

MFS — Self-Averaging Flow Sensor for the measurement of velocity or flow of air and other gases.

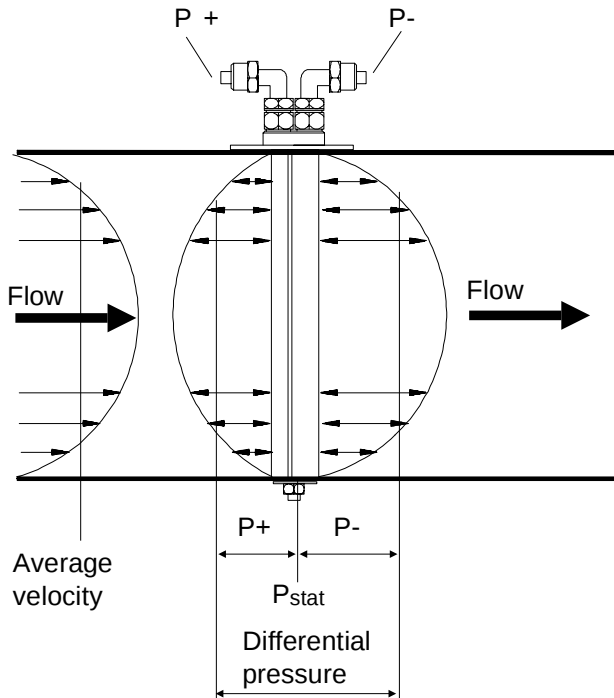
Data Sheet: MDE-1263/98

MFS



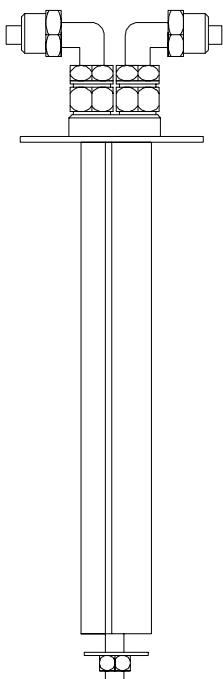
- Self-averaging flow sensor
- Circular and rectangular flow measuring stations
- Available in standard and special dimensions
- High precision
- High differential pressure
- Low pressure drop
- Patent-pending design

Micatrone's flow sensor, MFS, has been developed to meet the great demand for accurate air flow measurement in all types of air-handling systems. The MFS is based on the principle of averaging the velocity profile over the height or the diameter of the duct.



The MFS averages the velocity profile by measuring the total pressure, $P+$, which consists of the dynamic and static pressure, as well as an amplified negative pressure, $P-$. These form a differential pressure which is proportional to the flow.

The differential pressure is 2.5 times higher than acquired by Prandtl measurements.



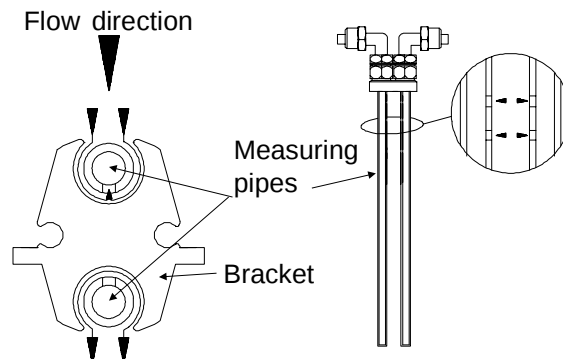
The construction of the MFS is patent pending and guarantees high precision and repeatability. Owing to its design, it also gives a 2.5 times higher differential pressure than Prandtl and similar methods are able to achieve. In spite of this, the pressure drop is very low.

The flow sensor is available both as a separate unit, which can be mounted in circular or rectangular ducts, and as a complete flow measuring station.

Construction

The flow sensor consists of a solid bracket, which is made of extruded, anodised aluminium, and two measuring pipes.

The measuring pipes are mounted inside the impact resistant bracket, which protects the pipes very well.



The measuring pipes are holed in accordance with reliable standards. The holes face towards the centre of the bracket.

An air gap surrounds the measuring pipes.

Thanks to this construction, the holes are situated at a point of no velocity, which prevents particles from entering the pipes.

This construction makes the measured pressure more stable and takes away the effect of edges at the holes, which would affect the measured pressure if the holes were turned towards the flow.

The stable construction of the MFS enables sensor lengths reaching 2000 mm.

