LMF

LaminarMasterFlow
SYSTEM

Reference Book

This reference book is solely aimed to qualified employees, who have achieved the necessary knowledge with regard to language understanding and contents.

The separate manual includes all information relevant for the operator.

The following text is a translation of the source document from the German language.

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Service

If there are any questions exceeding the contents of the provided product information, you may contact us at the address indicated above.

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In addition, you will find more information and data sheets of other products on our homepage: You are invited to visit www.tetratec.de.

Table of Contents

1 Introduction

1.1 Product Description

The LMF system consists of hardware and software.

1.1.1 Hardware

Vital components of the hardware are Controller S320 and one or several measuring sections.
The controller in its core consists of a very accurate floating point calculator in a standard switchboard installation rack. A very high flexibility is given by the modularity of the hardware and software.
The controller can be inserted in cases specific for application. To make easier the specific operation of the application, these cases can be equipped with additional buttons, displays or a PLC interface. The measuring sections can also be embedded in the case according to size and number, be installed on a mounting plate or be supplied loosely. Measuring sections typically consist of an arrangement of volumes or flow elements and connected sensors and/or correcting elements.
For being able to communicate with the analog or digital sensors, final control elements or a PLC, the controller is equipped with plug-in cards according to the application. In addition to various plug-in cards for special jobs the following plug-in cards are used frequently:

Type100 cards	Two analogue-digital converters
Type200 cards	Two digital-analogue converters
Type310 card	An analogue-digital converter and a digital-analogue converter each, 14 bit each, cycle time only 10 ms, conversion time 3ms. Hence, particularly suitable for fast control.
Type400 card	Bus module for digital extension modules, e.g. for PLC interface
Type500 card	Two inputs for pulse transmitters
Type510 card	Two frequency counters
Type520 card	Two frequency generators with adjustable pulse-width modulation

For detailed information and other cards please see our homepage.

1.1.2 Software

The software is arranged hierarchically:

- Operating System
- Config (registration and, if necessary linearization of the plug-in cards and configuration of the serial interfaces)
- LMF software, application-parameterized
- Switchable parameter sets for different measuring tasks (program 0 to 9)

Originally there has been different software for different types of application. But over and over again there have been requests for measuring systems exceeding the limitations between the software packages. Thus these different software packages have been integrated in the LMF software version by version. The applications now result from the specific configuration of the software. The LMF software therefore includes the following applications:

LMF	LaminarMasterFlow	Originally for the evaluation of Laminar Flow Elements (LFE), in the meantime generally for the evaluation of primary elements for flow measurements, i.e., in addition to LFEs also orifices, nozzles, Pitot tubes, gas meters etc.. Combined with actuators also for the regulation of pressure and flow.
PCS	PressureControlSystem	For pressure control
LFC	LaminarFlowControl	Flow controller
LMS	LeakageMeasuringSystem	Leakage measuring in closed volumes
CVS CAL	Constant Volume Sampling Calibration	Calibration equipment for CVS devices

1.2 Intended Use

The devices of the series LMF are exclusively determined according to the sales confirmation

- for measuring and controlling of
  - Volume flows
  - Mass flows
  - Pressures
  - Temperatures
  - Humidity
- for the calibration of other devices measuring and controlling such parameters
- For metering of gaseous media
- For leak testing

In special cases sensors for linear measurement and power measurement can be integrated.

Approved as a medium are (according to the sales confirmation)

- Air
- Gases
  - Argon
  - Carbon dioxide
  - Carbon monoxide
  - Helium
  - Hydrogen
  - Nitrogen
  - Oxygen
  - Methane
  - Propane
  - N-butane
  - Natural gas
  - Laughing gas

Note:
The proper use is exclusively restricted to the application and the media specified in the sales confirmation. I.e., even the use for one of the purposes mentioned above and the operation with a medium mentioned above will be recognized as improper use, provided that the device has not been specified for that purpose!
Tests and an approval in written form will be required with changes by TetraTec Instruments GmbH.

When being used as a measuring unit in complex machines, a combination of machines, an assembly line or system, the signal outputs must exclusively be used for the information of a superior control (e.g. PLC).
When being used as an independent laboratory measuring instrument with control function the regulations and indications for emergency stop functions and for the recovery of voltage after power failure must be observed.

Intended use also includes

- observing of all notes of the operating instructions
- compliance of the inspection and maintenance work.

Another use or a use beyond that will be considered as not intended. TetraTec Instruments GmbH will not be responsible for any damages arising from that.

1.3 Warranty and Liability

Our "General Sales and Delivery Specifications" are valid in principle. They will be available for the operator by the conclusion of a contract at the latest. Warranty and liability claims in the case of damages to persons and property will be excluded, if they are caused by one or more of the following reasons:

- Improper use of the device
- Faulty installing, taking into operation, operating and maintaining of the device and of the accessories (sensors, LFE).
- Operating of the device with defect safety equipment or safety and protection devices being installed improperly or not operatively.
- Ignoring of the instructions of the operating instructions in regard of transport, storage, installation, starting, operation, maintenance and setting of the machine.
- Arbitrary structural changes of the device, arbitrary changing of the measuring section and of the measurement set-up.
- Inadequate monitoring of accessory parts being subject to wear.
- Repairs performed faulty.
- Disasters resulting from circumstances caused by a third party or force majeure.

2 Safety

It is absolutely necessary to get used to the safety instructions before the installation is started!

2.1 Basic Safety Instructions

The knowledge of the basic safety instructions and of the safety regulations is a basic requirement for save handling and trouble-free operation of this equipment.
The operating instructions, particularly the safety instructions, have to be observed by anyone working with the equipment.
Furthermore the rules and regulations for the prevention of accidents valid for the site have to be observed.

2.1.1 Responsibility of the Operator

- The operator is committed to ensure that only persons will be working with the equipment who have been informed about the basic regulations of safety of work and the prevention of accidents and who have been instructed in the handling of the equipment.
- The responsibility of the staff must be clearly determined for mounting, taking into operation, operating, setting and servicing.
- The safety-conscious working of the staff will be inspected regularly.
- The electrical operational safety has to be inspected and to be recorded regularly.
- The pneumatic equipment has to be inspected and to be recorded regularly.
- In the event of dangerous media (other gases as air) the test section design has to be checked for leakage and to be recorded regularly. The devices must only be operated in monitored atmosphere, if necessary (gas alarm units).
- Control periods must be determined by the operator in consideration of the relevant legal requirements.

2.1.1.1 Training of the Staff

- Only trained and introduced staff is allowed to work with the equipment.
- The staff must have read, understood and confirmed by signature the safety chapter and the warning notes included in the operating instructions.
- Staff to be trained must only work with the equipment while being supervised by an experienced person.

2.1.1.2 Informal Safety Measures

- The operating instructions have to be kept at the location of the equipment all the time.
- The generally accepted and local regulations for the prevention of accidents and for environmental protection have to be provided and be observed as an amendment for the operating instructions.
- All instructions for safety and danger of the equipment and of the measuring section have to be kept legibly.

2.1.2 Responsibility of the Staff

All persons having been ordered to work on the equipment will be responsible before starting work:

- to observe the basic regulations of the safety of work and the prevention of accidents.
- to read the safety chapter and the warning notes of the operating instructions and to confirm having read and understood them by their signature.

2.1.3 <u>Inevitable Remaining Dangers by the Equipment</u>

The devices of the series LMF have been constructed according to the state of the art and the recognized safety regulations. However, it is possible that danger for life and physical condition of the operator or a third person or damage of the equipment or other real values may occur during operation.
The devices must only be used

- for proper use
- and in a correct safety condition.

Malfunctions which may have impact on the safety must immediately be corrected.

2.1.3.1 Dangers by Electric Energy

- ➢ Only an electric specialist must be allowed to work on the power supply or on a control box.
- ➢ Check the electrical equipment of the machine regularly. Immediately remove loose connections and broken cables and replace them by new cables.
- ➢ All necessary repairs must be performed by a certified service engineer of TetraTec Instruments GmbH.
- ➢ If work is indispensable on live components, a second person should be consulted to switch off the main switch in case of emergency.
- ➢ To exclude fire risk or danger of an electric impact, protect the device from rain, moisture and excessive humidity.

2.1.3.2 Dangers by pressure

Insufficiently fixed or aged flexible tubing, pipes etc. may become loosely or may burst.
Possible consequences:

- Parts may fly or whirl around and may cause damages or injuries.
- Involuntary movements or distractions caused by frightening may cause damages to property, injuries etc.
- Strong noise development, thus reduction of the response time and risk of hearing damages.

2.1.3.3 Dangers by gases

(applies only if gaseous media other than air are used)

Gases have the following dangerous properties depending on the type of gas:

- Oxygen and laughing gas have a fire-supporting impact
- Laughing gas and xenon have a hallucinogenic or anesthetic to toxic impact according to their concentration
- Carbon monoxide is very toxic.
- Hydrogen, carbon monoxide and carbon hydrides as for example propane are combustible and may provide explosive mixtures when being mixed up with air.
- By admixing gases (except oxygen) to the breath air its oxygen concentration will decline, so that a suffocating effect with high concentrations will be initialized.

Hence:

- ➢ Avoid emission of gases.
- ➢ Examine measuring setup regularly for leakage.
- ➢ Discharge dispersing gases to exhaust gas system.
- ➢ Work in a well ventilated environment.
- ➢ Monitor atmosphere in the work space with gas alarm units.

2.1.4 Switch-on characteristics with running PLC

The device may be configured in such a way that it will run in the automatic test cycle mode when being turned on after a power supply failure and voltage has returned.
In this mode some of the digital control outputs are active!
The operator is responsible for the protection against a restart of the machines / assemblies controlled by the PLC, which may be immediately dangerous for persons and appliances!

2.2 Notes for set-up, installation and operation of the equipment

2.2.1 Set-up, Installation

The device must be set-up at a dry place free of dust and free of vibration. If existing, the case must not be opened at all. It usually contains no parts to be maintained by the operator. If this should be the case anyway, the corresponding indications of the operating instructions have to be observed.

The opening and vent holes of the case must not be covered. Sufficient aerial circulation has to be provided. If assembled in a switch cupboard / built-in cupboard the operating temperature limits must be observed.

With loosely delivered measurement value transducers and primary elements it must be observed that the installation is free of contamination and in correct positional arrangement at the measuring point. If necessary, sensitive readings recorders must be particularly protected against damage.

The sensors and primary elements must not be exchanged or be allocated wrongly at all.
The allocation to the suitable measuring channel as well as to the suitable device must be absolutely maintained. If the assembly is exchanged, the calibration of the devices will be invalid. If sensors of different types are exchanged, there will be a risk of damage up to a total breakdown.

If sensors are integrated in the device the dependency of position of the sensors must be observed, if necessary. This is particularly valid for oil-filled sensors with a small measuring range, e. g. differential pressure sensors of the series 3051. Here the device must only be inclined by the centre line which corresponds to the normal vector of the measuring diaphragm. The centre line itself must be kept horizontally. Devices, for which this factor has to be observed, are often equipped with a water level. In addition, a corresponding indication can be found in the operating instructions.

2.2.2 Operating Conditions, Ambient Conditions

Operating temperature: 5°C up to 40°C. With special applications differing temperature limits may be valid for external test section designs.
Ambient pressure atmospheric pressure
working pressure: See application-specific operating instructions.
humidity range: 0 ... 90% of relative humidity, not condensing!
Before the device is turned on it must be adapted to the room temperature, the device must not be with dew at all.

2.2.3 Electric power supply / electrical connection

2.2.3.1 OEM-device or Controller S320 delivered as a component

Controller S320 is supplied with 24 V. The 0V connection has to be connected with the protective earth conductor.

2.2.3.2 Devices with uniphase mains supply

110 - 230 VAC (50/60 Hz)
Only the provided power cords or power cords with equivalent test sign must be used. The power supply must comply with the currently valid specifications.

2.2.3.3 Devices with protective case

110 - 230 VAC (50/60 Hz)

The connector assembly set must only be installed by a qualified electrician.

2.2.3.4 Devices with control box

Monophase and multiphase devices with control box must only be installed by a qualified electrician.

2.2.4 Cleaning of the Device

Wipe with a moist but not watery cloth.

2.2.5 Calibration, Measuring Accuracy

The devices are delivered by TetraTec Instruments GmbH being calibrated and completely configured. Any change of the calibration coefficient or other scaling factors and constants used internally may make the calibration invalid or reduce the measuring accuracy.

2.2.6 Structural Changes on Devices and Measuring Sections

All measures of conversion require tests and written approval by TetraTec Instruments GmbH.

- ➢ No changes, attachments or conversions of the device or measuring section must be carried out without approval of the manufacturer.
- ➢ Only use original spare parts and wearing parts.
  If parts are supplied by third companies there is no guarantee of being constructed and manufactured appropriately for stress and safety or that they meet metrological requirements.
- The exchange of sensors and measuring sections must be coordinated with TetraTec Instruments GmbH, because possibly a new measurement may be necessary.
- Only sensors and measuring sections supplied and calibrated by TetraTec Instruments GmbH must be used.

3 Components of a LMF System

3.1 Overview

According to the application different components are used, i.e., your system must not be equipped necessarily with all described components. The following table gives an overview of the components and their main operational areas.

Evaluation electronic	Controller S320 with various interface cards is the core of the evaluation electronic. For a description see sections 1.1.1 and 4.
Interfaces	The evaluation electronic can display the computed values by digital and analog interfaces. Analog outputs are also used for the activation of actuators, e.g., of proportional valves.
Protective casing	Depending on the desired protective class different protective cabinets are available. Depending on the size of the measuring section the protective cabinet may accommodate also sensors or even the complete measuring section in addition to the evaluation electronic and the power pack.
Primary elements	Primary elements is the generic term of LFEs, orifices, Pitot tubes, etc., which are used for flow measurement. Important sub-groups are: • Active pressure transmitter • Counter • Thermal mass flow sensors The most current primary elements are described in detail in the following paragraph.
Differential pressure sensor	Differential pressure sensors are used, for example, for the measurement of the active pressure of active pressure transmitters.
Absolute pressure sensors	The absolute pressure of a gas is required for all sorts of calculations, e.g., for the calculation of the standard volume flow or mass flow by an active pressure transmitter. If only the absolute pressure is required in a measuring point, this absolute pressure can be measured immediately with an absolute pressure sensor.
Relative pressure sensors	It turned out as an advantage to use only an absolute pressure sensor for the ambient pressure with several measuring points, and to equip all the other measuring points with relative pressure sensors. At the same time the ambient pressure serves as the reference pressure to which all measuring points can be equally adjusted (nullification of the relative pressure sensors). Then the absolute pressures in the measuring points are determined arithmetically.
Temperature sensors	Just as the absolute pressure the temperature is also required for various calculations
Humidity sensor	The air humidity influences the viscosity of air, indeed, not in the same range as temperature or pressure, nevertheless, it is an important measured variable in the case of high requirements of the measuring accuracy. For applications with pure gases or dry compressed air it is possible to calculate with a fixed value.
Port directional control valves	Port directional control valves are used in most different types and sizes and for the most different purposes. The valve arrangements for leak testing devices and for the nullification of the pressure sensors of active pressure transmitters (option) are to be highlighted.
Actuators	Typical actuators for our applications are proportional valves or electronic pressure control valves. They are used as final control elements for flow controls or pressure controls.
Cable sets and assembly material	The delivery of measuring sections completely mounted on mounting plates or in cabinets has gained increasing acceptance in recent years; as a result final assembly is made easy and it is easier to ensure leakproofness and functionality. The LMF system is always delivered including all necessary cables or mating plugs.

3.2 Primary elements

LFE is the primary element most often used by us, since among other things its linear behaviour allows a high accuracy over a wide span. Other primary elements like orifices, accutubes, critical nozzles, gas meters or mass flow meters have different advantages according to the measuring problem, which shall be briefly characterized here.

3.2.1 Active pressure transmitter

3.2.1.1 LFE

Mode of operation
The volumetric flow rate through the LFE generates a laminar flow in the capillaries or gaps of the LFE. The pressure drop of the laminar flow section is proportional to the product of the current volume flow and the current viscosity.

Accuracy
With LFE as a primary element the LMF system works with a typical measuring accuracy of 0.5 to 1% or better, referred to the measurement value of the current volume flow in the measuring range of 1:10 (1:50 optionally). This accuracy is also reached with variable line pressure or variable temperature, provided that the sensors for temperature and absolute pressure are integrated.
The system is applicable with slightly diminished accuracy with a span of up to 1:20 (1:100 optionally).
For the improvement of the measuring accuracy system-related non-linearities of the LFE as well as of the sensors are compensated arithmetically.

Operating conditions
Since the capillaries of the LFE are easily choked by condensates or particles, LFEs can only be operated reasonably with well filtered gases (or air).
In addition, there may be a temperature restriction by the used materials. E.g., the LFEs of the series 50MK10 are limited to 70℃, since the capillaries are poured in with epoxy resin.
LFEs, which do not intake atmospherically, are operated in closed line systems.

3.2.1.2 Orifices, subcritically operated nozzles

Mode of operation
A constriction causes an acceleration of the flowing medium and results in a pressure drop which can be measured between front and back side as differential pressure (active pressure). The active pressure behaves proportionally to the square of the flow or vice versa: The flow is proportional for the square root of the measured active pressure.
The pressure drop is remaining as a result of the turbulences.

Accuracy
As a result of the very non-linear characteristic curve a good accuracy can only be guaranteed by a very limited span.

Operating conditions
An adequate opening diameter is relatively insensitive against fouling. Due to this simple setup all components can be manufactured by heat-proof material. Another advantage is the small installation length, especially with the orifices. Here an easy replacement is often possible.
Orifices and nozzles are operated in closed line systems.

3.2.1.3 Venturi tubes

For mode of operation, accuracy and conditions of use the same is valid in principle as with orifices, however, the active pressure is measured between the inlet and the narrowest point of the Venturi tube. The soft cross-sectional extension following the constriction has the effect that a part of the flow energy is transformed back to pressure energy, whereby the remaining pressure drop is clearly less than the active pressure. A disadvantage is the clearly longer installation length and the higher costs according to the type of the toroid and conical segments.

3.2.1.4 Pitot tubes, Pitot crosses and similar ones

For mode of operation and accuracy the same is valid as with orifices, in principle, only that the acceleration is not caused by a constriction but by the displacement of the probes.
The operational area differs basically in the fact that the use is not bound to lines, i.e., it is possible outside in principle (e.g., as a speedometer aboard an airplane).

3.2.2 Counter

Counters are incremental or frequency transmitters. It is a common feature of all counters, that there is no valid measurement value as long as no least number of pulses has been entered. Hence, it cannot be avoided that at the beginning of the measurement no measurement result can be displayed and that any measurement result is a gliding and delayed average.

3.2.2.1 Turbine wheel gas meter

Mode of operation
A turbine wheel is rotationally moved by the flow. The rotating speed soon reaches a balance with the flow speed. The rotations are counted.

3.2.2.2 Drum gas meter, rotary piston gas meter, bellows-type gas meter, experimental gas meter

The counters of the enumerated models measure the flowing volume. The medium fills one or several measuring chambers alternately and thus drives a speedometer. As a rule the speedometer supplies only one pulse per each rotation, however, there are also types with a finer resolution.

3.2.3 Miscellaneous

3.2.3.1 Mass flow meters

Mass flow meters measure the transmission of heat which is performed by the flowing media. In addition, a defined surface (or also a wire) is kept on constant temperature in the middle of the pipe. The required electric power is a measure for the transmission of heat and thus for the mass flow.
An advantage is the small pressure loss with high accuracy and small installation length. The main disadvantage is the slowness, since a measurement is only valid in the thermal balance.

3.2.3.2 Overcritical nozzles

The flow of overcritical nozzles in the constriction is limited by the speed of sound. Hence, an overcritical nozzle can be used very well for generating a certain flow which basically depends on the geometry of the nozzle, the speed of sound (depending on temperature) and the density (depending on pressure) before the entry into the nozzle. Typical applications are test leaks and regulation tasks. Nozzles can be put together to nozzle galleries in combination with valves. Therefore different flows can be switched by the combination of different nozzles.

4 Operating Elements

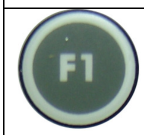
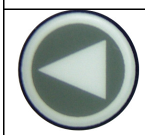
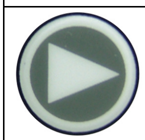
There are two cathegories of operating elements. The first are the keys, displays and interfaces of the controller, the second are the additional keys, LED’s and interfaces of an application containing the controller. The function and meanings of the operating elements of the first cathegory is independent from the controllers usage and periphery.
The number, design and function of the additional operating elements of the second cathegory and of the housing as well are customized and are described in the application specific part of the documentation. At this place can therefore only shown an example.

4.1 Operating elements a the front of the controller S320

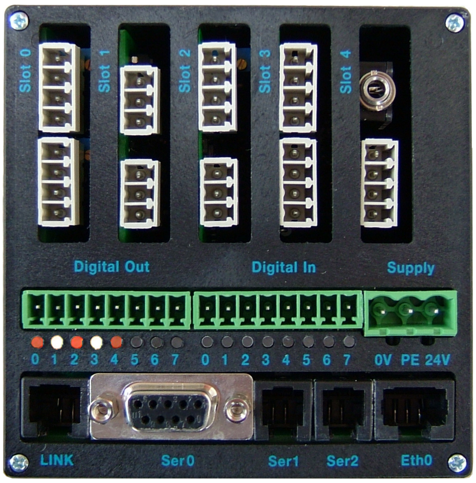
The controller S320 with ist displays and keys is the core of the LMF.

Display
Each of the three display lines contains a 6-digit display for numerical values and a smaller 4-digit display for text. This text is regulary used for displaying the measuring circle, the unit of a value or a identifier for the measurement value. At applications with two measuring circles the first line is assigned to the first measuring circle, the second to the second measuring circle.

