

Mondi Štětí a.s.

STANDARD

ST 10.02.02

FANS

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STANDARD

Part 10.02.02

FANS

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1 Design

1.1 General

- a) Ventilators must comply with the engineering specifications according to DIN 24166. Deviations from the Standard or equivalent standards as to design or materials must expressly be stated in writing.
- b) Motors must be priced separately and may, after cost comparison, be provided by Mondi.
- c) Motor base frames or plates must be suitable to accept the largest-possible motor driving the largest-possible impeller for a medium of 1.28 kg/m³.
- d) All rotating parts such as belt drive or coupling, etc. must protected by a suitable guard of steel primed with RAL 1016 according to Mondi Standard or of stainless steel, with yellow-black attention labels
- e) All ventilator components, including a possible base frame and excluding all parts of aluminium, stainless or galvanised steel, must be painted according to Mondi coating Standard.
- f) Ventilators must be dimensioned to allow for a future performance increase of 20% through impeller modification.
- g) Ventilators must be provided with condensation drainage at the lowest location.
- h) Ventilators transporting and operating in hot air must be capable of starting readily under cold air conditions (layout reserves in addition to those mentioned under item f).
- i) Ventilators must be dynamically balanced according to Q 6.3 of VDI Standard 2060 or Austrian Standard Ö-9032, partly identical with ISO 1940 - 1973.
- j) Ventilator speeds should preferably run between 950 and 1450 r. p. m.; at 3000 r. p. m. only in exceptional cases.

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1.2 Material selection

The material depends on the medium transported, if not otherwise determined by the respective mill department.

- a) Paper machine wet part
Housing and impeller: 1.4301 (17240)
Shaft : 1.4460/1.4462
Bearing housing : GG25 (cast iron)
- b) Paper machine dry part, finishing department
Housing : galvanised steel or 1.4301(17240)
Impeller : steel or cast aluminium, depending on r. p. m. and peripheral speed
Shaft : quenched and tempered steel or 1.4460/1.4462
- c) Gas exhaustion from pulp production and recovery plants.
All parts of 1.4436 (17352) or 1.4571 (17348), except shafts that are to be of 1.4460/1.4462.
A grease-filled labyrinth shaft sealing (for gas tightness) is to be used for the extraction of evil smelling gases. Compensators are to be teflon-coated.
- d) Room ventilation
Materials in line with above-specified allocations: smaller ventilators may be made all of plastic, housing and impeller

1.3 Lubrication

All grease lubrication is to be via flat grease cups according to Standard DIN 3404.

Inaccessible lubrication spots are to be pipe connected to readily accessible places, which are to be marked. The grease packing for the labyrinth shaft seals are to be provided with grease press fillers.

1.4 Coupling

Couplings are to comply with Mondi Standard ST 10.02.03, analogous to the provisions for pumps.

1.5 Belts and pulleys

See Mondi Standard ST 10.02.04.

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2 Ventilator supplements

2.1 Vibration dampers

See Mondi Standard ST 10.02.05.

2.2 Compensators

See Mondi Standard ST 10.02.06.

2.3 Suction ducts, pressure ducts

Duct connection should be made to achieve the best-possible flow conditions, possibly affecting the selection of the type of ventilator (radial or axial). No sharp bends and duct lines of round or square cross-section whenever possible. Cross-section changes of not more than 2:1 and over as long a distance as possible, with side changing ratios not more than 3:1.

Mounting and replacing of motor, ventilator, impeller and V-belts as well as the accessibility for lubrication is to be considered.

If an axial ventilator is entered via a curved duct which is closer to the entrance than the equivalent of five diameters, guide plates have to be mounted at the ventilator inlet.

Provision for the installation of drains, of droplet separators for humid air (e. g. wire section extraction) has to be made.

Suction and pressure sides of the ventilators are to be provided with 22-dia. holes through which pressure, head, humidity, etc. can be measured.

2.4 Silencers

All ventilators blowing into or sucking in from the open must be furnished with a pipe-type silencer (layout according to emission cadaster Standard ST 07).

Ventilators installed in the open require to be shielded in according to Standard ST 07.

Duct cross-sections (air flow rate) must be determined for limit emission levels; especially those in the open.

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Inlet- or discharge silencers are to be provided with extractable baffles. Other designs require written agreement.

3 Ventilator specification

Term or designation		usual	min	max	
Sequence no. / item no.				*
Number				*
Type of ventilator				(*)
Size and make of ventilator				
Operating conditions				
Medium delivered				*
Dry temperature / dew point	[° C]				*
Starting temperature	[° C]				*
Corrosive parts pH-value of condensate	[pH]				*
Density at operating temperature Starting temperature	[kg/m ³]				*
Relative humidity φ	[%]				*
Moisture content, x- value	[kg H ₂ O/kg dr.air]				*
Volume flow rate V_v	[Nm ³ /h]				*
Mass flow rate m_v	[kg dry air/h]				*
Water content w_v	[kg H ₂ O/h]				*
Pressure	[Pa]				(*)
Pressure at suction side	+ -[Pa]				(*)
Discharge pressure	[Pa]				(*)
Ventilator efficiency	[%]				
Power requirement	[kW]				
Motor output	[kW]				

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Motor revolutions	[1/min]			
Ventilator speed	[1/min]			
Transmission i				
Drive			
V-belt drive: V belt profile / belt length	[mm]/pc			
Term or designation		chosen, assessed:		
V-belt pulley on motor shaft Effective Ø / number of Vs / bore Ø Taperlock bushing no.	[mm]			
V-belt pulley on ventilator shaft Effective Ø / number of Vs / bore Ø Taperlock bushing no.	[mm]			
Design :				
Guide plates	[yes/no]			
Cross-section - suction side	[Ø mm;mm*mm]			
Cross-section - discharge side	[Ø mm;mm*mm]			
Bottom-to-centre height	[mm]			
Total height	[mm]			
Length, width	[mm]			
Impeller Ø Number of blades / blade angle	[mm]			
Shaft sealing			
Coupling; make / type				
Base plate dimensions	[mm]			
Motor:				
Motor size / design				
Power output / speed	[kW]/[U/min]			

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Voltage / nominal ampere	[V]/[A]				
Frequency / protection type	[Hz]				
Frequency converter					
Material :					
Housing					(*)
Impeller / guide wheel					(*)
Shaft / shaft sleeve					(*)
Wear part inserts					(*)
Bearing housing					(*)
Base frame					(*)
Motor console / bearing bracket					(*)
Shaft sealing					(*)
Compensators					(*)