The MFS is available in standard versions, suitable for all standardized duct sizes, and in special versions with dimensions ranging from 100—2000 mm.

Each test probe is provided with a label showing the constant, K_m , and formulas for the calculation of velocity and flow.

The constant

The constant is determined by an advanced computer programme and by empirical tests.

The constant has a maximum measurement error $< \pm 2\%$ of the actual undisturbed flow. The constant is linear within the range 2...25 m/s.

The total measurement error in the system is affected by where it is mounted and the number of sensors in comparison with the duct size.

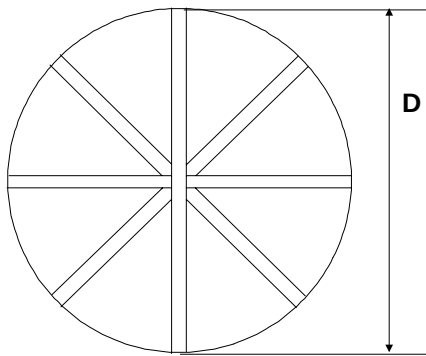
By following our recommendations the measurement error is $< \pm 3\%$ of the actual flow.

The number of sensors

It is important to adjust the number of sensors to the duct size in order to receive a measuring result with high accuracy.

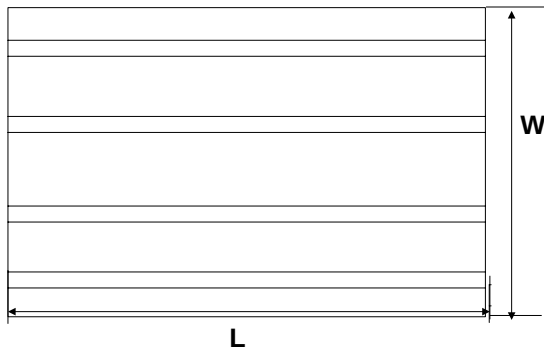
The following recommendations concern circular and rectangular ducts.

Circular Ducts



Diameter mm	Number of sensors
$100 \leq D < 400$	1
$400 \leq D < 900$	2
$900 \leq D < 1500$	3

Rectangular ducts



The sensors should always be mounted along the longest side of the duct, which is called the length. The shorter side of the duct is called the width.

Width mm	Number of sensors
$100 \leq W < 400$	1
$400 \leq W < 600$	2
$600 \leq W < 900$	3
$900 \leq W < 1500$	4

Flow measuring stations

Circular and rectangular flow measuring stations are available in a large number of dimensions. Circular flow measuring stations are available in dimensions from 100 up to 1200 mm.

Rectangular flow measuring stations are available in dimensions from 200 x 200 mm up to 2000 x 1200 mm.

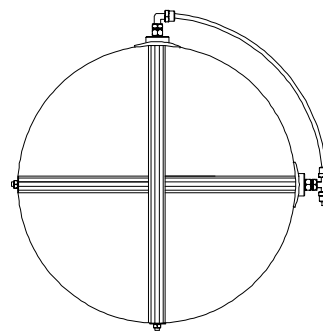
There are about 70 different standard dimensions available.

Circular flow measuring stations are provided with rubber packings, which easily enable mounting between the ducts. Rectangular flow measuring stations are made for mounting in guides.

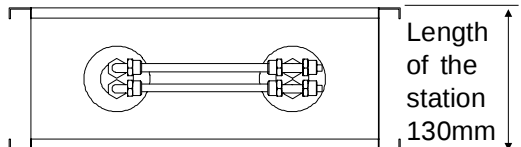
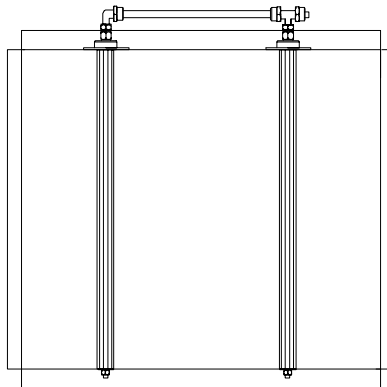
The sensors can be dismantled from the outside for inspection and cleaning. Cleaning of the ducts can thus be done without dismantling the whole flow measuring station.

With the construction of new systems, the installation cost decreases if complete measuring stations are chosen, because the measuring and drilling of holes need not be done.

All flow measuring stations, are delivered ready-tested with the sensors connected together. They are supplied with a label showing the constant and formulas for determining velocity and flow.



