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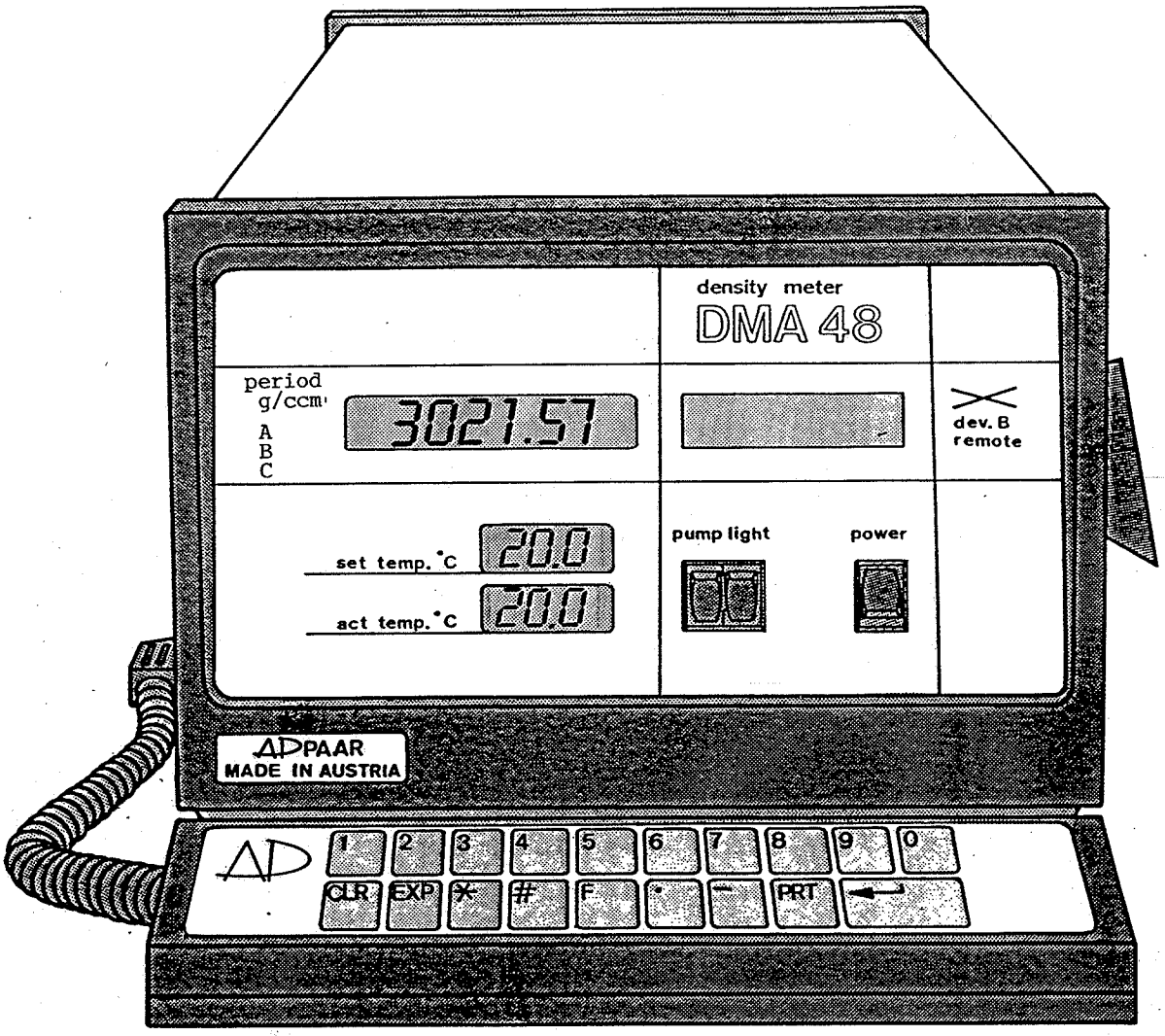
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density meter
DMA 48



PAAR

manual

density meter

DMA 48

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C O N T E N T S

	Page
1. Installation of the instrument	1
1.1 Fuses (main and primary fuses)	3
1.2 Mains connection	3
2. Function of elements	4
2.1 Controls of front panel	4
2.1.1 Switches	4
2.1.2 Display	4
2.1.3 Displayed parameters	4
2.2 Keyboard	5
2.3 Controls of rear panel	6
2.3.1 Electronics	6
2.3.2 Filling and rinsing system FRS (optional)	6
2.3.3 Computer/printer analog outputs	7
2.3.4 Connectors for external instruments	7
2.3.5 SP3 connection	7
2.3.6 Air pump	8
2.3.7 Water connectors	8
2.4 Filling equipment	9
2.4.1 Adapters for different applications	9
2.4.1.1 Filling and rinsing by a syringe	10
2.4.1.2 Filling and rinsing by FRS	10
2.4.1.3 Filling and rinsing by SP3	10
3. Start of operation	11
3.1 The very first start-up	11
3.2 Setting the sample temperature	14
3.3 Setting the stability criterion	15
3.4 Oscillator routines	15a

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8. Operation of optional modules 55

8.1 PAO analog output 56
8.1.1 PAO-connection 56
8.1.2 Activation/de-activation 56
8.1.3 Activation of the measuring value 57
8.1.4 Setting of limits 57
8.1.5 Specifications of the PAO analog output 57

8.2 Filling and rinsing system FRS 58
8.2.1 Hose connectors 58
8.2.2 FRS adapter 59
8.2.3 FRS activation/de-activation 60
8.2.4 Modes of operation 61

8.2.4.1 Normal filling and rinsing mode 62
8.2.4.2 Replacement mode 62
8.2.4.3 Cleaning mode 62
8.2.4.4 Syringe mode 62

8.2.5 Hints for working with the FRS 63
8.2.6 Starting the FRS 64
8.2.7 Interrupting the FRS cycle 64
8.2.8 Example 65

9. Possible errors - cause and correction 68

10. Maintenance 73

11. Theory of operation 74

11.1 Construction 75

12. Instruction set 76

13. Specifications 79

14. Tables 81

14.1 Table 1: Density of air depending on pressure and temperature 81

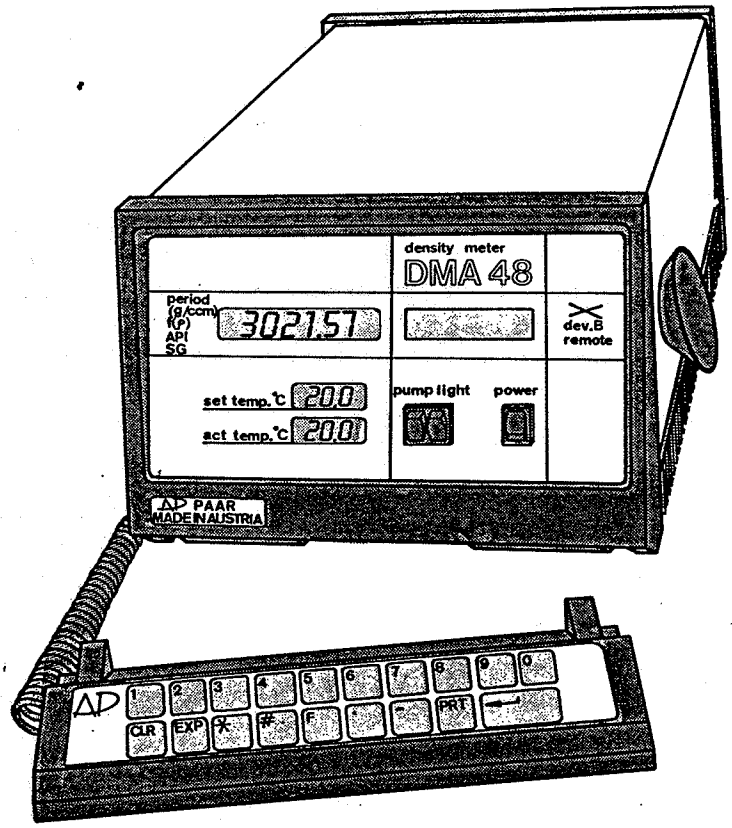
14.2 Table 2: Density of water depending on the temperature 82

<u>Conventions:</u> For printing reasons, the Greek character "rho" which is generally used for density, has been replaced here by "p". With the exception of air pressure in table 2, confusion between density and pressure should not occur because measurement under pressure is not discussed.

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1. INSTALLATION OF THE INSTRUMENT

The DMA 48 does not require any particular installation conditions. However, to maintain a stable temperature, the DMA 48 should not be placed near a heater or in direct sunlight. It is not necessary to level the DMA 48 nor to ensure that installation is completely vibration free (in contrast to precision balances). Nevertheless, a strong built-in cooling fan dissipates heat through the bottom of the DMA 48 (bottom is a heat exchanger). Care must therefore be taken that the inlet and outlet are not blocked. However, if the airflow is interrupted, the DMA 48 is protected from damage by an overload sensor. The overload sensor can be reset by switching the DMA 48 off and on.

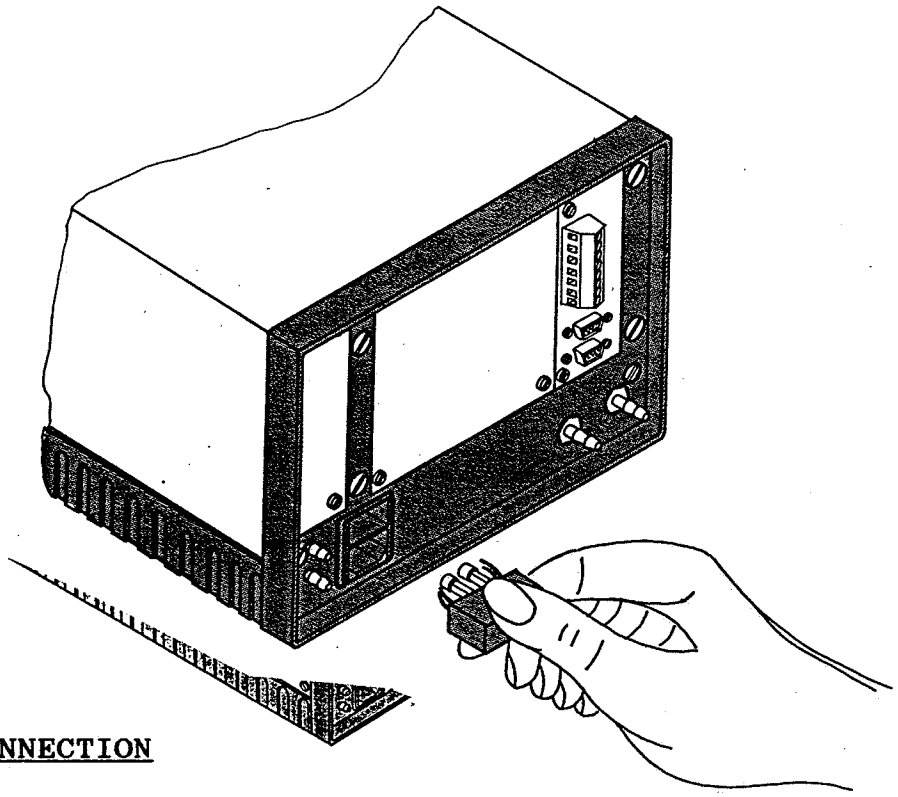


DMA 48 with keyboard

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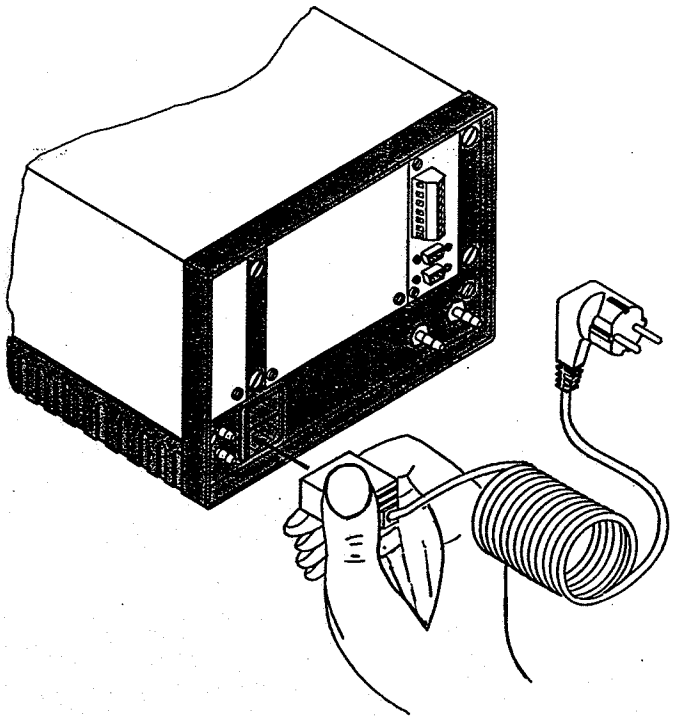
1.1 FUSES (Main and Primary Fuses)

Check whether the appropriate fuses (glass tube fuses 5 x 20 mm DIN 41662) are inserted at the rear of the instrument. Correct type and rating of the fuses are noted on the Technical Data Shield at the rear of the instrument.



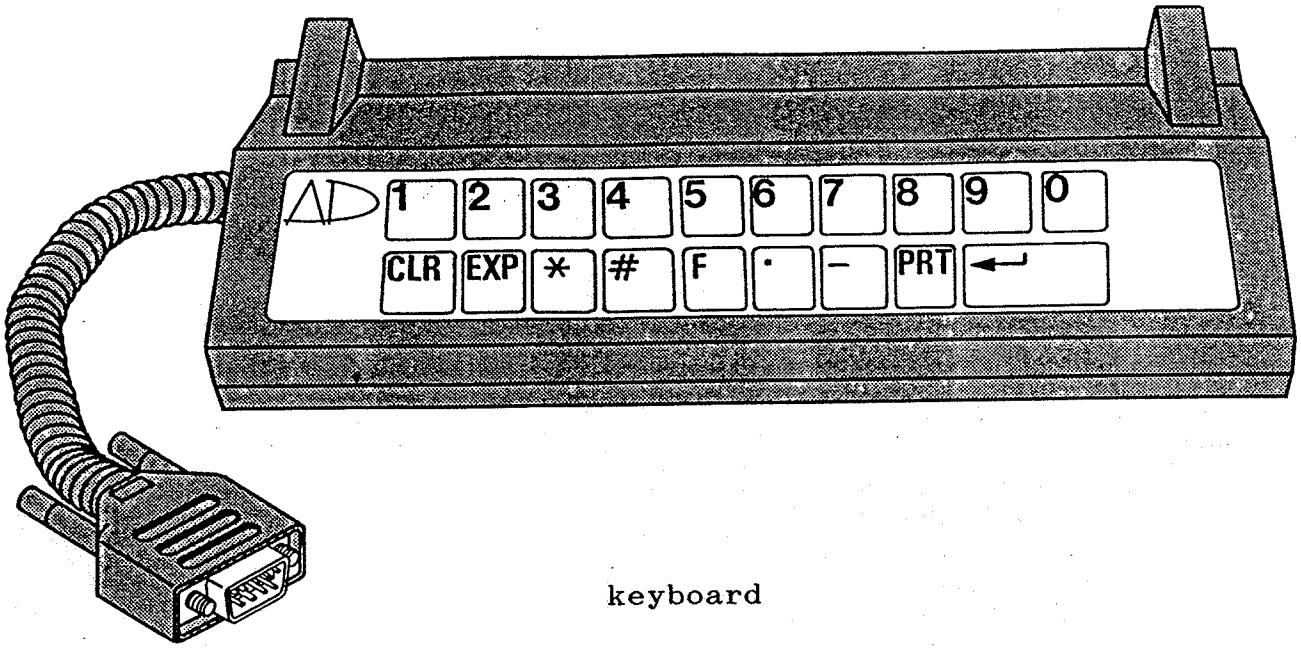
1.2 MAINS CONNECTION

Before plugging the DMA 48 in and switching it on, make sure that the correct mains voltage is given and appropriate fuses are used.



