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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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 analogue 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:

Typ100 cards	Two analogue-digital converters
Typ200 cards	Two digital-analogue converters
Typ310 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.
Typ400 card	Bus module for digital extension modules, e.g. for PLC interface
Typ500 card	Two inputs for pulse transmitters
Typ510 card	Two frequency counters
Typ520 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 Config (registration and linearization of the plug-in cards, if necessary, and configuration of the serial interfaces)
- LMF software, application-parameterized
- Switchable parameter sets for different measuring tasks (program 0 to 9)

The software is designed so that it can cover a wide range of different applications. The configuration for a particular application is carried out primarily through parameterization. If additional functions are required, the software can be extended by project-specific scripts. Under the umbrella of software LMF following typical applications have developed, the boundaries are project-specific fluently:

LMF	LaminarMasterFlow	Applications with a focus on flow measurement and flow control
PCS	PressureControlSystem	Applications with a focus on pressure control
LFC	LaminarFlowControl	Special series of units for gas metering
LMS	LeakageMeasuringSystem	Applications with focus on tightness testing
CVS CAL	Constant Volume Sampling Calibration	Special series of units for calibration of CVS systems.

1.2 Intended use

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

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

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
  - Water vapor (as part of humid air)
  - Xenon
  - Nitrogen monoxide
  - Neon
  - Krypton
  - Propene
  - Ethane
  - Ethene
  - Ammonia
  - Sulfur dioxide

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 system 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
- the compliance of the inspection and maintenance work.

Another use or a use beyond that will be considered as not intended. TetraTec Instruments will not be liable 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 system
- Faulty installing, taking into operation, operating and maintaining of the system and of the accessories (sensors, LFE).
- Operating of the system with defect safety equipment or safety and protection systems 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 system, 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 systems 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 Inevitable Remaining Dangers by the Equipment

The systems 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 systems 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 and keep records of this. 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.
- Working on active parts is neither allowed nor required! Disconnect the power plug before opening the case!
- If the case is damaged the system has to be put out of operation.
- To exclude fire risk or danger of an electric impact, protect the system 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, nitrogen monoxide and laughing gas have a fire-supporting impact.
- Laughing gas and xenon have a hallucinogenic or anesthetic to toxic impact according to their concentration.
- Nitrogen monoxide and Carbon monoxide are very toxic.
- Nitrogen monoxide is corrosive.
- 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:

- Operation only by persons, who verifiably participated in periodical safety instructions concerning the relevant gases.
- Don’t operate the system if there are indications of transport damage.
- When changing from oxygen or air to combustible gases or vice versa, intermediate evacuation or purging with nitrogen is required.
- Avoid emission of gases.
- Examine measuring setup regularly for leakage and keep records of this.
- 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 system 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 system 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 input as well as to the suitable system must be absolutely maintained. If the assembly is exchanged, the calibration of the systems 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 system 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 system 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. Systems, 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 system is turned on it must be adapted to the room temperature, the system must not be with dew at all.

2.2.3 Power supply, electric connection of systems with mains connection

2.2.3.1 OEM-system 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 Systems 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 Systems 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 Systems with control box

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

2.2.4 Cleaning of the system

Wipe with a moist but not watery cloth.
Note
Near open pressure-measuring lines, silencers or sensor inputs should not be cleaned with compressed air, because of sensitive sensors can be damaged!

2.2.5 Calibration, measuring accuracy

The systems are delivered by TetraTec Instruments being calibrated and readily 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 systems and measuring sections

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

- No changes, attachments or conversions of the system or measuring section must be carried out without approval of the manufacturer.
- Only use original spare parts and wearing parts.
  With parts 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 must be used.

2.2.7 Limit parameter access

It is possible to limit the parameter access in the editing mode.
The first paragraph of this chapter explains, according to which scheme the parameters are allocated to access levels defined by the factory. In the second paragraph there is information about the definition of own user groups and a documentation of the user groups preset by the factory and their passwords.

Note:
The operator or his system administrator is responsible for the changing of at least the passwords, keeping records of them and to keep this documentation at a save place.

Further information

- For the consequences of the restrictions of access in the editing mode see chapter 7.4.3.2
- Access restriction for TCP connection see chapter5.2.6

2.2.7.1 Level allocation of the parameters

On site each parameter is allocated to a lot of level. This is carried out by the attribute "level=n". Here "n" is a number the single bits of which encode the respective level.

Examples

term	**= binary**	**explanation**
level=1	0001	parameter is only accessible in level 0
level=12	1100	parameter is accessible in levels 2 and 3
level=9	1001	parameter is accessible in levels 0 and 3

2.2.7.2 Definition of users and their right of access

Up to 10 users can be defined in the block S05XX. Every user has an user name(e.g. "setter"), a password, and a lot of levels on which he take action. Just like the allocation of the parameters the allocation of users to levels is carried out by indicating a number, the particular bits of which indicate whether the user has access to the parameters in this level or not.

Example

S0500=" Egon" S050=1 S0502=1234	These parameters define a user with the name "Egon" (this name has to be selected when entering the editing mode). The user's password is "1234" and he has access to all parameters which are visible in level 0 (since 1 = 0001 binary)
S0500=" Egon" S0501=7 S0502=1234	As above, but the user “Egon” has only access to parameters of the levels 0, 1 and 2 (since 7 = 0111 binary).

Further information

- For block S05XX see chapter 9.7.3

Standard settings

Normally four users are defined, to whom exactly one level is allocated each. The appropriate four levels are arranged hierarchically in ascending order (i.e., the superior levels include all parameters of the lower levels respectively). The password is the number of the level respectively:

Name	Password	Access to parameter
"Level 0"	0	PN500 up to PN523
"Level 1"	1	PN400 up to PN499 and PN500 up to PN523 and PN701 up to PN722
"Level 2"	2	M0000 until M0999 and PN000 until PN999 and S0000 until S0013 and S0100 until S0311
"TetraTec"	3	C0000 up to C0199 and D0000 up to D1999 and E0000 up to E9999 and I0200 up to I0209 and M0000 up to M0999 and PN000 up to PN999 and S0000 up to S9999

Note

It goes without saying that the level “TetraTec” is only left for authorized staff (i.e., with the exception of changing passwords by the operator or his system administrator only employees of TetraTec Instruments GmbH), since the changing of basic parameters may result in considerable negative consequences.

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	Heart of the evaluation electronic is controller S320 with various interface cards. For a description see the chapters 1.1.1 and 4
Interfaces	The evaluation electronic can display the computed values by digital and analogue interfaces. The evaluation electronic can display the computed values by digital and analogue interfaces.
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 calculated 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	It has lately been increasingly implemented that the measuring sections are delivered completely mounted on mounting plates or in cabinets, by what the final assembly can be made easier as well as leakproofness and functionality will be better guaranteed. The LMF system is always delivered including all necessary cables or mating plugs.

3.2 Primary elements

The primary element most often used by us is the LFE, 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 other 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°C, 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 face and back 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
With adequate opening diameter relatively insensitive against fouling. All components consisting of highly heatable material can also be manufactured by this simple setup. 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 to pressure energy, whereby the remaining pressure drop is clearly less than the active pressure. A disadvantage is the clearly bigger 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. A common feature of all counters is, 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, impeller 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 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 Operational controls

There is a distinction to be made between the operational controls, displays and interfaces of the controller and the additional operational controls, displays and interfaces of an application which accommodates a controller. The function of the operational controls and displays of the controller is independent of being used for a primary installation in a control box as a switchboard installation device, or of being integrated in an application with an own case.

The number and type of the additional operational controls, displays and interfaces as well as the version of the case corresponds with the respective customer requirements and, hence, is documented in the part of the documentation specific for application. Hence, at this point only one example can be shown.

4.1 Front panel operational controls of the controller S320

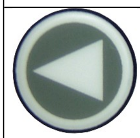
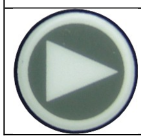
traditional display (until 2023)

touchscreen display (from 2022)

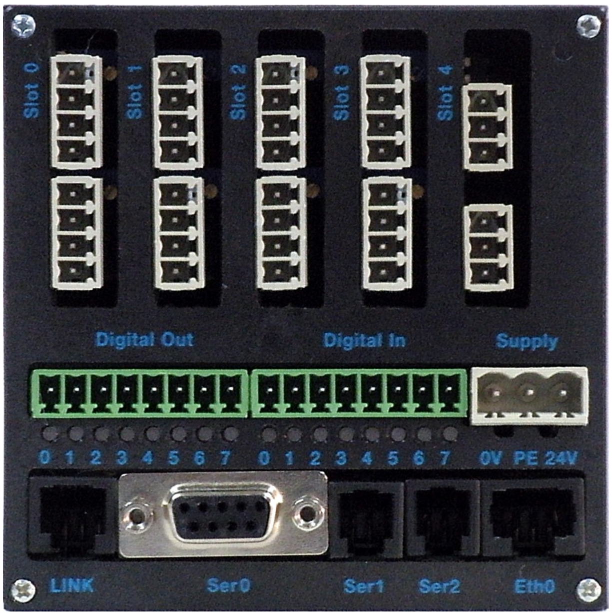
The controller S320 with its display lines and buttons is the core-piece of the LMF.

Display lines
Each of the three display lines consists of a 6-figure display for numerical values and a smaller 4-figure display for text. This text usually indicates the measuring circuit, unit or a designation of the measurement value. In applications with two measuring circuits the first line is usually allocated to the first measuring circuit, and the second one to the second measuring circuit.

Keys

	Key	Meaning
	F1	Short keystroke in the standard mode: Scrolling of different measurement values and operands of measuring circuit 0. Short keystroke in the test mode: Scrolling of different measurement values or analogous initial values of all measuring circuits. Long keystroke in the standard mode: Switchover to the editing mode. Short keystroke in the editing mode: Display next parameter. Keep F3 simultaneously pressed: Return to the standard mode again, but changes will be rejected.
	F2	Short keystroke in the standard mode: Scrolling of different measurement values and operands of measuring circuit 1. Short keystroke in the test mode: Reduction of the displayed places in the second display line (raw value). Long keystroke: Return to the standard mode again, but changes will be taken over.
	F3	Long keystroke in the standard mode: Switchover to the test mode. Short keystroke in the editing mode: Display previous parameter. Keep F1 simultaneously pressed: Return to the standard mode again, but changes will be rejected.
	Arrow on the left	In the test mode with inputs: Restores the factory setting of the sensor after nullification. Reducing of an analogous initial value (provided that it is just displayed). Otherwise: Reduces the displayed value (provided that it is editable).
	Arrow on the right	Long keystroke in the test mode: Nullification of the displayed measurement value. Otherwise: Raises the displayed value (provided that it is editable).

4.2 Interfaces of the controller S320



Interfaces of the controller S320
(example, assembly with interface cards specific for order)

Slots for interface cards
The controller is equipped with 5 slots for interface cards. The designation of the slots is imprinted. The slots are marked with “slot 0” to “slot 4” from the left to the right. The interface cards for analogue-digital conversion (and vice versa) usually operate two analogous devices (sensors or actuators) in each case, i.e., they usually have 2 ports. The upper port has the designation “Port0”, the lower one “Port1“. If cables are provided for the connection of the analogous devices, the connectors wear an adhesive label with an abbreviation for the indication of slot and port according to the pattern “Sl<Slot number>/<Port number>”.
Example: Sl3/1“ stands for slot 3, port 1, this means the fourth column below.

Integrated digital contacts
There are 8 outputs and inputs available in each case which are usually used for additional operational controls as for example buttons and their lighting. As integrated digital contacts they are not isolated by optoelectronic coupler. If isolated or additional digital contacts are required, digital expansion modules are required which can be activated by a Type400 card.
Capacity of each connection max.24V500mA

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

Link
Serial program interface. Connection of a laptop or PC with a serial 1:1 cable (9-pole). It is used by the S320 terminal program to transfer, e.g., the control program, the operating system or the configuration file.

Ser0
Serial RS232 interface for the exchange of ASCII data, e.g., for the query or changing of parameters, for the query of measurement values or for remote control commands.

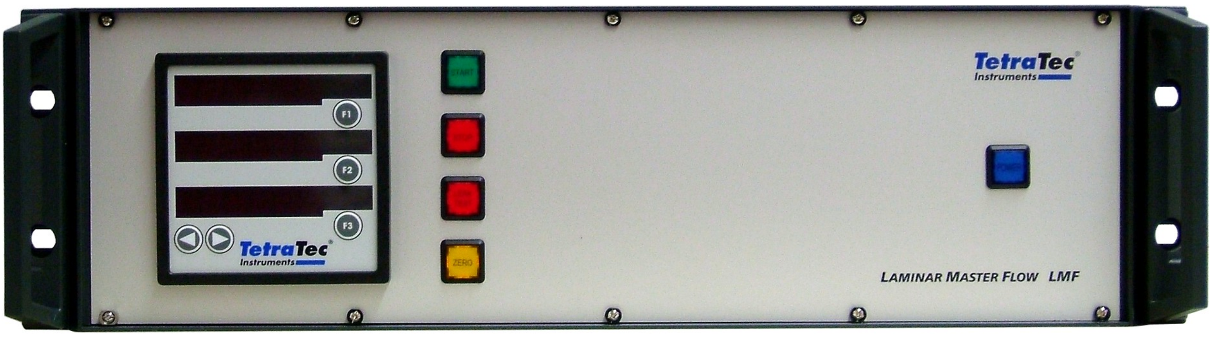
Ser1
Serial RS485 interfaces, is normally used for the interlinking of several controllers.

Ser2
Serial RS485 interfaces, is usually used for the connection of serial sensors.

Eth0
Ethernet interface (TCP/IP).

4.3 Additional front panel operational controls with installation in a horizontal 19” case

Note:
It only can be an example here. The real application may have less or more operational controls or the operational controls may look differently. Completely different cases can be used, even several controllers S320 can be accommodated in one case. The display corresponds with the most current configuration.



LMF front (example)

Keys

	Button	**Meaning**
	POWER	For switching the system on and off (main switch must be switched on). POWER does not completely isolate the system from the mains; to do this, use the main switch (usually on the back) or pull out the mains plug.
	START	Starts, depending on application, e.g. an averaging measurement.
	STOP	Ends a started application prematurely (e.g. an averaging measurement or a leak test). Ends the results display after a measurement is prematurely or automatically aborted.
	LEAK TEST	Starts a leak test (optional).
	ZERO	Starts a zero adjustment of the differential pressure sensors (optional).

4.4 <u>Interfaces on the backside with installation in a horizontal 19” case</u>

Note:
It only can be an example here. The concrete application may have another number and other types of interfaces. The interfaces can be arranged partly differently. In addition, pneumatic interfaces are also possible. Completely different cases can be used. The display corresponds with a largely equipped configuration.

LMF from the back (example)

Interfaces of the example from the left to the right

Power supply	With main switch, fuse holder, fan and name plate (serial number). The main switch separates the equipment bipolar from the power grid. Before connecting a mains cable the voltage indication on the name plate has to be compared with the local mains voltage.
Digital interfaces	Opto-isolated interfaces for digital inputs and outputs, alternatively supplied internally or externally. According to the type of the digital expansion module 16 outputs, 16 inputs, or 8 outputs and 8 inputs are available. Digital interfaces of this kind are used, e.g., for the connection of a manual remote control, for the activation of valves etc., or for the analysis of switches, or they are part of a PLC interface, which, e.g., can be lead out as 39-or 40-pole connector with the installation in a IP54 protective case.
Serial interfaces	Here the serial interfaces and the Ethernet interface of the Controller are led outward. The RS485 interfaces are terminated additionally. The serial interfaces can also be installed on the front panel, if required, but will not be available on the backside any more then.
Analogue outputs	Analogue outputs are indicated by „AO“. They are used, e.g., as an analogous measurement value output or for the activation of actuators with an analogue input signal, e.g., of Servo valves.
Analogue inputs	Analogue inputs are indicated by Indication „AI“. They are required for the connection of external analogue sensors.

5 Interfaces for Remote Control

For communication with terminal programs, the controller S320 contained in the LMF uses two logical interfaces:

- „Link“
- „Comm“
- „AK protocol“ (optional)

The interface “Link” supports the additional functions of the terminal program S320 provided on the CD for programming and installation, e.g. a graphic real time display of measurement values.

A complete remote control is possible by the interface “Comm”. It is possible to query and change parameters, query information, or trigger operations. The command HELP displays an overview of the available commands. In addition each standard terminal program(ASCII mode) can be used, for example the terminal program Telnet included in the scope of delivery of Microsoft Windows. The software S320 contained on the included CD also provides such a terminal.

The interface „AK protocol“ is an interface for remote control of cycles in master/slave operation, thus can be compared with a PLC interface. It is activated on special customer request and it is configured custom-designed. For general information about the „AK protocol“ see in section 5.6, for custom-designed additional information see in the “Operating Instructions and System Configuration” if necessary.

It is possible to establish a connection physically to all interfaces by the Ethernet connection (TCP/IP) or by both RS232 connections (with restrictions). Normally the RS232 connection for the interface “Comm” is indicated with “RS232/Ser0”.
If the Ethernet connection is used, all interfaces will be identified by the IP address of the controller and different port numbers. If a high data rate is required, (e. g. graphic real time display of numerous measurement values), the use of the Ethernet connection is recommended.

Example
telnet <IP address or name> <port number>

The IP address can be set by the interface „Link“ by using the appropriate RS232 connection for this purpose. The port numbers of the COMM interface and of the AK interface are determined by the parameters S0020 and S9600.

Notes:

- The RS485 connections are designed for the connection of serial sensors. Since by now there are better possibilities available for the cross linking of several controllers, the use of the RS485 connections is not supported any more for this purpose.
- If one of the two RS485 interfaces is required for internal serial sensors, the case connector usually provided for this interface is not allocated.
- For special cases only the required active connections are led through possibly.

5.1 Set up RS232 interface

The serial interface is preset, the settings can be seen in the configuration file. However, the settings are also accessible as a parameter, i.e., they may be changed with the front panel operational controls or with an existing serial connection.

5.1.1 Default settings in the configuration file:

Baud rate:
The transmission rate of the RS 232 interface
Standard setting: 9600 baud.

Parity:
Setting of the parity bit.
Standard setting: NONE (no parity bit)

Stop bits:
Number of stop bits of the RS 232 transmitter
Standard setting: 1 stop bit
(the receiver is always set to 1 stop bit),

Handshake:
Setting of the handshake process:
Standard setting: none
neither RTS/CTS (only hardware handshake)
nor XON/XOFF (software handshake)

Other settings are possible, if requested.

The settings are saved in the parameters S0006 to S0009, see chapter 9.7.1

5.1.2 Interface settings in the terminal program

If the terminal program S320 is used, the entries will be saved, so it is not necessary to care about it afterwards.

- ➢ Open the menu “Connect” and click on “Comm Settings“.
  The window “Global Settings” appears with the opened tab “Comm“.
- ➢ Enter the interface you are using, e.g., “com1”, in the left field
- ➢ If you also want to use the link connection, please repeat the settings in the tab “Link“.

Note
If you want to use both interfaces at the same time, you will need a second Comm interface or an USB serial adapter. In this case you must enter this other serial interface of your computer in the tab “Link”. However, if you only have one interface or only one cable, you can use the interfaces alternately only. Enter this interface in both tabs then.

- ➢ Close the window “Global Settings” with “OK“.

5.1.3 Test function of the serial interface

- ✓ You will need a serial 1:1 cable with control wire with a 9-pole D Sub jack and a 9-pole D Sub connector (included in delivery).
- ➢ Connect the serial interface of the LMF with the serial interface of your computer.
- ➢ If you use a general terminal program, provide a connection with the serial interface of your computer.

- or -

- ➢ If terminal program S320 is used, switchover to tab “CommMsg” and click on the button “Connect Comm” in the launch-pad.
- ➢ Press the enter key of your computer.
  The connection works properly if you receive the response “Press help for details”.

5.1.4 Test function of the link interface

You need
- ✓ a computer with the installed terminal program S320
- ✓ If an OEM controller shall be connected directly: a provided link cable

- or -
- ✓ If you want to connect a LMF with protective case: A serial 1:1 cable with control wire with a 9-pole D Sub jack and a 9-pole D Sub connector is required (included in delivery).

- ➢ Connect the link interface of the LMF with the serial interface of your computer.
- ➢ Click on “Connect Link” in the launchpad of the terminal program S320.
  The connection works properly if the successful setup of the link connection is displayed in the footer of the terminal program.

5.2 Set up network interface

Tip:
You will find detailed instructions with pictures in the document "S320_Short_Instructions.pdf", which is just like the S320 terminal software on the supplied CD.

You need
- ✓ a computer with the installed terminal program S320
- ✓ a working link connection
- ✓ a released IP address

5.2.1 Change the IP address of the LMF

Tip:
Consult your network administrator for the assignment of the IP address. If a DNS server is available, your network administrator can also assign a memorable computer name to the address what makes the access more comfortable later.

- ➢ To open the input mask for the IP address, click on the entry “Network Configuration” in the menu “System“.
- ➢ Make sure that the option “Network enabled” is active.
- ➢ So far required, overwrite the Default IP address and customize the net mask, if necessary.

5.2.2 Port Number of Link-Interface

The port number of the Link-Interface is fixed to 54490.

5.2.3 Port Number of Comm-Interface

As a rule the port number of the Comm-interface is set to 54491. It can be set different custom-designed, but this special setting will be documented in the project specific paperwork. To read out the port number of the Comm-interface query parameter S0020. It is recommended not to change it.

5.2.4 Usage of IP address and port number in the terminal program

The terminal program must know the IP address (or, instead, the name of the computer of the LMF) and the port number. With Telnet these entries are attached simply behind with the program request by command.
If the terminal program S320 is used, the entries will be saved, so it is not necessary to care about it afterwards.
- ➢ Open the menu “Connect” and click on “Comm Settings“.
  The window “Global Settings” appears with the opened tab “Comm“.
- ➢ Enter the IP address or the computer name of the LMF and the port number in the right field.
- ➢ If you also want to use the link connection, please repeat the settings in the tab “Link“.
- ➢ Close the window “Global Settings” with “OK“.

5.2.5 Test connection

- If a general terminal program is used, provide a connection with IP address and port number.

- or -

- If terminal program S320 is used, switchover to tab “CommMsg” and click on the button “Connect Comm” in the launchpad.

- Press the enter key of your computer.
  The connection works properly if you receive the response “Press help for details”.

5.2.6 Access restrictions

When using a network there are clearly more computers existing from which an access is possible compared to the access of other interfaces (e.g., RS232). Normally physical access to the system is not necessary any more. Even access by Internet is possible, for example.

To limit the number of computers, from which an access is possible, two string parameters with access lists exist for each network connection. These two string parameters are indicated as “Allow” and “Deny” for the following explanation. Each of these parameters contains an access list for the particular connection, e.g.,

S0021	Allow	for COMM connection with TCP
S0022	Deny	

S9308	Allow	for protocol printout, if S9300=8 (passive output with TCP)
S9309	Deny	

S9501	Allow	for virtual inputs and outputs
S9502	Deny	

Basic principles of the TCP/IP network protocol are necessary for the understanding of the access lists.

The following is valid, in principle: Only accesses of IP numbers or computer names can be configured. An access is allowed if and only if the Allow list allows access or if the Deny list does not forbid it. If both lists are used, the Allow list has higher priority.

Each of both string parameters may contain a list of IP numbers, or computer names as a substitute. The use of computer names only works properly if a valid DNS server is entered in the network configuration of the controller, which is able to break down the used computer names. In addition, for each specification the entry of a net mask is still possible. Several computers are separated by semicolons, the (optional) net mask is separated by a slash. A preceding exclamation mark negates the comparison.

Examples for the syntax of the access lists:

```
# A computer specified by its IP number
192.168.28.13

# Other representation with explicit net mask
192.168.28.13/32

# A computer specified by its name
frodo.example.org

# An entire Class C network
192.168.28.0/24

# All computers with exception of a Class of C network
!192.168.28.0/24

# Two computers
192.168.28.13;192.168.28.55

# Two computers and a Class C network
192.168.28.13;frodo.example.org;192.168.0.0/24
```

Examples for the use of the access lists
To allow access with the Comm interface for exactly one computer, this computer will be included in the suitable Allow list. The corresponding Deny list must include all the other computers:

```
S0021=192.168.28.13 #Allow list for COMM connection
S0022=0.0.0.0/0     #Deny list for COMM connection
```

An alternative configuration is possible with the help of the negation operator:

```
S0021=""                # Allow list is empty
S0022=!192.168.28.13    # Deny list contains all except one computer
```

Access for a local network, as well as for another computer:

```
S0021=192.168.28.0/24;myhost.lan    # Allow list
S0022=0.0.0.0/0                     # Deny list
```

Access for all computers with the exception of computer public.example.org:

```
S0021=""                    # Allow list is empty
S0022=public.example.org    # Deny list
```

The examples are also applicable for the other type of connections mentioned above.

5.3 Query and change of parameters

Note
While the LMF is in the editing mode, no values can be changed by the „Comm“ interface. If values have been changed by the „Comm“ interface, which still have not been acknowledged by “EXIT” or “SAVE”, these values cannot be changed in the editing mode using the keyboard.

5.3.1 Physical units

Many of the parameters represent physical values. If, in addition, there are several units (e.g., PSI and mbar as a unit for pressure), the unit can be selected in the editing mode. However, this does not apply for a query or change by remote control. Here the indication of the units is abandoned. This is why the values are always applied in SI units.
Hence, with the input of a parameter value the previous conversion to SI units has to be regarded. The input of physical units is not allowed.

5.3.2 Query parameters

Any parameter may be queried by simply entering its name. A list of parameters may be queried by replacing single digits in the name by the question mark.

Example:

```
p000?
```

Output of the controller:

```
P0000=0
P0001=1
P0003=2
P0004=1
```

If parameters have been changed, but up to now none of the commands TEMP or SAVE have been used to make the parameters effective, then the currently valid value, followed by a ‚#’ sign, and the new value will be displayed.

Example:

```
p0000
```

Output of the controller:

```
P0000=0 # 1
```

5.3.2.1 Query measurement values and arithmetic values

The measurement values and arithmetic values are saved in the R parameters. They can be queried as well as any other parameter.
In addition, there is the option to use the command "RPAR" which makes available substantially more information.
See also chapter 5.5.40.

Note
The R parameters belong to the parameters which cannot be changed.

5.3.3 Change parameters

Most parameters can be changed by entering an equals sign and a value after the parameter name.

Example:
`P0000=0`

Output of the controller:
`P0000=0`

For syntax of value indication see chapter 6.1.

The allocated value must be within the valid limits of the respective parameter, otherwise "Range Error" will be returned. Some parameters are only readable ("Read-only"), trying to change them will result in the message "Access denied" then.

Parameters which have been changed will not become effective immediately, but only if, in addition, one of the commands ACTIVATE, TEMP, or SAVE is entered.

Error messages with the entering of values

Bad data	Appears if the value for the type of parameter is invalid. Example: A number cannot be converted into the required number format.
No match	Appears if an input is recognized as a parameter, but this parameter does not exist in the present configuration.
Range error	Appears if a value shall be allocated to a parameter which is below its value range.
No such command	Appears if the input will not be recognized as a command.

5.4 Virtual inputs and outputs (virtual PLC interface Net-IO)

In addition to really existing digital inputs and outputs the application LMF also knows virtual ones which can be queried or set by a separate network interface.

The basic parameters for the connection are set in the parameter block S9500. The terms which determine the values of the virtual outputs are in parameter block S1300. Within control terms the value of a virtual input can be read with the function NI.

Further information
- Control terms see chapter 6.3
- Parameter block S1300 see chapter 9.7.7
- Parameter block S9500 see chapter 9.7.36

5.4.1 Communication

For communication with a remote station the system waits for an external starting of connection. Only one connection is possible at a time. The communication is carried out with readable (ASCII) strings, single lines are terminated with “Carriage Return” and “Line Feed”. The system understands the following messages:

```
QUIT
NI number
```

QUIT terminates the connection. With NI the system is informed of a change of the input signals. Each bit of the number indicated as a parameter corresponds to an input. The following number formats are allowed:
- Decimal: [0-9]+
- Decimal: [0-9]+d
- Hexadecimal: [0-9a-fA-F]+h
- Binary; %[01]+
- Octal: &[0-7]+
- Hexadecimal: $[0-9a-fA-F]+

On the other hand, the controller also announces any change of the virtual outputs by this connection. The format in which the data are sent with a change of the outputs is configurable with parameter S9507. The definition of the format corresponds with the format used with the protocol pressure (S93XX), except that exactly one single integer argument is available, namely the current output state. The initial state is sent by the controller once immediately after the connection setup, so that the remote station knows it.

Further information
- Format strings see chapter 6.2

5.4.2 Timeouts

Connection errors (e.g. pulled network cable) may, for technical reasons, only be noticed if both systems exchange data. To make sure that such errors do not remain unnoticed, the configuration of timeouts is possible (and recommended).

If a reception timeout is configured, then the LMF assumes an error, if no command was received by the remote station for longer than the set time. The existing connection is cancelled and the system waits for a new connection. Caution: If a reception time-out is configured, the remote station must transmit data at regular intervals, otherwise the connection will be cancelled.

If a transmission timeout is configured, then the LMF itself sends data at least in configured intervals. Since the state of the outputs is ordinarily only transmitted if something has been changed, the current state is even then transmitted in the case of a transmission timeout if the time-out has run off.

A value of 0 for the respective timeout parameter switches off the timeout process.

5.4.3 Access control

Two other parameters permit the restriction of the access to the interface. See also chapter 5.2.6.

5.5 List of the remote control commands of the Comm interface

Note
The remote control commands will be valid no matter by which physical interface the logical Comm interface has been built up. If the RS485 interface has been used, the system address must precede the remote control commands.

5.5.1 ACTIVATE

ACTIVATE transfers the change of parameters in the active working memory. As with TEMP, the changes are not saved in a power failure-proof manner, so they are only temporarily valid until the next restart of the controller. In contrast to TEMP, there is no initialization routine. In particular, no new scripts are loaded and certain parameters that are only evaluated when the system starts up (such as S1000 for the default program in measuring circuit 0) are not evaluated again, means changes to such parameters will not take effect.

See also
- DISCARD, section 5.5.8
- TEMP, section 5.5.49
- SAVE, section 5.5.43

5.5.2 AKSEND

AKSEND sends an AK command, which is dealt with as if coming from the AK interface. This is also performed, when the port for the AK interface (S9600) is switched off. The command must not include a start or termination sign. The answer to the command is displayed.

5.5.3 CACHECTRL

CACHECTRL is for the control of the fast binary memory for the parameters. Entering the command without parameters results in an output of the current settings or of the state of the fast memory. The following optional parameters are valid:

clear	Clears the memory contents
none	Switches off the use of the memory
base	Uses the memory for the basis parameters (without changes by the user)
full	Uses the memory for all parameters (including changes by the user)

5.5.4 CONTROL

The command CONTROL displays the parameters for a controller. Two arguments are expected: The number of the program and the number of the controller in the program (0 or 1).

Example:
```
Control 0 0
```

```
----- Control #0/0 -----
P0400 - Init mode      : 1 (manual)
*INFO - Mode           : 1 (manual)
P0401 - Hot edit       : FALSE
P0402 - T1             : +1.000000E-01
P0403 - TD             : +0.000000E+00
P0404 - TI             : +1.000000E+00
P0405 - VP             : +1.000000E+00
P0406 - Cor lower limit: +0.000000E+00
P0407 - Cor upper limit: +1.000000E+00
P0408 - Disc. time     : +2.000000E-02
P0411 - Actual value   : "R0035"
P0417 - Reset value    : ""
P0422 - Set point      : "F0000"
P0425 - SP ramp        : 0 (disabled)
P0430 - Lin method     : 0 (none)
P0435 - Jitter enable  : FALSE
```

The parameter number precedes the output of the single parameters in each case. Inactive parameters are not displayed.

5.5.5 DATE

The command DATE queries date and time of the controller, or sets them. Invoking without parameters returns the current values. Invoking with the entry of time and date as an argument sets the real time clock to the indicated value. The argument must have the format “dd.mm.yyyy hh:mm:ss”. The time will be saved fail-safe.

5.5.6 DEFAULTS

All parameters can be reset to the delivery state by the command DEFAULTS. The program requests for a second input for user settings not being deleted by mistake. This safety query can be switched off by parameter S0040.

Example:
```
defaults
```

Output of the controller:
```
Please enter: "DEFAULTS 4c6a" within 15 seconds
```

Input:
```
defaults 4c6a
```

Output of the controller:
```
DEFAULTS: OK - will reboot in a moment
```

After having established the delivery state the system will be started again, so that changes become effective. With the first start the reset must be confirmed on the controller by pressing F1 additionally.

5.5.7 DIR

DIR displays the directory of the flash ROM.

5.5.8 DISCARD

DISCARD discards all changes in the input buffer that have not yet been transferred to the active working memory with ACTIVATE, TEMP or SAVE.

See also

- ACTIVATE, section 5.5.1
- TEMP, section 5.5.49
- SAVE, section 5.5.43

5.5.9 DLIST

The command DLIST displays a display list. A numerical argument (the number of the desired display list) is expected.

Example:
```
dlist 0
```

Output of the controller:
```
--------- Display list 0 ---------
D0100 - Pages in list  : 11
D0101 - Mode           : 1 (row mode)
D0102 - Page #0        : 1
D0103 - Page #1        : 11
D0104 - Page #2        : 12
D0105 - Page #3        : 13
D0106 - Page #4        : 14
D0107 - Page #5        : 15
D0108 - Page #6        : 16
D0109 - Page #7        : 17
D0110 - Page #8        : 18
D0111 - Page #9        : 19
D0112 - Page #10       : 20
```

The parameter number precedes the output of the single parameters in each case. Inactive parameters are not displayed.

5.5.10 DMODE

DMODE displays an overview of the display lists used in the different modes.

Example:
```
dmode
```

Output of the controller:
```
--------- Display mode mapping ---------
Mode  0 (Conti):         0
Mode  1 (Poll):          1
Mode  2 (Meas):          2
Mode  3 (Fill):          3
Mode  4 (Calm):          4
Mode  5 (Cal):           1
Mode  6 (Vent):          1
Mode  7 (Wait):          1
Mode  8 (MeasResult):    1
Mode  9 (Zero):          0
Mode 10 (Leak):          0
Mode 11 (LeakResult):    0
```

5.5.11 DPAGE

With DPAGE single display pages can be displayed.

Example:
```
dpage 3
```

Output of the controller:
```
--------- Display page 3 ---------
D1030 - Upper row      : 10800 (R parameter in P0800)
D1031 - Middle row     : 10801 (R parameter in P0801)
D1032 - Bottom row     : 196 (R0196)
```

5.5.12 DUMP

Data available on the flash ROM can be displayed with DUMP. The file name is expected as argument.

Example:
```
dump /dat/i-init.dat
```

Display of the controller:
```
I0200 level=8 min=0 max=1 val=0
I0201 level=8 min=0 max=1 val=0
I0202 level=8 min=0 max=1 val=0
I0203 level=8 min=0 max=1 val=0
I0204 level=8 min=0 max=1 val=0
I0205 level=8 min=0 max=1 val=0
I0206 level=8 min=0 max=1 val=0
I0207 level=8 min=0 max=1 val=0
I0208 level=8 min=0 max=1 val=0
I0209 level=8 min=0 max=1 val=0
(End of file)
```

CAUTION: The text only offers reasonable outputs with text files.

5.5.13 EDITMENU

The command EDITMENU starts the editing menu of the controller and corresponds with the keyboard shortcut " F1 (long) " there.

5.5.14 EVAL

With EVAL expressions can be tested as they are used in the parameter blocks S14XX or S18XX, for example.

Example:
```
eval meas & (measmode = 1)
```

Output of the controller:
```
meas & (measmode = 1) => Integer (0)
```

The command EVAL can also be used as a small electronic calculator.

Example:
```
eval 2.0 * 3.14
```

Output of the controller:
```
2.0 * 3.14 => Float (+6.280000E+00)
```

5.5.15 EXTFUNC

EXTFUNC is for the display of parameters from the block H1000 (external adjustable functions). The argument of the command indicates the number of the external function (0..19).

Example:
```
extfunc 0
```

Display of the controller:
```
----- ExtFunc #0 -----
H1000 - Type           : 0 (expression)
H1001 - Expression     : "R0035*3.0"
```

5.5.16 FACDBG

FACDBG serves for the control of debugging displays and it is not provided for being used by the final user.

5.5.17 FILTER

FILTER is for the display of parameters from the block H5000 (external adjustable filter). The argument of the command indicates the number of the external filter (0..9).

Example:
```
filter 0
```

Display of the controller:
```
----- Filter #0 -----
H5000 - Type           : 0 (off)
```

5.5.18 FLIPFLOP

The command FLIPFLOP displays the settings of a flip-flop. The number of the input (0 .. 9) has to be indicated as a parameter.
Example:
```
flipflop 0
```

Display of the controller:
```
----- FlipFlop #0 -----
S1200 - What           : 3 (one-shot, not retriggerable)
S1201 - Set expression : "AKREM"
S1203 - Hold time      : +1.000000E+00
```

5.5.19 GASMIX

The command GASMIX displays information of a gas mixture. The number of the gas mixture (0 .. 9) has to be indicated as a parameter.
Example:
```
gasmix 0
```

Display of the controller:
```
----- GasMix #0 -----
M0000 - Name          : "Mixed gas 0"
M0001 - Count         : 2
M0010 - 0. Gas        : 1 (Air)
M0011 - 0. Frac       : +5.000000E+01
M0015 - 1. Gas        : 14 (N2O)
M0016 - 1. Frac       : +5.000000E+01
```

The parameter number precedes the output of the single parameters in each case. Inactive parameters are not displayed.

5.5.20 HASDEFAULTS

Examines if parameters have been changed compared with the state of delivery.

5.5.21 HEAPINFO

Displays information about the use of the dynamic memory.

5.5.22 HELP

HELP displays a short overview of the available commands.

Example:
```
help
```

Display of the controller:
```
CACHECTRL cmd           clear,none,base,full
CONTROL prog c          Query controller data
CTRLMENU                Enter the control menu
DATE [datetime]         Display/set time and DATE
DEFAULTS                Reset to manufacturer settings
DISCARD                 DISCARD modified parameters
DLIST n                 Show display list n
DMODE                   Print display mode mapping
DPAGE p                 Show display page p
EDITMENU                Enter the edit menu (hold F1)
EVAL [-t]               Evaluate an expression
FACDBG                  Enable/disable debug facilities
GASMIX n                Display gasmix data
HEAPINFO                Print heap info
HELP                    Print command descriptions
HIGHSPEED               Toggle high speed mode
HWERROR                 Display Hardware error statistics
INPUT n                 Display analogue input data
IVALVE n                Display impulse valve data
IZERO                   Zero one input
LASTSTATES              Print last states
LEAK                    Start the leak test
LOAD                    Load parameters from a file
LOGLEVEL                Set the log level
MEAS                    Start measurement
MELE n                  Display mechanical element data
NCOMBI n                Print nozzle combination for section n
OUTPUT n                Display analogue OUTPUT data
PORTMAP port prog       Display analogue output port mapping
PRIMARY n               Display PRIMARY element data
PROG [sec prog]         Query or set the running program
PROGMENU                Enter the prog menu (hold F2)
```

```
QUIT                        Terminate the network connection
RATING p                    Show rating criteria for program p
RPAR n                      Display read parameter n
SAVE                        SAVE parameters
SCRIPTINFO                  Script interpreter info
SISEND                      Send a command to a serial sensor
STOP                        Stop measurement/soft reset
SUBPROG n                   Display sub program data
TEMP                        Use modified parameters
TESTMENU                    Enter the test menu (hold F3)
TIMESTAT                    Print time statistics
VERS                        Print the software version number
ZERO                        Zero all inputs
param                       Query parameter value (i.e. P1234)
param=value                 Set parameter (i.e. P1234=1)
```

5.5.23 HIGHSPEED

Switches on or off the high-speed mode, if it has been configured.

