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UNIDO Project: MP/BRA/95/125

Modification of a refrigerant calorimeter at Elgin Maquinas
S.A., Brazil

Contract No.: 98/122/VK

Final Report

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Introduction

In the cause of worldwide efforts to phase out CFC's and HCFC's in order to protect the ozone layer from these ozone depleting substances, Elgin Maquinas has performed a redesign of their compressors for use with HFC's. As part of UNIDO Project No. MP/BRA/95/125, in which a conversion of the assembly line at Elgin Maquinas has been performed for an efficient production of the redesigned compressors, an old calorimeter, which has formerly been used to test the CFC and HCFC compressors is now to be converted to allow the testing of the redesigned compressors. The tasks included in the modification of the calorimeter have been assigned by UNIDO to *FKW* GmbH as a project under contract No. 98/122. The tasks are described in the corresponding terms of reference.

Several steps had to be taken in order to find a suitable solution for the modification of the calorimeter at Elgin Maquinas. In the following, the individual steps taken and the result obtained from these endeavors will be described.

Visit preparation

At the outset of this project, only very few information regarding the calorimeter and its current condition were available to *FKW*. These were merely some pictures of the calorimeter boiler and the board holding the electrical wiring as well as a few electrical wiring diagrams. Since the terms of reference issued by UNIDO made a visit to Elgin Maquinas mandatory, preparations to this visit were done based on the few information given in the project request for proposal and the few photographs and diagrams of the calorimeter. Additional information was inquired directly from Elgin Maquinas. Names, phone- and fax numbers of contact personnel at Elgin were supplied by UNIDO to *FKW*. The contacts named were Mr. Roberto Feder, Director at Elgin Maquinas and Mr. Carl G. Almén, Brazilian Consultant. These two were addressed by *FKW* and asked for a more detailed description of the tasks necessary to modify the calorimeter. In reply, a list of equipment and changes of the calorimeter as wished by Elgin Maquinas was sent to *FKW* including mainly the following four items:

1. Computerized data acquisition system for pressures, temperatures, amperage and wattage of compressor motor and power dissipated in heater and boiler.
2. Printed out report, based on data from item 1. for the determination of nominal capacity and compressor curves.
3. Automatic control of ambient temperature, boiler temperature, working pressure and level of secondary fluid.
4. Introduction of a flow meter in the system.

Based on these items, *FKW* started to evaluate different solutions for the modification of the calorimeter.

Computerized Data Acquisition System (DAS)

At the current status of the calorimeter, all measured values such as pressures, temperatures and electrical power consumption have to be read from digital temperature and pressure displays, pressure gauges, impulse counter units and analog ampmeter and voltmeter. The

measured data have to be written into a report by hand, thus requiring expensive manpower for the data acquisition. Also, the recorded data have to be converted into usable data such as cooling capacity, compressor power consumption and EER by hand calculation.

Modern Data Acquisition Systems in combination with a suitable software permit to record the data automatically and therefore eliminate the effort of manpower. These DAS also utilize internal functions which convert the measured data into the desired property automatically, thus eliminating the need for hand calculations, providing a complete measurement protocol.

In the case of calorimetric measurements, refrigerant property functions are required to calculate specific properties such as enthalpy, entropy and density from measured pressure and temperature. Therefore, a suitable DAS has to provide the refrigerant property functions internally.

Automatic control of working temperatures and pressures

The calorimeter at this point requires a lot of manpower effort to set the desired temperatures and pressures of the testing equipment. Whereas the power supply to the boiler heater is controlled by pressure gauge switches (after a certain base load has been set by hand), all other devices such as valves and room heater (to set ambient temperature) have to be controlled manually.

In order to save effort and time, an automatic handling of the system is desirable. This requires motor driven devices that are controlled by a computer system. The input data are fed to the controller through the data acquisition system and the corresponding output signal set the control devices.

However, the design of such a system can not be completed 'from scrap'. These systems have to be investigated thoroughly by experiment in order to determine the correct controller settings. To develop such a system for the calorimeter at Elgin Maquinas is not within the scope of this project. The time required for this development would by far exceed the schedule that was set for this project. Also, it would be necessary to transport the calorimeter boiler from Elgin Maquinas to the laboratories at *FKW* to perform the experimental investigations.

FKW has therefore envisioned a system that could be described as semi-automatic. Basically, this system would consist of exactly the same components required for a full automation of the system, but instead of setting the control devices through the controller automatically, the setting will be entered to the computer by an operator via the keyboard. This requires still manpower to run the calorimeter, but the operator remains seated in front of the computer and does not have to move between the individual devices. The operator can read the current set point from the computer screen and adjust the control devices accordingly. Once the operating set point has been reached, the system can be left alone and recording of the measured data will be performed by the DAS. However, the main advantage is that at a later point of time, the system can easily be switched to full automated operation. For this purpose, the PID controllers, which are part of the software packet supplied with the DAS, only need to be activated and the controllers take over the tasks of the operator, thus eliminating the need for an operator.

Introduction of a flow meter

As a backup measurement (as required by ISO 917) Elgin Maquinas wishes to have a flow meter implemented in the system in order to monitor sub-cooled refrigerant flow. Different

kind of flow meters can be considered as suitable devices for this application such as coriolis type of flow meters or turbo flow meter. Both of these comply with the accuracy laid down in ISO 917.

Visit at Elgin Maquinas

The visit of a *FKW*-employee (Mr. Nils P. Halm) at Elgin Maquinas took place from August 3rd to August 5th. On a first meeting between *FKW* and two engineers from Elgin Maquinas, Mr. Claudio Ismael da Luz (Chief of Refrigeration Division) and Mr. Gilberto D. S. Melo (Chief of Laboratory Dep.), under presence of Brazilian Consultant Mr. Carl G. Almén, the concept that had been elaborated by *FKW* in preparation to this visit was presented. Even though generally in agreement with the concept, the estimated additional costs of US\$ 80,000.- to US\$ 100,000.- were not acceptable to Elgin Maquinas. Elgin Maquinas was not aware of the financial frame of US\$ 34,400.- available to *FKW* when expressing their requirements for the modification of the calorimeter. After discussion of the financial situation, the following two options were elaborated:

Option 1:

FKW will setup a list of equipment including all costs for the hardware, software, engineering costs and shipment, required to equip the calorimeter at Elgin Maquinas with a Data Acquisition System and a flow meter. This will also include sufficient documentation of the installation of the Data Acquisition System and the flow meter in order to enable Elgin Maquinas to perform the installation themselves eliminating the need for a second visit of *FKW* personnel to Brazil in order to save money that can be better spent for the hardware components.

Any further modification as originally elaborated by *FKW* will not be conducted.

Background of this option (as well as of option 2) is, that Elgin Maquinas has been supplied with four new calorimeters by the British company H.E.A.T.. It seems very likely, that these calorimeters will provide enough capacity to cover up most of the compressor testing requirements at Elgin Maquinas. In that case, the old calorimeter will just be used for measurements of condensing units. For this application, a complete automation of the old calorimeter is not considered necessary by Elgin. The new calorimeters will be commissioned at the beginning of September. It has been agreed between *FKW* and Elgin to wait with a decision for any of the two options until functionality and effectiveness of the new calorimeter have been investigated.

Option 2:

If the costs in option 1 do exceed the financial frame, only a flow meter consisting of the sensor, a transmitter and a suitable display unit will be selected and purchased by *FKW* for Elgin. Additionally, a new transformer necessary to run the new calorimeters from H.E.A.T. will be purchased by *FKW* for Elgin.

Any further modification as originally elaborated by *FKW* will not be conducted.

Introduction of a data acquisition system (including software) and a flow meter

Even though the commissioning of the new H.E.A.T. calorimeters was scheduled for September 9th, no information on its functionality and capacity was made available to FKW before the first week of October. As it turned out then, the calorimeters were working sufficiently good but were not suitable for testing condensing units. It was therefore decided for option 1, i.e. FKW will supply a suitable data acquisition system including the necessary software and documentation and a flow meter to Elgin Maquinas.

The systems, as elaborated by FKW, will be described in the following shortly. The necessary documentation and further descriptions can be found in the appendix.

Specification of Data Acquisition System and Software

Different Data Acquisition Systems (DAS) have been evaluated. A system sold by a company called Kohlenberg Software GmbH has been selected as the most suitable for the application at Elgin Maquinas. Predominant reason for this selection was, that the system will be supplied with hardware and software, whereas from other specialists only hardware was available. Developing a software for the DAS would increase the costs substantially.

