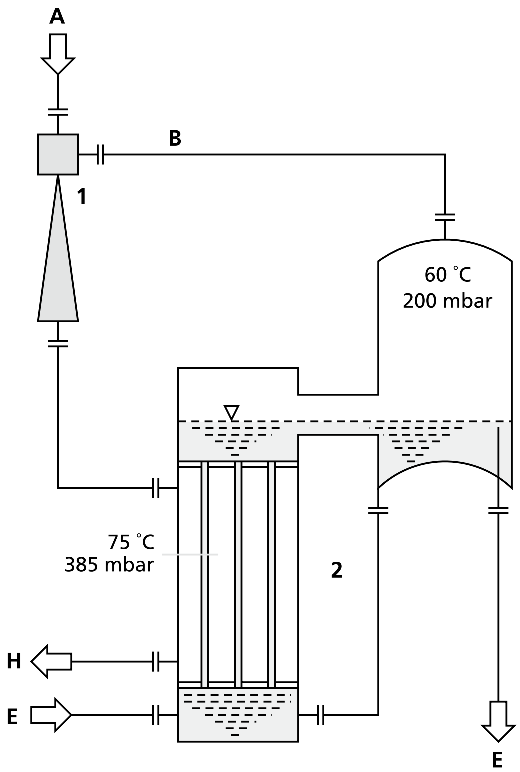


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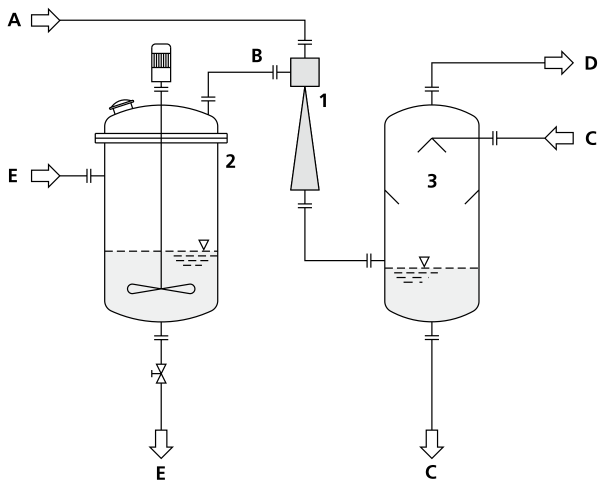
FIG. 5

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.



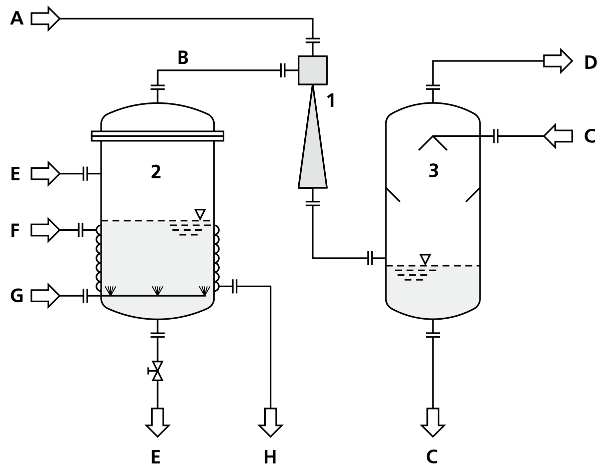
Agitator crystalliser with steam jet compressor for refrigeration

1	Steam jet compressor	A	Motive steam
2	Agitated crystalliser	B	Vapour
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 vapour and compresses it to the pressure in the condenser, e.g. 45 mbar.



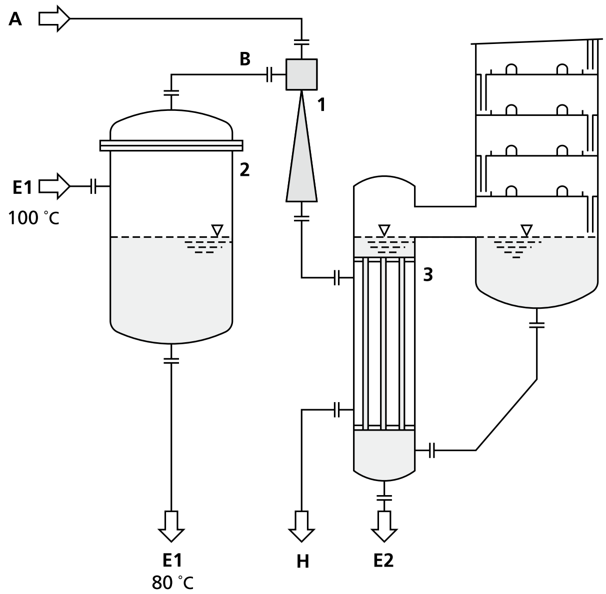
Deodoriser for edible oils with steam jet compressor to increase the vacuum

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	Vapour	H	Condensate

FIG. 7

HEAT RECOVERY

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

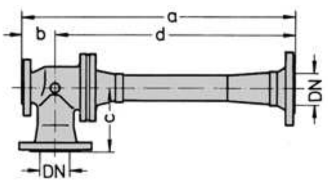


Heat recovery from process effluent water by using steam jet compressors as heat pump

1	Steam jet compressor	A	Motive steam
2	Tank	B	Vapour
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		5	7	10	15	32	38

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 and 50: housing and diffuser screwed
DN 80: housing and diffuser flanged, diffuser welded
Flanges according to DIN PN 10 or ASME 150 lbs

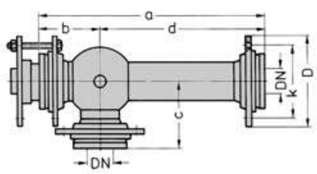
On request the steam jet compressors can be supplied in other sizes, constructions and materials. With the exception of porcelain construction, connecting flanges with the requested nominal pressure and according to the required standards can be offered.
The exact installation dimensions of the pumps 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, 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	120	150	170	185	215	240	265
Weight in kg		4	5	7	10	15	22	30

STANDARD CONSTRUCTION:

Housing and motive nozzle: temperature change resistant porcelain
Connection clamps: aluminium cast
Steam connections: aluminium cast

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

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

If required, the heads of jet compressors are provided with hand hole covers for easier cleaning.
Larger nominal bores on request.

For inquiries please use our questionnaire.

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Steam jet ventilators

APPLICATIONS

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

- to draw of waste air, exhaust gases and vapour
- 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

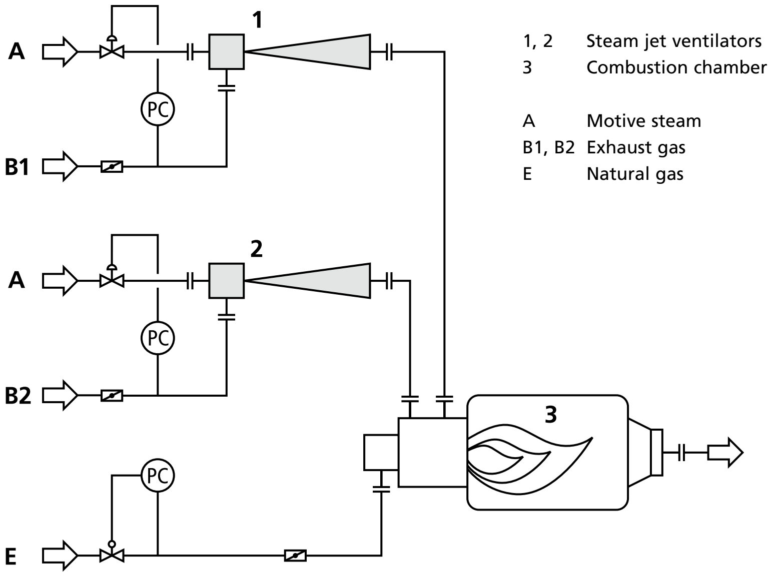
Instead of steam, it is also possible to use compressed air or another gas as motive fluid for jet ventilators. For more detailed information please refer to the section “Gas jet ventilators”, ↗ | gv 1.

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”, ↗ | 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 Δp = 0 to 500 mbar. Above 500 mbar, steam jet compressors are used (see also section “Steam jet compressors”, ↗ | bv1).

FIG. 1

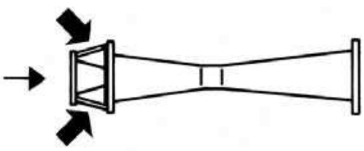


Steam jet ventilators to convey exhaust gases to thermal afterburning

CONSTRUCTIONS

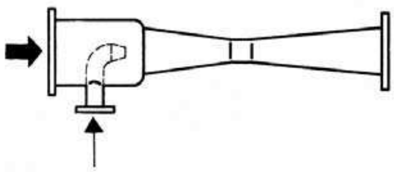
STEAM JET VENTILATORS ARE AVAILABLE IN THREE DIFFERENT CONSTRUCTIONS:

FIG. 2



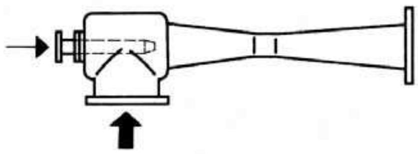
Design with free access of the sucked-in fluid from the environment

FIG. 3



Design with axial suction connection

FIG. 4



Design with lateral suction connection

DETERMINING THE MOTIVE STEAM CONSUMPTION

The diagram **fig. 5** 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 Δp = 0 to 500 mbar.

The motive liquid consumption is calculated by the following equation:

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

$\dot{M}_0$ 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

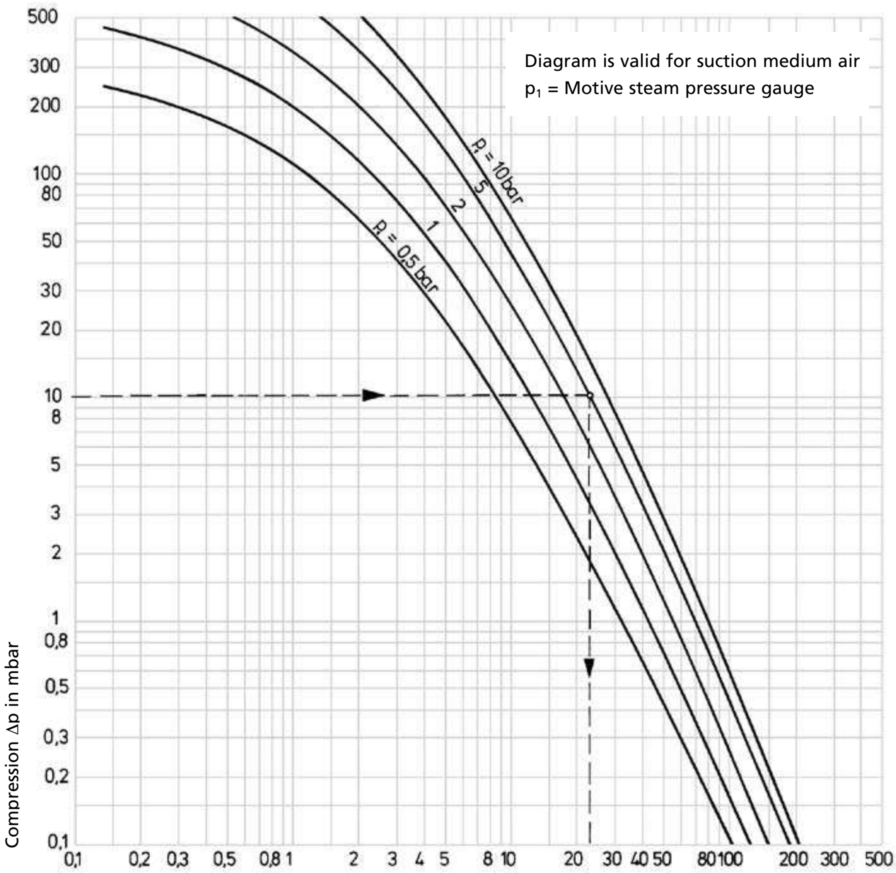
1. Required compression Δp = 10 mbar with motive steam at 5 bar, **fig. 5** shows a suction ratio of m = 23.5 kg/kg

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

2. Required compression Δp ~ 0 mbar with motive steam at 5 bar, **fig. 5** shows a suction ratio of m = ca. 190 kg/kg.

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

FIG. 5



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

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-GJL-200 (GG20), 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.

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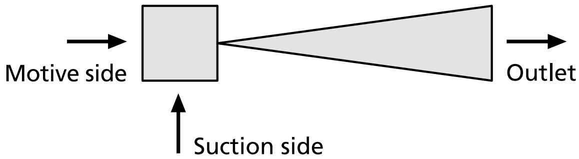
Questionnaire

for steam jet ventilators
dv1



1. MOTIVE SIDE

Motive medium . . . .

Motive pressure . . . . bar abs.

Temperature . . . . °C

Molecular weight . . . . kg/kmol

Specific heat capacity . . . . kJ/kg K

2. SUCTION SIDE

Suction medium . . . .

Suction flow . . . . kg/h

Suction pressure . . . . bar abs.

Temperature . . . . °C

Molecular weight . . . . kg/kmol

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:

DIN PN ☐

ASME lbs ☐

Others ☐

DESIGN CODE (if required):

AD ☐

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 . . . .

Steam jet liquid pumps

General information

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”, ↗ | abl 1).

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

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.

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, ρ = 1000 kg/m³ 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 reprocessing 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.

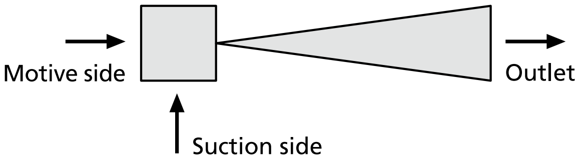
Cast iron

Stainless steel

Special construction for the nuclear industry

Questionnaire

for steam jet liquid pumps
dfp1, dfp2



1. MOTIVE SIDE

Motive pressure .... bar abs.

Temperature .... °C

2. SUCTION SIDE

Suction medium ....

Suction flow .... kg/h

Delivery head .... m WC

or suction pressure .... bar abs.