Keys

	Key	Function
	F1	Short key pressing in standard mode: Scrolling the measurement and calculation values of measuring circle 0. Short key pressing in test mode: Scrolling the measurement and analog output values of all measuring circles. Long key pressing in standard mode: Changing to the editing mode. Short key pressing in editing mode: Show next parameter. Simultaneous pressing with F3: From test mode: return to standard mode, changes are saved. From editing mode: return to standard mode, changes are not saved.
	F2	Short key pressing in standard mode: Scrolling the measurement and calculationvalues of measuring circle 1. Short key pressing in test mode: Reduction of displayed digits in second display line (raw value) Long key pressing in editing mode: Return to standard mode, changes are saved.
	F3	Long key pressing in standard mode: Changing to test mode. Short key pressing in editing mode: Show preceding parameter. Simultaneous pressing with arrow keys: Changing to program with higher or lower program number Simultaneous pressing with F1: From test mode: return to standard mode, changes are saved. From editing mode: return to standard mode, changes are not saved.
	Arrow left	Simultaneous pressing with F3 in standard mode: Selects a program with lower program number. In test mode: Restores the value of the sensor without zero adjustment. Decrements an analog output value (if currently shown) In edit mode: Decrements the value of the displayed parameter.
	Arrow right	Simultaneous pressing with F3 in standard mode: Selects a program with higher program number. Long key pressing in test mode: Zero adjustment of the shown measurement value. Incrments an analog output value (if currently shown) In edit mode: Increments the value of the displayed parameter.

4.2 Interfaces at the rear of the Controller S320



Interfaces of the controller.
(Example, assembly customized)

Slots for interface modules
The controller has 5 slots that can be used for interface modules. The identifier for the slots is printed on, from left to the right with “Slot 0” to “Slot 4”. The interface modules for analog-digital converting (and vice versa) regulary provide each two analog devices. That means, they regulary have two ports. The upper port is named “port0”, the lower “port1”. If cables to the analog devices are deliverd, the conectors are equipped with a sticker with a token. The token identifies the slot and port, the connector has to be pluged to. The pattern is “Sl<slot number>/<port number>”.
Example: “SL3/1” stands for slot 3, port 1, that means the 4th column, bottom.

Integrated digital contacts
The each 8 outputs and inputs can be used for additional operating elements, regulary for keys and their illumination. As integrated digital contacts the are not isolated by using an optocoupler. If isolated or additional digital contacts are needed, you require one or more digital expansion modules, that are driven by an interface module of type 400.
Maximum load for each contact: 24V/500mA

Supply
Supply of the controller
From the left to the right:
0V, PE, 24V

Link
Serial programming interface. Connector for a laptop or PC with a serial cable (1:1, 9 poles). Is used by the S320 terminal program, e. g. to transfer the control program, the operating system or the configuration file.

Ser0
Serial RS232 interface for exchange of ASCII data. Used to querry or change parameter values, to querry measurement values or to send remote control comands.

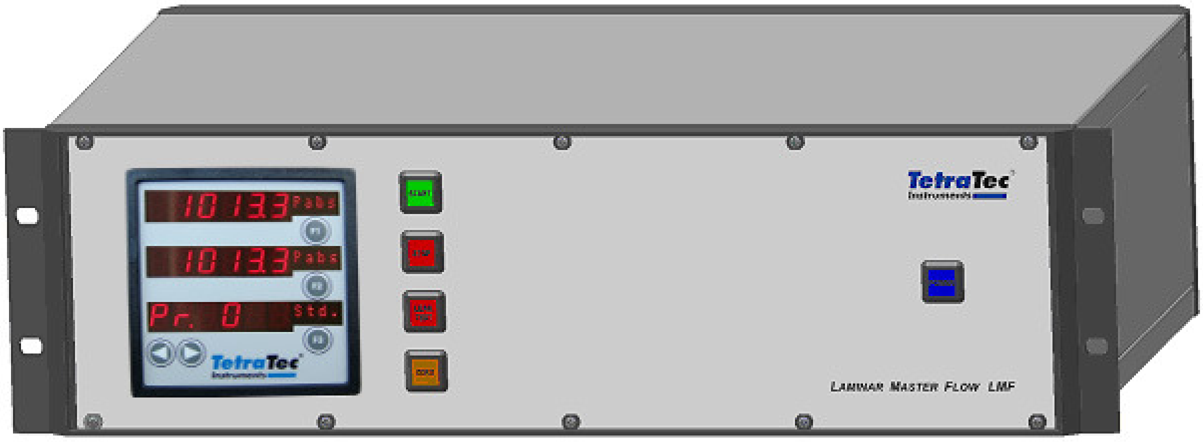
Ser1
Serial RS485 interface, regulary used to network several controllers.

Ser2
Serial RS485 interface, regulary used as bus for serial sensors.

Eth0
Ethernet interface.

4.3 Additional front sided operating elements when built in a horizontal 19“ housing

Note:
This can only be an example. The concrete application can have less or more operating elements, they can have a different design. Totally different housings can be used. It is possible, that more than one controller is built in. Illustration and description correspond to the most prevalent configuration.



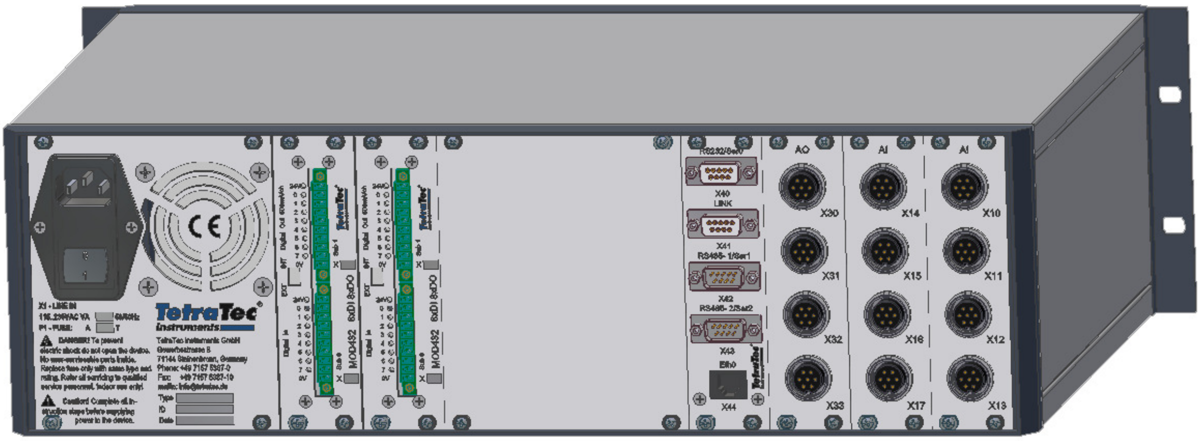
LMF front side (example)

Keys

	Key	Function
	POWER	Switches the device on and off (main switch musst be on). POWER does not separate the device from power. Do do this, use the main switch (in most cases at the rear side) or pull the plug.
	START	Starts a process of the application, e. g. an averaging measurement.
	STOP	Finishes a started process ahead of time (e. g. an averaging measurement or a leakage test). Finishes the display of results of a measurement. Is equivalent to the combination of the keys „F1+F3“ of the controller, to return to standard mode from test mode or editin mode.
	LEAK TEST	Starts a leak test (optional).
	ZERO	Starts a zero adjustment of differential pressure sensors (optional).

4.4 Rear sided interfaces when built in a horizontal 19“ housing

Note:
This can only be an example. The concrete application can have a different number and different types of interfaces. The interfaces can be different placed. Additional pneumatic interfaces are possible. Totally different housings can be used. Illustration and description correspond to a very rich equipped configuration.



LMF rear side (example)

Interfaces of the example from the left to the right

Power connector	With main switch, fuse, fan and type plate (serial number). The 2-pole main switch separates the device from power. Before connecting the power line make sure, the voltage is correct!
Digital interfaces	Digital in- and outputs, the optocouplers can be alternatively supplied internal or external. Depending on the type of the digital expansion modul there are 16 inputs, 16 outputs, or 8 in- and 8 outputs. Digital interfaces of these types are used e.g. for a remote operation modul, to control solenoid valves, to evaluate switches, or as an PLC interface. The later can be transduced as a 39-pole or 40-pole socket through an IP54 housing.
Serial interfaces	Here the serial interfaces and the ethernet interface of the controller are transduced. The RS485 interfaces are additionally terminated. The serial interfaces can be placed from the rear to the front side (as ordering option).
Analog outputs	Analog outputs are marked by the token „AO“. They are used for analog measurement value export, or to control devices with analog input signal, e. g. servo valves.
Analog inputs	Analog inputs are marked by the token „AI“. They are used for external analog sensors.

5 User Guidance for Operation

Due to the modular structure and great flexibility of the evaluation and control module of the Controller S320, the **LMF** can be configured and used for a great number of different tasks. Depending on hard- and software design some devices are limited in function support and setting. Nevertheless, every device can be adapted to additional or extra tasks.

Depending on the software the device can perform measurement and control of pressure, flow, leakage and leak test all in one. This provides for the user a unique and effective way of solving measurement problems.

The design of the new series of the LMF is to blend all possible applications concerning gas flow measurement and control with pressure control and measurement tasks (formerly performed by the PCS - Pressure Control System, its counterpart for pressure) using only one control and evaluation unit.
Hereby it was central to keep the particular qualities of precision and speed of the two lines of measuring devices. At the same time flexible ways of linking units with each other and connecting them to the master computer were created by integrating various serial interfaces (RS 232 and RS 485).

Free programmability of the controller S320 provides considerable intelligence in the field together with a new form of autonomy and self-sufficiency of the sub-system. This way complex measurement and control functions can be started up separately and connected simply to the master control system.

By introducing sets of parameters a homogenous and unique user surface for all the different applications is reached. The overall structure of this list is laid out in such a way, that all the measurement and control tasks that the controller performs simultaneously may be adjusted using the same structure of parameters. This is designed to facilitate the use of different systems of measurement performed by the Controller S320 and to allow a transparent handling for users and personnel in charge of the system.

In its standard-version as a calibration device the LMF can be used for measuring of volume flows. The gas data and sensor signals will be collected by the sensors for differential pressure, absolute pressure, temperature and relative humidity. This data serves to calculate the actual volume flow, mass flow and standard volume flow.

In the version as a test bench measuring device the hardware is extended by additional digital in- and outputs to be connected e.g. to a PLC.

An additional hardware equipment will be necessary depending on the additional measurement and control functions of the controller in pressure control and leak testing. The installed software also depends on the hardware and measurement requirements. The software can be adapted easily when the device is extended.

The general structure of the parameters described below applies to all versions of the device regardless of concrete applications.

5.1 Standard Mode

The standard mode is indicated by the text "Std." in the lowest display. In this mode of operation all calculation and measurement data will be displayed continuously. Pressing the function keys F1 to F3 the displays of all measurement and calculation data can be toggled through, starting from the standard display set. The standard display setting can be changed at the editing mode

5.1.1 Program selection for single section devices

Switching of programs is also available by the display function keys. Pressing of F3 shows the topical program. Holding F3 and simultaneously pressing of the arrow keys < or > will change the program immediately.

5.1.2 Program selection for double (triple) section devices

Pressing of F1 shows the topical program of the 1th measuring circle. Holding F1 and simultaneously pressing of the arrow keys < or > will change the program immediately.
Pressing of F2 shows the topical program of the 2nd measuring circle. Holding F2 and simultaneously pressing of the arrow keys < or > will change the program immediately.
Correspondingly with the 3rd measuring circle with F3 and simultaneously pressing of the arrow keys < or > will change the program.

5.2 Leak test

This mode serves to test the measuring circle for leakage. Leakages in the measurement system are the most frequent source for measurement errors and deviations. This function will help you to test the test sample and reference device for leakage using the pressure drop method.
Fill the system with pressure above or below atmospheric and then close the pressure supply. The leak testing button will switch the device into the leak testing mode. For status information a red LED will blink now. The parameters S8001 to S8007 define the display options and the measurement period. After the pressure drop measurement the result of the measurement will be shown.

P0:	pressure value at the beginning of the test
P1:	pressure value at the end of the test
Pmin:	lowest pressure value while testing
Pmax:	highest pressure value while testing
dpdt:	pressure difference per period

The results are calculated as follows:

$$\text{Pressure difference per period} = \frac{\text{start pressure} - \text{end pressure}}{\text{mesuring period}}$$

Pressing the STOP button will set back this special operation mode into the continuous measurement/standard mode.

If desired the LMF can be equipped with an alternative leakage test, see Chapter 7.1.11 S8000-Block: Special function: Leakage test, page 47.

5.3 Measurement with averaging

In the measurement mode all data are collected cyclically. All flow data are calculated and displayed. To obtain an average value of all sensor measurement data and calculated flow rates perform the following operation:
Pressing the START - button or the serial command “meas” switches the device from standard mode of continuous measurement into the averaging measurement mode. The start button starts the averaging operation according to the setting of the measurement period. Simultaneously the time of measurement is shown on the display. All current data of measurement are displayed. After the time of measurement the LED-display stops. On the display all averages as well as minimum/maximum data of flow and measurement rates are shown. They can be toggled through using the F1 key.
To stop the measurement mode press the STOP button to switch the device from the display of the results back into the standard mode continuous measurement. Pressing the STOP button while being in the measurement mode also allows for shorter times of measurement and stops the time of measurement at once. In this case the STOP button needs to be pressed a second time, in order to set the device back into the standard mode.

Note: If there are two measuring circles, the values are marked with 0 for section 0 and with 1 for section 1.

References concerning measurement programs:

Setting the Parameter S1000 allows to fix the standard selection of one of the 10 measurement program data records, numbered 0 to 9 after power on.

The individual settings allow a preconfiguration of each of the programs for a different application and easy selecting the program if needed.

5.4 Special functions for the experienced user:

5.4.1 Test mode

Pressing the function key F3 or sending the command "test" via the serial interface the controller goes into the test mode. Here the raw values of the connected sensors can be shown and checked for plausibility. Simultaneous pressing of F1 and F3 keys or pressing of the STOP-button leaves this mode.

This mode serves to edit the raw values of the input and output signals and allows zeroing / nullification of the sensors. The channel selection is made by pressing the F1-key. For a better resolution the digits of the values can be adjusted using the F2-key.
The < >-keys serve to zero the signal input newly or to change values for the analog output.

5.4.2 Operation with serial Interface RS232

Changing and requesting (scanning) the parameter settings via the serial interface can be performed with any commercially available terminal program in the ASCII-mode. The parameter settings for the serial interface according to RS232 are set at the configuration file and in the system parameters.

Basic behaviour is fixed at the hardware configuration file:

Baud-Rate:
The rate of transmission of the RS 232 interface
9600Baud .

Parity:
Adjustment of the parity bit.
NONE (no parity bit)

Stop bits:
Number of stop bits of the RS 232 transmitter
1 Stop bit
(the receiver is always adjusted to 1 Stop bit)

Handshake:
Adjustment of the Handshake-procedure:
none
neither RTS/CTS (only Hardware-Handshake),
nor XON/XOFF (Software-Handshake)

Adjustment of response format at the system parameter:

S0007:
The Parameter defines whether the system gives an echo answer for commands

S0008:
The Parameter defines the string end characters (CR, CRLF, LF)

Other adjustments available by request.

Notes:
The syntax of the strings is described at chapter 4.2.2 and following.
The Syntax of the serial interface is described in the following sections:
6.2.2.2 Editing using the serial interface
6.2.3 Inquiring measurement values
6.2.4 Remote control functions

5.4.3 Nullification

After changing the position or place of a differential pressure sensor an offset adjustment may be necessary, if it is position dependent. We recommend additional regular offset adjustments due to long time drifts.

Notes:

- Only the offset of differential pressure sensors and gauge pressure sensor may be reset.
- The zero adjustment only makes sense when there is absolutely no flow or pressure. Is this not sure the hoses at the differential pressure sensor must be disconnected and the connections must be linked with each other using a small piece of hose that is slipped on (in condition of draught/ventilators near the sensors).
- After switching on the device there should be a waiting period of at least 30 minutes to allow the device and the sensors to balance thermically. If thermostatic sensors are used the waiting period may be up to 4 hours! In this case device or sensor heat supplies should be switched on permanently.
- Unter certain prerequisites an automatical and cyclic offset correction of the differential pressure sensor ist available, see section 7.2.22 “Offset correction of the differential pressure sensor”.

5.4.3.1 Nullification using the function keys

The device must be in continuous operation and test mode. Devices in plc operation must be set to continuous operation first.

- To enter the edit mode press fuction key “F1” for 3 seconds.
  The display shows the strings “LEVEL”, “0”, “OK”.
- Change the Level with key “>” to level 1 and confirm with key “F2”.
  The display shows the strings “PASS”, “0”, “OK”.
- With key “>” change the password to “1” and confirm with key “F2”.
  The edit mode is active now, the display shows the system parameters “S 0000”, “0”, “ID”.
- Change to parameter “S 0010” using the keys “F1” and “F3”. Key “F1” selects the next bigger, “F3” selects the next smaller parameter.
  The display shows the strings “S 0010”, “1”. “ID”.
- Change the value to 0 using the key “<”.
- To confirm, press the key “F2” for at least 3 seconds.
  The confirmation is indicated by the flashing string “save”.
  The controller is in continuous operation now.

- To reach the test mode, press the key “F3” for 3 seconds.
  The display shows the string “Test” a raw data and the corresponding value.
- With the “F1” key toggle to the values of pdiff and prel sensors.
- To adjust a value to zero, press the key “>” for 3 seconds.
  The averaged offset will be subtracted.
- You can cancel the adjustment with the key “<”. By this way you can see the long time drift, if the sensor was not moved.
- To save the new adjustment press the key “Stop” or press the keys “F1” und “F3” at the same time.
  The saving is confirmed by the flashing string “save”. The Controller is back in the continuos mode. You can power on your pressure.

We recommend to check the offset again (press several times “F1” until the string “Pdiff” is shown). Offsets up to +/- 0,03 mbar can be adjusted. Exeeding offsets indicate a leakage.

For PLC operation the system parameter has to be set back to 1 by the following steps:

- Press the key “F1” for 3 seconds.
  The display shows the strings “LEVEL”, “0”, “OK”.
- Change the Level with key “>” to level 1 and confirm with key “F2”.
  The display shows the strings “PASS”, “0”, “OK”.
- With key “>” change the password to “1” and confirm with key “F2”.
  The edit mode is active now, the display shows the system parameters “S 0000”, “0”, “ID”.
- Change to parameter “S 0010” using the keys “F1” and “F3”.
  The display shows the strings “S 0010”, “0”. “ID”.
- Change the value to 1 using the key “>”.
- To confirm, press the key “F2” for at least 3 seconds.
  The confirmation is indicated by the flashing string “save”.
  The controller is in PLC operation now.

5.4.3.2 Nullification using the serial interface

If the LMF is integrated in fully automated installations controlled by PLC, it can be necessary, to perform the nullification automatically. This can easily be achieved using the serial interface. For details concerning the usage of the serial interface see chapter 6.2.2.2, for the basics concerning the nullification see chapter 5.4.3. The nullification using the serial interface follows the scheme illustraded by the following example, where a differential pressure is adjusted to zero:

1. Querry the current offset from parameter S2030. The LMF replies S2030=+1.0000000E+00” for example.
2. Querry the actual value using the read parameter R0001. The LMF replies R0001=+1.2000000E+00” for example.
3. Calculate the actual offset as the addition of the current offset and the actual value, in our example:
   (S2030 + R0001) ~ 1.0000000E+00 + 1,2000000E+00 = 2.2000000E+00 ~ S2030 (new!)
4. Send the new offset as the string “S2030=+2.2000000E+00”.
   The LMF replies “S2030=+2.2000000E+00”.
5. Save the current settings
   a) Power-failure-proof with the command “save”
   b) Temporary with the command “temp”.

Note:
If the offset is adjusted cyclically (once a day or more often) you should use the command “temp”. This takes less time and spares the flash ROM, which can be rewritten only finite times.

5.4.4 Network operation of several devices (Option)

Up to LMF version 4 all measurement systems from TetraTec Instruments GmbH can be connected with each other by RS485 bus similar like Ethernet (option upon consultation).
An unique bus address is assigned to each of the measurement systems. Via RS232 a PC can be connected to an arbitrary measurement device. All informations of all connected measurement devices are available to this PC on basis of the RS485 addresses. Therefore the character “A” and the two digit bus address (S0005) has to be pre added to the command. Please note that the RS 485 bus needs a termination! Devices with PLC interface this termination always is integrated.
If your PC is equipped with a RS 485 interface card, it can directly communicate with all devices by this.
Devices with LMF version 5 or higher can be connected with each other by LAN. Therefore RS485 interconnections are not supported by that devices.

5.4.5 Data collection (Option)

Due to customer requirements for each measurement system a “DATA” command can be defined. In a “DATA” command up to eight measurement values can be collected. The measurement values are data of type flow with a unit of choice, separated by blank or an other character of choice. Each “DATA”-reply can be pre added a date and time stamp, a shortcut of the measurement system, or the RS-485 address of the subsystem. The “DATA” commands can be querried like each other parameter via a connected subsystem.

It is an essential feature of the “DATA” command, that the measurement values are buffered until the next “DATA” set overwrites the buffer. Therefore the values can be querried in a relatively long time, for example during an automatical test sequence is running.
By this time, for each measurement system two “DATA” commands are projected. These are described in the following:

1. Command “data”
   In this data set the parameters, that are defined by the command “dat0”, are given in plain language.
2. Command “dat0”
   In this data set the desired measurement values are defined. The measurement values are available principally only after a measurement. The measurement can be started manually in manually mode or is started automatically by a PLC command.

5.4.6 Measurement ranges and linearization

The **LMF** supplies up to 5 measurement ranges for each primary, e.g. five complete calibration records for each primary element may be stored. Hereby the device can be configured for different measurement and calibration tasks.

These may be evaluated with up to 10 linearized sensors.

In the systems parameter block S2xxx and S5xxx to S7xxx the coefficients for linearization of the used sensors and primary element are defined. In the programm definitions these can be defined as active measuring sensors and flow elements. If a certain program is activated, these specific sensors are evaluated.
A change of the linearization coefficients is only necessary when a sensor or a primary element needs to be exchanged or calibrated anew due to change of its characteristics.

6 Configuration of the LMF

6.1 User guidance through configuration

Setting and configuration of the **LMF** is supported by a clear structured parameter set.
Each parameter is composed of an identification letter and a 4 digit number.
The parameters may be changed through the serial RS232-interface as well as through the front keys. A simultaneous change over the serial interface and the front keys is not permitted. Changing the parameters over the serial interface can be performed using any commercially available terminal program operating in the Ascii-mode. Every change should be concluded by SAVE, TEMP or EXIT (quit).
Pressing the function key F1 for at least 3 seconds will open the editing mode and allow the changing of the parameter through the LED-Display. The parameters are shown on the LEDs. Using the function keys F1 and F3 (Up and Down) one can scroll through and select the parameter; the values of the parameter can be set pressing the arrows left (<) and right (>) keys. After changing pressing the F2-key for 3 seconds causes SAVE and simultaneous pressing of F1 and F3 EXIT (quit without saving).

6.2 Setting of parameters

Note: Depending on the available hardware and used software sometimes not all parameters are available. See chapter 5 where these parameters are marked.