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2.2 KEYBOARD



keyboard

CLR ..... 1. Clear incorrect entries (must be used before quitting with ENTER (<--').
2. Stop the FRS mode.
3. If dev. B is flashing clear the calibration (not accepted).
4. Quit error messages.

* ..... 1. Start the FRS.
2. Quit error messages.

EXP ..... Input exponent

..... Numbering printout

F ..... Function key for commands

• ..... Decimal point

"-" ..... 1. Negative sign
2. For changing between OFF and ON at the installation of the modules.

PRT ..... Print command

◄┘ ..... 1. End of input

◄┘ ..... 2. Quit automatic display of density when calibration is done

◄┘ ..... 3. Quit "-CAL-"-display

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2.3.3 COMPUTER/PRINTER/ANALOG OUTPUTS

* Interface A - "Console Interface": Computer
(see item 7.1) V.24 (RS 232 C)
2400 baud
1 start bit
7 data bits
1 parity bit (even parity)
1 stop bit
no control lines

* Interface B - "Printer Interface": Printer
(see item 7.2) V.24 (RS 232 C)
9600 baud
1 start bit
7 data bits
1 parity bit (even parity)
1 stop bit
output only, no control lines

* PAO Analog output
(see item 8.1)

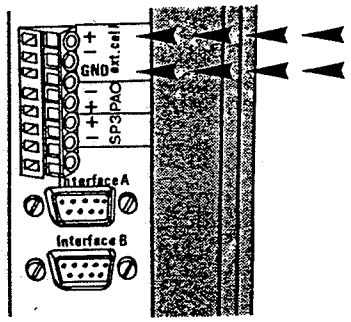
2.3.4 CONNECTORS FOR EXTERNAL INSTRUMENTS

External measuring cell

The DMA 48 can also be used as evaluation unit for external cells to be connected. You can connect DMA cells (e.g. DMA 512) or DPR cells (e.g. DPR 402) as external cells.

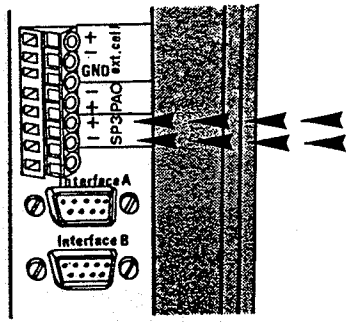
Connections:
For DMA cells: Lemo plug Pin 1 to -
Pin 3 to GND

For DPR cells: + to +
- to -



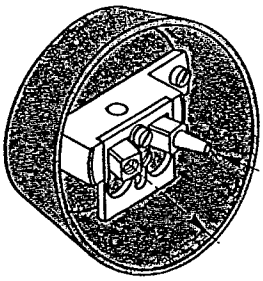
2.3.5 SP3 CONNECTION

The SP3 Autosampler has to be connected to the DMA 48 by two cables.
The SP3 is installed through command F900 (see SP3 manual).



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2.4 FILLING EQUIPMENT



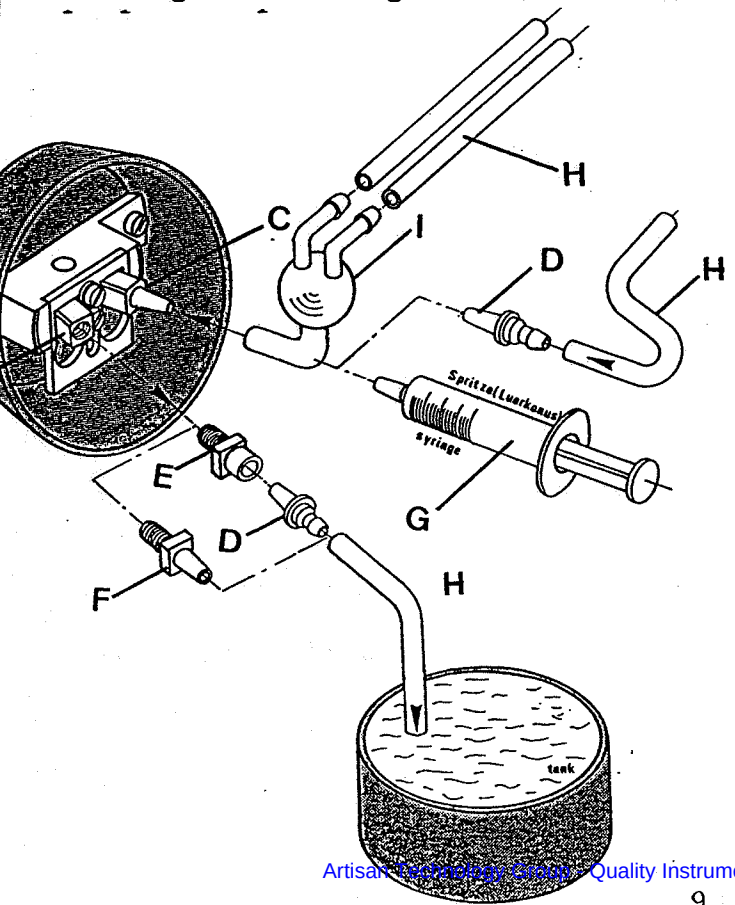
Particular care must be taken that samples are carefully introduced into the measuring cell. Therefore, the filling equipment (pressure-tight connectors) has to be used to reduce the possibility of breaking of the glass cell.

The filling procedure can either be performed manually using a syringe with appropriate sample and injection port, or automatically using the FRS system with the appropriate adapter, too.

In special situations, for example, if you have a very small amount of sample, should you fill the cell without the sample and injection port.
In this and only in this case (without sample and injection port) you can use a syringe with a Record cone. Otherwise you need a syringe with Luer cone.

2.4.1 ADAPTERS FOR DIFFERENT APPLICATIONS

In the following you can see an overview of the adapters used. Suggestions longerning which filling adapter to use in A given working mode are given on the next page.



Available adapters:

A ... socket: 1/4" UNF
B ... socket: female Luer
C ... socket: male Luer
D ... adapter: male Luer
E ... adapter: female Luer 1/4" UNF
F ... adapter: male Luer 1/4" UNF
G ... syringe Luer cone
H ... silicon hose 3 x 5
I ... glass ball

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3. START OF OPERATION

3.1 THE VERY FIRST START-UP

Prior to the very first start-up or after program errors (indicated by dashes on the display) which have caused a deletion of the memory content it is necessary to proceed as follows:

F51 ... P(51) = HHMMSS
Input of time
Enter without spaces and complete with key "<--'"

F52 ... P(52) = YYMMDD
Input of date
Enter without spaces and complete with key "<--'"

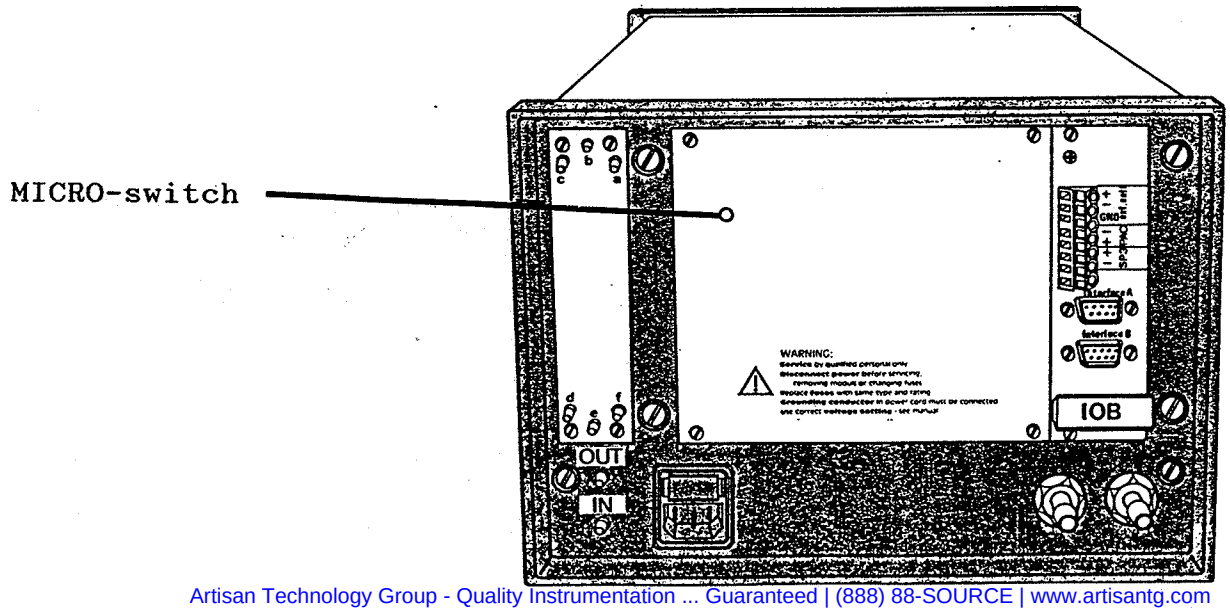
F55 ... P(55) = 1
Configuration completed
This parameter must be set to "1" after each initialization, otherwise the data entered cannot be accepted. After this the DMA 48 starts running in its normal mode.

The situation before the very first start-up can also be reached intentionally by deleting the battery-buffered memory.

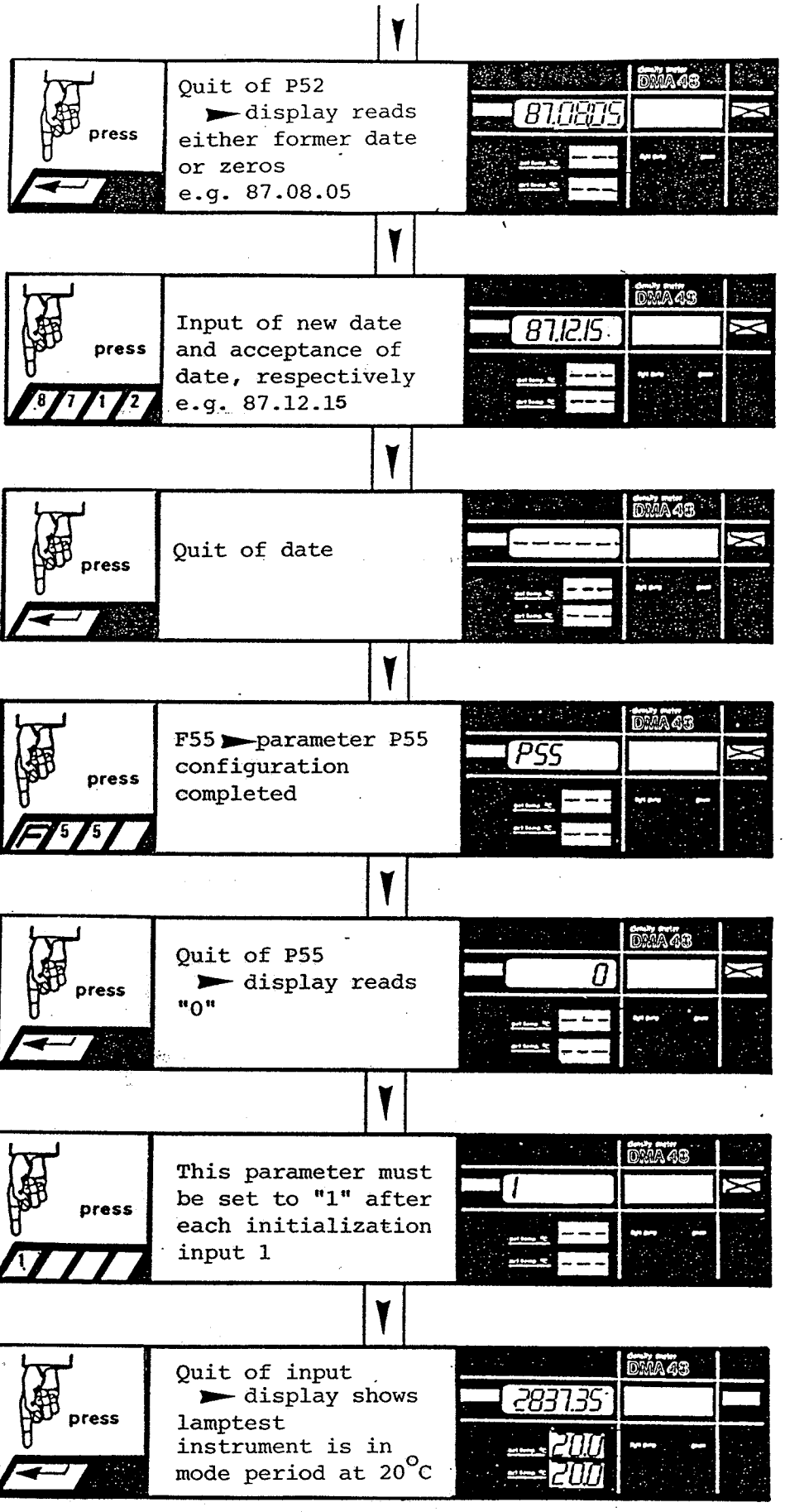
To do this, turn off the DMA 48. Depress the MICRO switch with a thin pin, and simultaneously turn on the DMA 48. The display will show -----. Re-enter the correct parameters in the usual way (F51, F52, F55).

You can only change the time and date parameters by deleting the battery-buffered memory.

All calibration values, FRS- and SP3-Parameters, etc. are lost during this operation.



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3.3 SETTING THE STABILITY CRITERION

F350 ..... stability criterion

"X" goes off as soon as the period of oscillation of the measuring cell is stable for a certain amount of time.

This time can be selected in steps of 10 within 5 to 85 seconds by setting:

F350 = 1 5 seconds
F350 = 2 15 seconds
F350 = 3 25 seconds
.
.
.
F350 = 7 65 seconds
F350 = 8 75 seconds
F350 = 9 85 seconds

Standard value: F350 = 4, meaning 35 seconds

For suspension- or colloid-type samples, the stability criterion has to be decreased in order to reach stability: e.g. 2

Press:	Reading:	Light Bars:
* Changing the stability criterion e.g. to 2.		
F350 **Enter** **2** **Enter**	**F350** **4** **2** **(Reading before)**	**X** **X**

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4. DENSITY CALIBRATION

Basically, a calibration is required to measure density and density related values correctly.