Temperature .... °C

Density .... kg/m³

Steam pressure .... bar abs.

3. OUTLET

Required discharge pressure .... bar abs.

4. FURTHER DATA

Material of construction ....

CONNECTIONS:

Flanges ☐

Thread ☐

Others ☐

FLANGES ACCORDING TO:

DIN PN ☐

ASME lbs ☐

Others ☐

DESIGN CODE (if required):

AD ☐

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 ....

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Steam jet liquid pumps

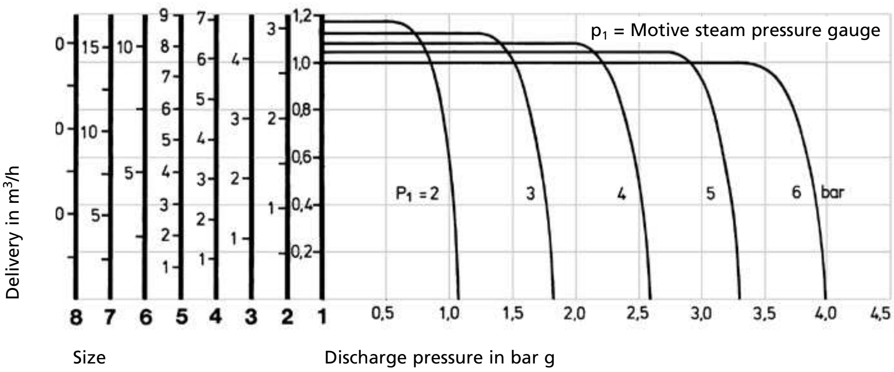
Class A

PERFORMANCE CHART

Steam jet liquid pumps class A are suitable for low suction heights, up to max. 1 m (where, density, ρ = 1000 kg/m³ 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.

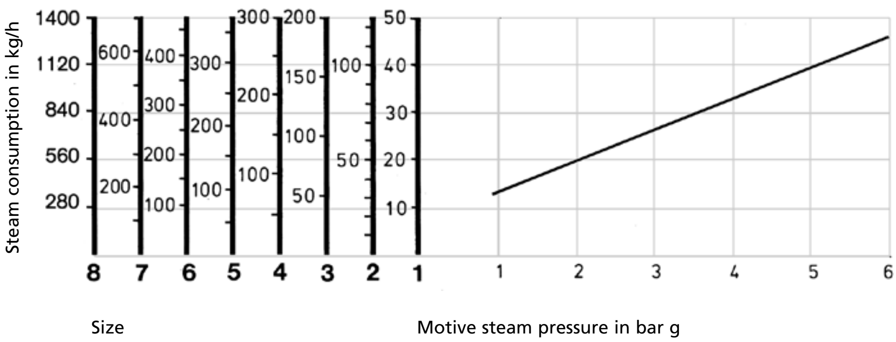
FIG. 1



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.

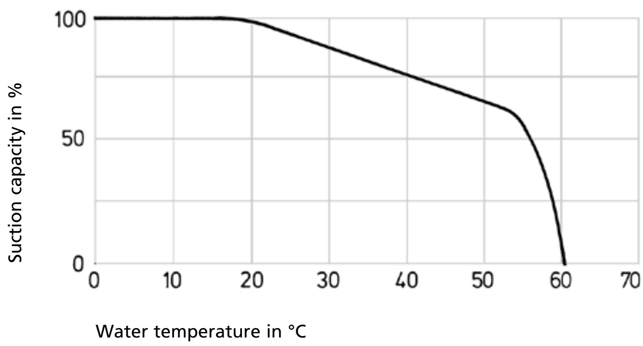
FIG. 2



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

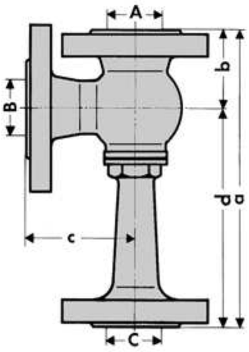
The liquid to be conveyed must not be too hot, so that the motive steam condenses in it and the total energy is available to convey the liquid (see diagram **fig. 3**).
It must be taken into consideration that not only higher temperatures, but also higher specific gravities of the liquid to be conveyed 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		2.5	4	5	8	12	12	17	26

STANDARD CONSTRUCTIONS:

I Housing: cast iron EN-GJL-200 (GG20), motive nozzle: brass
II Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel
III Housing: cast stainless steel (1.4581), motive nozzle: stainless steel
Flanges according to DIN PN 10

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 in accordance with the special testes and codes.
Dimensions, connections and special capacity data on request.

For inquiries please use our questionnaire.

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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.

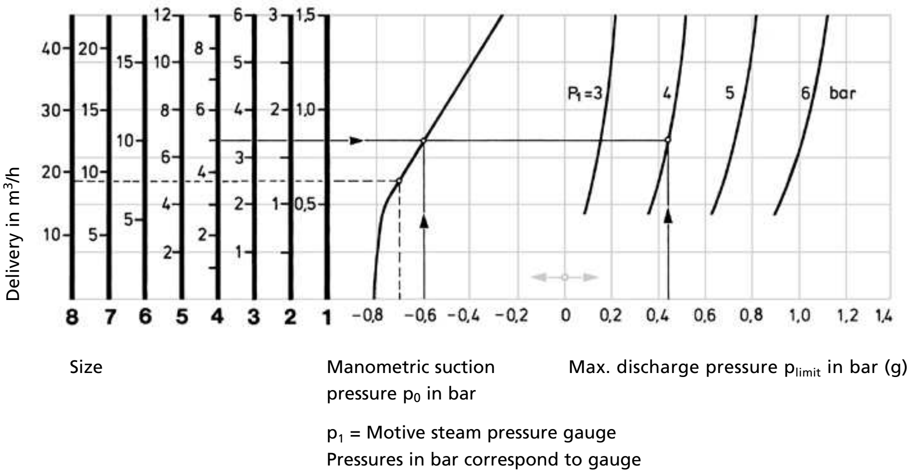
The example in **fig. 5** gives a size 4 pump and a motive steam pressure of 4 bar.

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.

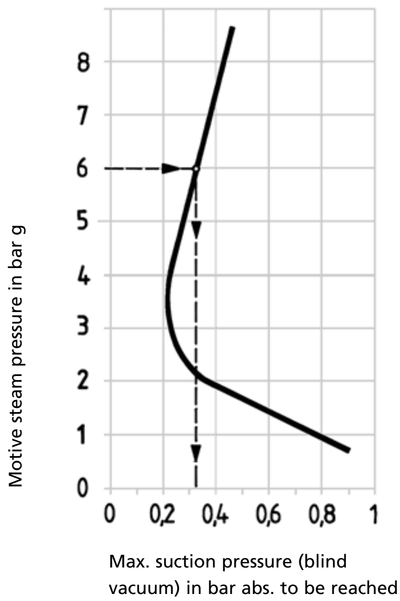
It must each time be checked by means of **fig. 7** whether at the motive steam pressure determined according to **fig. 5** the maximum suction pressure (blind vacuum) is lower than the necessary manometric suction pressure.

FIG. 5



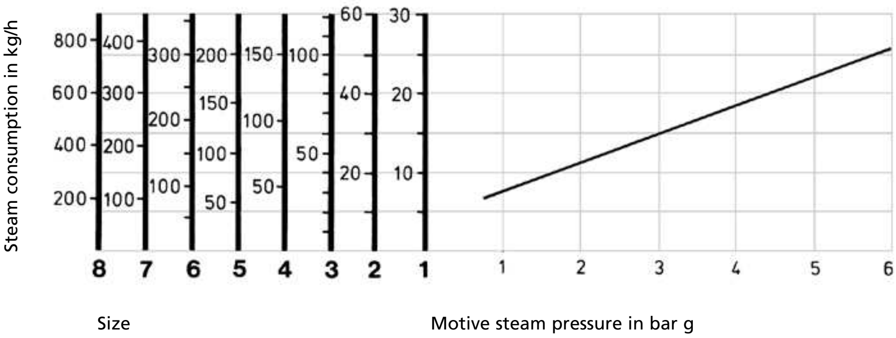
Delivery in m³/h of water at a temperature of 20 °C, depending on the suction and discharge pressure (limit discharge pressure) at different motive steam pressures p_1

FIG. 7



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

FIG. 6



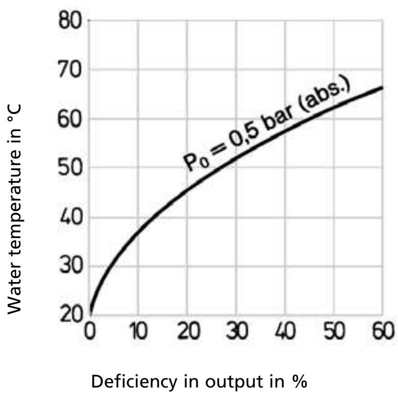
Steam consumption in kg/h of the individual sizes in relation to the motive steam pressure

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.

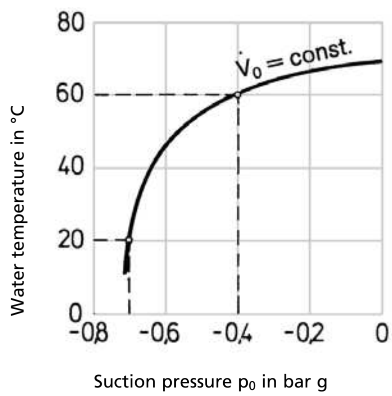
The theoretical suction pressure shown in **fig. 9** with the broken line, for the same delivery, changes from –0.7 bar at 20 °C to –0.4 bar at 60 °C.

FIG. 8



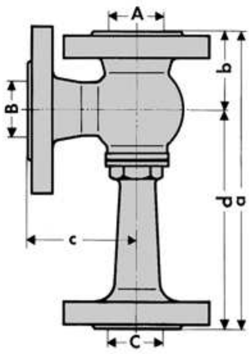
Influence of the water temperature on the delivery at a constant geodetic suction height of 5 m and a constant motive steam overpressure of 5 bar.

FIG. 9



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		2.5	4	5	8	12	12	17	26

STANDARD CONSTRUCTIONS:

I Housing: cast iron EN-GJL-200 (GG20), motive nozzle: brass
II Housing: cast iron EN-GJL-200 (GG20), motive nozzle: stainless steel
III Housing: cast stainless steel (1.4581), motive nozzle: stainless steel
Flanges according to DIN PN 10

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 in accordance with the special testes and codes.
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For inquiries please use our questionnaire.

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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

Steam jet heater for vessels with flanged connection

Steam jet heater type “L” for installation in pipelines, cast iron

Steam jet heater type “L” for installation in pipelines, stainless steel, welded

Steam jet heater, type “H” for passage and circulation heating systems, cast iron

Steam jet heater, type “H” for passage and circulation heating systems, stainless steel, welded

Condensation nozzle for steam jet heaters, type “L”, “H”, and “System Ciba-Geigy”

“System Ciba-Geigy”, for passage and circulation heating systems, cast iron

“System Ciba-Geigy”, for passage and circulation heating systems, stainless steel, welded

Questionnaire

for steam jet heaters for vessels
aw1

1. DIMENSIONS OF THE TANK OR BASIN

Volume of the tank or basin . . . . m^3

Diameter . . . . mm

Length . . . . mm

Width . . . . mm

Height . . . . mm

2. REQUIREMENTS ON THE HEATING

Heating capacity . . . . kW

Heating steam pressure . . . . bar abs.

Heating steam temperature . . . . °C

Heating time . . . . h

Initial temperature . . . . °C

Final temperature . . . . °C

FURTHER REQUIREMENTS: . . . .

. . . .

. . . .

3. FURTHER DATA

Material of construction . . . .

Installation according to catalogue sheet aw1 Fig. 3 ☐ Fig. 5 ☐ Fig. 7 ☐

CONNECTIONS:

Flanges ☐

Thread ☐

Others ☐

FLANGES ACCORDING TO:

DIN PN ☐

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 . . . .

attn. . . . .

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Steam jet heaters for vessels

Construction with thread

Construction with flange

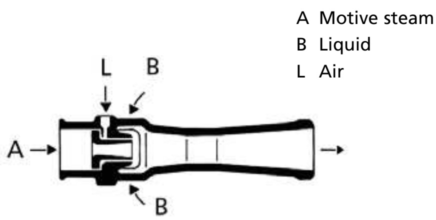
APPLICATION

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”, ↗ | abl 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 assists 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. 1**). 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).

FIG. 1



PERFORMANCE CHART

On the bottom scale, the chart in **fig. 2** 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:

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

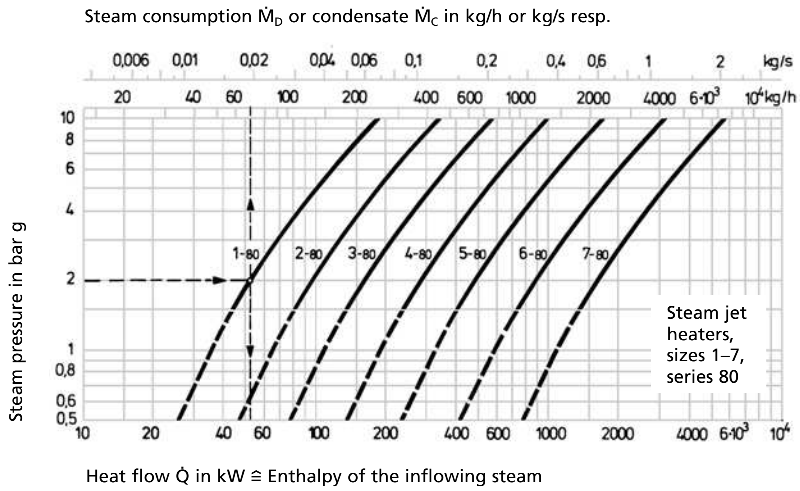
Whereas:

$\dot{Q}_{tr}$	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. 2** shows that size 1-80 matches the example.