The system selected displays the following features:

Hardware:

- μ Mac-1050 data Acquisition main board
- 16 analog input channels
 - 8 x Thermocouples Type T
 - 8 x 10 V or 4 - 20 mA (shunt)
- 2 analog output channels
- 6 digital I/O
 - 4 x impulse counting up to 25 Hz
 - 2 x impulse counting up to 1 MHz.

Software:

- MSR1 Software for μ Mac-1050
- MSR1 Software extension for protocol-output based on a protocol form used by Elgin Maquinas
- MSR1 Software extension for process-display in log P-h diagram
- MSR1 Software extension for evaluating thermophysical properties of four refrigerants

Since the prize of the hardware depends on the number of analog and digital I/O channels supplied, the system has been reduced to the number of channels that are required for the application at Elgin. In its full version, the data acquisition μ Mac-1050 can accommodate a larger number of measurement channels.

According to specification made by Elgin, the following properties need to be recorded:

- Ambient temperature
- Expansion valve temperature
- Suction temperature
- Discharge temperature
- Liquid sub-cooling temperature of the refrigerant
- Boiler temperature
- Compressor housing temperature
- Condenser half way temperature
- Suction pressure
- Discharge pressure
- Flow rate of the refrigerant
- Power consumption of the compressor
- Voltage to the compressor
- Current through the compressor
- Power consumption of the heaters in calorimeter boiler.

For all of these properties the data acquisition system provides suitable channels, so that all relevant data can be recorded.

In order to eliminate any potential source of problems associated with the software, the original version also has been modified in close co-operation between the Kohlenberg Software GmbH and FKW engineers.

In its original condition, the software features many more options than are actually needed to record data at the calorimeter at Elgin Maquinas. In its full version, the data acquisition system and the software permit not only to record data, but also to evaluate and process the data and to address and control controller-devices. This may become particularly beneficial, if Elgin decides later on yet to automate the calorimeter. However, at this point only options that are needed have been implemented in the software. This reduces the risk that the operator may accidentally change the setting of the software and thus cause problems with the system.

A documentation of the DAS and the software has been supplied in English.

The Flowmeter

Several types of flow meter have been evaluated for the calorimeter at Elgin Maquinas. A turbine flow meter has been selected. The turbine flow meter displays a sufficient accuracy at an acceptable price. The flow meter, sensor and the transmitter display the following features:

- measurement range: 0.003 - 0.1 l/s
- max. pressure: 500 bar
- temperature: 100 °C
- calibration: 10 Points at 1,2 cSt
- transmitter: output optional 0 - 10 V (supply power: 12 - 30 Vdc)

Since the flow meter monitors only the volumetric flow, the mass flow rate has to be calculated using the density of the refrigerant as it flows through it. The density can be evaluated by the software using temperature and pressure data recorded with the data acquisition.

A documentation of the flow meter, the sensor and the signal transducer as well as directions on how to install the flow meter have been supplied in English (see appendix).

Conclusions

FKW has been assigned by the United Nations Industrial Development Organization to modify and automate an existing calorimeter at Elgin Maquinas, Brazil.

After first preparations and evaluation of information available on the calorimeter, a visit to Elgin Maquinas in Mogi das Cruzes, Brazil, was performed by FKW personnel.

The different options that had been envisioned by FKW to modify the calorimeter were presented to Elgin Maquinas staff at that visit. As it turned out, the financial frame available did not allow to realize any of these options entirely. Instead, two alternatives were elaborated. One would include the provision of a data acquisition system, suitable software and a flow meter without automating the calorimeter any further. The other option would include the provision of a flow meter and a power transformer that was needed by Elgin Maquinas to run four new calorimeters received from the British company H.E.A.T.

It turned out that the new calorimeters from H.E.A.T. were suitable for compressor testing but not for testing of condensing units. It was therefore decided to realize option 1.

A suitable data acquisition system including software and a flow meter were selected by FKW. The software was modified and translated so that it would suit the specific needs and requirements of the calorimeter at Elgin Maquinas.

The different components were purchased and after some basic testing and thoroughly documenting sent to Elgin Maquinas.

Appendix

- Manual MSR1 Software
- Manual Data Acquisition μ Mac-1050
- Manual Turbine Flow Meter FT 4-8

Manual for

MSR1

Measure – Control – Regulate μ Mac-1050/1

Measurement Software for Data Acquisition μ Mac-1050

Graphic User Interface

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1 Introduction

The software MSR1 is a sophisticated tool to measure and control processes including a variety of different process variables. In combination with a powerful data acquisition system such as the μ Mac 1050 it allows to monitor variables, record these in numerical or graphical form, to process the monitored variables and to return output signals in order to control the process. It allows for printing or plotting of these graphics and copying the measured data into ASCII files which can be up loaded into table evaluation programs.

The version delivered to Elgin Maquinas is a modified one, in which some of the features which are not necessary for the measurements taken on the calorimeter have been taken out and others which make the use of this program more suitable for that kind of application have been added.

The original version of this software is only available in German. For Elgin Maquinas, the software has been translated into English. At some point, the user might still encounter menu options of the software that have accidentally not been translated or eliminated from the software surface.

The software as delivered to Elgin Maquinas does not display all the options that the original version offers but has been reduced in order to guarantee easy handling for the user. However, it has been agreed with the company supplying the software that, if at some future time Elgin Maquinas decides to further modernize the old Linde calorimeter, a more complete version of the MSR1 software will be supplied without charging for another license (but additional work for translating the entire version will be charged !).

The software can be run on any IBM compatible PC with at least a 80386DX processor with 4MB Ram and 10 MB available storage on the HDD (the program will not run on a Pentium II, because these processors do not support the programming language used).

2 Installation of the software

The software is delivered on a 3.5" disk. Before installing the software, make a back up of that disk by copying it.

All files have been included into a self-extracting file called INSTALL.EXE. In order to install the software from a WINDOWS environment, insert the disk into the disk drive. Start the installation process from the EXECUTE command window by typing

```
A:\INSTALL.EXE
```

The self extracting file will ask you where (in what directory) you want the software to have installed. It is recommended to accept the offered standard installation directory "C:\MSR".

The installation can also be performed from the DOS environment. In the DOS environment copy the file INSTALL.EXE to the desired installation directory ("C:\MSR"), that previously has to be created, and execute it from therein.

After you have installed all files on your hard disk drive, you don't have to add any more directories or change any of the files. Sub-directories necessary for the measurement will be created automatically by the program (for further explanation see below).

Some of the files are ASCII text files that allow you to change the words in the main menu and in the output protocol (for further explanation see below). **Be careful when you change any of the**

wording in these files and make sure that you don't change the general structure of these files (for example by accidentally adding extra lines or tab characters).

3 Graphic User Interface

Once the software is installed and the computer has been connected to the hardware (for hardware installation details see manual „Data Acquisition μ Mac 1050“), you can start the software and the data acquisition from the directory MSR in which the executable program MSR1.EXE has been installed. It is recommended to start the program from the DOS environment, but it is possible to start it from the WINDOWS environment also.

From DOS start by typing

```
C:\MSR\MSR1.EXE
```

From WINDOWS start by selecting the file MSR1.EXE in a file management program (e.g. the „File Manager“ in WINDOWS 3.1 or from „Windows Explorer“ in WINDOWS 95/98). Double click with the left mouse-button will start the program.

After the program has been started the μ Mac 1050 will be initiated and the software will bring you to the user interface.

The graphic user interface of the measurement program „MSR1“ is easy to use. The program is controlled by a small numbers of different keys (function keys, arrow keys, page-up, page-down, return key) and selection menus. At the bottom of each screen the actual function of the keys „F1“ to „F10“ is displayed in short words. The function keys may change their function when additionally the „Shift“- or „Alt“- key is held. With the help of the function keys the user gets access of the different input/output- and evaluation screens offered by the program. Depending on the active program screen the function keys may change their function. The use of the program and the different action of the function keys according to the different program screens will be explained in detail in the following.

After program start the main screen is displayed (figure 1).

3.1 Main Screen

In the main screen of the program the user gets access of 11 $x-t$ -diagrams (graphic 1, 2 and 4 to 12) and one log $p-h$ -diagram (graphic 3).

Up to 30 user defined measured values x (temperature, pressure, mass flow, impulses etc.) of the calorimeter rig can be monitored with time t in each $x-t$ -diagram. In the log $p-h$ -diagram (graphic 3) the points of state of the refrigerant in the calorimeter process are shown. Below each diagram for the measured point the actual values of the first 9 channels are displayed as numerical values.

Since only three of the possible 12 diagrams are shown at the screen at one time, the function keys F1 (graphic 1) to F6 (graphic 6) are used to switch to the different diagrams. The page-up/page-down keys change the function of keys F1 through F6 to graphic 7 to graphic 12, respectively. The chosen diagram will be printed in the upper left corner of the screen, followed by the next two.