If calibration was done more than 7 days ago, a "C" is shown on the display. If it was performed more than 93 days ago, the display reads "-CAL-". The calibration runs out after 100 days. After that, the period is the only value available and a recalibration is necessary. If either the period or the user function is displayed, neither C nor CAL are visible.
Two standards are required for calibration. Their density values must differ by more than 0.01 g/cm^3 and have to cover the total density range required. Otherwise the calibration is invalid.

Calibration routines are available as follows:
(density values of air and water are stored in the memory):

F100 ... Air Calibration

F101 ... Water Calibration

F102 ... Calibration using the first standard of known density. Density of the first standard is entered via the keyboard.

F103 ... Calibration of the second standard of known density. Density of the second standard is entered via the keyboard.

F110 ... Indication of the calibration data (see 4.6).



To avoid an invalid calibration the calibration points for the calculation of A and B have to be determined within 24 hours.

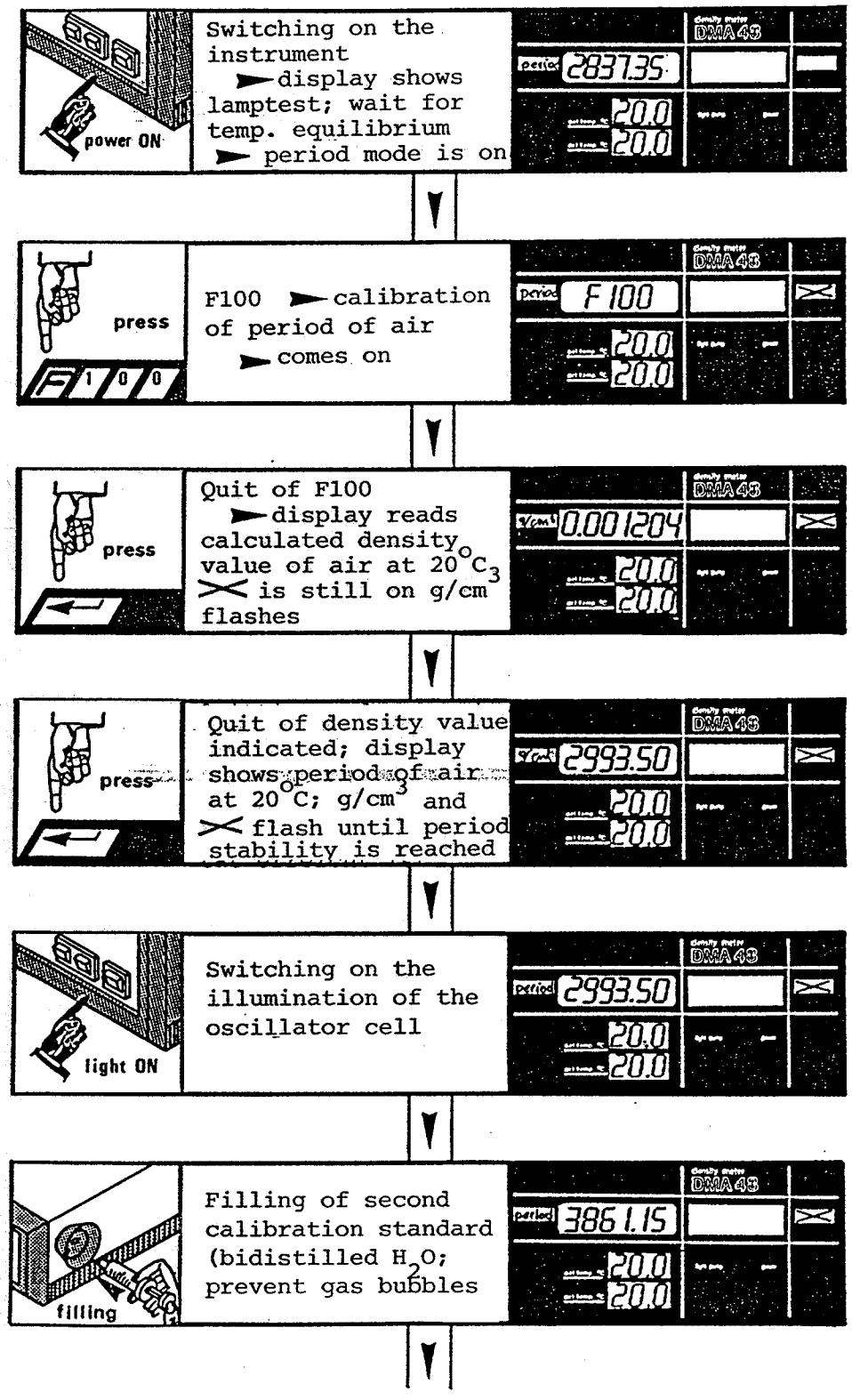
Up to 20 calibrations can be stored.

When storing the 21st calibration the oldest one becomes deleted.

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4.2 CALIBRATION USING AIR AND WATER

Example: A density calibration at 20°C should be performed. Prior to that the oscillator cell has to be rinsed carefully with alcohol and then dried. The temperature of 20°C and the measurement criterion were already set by command F300 (see item 3.2) and F350 (see item 3.3). Display mode: e.g. period



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4.3 CALIBRATION USING SUBSTANCES OF KNOWN DENSITY

F102 ... Calibration using density standard 1

F103 ... Calibration using density standard 2

For calibration substances other than air and water, proceed as follows:

Density values of both standards must differ by at least 0.01 g/cm³, with a known density to 5 decimals. Introduce the first substance of known density into the oscillator, without the presence of gas bubbles. After pressing F102 and "<--'", "g/cm³" flashes and "><" comes on. Enter density of first standard sample using the keyboard and quit with "<--'". Now "period" lights up, "g/cm³" and "><" flash and the display reads the period of the sample. "g/cm³" and "><" go off as soon as the calibration procedure with substance 1 is completed; "period" comes on.

Clean and dry the oscillator carefully and introduce the second substance of known density into the oscillator. Proceed with pressing F103, enter density of second substance and press "<--'". After stability of the period is ensured, i.e., the period does not change by more than the measurement criterion selected within 15 measurements, "g/cm³" and "><", and then "period" go off. "dev.B" flashes and the display shows the difference between the actual calibration constant B and the former B calculated at the same temperature. The calibration procedure is completed. Exit by pressing "<--'" or clear the calibration by pressing "CLR".



Both calibration points for the calculation of A and B have to be determined within 24 hours to ensure a correct and valid calibration.

For this kind of calibration you may also apply either air or water (F100, F101) as one known calibration standard. In this case o n e extra standard only is necessary.

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4.6 POSSIBLE SOURCES OF ERROR (CALIBRATION)

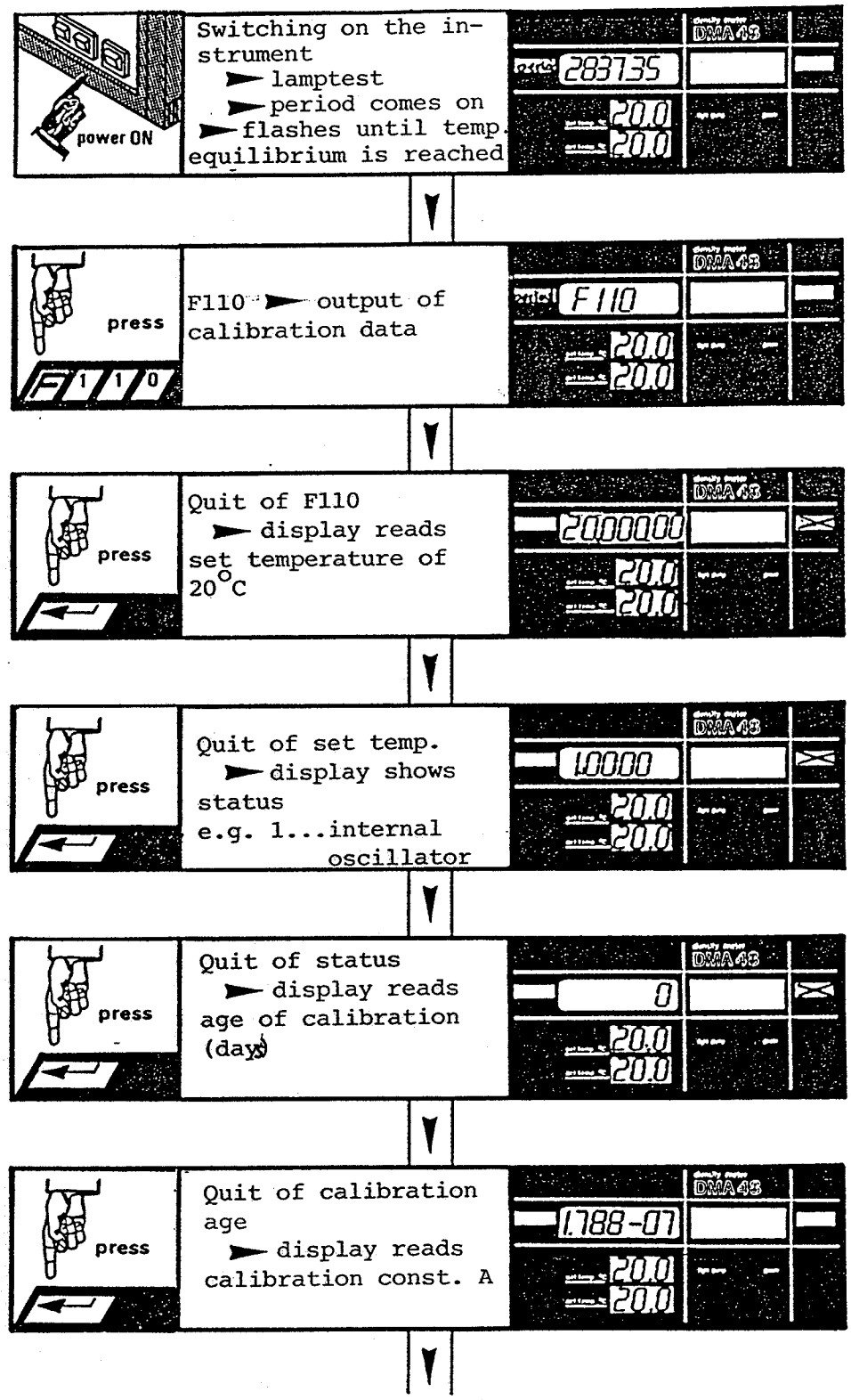
* Sample was introduced into oscillator cell too fast
* Gas bubbles within calibration standard
* Direct sunlight on the instrument
* Illumination of oscillator cell not switched off
* Sedimentation within the oscillator
* Difference in density not > 0.01 g/cm^3
* Calibration standard not filled beyond mounting points of U-tube
* Time exceeded (more than 24 hours)
* Dwell time of colloidal calibration substances within U-tube took too long
* Use of wrong calibration substances
* Non-linearity of the relationship between density and concentration



For large variations in temperature of more than 20°C (e.g. from 20°C to 40°C and down to 20°C again) the time for T-value equilibration should be at least 30 minutes before starting the calibration procedure in order to meet the specified accuracy of ±1 x 10^{-4} g/cm^3.

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Example: Output of calibration data for a calibration at 20°C
Display mode: e.g. period



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5. ACTUAL MEASUREMENT

5.1 GENERAL

In order to obtain accurate results the cell has to be cleaned and dried and the sample must be homogenous and free of even the smallest gas bubbles.

The sample to be measured (approx. 0.7 cm^3) is loaded into one opening of the oscillator cell using a plastic-tipped hypodermic syringe. Proper filling of the oscillator can be observed through the window when the light has been switched on. Filling is complete when the sample has passed from the thin part to the thick part of the opposite end of the oscillator. Leave the syringe in this position and switch off the light in order to maintain temperature stability. As soon as temperature equilibrium has been reached "ready" goes off.

The sample and injection port that are supplied with the DMA 48 should always be used. Use only syringes equipped with Luer cone.



There is no warranty for cracked glass!

If you do not use the sample and injection port, insert the plastic-syring equipped with record cone into the opening of the cell very carefully and keep the syringe aligned with the cell to ensure proper sealing.



Colloidal samples may tend to separate in the cell, giving incorrect results. Such samples should remain in the oscillator only briefly. It is therefore recommended to pre-thermostate them before injection.

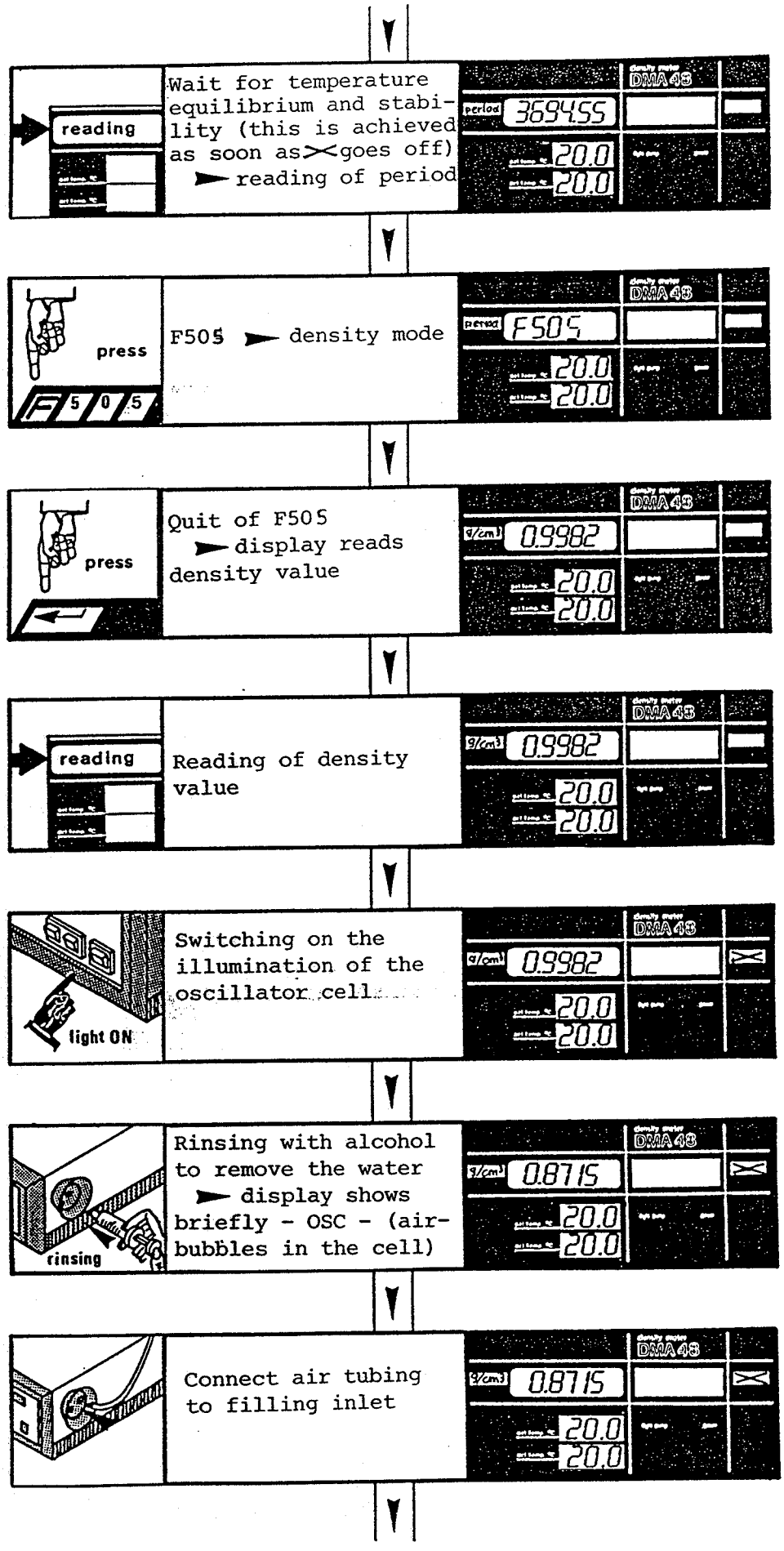


If the sample to be measured tends to form bubbles during the temperature equilibrium or measurement, either introduce your sample at a higher temperature or put the meter at an angle to allow the bubbles to leave (buoyancy).