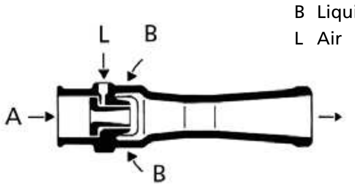
FIG. 2



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

Steam jet heater with thread, type 18.1

A Motive steam
B Liquid
L Air



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

FIG. 3

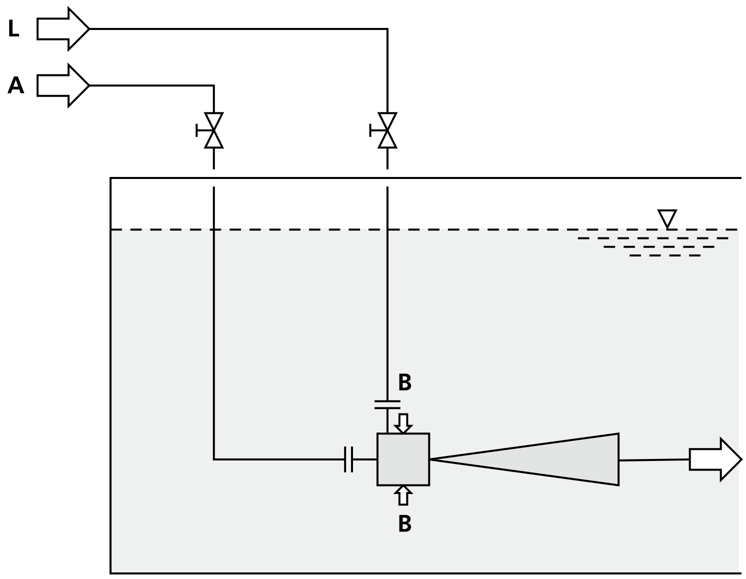
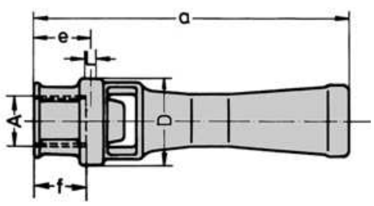


FIG. 4



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

	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		1	2	3	5	7	12	21

STANDARD CONSTRUCTIONS:

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

SPECIAL CONSTRUCTIONS are possible in most of the usual materials.
Please indicate size, type and material with your order.

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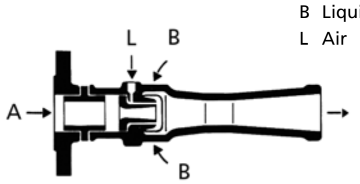
Steam jet heater with flange, type 28.1

A Motive steam
B Liquid
L Air



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

FIG. 5

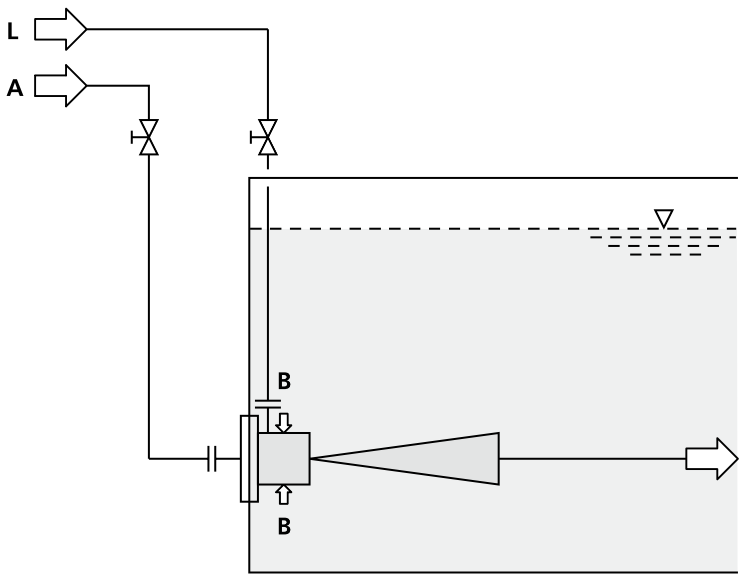
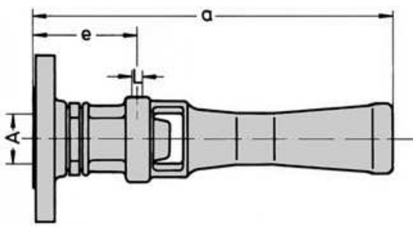


FIG. 6



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

	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		2	3	5	7	10	17	28

STANDARD CONSTRUCTIONS:

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

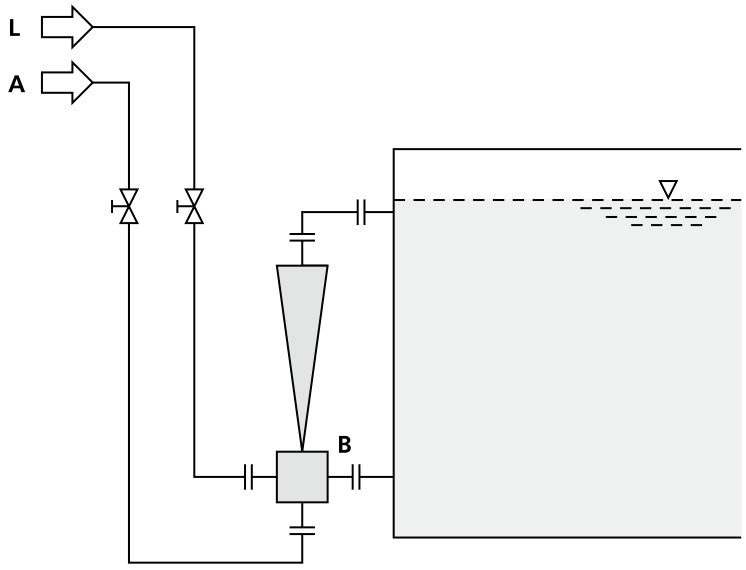
SPECIAL CONSTRUCTIONS are possible in most of the usual materials.
Please indicate size, type and material with your order.

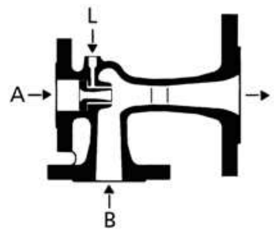
For inquiries please use our questionnaire.

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

SPECIAL CONSTRUCTIONS DESIGNED ACCORDING TO THE CUSTOMER'S SPECIFICATION

FIG. 7





A Motive steam
B Liquid
L Air

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.

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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 °C.

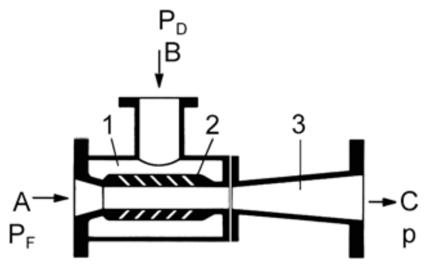
MODE OF OPERATION

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.
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.
Fig. 9 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.

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. 9**).

Cast iron

FIG. 8



1 Housing
2 Condensation nozzle
3 Diffuser

p_F Liquid inlet pressure

p_D Steam pressure
p Discharge pressure

A, C Liquid
B Steam

FIG. 9

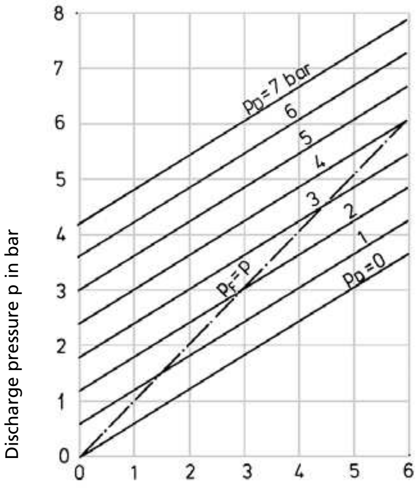
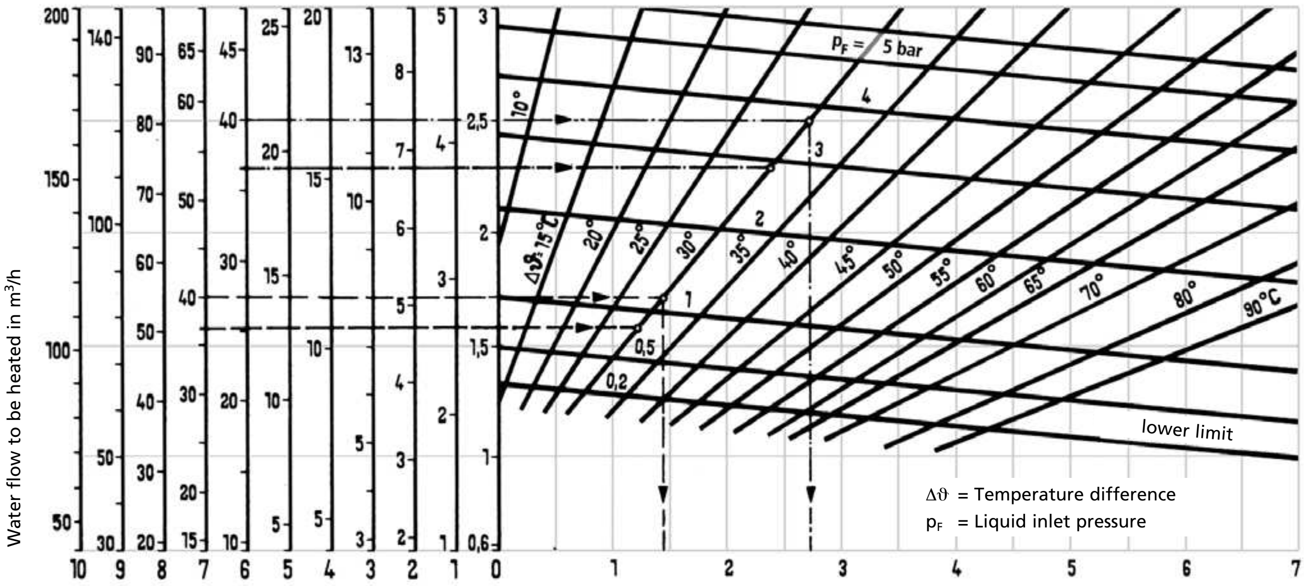


FIG. 10



PERFORMANCE CHART

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. 11** 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. 10**.

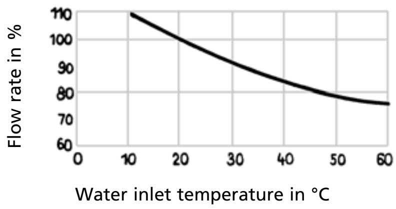
Water inlet pressure at size 6: 3.0 bar at size 7: 0.8 bar

Fig. 10 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 (pressure indications in bar g).

The described heaters can also be prepared for heating and steam pressures other than indicated in **fig. 10**, in particular also for exhaust steam.

DETERMINATION OF THE STEAM CONSUMPTION: According to **fig. 12**, the steam consumption at a steam pressure of 1.4 bar and size 0 amounts to approx. 80 kg/h.

FIG. 11

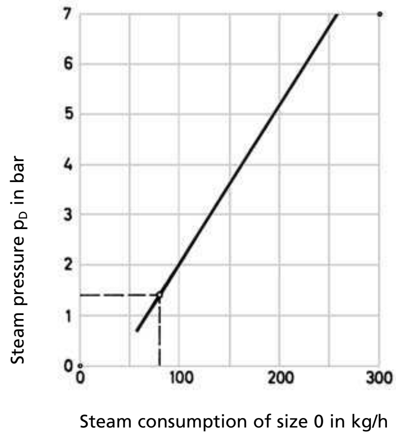


Influence of the liquid inlet temperature on the liquid flow rate

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.

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.

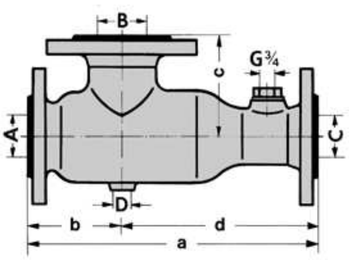
FIG. 12



Steam consumption of size 6 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. 13



CONNECTIONS, DIMENSIONS AND WEIGHTS

	Size	0	1	2	3	4	5	6	7	8	9	10
Nominal	A	25	32	40	50	65	65	80	100	125	150	150
diameter	B	32	40	50	65	80	100	125	150	200	200	250
	C	25	32	40	50	65	65	80	100	125	150	150
	D	G 3/8	G 3/8	G 3/8	G 3/8	G 3/8	G 3/8	G 3/4	G 3/4	G 3/4	G 3/4	G 3/4
Dimensions	a	230	265	310	350	380	425	650	890	975	1275	1275
in mm	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		6	9	14	18	23	30	50	56	62	80	80

STANDARD CONSTRUCTIONS:

SIZE 0 TO 6:

I Housing: cast iron EN-GJL-200 (GG20), condensation nozzle: red brass

II Housing: cast iron EN-GJL-200 (GG20), condensation nozzle: stainless steel

III Housing: cast stainless steel (1.4581), condensation nozzle: stainless steel (up to size 5 only)

SIZE 7 TO 10:

IV Housing: steel, condensation nozzle: red brass, loose flange: steel

V Housing: steel, condensation nozzle: stainless steel, loose flange: steel

VI Completely stainless steel

Flanges: DIN PN 16

SPECIAL CONSTRUCTIONS are possible in most of the usual materials.
For inquiries please use our questionnaire.

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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.

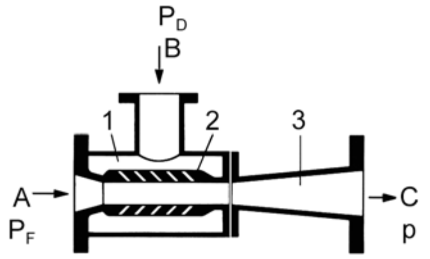
- heating to max. 30 °C per pass
- steam flow control range up to max. 5:1

For greater control ranges see "Steam jet heaters, System Ciba Geigy", ↗| 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.
This takes place at the point of highest velocity of the liquid, its lowest pressure and its greatest turbulence.