	Price [Sk]
Ventilator without motor	
Motor	
Motor mounting	
Coupling	
Compensators	
Vibration damper	
Ventilator mounting / one unit	
Unit price	
Total price	
Discount	
Delivery time	
Price quotation	
Weight without / with motor	[kg]

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Weight of delivery	[kg]	
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* ... to be filled in by client

(*) ... eventually to be filled in by supplier

4 General layout guidelines

- ★ Preference for an axial or a radial ventilator is primarily determined by the specific mounting conditions, duct connection and the price. The selection may, however, be pre-determined by the general contractor.
- ★ Ventilators that are to operate and be shut down at temperatures beyond 80°C should be radial ventilators since axial ventilator bearings tend to be sufficiently cooled only under operating conditions.
- ★ Axial ventilators are suitable for pressures up to 4,000 Pa, one-stage radial ventilators for about 40,000 Pa.
- ★ For the extraction of chips, granulates and grains, ventilators must, in certain cases, be equipped with special impellers.
- ★ Velocity of flow:
 Intake : approx. around 10 m/s, not over 15 m/s
 Discharge : approx. around 15 - 20 m/s, not over 25 m/s
 The duct dimensioning is also affected by the permissible noise development.
- ★ In rectangular duct cross-section changes, the side ratio should not exceed 4:1.
- ★ The required ventilator pressure corresponds with total static head loss between intake and discharge. The pressure finally specified should, however, be multiplied by a factor of 1.2, to compensate for possible errors in assumptions and other kind of deviations.
- ★ If two ventilators with very different flow rates deliver into a common duct, the pressure of the smaller ventilator should be 1.3 times the pressure of the larger ventilator.

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5 Ventilator layout, calculations

5.1 Density, humidity and other medium-specific data

Method

Measuring of the dry temperature t_{tr} [° C] and the dew point temperature t_d [° C] with the humidity sensor of TESTOTERM 452.

Vapour pressure

$$P_D = 10^{(8,11594 - \frac{1690}{230 + t_d})} \quad [\text{Pa}]$$

$t_d \dots$ [° C] dew point

Saturation vapour pressure

$$P_{D0tr} = 1,3 * 10^{(8,002 - \frac{1690}{230 + t_{tr}})}$$

$t_{tr} \dots$ [° C] Dry temperature

Relative humidity

$$\varphi = \frac{P_D}{P_{D0tr}} * 100 \quad [\%]$$

Relative humidity can be also taken from the attached humidity diagram (page 16) from cross-section of the measured temperatures t_{tr} and t_d .

Moisture content

$$x = \frac{P_D * 0622237}{970 - P_D} \quad [\text{kg H}_2\text{O} / \text{kg dry air}]$$

Specific volume

$$461,5 * (t_{tr} + 273,16)$$

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$$v_{1+x} = \frac{\quad}{970 \cdot 100} \cdot (0,622237 + x) \quad [\text{m}^3/\text{kg}]$$

$$t_{tr} \dots [^\circ \text{C}]$$

$$x \dots [\text{kg}/\text{kg}]$$

The delivery volume V, \bullet is specified in Nm^3/h .

Mass flow

$$m, \bullet = \frac{V[\text{m}^3/\text{h}]}{v_{1+x}} \quad [\text{kg dry air} / \text{h}]$$

Water content

$$w, \bullet = m, \bullet [\text{kg dry air} / \text{h}] \cdot x [\text{kg H}_2\text{O} / \text{h}] \quad [\text{kg H}_2\text{O} / \text{h}]$$

Density at operating temperature

$$\rho_{oper} = \frac{m [\text{kg dry air} / \text{h}]}{V [\text{m}^3/\text{h}]} \quad [\text{kg}/\text{m}^3]$$

Density at starting temperature

$\rho_{start.}$ to be taken from the table on page 15.

$$760 \text{ Torr} \cong 10,000 \text{ mm WH} \cong 1.0 \text{ bar} \cong 100,000 \text{ Pa} [\text{N}/\text{m}^2]$$

The values of the underlined parameters are to be entered into the ventilator specification.

5.2 Duct cross-sections

$$V, \bullet = A \cdot v$$

V, \bullet	...	Supply volume	$[\text{m}^3/\text{s}]$
A	...	Duct cross-section	$[\text{m}^2]$
v	...	Velocity of flow	$[\text{m}/\text{s}]$

Velocities:

Intake : approx. around 10 m/s, not over 15 m/s

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Discharge : approx. around 15 - 20 m/s, not over 25 m/s

The velocity of the flow is also dependent on the permissible noise level. The side ratio a : b of rectangular cross-sections should not exceed 4:1 in order to limit possible pressure deviations (on account of the hydraulic equivalent diameter).

See layout table for dimensioning!

5.3 Pressures required to overcome flow resistance

Basic formula : $\Delta P = \Delta P_R + \Delta P_E$

ΔP	...	total static head loss	[Pa] = [N/m ²]
ΔP_R	...	pipe friction loss	[Pa]
ΔP_E	...	Σ of individual pressure losses	[Pa]

$$\Delta P_R = \zeta * \frac{l}{d_{gl}} * \frac{\rho v^2}{2} \quad \zeta \dots \text{Friction coefficient}$$

(sheet metal ducts 0,01; cement 0,015; cast 0,018; concrete 0,019; brickwork 0,02; Rabbitz plaster 0,017; plywood 0,016)

$$d_{gl} = \frac{2 * a * b}{a + b}$$

(rectangular ducts)

l ... pipe length [m]
suction and pressure side!

d_{gl} ... pipeline diameter or
hydraulic equivalent diameter [m]

ρ ... density of delivered medium [kg/m³]
at operating temperature

v ... velocity of flow [m/s]

The ΔP_R of different cross-section duct-sections must be calculated individually!

$$\Delta P_E = \sum \zeta * \frac{\rho v^2}{2}$$

$\sum \zeta$... sum of individual resistance coefficients from attached tables.

ρ ... density of delivered medium [kg/m³]

v ... velocity of flow [m/s]

Here again, pressure losses of different cross-sections duct-sections must be calculated individually!

Simplified calculation of ΔP_R from the pipe friction diagram (see applied pages).

$$\Delta P_R = l * R$$

l ... pipe-section length [m]

R ... specific pressure loss [Pa/m]

R is read as distance from the x-axis or y-axis, depending on the diagram, to the point of intersection between delivered quantity and pipeline diameter (or hydraulic equivalent diameter).

For duct forms not contained in the diagrams, interpolated ζ -values of most similar forms are to be taken.