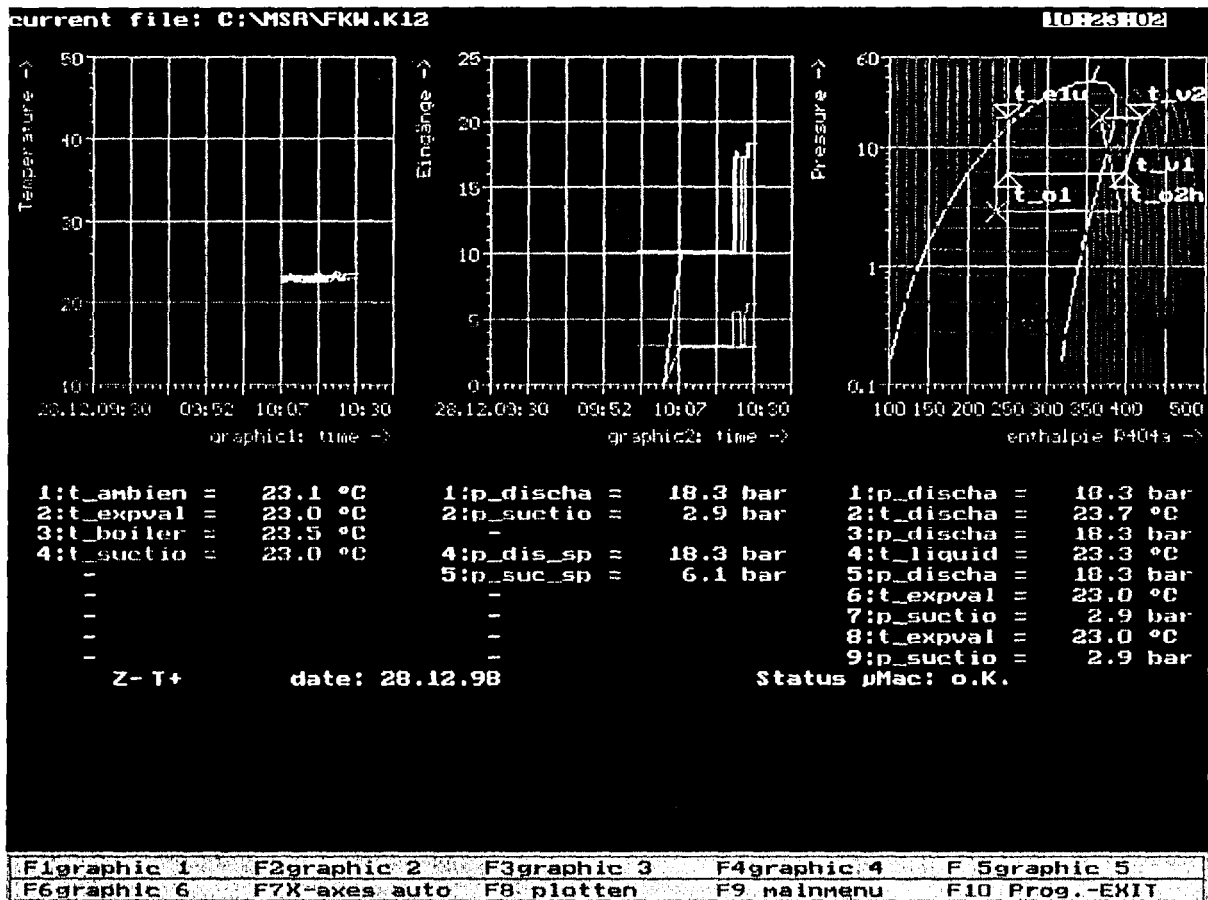


Figure 1: Main Screen

The other 4 function keys of the main screen are:

- F7: X-axes auto
The t -axis will be automatically adjust with decreasing program running time to display the actual measured values in the graphic. When the shift key is pressed, F7 changes to „table on” and Shift-F7 switches to tabular output format of the measured values.
- F8: plotter
When a plotter is used, function key F8 creates a plot of the screen. When no system plotter is installed the plot may be copied to a plot file. When the shift key is pressed, F8 changes to „hard copy” and Shift-F8 prints a screen shot on the printer installed.
- F9: main menu
Key F9 displays the main menu for configuration of the program, calibration of the installed sensors as well as starting and evaluation of the measurement. The main menu will be described in detail below.
- F10: Prog.-EXIT
Press F10 to exit the program.
While a measurement is running, F10 changes to „Measurement. Cont” (Measurement Control), which enables the user to stop the current measurement run.

3.2 Main Menu (F9 in Main Screen)

Pressing the function key F9 while the main screen is active displays a number of six menu items (figure 2):

Item 1: Configuration: standard diagram

Item 2: Configuration: log p-h-diagram

Item 3: Configuration: refrigerant

Item 4: Calibration: sensor calibration

Item 5: Measurement: start measurement

Item 6: Measurement: evaluation

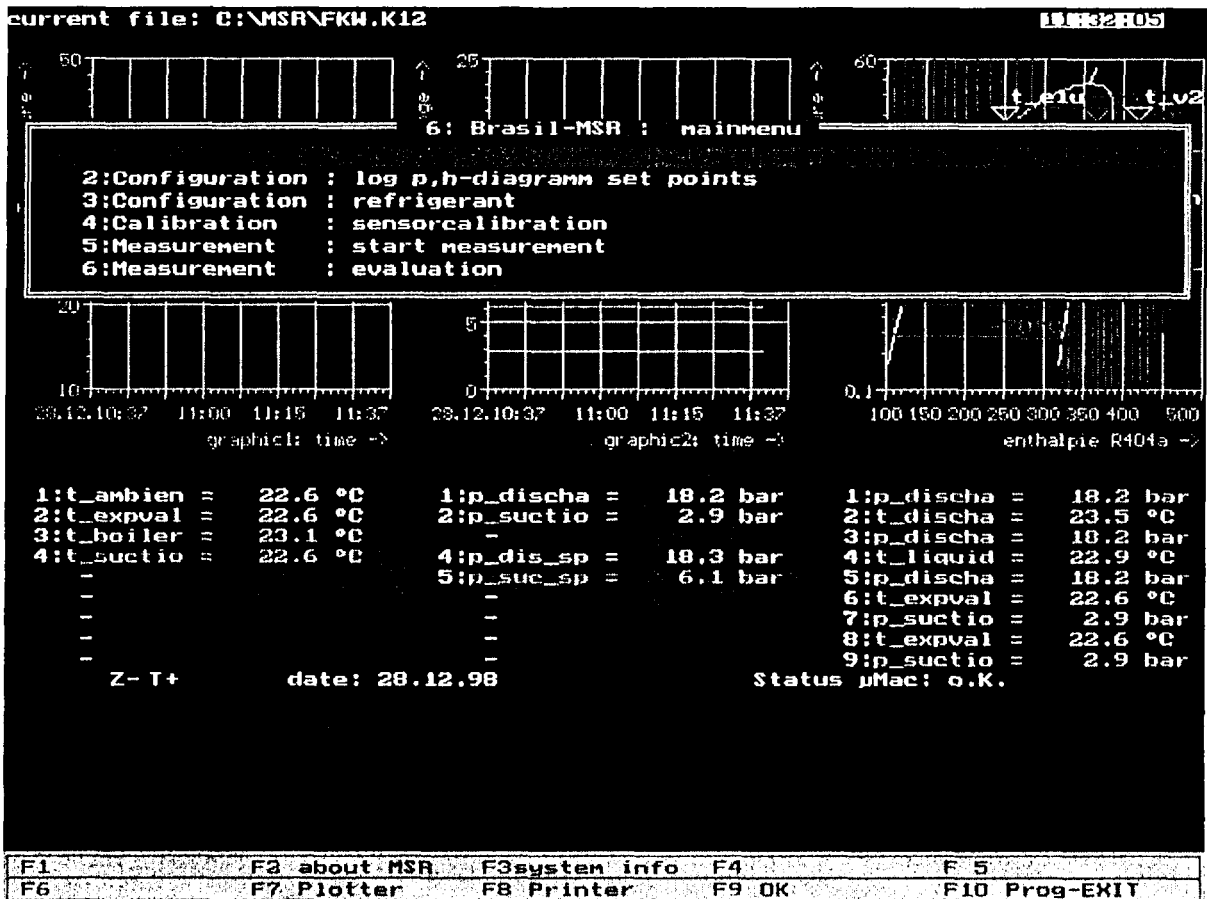


Figure 2: Main Menu

While the main menu window is open the function keys of the main screen change to configuration tools:

- F2: about MSR
displays version and copyright information of the program,

- F3: system info
displays system information like installed CPU, printer and plotter devices,
- F7: Plotter
displays a window to select a plotter;
to plot the output to the file currently named "file.plt" the plotter "file.pln" has to be chosen from the list;
and
- F8: Printer
displays a window to select a printer;
to print the output to the file currently named "file.prt" the printer "file.prn" has to be chosen from the list.