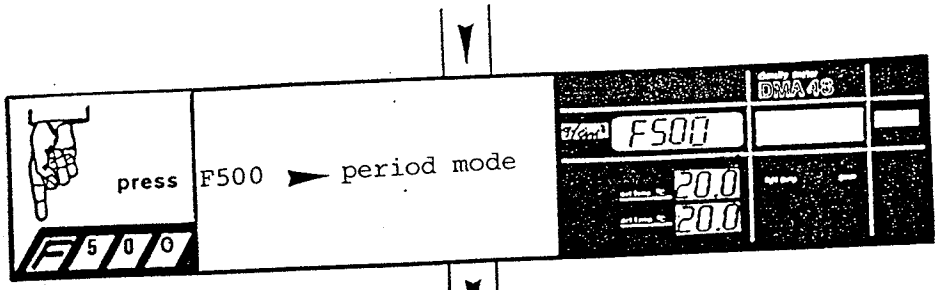
Pre-thermostatization of the sample shortens the time required for temperature equilibrium.

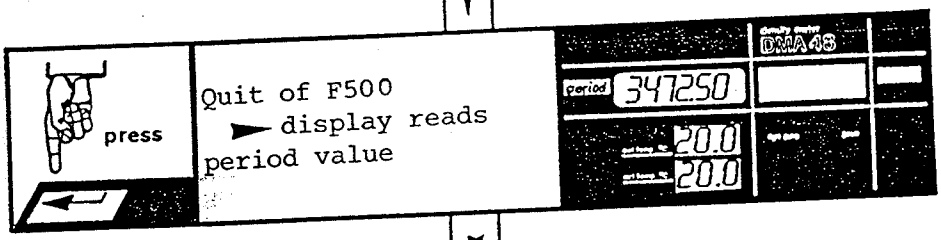
Loading the sample too fast may cause the formation of invisible gas bubbles. In this case the period can't be stabilized and the error message E-00-02 is shown.

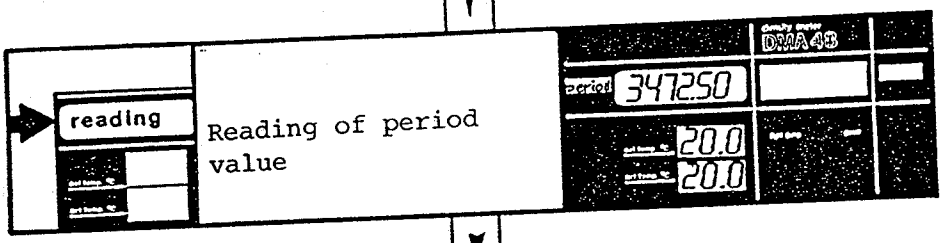
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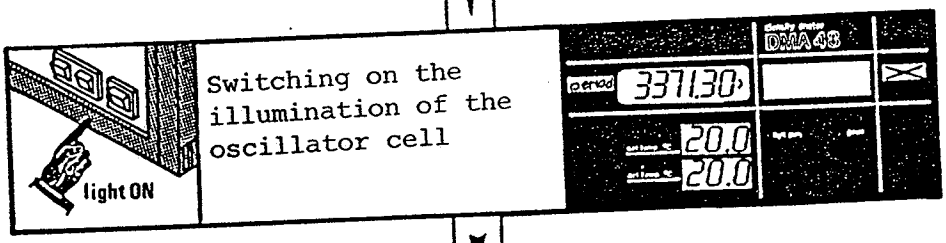


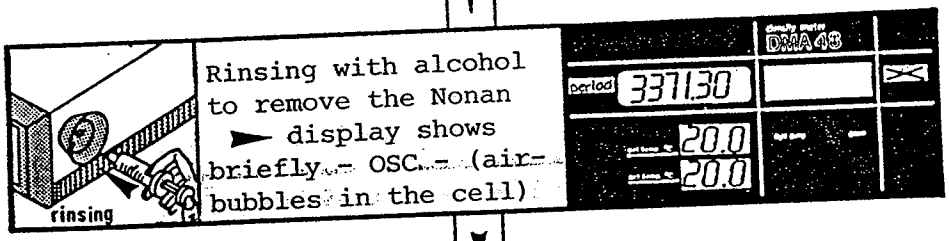
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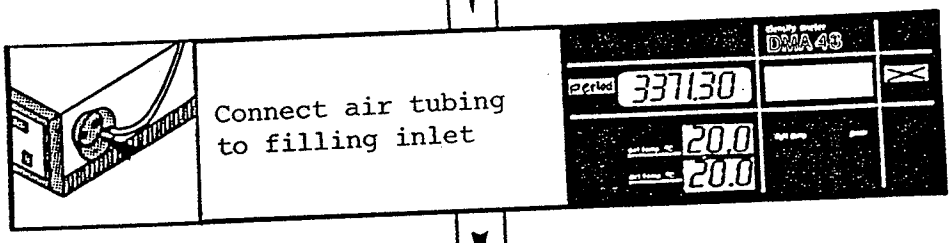


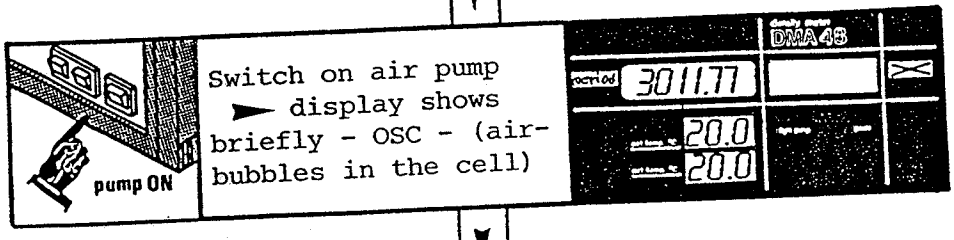












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5.3 POSSIBLE SOURCES OF ERROR (Measurement)

* Gas bubbles within the sample to be measured
* Direct sunlight on the instrument
* Calibration error
* Illumination of oscillator cell not switched off
* Sedimentations within the oscillator
* Sample not filled beyond mounting points of U-tube
* Colloidal calibration substances or colloidal samples
* Dwell time of colloidal samples within U-tube took too long
* Condensate due to high air humidity and low cell temperature



For large variations in temperature of more than 20°C (e.g. from 20°C to 40°C and down to 20°C again) the time for T-value and density equilibration, respectively, should be at least 30 minutes in order to meet the specified accuracy of ±1 x 10^{-4} g/cm³.

Influence of viscosity on density measurement



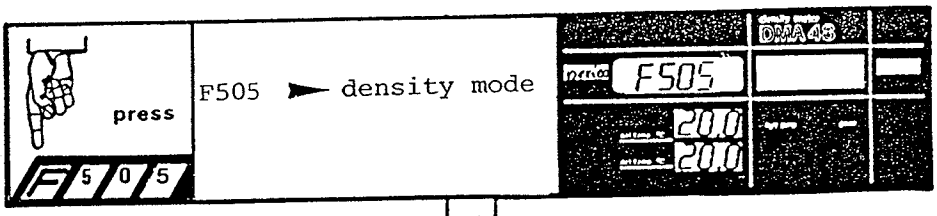
For viscosities between 0 and 100 mPas this influence is negligible.

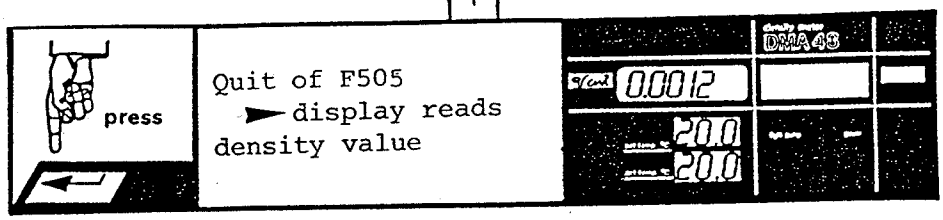
For samples with a viscosity between 100 and 500 mPas the density has to be corrected as follows:

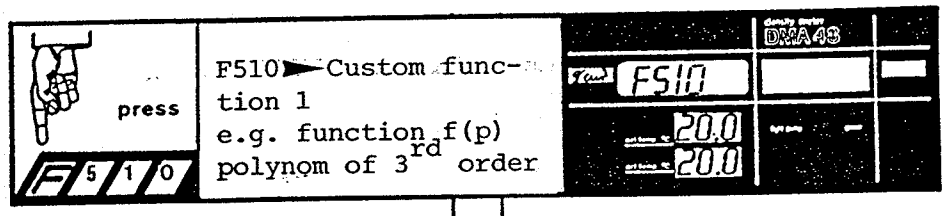
rho(corrected) = rh(measured)-(sqr(eta)-10)*0.000048

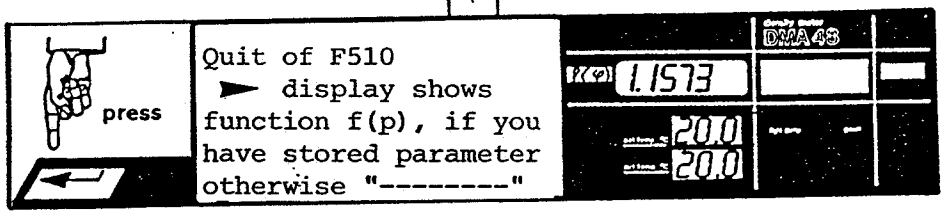
If the viscosity exceeds 500 mPas you have to subtract a value of 0.0006 g/cm³ from the density read on the display.

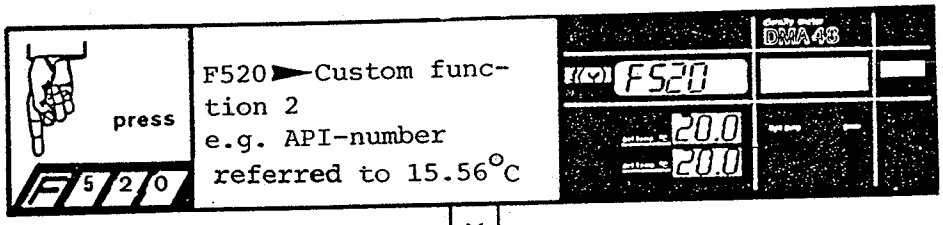
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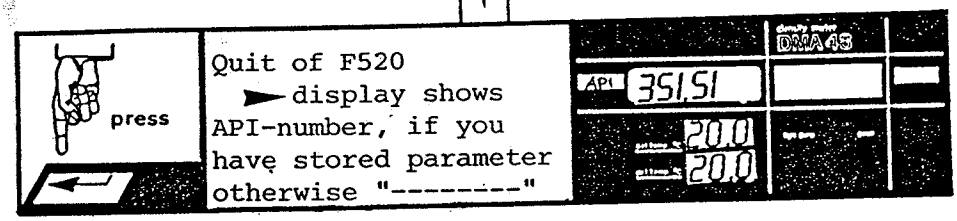


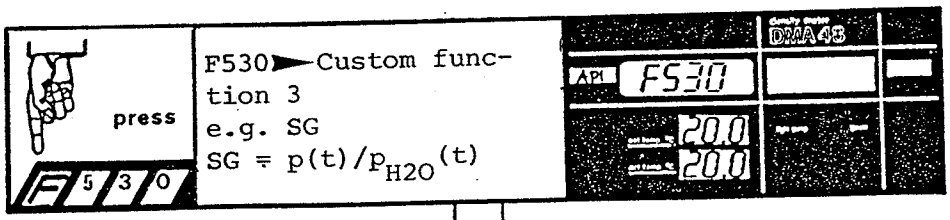


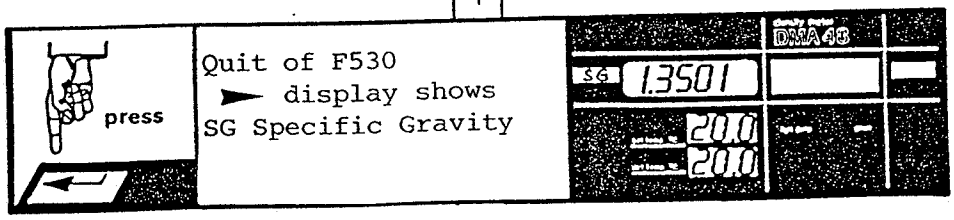












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6.2 CUSTOM FUNCTIONS

6.2.1 GENERAL

The custom function is a specific density-related function that is programmed into the DMA 48. The most common kind of custom function is one where a density measurement is converted to concentration, such as percent sugar in solution, or percent acid in solution.

Many density/concentration tables are available from your local distributor and can be programmed into your DMA 48 upon request. A maximum of three tables can be stored. Density tables developed by customers are sometimes also programmable into the DMA 48. Contact your distributor for a list of the available tables and other details.

6.2.2 WORKING WITH THE CUSTOM FUNCTION

If you have installed your specific custom functions (three different custom functions are possible) you can easily select your function:

e.g.

F510 ... Custom function 1 e.g. - % Acetone

F520 ... Custom function 2 e.g. - % Fructose

F530 ... Custom function 3 e.g. - ° Brix

6.2.3 CHANGING THE PARAMETERS OF THE CUSTOM FUNCTION

To select the parameter of the custom function you have to proceed as follows:

F3xy ... Enter or change the coefficient of the custom function x

F3x0 ... Enter of change the coefficient of the custom function x one after another

x = 1 ... custom function 1
x = 2 ... custom function 2
x = 3 ... custom function 3

y = 1, 2, 3, 4, 5 ... Index of the coefficients

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6.2.4 TABLES

With function F200 and F250 you can only display and change the stored table value of the custom function selected.