The ventilator pressure required corresponds with ΔP , the total static head loss. For possible deviations or errors of assumption, the finally required ventilator pressure should, however, be assumed to be 1.2 ΔP .

If two ventilators with very different flow rates deliver into a common duct, the pressure of the smaller ventilator should be 1.3 times the pressure of the larger ventilator.

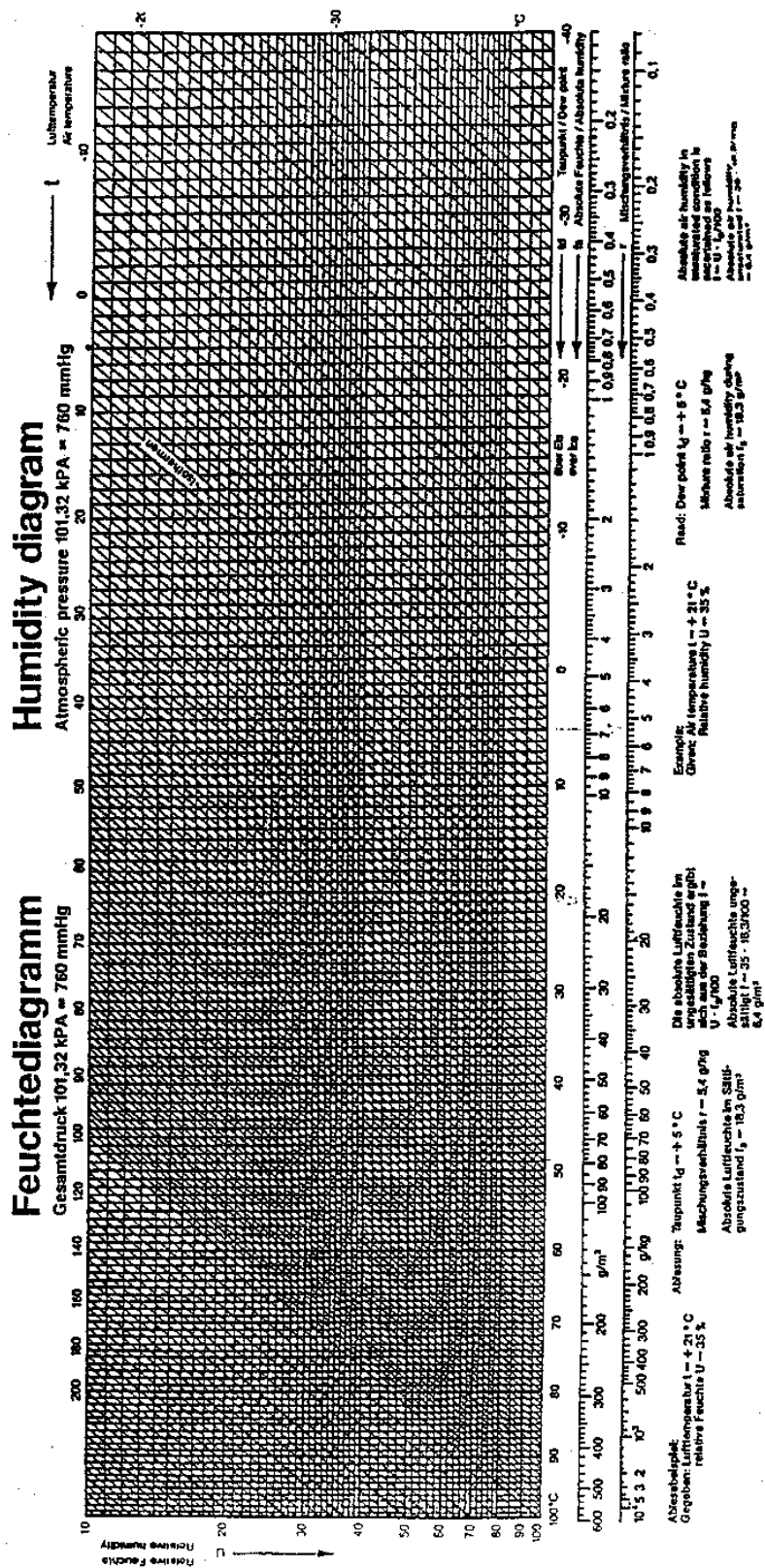
For a check of the ventilator power requirement see VDI-diagram on page 22 and a corresponding example on page 23.

5.4 Tables

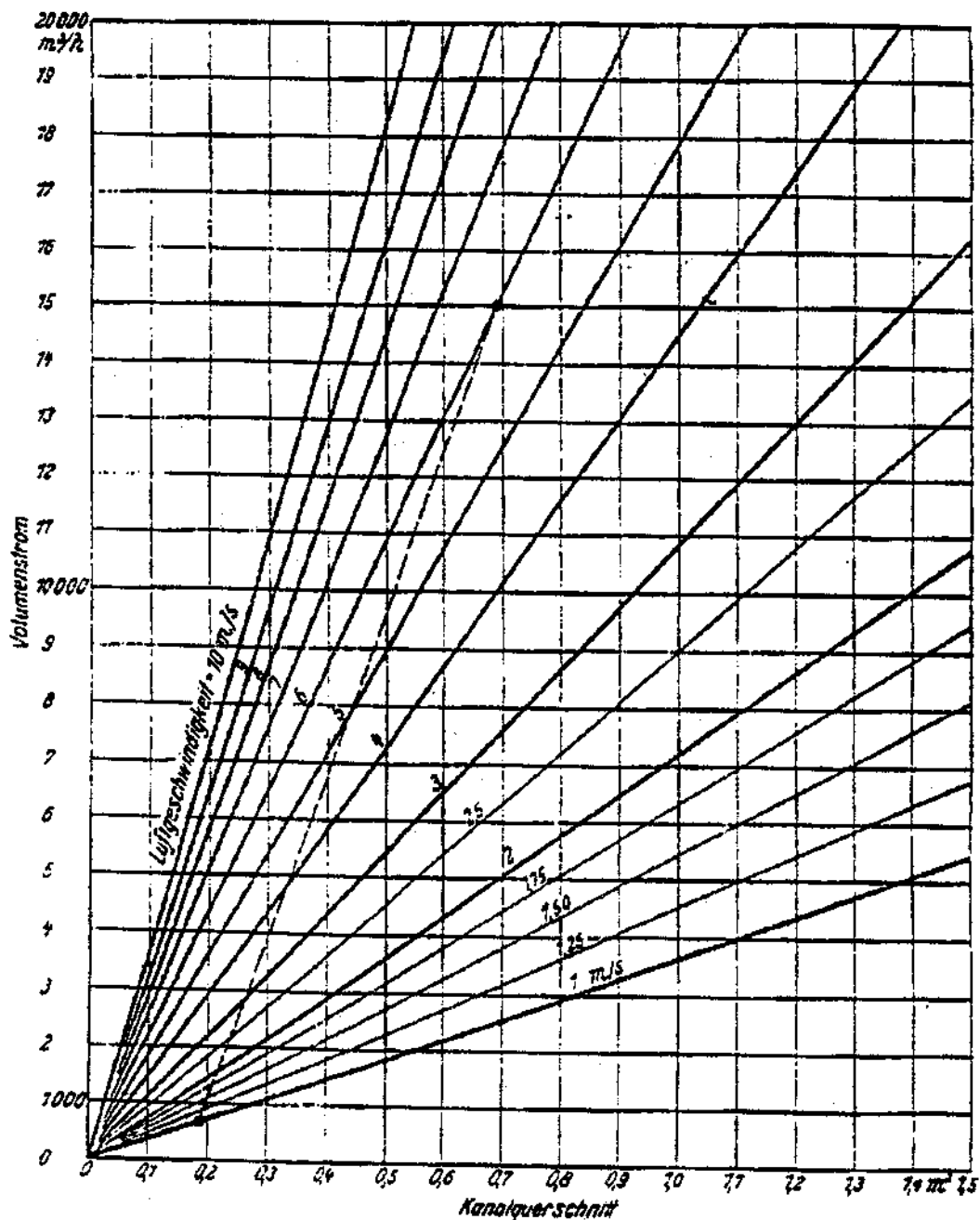
Air density (kg/m³ at 60, 80 and 100% relative humidity at temperatures from - 10° to + 50°C and barometric pressures from 720 bis + 50 °C