5.5.24 HWERROR

Gives information about a hardware error. See parameter block S0350 ff.

5.5.25 INPUT

INPUT displays information about an analogue input. The number of the input (0 .. 19) has to be indicated as a parameter. The data correspond with the parameters of an input of the S-parameter block S2XXX / S3XXX.

Example:
```
input 0
```

Display of the controller:
```
----- Input #0 -----
S2000 - Type           : 0 (internal AI)
S2001 - Lin method     : 0 (Polynom)
S2005 - Lin poly order : 1
S2010 - Lin factor #0  : -7.500000E+02
S2011 - Lin factor #1  : +1.875000E+02
S2020 - Lin X factor   : +1.000000E+00
S2021 - Lin Y factor   : +1.000000E+00
S2022 - Serial number  : ""
S2030 - Offs           : +0.000000E+00
S2031 - Offs method    : 0 (before linearization)
S2032 - Zero input     : 0 (no)
S2033 - Zero timeout   : +0.000000E+00
S2034 - Zero group     : 0
S2035 - 4 mA Check     : FALSE
S2036 - Range check    : 0 (no)
S2039 - Damping        : 1
S2050 - Port number    : 0
```

The parameter number precedes the display of the single parameters in each case. Inactive parameters are not displayed.

5.5.26 IVALVE

The command IVALVE gives information about an impulse valve. The number of the impulse (0 .. 9) has to be indicated as a parameter. The data correspond to a block of the parameter range S16XX.

Example:
```
ivalve 0
```

Display of the controller:
```
----- IValve #0 -----
S1600 - Open port       : 4
S1601 - Close port      : 5
S1602 - State expr      : "(STATE >= 2400) && (STATE < 2500)"
```

The parameter number precedes the display of the single parameters in each case. Inactive parameters are not displayed.

5.5.27 IZERO

IZERO zeros a single input. The number of the input must be entered as a parameter. The command is only permissible in the standard mode. A feedback is carried out only with severe syntax errors of the input.

Example:
```
izero 0
```

5.5.28 LASTSTATES

With LASTSTATES a list of the last 10 internal states can be displayed. This command is applicable only sensefully for troubleshooting and for developer purposes, and it should be used only by specialist staff.

5.5.29 LEAK

The command LEAK starts a leak testing. If the measuring section is equipped accordingly, shut-off valves are closed on the inputs and outputs of the measuring section and the pressure change will be measured for a configurable time.

5.5.30 LOAD

Allows the loading of a parameter file during runtime. The file must be saved in the file system of the controller and it must include reasonable parameters.

5.5.31 LOGLEVEL

The output of messages can be queried or influenced by the command LOGLEVEL. This command is applicable only sensefully for troubleshooting and for developer purposes, and it should be used only by specialist staff.

5.5.32 MEAS

The command MEAS starts a mean-taking measurement.

5.5.33 MELE

MELE displays information about a mechanical element (parameter block M1000-M1099). The argument is the number of a mechanical element.

Example:
```
mele 0
```

Controller output:
```
----- Element #0 -----
M1000 - Name            : "Elementname"
M1001 - Move[0]         : "Bewegung GS"
M1002 - Move[1]         : "Bewegung AS"
M1003 - Error[0]        : "Fehler GS"
M1004 - Error[1]        : "Fehler AS"
M1005 - Actual expr     : "-1"
M1006 - Timeout         : +5.000000E+00
*INFO - Actual state    : -1
```

```
*INFO - Target state   : 0
*INFO - Element state  : 3 (Timeout)
```

5.5.34 NCOMBI

NCOMBI displays information about a nozzle combination (parameter block C0000-C0199). The argument is the number of the nozzle combination.

Example:
```
Ncombi 0
```

Display of the controller:
```
Nozzle combination is not available
```

5.5.35 OUTPUT

OUTPUT displays information about an analogue output. The number of the output (0 .. 9) has to be indicated as a parameter. The data correspond to the parameters of an output of the S-parameter block S8XXX.

Example:
```
output 0
```

Display of the controller:
```
----- Output #0 -----
S8000 - Type    : 0 (Internal AO)
S8001 - Output expr    : "(RPAR[2]-80000.0)/(120000.0-80000.0)"
S8005 - Error handling : 1 (use fixed value)
S8006 - Error value    : +0.000000E+00
S8050 - Port number    : 0
```

The parameter number precedes the display of the single parameters in each case. Inactive parameters are not displayed.

The expression in S8001 must result in a value between 0 and 1, corresponding to 0 to 100% of the electrical output signal. In the example given, the value of the R parameter R0002 (this is the absolute measuring pressure) is scaled to the value range 800 to 1200 mbar, whereby the limits are usually specified in SI units (exceptions: current in mA, R parameter Ry060 up to Ry064 matching the stored formulas). The expression cannot be changed in the edit menu. Of course, references to other parameters can also be used in the expression, for example so that the minimum, maximum and number of the R parameter to be output can be edited in project-specific parameters. This project-specific parameter assignment is, if necessary, documented in the “Operating Instructions and System Configuration” document.

5.5.36 PRIMARY

The command PRIMARY gives information about a primary element. The number of the input (0 .. 139) has to be indicated as a parameter. The data correspond to the parameters of a primary element of the parameter blocks S4XXX/S5XXX/S6XXX/S7XXX or EXXXX.

Example:
```
primary 1
```

Display of the controller:
```
----- Primary #1 -----
S4100 - Type           : 0 (Standard LFE)
S4101 - Cal Gas        : 1 (Air)
S4102 - Cal pressure   : +1.013207E+05
S4103 - Cal temperature: +2.942610E+02
S4104 - Cal humidity   : +0.000000E+00
S4105 - Lin poly order : 3
S4110 - Lin factor #0  : +0.000000E+00
S4111 - Lin factor #1  : +5.536489E-04
S4112 - Lin factor #2  : -5.144490E-07
S4113 - Lin factor #3  : +0.000000E+00
S4120 - Lin X factor   : +1.000000E-02
S4121 - Lin Y factor   : +6.000000E+04
S4122 - Serial number  : "752970-J9"
```

The parameter number precedes the display of the single parameters in each case. Inactive parameters are not displayed.

5.5.37 PROG

The command PROG is used to query or select the currently running program. In order to select a program, the combination of the measuring circuit number and the program number is required. With systems with only one measuring circuit, the measuring circuit number always is 0.

Examples
Polling of the current program, system with only one measuring circuit:
Command: `PROG`
Reply: `0`

Polling of the current program, system with two measuring circuits:
Command: `PROG`
Reply: `0 5`

Selecting program 2 in measuring circuit 0:
Command: `PROG 0 2`
Reply: `OK`

Note
The command PROG only changes the currently running program. After running through an initialization routine (e.g. after entering TEMP or SAVE) or after restarting the controller, the program is determined again by parameter S100x.

5.5.38 PROGMENU

The command PROGMENU invokes the program menu of the controller. The command corresponds to the keyboard shortcut ” F2 (long) “.

5.5.39 QUIT

QUIT quits an existing network connection.

5.5.40 RATING

The command expects a program number as an argument. The evaluation criteria for this program are displayed (parameter Pn500 ff.).

Example:
```
rating 0
```

Display of the controller:
```
----- Rating for Program 0 -----
P0500 - What          : 0 (off)
P0501 - Value         : R0030
P0502 - Limit low     : +0.000000E+00
P0503 - Limit high    : +0.000000E+00
P0510 - What          : 0 (off)
P0511 - Value         : R0030
P0512 - Limit low     : +0.000000E+00
P0513 - Limit high    : +0.000000E+00
P0520 - What          : 0 (off)
P0521 - Value         : R0030
P0522 - Limit low     : +0.000000E+00
P0523 - Limit high    : +0.000000E+00
P0530 - What          : 0 (off)
P0531 - Value         : R0030
P0532 - Limit low     : +0.000000E+00
P0533 - Limit high    : +0.000000E+00
```

5.5.41 RPAR

The command RPAR gives information about a R parameter. In contrast to a query via RXXXX not only the value of the parameter is available, but also additional information, as for example the error code. The command needs the number of the R parameter as an argument.

Example:
```
rpar 1
```

Display of the controller:
```
----- R0001 -----
Error  = OK
Val    = +8.548035E+00 Pa
Val    = +8.548035E-02 mbar
Disp   =   0.085 mbar
Digits = 3
Unit   = 3
Desc   = "Pdif\4U"
```

The first value with the designation “Val” is the value in SI units. The second one is the same value converted to the respective display unit. Disp” is the value which is displayed on the controller display. “Digits” and “Unit” are post comma places and unit.

5.5.42 RUN

Short pieces of script code can be carried out with RUN for test purposes. The function is not intended for final users.

5.5.43 SAVE

SAVE transfers the change of parameters in the active working memory and starts an initialization routine. ALL changes that have been transferred to the active memory since switching on are saved in a power failure-proof manner.
Note
It has to be made sure that during the saving process (controller indicates SAVE in the right, upper display) the power supply is not interrupted.

See also
- ACTIVATE, section 5.5.1
- DISCARD, section 5.5.8
- TEMP, section 5.5.49

5.5.44 SCRIPTINFO

SCRIPTINFO displays a list of the functions and variables applicable in expressions as a little memory.

Example:
```
scriptinfo
```

Display of the controller:
```
Symbol table
----------------------------
ABS (FLOAT): FLOAT
ABS (INT): INT
ACTIVATE ()
AKACK: INT
AKCALMAX: INT
AKCALMIN: INT
AKGO: INT
AKLDET: INT
AKPROG: INT[3]
AKREM: INT
AKSTART: INT
AKVDET: INT
AKZERO: INT
CYCLE: FLOAT
CYCLECOUNT: INT
```

```
DI: INT[8]
E: CONST FLOAT
```

5.5.45 SISEND

By SISEND commands can be sent with the RS485 bus to which serial sensors are connected. This command is applicable only sensefully for troubleshooting and for developer purposes, and it should be used only by specialist staff.

5.5.46 STOP

Terminates a started application prematurely (e.g. an average-building measurement or a tightness test).
Terminates the display of the results after premature or automatic break off of a measurement.

5.5.47 SUBPROG

The number of a subprogram is expected as an argument. Displays the U parameters of the appropriate subprogram.

5.5.48 SUBS

This command returns information about a subscription. The function is not intended for end users.

5.5.49 Temp

TEMP transfers the change of parameters in the active working memory. In contrast to ACTIVATE, an initialization routine is started. In contrast to SAVE, the changes are not saved in a power failure-proof manner, so they are only temporarily valid until the next restart of the controller.

See also

- ACTIVATE, section 5.5.1
- DISCARD, section 5.5.8
- SAVE, section 5.5.43

5.5.50 TESTMENU

The command TESTMENU invokes the test mode of the controller. The command corresponds to the keyboard shortcut ”F3 (long)“.

5.5.51 TIMESTAT

The command TIMESTAT displays information about the duration of the steps of processing carried out in the controller. The outputs can only be used sensefully by developers.

5.5.52 VERS

VERS displays the state of the software version and an internal release number.

Example:

```
vers
```

Display of the controller:

```
Serial number:     632C134
Project:           AE30
Software version:  7.0.6 / 47330
SPELLOS version:   47243
Compiled on:       2016-08-26 10:44:18
Compiler used:     7.0.0g / 46058
Current date:      31.08.2016 13:40:34
```

5.5.53 ZERO

The sequence for the nullification of the sensors is started by the command ZERO. There all sensors will be zeroed whose inputs are defined as zeroable. This property is saved in the parameters S2x32, where x stands for the number of the input.
Depending on the equipment of the measuring section defined working conditions can be produced, e.g., by the switching of the valves which separate the pressure sensors from the measuring section and which produce a pressure equalization. Parameter block S1800 defines which valves are switched in which operating conditions.

Up to the achievement of a pressure equalization incl. thermalization a stabilization period is necessary as a rule. Now it is possible to define up to three stabilization periods and up to three groups of sensors which are zeroed at the end of the respective stabilization period at the same time. The stabilization periods are saved in the parameters S1100, S1101 and S1102.

Each sensor input can be allocated to one of the groups. This allocation is saved in the parameters S2x34, where x stands for the number of the input again.

Notes in regard of the operations

- The stabilization periods should be selected in such a way that the assumption is right that the sensor will measure physically a zero value at the end of the stabilization period.
- A real sensor will transmit a signal other than zero (offset). It now depends on the setting of parameter S2x31 whether the offset will be calculated by the signal being really present at the input (e.g., of a tension), or by the physical value calculated by the linearization polynomial. As a rule the latter is to be preferred.
- After all stabilization periods have been terminated and all sensor groups have been zeroed, the previous operating conditions will be continued.
- The offset values are not stored fail-safe. To reach this, the command SAVE must be transmitted additionally. Nevertheless, this has to be used reluctantly, since the flash ROM is not writeable infinitely.
- Each sensor can be aligned automatically regardless of remote control commands or function keys on the system in solid time intervals. The interval is saved in the parameter S2x33.

For further information and notes in regard of requirements of the nullification see chapter 7.4.2

5.6 AK protocol

The AK protocol is an ASCII master slave protocol. There a superior control serves as master and the LMF as slave.

The physical connection is set by the Ethernet interface by default.
Alternatively the RS232 interface may be used. However, there is the disadvantage that the RS232 interface is not available any more for the (logical) COMM interface. In addition, the values of two parameters have to be changed for that:

Parameter	Ethernet interface	RS232 interface
S0006	5	0
S9600	54489	-1

Caution
Improper changing of these parameters may result in loss of functionality of the system and is therefore reserved for the staff of TetraTec Instruments GmbH.

5.6.1 Structure of the protocol

The commands of the master and the answers of the LMF always start with the control character <STX> and end with the control character <ETX>.
Strings, which do not start with <STX> and do not end with <ETX>, are not recognized as interpretable commands and ignored.

Command of the master

Byte #	Byte	Description
1	<STX>	Control character for the start of the transmission
2	<DC>	Don’t care byte (is ignored)
3	FC1	First byte of the command code
4	FC2	Second byte of the command code
5	FC3	Third byte of the command code
6	FC4	Fourth byte of the command code
7	Blank	Blank
8	CH1	First byte of the channel, here always “K”
9	CH2	Second byte of the channel, here always „0“
	Data	optional data strings, each separated by a blank
n	<ETX>	Control character for termination of the transmission

Apart from the described control characters and separators, the command consists
- of the command code (4 Bytes),
- of the channel number (2 Bytes)
- and of a number of data strings depending on the command code.

The command code consists of 4 capital letters, whereby the first character must be a ‚A’, ‚E’ or ‚S’.
- Commands beginning with ‚A’ (“inquiry commands”) can always be executed.
- Commands beginning with ‚E’ (“setting-up command”) or ‘S’ (“control commands”) are only executed if the LMF is in the remote mode.
  Exception
  The command SREM switches the LMF to the remote mode and hence can be executed always.

The channel number specifies, which system is activated by the master. The LMF in principle expects the channel number “K0”.

Depending on the command code the LMF expects a fixed number of data strings.
Number, meaning and format of the data strings are determined during the description of the individual commands.

Answer of the LMF:

Byte #	Byte	Description
1	<STX>	Control character for the start of the transmission
2	<DC>	Don't care byte (here always blank)
3	FC1	First byte of the received command code
4	FC2	Second byte of the received command code
5	FC3	Third byte of the received command code
6	FC4	Fourth byte of the received command code
7	Blank	Blank
8	<STS>	Alarm byte
	Data	optional data strings, each separated by a blank
n	<ETX>	Control character for termination of the transmission

Apart from the described control characters and separators, the command consists
- of a repetition of the received command code,
- of an alarm byte
- and of a number of data strings depending on the command code.

The alarm byte contains the value "0 ', if at the time of the inquiry no error is present, otherwise one of the values '1' to '9'.
- With the first occurrence of an error the alarm byte contains the value '1'.
- If the error state continues, the alarm byte is incremented by 1 for each new inquiry.
- The value '1' follows to the value '9' of the alarm byte again.

Possible error causes are system-dependent.

The reception of a command which cannot be executed (syntax error, command cannot be executed in the current state, etc., see section 5.6.2) does not result in setting the alarm byte.

Number, meaning and format of the data strings depend on the executed command, for details see the description of the individual commands.

5.6.2 Reaction to not executable commands

In the following the situations and the answer of the LMF are described, by which a command cannot be executed.

- The command code consists of less than 4 characters. In this case the command cannot be sent back, the error "SE" (syntax error) is returned.
  Example:
  Command: <STX> ABC<ETX>
  Answer: <STX> ???? 0 SE<ETX>

- Even in the following cases a syntax error will be returned>
  - The command code exists of 4 characters indeed, but not of 4 capital letters.
  - The first character is neither ‚A' nor ‚E' or 'S'.
  - There is no blank following.
  - The indication of the channel is incomplete.
  - The command code is formally correct indeed, but unknown.

  If the command is known and the command is followed by at least 3 characters, the command will be returned.
  Example:
  Command: <STX> SREMK <ETX>
  Answer: <STX> SREm 0 SE<ETX>

  Otherwise (command is unknown or it is followed by less than 3 characters, „????" will be returned.
  Example:
  Command: <STX> SREm K0<ETX>
  Answer: <STX> ???? 0 SE<ETX>

- «K0» was not received as channel number. In this case the error message „NA“ (not available) is returned.
  Example:
  Command: <STX> SREM K1<ETX>
  Answer: <STX> SREM 0 NA<ETX>
- In the case of a faulty data string the error message „DF“ is returned.
  - The required number of data has not been received.
  - The data cannot be interpreted formally (e.g., data string cannot be interpreted as floating point number though this is expected)
  - The data values are outside of allowed ranges.

  Example: Parameters are falsely added to the command SREM
  Command: <STX> SREM K0 1.2345<ETX>
  Answer: <STX> SREM 0 DF<ETX>
- The system is not in the remote mode and the sent command is neither an inquiry command nor the command SREM. In this case the error message „OF“ („Offline“) is returned.
  Example:
  Command: <STX> SACT K0<ETX>
  Answer: <STX> SACT 0 OF<ETX>
- The sent command is formally correct, but it cannot be executed at the momentary time / in the momentary condition of the system. In this case the error message „BS“„(„Busy“) is returned.
  Example: During an average-building measurement in the manual mode it is not possible to switch over to the remote mode.
  Command: <STX> SREM K0<ETX>
  Answer: <STX> SREM 0 BS<ETX>

The situations, in which a command cannot be executed, are command specific and are described in detail with the documentation of the individual commands.

5.6.3 APAR

Query of parameters

Parameter: <Parameter number>
Answer: <Value of the parameter queried>

Examples
Query of the serial number of the system (parameter S0099, serial number P7306):
APAR K0 S0099
APAR 0 P7306

Query of the standard pressure (parameter S0101, standard pressure 1013,25 mbar):
APAR K0 S0101
APAR 0 +1.013250E+05

Query of the measuring time in program 0 (parameter P0701, measuring time 20 sec):
APAR K0 P0701
APAR 0 +2.000000E+01

Query of the current temperature (parameter R0003, temperature 22,8°C):
APAR K0 R0003
APAR 0 +2.959857E+02

Notes
- In principle, all parameters can be queried by the command APAR, in particular:
  - system parameters (S parameter, Sxxxx).
  - program-dependent parameters (P parameter, Pnxxx).
  - all sensor measurement values and all values calculated from that (R parameters, R0xxx).
- The returned values are, depending on the parameter, integers, floating point numbers, or strings.
- Floating point numbers are returned in the format +1.123456E+01.
- Values full of units are basically returned in SI units.
- A short compilation of the most important parameters can normally be found in the project-specific short manual. A complete overview of all parameters can be found in the Reference Manual in chapter 9.10

5.6.4 ASTF

Query of the error status

Parameter: -
Answer: <Error code>

Examples
No Error:
ASTF K0
ASTF 0 0

Sensor error with temperature sensor (see notes):
ASTF K0
ASTF 1 4

Notes
- A numeric error code is returned.
- If there is no error, the error code "0" will be returned.
- The other error codes are parameterized user-specifically. The standard parameterization encodes binary sensor errors of the sensors for differential pressure, absolute pressure and temperature and the general error FAIL
  - Error with differential pressure: 1
  - Error with absolute pressure: 2
  - Error with temperature: 4
  - FAIL: 8
- FAIL is set, for example, if no valid program has been selected (see command SPRG, section 5.6.10), or if a testing schedule has been interrupted before the actual measurement phase starts. The error FAIL will be set back not before the next test has been started (with SRUN).

5.6.5 ASTZ

Query of the system status

Parameter: -
Answer: <Remote status> <error status> <test status> <custom-designed> <custom-designed> <> <custom-designed> <custom-designed> <custom-designed>

Examples
The system is in the remote mode and it is ready for a new measurement (READY bit set):
ASTZ K0
ASTZ 0 SREM 0 1 0 0 0 0 0

A measurement has been started, but it is still not terminated (neither READY bit nor END bit set):
ASTZ K0
ASTZ 0 SREM 0 0 0 0 0 0 0

A measurement has been terminated (END bit set):
ASTZ K0
ASTZ 0 SREM 0 2 0 0 0 0 0

Notes
Meaning of the returned data:
- <Remote status>: System is in remote state or in manual mode, SREM or SMAN will be returned.
- <Error status>: The same error code as with ASTF will be returned (see section 5.6.4).
- <Test status>: The status of the testing schedule is returned coded in bits, where the individual bits have the following meaning:
  - Bit 0: READY: The system is ready for a new testing schedule. It is started by SRUN.
  - Bit 1: END: A testing schedule started by SRUN was terminated regularly. Now, if necessary, result data can be read. After the command SSTP has been sent, the system changes to the state READY again.
  - Bit 2: LOCK: The system is in the status LOCK, a new test is only possible after the command SACK has been sent. The system only changes to the status LOCK, if the OK / NOK evaluation has been activated, if the error counter is activated and if a parameterizable number of tests have been evaluated in series with NOK.

- The following 5 data (numerical data or character strings) are parameterized user-specifically, if necessary. A description of this user–specific data can be found in the “Operation Instructions and System Configuration”, if necessary.

5.6.6 EPAR

Change of parameter values

Parameter: <Parameter number> <Value>
Answer: -

Examples
Changing the standard atmospheric pressure to 1000 mbar:
EPAR K0 S0101 1E5
EPAR 0

Select propane as gas type for program 1 (P0001 is the parameter, which determines the gas type, 10 is the numerical code for propane):
EPAR K0 P0001 10
EPAR 0

Setting the set value in program 0 to 200 Nml/min (corresponding with 3.333333E-06 m³/s)
EPAR K0 P0422 3.333333E-06
EPAR 0

Notes
- The parameter <value> has to be entered as integers, floating point number or string depending on the parameters.
- Floating point numbers should be entered in the form +1.123456E+01, but it is also possible e.g.:
  - 1.12345
  - 1.12345
  - 1.12E6
  - 1
- Values full of units must be basically entered in SI units.
- Entries which are non-interpretable will be acknowledged by the error “DF” (data error). Examples of non-interpretable entries:
  - The parameter number does not exist.
  - A floating point value has been entered for an integer parameter.
  - The entered value is outside the permitted range.
  - It has been tried to set a R parameter (measurement value).
- Modified parameter values will be activated only after the command SACT has been sent.
- If a parameter is changed by EPAR and it is then queried by the command APAR before activating the change with SACT, the (still) active value is returned (i.e., not the value newly set by EPAR).
- The activating/saving of changed parameters is carried out not fail-save.
- The command EPAR is possible any time.

5.6.7 SACK

Sending the signal SACK

The command SACK confirms the recognizing of the error lock, the system then changes from the status LOCK to the status READY (see also ASTZ, section 5.6.5).

Parameter: -
Answer: -

Example
SACK K0
SACK 0

Note
- The command is only permitted if the system is in the status LOCK, otherwise the acknowledgement is done by the error message BS (“busy”).

5.6.8 SACT

Activation of changed parameters

Parameter: -
Answer: -

Example
SACT K0
SACT 0

Notes
- Parameters, which have been changed by EPAR, are activated by the command SACT.
- The command is always possible in the remote mode, even during a running test.
- The changes are not stored fail-safe.

5.6.9 SMAN

Activate manual mode

Parameter: -
Answer: -

Example
SMAN K0
SMAN 0

Note
- The command is possible only if the system is in the status READY (see command ASTZ, section 5.6.5), i.e., not during a running test.

5.6.10 SPRG

Setting of the program

Parameter: <Program>
Answer: -

Example
Switch to program 3:
SPRG K0 3
SPRG 0

Notes
- Programs 0 to 9 are permitted
- For systems with 2 (3) measuring circuits 2 (3) parameters are required (first parameter for measuring circuit 0, second for measuring circuit 1 ...)
- Before a testing schedule is started for the first time with (SRUN) a program has to be selected with SPRG. If no program has been selected, the error FAIL will be set after execution of SRUN (see command ASTF, section 5.6.4).

5.6.11 SREM

Activate remote mode

Parameter: -
Answer: -

Example
SREM K0
SREM 0

Note
- The command is effective only if the system is in the status READY (see command ASTZ, section 5.6.5), i.e. not during a test which has been started manually by the operator (by keystroke). Otherwise the acknowledgement is done by BS (“busy”).

5.6.12 SRUN

Start measuring run

Parameter: <Special function>
Answer: -

Example
SRUN K0 0
SRUN 0

Notes

- The parameter <special function> transmits with a bit-code, which (additional) special functions are carried out in the following testing schedule. Possible special functions:
  - Bit 0: ZERO: Carry out nullification.
  - Bit 1: CALMIN: only relevant with geometric measurement systems.
  - Bit 2: CALMAX: only relevant with geometric measurement systems.
  - Bit 3: LDET: only relevant with leak measurement systems.
  - Bit 4: VDET: only relevant with leak measurement systems.
- The command is only permitted if the system is in the status READY.

5.6.13 SSTP

Terminate testing schedule

Parameter: -
Answer: -

Example
SSTP K0
SSTP 0

Notes

- If the command SSTP is sent during a running test, the test will be cancelled or prematurely terminated, then the system switches to the status END and then to the status READY (see command ASTZ, section 5.6.5).
- If the command SSTP is sent after the regular end of a test (the system is in the status END then), the system changes to the status READY.

6 Syntax

This chapter includes the syntax of

- figure formats for the input of numerical parameter values
- format strings, e.g. protocol pressure functions (see chapter 9.7.32)
- control terms

The special syntax of access lists for network connections is documented in an appropriate place, see chapter 5.2.6

6.1 Figure formats for the input of numerical parameter values

Figures in exponent notation	#.#######E## ±#.#######E±##	• Positive signs may be left out. • The number of digits of mantissa and exponent are variable. • The values can be also entered in fixed-point notation. • A decimal comma instead of a decimal point is not permissible.
Figures in fixed-point notation	#.####### ±#.#######	• Positive signs may be left out. • The number of the decimal and pre-comma places is variable. • If queried the display appears in exponent notation • A decimal comma instead of a decimal point is not permissible.
Integers	####### ±#######	• The number of the digits is variable.
Selection parameter	####### ±#######	• Selection parameters differ from the type “integer” by the fact that only certain values are admitted.

6.2 Format strings for protocol printout functions

You can define up to 4 format strings concerning the protocol printout function (S9301-S9304).
The format strings consist of a sequence of:

- placeholders with format specification,
- control character and
- normal signs:

The syntax %a$fw.ps is followed by a placeholder with format specification, where the following is valid:

- a is the number of the argument of S932X which should be inserted here.
- f are individual characters which influence the output:
  - +: An algebraic sign is also displayed with positive figures.
  - -: The output is done left-aligned within the field width.
  - !: The output is done concentric within the field width.
  - 0: In case of right-aligned output for format ‘f’, the left side is filled in with zeros.
- w is the total width in which the argument is formatted. w is optional.
- p is the accuracy. For floating point figures (s = e, E or f) the accuracy is the number of the decimal places. The accuracy is the number of digits for integers (f = d,x,X). This means that the number is filled up with zeroes to the left. p is optional, if it is not indicated, then the point in front of it must also be cancelled. If no accuracy is indicated, then the default will be 6 for floating point figures and 0 for integers.
- s is the real format. ‚d’ is a decimal integer format, ‚x’ and ‚X’ are integers in the hexadecimal format, ‚f’ is floating point without exponent, ‚e’ and, ‚E’ are floating point with exponent and a precomma place in the mantissa, ‚s’ is a string.

Control character
Control characters are initiated with a backslash. The following control characters are available:
- \t Tab character.
- \\ backslash
- \r carriage return
- \n linefeed

Normal characters
All characters not recognized as control characters or as a format specification are copied 1:1 in the output.

Example placeholders with format specification for protocol printout function
- „%2$d“displays the value of S9322 as an integer: „42“.
- „%2$0.4d“ displays the value of S9322 as an integer with 4 places and leading zeros: „0042“.
- „%2$+0.4d“ displays the value of S9322 as an integer with 4 places, leading zeros and an algebraic sign even with positive figures: „+042“.
- „%2$+010.4d“ displays the value of S9322 as an integer with 4 places, leading zeros, an algebraic sign even with positive figures, and a total width of 10 signs: „   +042“.
- „%2$-2+010.4d” displays the value of S9322 as an integer with 4 places, leading zeros, an algebraic sign even with positive figures, and a total width of 10 signs left-aligned: „+042   “.
- „%0$.3f“ displays the value of S9320 as a floating point figure with 3 decimal places: „42.000“.
- „%0$E“ displays the value of S9320 as a floating point figure with 6 decimal places: „4.200000E01“.
- „%0$.3e“ displays the value of S9320 as a floating point figure with 3 decimal places: „4.200E01“.

Note
In other contexts the format specifications can be used the same way without the first two characters.

6.3 Control terms

To be able to customize the system easier to different application scenarios, terms are used at many places for the determination of input or output signals. The calculation is carried out within these terms and access to inputs or status variables used in the software is possible.

6.3.1 Types

Operands of different types are processed in terms. Available types are: INTEGER (integer values), FLOAT (floating point values) and STRING (strings). An automatic conversion of the types into each other will not be carried out!

6.3.2 Operators and their priorities

Op	Name	Description	Prio
Id	Variable	Values of the variable at the analysis time	0
Id[]	Array	A field of a type. The index is of the type INTEGER.	0
Id()	Function	Arguments are indicated in brackets, the number and type of which depend on the function. Functions may be overloaded, i. e., a function with a name may expect different types and numbers of arguments. A function always has an individual value as a result.	0
()	Brackets		0
-	Unary minus		0
+	Unary plus		0
!, NOT	Boole NOT	Operand must be of the type INTEGER.	0
~, BITNOT	Unary NOT	Operand must be of the type INTEGER.	0
_	Debug output	The operator _ must be followed by an integer literal. During the analysis of the term the integer constant and the value of the following partial term will be displayed on the console. This allows for the test of more complex terms.	0
*	Multiplication	Operands can be INTEGER or FLOAT. The result is of the type of the operand.	1

<table>
<tr><td>/</td><td>Division</td><td>Operands can be INTEGER or FLOAT. The result is of the type of the operand.</td><td>1</td></tr>
<tr><td>\</td><td>Modulo</td><td>Operands must be of the type INTEGER.</td><td>1</td></tr>
<tr><td>&, BITAND</td><td>Binary AND</td><td>Operands are INTEGER</td><td>1</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>+</td><td>Addition</td><td>Operands can be INTEGER or FLOAT. The result is of the type of the operand.</td><td>2</td></tr>
<tr><td>-</td><td>Subtraction</td><td>Operands can be INTEGER or FLOAT. The result is of the type of the operand.</td><td>2</td></tr>
<tr><td>|, BITOR</td><td>Bit by bit OR</td><td>Operands must be of the type INTEGER.</td><td>2</td></tr>
<tr><td>^, BITXOR</td><td>Bit by bit XOR</td><td>Operands must be of the type INTEGER.</td><td>2</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td><<, SHL</td><td>Left shift</td><td>Operands must be of the type INTEGER. The result is also of this type.</td><td>3</td></tr>
<tr><td>>>, SHR</td><td>Right shift</td><td>Operands must be of the type INTEGER. The result is also of this type.</td><td>3</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>=</td><td>Equal</td><td>Works with INTEGER or FLOAT as operands. The result is an INTEGER with value 0 or 1.</td><td>4</td></tr>
<tr><td>!=, <></td><td>Unequal</td><td>Works with INTEGER or FLOAT as operands. The result is an INTEGER with value 0 or 1.</td><td>4</td></tr>
<tr><td><</td><td>Smaller than</td><td>Works with INTEGER or FLOAT as operands. The result is an INTEGER with value 0 or 1.</td><td>4</td></tr>
<tr><td>></td><td>Greater than</td><td>Works with INTEGER or FLOAT as operands. The result is an INTEGER with value 0 or 1.</td><td>4</td></tr>
<tr><td>>=</td><td>Greater or equal than</td><td>Works with INTEGER or FLOAT as operands. The result is an INTEGER with value 0 or 1.</td><td>4</td></tr>
<tr><td><=</td><td>Smaller or equal than</td><td>Works with INTEGER or FLOAT as operands. The result is an INTEGER with value 0 or 1.</td><td>4</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>&&, AND</td><td>Boole AND</td><td>Operands must be of the type INTEGER.</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>||, OR</td><td>Boole OR</td><td>Operands must be of the type INTEGER.</td><td>6</td></tr>
<tr><td>^^, XOR</td><td>Boole XOR</td><td>Operands must be of the type INTEGER.</td><td>6</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>?:</td><td>Ternary operator (IF query)</td><td>The expression INTEGER to the left of the ? will be evaluated. If it is unequal to 0 (TRUE), then the result of the operator will be the left result expression, otherwise the right one.
Example:
DI (8) & 1? 5: 0
If bit 0 of the digital input 8 is set, then the result is 5, otherwise 0.</td><td>7</td></tr>
</table>

Table 1 Operators and their priorities

6.3.3 Variables

Name	Description
AKACK	INTEGER. TRUE, if the SACK command has been sent by the AK interface. Will be automatically cancelled with the start of a measuring cycle.
AKCALMAX	INTEGER. TRUE, if the CALMAX bit has also been set by the AK interface when the measuring cycle is started.
AKCALMIN	INTEGER. TRUE, if the CALMIN bit has also been set by the AK interface when the measuring cycle is started.
AKGO	INTEGER. Always 0 at present.
AKLDET	INTEGER. TRUE, if the LDET bit has also been set by the AK interface when the measuring cycle is started.
AKREM	INTEGER. TRUE, if remote has been switched to by the AK interface.
AKSTART	INTEGER. TRUE, if the measuring cycle has been started by the AK interface.
AKVDET	INTEGER. TRUE, if the VDET bit has also been set by the AK interface when the measuring cycle is started.

AKZERO	INTEGER. TRUE, if the ZERO bit has also been set by the AK interface when the measuring cycle is started.
CYCLE	FLOAT. Indicates the current cycle time (corresponds to S0301).
CYCLECOUNT	INTEGER. Includes a cycle counter.
FAULT	INTEGER. Includes the error flags for inputs and outputs in the individual bits. See parameter description for block S0350 ff.
MEAS	INTEGER. TRUE, if a mean taking measurement runs.
MEASAVAIL	INTEGER. TRUE, if a measurement result is available.
MEASMODE	INTEGER. Indicates the type of measurement. 0 = mean taking measurement. 1 = leak test.
SPSCALMAX	INTEGER. State of the input CALMAX (see S1408) when the main cycle starts.
SPSCALMIN	INTEGER. State of the input CALMIN (see S1407) when the main cycle starts.
SPSDAVAIL	INTEGER. TRUE, if the removal of the PLC start signal is waited for. The variable indicates the end of the cycle and thus the availability of the evaluation data. The signal is only cancelled again when a new cycle has been started.
SPSEND	INTEGER. TRUE, if the removal of the PLC start signal is waited for. The variable SPSEND is set inactive again, as soon as the PLC cancels the start signal. However, it is valid in the state WAIT for at least one cycle.
SPSFAIL	INTEGER. TRUE, if an error has occurred during the PLC program cycle.
SPSIN0	INTEGER. State of the extension signal #0 (see S1411) when the main cycle starts.
SPSIN1	INTEGER. State of the extension signal #1 (see S1412) when the main cycle starts.
SPSIN2	INTEGER. State of the extension signal #2 (see S1413) when the main cycle starts.
SPSLDET	INTEGER. State of the input LDET (see S1409) when the main cycle starts.
SPSLOCK	INTEGER. TRUE, if the error acknowledgement signal of the PLC is waited for.
SPSMODE	INTEGER. Program mode (corresponds to S0010).
SPSREADY	INTEGER. TRUE, if the program waits for the START signal of the PLC.
SPSSTART	INTEGER. State of the start signal of the PLC.
SPSVDET	INTEGER. State of the input VDET (see S1410) when the main cycle starts.
SPSZERO	INTEGER. State of the input ZERO (see S1406) when the main cycle starts.
STATE	INTEGER. State of the finite state machine.
STAUTH	INTEGER. Includes 1 during the password query, otherwise 0.
STCAL	INTEGER. Includes 1 during the calibration phase, otherwise 0.
STCALM	INTEGER. Includes 1 during the stabilization period, otherwise 0.
STEDIT	INTEGER. Includes 1 in the editing menu, otherwise 0.
STERROR	INTEGER. Includes 1 during the display of an error, otherwise 0.
STFILL	INTEGER. Includes 1 during the filling phase, otherwise 0.
STLDET	INTEGER. Includes 1 during the determination of the system leakage (LMS), otherwise 0.
STMEAS	INTEGER. Includes 1 during the measuring phase, otherwise 0.
STPFIL	INTEGER. Includes 1 during the pre-fill phase, otherwise 0.
STPOLL	INTEGER. Includes 1 during the polling phase, otherwise 0.
STPROG	INTEGER. Includes 1 in the program menu, otherwise 0.
STSAVE	INTEGER. Includes 1 during saving, otherwise 0.
STTEMP	INTEGER. Includes 1 during the transfer of parameters, otherwise 0.
STVDET	INTEGER. Includes 1 during the determination of the test sample volume (LMS), otherwise 0.
STVENT	INTEGER. Includes 1 during the venting phase, otherwise 0.
STWAIT	INTEGER. Includes 1 during the waiting for the PLC stop, otherwise 0.
STZERO	INTEGER. Includes 1 during the nullification phase, otherwise 0.

Table 2 Variables

Note
The variables STxxx are set by the help of the state of the internal finite state machine and they do not only cover the real operation, but also initializations and transitional states.