FIG. 14



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. $\Delta\vartheta = 30$ °C 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 x 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:

$$\dot{M}_D = \dot{V}\cdot\rho\cdot\frac{c_L\cdot\Delta\vartheta}{h - c_C\cdot\vartheta}$$

$\dot{M}_D$	Steam consumption in kg/h
$\dot{V}$	Flow rate in m³/h
ρ	Density of the liquid in kg/m³
c_L	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)
$\Delta\vartheta$	Temperature of the heated water in °C
h	Specific enthalpy of the steam in kJ/kg
ϑ	Temperature of the liquid at the discharge of the heater in °C

Stainless steel, welded

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:

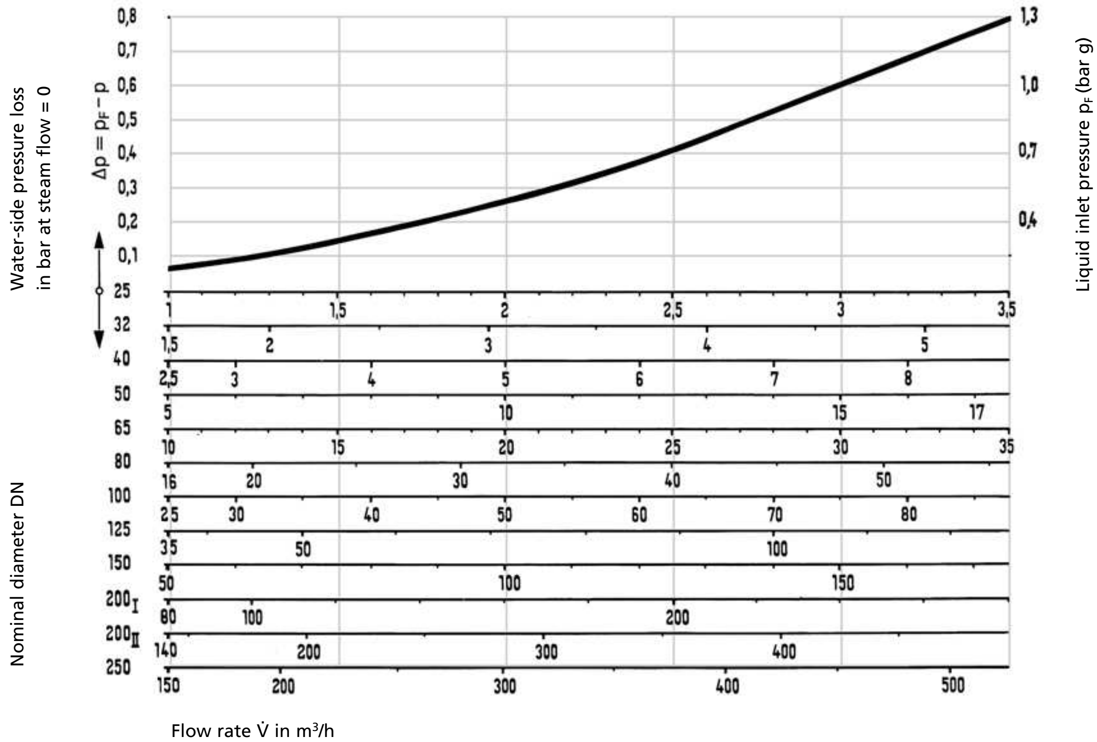
$$\dot{M}_D = 50\cdot 1000\cdot\frac{4.2\cdot(50-20)}{2\,736 - 4.2\cdot 50} \approx 2\,500\,\frac{kg}{h}$$

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

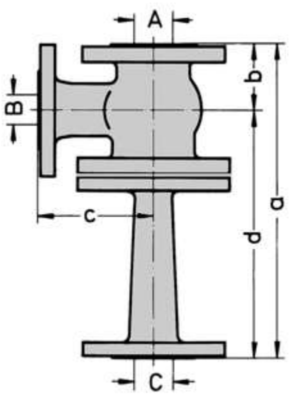
Due to the condition that liquid inlet pressure $0.5 \leq p_F \leq 1$ bar g, size DN 100 is selected.

FIG. 15



Relation between flow rate, heating and steam consumption

FIG. 16



CONNECTIONS, DIMENSIONS AND WEIGHTS

	Size	25	32	40	50	65	80	100	125	150	200 I	200 II	250
Nominal	A	25	32	40	50	65	80	100	125	150	200	200	250
diameter	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	a	230	265	260	280	350	450	500	685	750	1000	1050	1400
in mm	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		7	10	15	20	22	32	35	50	55	85	100	150

STANDARD CONSTRUCTIONS:

DN 25 TO DN 100:

I Housing: cast iron EN-GJL-200 (GG20), condensation nozzle: red brass
II Housing: cast iron EN-GJL-200 (GG20), condensation nozzle: stainless steel
III Housing: cast stainless steel (1.4581), condensation nozzle: stainless steel (DN 25 – DN 40 only)

DN 125 TO DN 250:

IV Housing: steel, condensation nozzle: red brass, loose flange: steel
V Housing: steel, condensation nozzle: stainless steel, loose flange: steel
VI Housing: stainless steel, condensation nozzle: stainless steel, loose flange: steel (DN 50-DN 250)
Flanges according to DIN PN 10/16

SPECIAL CONSTRUCTIONS are possible in most of the usual materials.
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Steam jet heaters "System Ciba-Geigy"

for passage and circulation heating systems

Cast iron

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:

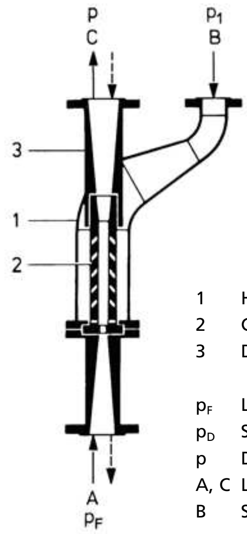
- flow rates of 2–700 m³/h
- heating per pass up to approx. 30 °C
- control range of heating capacity up to 200:1
- heating up to approx. 5 °C below the saturated steam temperature of the heating steam

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. 17**).
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 ajusted to the required operating conditions, by means of a temperature control circuit (**fig. 18**).

FIG. 17



1 Housing
2 Condensation nozzle
3 Diffuser

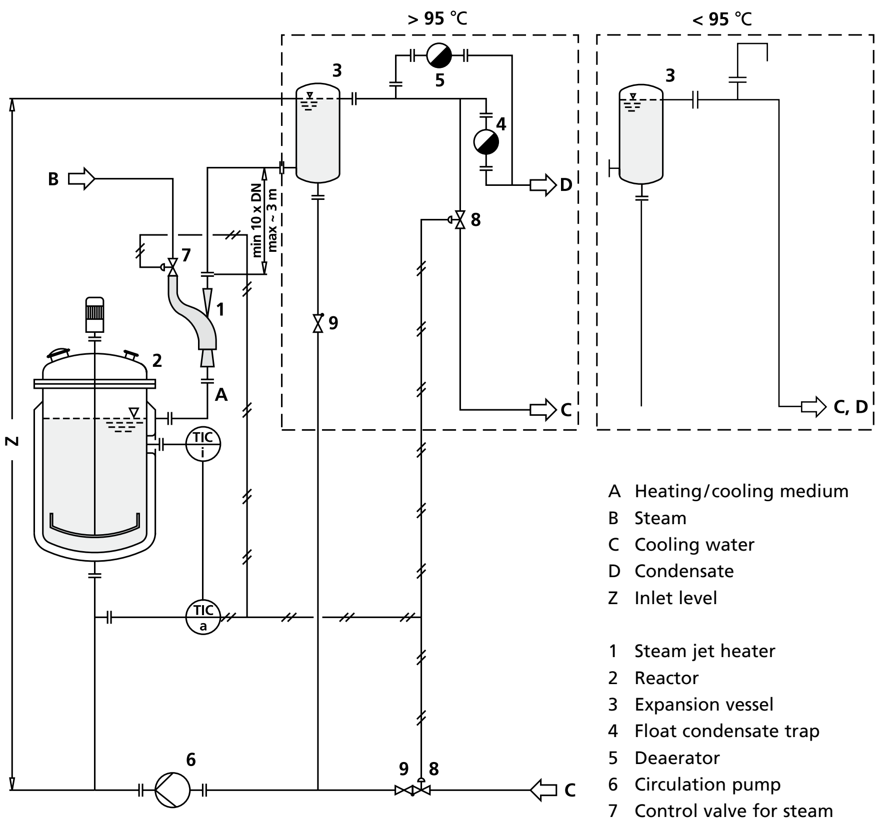
p_F Liquid inlet pressure
p_D Steam pressure
p Discharge pressure
A, C Liquid
B Steam

In many cases in process technology, a large control range is required.
The steam jet heater "System Ciba-Geigy" by GEA Wiegand 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. 19**

FIG. 19



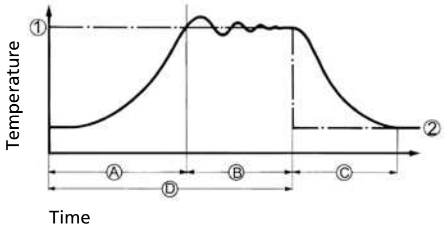
Circulating heating and cooling system

A Heating/cooling medium
B Steam
C Cooling water
D Condensate
Z Inlet level

1 Steam jet heater
2 Reactor
3 Expansion vessel
4 Float condensate trap
5 Deaerator
6 Circulation pump
7 Control valve for steam
8 Control valves for water
9 Non-return flaps

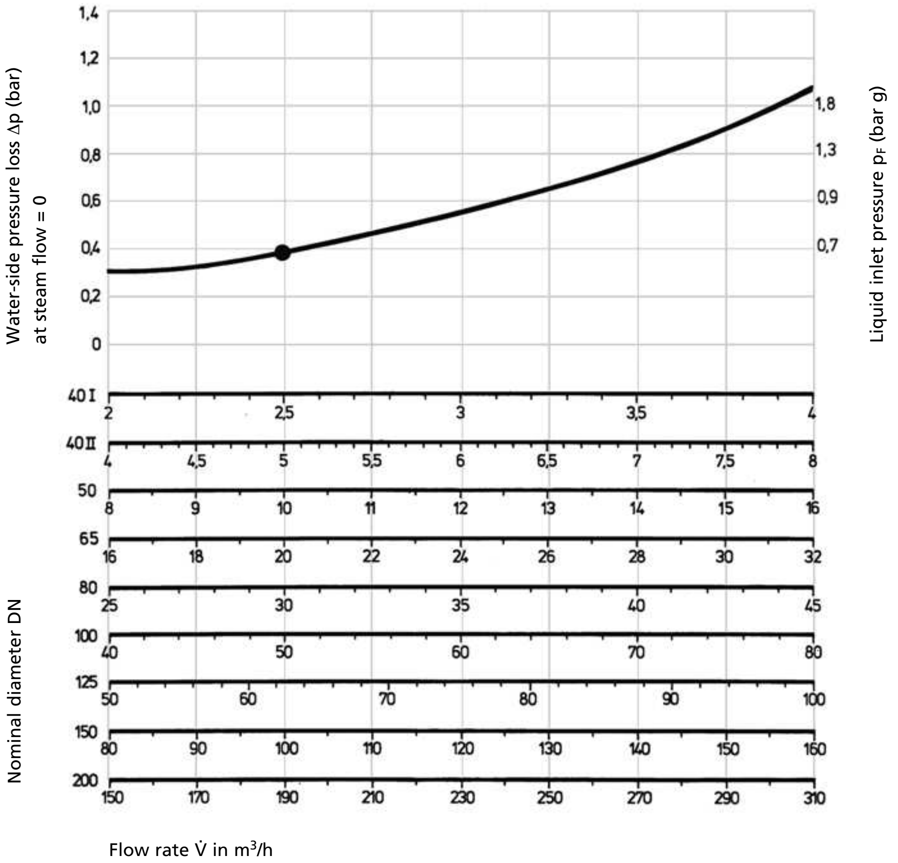
FIG. 18

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. 20



PERFORMANCE CHART

The flow rate and the pressure loss determine the size of the steam jet heater. In **fig. 20**, 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:

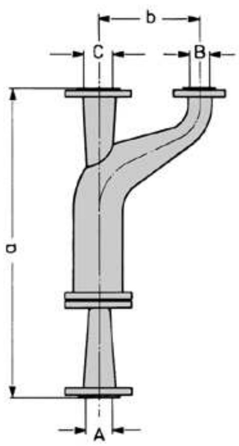
$$\dot{M}_D = \dot{V} \cdot \rho \cdot \frac{c_L \cdot \Delta\vartheta}{h - c_C \cdot \vartheta}$$

- $\dot{M}_D$ 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 of the heated water in °C
- h Special enthalpy of the steam in kJ/kg
- ϑ Temperature of the liquid at the outlet of the heater in °C

FIG. 21

CONNECTIONS, DIMENSIONS AND WEIGHTS

	Size	40 I	40 II	50	65	80	100	125	150	200
Nominal	A	40	40	50	65	80	100	125	150	200
diameter	B	40	40	40	50	65	65	80	100	150
	C	40	40	50	65	80	100	125	150	200
Dimensions	a	450	450	500	630	800	900	1120	1300	1700
in mm	b	158	158	188	205	217	250	305	400	535
Weight in kg		21	21	28	40	32	45	70	125	190



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

DN 40 TO 200:

III Housing: steel, condensation nozzle: brass
IV Housing: steel, condensation nozzle: stainless steel
V Completely stainless steel
Flanges DIN PN 16

SPECIAL CONSTRUCTIONS are available in most of the materials.
For inquiries please use our questionnaire.

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 °C.

PARAMETERS TO BE FOUND: Required steam flow, size of the steam jet heater and liquid inlet pressure.

SOLUTION: Determination of the steam consumption:

$$\dot{M}_D = 50 \cdot 1000 \cdot \frac{4.2 \cdot 20}{2\,736 - 4.2 \cdot 80} \approx 1750\,\frac{kg}{h}$$

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.