Temperatur des trockenen Thermometers	Torr	720			730			740			750			760			770		
	Relative humidity	60	80	100	60	80	100	60	80	100	60	80	100	60	80	100	60	80	100
↑	-10	1,271	1,271	1,271	1,289	1,289	1,289	1,307	1,307	1,307	1,325	1,325	1,325	1,342	1,342	1,342	1,360	1,360	1,360
	-8	1,261	1,261	1,261	1,279	1,279	1,279	1,297	1,297	1,297	1,316	1,316	1,315	1,332	1,332	1,332	1,350	1,350	1,350
	-6	1,252	1,252	1,251	1,270	1,270	1,269	1,288	1,288	1,287	1,307	1,307	1,306	1,322	1,322	1,322	1,340	1,340	1,340
	-4	1,243	1,243	1,242	1,260	1,260	1,260	1,278	1,278	1,277	1,297	1,297	1,296	1,311	1,311	1,311	1,330	1,330	1,330
	-2	1,234	1,233	1,232	1,251	1,250	1,250	1,268	1,268	1,267	1,287	1,286	1,285	1,301	1,300	1,300	1,320	1,319	1,319
	+ 0	1,225	1,224	1,223	1,242	1,241	1,240	1,259	1,258	1,257	1,277	1,276	1,275	1,291	1,290	1,290	1,310	1,309	1,309
	+ 2	1,216	1,215	1,214	1,233	1,232	1,231	1,249	1,248	1,247	1,267	1,266	1,265	1,282	1,281	1,280	1,301	1,300	1,300
	+ 4	1,207	1,206	1,205	1,224	1,223	1,222	1,240	1,239	1,238	1,257	1,256	1,255	1,273	1,272	1,271	1,291	1,290	1,289
	+ 6	1,198	1,197	1,196	1,215	1,214	1,213	1,230	1,229	1,228	1,248	1,247	1,246	1,264	1,263	1,262	1,281	1,280	1,279
	+ 8	1,189	1,188	1,187	1,205	1,204	1,203	1,221	1,220	1,219	1,239	1,238	1,237	1,255	1,254	1,253	1,271	1,270	1,269
	+10	1,180	1,179	1,178	1,196	1,195	1,194	1,212	1,211	1,210	1,230	1,229	1,228	1,245	1,244	1,243	1,262	1,261	1,260
	+12	1,172	1,170	1,169	1,187	1,186	1,185	1,203	1,202	1,201	1,221	1,220	1,219	1,235	1,234	1,233	1,253	1,252	1,251
	+14	1,163	1,161	1,160	1,178	1,177	1,176	1,194	1,193	1,192	1,212	1,211	1,210	1,226	1,225	1,224	1,244	1,243	1,242
	+16	1,154	1,152	1,151	1,169	1,168	1,167	1,185	1,183	1,181	1,203	1,201	1,199	1,217	1,215	1,213	1,235	1,233	1,231
	+18	1,145	1,143	1,141	1,161	1,159	1,157	1,176	1,174	1,172	1,194	1,192	1,190	1,208	1,206	1,204	1,225	1,223	1,221
	+20	1,136	1,134	1,132	1,152	1,150	1,148	1,167	1,165	1,163	1,185	1,183	1,181	1,199	1,197	1,195	1,216	1,214	1,212
	+22	1,127	1,125	1,123	1,143	1,141	1,139	1,158	1,156	1,154	1,176	1,174	1,172	1,190	1,188	1,186	1,207	1,205	1,203
	+24	1,118	1,116	1,114	1,134	1,132	1,130	1,150	1,147	1,144	1,167	1,164	1,162	1,181	1,178	1,175	1,198	1,195	1,192
	+26	1,110	1,107	1,104	1,125	1,123	1,121	1,141	1,138	1,135	1,158	1,155	1,152	1,172	1,169	1,166	1,189	1,186	1,183
	+30	1,094	1,090	1,087	1,109	1,105	1,101	1,124	1,120	1,116	1,140	1,136	1,132	1,154	1,150	1,146	1,171	1,167	1,163
	+34	1,077	1,072	1,068	1,092	1,087	1,082	1,107	1,102	1,097	1,122	1,117	1,112	1,136	1,131	1,126	1,153	1,148	1,143
	+38	1,069	1,063	1,047	1,074	1,068	1,062	1,090	1,084	1,078	1,104	1,098	1,092	1,118	1,112	1,106	1,135	1,129	1,123
	+42	1,041	1,034	1,027	1,056	1,049	1,042	1,072	1,065	1,058	1,086	1,079	1,072	1,100	1,093	1,086	1,117	1,110	1,103
	+46	1,023	1,015	1,007	1,038	1,030	1,022	1,054	1,046	1,038	1,068	1,060	1,052	1,082	1,074	1,066	1,098	1,090	1,082
	+50	1,005	0,995	0,985	1,020	1,010	1,000	1,035	1,025	1,015	1,050	1,040	1,030	1,064	1,054	1,044	1,079	1,069	1,059

dry-thermometer temperature



Air duct cross-sections



Example: Flow rate at the blower: 15.000 m³/h flow velocity chosen 6 m/s

Flow rate at end of duct: 700 m³/h

flow velocity chosen 1 m/s

The connection line between the two reference points permits selection of duct cross-sections (and reading of pertinent flow velocity) for stepped lowering of flow velocity. The connection line must not necessarily be a straight line.