6.3.4 Fields

Name	Description
AKPROG[3]	Includes the programs for the measuring circuits, as they have been set by the AK interface with the SPRG command.
DI[n]	Includes the state of the digital inputs. Element type is an INTEGER. The current input value stands in bit 0, bit 1 indicates whether a change of state has occurred in the last cycle. Thus 0: Input is steady on OFF. 1: Input is steady on ON 2: Input has changed from ON to OFF. 3: Input has changed from OFF to ON.
F[100]	Generic FLOAT variables. Can be described by script code. The values can be queried by the parameters R2800 to R2899.
FF[20]	Supplies the initial value of a flip flop (see S12xx). The parameter for the function is the number of the flip flop (0..9).
FPAR[100]	Includes the values of the F parameters. The result is of the type FLOAT. CAUTION: Access to non-existing or faulty F parameters results in an error.
I[100]	Generic INTEGER variables. Can be described by script code.
IPAR[100]	Includes the values of the I parameters. The result is of the type INTEGER. CAUTION: Access to non-existing or faulty I parameters results in an error.
GCFreq[3]	Frequency setting for the simulated gas meter.
NI[32]	Supplies the value of a virtual input. The bit definition corresponds to that of the function DI.
PROG[3]	Includes the programs running in the measuring circuits.
RERR[3000]	Includes the error code for a R parameter. The result is of the type INTEGER. A value of 0 means „no error“. CAUTION: Access to non-existing R parameters results in an error.
RPAR[3000]	Includes the values of the R parameters. The result is of the type FLOAT. CAUTION: Access to non-existing or faulty R parameters results in an error.
S[10]	Generic FLOAT variables. Can be described by script code. Max. 255 characters.
SPSOK[3]	Includes one flag per measuring circuit, which is TRUE, if a test has been carried out in the measuring circuit and the result is OK.

Table 3 Fields

6.3.5 Functions

Name	Description
ABS(VAR)	Returns the absolute value of the argument. The result is of the type of the argument.
RELHUM(FLOAT,FLOAT,FLOAT)	Calculates the relative humidity. Arguments in turn: Pressure (as absolute pressure in Pa), temperature (in °K), molar humidity
RES(INT)	Returns the evaluation of the test in the appropriate measuring circuit. Function result: 1 = NOTAVAIL, 8 = FAIL, 16 = OK, 32 = NOK, 64 = OFF.
RES(INT, INT)	Returns the individual evaluation of a test in the appropriate measuring circuit. First parameter is the measuring circuit, second parameter is the number of the individual evaluation. Function result: 1 = NOTAVAIL, 2 = LOW, 4 = HIGH, 8 = FAIL, 16 = OK.
SP(INT, INT)	Returns the sub program in a measuring circuit. First parameter is the measuring circuit, second parameter is the number of the sub program parameter set.
XV(FLOAT,FLOAT,FLOAT)	Calculates the molar humidity. Arguments in turn: Pressure (as absolute pressure in Pa), temperature (in °K), relative humidity

Table 4 Functions

Many functions are so special that it would go beyond the scope of this manual to list them all. Further information is available by the command SCRIPTINFO.

7 Operating modes

This chapter explains the most important operational modes except the PLC mode. An own chapter is dedicated to the PLC operational mode, see chapter 16.

7.1 STANDARD MODE

The standard mode is the mode which is active after the switch-on. It is also active if one of the other modes has been quit. As a rule the lower display line is used in the standard mode to display the current measuring program. Nevertheless, this can be initialized and, hence, deviations are possible in this item.
All arithmetic values and measurement values are continuously displayed in the standard mode. The displayed values can be toggled with the function keys “F1”, “F2” and “F3” starting from the default. The standard display setting is determined in the parameters and it can be changed in the editing mode.

7.1.1 Program selection

The LMF makes available up to 10 different measuring programs. They cannot be distinguished by the software, but they are alternative parameter sets with which, e.g., different sensor sets or measuring ranges are selected.

- In order to reach the program selection, press function key „F2 “for approx. 3 seconds.
  In the upper display line the highest permissible program number is displayed.
  In the middle display line the current program number is displayed, and on the right side the appropriate measuring circle.
  In the lower display line the lowest permissible program number is displayed.
- Select the desired measuring circuit using the function keys “F1” and “F3” (provided that more than one measuring circuit exist).
- Select the desired program number using the function keys “<” und “>“.

- To take over the changes safe guardedly, press function key „F2 “ for 3 seconds.

-or-

- In order to reject the changes, press the key „STOP“ or simultaneously press the function keys „F1“ and „F2“ for 3 seconds.

7.2 LEAK TESTING

This mode is intended as an accessory for the checking of the test section design for tightness. Leakages in the measuring system are the most frequent cause for faulty measurements and measuring deviations. With this function the test sample and the reference can be checked for leakage by the pressure drop method.

- Fill the system with overpressure and vacuum and separate the pressure supply again.
- To activate the leak test press the button “LEAK Test”.

The parameters S8001 to S8007 (cf.) determine the display options and the test period. After the pressure drop measurement has been finished the measurement result appears on the LED displays:

P0:	Pressure at the beginning of the leak test
P1:	Pressure at the end of the leak test
Pmin:	the lowest pressure having appeared during the test
Pmax:	the highest pressure having appeared during the test
dpdt:	Pressure gradient during the test

The calculation of the result is done by equation:

$$\text{Pressure drop / rise per time} = \frac{\text{final pressure - initial pressure}}{\text{Measuring time}}$$

The result is treated with correct signs.

- To quit the leak testing press the button “STOP” or press the function keys “F1” and “F2” at the same time and keep them pressed for 3 seconds.

7.3 MEASUREMENT with taking the mean

- To start a measurement with taking the mean, press the button “START”, or transmit the command “MEAS” by remote control.
  The LMF starts with the cyclic recording of the measurement values and computed values.
  During the measurement both upper display lines continue to display the current measurement values (can be configured). The measuring time is displayed in the lower display line.
  At the end of the measuring time the results are displayed. For any flow rate and sensor value the minimum values and maximum values are also displayed in addition to average. As long as the results are displayed, the LMF carries out no measurements.

Note
The measurement can be finished prematurely by pressing the button “STOP” or by pressing of the function keys “F1” and “F3” at the same time. Even in this case the results will also be displayed.

- To view the different averages of the sensor values and flow rates toggle them with the function key “F1”.
- To return to the standard mode again, press the button “STOP” or press the function keys “F1” and F3 ” at the same time.

Note:
With double section systems the measurement values and results are marked, in addition, with 0 for distance 0 and with 1 for distance 1. Limits as well as minima and maxima are always indicated with the accompanying physical value.

7.4 Special modes for the experienced user

7.4.1 Test mode

The test mode is for looking at the input signals and for editing the output signals. By the simultaneous display of the raw value and the value calculated out of it there is the possibility of a plausibility test.

- To activate the test mode, keep the function key “F3” pressed for 3 seconds.
  In the upper display line the test mode is indicated.
  In the middle display line the current raw value of the input or output is indicated.
  In the lower display line the physical value calculated with the linearization polynomial is indicated.
- Select the desired input or output using the function keys “F1” and “F3”.

Note
Only inputs which are active in the current program are displayed.

If you have selected an input:
- Press function key “F2” to change the number of the displayed digits.

If you have selected an output:
- Set desired output signal using the arrow keys “<” and “>“.

Note
In the test mode the arrow keys “<” and “>” have functions for the nullification of the inputs. For this purpose absolutely follow chapter 7.4.2!

- To take over the changes safe guardedly, press function key „F2 “ for 3 seconds.

-or-
- In order to reject the changes, press the key „STOP“ or simultaneously press the function keys „F1“ and „F2“ for 3 seconds.

7.4.2 Nullification

Since the differential pressure sensors and relative pressure sensors may be dependent on position, a nullification must always be carried out when changing the place of installation for the differential pressure sensors or relative pressure sensors.
In addition, the nullification should be carried out in regular time intervals to compensate long-term drifts of the sensors.
The nullification applies to all sensor inputs which are released for a nullification. Each sensor input may be allocated to one of up to three groups. All sensors of the same group are matched at the same time.

Make sure that position dependent sensors as e.g. oil-filled pressure sensors are properly orientated. Especially with differential pressure sensors of the 3051 series it frequently happens, that with even a slight inclined position the unbalanced weight of the oil filling burdens the measurement cell resulting the measurement interval shifting at least in part outside the electrical signal range. The nullification described here can not compensate that effect!

The alignment of pressure sensors only makes sense in a state completely free of flow or free of pressure. If this operating condition is not automatically produced by valves, suitable operating conditions must be produced by adequate interventions. E.g., it is recommended for differential pressure sensors to connect the pressure connections with each other. Effects as draft etc. will be avoided with that.

The nullification is only reasonable with a thermally balanced system. I.e., after having switched on the system there should be a waiting period of approximately 30 minutes, in the case of a change of the ambient temperature caused by a change of location even clearly longer. Independent of that the waiting period of thermostat sensors may be up to 4 hours! In this case possibly leave the system or the sensor supply always switched on.

The nullification can be carried out for each sensor individually by hand or be started as an automatic cycle by remote control command (RS232, network or PLC) or by keystroke. The automatic cycle is documented in chapter.

7.4.2.1 Manual nullification of individual sensors

The manual nullification is only possible in the test mode. The test mode is not accessible if the controller is set by S0010 to external control (e.g. PLC operation).

- If the controller is set to external control, activate the editing mode with the functional key “F1”, scroll to parameter S0010, write down the original value and change the value according to the information of parameter S0010 (see chapter 9.7.1). Leave the editing mode by taking over the change (keep functional key “F2” pressed for 3 seconds).
- Activate the test mode using function key "F3" and select the input of the sensor, which should be aligned to zero, using function key "F1".
- To align the sensor to zero, keep right arrow key “>” pressed for 3 seconds.
  If a nullification is released for the selected sensor, the LMF carries out a mean taking measurement and calculates an offset correction from it. The process for that is saved in parameter S2x31, and x stands for the number of the input.

- or -

- To restore the offset value of the original factory setting saved in the source text, keep the left arrow key “<” pressed for 3 seconds.

Now it is possible to immediately align the next sensor to zero, or to leave the test menu by saving the changes (keep function key “F2” pressed for 3 seconds).

- If you have changed the parameter S0010, restore the original value again.

7.4.3 Editing mode

In the editing mode there is access to the parameters which are defined in your application, as far as they are not classified as “read-only”. There is an overview of the parameter structure in chapter, detailed information about the meaning and about the range of adjustment of each parameter can be found in the parameter list (chapter).

Editing mode and access by remote control are not possible simultaneously.

7.4.3.1 Read-only parameter

There are system parameters which must not be changed. There is no access to them in the editing mode. They can be queried at best by the terminal program, but it is not possible to change them.

7.4.3.2 User administration

Up to 10 access levels may be defined, where each level is allocated to one user group. An own password is allocated to each level. Beginning with version 5 it is not the case any more that users of a high level have also automatically access to the parameters which are accessible in a lower level. Just as for the quality “Read-only” it can be determined for each parameter in which level any access is possible or not. Particularly users of a high level have the advantage of finding a specific selection of relevant parameters for them and they need not search for thousands of parameters.
The user groups are defined in the parameter block S0500 (see chapter 9.7.3).

7.4.3.3 Activate and use editing mode

✓ You are in the standard mode

➢ Press the key F1 for 3 seconds.
You are asked to set an access level.
➢ Set the access level using the arrow keys “<” and “>” and confirm the setting with function key “F2“.
You are asked to set the password which corresponds to the level.
➢ Set the password using the arrow keys “<” and “>” and confirm the setting with function key “F2“.
The first parameter is indicated.

In the upper line of the display the parameter identification is indicated, consisting of the initial letter and a four-digit number. In the middle line the value of the parameter is indicated.

➢ To indicate the desired parameter, scroll forward with function key “F1” or scroll back with the function key “F3”.
➢ To change the value of the indicated parameter, use the arrow keys “<” and „>“. Depending on the data format there are some tips which can be found below (sections 7.4.3.4. to 7.4.3.7).

Now it is possible to change the next parameter or to leave the editing menu (section 7.4.3.8).

7.4.3.4 Editing figures in exponential form

As a default the arrow keys “<” and “>” have an effect on the smallest digit of the mantissa. By pressing function key “F2” repeatedly it is possible to set the effect of the arrow keys on the exponent or on a certain digit of the mantissa. Thus a very comfortable setting is possible. Exponent and digits are periodically toggled. If you open a parameter, first of all no particular digit will be selected. With every keystroke of the function key “F2” the digits are selected in the following order:

- Exponent
- 4. digit following the decimal point
- 3. digit following the decimal point
- 2. digit following the decimal point
- 1. digit following the decimal point
- Digit before the decimal point including sign
- No digit selected.

7.4.3.5 Editing of figures in fixed decimal point notation

Figures in fixed decimal point notation are always tied together with a physical unit. If the physical unit is changed, the value is converted accordingly, so that a comfortable input is possible.
For the qualities of the function key “F2” there is the same as with the figures in exponential form, differing in the fact that the exponent is cancelled and instead the physical unit is changed (e.g., PSI instead of mbar).

7.4.3.6 Editing of integers

Only the arrow keys “<” and “>” are available. The values are incremented and decremented at increasing speed by pressing the key longer.

7.4.3.7 Editing of selection parameters

Selection parameters are non-numerical parameters with solid values which only can be advanced in turn (toggle parameter). The change is only possible by the arrow keys "<" und ">".

7.4.3.8 Leave editing mode

- To take over the change with mains failure protection, keep the function key “F2” pressed for 3 seconds.
  The changed values are saved in the “persistent data area” of the flash ROM.

-or-

- To reject the change, press the key “STOP” or press the function keys “F1” and “F2” at the same time and keep them pressed for 3 seconds.

8 Parameter structure

8.1 Parameter structure und Overview

The individual parameter names are built up of an identification letter and a four-digit number. According to their function they can be summarized in the following content units:

8.1.1 C parameter nozzle combinations

Cxxxx block   nozzle combinations

8.1.2 D parameter display configurations

D00xx block   linkage program state with display list
D01xx-Block   Linkage of display pages to a display list
D1xxx-Block   Definitions of the display pages

8.1.3 E parameter extension flow elements

E0000-Block   Linearization and type preselection flow elements
The data of 100 primary elements follow in a distance of 100 each up to the E9900 block, according to the same setup structure as the S4000 block

8.1.4 F parameter: freely usable float parameters

F00xx-Block   Float variables and constants for use in control terms
F0000 to F0099 dimensionless
F0100 to F0199 potentially with attributes dimension, unit, min, max, description,…

8.1.5 H parameter functions

H0000-Block   Switch over vectors for sub programs
H1000-Block   External, parameterizable functions
H5000-Block   External, parameterizable filters
H7000-Block   user-defined units

8.1.6 I parameter: freely usable integer parameters

I00xx-Block   Integer variables and constants for use in control terms
Available: I0000 to I0099

8.1.7 M parameter - gas mixtures and mechanical elements

M0000-Block   Gas mixture definitions
M1000-Block   Mechanical elements

8.1.8 P parameter – measuring programs

10 different configurations of the measuring system can be deposited in the 10 measuring programs. For the measurement values and arithmetic values of the measuring program the type of gas, allocation of the primary elements and sensors, determination and scaling of the measuring ranges, notation in physical units and comma digits, limits, measuring times, display settings, scaling and allocation of the analogue output is determined here among other things:

N is the operation exponent for the measuring program from 0 to 9 here.

8.1.8.1 Pn000 block: Primary elements, basic description

Pn010 block: Primary signal (differential pressure)
Pn020 block: Test pressure absolute
Pn030 block: Measuring temperature
Pn040 block: Measurement humidity
Pn050 block: Reference pressure absolute
Pn060 block: Reference temperature
Pn070 block: Reference humidity
Pn075 block: Auxiliary input 0 Aux 0
Pn080 block: Auxiliary input 1 Aux 1
Pn085 block: Auxiliary input 2 Aux 2
Pn090 block: Auxiliary input 3 Aux 3
Pn095 block: Auxiliary input 4 Aux 4
Pn100 block: Units and decimal places for quantities
Pn200 block: Units and decimal places for R parameters
Pn300 block: Reference and correction pressure calculation
Pn310 block: Functions
Pn350 block: Calculated R parameters
Pn400 block: Control 1
Pn450 block: Control 2
Pn500 block: Limit values
Pn550 block: Automatic program toggle
Pn700 block: Process times
Pn800 block: Display options

8.1.9 R parameter - read parameter, measurement results of the measuring programs

The read parameters are for the quick and direct query of the measurement and arithmetic results. An overview of all values can be found in the Ryxxx block. (Y: measuring circuit index)
The desired measuring circle is described here by Y (e. g.: 0 is the first distance and 1 is the second one with the double section system). xxx" is the placeholder for the address of the value in the Ryxxx block.
Measuring circuits are simultaneously active. A measuring program can be allocated to each measuring circuit.

8.1.9.1 Error codes with the output of R-parameters

The error codes described here appear with the indication of R parameters on the display (e.g., in the standard mode), or by the query with the command "RPAR". They are not important for a query with R????.

There are two different error possibilities with the output of R parameters on the display:

- On the one hand, the number of the R parameter can be invalid. In this case "RXXXX" is displayed on the left, and some question marks are displayed on the right.
- Secondly the R parameters themselves can be subject to errors, perhaps values could not be computed because of sensor errors, or the value is not available because the calculation has not been carried out. In this case the name and the unit of the R parameter is displayed on the right, but not the numerical value appears on the left, but one of the following texts.

Display	Internal code	Meaning
noPort	ENOPORT	The input does not exist. This message may only appear with R parameters which represent direct analogous inputs.
noCALC	ENOTAVAIL	The value has not been calculated or read.
S-OFF	EOFF	The sensor is switched off.
S-FAIL	EFAIL	Input values for the calculation are beyond the range of validity (violation of limits, division by 0, ...).
C-FAIL	EREL	A value which is required for the calculation has an error, as a result the value could not be determined.
ConFiG	ECONFIG	Due to errors in the parameters necessary for the calculation the value could not be computed.

The syntax of the responses corresponds with those of figures in exponential form or fixed decimal point numbers.

8.1.10 S parameter – system parameter

In the system parameter range all basic and general settings and configurations are determined. It is structured as follows:

S0000 block: general parameters
S0350 block: Error conditions of inputs and outputs
S0500 block: User administration
S1000 block: Preselection of program
S1100 block: Stabilization periods nullification
S1200 block: Flip-flops (flags)
S1300 block: Virtual outputs
S1400 block: PLC control inputs
S1500 block: Input and output allocations
S1600 block: Impulse valves
S1800 block: Digital outputs
S2000 block: Linearization of sensors
S3000 block: Linearization of sensors
S4000 block: Linearization of primary elements
S5000 block: Linearization of primary elements
S6000 block: Linearization of primary elements
S7000 block: Linearization of primary elements
S8000 block: Scaling of analogue outputs
S9000 block: Possible special functions:
S9300 block: Protocol printout
S9500 block: Definition of connection for virtual outputs
S9600 block: Configuration AK interface
S9700 block: Process control
S9800 block: Script code

The behaviour of the serial interface RS 232, the sensor element and primary element linearization data as well as special functions are saved in the system parameter range. The definition of the measuring circuits and their allocation to the measuring programs serves for simultaneous supply of results for parallel running measurements and their query of results.

8.1.11 U parameter – sub programs

In this parameter field sub programs are administrated.

9 Parameter list

9.1 C parameter: Nozzle combinations

The parameter block Cxxxx (C0000-C0199) includes 10 data sets for nozzle combinations with a distance of 20, which can be used for Pn000 instead of a primary element. For that purpose a negative primary element number has to be indicated for Pn000. -1 corresponds to the nozzle combination of C0000, -2 corresponds to C0020 etc. Only nozzles with the same type of evaluation (according to PTB or CFO calibration) can be combined respectively, calibration gas type, calibration conditions etc. must also correspond to each other.
In the following the data record is displayed exemplarily with C0000:

Parameter	Meaning	Values	Explanations	
C0000	Number of combined nozzles	0...16	0	nozzle combination invalid
			1...16	Combine N nozzles from C0001..C0016
C0001	Nozzle #1	0...139	Number of the nozzle data record from S4000-S7000 or Exxxx	
...				
C0016	Nozzle #16	0...139	Number of the nozzle data record from S4000-S7000 or Exxxx	

Table 5 Cxxxx block: Nozzle combinations

9.2 D parameter: Display lists

Block Dxxxx defines the display options in the different modes of the program.

9.2.1 D0000-D0019 block: Linkage program mode with display list

Parameter	Meaning	Values	Explanations
D0000	|Linkage mode #0 with a display list.	String „0“	The display list indicated here is used in the program mode 0.
...			
D0019	Linkage mode #19 with a display list.	String „0“	The display list indicated here is used in the program mode 19.

Table 6 D0000 block: Linkage program mode with display list

Currently used program modes are:

Mode	Description
0	Continuous operation
1	Display of the measurement result during poll and in the standard mode
2	Display during measurement
3	Fill
4	Calm
5	Calibrate
6	Venting
7	Wait for PLC STOP
8	Display of the measurement result in the PLC mode (separate step)
9	Display during nullification
10	Display during the system leak test
11	Display of the results of the system leak test

The corresponding program mode is linked with a list by a term. In the most simple case the term includes only one number, which indicates the list to be used. However, more complex terms are possible. The display list can be switched, for example, if the program in the measuring circuit is changed.

9.2.2 D0100-D0499 block: Linkage of display pages to a display list

Several display pages are summarized to a page list in block D0100-D0499. Each list may include up to 18 single pages which can be toggled with buttons. A maximum of 20 of such lists can be defined with a distance of 20. Here, as an example, the definition of list #0, display list #1 follows with D0120.

Parameter	Meaning	Values	Explanations
D0100	Number of pages in list #0.	0...18 [1]	N pages to be displayed starting from D0102
D0101	Display mode	0...1 [0]	0: Display page-by-page. It is possible to toggle by F1 or F3. All displays are always switched to the new page. 1: Display line-by-line. Each display line indicates a section of a page. F1 toggles the upper display to the following page, F2 the middle display, and F3 the lower display, regardless of the other displays. Scrolling back is not possible.
D0102	Page #1	0...99	Number of the first page in the list. The number refers to the page definitions in D1000-D1999.
D0119	Page #18	0...99	Number of page 18 in the list. The number refers to the page definitions in D1000-D1999.

Table 7 D0100 block: Linkage of display pages to a display list

9.2.3 D1000-D1999 block: Definitions of the display pages

The block D1000-D1999 defines the individual display pages which are referred to in block D0100-D0499. Page #0 is defined in D1000-D1002, page #1in D1010-D1012 etc.

In addition to the display of certain predefined data there are two possibilities to indicate the value of R parameters on the display:

- Display of a directly allocated parameter
- Display of the R parameter, which is saved in an allocated P parameter (see also chapter 9.8.23) for this

At this point it is a matter of determining whether a standard size or the value of a R parameter should be displayed, and whether the R parameter is allocated directly or indirectly, if necessary.

Parameter	Meaning	Values	Explanations
D1000	Display value of upper display	-7...-1 0...59999 [-1]	-12: Name of the program in MK 2 -11: Name of the program in MK 1 -10: Name of the program in MK 0 (from Pn899 respectively, see there) -7: Evaluation of measuring circuit 2 -6: Evaluation of measuring circuit 1 -5: Evaluation of measuring circuit 0 -4: Current time -3: Current date -2: Program no. of the measuring circuit -1: Empty display 0...2999: R parameter number 3000...9999: not allocated 10000...52999: P parameter no. of the R parameters includes. There, the thousands digit indicates the measuring circuit. The ten thousands digit indicates, whether the R parameter itself should be used: 1xxxx: Use continuous value. 2xxxx: Use average. 3xxxx: Use sum. 4xxxx: Use minimum. 5xxxx: Use maximum.
D1001	Display value of middle display	-7...-1 0...59999 [-1]	as D1000
D1002	Display value of lower display	-7...-1 0...59999 [-1]	as D1000

Table 8 D1000-D1999 block: Definitions of the display lists

9.3 E parameter: Extension primary elements

Parameter block Exxxx (E0000-E9999) includes the definitions of 100 additional primary elements (numbers 40-139). The individual elements are arranged in a distance of 100 and they are identically in their structure with the definitions in block S4000-S7000.

9.4 F and I parameter: Freely usable parameters

Freely usable parameters can be used in calculations (e. g. terms or scripts) as a constant. The advantage compared with the direct use of the values is that the values of the parameters can be made available in the editing menu, so that the user can see and edit the values. However, changes are only active after „Save“, „Temp“ or „Activate“.

There are parameters for two different data types:

- F parameters F00xx can be used for float values
  F0000 to F0099 dimensionless
  F0100 to F0199 potentially with attributes dimension, unit, min, max, description,…
- I parameters I00xx can be used for integer values

The parameters F0000 up to F0199 and I0000 up to I0099 are available.

The meaning is usually documented in the “Operating Instructions and System Configuration”.

9.5 H parameter: Functions

9.5.1 H0000-H0499 block: Switching over vectors

The switching over vectors are used then, if switchable sub programs are used, and if the switching over is released by the value of a R parameter. Explanations fort he sub programs and the different options to determine their switching over behaviour can be found in section 9.9.

The parameter block Hxxxx (H0000-H0499) includes 50 data sets with a distance of 10, one for a possible sub program respectively. In the following the data record is displayed exemplarily with H0000:

Parameter	Meaning	Values	Explanations
H0000	Number of the R parameter which is to be evaluated	0...2999	
H0001	Lower limit		Lower limit for the R parameter in H0000
H0002	Upper limit		Upper limit for the R parameter in H0000
H0003	Switch over limit when falling below	0...9	If the R-Parameter in H0000 falls below the upper limits in H0001, a switch over to the sub program indicated here is carried out.
H0004	Switch over limit when exceeding	0...9	If the R-Parameter in H0000 exceeds the upper limits in H0002, a switch over to the sub program indicated here is carried out.

Table 9 H0000 block: Switching over vectors

9.5.2 H1000-H2999 block: External, parameterizable functions

Functions are available fort he internal script interpreter, for which more parameters are required in addition to the input value. 20 of such functions can be defined in block H1000-H2999. They are invoked in terms with EXTFUNC (number, input value), where the number is the number of the external function. The corresponding parameters are in a distance of 100 with H1000. Function 0 with H1000, function with H1100 etc. function 0 is presented in the following as an example.

Parameter	Meaning	Values	Explanations	H1000
H1000	Type of function	0...12	0: Result is term from H1001 1: Polynomial 2: Root polynomial 3: Limit with definition 4: Limit with FAIL 5: Conversion of units 6: PSI function 7: Triangle 8: Rectangle 9: Saw tooth 10: Reversed saw tooth 11: Sine 12: Cosine	
H1001	Term	String		0
H1005	Order polynomial	0...9	Order of the polynomial	1.2
H1010	Polynomial coefficient order 0		Coefficient order 0 a0	1.2
H1011	Polynomial coefficient order 1		Coefficient order 1 a1	1.2
H1012	Polynomial coefficient order 2		Coefficient order 2 a2	1.2
H1013	Polynomial coefficient order 3		Coefficient order 3 a3	1.2
H1014	Polynomial coefficient order 4		Coefficient order 4 a4	1.2
H1015	Polynomial coefficient order 5		Coefficient order 5 a5	1.2
H1016	Polynomial coefficient order 6		Coefficient order 6 a6	1.2
H1017	Polynomial coefficient order 7		Coefficient order 7 a7	1.2
H1018	Polynomial coefficient order 8		Coefficient order 8 a8	1.2
H1019	Polynomial coefficient order 9		Coefficient order 9 a9	1.2
H1020	Polynomial X factor		Scaling factor between sensor raw value and polynomial x value	1.2
H1021	Polynomial Y factor		Scaling factor between polynomial y value and polynomial value in SI units	1.2
H1023	Polynomial Y correction	0.998 … 1.002 [1.000]	Multiplicative correction factor for the result of the polynomial	1.2
H1030	Lower limit		Lower limit for limit function	3.4
H1031	Upper limit		Upper limit for limit function	3.4
H1032	Lower display value		This value will be displayed, if the lower limit falls short.	3
H1033	Upper display value		This value will be displayed, if the upper limit is exceeded.	3
H1035	Quantity when converting the units	0..22	See chapter 10	5
H1036	Original unit	0...99	Depending on H1035, see chapter 10	5
H1037	Required unit	0...99	Depending on H1035, see chapter 10	5
H1040	Gas type for PSI function	1...16	See chapter 9.8.1	6
H1045	Frequency		Frequency for cyclical functions	7-13
H1046	Amplitude		Amplitude for cyclical functions	7-13

Table 10 H1000 block: External, parameterizable functions

9.5.3 H5000-H6999 block: External, parameterizable filters

Up to 20 digital filters can be configured for special applications. The filters use the formula

$$y_{n+1}=\alpha_0 \cdot x_{n+1}+\alpha_1 \cdot x_n+\alpha_2 \cdot x_{n-1}-\beta_0 \cdot y_n-\beta_1 \cdot y_{n-1}$$

i. e. the new output value is calculated from the input and output values of the last two cycles and the current input value. Using this version transfer terms up to order 2 can be implemented. The filters can be defined either directly by indication of the coefficients , or for pre-defined transfer terms as PT1 etc. by indication of the characteristic value.
The parameters for each filter allocate one 100 block, block H5000-H5099 is displayed in the following as an example. The results are part of the R parameters R1860-R1879.

Parameter	Meaning	Values	Explanations	H5000
H5000	Type of filter	0...7	0: Switched off 1: Coefficients as indicated 2: PT1 term 3: I term 4: PI term 5: PIDT1 term	
H5001	Input value	String	The term indicated here determines the input value of the filter	
H5005	Minimum output value		Output value is limited by this value.	
H5006	Maximum output value		Output value is limited by this value.	
H5010	Coefficient α_0		Filter coefficient	1
H5011	Coefficient α_1		Filter coefficient	1
H5012	Coefficient α_2		Filter coefficient	1
H5013	Coefficient β_0		Filter coefficient	1
H5014	Coefficient β_1		Filter coefficient	1
H5020	P		Factor P for PT1 term	2
H5021	T1		Factor T1 for PT1 term	2
H5025	I		Factor I for I term	3
H5030	P		Factor P for PI term	4
H5031	I		Factor I for PI term	4
H5035	P		Factor P for PIDT1 term	5
H5036	I		Factor I for PIDT1 term	5
H5037	D		Factor D for PIDT1 term	5
H5038	T1		Factor T1 for PIDT1 term	5

Table 11 H5000 block: External, parameterizable filters

9.5.4 H7000 block: User-defined units

Block H7000 allows to configure up to 10 user-defined units for the quantity with code 17. They can be used like the pre-defined units. Restrictions are:

- The first unit is always understood implicitly as SI unit. Factor and offset of H7000 are therefore always 1.0/0.0 and hey cannot be changed.
- The maximum string length for the display is 7 characters. Longer strings are cut off for the display. There is no error message.
- In some cases the quantity of a value is checked. The LMS module checks, for example, whether the R parameter used as input value has the quantity falling pressure.

The final value is determined from the value in SI units by subtraction of the offset and division by the indicated factor. If the scaling factor is 0, a run-time error occurs.
The block at H7000 presented in the following is repeated for 10 times with a distance of 10.

Parameter	Meaning	Values	Explanations
H7000	Displayed unit	String	Maximum 7 characters. Up to 4 characters are displayed directly, in the case of longer inputs the display changes between the characters 0-3 and the remaining ones.
H7001	Scaling factor		SI factor for conversion
H7002	Offset a0		Offset

Table 12 H7000 block: User-defined units

Also compare with chapter 10.

9.6 M parameter: Gas mixtures

9.6.1 M0xxx block: Definition of gas mixtures

The area M0xxx contains 10 definitions for gas mixtures in a distance of 100.

Parameter	Meaning	Values	Explanations
M0000	Name of the mixture	String “ „	Name of the gas mixture
M0001	Number of gases	1..10	Defines how many gas entries are valid beginning from M0010
M0010	Gas 0	1...15	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 15: Water vapor 16: Xenon 17: Nitrogen monoxide
M0011	Portion gas 0	1E-3...1E6	Molar portion of gas 0.
M0015	Gas 1	1...15	as M0010
M0016	Portion gas 1	1E-3...1E6	Molar portion of gas 1.
M0020	Gas 2	1...15	as M0010
M0021	Portion gas 2	1E-3...1E6	Molar portion of gas 2.
M0025	Gas 3	1...15	as M0010
M0026	Portion gas 3	1E-3...1E6	Molar portion of gas 3.
M0030	Gas 4	1...15	as M0010
M0031	Portion gas 4	1E-3...1E6	Molar portion of gas 4.
M0035	Gas 5	1...15	as M0010
M0036	Portion gas 5	1E-3...1E6	Molar portion of gas 5.
M0040	Gas 6	1...15	as M0010
M0041	Portion gas 6	1E-3...1E6	Molar portion of gas 6.
M0045	Gas 7	1...15	as M0010
M0046	Portion gas 7	1E-3...1E6	Molar portion of gas 7.
M0050	Gas 8	1...15	as M0010
M0051	Portion gas 8	1E-3...1E6	Molar portion of gas 8.
M0055	Gas 9	1...15	as M0010
M0056	Portion gas 9	1E-3...1E6	Molar portion of gas 9.

Table 13 M0xxx block: Gas mixtures

9.6.2 M1xxx block: Mechanical Elements

The area M1xxx contains 10 definitions of mechanical elements spaced by 10.

Parameter	Meaning	Values	Explanations
M1000	Name of element	String	Name of the mechanical element
M1001	Desc. of movement to home position	String	The parameter contains a description of the movement to home position for display or logging purposes
M1002	Desc. of movement to work position	String	The parameter contains a description of the movement to work position for display or logging purposes
M1003	Message for errors when moving to home position	String	The parameter contains an error message if movement to home position failed
M1004	Message for errors when moving to work position	String	The parameter contains an error message if movement to work position failed
M1005	Actual state expression	String	The parameter must contain an expression that results in the current position when evaluated. 0 means home position, 1 means work position and –1 means that the actual position is unknown.
M1006	Timeout	0.02...120.0	Timeout for the movement of the mechanical element

Table 14 M1xxx block: Mechanical Elements

9.7 S parameter: System parameter

9.7.1 S0000 block: general parameters

Parameter	Meaning	Values	Explanations
S0001	Step-by-step operation	0...1 [0]	0: Switched off 1: Step operation active
S0002	Display initialization	0...1 [0]	0: Switched off 1: Display is initialized again in each cycle
S0003	Watchdog	{0...1|0...1} [0]	0: Do not use watchdog 1: Activate watchdog
S0004	Time synchronization	0...864000 [0]	0: No time sync Otherwise: Interval for the time synchronization in seconds. Values less than 60 seconds are rounded up.
S0006	Serial port (Ser0) baud rate, if used for the logical interface COMM. Values > 0 override the default setting from the config.dat.	0...9 [5]	0: Usage of Ser0 for other purposes, e.g. AK interface or scanner 1: 300 Baud 2: 600 3: 1200 4: 4800 5: 9600 6: 19200 7: 38400 8: 57600 9: 115200
S0008	Serial output String block mark	0...2 [0]	0: CRLF 1: CR 2: LF 3: ETX
S0009	RTS/CTS Handshake	0...1 [0]	0: Off (no handshake) 1: On (RTS/CTS handshake)
S0010	Mode (Operating mode)	0...63	Bit-encoded value for adjusting the mode of operation. Bit 0: 1=complete cycle, 0=sub-cycle Bit 1: 1=External control, 0=Keys Bit 2: 1=External program selection Bit 3: 1=Stop interrupts measurement, 0=Stop terminates measurement Bit 4: 1=Error with measurement terminates a test with several cycles, 0=all cycles are carried out Bit 5: 1=Measurement stops if all measurement circuits are done or have errors, 0=Measurement stops on an error in any measurement circuit Valid values: 0: Standard mode 9: LMS with manual control 15: PLC cycle
S0011	Number of cycles	1...999	
S0012	Program step, if S0011 > 1	0, 1 [0]	0: No program step 1: Program step
S0013	Counter NOK Lock active at n x NOK	0...10 [0]	0: n = 0, not active 1: n = 1, active at 1 x NOK etc. up to 10: n = 10, active at 10 x NOK
S0014	Determination system leakage (LMS cycle): number of flows whose result is ignored	{0...100| 0...100} [0]	The total number of the flows is determined by S0014 + S0015.

S0015	Determination system leakage (LMS cycle): number of flows whose result is evaluated	1...100 [1]	The total number of the flows is determined by S0014 + S0015.
S0016	Save system leakage continuously after determination	0...1 [1]	0: Take over only temporarily. 1: Save continuously.
S0017	Determination of the test sample volume (LMS cycle): number of flows whose result is ignored	0...100 [0]	The total number of the flows is determined by S0017 + S0018.
S0018	Determination of the test sample volume (LMS cycle): number of flows whose result is evaluated	1...100 [1]	The total number of the flows is determined by S0017 + S0018.
S0019	Save test sample volume continuously after determination	0...1 [1]	0: Take over only temporarily. 1: Save continuously.
S0020	TCP port for Comm connection	0..65535 [54491]	0: no Comm connection via network 1...65535: TCP port number
S0021	List of permitted remote stations	String [„“]	These remote stations are permitted to establish a connection
S0022	List of unpermitted remote stations	String [„“]	These remote stations must not provide a connection.
S0023	Use TCP cork mode for the Comm connection	0…1 [1]	TCP cork mode merges small network packets into bigger ones. This mode **must** be used on the new hardware, otherwise connections may hang.
S0030	Time-out for DNS operations	0.0...90.0 [1.0]	Timeout for DNS queries in seconds.
S0031	Syslog Server	String [„“]	Address or host name of a syslog server. If the parameter value is an empty string, the current settings of the operating systems are kept. Changes will be active until the next reboot.
S0040	Behaviour of the DEFAULTS command	0...3 [0]	Bit 0: Disable security query Bit 1: Create an empty param.dat file
S0050	Current feed time for impulse valves	0.02...5.0 [0.2]	The time in seconds for which current is fed to the impulse valves (S16xx).
S0051	Maximum number of impulse valves that are fed simultaneously	1..20 [20]	Switching a large number of valves may overload the power supply. The program will never activate more than the given number of impulse valves simultaneously. If this number is reached, switching of additional impulse valves is delayed.
S0060	Number of samples when zeroing	1..250 [10]	Number of samples taken when calculating the zero offset for an input
S0070	Wait for echo on Ser1	0..1 [1]	0: no echo (RS232) 1: echo (RS485 – default)
S0071	Wait for echo on Ser2	0..1 [1]	0: no echo (RS232) 1: echo (RS485 – default)

S0080	Digital output port which is set active with a runtime error.	-1...99 [-1]	-1: switched off. Otherwise: The number of the digital output port (DOnn in the configuration) which is set active with runtime errors. Caution: This only works with runtime errors which appear after the reading of the parameters, i.e. not during the start-up phase.
S0081	Digital output port which is set inactive with a runtime error.	-1...99 [-1]	-1: switched off. Otherwise: The number of the digital output port (DOnn in the configuration) which is set inactive with runtime errors. Caution: This only works with runtime errors which appear after the reading of the parameters, i.e. not during the start-up phase.
S0090	Term which defines the subsequent state after the display of errors.	String	The term defines to which machine state is branched to, after errors have been confirmed by the user in state 1810. The term is evaluated in state 1820. Faulty terms result in a emergency stop.
S0098	Number of active measuring circles:	1..3 [1]	Readable only.
S0099	Controller identifcation	String [„unknown“]	Readable only.
S0100	Version number of the software	String	Readable only. More information can be read by the VERS command.
S0101	Standard condition absolute pressure	[101325.0]	in Pascal
S0102	Standard condition temperature	[273.15]	in Kelvin
S0103	Standard condition humidity	[0.0]	0..1 r. h.
S0300	Activated modules in the standard mode	0... $7FFFFFFF [$7FFFFFFF] (all Bits set)	Each bit of the indicated value switches on or off a module in the standard mode (bit deleted = off, bit set = on). Bit 0: Sub programs Bit 1: Digital inputs Bit 2: Virtual inputs and outputs Bit 3: Mathematical functions Bit 4: Calculated R parameters Bit 5: Flip-flops Bit 6: Analogue outputs Bit 7: Digital outputs Bit 8: Impulse valves Bit 9: Graphic display Bit 10: Controller Bit 11: Main cycle commands Bit 12: Automatic program toggle Bit 13: Publish Bit 14: Subscribe Bit 15: Script bound to states Bit 16: Ubiquitous script Bit 17: Parameterizable filters Bit 18: AK protocol Bit 19: Unused Bit 20: Display list Bit 21: Mechanical elements Bit 24: Sensors (Pn0xx) Bit 25: Flow calculations Bit 26: SPS start signal

S0301	Cycle time in the standard mode	0.02...2.0 [0.02]	in seconds
S0302	Activated modules in the high-speed mode	0... $7FFFFFFF [$7FFFFFFF] (all Bits set)	Each bit of the indicated value switches on or off a module in the high-speed mode (bit deleted = off, bit set = on). Bit allocation exactly as with S0300
S0303	Cycle time in the high-speed mode	0.001...2.0 [0.002]	in seconds
S0311	Display update	0.02...5.0 [0.3]	Display only each n seconds

*) only if full cycle in S0010 enabled

Table 15 S0000 block: general parameters

Further information

- Access restriction for TCP connection see chapter 5.2.6

9.7.1.1 Several test flows with a test sample

Optionally several measurements can be carried out with one test sample (without deadaptation, without interruption of the control, if available), where the following cycle is kept (shift and intermediate steps are not listed):

- Select program
- Fill
- Calm
- Measurement
- Distinction of cases:
  - the flow which has been just carried out was not the last flow: back to “fill”, then next cycle.
  - the cycle which has been just carried out pass was the last cycle: go on with “Ventilation“.
- Venting

9.7.1.2 Automatic program step:

If by S0011> 1 several flows are initialized, there is optionally the possibility to increase the program with each flow by 1:

- 1. Cycle: start routine, as specified by S1400-S1402.
- 2. Cycle: start routine + 1.
- etc.