The main menu items are selected by the menu bar and entered by pressing „return“. The names of the different menu items are taken from an ASCII file called SCREEN.TXT. The names of the menu items could, for example be translated into Portuguese.

If changing the nomenclature, make absolutely sure, that only the words are changed but not the structure of that file, i.e. do not add any extra lines or tab characters, for this might effect the entire software! If not absolutely necessary, do not change it!

3.2.1 Main Menu Item 1: Configuration: standard diagram

Main menu item 1 enables the user to set up the format of the output diagrams. On enter, the configuration screen of the actual active (left) graphic is shown (figure 3).

Press page-up/page-down to switch through the configuration screens for graphic 1 to 12. An additional screen shows the common configuration for all graphics.

On the configuration screen each field or entrance that can be edited or changed by the user is of either purple or light blue color. Navigation through the different edit fields is done by using the up/down arrow keys. The active field changes its color to yellow. While the light blue fields are edited directly by the user (by typing), the purple fields display a list of possible options by pressing „return“.

In the upper part of the configuration screen, the settings of the x-axis (length of main ticks, sub-ticks, begin and end values in date/time, caption text (time)) can be changed. The x-axis configuration is the same for all screens, which means that if the setting of the x-axis in one graphic is changed, this change will also apply to all other graphics. Another option allows to change between linear and logarithmic representation of the y-axis.

In the middle part the setting for the y-axis can be changed (length of main ticks, sub-ticks, begin and end values, caption text).


```

configuration Screen Number 1 | |
                                                                    page↑
mastertick as long line          Y-axis linear
sec.-tick as short line

----- configuration X - axis -----
X-begin      = 28.12 Day.Mon 1998 Year 11:00 hh:mm
X-end        = 28.12 Day.Mon 1998 Year 12:00 hh:mm
number of masterticks = 8          number of sec.-ticks = 5
X-axis Text   : time

----- configuration Y - axis -----
Y-begin      = 10.00000
Y-end        = 50.00000
number of masterticks = 4          number of sec.-ticks = 5
Y-axis Text   : Temperature

----- configuration of graph 1 - 9 -----
graph 1 : K019: t_ambien  [°C] 1 dg = 1 color : ██████
graph 2 : K020: t_expval  [°C] 1 dg = 1 color : ██████
graph 3 : K021: t_boiler  [°C] 1 dg = 1 color : ██████
graph 4 : K024: t_suctio  [°C] 1 dg = 1 color : ██████
graph 5 : no channel                dg = 1 color :
graph 6 : no channel                dg = 1 color :
graph 7 : no channel                dg = 1 color :
graph 8 : no channel                dg = 1 color :
graph 9 : no channel                dg = 1 color :
                                                                    page↓

F1      F2      F3      F4 delete  F.5 X-axis
F6      F7      F8graph 10..30 F9 OK    F10

```

Figure 3: Graphic Configuration Screen

In the lower part of the screen the channels and the variables that are associated with these channels that are to be displayed on the graphic can be chosen. Up to 9 channels can be freely chosen for each graphic together with a numerical representation of the measured values underneath the graphic. The channels can be chosen from a list that is displayed in a window that opens up when the corresponding channel is selected and the return key is pressed. Additional 21 channels can be selected and configured for each graph via the F8 key without numerical representation. Configuration of each graphic channel includes selection of the channel (variable), number of digits to be displayed in the numerical representation (only for channels 1 to 9) and color of the graphical representation in the $x-t$ -diagram.

log p-h diagram

The log $p-h$ diagram allows to display the current status of the calorimeter cycle in a familiar representation. Set points for the cycle can be entered and the current value of different process variables are displayed in comparison to the set points. This tool will help to control the calorimeter in order to run it at the defined set points.

In difference to the $x-t$ -diagrams, in the log $p-h$ -diagram the measurement channels are related to the pre-defined process points of the diagram (figure 4). The user may choose the colors of the diagram and the number of digits of the first 9 digital values that are shown below the diagram in the main screen. **For some channels, it might be a little confusing that the description of that channel and the actual channel chosen do not match. But the channels chosen are the correct ones that are**

necessary for the calculation of the different process points! These settings should not be changed!

By pressing function key F2 („set points“) while the configuration screen for graphic 3 is active, an additional window opens to enter the desired set points (as temperature in °C) of the calorimeter process, which are displayed in the log p - h -diagram (figure 5). The discharge temperature of course is not really a set point. Here, a reasonable value has to be assumed. For measurement of condensing units, the condensation temperature won't be a set point either. For that case, a reasonable value has to be assumed also.

```

lg p,h-diagram in graphic screen 3
mastertick as long line      Y-axis logarithm,
sec.-tick as short line     refrigerant : R404A (HP62)
Y-begin = 0.10000           number of masterticks = 10
Y-end   = 60.00000         number of sec.-ticks  = 5
Y-axis text : Pressure
X-begin = 100.00000        number of masterticks = 8
X-end   = 500.00000       number of sec.-ticks  = 5
X-axis text : enthalpie R404a
isotherms :  boiling/dew point line : 
lg p,h-diagram measure :  lg p,h-diagram setpoint: 

compressor out      p_c2 : K027: p_discha  lbar  1 dg = 1 color : 
                   t_c2h : K023: t_discha  l°C   1 dg = 1 color : 
pressure cond.     p_c  : K027: p_discha  lbar  1 dg = 1 color : 
subcooling         t_c2u : K022: t_liquid l°C   1 dg = 1 color : 
expansion valve    p_e1 : K027: p_discha  lbar  1 dg = 1 color : 
                   t_e1u : K020: t_expval  l°C   1 dg = 1 color : 
boiler in          p_o1 : K028: p_suctio  lbar  1 dg = 1 color : 
                   t_o1 : K020: t_expval  l°C   1 dg = 1 color : 
pressure evap.     p_o  : K028: p_suctio  lbar  1 dg = 1 color : 
boiler out         t_o2h : K021: t_boiler  l°C   1 dg = 1 color : 
compressor in      p_v1 : K028: p_suctio  lbar  1 dg = 1 color : 
                   t_v1h : K024: t_suctio  l°C   1 dg = 1 color : 

F1 F2 set points F3 F4 delete F5 X-axis
F6 F7 F8 F9 OK F10

```

Figure 4: Log p - h -Diagram Configuration Screen

3.2.2 Main Menu Item 2: Configuration: log p - h -diagram set points

Choosing menu item 2 of the main menu leads the user directly to the set point window for the log p - h -diagram described above.

3.2.3 Main Menu Item 3: Configuration: refrigerant

In the additional window of the main screen the desired refrigerant may be selected. The refrigerants implemented in the program are R-22, R-134a, R-404A and R-407C. For the chosen refrigerant the corresponding log p - h -diagram is displayed in graphic 3.

3.2.4 Main Menu Item 4: Calibration: sensor calibration

The selection of this item displays a window that enables the user to set the offset of the thermocouples connected to the 8 temperature channels of the μ Mac-1050 as well as the constants A and B in the calibration function $p = A + B \cdot x$, where x is in Volt (V, signal from the sensor), A in bar and B in bar/V (figure 6). If for example a pressure sensor with range of 0 bars to 20 bars with a corresponding output signal of 0 V to 10 V is used, the calibration constants have to be set to $A = 0$ and $B = 2$, resulting in a transfer function $p [\text{bar}] = 2 [\text{bar/V}] \cdot x [\text{V}]$.

If a pressure sensor (or any sensor) with the same range but with an output signal of 4 mA- 20 mA is used, the hardware has to be modified by placing a shunt of 500 Ω across the 5B module (see manual „Data acquisition μ Mac-1050“). That means, that at 0 bars, the data acquisition will read 2 V and at 20 bar it will read 10 V. Therefore, the constants have to be set to $A = -5$ and $B = 5/2$, resulting in a transfer function $p [\text{bar}] = -5 [\text{bar}] + 5/2 [\text{bar/V}] \cdot x [\text{V}]$.