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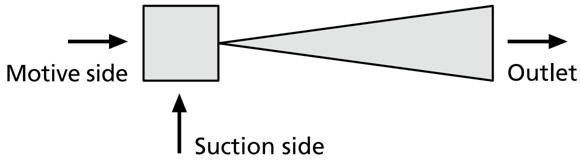
Questionnaire

for steam jet heaters, type "L", aw4
steam jet heaters, type "H", aw5
steam jet heaters "System Ciba-Geigy", aw6



1. LIQUID INLET

Medium ....

Liquid inlet pressure .... bar abs.

Rate of liquid flow .... m³/h

Density .... kg/m³

Temperature .... °C

2. OUTLET

Requested final temperature .... °C

Required discharge pressure .... bar abs.

3. HEATING STEAM

Pressure .... bar abs.

Temperature .... °C

4. FURTHER DATA

Material of construction ....

CONNECTIONS:

- Flanges ☐
- Thread ☐
- Others ☐

FLANGES ACCORDING TO:

- DIN PN ☐
- ASME lbs ☐
- Others ☐

DESIGN CODE (if required):

- AD ☐
- ASME ☐
- Others ☐

APPLICATION:

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

DESIGN:

Temperature .... °C

Pressure .... bar g

FURTHER NOTES: ....

....
....

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

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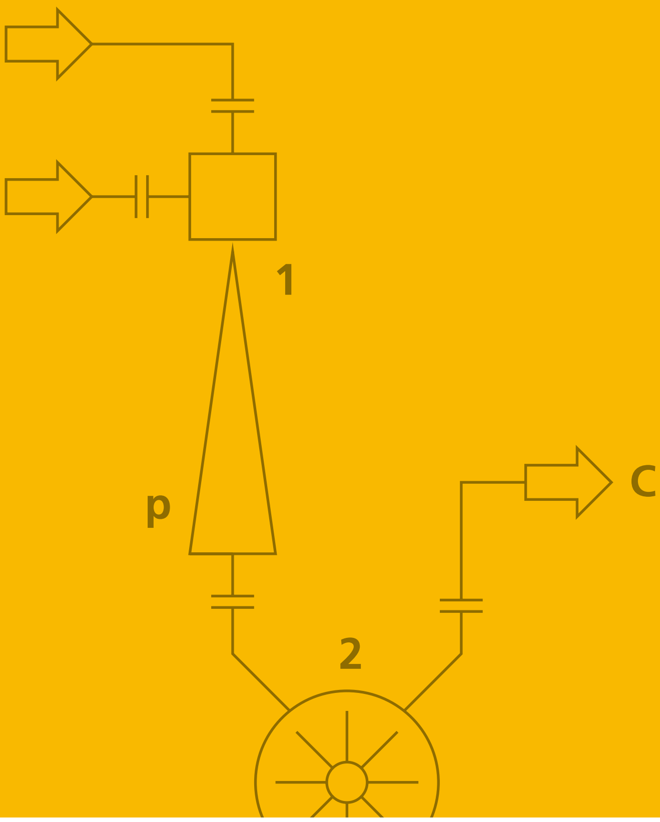


Gas/air jet pumps

- 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 compressor for the natural gas industry

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”, ↗ l abl 1.
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.


Gas jet vacuum pump

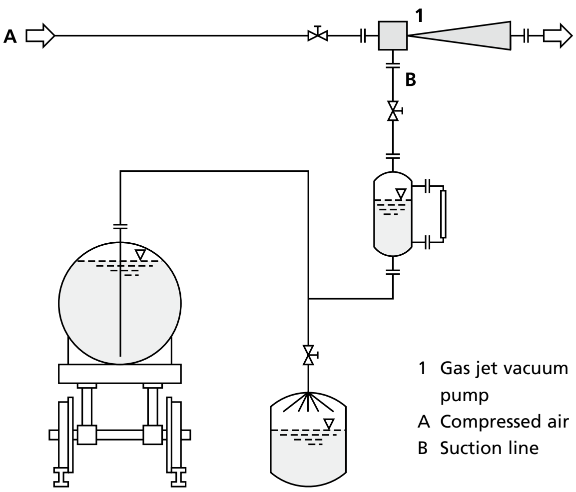

Gas jet vacuum pump for the nuclear industry

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.

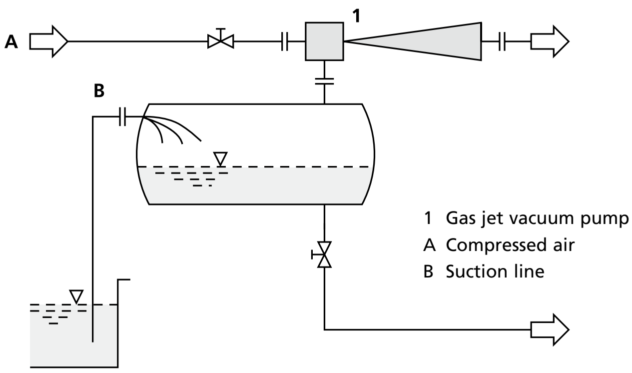
TYPICAL APPLICATIONS FOR GAS JET VACUUM PUMPS

FIG. 1



EXAMPLE 1: EVACUATION OF A SIPHONING INSTALLATION

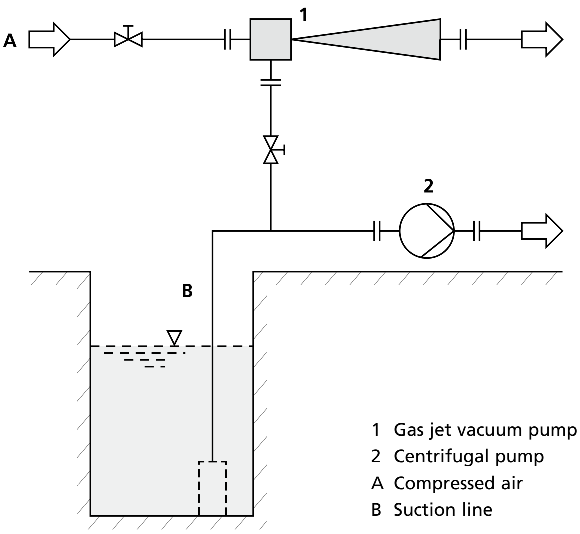
FIG. 2



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.

FIG. 3



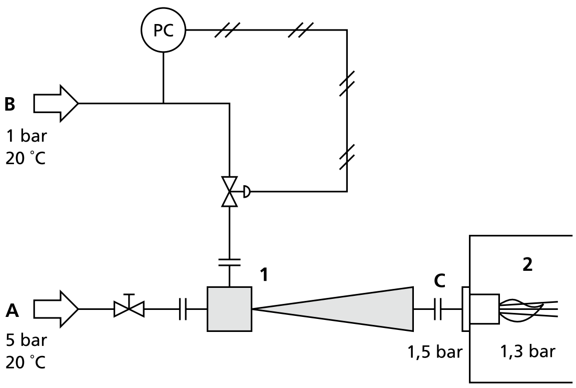
EXAMPLE 3: EVACUATION OF THE SUCTION LINE OF A CENTRIFUGAL PUMP

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

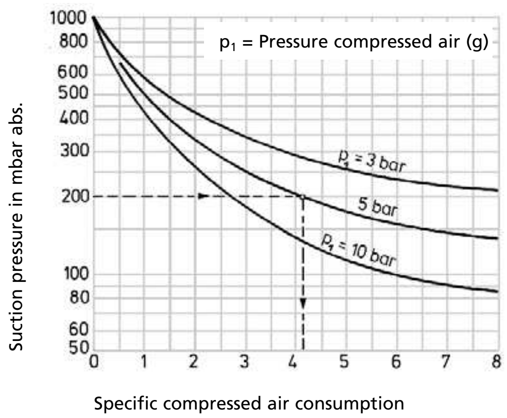
EXAMPLE

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



$A_{spec.}$ in $\frac{\text{kg Compressed air}}{\text{m}^3 \text{ of vol. to be evacuated}}$

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.

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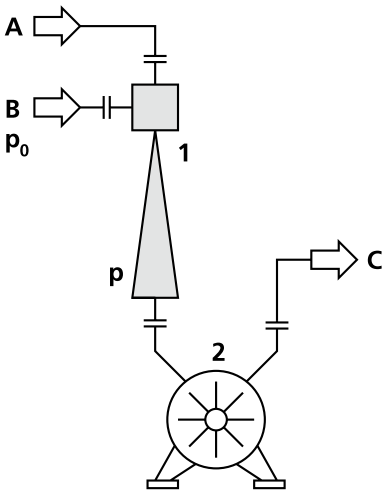
Air jet vacuum pumps

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.

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

Method of operation of an air jet vacuum pump for connection to the suction side of a liquid ring vacuum pump

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.

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.

MATERIALS, CONSTRUCTION AND CONNECTING DIMENSIONS

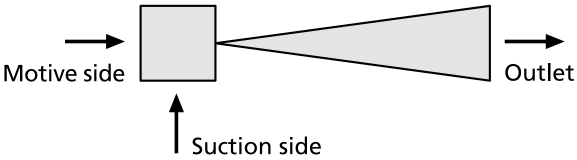
Air jet vacuum pumps are specially calculated and fabricated to correspond to the particular operating conditions and can be supplied in the following materials:
Cast iron EN-GJS-400-15 (GGG40), steel, stainless steel, plastics, porcelain. Further, special materials of construction are possible, such 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



1. MOTIVE SIDE

Motive medium . . . .

Motive pressure . . . . bar abs.

Temperature . . . . °C

Molecular weight . . . . kg/kmol

Specific heat capacity . . . . kJ/kg K

2. SUCTION SIDE

Suction medium . . . .

Suction flow . . . . kg/h

Suction pressure . . . . bar abs.

Temperature . . . . °C

Molecular weight . . . . kg/kmol

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:

DIN PN ☐

ASME lbs ☐

Others ☐

DESIGN CODE (if required):

AD ☐

ASME ☐

Others ☐

APPLICATION:

. . . .

. . . .

. . . .

DESIGN:

Temperature . . . . °C

Pressure . . . . bar g

FURTHER NOTES: . . . .

. . . .

. . . .

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

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Gas jet ventilators

APPLICATIONS

Gas jet ventilators convey air, gases and vapours against pressure differences up to approximately 500 mbar.
Gas jet ventilators are used:

- to draw off stale air, ill-smelling gases and vapours 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

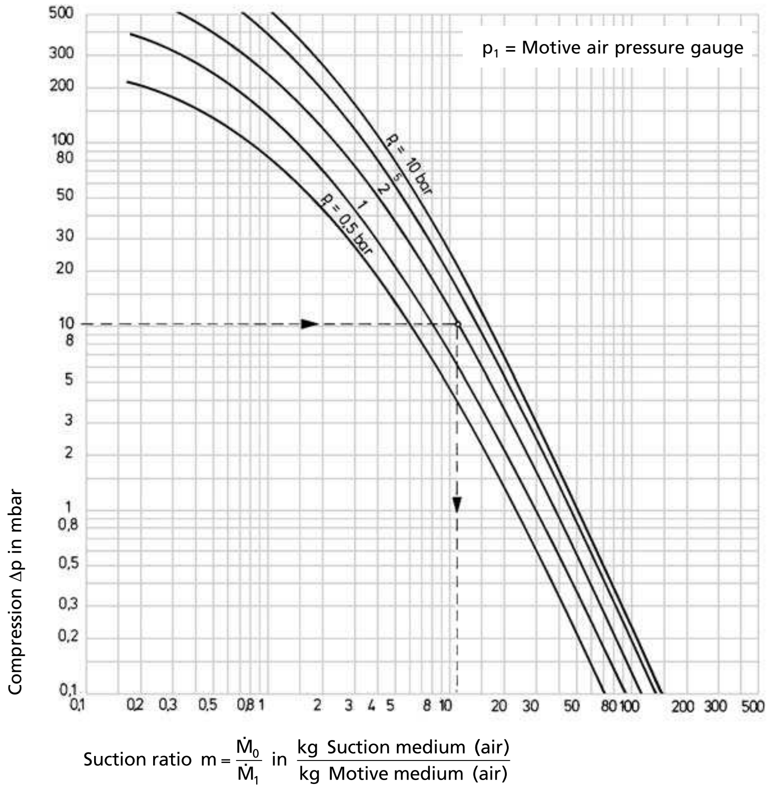
The achievable pressure difference between the suction and discharge pressure is the compression of a gas jet ventilator.

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 (↗ | dv 1) or liquid jet ventilators (↗ | fv 1).
As opposed to liquid jet ventilators, gas or steam jet ventilators have the advantage that they can be installed in any installation position and that larger pressure differentials can be obtained.

FIG. 1



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.