6.2.1 Password shelter

To change parameter configuration / setting in the field at the device via the front keys, press F1-key to enter the editing-mode. Before opening the list of parameters the device will ask you the level, in which changes are to be performed:

Level 0: Only test limits, test periods and program selection
Level 1: All parameters of the device except linearization (S2xxx to S7xxx)
Level 2: All parameters

The level is adjusted by pressing the arrow keys < > left / right. To confirm input press F2.
Next a "Code" = Password (4-digit number) is required. This password may be adjusted differently for each level (Parameter S0000 to S0002). Ex works the definitions are as follows:

Level 0: pass = 0
Level 1: pass = 1
Level 2: pass = 2

The password may be adjusted as a 4-digit number by using the arrow keys < > left / right to fix the value. Once again the input is confirmed by pressing F2. Only now access is granted to the list of parameters corresponding to the adjusted level.

6.2.2 Editing mode

Pressing the function key F1 for at least 3 seconds will open the editing mode and allow the changing of the parameter through the LED-Display. After entering the password the first parameter is shown on the LED-display. Using the function key F1 the next parameter of the list is shown and by pressing F3 (Up and Down) the later. In the first LED line parameter number of the selected parameter which is edited will be shown. It consists of a letter S (system parameter) or P (program parameter) and a 4 digit number. The values of the parameter can be set pressing the arrow keys left (<) and right (>). After changing pressing the F2-key for 3 seconds will SAVE the changed values. The changed will then be written into the persistant data area of the Flash ROM.

Simultaneous pressing of F1 and F3 will EXIT (quit without saving) the edit mode without that the changes getting valid. Pressing the Stop button, if available, will perform the same function (Quit).

6.2.2.1 Editing using front keys:

The parameter editor allows changing of the (mainly numeric) parameter. The editor is active as long as it will be left by „SAVE“ or „EXIT“ again.

Numeric parameter:

This can be whole numbers, decimal digit numbers or numbers in exponential representation.

Numbers in exponential representation:

The fixing of the values is performed by pressing the keys < or >, shortly pressing of the F2-key will switch to editing of the exponent. The later can be changed again by pressing the< , > -keys. The range of the values of the multiplicator is between
-9.9999< -1.0000 and 1.0000 > 9.9999. By pressing the F2-key again the displayment of the decimal digits (only valid during entering for comfortable adjustment) can be changed. Hereby the last in front of the F2-key placed decimal digit can be changed by pressing < , > and by pressing of F2 again the next decimal digit will be moved in to fix it.

Decimal digit numbers:

Decimal digit numbers are always combined with a physical unit. The adjustment of the values also can be done by using the < , > -keys, shortly pressing of the F2-key will switch the editor to the physical unit. The later can be changed again by pressing the< , > -keys. The range of the values is between -9.9999 and 9.9999. If the physical unit is changed the correlated values will be calculated correspondingly, so that a comfortable adjustment is possible.

Whole numbers:

The adjustment of the values is done by the < , > -keys.

Selection parameter:

They are non-numerical parameter with fixed values, that can only be toggled through (Toggle-Parameter). The adjustment can only be done by the < , > -keys.

„SAVE“ or „EXIT“ again is done as described above.

6.2.2.2 Editing using the serial interface

By sending Pxxxx? the parameter xxxx can be displayed.
Sending Pxxxx= .... the parameter will be changed to the specified value.

xxxx here is the number of the parameter’s address. The four number are obliged.

Using the letter x at questioning has the function of a joker sign (Wildcard-Function). Using instead of x a number value, will filter the questionaire result. By doing so for example selected parameter blocks can be received.

The mentioned syntax is valid correspondingly for the system parameter, where instead of the letter P the letter S is used.

During editing from the display of the Controller S320, no values can be changed from the serial connection RS 232. Are there first values be changed via the serial connection, but yet not confirmed by Exit or Save, so no values can be changed from the display side at the same time.

<u>Syntax of the different number formats:</u>

Numeric Parameter:

<u>Numbers in exponential representation</u>:

By Editing of parameter in exponential representation the following syntax is used:

```
P????= #.#######E+##
S      +          -
       -
```

Equivalent is the possibility to enter the numbers as decimal digit number:

```
P????= #.#######
S      +
       -
```

The number of decimal digits as well as the digits of the exponent are varying.

<u>Decimal digit numbers:</u>

By editing of a parameter in decimal digit representation the following syntax is used:

```
P????= #.#######
S      +
       -
```

The number of decimal digits are varying.

Each numeric parameter which in the display edit mode is represented by a decimal digit number with physical unit, will be displayed via the serial RS 232 connection in exponential representation.

<u>Whole numbers</u>:

Editing of parameters, which allow only whole numbers to enter, the syntax is as follows:

```
P????= #######
S      +
       -
```

The number of digits is varying.

Note: Is a value linked with a physical unit, it always has to be converted into the corresponding value in the SI-unit before entering. The parameter values entered via the serial connection RS 232 always has to be entered in SI units. Statements of the physical unit via RS 232 are not allowed.

Selection parameter:

Editing of selection parameters the following syntax is used:

```
P????= #######
S      +
       -
```

Selection parameter only can have fixed values in allowed limits.

6.2.2.3 Error messages:

- **Conversion not possible**: Appears if a number can not be converted into the desired number format.
- **No match**: Appears if a entered parameter will be recognized as a parameter but is not supported in the topical version.
- **Value below minimum!:** Appears if a entered number is below the minimum of its value range.
- **Value exceeds maximum!**: Appears if a entered number is below the maximum of its value range.
- **Illegal Command**: Appears if a entered code or command is not known.

6.2.3 Inquiring measurement values

The inquiry of the measurement and calculation values is similar to the description above:

Rxxxx provides all result values (in exponential representation and SI-units), xxxx is the number of the result as listed in chapter 5. The four numbers are absolutely necessary. Special meanings have:

Rinpu[t] - Provides only input values
Rflow - Provides only flow values
Ratio - Ratio of the standard volume flows of measuring circle 0 to section1 (only double section device)

Notice: At inquiring of measurement values the above explained number formats are used. Are values linked with a physical unit the unit will be displayed at the serial inquiry. The physical unit and the value are separated by a blank sign.

6.2.4 Remote control functions

When a serial connection to a device is established, after pressing the enter key of the PC the device replies “Type Help for details”. This confirms the correct function of the serial interface. After entering “help” and pressing the enter key, the terminal program displays the following help:

```
Set parameter  : 'Sxxxx=value', 'Pxxxx=value'
Query parameter: 'Sxxxx'      , 'Pxxxx'
Query result   : 'Rxxxx'

Save changes   : 'Save'
Reset changes  : 'Exit'
Set mode       : 'Test'
Stop function  : 'Stop'
Query state    : 'Stat'
Sensor  Snr    : 'SSNr*[=....]' * 0..9
LFE,UFL Snr    : 'LSNr*[=....]', LFE: * 0..4, UFL: * 5..9
Ser.PDP Data   : 'SerPDP*', * 0..9
Vers           : 'Versionsabfrage'
```

With the following meanings:

Save	- Stores the altered parameter power failure safe.
Exit	- Quits all the alterations.
Temp	- Applies changings temporarily, after power off they are lost.
Meas	- Switches to operation mode measurement with mean value (corresponds to START-button)
Leak	- Switches to operation mode leak testing
Test	- Switches to operation mode sensor testing
Stop	- corresponding to function of STOP-button
Vers	Lists the version of the software

STAT allows to control the operation state providing one of the following answers:

READY	: Ready for input of new operation
FAIL	: Error in sensory analysis
BUSY	: Test/measurement still active
EDIT	: Controller is in manual input mode

6.3 Structure of parameter and overview

Each parameter is composed of an identification letter and a 4 digit number (as shown above). According to their function they may be grouped into the following containing units:

6.3.1 System parameter

In the systems parameter range all the basic and comprehensive settings and configurations are performed. It is composed as follows:

S0000-block: General parameters
S1000-block: Measuring circles and analog outputs
S2000-block: Linearization of sensors
S5000-block: Linearization of Laminar Flow Elements; Hagen-Poisseuille calculation
S5500-block: Linearization of Laminar Flow Elements; universal flow calculation
S6000-block: Linearization PD-meter
S6500-block: Linearization sonic nozzles
S7000-block: Linearization orifices
S7500-block: Linearization accutubes
S8000-block: Special function leak check
S9000-block: Special functions

At the system parameters the settings of the serial interface RS232, of the analog outputs, the sensor and primary element linearization data and determination of special functions are defined.
The definition of the measuring circles and their assignment to the measurement programs serves to simultaneously prepare results for parallel running measuring circle in different hardware composition and their result readings.

Measuring circles are active simultaneously. Each measuring circle can be configured by one of the ten available programs. The analog outputs also can be dedicated to an active measuring circle. The detailed configuration of the analog output (scaling) is done in the program parameter section.

6.3.2 Measuring programs

In the 10 measuring programs 10 different configurations of the measuring system can be defined. Here the type of gas, the assignment of the flow elements and sensors, the setting and scaling of the measuring ranges, representation in engineering units and decimal digits, measuring times, limits, display, scaling and assignment of the analog output etc. are defined.

Px000-block: Primary element, basic description
Px010-block: Differential pressure
Px015-block: Direct mass flow input
Px020-block: Absolute pressure
Px030-block: Temperature
Px040-block: Humidity
Px050-block: Reference absolute pressure
Px060-block: Reference temperature
Px070-block: Reference humidity
Px080-block: Gauge pressure
Px100-block: Volume flow
Px120-block: Mass flow
Px140-block: Density
Px160-block: Viscosity
Px400-block: Control
Px500-block: Test limits
Px700-block: Process times
Px800-block: Display options
Px900-block: Analog outputs

x: index for measuring program running from 0 to 9

6.3.3 Measuring results of measuring programs, Readparameter

The Readparameter are designed to obtain direct and fast results of measurement and calculation. All values are listed in the Ryxxx-block:

Ryxxx-block: Results according to the definition of the measuring circle

y: index of measuring circle running from 0 to 2 (single to triple section)

y contains the measuring circle (e.g. y = 0 is the first section and y = 1 is the second section at the double section device). “xxx” is the number / address of the result value as listed in the Ryxxx-block.

The syntax of the answers is the same as that of numbers in exponential representation as described before.

7 List of parameters

7.1 System parameter

7.1.1 S0000-Block: General parameter

S0000	Code Level 0	0...9999 [0]	Password Level 0	
S0001	Code Level 1	0...9999 [1]	Password Level 1	
S0002	Code Level 2	0...9999 [2]	Password Level 2	
S0005	Bus address RS485 network	0 .. 99 [1]	Bus address using several systems from TTI*) together	
S0006	Baud rate of the serial interface ser0	0..6 [4]	0: 300 Baud 1: 600 2: 1200 3: 4800 4: 9600 5: 19200 6: 38400	
S0007	Serial answer RS232 Local Echo	0-1 [0]	0: no Echo 1: Echo	
S0008	Serial answer RS232 String end sign	0 .. 3 [0]	0: CRLF 1: CR 2:– LF 3: ETX	
S0010	Mode of Operation	0 .. 2 [1]	0: Continuous 1: PLC automatic 2: PLC step operation	***)
S0011	Number of passes	1 .. 999		***)
S0012	Next program (if S0011>1)	0 .. 1	0: remain in actual program 1: next program	
S0101	Standard condition absolute pressure	[100000.0]	in Pascal	
S0102	Standard condition Temperature	[293.15]	in Kelvin	
S0103	Standard condition Humidity	[0.0]	in 0..1 rH.	
S0300	Ring buffer analog inputs, damping	1…5 [5]	Calculating the average of n measurement values	
S0301	Cycle period of program	0.1	in seconds, only for information	
S0311	Display-Update	1-20 [3]	Display-reading only every n-th program cycle	

***) only PLC-device

Table 1: S0000-Block: general Parameter

7.1.2 S1000-Block: Program selection and analog outputs

A measuring setup with a set of sensors for evaluation of a flow element is called a measuring circle. The Laminar Master is able to calculate upto three measuring circles simultaneously.
Each measuring program definition can be assigned to a measuring circle. The analog output can also be assigned to an active measuring circle. The detailed settings of the analog output are done in the measuring program definition (Px900).
The parameter S1101 to 1104 do only exist, if the hardware includes analog outputs.

S1000	Measuring circle 0 (single (first) section)	0 .. 9	Assignment to measuring program 0-9	
S1001	Measuring circle 1 (double (second) section)	0 .. 9	Assignment to measuring program 0-9	*)
S1002	Measuring circle 2 (triple (third) section)	0 .. 9	Assignment to measuring program 0-9	*)
S1010	Lowest valid program number measuring circle 0	0 .. 9	Assignment to measuring program 0-9	
S1011	Lowest valid program number measuring circle 1	0 .. 9	Assignment to measuring program 0-9	*)
S1012	Lowest valid program number measuring circle 2	0 .. 9	Assignment to measuring program 0-9	*)
S1020	Highest valid program number measuring circle 0	0 .. 9	Assignment to measuring program 0-9	
S1021	Highest valid program number measuring circle 1	0 .. 9	Assignment to measuring program 0-9	*)
S1022	Highest valid program number measuring circle 2	0 .. 9	Assignment to measuring program 0-9	*)
S1030	Use limits of measuring circle 0, defined in Px511 to Px513	0 .. 2	0: of 1: limits (good/bad) 2: automatical program switching Px512 back switching limit Px513 foreward switching limit	
S1031	Use limits of measuring circle 1, defined in Px511 to Px513	0 .. 2	0: of 1: limits (good/bad) 2: automatical program switching Px512 back switching limit Px513 foreward switching limit	*)
S1032	Use limits of measuring circle 2, defined in Px511 to Px513	0 .. 2	0: of 1: limits (good/bad) 2: automatical program switching Px512 back switching limit Px513 foreward switching limit	*)
S1035	Waiting time for calming after a automatical program switch	0 .. 300	Time in seconds until Px512 is established	
S1101	Analog output 1	0 .. 1	0: Off 1: Active / On	**)
S1102	Analog output 1	0 .. 1	Assignment to measuring circle y	**)
S1103	Analog output 2	0 .. 1	0: Off 1: Active / On	**)
S1104	Analog output 2	0 .. 1	Assignment to measuring circle y	**)

*) only double section or triple section device
**) only if existent

Table 2: S1000-Block: Program Selection and Analog Outputs

7.1.3 S2000-Block: Linearization of Sensors / Analog Channels

x: Number of Sensor Channel:

x = 0 Sensor 0, connected to Slot 0 Port 0
x = 1 Sensor 1, connected to Slot 0 Port 1
x = 2 Sensor 2, connected to Slot 1 Port 0
x = 3 Sensor 3, connected to Slot 1 Port 1
x = 4 Sensor 4, connected to Slot 2 Port 0
x = 5 Sensor 5, connected to Slot 2 Port 1
x = 6 Sensor 6, connected to Slot 3 Port 0
x = 7 Sensor 7, connected to Slot 3 Port 1
x = 8 Sensor 8, connected to Slot 4 Port 0
x = 9 Sensor 9, connected to Slot 4 Port 1

Querry of the integrated sensors serial numbers (block S2000)

SSNRx	Sensor chanel number x, serial number	0 .. 9	Querry serial number	

S2x00	Type of Linearization Channel / Sensor	0 .. 2 [0]	0: Polynome calculation 1: PT100/PT1000 Linearization 2: without Linearization (raw values)	
S2x01	Display sensor error if the current of 4 – 20mA transmitters is below 3.5mA	0 .. 1	0: inactive 1: active	
S2x02	Display sensor error if the raw value exeeds the limit S2x03 or S2x04	0 .. 1 [0]	0: inactive 1: active	
S2x03	Minimal valid sensor raw value	[0.0]		
S2x04	Maximal valid sensor raw value	[2.0]		
S2x05	Linearization SENSOR x Order of the polynome	1 .. 9	Order of polynome	
S2x10	Linearization SENSOR x Coefficient order 0		Coefficient order 0; a(0)	
S2x11	Linearization SENSOR x Coefficient order 1		Coefficient order 1; a(1)	
S2x12	Linearization SENSOR x Coefficient order 2		Coefficient order 2; a(2)	
S2x13	Linearization SENSOR x Coefficient order 3		Coefficient order 3; a(3)	
S2x14	Linearization SENSOR x Coefficient order 4		Coefficient order 4; a(4)	
S2x15	Linearization SENSOR x Coefficient order 5		Coefficient order 5; a(5)	
S2x16	Linearization SENSOR x Coefficient order 6		Coefficient order 6; a(6)	
S2x17	Linearization SENSOR x Coefficient order 7		Coefficient order 7; a(7)	
S2x18	Linearization SENSOR x Coefficient order 8		Coefficient order 8; a(8)	
S2x19	Linearization SENSOR x Coefficient order 9		Coefficient order 9; a(9)	
S2x20	Linearization SENSOR x X-factor		Scaling value between sensor raw value and polynome (SI based)	
S2x21	Linearization SENSOR x Y-factor		Scaling value between polynome and physical representation (SI based)	

S2x30	SENSOR x Offset value		sensor zero value in SI-based units	
S2x31	SENSOR x Offset operation	0..1	0: Compensation before linearization 1: Compensation after linearization	

Table 3: S2000-Block: Linearization of Sensors / Analog Channels

Note:
The linearization procedure for the sensors is described in chapter 9.1. Changing the coefficients causes the loss of the calibration. Therefore changing the coefficients normally is reserved to employees of the TetraTec Instruments GmbH.

7.1.4 3000-Block: serial sensors at Ser2 (RS 485)

X: Number of the serial sensor channel (0…9)

S3x00	Preselection of sensor type, channel assignment for Ser2	0 .. 2	0: direct input, uncalled sending, RPT for example. This type can be used only once and not in combination with other types. (This parameter replaces the former command –3 for sensorport) 1: PDP, input for differential pressure 2: PDP, input for static pressure	
S3x01	PDP RS 485 address	0 .. 99	PDP RS 485 address	
S3x02	Display sensor error, if sensor raw value exeeds limit S3x03 or S3x04	0 .. 1 [0]	0: inactive 1: active	
S3x03	Minimal valid sensor raw value	[-0.98]		
S3x04	Maximal valid sensor raw value	[+0.98]		
S3x05	Linearization SENSOR x, order of polynom	1 .. 9	Order of polynom	
S3x10	Linearization SENSOR x coefficient order 0		Coefficient order 0; a(0)	
S3x11	Linearization SENSOR x coefficient order 1		Coefficient order 1; a(1)	
S3x12	Linearization SENSOR x coefficient order 2		Coefficient order 2; a(2)	
S3x13	Linearization SENSOR x coefficient order 3		Coefficient order 3; a(3)	
S3x14	Linearization SENSOR x coefficient order 4		Coefficient order 4; a(4)	
S3x15	Linearization SENSOR x coefficient order 5		Coefficient order 5; a(5)	
S3x16	Linearization SENSOR x coefficient order 6		Coefficient order 6; a(6)	
S3x17	Linearization SENSOR x coefficient order 7		Coefficient order 7; a(7)	
S3x18	Linearization SENSOR x coefficient order 8		Coefficient order 8; a(8)	
S3x19	Linearization SENSOR x coefficient order 9		Coefficient order 9; a(9)	
S3x20	Linearization SENSOR x X-factor		Scaling factor connecting the sensor raw value with the polynom in SI units	
S3x21	Linearization SENSOR x Y-factor		Scaling factor connecting the polynom with a physical representation based on SI units	

S3x30	SENSOR x offset value		Sensor offset in SI basic units	
S3x31	SENSOR x offset method	0 .. 1	0: compensation bevor application of characteristic curve 1: compensation after application of characteristic curve	
S3x35	Read linearization data from Sensor (PDP only)	0 .. 1 [0]	0: inactive 1: active	

Table 4: S3000-Block: Serial sensors at Ser2 (RS 485)

To link serial sensors with input values, the parameters Px010, Px020, Px050, Px080 (for pressure sensors) and/or S9110 (for system absolute pressure) have to be used. The adjustable values are increased. The value 10 corresponds with the first, the value 19 with the last serial sensor after S3xxx. The former command –3 for RS 485 Sensorport is no longer applicable, for example for Px020.

Error handling:
If simultaneousely a serial sensor with direct input (the sensor sends uncalled) and other serial sensors (a PDP for example), or more than one serial sensors with direct input are present, the program is stopped, until the risk of bus collisions is patched by a change of parameters. This error and communication errors, that occur during initialization, are displayed as a ticker.

Serial sensors can be nullified and their values displayed in the test mode in the same way as physical inputs.
The number of active serial sensors is specified with deliveriy. The default number is two.

7.1.5 S5000-Block: Linearization Laminar Flow Element (Standard)

x: LFE-Number : 0 to 4, calculation according to Hagen-Poisseuille

Querry of the serial numbers of the integrated LFE (Block S5000):

LSNRx	LFE chanel-no. x, serial-no.	0 .. 4	Querry of serial no.	

S5x01	Linearization LFE x Type of gas at calibration	1 .. 14 [1]	Type of gas at time of calibration 1: Air 2: Argon 3: Carbondioxide 4: Carbonmonoxide 5: Helium 6: Hydrogen 7: Nitrogen 8: Oxygen 9: Methane 10: Propane 11: n-Butane 12: Natural gas type H 13: Natural gas type L 14: Laughing gas, N2O	
S5x02	Linearization LFE x Calibration pressure	0 .. 1000000 [101320.7]	Absolute pressure at time of calibration in Pascal (SI based)	
S5x03	Linearization LFE x Calibration temperature	0 .. 1000 [294.261]	Temperature at time of calibration in Kelvin (SI based)	
S5x04	Linearization LFE x Calibration humidity	0 .. 1 [0.0]	Humidity at time of calibration from 0 to 1 (0 – 100%rH)	
S5x05	Linearization LFE x order polynome	1 – 9 [3]	Order of the polynome	
S5x10	Linearization LFE x Coefficient order 0		Coefficient order 0; a(0)	

S5x11	Linearization LFE x Coefficient order 1		Coefficient order 1; a(1)	
S5x12	Linearization LFE x Coefficient order 2		Coefficient order 2; a(2)	
S5x13	Linearization LFE x Coefficient order 3		Coefficient order 3; a(3)	
S5x14	Linearization LFE x Coefficient order 4		Coefficient order 4; a(4)	
S5x15	Linearization LFE x Coefficient order 5		Coefficient order 5; a(5)	
S5x16	Linearization LFE x Coefficient order 6		Coefficient order 6; a(6)	
S5x17	Linearization LFE x Coefficient order 7		Coefficient order 7; a(7)	
S5x18	Linearization LFE x Coefficient order 8		Coefficient order 8; a(8)	
S5x19	Linearization LFE x Coefficient order 9		Coefficient order 9; a(9)	
S5x20	Linearization LFE x X-factor		Normating / scaling value for the LFE differential pressure (SI based)	
S5x21	Linearization LFE x Y-factor		Normating / scaling value for the LFE volume flow (SI based)	

Table 5: S5000-Block: Linearization Laminar Flow Element

Note:
The linearization procedure for the LFE is described in chapter 9.2. Changing the coefficients causes the loss of the calibration. Therefore changing the coefficients normally is reserved to employees of the TetraTec Instruments GmbH.

