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Operation Manual

LFE-LDS

Flow Element

*** VERSION 2.0 ***
Update: 30.03.2012

GENERAL HINTS

Typographical Conventions

MEANS OF DISPLAY

→


marks a work procedure, which you must implement
references marks which you should not neglect otherwise your health or the operability of the equipment is endangered

marks important additional information, hints and recommendations

referring to precautionary measures mark during the handling of electrostatically unloading-endangered elements or modules.

TYPES OF DISPLAY

Menu Items
Texts of screen displays were shown in cursive letter
(e.g.: *End Program*).

Predefined Parameter
Parameter which are set at the delivery of the unit as factory settings were underlined. (i.e.: 0 ... 9999)

SAFTEY HINTS

Please consider the references of this manual as well as the operating conditions and permissible data, which are specified in the data sheets of the device, so that the equipment functions perfectly and for a long time remains operational:

Adhere with operational planning and the enterprise of the equipment to the general rules of the technology!

Installation and maintenance work may take place only with technical personnel and with suitable tools!

Consider the valid accident prevention and safety regulations for electrical devices during the enterprise and maintenance of the equipment!

Switch off power supply before interferences into the system in any case!

Meet suitable measures, in order to exclude unintentional operation or inadmissible impairment!

Ensure after an interruption of the electrical supply a defined and controlled restart of the process!

INTRODUCTION

This manual describes the LFE-LDS slit type Laminar Flow Elements for all kind of different flow channel shapes which have a full scale flow between 0,05 SL/min to 150 SL/min air. This slit type LFE can be evaluated with any differential pressure measurement devices to determine the flow of air and gases. The LFEs are calibrated with air at room temperature between 16 – 26°C. A simple conversion for other gases can be made with the viscosity relation of air and the operating gas by using the formula of Hagen-Poiseuille. The LFE-LDS measure the actual volume flow with the differential pressure (drop) which is created by friction! The total pressure drop across the LFE is about 1,5 to 2-times of the measured DP. The flow direction is preferred in unidirectional way, can be principally also used in bi-directional way. The LFE-LDS are calibrated normally for atmospheric pressure (1 bar abs.). But they can also be used in the pressure range between 0,1 – 2 bar abs.. Higher static pressures are possible respectively with a reduced DP range.

Suppliable LFE-LDS Laminar Flow Meter

Supplied can be the „LDS-ES“ type made of stainless steel, as well as „LDS-AL“ made of aluminium. The series „ES“ is designed for flow rate full scales between 0,01 l/min to 5 l/min. The series „AL“ is designed for flow rate full scales between 10 l/min und 150 l/min. The nominal differential pressure across the LFE -LDS is as a standard for all flow rate full scales 10 mbar. It can be extended without a bigger problem to 20 mbar on request. Beside of the LFE-LDS standard model series-we can laso supply on customer request special sizes and intermediate sizes.

Specific safety instructions for secure handling of the LFE-LDS elements

The very small size of the flow channel is quite sensible against pollution. So please ensure that these LFE are only operated with clean dry air and gases. If the flow channel is closed partially the characteristics will change and the original calibration may no more be valid anymore. In this case the LFE-LDS must be cleaned and recalibrated in the factory.

Check Delivery Content

- The LFE-LDS comes along with a manual of operation and a calibration data sheet
- The LFE-LDS were supplied with closing caps on the thread connection. Dismount these and have a look through the flow channel cross section against a bright light. There should be none of the flow paths closed.

Installation Requirements

Ensure before mounting: connect the LFE-LDS into a pipe, tube or measurement section only if there is no dirt or other particles inside to see. If dirt is not to exclude in operation and the section will not stay clean for ever it is strictly recommended to use an inlet filter with a filter rate of equivalent to 5µm.
The two pressure connection lines for the DP pressure transmitter should have about the same pipe length and diameter if possible and should be absolutely tight.
The temperature sensor should have a distance of about twice of the used pipe diameter in front of the LFE-LDS input. If an absolute pressure sensor is used it should be connected at the positive (+ plus) pressure tap of the DP.