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 Δp = 0 to 500 mbar. Above 500 mbar, gas jet compressors are used, ↗ | 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 ≘ 1250 m³/h
Compressed air pressure: 2 bar (g)

1. Required compression Δp = 10 mbar
   According to **fig. 1**, with compressed air at 2 bar, there is a suction ratio m = approx. 12.7 kg/kg.

$$\text{Compressed air consumption} = \frac{1500}{12.7} = 118\ \frac{\text{kg}}{\text{h}}$$

2. Required compression Δp ~ 0 mbar
   According to **fig. 1**, with compressed air at 2 bar, there is a suction ratio m = approx. 120 kg/kg.

$$\text{Compressed air consumption} = \frac{1500}{120} = 12.5\ \frac{\text{kg}}{\text{h}}$$

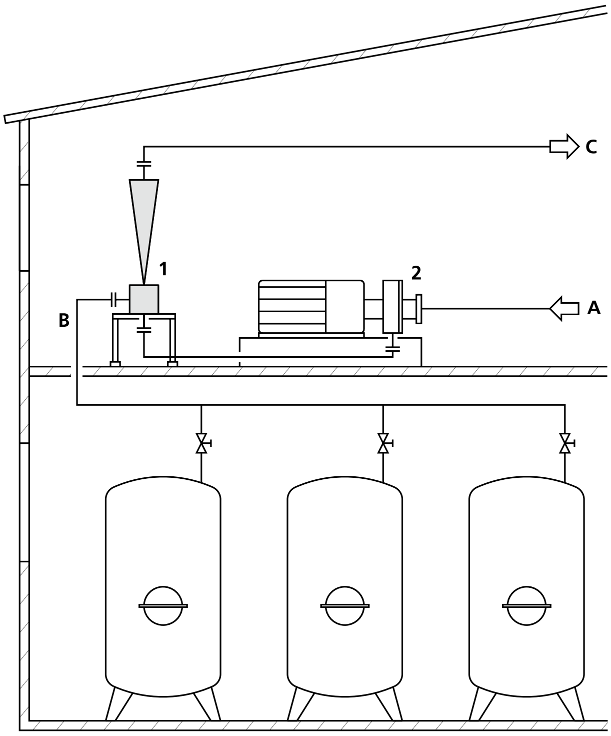
APPLICATION SUCTION PLANT

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

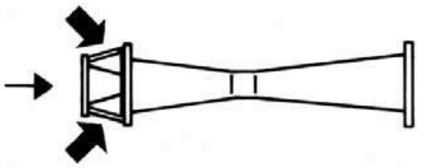
Suction plant with a low-pressure gas jet ventilator

1 Gas jet ventilator
2 Compressor
A Air
B Exhaust gas
C To exhaust gas cleaning plant



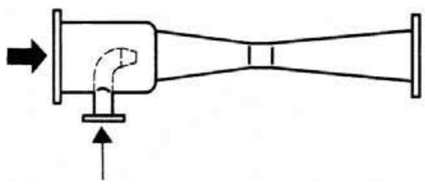
CONSTRUCTIONS OF GAS JET VENTILATORS

FIG. 3



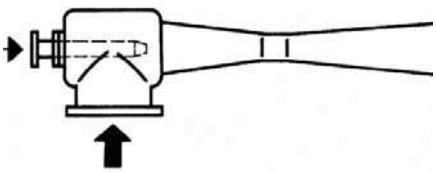
Design giving free access of the sucked-in medium from the environment

FIG. 4



Design with axial suction connection

FIG. 5



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.

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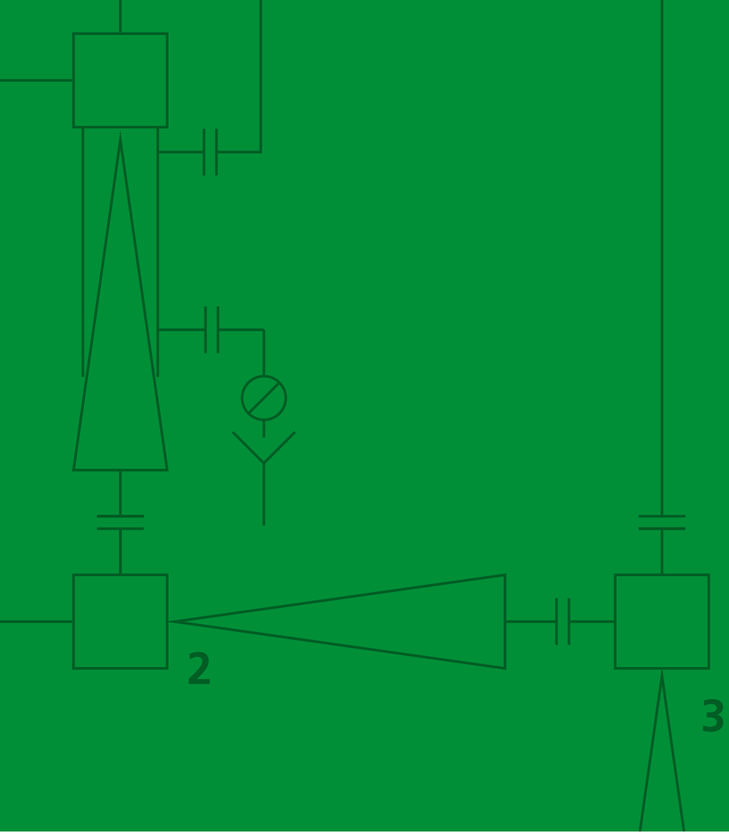


Vacuum systems

- 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 porcelain/graphite
- Arrangements of steam jet vacuum pumps
- Laboratory steam jet vacuum pumps
- Planning a steam jet vacuum pump

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

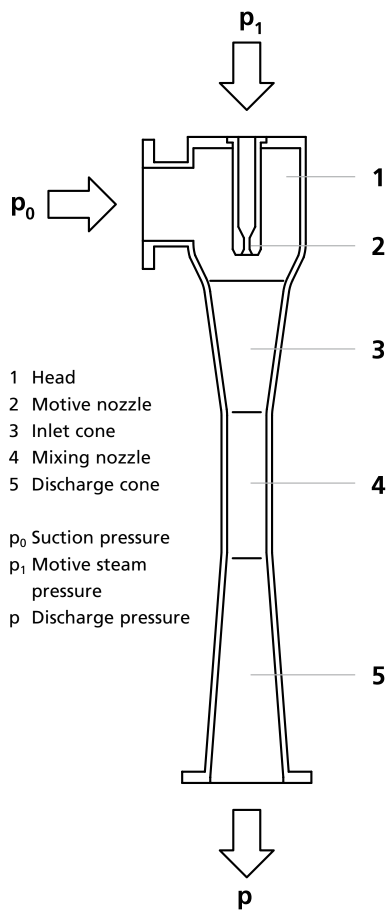
ADVANTAGES:

- 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”, ↗ | abl 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 $56 : 0.3 \cong 187$), 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 $56 : 0.1 \cong 560$, 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 diphyl, 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 porcelain, graphite and glass are used.

For more detailed information on the discussed topics please refer to section “Planning a steam jet vacuum pump”, ↗ | gdp3.

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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 vapours 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 vapours 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 vapours 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

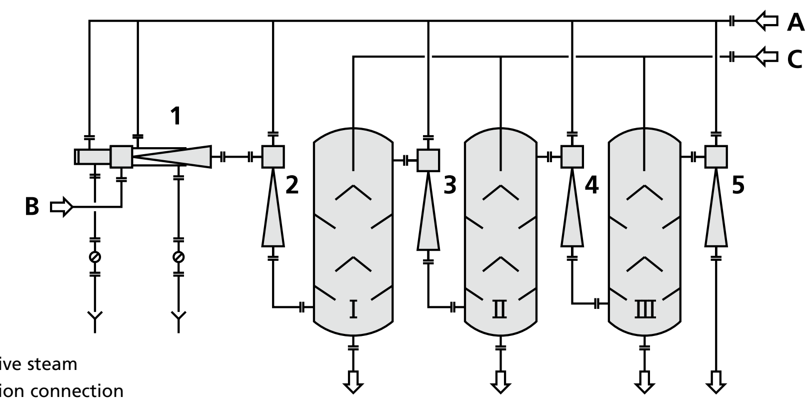
STAGE 5: compresses to atmospheric pressure for discharge to the ambient air via a scrubber or a mixing condenser

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”, ↗ | 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

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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 vapours 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 vapours 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.

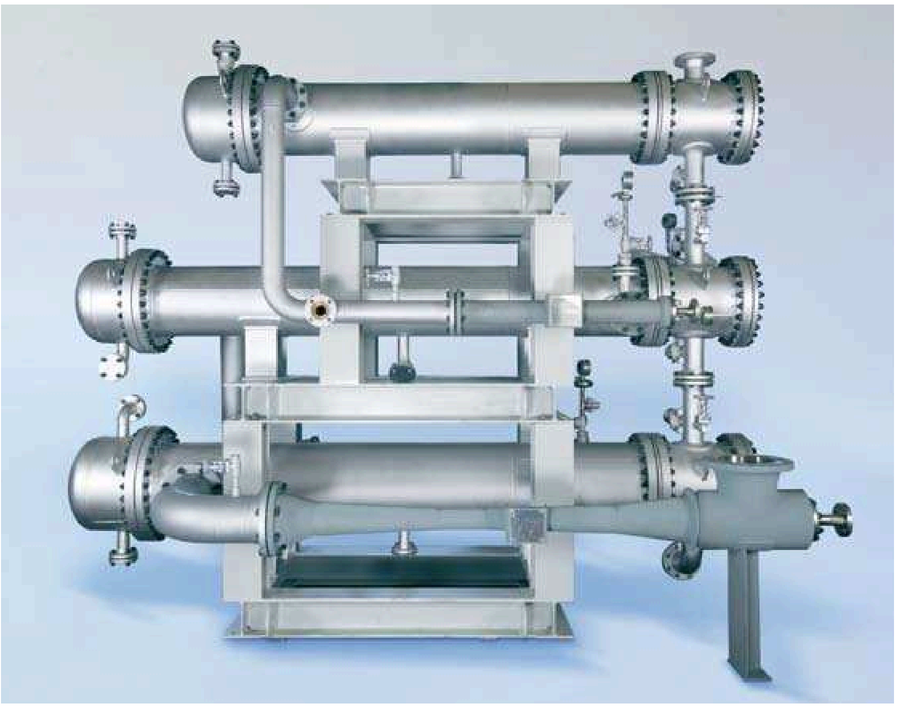
STAGE 3: stage extracts all gases and vapours which were not condensed in the surface condenser I for compression to a pressure of 320 mbar

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

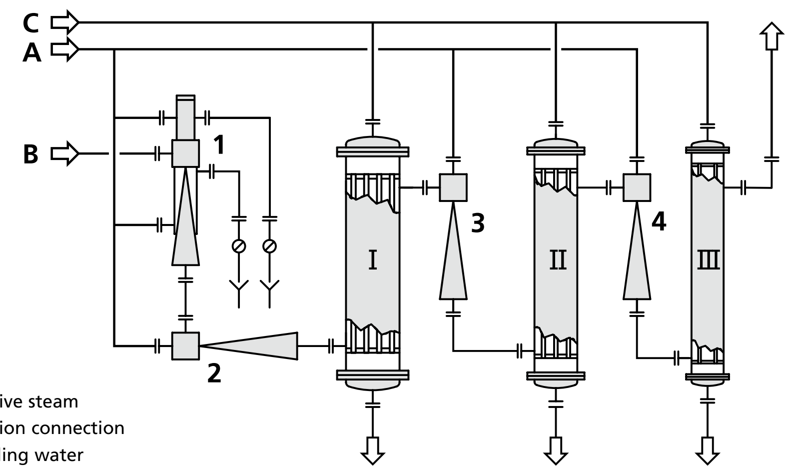
SURFACE CONDENSER III: condenses the remaining suction flow and the motive steam of the upstream arranged stage

See also “Planning a steam jet vacuum pump”, ↗ | gdp 3.



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. 1 050 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.

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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.

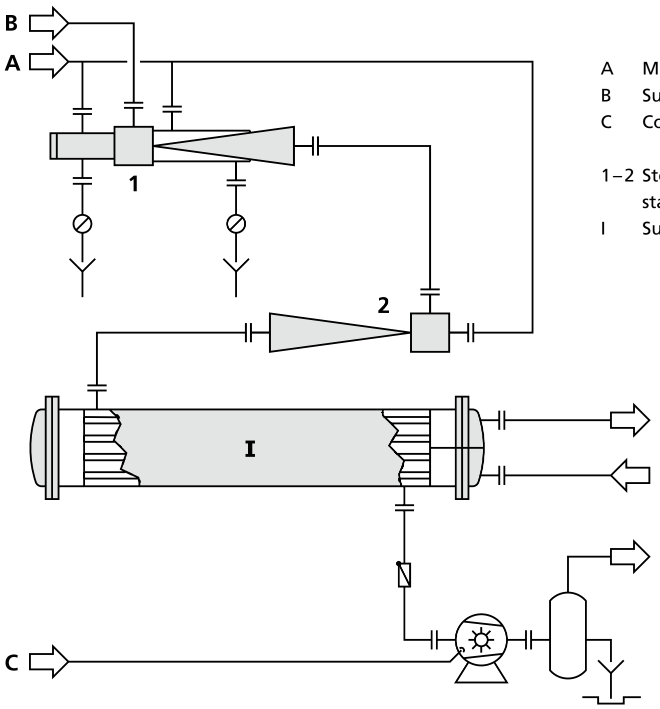
TWO-STAGE PUMP FOR A NOMINAL SUCTION PRESSURE OF 1 mbar (FIG. 1)

The 2nd stage is connected to the vacuum plant and extracts the vapours 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”, ↗ | gdp 3.

Suction capacity: 4.5 kg/h of air/benzyl alcohol from 2 mbar

FIG. 1



A Motive steam
B Suction connection
C Cooling water

1–2 Steam jet pumps, stages 1 and 2
I Surface condenser

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

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Multi-stage steam jet vacuum pumps

in porcelain/graphite

DESIGN AND MODE OF OPERATION

Multi-stage steam jet vacuum pumps in porcelain/graphite are used to extract corrosive gases and vapours, 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 vapours 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 vapour 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 vapours 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 vapour 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.

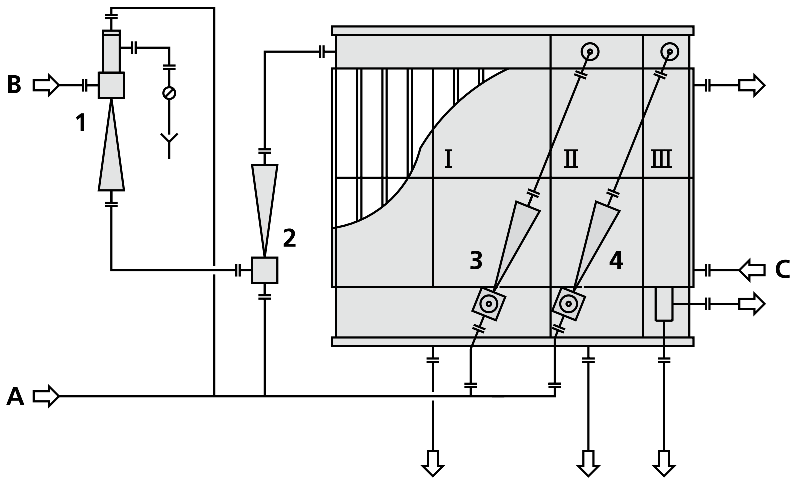
The condensate lines can be made in plastic, porcelain or glass tubes.