The tables are stored via a PC.

To store either a public table or your own table, please contact your local distributor.

F200 ... Change or display a value of the first column of the stored table.

F250 ... Change or display a value of the second column of the stored table.



Before changing the table value you have to select the corresponding custom function: e.g. F520.

How to change a table value:

First you have to know the table to be changed (you will get the stored custom function from your local distributor).

e.g. Table:

Row number	column 1 [%]	column 2 (dens)
1	0.00	0.9932
2	0.50	1.0023
3	**0.70**	1.0423
4	1.50	**1.0567**
.		
.		
.		
100		

Example:

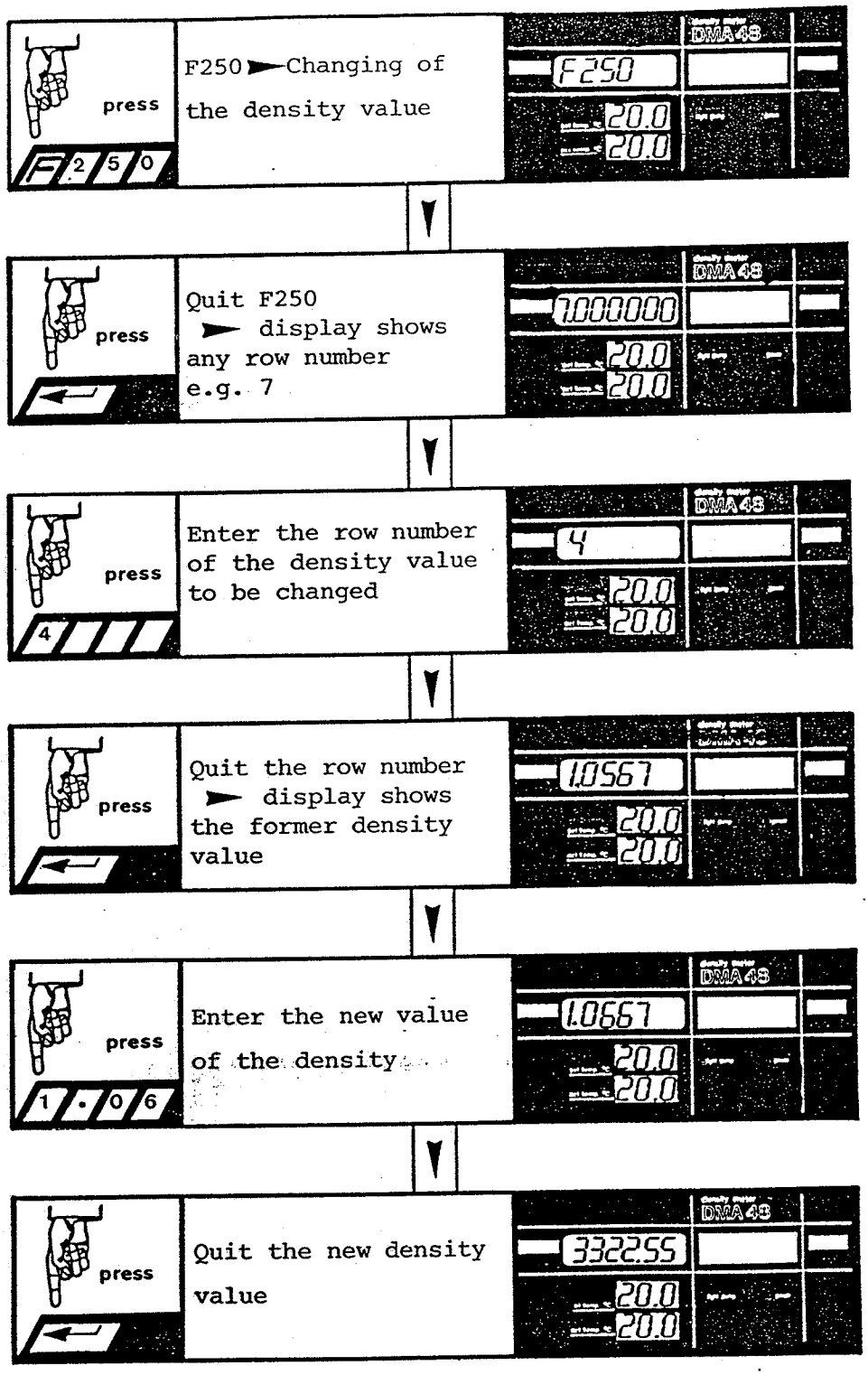
Now change no. 3 (concentration from 0.70 % to 1 %) and no. 4 (density from 1.0567 to 1.0667).

NOTE: There are only 100 rows, so your selection must be between 1 and 100.

See pictures page 39 and 40.

First, select the custom function of the table to be changed.

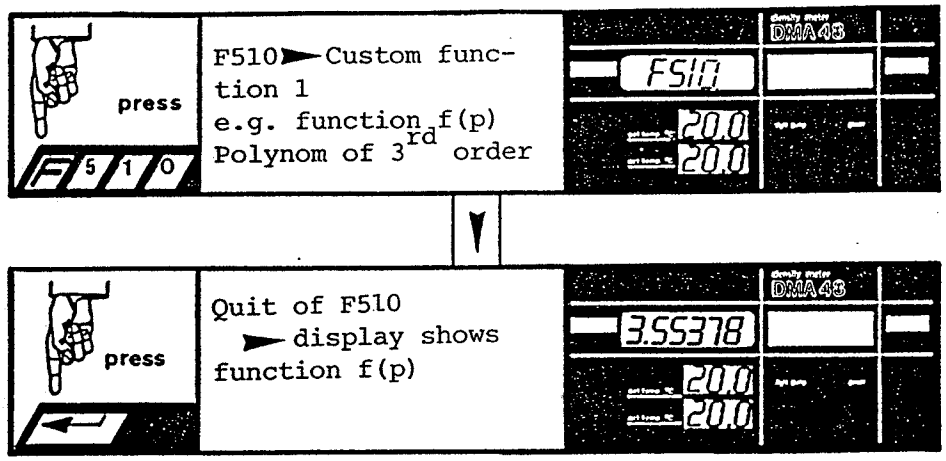
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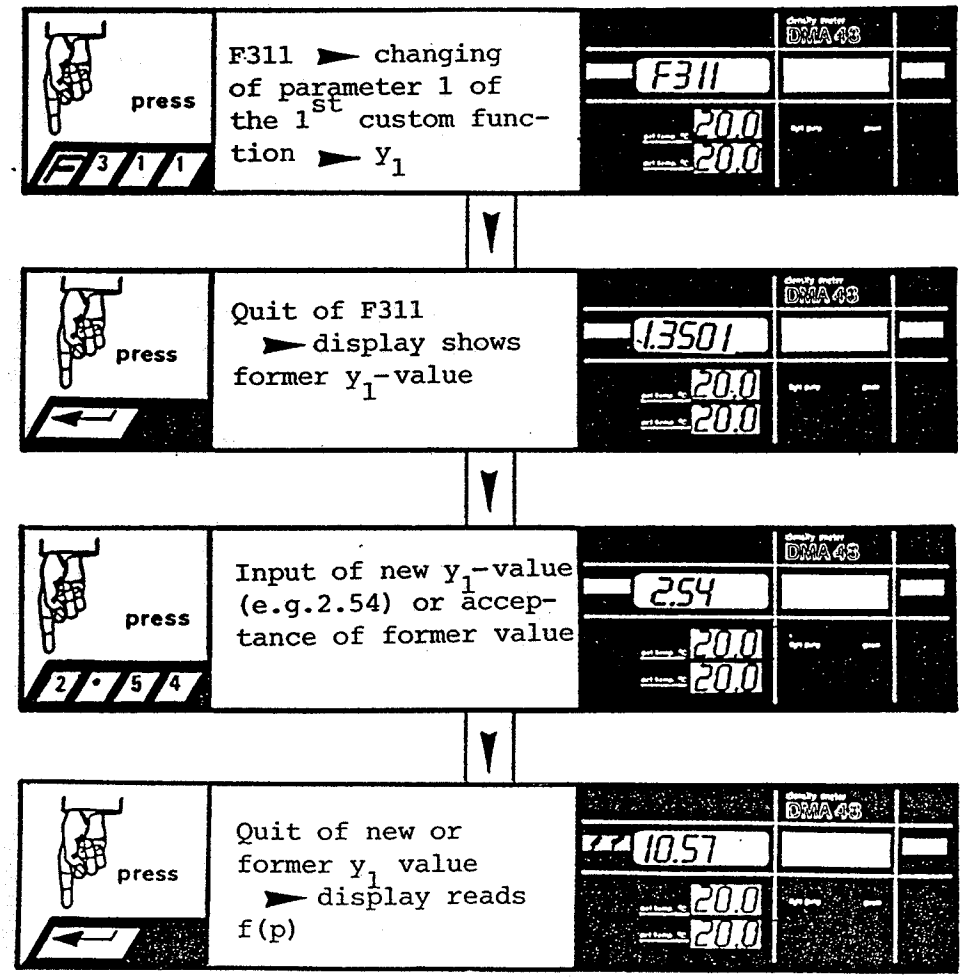
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Changing the parameter f(p): The parameters can individually be called and changed (F311/F312/F313/F314) or may be called and changed or accepted, respectively, one after another by pressing F310.

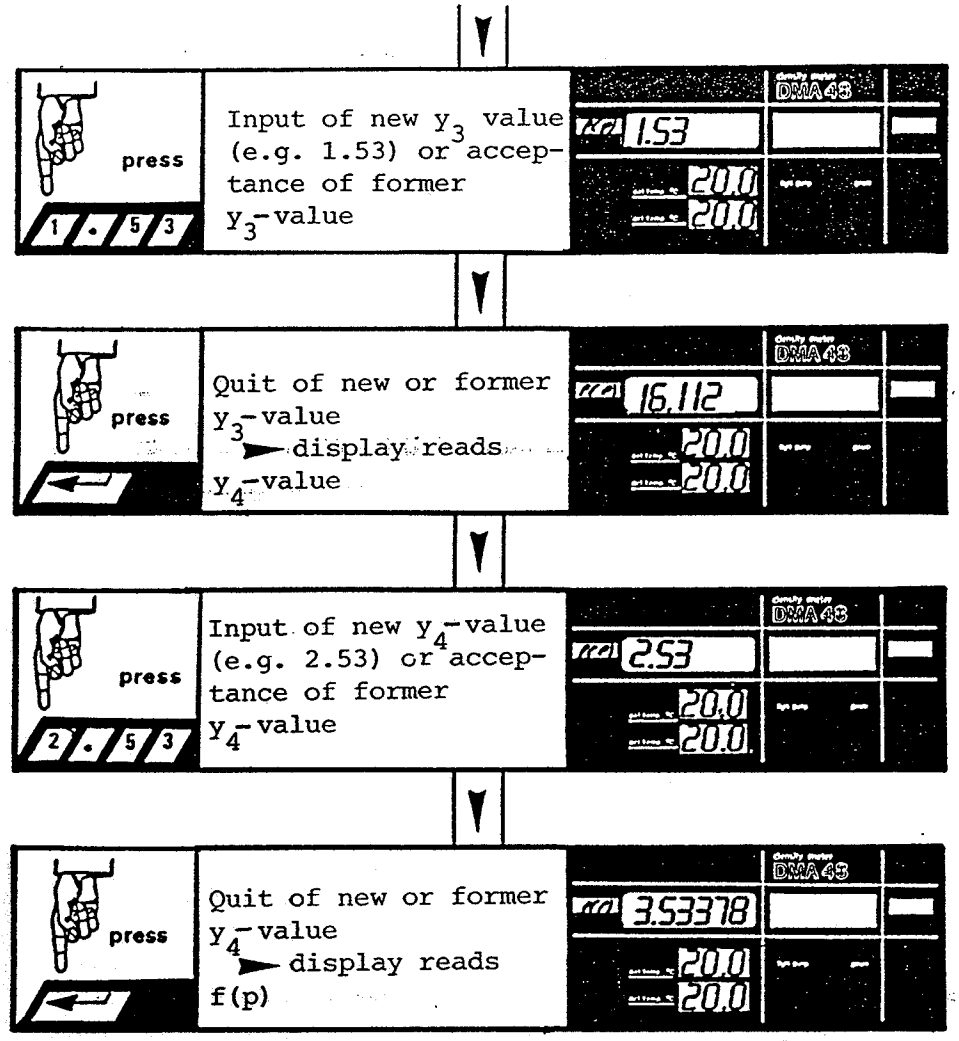
Selection of custom function 1: f(p):



Changing the parameters f(p) individually:
Change of parameter y_1:

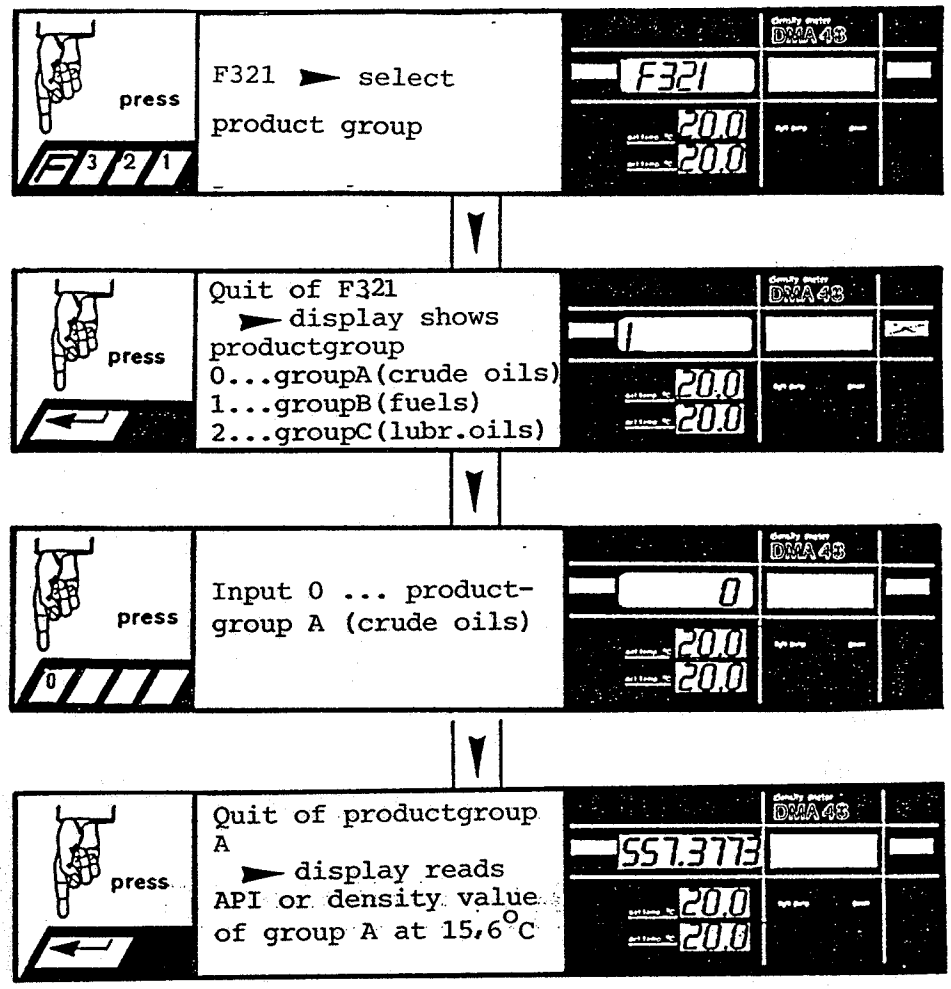


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How to select appropriate product group:

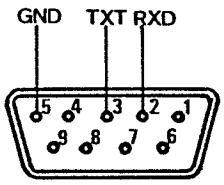


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7. INPUTS AND OUTPUTS

7.1 COMPUTER "INTERFACE A": RS 232 C SERIAL INTERFACE

Interface A: "Console Interface":
V.24 (RS 232 C)
2400 baud
1 start bit
7 data bits
1 parity bit (even parity)
1 stop bit
no control lines



GND ... ground
TXD ... transmit data
RXD ... receive data

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```
<018>                    <018>                    new data request
  .                        .
  .                        .
<002>                                             end remote control
```

If anything goes wrong during the data transmission, the external computer has to transmit

<001>
<127>

and to resume with the whole operation.

D(213) shows the current condition of the measurement, i.e.

- which value is given with D(210) (period/density/customfunction 1, 2 or 3/originated from internal or external measuring cell),
- whether the measuring value is stable,
- whether the instrument is in measuring mode or in another mode (e.g. calibrating), etc.

It appears in the following way: D(213)=+1xxx1yyyE+00

xxx = 000 means measuring value is stable.

128 means measuring value is not stable (e.g. temperature equilibrium not yet reached).

Other values will occure in the process of calibrating or checking the instrument. Any value other than 000 indicates that the measuring value given with D(210) is invalid.

yyy indicates which value is given with D(210).

= 000 wrong function selected (e.g. a non-existent customfunction 1, 2 or 3), dashes are displayed on the DMA 48.

001 customfunction 3, internal cell
002 " 2, "
004 " 1, "

008 density, internal cell

016 period of oscillation of internal cell

033 customfunction 3, external cell
034 " 2, "
036 " 1, "

040 density, external cell
048 period of oscillation of external cell

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7.2.6 MANUAL PRINTOUT WITH SAMPLE NUMBER

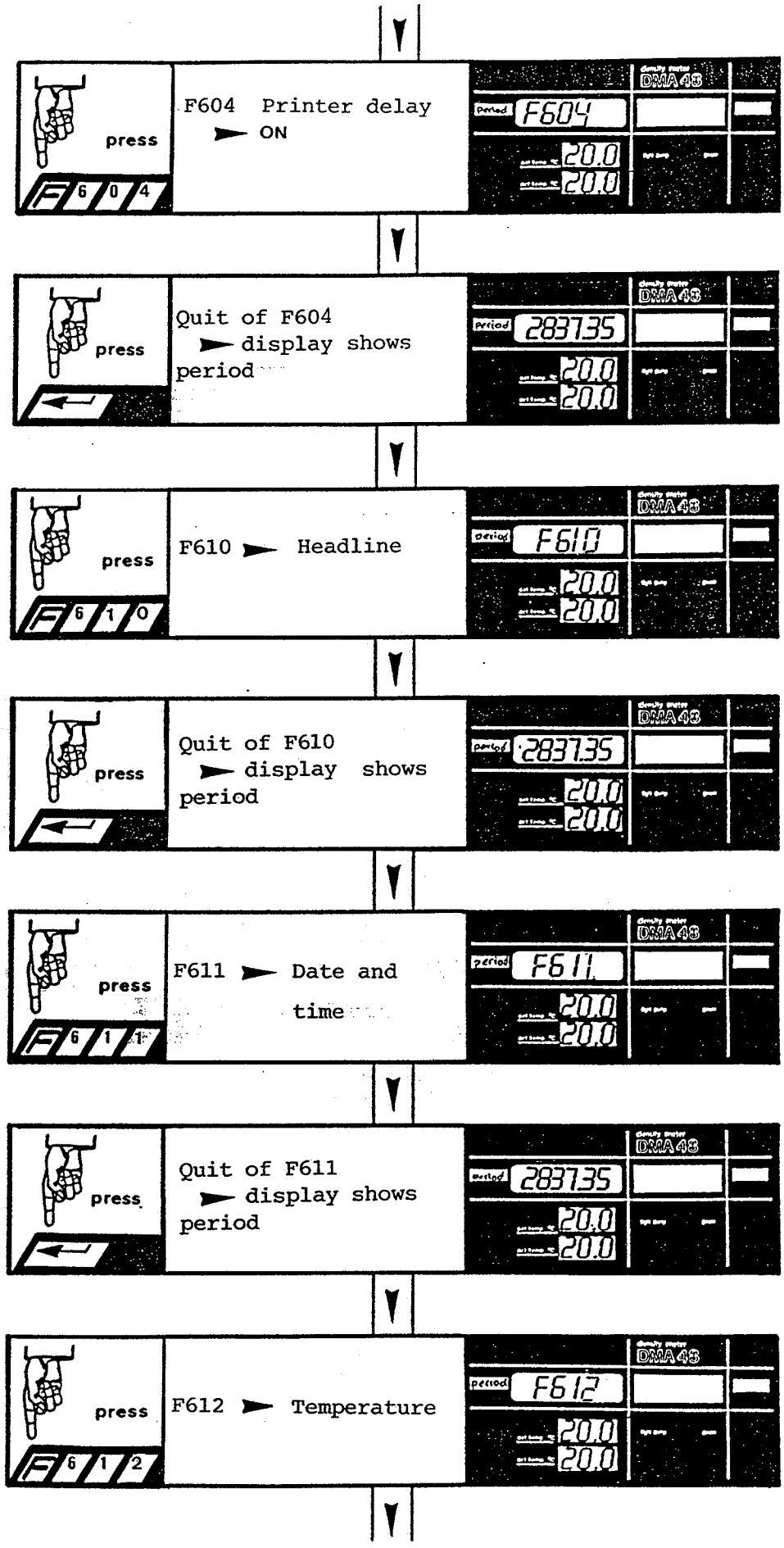
Keying:	Reading:
* Printout the sample number on display, e.g. 1.	
# 1	S S1
* Start the printout with "PRT".	
PRT	(Reading before)

7.2.7 AUTOMATIC PRINTOUT WITH SAMPLE NUMBER AND STORED VALUE ON DISPLAY

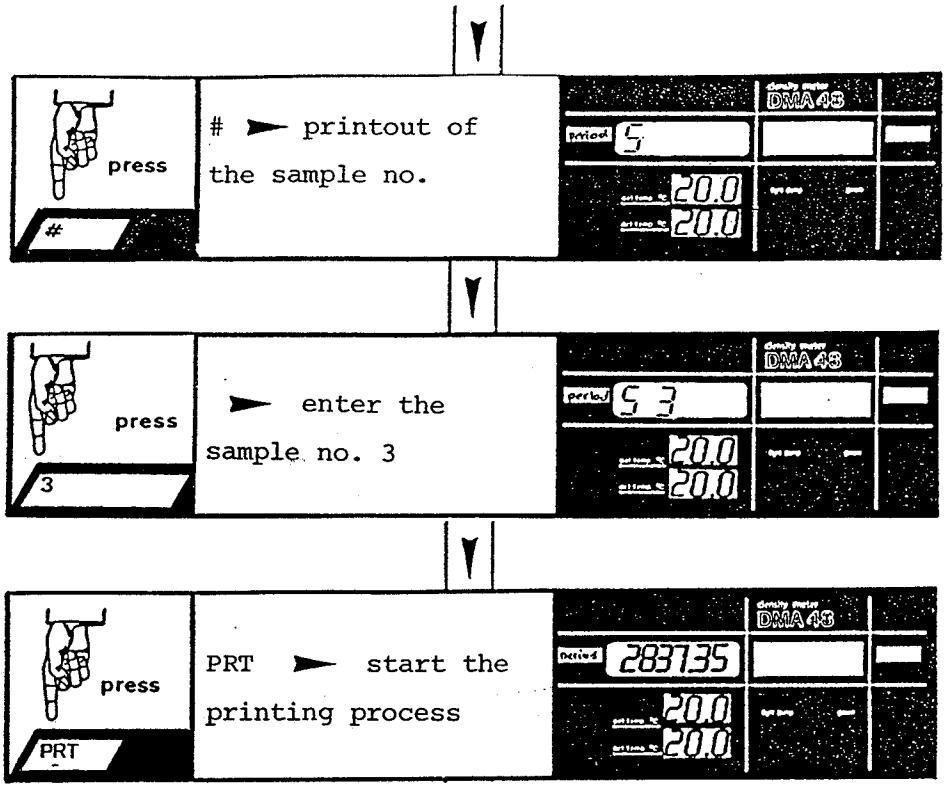
Keying:	Reading:
* Printout the sample number on display, e.g. 1.	
# 1	S S1
* Start the automatic printout with "*".	
*	(Reading before)

If a FRS is installed and activated, it will be started also.

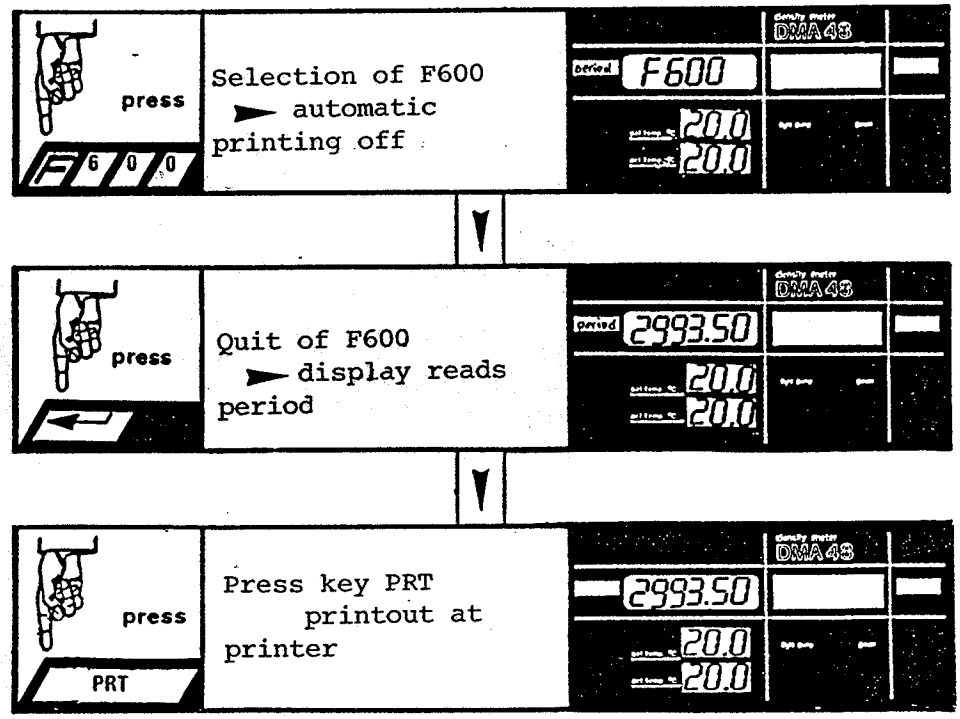
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If you want to stop automatic printing without changing the printer program, press F600. Density or period values can now be printed by pressing the PRT key.

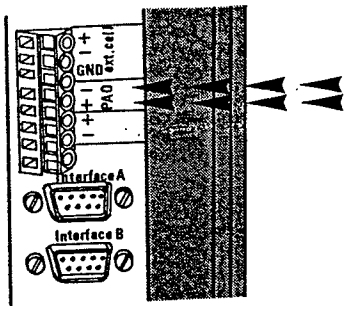


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8.1 PAO ANALOG-OUTPUT

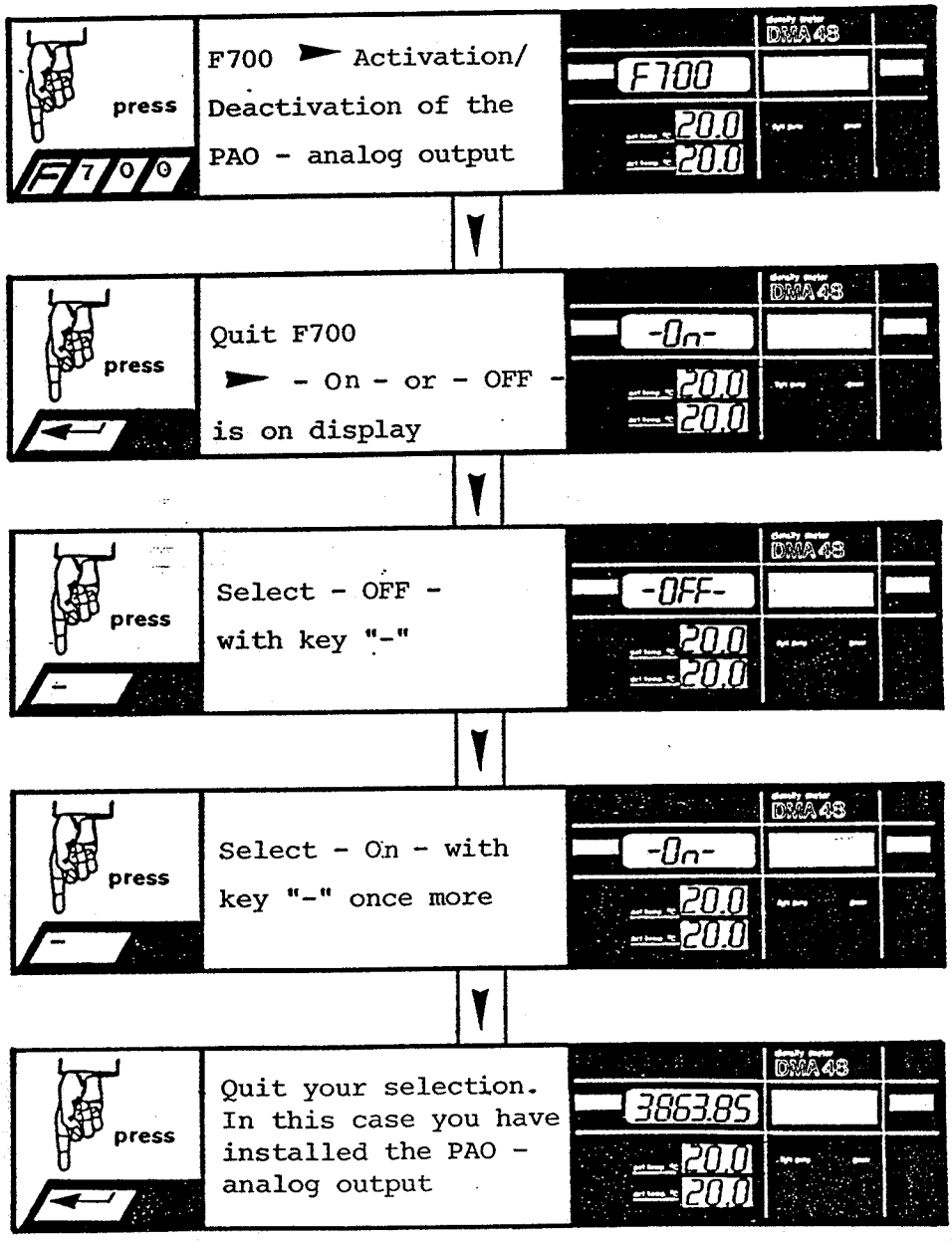
8.1.1 PAO - CONNECTION

Connect the cables of the analog meter to the IOB.



8.1.2 ACTIVATION/DE-ACTIVATION

F700 ... Activation and De-activation of the analog output



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8.2 FILLING AND RINSING SYSTEM FRS

In contrast to the SP3 automatic sample changer the FRS represents a semi-automatic filling and rinsing system allowing splash-free operation and thus is ideally suited for lab application.

The FRS is available as an option.

Outputs of the FRS are located at the rear of the instrument (left side).

8.2.1 HOSE CONNECTORS

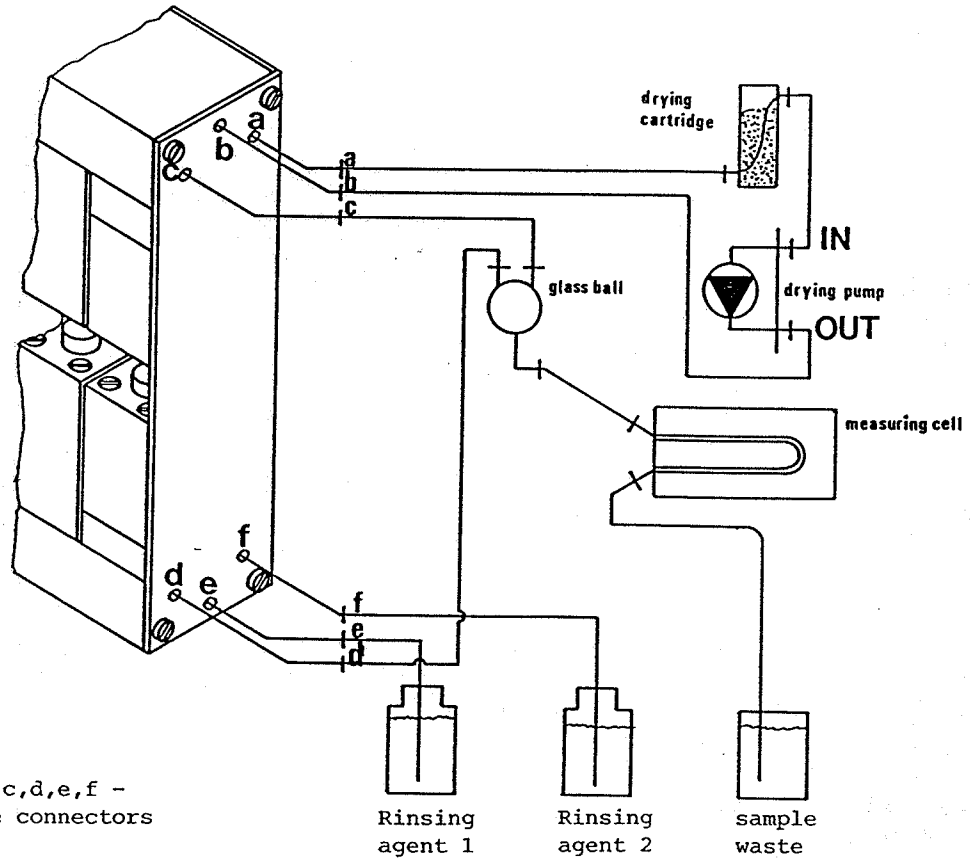
These are designated with letters:

Air connctions:
a to In
b to Out
c to Glass ball

Filling and rinsing connections:
d to Glass ball
e to Rinsing agent 1
f to Rinsing agent 2

Do not connect an air hose to a filling and rinsing connection.

The air pump is designated with IN and OUT.



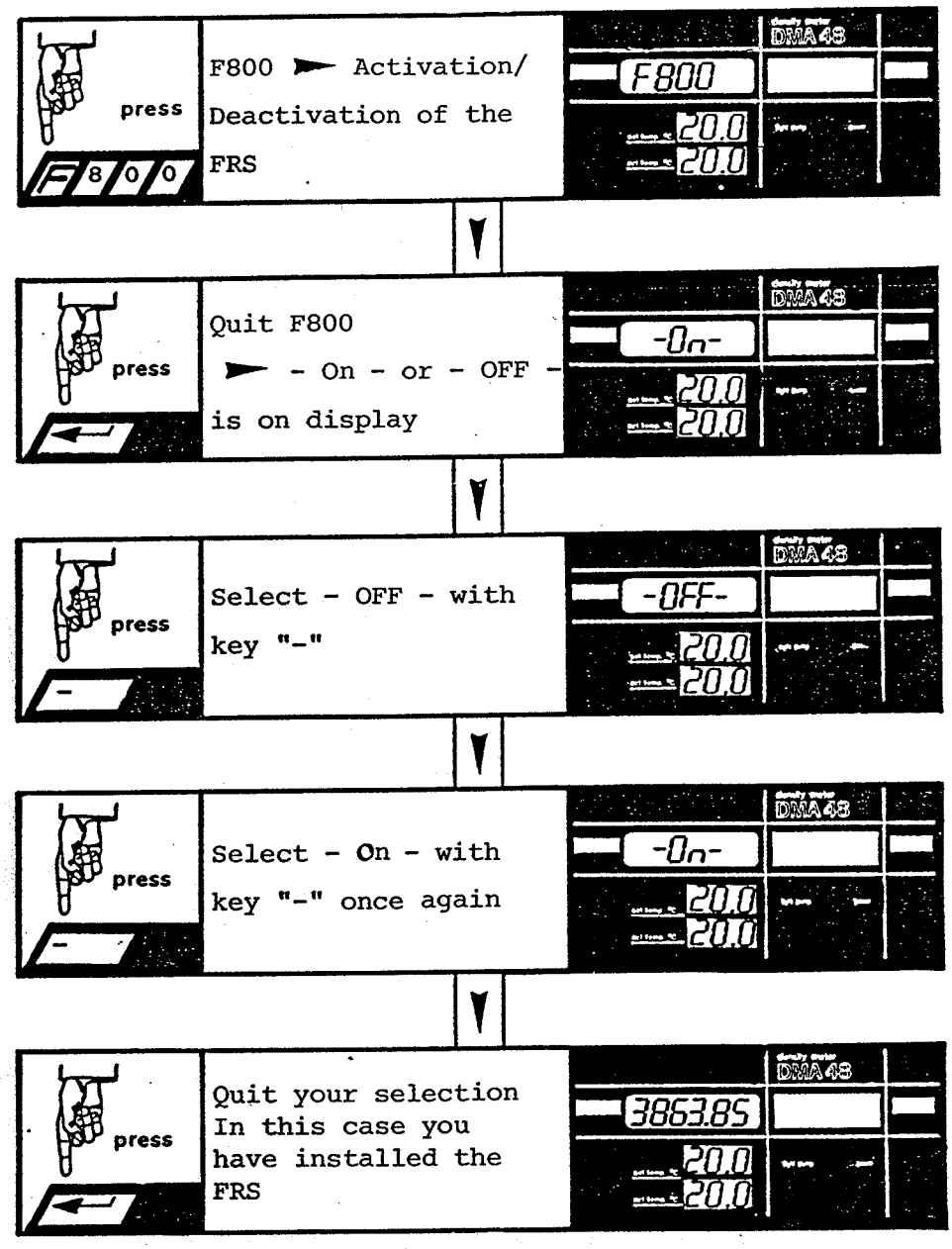
a,b,c,d,e,f -
Hose connectors

Hose connection system for FRS plug-in unit

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8.2.3 FRS - ACTIVATION/DE-ACTIVATION

F800 ... Activation and Deactivation of the filling and rinsing system



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8.2.4.1 NORMAL FILLING AND RINSING MODE

Oscillator cell is filled with the sample to be measured, then rinsed with two agents and automatically dried.

Example for water: **123246**

8.2.4.2 REPLACEMENT MODE

* Sample is loaded

* Measurement

* Replacement of the sample. The sample is pumped through the FRS and drains off at connector e (previously used for rinsing agent 1). At the same time, the next sample is loaded into the oscillator.



Do not measure strong acids with the replacement mode. Acids may corrode the valves.

Example for water: **220030**

8.2.4.3 CLEANING MODE

For rinsing and drying of the oscillator cell.
This mode is recommended if one wants to clean the cell during a measuring cycle without removing all the hoses.

Example: **303215**

8.2.4.4 SYRINGE MODE

After removing the tube between oscillator inlet and sample vessel, the sample is filled by means of the syringe (equipped with Luer cone). If the oscillator has been filled properly (without air bubbles) start this mode with "*".
Then take off the syringe and connect the tube to the vessel.



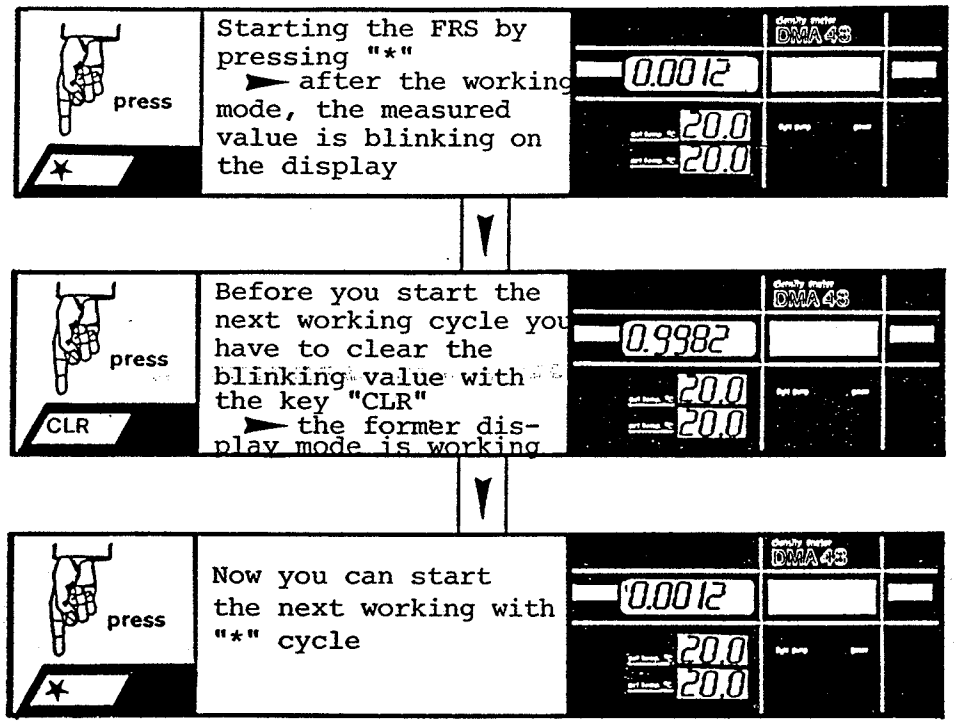
This mode should not run longer than five minutes.

Example: **403215**

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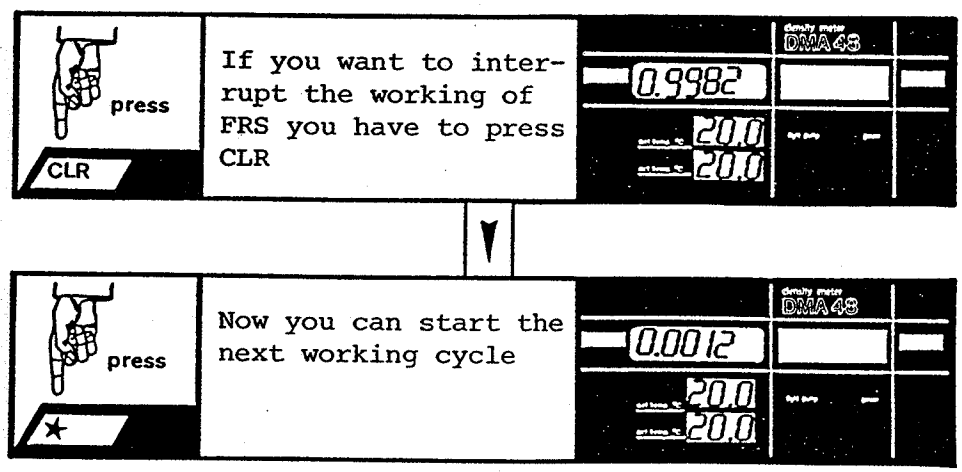
8.2.6 STARTING THE FRS

If you have installed and programmed the FRS you can start the working mode with key "*".

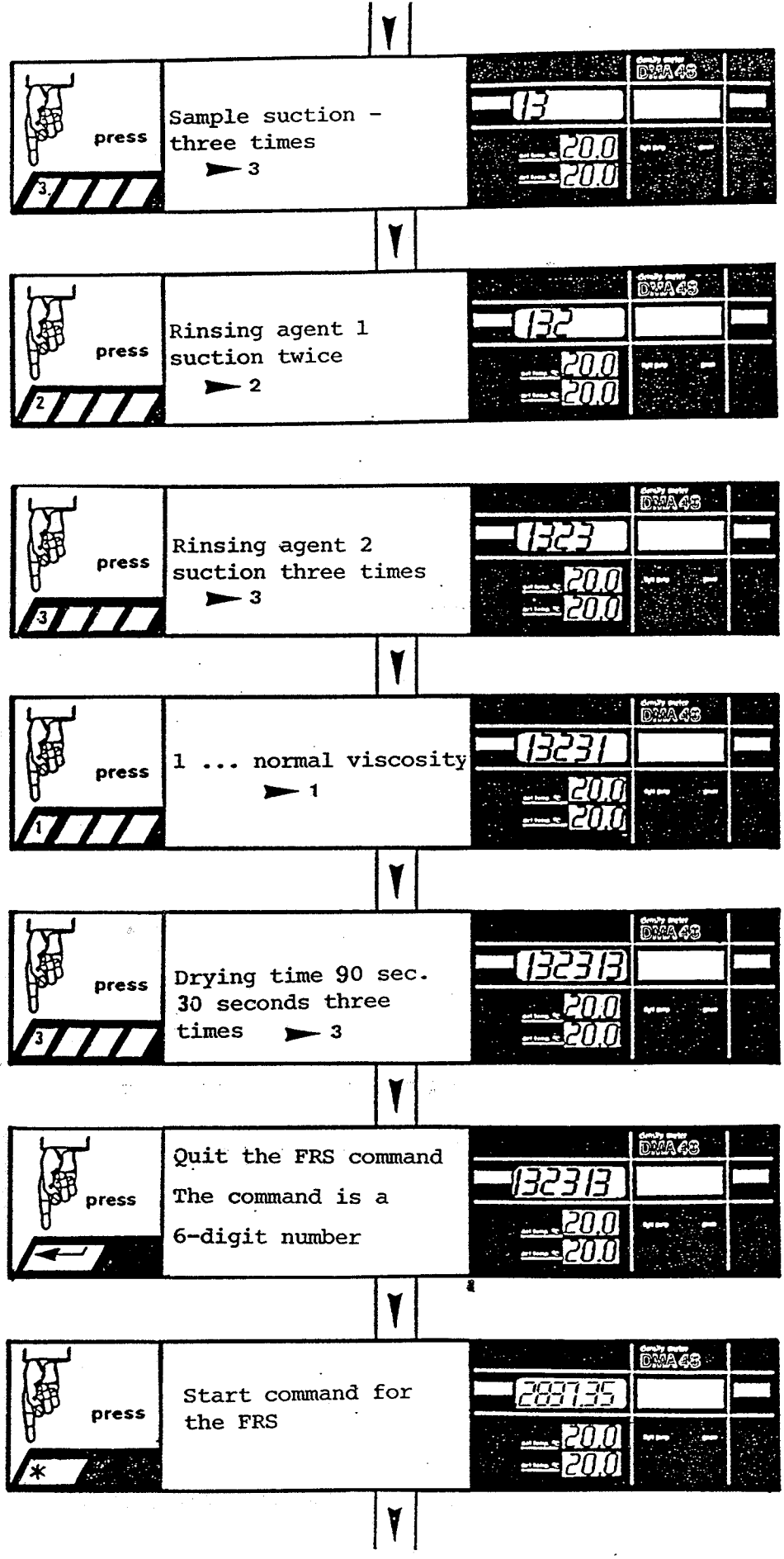


8.2.7 INTERRUPTING THE FRS CYCLE

If the FRS cycle needs to be interrupted (e.g. air bubbles in the cell) you have to press CLR. Then you can start the FRS again with key "*".



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9. POSSIBLE ERRORS - CAUSE AND CORRECTION

Errors which occur during operation of the DMA 48 are shown on the display in the format as follows:

E-xx-yy

xx ... Error location

- 00 ... Error at processor IPC
- 02 ... Error at temperature controller TR
- 03 ... Error at frequency meter DSP
- 04 ... Error at analog module PAO