7.1.6 S5500-Block: Linearization LFE (universal calibration)

x: LFE-Number : 5 to 9; calculation according the universal flow equation for high pressure, high temperature or multiple gas applications. Querry of integrated LFE's serial numbers (Block S5000):

LSNRx	ULFE channel number x, serial number	5 .. 9	Querry serial number	

S5x05	Linearization LFE x order polynome	1 – 9 [3]	Order of the polynome	*)
S5x10	Linearization LFE x Coefficient order 0		Coefficient order 0; a(0)	*)
S5x11	Linearization LFE x Coefficient order 1		Coefficient order 1; a(1)	*)
S5x12	Linearization LFE x Coefficient order 2		Coefficient order 2; a(2)	*)
S5x13	Linearization LFE x Coefficient order 3		Coefficient order 3; a(3)	*)
S5x14	Linearization LFE x Coefficient order 4		Coefficient order 4; a(4)	*)
S5x15	Linearization LFE x Coefficient order 5		Coefficient order 5; a(5)	*)
S5x16	Linearization LFE x Coefficient order 6		Coefficient order 6; a(6)	*)
S5x17	Linearization LFE x Coefficient order 7		Coefficient order 7; a(7)	*)
S5x18	Linearization LFE x Coefficient order 8		Coefficient order 8; a(8)	*)

S5x19	Linearization LFE x Coefficient order 9		Coefficient order 9; a(9)	*)
S5x20	Linearization LFE x X-factor		Normating scaling value for the LFE differential pressure (SI based)	*)
S5x21	Linearization LFE x Y-factor		Normating scaling value for the LFE volume flow (SI based)	*)

*) optionally

Table 6: S5500-Block: Linearization Laminar Flow Element (universal calibration)

7.1.7 S6000-Block: Linearization turbine flow meter (TFM)

Only optional

x: PD- or Turbine flow meter data set No. : 0 to 4,

Note:
This block is dropped at devices operating with 10 nozzles. The parameters beginning with S6000 are then used for the additional nozzles. Refer to S6n00 block.

S6x00	Evaluation method	0 .. 1	0: pulse counting 1: frequency measurement	*)
S6x01	Counter input No.:	0 .. 1	Channel N on Type 510 card	*)
S6x02	Frequency input No.:	0 .. 1	Channel N on Type 510 card	*)
S6x03	Volume per pulse		in m^3	*)
S6x04	Pulses per turn		For pulse counting	
S6x05	Linearization TFM x order polynome	1 .. 9 [3]	Order of the polynome	*)
S6x10	Linearization TFM x Coefficient order 0		Coefficient order 0; a(0)	*)
S6x11	Linearization TFM x Coefficient order 1		Coefficient order 1; a(1)	*)
S6x12	Linearization TFM x Coefficient order 2		Coefficient order 2; a(2)	*)
S6x13	Linearization TFM x Coefficient order 3		Coefficient order 3; a(3)	*)
S6x14	Linearization TFM x Coefficient order 4		Coefficient order 4; a(4)	*)
S6x15	Linearization TFM x Coefficient order 5		Coefficient order 5; a(5)	*)
S6x16	Linearization TFM x Coefficient order 6		Coefficient order 6; a(6)	*)
S6x17	Linearization TFMx Coefficient order 7		Coefficient order 7; a(7)	*)
S6x18	Linearization TFM x Coefficient order 8		Coefficient order 8; a(8)	*)
S6x19	Linearization TFM x Coefficient order 9		Coefficient order 9; a(9)	*)
S6x20	Linearization TFM x X-factor		Normating / scaling value for the TFM pulse / frequency value (SI based)	*)
S6x21	Linearization TFM x Y-factor		Normating / scaling value for the TFM volume flow (SI based)	*)
S6x30	Timeout		only counter pulse evaluation: in s (seconds)	*)
S6x32	N pulses to wait at continuous measurement as base		only counter pulse evaluation: N start pulses to wait before continuous measurement display	*)

S6x40	Exponent to the base 2 of the prescale adjustment at frequency measurement	1 .. 8	only counter frequency evaluation: 1: 2 2: 4 3: 8 4: 16 5: 32 6: 64 7: 128 8: 256	*)

*) optionally

Table 7: S6000-Block: Linearization turbine flow meters (TFM)

Note:
Changing the coefficients causes the loss of the calibration. Therefore changing the coefficients normally is reserved to employees of the TetraTec Instruments GmbH.

7.1.8 S6n00-Block: Linearization sonic nozzles

Only optional

Two variants are possible:

1 – The device containts the TFM-evaluation (S6000-Block):
- 5 nozzles possible
- nozzle parameters start at S6500 (n=5)
- nozzle number x from 5 to 9

2 – The device contains no TFM evaluation:
- 10 nozzels possible
- nozzle parameters start at S6000 (n=0, TFM parameters are dropped)
- nozzle number x from 0 to 9

S6x00	Evaluation method	0 .. 1 [0]	0: critical nozzle calculated for air corresponding to the german PTP 1: CFO-Calibration	*1) *1)
S6x03	Nozzle characteristic value QVtr	0 .. 1	QVtr in m³/s for S6x00=0	*1) *3)
S6x04	C* correctur factor for input pressure dependency		C* in 1/Pa for S6x00=0	*1) *3) *4)
S6x05	CFO-calibration nozzle x, order of polynom	0 .. 9	Order of the polynome	*1)
S6x06	Calibration nozzle x, type of gas at calibration	1 .. 14 [1]	Type of gas at time of calibration 1: Air 2: Argon 3: Carbondioxide 4: Carbonmonoxide 5: Helium 6: Hydrogen 7: Nitrogen 8: Oxygen 9: Methane 10: Propane 11: n-Butane 12: Natural gas type H 13: Natural gas type L 14: Laughing gas, N2O	*1) *2)
S6x07	Calibration nozzle x, calibration pressure	0 .. 1000000 [100000]	Absolute pressure at calibration in Pascal for S6x00=1	*1)

S6x08	Calibration nozzle x calibration temperature	0 .. 1000 [273,15]	Temperature at calibration in Kelvin for S6x00=1	*1)
S6x09	Calibration nozzle x calibration humidity	0 .. 1 [0.0]	Relative humidity at calibration For S6x00=1	*1)
S6x10	CFO-calibration nozzle x, coefficient order 0		Coefficient order 0; a(0)	*1)
S6x11	CFO-calibration nozzle x, coefficient order 1		Coefficient order 1; a(1)	*1)
S6x12	CFO-calibration nozzle x, coefficient order 2		Coefficient order 2; a(2)	*1)
S6x13	CFO-calibration nozzle x, coefficient order 3		Coefficient order 3; a(3)	*1)
S6x14	CFO-calibration nozzle x, coefficient order 4		Coefficient order 4; a(4)	*1)
S6x15	CFO-calibration nozzle x, coefficient order 5		Coefficient order 5; a(5)	*1)
S6x16	CFO-calibration nozzle x, coefficient order 6		Coefficient order 6; a(6)	*1)
S6x17	CFO-calibration nozzle x, coefficient order 7		Coefficient order 7; a(7)	*1)
S6x18	CFO-calibration nozzle x, coefficient order 8		Coefficient order 8; a(8)	*1)
S6x19	CFO-calibration nozzle x, coefficient order 9		Coefficient order 9; a(9)	*1)
S6x20	CFO-calibration nozzle x, X-factor	[1.45038E-4] [Pa -> psia	Scaling factor polynom and absolute pressure	*1)
S6x21	CFO-calibration nozzle x, Y-Factor	[2.1187E+03] [SCFM –Y m³/s]	Scaling factor polynom and flow	*1)
S6x22	CFO-calibration nozzle x, Xt-factor	[1.8] [°K -> °R]	Scaling factor for input, temperature correction	*1)
S6x23	Lower limit input pressure		Pa	*3)
S6x24	Upper limit input pressure		Pa	*3)

*1) optional, standard conditions see S6x07 to S6x09
*2) The type of gas has to be identical with the gas type at measurement (Px001). Otherwise the error “Error Qvac” is displayed.
For S6x00=0 (PTB) only air is calculated with humidity.
*3) Parameter number changed since V4.081!
*4) Unit standarsized on SI-Units since V4.081!

Table 8: S6500-Block: Linearization sonic nozzles

Note:
Changing the coefficients causes the loss of the calibration. Therefore changing the coefficients normally is reserved to employees of the TetraTec Instruments GmbH.

7.1.9 S7000-Block: Linearization 0rifice and Venturi element

Only optional

x: orifice-Number : 0 to 4

S7x00	Kind of pressure measurement kind of Venturi element	0 – 3	0: Orifice flansh pressure taps 1: Orifice corner pressure taps 2: Orifice D- and D/2 pressure taps 3: Venturi nozzle 4: Venturi pipe, cast iron, coarse 5: Venturi pipe, with machined inflow konus 6: Venturi pipe, coarse inflow konus made of weldet steel sheet	*)
S7x01	inside diameter upset the flow		[m], SI-unit	*)
S7x02	orifice diameter during operation		[m] , SI-unit	*)
S7x05	Linearization Orifice x, order of polynom	0 .. 9 [0]	Order of polynom 0: calculation according ISO 5167 and DIN 1952 >0: calibrated orifice with coefficients S7x10 …S7x19	
S7x06	Linearization Orifice x, type of gas at calibration	1 .. 14 [1]	Type of gas at time of calibration 1: Air 2: Argon 3: Carbondioxide 4: Carbonmonoxide 5: Helium 6: Hydrogen 7: Nitrogen 8: Oxygen 9: Methane 10: Propane 11: n-Butane 12: Natural gas type H 13: Natural gas type L 14: Laughing gas, N2O	
S7x07	Linearization Orifice x, calibration pressure	0 .. 1000000 [100000]	Absolute pressure at calibration in Pascal	
S7x08	Linearization Orifice x, calibration temperature	0 .. 1000 [273,15]	Temperature at calibration in Kelvin	
S7x09	Linearization Orifice x, Calibration humidity	0 .. 1 [0.0]	Relative humidity at calibration	
S7x10	Linearization Orifice x, coefficient order 0		Coefficient order 0; a(0)	
S7x11	Linearization Orifice x, coefficient order 1		Coefficient order 1; a(1)	
S7x12	Linearization Orifice x, coefficient order 2		Coefficient order 2; a(2)	
S7x13	Linearization Orifice x, coefficient order 3		Coefficient order 3; a(3)	
S7x14	Linearization Orifice x, coefficient order 4		Coefficient order 4; a(4)	
S7x15	Linearization Orifice x, coefficient order 5		Coefficient order 5; a(5)	

S7x16	Linearization Orifice x, coefficient order 6		Coefficient order 6; a(6)	
S7x17	Linearization Orifice x, coefficient order 7		Coefficient order 7; a(7)	
S7x18	Linearization Orifice x, coefficient order 8		Coefficient order 8; a(8)	
S7x19	Linearization Orifice x, coefficient order 9		Coefficient order 9; a(9)	
S7x20	Linearization Orifice x, X-factor		Scaling factor polynom and absolute pressure	
S7x21	Linearization Orifice x, Y-factor		Scaling factor polynom and flow	
S7x23	lowest Reynolds number at iteration		dimensionless, minimum value of Reynolds number	*)
S7x24	highest Reynolds number at iteration		dimensionless, maximum value of Reynolds number	*)
S7x25	Tolerance of mass flow calculation break condition for iteration		[kg/s], SI-unit smallest mass flow resolution to stop the iteration procedure.	*)

*)optional

Table 9: S7000-Block: Linearization Orifice

Note:
Changing the coefficients causes the loss of the calibration. Therefore changing the coefficients normally is reserved to employees of the TetraTec Instruments GmbH.

7.1.10 S7500-Block: Linearization Accutubes

x: Accutube-Number : 5 to 9

S7x01	K: mean value of Kflow		dimensionless	*)
S7x02	Line size diameter		in [m]	*)
S7x03	Standard temperature to correct the expansion of the inside diameter	233.15 .. 333.15 [294.261]	in [K]	*)
S7x04	Thermal expansion correction factor μ		in Si units	*)
S7x05	Linearization Accutube x order polynome	0 .. 9	Order of the polynome	*)
S7x10	Linearization Accutube x Coefficient order 0		Coefficient order 0; a(0)	*)
S7x11	Linearization Accutube x Coefficient order 1		Coefficient order 1; a(1)	*)
S7x12	Linearization Accutube x Coefficient order 2		Coefficient order 2; a(2)	*)
S7x13	Linearization Accutube x Coefficient order 3		Coefficient order 3; a(3)	*)
S7x14	Linearization Accutube x Coefficient order 4		Coefficient order 4; a(4)	*)
S7x15	Linearization Accutube x Coefficient order 5		Coefficient order 5; a(5)	*)
S7x16	Linearization Accutube x Coefficient order 6		Coefficient order 6; a(6)	*)
S7x17	Linearization Accutube x Coefficient order 7		Coefficient order 7; a(7)	*)
S7x18	Linearization Accutube x Coefficient order 8		Coefficient order 8; a(8)	*)
S7x19	Linearization Accutube x Coefficient order 9		Coefficient order 9; a(9)	*)
S7x23	lowest Reynolds number at FRA iteration		dimensionless, minimum value of Reynolds number	*)
S7x24	highest Reynolds number at FRA iteration		dimensionless, maximum value of Reynolds number	*)
S7x25	Tolerance of actual volume flow calculation break condition for iteration		[m^3/s], SI-unit smallest volume flow resolution to stop the iteration procedure.	*)

*)optional

Table 10: S7500-Block: Linearization accutubes

Note:
Changing the coefficients causes the loss of the calibration. Therefore changing the coefficients normally is reserved to employees of the TetraTec Instruments GmbH.

7.1.11 S8000-Block: Special function: Leakage test

S8000	Pressure value for leakage test	002, 012, 020 [002]	R-parameter of pressure value	
S8001	Test period leakage	– 300.0 [1.0]	in seconds	
S8002	Display unit pressure drop during leak testing	0 – 14 [9]	0: Pascal [Pa] 1: HektoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inchWC [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mm Watercolumn [mmWC] 13: Pounds/in^2 [psi] 14: Torr [Torr]	
S8003	Pressure drop, Display of decimal digits	0 – 5 [2]	Number of decimal digits	
S8004	Display unit pressure drop per time after leak testing	0 – 11 [10]	0: Pascal/sec. [Pa/s] 1: Pascal/min.[Pa/m] 2: Pascal/h [Pa/h] 3: Millibar/sec [mb/s] 4: Millibar/min [mb/m] 5: Millibar/hour [mb/h] 6: Bar/sec [b/s] 7: Bar/min [b/m] 8: Bar/hour [b/h] 9: psi/sec [PSIs] 10: psi/min [PSIm] 11: psi/hour [PSIh]	
S8005	Pressure drop per time, display of decimal digits	0 – 5 [3]	Number of decimal digits	
S8006	Display unit leak test pressure during leak testing	0 – 14 [9]	0: Pascal [Pa] 1: HektoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inch Watercolumn [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mm Watercolumn [mmWC] 13: Pounds/in^2 [psi] 14: Torr [Torr]	

S8007	Leak test pressure, Display of decimal digits	0 – 5 [3]	Number of decimal digits	
S8010	Selection measuring circle for leakage test	[0]		

Table 11: S8000-Block: Special Function Density

7.1.12 S8000-Block: Special function: Leakage test (alternative)

On consultation, only on extra request!!!

In opposite to the standard leakage test basing on pressure drop measurement over time, the alternative leakage test is pressure controlled.

After the start of the leakage test by a serial or digital signal the program waits until the relevant pressure for the leakage test (S8000) reaches the filling pressure P0 (S8011). The measured pressure is displayed in the first display line. The filling mode is indicated by the string “Fill” in the lower right corner of the display.

If the filling pressure is not reached during the period of time defined by S8021, the measurement is cancelled. The last measured pressure remains fixed on the display. Aside the message “Leakage Test Timeout” is displayed as a ticker. The result parameters remain initialized (0.0).

The time measurement starts after the calming time defined in S8022 during wich the pressure has to drop from the filling pressure to the start pressure P1, defined in S8012). If the start pressure is not reached during this period of time, a timeout message is given as well as in the filling mode.

The test is correctly finished, when the end pressure defined in S8013 is reached or the maximum test period T defined in S8020 is exceeded. This time out is not taken as an error, because a correct evaluation of the test is possible. This evaluation is based on the starting pressure, the end pressure and the pressure drop over time.

The essential result of this test is the duration of the leakage test (Ry310). If the duration is equal to the maximal test period, the end pressure is available as result (Ry312). The pressure drop over time (Ry315) is an evaluation value independent from the end condition.

Because slight deviations are even possible, if the pressure limits P1 and P2 are reached, the reached limits are available too with the parameters Ry311 and Ry312.

The display of the results can be left with the stop signal.

This leakage test can be performed only at one measuring circle at a time, even for devices mit more than one measuring circles. Here the parameter S8010 defines, which measuring circle will be leakage tested. This parameter is available at level 0. Therefore it can easily selected and editet using the front keys. On devices with more than one measuring circle, the number of the current program is also displayed.

S8000-Block: Special function: Leakage test (alternative)

On consultation, only on extra request!!!

S8000	Pressure value for leakage test	002, 012, 020 [002]	R-parameter of pressure value	
S8004	Display unit pressure drop per time after leak testing	0 .. 11 [10]	0: Pascal/sec. [Pa/s] 1: Pascal/min.[Pa/m] 2: Pascal/h [Pa/h] 3: Millibar/sec [mb/s] 4: Millibar/min [mb/m] 5: Millibar/hour [mb/h] 6: Bar/sec [b/s] 7: Bar/min [b/m] 8: Bar/hour [b/h] 9: psi/sec [PSIs] 10: psi/min [PSIm] 11: psi/hour [PSIh]	
S8005	Pressure drop per time, display of decimal digits	0 .. 5 [3]	Number of decimal digits	
S8006	Display unit leak test pressure during leak testing	0 .. 14 [9]	0: Pascal [Pa] 1: HektoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inch Watercolumn [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mm Watercolumn [mmWC] 13: Pounds/in^2 [psi] 14: Torr [Torr]	
S8007	Leak test pressure, Display of decimal digits	0 .. 5 [3]	Number of decimal digits	
S8008	Period of testing, display unit	0 .. 2 [0]	0: seconds 1: minutes 2: hours	
S8009	Period of testing, decimal digits	0 .. 5 [0]		
S8010	Selection measuring circle for leakage test	[0]		
S8011	Filling pressure for leakage test	0 .. 2.0E+6 [1.0E+5]	Pressure required before starting the leakage test	
S8012	Pressure starting the leakage test	0 .. 2.0E+6 [1.0E+5]	See description above	
S8013	Pressure finishing the leakage test	0 .. 2.0E+6 [1.0E+5]	See description above	
S8020	Maximum measurement time	0.02..10000 [1.0]	Time in seconds	
S8021	Timeout for reaching the filling pressure	0.02..10000 [1.0]	Time in seconds	
S8022	Calming time	0.02..10000 [1.0]	Time in seconds	

7.1.13 S9000-Block: Special functions

S9000	Function for printing protocols. If this parameter is activated, the device sends a string over the serial interface after a measurement or test is finished. The structure of the string is specified according to the customers demands.	-1 0 .. 1	-1: swiched off 0: after test is finished, the result is output to Ser0 (RS232) 1: after test is finished, the result is output to Ser1 (RS485)	
S9001	Display definition in the measuring mode	0 .. 1 [0]	0: fixed display (as Px851, Px852) 1: automatical switching of display corresponding to test step	*)
S9002	Simultaneous measurement stop at double section device	0 .. 1 [0]	0: inactive 1: active	
S9003	Calculation using reference Sensors	0 .. 1 [0]	0: inactive 1: active	
S9004	Display densities	0 .. 1 [0]	0: do not display 1: display	
S9005	Display viscosities	0 .. 1 [0]	0: do not display 1: display	
S9006	Display flow ratio	0 .. 2 [0]	0: do not display flow ratio 1: display flow ratio 2: display sum of flows sections 1 and 2	**)
S9007	Display molar water proportion Xv	0 .. 1 [0]	0: do not display 1: display	
S9008	Display volume flow corrections	0 .. 4 [0]	0: inactive 1: Cqva as actual volume flow 2: CQvn as standard volume flow 3: CQvr as reference volume flow 4: Cqma as mass flow	
S9010	Display flow values in measuring circle 0	-1 0 .. 4	-1: display all flow values 0: do not display 1: QVa 2: QVn 3: QVb 4: QMa	
S9011	Display flow values in measuring circle 1	-1 0 .. 4	-1: display all flow values 0: do not display 1: QVa 2: QVn 3: QVb 4: Qma	
S9012	Display flow values in measuring circle 2	-1 0 .. 4	-1: display all flow values 0: do not display 1: QVa 2: QVn 3: QVb 4: Qma	
S9016	Decimal digits for flow ratio	0 .. 5 [2]		
S9020	Correction of statical pressure offset of Pdif	0 .. 1 [1]	0: inactive 1: active, see Px014	
S9100	Calculate molar water proportion Xv for measurement system based on humidity channel	-2 -1 0 .. 9 [-2]	-2: inactive -1: use standard value specified in S9101 0: channel 0 (Port 0 Slot 0) up to 9: channel 9 (Port 4 Slot 1)	