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 porcelain steam jet vacuum pumps, where mixing condensers of temperature-change resistant porcelain are used for inter-condensation.

Steam jet vacuum pump with block condenser made of graphite
Suction capacity: 2.5 kg/h of air from 1.3 mbar

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

PORCELAIN has been used by us for the construction of jet pumps (and mixing condensers) for many years. It is insensitive to temperature changes and hydrofluoric acid is virtually the only material that will attack it. With wall thicknesses of 10-30 mm, the risk of breakage is negligible, if used correctly.

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 vapours 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 porcelain jet pumps and connection lines are mainly constituent parts of our standard types and are, therefore, generally available from stock.

Fig. 2
5-stage steam jet vacuum pump in corrosion-resistant design
Materials: jet pump in porcelain, mixing condensers in C-steel enamelled
Suction capacity: 5 kg/h of air from 2.5 mbar abs.

Fig. 3
4-stage steam jet vacuum pump with surface condenser
Materials: porcelain and graphite
Suction capacity: 22.7 kg/h from 16 mbar abs.

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Arrangements of steam jet vacuum pumps

FIGURES 1-2

FIG. 1

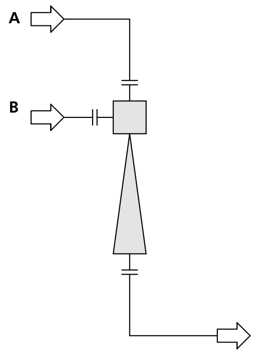
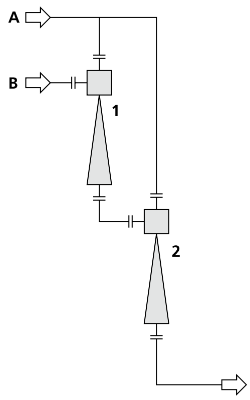


FIG. 2



A Motive steam
B Suction connection
C Cooling water

Single-stage steam jet vacuum pump

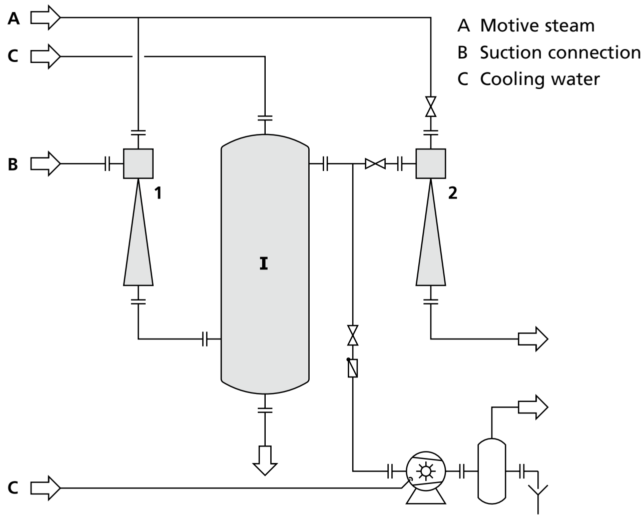
2-stage steam jet vacuum pump

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

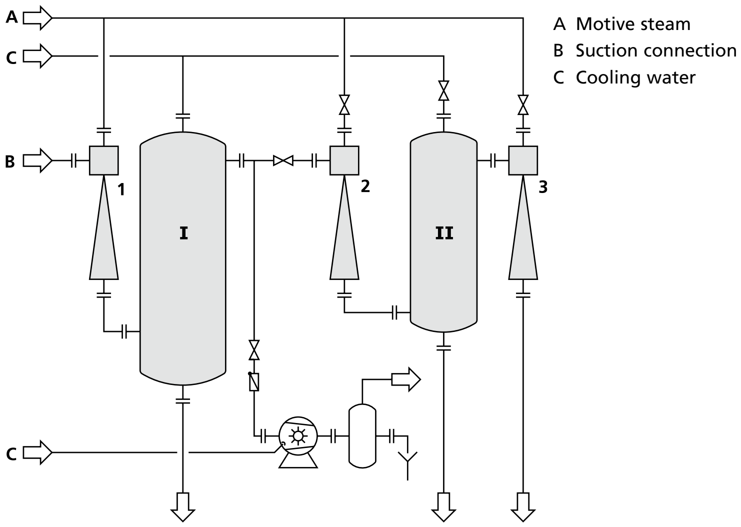
FIG. 3



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

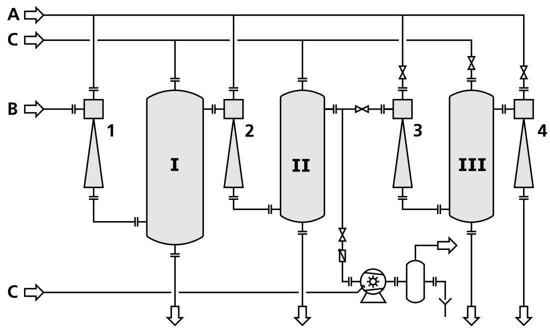


3-stage steam jet vacuum pump

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

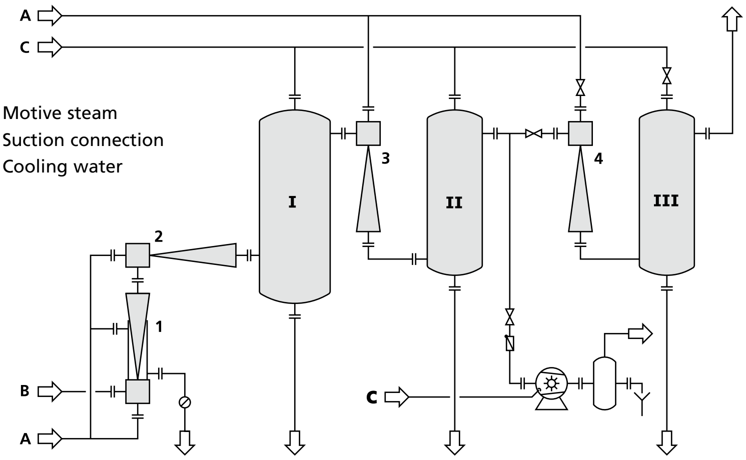


A Motive steam
B Suction connection
C Cooling water

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 vapours from various types of vacuum plants

FIG. 6



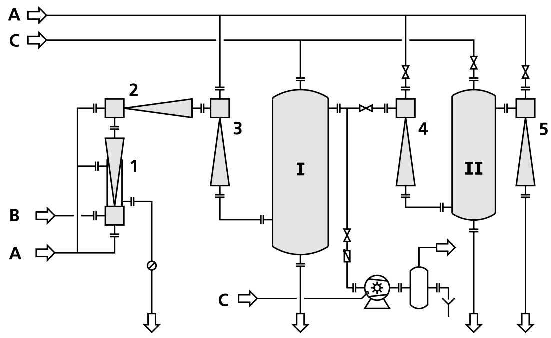
A Motive steam
B Suction connection
C Cooling water

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”, ↗ | 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.

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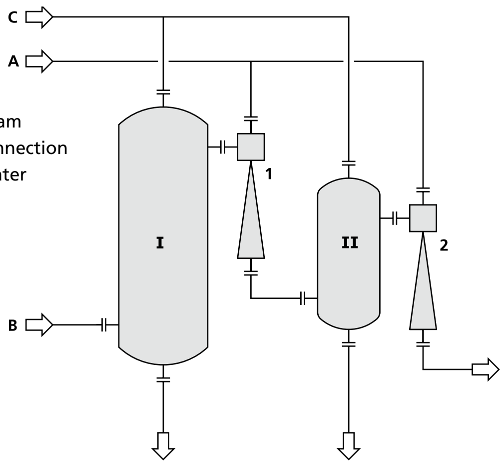
FIGURES 8-9

FIG. 8

A Motive steam
B Suction connection
C Cooling water

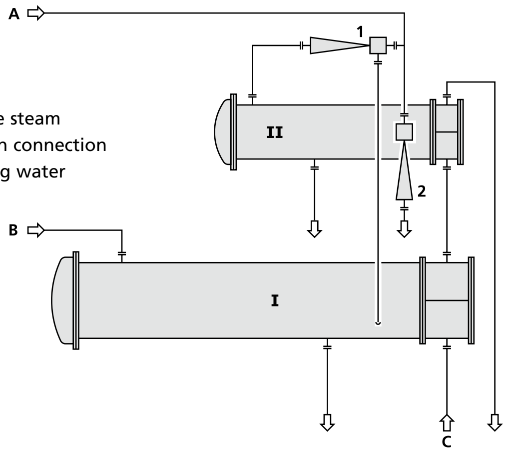


Condensation system with mixing condensers and de-aeration station

Condensation system with mixing condensers and de-aeration station for the condensation of vapours, 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

A Motive steam
B Suction connection
C Cooling water



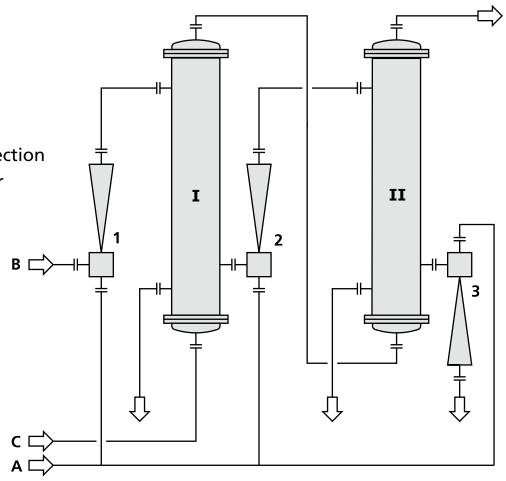
Condensation system with surface condensers with de-aeration station

Condensation system with surface condensers with de-aeration station for the condensation of vapours, 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 vapours to be condensed and cooling water is not acceptable.

FIGURES 10-11

FIG. 10

A Motive steam
B Suction connection
C Cooling water

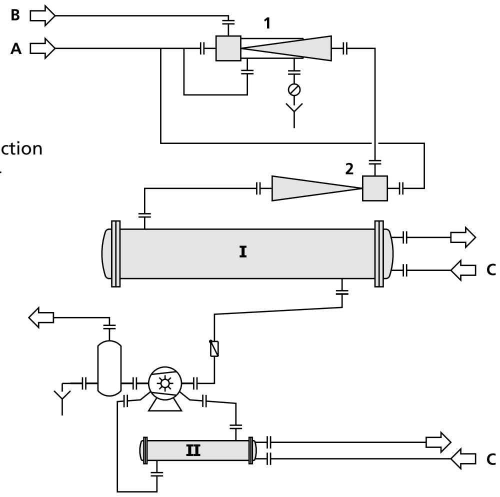


3-stage steam jet vacuum pump

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

A Motive steam
B Suction connection
C Cooling water

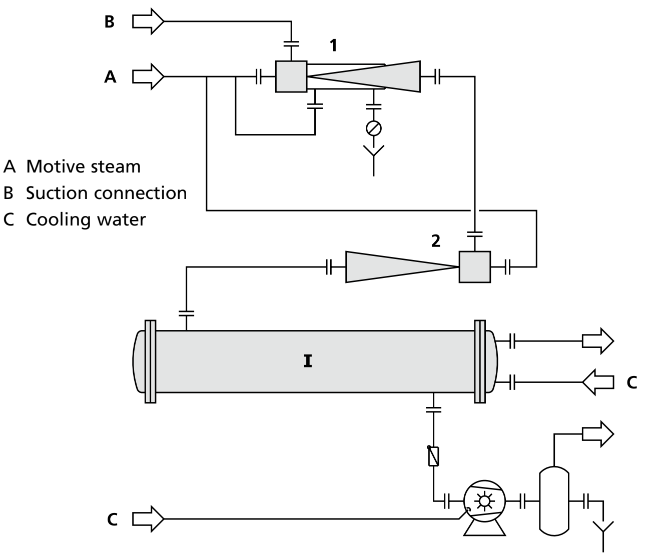


3-stage steam jet liquid ring vacuum pump with surface condensers

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

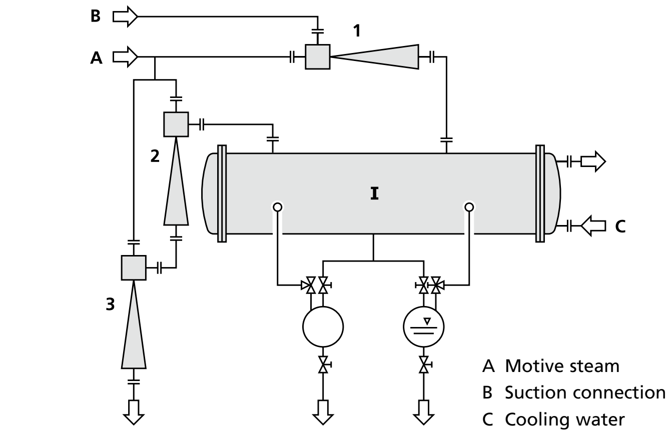


One or multi-stage steam jet liquid ring vacuum pump

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

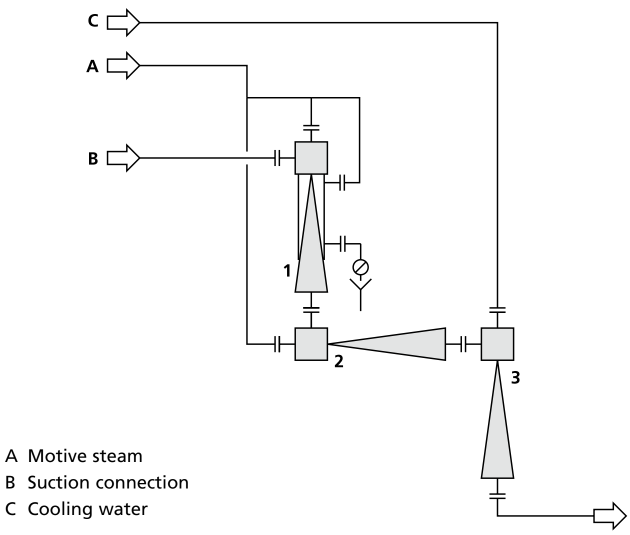
FIG. 13



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 in metal, porcelain, and glass with and without cooling water re-circulation.
A water jet pump (3) will be used for condensation.