The program step is limited by the parameters S1010 (the lowest valid program number of measuring circuit 0) and S1020 (the highest valid program number of measuring circuit 3). By exceeding the highest program number there is a program step to the lowest program number (cyclic behaviour).

9.7.2 S0350 block: Error conditions of inputs and outputs

Block S0350 configures by which conditions error flags are set for inputs or outputs. For this purpose inputs and outputs are split in groups: Analogue inputs, analogue outputs, type 400 cards (digital inputs and outputs) and serial sensors. As soon as there are errors in a group for an adjustable time, an error flag will be set. This error flag will be reset, as soon as - for an adjustable time again - no more errors occur. The error flag is made available to the Script interpreter by the variable FAULT and it can then be used, for example, to return the error condition by a digital output.

Parameter	Meaning	Values	Explanations
S0350	error handling analogue inputs on / off	0...1 [0]	0: Switched off 1: error analysis active
S0351	time until error occurs	0.02...60.0 [2.0]	Time in seconds for which an error must permanently be present until the mistake flag is set.
S0352	time until reset of error flag	0.02...60.0 [2.0]	Time in seconds which must pass after activation of the error flag without errors, until the error flag will be reset again.

According to this example block S036n contains parameters for analogous outputs, block S037n parameters for type 400 cards, and block S038n parameters for serial sensors.

Further notes:

- A responding of an exceeding of limits (S2n36 ff.) is evaluated as an error with analogue inputs.
- Errors with analogous outputs are only returned by type 200 cards in the 4-20mA operation.
- The query cycle of the serial sensors depends on the type and on the number of the configured sensors. An error is triggered when there was no last query, or if with the last query an error occurred. The error is triggered in each cycle as long as the sensor has been queried successfully.

9.7.3 S0500 block: User administration

Parameter	Meaning	Values	Explanations
S0500	Description user 0	String [„“]	name of the user group
S0501	group affiliation user 0	0...$7FFFFFFF	bit-encoded, each set bit activates the affiliation to a group.
S0502	Password user 0	0...9999	password to be entered

The parameters S0510-S0599 contain other 9 user definitions of the same scheme.

Further information

- For examples and default settings see paragraph 2.2.7.2
- For consequences of the user-specific restrictions of access in the editing menu see paragraph 7.4.3.2.

9.7.4 S1000 block: Preselection of program

A measuring section with a set of sensors for the analysis of a flow element is indicated as measuring circuit. The Laminar Master may compute simultaneously up to three measuring circuits being active at the same time.
A program in which the definition of the measuring section is determined can be allocated to each measuring circuit.

Parameter	Meaning	Values	Explanations
S1000	measuring circuit 0 (single section)	0...9	Allocation program 0 – 9
S1001	Measuring circuit 1 (double section)	0...9	Allocation program 0 – 9
S1002	Measuring circuit 2 (triple section)	0...9	Allocation program 0 – 9
S1010	Lowest program number MK 0	0...9	Allocation program 0 – 9
S1011	Lowest program number MK 1	0...9	Allocation program 0 – 9
S1012	Lowest program number MK 2	0...9	Allocation program 0 – 9
S1020	Highest program number MK 0	0...9	Allocation program 0 – 9
S1021	Highest program number MK 1	0...9	Allocation program 0 – 9
S1022	Highest program number MK 2	0...9	Allocation program 0 – 9

S1030	Toggle program in measuring circuit 0 automatically.	0...3 [0]	0: No toggle 1: Toggle to block Pn550 2: Toggle to block Pn560 3: Toggle to block Pn550 and Pn560
S1031	Toggle program in measuring circuit 1 automatically.	0...3 [0]	0: No toggle 1: Toggle to block Pn550 2: Toggle to block Pn560 3: Toggle to block Pn550 and Pn560
S1032	Toggle program in measuring circuit 2 automatically.	0...3 [0]	0: No toggle 1: Toggle to block Pn550 2: Toggle to block Pn560 3: Toggle to block Pn550 and Pn560
S1035	Waiting time/stabilization time for automatic program toggle in measuring circuit 0.	0...300 [0.0]	Time in seconds, until the next automatic toggle is possible.
S1036	Waiting time/stabilization time for automatic program toggle in measuring circuit 1.	0...300 [0.0]	Time in seconds, until the next automatic toggle is possible.
S1037	Waiting time/stabilization time for automatic program toggle in measuring circuit 2.	0...300 [0.0]	Time in seconds, until the next automatic toggle is possible.
S1040	Carry out good/bad evaluation with block Pn500 (limit values) in the measuring circuit 0	0...1 [0]	0: Off, no evaluation 1: On, carry out evaluation
S1041	Carry out good/bad evaluation with block Pn500 (limit values) in the measuring circuit 1	0...1 [0]	0: Off, no evaluation 1: On, carry out evaluation
S1042	Carry out good/bad evaluation with block Pn500 (limit values) in the measuring circuit 2	0...1 [0]	0: Off, no evaluation 1: On, carry out evaluation

Table 16 S1000 block: Measuring circuits and analogue outputs

9.7.5 S1100 block: Stabilization periods nullification

Parameter	Meaning	Values	Explanations
S1100	Stabilization time before nullification, group 0	0...600 [0.0]	Time in seconds
S1101	Stabilization time before nullification, group 1	0...600 [0.0]	Time in seconds
S1102	Stabilization time before nullification, group 2	0...600 [0.0]	Time in seconds

Table 17 S1100 block: Stabilization periods nullification

9.7.6 S1200 block: Flip-flops (flags)

Up to 10 flip-flops can be defined in block 1200. The initial state of the flip-flops can be queried with the FF function of the Script Interpreter. The flip-flops are set, if the set print has a value other than 0. The reinitialization is carried out according to the type of flip-flop respectively:

- With type 1, if the reset output has a value <> 0.
- With types 2 and 3 after expiry of the defined stop-time.

Types 2 and 3 differ in trigger behaviour: Type 2 can be retriggered, i.e., the set expression is checked again in each cycle, and the preservation time is started again, if necessary. Type 3 can not be triggered again, and it falls for one cycle after the preservation time has expired, before the set term is evaluated again.

The new output values of the flip-flops are calculated in the sequence 0...9 in each cycle. A flip-flop definition, which queries the output of another flip-flop, reads the new value in the same cycle, if and only if the number of the queried flipflop is smaller.

The following table shows only one flip-flop, the parameters of nine others follow with S1210, S1220 etc.

Parameter	Meaning	Values	Explanations
S1200	Type of flag	0...3 [0]	0: Switched off 1: RS Flipflop 2: Monostable, can be retriggered 3: Monostable, cannot be retriggered
S1201	Set term	String [„“]	Term which sets the flag, if its value is <> 0. Applies for types 1-3.
S1202	Reset term	String [„“]	Term which resets the flag, if its value is <> 0. Applies for type 1.
S1203	Preservation time	0.02...86400 [1.0]	Preservation time for the flags type 2 and 3 in seconds

Table 18 S1200 block: Flip-flops (flags)

9.7.7 S1300 block: Outputs of the virtual PLC interface Net-IO

Parameter	Meaning	Values	Explanations
S1300	Term for output 0	String [„“]	The term will be evaluated in each cycle, if a connection exists.
…	…	…	…
S1331	Term for output 31	String [„“]	The term will be evaluated in each cycle, if a connection exists.

Table 19 S1300 block: Virtual outputs

Further information
- For syntax of control indication see chapter 6.3

9.7.8 S1400 block: PLC control inputs

Parameter	Meaning	Values	Explanations
S1400	Term which determines the program for the measuring circuit 0 in the PLC mode.	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1401	Term which determines the program for the measuring circuit 1 in the PLC mode.	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1402	Term which determines the program for the measuring circuit 2 in the PLC mode.	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1403	Term which determines the start signal for the PLC in the PLC mode.	String [„“]	The term will be evaluated in each cycle, if the PLC mode is active.
S1404	Term which determines the GO signal.	String [„“]	The term will be evaluated in each cycle, if the PLC mode is active.
S1405	Term which determines the ACK signal (reset of the NOK counter).	String [„“]	The term will be evaluated if a lockout exists due to too many errors.
S1406	Term which determines the ZERO signal.	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1407	Term which determines the CALMIN signal.	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1408	Term which determines the CALMAX signal.	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1409	Term which determines the LDET signal (determination of the system leakage).	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1410	Term which determines the VDET signal (determination of the test sample volume).	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.

S1411	Term for the extension signal #0 (specific to the product)	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1412	Term for the extension signal #1 (specific to the product)	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.
S1413	Term for the extension signal #2 (specific to the product)	String [„“]	The term will be evaluated after the start signal has been triggered by the PLC.

Table 20 S1400 block: Control inputs

Further information
- For the syntax of control indication see chapter 6.3

9.7.9 S1500 block: Input/output allocations

Parameter	Meaning	Values	Explanations
S1500	Number of the digital input for the STOP key	-1 0...99 [1]	Number of the digital input or -1 if none is defined.
S1501	Number of the digital input for the TEST key	-1 0...99 [-1]	Number of the digital input or -1 if none is defined.
S1502	Number of the digital input for the START key	-1 0...99 [0]	Number of the digital input or -1 if none is defined.
S1503	Number of the digital input for the SAVE key	-1 0...99 [-1]	Number of the digital input or -1 if none is defined.
S1504	Number of the digital input for the TEMP key	-1 0...99 [-1]	Number of the digital input or -1 if none is defined.
S1505	Number of the digital input for the ZERO key	-1 0...99 [3]	Number of the digital input or -1 if none is defined.
S1506	Number of the digital input for the EDIT key	-1 0...99 [-1]	Number of the digital input or -1 if none is defined.
S1507	Number of the digital input for the PROG key	-1 0...99 [-1]	Number of the digital input or -1 if none is defined.
S1508	Number of the digital input for the LEAK key	-1 0...99 [2]	Number of the digital input or -1 if none is defined.

Table 21 S1500 block: Input/output allocations

9.7.10 S1600 block: Impulse valves

Block S1600 includes the data for 40 impulse valves. The data displayed below at S1600 are repeated for 40 times with a distance of 5.

Parameter	Meaning	Values	Explanations
S1600	Number of the digital output for the opening of impulse valve 0.	-1 0...99 [-1]	Number of the digital input or -1 if none is defined.
S1601	Number of the digital output for the closing of impulse valve 0.	-1 0...99 [-1]	Number of the digital input or -1 if none is defined.
S1602	Term which determines the status of impulse valve 0	String [„“]	The term is evaluated in each cycle and it determines the status of the valve.

Table 22 S1600 block: Impulse valves

Further information
- For the syntax of the control terms see chapter 6.3

9.7.11 S1800 block: Digital outputs

Block S1800 allows to allocate terms for up to 50 digital outputs, which determine the status of these outputs. The terms are evaluated in each cycle. The following definition of S1800 repeats 50 times (up to S1899) with an interval of 2.

Parameter	Meaning	Values	Explanations
S1800	Number of the digital output, the status of which is determined in S1801	-1, 0...99	Number of the digital output or -1 if none is defined.
S1801	Term which is evaluated for the determination of the status of the port defined in S1800.	String	
S1802	Number of the digital output, the status of which is determined in S1803.	-1, 0...99	Number of the digital output or -1 if none is defined.
S1803	Term which is evaluated for the determination of the status of the port defined in S1802.	String	
etc.	etc.	etc.	etc.

Table 23 S1800 block: Digital outputs

By template, the first four outputs are assigned to the LED functions of the standard keys. The actual assignment of the outputs of your system may differ. See "Operating Instructions and System Configuration".

Further information
- For the syntax of the control terms see chapter 6.3

9.7.12 S2000/S3000 block: Linearization of sensors

For understanding
The following parameters are repeated for each analogue input (where „analogue“ at this point means all values continuously changeable in the frame of resolution, e. g. also measurement values of serial sensors). The lower case letter n in the parameter number represents the number of the data set. This number must not necessarily correspond to the channel number of a converter board, see also parameter S2n50. Value range 0 up to 19 according to the data sets S20xx up toS39xx.

Parameter	Meaning	Values	Explanations
S2n00	Type of sensor	-1...4 [-1]	-1: Switched off 0: Integrated analogue input 1: Serial sensor 2: R parameter 3: Integrated frequency counter input 4: Integrated incremental counter
S2n01	Type of linearization	-1...2 [0]	-1: without linearization / polynomial 0: Polynomial calculation 1: PT100/PT1000 linearization 2: Polynomial calculation with root (x)
S2n05	Order	-99...99 [1]	Generalized order of the polynomial. The first digit including sign is the smallest power (in most cases 0). The second number indicates the number of coefficients minus 1. The greatest power is derived from the sum of the two digits incl. sign. Example: S2n05 = -25 means smallest power is -2, largest 3.
S2n10 … S2n19	Maximal 10 coefficients (FLOAT numbers)		
S2n20	X factor	[1.0]	Scaling factor between sensor raw value and polynomial x value

S2n21	Y factor	[1.0]	Scaling factor between polynomial y value and polynomial value in SI units
S2n22	Serial number of the sensor	String	
S2n23	Y correction	0.998 …1.002 [1.000]	Multiplicative correction factor for the y value of the polynomial
S2n25	Factor r0 for PT100 calculation	99.0 ... 1010.0 [100.0]	The values r0, r1, r2 and r4 are the coefficients for the PT100 polynomial as defined in DIN EN 60751.
S2n26	Factor r1 for PT100 calculation	3.5E-3 ... 4.5E-3 [3.9083E-3]	
S2n27	Factor r2 for PT100 calculation	-6.5E-7 ... -5E-7 [-5.775E-7]	
S2n28	Factor r4 for PT100 calculation	-4.8E-12 ... -3.5E-12 [-4.183E-12]	
S2n30	Offset value	[0.0]	Sensor offset in SI base unit (also applies for PT100)
S2n31	Offset process	0...1 [1]	0: Compensation before characteristic curve 1: Compensation after characteristic curve
S2n32	Nullification	0...7 [0]	Configuration bit-by-bit. A set bit switches the function on, a non set bit switches it off. Bit 0: Nullification in groups (command ZERO, nullification key or PLC) on/off. Bit 1: Manual nullification on (command IZERO or test menu) on/off. Bit 2: Offset test after nullification on/off. The result of the nullification is rejected, if the determined offset is not within the limits indicated in S2n40/S2n41.
S2n33	Interval for automatic nullification	0...97200 [0.0]	0: no automatic nullification otherwise: interval in seconds
S2n34	Arrangement for nullification	0...2 [0]	Sensors in the same group are nullified together. The parameter indicates the allocation to one of three possible groups.
S2n36	Handling of limit value exceeding (limit values in S2n37 & S2n38).	0...4 [0]	0: inactive 1: active, check raw value and trigger sensor error if violated 2: limit raw value to limit value 3: active, check linearized value and trigger sensor error if violated 4: limit linearized value to limit value
S2n37	minimum admissible sensor value	[0.0]	
S2n38	maximum admissible sensor value.	[0.0]	
S2n39	size of the ring buffer for attenuation	1...5 [1]	Calculate average of n measuring values
S2n40	Lower limit for offset after nullification.	[-1E30]	Only valid if bit 2 of S2n32=1
S2n41	Upper limit for offset after nullification.	[+1E30]	Only valid if bit 2 of S2n32=1

Table 24 S2000/3000 block: Linearization of sensors

9.7.12.1 Offset correction of the differential pressure sensors

Requirement:
The measuring system is equipped with valves, which separate the differential pressure sensor from the primary element and which short its inputs.

Principle:
Both inputs of the differential pressure sensor are pneumatically shorted, the differential pressure measured after a stabilization time is used then as a zero point by the control software.

The nullification is triggered by:
- Pressing the key “Zero“
- Sending the special command “ZERO” by a serial interface (RS232)
- Automatically within defined intervals. The interval is determined for each analogue input with parameter S2n33, S2n33=0.0 disables the automatic nullification. All inputs of a nullification group (S2n34) will be nullified together, as soon as the smallest interval within the group has expired. The parameters S110n determine the stabilization time for each group of inputs.

Characteristics of nullification:
- The nullification is only carried out in the standard mode.
- With double section systems the nullification for the differential pressure sensors of both measuring circuits is carried out simultaneously.
- Each sensor that can be nullified is assigned to a nullification group by parameter S2n34. All sensors of a group are nullified simultaneously. If there are several groups these are nullified one after the other, with intermediate valves can be switched depending on the equipment.
- The manually triggered nullification is only triggered with PLC operation, if at the time of pressing the key “ZERO” the system is in the state “POLL”. The time interval induced nullification is carried out in the following state “POLL” respectively.

9.7.13 Extended parameter set for integrated analogue inputs

S2n50	Number of the integrated analogue input (hardware channel)	0...9	Has access to the input named AInn in the configuration (nn corresponds with the number of the analogue input).
S2n51	Filter frequency	0...1000 [0]	Filter frequency for the analogue input in Hz. If a value <> 0 is displayed here, the filter of the analogue card will be set to this value then.

Table 25 Extended parameter set for integrated analogue inputs

9.7.14 Extended parameter set for serial analogue inputs

S2n60	Sensor type	0...6 [0]	0: direct input, send without request, e. g. RPT. It may only occur once and not together with other types. 1: Meriam ZM1500 2: unused 3: DTM 4: Meriam M1500 5: Honeywell PPT 6: Mensor 6000/6100/6180
S2n61	RS485 address	0...99	RS485 address of the serial sensor
S2n62	RS485 bus	0...1 [1]	0: Ser1 1: Ser2

Table 26 Extended parameter set for serial analogue inputs

9.7.15 Extended parameters set for R parameter as inputs

S2n70	Number of the R parameter	0..2999	To generate the number of the R parameter, which is read, with the value for the input.

Table 27 Extended parameters set for R parameter as inputs

9.7.16 Extended parameter set for integrated frequency inputs

S2n80	Number of the integrated frequency input	0...9	Has access to the input named FQnn in the configuration (nn corresponds with the number of the frequency input).
S2n81	Prescaler value	1...8 [1]	Exponent for the base 2 of the prescaler value (see documentation of the T500 and T510 cards). 1: Prescaler 2 2: Prescaler 4 3: Prescaler 8 4: Prescaler 16 5: Prescaler 32 6: Prescaler 64 7: Prescaler 128 8: Prescaler 256
S2n82	Minimum frequency	0..5E7 [0]	Minimum input frequency. This value determines together with the prescaler value the time necessary to detect an invalid input (for example a DC signal).

Table 28 Extended parameter set for integrated frequency inputs

9.7.17 Extended parameter set for integrated counter inputs

S2n90	Number of the integrated counter input	0...9	Has access to the input named AInn in the configuration (nn corresponds with the number of the counter input).

Table 29 Extended parameter set for integrated counter inputs

Note:
Since any changing of coefficients may result in loosing calibration, it is generally reserved to the manufacturer TetraTec Instruments.

Error handling:
The simultaneous occurring of a serial sensor with direct input (i.e., a sensor sending without request) and other serial sensors (e.g., PDP) or several sensors with direct serial inputs the program will be stopped, until the conflict (danger of bus collisions) has been removed by changing the parameters. This error and communication errors occurring with the initialization of serial sensors, are displayed with a ticker.

Serial sensors can be displayed and zeroed like physical inputs.

9.7.18 S4000-S7000 block: Linearization of primary elements

The data of the primary elements follow in an interval of 100 respectively.

Parameter	Meaning	Values	Explanations
S4n00	Type of the primary element and type of evaluation	0...1 20...21 40...43 45...49 60 80 100...101 120 140 [0]	Type of the primary element and type of evaluation 0: Standard LFE 1: Uniflow LFE 20:Critical nozzle according to PTB 21:Critical nozzle according to CFO 40: Orifice with drawing pressure by flange 41: Orifice with drawing pressure from the corner 42: Orifice with D-D/2 drawing of pressure. 45: Venturi nozzle 46: Venturi pipe casted rough 47: Venturi pipe processed 48: Venturi pipe, welded 49: SAO nozzle 60: Accutube 61: Betaflow 80: Gas meter 81: Simulated gas meter 100: Direct mass flow input 101: Direct volume flow input 120: Leakage measurement (LMS) 140: No primary element
S4n01	Type of gas with calibration	0...15 [1]	Type of gas with calibration 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 15: Water vapor 16: Xenon 17: Nitrogen monoxide (not relevant with S4n00=1)
S4n02	Calibration pressure	0...1000000 [101325]	Absolute pressure in Pascal (not relevant with S4n00=1 or > 79)
S4n03	Calibration temperature	0...1000 [294.26]	Temperature in Kelvin (not relevant with S4n00=1 or > 79)
S4n04	Calibration humidity	0...1 [0.0]	Humidity without dimension (not relevant with S4n00=1 or > 79)
S4n05	Order	-99...99 [1]	Generalized order of the polynomial. The first digit including sign is the smallest power (in most cases 0). The second number indicates the number of coefficients minus 1. The greatest power is derived from the sum of the two digits incl. sign. Example: S4n05 = -25 means smallest power is -2, largest 3.

S4n10 … S4n19	Maximal 10 coefficients (FLOAT numbers)		
S4n20	X factor	[0.01]	Scaling factor polynomial input value from SI units to polynomial units
S4n21	Y factor	[60000]	Scaling factor polynomial output value (flow) from polynomial units to SI units
S4n22	Serial number of the primary element	String [„“]	
S4n23	Y correction	0.998 … 1.002 [1.000]	Multiplicative correction factor for the y value of the polynomial
S4n25	Precondition for calculation	String [„“]	Preconditions for the calculation can be defined with this term. If the term is evaluated to 0 (FALSE), there is no calculation been carried out and all depending flow rates are faulty. If the term has a value unequal to 0, the calculation will be carried out. The script variable THIS includes the measuring circuit when evaluating the term.

Table 30 S4000-S7000 block: Linearization of primary elements

9.7.19 Extended parameters set for direct inputs

Parameter	Meaning	Values	Explanations
S4n30	Direct input value	String [„“]	Expression that results in the direct mass or volume flow input value.

Table 31 Extended parameters set for direct inputs

9.7.20 Extended parameter set for leakage measuring (LMS)

Parameter	Meaning	Values	Explanations
S4n40	R parameter of pressure drop	0...2999 [110]	Number of the R parameter containing the pressure drop for the leakage measuring.
S4n41	Test sample volume	-1.0...1.0 [10E-3]	Test sample volume in m^3
S4n42	Reference leakage	-1.0...1.0 [0.0]	Leakage of the reference leak in m^3/s.
S4n43	Self-leakage	-1.0E3... 1.0E2 [0.0]	Self-leakage of the system in Pa/s.

Table 32 Extended parameter set for leakage measuring (LMS)

9.7.21 Extended parameter set for critical nozzles

Parameter	Meaning	Values	Explanations
S4n50	Nozzle characteristic QVtr	0...1 [0.001]	QVtr in m3/s
S4n51	C* Correction factor for input pressure dependence	[0.0]	C* in 1/Pa
S4n52	CFO calibration nozzle x Xt factor	[1.0]	Input scaling temperature correction 1.0: with polynomial in SI units 1.8: with polynomial in US units

Table 33 Extended parameter set for critical nozzles

9.7.22 Extended parameter set for orifices, Venturi-Elements, Betaflows and SAO nozzles

Valid for primary elements of type 40 to 49 and 61

Parameter	Meaning	Values	Explanations
S4n60	Internal tube diameter with operating conditions	[0.1]	Tube diameter in m (SI unit). on orifice input
S4n61	Diameter of the throttle opening by operating conditions	[0.05]	in m (SI unit)
S4n62	Smallest Reynolds number* with iteration (S4n66=1 or 2)	[2000.0]	Minimum value without dimension of the Reynolds number
S4n63	Biggest Reynolds number* with iteration (S4n66=1 or 2)	[20000000]	Maximum value without dimension of the Reynolds number
S4n64	Tolerance mass flow: Break-off condition of the iteration	[0.001]	Break-off condition of the iteration in kg/s (SI unit): If the change in mass flow from one iteration step to the next is less than this value, the iteration is terminated.
S4n65	Calculation method flow coefficient	0...2 [0]	0: Calculation according to DIN EN ISO 5167 1: Polynomial calculation with differential pressure 2: Polynomial calculation with Reynolds number*
S4n66	Conversion factor for the display of the K factor with Betaflow	[775.428]	Factor, which is multiplied with the K factor based on SI units, before being made available in the R parameters.

Table 34 Extended parameter set for orifices, Venturi-Elements, Betaflows and SAO nozzles

*** Hints for S4n65=2**

- For the calculation method "polynomial over Reynolds number" the Reynolds number refers to the throttle diameter d, given in S4n61. (In contrast to DIN EN ISO 5167)
- Starting value for the iteration is the geometric mean of the limits defined in S4n62 and S4n63
- For the iteration to work, the polynomial CD (Re) must be strictly monotonous.

9.7.23 Extended parameter set for accutubes

Parameter	Meaning	Values	Explanations
S4n80	K: Average KFlow	[0.6]	
S4n81	Tube diameter DI	1E-4…1.0 [0.1]	in m
S4n82	Determination temperature for the correction of the thermal expansion	173.15… 473.15 [288.7] (519.67 °R)	in Kelvin
S4n83	Thermal expansion coefficient of the tube material	[0.0]	in SI
S4n84	Smallest Reynolds number with Fra interpolation	[2000]	without dimension Minimum value of the Reynolds number
S4n85	Highest Reynolds number with Fra interpolation	[20000000]	without dimension Maximum value of the Reynolds number
S4n86	Tolerance volume flow: Break-off condition of the iteration	[0.001]	in m3/s (SI unit) Break-off condition of the iteration

Table 35 Extended parameter set for accutubes

9.7.24 Extended parameter set for gas meters

Parameter	Meaning	Values	Explanations
S4n70	Input channel	0...9 [0]	Channel CTn on counter card
S4n71	Volume per pulse	[0.001]	in m3
S4n72	Consider N pulses with continuous measuring	2...1000 [2]	only with counter operation: A sliding average is formed over the specified number of pulses and is output as the current measured value. Note: The averaging in phase MEAS is independent of this.
S4n73	Timeout	1...86400 [5.0]	The flow is set to 0 in continuous operation, if more time than set here lies between two pulses. With a measuring taking the mean the value set here is used as a break-off criteria for the start pulse.

Table 36 Extended parameter set for gas meters

9.7.25 S8000 block: Scaling of analogue outputs

Parameter	Meaning	Values	Explanations
S8n00	Type of output	-1, 0 [-1]	-1: Switched off 0: Integrated analogue output 1: Reserved 2: Frequency output 3: PWM output
S8n01	Value to be displayed	String	Term, which determines the value to be displayed. The result of the term must be a floating point number.
S8n05	Behaviour with errors	0...1 [1]	If errors occur with the evaluation in S8n01, the reaction is as follows: 0: Old value is continuously displayed 1: Value from S8n06 is displayed.
S8n06	Fixed value for output	0.0...1.0 [0.0]	If the term in S8n01 produces errors and S8n05 = 1, then this value is displayed on the output.

Table 37 S8000 block: Scaling of analogue outputs

The term in S8n01 must result in a floating point number with a value between 0.0 and 1.0, corresponding 0 up to 100% of the electrical output signal. In the following example the value of the R parameter R0002 (absolute test pressure) is scaled to the value range of 800 up to 1200 mbar for output number 0, where the limits have to be specified generally in SI units (exception: R parameter Ry060 up to Ry064 compatible to the saved formulas), so in this example in Pascal:

Example:
```
S8001="(RPAR[2]-80000.0)/(120000.0-80000.0)"
```

The term cannot be changed in the editing menu. It is possible to use reference to other parameters in the term, e.g., for editing minimum, maximum and number of the R parameter to be displayed in project-specific parameters. This project-specific allocation of parameters is described in the document „Operating Instructions and System Configuration“, if necessary.

9.7.26 Extended parameter set for integrated analogue outputs

Parameter	Meaning	Values	Explanations
S8n50	Number of the analogue port	0...9	Port AOxx in the hardware configuration.

Table 38 Extended parameter set for integrated analogue outputs

9.7.27 Extended parameter set for integrated frequency outputs

Parameter	Meaning	Values	Explanations
S8n70	Number of the frequency output	0...9	Port FOxx in the hardware configuration.
S8n71	Pulse-width	0.0 .. 1.0	Pulse/interval ratio of the output signal.

Table 39 Extended parameter set for integrated frequency outputs

9.7.28 Extended parameter set for integrated PWM outputs

Parameter	Meaning	Values	Explanations
S8n80	Number of the PWM output	0...9	Port FOxx in the hardware configuration.
S8n81	Frequency	0.1 .. 1E5	Frequency of the output signal.

Table 40 Extended parameter set for integrated PWM outputs

9.7.29 S9000 block: Special functions

<table>
<tr><th>Parameter</th><th>Meaning</th><th>Values</th><th>Explanations</th></tr>
<tr><td>S9000</td><td>Measuring time for the system leak test</td><td>0...9.72E4
[10.0]</td><td>(in seconds)</td></tr>
<tr><td>S9001</td><td>Stabilization time before system leak test</td><td>0...300
[0.0]</td><td>(in seconds)</td></tr>
<tr><td rowspan="2">S9002</td><td>Synchronize measuring.</td><td>0...1
[0]</td><td>0: not active
1: active
The measuring taking the mean is synchronized between the measuring circuits with several measuring circuits.</td></tr>
<tr><td colspan="3">Influence of the synchronization switch S9002:

Synchronization not active:
Measuring or measuring time starts for all primary elements immediately. However, a gas meter counts from the next pulse at first, i.e., the real measuring time for the gas meter is shortened. Each primary element measures according to the set measuring time, the measuring is finally finished, if all primary elements are ready.

Synchronization active:
If gas meters are in the system the measuring does not start prior to one of the gas meters has read the first pulse. The time from S4n73 is used as timeout up to the first pulse. Then the measuring time is reset again and the measuring starts. The complete measuring is finished, if the measuring of all gas meters has been carried out. If measuring times of individual measuring circuits are shorter than this time, then the measuring in these measuring circuits will be already finished before.</td></tr>
</table>

Table 41 S9000 block: Special functions

9.7.30 S9010 block: System absolute pressure

S9010	System absolute pressure for measuring programs with relative pressure measuring	-2, -1, 0...19 [-1]	-2: off -1: Fixed value of S9011 0 to 19: Sensor of block S20xx - S39xx
S9011	System absolute pressure Fixed value	0…1.0E06 [1.0E05]	Fixed value in Pascal
S9012	Display unit for the system absolute pressure Pbas	0...16 [0]	Coding see chapter 10
S9013	Pbas decimal places	0...5 [0]	Number of decimal places
S9014	Correction	String [„“]	Term, by which the test pressure can be corrected. It is possible to have access on the uncorrected test pressure included in the term by the variable THIS

Table 42 S9010 block: System absolute pressure

9.7.31 S9100-Block: Subscribe

“Subscribe” is configured using the following three blocks of 30 S parameters. Each block allows this controller to request data from others. As an example, the block at S9100 is shown. Two more such blocks follow in steps of 30:

The parameters starting at S9110 (or S9140, S9170 respectively) determine which data is expected, and where it goes. The first parameter defines the number of data fields, the following parameters define the format and target of each received parameter. The following table shows only the first target definition parameter.

Parameter	Meaning	Values	Explanations
S9100	Host name or serial number	String [„“]	Depending on the value in S9103 this parameter either includes the name/IP address or the serial number of the controllers, of which the data shall be received.
S9101	UDP port	1...65535 [54491]	Number of the UDP port, from which data shall be received. Must correspond to S9401 of the other system.
S9102	Data set number, see Table 47	0...12 [0]	Number of the data set, to which the subscription refers.
S9103	Meaning of S9100	0..1 [0]	0: Recognition of the remote station by host name or IP number 1: Recognition of the remote station by serial number. The IP address is determined automatically. The remote station must have at least SPELLOS 6.0.7 running.
S9110	Count	0..19 [0]	Tells how many of the following parameters are valid.
S9111 … S9129	Parameter #0 … Parameter #19	-549..52999 [0]	Defines the data value 0 in the user defined subscribe data block: -549..-500: The value of an I variable is accepted 0..2999: The value of a R parameter in TMS format is expected 10000..12999: Error code and value of a R parameter in TMS format are expected 20000..22999: A complete R parameter in TMS format is expected 30000..32999: The value of a R parameter in IEEE format is expected 40000..42999: Error code and value of a R parameter in IEEE format are expected 50000..52999: A complete R parameter in IEEE format is expected

Table 43 S9100 block: Parameters for “Subscribe“

Further information

- Publish see chapter 9.7.35

9.7.32 S9300 block: Protocol printout

Protocol printout functions are defined in block S9300. At the end of each mean taking measurement a string with results of the measurement can optionally be issued by one of the available interfaces or be saved in a file.

Parameter	Meaning	Values	Explanations
S9300	Protocol function after test end	0...8 [0]	0: inactive 1: Output by link interface 2: Output by terminal interface 3: Output by RS485/1 4: Output by RS485/2 5: Output in file without flush 6: Output in file with flush 7: Output by network link (active)[1)] 8: Output by network link (passive)[2)]
	[1)]“Active network connection” means, that the program provides a TCP connection to the remote station defined in S9306/S9307. If errors occur the running for a connection is repeated before each output of a protocol printout string. [2)]“Passive network connection” means, that the program responds to external runnings for connection on the port defined in S9307. The host name in S9006 will be ignored at the same time.		
S9301	Format string #0 with placeholders	STRING [„“]	See below.
S9302	Format string #1 with placeholders	STRING [„“]	See below.
S9303	Format string #2 with placeholders	STRING [„“]	See below.
S9304	Format string #3 with placeholders	STRING [„“]	See below.
S9305	File name	STRING [“”]	Name of the file which shall be typed into. **Only if S9300 = 5 or 6!**
S9306	Host name	STRING [“”]	Name or IP number of the remote station in the case of output by the network. **Only if S9300 = 7!**
S9307	Port number	1...65535 [54493]	TCP port number in the case of output by the network. **Only if S9300 = 8!**
S9308	List of permitted remote stations	String [„“]	These remote stations are permitted to provide a connection. **Only if S9300 = 7 or 8!**
S9309	List of unpermitted remote stations	String [„“]	These remote stations must not provide a connection. **Only if S9300 = 7 or 8!**
S9310	Timeout	0.1...90.0 [1.0]	Timeout for the providing of a connection. **Only if S9300 = 7 or 8!**
S9320	Term #0	STRING	Term which is inserted for placeholders in S9301.
S9321	Term #1	STRING	Term which is inserted for placeholders in S9301.
S9322	Term #2	STRING	Term which is inserted for placeholders in S9301.
S9323	Term #3	STRING	Term which is inserted for placeholders in S9301.
S9324	Term #4	STRING	Term which is inserted for placeholders in S9301.
S9325	Term #5	STRING	Term which is inserted for placeholders in S9301.
S9326	Term #6	STRING	Term which is inserted for placeholders in S9301.
S9327	Term #7	STRING	Term which is inserted for placeholders in S9301.

S9328	Term #8	STRING	Term which is inserted for placeholders in S9301.
S9329	Term #9	STRING	Term which is inserted for placeholders in S9301.

Table 44 S9300 block: Protocol printout

Further information
- Restriction of access see chapter 5.2.6
- For the syntax of format strings see chapter 6.2
- For the syntax of the control terms see chapter 6.3

9.7.33 S9350 block: Type editor

The built-in type editor needs additional script code to be usable. For one, a state change into the type editor has to be forced by a script. Second, the list of available types has to be setup by a script. And third, the display can be controlled by a script.

Parameter	Meaning	Values	Explanation
S9350	Type of source	0...2 [0]	0: Source is string in S9351 1: Source is file with name in S9351 2: S9351 names a script function
S9351	Source of the script	String [„“]	Script, name of the file or function name. When used as a file name /dat/ is always put in front.

Table 45 S9350 block: Type editor

9.7.34 S9370 block: Serial display

The parameter block at S9370 contains definitions for the module that drives a serial LCD display.

Parameter	Meaning	Values	Explanation
S9370	Serial port	-1..3	Defines the serial port that is used to connect the display. -1: Display is switched off 0: Ser0 1: Ser1 2: Ser2 3: Ser3
S9371	Number of lines	1...16 [4]	Number of display lines
S9372	Number of characters per line	20..80 [20]	Number of characters per line for the connected display

Table 46 S9370-Block: Serial display

9.7.35 S9400 block: Publish

If several controllers are connected by a network, each controller can have access to a part of the data of the other controllers, as far as provided. This data exchange is only reasonable within a trusted environment, and it requires, that the data structures are carefully coordinated.
Each controller provides several data sets for other authorized participants (see parameters S6401 and S9402, Table 48), but has no network activities at first. Only if another controller requests parts of this provided data sets („Subscribe“, see chapter 9.7.31), they are actively sent („Publish“). The number of recipients is only limited by the available memory.

The LMF application currently defines the following data sets:

Data set number	Description
0	First block of user-defined publish data (see S9420 ff.).
1	Second block of user-defined publish data (see S9440 ff).
2	Third block of user-defined publish data (see S9460 ff.).