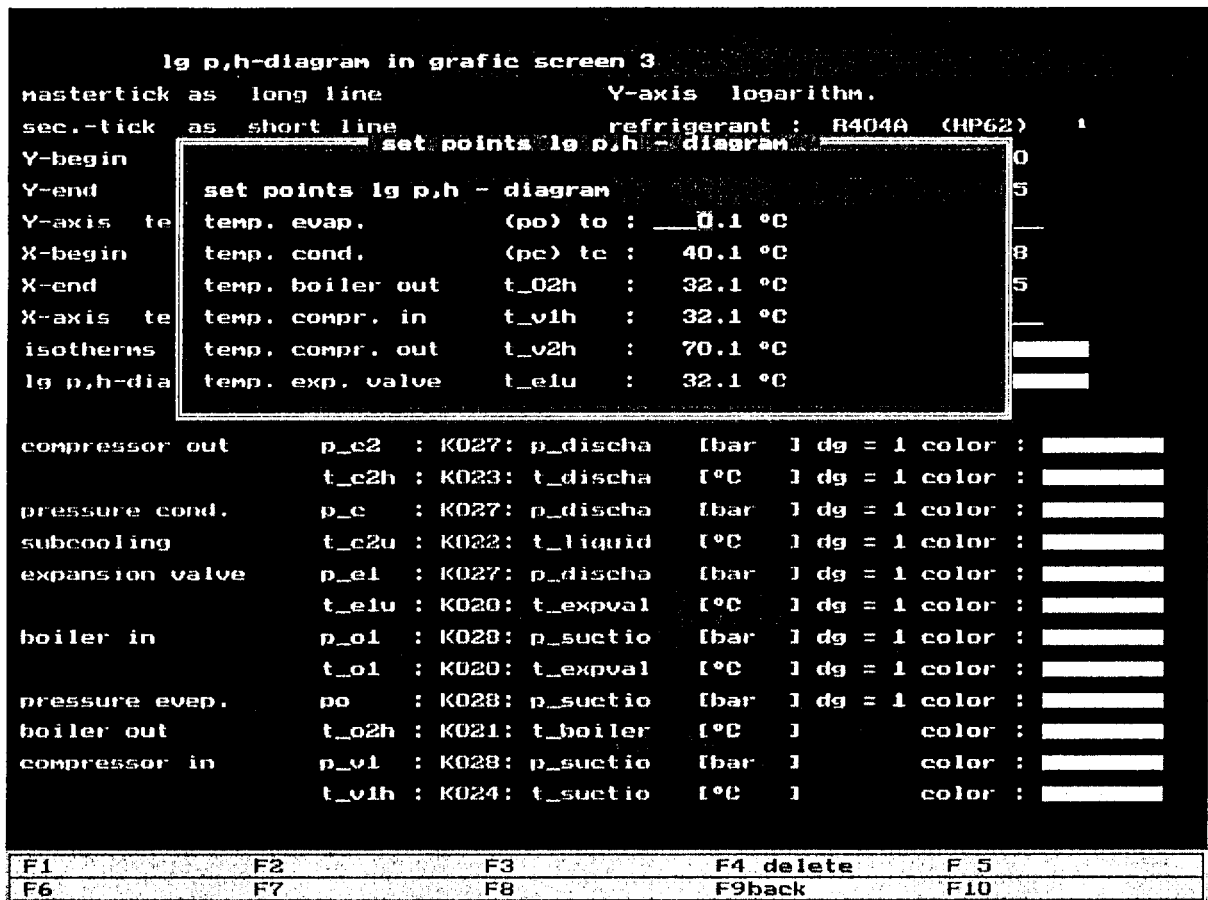


Figure 5: Set Points Window of Log p - h -Diagram

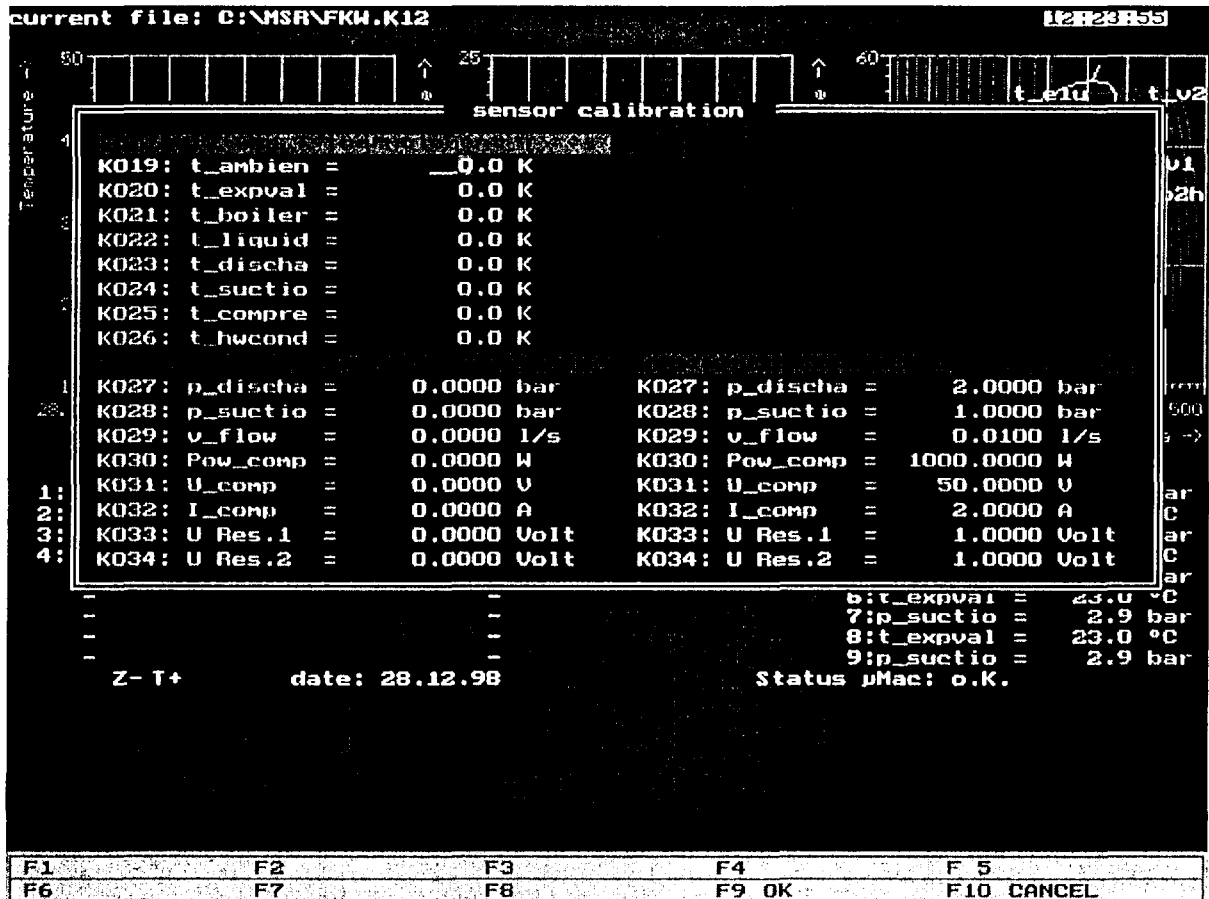


Figure 6: Sensor Calibration Window

3.2.5 Main Menu Item 5: Measurement: start measurement

Selection of main menu item 5 opens a window to edit additional information for the measurement. The measurement will be started by pressing F9. After the measurement has been started, the operator does not have to watch over the measurement anymore, everything will be performed automatically until the measurement is done.

When a measurement is running (figure 7), this is indicated by a green bar at the top of the main screen and function key F10 changed to „Measurement Control” (to stop the measurement). The key „1” displays a status bar at the top of the main screen. The status bar shows duration and number of counts (set of saved measured values) for the running measurement as well as the end time. The automatic measurement time is 1 hour.

During that time, the software will record data every 15 minutes and store these for the protocol. Over each time period of 15 minutes, the number of impulses counted from the impulse generator (measuring power supply to the calorimeter heaters) will also be recorded. After the period of 1 hour, the program automatically stops the measurement and is ready for evaluation of the recorded data.