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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.

Laboratory steam jet vacuum pump in porcelain with water circuit for a suction pressure of up to 1 mbar

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.

Fig. 1
2-stage steam jet vacuum pump for laboratory operation resistant against corrosion, mobile, with downstream arranged liquid ring pump combination
Capacity: 1 kg/air from 5 mbar

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.

Designation	Suction flow		Water consumption	Steam consumption	Evacuation time for a unit volume	
	kg/h air	from mbar	m³/h	m³/h	from m³	minutes
01.1	0.3 0.1 0.0	1.50 1.00 0.75	3.4	25	0.2	10
01.1-K	0.3 0.1 0.0	1.50 1.00 0.75	0.6-2.5	25	0.2	10
05.3	0.5 0.0	2.80 1.40	3.9	40	0.5	18
05.3-K	0.5 0.0	2.80 1.40	1-2.5	40	0.5	18
1.2	1.0 0.0	2.00 1.00	5.5	75	1.0	15
1.2-K	1.0 0.0	2.00 1.00	2-4	75	1.0	15

CONSTRUCTIONS

01.1; 01.1-K in porcelain and glass
05.3; 05.3-K in porcelain and glass
1.2; 1.2-K in porcelain

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 dead end vacuum).

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 m^3 equals the required suction capacity in kg/h.

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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 VAPOURS 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 "Vapours and gases in vacuum" and "Water vapour and air in vacuum", ↗ | abl 7.
To determine the condensability of the vapours involved, their vapour 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 vapours 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 vapours to be extracted is very important for the design of a steam jet vacuum pump.

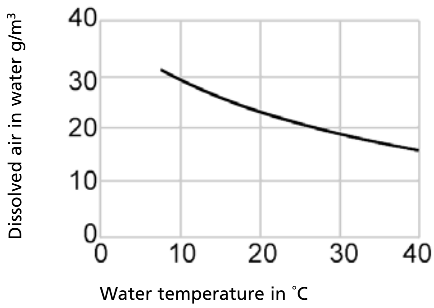
1.2 AIR AND GASES RELEASED FROM THE COOLING WATER

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

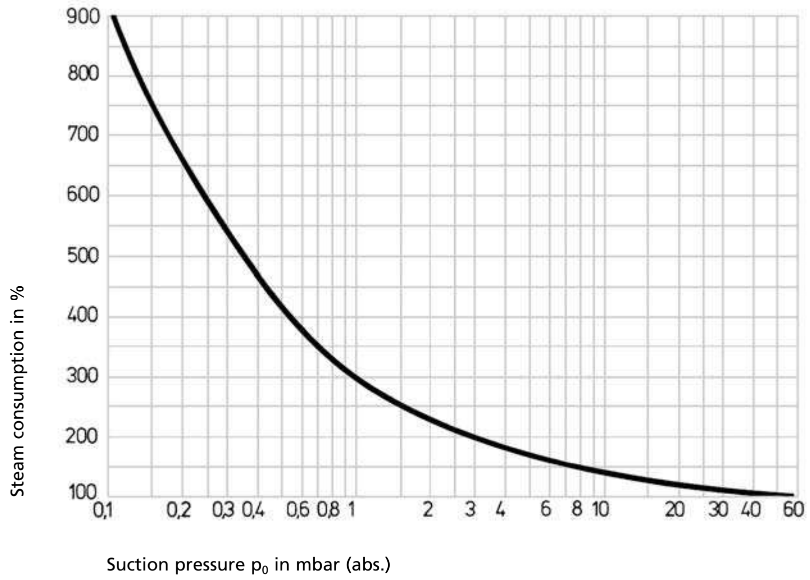
When the actual leakage air flow cannot be accurately determined, excessive safety margins are often applied when theoretically determining the suction flow for a vacuum pump.
See also "Air leakage into vacuum vessels", ↗ | abl 8.
This entails increased motive steam consumption rates, even if later the 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 vapours can be condensed in a surface condenser (pre-condenser), the condensate can be recovered in a pure state.
When, however, gases and vapours are sucked by a steam jet vacuum pump and precipitate in a downstream arranged surface condenser, the motive vapour 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.

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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.

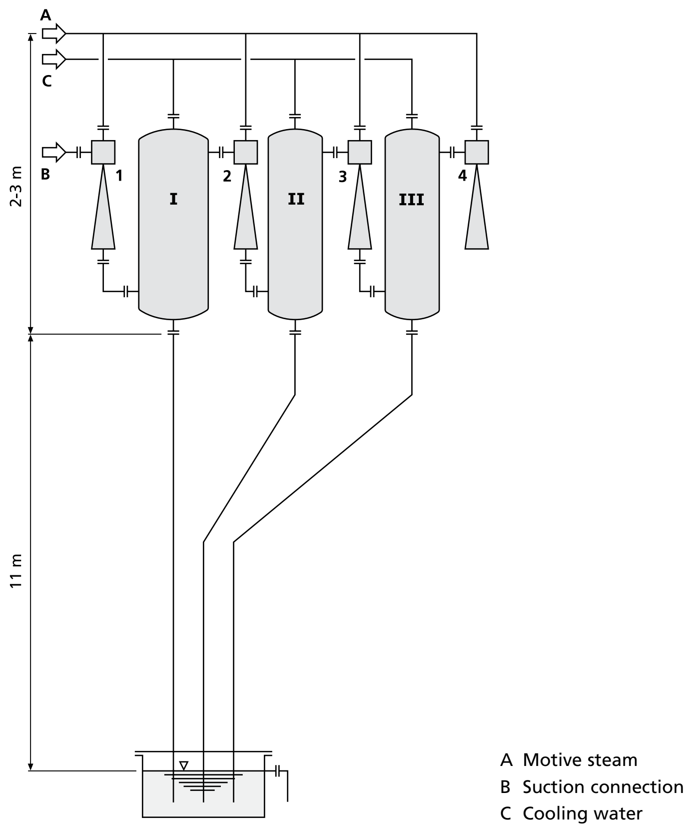
4. TYPE OF INSTALLATION

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



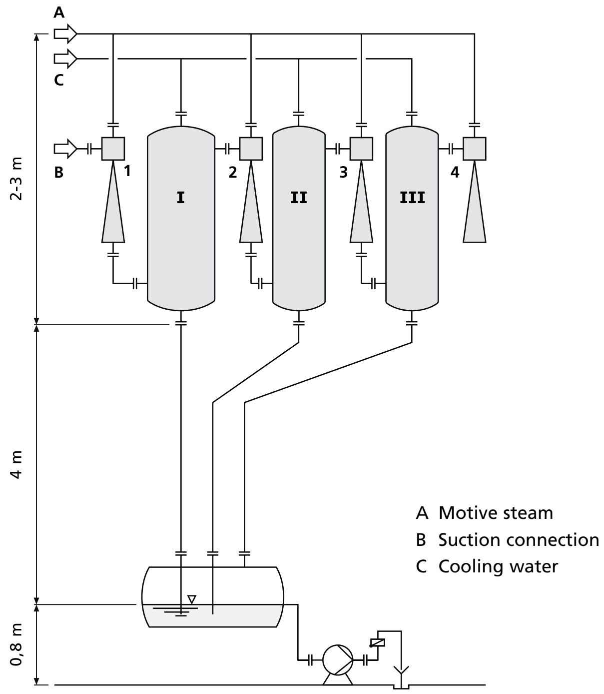
Barometric installation of a steam jet vacuum pump with mixing condensers

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.

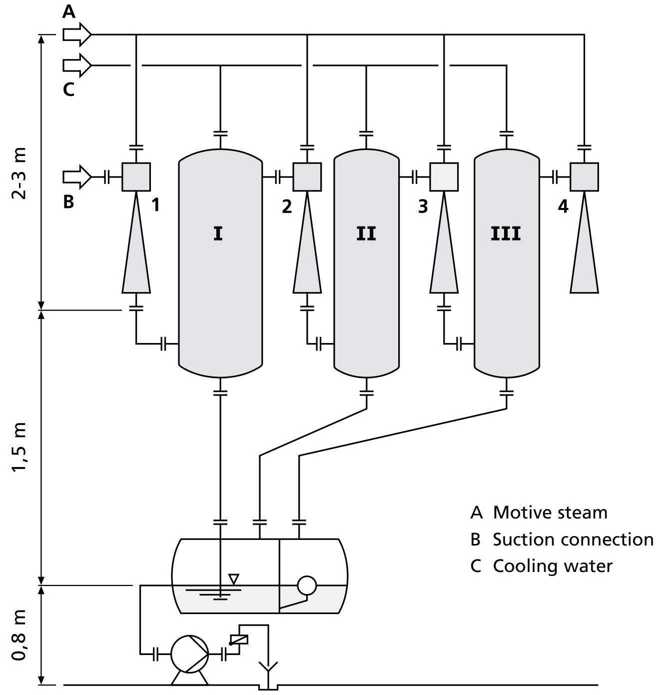
The possible installation options shown in **fig. 4 and 5** are – in analogy – also applicable to surface condensers.

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

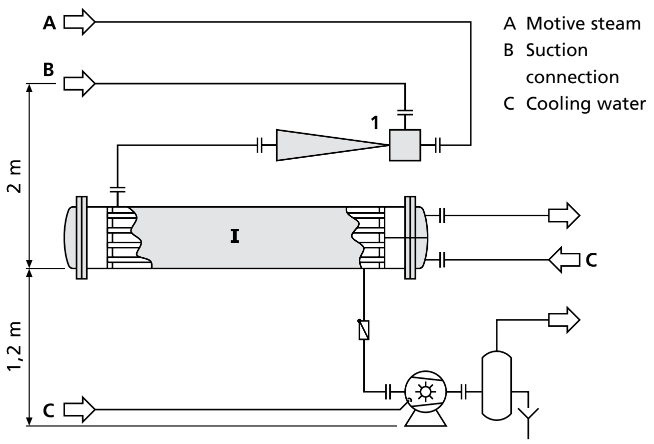
4.3 NON-BAROMETRIC INSTALLATION

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**.

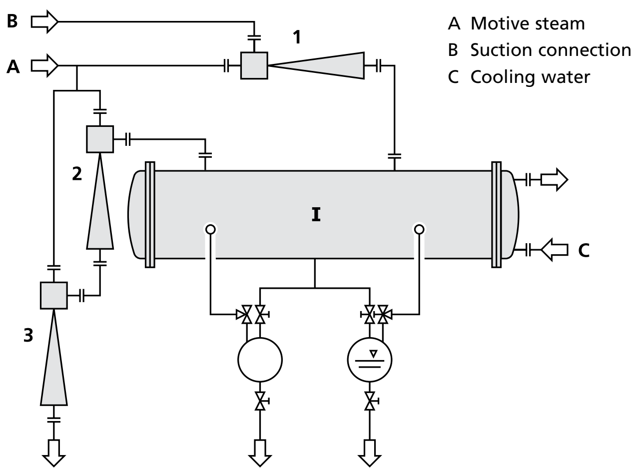
See also "Arrangement of steam jet vacuum pumps", **fig. 13**, ↗ | gdp 2).

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

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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 there 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 vapour is used. The condensate of the motive vapour 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 vapours 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 vapours 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 vapours, 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 vapours 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 vapour 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, glass 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 vapours 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 vapours 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", ↗ | abl 8, and "Steam jet vacuum pumps", ↗ | dvp 1.

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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 vapours, such as for example hydrocarbon vapours. 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 vapours
- 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.

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Questionnaire

for the planning of a steam jet vacuum pump
or a vacuum condensation plant

*) Several components to be stated separately.

1. SUCTION FLOW

Suction temperature . . . . °C

Air . . . . kg/h
Non-condensable gases . . . . kg/h
Mol weight . . . . kg/kmol

Water vapour . . . . kg/h
Condensable vapours *) . . . . 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

Company . . . .
Street/P.O. Box . . . .
Telephone . . . .

attn. . . . .
ZIP code/City . . . .
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Country . . . .
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Overview on our Range of Products

Evaporation plants
to concentrate any type of fluid food, process water, organic and inorganic solutions and industrial waste water; with additional equipment for heating, cooling, degassing, crystallization and rectification.

Membrane filtration – GEA Filtration
to concentrate and process fluid food, process water and industrial waste water, to separate contaminations in order to improve quality and recover valuable substances.

Distillation/rectification plants
to separate multi-component mixtures, to recover organic solvents; to clean, recover and dehydrate bio-alcohol of different qualities.

Alcohol production lines
for potable alcohol and dehydrated alcohol of absolute purity; integrated stillage processing systems.

Condensation plants
with surface or mixing condensers, to condense vapour and steam/gas mixtures under vacuum.

Vacuum/steam jet cooling plants
to produce cold water, cool liquids, even of aggressive and abrasive nature.

Jet pumps
to convey and mix gases, liquids, and granular solids; for direct heating of liquids; as heat pumps; and in special design for the most diverse fields of application.

Steam jet vacuum pumps
also product vapour driven; also in combination with mechanical vacuum pumps (hybrid systems); extensive application in the chemical, pharmaceutical and food industries, in oil refineries and for steel degassing.

Heat recovery plants
to utilize residual heat from exhaust gases, steam/air mixtures, condensate and product.

Vacuum degassing plants
to remove dissolved gases from water and other liquids.

Heating and cooling plants
mobile and stationary plants for the operation of hot water heated reactors, contact driers.

Gas scrubbers
to clean and dedust exhaust air, separate aerosols, cool and condition gases, condensate vapours and absorb gaseous pollutants.

Project studies, engineering for our plants.

GEA Process Engineering

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