S9101	Standard value Xv	0 .. 1 [0.01]	Fixed value molar water proportion Xv adjustable, dimensionless	
S9103	Sensor or channel number absolute pressure measurement at humidity measurement place	0 .. 9	0: channel 0 (Port 0 Slot 0) up to 9: channel 9 (Port 4 Slot 1)	
S9105	Sensor or channel number temperature measurement at humidity measurement place	0 .. 9	0: channel 0 (Port 0 Slot 0) up to 9: channel 9 (Port 4 Slot 1)	
S9110	Sensor or channel number absolute system pressure measurement for measurement programms with gauge pressure measurement	-1 -1 0 .. 9 10 .. 19 [-2]	-2: inactive -1: use standard value specified in S9111 0: channel 0 (Port 0 Slot 0) up to 9: channel 9 (Port 4 Slot 1) 10 up to 19 : serial sensors according to S3000 block	
S9111	Standard value system absolute pressure	0..1.0E06 [1.0E05]	Standard value system absolute pressure given in Pascal	
S9112	Display of added values	0 .. 1 [1]	0: no display 1: display added values	
S9200	Method for calculation of corrections of volume or mass flows, with normalization related on standard values listed below	0 .. 4 [0]	0: inactive 1: sonic speed (T) 2: orifice (density) 3: orifice (density, dP) 4: viscosity	
S9201	Actual pressure absolute, standard correction value	0..1.0E06 [1.0E05]	Standard value absolute actual pressure, given in Pascal	
S9202	Actual temperature, standard correction value	233.15 .. 333.15 [293.15]	Standard value actual temperature given in Kelvin	
S9203	Actual humidity, standard correction value	0 .. 1 [0.0]	Standard value actual humidity	
S9208	Gauge pressure, standard correction value	-1.0E6 .. 1.0E06 [0.0]	Standard value gauge pressure given in Pascal	

*) only to use with active control function (Px400)
**) only with double section device

Table 12: S9000-Block: Special functions

7.2 Measuring Program Definitions:

7.2.1 Px000-Block: Primary Element, Basic Description

Px000	Preselection of calculation and linearization data set		0: Direct mass flow input (Px015) 5: LFE evaluation (Px005) 6: PD-meter/nozzle eval. (Px006) 7: Orifices, accutubes (Px007)	
Px001	Display of gas	1 .. 14 [1]	1: Air 2: Argon 3: Carbondioxide 4: Carbonmonoxide 5: Helium 6: Hydrogen 7: Nitrogen 8: Oxygen 9: Methane 10: Propane 11: n-Butane 12: Natural gas type H 13: Natural gas type L 14: Laughing gas, N2O	
Px002	Linearization set Laminar Flow Element	Replaced =Px005	since Version 3.41 replaced by Px000 and Px005	
Px003	Calculations of density	0 .. 1 [1]	0: ideal 1: real, calculation with virial coefficients, natural gas not supported 2: real, BIMP recommendation (air only)	
Px004	Calculations of viscosity	0 .. 1 [1]	0: ideal, Daubert&Danner 1: real, Kestin-Whitelaw (air only)	
Px005	Linearization data set Laminar Flow Element	0 .. 9	0 .. 4: LFE standard calibration 5 .. 9: LFE universal flow calibration	*)
Px006	Linearization data set PD-meter, sonic nozzle	0 .. 9	0 .. 4: PD-meter 5 .. 9: Sonic nozzle or optional variant: 0 .. 9: sonic nozzles, no PD-meters	*) **)
Px007	Linearization data set Orifice, accutube	0 .. 9	0 .. 4: Orifice 5 .. 9: Accutube or optional variant: 0 .. 9: orifices, no accutubes	*) *)

*) optional
**) Additional to the selection of single nozzles (number 0 .. 9) you can combine up to 4 nozzles in parallel by an 8 digit number.
Examples:
P0008=01020304 selects combination of nozzles 1, 2, 3, und 4
P0008=00000102 selects combination of nozzles 1 and 2 as well as
P0008=102 (the leading zeros can be dropped) and
P008=02000001 (sequence arbitrary)
You can only combine nozzles with identical evaluation method (according to PTB or CFO-Calibration). Additional the calibration gas type, calibration conditions etc have to be equal.

Table 13: Px000-Block: Primary element, Basic Description

7.2.2 Px010-Block: Differential pressure

Px010	Sensor- / channel selection Differential pressure	-1 0 .. 9 10 … 19	-1: standard value from Px011 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1) 10 to 19: serial sensors according to S3000 block	
Px011	Differential pressure Standard value	-10000 to 10000 [0]	Standard value for the differential pressure in Pa	
Px012	Differential pressure, Display unit	0 .. 14 [1]	0: Pascal [Pa] 1: HectoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inchWatercolumn [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mmWatercolumn [mmWC] 13: Pounds/in^2 [psiD] 14: Torr [Torr]	
Px013	Differential pressure, Display of decimal digits	0 .. 5 [2]	Number of decimal digits	
Px014	Compensation of differential pressure with static pressure	-100 to 100 [0]	In Pascal or bar related on standard condition for absolute pressure (S0101	*)

*) dorrection of the differential pressure sensors dependency on the static pressure (measured with Pabs). Only used if S9020=1.

Table 14: Px010-Block: Differential Pressure

7.2.3 Px015-Block: Direct mass flow input

Px015	Sensor- / channel selection mass flow	-2 -1 0 .. 9	-2: ignore mass flow input -1: standard value from Px016 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1)	*)
Px016	Mass flow standard value		Standard value of mass flow in kg/s	*)

*) optionally

Table 15: Px015-Block: direct mass flow input

7.2.4 Px020-Block: Actual pressure absolute (Pabs)

Px020	Sensor- / channel selection Actual pressure absolute	-1 0 .. 9 10 … 19	-1: standard value from Px021 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1) 10 to 19: serial sensors according to S3000 block	
Px021	Actual pressure absolute Standard value	0 .. 1.0E06 [1.0E05]	Standard value for the actual pressure absolute in Pa	
Px022	Actual pressure absolute Display unit	0 .. 14 [1]	0: Pascal [Pa] 1: HectoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inchWatercolumn [inWC] 9: Pounds/in² [lbi²] 10: Pounds/ft² [lbf²] 11: mmMercury [mmHG] 12: mmWatercolumn [mmWC] 13: Pounds/in² [psi A] 14: Torr [Torr]	
Px023	Actual pressure absolute Display of decimal digits	0 .. 5 [1]	Number of decimal digits	
Px024	Addition for calculation of actual pressure	0 .. 1 [0]	0: none 1: actual pressure + system absolute pressure* *as specified in S9110	

Table 16: Px020-Block: Actual pressure absolute

7.2.5 Px030-Block: Actual temperature (Tem)

Px030	Sensor- / channel selection Actual temperature	-1 0 .. 9	-1: standard value from Px031 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1)	
Px031	Actual temperature Standard value	233.15 to 333.15 [233.15]	Standard value for the Actual temperature in K	
Px032	Actual temperature Display unit	0 .. 4 [2]	0: Kelvin [K] 1: Degree Celsius 2: Fahrenheit 3: Rankine	
Px033	Actual temperature Display of decimal digits	0 .. 5 [1]	Number of decimal digits	

Table 17: Px030-Block: Actual temperature

7.2.6 Px040-Block: Actual Humidity (Hum)

Px040	Sensor- / channel selection Actual humidity	-1 0 .. 9	-1: standard value from Px041 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1)	
Px041	Actual humidity Standard value	0 .. 1 [0.0]	Standard value for the actual humidity (dimensionless)	
Px042	Actual humidity Display unit	0 .. 1 [1]	0: 0..1 (dimensionless) 1: 0..100% rH.	
Px043	Actual humidity Display of decimal digits	0 .. 5 [1]	Number of decimal digits	

Table 18: Px040-Block: Actual Humidity

7.2.7 Px050-Block: Reference Pressure Absolute (PabsB)

Px050	Sensor- / channel selection Reference pressure absolute	-1 0 .. 9 10 .. 19	-1: standard value from Px051 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1) 10 to 19: serial sensors according to S3000 block	
Px051	Reference pressure absolute Standard value	0 to 1000000 [1.0E05]	Standard value for the Reference pressure absolute in Pascal	
Px054	Addition for calculation of Reference pressure	0 .. 2 [0]	0: none 1: Reference pressure + actual pressure* 2: Reference pressure + actual pressure* - differential pressure *as set in S9110 1,2 only reasonable, if reference pressure is a gauge pressure and actual pressure is an absolute pressure	

Table 19: Px050-Block: Reference Pressure Absolute

Note: Units and decimal digits are equal and fixed to settings at Px020. Compare settings at S9003.

7.2.8 Px060-Block: Reference Temperature (TemB)

Px060	Sensor- / channel selection Reference temperature	-1 0 .. 9	-1: standard value from Px061 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1)	
Px061	Reference temperature Standard value	233.15 to 333.15 [233.15]	Standard value for the Reference temperature in K	

Table 20: Px060-Block: Reference Temperature

Note: units and decimal digits are equal and fixed to settings at Px030. Compare settings at S9003.

7.2.9 Px070-Block: Reference Humidity (HumB)

Px070	Sensor- / channel selection Reference humidity	-2 -1 0 .. 9	-2: calculate humidity f. system Xv -1: standard value from Px071 0: channel 0 (Port 0 Slot 0) …: to 9: channel 9 (Port 4 Slot 1)	
Px071	Reference humidity Standard value	0 to 1 [0.0]	Standard value for the Reference humidity (dimensionless)	

Table 21: Px070-Block: Reference Humidity

Note: units and decimal digits are equal and fixed to settings at Px040. Compare settings at S9003.

7.2.10 Px080-Block: Auxiliary Sensor / Gauge Pressure (Pre)

Px080	Sensor- / channel selection Reference gauge pressure	-1 0 .. 9 10 .. 19	-1: standard value from Px081 0: channel 0 (Port 0 Slot 0) to 9: channel 9 (Port 4 Slot 1) 10 to 19: serial sensors according to S3000 block	*)
Px081	Reference gauge pressure Standard value	-10E6 .. 10E06 [0.0]	standard value for the Reference gauge pressure in Pascal	*)
Px082	Reference gauge pressure Display unit	0 .. 14 [8]	0: Pascal [Pa] 1: HectoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inchWatercolumn [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mmWC [mmWC] 13: Pounds/in^2 [psi] 14: Torr [Torr]	*)
Px083	Reference gauge pressure Display of decimal digits	0 .. 5 [1]	Number of decimal digits	*)
Px084	Addition gauge pressure	0 .. 3 [0]	0: none 1: Reference pressure + actual pressure* 2: Reference pressure + actual pressure* - differential pressure 3 : Gauge pressure – gauge pressure 2 *as set in S9110 1,2 only reasonable, if reference pressure is a gauge pressure and actual pressure is an absolute pressure 3 only reasonable, if second gauce pressure exists	*)

*) only exist, if an additional auxiliary input is available. As a standard it is defined as a gauge pressure. It can be customized also on demand. In this case the definition will be described at the appendix with an additional block Px090

Table 22: Px080-Block: Auxiliary Sensor / Gauge Pressure

7.2.11 Px085-Block: Auxiliary Sensor 2 / Gauge Pressure 2

Px085	Sensor- / channel selection Gauge pressure 3	-1 0 .. 9 10 .. 19	-1: standard value from Px086 0: channel 0 (Port 0 Slot 0) to 9 : channel 9 (Port 4 Slot 1) 10 to 19: serial sensors according to S3000 block	*)
Px086	Gauge pressure 3 Standard value	-10E6 .. 10E06 [0.0]	standard value for the Reference gauge pressure in Pascal	*)
Px087	Gauge pressure 3 Display unit	0 .. 14 [8]	0: Pascal [Pa] 1: HectoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inchWatercolumn [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mmWC [mmWC] 13: Pounds/in² [psi] 14: Torr [Torr]	*)
Px088	Gauge pressure 3 Display of decimal digits	0 .. 5 [1]	Number of decimal digits	*)
Px089	Addition gauge pressure 3	0 .. 2 [0]	0: none 1: Gauge pressure 3 + actual pressure* 2: Gauge pressure 3+ actual pressure* - differential pressure 3: Gauge pressure 3 – gauge pressure 2 *as set in S9110 1,2 only reasonable, if reference pressure is a gauge pressure and actual pressure is an absolute pressure 3 only, if second gauge pressure input is present	*)

*) only exist, if an additional auxiliary input is available. As a standard it is defined as a gauge pressure. It can be customized also on demand. In this case the definition will be described at the appendix with an additional block Px090

Table 23: Px090-Block: Auxiliary Sensor 2/ Gauge Pressure 2

7.2.12 Px090-Block: Auxiliary Sensor 3 / Gauge Pressure 3

Px090	Sensor- / channel selection Reference gauge pressure 2	-1 0 .. 9 10 .. 19	-1: standard value from Px081 0: channel 0 (Port 0 Slot 0) to 9 : channel 9 (Port 4 Slot 1) 10 to 19: serial sensors according to S3000 block	*)
Px091	Reference gauge pressure 2 Standard value	-10E6 .. 10E06 [0.0]	standard value for the Reference gauge pressure in Pascal	*)
Px092	Reference gauge pressure 2 Display unit	0 .. 14 [8]	0: Pascal [Pa] 1: HectoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inchWatercolumn [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mmWC [mmWC] 13: Pounds/in^2 [psi] 14: Torr [Torr]	*)
Px093	Reference gauge pressure 2 Display of decimal digits	0 .. 5 [1]	Number of decimal digits	*)
Px094	Addition gauge pressure 2	0 .. 2 [0]	0: none 1: Reference pressure + actual pressure* 2: Reference pressure + actual pressure* - differential pressure *as set in S9110 1,2 only reasonable, if reference pressure is a gauge pressure and actual pressure is an absolute pressure	*)

*) only exist, if an additional auxiliary input is available. As a standard it is defined as a gauge pressure. It can be customized also on demand. In this case the definition will be described at the appendix with an additional block Px090

Table 24: Px090-Block: Auxiliary Sensor 3/ Gauge Pressure 3

7.2.13 Px085-Block: Auxiliary Sensor 4 / Gauge Pressure 4

Px095	Sensor- / channel selection Gauge pressure 4	-1 0 .. 9 10 .. 19	-1: standard value from Px096 0: channel 0 (Port 0 Slot 0) to 9 : channel 9 (Port 4 Slot 1) 10 to 19: serial sensors according to S3000 block	*)
Px096	Gauge pressure 4 Standard value	-10E6 .. 10E06 [0.0]	standard value for the Reference gauge pressure in Pascal	*)
Px097	Gauge pressure 4 Display unit	0 .. 14 [8]	0: Pascal [Pa] 1: HectoPascal [hPa] 2: KiloPascal [kPa] 3: Millibar [mbar] 4: Bar [bar] 5: techn. Atmosphere [at] 6: phys. Atmosphere [atm] 7: inchMercury. [inHG] 8: inchWatercolumn [inWC] 9: Pounds/in² [lbi2] 10: Pounds/ft² [lbf2] 11: mmMercury [mmHG] 12: mmWC [mmWC] 13: Pounds/in^2 [psi] 14: Torr [Torr]	*)
Px098	Gauge pressure 4 Display of decimal digits	0 .. 5 [1]	Number of decimal digits	*)
Px099	Addition gauge pressure 4	0 .. 2 [0]	0: none 1: Gauge pressure 3 + actual pressure* 2: Gauge pressure 3+ actual pressure* - differential pressure 3: Gauge pressure 4 – gauge pressure 2 *as set in S9110 1,2 only reasonable, if reference pressure is a gauge pressure and actual pressure is an absolute pressure 3 only, if second gauge pressure input is present	*)

*) only exist, if an additional auxiliary input is available. As a standard it is defined as a gauge pressure. It can be customized also on demand. In this case the definition will be described at the appendix with an additional block Px090

Table 25: Px090-Block: Auxiliary Sensor 4/ Gauge Pressure 4

Note: Setting parameters Px089 and Px099 („Addition gauge pressure“) to values unequal 0 makes sense only with corresponding setup of the measurement section. The meaning ot this parameters can be adapted to the customer needs on demand.

7.2.14 Px100-Block: Volume Flows / Frequencies

Px101	Actual volume flow, Display unit	0 .. 14 [10]	0: m^3/sec [m3/s] 1: m^3/min [m3/m] 2: m^3/hour [m3/h] 3: Litre/sec [L/s] 4: Litre/min [L/m] 5: Litre/hour [L/h] 6: cm^3/sec [cm3s] 7: cm^3/min [cm3m] 8: cm^3/hour [cm3h] 9: ft^3/sec [ACFS] 10: ft^3/min [ACFM] 11: ft^3/hour [ACFH] 12: $inch^3$/sec [ACIS] 13: $inch^3$/min [ACIM] 14: $inch^3$/h [ACIH]	
Px102	Actual volume flow Display of decimal digits	0 .. 5	Number of decimal digits	
Px103	Total actual volume, Display unit	0 .. 4 [3]	0: m^3 [m3] 1: Litre [Lit.] 2: cm^3 [cm3] 3: ft3 [CF] 4: $inch^3$ [CI]	
Px104	Total actual volume, Display of decimal digits	0 .. 5	Number of decimal digits	
Px105	Standard volume flow, Display unit	0 .. 14 [10]	0 .. 14 as Px101 where 9..14: [SC..]	
Px106	Standard volume flow Display of decimal digits	0 .. 5 [3]	Number of decimal digits	
Px107	Total standard volume, Display unit	0 .. 4 [3]	as Px103	
Px108	Total standard volume Display of decimal digits	0 .. 5 [3]	Number of decimal digits	
Px109	Reference volume flow, Display unit	0 .. 14 [10]	0 .. 14 as Px101	
Px110	Reference volume flow, Display of decimal digits	0 .. 5 [3]	Number of decimal digits	
Px111	Total reference volume, Display unit	0 .. 4 [3]	0 .. 4 as Px103	
Px112	Total reference volume, Display of decimal digits	0 .. 5 [3]	Number of decimal digits	
Px115	Frequency, unit	0 .. 4	0: Hz 1: kHz 2: MHz 3: 1/min 4: 1/h	
Px116	Frequency Display of decimal digits	0 .. 5	Number of decimal digits	

Table 26: Px100-Block: Volume Flows / Frequencies

7.2.15 Px120-Block: Mass flow

Px121	Mass flow, Display unit	0 .. 10 [7]	0: kg/sec [kg/s] 1: kg/min [kg/m] 2: kg/hour [kg/h] 3: g/sec [g/s] 4: g/min [g/m] 5: g/hour [g/h] 6: pounds/sec [PPS] 7: pounds/min [PPM] 8: pounds/hour [PPH]	
Px122	Mass flow, Display of decimal digits	0 .. 5	Number of decimal digits	
Px123	Total mass, Display unit	0 .. 2 [2]	0: kg [kg] 1: g [g] 2: pounds [lb]	
Px124	Total mass, Display of decimal digits	0 .. 5	Number of decimal digits	

Table 27: Px120-Block: Mass flow

7.2.16 Px130-Block: Heat output

Px130	Heat output	0 .. 2 [0]	0: do not calculate 1: calculate as calorific value 2: calculate as fuel value	
Px131	Heat output, unit	0 .. 6	0: Watt [W] 1: kW [kW] 2: MW [MW] 3: cal/sec [c/s] 4: kcal/hour [kc/h] 5: BTU/min [btum] 6: BTU/hour [btuh]	
Px132	Heat output, display of decimal digits	0 .. 5	Number of decimal digits	
Px133	Heat quantity, unit	0 .. 7	0: Joule [J] 1: Ws [Ws] 2: Wh [Wh] 3: kWh [kWh] 4: MWh [MWh] 5: cal [c] 6: kcal [kcal] 7: btu [btu]	

Table 28: Px130-Block: Heat output

7.2.17 Px140-Block: Density

Px141	Density, Display unit	0 .. 3 [3]	0: Kg/m^3 [kgm3] 1: g/m^3 [g/m3] 2: pounds/cubic feet [lbcf] 3: pounds/cubic inch [lbci]	
Px142	Density Display of decimal digits	0 .. 5 [3]	Number of decimal digits	

Table 29: Px140-Block: Density

Note:
The configuration specified with Px141 and Px142 is valid for all possible kinds of density: actual density, standard density, reference density and calibration density.

7.2.18 Px160-Block: Viscosity

Px161	Viscosity, Display unit	0 .. 2 [1]	0: Pascalsec. [Pa*s] 1: Micropoises [uPoi] 2: Centipoises [cPoi]	
Px162	Viscosity, Display of decimal digits	0 .. 5 [3]	Number of decimal digits	

Table 30: Px160-Block: Viscosity

Note:
The configuration specified with Px161 and Px162 is valid for all possible kinds of viscosity: actual viscosity, standard viscosity, reference viscosity and calibration viscosity.

7.2.19 Px400-Block: Controller

The integrated PID controller may be configured as a controller for all measured or calculated values using the LMF (e.g. pressures and volume flows).
The definition and configuration of the analog output to create the controller output signal is done at the Px900-block (analog output).

The controller can be configured as a P-, PI- or PIDT1-controller. The controller output is connected to an analog output (refer to Px900-block). Any measured or calculated value can be defined as actual control value with the help of the Ry000-block.
The following table specifies the parameters used to configure this controller. The determination of the control parameter (Px402 .. Px405) may e.g. be carried out according to the reference instructions of Ziegler - Nichols (see below).

In order to do so, the controller firstly is defined as a pure P-controller ($T_I = 0$, $T_D = 0$) [refer to table of control parameter]. Then, the controller amplification K_R is set to a value which causes a stable continuous oscillation of the actual control value. This value for K_R is named $K_{krit.}$. The period of this continuous oscillation (T_{krit}) should be measured by means of a chart recorder or an oscilloscope.

Knowing these critical values for amplification $K_{krit.}$ and oscillation period T_{krit}, the control parameter can be adjusted according to the following table.
Once defined these values are used for the parameter Px403 .. Px405.