Length
70—130mm



Length
of the
station
130mm

The differential pressure of the flow sensor

The differential pressure, Δp , varies with the velocity and is calculated according to the following formula:

$$\Delta p = \left(\frac{v}{K_m} \right)^2$$

v = velocity m/s

K_m = the constant of the sensor. (See the table)

If the constant is 0.85 the following values will be arrived at:

35 Pa for	5 m/s
138 Pa for	10 m/s
311 Pa for	15 m/s
553 Pa for	20 m/s

Lasting pressure drop in the duct

The flow sensor causes only a low pressure loss in the duct system.

The pressure loss is calculated by the following formula:

Pressure Loss (Pa) = Blockage x Number of sensors x Differential pressure (Pa).

The sensor's blockage of the duct is stated in the table.

Example:

Circular duct: 400 mm with one sensor.
Velocity: 10 m/s
Blockage: 0.069

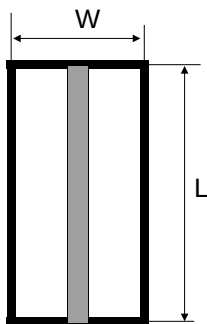
Pressure loss: $0.069 \times 1 \times 138 = 9.52$ Pa

The constant

The constant, K_m , has been calculated by an advanced computer programme and by empirical tests. By using the computer programme it is possible to calculate a correct constant even for special dimensions.

The constant is determined mainly by two factors, the shape of the sensor and the blockage caused by the sensor in the duct.

The constant is valid for air at a temperature of 20°C and a pressure of 1013mbar. For rectangular ducts, the length of the sensor equals the longest side (L) of the duct. The constant therefore varies with the width (W) of the duct.



Flow constant K_m for circular ducts

Diameter	Blockage	K_m
1250	0.022	0.864
1000	0.028	0.862
800	0.035	0.860
630	0.044	0.856
600	0.046	0.856
500	0.055	0.852
400	0.069	0.848
315	0.088	0.841
250	0.110	0.833
200	0.138	0.823
160	0.173	0.810
150	0.184	0.805
125	0.221	0.792
100	0.276	0.771

Flow constant K_m for rectangular ducts

Width	Blockage	K_m
2000	0.011	0.868
1800	0.012	0.868
1600	0.014	0.867
1400	0.016	0.866
1200	0.018	0.866
1000	0.022	0.864
900	0.024	0.863
800	0.027	0.862
700	0.031	0.861
600	0.036	0.859
500	0.043	0.857
400	0.054	0.853
300	0.072	0.846
250	0.087	0.841
200	0.109	0.833
150	0.145	0.820
100	0.22	0.793

Calculation of flow and velocity.

The following formulas are valid for air at 20°C and 1013 mbar. If the temperature or pressure differs from this, an adjustment needs to be done due to the changed air density.

$$v = K_m \times \sqrt{\Delta p} \text{ (m/s)}$$

$$Q = A \times K_m \times \sqrt{\Delta p} \text{ (m}^3\text{/s)}$$

v = velocity (m/s)

K_m = constant of the sensor

Δp = differential pressure (Pa)

A = area of the duct (m²)

Q = flow (m³/s)

ρ = density of the air (kg/m³)

B = air pressure (mbar)

t = air temperature (°C)

Adjustment for temperature or the barometer pressure

$$\rho = 1.293 \times \frac{B}{1013} \times \frac{273}{273 + t} \text{ (kg/m}^3 \text{)}$$

$$Q = A \times K_m \sqrt{\Delta p \frac{1.2}{\rho}} \text{ (m}^3\text{/s)}$$

Duct area of rectangular and circular measuring stations

To calculate the air flow, multiply the velocity by the duct area.

Area of a rectangular measuring station:

$$A = \text{width} \times \text{length} \text{ (m}^2\text{)}$$

Area of a circular measuring station:

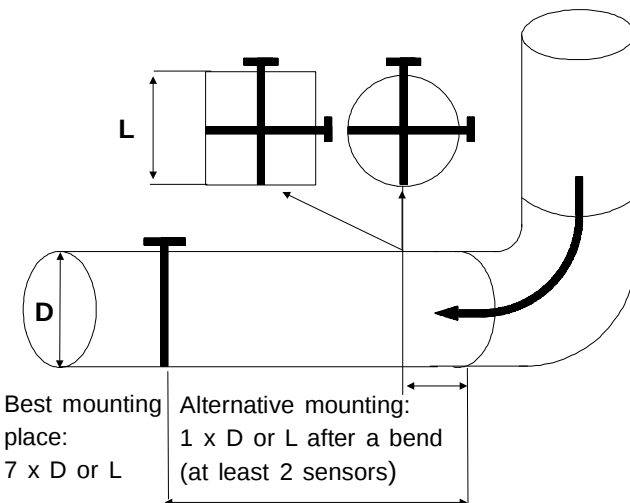
$$A = 3.14 \times \text{radius}^2 \text{ (m}^2\text{)}$$

$$\text{Radius} = \frac{\text{nominal diameter} - 4\text{mm}}{2}$$

Mounting

To achieve the best measuring result, it is important that the flow sensor measures a correct velocity profile.

The following recommendations should be taken into consideration during purchase and installation. In some cases a reference measurement should be performed in order to correct the constant.



To achieve the best measuring result, the sensor should be mounted at a distance from any source of disturbance such as filters, heat exchangers, etc. For circular ducts the minimum distance is seven times the diameter of the duct, and for rectangular ducts seven times the longest side of the duct. The measurement error then is < ±3% of the actual flow.

In circular ducts the sensor can also be mounted at a minimum distance that equals the duct diameter. At least two sensors should then be mounted perpendicularly to each other. The measurement error then increases by 1%. Deviations from these mounting places could cause measuring errors up to ±10% of the actual value.

Depending on the design of the system and desired accuracy, the sensor may be mounted at other places. The approximate maximum measurement error is found in the table below.

Distance from the disturbance	Measurement error % of actual value
No. of diam. or lengths	
7	2—3
5—6	3—4
3—4	4—6
1—2	5—10
1 (90° bend, 2 sensors)	2—4

The sensor or the flow measuring station should never be mounted closer than 7 times W or L from a single leaf damper. Disturbance caused by filters only give less errors in measurement than the values stated above.

Checking flow deviations

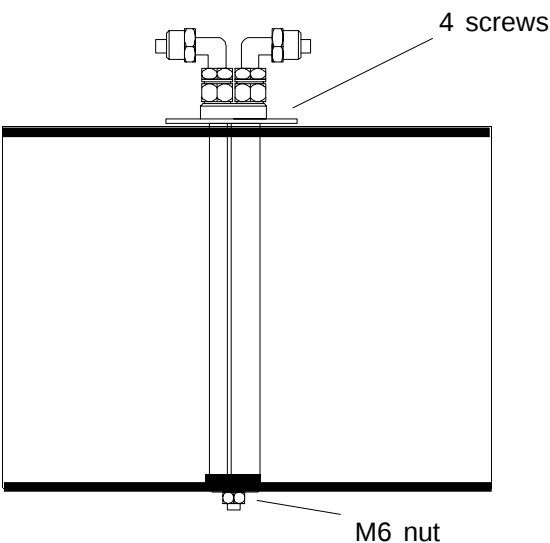
If the purpose of the measurement only is to check deviations from the normal flow, there is no need to measure with full accuracy, and one sensor is sufficient although the duct is large.

Installation

The sensor is fastened in the duct by four self-tapping screws at the top end and by one nut, M6, at the bottom. Mark the mounting place, drill or cut open a 25-milimeter hole for the upper part. Drill one 7 mm hole for the bottom attachment. Mount the sensor and fasten the nut. Adjust the direction by the use of the flow arrows of the anchor plate.

The permitted deviation is ±5 degrees.

Drill four 2.8 mm holes and use the anchor plate as a mould. Fasten with four self-tapping screws.



Connection of sensors in parallel

Replace the revolving angular pipe fitting by a T-shaped pipe fitting.
Connection sets are available for 2-4 sensors.



Flow-linear output signal

The sensor gives a differential pressure, Δp, which relates to the velocity according to the following formula:

$$\Delta p = \left(\frac{v}{K_m} \right)^2$$

v = velocity m/s

K_m = the constant of the sensor

To make the output signal linear to the air flow or velocity, the sensor must be connected to a differential pressure transmitter with a flow-linearised output signal.

Flow measurement

Micatrone's transmitter, MG-1000-FLD, is equipped with flow linearisation and digital indication of velocity and flow. The measurement error of the MG-1000-FLD, within the pressure range 10...100%, is < ±3% of full scale, FS.

The pressure range 10...100% corresponds to a flow measuring range of 30...100%.

See Data sheet MDE-1229.