Table 47 Provided data sets

The S parameters at S9400 are for the configuration of "Publish":

Parameter	Meaning	Values	Explanations
S9400	UDP port	0...65535 [54491]	Number of the UDP port, on which the controller receives queries. A value of 0 turns off the feature.
S9401	List of permitted remote stations	String [„"]	These remote stations may subscribe data.
S9402	List of unpermitted remote stations	String [„"]	These remote stations must not subscribe data.
S9403	Minimum time between two updates	0.0...2.4 [0.2]	Value in seconds. The time between two updates is never less as the time set here.
S9404	Update mode	0...1 [0]	Determines, whether an update is sent always after the minimum period has expired, or only if data have been changed. 0: Only send with changes 1: Send always

Table 48 S9400 block: Parameters for „Publish"

The parameters starting at S9420 are used to define 3 blocks of publish data. Each block consists of 20 parameters. The first parameter is the number of data elements to publish. The following parameters define the data elements that should be published. The following table shows the block at S9420. Two more such blocks follow at S9440 and S9460.

Parameter	Meaning	Values	Explanations
S9420	Count	0..19 [0]	Tells how many of the following parameters are valid.
S9421 … S9439	Parameter #0 … Parameter #19	-549..52999 [0]	Defines the data value 0 in the user defined publish data block: -549..-500: The value of an I variable -499..-400: The value of a Net-IO output -399..-300: The value of a Net-IO input -299.-200: The value of a digital output (index in S1800 ff.) -199..-100: The value of a digital input -3: A random id that changes with every reconfiguration -2: The current controller time in ticks -1: The current main state 0..2999: Value of a R parameter in TMS format 10000..12999: Error code and value of a R parameter in TMS format 20000..22999: A complete R parameter in TMS format 30000..32999: Value of a R parameter in IEEE format 40000..42999: Error code and value of a R parameter in IEEE format 50000..52999: A complete R parameter in IEEE format

Table 49 S9420 block: Publish data

Further information

- Restriction of access see section 5.2.6

9.7.36 S9500 block: Connection definitions of the virtual PLC interface Net-IO

The system can provide the result of the terms defined in block S130x by a network connection. Virtual inputs are also provided by this network connection which can be queried in terms with the integrated function NI(). The following block specifies the connection parameters for the network connection.

Parameter	Meaning	Values	Explanations
S9500	TCP port	0...65535 [0]	Number of the TCP port on which the controller waits for incoming connections. A value of 0 turns off the feature. Standard value with virtual PLC interface: 54488 (former 54492)
S9501	List of permitted remote stations	String [„“]	These remote stations are permitted to provide a connection.
S9502	List of unpermitted remote stations	String [„“]	These remote stations must not provide a connection.
S9505	Timeout for virtual inputs	0...86400 [0]	Value in seconds. If no input is received for a longer period of time than the one to be set the system will terminate the connection. A value of 0 turns off the timeout.
S9506	Timeout for virtual outputs	0...86400 [0]	Value in seconds. If no output value is provided for a longer period of time than the one to be set, because there are no changes, the sending will be forced. A value of 0 turns off the timeout.
S9507	Format of the output	String [„NO %Xh\r\n“]	A string, which indicates in what format the output data will be sent.

Table 50 S9500 block: Connection definitions of the virtual PLC interface Net-IO

Further information

- Restriction of access see chapter 5.2.6
- For the description of the virtual inputs and outputs see chapter 5.4
- For the syntax of format strings see chapter 6.2

9.7.37 S9600 block: Configuration AK interface

The system has a AK protocol interface via TCP/IP, which can be configured with the following parameters.

Parameter	Meaning	Values	Explanations
S9600	TCP port and flag	-1...65535	Number of the TCP port on which the controller waits for incoming connections. A value of 0 turns off the feature. The value –1 selects the serial interface (Ser0) instead. CAUTION: If the Comm connection via Ser0 has not been switched off, then runtime errors may occur.
S9601	List of permitted remote stations	String [„“]	These remote stations are permitted to provide a connection.
S9602	List of unpermitted remote stations	String [„“]	These remote stations must not provide a connection.
S9610	Start code	1...255 [2]	Messages are started with this code. The value is normally STX (2).
S9611	Termination code	1...255 [3]	Messages are terminated with this code. The value is normally ETX (3).
S9612	Don’t Care Byte	1...255 [32]	This value is set with the sending of telegrams as replacement for the „Don’t Care“ Byte. Standard value is a blank (32).
S9620	Term for error	String	This term is fort he AK module for the determination of the error state of the system. 0 = no error.
S9621	Term for PLC inputs	String	The value determined here must reflect the following status lines: Bit 0: PLC Ready Bit 1: PLC End Bit 2: PLC Lock
S9622	User-defined value for ASTZ	String	See description AK protocol.
S9623	User-defined value for ASTZ	String	See description AK protocol.
S9624	User-defined value for ASTZ	String	See description AK protocol.
S9625	User-defined value for ASTZ	String	See description AK protocol.
S9626	User-defined value for ASTZ	String	See description AK protocol.

Table 51 S9600 block: Configuration AK interface

Further information

- Restriction of access see chapter 5.2.6

9.7.38 S9700 block: Process control

The block S9700 includes 20 script allocations. The parameters on S9700...S9702 repeat themselves for 20 times with a distance of 5.

Parameter	Meaning	Values	Explanations
S9700	State of machine	0...9999 [0]	State of machine, to which the script in S9702 shall be connected.
S9701	Type of source	0...2 [0]	0: Source is string in S9702 1: Source is file with name in S9702 2: S9702 names a script function
S9702	Source of the script	String [„“]	Script, name of the file or function name. When used as a file name /dat/ is always put in front.

Table 52 S9700 block: Process control

9.7.39 <u>S9800 block: Script code</u>

Block S9800 defines a script that is executed in each cycle depending on a condition.

Parameter	Meaning	Values	Explanations
S9800	Term	String [„“]	Term, which is evaluated in each cycle. The script is carried out, if the term is evaluated to an INTEGER <> 0.
S9801	Type of source	0...2 [0]	0: Source is string in S9802 1: Source is file with name in S9802 2: S9802 names a script function
S9802	Source of the script	String [„“]	Script, name of the file or function name. When used as a file name /dat/ is always put in front.

Table 53 S9800 block: Script code

The block from S9810 to S9849 defines up to 4 scripts, that are executed when a matching command is entered on the Comm connection. The following block parameters starting at S9810 are repeated at S9820, S9830 and S9840.

Parameter	Meaning	Values	Explanations
S9810	Command	String [„“]	Command string that triggers the script
S9811	Type of source	0...2 [0]	0: Source is string in S9812 1: Source is file with name in S9812 2: S9812 names a script function
S9812	Source of the script	String [„“]	Script, name of the file or function name. When used as a file name /dat/ is always put in front.

Table 54 S9810 block: Script code for commands

9.8 P parameter: Definitions of measuring programs

For understanding:
In the following sections the lower case letter n in the parameter number represents the program number. There are 10 programs with numbers 0 up to 9. These programs are allocated depending on the application, not all programs must always be allocated.

9.8.1 Pn000 block: Primary element, basis description

Parameter	Meaning	Value range	Explanations
Pn000	Number primary element	-10 . –1 0...39 40...139 [0]	-10 . -1 nozzle combinations of Cxxxx 0...39 Flow element of S40xx-S70xx 40...139 Flow element of E00xx-E99xx
Pn001	Gas by primary element	-9...0 1...15 [1]	-9: Mixed gas 9 (see M09xx) ... -1: Mixed gas 1 (see M01xx) 0: Mixed gas 0 (see M00xx) 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 15: Water vapor 16: Xenon 17: Nitrogen monoxide 18: Neon 19: Krypton 20: Propene 21: Ethane 22: Ethene 23: Ammonia 24: Sulfur dioxide
Pn003	Tightness calculations	0...2 [1]	0: Ideal (Ideal Gas Law) 1: Real, virial coefficient calculation 2: real, BIPM recommendation 1979 (air only) 3: real, CIPM recommendation 2007 (air only, T [15...27°C], P [600...1100mbar])
Pn004	Viscosity calculations	0...14 [1]	0: ideal, PTB (air), Daubert & Danner (others) 1: real, Kestin-Whitelaw (air only) 2: ideal, Daubert & Danner 3: ideal, Sutherland PTB (air, no humidity) 4: ideal, Sutherland VDI/VDE 2040 (air, no humidity) 12: real, Daubert & Danner (air with humidity correction) 13: real, Sutherland PTB (air with humidity correction) 14: real, Sutherland VDI/VDE 2040 (air with humidity correction)

Table 55 Pn000 block: Primary element, basis description

9.8.2 Pn010 block: Differential pressure (Pdif)

Parameter	Meaning	Value range	Explanations
Pn010	Dataset number Differential pressure	-2...19 [0]	-2: Ignore input -1: Fixed value of Pn011 0 to 19: Sensor of block S20xx - S39xx
Pn011	Fixed value	-2E3...5E4 [2E3]	Fixed value for sensor in SI units (beside correction, see Pn014)
Pn012	Display unit	0...16 [3]	Coding see chapter 10
Pn013	Display decimal places	0...5 [3]	Display decimal places Number of decimal places
Pn014	Correction	String [„“]	Term, by which the test pressure can be corrected. It is possible to have access on the uncorrected test pressure included in the term by the variable THIS.

Table 56 Pn010 block: Primary measurand, e. g. differential pressure

9.8.3 Pn020 block: Test pressure absolute (Pabs)

Parameter	Meaning	Value range	Explanations
Pn020	Dataset number Test pressure absolute	-2...19 [1]	-2: Ignore input -1: Fixed value of Pn021 0 to 19: Sensor of block S20xx - S39xx
Pn021	Fixed value	0...2.0E6 [1.0E05]	Fixed value for sensor in SI units (Pascal) (beside correction, see Pn024)
Pn022	Display unit	0...16 [3]	Coding see chapter 10
Pn023	Display decimal places	0...5 [1]	Number of decimal places
Pn024	Correction	String [„“]	Term, by which the test pressure can be corrected. It is possible to have access on the uncorrected test pressure included in the term by the variable THIS.

Table 57 Pn020 block: Test pressure absolute

Example for Pn024:
It is presumed that the test pressure is measured by a gauge pressure sensor, but for further calculations it will be needed as absolute pressure. Then the following settings will be required:
(exemplarily for program 0, space characters are to be disregarded)
S9010: Selection absolute pressure sensor (Pbas)
P0020: Selection gauge pressure sensor (Prel)

P0024="THIS + RPAR[0]"

Further information:
- For parameter S9010 see paragraph 9.7.29
- For the allocation of sensors see paragraph 9.7.12
- For the function RPAR() see paragraph 5.5.41
- For the available R parameters see paragraph 9.10
- Explanations see section 11.6.1.1

9.8.4 Pn030 block: Measuring temperature (Tem)

Parameter	Meaning	Value range	Explanations
Pn030	Dataset number Measuring temperature	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn031 0 to 19: Sensor of block S20xx - S39xx
Pn031	Fixed value	233.15... 1.07315E3 [273.15]	Fixed value for sensor in SI units (Kelvin) (beside correction, see Pn034)
Pn032	Display unit	0...4 [1]	Coding see chapter 10
Pn033	Display decimal places	0...5 [1]	Number of decimal places
Pn034	Correction	String [„“]	Term, by which the measuring temperature can be corrected. It is possible to have access on the uncorrected measuring temperature included in the term by the variable THIS.

Table 58 Pn030 block: Measuring temperature

Explanations see section 11.6.1.3

9.8.5 Pn040 block: Measurement humidity (Hum)

Parameter	Meaning	Value range	Explanations
Pn040	Dataset number Measurement humidity	-2...19 [3]	-2: Ignore input -1: Fixed value of Pn041 0 to 19: Sensor of block S20xx - S39xx
Pn041	Fixed value	0..1 [0.0]	Fixed value for sensor (without dimension) (beside correction, see Pn044)
Pn042	Display unit	0...1 [1]	Coding see chapter 10
Pn043	Display decimal places	0...5 [1]	Number of decimal places
Pn044	Correction	String [„“]	Term, by which the measurement humidity can be corrected. It is possible to have access on the uncorrected measurement humidity included in the term by the variable THIS.

Table 59 Pn040 block: Measurement humidity

Explanations see section 11.6.1.4

9.8.6 Pn050 block: Reference pressure absolute (RPab)

Parameter	Meaning	Value range	Explanations
Pn050	Dataset number Reference pressure absolute	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn051 0 to 19: Sensor of block S20xx - S39xx
Pn051	Fixed value	0…2.0E06 [1.0E05]	Fixed value for sensor in SI units (Pascal) (beside correction, see Pn054)
Pn052	Display unit	0...16 [3]	Coding see chapter 10
Pn053	Display decimal places	0...5 [1]	Number of decimal places
Pn054	Correction	String [„“]	Term, by which the reference pressure can be corrected. It is possible to have access on the uncorrected reference pressure included in the term by the variable THIS.

Table 60 Pn050 block: Reference pressure absolute

Explanations see section 11.6.2.1

9.8.7 Pn060 block: Reference temperature (RTem)

Parameter	Meaning	Value range	Explanations
Pn060	Dataset number Reference temperature	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn061 0 to 19: Sensor of block S20xx - S39xx
Pn061	Fixed value	233.15... 1073.15 [293.15]	Fixed value for sensor in SI units (Kelvin) (beside correction, see Pn064)
Pn062	Display unit	0...4 [1]	Coding see chapter 10
Pn063	Display decimal places	0...5 [1]	Number of decimal places
Pn064	Correction	String [„“]	Term, by which the reference temperature can be corrected. It is possible to have access on the uncorrected reference temperature included in the term by the variable THIS.

Table 61 Pn060 block: Reference temperature

Explanations see section 11.6.2.2

9.8.8 Pn070 block: Reference humidity (RHum)

Parameter	Meaning	Value range	Explanations
Pn070	Dataset number Reference humidity	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn071 0 to 19: Sensor of block S20xx - S39xx
Pn071	Fixed value	0...1 [0.0]	Fixed value for sensor (without dimension) (beside correction, see Pn074)
Pn072	Display unit	0...1 [1]	Coding see chapter 10
Pn073	Display decimal places	0...5 [1]	Number of decimal places
Pn074	Correction	String [„“]	Term, by which the reference humidity can be corrected. It is possible to have access on the uncorrected reference humidity included in the term by the variable THIS.

Table 62 Pn070 block: Reference humidity

Explanations see section 11.6.2.3

9.8.9 Pn075 block: Auxiliary input 0 (Aux0)

Parameter	Meaning	Value range	Explanations
Pn075	Dataset number Auxiliary input 0	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn076 0 to 19: Sensor of block S20xx - S39xx
Pn076	Fixed value	-2.0E7.. 2.5E7	Fixed value for sensor in SI units (beside correction, see Pn079)
Pn077	Display unit	0...14 [0]	Coding see chapter 10
Pn078	Display decimal places	0...5 [1]	Number of decimal places
Pn079	Correction	String [„“]	Term, by which the auxiliary input can be corrected. It is possible to have access on the uncorrected input value included in the term by the variable THIS.

Table 63 Pn075 block: Auxiliary input 0 (Aux0)

Explanations see section 11.6.3

9.8.10 Pn080 block: Auxiliary input 1 (Aux1)

Parameter	Meaning	Value range	Explanations
Pn080	Dataset number Auxiliary input 1	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn081 0 to 19: Sensor of block S20xx - S39xx
Pn081	Fixed value	-2.0E7.. 2.5E7	Fixed value for sensor in SI units (beside correction, see Pn084)
Pn082	Display unit	0...14 [0]	Coding see chapter 10
Pn083	Display decimal places	0...5 [1]	Number of decimal places
Pn084	Correction	String [„“]	Term, by which the auxiliary input can be corrected. It is possible to have access on the uncorrected input value included in the term by the variable THIS.

Table 64 Pn080 block: Auxiliary input 1 (Aux1)

Explanations see section 11.6.3

9.8.11 Pn085 block: Auxiliary input 2 (Aux2)

Parameter	Meaning	Value range	Explanations
Pn085	Dataset number Auxiliary input 2	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn086 0 to 19: Sensor of block S20xx - S39xx
Pn086	Fixed value	-2.0E7.. 2.5E7	Fixed value for sensor in SI units (beside correction, see Pn089)
Pn087	Display unit	0...14 [0]	Coding see chapter 10
Pn088	Display decimal places	0...5 [1]	Number of decimal places
Pn089	Correction	String [„“]	Term, by which the auxiliary input can be corrected. It is possible to have access on the uncorrected input value included in the term by the variable THIS.

Table 65 Pn085 block: Auxiliary input 2 (Aux2)

Explanations see section 11.6.3

9.8.12 Pn090 block: Auxiliary input 3 (Aux3)

Parameter	Meaning	Value range	Explanations
Pn090	Dataset number Auxiliary input 3	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn091 0 to 19: Sensor of block S20xx - S39xx
Pn091	Fixed value	-2.0E7.. 2.5E7	Fixed value for sensor in SI units (beside correction, see Pn094)
Pn092	Display unit	0...14 [0]	Coding see chapter 10
Pn093	Display decimal places	0...5 [1]	Number of decimal places
Pn094	Correction	String [„“]	Term, by which the auxiliary input can be corrected. It is possible to have access on the uncorrected input value included in the term by the variable THIS.

Table 66 Pn090 block: Auxiliary input 3 (Aux3)

Explanations see section 11.6.3

9.8.13 Pn095 block: Auxiliary input 4 (Aux4)

Parameter	Meaning	Value range	Explanations
Pn095	Dataset number Auxiliary input 4	-2...19 [-2]	-2: Ignore input -1: Fixed value of Pn096 0 to 19: Sensor of block S20xx - S39xx
Pn096	Fixed value	-2.0E7.. 2.5E7	Fixed value for sensor in SI units (beside correction, see Pn099)
Pn097	Display unit	0...14 [0]	Coding see chapter 10
Pn098	Display decimal places	0...5 [1]	Number of decimal places
Pn099	Correction	String [„“]	Term, by which the auxiliary input can be corrected. It is possible to have access on the uncorrected input value included in the term by the variable THIS.

Table 67 Pn095 block: Auxiliary input 4 (Aux4)

Explanations see section 11.6.3

9.8.14 Pn100 block: Units and decimal places for quantities

Using the parameters Pn100 to Pn199 up to 10 program-specific units and decimal places can be defined for all R parameters with a determined physical quantity.

Exceptions

- Units and decimal places for sensor values, fixed values and auxiliary inputs are set as described in the previous sections. The Pn100 block is for a general setting for the display of dimensions of periods and calculated quantities.
- General settings can be transcribed in the Pn200 block for defined R parameters, see also section 9.8.15.

The setting for the first quantity lies in segment Pn100, the next follows in segment Pn110 and so on. The sequence of the allocation of the quantity to the segments is irrelevant. In general, each segment for a physical quantity has the following structure:
Using the parameters Pn100 to Pn199 up to 10 program-specific units and decimal places can be defined for all R parameters with a determined physical quantity. For this purpose, the following data set indicated as an example is repeated with a distance of 10 at Pn100.

Parameter	Meaning	Value range	Explanations
Pn100	Physical quantity	-1 .. 21 [1]	Coding see section 10. Keyword „**Type Code**“ in the first column -1: Entry is not used
Pn101	Unit	0 .. 19 [2]	Coding see section 10 fifth column „**Unit Code**“
Pn102	Display decimal places	0 .. 5 [1]	Number of decimal places

Table 68 Pn100 block: Units and decimal places for quantities

The default allocation is indicated here for better understanding. Please note that it can be transcribed project-specifically, see also the project-specific document „Operating Instructions and System Configuration“, if necessary.

Parameter	Meaning	Value	Explanations
Pn100	Physical quantity	1	Volume flow
Pn101	Unit	2	m^3/h
Pn102	Display decimal places	1	One decimal place
Pn110	Physical quantity	2	Mass flow
Pn111	Unit	2	kg/h
Pn112	Display decimal places	1	One decimal place
Pn120	Physical quantity	7	Time
Pn121	Unit	0	Sec.

Pn122	Display decimal places	1	One decimal place
Pn130	Physical quantity	-1	Segment is not used
Pn131	Unit	0	irrelevant
Pn132	Display decimal places	2	irrelevant

Table 69 Pn100 block: Example default allocation

9.8.15 Pn200 block: Units and decimal places for R parameters

Using the parameters Pn200 to Pn299 up to 20 R parameters can be allocated program-specifically unit and decimal places for the display. For this purpose, the block displayed below is repeated for 20 times with a distance of 5 at Pn200.

The general settings in the parameters Pn100-Pn199 are used **before** the special settings in Pn200 and the following there. So it is possible, for example, to allocate a defined unit to all R parameters of one quantity, but to define exceptions with the parameters in block Pn200.

Parameter	Meaning	Value range	Explanations
Pn200	R parameter	-1 .. 999 [-1]	Number of the R parameter or –1, if the entry is not used. The thousands digit of the R parameter (measuring circuit) is automatically complemented.
Pn201	Unit	0.. 99 [0]	Coding see chapter 10
Pn202	Display decimal places	0.. 5 [2]	Number of decimal places

Table 70 Pn200 block: Units and decimal places for R parameters

9.8.16 Pn300 block: Reference and correction calculation

Parameter	Meaning	Value range	Explanations	Level
Pn300	Reference calculation	0...1 [0]	0: not active 1: active	
Pn301	Correction calculation for volume and mass flows, with standardization to reference conditions displayed below	0...4 [0]	0: off 1: Speed of sound (T) 2: Orifice 3: Viscosity 4: Direct correction value (in Pn305)	
Pn302	Reference pressure	0…2.0E06 [1.0E05]	Reference pressure absolute Fixed value in Pascal	1,2,3,4
Pn303	Reference temperature	233.15...1073.15 [293.15]	Reference temperature Fixed value in Kelvin	1,2,3,4
Pn304	Reference humidity	0…1 [0.0]	Reference humidity Fixed value 0...1	1,2,3,4
Pn305	Expression, meaning depends on Pn301	String [„“]	If Pn301=2 or 3: The expression shall calculate the ratio of the reference differential pressure to measured differential pressure. If Pn301=4: The multiplicative correction value is solely defined by the expression in Pn305	2, 3, 4

Table 71 Pn300 block: Reference pressure and correction calculation

Detailed explanations are given in chapter 11.7.
The factors for the correction calculation are given by the R parameters Ry130 (for continuous operation) and Ry131 (for average-building operation).

9.8.17 Pn310 block: Functions

Parameter	Meaning	Value range	Explanations
Pn310	Type of function	0...1 [0]	0: Switched off 1: Straight line of regression
Pn311	Minimum time	0.02...3600.0 [5.0]	Shortest time providing valid values.
Pn312	Maximum time	0.02...3600.0 [10.0]	Longest time providing valid values.
Pn313	Input value of the function	0...2999 [1]	Number of the R parameter building the X value of the function.

Table 72 Pn310 block: Functions

The function results will be placed in the R parameters Ry110 to Ry119. In case of the regression line, the meaning of the parameters is as follows:

- Ry110: Gradient of the line
- Ry111: Axis intersection
- Ry112: Correlation coefficient
- Ry113: Time for which the line is calculated
- Ry114: Standard deviation of the values
- Ry115: Standard deviation of the time values
- Ry116: Average of the values
- Ry117: Average of the time values
- Ry118: Difference between two time values

9.8.18 Pn350 block: Calculated R parameters

The values in block Pn350 are used to allocate calculated values depending on the program to the R parameters. These values can be used, e.g., for the ratio formation to show the deviation of a measurement value and a fixed value, to display fixed values to analogue outputs, or to carry out conversions to other units.

There are 5 calculated R parameters possible at all. The parameters at Pn350-Pn359 are still repeated for 4 times at Pn360, Pn370, Pn380 and Pn390 for this purpose. The results are appropriately ending up in Ry061, Ry062, etc.

With an average-building measurement sums, averages etc. are provided by calculated R parameters, as it is also done with other R parameters. They are written in Ry260, Ry360 etc. In some cases the calculated values are wrong for sums and average values. If the term is a ratio of two R parameters, for example, then the calculation of the sum as a summation of the individual ratio values is not necessarily equal to the ratio of the sum of the individual values. Partly (gas meters) more exact values are only available at the end of the measurement. Therefore a separate term is still available for the sum and the average value at Pn351 or Pn352. If terms are indicated here, then sum and average value of the calculated R parameter are overwritten at the end of the measurement by the result of the term.

Parameter	Meaning	Value range	Explanations
Pn350	Calculated R parameter #0	String [„“]	Result will be written to Ry060.
Pn351	Sum of the calculated R parameter #0	String [„“]	Result will be written to Ry360.
Pn352	Average value of the calculated R parameter #0	String [„“]	Result will be written to Ry260.

Table 73 Pn350 block: Calculated R parameters

Further information

- For the syntax of the control terms see chapter 6.3

9.8.19 Pn400 and Pn450 blocks: Control

Two controllers are available for each program. For this purpose always one parameter block is available with Pn400, and a second one with Pn450. In the cycle the first controller (with Pn400) and then the second one (with Pn450) is calculated at first. This sequence has to be considered in the case of cascading the controllers. In this case the first controller should be used as an outside controller and the second one as an inside controller.

Both integrated PID controllers can be configured as controllers for all quantities measured and calculated with the Laminar Master (e.g. pressures and volume flows).
The scaling and definition of the analogue output for the issue of the control variable is done in the block S8nxx (see section 9.7.25,analog outputs).

Each controller can be configured as a P, PI or PIDT1 controller. An arbitrary measured variable or operand can be defined as a control variable from the Ry000 block.
The following table indicates parameters for the configuration of the controller. The determination of the controller parameters (Pn402-Pn405) can be done, e.g., according to the adjustment rules of *Ziegler - Nichols* (see below).

For this purpose the controller will be defined as a mere P controller at first (TI = 0, TD = 0) (see also table adjustment parameter control). Then the loop gain KR will be set to a value, which results in a steady cycle of the actual value, i.e. control variable. This value for KR is indicated as Kkrit. The cycle time of the cycle (Tkrit.) should be measured by a writer or oscilloscope.
Using the values for Kkrit. and Tkrit. the controller parameters can be defined then according to the following table.
These values must be entered then as values for the parameters Pn403 - Pn405.

Adjustment rules for PID controllers according to Ziegler, Nichols:

Controller	**KR**	**TI**	**TD**
P	0,5 * Kkrit		
PI element	0,45 * Kkrit	0,85 * Tkrit	
PID	0,6 * Kkrit	0,5 * Tkrit	0,12 * Tkrit

Parameter	**Meaning**	**Value range**	**Explanations**
Pn400 (Pn450 following)	Control mode	0...2 [0]	0: Control off 1: Manual control 2: Automatic control
Pn401	Hot edit on/off	0...[0]	0: Changing the controller parameters in the controller menu only with manual operation. 1: Changing of the controller parameters in the controller menu also with running controller.
Pn402	Control time constant (T1)	[0,1]	Delay time for the D portion in seconds. For discretizational reasons T1 must be as long as the cycle time at least. In this case the controller is all but an ideal PID controller.
Pn403	Control differential portion (TD)	[0]	D portion of the controller in seconds. If TD=0, then no D portion, i.e.Pn402 without effect (PI controller)
Pn404	Control integral portion (TI)	[1]	I portion of the controller in seconds. If TI =0 (corresponds with ∞ !), then no I portion and no D portion, i.e., Pn402 and Pn403 without effect (P controller)
Pn405	Closed loop-gain (KR)	[1]	P portion of the controller, without dimension, as floating point number
Pn406	Restriction of control variable lower limit	[0]	floating point number without dimension.
Pn407	Restriction of control variable upper limit	[1]	floating point number without dimension.

Pn408	Discretizational time controller	1E-3...1E3 [0.02]	Discretizational time of the controller. Corresponds with the cycle time of fast controllers, can be extended with very slow controllers to avoid problems with regard of accuracy of calculation.
Pn411	Control variable, actual value	String [„“]	Term, which results in the actual value of the controller.
Pn417	Output value after reset	String [„“]	Term, which has the expected control value as a result when the controller is booted again.
Pn422	Set point controller	String [„“]	Term, which has the set point of the controller as a result.
Pn423	Set value ramp		Speed of increase absolute in SI units of the control variable per second
Pn424	Set value ramp, initial value		in SI units of the control variable
Pn425	Set value guide ramp	-1...0...1 [0]	-1: use, initial value according to Pn424 0: not used 1: use, initial value = current value
Pn430	Linearization of the output	0...2 [0]	0: Linearization off 1: Rotary servo valve 3/4: KV = 0.428 2: Rotary servo valve 3/6: KV = 0.672
Pn435	Interference of the output signal with a jitter configured in Pn436 and Pn437	0...1 [0]	0: inactive 1: active
Pn436	Maximum set point/actual value difference for jitter	0..1E30 [0]	The jitter signal is only active, if the set point/actual value difference is smaller than the value set here.
Pn437	Double jitter amplitude	0..1E30 [0]	The control value is increased or decreased in each cycle by the half of the value set here.
Pn440	Quantity of the set point and actual value	0...21 [10]	Coding see chapter 10

Table 74 Pn400 block: Control

9.8.20 Pn500 block: Limit values

In block Pn500 4 different evaluation criteria are defined, with the help of which one parameter can be monitored at the end of the test or permanently. The final result is the combination of all activated individual evaluations. The parameters for the first evaluation criterion are indicated in the following as an example. The block repeats itself for still three times at Pn510, Pn520 and Pn530.

Parameter	Meaning	Value range	Explanations
Pn500	Type of evaluation	0...2 [0]	0: switched off (always good). 1: Evaluate after termination of test. 2: Evaluate continuously.
Pn501	Quantity to be controlled	0...2999	Number of the R parameter to be evaluated.
Pn502	Lower limit	-1E38...1E38	Lower limit value in SI units
Pn503	Upper limit	-1E38...1E38	Upper limit value in SI units
Pn504	Override for evaluation	String	The term indicated here will be evaluated before each rating. If the result is <> 0, then the result of the individual rating is always “good“. If the value of the term is < 0, then the result of the individual rating is always „bad“ („value too high“ is used). If no term exists, or it is 0, then a normal rating will be carried out.

Table 75 Pn500 block: Limit values

9.8.21 Pn550 block: Automatic program toggle

For the automatic program toggle two R parameters per program can be evaluated, according to the settings in S1030 (S1031, S1032). Block Pn550 will be repeated with Pn560 again.

Parameter	Meaning	Value range	Explanations
Pn550	R parameter to be evaluated	0...2999 [0]	Number of the R parameter, which shall initialize a program toggle in the case of a limit being exceeded.
Pn551	Lower limit value for program toggle	[0]	A falling below of this value results in a toggle of the program according to Pn553.
Pn552	Upper limit value for program toggle	[1E+08]	An exceeding of this value results in a toggle of the program according to Pn554.
Pn553	New program if the limit value falls below in Pn551.	0...9 [0]	If the limit value falls below in Pn551, there is a toggle to this program, provided that it is in the valid range of the corresponding measuring circuit (S101k, S102k).
Pn554	New program if the limit value is exceeded in Pn552.	0...9 [1]	if the limit value is exceeded in Pn552, there is a toggle to this program, provided that it is in the valid range of the corresponding measuring circuit (S101k, S102k).

Table 76 Pn550 block: Automatic program toggle

9.8.22 Pn700 block: Process times

Parameter	Meaning	Value range	Explanations
Pn701	Measuring time	0...86400.0	(in seconds)
Pn705	Number of measuring pulses with gas meter according to pulse counting method	2...100000 [2]	Measuring time is terminated after pulse number has expired (target time measurement).
Pn710	Pre-fill time	0.0...86400.0	in seconds
Pn711	Filling period	0.0...86400.0	in seconds
Pn712	Stabilization period	0.0...86400.0	in seconds
Pn713	Venting time	0.0...86400.0	in seconds
Pn714	Time for display of the measurement results	0.0...86400.0	in seconds

Table 77 Pn700 block: Process times

Notes:
Normally only the following values are reasonable for Pn714:
0: no waiting time for the result display, behaviour as in the standard version, “GO” signal without effect Very high value: the result display is always terminated by the “GO” signal

For double section systems the process times of both systems can be asynchronous. However, for the setting of the (common) test end the process times of the longest operating section are valid! Comparison: S9002 " Synchronize measurement "

The phases “fill” and “display result” can be terminated prematurely by the signal “GO” before the corresponding waiting time expires. This can be reasonable, e.g., if during the phase “Fill” manual settings shall be carried out, if the phase “Fill” shall be terminated by an incident, which is evaluated by the superior control, or if the measurement result shall be evaluated manually (especially during operation with several cycles, see below.). The signal “GO” is implemented by the term defined in S1404.

9.8.23 Pn800 block: Display parameters depending on the program

In addition to the display of certain predefined data there are two possibilities to indicate the value of R parameters on the display (see also chapter 9.2.3):

- Display of a directly allocated R parameter
- Display of the R parameter, which is saved in an allocated P parameter

Here the focus lies on the P parameters, in which those R parameters are saved, in which values shall be displayed This direct allocation has the advantage that different magnitudes can be displayed specific to the program.

Parameter	**Meaning**	**Value range**
Pn800	Display parameter #0	y000 - y999
Pn801	Display parameter #1	y000 - y999
Pn802	Display parameter #2	y000 - y999
Pn803	Display parameter #3	y000 - y999
Pn804	Display parameter #4	y000 - y999
Pn805	Display parameter #5	y000 - y999
Pn806	Display parameter #6	y000 - y999
Pn807	Display parameter #7	y000 - y999
Pn808	Display parameter #8	y000 - y999
Pn809	Display parameter #9	y000 - y999
Pn810	Display parameter #10	y000 - y999
Pn811	Display parameter #11	y000 - y999
Pn812	Display parameter #12	y000 - y999
Pn813	Display parameter #13	y000 - y999
Pn814	Display parameter #14	y000 - y999
Pn815	Display parameter #15	y000 - y999
Pn816	Display parameter #16	y000 - y999
Pn817	Display parameter #17	y000 - y999
Pn818	Display parameter #18	y000 - y999
Pn819	Display parameter #19	y000 - y999

Table 78 Pn800 block: Display parameters depending on the program

Parameter	**Meaning**	**Value range**	**Explanations**
Pn899	Program name	String [„n|Prog“]	The program name can be shown on the display by using the value –10 (or –11, -12 for MK1 and 2) in the display list. A ‚|' sign separates the left and the right display side. Displays which are too long are flashing or scroll automatically.

Table 79 Pn899 block: Program name

9.9 U parameter: Sub programs

The program determines the used P parameter set. It is possible to select parts of this parameter set independent of the program by using sub programs. The parts of the P parameter set switchable by sub programs are indicated as parameter segments. For each parameter segment a set of configuration parameters exists (U parameter set), in which the behaviour of the appropriate sub program is determined (confer Table 80).

All sub programs are coupled with the program in the basic configuration. This corresponds with the state before the introduction of the sub programs. Alternatively a sub program can be determined by an expression, or - similar to the program - it can be switched over automatically.

The switch over of parameter segments makes possible, for example, the switch over of a sensor in the case of a measuring range switch over without the need of switching over the complete program. Thus more programs are available for different evaluations, automated measuring cycles or other tasks.

If a sub program shall not be connected with the program, there are two different possibilities to define the switch over behaviour:

- The switch over is carried out independently of the state of a control expression.
- The switch over is carried out automatically, if a R parameter exceeds an upper limit or falls below a lower limit. In this case the R parameter to be monitored, the limit values and the appropriate switch over targets are defined in the H parameters. See also paragraph 9.5.1 for that.

Switch over actions must not occur any time. E.g., it is possible to define that a certain waiting time has to be respected between two switch over actions, or that switch over actions are eliminated in certain states, as e.g., during a measuring taking the mean.

Note:
The waiting time is also valid if the sub program is coupled firmly with the program. If, for example, a waiting time of 2 seconds has been determined for a sub program, the sub program will be switched over possibly only after 2 seconds have passed after the program has changed!

For each parameter segment there is an own U parameter set. The individual U parameter sets follow with a distance of 20. There, the thousands digit indicates the measuring circuit.

Existing U parameter sets at the moment:

Number of the U parameter set	**Start U parameter**	**Parameter Segment**	**Explanations**
0	Uy000	Pn100-Pn149, Pn200-Pn249	Units and decimal places, first half
1	Uy020	Pn150-Pn199, Pn250-Pn299	Units and decimal places, second half
2	Uy040	Pn899	Program name
10	Uy200	Pn000, Pn003, Pn004	Primary element, see paragraph 9.8.1
11	Uy220	Pn001	Gas type, see paragraph 9.8.1
12	Uy240	Pn010-Pn014	Primary measurand, see paragraph 9.8.2
13	Uy260	Pn020-Pn024	Absolute pressure, see paragraph 9.8.3
14	Uy280	Pn030-Pn034	Measuring temperature, see paragraph 9.8.4
15	Uy300	Pn040-Pn044	Measurement humidity, see paragraph 9.8.5
16	Uy320	Pn050-Pn055	Reference pressure absolute, see paragraph 9.8.6
17	Uy340	Pn060-Pn064	Reference temperature, see paragraph 9.8.7
18	Uy360	Pn070-Pn074	Reference humidity, see paragraph 9.8.8
19	Uy380	Pn075-Pn079	Auxiliary input 0, see paragraph 9.8.9
20	Uy400	Pn080-Pn084	Auxiliary input 1, see paragraph 9.8.10
21	Uy420	Pn085-Pn089	Auxiliary input 2, see paragraph 9.8.11
22	Uy440	Pn090-Pn094	Auxiliary input 3, see paragraph 9.8.12
23	Uy460	Pn095-Pn099	Auxiliary input 4, see paragraph 9.8.13

Table 80 U parameter sets. y = measuring circuit

In the following the U parameter set starting at U0200 is shown as an example. The other U parameter sets are structured identically:

Parameter	Meaning	Values	Explanations
U0200	Coupling	0...2 [0]	0: Coupling with the program. 1: Determination by the expression in U0204. 2: Automatic switch over with vectors in U0210-U0219.
U0201	Initial sub program	0...9 [0]	Initial value for the sub program.
U0202	Waiting period	0...3600 [0]	Waiting period between switch over actions. After a switch over of the sub program other switch over actions are eliminated for the time set here in seconds.
U0203	Allow switch over?	String [„“]	If U0200 has the value 1 or 2, then the term in U0203 determines, whether a switch over is permitted or not. If the term is empty or invalid, then a switch over is always permitted.
U0204	Term for sub program	String [„“]	If U0200 has the value 1, then the sub program is determined by the term specified here.
U0210	Switch over vector	0...49 [0]	Refers to a H parameter set. If U0200 has the value 2 and the current sub program is 0, then this switch over vector is used to determine a new sub program, if necessary.
U0211	Switch over vector	0...49 [0]	H parameter set, if sub program = 1.
U0212	Switch over vector	0...49 [0]	H parameter set, if sub program = 2.
U0213	Switch over vector	0...49 [0]	H parameter set, if sub program = 3.
U0214	Switch over vector	0...49 [0]	H parameter set, if sub program = 4.
U0215	Switch over vector	0...49 [0]	H parameter set, if sub program = 5.
U0216	Switch over vector	0...49 [0]	H parameter set, if sub program = 6.
U0217	Switch over vector	0...49 [0]	H parameter set, if sub program = 7.
U0218	Switch over vector	0...49 [0]	H parameter set, if sub program = 8.
U0219	Switch over vector	0...49 [0]	H parameter set, if sub program = 9.