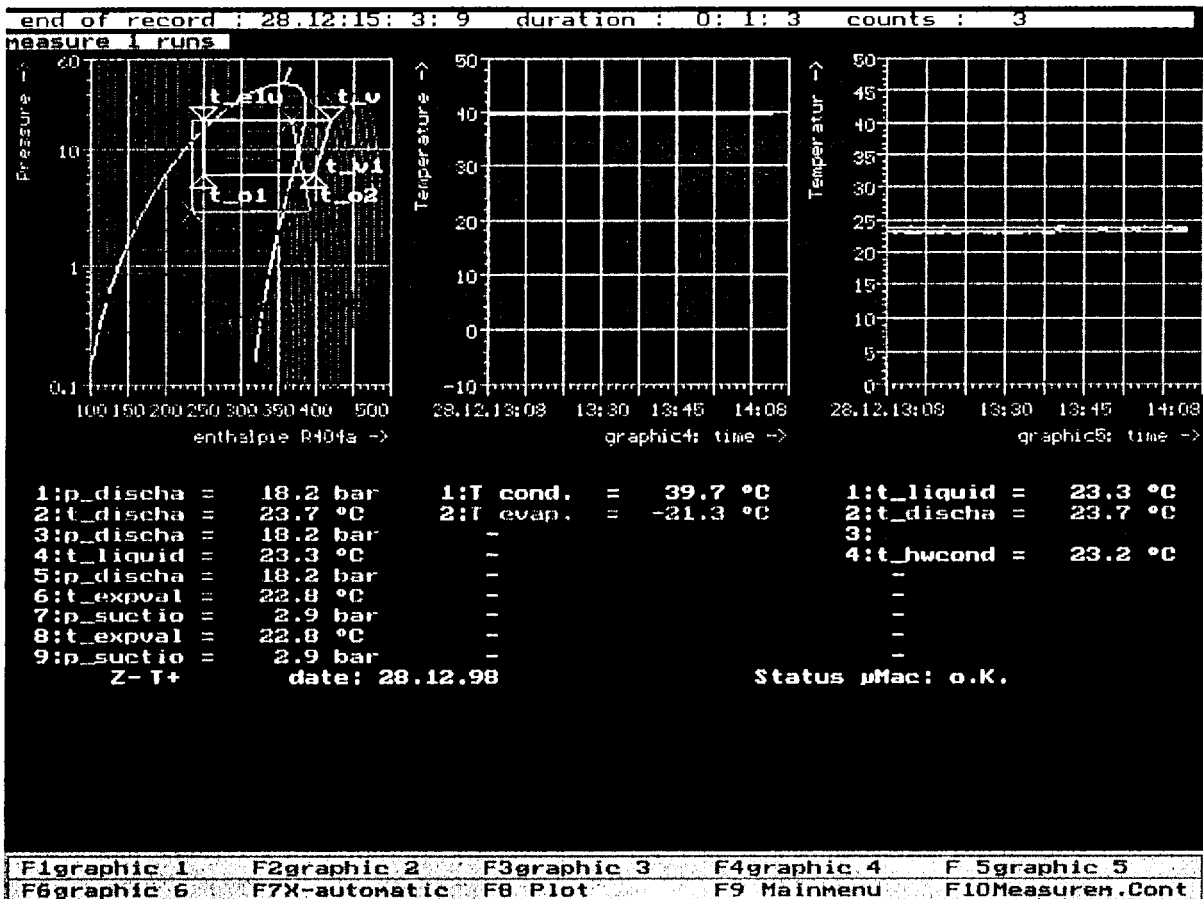


Figure 7: Measurement Screen

3.2.6 Main Menu Item 6: Measurement: Evaluation

This main menu item leads the user to a window to select a data file of a prior saved measurement (figure 8). The filename is generated automatically for each measurement in the following way. The directory to which the data file is saved is named according to the year and the month of the date of measurement in the format „/yymm”, e.g. /9812. The filename includes the day and the start time of the measurement in the form „dd_hhmm.M12”.

While the measurement data file selection window is open, the function key F4 starts a simple file manager and the function key F9 displays additional information for the selected data file.

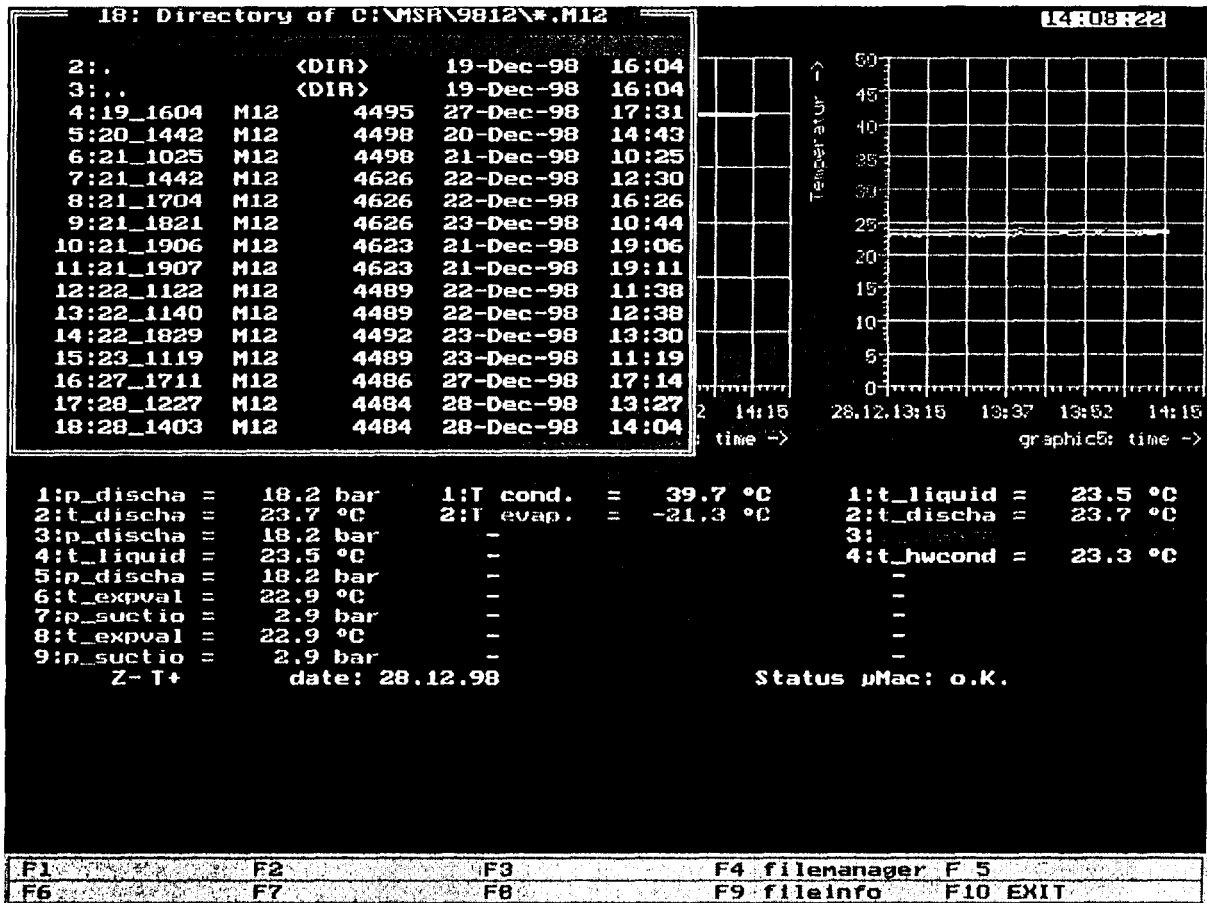


Figure 8: Data File Window

Choosing a desired file by pressing „return” opens the evaluation screen (figure 9).

```

start record : 28. December 1998 12:27 Uhr
end of record : 28. December 1998 13:27 Uhr
filename      : C:\MSR\9812\28_1227 .M12
number of channels 27 in channelgroup 1 with 122 counts

storagecycle : 30.0 sec      save mean values ? N O
project : _____ operator : _____

```

10 lines for description of measurement			
Compressor	123xxx		
fkW01co2			
nr.	2		
	104.2		
	32.2		

F1	F2ascii-protocol	F3	F4 status	F5 graphic
F6ASCII-Export	F7pcl-protocol	F8 Edit	F9 OK	F10

Figure 9: Evaluation Screen

3.3 Evaluation of Measurements

3.3.1 Evaluation of measurements within MSR1.EXE

The evaluation protocol of the measurement may be generated in two ways. While the evaluation screen is active, the function key F7, pcl-protocol, prints the protocol table to a connected pcl-printer (pcl-printer refers to Hewlett-Packard printers. PCL is the printer language used by these printers. Special commands in that language allow to direct characters, lines etc. to a certain location in the output. At Elgin Maquinas Canon-printers, mostly Canon Bubble-Jet, are used. If the pcl-protocol option is used with these printers, the format of the output will change and might not look as nice as on a Hewlett-Packard printer. It is therefore recommended, to provide a Hewlett-Packard printer). However, if no PCL compatible printer is available the protocol may be generated as tab-separated ASCII-text by using F2, ASCII-protocol, so that the protocol file can be opened within an editor or within a table calculation program like MS Excel. The name of this file is the same as the name of the measurement data file as mentioned above (saved in the same directory), while the extension is „.txt“ instead of „.M12“. Within the table evaluation program such as Excel the protocol can be edited until it has the desired output format and can be printed from **any** printer. An evaluation protocol generated via F2, ASCII-protocol, and opened in Excel is shown on the next page. (This table is to show the format in example, without real measured values have been taken.)