Setting rules for PID-controller according to Ziegler, Nichols:

Controller type	K_R	T_I	T_D
P	0,5 * K_{krit}		
PI	0,45 * K_{krit}	0,85 * T_{krit}	
PID	0,6 * K_{krit}	0,5 * T_{krit}	0,12 * T_{krit}

Typical values e.g.: for a pure PI-controller:

for flow control: K_{krit} = 1,0 ... 4,0, T_{krit} = 10 ... 60 s
for pressure control: K_{krit} = 0,1 ... 1,0, T_{krit} = 10 ... 120 s

Px400-Block: Controller

Px400	Control function on/off	0 .. 1	0: Controller off 1: Controller on	
Px402	Control time constant (T_1)	[0,1 sec.]	Delay time for D-part in sec. Because of discrete steps $T_1 \geq$ 0,1 sec. At T_1 = 0,1 sec. the controller can be considered as a quasi ideal controller.	
Px403	Control differential part (T_D)		D-part of the controller in sec. If T_D = 0, no D-part, that means also Px402 without any effect (PI-controller)	
Px404	Control integral part (T_I)		I-part of the controller in sec. If T_I =0 (equal ∞ !), then no I-part <u>and</u> no D-part, that means Px402 and Px403 without effect (P-controller)	
Px405	Control amplification (K_R)		P-part of the controller, dimensionless, as a floating point number	
Px406	Controller output limitation lower limit	0,0...1,0	dimensionless	
Px407	Controller output limitation upper limit	0,0...1,0	dimensionless	
Px411	Actual control value	y000-y999	Assignment to R-parameter	
Px418	Controller output: Scaling of set point addition, Minimum value, 0% addition of set point to controller output		Up to this value of the set point no addition of set point to controller output (in SI-unit of the actual control value) (only if Px420=1)	
Px419	Controller output: Scaling of set point addition, Maximum value, 100% addition of set point to controller output		From this value of the set point on 100% addition of set point to controller output (in SI-unit of the actual control value) / (only if Px420=1)	
Px420	Set point addition on/off	0 .. 1	0: off, 1: on. The set point addition is a preset of the controller output in dependency of the set point and reduces the period of start oscillation.	*)
Px421	Set point controller / Channel No.	-1 0 .. 9	-1: Constant set point from Px422 0: Channel No. 0 (Port 0 Slot 0) to 9: Channel No. 9 (Port 4 Slot 1)	
Px422	Set point controller Setting of standard value	0 ..	Constant set point for the controller in SI-units of the actual control value, see Px411 corresponding R-parameter.	

Px423	Set point ramp function – ramp period	0.0 .. 1200.0 time in s	– ramp off. >0.0: The Set point ramp function helps to set the Set point slowly.	
Px424	Ramp, Start value Standard value		Constant Start value of the ramp in SI-units of the actual control value	
Px425	Ramp, Start value Assignment	0 .. 1	0: Start value = actual control value 1: Standard value as defined in Px424	
Px430	Linearization of output	0 .. 2 [0]	0: inactive 1: rotary slide servo valve 3/4: Kv = 0.428 2: rotary slide servor valve 3/6: Kv = 0.672	
Px441	Controller output, Display unit	0 .. 1	0: absolute (0,0...1,0) 1: percent (0 .. 100,0%)	
Px442	Controller output, Display of decimal digits	0 .. 5	Number of decimal digits	

Table 31: Px400-Block: Controller

7.2.20 Px500-Block: Limits

Px511	Type of Flow limit	y101 .. y109 y191 .. y199 y211 .. y219 y291 .. y299 [212]	R-Parameter of flow mean value	
Px512	Lower limit flow value	0.0 .. 999.999	Value of flow-parameter shown above in SI-units	
Px513	Upper limit flow value	0.0 .. 999.999	Value of flow parameter shown above in SI-units	
Px514	NOK – Counter Counter for hurting of flow limits for setting of failure DO after N bad results:	0 .. 10 [0]	Setting of failure signal after N bad measurement results: 0: not active 1: N=1 (1x bad = NOK) to 10: N=10 (10x bad = NOK)	***)
Px521	Controlling of test pressure	y002 .. y020 [0]	0: Actual pressure absolute 1: Reference pressure absolute 2: Gauge pressure	
Px522	Lower limit pressure control	-100000.0 +500000.0	Pressure limit value in Pascal	
Px523	Upper limit pressure control	-100000.0 +500000.0	Pressure limit value in Pascal	

***) only PLC device

Table 32: Px500-Block: limits

7.2.21 Px700-Block: Process Periods

Px701	Measuring period	0.1 .. 300.0 [1.0]	Time in seconds for measurement	
Px702	Measuring period Display unit	0..2 [0]	0- seconds [s] 1- minutes [min] 2- hours [h]	
Px703	Measuring period Display of decimal digits	0 .. 5 [1]	Number of decimal digits	
Px705	Gate period of measurement: Number of pulses to count for PD-meter measurement	2 .. 100000	Measurement will be stopped after this number of pulses	*)
Px711	Filling period	0.1 .. 300.0	Time in seconds for filling of section	***)
Px712	Calming period	0.1 .. 300.0	Time in seconds for calming of section	***)
Px713	Venting period	0.1 .. 300.0	Time in seconds for venting of section	***)
Px714	Result displaying period	0 .. 97200	In seconds	***)
Px721	Switching period (break time)	0.1 .. 300.0	Time in seconds for switching the steps	***)

*) only with integrated PD- or turbine-flow meter
***) only PLC device

Table 33: Px700-Block: Process Periods

Using a double section device, both sections can work simultaneously by using different periods. But the termination time of the test cycle will be the sum of the periods of the longest running section!
Refer to S9002: Simultaneous measurement stop at double section devices

7.2.22 Offset correction of the differential pressure sensor

Since version 4.092 optional a zero-adjustment of the differential pressure sensor is available during operation (under pressure).

Prerequisite:
- ✓ The measurement system is equipped with valves, tha isolate the differential pressure sensor from the primary element and short-cut its inputs.

Prinziple:
The two inputs of the differential pressure sensor are pneumatically connected. After a calming time the differential pressure is measured and the value is stored as zero offset.

The zero-adjustment is started by:
- Pressing the „Zero“ key
- Sending the special command „ZERO“ via serial interface (RS232)
- Automatically in programmed time cycles. The cycle time is defined by parameter Px730. Px730=0.0 suppresses the automatical zero-adjustment.

Notes:
- The zero-adjustment is performed only in the continuous measuring mode.
- With two parallel measurement sections the zero-adjustment is performed simultaneously.
- If the system is equipped with more than one differential pressure sensors for one measurement section (e.g. for measurement range switching) only that sensor is nullified, that is used in the current program.
- With PLC-operation the manually started zero-adjustment will only be performed, if the system is in state “POLL”, while the “ZERO” key is pressed.
  The cyclic zero-adjustment is performend with the following “POLL” state.

Parameter

Px730	Interval for automatical zero-adjustment of the differential pressure sensor	0...97200	0 : no zero-adjustment else : interval in sec	
Px731	Calming time before start of the automatical zero-adjustment of the differential pressure sensor	0...600	Calming time in sec	

7.2.23 Px800-Block: Display options

1. Single section device:

Px851	Display during measurement Display line 1	y000 .. y999	Assignment to R-Parameter	
Px852	Display during measurement Display line 2	y000 .. y999	Assignment to R-Parameter	

Table 34: Px800-Block: Display options single section device

2. Double section device:

Px851	Display during measurement display line 1-2	y000 .. y999	Assignment to R-Parameter	

Table 35: Px800-Block: Display options double section device

The selection for the display by Px851 is valid for that display line 1 to 2 where this corresponding program number is adjusted

3. Triple section device

Px851	Display during measurement Display line 1-3	y000 .. y999	Assignment to R-Parameter	

Table 36: Px800-Block: Display options triple section device

The selection for the display by Px851 is valid for that display line 1 to 3 where this corresponding program number is adjusted.

7.2.24 Px900-Block: Anlog outputs

In this menu the values, the display units and the representation of the displayed value on the analog output are selected.

Px9z1	Analog output z Assignment R-Parameter	y000 .. y999	Assignment to R-Parameter	*)
Px9z2	Analog output z Output signal 0.0	0 .. 1.0E06 [0.0]	This lowest value in SI units of the R-Parameter produces 0% of the analog output signal.	*)
Px9z3	Analog output z Output signal 1.0	0 .. 1.0E06 [1.0]	This highest value in SI units of the R-Parameter produces 100% of the analog output signal.	*)

Z = number of the analog output, 0 to 7, as physical present
*) only if one or more analog outputs are available

Table 37: Px900-Block: analog outputs

Note:
Don’t use the same values for the parameters Px902 and Px903!
Don’t use the same values for the parameters Px912 and Px913!

The parameters for each analog output are only valid if the output is supported by hardware and software (option analog output).

7.2.25 Ry000-Block: Readparameter, Measuring Results

y: index for measuring circle running from 0 to 2 (single to triple section)

Parameter	Designation of parameter physical value	Abbreviation single meas. Section, y=0	Abreviation with index for multiple meas. section y=0–; y=1, y=2	
Ry000	System absolute pressure	Pbas	Pba0	Pba1
Ry001	Differential pressure	Pdif	Pdi0	Pdi1
Ry002	Actual pressure absolute	Pabs	Pab0	Pab1
Ry003	Actual temperature	Temp	Tem0	Tem1
Ry004	Actual humidity	Hum	Hum0	Hum1
Ry012	Reference pressure absolute	RPab	RPa0	RPa1
Ry013	Reference temperature	RTem	RTe0	RTe1
Ry014	Reference Humidity	RHum	RHu0	RHu1
Ry020*)	Gauge pressure	P1re	P1r0	P1r1
Ry021*)	Gauge pressure 2	P2re	P2r0	P3r1
Ry030*)	Direct mass flow input	Qmd	Qmd0	Qmd1
Ry051	Controller, set value	SetP	Set0	Set1
Ry052	Controller, actual value	ActV	Act0	Act1
Ry053	Controller output	Corr	Cor0	Cor1
Ry101	Actual volume flow	QVac	QVa0	QVa1
Ry102	Standard volume flow	QVno	QVn0	QVn1
Ry103	Reference volume flow	QVre	QVr0	QVr1
Ry107	Heat output	HPwr	HPw0	HPw1
Ry109	Mass flow	Qmas	Qma0	Qma1
Ry110	Reynolds number	Re	Re 0	Re 1
Ry121	Actual density	Aden	Ade0	Ade1
Ry122	Standard density	Nden	Nde0	Nde1
Ry123	Reference density	Rden	Rde0	Rde1
Ry131	Actual viscosity	Avis	Avi0	Avi1
Ry132	Calibration viscosity	Cvis	Cvi0	Cvi1
Ry133	Reference viscosity	Rvis	Rvi0	Rvi1
Ry141	Molar water proportion	Xv	Xv 0	Xv 1
Ry166	Turns / frequency	Rev.	Rev0	Rev1
Ry190	Actual ratio value as ratio or sum	Rate	Rat0	Rat1
Ry191	Correction actual volume flow	Cqva	Cqa0	Cqa1
Ry192	Correction standard volume flow	CQvn	CQn0	CQn1
Ry193	Correction reference volume flow	CQvr	CQr0	CQr1
Ry199	Correction mass flow	CQMa	CQM0	CQM1

Ry200	Measuring period	Tmea	Tme0	Tme1
Ry201	Differential pressure (mean value)	Mpdi	Pdi0	Pdi1
Ry202	Actual pressure absolute (mean value)	Mpab	Pab0	Pab1
Ry203	Actual temperature (mean value)	Mtem	Tem0	Tem1
Ry204	Actual humidity (mean value)	Mhum	Hum0	Hum1
Ry205	Reference pressure absolute (mean value)	MRPa	Rpa0	Rpa1
Ry206	Reference temperature (mean value)	MRTe	Rte0	Rte1
Ry207	Reference Humidity (mean value)	MRHu	Rhu0	Rhu1
Ry209	System absolute pressure (mean value)	Pbas	Pba0	Pba1
Ry211	Actual volume flow (mean value)	MQVac	QVa0	QVa1
Ry212	Standard volume flow (mean value)	MQVno	QVn0	QVn1
Ry213	Reference volume flow (mean value)	MQVre	QVr0	QVr1
Ry217	Heat output (mean value)	HPwr	HPw0	HPw1
Ry219	Mass flow (mean value)	Qmas	Qma0	Qma1
Ry221	Actual volume flow (lowest value)	Min	Min	Min
Ry222	Standard volume flow (lowest value)	Min	Min	Min
Ry223	Reference volume flow (lowest value)	Min	Min	Min
Ry229	Mass flow (lowest value)	Min	Min	Min
Ry231	Actual volume flow (highest value)	Max	Max	Max
Ry232	Standard volume flow (highest value)	Max	Max	Max
Ry233	Reference volume flow (highest value)	Max	Max	Max
Ry239	Mass flow (highest value)	Max	Max	Max
Ry241	Total actual volume flow	Avol	Sva0	Sva1
Ry242	Total standard volume flow	Nvol	SVn0	SVn1
Ry243	Total reference volume flow	Rvol	SVr0	SVr1
Ry247	Heat quantity, energy	Hen.	Hen0	Hen1
Ry249	Total mass flow	Mass	SMa0	SMa1

Ry251*)	Gauge pressure (mean value)	P1re	P1r0	P1r1
Ry252*)	Gauge pressure 2 (mean value)	P2re	P2r0	P2r1
Ry254*)	Minimum Gauge pressure (lowest value)	Min	Min	Min
Ry255*)	Minimum Gauge pressure 2 (lowest value)	Min	Min	Min
Ry257*)	Maximum Gauge pressure (highest value)	Max	Max	Max
Ry258*)	Maximum Gauge pressure (highest value)	Max	Max	Max
Ry260	Direct mass flow input (mean value)	Qmd	Qmd0	Qmd1
Ry265*)	Pulses after measurement	Imp.	Imp0	Imp1
Ry266*)	Frequency after measurement	Frq.	Frq0	Frq1
Ry270	Minimum differential pressure	Min	Min	Min
Ry271	Maximum differential pressure	Max	Max	Max
Ry290	Actual ratio value as ratio or sum (mean value)	Rate	Rat0	Rat1
Ry291	Correction actual volume flow (mean value)	CQva	Cqa0	Cqa1
Ry292	Correction standard volume flow (mean value)	CQvn	CQn0	CQn1
Ry293	Correction reference volume flow (mean value)	CQvr	CQr0	CQr1
Ry299	Correction mass flow (mean value)	CQMa	CQM0	CQM1
Ry301	Leak test, initial pressure	P0	P0 0	P0 1
Ry302	Leak test, final pressure	P1	P1 0	P1 1
Ry303	Leak test, lowest pressure	Pmin	Pmi0	Pmi1
Ry304	Leak test, highest pressure	Pmax	Pma0	Pma1
Ry305	Leak test, pressure loss per period	dpdt	dPt0	dPt1
Ry310	Alternative leak test, period from start pressure to end pressure	LTim	LTi0	LTi1
Ry311	Alternative leak test, measured start pressure	P1	P1 0	P1 1
Ry312	Alternative leak test, measured end pressure	P2	P2 0	P2 1
Ry315	Alternative leak test, pressure drop over period	dpdt	dPd0	dPd1

*) only if available
y: measuring circle index runs from 0 to 2 (single to triple section device)

Table 38: Ry000-Block: Read-parameter

8 Calculation specifications

During the 19th century the French and English physicians Gay-Lussac, Boyle and Mariotte carried out the basic work to describe the thermodynamical behaviour of gases. They defined the

Equation of state of the (ideal) gases:

$$\frac{p_1 \cdot V_1}{T_1} = \frac{p_2 \cdot V_2}{T_2} \qquad \text{or} \qquad \frac{p \cdot V}{T} = const.$$

In the case of a certain amount (mass m) of a gas the result of pressure times volume divided by the absolute temperature is constant. The equation of state is only true in case of ideal gas and for real gases only as a first approximation. It is not true for any kind of steam. The equation of state comes with three special cases:

Overview:	**Special cases of**	**the equation of**	**state**
designation:	Isobar change of state	Isochorous change of state	Isothermal change of state
condition:	P=const.	V=const.	T=const.
formula:	$\frac{V_1}{V_2} = \frac{T_2}{T_2}$	$\frac{p_1}{p_2} = \frac{T_2}{T_2}$	$\frac{p_1}{p_2} = \frac{V_2}{V_1}$
law of:	Gay-Lussac	Gay-Lussac	Boyle-Mariotte

As regards the equation pV/T = constant the numerical value of the constant quotient depends on the mass of the included gas. When referring the equation to 1 kg, thus it is to be divided by m:

$$\frac{p \cdot V}{m \cdot T} = const. = R_i$$

Here R_i is the **special gas constant**, depending on the kind of gas. The equation also performs the correlation of volume flow and corresponding measuring condition which in turn is required as a basis to convert volume flows:

Standard volume flow Qvnorm at standard conditions: Tnorm, Pnorm, (rHnorm)

Calibration volume flow Qvcal at calibration conditions Tcal, Pcal, (rHcal)

Statement of calibration conditions, e.g. prevailing conditions at time of calibrating the LFEs. The conditions may be taken from the calibration data sheets of the LFEs.
They are generally identical for all the LFEs.
The nominal volume flow is the volume flow through the LFE flowing under conditions of calibration at the final value of the differential pressure. It is a reference value for the volume flow that may actually prevail. This volume flow is not a fixed upper limit, for the integrating transformers of the **LMF** may operate up to 20% above the nominal range.

8.1 Adjustable types of gas

Settings in Px000-block:

Air under atmospheric conditions is the usual medium of calibration. Maximum
accuracy is achieved by using the most precise approximations of gas properties for air in a range of 5 to 35 °C, 800 to 1200 hPa absolute pressure and 0 to 95% relative humidity as announced by a recommendation of the PTB.

As a standard the following types of gas are stored in the LMF:

1: Air
2: Argon
3: Carbon dioxide
4: Carbon monoxide
5: Helium
6: Hydrogen
7: Nitrogen
8: Oxygen
9: Methane
10: Propane
11: n-Butane
12: natural gas H
13: natural gas L
14: laughing gas, N2O

For other gases please request the TetraTec Instruments GmbH.

8.2 Calculation of density

Settings in Px000-block: Px003

Ideal:

The setting ideal does not perform any real gas corrections for the density beside of humidity of air. The correction is done following the recommendations of the PTB. They are only valid, however, for air and in a limited range of temperature (5 .. 30 °C.

Real:

The setting real does perform an real gas correction for the density. The calculation is based on the real gas law and follows recommendations of PTB, Germany. It is performed by using the Virial coefficient development for the real gas factor.

8.3 Calculation of viscosity

Settings in Px000-block: Px004

Ideal:

The setting ideal does perform a universal correction of temperature of viscosity. The calculation for all types of gas is based on the recommendations of Daubert & Danner. It is valid across a wide range of temperature.

Real:

The setting real does perform an real gas correction for the viscosity of humid air. The calculation is based on the Kestin-Whitelaw-law and is only valid for air.
In future it is planned to offer here pressure dependent correction for the viscosity, important for applications above 5 bar absolute.

8.4 Actual- and Reference Sensors, Compensation Calculation

The blocks Px010 to Px080 of the program parameters have three functions:

1. Input of sensor-configuration corresponding to hardware, configuration of the device and the measurement problem
2. Adaptation of calculated values to measurement problem (translation, compensation calculation)
3. Input of user defined standard values for sensors not available set-value)

8.4.1 Measuring sensors

Pabs: Absolute pressure of gas in inlet section of the measuring device (e.g. LFE, turbine flow-meter or nozzle.

Range of values: CONST | SENSOR | Pabs+Pdif

CONST: Input of absolute pressure as standard value (in Pa)
SENSOR: Measurement of absolute pressure at inlet side of the primary element an with absolute pressure sensor
=Pabs+Pdif: Measurement of absolute pressure at outlet side and calculation of absolute pressure at inlet side as the summed up value of absolute and differential pressure. (Special case to protect absolute pressure sensors against over pressure
Temp: Temperature of gas in inlet section of primary element (e.g. LFE, turbine flow-meter or nozzle).

Range of values: CONST | SENSOR

CONST: Input of temperature as a set standard value (in K)
SENSOR: Measurement of temperature in gas flow.

Hum: Relative humidity of gas in inlet section of primary element (e.g. LFE, turbine flow-meter or nozzle.

Range of values: CONST | SENSOR

CONST: Input of relative humidity as a set standard value
SENSOR: Measurement of relative humidity in gas flow.

8.4.2 Reference sensors

Reference sensors may be used to convert the volume flow rate and to compensate differences between different thermodynamical conditions at the location of LFE and the location of the unit under test (UUT).
(For using reference sensors additional hardware is necessary).

RPab: Absolute pressure of gas at inlet of UUT.
Prel: Gauge pressure of gas at inlet of UUT.

Range of values: CONST / =RPab / = Prel + Pabs / = Prel+(Pabs-Pdif) / = Pabs

CONST: Input of absolute pressure as a set standard value.
=RPab Measuring of absolute pressure at UUT with a second absolute pressure sensor.

Rpab
= Prel+Pabs Calculating the absolute pressure at UUT by adding the value of a gauge or differential pressure sensor at UUT to Pabs of flow meter, if flowmeter outlet is on atmosphere and Pdif is neglectable.

=Prel+(Pabs-Pdif) Calculating the absolute pressure at UUT by adding the value of a gauge or differential pressure sensor at UUT to Pabs of flow meter, if flowmeter outlet is on atmosphere.

=Pabs Setting the reference as the same as the flow meter's inlet pressure, assuming that the measured device doesn´t produce any important pressure drop.

RTemp: Temperature of gas at inlet of UUT.

Range of values: CONST | SENSOR | =TEMP

CONST: Input of temperature as a constant set value (in K)
SENSOR: Measuring of temperature at UUT / a second with reference sensor

=Temp: Setting the reference as a constant the same as the flow meter's inlet pressure, assuming that the measured device doesn´t produce any important pressure drop.

RHum: Relative humidity of gas by means of reference or standard measuring device.

Range of values: CONST | SENSOR | rH

CONST: Input of temperature as a constant set value (in %rH)
SENSOR: Measuring of temperature at UUT / a second with reference sensor

=rH: Setting the reference as a constant the same as the flow meter's inlet pressure, assuming that the measured device doesn´t produce any important pressure drop.

To measure with reference sensors additional hardware is required!

9 Linearization of sensors and primary elements

9.1 Linearization of sensors and analog input signals

There may be stored up to ten different sensor data sets in the **LMF** system. Scaling and linearization data may be needed for every one. Linearization of the sensors and analog signal will increase the accuracy of the system. Usually the Laminar Master is fully equipped with all the needed sensors and fully configured. If changing or recalibrating of a sensor is necessary new linearization data have to be entered into the system. Three different methods of sensor linearizition are implemented in the in the Laminar Master:

1. Linearization via polynome
2. PT100 / PT1000 linearization
3. Without linearization (linear equal to the raw values of the sensor)

The principle of linearization via polynome is as follows:

Sensor Raw value (mA / V)	⇨	X-factor =1.0 (S2x20)	⇨	Linearization calculation (S2x10 to 19)	⇨	Y-factor =1/SI factor (S2x21)	⇨	Sensor value in SI unit

The corrected sensor value will be calculated by using the following linearization polynome equation:

$$y = a(9)x^9 + a(8)x^8 + ... + a(1)x + a(0)$$

The sensor signal (raw value) is the input value for the polynome calculation. Normally the output signal of the sensor (mV, V, mA ...) is equivalent to the input value for the polynome calculation. So in standard configuration of the hardware the X-factor (S2x020) will be equal to 1.0. With this input value the polynome calculation will calculate the output value, the physical representation of this value. The internal calculation now of the software is always running in SI-units. Using a further factor after polynome calculation, the so called Y-factor (S2x021=.......) offers the possibility of using different polynomes (output values scaled in different physical units) for a sensor and transform it afterwards into the necessary SI unit again. A list of corresponding conversion factors is provided in chapter 12.