- 05 ... Error at filling and rinsing system FRS

yy ... Error-code

ERRORS AT PROCESSOR IPC

Display	Error/Cause	Correction
E-00-00	Calibration error (time exceeding 24 hrs, stop)	"CLR" and recalibrate Calibrate using second standard within 24 hours
E-00-01	Calibration error (difference in density < 0.01 g/cm³)	"CLR" and recalibrate using standards of density difference > 0.01 g/cm³
***E-00-02**	READY hasn't been reached within 10 minutes	Particles in sample may be settling. Prethermostate the sample or increase the measurement criterion (see item 3.3)
E-00-50	S-BUS defect	OFF/ON
E-00-90	Arithmetical error at IPC-program	ON/OFF
E-00-95	Error in one custom function	OFF/ON Check the custom function, if the problem still remains contact your local distributor
E-00-99	NVRAM error at IPC	Replace IPC



If the IPC-board is defective or not locked correctly the display shows only the light bars or only one or two digits.

Correction: Check if IPC board has locked correctly.
Replace defective IPC board.

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ERRORS AT ANALOG OUTPUT MODULE PAO

Display	Error/Cause	Correction
E-04-00	PAO module defective or not existing	Check if PAO board has locked correctly Replace if defective
E-04-99	RAM error	OFF/ON

ERRORS AT FRS

Display	Error/Cause	Correction
***E-05-00**	No filling and rinsing system installed	Install filling and rinsing system with F800 and select - ON -
***E-05-10**	Command error	Check command
E-05-05	Handshake error	OFF/ON

ERRORS WITH SP3

Display	Error/Cause	Correction
E-06-00	Sample changer not installed	Install SP3 with F900 and select - ON -
E-06-10	Command not correct	Check command Command must consist of 6 digits
E-06-11	Needle broken	Replace needle
E-06-05	Handshake-Error	OFF/ON

Errors which are designated with "*" are displayed briefly and then terminated automatically.



In general, it is possible to erase the errors by pressing "CLR". If this does not work, switch the instrument off and on again. Should the error still exist, contact our service department.

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ERROR	CAUSE	CORRECTION
Display fluctuates in a daily rhythm.	Fluctuation in ambient temperature is influencing the results.	Do not subject the meter to direct sunlight or place near central heating or fans.
Measured values do not correlate with conversion tables.	a) The use of wrong density-related units can lead to errors. b) Density measurement was carried out using inappropriate calibration substances or density standards, e.g. tap water instead of distilled water.	Conform to density-standards and check the proper units as used in the tables.
Measured values are wrong.	An inappropriate calibration substance has been used. The relationship between density and concentration is non-linear and you are trying to measure too much of the curve.	Each concentration measurement can only be carried out using the corresponding calibration standard (check using distilled water or the calibration standard respectively). The measuring range limits should be specified and the calibration points should be moved closer to the measuring range. Otherwise use function f(p).

-OSC- .... is not an error message of the instrument but a message of an improper operation.

-OSC- .... is read on the display if the oscillator has not been properly filled or dried.
This message disappears when cleaning and drying is performed again or, after proper filling of the oscillator.
If the - OSC - message still remains after having cleaned and dried carefully, the excitation amplifier board could be defective.

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11. THEORY OF OPERATION

The DMA 48 density meter determines density p (mass divided by volume) of liquids and gases by measuring the period of oscillation electronically.

To do this, the sample is introduced into a system which can oscillate and whose natural frequency is influenced by the mass of the sample. This system is a U-shaped tube which is excited to undamped oscillation by electronic means. Both straight sections of the U-shaped tube form the spring element of the oscillator. The direction of the oscillation is perpenticular to the plane of the U-shaped tube. The oscillating volume V is limited by the mounting points which are fixed. If the oscillator has been filled with the sample at least up to the mounting points, then the same known volume V of sample also oscillates. The mass of the sample can therefore be taken as proportional to its density. If the oscillator has been filled beyond the mounting points, this has no effect on the measurement. For this reason, the oscillator can also measure the densities of samples flowing through it.

Assuming that the temperature is held constant, the density can be calculated from the period by considering a hollow body with mass M suspended on a spring with a spring constant c. The volume V of the hollow body is then filled with a sample of density p. The natural frequency of this spring mass system is

$$f = \frac{1}{2\pi} \sqrt{\frac{c}{M+pV}}$$

and the period T is

$$T = 2\pi \sqrt{\frac{M+pV}{c}} \qquad p = T^2 . \frac{c}{4\pi^2 . V} - \frac{M}{V}$$

Using the abbreviations $A = c/4\pi^2 . V$

and $B = M / V$

we arrive at $p = A.T^2 - B$

Constants A and B comprise the spring constant of the oscillator, the mass of the empty tube and the volume of the sample involved in the oscillation. A and B are therefore device constants for each individual oscillator. They can be derived from two period measurements when the oscillator has been filled with substances of known density (normally air and water).

The proportional relationship between density difference and the difference of the squares of the corresponding periods can be solved to an accuracy of $\pm 1 \times 10^{-4}$ g/cm³ for a density interval of < 0.5 g/cm³ using the oscillator in the density meter DMA 48. This means an accuracy of $\pm 1 \times 10^{-4}$ g/cm³ for a measurement range of 0.5 to 1.5 g/cm³ if the constants were determined using air and water.

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12. INSTRUCTION SET