Table 81 U0000 block: Structure of a U parameter set

9.10 Ryxxx block: Read parameter, measurement results

For understanding
Most of the systems have only one measuring circuit (measuring circuit 0). But up to 3 measuring circuits are possible. In the following table the lower case letter y in the parameter number represents the number of the measuring circuit, and it can take the values 0, 1 or 2.

Parameter	Meaning/physical quantity	Display Name	Supplement
Ry000	System absolute pressure	Pbas	
Ry001	Differential pressure	Pdif	
Ry002	Test pressure absolute	Pabs	
Ry003	Measuring temperature	Temp	
Ry004	Measurement humidity	Hum	
Ry010	Reference pressure absolute [1)]	RPab	
Ry011	Reference temperature [1)]	RTem	
Ry012	Reference humidity [1)]	RHum	
Ry015	Auxiliary input 0	Aux0	
Ry016	Auxiliary input 1	Aux1	
Ry017	Auxiliary input 2	Aux2	
Ry018	Auxiliary input 3	Aux3	
Ry019	Auxiliary input 4	Aux4	
Ry030	Measuring flow rate	QVac	
Ry031	Standard flow rate	QVno	
Ry032	Reference volume flow [1)]	RQVa	
Ry033	Heating capacity	CPwr	
Ry034	Heat quantity	HQty	
Ry035	Mass flow	QMas	
Ry036	Reynolds number flow element	Re_d	
Ry037	Reynolds number tube	Re_d	
Ry038	Velocity flow element	v_d	
Ry039	Velocity tube	v_D	
Ry040	K factor betaflow	K	
Ry041	Pressure drop LMS	dpdt	
Ry051	Correction measuring flow rate [2)]	CQVa	
Ry052	Correction standard flow rate [2)]	CQVn	
Ry053	Correction reference flow rate [1) 2)]	CQVr	
Ry054	Correction mass flow [2)]	CQMa	
Ry060	Calculated R parameter of Pn350	Cal0	
Ry061	Calculated R parameter of Pn360	Cal1	
Ry062	Calculated R parameter of Pn370	Cal2	
Ry063	Calculated R parameter of Pn380	Cal3	
Ry064	Calculated R parameter of Pn390	Cal4	
Ry090	Calibration density	KDen	
Ry091	Measurement density	ADen	
Ry092	Standard density	NDen	
Ry093	Reference density [1)]	RDen	
Ry094	Correction density [2)]	CDen	
Ry095	Calibration viscosity	KVis	
Ry096	Measuring viscosity	AVis	
Ry097	Standard viscosity	NVis	
Ry098	Reference viscosity [1)]	RVis	
Ry099	Correction viscosity [2)]	CVis	

Ry110	Functional result 0 (with regression: gradient)	FuncRes0	
Ry111	Functional result 1 (with regression: axis intersection)	FuncRes1	
Ry112	Functional result 2 (with regression: correlation coefficient)	FuncRes2	
Ry113	Functional result 3 (with regression: real measurement time, means number of periods multiplied by period duration)	FuncRes3	
Ry114	Functional result 4 (with regression: standard deviation of the values)	FuncRes4	
Ry115	Functional result 5 (with regression: standard deviation of time)	FuncRes5	
Ry116	Functional result 6 (with regression: average of the values)	FuncRes6	
Ry117	Functional result 7 (with regression: average of the time)	FuncRes7	
Ry118	Functional result 8 (with regression: period duration)	FuncRes8	
Ry119	Functional result 9	FuncRes9	
Ry130	Result of the correction calculation (continuous) [2)]	Corr Cont	
Ry131	Result of the correction calculation (averaging) [2)]	Corr Avrg	
Ry150	Control 1, set value	Set1	
Ry151	Control 1, actual value	Act1	
Ry152	Control 1, output correcting variable	Cor1	
Ry160	Control 2, set value	Set2	
Ry161	Control 2, actual value	Act2	
Ry162	Control 2, output correcting variable	Cor2	
Ry170	Evaluated quantity of Pn501		
Ry171	Lower limit value of Pn502		
Ry172	Upper limit value of Pn503		
Ry173	Evaluated quantity of Pn511		
Ry174	Lower limit value of Pn512		
Ry175	Upper limit value of Pn513		
Ry176	Evaluated quantity of Pn521		
Ry177	Lower limit value of Pn522		
Ry178	Upper limit value of Pn523		
Ry179	Evaluated quantity of Pn531		
Ry180	Lower limit value of Pn532		
Ry181	Upper limit value of Pn533		
Ry190	Number of pulses during measurement (gas meter)	Pulse	
Ry194	Balance time, Pre-Fill	Pfil	
Ry195	Balance time, Fill	Fill	
Ry196	Balance time, Calm	Calm	
Ry197	Balance time, Stabilize (ZERO)	Zero	
Ry198	Balance time, Venting	Vent	
Ry199	Time, Measurement (MEAS, LEAK)	TMEAS	
Ry200	Average value, System absolute pressure	Pbas	Avrg
Ry201	Average value, Differential pressure	Pdif	Avrg
Ry202	Average value, Test pressure absolute	Pabs	Avrg
Ry203	Average value, Measuring temperature	Temp	Avrg
Ry204	Average value, Measurement humidity	Hum	Avrg
Ry210	Average value, Reference pressure absolute [1)]	RPab	Avrg
Ry211	Average value, Reference temperature [1)]	RTem	Avrg
Ry212	Average value, Reference humidity [1)]	RHum	Avrg
Ry215	Average value, Auxiliary input 0	Aux0	Avrg

Ry216	Average value, Auxiliary input 1	Aux1	Avrg
Ry217	Average value, Auxiliary input 2	Aux2	Avrg
Ry218	Average value, Auxiliary input 3	Aux3	Avrg
Ry219	Average value, Auxiliary input 4	Aux4	Avrg
Ry230	Average value, Measuring flow rate	QVac	Avrg
Ry231	Average value, Standard flow rate	QVno	Avrg
Ry232	Average value, Reference volume flow [1)]	RQVa	Avrg
Ry233	Average value, Heating capacity	CPwr	Avrg
Ry234	Average value, Heat quantity	HQty	Avrg
Ry235	Average value, Mass flow	QMas	Avrg
Ry236	Average value, Reynolds number flow element	Ref	Avrg
Ry237	Average value, Reynolds number tube	Ret	Avrg
Ry238	Average value, Velocity flow element	Vf	Avrg
Ry239	Average value, Velocity tube	Vt	Avrg
Ry240	Average value, K factor	K	Avrg
Ry241	Average value, Pressure drop LMS	dpdt	Avrg
Ry251	Average value, Correction measuring flow rate [2)]	CQVa	Avrg
Ry252	Average value, Correction standard flow rate [2)]	CQVn	Avrg
Ry253	Average value, Correction reference flow rate [1) 2)]	CQVr	Avrg
Ry254	Average value, Correction mass flow [2)]	CQMa	Avrg
Ry260	Average value, Calculated R parameter of Pn350	Cal0	Avrg
Ry261	Average value, Calculated R parameter of Pn360	Cal1	Avrg
Ry262	Average value, Calculated R parameter of Pn370	Cal2	Avrg
Ry263	Average value, Calculated R parameter of Pn380	Cal3	Avrg
Ry264	Average value, Calculated R parameter of Pn390	Cal4	Avrg
Ry290	Average value, Calibration density	KDen	Avrg
Ry291	Average value, Measurement density	ADen	Avrg
Ry292	Average value, Standard density	NDen	Avrg
Ry293	Average value, Reference density [1)]	RDen	Avrg
Ry294	Average value, Correction density [2)]	CDen	Avrg
Ry295	Average value, Calibration viscosity	KVis	Avrg
Ry296	Average value, Measuring viscosity	AVis	Avrg
Ry297	Average value, Standard viscosity	NVis	Avrg
Ry298	Average value, Reference viscosity [1)]	RVis	Avrg
Ry299	Average value, Correction viscosity [2)]	CVis	Avrg
Ry300	Sum system absolute pressure	Pbas	Sum
Ry301	Sum Differential pressure	Pdif	Sum
Ry302	Sum Test pressure absolute	Pabs	Sum
Ry303	Sum Measuring temperature	Temp	Sum
Ry304	Sum Measurement humidity	Hum	Sum
Ry310	Sum Reference pressure absolute [1)]	RPab	Sum
Ry311	Sum Reference temperature [1)]	RTem	Sum
Ry312	Sum Reference humidity [1)]	RHum	Sum
Ry315	Sum Auxiliary input 0	Aux0	Sum
Ry316	Sum Auxiliary input 1	Aux1	Sum
Ry317	Sum Auxiliary input 2	Aux2	Sum
Ry318	Sum Auxiliary input 3	Aux3	Sum
Ry319	Sum Auxiliary input 4	Aux4	Sum
Ry330	Sum Measuring flow rate	QVac	Sum
Ry331	Sum Standard flow rate	QVno	Sum
Ry332	Sum Reference volume flow [1)]	RQVa	Sum
Ry333	Sum Heating capacity	CPwr	Sum
Ry334	Sum Heat quantity	HQty	Sum
Ry335	Sum Mass flow	QMas	Sum

Ry336	Sum Reynolds number flow element	Ref	Sum
Ry337	Sum Reynolds number tube	Ret	Sum
Ry338	Sum Velocity flow element	Vf	Sum
Ry339	Sum Velocity tube	Vt	Sum
Ry340	Sum K factor	K	Sum
Ry341	Sum Pressure drop LMS	dpdt	Sum
Ry351	Sum Correction measuring flow rate 2)	CQVa	Sum
Ry352	Sum Correction standard flow rate 2)	CQVn	Sum
Ry353	Sum Correction reference flow rate 1) 2)	CQVr	Sum
Ry354	Sum Correction mass flow 2)	CQMa	Sum
Ry360	Sum Calculated R parameter of Pn350	Cal0	Sum
Ry361	Sum Calculated R parameter of Pn360	Cal1	Sum
Ry362	Sum Calculated R parameter of Pn370	Cal2	Sum
Ry363	Sum Calculated R parameter of Pn380	Cal3	Sum
Ry364	Sum Calculated R parameter of Pn390	Cal4	Sum
Ry390	Sum Calibration density	KDen	Sum
Ry391	Sum Measurement density	ADen	Sum
Ry392	Sum Standard density	NDen	Sum
Ry393	Sum Reference density 1)	RDen	Sum
Ry394	Sum Correction density 2)	CDen	Sum
Ry395	Sum Calibration viscosity	KVis	Sum
Ry396	Sum Measuring viscosity	AVis	Sum
Ry397	Sum Standard viscosity	NVis	Sum
Ry398	Sum Reference viscosity 1)	RVis	Sum
Ry399	Sum Correction viscosity 2)	CVis	Sum
Ry400	Minimum System absolute pressure	Pbas	Min
Ry401	Minimum Differential pressure	Pdif	Min
Ry402	Minimum Test pressure absolute	Pabs	Min
Ry403	Minimum Measuring temperature	Temp	Min
Ry404	Minimum Measurement humidity	Hum	Min
Ry410	Minimum Reference pressure absolute 1)	RPab	Min
Ry411	Minimum Reference temperature 1)	RTem	Min
Ry412	Minimum Reference humidity 1)	RHum	Min
Ry415	Minimum Auxiliary input 0	Aux0	Min
Ry416	Minimum Auxiliary input 1	Aux1	Min
Ry417	Minimum Auxiliary input 2	Aux2	Min
Ry418	Minimum Auxiliary input 3	Aux3	Min
Ry419	Minimum Auxiliary input 4	Aux4	Min
Ry430	Minimum Measuring flow rate	QVac	Min
Ry431	Minimum Standard flow rate	QVno	Min
Ry432	Minimum Reference volume flow 1)	RQVa	Min
Ry433	Minimum Heating capacity	CPwr	Min
Ry434	Minimum Heat quantity	HQty	Min
Ry435	Minimum Mass flow	QMas	Min
Ry436	Minimum Reynolds number flow element	Ref	Min
Ry437	Minimum Reynolds number tube	Ret	Min
Ry438	Minimum Velocity flow element	Vf	Min
Ry439	Minimum Velocity tube	Vt	Min
Ry440	Minimum K factor	K	Min
Ry441	Minimum Pressure drop LMS	dpdt	Min
Ry451	Minimum Correction measuring flow rate 2)	CQVa	Min
Ry452	Minimum Correction standard flow rate 2)	CQVn	Min
Ry453	Minimum Correction reference flow rate 1) 2)	CQVr	Min
Ry454	Minimum Correction mass flow 2)	CQMa	Min

Ry460	Minimum Calculated R parameter of Pn350	Cal0	Min
Ry461	Minimum Calculated R parameter of Pn360	Cal1	Min
Ry462	Minimum Calculated R parameter of Pn370	Cal2	Min
Ry463	Minimum Calculated R parameter of Pn380	Cal3	Min
Ry464	Minimum Calculated R parameter of Pn390	Cal4	Min
Ry490	Minimum Calibration density	KDen	Min
Ry491	Minimum Measurement density	ADen	Min
Ry492	Minimum Standard density	NDen	Min
Ry493	Minimum Reference density [1)]	RDen	Min
Ry494	Minimum Correction density [2)]	CDen	Min
Ry495	Minimum Calibration viscosity	KVis	Min
Ry496	Minimum Measuring viscosity	AVis	Min
Ry497	Minimum Standard viscosity	NVis	Min
Ry498	Minimum Reference viscosity [1)]	RVis	Min
Ry499	Minimum Correction viscosity [2)]	CVis	Min
Ry500	Maximum System absolute pressure	Pbas	Max
Ry501	Maximum Differential pressure	Pdif	Max
Ry502	Maximum Test pressure absolute	Pabs	Max
Ry503	Maximum Measuring temperature	Temp	Max
Ry504	Maximum Measurement humidity	Hum	Max
Ry510	Maximum Reference pressure absolute [1)]	RPab	Max
Ry511	Maximum Reference temperature [1)]	RTem	Max
Ry512	Maximum Reference humidity [1)]	RHum	Max
Ry515	Maximum Auxiliary input 0	Aux0	Max
Ry516	Maximum Auxiliary input 1	Aux1	Max
Ry517	Maximum Auxiliary input 2	Aux2	Max
Ry518	Maximum Auxiliary input 3	Aux3	Max
Ry519	Maximum Auxiliary input 4	Aux4	Max
Ry530	Maximum Measuring flow rate	QVac	Max
Ry531	Maximum Standard flow rate	QVno	Max
Ry532	Maximum Reference volume flow [1)]	RQVa	Max
Ry533	Maximum Heating capacity	CPwr	Max
Ry534	Maximum Heat quantity	HQty	Max
Ry535	Maximum Mass flow	QMas	Max
Ry536	Maximum Reynolds number flow element	Ref	Max
Ry537	Maximum Reynolds number tube	Ret	Max
Ry538	Maximum Velocity flow element	Vf	Max
Ry539	Maximum Velocity tube	Vt	Max
Ry540	Maximum K factor	K	Max
Ry541	Maximum Pressure drop LMS	dpdt	Max
Ry551	Maximum Correction measuring flow rate [2)]	CQVa	Max
Ry552	Maximum Correction standard flow rate [2)]	CQVn	Max
Ry553	Maximum Correction reference flow rate [1) 2)]	CQVr	Max
Ry554	Maximum Correction mass flow [2)]	CQMa	Max
Ry560	Maximum Calculated R parameter of Pn350	Cal0	Max
Ry561	Maximum Calculated R parameter of Pn360	Cal1	Max
Ry562	Maximum Calculated R parameter of Pn370	Cal2	Max
Ry563	Maximum Calculated R parameter of Pn380	Cal3	Max
Ry564	Maximum Calculated R parameter of Pn390	Cal4	Max
Ry590	Maximum Calibration density	KDen	Max

Ry591	Maximum Measurement density	ADen	Max
Ry592	Maximum Standard density	NDen	Max
Ry593	Maximum Reference density 1)	RDen	Max
Ry594	Maximum Correction density 2)	CDen	Max
Ry595	Maximum Calibration viscosity	KVis	Max
Ry596	Maximum Measuring viscosity	AVis	Max
Ry597	Maximum Standard viscosity	NVis	Max
Ry598	Maximum Reference viscosity 1)	RVis	Max
Ry599	Maximum Correction viscosity 2)	CVis	Max
Ry600	Standard deviation System absolute pressure	Pbas	Dev
Ry601	Standard deviation Differential pressure	Pdif	Dev
Ry602	Standard deviation Test pressure absolute	Pabs	Dev
Ry603	Standard deviation Measuring temperature	Temp	Dev
Ry604	Standard deviation Measurement humidity	Hum	Dev
Ry610	Standard deviation Reference pressure absolute 1)	RPab	Dev
Ry611	Standard deviation Reference temperature 1)	RTem	Dev
Ry612	Standard deviation Reference humidity 1)	RHum	Dev
Ry615	Standard deviation Auxiliary input 0	Aux0	Dev
Ry616	Standard deviation Auxiliary input 1	Aux1	Dev
Ry617	Standard deviation Auxiliary input 2	Aux2	Dev
Ry618	Standard deviation Auxiliary input 3	Aux3	Dev
Ry619	Standard deviation Auxiliary input 4	Aux4	Dev
Ry630	Standard deviation Measuring flow rate	QVac	Dev
Ry631	Standard deviation Standard flow rate	QVno	Dev
Ry632	Standard deviation Reference volume flow 1)	RQVa	Dev
Ry633	Standard deviation Heating capacity	CPwr	Dev
Ry634	Standard deviation Heat quantity	HQty	Dev
Ry635	Standard deviation Mass flow	QMas	Dev
Ry636	Standard deviation Reynolds number flow element	Ref	Dev
Ry637	Standard deviation Reynolds number tube	Ret	Dev
Ry638	Standard deviation Velocity flow element	Vf	Dev
Ry639	Standard deviation Velocity tube	Vt	Dev
Ry640	Standard deviation K factor	K	Dev
Ry641	Standard deviation Pressure drop LMS	dpdt	Dev
Ry651	Standard deviation Correction measuring flow rate 2)	CQVa	Dev
Ry652	Standard deviation Correction standard flow rate 2)	CQVn	Dev
Ry653	Standard deviation Correction reference flow rate 1) 2)	CQVr	Dev
Ry654	Standard deviation Correction mass flow 2)	CQMa	Dev
Ry660	Standard deviation Calculated R parameter of Pn350	Cal0	Dev
Ry661	Standard deviation Calculated R parameter of Pn360	Cal1	Dev
Ry662	Standard deviation Calculated R parameter of Pn370	Cal2	Dev
Ry663	Standard deviation Calculated R parameter of Pn380	Cal3	Dev
Ry664	Standard deviation Calculated R parameter of Pn390	Cal4	Dev
Ry690	Standard deviation Calibration density	KDen	Dev
Ry691	Standard deviation Measurement density	ADen	Dev
Ry692	Standard deviation Standard density	NDen	Dev
Ry693	Standard deviation Reference density 1)	RDen	Dev
Ry694	Standard deviation Correction density 2)	CDen	Dev
Ry695	Standard deviation Calibration viscosity	KVis	Dev
Ry696	Standard deviation Measuring viscosity	AVis	Dev
Ry697	Standard deviation Standard viscosity	NVis	Dev
Ry698	Standard deviation Reference viscosity 1)	RVis	Dev
Ry699	Standard deviation Correction viscosity 2)	CVis	Dev
Ry700	Change 3) System absolute pressure	Pbas	ddt

Ry701	Change [3] Differential pressure	Pdif	ddt
Ry702	Change [3] Test pressure absolute	Pabs	ddt
Ry703	Change [3] Measuring temperature	Temp	ddt
Ry704	Change [3] Measurement humidity	Hum	ddt
Ry710	Change [3] Reference pressure absolute [1]	RPab	ddt
Ry711	Change [3] Reference temperature [1]	RTem	ddt
Ry712	Change [3] Reference humidity [1]	RHum	ddt
Ry715	Change [3] Auxiliary input 0	Aux0	ddt
Ry716	Change [3] Auxiliary input 1	Aux1	ddt
Ry717	Change [3] Auxiliary input 2	Aux2	ddt
Ry718	Change [3] Auxiliary input 3	Aux3	ddt
Ry719	Change [3] Auxiliary input 4	Aux4	ddt
Ry730	Change [3] Measuring flow rate	QVac	ddt
Ry731	Change [3] Standard flow rate	QVno	ddt
Ry732	Change [3] Reference volume flow [1]	RQVa	ddt
Ry733	Change [3] Heating capacity	CPwr	ddt
Ry734	Change [3] Heat quantity	HQty	ddt
Ry735	Change [3] Mass flow	QMas	ddt
Ry736	Change [3] Reynolds number flow element	Ref	ddt
Ry737	Change [3] Reynolds number tube	Ret	ddt
Ry738	Change [3] Velocity flow element	Vf	ddt
Ry739	Change [3] Velocity tube	Vt	ddt
Ry740	Change [3] K factor	K	ddt
Ry741	Change [3] Pressure drop LMS	dpdt	ddt
Ry751	Change [3] Correction measuring flow rate [2]	CQva	ddt
Ry752	Change [3] Correction standard flow rate [2]	CQvn	ddt
Ry753	Change [3] Correction reference flow rate [1] [2]	CQvr	ddt
Ry754	Change [3] Correction mass flow [2]	CQMa	ddt
Ry760	Change [3] Calculated R parameter of Pn350	Cal0	ddt
Ry761	Change [3] Calculated R parameter of Pn360	Cal1	ddt
Ry762	Change [3] Calculated R parameter of Pn370	Cal2	ddt
Ry763	Change [3] Calculated R parameter of Pn380	Cal3	ddt
Ry764	Change [3] Calculated R parameter of Pn390	Cal4	ddt
Ry790	Change [3] Calibration density	KDen	ddt
Ry791	Change [3] Measurement density	ADen	ddt
Ry792	Change [3] Standard density	NDen	ddt
Ry793	Change [3] Reference density [1]	RDen	ddt
Ry794	Change [3] Correction density [2]	CDen	ddt
Ry795	Change [3] Calibration viscosity	KVis	ddt
Ry796	Change [3] Measuring viscosity	AVis	ddt
Ry797	Change [3] Standard viscosity	NVis	ddt
Ry798	Change [3] Reference viscosity [1]	RVis	ddt
Ry799	Change [3] Correction viscosity [2]	CVis	ddt
R0800	Raw input value dataset number 0	IN00	Raw
R0801	Raw input value dataset number 1	IN01	Raw
R0802	Raw input value dataset number 2	IN02	Raw
R0803	Raw input value dataset number 3	IN03	Raw
R0804	Raw input value dataset number 4	IN04	Raw
R0805	Raw input value dataset number 5	IN05	Raw
R0806	Raw input value dataset number 6	IN06	Raw
R0807	Raw input value dataset number 7	IN07	Raw
R0808	Raw input value dataset number 8	IN08	Raw
R0809	Raw input value dataset number 9	IN09	Raw
R0810	Raw input value dataset number 10	IN10	Raw
R0811	Raw input value dataset number 11	IN11	Raw

R0812	Raw input value dataset number 12	IN12	Raw
R0813	Raw input value dataset number 13	IN13	Raw
R0814	Raw input value dataset number 14	IN14	Raw
R0815	Raw input value dataset number 15	IN15	Raw
R0816	Raw input value dataset number 16	IN16	Raw
R0817	Raw input value dataset number 17	IN17	Raw
R0818	Raw input value dataset number 18	IN18	Raw
R0819	Raw input value dataset number 19	IN19	Raw
R0820	Linearized input value dataset number 0	IN00	Lin
R0821	Linearized input value dataset number 1	IN01	Lin
R0822	Linearized input value dataset number 2	IN02	Lin
R0823	Linearized input value dataset number 3	IN03	Lin
R0824	Linearized input value dataset number 4	IN04	Lin
R0825	Linearized input value dataset number 5	IN05	Lin
R0826	Linearized input value dataset number 6	IN06	Lin
R0827	Linearized input value dataset number 7	IN07	Lin
R0828	Linearized input value dataset number 8	IN08	Lin
R0829	Linearized input value dataset number 9	IN09	Lin
R0830	Linearized input value dataset number 10	IN10	Lin
R0831	Linearized input value dataset number 11	IN11	Lin
R0832	Linearized input value dataset number 12	IN12	Lin
R0833	Linearized input value dataset number 13	IN13	Lin
R0834	Linearized input value dataset number 14	IN14	Lin
R0835	Linearized input value dataset number 15	IN15	Lin
R0836	Linearized input value dataset number 16	IN16	Lin
R0837	Linearized input value dataset number 17	IN17	Lin
R0838	Linearized input value dataset number 18	IN18	Lin
R0839	Linearized input value dataset number 19	IN19	Lin
R0840	Raw output value analogue output 0	Out0	Raw
R0841	Raw output value analogue output 1	Out1	Raw
R0842	Raw output value analogue output 2	Out2	Raw
R0843	Raw output value analogue output 3	Out3	Raw
R0844	Raw output value analogue output 4	Out4	Raw
R0845	Raw output value analogue output 5	Out5	Raw
R0846	Raw output value analogue output 6	Out6	Raw
R0847	Raw output value analogue output 7	Out7	Raw
R0848	Raw output value analogue output 8	Out8	Raw
R0849	Raw output value analogue output 9	Out9	Raw
R0899	Actually required cycle time	Cycle time	Orig
R1860	Result of filter defined in H5000 block	Filter0	
…	…	…	
R1879	Result of filter defined in H6900 block	Filter19	
R2800	Value of the generic float variable F[0]	Floatvar	
...	…	…	
R2899	Value of the generic float variable F[99]	Floatvar	
Ry900	System absolute pressure, uncorrected	Pbas	Orig
Ry901	Differential pressure, uncorrected	Pdif	Orig
Ry902	Test pressure absolute, uncorrected	Pabs	Orig
Ry903	Measuring temperature, uncorrected	Temp	Orig
Ry904	Measurement humidity, uncorrected	Hum	Orig
Ry910	Reference pressure absolute, uncorrected 1)	RPab	Orig
Ry911	Reference temperature, uncorrected 1)	RTem	Orig
Ry912	Reference humidity, uncorrected 1)	RHum	Orig
Ry915	Auxiliary input 0, uncorrected	Aux0	Orig

Ry916	Auxiliary input 1, uncorrected	Aux1	Orig
Ry917	Auxiliary input 2, uncorrected	Aux2	Orig
Ry918	Auxiliary input 3, uncorrected	Aux3	Orig
Ry919	Auxiliary input 4, uncorrected	Aux4	Orig

Table 82 Ry000 block: Read parameter

1) Reference values are only calculated with reference calculation activated in Pn300.
2) Correction values are only calculated with reference calculation activated in Pn300 and a correction method defined in Pn301.

3) Change is calculated as follows: $\frac{\Delta Value}{\Delta Time} = \frac{Value_{End} - Value_{Beginning}}{Time_{End} - Zeit_{Beginning}}$

10 Basis Units – Conversion (X and Y Factors)

SI factor	X or Y factor: 1/SI factor	A = a0	Unit	Unit Code	Display Abbreviation
Pressure: Type Code 0			**Differential pressure Absolute pressure Reference absolute pressure Relative pressure**		**Pdif Pabs RPab Prel**
1,00000E-00	1,00000E-00	0,000	Pascal	0	Pa
1,00000E+02	1,00000E-02	0,000	HectoPascal	1	hPa
1,00000E+03	1,00000E-03	0,000	KiloPascal	2	kPa
1,00000E+02	1,00000E-02	0,000	Millibar	3	mbar
1,00000E+05	1,00000E-05	0,000	Bar	4	bar
9,80670E+04	1,01971E-05	0,000	techn. atmosphere	5	at
1,01325E+05	9,86923E-06	0,000	phys. atmosphere	6	atm
3,38639E+03	2,95300E-04	0,000	inch mercury @0°C	7	inHG
2,49089E+02	4,01463E-03	0,000	inch Ws @4°C	8	inWC
6,89476E+03	1,45038E-04	0,000	Pounds/in2	9	lbi2
4,78802E+01	2,08855E-02	0,000	Pounds/ft2	10	lbf2
1,33322E+02	7,50062E-03	0,000	mm mercury @0°C	11	mmHG
9,80670E-00	1,01971E-01	0,000	mm water @4°C	12	mmWC
6,89476E+03	1,45038E-04	0,000	Pounds /in²	13	psi
1,33322E+02	7,50062E-03	0,000	Torr	14	Torr
9,79000E-00	1,02145E-01	0,000	mm water @20°C	15	mmWC
2,48648E+02	4,02175E-03	0,000	inch Ws @20°C	16	inWC
Change of pressure per time: Type Code 6			**Change of pressure per time:**		**dpdt**
1,00000E-00	1,00000E-00	0,000	Pascal/sec.	0	Pa/s
1,66667E-02	6,00000E+01	0,000	Pascal/Min.	1	Pa/m
2,77778E-04	3,60000E+03	0,000	Pascal/h	2	Pa/h
1,00000E+02	1,00000E-02	0,000	Millibar/sec	3	mb/s
1,66667E-00	6,00000E-01	0,000	Millibar/min	4	mb/m
2,77778E-02	3,60000E+01	0,000	Millibar/hour	5	mb/h
1,00000E+05	1,00000E-05	0,000	Bar/sec	6	b/s
1,66667E+03	6,00000E-04	0,000	Bar/min	7	b/m
2,77778E+01	3,60000E-02	0,000	Bar/hour	8	b/h
6,89476E+03	1,45038E-04	0,000	Pounds /in²/sec	9	PSIs
1,14913E+02	8,70227E-03	0,000	Pounds /in²/min	10	PSIm
1,91521E-00	5,22136E-01	0,000	Pounds /in²/hour	11	PSIh
Mass flow: Type Code 2			**Mass flow**		**Qmas**
1,00000E-00	1,00000E-00	0,000	kg/sec	0	kg/s
1,66667E-02	6,00000E+01	0,000	kg/min	1	kg/m
2,77778E-04	3,60000E+03	0,000	kg/hour	2	kg/h
1,00000E-03	1,00000E+03	0,000	g/sec	3	g/s
1,66667E-05	6,00000E+04	0,000	g/min	4	g/m
2,77778E-07	3,60000E+06	0,000	g/hour	5	g/h
4,53590E-01	2,20463E-00	0,000	lb/sec	6	PPS
7,55980E-03	1,32279E+02	0,000	lb/min	7	PPM
1,25000E-04	8,00000E+03	0,000	lb/hour	8	PPH

Mass: **Type Code 9**			**Total mass**		**Mass**
1,00000E-00	1,00000E-00	0,000	kg	0	kg
1,00000E-03	1,00000E+03	0,000	g	1	g
4,53590E-01	2,20463E-00	0,000	lb	2	lb
1,00000E+03	1,00000E-03	0,000	t	3	t
Volume flow: **Type Code 1**			**Current volume flow** **Standard volume flow** **Reference volume flow**		**QVac** **QVno** **RQva**
1,00000E-00	1,00000E-00	0,000	m³/sec	0	m3/s
1,66667E-02	6,00000E+01	0,000	m³/min	1	m3/m
2,77778E-04	3,60000E+03	0,000	m³/hour	2	m3/h
1,00000E-03	1,00000E+03	0,000	Liter/sec	3	L/s
1,66667E-05	6,00000E+04	0,000	Liter/min	4	L/m
2,77778E-07	3,60000E+06	0,000	Liter/hour	5	L/h
1,00000E-06	1,00000E+06	0,000	cm³/sec	6	cm3s
1,66667E-08	6,00000E+07	0,000	cm³/min	7	cm3m
2,77778E-10	3,60000E+09	0,000	cm³/hour	8	cm3h
2,83170E-02	3,53145E+01	0,000	ft³/sec	9	CFS
4,71950E-04	2,11887E+03	0,000	ft³/min	10	CFM
7,86580E-06	1,27133E+05	0,000	ft³/hour	11	CFH
1,63870E-05	6,10240E+04	0,000	inch³/sec	12	CIS
2,73120E-07	3,66139E+06	0,000	inch³/min	13	CIM
4,55190E-09	2,19688E+08	0,000	inch³/h	14	CIH
1,00000E-06	1,00000E+06	0,000	cm³/sec	15	ml/s
1,66667E-08	6,00000E+07	0,000	cm³/min	16	ml/m
2,77778E-10	3,60000E+09	0,000	cm³/hour	17	ml/h
Volume: **Type Code 8**			**Current total volume** **Standard total volume** **Reference total volume**		**Avol** **Nvol** **Rvol**
1,00000E-00	1,00000E-00	0,000	m³	0	m3
1,00000E-03	1,00000E+03	0,000	Liter	1	Lit.
1,00000E-06	1,00000E+06	0,000	cm³	2	cm3
2,83170E-02	3,53145E+01	0,000	ft³	3	CF
1,63870E-05	6,10240E+04	0,000	inch³	4	CI
Density: **Type Code 3**			**Current density** **Standard density** **Reference density**		**ADen** **NDen** **RDen**
1,00000E-00	1,00000E-00	0,000	Kg/cubic meter	0	kgm3
1,00000E-03	1,00000E+03	0,000	g/cubic meter	1	g/m3
1,60185E+01	6,24278E-02	0,000	lb/cubic feet	2	lbcf
2,76799E+04	3,61273E-05	0,000	lb/cubic inch	3	lbci
Temperature: **Type Code 5**			**Temperature** **Reference temperature**		**Temp RTem**
1,00000E-00	1,00000E-00	0,000	Kelvin	0	"K
1,00000E-00	1,00000E-00	273,150	Celsius	1	"C
5,55556E-01	1,80000E-00	255,372	Fahrenheit	2	"F
5,55556E-01	1,80000E-00	0,000	Rankine	3	"R
Humidity: **Type Code 10**			**Humidity** **Reference humidity**		**Hum RHum**
1,00000E-00	1,00000E-00	0,000	Rel. humidity	0	-
1,00000E-02	1,00000E+02	0,000	Rel. humidity.[%]	1	%rH
Viscosity: **Type Code 4**			**Current viscosity** **Calibration viscosity** **Reference viscosity**		**AVis** **CVis** **RVis**

1,00000E-00	1,00000E-00	0,000	Pascal sec.	0	Pa*s
1,00000E-07	1,00000E+07	0,000	Micropoises	1	uPoi
1,00000E-03	1,00000E+03	0,000	Centipoises	2	cPoi
1,78583E+01	5,59965E-02	0,000	lbm / (in * s)	3	lbis
Time: **Type Code 7**			**Time:**		**TMea**
1,00000E-00	1,00000E-00	0,000	Second (s)	0	sec.
6,00000E+01	1,66667E-02	0,000	Minute (min)	1	min.
3,60000E+03	2,77778E-04	0,000	Hour (h)	2	hour
8,64000E+04	1,15741E-05	0,000	Day	3	day
1,00000E-03	1,00000E+03	0,000	Millisecond	4	msec
1,00000E-06	1,00000E+06	0,000	Microsecond	5	usec
Frequency: **Type Code 21**			**Frequency:**		**f**
1,00000E-00	1,00000E-00	0,000	Hertz	0	Hz
1,00000E+03	1,00000E-03	0,000	KiloHertz	1	kHz
1,00000E+06	1,00000E-06	0,000	MegaHertz	2	MHz
1,66667E-02	6,00000E+01	0,000	1/Minute	3	1/m
2,77778E-04	3,60000E+03	0,000	1/hour	4	1/h
Way / length: **Type Code 14**			**Measuring time:**		**D / d / S / s**
1,00000E-00	1,00000E-00	0,000	Meter (m)	0	m
1,00000E+02	1,00000E-02	0,000	Centimeter (cm)	1	cm
1,00000E+03	1,00000E-03	0,000	Millimeter (mm)	2	mm
1,00000E+03	1,00000E-03	0,000	Kilometer (m)	3	km
3,048006E-01	3,2808334E-00	0,000	Feet (ft)	4	feet
2,540005E-02	3,39370E+01	0,000	inch (in)	5	inch
9,144018E-01	1,0936111E-00	0,000	yard (yd)	6	yard
1,609344E+03	6,213711E-04	0,000	mile (mil)	7	mile
1,00000E+06	1,00000E-06	0,000	Micrometer (µ)	8	mu
Velocity: **Type Code 15**			**Velocity:**		**v**
1,00000E-00	1,00000E-00	0,000	Meter/second (m/s)	0	m/s
6,00000E+01	1,66667E-02	0,000	Meter/minute (m/min)	1	m/mi
3,60000E+03	2,77778E-04	0,000	Kilometer/hour (km/h)	2	km/h
1,00000E+03	1,00000E-03	0,000	Kilometer/second (m/s)	3	km/s
2,540005E-02	3,39370E+01	0,000	Inch/second (in/s)	4	in
3,048006E-01	3,2808334E-00	0,000	Foot/Second (ft/min)	5	ft/s
9,144018E-01	1,0936111E-00	0,000	Yard/second (yd/s)	6	yd/s
1,609344E+03	6,213711E-04	0,000	Mile/second (mil/s)	7	mils
2,68244E+01	3,72823E-2	0,000	Miles/minute (mil/min)	8	milm
4,47040E-00	2,23694E-00	0,000	Miles/hour (mil/h)	9	milh
5.14444E-01	1,94384E-00	0,000	Knots	10	knot
Acceleration: **Type Code 16**			**Acceleration:**		**a**
1,00000E-00	1,00000E-00	0,00	Meter/second^2 (m/s^2)	0	m/s2
3,048006E-01	3,2808334E-00	0,00	Feet/second^2 (ft/s^2)	1	fts2
Force: **Type Code 18**			**Force:**		**F**
1,00000E-00	1,00000E-00	0,00	Newton	0	N
1,00000E-05	1,00000E+05	0,00	Dyn	1	dyne
1,00000E+03	1,00000E-03	0,00	KiloNewton	2	kN
4,44822E-00	2,24809E-01	0,00	pound force	3	lbf
1,38255E-01	7,23301E+00	0,00	poundel	4	pdl
Energy: **Type Code 19**			**Energy:**		**W**
1,00000E-00	1,00000E-00	0,00	Joule	0	J

1,00000E-00	1,00000E-00	0,00	Wattsecond	1	Ws
3,60000E+03	2,77778E-04	0,00	Watthour	2	Wh
3,60000E+06	2,77778E-07	0,00	KiloWatthour	3	kWh
3,60000E+09	2,77778E-10	0,00	MegaWatthour	4	MWh
4,1868 E+00	2,38846E-01	0,00	Calorie	5	cal
4.1868 E+03	2,38849E-04	0,00	Kilocalorie	6	kcal
1,05506E+03	9,47813E-04	0,00	British Thermal Unit	7	btu
Power: Type Code 20			**Power:**		**P**
1,00000E-00	1,00000E-00	0,000	Watt	0	W
1,00000E+03	1,00000E-03	0,000	KiloWatt	1	kW
1,00000E+06	1,00000E-06	0,000	MegaWatt	2	MW
4,1868 E+00	2,38846E-01	0,000	Calorie/second	3	c/s
1,163 E+00	8,59845E-01	0,000	Kilocalorie / hour	4	kc/h
1,75843E+01	5,68688E-02	0,000	BTU/minute	5	btum
2,93072E-01	3,41213E+00	0,000	BTU/hour	6	btuh
Without dimension: Type Code 10			**Number of measuring values:**		**Nval**
1,00000E-00	1,00000E-00	0,000	without dimension factor 1	0	-
1,00000E-02	1,00000E+02	0,000	Percent %	1	%
1,00000E+03	1,00000E-03	0,000	Kilo	2	E+03
1,00000E+06	1,00000E-06	0,000	Mega	3	E+06
1,00000E-03	1,00000E+03	0,000	Milli	4	E-03
1,00000E-06	1,00000E+06	0,000	Micro	5	E-06
Voltage: Type Code 11			**Voltage:**		**U**
1,00000E-00	1,00000E-00	0,000	Volt	0	V
1,00000E-03	1,00000E+03	0,000	MilliVolt	1	mV
1,00000E-06	1,00000E+06	0,000	MicroVolt	2	uV
Current: Type Code 12			**Current:**		**I**
1,00000E-00	1,00000E-00	0,000	Ampere	0	A
1,00000E-03	1,00000E+03	0,000	Milliampere	1	mA
1,00000E-06	1,00000E+06	0,000	Microampere	2	uA
Resistance: Type Code 13			**Resistance:**		**R**
1,00000E-00	1,00000E-00	0,000	Ohm	0	Ohm
1,00000E-03	1,00000E+03	0,000	MilliOhm	1	mOhm
1,00000E+03	1,00000E-03	0,000	KiloOhm	2	kOhm
1,00000E+06	1,00000E-06	0,000	MegaOhm	3	MOhm

Table 83 Basis Units – Conversion (X and Y Factors)

Code 17: User definable, see chapter 9.5.4

11 Indications to the Methods of Calculation

11.1 Ideal gas law

The decisive tests for the description of the thermodynamic behaviour of gases were already carried out in the 19-th century by the French and English physicists Gay-Lussac, Boyle and Mariotte. They defined the ideal gas law:

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

The product of pressure and volume divided by the absolute temperature is consistent with a defined amount (mass m) of a gas.
The equation of state is precisely valid only for ideal gases, for real gases with good approximation, but not for vapors. The equation of state includes three special cases:

Overview:	**Special cases of the equation of state**		
Indication:	Isobar change of state	Isochor change of state	Isotherm change of state
Condition:	P=const.	V=const.	T=const.
Formula:	$\frac{V_1}{V_2} = \frac{T_1}{T_2}$	$\frac{p_1}{p_2} = \frac{T_1}{T_2}$	$\frac{p_1}{p_2} = \frac{V_2}{V_1}$
Law of:	Gay-Lussac	Gay-Lussac	Boyle-Mariotte

In pV/t = constant the numerical value of the constant quotient depends on the mass of the enclosed gas. If the equation refers to more than 1 kg of mass, a division by the mass m has to be made, resulting in:

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

There Ri is the **special gas constant** depending on the type of gas. If the special gas constant is multiplied by the molar mass M, the universal gas constant **R** = 8,314 J/kmol K is received. Using the definition for density

$$\rho = \frac{m}{V}$$

the following correlation can be derived for tightness:

$$\rho = \frac{p}{R_i \cdot T}$$

The density of an ideal gas at a known special gas constant Ri can be determined by the measured variables (absolute) pressure and temperature from this equation.