Example for a sensor linearization:

You have got the calibration (polynome) coefficients for a sensor. The output signal range is from 0 .. 10 V corresponding to the physical representation in 0 .. 20 mbar. The internal calculation delivers every value in SI (Standard International) units. The sensor raw values are coming directly from the hardware (slot card) as a standard in a range 0..10 (V). Therefore no further scaling of the input value is needed. The X-factor (=S2x20) is 1.0. The output value of the linearization calculation will come in the range of 0 to 20 mbar. To convert the mbar values back into SI units, e.g. here Pascal, the Y-factor must be used to rescale, in this example S2x21=1.0E-02.

9.2 Linearization of primary elements

There may be stored up to five different data sets for each primary element type in the **LMF** system. Scaling and linearization data may be needed for every primary element. Linearization of the primary elements will increase the accuracy of the system. Usually the Laminar Master is fully equipped with all the needed primary element data sets and fully configured. If changing or recalibrating of a primary element is necessary new linearization data have to be entered into the system. The principle of linearization from e.g. LFEs is the same as described before. The input and the output values of the linearization calculation are different. The input value is the differential pressure at the LFE and the output value is the actual volume flow. The differential pressure at the LFE is calculated internally using SI units. Therefore the differential pressure must be converted using the X-factor into the input unit needed for the polynome linearization. And also the flow output of the linearization again has to be converted back into SI-units with the Y-factor:

SI unit [Pa] Pdif	⇨	X-factor =1/SI-factor (S5x20)	⇨	Polynom linearization In:Pdif out:Qvac (S5x10 to 19)	⇨	Y-factor =1/SI-factor (S5x21)	⇨	SI unit $[m^3/s]$ Qvac

Example for a LFE linearization:

You have got the polynome coefficients for a LFE calibration. Out of the data sheet of the Laminar Flow Element you can find the polynome coefficients A, B and C corresponding a(0), a(1) and a(3). The input value for the polynome calculations is the differential pressure caused by the LFE. The result is the actual volume flow through the LFE. The differential pressure is calculated internaly scaled in Pascal. The data base for coefficients may have been scaled in inch water column ⇔ cubic feet per minute. The X-factor is used now to rescale the internal calculated pressure from Pascal to inch water column. In this example the X-factor S5x20= 4.01463E-03. The output of the polynome calculation (actual flow) will come now scaled from 0 to 150 cubic feet per minute. The internally needed unit for flow calculations is cubic meters per second. Therefor this polynome output has to be converted with the Y-factor (S5x21=2,11887E+03) from cubic feet per minute to cubic meters per second again.

10 Assignment of sensors and primary elements

The assignment of the sensors and primary elements to the measuring circles and programs is explained at the following using an example:

Example:
Double section device equipped with 7 sensors and 2 LFEs:

Sensor 0: differential pressure section 0
Set of parameters: S2000 .. S2031 for linearization and scaling

Sensor 1: absolute pressure section 0
Set of parameters: S2100 .. S2131 for linearization and scaling

Sensor 2: actual temperature section 0
Set of parameters: S2200 .. S2231 for linearization and scaling

Sensor 3: actual humidity pressure section 0
Set of parameters: S2300 .. S2331 for linearization and scaling

Sensor 4: differential pressure section 1
Set of parameters: S2400 .. S2431 for linearization and scaling

Sensor 5: absolute pressure section 1
Set of parameters: S2500 .. S2531 for linearization and scaling

Sensor 6: actual temperature section 1
Set of parameters: S2600 .. S2631 for linearization and scaling

LFE 0: LFE section 0
Set of parameters: S5000 .. S5031 for linearization and scaling

LFE 1: LFE section 1
Set of parameters: S5100 .. S5131 for linearization and scaling

First a measuring program is assigned to a measuring circle:

S1000 = 0
S1001 = 4

Measuring circle 0 will be evaluated by using measuring program 0, measuring circle 1 by measuring program 4.

At every program now the different input values for the flow calculation and the display configuration has to be defined:
Program 0:
P0000 = 5; Preselection for LFE evaluation used by program 0
P0010 = 0; LFE0 data set used by program 0
P0010 = 0; Sensor 0 measures differential pressure used by program 0
P0020 = 1; Sensor 1 measures actual absolute pressure used by program 0
P0030 = 2; Sensor 2 measures actual temperature used by program 0
P0040 = 3; Sensor 3 measures actual humidity used by program 0
P0050 = -1; Reference absolute pressure is a standard value used by program 0
P0060 = -1; Reference temperature is a standard value used by program 0
P0070 = -1; Reference humidity is a standard value used by program 0
P0080 = -1; Relative gauge pressure is a standard value used by program 0

Program 4:
P4000 = 5; Preselection for LFE evaluation used by program 4
P4005 = 1; LFE1 data set used by program 4
P4010 = 4; Sensor 4 measures differential pressure used by program 4
P4020 = 5; Sensor 5 measures actual absolute pressure used by program 4
P4030 = 6; Sensor 6 measures actual temperature used by program 4
P4040 = -1; Actual humidity is a standard value used by program 4
P4050 = -1; Reference absolute pressure is a standard value used by program 4
P4060 = -1; Reference temperature is a standard value used by program 4
P4070 = -1; Reference humidity is a standard value used by program 4
P4080 = -1; Relative gauge pressure is a standard value used by program 4

After selecting the sensors and primary elements as shown above the basic configuration is done. In a next step the fine tuning / adjustment has to be done:
Units, decimal digits, flow rates has to be configured for displaying the measurement and calculation values.

11 Design of the measuring section

Because the LFE is the most used primary element in the following the construction of the measuring circle is described with it. But general properties of flowing gases recommend the same constructions for all of the primary elements.

11.1 Installing a Laminar Flow Element

Laminar sections need a straight inlet section that is at least10 times as long as the diameter of the active part of the LFE or the diameter of the inlets respectively (the smaller value counts). It also needs a straight outlet section that is at least 5 times
as long as the diameter above mentioned. Thus the flow profile gets more homogeneous and the LFE is installed in the way calibrated by the manufacturer. The inlet section should be in alignment and have no edges etc.

The LFE may not be dirty, neither by solid particles (dust) nor by liquids (oil, water), because destruction of capillaries or film forming and narrowing may lead to a state where the calibration is no more correct and valid.

The connections (if they have to be installed differently) have to be absolutely leakproof.
The absolute pressure sensor position is preferably installed at the inlet side of the differential pressure sensor (by T-or L-piece) or directly at the second positive inlet of the differential pressure sensor (the later configuration is commonly supplied by **TetraTec Instruments GmbH**).

Inlet section: Straight, at least 10 times as long as the LFE-diameter!

Outlet section: At least 5 times as long as LFE-diameter!

Keep the LFE clean! Solid particles (dust), liquid (oil, water) may choke some capillaries and the calibration of the LFE will be invalid.

11.2 Construction of the flow-section

Two contrary requirements have a determining influence on the flow-section :
a) small volume
b) small flow resistance

11.2.1 Connections between LFE and dP-sensor

The connection should be short and consist of rigid, non elastic hoses. Long hoses may lead to longer evaluation times of the device. If very small flows are to be measured (leakage measuring at the high-pressure side); to fasten the measurement it may be necessary to use very short, thin tubes.

11.2.2 Formation of Test-sample, LFE and (switching-) valves

Method 1: The LFE should be installed as close to the outlet side of the test sample as possible. The valve, that opens the test pressure, should also be installed near the test sample. However, it should be installed in front of the temperature sensor (because the valve may warm up the test air considerably) and in front of an optional absolute pressure sensor for evaluation and compensation of the test pressure.

Method 2: The LFE should be installed directly in front of the valve that switches on the test pressure. The section between valve and test item should be as short as possible. Big volume at the inlet side of the LFE will cause no harm. By no means should the test pressure in front of the LFE be switched on and off, because filling and venting of the test section includes the air in the LFE and unnecessary filling, venting and stabilisation times have to be taken into account.

Method 3: The LFE has to be installed as close as possible to the test-sample. It is recommended to install the test vacuum as close to the LFE as possible. Filtering air at the inlet side of the LFE is unproblematic since a big filter can be used that will not lead to a major pressure drop.

11.3 Protection of sensors

11.3.1 Mechanical protection

The electrical connections of some sensors are relatively sensitive to damage. Therefore handle it with great care and install with a protection connection or a protection cap.

Do not set the connection cables under tension load or extreme bending load. Fix the cables properly.

If thin temperature sensors are used (e.g. PT100, PT1000) danger of deformation or internal parting of cable is very likely. We therefore recommend to protect these sensors extra carefully against bending. It is absolutely necessary to protect the connection cables against tension force.

Sensors with frontside O-ring or profile-ring seals must not be tightened with high torque moments. It is absolutely forbidden to tie them into a conical thread. All surfaces have to be flat and free of dirt and edges.

11.3.2 Pneumatical protection

This mainly refers to absolute pressure sensors in a measuring section design according to method 1. If a test sample is missing or the pressure over the LFE does exceed the maximum flow value of the LFE by a multiple the inlet of the LFE may be possibly under full pressure. This especially applies to LFEs that measure small or extremely small leakage. An absolute pressure sensor designed for atmospheric conditions (ambient pressure) may thus get damaged permanently.

Two solutions are recommended:
a.) Use an absolute pressure sensor able to tolerate full test pressure. Then the disadvantage is that the resolution of the measurement is lower.
b.) Change of design of measuring section. Mounting the absolute pressure sensor at outlet (atmospheric) side of the LFE. Setting the parameter Px024 in the parameter menu to the correct selection is necessary.

11.4 Dimensioning of LFE's for higher system pressure

Laminar Flow Elements usually are designed for atmospherical conditions. Under these conditions the flow in the capillaries is laminar. For the (constructive) dimensioning of the LFE the 'Reynolds criteria' is used (Reynolds number, Re). It is used to describe the state of the flow. The capillaries of the LFE are dimensioned in a way that the Reynolds' number is about 600 at the highest volume flow. At a Reynolds number of about 1200
the flow turns from laminar to turbulent. The Reynolds' number is calculated from the geometry of the capillaries and is proportional to the velocity of flow and the density of the gas. Therefore if the density of gas increases the Reynolds' number increases as well.

For the purpose of dimensioning the LFE it means that the product of density of gas and velocity of flow has to remain constant.

Rule: If a LFE is used under higher pressure, it has to be dimensioned as if a volume flow under atmospherical (standard) conditions would be measured. That means if the test pressure is higher by a certain factor than atmospherical pressure the maximum volume flow rate through the LFE is lowered by that factor.

E.G.: A LFE considered for use under 3 bar absolute pressure to measure 1 l/min must have a volume flow rate of 3 l/min under atmospherical conditions according to the data sheets.

When using a LFE under higher pressures and therefore lower flow rates the differential pressure over the LFE drops accordingly. This drop of differential pressure then sets a limit for use of LFEs for volume flow measurements under higher pressure according this method because only a small part of the measuring range of the differential pressure sensor is being used.

As an alternative it is possible for high pressure applications to work instead of Hagen-Poisseuille with the universal flow calibration and calculation. In case of doing so the full range of the actual flow range of the LFE can be used. Even with a special calibration one can leave the base of the classical calibration and use a wider Reynolds number range. So the differential pressure measurement can also be done by using bigger measurement ranges, what is easier concerning the accuracies and even cheaper.

11.5 Operating the measuring device with other gases or gas mixtures

In principal all non-corrosive gases or gas mixtures may be measured by LFEs. For a correct evaluation of the volumetric flow the viscosity of the gas must be known.

To determine mass flow or standardized volumetric flow the density of the gas (especially the real gas factor in dependency on the temperature, humidity and pressure) must be known.

The **LMF** devices are prepared to measure other gases as well.
More details may be requested at TetraTec Instruments GmbH.

12 Measuring and Correction methods

Some remarks on measuring methods for gap and orifice geometries.

A widely used measuring method for measuring gap-, annular gap-, nozzle-, opening and orifice geometries is to measure the volume flow or mass flow in a system where air is flowing through. It is assumed that the test item behaves like a nozzle in a more or less ideal critical flow. Three kinds of set-up have to be differentiated:

Method 1:

The test sample is set under compressed pressure (mostly about 2.5 bar overpressure to maintain the critical pressure ratio). The outflowing air *behind* the test sample is to be measured applying the LFE.
The volume flow through the test sample depends on the following variables:

* Absolute pressure in front of the test sample (nearly proportional)
* Temperature of test air (proportional to square root of absolute temperature).
* Absolute pressure on the outlet side (atmospherical pressure), dependence being almost inversively proportional.

To compensate variations of atmospherical pressure the volume flow at the outlet side of the test sample has to be recalculated as the so called standardized volume flow, that means the **standardized volume flow** has to be evaluated.

If the inlet pressure widely varies the absolute pressure in front of the test sample has to be measured to make a mathematical inlet pressure correction. The temperature of the inlet pressure may also differ from the air temperature flowing through the LFE; therefore an additional temperature sensor may be installed to measure the inlet pressure.

When applying this method the LFE may get soiled by dust, chips, abrasion and oil running out of the test sample. The use of a filter is highly recommended.

Method 2:

Set the test sample under a compressed pressure (mostly about 2.5 bar overpressure to maintain the critical pressure ratio). The volume flow ***in front of*** the test sample is to be measured applying the LFE. Volume flow is to be calculated.
The volume flow in front of the test sample depends on the following variables:

* Temperature of the test air (proportional to the square root of the absolute temperature).

* The volume flow hardly depends on the inlet pressure (a nozzle under ideal critical flow would set the volume flow almost independent of the inlet pressure). It is also nearly independent of the pressure at the outlet side (atmospherical pressure).

This method allows the LFE to be used under guaranteed dry, oilfree and dirtfree air.

Method 3:

The test sample is connected with a vacuum pump. The volume flow in front of the test sample (inlet from atmosphere) will be measured by the LFE. Using this method the **volume flow** will be calculated.
The volume flow in front of the test sample depends on the following variables:

* Temperature of test air (proportional to the square root of the absolute temperature).

* The volume flow hardly depends on the inlet pressure. A nozzle under ideal critical flow would set the volume flow almost independent of the inlet pressure. It is also nearly independent of the - suction pressure of the vacuum pump, as long as the critical pressure ratio is kept) - pressure at the outlet side (atmospherical pressure).

Here the LFE will not get soiled by the test sample, however, the atmospherical pressure should be filtered.

The correction of temperature dependency of the volume flow across the test sample is performed according to method 2.

Especially in the automotive industry suppliers a lot of actuators are measured and tested, that are supposed to set a certain mass flow (e.g. auxiliary air regulator, E-gas flaps, venting valves etc.). Therefore test specifications often require mass flow measurements.

However, using mass flow as variable is not the appropriate method to test geometry, flow charts etc. in production lines. It is preferable to use the volume flow or standardized volume flow with respective corrections, depending of the test section design. Measuring the mass flow using methods 2 or 3 would lead to the same dependencies of inlet and atmospherical conditions as in method 1!

We recommend method 3 for measurement and evaluation of new products whose test specifications have not yet been laid down. This method offers the simplest and most reliable test section design, the fastest reaction time (= fastest stabilization time of flow conditions) and the lowest degree of soiling.

13 Measurement Uncertainty

13.1 Basic considerations Qv , Qm , ρ(p , T, xv)

The determination of the actual volume flow Q_v of the unit under test (uut) is generally done by measurement of the actual volume flow of the calibration-standard (Master) and conversion with the density ratio (density ρ) to the conditions of the unit under test.

$$Q_{v,uut} = Q_{v,Master} * \rho_{Master} / \rho_{uut}$$

The measured quantity mass flow (Q_m) is calculated as the product of the actual volume flow and the density and has the same value in each point of the measuring system.

$$Q_{m,uut} = Q_{m,Master} = Q_{v,Master} * \rho_{Master}$$

The effect of error propagation of the relative uncertainty of measurement from the different measured quantities is determined according to ISO/TR 5168 as the *standard deviation*.

$$u_{ges,std} = \sqrt{\sum_i u_i^2}$$

The *extended uncertainty of measurement* u_{ges} , resulting from the relative standard uncertainty of measurement $u_{ges,std}$ by multiplication with the extension factor k = 2, is corresponding to the interval in which the measurement value lies with a probability of 95%. The smallest assignable extended uncertainty of measurement of the reference measurement (calibration) is identical with this extended standard uncertainty of measurement. In the standard uncertainty of measurement of the unit under test, another contribution has to be taken into account which describes the spread of the unit under test resp. the calibration results.

Decisive point for the uncertainty of measurement of the reference measurement is the uncertainty of the determination of the actual volume flow through the calibration standard. Furthermore there´s an uncertainty when determining the density ratio between master and the unit under test (for quantity actual volume flow), resp. in the determination of the density of the calibration standard (for quantity mass flow) from the measurement quantities like humidity, pressure and temperature of the calibration standard resp. the unit under test.

13.2 Measurement uncertainty caused by leakages in the measuring circle

In the forfield of any reference measurement, one has to make sure by a leak test of the system (pressure-drop method) that the maximum error by leaks will stay below a fixed value.
Let the volume of the measuring circle be V, the operating pressure for leak test p and the smallest flow to be calibrated Q_{min} , so the maximum pressure drop allowed in the measuring circle for an uncertainty u_L is

$$dp/dt \le u_L \cdot Q_{min} \cdot p / V$$

13.3 Uncertainty of measurement during calibration with Laminar Flow Elements:

The extended standard uncertainty of measurement of the reference standards is fixed by the calibration within a continuous measurement chain related to the PTB Physikalisch-Technische Bundesanstalt. The calculation of the actual volume flow at the unit under test with reference measurement by Laminar Flow Elements is done according to the following relation (Hagen-Poiseuille Equation and conservation of mass / continuity equation):

$$Q_{vol,uut} = Q_{cal,LFE}\,(dp) \cdot \eta_{cal}/\eta_{uut} \cdot \rho_{LFE}/\rho_{uut}$$

The uncertainty of measurement for calibration with Laminar Flow Elements consists of the following factors:

uncertainty of measurement u_{cal} of the reference standard calibration, typically u_{Kal} = 0,325%v.M. (Half of the extended measurement uncertainty of typically 0,65%)
uncertainty of measurement u_{dp} for measurement of the differential pressure at the LFE
For measurement of the differential pressure of the LFE, at works-calibration as well as at external reference measurement , the same differential pressure sensor is used, so that not the absolute precision of the sensor is relevant but only the repeatability of the measurement values. In addition the thermal and long-time drift of the sensor has to be taken into account. Typical values in the dp-interval 2 – 25 hPa:

relative measurement uncertainty	u_{dp} = 0,15%v.M.
thermal uncertainty:	u_L = 0,02% v.M./℃.
zero point of the sensor:	u_N = 0,05% v.E.

uncertainty of measurement u_η for the viscosity ratio by calculation from calibration conditions to actual conditions during reference measurement, typically
u_η = 0,056%
uncertainty of measurement u_ρ for the density ratio. Mainly the accuracy of the measurement of temperature and pressure as well as for air the humidity is significant for the conversion from conditions of the calibration standard to conditions of the unit under test, typically
u_ρ = 0,14% for mass flow
u_ρ = 0,12% for volume flow
uncertainty of measurement u_{LFE} for reference measurement with Laminar Flow Elements. This part of uncertainty includes the standard deviation of the calibration points in regard to polynomial linearisation, as well as an estimation of the short- and long-time drift behaviour between reference measurements. The value in first instance is fixed and will later be adjusted by historical data.
u_{LFE} = 0,15%

For the extended uncertainty of measurement it follows:
$$u_{ges} = 2 \cdot (u_{Kal}^2 + u_{dp}^2 + u_\eta^2 + u_\rho^2 + u_L^2 + u_{LFE}^2)^{1/2} + 2 \cdot u_N$$

For the example volume flow follows:
$$u_{ges} = 2 \cdot (0{,}325^2 + 0{,}15^2 + 0{,}056^2 + 0{,}12^2 + 0{,}02^2 + 0{,}15^2)^{1/2} = 0{,}82\%\text{v.M.} + 0{,}1\%\text{ v.E.}$$

and finally the worst case for the mass flow of humid air is:
$$u_{ges} = 2 \cdot (0{,}325^2 + 0{,}15^2 + 0{,}056^2 + 0{,}14^2 + 0{,}02^2 + 0{,}15^2)^{1/2} = 0{,}84\%\text{v.M.} + 0{,}1\%\text{ v.E.}$$

13.4 Uncertainty of measurement during calibration with Orifices:

The extended standard uncertainty of measurement of the reference standards is fixed by the calibration within a continuous measurement chain related to the PTB Physikalisch-Technische Bundesanstalt. The calculation of the actual volume flow at the unit under test with reference measurement by Orifices is done according to the following relation (Bernoulli Equation and conservation of mass / continuity equation):

$$Q_{vol,uut} = (dp \cdot \rho_{uut})^{0,5} \cdot C_{cal}\,(Re) \cdot / \rho_{uut}$$

The uncertainty of measurement for calibration with orifices consists of the following factors:

uncertainty of measurement u_{cal} of the reference standard calibration, typically u_{Cal} = 0,325%v.M. (Half of the extended measurement uncertainty of typically 0,65%)
uncertainty of measurement u_{dp} for measurement of the differential pressure at the orifices.
For measurement of the differential pressure of the orifices, at works-calibration as well as at external reference measurement , the same differential pressure sensor is used, so that not the absolute precision of the sensor is relevant but only the repeatability of the measurement values. In addition the thermal and long-time drift of the sensor has to be taken into account. Typical values in the dp-interval 2 – 25 hPa:

relative measurement uncertainty u_{dp} = 0,15%v.M.
thermal uncertainty: u_L = 0,02% v.M./°C.
zero point of the sensor: u_N = 0,05% v.E.

uncertainty of measurement u_{Re} for the Reynolds number influence by calculation of the flow coefficient C_{cal} (Re), typically
u_{Re} = 0,06%
uncertainty of measurement u_ρ for the density ratio. Mainly the accuracy of the measurement of temperature and pressure as well as for air the humidity is significant for the conversion from conditions of the calibration standard to conditions of the unit under test, typically
u_ρ = 0,14% for mass and volume flow
uncertainty of measurement u_{OR} for reference measurement with orifices. This part of uncertainty includes the standard deviation of the calibration points in regard to polynomial linearisation, as well as an estimation of the short- and long-time drift behaviour between reference measurements. The value in first instance is fixed and will later be adjusted by historical data.
u_{OR} = 0,15%

For the extended uncertainty of measurement it follows:
$u_{ges} = 2 \cdot (u_{Kal}^2 + 0,5 \cdot u_{dp}^2 + u_{Re}^2 + 0,5 \cdot u_\rho^2 + u_L^2 + u_{OR}^2)^{1/2} + 2 \cdot u_N$

For the mass and volume flow follows:
$u_{ges} = 2 \cdot (0,325^2 + 0,5 \cdot 0,15^2 + 0,06^2 + 0,5 \cdot 0,14^2 + 0,02^2 + 0,15^2)^{1/2}$ = 0,76%v.M. + 0,1% v.E.