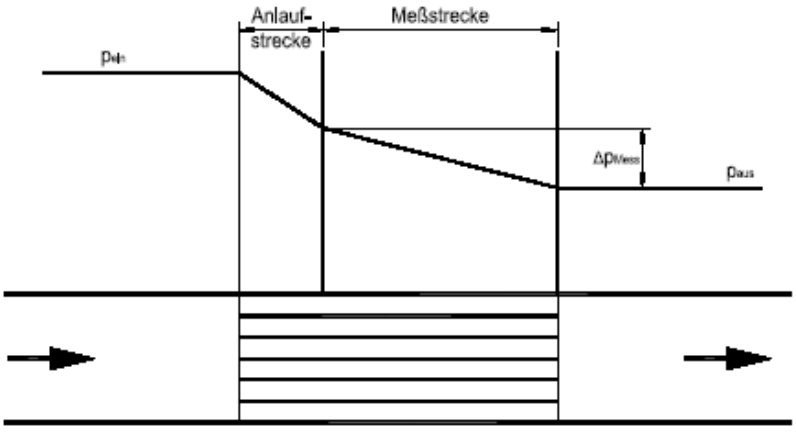
The LFE-LDS can be connected into the line by a thread connection. In any case please verify and respect the flow direction of the LFE-LDS (see arrow mark). Concerning the mounting direction there is no limitation. In general the horizontal mounting direction is preferred compared to the vertical direction, because the temperature may increase with 1°C/m height.
To achieve good measurement results one have to pay attention that the free cross section close to the process connections is reduced as little as possible. This means that the wall thickness of threads or directly screwed pipes shouldn’t be larger than 2 mm. Is it not possible to hold this recommendation the LFE-LDS should be calibrated from the manufacturer with the actually used flow sections. This allows the maximum possible accuracy for your application.

FUNCTIONAL PRINCIPLE

By flow measurement you have to differentiate between mass flow $q_M [kg/s]$ and volume flow $q_V [m^3/s]$. Both values correspond with the density ρ of the medium.

$q_M = \rho \cdot q_V$

The laminar flow meters use the pressure drop Δp in a laminar pipe or crack stream to designate the volume flow q_V.

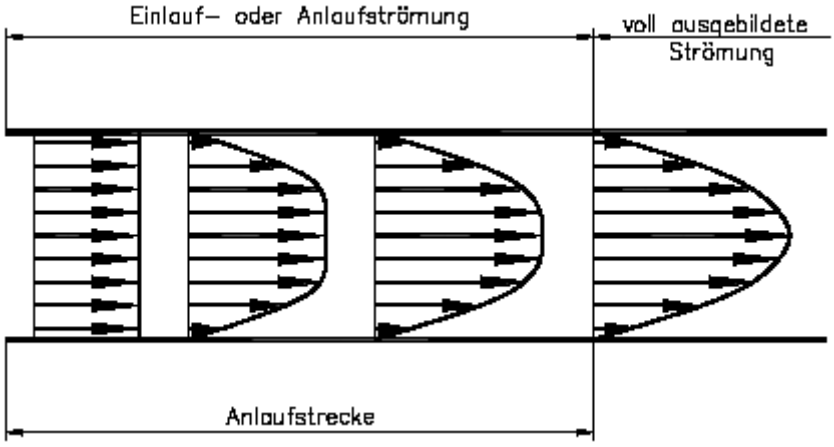


Laminar-Durchflußmesser

The volume flow results by the equation:

$$q_V = \frac{k}{\eta} * \Delta p$$

At this is k a device specific absolute term and η the dynamic viscosity or durability of the gas. Because the dynamic viscosity η of the gases is independent of the pressure in a wide range (up to 6 bar), it is possible to realize an almost operation pressure independent actual volume flow measurement.
Conditions therefore are:
Stabilisation of laminar flow, means a lower and upper flow limit mustn't overshoot. The lower limit of sensibility is defined by the accuracy of the pressure measuring device only. By the dimensioning of the laminar flow meter you have to divers between the entrance region of the stream into the flow channel and the range of the well-established laminar profile.



entrance region

A linear device function can be reached only if the inlet length of the section is long enough. In the development of the laminar flow meter it was paid high attention to eliminate all disturbing fluid mechanical effects (starting range effects, transition e.g.). To minimize risks by pollution there are used rectangle cracks or cylindrical ring cracks with a crack waists of 0,5 up to 1 mm.