Each command starts with "F" and is followed by a 3-digit number. The following instructions are available:

C A L I B R A T I O N R O U T I N E S

F100 ... Air calibration

F101 ... Water calibration

F102 ... Calibration with known density - standard 1

F103 ... Calibration with known density - standard 2

F110 ... Display of calibration data

P A R A M E T E R R O U T I N E S

F300 ... Change of set temperature

F3xy ... Change of y-coefficients of x^{th} custom function

F3x0 ... Change all coefficients of x^{th} custom function one after another

x = 1 ... custom function 1
x = 2 ... - " - 2
x = 3 ... - " - 3

y = 1, 2, 3, 4, 5 ... indices of coefficients

F350 ... Setting the measurement and equilibration criterion

O S C I L L A T O R R O U T I N E S

F400 ... Internal oscillator

F401 ... External oscillator with temperature transmission

NOTE: External cells must be connected first.

F402 ... External oscillator without temperature transmission

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PRINTER SPECIFICATION

DISPLAY FORMAT FOR PRINTOUT

ANALOG OUTPUT ROUTINES

F700 ... Activation/De-activation

F702 ... Lower limit of activated measuring value

F703 ... Upper limit of activated measuring value

F710 ... Temperature at analog output

F715 ... Period at analog output

If a valid calibration exists you may select from the following options:

F720 ... Density at analog output

F721 ... Custom function 1 at analog output

F722 ... Custom function 2 at analog output

F723 ... Custom function 3 at analog output

FILLING AND RINSING-SYSTEM FRS

F800 ... FRS - Activation/De-activation

F802 ... FRS Working commands

SAMPLE CHANGER ROUTINES

F900 ... Sample changer activation/de-activation

F902 ... Sample changer commands

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Temperature limits for emergency shut-off

1. Oscillator cell

The meter goes off for temperatures between 70°C and 82°C.

2. Heat exchanger

As above, the meter goes off for temperatures between 70°C and 82°C.
The fan automatically comes on at temperatures from 42°C to 48°C and goes off at 25°C to 30°C.

3. Housing

The meter goes off as soon as the temperature range between 56°C and 65°C is exceeded.

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14.2 TABLE 2

Table 2: Density of water (kg/cm³) depending on the temperature in °C on the International Practical Temperature Scale (1968)

0-50°C

t°C	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
0	999.84	999.85	999.85	999.86	999.87	999.87	999.88	999.88	999.89	999.89
1	999.90	999.90	999.91	999.91	999.92	999.92	999.93	999.93	999.93	999.94
2	999.94	999.94	999.95	999.95	999.95	999.95	999.96	999.96	999.96	999.96
3	999.96	999.97	999.97	999.97	999.97	999.97	999.97	999.97	999.97	999.97
4	999.97	999.97	999.97	999.97	999.97	999.97	999.97	999.97	999.97	999.97
5	999.96	999.96	999.96	999.96	999.96	999.95	999.95	999.95	999.95	999.94
6	999.94	999.94	999.93	999.93	999.93	999.92	999.92	999.91	999.91	999.91
7	999.90	999.90	999.89	999.89	999.88	999.88	999.87	999.87	999.86	999.85
8	999.85	999.84	999.84	999.83	999.82	999.82	999.81	999.80	999.79	999.79
9	999.78	999.77	999.76	999.76	999.75	999.74	999.73	999.72	999.72	999.71
10	999.70	999.69	999.68	999.67	999.66	999.65	999.64	999.63	999.62	999.61
11	999.60	999.59	999.58	999.57	999.56	999.55	999.54	999.53	999.52	999.51
12	999.50	999.48	999.47	999.46	999.45	999.44	999.43	999.41	999.40	999.39
13	999.38	999.36	999.35	999.34	999.32	999.31	999.30	999.28	999.27	999.26
14	999.24	999.23	999.21	999.20	999.19	999.17	999.16	999.14	999.13	999.11
15	999.10	999.08	999.07	999.05	999.04	999.02	999.01	998.99	998.97	998.96
16	998.94	998.92	998.91	998.89	998.88	998.86	998.84	998.82	998.81	998.79
17	998.77	998.76	998.74	998.72	998.70	998.68	998.67	998.65	998.63	998.61
18	998.59	998.57	998.56	998.54	998.52	998.50	998.48	998.46	998.44	998.42
19	998.40	998.38	998.36	998.34	998.32	998.30	998.28	998.26	998.24	998.22
20	998.20	998.18	998.16	998.14	998.12	998.10	998.08	998.05	998.03	998.01
21	997.99	997.97	997.95	997.92	997.90	997.88	997.86	997.84	997.81	997.79
22	997.77	997.75	997.72	997.70	997.68	997.65	997.63	997.61	997.58	997.56
23	997.54	997.51	997.49	997.46	997.44	997.42	997.39	997.37	997.34	997.32
24	997.29	997.27	997.24	997.22	997.19	997.17	997.14	997.12	997.09	997.07
25	997.04	997.02	996.99	996.97	996.94	996.91	996.89	996.86	996.83	996.81
26	996.78	996.76	996.73	996.70	996.67	996.65	996.62	996.59	996.57	996.54
27	996.51	996.48	996.46	996.43	996.40	996.37	996.34	996.32	996.29	996.26
28	996.23	996.20	996.17	996.15	996.12	996.09	996.06	996.03	996.00	995.97
29	995.94	995.91	995.88	995.85	995.83	995.80	995.77	995.74	995.71	995.68
30	995.65	995.62	995.58	995.55	995.52	995.49	995.46	995.43	995.40	995.37
31	995.34	995.31	995.28	995.25	995.21	995.18	995.15	995.12	995.09	995.06
32	995.02	994.99	994.96	994.93	994.90	994.86	994.83	994.80	994.77	994.73
33	994.70	994.67	994.64	994.60	994.57	994.54	994.50	994.47	994.44	994.40
34	994.37	994.34	994.30	994.27	994.23	994.20	994.17	994.13	994.10	994.06
35	994.03	994.00	993.96	993.93	993.89	993.86	993.82	993.79	993.75	993.72
36	993.68	993.65	993.61	993.58	993.54	993.51	993.47	993.43	993.40	993.36
37	993.33	993.29	993.25	993.22	993.18	993.15	993.11	993.07	993.04	993.00
38	992.96	992.93	992.89	992.85	992.82	992.78	992.74	992.70	992.67	992.63
39	992.59	992.55	992.52	992.48	992.44	992.40	992.37	992.33	992.29	992.25
40	992.21	992.18	992.14	992.10	992.06	992.02	991.98	991.94	991.91	991.87
41	991.83	991.79	991.75	991.71	991.67	991.63	991.59	991.55	991.51	991.47
42	991.44	991.40	991.36	991.32	991.28	991.24	991.20	991.16	991.12	991.08
43	991.03	990.99	990.95	990.91	990.87	990.83	990.79	990.75	990.71	990.67
44	990.63	990.59	990.55	990.50	990.46	990.42	990.38	990.34	990.30	990.25
45	990.21	990.17	990.13	990.09	990.05	990.00	989.96	989.92	989.88	989.83
46	989.79	989.75	989.71	989.66	989.62	989.58	989.54	989.49	989.45	989.41
47	989.36	989.32	989.28	989.23	989.19	989.15	989.10	989.06	989.02	988.97
48	988.93	988.88	988.84	988.80	988.75	988.71	988.66	988.62	988.57	988.53
49	988.49	988.44	988.40	988.35	988.31	988.26	988.22	988.17	988.13	988.08

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