Measurement Protocol Table

ELGIN	LABRATORIO DE ENGENHARIA					
	TESTE CALORMETRICO					
Modelo	Compressor 123xxx					
Serie	fkw01co2					
Calorimetro	nr. 2					
	Cond. de teste					
T_evap	ϕ F	104.2	ϕ C	40.1		
T_cond.	ϕ F	32.2	ϕ C	0.1		
LEITURA	UNID.	1	2	3	4	MEDIA
PRESSAO BAROMETRICA	mmHg					
PRESSAO SUCCAO	bar	2.87	2.87	2.87	2.87	2.87
PRESSAO DE DESCARGA	bar	18.18	18.17	18.17	18.16	18.17
TENSAO	V	143.60	143.59	143.57	143.56	143.58
CORRENT	A	5.74	5.74	5.74	5.74	5.74
ROTACAO	RPM					
MASS FLOW (FLOWMETER)	kg/s	0.03	0.03	0.03	0.03	0.03
MASS FLOW (CALORIMETER)	kg/s	0.000	0.000	0.000	0.000	0.000
TOPO DO COMPRESSOR	ϕ C	23.20	23.24	23.18	23.16	23.20
REGIAO DO FUSITE	ϕ C					
REGIAO DO OLEO	ϕ C					
ENTRADA DO COMPRESSOR	ϕ C	22.79	22.75	22.72	22.71	22.74
SAIDA DO COMPRESSOR	ϕ C	23.72	23.81	23.77	23.75	23.76
TEMPERATURA AMBIENTE	ϕ C	22.76	22.79	22.73	22.73	22.75
ENTRADA DO CONDENSADOR	ϕ C					
MEIO DO CONDENSADOR	ϕ C					
DOIS TUBOS ANTES	ϕ C					
SAIDA DO CONDENSADOR	ϕ C					
INFERIOR DO TANQUE DE LIQUIDO	ϕ C					
MEIO DO TANQUE DE LIQUIDO	ϕ C					
LINHA DE LIQUIDO	ϕ C	23.19	23.19	23.06	23.05	23.12
ENTRADA VALVULA DE EXPANSAO	ϕ C	22.77	22.77	22.71	22.69	22.74
SAIDA DO BOYLER	ϕ C	23.34	23.41	23.36	23.34	23.36
ENTRADA DO BOYLER	ϕ C					
SUB_RESFRIAMENTO	ϕ F	9.19	9.18	9.25	9.25	9.22
POTENCIA FINAL DO CALORIMETRO	imp.	0	0	0	0	0
POTENCIA INICIAL DO CALORIMETRO	W					
POTENCIA DO CALORIMETRO	W					
POTENCIA DO COMPRESSOR	W	2869.87	2869.79	2869.43	2869.16	2869.56
RESISTENCIA A FRIO						
RESISTENCIA A QUENTE						
TEMP. DO MOTOR	ϕ C					
	RESULTADOS OBTEDOS					
CAPACIDADE	BTU/h	0				
POTENCIA	W	2869.56				
CAPACIDADE CORRIGIDA	BTU/h	0				
EFFICIENCIA	BTU/Wh	0.00				
FATOR DE POTENCIA	-					
TENSAO NO CAPACITOR	V					
FEITO POR:						
DELABRE:						
DATA:						
DURACAO DO TESTE:						
Refrigerant:	R404A					
FILE:	C:\MSR\9812\28_1227					

The protocol that can be obtained from direct printing (F7 pel-protocol) or from saving it into a text format (F2, ASCII protocol) and up-loading it into Excel and printing from there, has been designed with reference to the type of protocol used by Elgin Maquinas so far. The names of the different items are in Portuguese. When evaluating the protocol, the program reads these names from an ASCII-file named PROTOCOL.TXT, which is in the MSR directory.

If desired, these names can be changed by the user. If changing the nomenclature, make absolutely sure, that only the words are changed but not the structure of that file, i.e. do not add any extra lines or tab characters, for this might effect the output form of the protocol!

With function key F8, Edit, the additional measurement information listed on the evaluation screen may be edited (however, these additional information will not appear in the protocol, whose format is fixed).

Pressing F4, status, the user can view the channel numbers related to the measured values. The displayed channel screen has the function key F4 to print a list of the channels which hold the values that are saved during a measurement.

The function key F6, ASCII-export, in the evaluation screen generates a file (filename and location have to be entered by the user) that holds the whole data saved during the measurement in ASCII-format (data are taken every 30 seconds).

Finally, the function key F5, graphic, displays the measured values in a $x-t$ -diagrams and the log $p-h$ -diagram as known from the main screen described above. The evaluation function graphic shows each diagram in full screen view (figure 10), the user may switch through the graphics 1 to 12 by using the function keys F1 to F6 (graphic 1 to 6, page-up/page-down keys switch function to graphic 7 to 12, respectively).

On the corresponding graphic screen discrete measured values are printed above the shown diagram. These values refer to the vertical cursor line that is navigated through the measurement time (the diagram) with the right/left arrow keys. The function key F7, change, enables the user to change the configuration of the diagram (axis format, screen colors, displayed measured values, number of digits) like it is mentioned above for the main screen. F8, plotter, plots the graphic on a plotter or in a plot-file. Use Shift-F8 for a hard copy print of the screen to your printer.

3.3.2 Evaluation of measurements using MSR1.EXE

The software offers the possibility to evaluate measurements on any computer without having that computer connected to the data acquisition. For that purpose, an executable program called MSR1.EXE has been added. Upon starting the program, you will first see the same screen that appears when MRS1.EXE is started. However, pressing the F9 key, it will offer you only one option which is 'Evaluation'. For evaluation refer to subsection 3.3.1.

In order to perform the evaluation from another computer, go through the installation procedure as described above. All files will be installed. You can not start MRS1.EXE without the data acquisition but you can run MSR1.EXE. In order to evaluate measurements that were taken on the data acquisition and the host computer, you have to transfer the measurement files (these are *.d12, *.g12 and *.m12 files) to the evaluation computer (you can do this either by using a disk or if available, send the files via your net work). Once the files are on the computer, you can do the evaluation (printing or plotting) as described above.