11.2 Correlation between the flow variables

Gases are compressible media and gas flow is thus depending on density. With the help of the continuity equation (law of the conservation of mass) the following correlation can be indicated for the flow of a gas:

$$\dot{m} = QMas = \rho \cdot QV = \rho_{ac} \cdot QVac = \rho_{no} \cdot QVno = \rho_{re} \cdot QVre$$

This correlation makes clear that the different volume flows can be converted into each other with the density ratio any time. In the following chapter the different volume flows computed by the LMF are briefly explained.

Among other things, the LMF makes available the following flow measured variables:

- current volume flow (QVac)
- mass flow (QMas)
- standard volume flow (QVno)
- reference volume flow (RQva)

Current volume flow (QVac)
The current volume flow (QVac) is determined on the input of the volume flow measuring instrument (e.g., LFE). It is the primary parameter of the LMF. The current volume flow results from the pressure drop of the LFE (differential pressure) in connection with the calibration data of the LFE (see calibration protocol, if necessary). With Laminar-Flow elements the basic principle for that is the law of Hagen-Poiseuille for the pressure drop in straight pipes which are laminar flowed. The current volume flow is corrected by the ratio of calibration viscosity to current viscosity. The calibration conditions are the conditions which existed with the calibration of the LFE and they have to be taken from the calibration data sheets of the LFE.
The current volume flow is to be understood as "surface" x "flow speed" = "volume per time ".
SI unit: m^3/s

Mass flow (QMas)
The mass flow in a section of a pipeline system sealed against external leaks is a constant. For the calculation of the mass flow the current volume flow is multiplied by the current density (at current temperature, current absolute pressure and current humidity).
SI Unit: kg/s

Standard volume flow (QVno)
The standard volume flow is a volume flow relating to a standard density. The standard density is normally determined by specifying the medium (e.g. air) and the standard conditions (pressure, temperature, humidity). Because there are different international and national standards and, furthermore, works standards deviating from this, specifying a standard volume flow is only then useful if it is known on which standard conditions the data is based. Examples of different standard conditions:

ANSI	1013.25 mbar	21.11°C	0 % relative humidity
ISO 6358	1000 mbar	20°C	0 % relative humidity
DIN 1343	1013.25 mbar	0°C	0 % relative humidity
DIN 2533	1013.25 mbar	15°C	0 % relative humidity

The standard conditions used in your system are determined in the parameters S0101, S0102 and S0103. Make sure that the values given there must be in SI units.

The standard volume flow is calculated in which the mass flow is divided by the standard density. Because the standard conditions once selected are determined, the conversion to the mass flow is always in a constant ratio, i.e. the standard volume flow is nothing else than a possible vivid synonym for the mass flow. In particular, the term "standard volume flow" need not necessarily have something to do with a test standard!
SI unit: m^3/s

Reference volume flow (RQva)
The reference volume flow is a calculated, actual volume flow related to a reference density. This can be determined similar to a standard volume flow by fixed defined reference conditions pressure, temperature and humidity, however, frequent interest is paid to e.g. the actual volume flow at the input of a unit, because the conditions there are normally different than at the input of the primary element for measuring the flow. If the conditions at the input of the unit are measured (= reference conditions) the LMF calculates the reference density and, thus, in the next step, the reference volume flow, by dividing the mass flow by the reference density. For details refer to Section 11.6.2.
SI unit: m^3/s

11.3 Adjustable types of gas

Settings Pn001, gas by primary element: operational kind of gas

Air under atmospheric conditions is often the standard calibration media of primary elements for cost reasons. By use of the real density calculation for air in a range of 5..35°C, 800..1200 hPa absolute pressure and 0..95% of relative humidity, announced by a BIPM recommendation, the highest calculation accuracies are achieved.
With precision applications the type of gas should possibly correspond with the operational type of gas when being calibrated.
If another type of gas is applied, it must be made sure that the Reynolds number of the flow to be measured is similar to the Reynolds number of the calibration. Then with LFE there is the option to operate with another operational type of gas as well.

As a default the following types of gas are deposited 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
15 - Water vapor
16 - Xenon
17 - Nitrogen monoxide
18 - Neon
19 - Krypton
20 - Propene
21 - Ethane
22 - Ethene
23 - Ammonia
24 - Sulfur dioxide

For other gases please ask TetraTec Instruments

11.4 Density calculation

The density is determined by the measured variables for temperature, absolute pressure and, if necessary, humidity. The following correlation can be used as a fist formula for the error estimation:

1° Temperature error, corresponds to
3 mbar pressure error, corresponds to
45% humidity error, corresponds to
appr. 0.3% of error with density calculation!

From this correlation the weighting of the sensors can be recognized, i.e., disregarding the humidity measurement causes the most minor error in the density calculation, for example.
With the LMF the density can be calculated according to different models. These models are adjusted in parameter Pn003. In the following the different arithmetic models are explained.

Ideal: [0] (Pn003=0)
With the setting ideal no real gas corrections will be carried out. The calculation runs purely according to the ideal gas law without consideration of the current humidity.

Real: [1] (Pn003=1)
With the setting Real [1] real gas corrections are carried out for high pressures. The calculation runs taking into account the Real gas behaviour. By means of real gas factors and their development according to virial coefficients the pressure behaviour of real gases is described. This arithmetic model applies to <u>all</u> (dry) gases and should be always used with pressures >4 bar even with air.

Real: [2] (Pn003=2)
With the setting Real [2] real gas corrections are carried out taking into account humidity. The calculation is made according to BIPM and PTB recommendations. This arithmetic model <u>only</u> applies to air ≤ 4 bar taking into account humidity and it is the default setting for air.

11.5 Viscosity calculation

The viscosity is determined from the measured variables for temperature and, if necessary, humidity. The following correlation can be used as a fist formula for the error estimation:

1° Temperature error, corresponds to
45% humidity error, corresponds to
appr. 0.2% of error with viscosity calculation!

The viscosity is absolutely independent of pressure up to approx. 7 bar. With the LMF the viscosity can be computed according to different models. These models are adjusted in parameter Pn004. In the following the different arithmetic models are explained.

Ideal:
With the setting ideal a universal temperature correction of the viscosity of pure gases is carried out. Thus, only the behaviour of dry air is considered. The calculation with all types of gas runs according to the recommendations of Daubert & Danner. It applies for a wide range of temperature.

Real:
With the setting real the exact viscosity correction is carried out, in addition, by taking into account humidity, this is the default setting for air. The calculation proceeds according to the law of Kestin-Whitelaw and it applies only for air.

Another arithmetic model for viscosity is planned for future times. This model should then, in addition, absolutely correct the pressure dependence of the viscosity with pressures ≥ 7 bar.

11.6 Measuring and reference sensors

The flow measurement requires specific input variables with predefined meanings, e.g. to calculate the density and viscosity. In addition, there are optional input variables whose meaning can be determined to a specific project. Allocation of the sensors is carried out at multiple levels:

- Initially, the sensors can be fundamentally allocated arbitrarily to the hardware input available. Normally, this allocation is determined at the start of the project by the project manager according to specific conventions. Subsequent change is no longer easily possible.
- Within the framework of commissioning, each sensor is allocated to a minimum of one linearization data set (S2nxx-Blocks, n = dataset number). Amongst other things, each linearization data set contains how the linearization procedure is determined, the compensation polynomial, an input and output scale, the serial number, monitoring limits and allocation to the hardware input. The sequence of the linearization data sets is generally arbitrary. More linearization data sets can also be allocated than is necessary for the flow measurement. For example, multiple linearization data sets can access the same hardware input (sensor), e.g. in order to be able to select between alternative linearization procedures.
- In the same manner, a minimum of one linearization data set can be created for each primary element (S4nxx-Blocks). This contains, et al., data about the type of primary element, medium, calibration conditions, compensation polynomial, scaling factors and serial number. If multiple types of gas or test conditions are used, there are frequently multiple linearization data sets for the same primary element.
- The P-Parameters are specific to the program. There are 10 programs that equate to the parameter blocks P0xx to P9xx. There are specific parameter blocks for specific input variables in each program. Here, amongst other things, it is determined which sensor is used for the according input variable, by selecting the suitable linearization data set.

An overview of the parameter blocks and their meanings are given as follows:

1. Pn000-Block: Primary element
   A primary element can be, e.g. an active pressure transmitter such as a LFE, an orifice or a Venturi tube. However, it can also be a counter, mass flow sensor etc.

2. Pn010-Block: Primary measurand
   If a primary element, e.g. a LFE, an orifice or a Venturi tube be used for the flow measurement, the primary measurand is the active pressure, i.e. the differential pressure between the input and output and constriction.

3. Pn020, Pn030 and Pn040-Blocks: Sensors for the measurement conditions
   To calculate the flow, the measurement conditions of static absolute pressure, temperature and relative humidity are required. Using these, the variables density and viscosity at the input of the primary element are calculated. In turn, these are required in order to calculate the volume flows and, insofar as the primary element is not a mass flow sensor, also the mass flow. Also refer to Sections 11.6.1.1, 11.6.1.3 and 11.6.1.4.
4. Pn050, Pn60 and Pn070-Blocks: Sensors for reference conditions
   Reference conditions at an arbitrary measuring point in the flow system, e.g. at the input of the unit (test conditions). Using the reference conditions, it is possible to calculate, e.g. the density at the location of the reference measuring point and, thus, if the mass flow is known, the local volume flow. In addition, the reference conditions can be used for correction calculations with the objective to compensate for external influences and, thus, to define a measured variable that only correlates with the existing characteristics of the unit.
   Also refer to Sections 11.6.2.1, 11.6.2.2 and 11.6.2.3.
5. Pn075, Pn080, Pn085, Pn090 and Pn095-Blocks: Auxiliary inputs
   The auxiliary inputs (Aux0 to Aux 4) can be arbitrarily defined, e.g. for additional relative or differential pressure sensors or a mass flow sensor.
   Also refer to Section 11.6.3.
   Special handling of mass flow sensor:
   In order to also interpret the signal of a mass flow sensor regarding the complete flow measurement as mass flow, the mass flow sensor must be established as a sensor, auxiliary input and as primary element:
   - Initially, it is created as a sensor in a S2nxx dataset, e.g. in the S27xx-Block
   - An auxiliary input accesses the linearization data set of this sensor, e.g. auxiliary input 0 (Pn075-Block). Then Pn075=7 is set.
   - Subsequently, the mass flow sensor is created in a S4nxx dataset as a primary element, e.g. in the S43xx-Block. Then S4300=100 is set (type direct mass flow input) and S4330=0 is set (auxiliary input 0)
6. S9010-Block: Basic system pressure
   The basic system pressure is the central absolute pressure that is used to be able to convert the relative pressure to absolute pressures. The relative pressures are frequently correlated to the ambient pressure. In this case, the basic system pressure is synonymous with the barometric ambient pressure.

The following sections give an overview of the different settings of the sensors that can be connected to determine the density and viscosity at the LMF (independent of the primary element).

11.6.1 Measuring sensors

11.6.1.1 Pdiff

Difference of the pressure of the gas at the pressure tabs of the primary element (LFE, Venturi tube or orifice).

Measuring by:

Differential pressure sensor Pn010	Measuring the differential pressure at the pressure tabs of the primary element using a differential pressure sensor (Pn010 contains the number of the dataset for linearization of the differential pressure sensor)

11.6.1.2 Pabs

Absolute pressure of the gas in the inlet section of the primary element (LFE, gas meter or nozzle).

Measuring alternatively by:

Absolute pressure sensor Pn020	Measuring the absolute pressure at the input of the primary element using an absolute pressure sensor (Pn020 contains the number of the dataset for linearization of the absolute pressure sensor)
Relative pressure sensor Pn020	The absolute pressure is calculated (refer to the arithmetic value) by measuring the relative pressure at the input of the primary element and this is added to the centrally measured ambient absolute pressure (= system absolute pressure.
Constants Pn021	Input of the absolute pressure, in Pascal, in parameter Pn021 as a constant value if Pn020 is set to -1.
Arithmetic value Pn024	In Pn024, an arbitrary term can be defined that overwrites the value determined by Pn020 and Pn021, which itself is available as "THIS“. The term "THIS + RPAR[0]“ is frequent. Significance: relative pressure measured in Pn020 + system absolute pressure For the system absolute pressure, refer to parameter S9010 to S9014 (Section 9.7.30)

11.6.1.3 Temp

Temperature of the gas in the inlet section of the primary element (LFE, gas meter or nozzle).

Measuring alternatively by:

Sensor Pn030	Measuring the temperature in the gas flow using a temperature sensor (Pn030 contains the number of the dataset for linearization of the temperature sensor)
Constants Pn031	Input of the temperature, in Kelvin, in parameter Pn031 as a constant value if Pn030 is set to -1

11.6.1.4 Hum

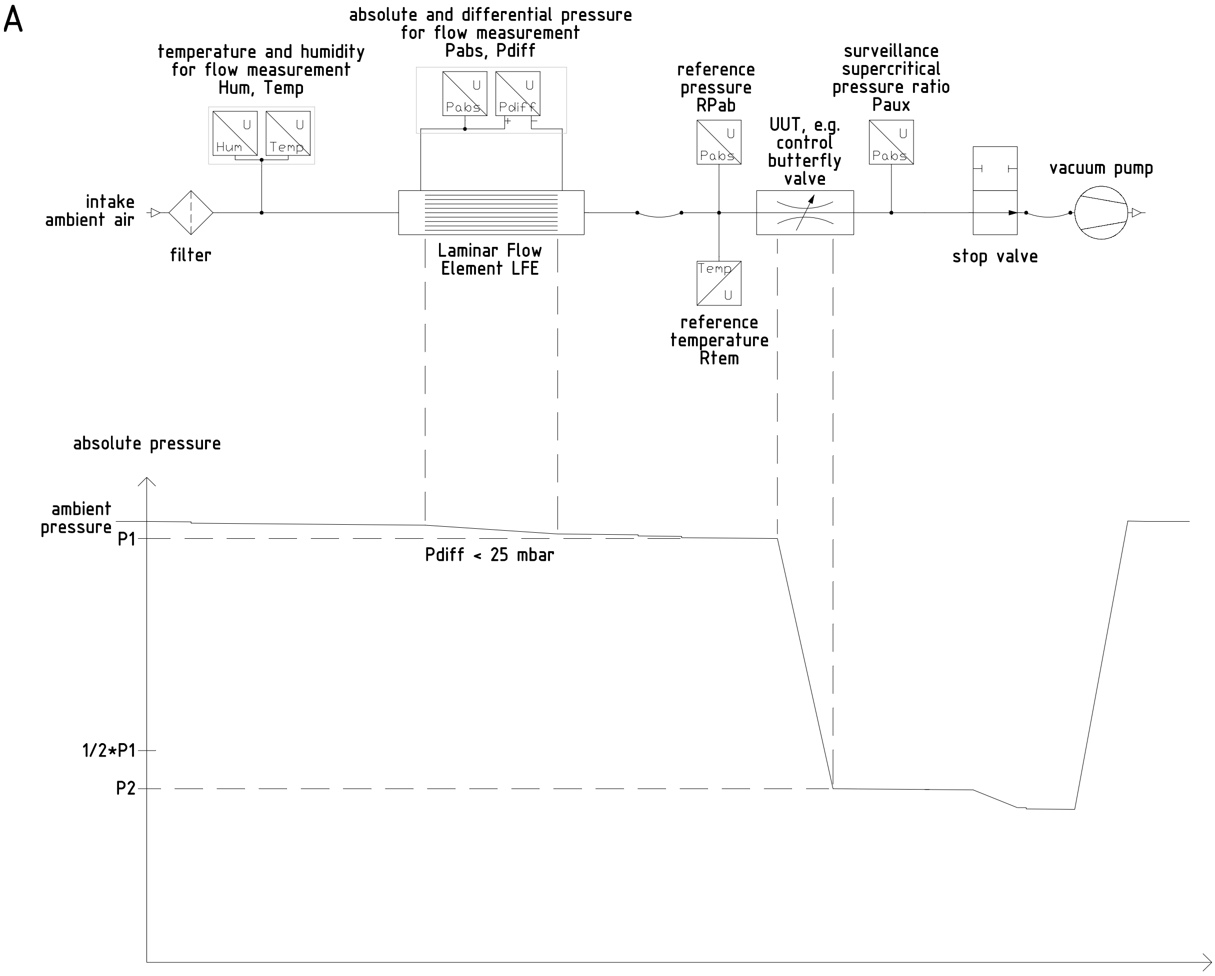
Relative humidity of the gas in inlet section of the primary element (LFE, gas meter or nozzle).

Measuring alternatively by:

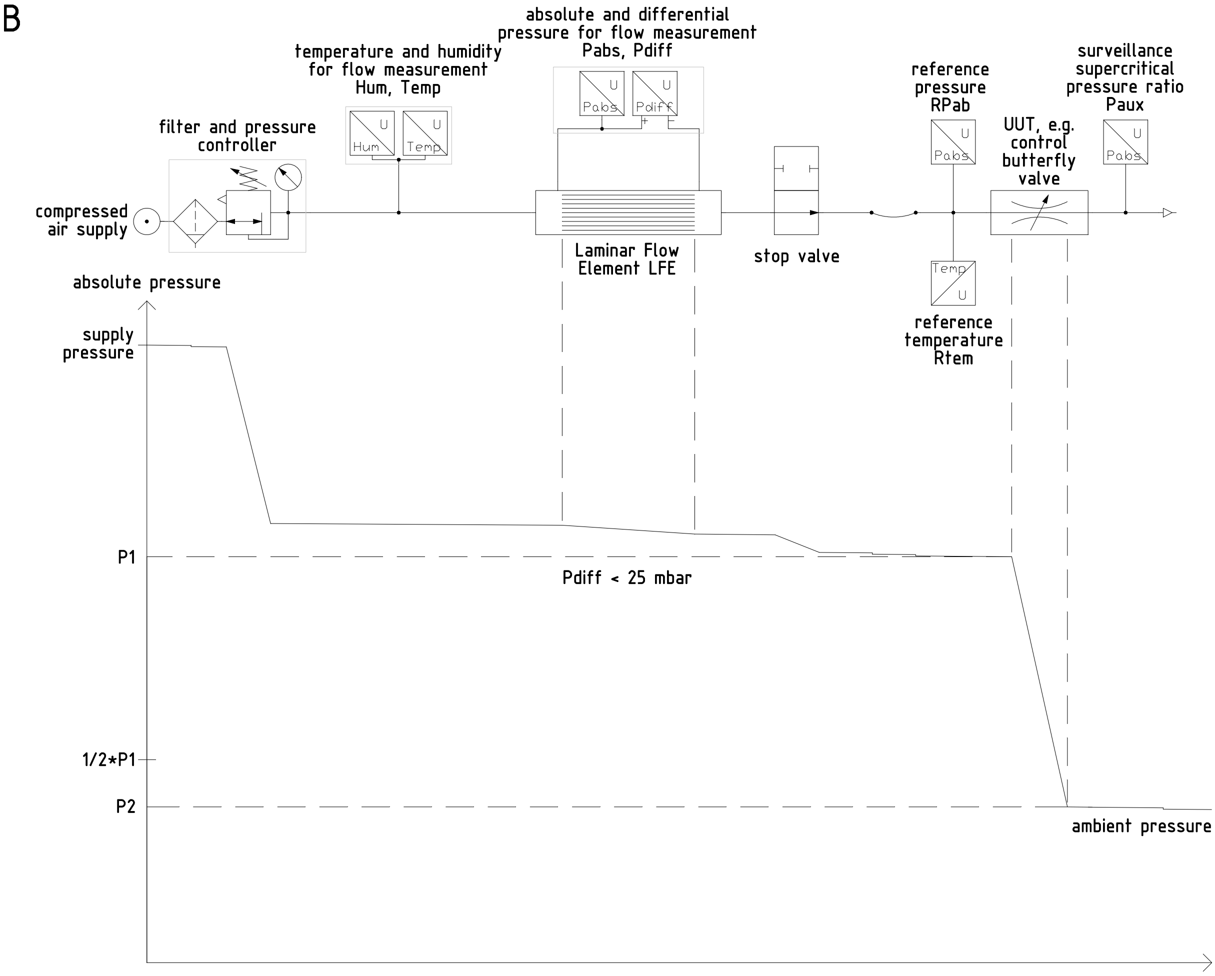
Sensor Pn040	Measuring the rel. humidity in the gas flow using a humidity sensor (Pn040 contains the number of the dataset for linearization of the humidity sensor)
Constants Pn041	Input of the relative humidity in parameter Pn041 as a constant value if Pn040 is set to -1
Arithmetic value Pn044	In Pn044, an arbitrary term can be defined that overwrites the value determined by Pn040 and Pn041, which itself is available as "THIS“. On rare occasions, instead of using a sensor for the relative humidity, e.g. a sensor is used that directly emits the molar humidity or dew point temperature. The term in Pn044 then calculates the relative humidity, because the flow calculation requires this as input variable. For this, the functions XV and RELHUM are available, refer to Chapter 6.3.5.

11.6.2 Reference sensors

It is not always possible to operate the primary element for the flow measurement (e.g. a Laminar-Flow-Element) under the same conditions (pressure, temperature, humidity) as the unit. Depending on the characteristics of the unit and objective of the measurement, different measuring attachments are used, two examples as follows:



Pressure profile along the measuring section with supercritical measurement using underpressure



Pressure profile along the measuring section with supercritical measurement using compressed air

In order to be able to transmit the flow measurement value to the conditions at the unit, reference sensors are used. Thereby, exploitation is made of the fact that the mass flow in a section of a pipeline system sealed against external leaks is a constant; and the molar humidity as well, so fare there are no condensation, chemical or sorption processes. Therefore, the LMF not only always calculates the volume flow at the primary element, but also the density at the input of the primary element and, in the next step, the mass flow. Using the reference conditions RPab, RTem, Rhum, the density can at the input of the unit can be calculated and, thus, in the next step, also the volume flow prevailing there.

Note
The reference calculation is only carried out if it is interpolated in Pn300!

11.6.2.1 RPab

Absolute pressure of the gas at the input of the unit

Measuring alternatively by:

Absolute pressure sensor Pn050	Measuring the absolute pressure at the input of the primary element using an absolute pressure sensor (Pn050 contains the number of the dataset for linearization of the absolute pressure sensor)
Relative pressure sensor Pn050	The absolute pressure is calculated (refer to the arithmetic value) by measuring the relative pressure at the input of the unit and adding this to the centrally measured ambient absolute pressure (= system absolute pressure.
Constants Pn051	Input of the absolute pressure, in Pascal, in parameter Pn051 as a constant value if Pn050 is set to -1.
Arithmetic value Pn054	In Pn054, an arbitrary term can be defined that overwrites the value determined by Pn050 and Pn051, which itself is available as "THIS“. The term "THIS + RPAR[0]“ is frequent. Significance: relative pressure measured in Pn050 + system absolute pressure For the system absolute pressure, refer to parameter S9010 to S9014 (Section 9.7.30)

11.6.2.2 Rtem

Temperature of the gas at the input of the unit.

Measuring alternatively by:

Sensor Pn060	Measuring the temperature in the gas flow using a temperature sensor (Pn060 contains the number of the dataset for linearization of the temperature sensor)
Constants Pn061	Input of the temperature, in Kelvin, in parameter Pn061 as a constant value if Pn060 is set to -1

Note
If it is anticipated that no significant changes in temperature occur between the primary element and unit and no excessive requirements are placed on the accuracy, there is no requirement for the sensor for the temperature at the input of the unit. In this case, Pn060 is set to the same linearization data set as the temperature sensor at the input of the primary element (Pn030).

11.6.2.3 Rhum

Relative humidity of the gas at the input of the unit

Measuring alternatively by:

Sensor Pn070	Measuring the rel. humidity in the gas flow using a humidity sensor (Pn070 contains the number of the dataset for linearization of the humidity sensor)
Constants Pn071	Input of the relative humidity in parameter Pn071 as a constant value if Pn070 is set to -1
Arithmetic value Pn074	In Pn074, an arbitrary term can be defined that overwrites the value determined by Pn070 and Pn071, which itself is available as "THIS“. Very frequently, a second humidity sensor is not required and the fact that the molar humidity in a section of a pipeline system sealed against external leaks is a constant, as long as no condensation, evaporation or chemical reaction takes place. Here, also refer to functions XV and RELHUM, Chapter 6.3.5.

11.6.3 Auxiliary

Up to five auxiliary inputs are available. The term "auxiliary input“ is possibly somewhat confusing. It does not necessarily indicate additional electrical inputs, but is primarily an extension of the LMF software, with which further sensor values can be integrated without predefined application. That can be other sensors, it can also be the same sensors again integrated that are already integrated for the predefined applications. Frequent applications:

- If the actual measurement value is overwritten by a term (e.g. in Pn024), the actual measurement value is also required (e.g. in order to present it on the display), an auxiliary input is readily used that accesses the same linearization data set, however, without a correction term. Frequently used for relative pressure sensors utilized for determining the absolute measuring pressure, using a correction term in Pn024.
- If multiple sensors are operated in parallel for the same measuring task (e.g. with different measuring ranges), it is desired that all sensor values are presented on the display and not only those currently used. In this case, these sensors are readily applied to an auxiliary input, parallel to the application for the flow calculation.
- If other measurands should be recorded in addition to the flow and if it is only for the purpose of documentation, the associated sensors are applied to the auxiliary inputs. Examples: Sensors for travel, force, control signal at the unit etc.

11.7 Correction calculations

For industrial measuring tasks, it is frequently not the flow itself that is interesting, but to determine a specific characteristic of the unit using the flow, e.g. the diameter of an opening. However, because the flow is not only dependent on this characteristic of the unit, but also from further influencing variables, e.g. temperature and ambient pressure, comparability of the measured values can be improved by compensating these influences using correction calculations. Thereby, it is not only about the comparability of the measured values of different units measured in one day but, in particular, about the long-term stability. Briefly: A measured value is required that is not dependent on the weather.
A prerequisite for such correction calculations is that the physical characteristics of the flow through the unit is known and the influences to be compensated can be modelled.

11.7.1 Correction calculations for the LMF

The LMF supports different correction calculations for different physical models, also refer to Pn300-Block, Section 9.8.16. The results are available in the parameters Ry051 to Ry054 (whereby, y stands for the measuring circuit number).

Note
The correction calculations are only carried out if the reference calculation is interpolated in Pn300 and a correction procedure is selected in Pn301.

Detail information about the different correction calculations:

a) Correction of speed of sound (Pn301=1)
If nozzles with an overcritical pressure ratio (empirical formula: input pressure = double output pressure) are used, the actual speed of sound is attained in the tightest cross-section of the nozzle, which implies that the actual volume flow of a nozzle operated overcritically only depends on the speed of sound. With the speed of sound correction, temperature dependency on the speed of sound is standardized on a correction temperature (Pn303). This compensates fluctuations of the volume flow due to changes of the actual speed of sound.
Correction factor for the actual volume flow for the initial approximation:

$$f_{corr.} = \sqrt{\frac{T_0}{T_{act.}}}$$

The calculation requires all input variables air pressure (Pn302), the temperature (Pn303) and humidity (Pn304)

b) Density correction for orifice with Δp = constant (Pn301=2, Pn305="1")
If nozzles are operated below the critical pressure ratio, they have the characteristics of orifices. The following correlation applies to orifices for the actual volume flow:

$$\dot{V} = c \cdot \sqrt{\frac{\Delta p}{\rho_{act.}}}$$

This correlation is a simplification which can be derived from the Bernoulli equation. From this correlation, the dependency of the actual volume flow from the actual differential pressure and the current density is detected. A lower density with the same differential pressure, i.e. the propelling force of the volume flow, effects a greater speed of flow. A greater current volume flow (= surface x speed) is the result. In order to compensate this change of the volume flow, by applying the density correction, the volume flow is standardized to a correction density with correction values for the air pressure (Pn302), temperature (Pn303) and humidity (Pn304) and the ratio of the differential pressures (Pn305) set to "1". Correction factor for the actual volume flow:

$$f_{corr.} = \sqrt{\frac{\rho_{act.}}{\rho_0}}$$

c) Density correction for orifice with variable differential pressure (Pn301=2, Pn305="Term")
The density correction for variable differential pressure is carried out the same as for the density correction for Δp = constant. However, in addition, the differential pressure to change is standardized to a correction differential pressure. The characteristics of the differential pressures must then be calculated in the term in Pn305. Correction factor for the actual volume flow:

$$f_{corr.} = \sqrt{\frac{\rho_{act.} \cdot \Delta p_0}{\rho_0 \cdot \Delta p_{act.}}} = \sqrt{\frac{\rho_{act.}}{\rho_0} \cdot result(Term)}$$

d) Viscosity correction for laminar test leaks for ∆p = constant (Pn301=3, Pn305="1")
When air or gas flows through thin tubes (capillaries) a flow is generated proportional to the pressure drop. According to the law of Hagen-Poiseuille, the flow through this tube can be described dependent on the differential pressure and actual viscosity as follows:

$$\dot{V} = c \cdot \frac{\Delta p}{\eta}$$

The viscosity primarily depends on the temperature, which is the reason why this is standardized to the correction temperature (Pn303). Correction factor for the actual volume flow for the initial approximation:

$$f_{corr.} = \frac{\eta_{act.}}{\eta_0}$$

The calculation requires all input variables air pressure (Pn302), the temperature (Pn303) and humidity (Pn304)

e) Viscosity correction for laminar test leaks with variable differential pressure (Pn301=3, Pn305="Term")
The viscosity correction for variable differential pressure is carried out the same as for the density correction for ∆p = constant. However, in addition, the differential pressure to change is standardized to a correction differential pressure. The characteristics of the differential pressures must then be calculated in the term in Pn305. Correction factor for the actual volume flow:

$$f_{corr.} = \frac{\eta_{act.}}{\eta_0} \cdot result(Term)$$

f) Arbitrary correction (Pn301=4, Pn306="Term")
In the event that the models mentioned above are insufficient, an arbitrary correction formula can be defined in Pn306.

11.7.2 Example: corrected mass flow

The procedure for correction of physical effects on the example corrected ("standardized") mass flow of air, on the one hand theoretically and, on the other hand practically (setting the appropriate parameters) are explained as follows. This procedure is applied, e.g. for measuring the characteristic curve of control butterfly valves, on which the mass flow should be presented as a function of the valve position with constant differential pressure across the valve. Hereby, measurement of the mass flow is carried out with the aid of the LMF, using a LFE as primary element.

Based on the actual mass flow, the corrected mass flow $\dot{M}_{corr.}$ should be calculated with the aid of a correction calculation.
The objective of this correction is to calculate a mass flow that is independent of the actual ambient conditions, i.e. the actual density.
Here, initially a density is defined for correction conditions = ρ_0. The correction conditions are determined values for air pressure (Pn302), temperature (Pn303) and humidity (Pn304).
The mass flow is corrected to these conditions.

Mass flow for a control element with orifice characteristics (e.g. control butterfly valve):
The volume flow for an orifice can be described with the following correlation:

$$\dot{V} = c \cdot \sqrt{\frac{\Delta p}{\rho_{act.}}}$$

whereby, the constant c is the orifice factor which, amongst other things, includes the geometry of the orifice and similar. Assuming Δp = constant and after multiplication by $\rho_{act.}$ the result for the actual mass flow is:

$$\dot{M} = c_2 \cdot \sqrt{\rho_{act.}}$$

From the dependency of the mass flow on the actual density, it can be explained why the same unit provides different characteristic curves on different days according to weather, i.e. actual density.

The mass flow for a final control element with orifice characteristics for correction conditions, i.e. for the correction density ρ_0 the mass flow can be defined as: $\dot{M}_0 = c_2 \cdot \sqrt{\rho_0}$.

The objective is to maintain a constant measurand for the mass flow. For this purpose, the corrected mass flow is $\dot{M}_{corr.} = \dot{M}_0 = \dot{M} \cdot f_{corr.}$ defined. For the correction factor, inserting and resolving in accordance with f_{corr}. results in:

$$f_{corr.} = \frac{c_2 \cdot \sqrt{\rho_0}}{c_2 \cdot \sqrt{\rho_{act.}}} = \sqrt{\frac{\rho_0}{\rho_{act.}}}$$

This is the correction function that we recognize from the previous section, Point b).

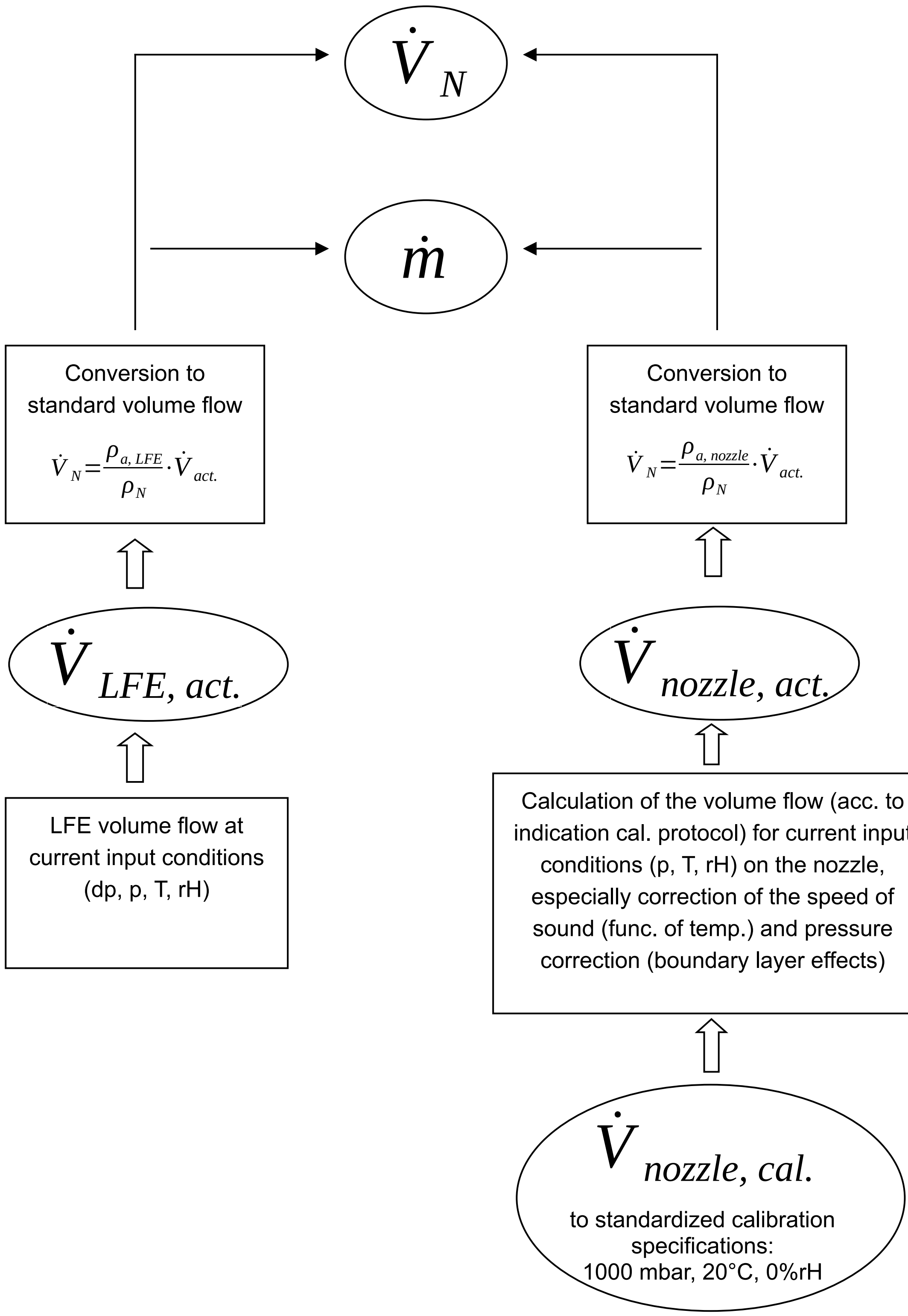
Specific example
Assuming that we require the correction in program 0, the following parameter settings are necessary:

P0300=1	Reference calculation is necessary, otherwise the complete correction calculation does not make sense
P0301=2	Correction calculation for orifices
P0302=101325.0	Absolute pressure on which the correction should be based, in Pascal (example)
P0303=293.15	Temperature on which the correction should be based, in °K (example)
P0304=0.0	Humidity on which the correction should be based, dimensionless (example)
P0305="1"	No further correction factor

Assuming that we have a system with only one measuring circuit, the corrected mass flow is available with parameter R0054.