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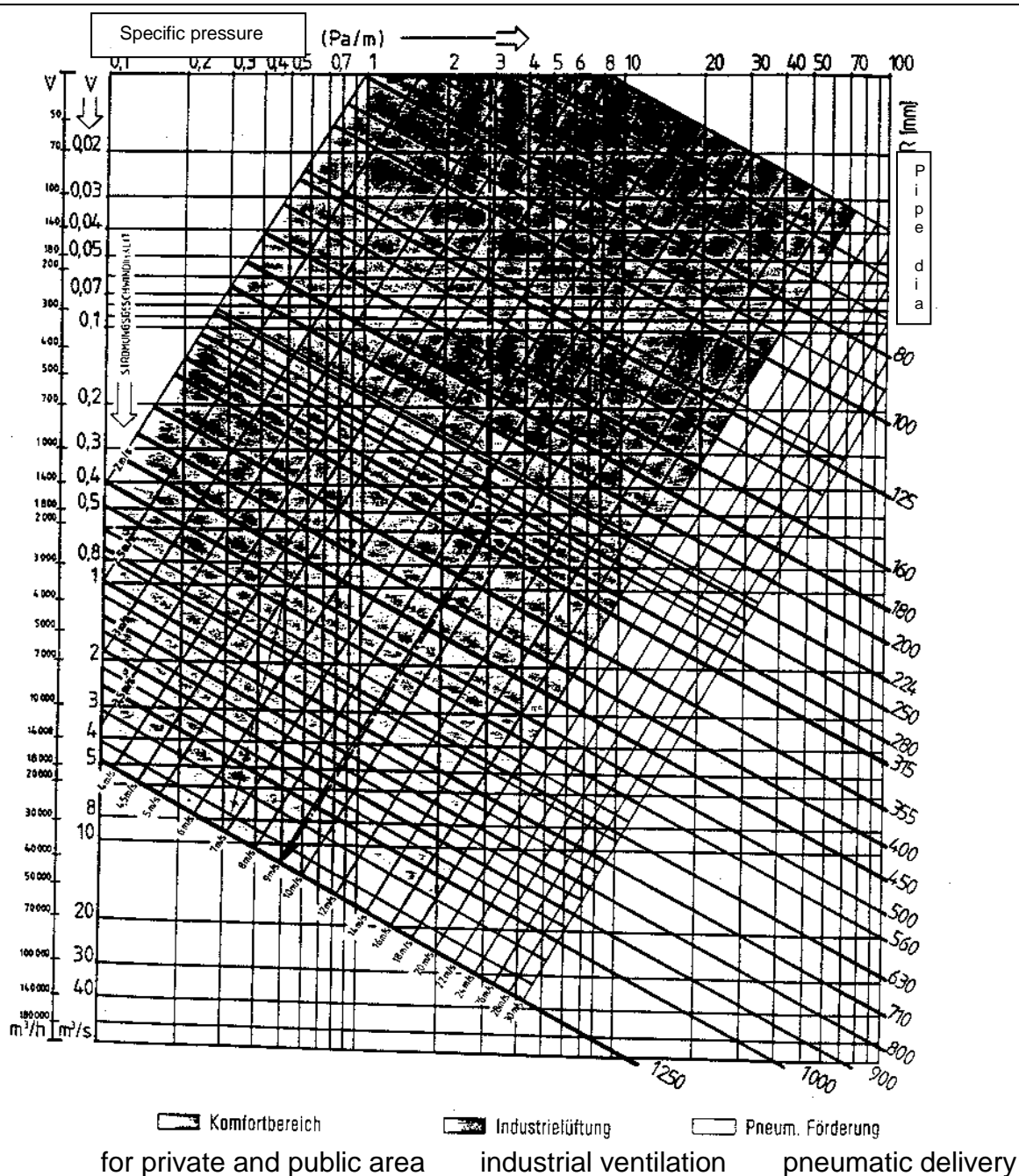
Pipe friction diagram

(Valid for round and rectangular sheet metal ducts with $\zeta = 0.15$, $P = 1013 \text{ mbar}$ and $Re > 2320$)

For other roughness, the specific pressure loss R from the table is to be multiplied by the following factors to arrive at realistic practical values:

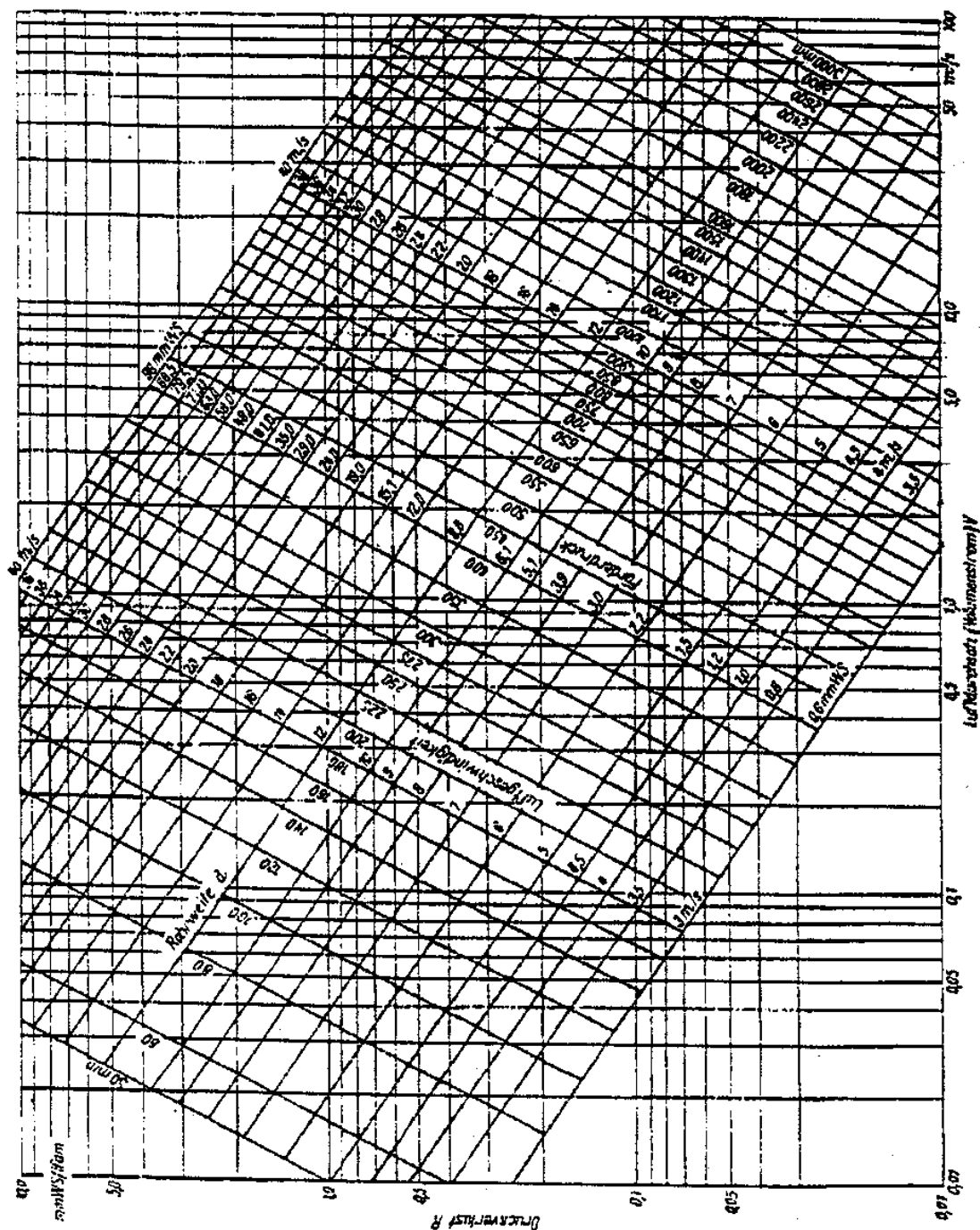
Asbestos cement :	1,4	Cast :	1,8	Concrete :	1,9
Plywood :	1,5	Plaster :	1,7	Brickwork:	2,0

For rectangular ducts the equivalent diameter d_{gr} is to be used.



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Dr **Pressure loss in round air ducts for flow rates up to 50 m³/h**



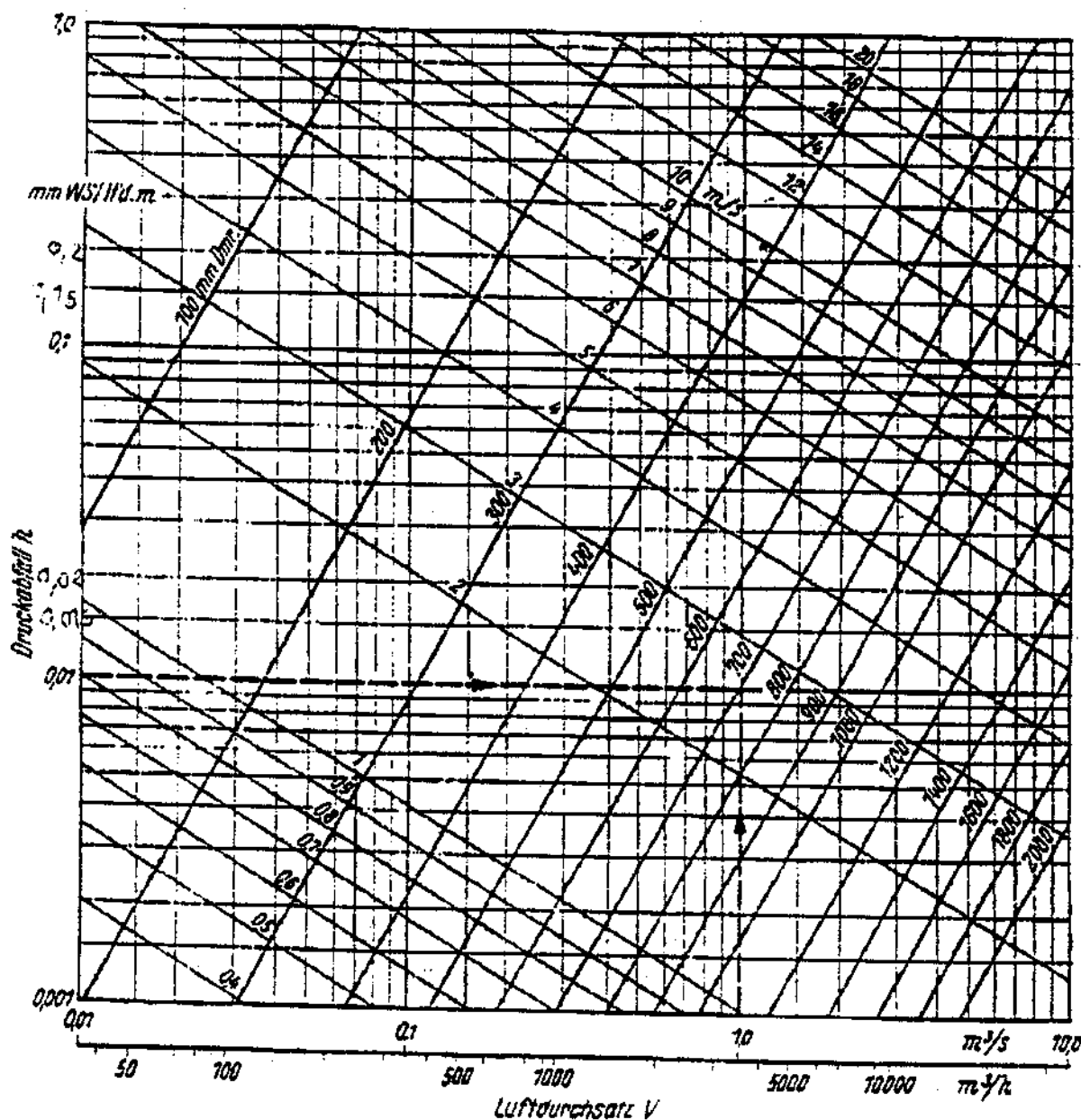
The pressure losses in the diagram are valid for sheet metal ducts.

For asbestos cement ducts, (not to use) the loss is $h_a = (50 / 55) \cdot h$,
and for brickwork ducts, it is $h_m = (60 / 50) \cdot h$.