Advantages of laminar flow meter
Laminar flow meter have no moveable parts. Thereby they are little accident-sensitive.
The temporal response behaviour of the laminar flow meter is very fast. Volume flow variations in the range of less than 10Hz are resoluted. It is independent to the operation pressure as long as the product

$$p_{System} * q_V$$

fulfills a limit value, which guarantees a laminar flow. The measuring value ΔP is proportional to the volume flow q_v in the laminar range which makes an evaluation easier. The measuring value ΔP can be displayed with direct indicating devices, with U-pipes, Betz manometer and micro manometer or with electronical differential pressure transmitter.
The resting pressure drop *1.5-2 ** ΔP is very small. The relative failure lies below one percent of the measuring value. The resolution is dependent of the used pressure transmitter. The laminar flow transmitter are calibrated by a ambient air temperature of 20°C. By using established gas data it is easily possible to convert the calibration factor to other gases and other temperatures. For the calculation of the mass flow rate q_M only the gas density ρ is needed (continuity law).

Ideal laminar elements measure the volume flow q_v independent on gas density ρ.
The measuring value ΔP is dependent in the laminar range only to the dynamic viscosity of the medium. For controlling a process the type of flow measurement should be configured to the specific circumstances. The following table shows the primary measuring dimensions of different flow meter and the dependence of the measuring dimensions of flow and gas characteristics.

Flow Meter	Primary dimension	
Volumetric meter	Frequency	$\sim q_V$
Laminar pipe	Δp	$\sim \eta q_V$
Thermical mass flow meter	ΔT	$\sim c_p \eta q_V$ resp. $\sim c_p q$
Venturi flow meter	Δp	$\sim \rho q_V^2$
Norm orifice	Δp	$\sim \rho q_V^2$

At volumetric laminar pipes it counts the primary measuring dimension

$$\Delta p \sim \eta q_V$$

whereas η is the dynamic viscosity of the medium and q_V is the volume flow.

At thermical mass flow meter it counts:

$$\Delta T \sim q_M c_p$$

whereas c_p is the specific heat and q_M is the mass flow.
For venturi flow meter and norm orifices counts:

$$\Delta p \sim \rho q_V^2$$

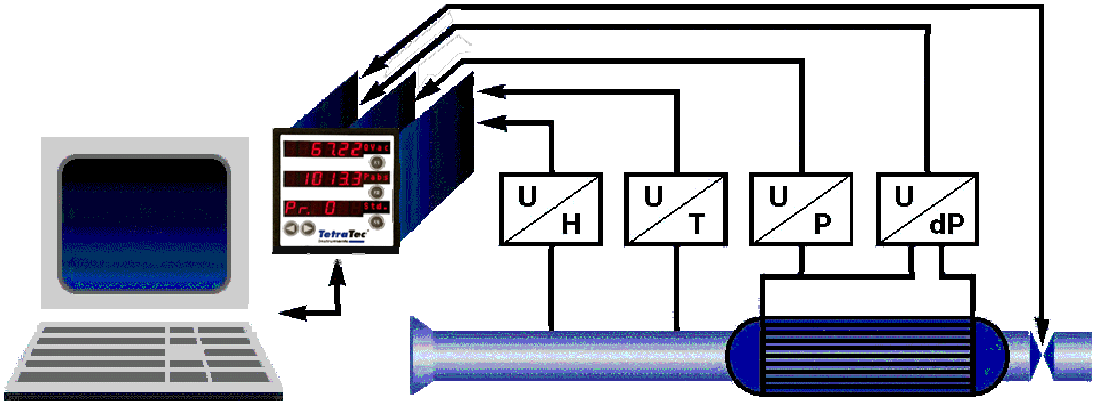
According to this the characteristic curve is in q_v quadratic. For the determination of q_v additionally the gas density have to be established.

OPERATION

Procedure:

- Put at first the line into operation.
- Measure the differential pressure at the DP-pressure taps.
- Measure the gas temperature and if required the humidity of the flowing air.
- For the accurate evaluation of the volume or mass flow one has to measure also the static absolute pressure in the line to calculate the density and also the viscosity of the flowing gas correctly.
- With all of these measured sensor data later the evaluation can be done. The flow can be calculated manually or by using a flow computer what does do this calculation online.