The standard measuring range of the flow transmitter is selected on the basis of the maximum velocity in the duct according to the following:

(The constant selected is 0.85, see table on page 4)

Pressure range		velocity (m/s)	
Min	Max	Min	Max
0 (10)*	100 Pa	2.7	8.5
0 (20)*	200 Pa	3.8	12.0
0 (50)*	500 Pa	6.0	19.0
0 (100)*	1000 Pa	8.5	26.9

* Min. level for flow measurement

Flow control

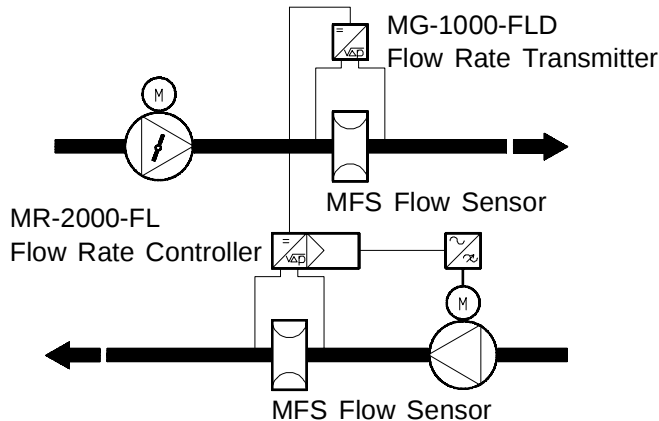
Micatrone's flow controller, MR-2000-FL, is equipped with flow linearisation, indication of velocity or flow and a pulse zone controller with an increase/decrease output signal. To get a continuous output signal, the output signal must be connected to a ramp generator.

Example:

The flow sensor, MFS, in the intake air duct gives a differential pressure which can be transformed

to a linearised-flow signal in the MG-1000-FLD. This signal forms the set point for the exhaust air. The flow of the exhaust air duct is measured by a flow sensor. It is transformed and controlled by the flow rate controller, MR-2000-FL.

The flow rate controller controls, via a ramp generator and a frequency converter, the rotation speed of the fan in order to achieve a balance between intake and exhaust air.



Total measurement error

To minimize the measurement error of the flow transmitter it is important to choose a measurement range which is as small as possible. The measurement errors of the pressure transmitter and flow transmitter are always calculated as a percentage of full scale, that is, the measuring range.

The measurement error of the sensor is stated as a percentage of the actual value. Depending on the square relation between flow and differential pressure, the lowest velocity should not be below 2.7 m/s, which corresponds to a differential pressure of about 10 Pa.

The following example shows the measurement error of the actual flow with a sensor, MFS, connected to the flow transmitter, MG-1000-FLD. The total measurement error is calculated according to the probability method.

$$Total\ error = \sqrt{error\ sensor^2 + error\ transmitter^2}$$

Example:

An MFS Sensor, (measurement error ± 3% of actual flow, flow constant 0.85) is connected to an MG-1000-FLD (0...100 Pa, measurement error ± 3% of full scale, FS)

A pressure of 100 Pa equals a velocity of 8.5 m/s. The measurement error of the transmitter (± 3% of FS) gives a velocity deviation of:

$$8.5 \times 0.03 = \pm 0.25\ m/s\ over\ the\ whole\ measuring\ range.$$

Actual measurement error at 100% flow

$$Error\ flow\ transmitter\ \frac{0.25}{8.5} = \pm 3\%$$

$$Total\ measurement\ error\ \sqrt{3^2 + 3^2} = \pm 4.2\%$$

Actual measurement error at 50% flow

Error flow transmitter : $\frac{0.25}{4.25} = \pm 5.8\%$

Total measurement error : $\sqrt{3^2 + 5.8^2} = \pm 6.5\%$

Actual measurement error at 30% flow

Error flow transmitter : $\frac{0.25}{2.55} = \pm 10.2\%$

Total measurement error : $\sqrt{3^2 + 9.8^2} = 10.2\%$

The following table displays total measurement error of the flow transmitter MG-1000-FLD, within the ranges 0...100 Pa up to 0...1000 Pa connected to the flow sensor MFS. The flow transmitter has a measurement error of $\pm 3\%$ of FS. The sensor has a measurement error of $\pm 3\%$ of actual value.