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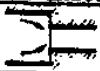

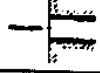

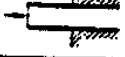
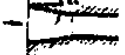



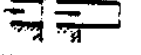
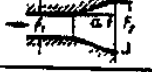



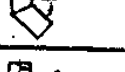
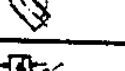
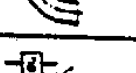
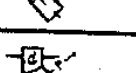

Pressure losses in round air ducts for air flow rates from 0,01 to 10 m³/h


The pressure losses in the diagram are valid for sheet metal ducts.

For asbestos cement ducts, (not to use) the loss is $h_a = (50 / 55) \cdot h$,
and for brickwork ducts, it is $h_m = (60 / 50) \cdot h$.

Example : The pressure loss in the graph of 0,01 mm water head per metre, at an air flow rate of 1 m³/s and air velocity 2.5 m/s, requires a duct diameter of 700 mm.

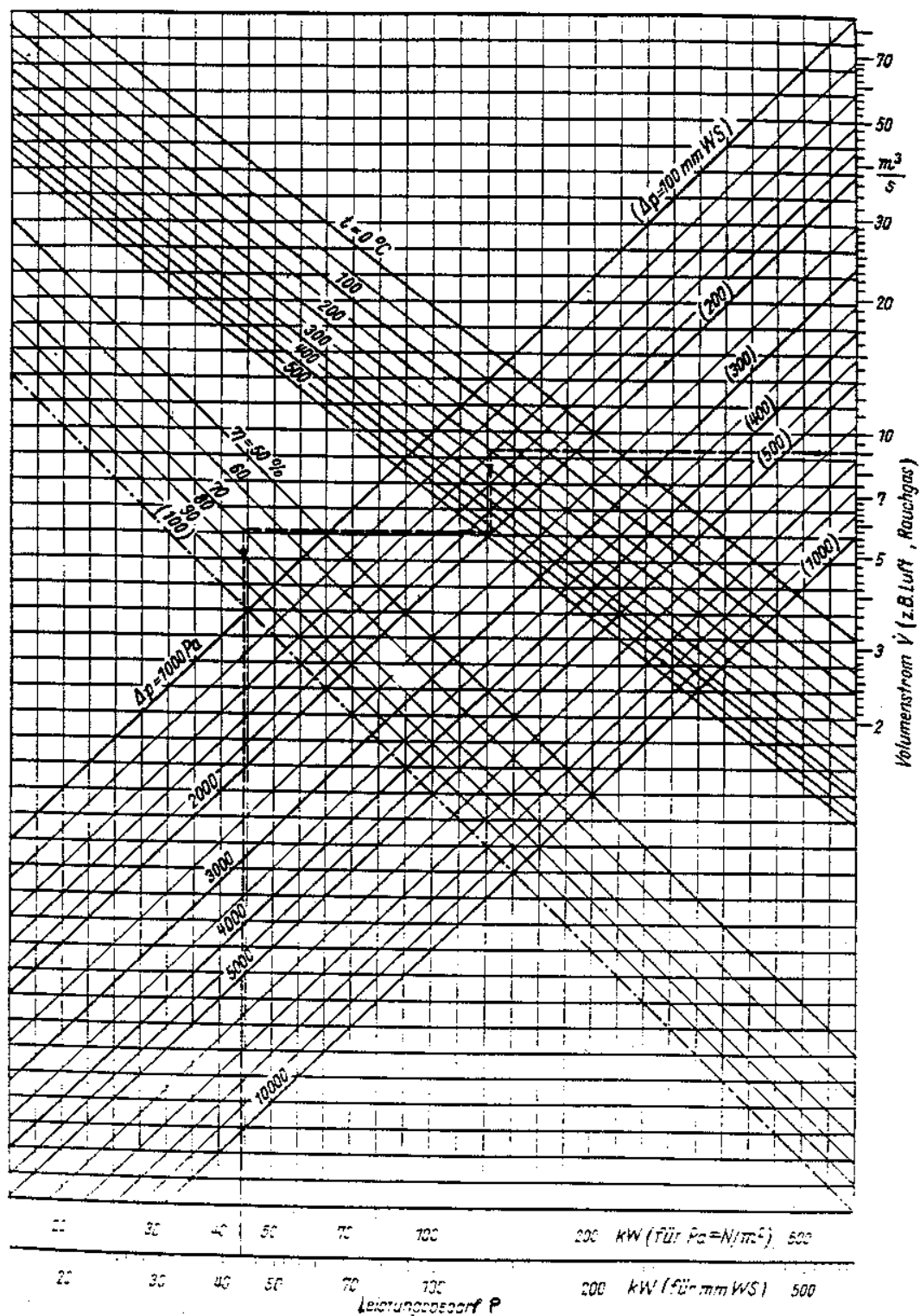
Resistance coefficients ζ for air ducts

Nr.	Strömungsbild		ζ														
bei Querschnittsänderungen:																	
1		Sudden reduction	 0,01...0,35														
2		Sudden entry from the open into intake opening	 0...0,35														
3		Sharp-edge entry into duct	0,5														
4		Cone-shaped entry	bei $\alpha \sim 45^\circ$ - 0														
5		Gradual reduction	0...0,05														
6		Sudden expansion	<table><tr><td>F_2/F_1</td><td>1,2</td><td>1,5</td><td>2</td><td>3</td><td>∞</td></tr><tr><td>ζ</td><td>0,03</td><td>0,11</td><td>0,25</td><td>0,45</td><td>1,0</td></tr></table>	F_2/F_1	1,2	1,5	2	3	∞	ζ	0,03	0,11	0,25	0,45	1,0		
F_2/F_1	1,2	1,5	2	3	∞												
ζ	0,03	0,11	0,25	0,45	1,0												
7		Gradual expansion over a max. angle $\alpha = 8^\circ$	<table><tr><td>F_1/F_2</td><td>∞</td><td>0,2</td><td>0,4</td><td>0,6</td><td>0,8</td><td>1,0</td></tr><tr><td>ζ</td><td>1,0</td><td>0,64</td><td>0,36</td><td>0,16</td><td>0,04</td><td>0</td></tr></table>	F_1/F_2	∞	0,2	0,4	0,6	0,8	1,0	ζ	1,0	0,64	0,36	0,16	0,04	0
F_1/F_2	∞	0,2	0,4	0,6	0,8	1,0											
ζ	1,0	0,64	0,36	0,16	0,04	0											
8		Sharp-edge exit	1,0														
9		Gradual expansion, rectangular cross-section	<table><tr><td>$\alpha =$</td><td>60°</td><td>120°</td><td>180°</td><td></td></tr><tr><td>2-seitig</td><td>0,10</td><td>0,25</td><td>0,30</td><td rowspan="2">$1 - (F_1/F_2)^2$</td></tr><tr><td>4-seitig</td><td>0,15</td><td>0,35</td><td>0,45</td></tr></table>	$\alpha =$	60°	120°	180°		2-seitig	0,10	0,25	0,30	$1 - (F_1/F_2)^2$	4-seitig	0,15	0,35	0,45
$\alpha =$	60°	120°	180°														
2-seitig	0,10	0,25	0,30	$1 - (F_1/F_2)^2$													
4-seitig	0,15	0,35	0,45														
10		Venturipipe	<table><tr><td>F_0/F</td><td>0,9</td><td>0,7</td><td>0,5</td><td>0,4</td></tr><tr><td>ζ</td><td>0,035</td><td>0,16</td><td>0,45</td><td>0,79</td></tr></table>	F_0/F	0,9	0,7	0,5	0,4	ζ	0,035	0,16	0,45	0,79				
F_0/F	0,9	0,7	0,5	0,4													
ζ	0,035	0,16	0,45	0,79													
bei Richtungsänderungen:																	
1		Sharp 90° bend, elbow	<table><tr><td>ohne Leitbl.</td><td>1,50</td></tr><tr><td>mit Leitbl.</td><td>0,15</td></tr></table>	ohne Leitbl.	1,50	mit Leitbl.	0,15										
ohne Leitbl.	1,50																
mit Leitbl.	0,15																
2		Round 90° bend, elbow	0,50														
3		Sharp >90° bend, elbow	0,50														
4		Round >90° bend, elbow	0,20														