Typical Sensors for Evaluation



H = rel. humidity / T = temperature / P = absolute pressure / dP = differential pressure

Calibration curves /- tables

Each LFE-LDS is calibrated against a "calibration master device" which is traceable to the PTB (the highest german calibration institute). As a standard the LFE-LDS is calibrated with dry clean air and the calibration results will be converted and corrected on standard calibration conditions of 21,1°C, 1013,25 mbar abs. and 0% rel. humidity.
Every LFE-LDS comes with an own calibration certificate. For this purpose at the order should be defined the measurement units of the customer at least if they should be different than our standard. Based on the calibration data the actual flow rate Q can be calculated:

$Q = (B \times dP + C \times dP^2) \times F = Q_{cal} \times F$

B, C = calibration coefficients; shown for every LFE-LDS in the calibration certificate

F = viscosity correction factor = calibration viscosity / actual viscosity

Q_{cal} = volume flow at calibration condition

Please confirm that you are using the right calibration certificate for the LFE. (Compare the serial number).

Calculating the Flow

With the formulas, tables and diagrams shown in the calibration certificate the volume flow can be calculated.

Air Flow Measurement

Procedure:

- Read the differential pressure.
- Use the formula to calculate the flow:

$Q_{cal} = B \times dP \times + C \times dP^2$

The resulting calibration volume flow must be corrected with the viscosity factor to achieve the actual volume flow and this again has to be multiplied with the density to receive the mass flow

Gas Flow Measurement (other gases than air)
The same procedure as described above can be applied in principal for any other Gas than air. But the actual volume flow must be calculated with the viscosity factor, the actual viscosity of the actual gas as well as the density of the used media must be used for the calculation of the mass flow. This procedure is only valid if the LFE-LDS is operated within the same Reynolds number range as found in the calibration!

MAINTENANCE

Because the LFE-LDS has no moving parts it is almost free of service. But it is recommended to clean the LFE-LDS in regular periods of 3 to 5 years and shelter it also by a suitable filtration (better 5 μm) of the flowing media against bringing in dust and dirt into the slit.

Cleaning
Procedure:

- Take the LFE-LDS out of the line
- Inspect the slits for mechanical damages and on closing dirt of the flow paths
- Try to blow out the LFE-LDS with clean and oil free compressed air against the recommended flow direction.
- If you find oily or gluing dirt on the LFE-LDS it may only be cleaned with proper and completely in water resolving cleaning means which don't build sedimentation. Please contact our company for accepted cleaning fluids, because not acceptable cleaning fluids can lead to damages of the LFE.

HINTS **For maintenance and repair we offer a special cleaning and recalibration service.**

Search and solving problems

Problem	Possible cause	Solving problem
Display shows unrealistic differential pressure or wrong flow value	Recommended straight in- and outlet sections not present	Straight inlet section 10 x D Straight outlet section 5 x D i.e.: D = 100 mm inlet 1 m, outlet section 0,5 m
	LFE-LDS slit polluted	Clear or change LFE
	Line and DP connecting tubes could be bended to narrow so that flow and pressure measurement cannot work properly	Control line and DP connection tubes for straight and reasonable bending and correct that if that solves the error.
	DP connecting tubes have a different length and / or diameter or are laid out in different positions	Correct that if that solves the error
	Reducers are directly at the in-/outlet into the LFE-LDS and are limiting the flow.	Use an appropriate connection diameter.
differential pressure is pulsating	Turbulent flow profile in the LFE-LDS or leakage Leak in DP connecting tubes.	Lower static pressure or lower flow, tightening of the leakage.

SPECIFICATIONS

Serie ES

Type LDS-ES-	qv [l/min]	qv [m³/h]	DP Δp [mbar]	
0.01	10	0.6	10	**Measuring range final values:** 0 – nominal volume flow The resolution is defined by the used pressure transmitter.
0.025	25	1.5	10	
0.05-10	50	3	10	
0.1-10	100	6	10	
0.25-10	250	15	10	
0.5-10	500	30	10	
1-10	1000	60	10	
2.5-10	2500	150	10	
5-10	5000	300	10	