The lower limit of the flow measurement is 10%

Total measurement error as percentage of the actual value Deviation limits for velocity measured in m/s				
Veloc. m/s	0...100 Pa	0...200 Pa	0...500 Pa	0...1000 Pa
26.9				4.2% 25.8...28.0
19			4.2% 18.2...19.8	5.2% 18.0...20
12		4.2% 11.5...12.5	5.6% 11.3...12.7	7.4% 11.1...12.9
8.5	4.2% 8.1...8.8	5.2% 8.1...8.9	7.3% 7.9...9.1	10% 7.7...9.3
6	5.2% 5.7...6.3	6.7% 5.6...6.4	10% 5.4...6.6	
3.8	7.3% 3.5...4.1	10% 3.4...4.2		

of the pressure range.



Example:

A transmitter, 0...200 Pa, which is connected to a sensor gives a total measurement error of 5.2% of the actual value, which is 8.5 m/s. This means that the flow indication and the output signal can vary between 8.1 and 8.9 m/s.

Mounting considerations

The measurement of the flow must be correctly dimensioned in order to obtain the lowest total measurement error. Avoid extensive measuring ranges! If this is not possible, perform several sub-flow measurements, and obtain the total flow by adding the sub-flows.

When measuring flows in laboratories and industries, where exhaust hoods are used, always provide each exhaust with a sensor.

The total measurement error can then be limited to about $\pm 5\%$, regardless of the number of exhausts. This is to be compared with a flow measurement performed in the main duct only, where a measurement error of 5—30% may occur, depending on the load.

SPECIFICATIONS

Measuring range	2...25 m/s
Max. temperature	80°C
Measurement error	< $\pm 3\%$ (see datasheet)
Max. static pressure	100 kPa

Material	Detailj
Bracket	Anodised aluminium
Measuring pipes	Aluminium
Bottom attachment	Chromed steel
Anchor plate	Anodised aluminium
Pressure connections	Nickel-coated brass, for 8/6-mm hose
Sealings	Expanded rubber
Measuring station	1 mm galvanized sheet

Special

Special designs can be made according to customer's requirements.

Example:

Higher pressure or temperature, higher corrosion prevention, reinforced self supporting anchor plate for mounting at the top end only, and so on.

ORDERING CODES

1. Flow measuring stations for rectangular ducts MFS-SR

Length mm	Description MFS-										
	100	150	200	250	300	400	500	600	800	1000	1200
200			SR-01								
250			SR-02	SR-03							
300			SR-04	SR-05	SR-06						
400			SR-07	SR-08	SR-09	SR-10					
500			SR-11	SR-12	SR-13	SR-14	SR-15				
600			SR-16	SR-17	SR-18	SR-19	SR-20	SR-21			
800			SR-29	SR-30	SR-31	SR-32	SR-33	SR-34	SR-36		
1000				SR-47	SR-48	SR-49	SR-50	SR-51	SR-53	SR-55	
1200					SR-58	SR-59	SR-60	SR-61	SR-63	SR-65	SR-66
1400						SR-70	SR-71	SR-72	SR-73	SR-74	SR-75
1600						SR-79	SR-80	SR-81	SR-82	SR-83	SR-84
1800							SR-86	SR-87	SR-88	SR-89	SR-90
2000							SR-92	SR-93	SR-94	SR-95	SR-96

2. Flow measuring stations for circular ducts MFS-SC

Diameter mm	Description MFS-
100	SC-100
125	SC-125
160	SC-160
200	SC-200
315	SC-315
400	SC-400
500	SC-500
630	SC-630
800	SC-800
1000	SC-1000
1250	SC-1250

3. Flow measuring sensors for circular ducts MFS-C

Diameter mm	Description MFS-
100	C-100
125	C-125
150	C-150
160	C-160
200	C-200
250	C-250
315	C-315
400	C-400
500	C-500
600	C-600
630	C-630
800	C-800
1000	C-1000
1250	C-1250
special	C-length mm

4. Flow measuring sensors for rectangular ducts MFS-R

Length mm	Description MFS-
100	R-100
150	R-150
200	R-200
250	R-250
300	R-300
400	R-400
500	R-500
600	R-600
700	R-700
800	R-800
900	R-900
1000	R-1000
1200	R-1200
1400	R-1400
1600	R-1600
1800	R-1800
2000	R-2000
special	R-length mm

Example of Order:

Circular flow measuring station
for circular duct, 630mm.

MFS-SC-630.

Accessories

Connection Set, for connection of 2 sensors,

MFS-F2

Connection Set, for connection of 3 sensors,

MFS-F3

Connection Set, for connection of 4 sensors,

MFS-F4

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