11.7.3 Calibration of the LMF with the help of calibration leaks

A widespread method of checking the calibration of a volume flow measuring instrument is the comparison with an overcritical nozzle. The overcritical nozzle sets a current volume flow which is largely independent of density. To compare two volume flow measuring systems with each other, the comparison of the mass flows is usually used. The following scheme should give an overview of the arithmetic steps which are necessary to compare a calibrated nozzle to the measurement values of the LMF:



12 Linearization of Sensors and Primary Elements

The linearization of the sensors increases the measuring accuracy. Even the exchange of a linearized sensor is possible with minimum deviations of the complete system. It is sufficient then to also replace the data of linearization.

The linearization of a primary element has to be distinguished from that. Here the topic is the calculation of a flow rate. In the first attempt it could be calculated from the linearized sensor data and the indications for the configuration of the primary element according to the valid theory respectively. Nevertheless, there are light deviations in reality. They are measured during calibration and corrected by means of the linearization polynomial.

12.1 Linearization of the analogous value sensors with analogous or serial output

Up to 20 linearization data sets for analogous or serial sensors can be defined. At the same time, the number of sensors with analogous output signal is limited by number and type of the analogous input cards (maximum 10 with 5 Typ100 cards). The LMF is typically equipped and configured according to the application. The LMF offers three different linearization options:

0. Polynomial linearization
1. PT100/PT100 / PT1000 Linearization
2. No linearization (linear according to the raw values of the sensors)

The correlation between sensor signal (raw value, x) and physical value (measurement value, y) is measured within the scope of the calibration. Any calibration supporting point delivers a value pair (xi, yi). The values xi and yi lie in the intervals X and Y. Now a distinction has to be made between scaling and linearization.
At first the scaling has to be determined, since it influences the coefficients of the linearization polynomial. With the help of the scaling factors Fx and Fy the values xi and yi can be mapped, e.g., in the numerically advantageous interval [0...1. Or the values of the units used with the measurement can be converted to divergent units, e.g., SI units. For the special case that the scaling factor has the value 1.0 the linearization polynomial maps the raw values immediately on the (corrected) measurement value.
The linearization is the attempt to map the (scaled) raw values of the sensor on the physical value which the master sensor has measured during calibration with an error as small as possible. For this purpose the polynomial having the smallest deviations compared with the calibration supporting points (method of the smallest error squares) is determined by means of established numerical processes.

Example of a linearization:

Sensor signal (mA / V)	⇨	X factor =1.0 (S2x20)	⇨	Linearization polynomial (S2x10 to 19)	⇨	Y factor =1/SI-Factor (S2x21)	⇨	Sensor value in SI units
x_s		Fx		y = p(x)		Fy		Ya

The linearization polynomial p (x) of the sensor signal is calculated by the following equation:

$$y = a_0 + a_1 x + \cdots + a_8 x^8 + a_9 x^9$$

The scaling factors and the linearization polynomial are used in such a way that each sensor value x_s is at first multiplied by the X factor Fx, then the function value of the linearization polynomial p (x) is calculated at this point and this function value is still converted by division of Fy in SI units.

Note
Regardless of the unit used with the calibration or the desired output the conversion to SI units is obligatory, since the LMF internally operates exclusively in SI units. A suitable selection of Fy must be observed. The unit for the output is defined at another place and it can be selected arbitrarily.
The final calculation is then:

$$y_a = \frac{a_0 + a_1 x + \cdots + a_8 x^8 + a_9 x^9}{Fy}$$

A list of the suitable factors is included in section 10.

Example of a sensor linearization
There is the correction polynomial of a pressure sensor to be connected which supplies a signal of 0-10 V and which is calibrated on 0 - 20 mbar (according to the pressure value) lying in front of you. The value read in by the sensor, e.g., 0-10V serves as input quantity for the correction calculation. Since for this example this already corresponds with the required polynomial input quantity, the X factor has to be selected with 1.0. As a polynomial output size 0 - 20mbar is received. For the processing of the sensor the measurement value is required in SI units, i.e., in Pascal. The Y factor, by which the polynomial value is divided, is used for conversion. The Y factor is 1.0E-02 in this example, because 1 mbar = 100 Pa or 1 Pa = 1.0E-02 mbar.

12.2 Linearization of primary elements

The LMF can manage up to 140 different linearization data sets for primary elements. The following primary element types are supported by the LMF (see definition parameter S4x00, chapter 9.7.18):

- LFE according to Hagen-Poiseuille or Universal Flow
- Critical nozzles according to PTB or CFO
- Orifices with different pressure-extracting assemblies
- Pitot tubes / Accutubes according to manufacturer's regulation
- Different types of Venturi nozzles and Venturi tubes
- SAO nozzles
- Accutubes
- Beta-Flows (Pdiff or polynomial about Reynolds number)
- Gas meter
- Mass flow meters (direct input)

The theory of these primary elements is partially so complicated that their complete description would go beyond the scope of this reference manual. This is why the characteristics of these primary elements will only be treated briefly.

12.2.1 LFE according to Hagen-Poiseuille

Linearization increases the measuring accuracy. The LMF is typically equipped and configured according to the application. A change, e.g., of the LFE data is only required with change, fouling or cleaning of a LFE. The principal approach corresponds with that being described in chapter 12.1 The input quantity of the LFE linearization according to Hagen-Poiseuille is, for example, the originating differential pressure. The output quantity is the current volume flow. The calculation of the LMF calculates the differential pressure in Pascal. If another polynomial input scaling is required, it will be correspondingly converted with the help of the X factor = 1/SI factor (table see chapter 10). The volume flow in the polynomial output scaling must scaled back again tot the SI unit with the Y factor.

SI unit [Pa] Pdif	⇨	X factor =1/SI- Factor (S4x20)	⇨	Polynomial linearization In: Pdif out: QVac (S4x10 to 19)	⇨	Y factor =1/SI- Factor (S4x21)	⇨	SI unit (m^3/s) QVac

Example
There is the correction polynomial of a used LFE with the input quantity in 0 - 8 inches water column (inWC) for the differential pressure and the output size 0 - 150 ccm/min (according to the flow) lying in front of you.

The internal calculation calculates the measured differential pressure with the SI unit Pa. With the help of the X factor the pressure in Pa will be scaled on the necessary polynomial input quantity. In this example the X factor is (S5x020 =) 4,01463E-03.
As a polynomial output size 0 - 150 cfm/min is received (cubic feet per minute). For further processing the result is required in SI unit, i.e., in m3 / sec. The Y factor serves for conversion. In this example the Y factor is (S5x021 =) 2,11887E+03 for the conversion from cfm/min to m3/sec.

12.2.2 LFE according to Universal Flow

If laminar flow elements are used with higher pressures, the atmospheric calibration according to Hagen-Poiseuille fails, since, e.g., density, viscosity and pressure are no independent variables. With these applications the Universal Flow calibration is used. This is a process in which the calibration supporting points are converted to independent variables at first.

12.2.3 Overcritical nozzles according to DIN EN ISO 9300

Overcritical nozzles supply a current volume flow which is widely independent of input pressure and output pressure. But it is necessary there that the overcritical nozzles are operated with a pressure ratio pe/pa ≥ 2. Basic principle for this effect is that with a overcritically operated nozzle the flow reaches speed of sound in the smallest cross section. The speed of sound depends (indirectly) on temperature. To compensate the temperature dependence with the evaluation of the overcritical nozzle, a temperature measurement is necessary in addition to pressure measurement therefore.

12.2.4 Gas meter

When calibrating data for gas meters irregularities of the gas meter are compensated with the help of the linearization polynomial. These irregularities are based, e.g., on leakage, friction, resonances and machining tolerances.

12.2.5 Orifices, Venturi tubes, Pitot tubes / Accutubes...

With these so-called “square root devices” a pressure drop arises, which is proportionally to the square of the volume flow or, in other words, the volume flow is proportional to the square root of the measured pressure drop:

$$\dot{V} \sim \sqrt{\Delta p}$$

“Square root devices”, as a rule, can only be used in the measuring range 1:6, since the differential pressure must be measured otherwise with a too high (any more payable) accuracy.
Another important size in the operation of these primary elements is the Reynolds number. The Reynolds number characterizes the flow and it is taken into consideration with the calculation of the volume flow

13 Allocation of the Sensors and Primary Elements

The allocation of the sensors and the primary elements to the measuring sections and programs shall be explained with an example.

Example
A double section measuring instrument is equipped with 7 sensors and 2 LFE.

Sensor 0:	Differential pressure (active pressure), section 0; Parameter set: S2000 - S2031 for linearization
Sensor 1:	Absolute pressure, section 0; Parameter set: S2100 - S2131 for linearization
Sensor 2:	Gas temperature, section 0; Parameter set: S2200 - S2231 for linearization
Sensor 3:	Humidity, section 0; Parameter set: S2300 - S3231 for linearization
Sensor 4:	Differential pressure (active pressure), section 1; Parameter set: S2400 - S2431 for linearization
Sensor 5:	Absolute pressure, section 1; Parameter set: S2500 - S2531 for linearization
Sensor 6:	Gas temperature, section 1; Parameter set: S2600 - S2631 for linearization
LFE 0:	LFE, section 0; Parameter set: S4000 – S4022 for linearization
LFE 1:	LFE, section 1; Parameter set: S4100 – S4122 for linearization

At first a program is allocated to the measuring circuits (section 0 or section 1):
S1000 = 0
S1001 = 4

Section 0 is evaluated therefore with measuring program 0, section 1 is evaluated with measuring program 4.

Each measuring program now needs the different input quantities for the flow calculation.

Program 0:
P0000 = 0; in program 0 the primary element defined in parameter set P4000 to P4022 is evaluated
P0010 = 0; in program 0 sensor 0 is used for the differential pressure measurement
P0020 = 1; in program 0 sensor 1 is used for the absolute pressure measurement
P0030 = 2; in program 0 sensor 2 is used for the temperature measurement
P0040 = 3; in program 0 sensor 3 is used for the humidity measurement
P0050 = -1; in program 0 the fixed value from P0051 is used for the absolute reference pressure
P0060 = -1; in program 0 the fixed value from P0061 is used for the reference temperature
P0070 = -1; in program 0 the fixed value from P0071 is used for the reference humidity

Program 4:
P4000 = 1; in program 4 the primary element defined in parameter set P4100 to P4122 is evaluated
P4010 = 4; in program 4 sensor 4 is used for the differential pressure measurement
P4020 = 5; in program 4 sensor 5 is used for the absolute pressure measurement
P4030 = 6; in program 4 sensor 6 is used for the temperature measurement
P4040 = -1; in program 4 the fixed value from P4041 is used for humidity
P4050 = -1; in program 4 the fixed value from P4051 is used for the absolute reference pressure
P4060 = -1; in program 4 the fixed value from P4061 is used for the reference temperature
P4070 = -1; in program 4 the fixed value from P4071 is used for the reference humidity

Thus the basic configuration is specified for each of both measuring programs and the desired sensors are taken into consideration for the measurement.
Now the fine tuning in the next steps remains:
Units, comma place, measured variables etc. must be configured for the display.

14 Measuring and Correction Processes

A widespread measuring method for the measurement of gap geometries, annular gap geometries, nozzle geometries, opening geometries and orifice geometries is the flow of air and the measurement of the volume flow or mass flow. It is assumed that the test sample behaves like a more or less critically flowed nozzle. There three measurement setups must be distinguished.

Method 1:
The test sample is charged with compressed air (mostly approx. The out flowing air is measured **behind** the test sample with the LFE. The volume flow by the test sample depends on the following quantities:

- Absolute pressure before the test sample (roughly proportional).
- Temperature of the test air (proportional to the square root of the absolute temperature).
- Absolute pressure on the outlet side (atmospheric pressure), the dependence is proportional roughly vice versa.

To compensate the variations of the atmospheric pressure, the volume flow on the outlet side of the test sample must be converted to standard conditions therefore, i.e., the standard volume flow must be evaluated.

In addition, with highly fluctuating inlet pressure the absolute pressure before the test sample must be measured as an inlet pressure correction. The temperature of the test air may also deviate from the air flowing through the LFE. Therefore, the test air temperature can be measured with an additional temperature sensor.

The LFE will be possibly contaminated with this arrangement by dust, splinters, abrasion and oil of the test sample. The installation of a filter is highly recommended.

Method 2:
The test sample is charged with compressed air (mostly approx. The volume **before** the test sample is measured by means of LFE. For evaluation the volume flow must be consulted.
The volume flow before the test sample is depending on the following quantities:

- Temperature of the test air (proportional to the square root of the absolute temperature).
- It is little depending on the absolute pressure of the test air (an ideal critically flowed nozzle would set the volume flow independent of the inlet pressure) and very little depending on the outlet pressure (atmospheric pressure).

The LFE can be operated with this method by guaranteed dry, dust-free and oil-free air.

Method 3:
The test sample is connected to a vacuum pump. The volume flow before the test sample (air intake from the atmosphere) is measured by LFE. With this measuring method the volume flow is also valued.
The volume flow before the test sample is depending on the following quantities:

- Temperature of the test air (proportional to the square root of the absolute temperature)
- It is little depending on the absolute pressure of the test air, which is the atmospheric air pressure with this arrangement. A overcritically flowed nozzle would set the volume flow almost independently of the inlet pressure. It is very little depending on the suction pressure of the vacuum pump, provided that the critical pressure ratio is kept.

Even here the LFE cannot be contaminated by the test samples. However, the atmospheric air should be filtered.

A correction of the temperature dependence of the flow by the test sample has to be carried out as with measuring method 2.

Particularly the subcontractors to the automotive industry check and calibrate many final control elements which are for setting a certain air mass flow (no-load operation actuator, E-gas flaps, venting valves). Therefore, mass flow values are often prescribed in test specifications.

However, for testing geometry, outlet characteristics, etc. in manufacturing the mass flow is not a suitable size for evaluation, but - depending on the measurement setup - only volume flow or standard volume flow are so. The evaluation of the mass flow would introduce the same undesirable dependencies of the measurement value of test air and ambient conditions to method 2 and 3 as method 1!

TetraTec Instruments recommends method 3 for the measurement of new products, the test specifications of which are still not determined, since this method includes the simplest and safest test section design and shows the quickest response time (= shortest stabilization time of the flow conditions) and the slightest fouling problems.

15 Uncertainty of Measurement Budget

15.1 Basic considerations Qv, Qm, r(p, T, xv)

The determination of the current volume flow Q_v in the test sample is done generally by the measurement of the current volume flow on the normal comparative value (master) and conversion to the conditions on the test sample by the density ratio (density r).

$$Q_{v,\ testsample} = Q_{v,\ Master} \cdot \frac{\rho_{Master}}{\rho_{testsample}}$$

The measured variable mass flow (Q_m) is calculated as the product of current volume flow and density and it is identical on each point of the measuring system

$$Q_{m,\ testsample} = Q_{m,\ Master} = Q_{v,\ Master} \cdot \rho_{Master}$$

The effect of the error propagation by the relative uncertainty of measurement of the individually measured variables is determined according to ISO / TR 5168 by standard deviation.

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

The extended uncertainty of measurement u_{total} which results from the relative standard uncertainty of measurement $u_{total,\ std.}$ by multiplication with the extension factor k = 2 corresponds to the interval in which the measurement value lies with a probability of 95%. The smallest extended uncertainty of measurement of the comparative measurement to be indicated is identical with this extended standard uncertainty of measurement. With the standard uncertainty of measurement of a test sample an additional value has to be taken in consideration which describes the dispersions of the test sample, or of the calibration results.

Crucial for the uncertainty of measurement of the comparative measurement is at first the uncertainty with the determination of the current volume flow on the normal comparative value. The uncertainty with the determination of the density ratio between normal comparative value and test sample is added (for the measured variable current volume flow), or with the determination of the density on the normal comparative value (for the measured variable mass flow) from the measured variables relative air humidity as well as absolute pressure and temperature on the normal comparative value or test sample.

15.2 Percentage of uncertainty caused by leakage in the test section design

In the run-up phase of each comparative measurement it has to be made sure by a tightness test (pressure drop test) that the maximum error caused by leakage in the test section design remains below an agreed value.
If the volume of the test section design is V, the test pressure with leak testing is p and the smallest flow to be calibrated is Q_{min}, the maximum allowed pressure drop in the test section design for an uncertainty u_L is

$$\frac{dp}{dt} \leq u_L \cdot Q_{min} \cdot \frac{p}{V}$$

$$u_L = \frac{Q_L}{Q_{min}} \leq 0,1\%$$

15.3 Uncertainties of measurement on comparative measurements with Laminar Flow Elements

The extended standard uncertainty of measurement of the normal comparative value is determined by the calibration in a measuring chain which can be referred to the Physikalisch-Technische Bundesanstalt (German Federal Institute for Physics and Engineering). The calculation of the current volume flow in the test sample with comparative measurement against Laminar Flow elements is done according to the following measuring chain (Law of Hagen-Poiseuille and Law of Conservation of Mass / Continuity Equation):

$$Q_{vol,\,testsample} = Q_{cal,\,LFE}(dp) \cdot \frac{\eta_{cal}}{\eta_{act}} \cdot \frac{\rho_{LFE}}{\rho_{testsample}}$$

The uncertainty of measurement with the comparative measurement against Laminar Flow elements consists of the following factors:

- uncertainty of measurement u_{cal} of the normal comparative value during its calibration, typically $u_{cal} = 0{,}325\%\ o.R.$ (Half of the extended uncertainty of measurement of typically 0.65%)
- Uncertainty of measurement u_{dp} for the measurement of the differential pressure in the LFE. For the measurement of the differential pressure in the LFE the identical differential pressure sensor is used with the factory calibration as well as with external comparative measurement, so that its absolute accuracy is not necessarily decisive, but only the ability of reproduction of the measurement values. In addition, the uncertainty by thermal and long-term drift of the sensor has to be taken into consideration. Typical values in the margin 2 - 25 hPa:
  relative uncertainty of measurement $u_{dp} = 0{,}15\%\ o.R.$
  thermal uncertainty: $u_t = 0{,}02\%\ o.R./°C$
  zero point drift of the sensor: $u_N = 0{,}05\%\ FS$
- uncertainty of measurement uh for the viscosity ratio by the conversion of calibration conditions on current conditions with the comparative measurement, typically $u_\eta = 0{,}056\%$
- uncertainty of measurement uρ for the density ratio. The accuracies of the absolute pressure measurement and temperature measurement, as well as humidity by the conversion of conditions on the normal comparative value to conditions in the test sample, typically
  $u_\rho = 0{,}14\%$ for mass flow
  $u_\rho = 0{,}12\%$ for volume flow
- Uncertainty of measurement u_{LFE} for the comparative measurement with Laminar Flow to elements. This insecurity interest includes the standard deviation of the calibration points with regard to the polynomial linearization, as well as an evaluation of the short-temporal and long-temporal drift behaviour between the comparative measurements. The value is settled at first and is customized in the long term on the basis of historical data.
  $u_{LFE} = 0{,}15\%$

For the extended total uncertainty of measurement therefore applies:

$$u_{total} = 2 \cdot \sqrt{u_{cal}^2 + u_{dp}^2 + u_\eta^2 + u_\rho^2 + u_t^2 + u_L^2 + u_{LFE}^2} + 2 \cdot u_N$$

This is for the example of the volume flow:

$$u_{total} = 2 \cdot \sqrt{0{,}325^2 + 0{,}15^2 + 0{,}056^2 + 0{,}12^2 + 0{,}02^2 + 0{,}1^2 + 0{,}15^2} + 2 \cdot 0{,}05\%\ FS$$
$$= 0{,}85\%\ o.R. + 0{,}1\%\ FS$$

and for the mass flow in the worst case (for humid air):

$$u_{total} = 2 \cdot \sqrt{0{,}325^2 + 0{,}15^2 + 0{,}056^2 + 0{,}14^2 + 0{,}02^2 + 0{,}1^2 + 0{,}15^2} + 2 \cdot 0{,}05\%\ FS$$
$$= 0{,}86\%\ o.R. + 0{,}1\%\ FS$$

15.4 Uncertainties of measurement with comparative measurements with orifices

The extended standard uncertainty of measurement of the normal comparative value is determined by the calibration in a measuring chain which can be referred to the Physikalisch-Technische Bundesanstalt (German Federal Institute for Physics and Engineering). The calculation of the current volume flow on the test sample with comparative measurement against orifices is done according to the following measuring chain (Law of Bernoulli Law and Law of Conservation of Mass / Continuity Equation):

$$Q_{vol,\,testsample} = \sqrt{dp \cdot \rho_{testsample}} \cdot \frac{C_{cal}(Re)}{\rho_{testsample}}$$

The uncertainty of measurement with comparative measurements against orifices is thus made of the following factors:

- uncertainty of measurement u_{cal} of the normal comparative value during its calibration, typically $u_{cal} = 0{,}325\%\ o.R.$ (Half of the extended uncertainty of measurement of typically 0.65%)
- uncertainty of measurement u_{dp} for the measurement of the differential pressure on orifices
  For the measurement of the differential pressure on orifices the identical differential pressure sensor is used with the factory calibration as well as with external comparative measurement, so that its absolute accuracy is not necessarily decisive, but only the ability of reproduction of the measurement values. In addition, the uncertainty by thermal and long-term drift of the sensor has to be taken into consideration. Typical values in the margin 2 - 25 hPa:
  relative uncertainty of measurement $u_{dp} = 0{,}15\%\ o.R.$
  thermal uncertainty: $u_L = 0{,}02\%\ o.R.\ /\ °C$
  zero point drift of the sensor: $u_N = 0{,}05\%\ FS$
- uncertainty of measurement u_η for the influence of the Reynolds number with the determination of the flow coefficient $C_{cal}(Re)$, typically $u_{Re} = 0{,}06\%$
- uncertainty of measurement u_ρ for the density ratio. The accuracies of the absolute pressure measurement and temperature measurement, as well as humidity by the conversion of conditions on the normal comparative value to conditions in the test sample, typically $u_\rho = 0{,}14\%$ for mass and volume flow.
- uncertainty of measurement u_{OR} for the comparative measurement with orifices. This insecurity interest includes the standard deviation of the calibration points with regard to the polynomial linearization, as well as an evaluation of the short-temporal and long-temporal drift behaviour between the comparative measurements. The value is settled at first and is customized in the long term on the basis of historical data.
  $u_{OR} = 0{,}15\%$

For the extended total uncertainty of measurement therefore applies:

$$u_{total} = 2 \cdot \sqrt{u_{cal}^2 + 0{,}5 \cdot u_{dp}^2 + u_{Re}^2 + 0{,}5 \cdot u_\rho^2 + u_L^2 + u_{OR}^2} + 2 \cdot u_N$$

The example of the mass flow and volume flow results in:

$$u_{total} = 2 \cdot \sqrt{0{,}325^2 + 0{,}5 \cdot 0{,}15^2 + 0{,}06^2 + 0{,}5 \cdot 0{,}14^2 + 0{,}02^2 + 0{,}15^2} + 2 \cdot 0{,}05\%\ FS$$
$$= 0{,}76\%\ o.R. + 0{,}1\%\ FS$$

15.5 Uncertainties of measurement with comparative measurements with critical nozzles

The extended standard uncertainty of measurement of the normal comparative value is determined by the calibration in a measuring chain which can be referred to the Physikalisch-Technische Bundesanstalt (German Federal Institute for Physics and Engineering). The calculation of the current volume flow in the test sample with comparative measurement against critical nozzles (CFO) is done according to the following measuring chain (Law of Sound of Speed and Law of Conservation of Mass / Continuity Equation):

$$Q_{vol,\ testsample} = Q_{vol,\ CFO} \cdot \frac{\rho_{CFO}}{\rho_{testsample}} = F(c(T)) \cdot \frac{\rho_{CFO}}{\rho_{testsample}}$$

The uncertainty of measurement with the comparative measurement against critical nozzles (CFO) consists of the following factors:

- uncertainty of measurement u_{cal} of the normal comparative value during its calibration, typically $u_{cal} = 0{,}325\%\ o.R.$ (Half of the extended uncertainty of measurement of typically 0.65%)
- uncertainty of measurement u_c for the dependency on sound of speed by temperature, typically $u_c = 0{,}06\%$
- uncertainty of measurement u_ρ for the density ratio. The accuracies of the absolute pressure measurement and temperature measurement, as well as humidity by the conversion of conditions on the normal comparative value to conditions in the test sample, typically
  $u_\rho = 0{,}14\%$ for mass flow
  $u_\rho = 0{,}12\%$ for volume flow
- Uncertainty of measurement u_{CFO} for the comparative measurement with critical nozzles (CFO). This insecurity interest includes the standard deviation of the calibration points with regard to the polynomial linearization, as well as an evaluation of the short-temporal and long-temporal drift behaviour between the comparative measurements. The value is settled at first and is customized in the long term on the basis of historical data.
  $u_{CFO} = 0{,}15\%$

For the extended total uncertainty of measurement therefore applies:

$$u_{total} = 2 \cdot \sqrt{u_{cal}^2 + u_c^2 + u_\rho^2 + u_{CFO}^2}$$

This is for the example of the volume flow:

$$u_{total} = 2 \cdot \sqrt{0{,}325^2 + 0{,}06^2 + 0{,}12^2 + 0{,}15^2} = 0{,}77\%\ o.R.$$

and for the mass flow in the worst case (for humid air):

$$u_{total} = 2 \cdot \sqrt{0{,}325^2 + 0{,}06^2 + 0{,}14^2 + 0{,}15^2} = 0{,}78\%\ o.R.$$

16 PLC Interface

The PLC interface is for remote control of automatic test procedures. Besides, it is unimportant for the LMF whether it communicates with a classical programmable logic controller (PLC), a PC, or with a manual remote control.

This chapter informs about:
- Overview of test steps and functions (paragraph 16.1)
- Detailed information for the particular test steps (paragraph 16.2)
- overview and explanation of the signals used for control (paragraph 16.3)
- configuration of the interface (allocation of the signals, paragraph 16.4)
- schematic signal functions (paragraph 16.5)

Note
The functionality of the PLC interface can be flexibly adapted through appropriate configuration to meet different needs, and testing applications. In this chapter only the simple basic flow is described . The example is about a system in which a regulated test pressure and a flow rate is measured and evaluated. About your application-specific features, please refer to the “Operating Instructions and System Configuration" of your system.

16.1 Overview of test steps and procedures

The test schedules are divided in single test steps which are partly an automatic or dependent sequence of parameter settings, events or signals.

In standard cases, the sequence of the test steps is executed once, at the end of the test sequence result signals are set.

Standard test procedure
The standard test procedure typically looks as follows:
- Setting the signal "Ready"
- Wait for PLC start
- Program selection based on the set program signals, possibly evaluate control signals for special functions (e.g. Zeroing)
- If necessary, perform zeroing
- Pre-Fill
- Fill
- Calm
- Measure (with continuous monitoring of the testing pressure)
- Evaluate result (e.g. mean value of volume flow)
- Indicate result on display
- Venting
- Setting signal “End”
- Wait for reset of PLC start
- Resetting signal “End”
- Setting signal “Ready”

16.2 Detailed information for the particular test steps

16.2.1 Wait for PLC start

If the system is ready to start, the signal “Ready” is set. With standard configuration the indication “Poll” appears below on the display.

If the NOK counter is set, and too many test samples have been recognized as bad before, (parameter S0013 default), the message "Lock" will appear instead of that. This results in a lockout which must be acknowledged explicitly.

Before the PLC start signal is set, the program to be executed (see section 16.2.2) and control signals for any special functions (e. g. as zeroing, see section 16.2.3) must be set.

After starting the PLC sequence:
If there are still test result signals of a preceding test, these will be reset immediately.

The times for the individual steps like pre-filling, filling, calming, etc. are specified in the program-specific parameter block Pn700 (n stands for the program number). See also parameter list section 9.8.22.

Note
The signal “PLC start” must be present during the whole testing schedule up to the end of the test. An untimely reset will be interpreted as a stop signal.

16.2.2 Program selection

With automatic PLC operation the program is read according to the selected bit-encoded program inputs 0 to 3. A signal must be set! If all inputs are deactivated, this will be interpreted as a non-readiness, error: "No program defined".
The program signals are evaluated on the rising edge of the “PLC Start” signal.

Digital signal on program inputs 0-3:	Program allocation LMF
0 0 0 0	invalid
1 0 0 0	0
0 1 0 0	1
1 1 0 0	2
0 0 1 0	3
1 0 1 0	4
0 1 1 0	5
1 1 1 0	6
0 0 0 1	7
1 0 0 1	8
0 1 0 1	9
1 1 0 1 ... 1 1 1 1	invalid

Table 84 Digital program input

With valid program selection the selected program is displayed in the lower line of the display.

With invalid program selection an error message appears in the display.

16.2.3 Nullification

The nullification of differential or gauge pressure sensors is carried out it the signal “Zero” was set with the rising edge of the signal “PLC Start”. The separate settling times before zeroing are set in the parameters S1100 to S1102. Parameters S1101 and S1102 only play a role, of not all nullable sensors can be zeroed together in a group. See also parameter list sections 9.7.5 and 9.7.12.

While zeroing the signal "Zero Active" is set.

Zeroing can not be terminated prematurely by the signal "GO".

After zeroing the signal "Zero Active" is withdrawn.

16.2.4 Pre-Fill

During the fill the signal "Fill" is set. The pressure is adjusted.

The selected program is displayed on the left side below, the indication "Pfil".

The duration of the phase “pre-fill” is determined by parameter Pn710. The phase “fill” can be quit just as the phase “display result” by the signal “Go” prematurely before the respective waiting period. This may make sense, for example, if the phase “fill” shall be quit by an event which is evaluated by the superior control.
If the waiting period is set to 0 or has already run off, the signal “Go” has no effect.

16.2.5 Fill

During the fill the signal "Fill" is set.
The selected program is displayed on the left side below, the indication "Fill" on the right side.

The duration of the phase “Fill” is determined by parameter Pn711. The phase “fill” can be terminated prematurely by the signal "GO".

If the waiting period is set to 0 or has already run off, the signal “Go” has no effect.

At the end of the phase “fill” the signal “fill” will be reset.

16.2.6 Calm

Display as above, only with the indication "Calm" on the right side below.
Signal "calm" set.

The duration of the phase “Calm” is determined by parameter Pn712.

The phase “Calm” can be terminated prematurely by the signal "GO".

At the end of the phase “Calm” the signal “Calm” will be reset.

16.2.7 Measurement

Signal “Measure” is set.
Usually the relevant variables (i.e. in the example chosen the regulated test pressure and the resulting volume flow) and the measurement time are displayed.

The duration of the phase “Measure” is defined by the parameter Pn701.

The testing pressure is continuously monitored. If the test pressure is outside a parameterized value range, the measurement is terminated prematurely. The average value of the variable relevant to the rating of the specimen is evaluated.

With properly test pressure, after the set measuring time the average values of all parameters are calculated.

Finally the result signals are set (see section 16.3.4). They are reset only with the start of the next test.

The measurement results are summarized in various display pages. Starting from the default display page these can be toggled with the functions keys F1 and F3. The designations correspond to the data in the table of the Read parameters Ryxxx, see section 9.10. The result displays differ depending on the configuration and the system features and are not listed here explicitly.

The results ore only withdrawn from display with start of the next test (then again the current readings are displayed).

With each NOK rating the “NOK counter” is incremented. With each OK rated test, the “NOK counter” is reset. In case of so may successive “NOK” rated tests that the NOK counter reaches the value stored in S0013, the signal “Lock” is set, which must be explicitly acknowledged by the signal “Acknowledgement”. If S0013=0 the NOK counter is disabled.

The signal “Measure” is withdrawn.

16.2.8 Venting

The signal "Venting" is set.
On the display the identification "Vent" appears.
There is a pressure equalization.

The duration of the phase “Venting” is defined by parameter Pn713.

At the end of the phase “Venting” the signal “Venting” will be reset.

16.2.9 Wait for PLC stop

At the conclusion of the test sequence, whether properly closed or cancelled, the signal “End” is set.

The system remains in this state until a stop signal (removal of the signal “PLC start”) is received. The signal “end” is then withdrawn, the signal “Ready” is set.

16.3 Overview of the signals

A detailed allocation of the signals to the pins or ports of the PLC interface is included in chapter 16.4.

16.3.1 Control inputs

Signals which the PLC sets for the realization of the testing schedule:

Prog. Bit 0	selects the program number according to the entries in Table 84.
Prog. Bit 1	
Prog. Bit 2	
Prog. Bit 3	
PLC start	starts the testing schedule. If the signal is left out, this will be interpreted as a stop signal.
GO	The phases “Pre-Fill”, “Fill” and “Calm” can be quit by the signal “Go” prematurely before the respective waiting period.
Zero	If the signal “Zero2 is set with the rising edge of the signal “PLC start”, the nullification of the pressure sensors is carried out at the beginning of the following test procedure.
Acknowledgement	For the continuation after the occurrence of states which must be acknowledged see also next paragraph.

16.3.2 Control outputs

Signals which the LMF sets to display states to be acknowledged.

Lock	If S0013 is set to a value different to zero, the number of consecutive NOK events will be monitored. If the NOK counter reaches the value defined in S0013, the LMF sets the signal to lockout. The LMF sets a signal “Ready” only again if the signal “Lockout” has been acknowledged by the signal “Acknowledgement”.

16.3.3 Status outputs

Signals which the LMF sets to inform the PLC about the momentary state of the testing schedule (in which phase the test is):

Ready	Signals that the LMF waits for the signal PLC start
Zero Active	Signals the phase in which the nullification is performed.
Fill	Signals the phase in which the test conditions are produced.
Calm	Signals the phase in which the test conditions stabilize.
Measurement	Signals the phase in which the real measurement takes place.
Venting	Signals the phase, in which the pressure equalization with the environment is produced.
End	Signals the end of the testing schedule.

16.3.4 Result outputs

Signals set by the LMF to inform the PLC about the result of the last test carried out.

OK	The test has been quit free of errors and the measurement value lies in the specified value range.
NOK	The measurement value lies beyond the specified valuation, or no valid measurement value could be measured, e.g., with too low test pressure or with program termination.
NOKL	The measurement value lies below the specified valuation.
POK	The required test pressure was kept during the measurement.

16.3.5 The signal "no error"

The signal "no error" is withdrawn under the following conditions:

- There is a sensor failure. The signal is withdrawn with the occurrence of a sensor failure. It is set again as soon as the problem is solved.
- No valid program selected. The signal is set immediately after the signal "PLC start" was received with invalid program selection. It is only set again at the start of the next test (with valid program selection).
- The test procedure was prematurely terminated by the removal of the start signal from the PLC. The signal is set again only at the start of the next test.

16.4 Standard configuration of the PLC digital interface

If a divergent configuration is specified, this is documented in the "Operating Instructions and System Configuration" of the system.

24V Hardware interface or virtual PLC interface Net-IO
According to the equipment of the system either a digital hardware interface or a virtual interface via TCP/IP (Ethernet) is used for the communication with the PLC. The port used for the virtual interface is set in parameter S9500. If a virtual interface is configured, usually port 54488 is used. A different port allocation will be given in the "Operating Instructions and System Configuration".
The electrical connections of the hardware interface or the inputs of the virtual interface respectively are designated as follows:

DI	Digital In	Designation for a 24V input of the digital interface
DO	Digital Out	Designation for a 24V output of the digital interface
NI	Network In	Designation for an input of the virtual interface Net-IO
NO	Network Out	Designation for an output of the virtual interface Net-IO

Notes

- If you use a hardware interface with external supply of the optoelectronic couplers for reasons of the galvanic separation, specific pins must be supplied with 24 V for this purpose. Thus follow the circuit diagram!
- Details for communication with the virtual PLC interface Net-IO can be found in section 5.4

The following tables show the default assignment of the virtual PLC interface Net-IO and the hardware interface:

Inputs

Virtual NI	Digital DI	Function	Note
0	DI08		Reserve
1	DI09		Reserve
2	DI10		Reserve
3	DI11		Reserve
4	DI12	Zero	
5	DI13	Go	
6	DI14	SPS-Start	
7	DI15	Acknowledgement	
8	DI16		Reserve
9	DI17	Prog. Bit 0	
10	DI18	Prog. Bit 1	
11	DI19	Prog. Bit 2	
12	DI20	Prog. Bit 3	
13	DI21		Reserve
14	DI22		Reserve
15	DI23		Reserve

Outputs

Virtual NO	Digital DO	Function	Note
0	DO08	Measurement	
1	DO09	NOKL	
2	DO10	Venting	
3	DO11	Fill	
4	DO12	Calm	
5	DO13		Reserve
6	DO14	Ready	
7	DO15	OK	
10	DO16	NOK	
11	DO17	no error	
12	DO18	Lock	
13	DO19	End	
14	DO20	POK	
15	DO21	Zero Active	
16	DO22		Reserve
17	DO23		Reserve

16.5 Schematic signal functions

16.5.1 Regular testing schedule

16.5.1.1 Procedure

PLC	LMF
	• The LMF sets the signal “Ready“ Result outputs of the previous test are still set (except on the first test after turning on).
• The PLC sets the signals for program selection.	
• If necessary the PLC sets the signal for zeroing.	
• The PLC sets the signal PLC start.	• The result signals of the previous test are reset. • The signal “Ready” is reset. The testing schedule begins. The LMF sets the signals according to the current test step: - Fill - Calm - Measurement - The result signals are set - Venting Test finished: - The LMF sets the signal “End“
	The LMF waits for the reset of the signal PLC start by the PLC
• The PLC resets the signal PLC start	
	• The LMF resets the signal “End” • The LMF sets the signal “Ready“ Result signals are not reset

16.5.1.2 Result signals

After a regular testing schedule with correct test pressure and without malfunction the following result signals are set:

Signal	Note
POK (Test pressure OK)	Is set.
OK	Is set if the measured variable to be valued lies within the parameterized range.
NOK	Is set if the measured variable to be valued lies outside the parameterized range.
NOKL	Is set (in addition to signal NOK) if the measured variable to be valued lies below the lower limit.

16.5.2 Testing schedules with malfunction

16.5.2.1 Termination of test by faulty test pressure

The test pressure is monitored throughout the phase “Measuring” (and only then). If during the phase “Measuring” the test pressure is outside the defined limits, the test procedure is aborted (the phase Measurement” is terminated prematurely). The following result signals will be set:

Signal	Note
POK (Test pressure OK)	Is not set.
OK	Is not set.
NOK	Is set.
NOKL	Is not set.

16.5.2.2 Testing schedule without correctly set program inputs

The testing schedule is cancelled under the following circumstances immediately after having set the signal PLC start:

- None of the signals Prog Bit 0 to Prog Bit 3 is set

- or -

- The signals Prog Bit 0 to Prog Bit 3 encode a program, which is not allowed (example: all 4 signals are set, this corresponds to the selection of program 14, nevertheless, the highest possible program number is 9).

Reaction of the LMF:

PLC	LMF
	• The signal NOK is set • The signal no error is withdrawn. • The signals OK and NOKL are not set. • The signal “End” is set.
	The LMF waits for the reset of the signal PLC start by the PLC
• The PLC resets the signal PLC start	
	• The signal “End” is reset. • The signal “Ready” is set. • The result signals and the signal “no error” remain unchanged.

16.5.2.3 Termination of test by the PLC

The PLC can quit prematurely the test any time by resetting the signal PLC start

Then the LMF changes immediately to the phase Venting.
After the phase Venting has finished the following signals are displayed:

Signal	Note
POK (Test pressure OK)	Is not set.
OK	Is not set.
NOK	Is set.
NOKL	Is not set.