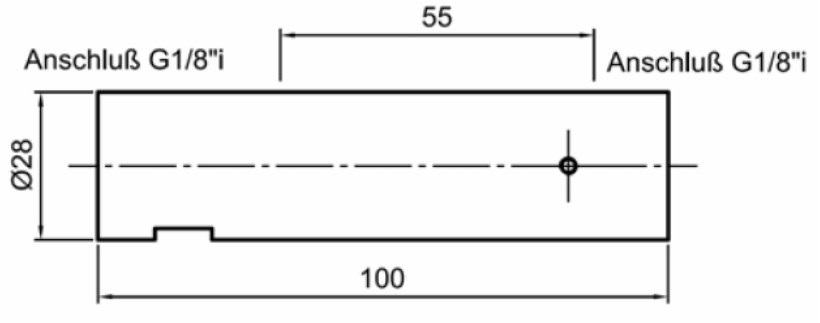
Serie AL

Type LDS-AL-	qv [l/min]	qv [m³/h]	DP Δp [mbar]	
10	10	0.6	10	**Measuring range final values:** 0 – nominal volume flow The resolution is defined by the used pressure transmitter.
			5	
25	25	1.5	10	
50	50	3	5	
			10	
75	75	4.5	5	
			10	
125	125	7.5	5	
			10	
150	150	9	10	
			10	

DIMENSIONS

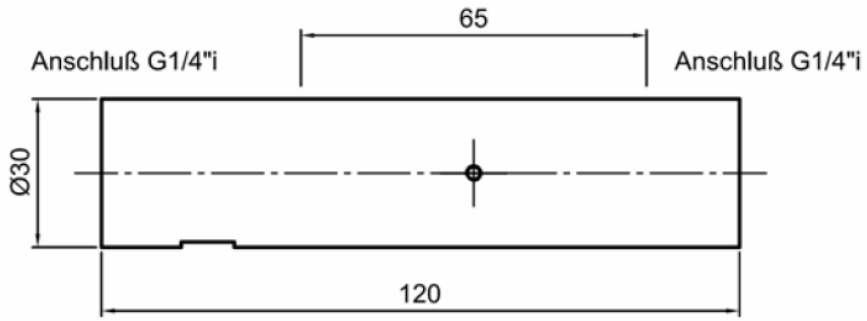
Serie ES

LDS-ES-0.01-10 up to LDS-ES-1-10



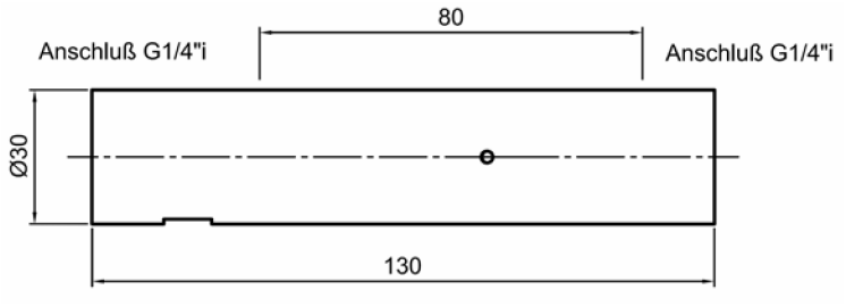
weight: 480 g

LDS-ES-2.5-10



weight: 630 g

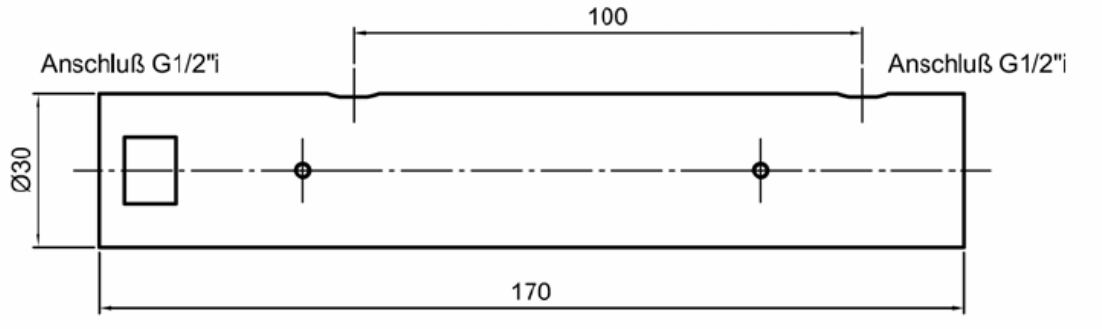
LDS-ES-5-10



weight: 690 g

Serie Al

LDS-AL-10-10 up to LDS-AL-25-10



LDS-AL-50-10 up to LDS-AL-150-10