13.5 Uncertainty of measurement during calibration with critical nozzles:

The extended standard uncertainty of measurement of the reference standards is fixed by the calibration within a continuous measurement chain related to the PTB Physikalisch-Technische Bundesanstalt. The calculation of the actual volume flow at the unit under test with reference measurement by critical nozzles / critical flow orifices (CFO) is done according to the following relation (equation for the velocity of sound and conservation of mass / continuity equation):

$$Q_{vol,uut} = Q_{vol,CFO} \cdot \rho_{CFO}/\rho_{uut} = F(c(T)) \cdot \rho_{CFO}/\rho_{Prüfling}$$

The uncertainty of measurement for calibration with critical nozzles consists of the following factors:

uncertainty of measurement u_{cal} of the reference standard calibration, typically u_{Kal} = 0,325%v.M. (Half of the extended measurement uncertainty of typically 0,65%)
uncertainty of measurement u_c for the dependence of the sonic velocity on temperature typically
u_c = 0,06%
uncertainty of measurement u_ρ of density ratio. Mainly the accuracies of pressure and temperature measurement, and furthermore for air the humidity is significant for conversion from conditions at the reference standard to conditions at the unit under test, typically
u_ρ = 0,14% for mass-flow
u_ρ = 0,12% for volume-flow
uncertainty of measurement u_{CFO} for reference measurement with Laminar Flow Elements. This part of uncertainty includes the standard deviation of the calibration points in regard to polynomial linearisation, as well as an estimation of the short- and long-time drift behaviour between reference measurements. The value in first instance is fixed and will later be adjusted by historical data.
u_{CFO} = 0,15%

For the extended measurement uncertainty for an orifice follows:
$u_{ges} = 2 \cdot (u_{Kal}^2 + u_c^2 + u_\rho^2 + u_{CFO}^2)^{1/2}$

For the example volume flow follows:
$u_{ges} = 2 \cdot (0,325^2 + 0,06^2 + 0,12^2 + 0,15^2)^{1/2}$ = 0,77%v.M.

and finally the worst case for the mass flow of humid air is:
$u_{ges} = 2 \cdot (0,325^2 + 0,06^2 + 0,14^2 + 0,15^2)^{1/2}$ = 0,78%v.M.

14 Using the PLC interface

The following sections describe the individual test steps. Here the PLC is the programmable loop controller often used for test bench control. The Laminar Master System with a PLC Interface is able to be remote controlled by using digital in- and outputs by the PLC. The Laminar Master evaluates and qualifies the measurement results. The result then is available at the digital outputs as good / bad.

The standard type including the PLC interface provides the at the following listed signals. There are two different socket connectors supported. One 39-pol. HD-connector and one 40-pol. HD-connector. (See appendix for your type)

14.1 Socket connector 39-pol. HD-Connector

mounted on the back of the 19” rack:

	Inputs / Outputs	Outputs	Inputs
	A	B	C
1	PE	Measuring	Reserved
2	0Vext	NOK1-Low	Reserved
3	24Vext	Venting	Reserved
4	24Vext	Filling	Reserved
5	24Vext	Calming	Reserved
6	24Vext	Reserved	Reserved
7	24Vext	Ready	PLC-Start
8	Reserved	OK1	Confirm
9	Reserved	NOK1	Reset
10	Reserved	Failure	Prog0
11	OK2	Lock	Prog1
12	NOK2	Test completed	Prog2
13	NOK2-Low	Test pressure POK	Prog3

Table 39: PLC Interface 39-pol.:

14.2 Socket connector 40-pol. HD-Connector

mounted on IP 54 casings:

	Outputs	Inputs / Outputs	Inputs	
	A	B	C	D
1	Ready	Measuring	Reserved	Reserved
2	Test completed	Venting	Reserved	Reserved
3	OK1	OK2	Confirm	Reserved
4	NOK1	Lock	PLC-Start	Reserved
5	NOK1-Low	Calming	Reserved	0Vext
6	NOK2	Reserved	Reset	24Vext
7	NOK2-Low	Prog0	Reserved	24Vext
8	Test-pressure POK	Prog1	Reserved	24Vext
9	Failure	Prog2	Reserved	24Vext
10	Filling	Prog3	Reserved	24Vext

Table 40: PLC Interface:

14.3 Scheme of test procedure

There are two modes of test procedure for PLC available:
- Automatic test procedure with PLC (S0010 = 1)
- Step by step test procedure with PLC (S0010 = 2)

If the device should run continuously S0010=0 should be set.

Note: The PLC-Interface is not available with triple section device.

The following steps are implemented in the Laminar Master System
- Waiting for PLC start
- Loading program (parameter set)
- Filling
- Switch
- Calming
- Pressure check
- Measuring
- Show results on displays
- Switch
- Venting
- Switch
- Setting digital outputs
- Wait for Stop Signal

14.4 Wait for PLC start

As soon as the device is ready to start, the „Poll“ reference is displayed on the lower right corner of the display. Then the „Ready“-signal is set.
The „lock“ message is displayed provided the N O K - counter is set and too many units have been regarded as insufficient in advance (parameter Px514 specification). The lock (interruption) caused herewith must be confirmed .In the case of automatic operation this is carried out by entering the „confirm“ input and in the case of manual operation by pressing the STOP-button. After having removed the lock, the ready-signal is set.

The PLC-operation is started by:

- the „PLC-Start“ signal in the case if automatic operation.
- the START button in the case of step-by-step mode.

If result signals are pending due to a proceeding test, they will immediately be reset after the test has been started again. A minimal delay will be caused.

In the case of automatic operation the PLC-operation will be executed according to the times determined by the parameter set. In the case of double section device the steps will be changed independently. But the test will be completed synchronously, that means, as soon as a test section has executed the test it waits until the second test section has finished this very test. Not until then the test is completed, the ready signal appears and the next test can be executed.

In the case of step-by-step operation the test step will not be left but until the next step is requested by entering the START-button.

14.5 Program start

During automatic PLC-operation the PLC- start is activated when receiving a High signal. The start signal has to be activated during the entire test procedure and it must not be deactivated but until the test has been completed. Deactivation of the start signal will be interpreted a stop signal. Using the manual SPC-step-by-step mode, the permanent activation of the START-button will not be required.

Program selection (in automatic mode):
Using the automatic PLC-operation the program reads the parameter set to be used from the digital inputs Prog0 up to Prog3. A signal must be set! Provided that all program inputs are deactivated, this will be regarded as a not ready „no program defined“ error.

Digital Signals high/low (0/1)at Program inputs 0123	Program selection Section 0 (only single section device)	Program selection Section 0 (only double section device)	Program selection section 1 (only double section device)
0000	Not valid	Not valid	Not valid
1000	0	0	1
0100	1	Not valid	Not valid
1100	2	2	3
0010	3	Not valid	Not valid
1010	4	4	5
0110	5	Not valid	Not valid
1110	6	6	7
0001	7	Not valid	Not valid
1001	8	8	9
0101	9	Not valid	Not valid
1101 .. 1111	Not valid	Not valid	Not valid

Table 41: Program select with PLC-Interface

In the case of an invalid program selection the „Failure“ output and the test end signal will be set. The program displays an error until the stop signal (deactivation of the start signal) is activated. The test end signal is reset immediately. As described above, the error signal is activated as long as the device remains in the „wait for PLC-Start“ mode.
„Lock“ will not be caused by this error. Thus it is ready to operate as soon as the stop signal is received.

The selection of the topical active program will be displayed in the lower line of the controller display.

Program selection with step-by-step mode

In the case of manual operation the program selection is set from the parameter list (S1000 and with double section version additionally S1001).

14.6 Filling

The „fill- signal“ is set when filling. The pressure is controlled. The values set in the Px850 group will be displayed as the standard display. If switch is set S9001 = 1, the current filling pressure is displayed in the upper line of the display. The output signal of the controller (single section version) resp. the filling pressure of the second test section is displayed in the middle line of the display.
The selected program will still be displayed in the lower line of the display. The lower right displays the „fill“ status.

14.7 Switch

The output “Fill” is reset.

14.8 Calm

Display as above. The „calm“ status is displayed in the lower right corner of the display.
„Calm „ output is set.

14.9 Test pressure control

Only the „ChkP“ (check pressure) condition is displayed in the lower line. The „calm“ output is reset. The test pressure will be evaluated by the limits specified by the Px522 and Px523 parameter. If the test pressure is not within the specified „window“, the measuring will be skipped by setting measuring time = 0. As a result the test of the double section is not aborted only because one of the testers did not reach the filling pressure. The result output of the invalid measuring will then be retained until the valid measuring has been completed.

14.10 Measuring

The „measuring“ output is set. If S9001 = 0 is set the displays will still correspond to the setting of the Px850-group. In the case of S9001 = 1 automatic setting at the upper part of the display the flow value which has been specified as the flow criteria (parameter Px511) is displayed .
Below the measuring time is running. If a sensor error occurs, the measuring is interrupted immediately.

14.11 Results

The „measuring“ output is pending.

If the test pressure is not accessed, on the displays belonging to the test circuits (test section 0= upper, test section 1: middle) the pressure accessed after the last calming period will be displayed.
In the case of the single section version, the „gros“ message is displayed in the lower right part of the display.

If the measuring fails due to a sensor fault, the „error“ message appears on the corresponding display. To its right the ID of the sensor which caused the error is also displayed.

If the measuring is carried out correctly, the evaluation is carried out due to window defined by the parameters Px512 and Px513.

Possibilities:

Flow value within the window: OK
Flow value below the window: low
Flow value upper the window: High

Starting from this testing step the result will be output on the display up to the next test mode start. It differs between single section and double section version. You can switch between these displays by pressing any optional function key.

Display of result
The measuring results are combined in various display figures. Starting from the configured standard display they may be toggled by the F1 and F3 function keys. The designations correspond to the specifications to be found in the read parameter block Ryxxx. According to configuration and equipment the result displays may differ. Here, they are not listed up explicitly.

14.12 Switch

The output “Measuring” is reset.

14.13 Vent

The output “Venting” is set. “Vent will be displayed on the third display line.

14.14 Switch

The output “Venting” is reset.

14.15 Setting digital output results

If the test pressure has not been obtained, the to the corresponding test sections belonging NOK and POK signals will be set.

If the measuring failed due to a sensor error, the NOK and Fail outputs will be set.

If the measuring has been carried out correctly, the evaluation will be carried out due to the window defined by the Px512 and Px513 parameters.

Single section device:

- Flow value within window: OK1 output is set
- Flow value lower window: NOK1 and NOK1-LOW are set
- Flow value upper window: NOK1putput is set

Double section device:

1st section:

- Flow value within window: OK1 output is set
- Flow value lower window: NOK1 and NOK1-Low outputs are set
- Flow value upper window: NOK1 output is set.

2nd section:

- Flow value within window: OK2 output is set
- Flow value below window: NOK2 and NOK2.Low are set
- Flow value upper window: NOK2 output is set.

The „lock“ counter is increased with all NOK evaluations. The counter is rest with each test assessed with „OK“. When obtaining the specification due to the Px514 parameter, that means, the number of successive test which have been assessed as set value specified by the Px514 parameter, then the „lock“ output is set. This, in turn, must explicitly be acknowledged via the digital „confirm“ .input
If Sx514 = 0, then the counter is deactivated.
The double section device comes with two independent counters.

After completion of the entire tests or after a test which might have been aborted by not setting or wrongly setting the PLC-program, the digital test end output is set.
If the Lock-signal is not set, the ready output is set. If not, the ready-signal will not be set but until the acknowledgement has been carried out.

14.16 Wait for PLC Stop

This condition is kept until the stop signal (resetting the PLC-Start signal in the case of automatic operation or in the case of manual operation by pressing the Stop-button) has been received. The ready output is set and end of test is reset immediately. As long as the device is in the „ready“ mode resp. the „wait for PLC stop“ mode, the result set at last remains on the display. They are reset as soon as a new test is started or if the S320 controller is set to the editing mode by keeping the F1 key pressed.

15 Basic unit conversions (X- and Y-factors)

SI-Factor	X- or Y-Factor: 1/SI-Faktor	A = a(0)	Units and sensor / calculation values	display abreviation
Pressure:			Differential pressure Absolute pressure Reference press. abs. Gauge pressure	Pdif Pabs Rpabs Prel
1,00000E+00	1,00000E+00	0,000	Pascal	Pa
1,00000E+02	1,00000E-02	0,000	HektoPascal	hPa
1,00000E+03	1,00000E-03	0,000	KiloPascal	kPa
1,00000E+02	1,00000E-02	0,000	Millibar	mbar
1,00000E+05	1,00000E-05	0,000	Bar	bar
9,80670E+04	1,01971E-05	0,000	techn. Atmosphere	at
1,01325E+05	9,86923E-06	0,000	phys. Atmosphere	atm
3,38639E+03	2,95300E-04	0,000	inch Mercury	inHG
2,49089E+02	4,01463E-03	0,000	inch Watercolumn	inWC
6,89476E+03	1,45038E-04	0,000	Pounds/in^2	psi
4,78802E+01	2,08855E-02	0,000	Pounds/ft^2	psft
1,33322E+02	7,50062E-03	0,000	mm Mercury	mmHG
9,80670E+00	1,01971E-01	0,000	mm Watercolumn	mmWC
6,89476E+03	1,45038E-04	0,000	Pounds /in^2	psi
1,33322E+02	7,50062E-03	0,000	Torr	Torr
Density:			Actual density Standard density Reference density	ADen NDen RDen
1,00000E+00	1,00000E+00	0,000	kg/m^3	kgm3
1,00000E-03	1,00000E+03	0,000	g/m^3	g/m3
1,60185E+01	6,24278E-02	0,000	pounds/cubic foot	lbcf
2,76799E+04	3,61273E-05	0,000	pounds/cubic inch	lbci
Mass flow:			Mass flow	Qmas
1,00000E+00	1,00000E+00	0,000	kg/sec	kg/s
1,66667E-02	6,00000E+01	0,000	kg/min	kg/m
2,77778E-04	3,60000E+03	0,000	kg/hour	kg/h
1,00000E-03	1,00000E+03	0,000	g/sec	g/s
1,66667E-05	6,00000E+04	0,000	g/min	g/m
2,77778E-07	3,60000E+06	0,000	g/hour	g/h
4,53590E-01	2,20463E+00	0,000	pounds/sec	PPS
7,55980E-03	1,32279E+02	0,000	pounds/min	PPM
1,25000E-04	8,00000E+03	0,000	pounds/hour	PPH
Total mass:			Total mass	Mass
1,00000E+00	1,00000E+00	0,000	kg	kg
1,00000E-03	1,00000E+03	0,000	g	g
4,53590E-01	2,20463E+00	0,000	lb	lb

Volume flow:			Actual volume flow Standard volume flow Reference volume flow	Qvac Qvno Qvre
1,00000E+00	1,00000E+00	0,000	m^3/sec	m3/s
1,66667E-02	6,00000E+01	0,000	m^3/min	m3/m
2,77778E-04	3,60000E+03	0,000	m^3/hour	m3/h
1,00000E-03	1,00000E+03	0,000	Litre/sec	L/s
1,66667E-05	6,00000E+04	0,000	Litre/min	L/m
2,77778E-07	3,60000E+06	0,000	Litre/hour	L/h
1,00000E-06	1,00000E+06	0,000	cm^3/sec	cm3s
1,66667E-08	6,00000E+07	0,000	cm^3/min	cm3m
2,77778E-10	3,60000E+09	0,000	cm^3/hour	cm3h
2,83170E-02	3,53145E+01	0,000	cubic feet/sec	CFS
4,71950E-04	2,11887E+03	0,000	cubic feet/min	CFM
7,86580E-06	1,27133E+05	0,000	cubic feet/hour	CFH
1,63870E-05	6,10240E+04	0,000	cubic inch/sec	CIS
2,73120E-07	3,66139E+06	0,000	cubic inch/min	CIM
4,55190E-09	2,19688E+08	0,000	cubic inch/hour	CIH
Total volume:			Actual total flow Standard total flow Reference total flow	Avol Nvol Rvol
1,00000E+00	1,00000E+00	0,000	Cubicmeter	m3
1,00000E-03	1,00000E+03	0,000	Litre	Lit.
1,00000E-06	1,00000E+06	0,000	Cubiccentimeter	cm3
2,83170E-02	3,53145E+01	0,000	Cubic feet	CF
1,63870E-05	6,10240E+04	0,000	Cubic inch	CI
Humidity:			Humidity Reference humidity	Hum RHum
1,00000E+00	1,00000E+00	0,000	Humidity	-
1,00000E-02	1,00000E+02	0,000	Humidity [%]	%rH
Temperature:			Actual temperature Reference Temperature	Temp RTem
1,00000E+00	1,00000E+00	0,000	Kelvin	"K
1,00000E+00	1,00000E+00	273,150	Celsius	"C
5,55556E-01	1,80000E+00	255,372	Fahrenheit	"F
5,55556E-01	1,80000E+00	0,000	Rankine	"R
Viscosity:			Actual viscosity Calibration viscosity Reference viscosity	AVis CVis RVis
1,00000E+00	1,00000E+00	0,000	Pascalsec.	Pa*s
1,00000E-07	1,00000E+07	0,000	Micropoises	uPoi
1,00000E-03	1,00000E+03	0,000	Centipoises	cPoi

Pressure drop per period:			Pressure drop per period	dpdt
1,00000E+00	1,00000E+00	0,000	Pascal/sec.	Pa/s
1,66667E-02	6,00000E+01	0,000	Pascal/Min.	Pa/m
2,77778E-04	3,60000E+03	0,000	Pascal/h	Pa/h
1,00000E+02	1,00000E-02	0,000	Millibar/sec	mb/s
1,66667E+00	6,00000E-01	0,000	Millibar/min	mb/m
2,77778E-02	3,60000E+01	0,000	Millibar/hour	mb/h
1,00000E+05	1,00000E-05	0,000	Bar/sec	b/s
1,66667E+03	6,00000E-04	0,000	Bar/min	b/m
2,77778E+01	3,60000E-02	0,000	Bar/hour	b/h
6,89476E+03	1,45038E-04	0,000	Psi/sec	PSIs
1,14913E+02	8,70227E-03	0,000	Psi/min	PSIm
1,91521E+00	5,22136E-01	0,000	Psi/hour	PSIh
Time:			Measuring period	Tmea
1,00000E+00	1,00000E+00	0,000	Second	sec.
6,00000E+01	1,66667E-02	0,000	Minute	min.
3,60000E+03	2,77778E-04	0,000	Hour	hour
Dimension less:			Number of measured values	Nval
1,00000E+00	1,00000E+00	0,000	dimensionless -	-
1,00000E-02	1,00000E+02	0,000	Percent %	%
Voltage			Voltage	U
1,00000E+00	1,00000E+00	0,000	Volt	V
1,00000E-03	1,00000E+03	0,000	MilliVolt	mV
Current			Current	I
1,00000E+00	1,00000E+00	0,000	Ampere	A
1,00000E-03	1,00000E+03	0,000	MilliAmpere	mA

Table 42: Basic Units (X- and Y-factor)

16 General technical data

16.1 Using the 19'' housing

Housing	19", 3HE (84 TE) rack unit Depth (depending on device configuration): 280 mm or 380 mm (See appendix)
El. supply AC: Fuse:	110V .. 230 V, 50/60 Hz, ca. 60 VA 1A slow
Measurement inputs:	suitable for supplied sensors
Analog output:	0..10 volt, 1 kΩ minimum resistor 0/4..20 mA, 500 Ω maximum resistance resolution: 14 bit or 16bit effective
Digital inputs: Voltage range: Input current:	0 up to 16, optoisolated, common mass 12..30 V DC max. 10 mA at 24 volt
Digital outputs: Voltage range:	0 up to 16, optoisolated, common plus-supply, 24 VDC supply from internal control voltage, 3A per output, total max. 8A 5..30 VDC with external supply 16A max.
AD-Converter Resolution: 24 bit	Principle: Continuous integrating SigmaDelta AD- converter
Measuring rate:	Maximum 30 values per second
Data storage:	Permanent in FlashROM

16.2 Using the S320 as stand alone device

See manual S320.

17 List of Error Codes

Code-No.	Code	Meaning	Comment
0	VMENoError	No Error	
1	VMEBreak	Unexpected Breakpoint	Internal processing error
2	VMENotImp	Function Not Implemented	Code for function not found
3	VMEIllegal	Illegal Instruction	Internal processing error
4	VMEIllegalCase	Illegal Case	No matching label in a CASE statement
5	VMEStrOverflow	String Too Long	More than 127 characters
6	VMEDivByZero	Division By Zero	Denominator is zero
7	VMEModByZero	Modulo Operation With Zero	as previous error for modulo operation
8	VMERange	Range Error	Index is higher than defined dimension or less than zero
9	VMEOverflow	Overflow Error	Number is higher than greatest representable number
10	VMEUnderflow	Underflow error	Number is smaller than smallest representable number
11	VMEDomain	Domain Error	Floating-point number exceeds limits
12	VMESing	Singularity Error	
13	VMEPLoss	Partial Loss Of Significance	Operation cannot be correctly evaluated (Argument at limit of value range)
14	VMETLoss	Total Loss Of Significance	Operation cannot be evaluated at all
15	VMEFPError	Floating-Point Error	Internal processing error
16	VMEIllegalExt	Unsupported External Function	The code number following the `EXTERNAL` keyword is not supported
17	VMEExtParam	Invalid Parameter For External Function	The parameters passed to an external function do not match the function definitions. (Often: the name passed to the function `OpenPort` is different from the one in the configuration file
18	VMEInternal	Internal Error	Internal processing error
19	VMEStack	Stack Overflow	Stack overflowed

Table 43: Error Listing

If there is an error because of configuration or config-file additionally an error location is shown:

For example :

4_0 S/P => Slot 4 / Port 0
200MOD => Module 200
6 => Error code 6 (division by zero)