5		90° elbow	<table><tr><td>$r = d$</td><td>0,30</td></tr><tr><td>$r \approx 2d$</td><td>0,15</td></tr><tr><td>$r \approx 6d$</td><td>0,01</td></tr></table>	$r = d$	0,30	$r \approx 2d$	0,15	$r \approx 6d$	0,01								
$r = d$	0,30																
$r \approx 2d$	0,15																
$r \approx 6d$	0,01																
6		135° elbow	0,05														
7		90° sectioned elbow	<table><tr><td>$r = 1,5 d$</td><td>0,50</td></tr><tr><td>$r = 2 d$</td><td>0,45</td></tr><tr><td>$r = 2,5 d$</td><td>0,40</td></tr><tr><td>$r = 3 d$</td><td>0,35</td></tr></table>	$r = 1,5 d$	0,50	$r = 2 d$	0,45	$r = 2,5 d$	0,40	$r = 3 d$	0,35						
$r = 1,5 d$	0,50																
$r = 2 d$	0,45																
$r = 2,5 d$	0,40																
$r = 3 d$	0,35																

Resistance coefficients ζ for air canals

Nr.	Strömungsbild	ζ													
bei Richtungsänderungen:															
8		135° sectioned	$r = 1,5 d$ 0,30 $r = 2 d$ 0,25 $r = 2,5 d$ 0,20 $r = 3 d$ 0,15												
9		Two 90°	3,0												
10		Passing elbow	$r \approx 3 d$ 0,4 $r \geq 8 d$ 0												
bei Abzweigen und Gabelungen:															
1		Branch	α 150° 0 0,1 300° 0 II 0,2 450° 0 II 0,25 600° 0 0,5												
2		Branch	I 0 II 0,6												
3		Branch	I 0 II 1,2												
4		Branch	I 0 II 1,0												
5		Narrow fork	je abgehende Leitung 0,2												
6		Wide fork	For each branch 0,6												
7		Bent fork	For each branch 0,1												
8		Segmented fork	For each branch ende 90° 0,4 60° 0,3												
9		Branch	For each branch $r = d$ 0,3 $r \approx 2 d$ 0,15 $r \approx 5 d$ 0,01												
10		Branch	With internal guides, approximately: 2 * 1,5												
11		Branch with internal guide	<table><tr><th>$r = \frac{d}{4}$</th><th>$\frac{d}{2}$</th><th>d</th><th>2d</th><th>3d</th><th>5d</th></tr><tr><td>0,22</td><td>0,14</td><td>0,1</td><td>0,07</td><td>0,05</td><td>0,02</td></tr></table>	$r = \frac{d}{4}$	$\frac{d}{2}$	d	2d	3d	5d	0,22	0,14	0,1	0,07	0,05	0,02
$r = \frac{d}{4}$	$\frac{d}{2}$	d	2d	3d	5d										
0,22	0,14	0,1	0,07	0,05	0,02										
12		Branch without internal guide	<table><tr><th>$r = \frac{d}{4}$</th><th>$\frac{d}{2}$</th><th>d</th><th>2d</th><th>3d</th><th>5d</th></tr><tr><td>0,4</td><td>0,25</td><td>0,2</td><td>0,14</td><td>0,1</td><td>0,05</td></tr></table>	$r = \frac{d}{4}$	$\frac{d}{2}$	d	2d	3d	5d	0,4	0,25	0,2	0,14	0,1	0,05
$r = \frac{d}{4}$	$\frac{d}{2}$	d	2d	3d	5d										
0,4	0,25	0,2	0,14	0,1	0,05										
13		Y-duct	wie Nr. 12												
14		Bent fork	For each branch 0,15												

Ventilator power requirement



Version: 01

Printouts, if any, are not controlled.

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Example to diagram on page 22

Example (Air)

Flow rate	$x = 9.0 \text{ m}^3/\text{s}$
Temperature	$t = 200^\circ \text{ C}$
Pressure increase	$\Delta p = 2,000 \text{ Pa (2,000 N/m}^2\text{)}$
Ventilator efficiency	$\eta = 0.70 / 70\%$

Yields a

Power requirement of $P = 44 \text{ kW}$

The diagram may be used also for ventilation sections. The pressure increase is then entered in mm water head and the result is read from the bottom scale. For the example above, a power requirement of $P = 43 \text{ kW}$ is read at a water head of $\Delta p = 200 \text{ mm}$.

The diagram is based on the following formula (with above-specified units)

$$P = \frac{V (1+t/273) \Delta p}{10^2 \eta} \quad [\text{mm WS}]$$

The diagram is valid for an input pressure of

$$p_0 = 760 \text{ Torr} = 1.033 \text{ at} = 1.013 \text{ bar}$$

For other input pressures p_1 , the result is to be multiplied by the factor p_0 / p_1 .