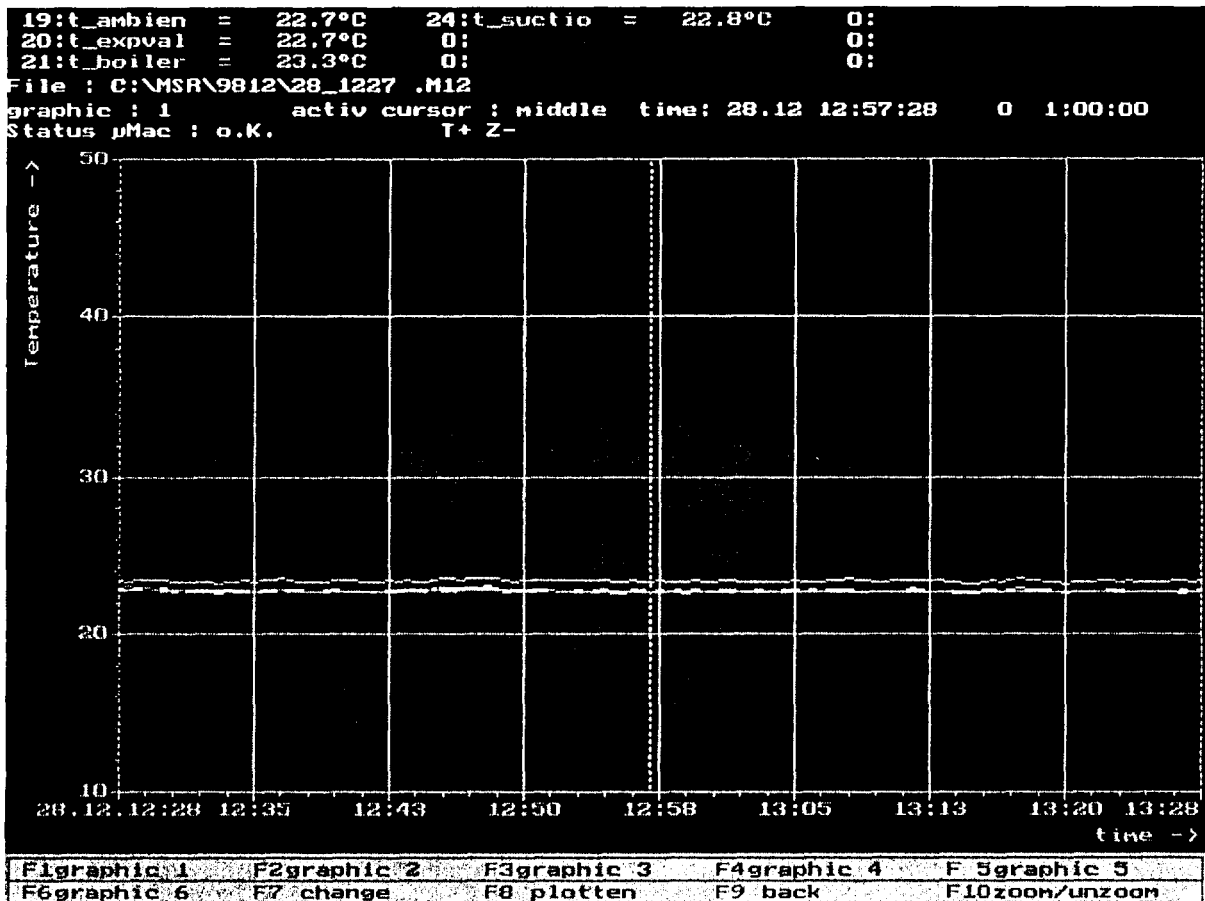


Figure 10: Evaluation Graphic Screen

4 Current configuration of graphic screens

The software as supplied to Elgin Maquinas has already been configured. The individual configurations of the different graphics and the calibration will be explained in the following.

Graphic 1

In graphic 1 the following channels have been implemented:

- t_ambien
- t_expval
- t_boiler
- t_suctio.

Here, 't_ambien' is the sensor measuring the ambient temperature. The channel named 't_expval' represents the thermocouple measuring the refrigerant temperature before the expansion valve. The channel 't_boiler' is the boiler temperature and 't_suctio' is the suction temperature at the compressor inlet.

Since these temperatures are important to direct the calorimeter to the set point, they have been placed in one diagram.

Graphic 2

In graphic 2 the following channels have been implemented:

- p_discha
- p_suctio
- p_dis_sp
- p_suc_sp

The channels named 'p_discha' and 'p_suctio' label the measured discharge pressure and suction pressure, respectively. The channels 'p_dis_sp' and 'p_suc_sp' label the discharge and suction pressure as calculated from the set points that were entered under menu option "log p-h diagram: set points". The corresponding pressures are calculated with refrigerant property function which is included in the software, i.e. $p_{dis_sp} = f(\text{condensation temperature})$ and $p_{suc_sp} = f(\text{evaporation temperature})$. These can be used as a navigation help when attempting to set the desired test set point on the calorimeter.

Graphic 3

Graphic 3 displays the current points of the refrigerant properties in the calorimeter and the set points as described above.

Graphic 4

In graphic 4 the condensation temperature $T_{cond.}$ and the evaporation temperature $T_{evap.}$ are displayed. These values are also calculated from the momentary measured value of the discharge pressure and the suction pressure.

Graphic 5

Graphic 5 displays measured temperatures which are not required to direct the calorimeter settings to the test set point. Temperature t_{liquid} represents the sub-cooled refrigerant temperature, t_{discha} the temperature of the discharged refrigerant, t_{compre} the temperature of the compressor housing and t_{hwcond} the temperature at half way of the condenser.

Graphic 6

In graphic 6 the flow rates are represented as volumetric flow rate and mass flow rate. The volumetric flow rate v_{flow} is the measured flow rate in l/s, the mass flow rate is calculated from $m_{flow} = v_{flow} \cdot \rho_{liquid}$, where ρ_{liquid} is the density of the refrigerant as it flows through the flow meter. The density is calculated from measured temperature at that point using the refrigerant property function.

Graphic 7

In graphic 7 the number of impulses as counted are displayed. This number is set back to zero at

- each time the program is started
- each time a measurement is started.

Graphic 8

In graphic 8, all measured properties concerning the electrical behavior of the compressor are displayed., where Pow_comp is the power consumption (make sure when setting the calibration constants that these translate the measured signal from the transducer (0 – 10 V or 4 – 20 mA) into Watt (W)), U_comp is the Voltage on the compressor and I_comp is the current through the compressor.

The remaining graphics have not been configured yet and are therefore available for extra configuration by Elgin Maquinas.

The current configuration can of course be changed if it is found to be unsuitable. Explanations on how to change the configuration are detailed above.

Calibration

The calibration coefficients, which can be changed or edited in the main menu option ‘Calibration: sensor calibration’ have been chosen to match the sensors as far as sensors were known. When installing pressure sensors for the suction and discharge pressure, make sure to adjust the coefficients as described above. The converted sensor signals have to be in the unit ‘bar’ !

The same applies for the power, voltage and current transducers. Make sure the converted signal of the power measurement is in ‘Watts’ !!

As for the thermocouples, these should be calibrated at 0 °C (e.g. in an ice-bath) to adjust the zero off-set.

5 Taking a measurement

In the following, a short description of how to run a measurement on the calorimeter will given as an example.

The software has been configured, so that no changes on the diagrams are necessary. After starting the software and the data acquisition, first select the refrigerant from the main menu option „refrigerant“.

Then enter the set values that you are striving for in the main menu option. Notice that the set points have to be entered in °C. If you are running a test, e.g. according to ARI standards, where the set points are given in ° F, remember to convert these into Celsius first.

When controlling the calorimeter valves, boiling heaters and room heaters of the calorimeter room to reach the desired set points, follow that process in the graphical and numerical representation of the measured values in graphic screens 1 and 2 and also in the log p-h diagram.

Once you have reached steady state conditions at the desired set point, you can start the measurement, by selecting the corresponding menu option in the main menu „Start measurement“. After that, the measurement will be conducted automatically by the program and will end the measurement after one hour.

After the measurement is through, the evaluation of the test can be performed as described above.

Manual for

Data Acquisition μ Mac 1050

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1 General Description

The μ Mac-1050 is a distributed fixed-function machine which provides an interface to a variety of signals. When connected to process I/O and a host computer running application software, it is a complete monitoring and control solution.

The μ Mac-1050 provides a simple means to interface to real world signals with a host computer. A host computer running application software, a μ Mac-1050, and a +5 V power supply is all that is required to use the μ Mac-1050 in its simplest configuration. In this configuration, analog input signals can be monitored directly through screw terminals provided on the unit. Two analog outputs are also provided. Digital I/O, including low and high speed event counting, period measurement, or time proportional outputs can be accessed directly as TTL level signal on the unit. Expansion of both analog and discrete I/O is possible independently to provide a maximum of 48 analog inputs, 10 analog outputs and 64 discrete I/O.

The μ Mac-1050 continuously scans the I/O and performs various operations on the data to offload the host. Upon request from the host, the data in engineering units is sent back over a serial communications link ready for the application program to use.

A powerful 16-bit microprocessor controls all inputs and outputs to real world I/O and communication to the host computer. Configuration data for all I/O is stored in EEPROM so that after the initial setup, it is saved when the unit is powered down. System firmware stored in PROM contains the I/O drivers and scanners to access the I/O.

The μ Mac-1050 is controlled by software running on a host computer. The host computer requests and receives data from the μ Mac-1050 over a serial link. The data is communicated in a binary protocol which provides a substantial increase in speed over ASCII type protocols since the data is more tightly packed. The μ Mac-1050 thus provides high data throughput with a low cost serial link.

All functions of the μ Mac-1050 are accessed by commands sent over the serial link. These commands configure the I/O, read from and write to configured channels, and perform unit functions not related to the I/O, such as storing configuration in EEPROM or resetting the unit.

Configuration commands are used first to set up the machine with the proper I/O configuration. Once these are executed, the μ Mac-1050 knows which of its channels will be used and how it will use them. This includes setting the I/O type such as thermocouple or voltage, defining scaling or linearization that will be performed on the incoming signal, activating alarms on particular channels, configuring digital channels as input or output, configuring digital I/O as low speed pulse I/O, and configuring a digital port as a cam sequencer. Once all the I/O channels are configured, the information can be stored in EEPROM, and the unit is ready to perform its application. EEPROM saves this data when the unit is powered down after configuration.

The μ Mac-1050 can be used with any host computer that has RS-232C or RS-422/485 communication port. There is a variety of software from ANALOG DEVICES and from other vendors that runs on PC/XT and PC/AT. Customers can write drivers for other computers and software packages.

2 Input Modules for Voltage and Thermocouple

In the current configuration (as supplied to Elgin Maquinas) altogether 22 input channels are available. Eight of these channels are analog inputs, eight are (analog) thermocouples and six are digital inputs.

The analog inputs are single-ended so called 5B modules which are located externally to the μ Mac-1050 base plate. Four of the digital inputs are suitable for impulse counting up to a rate of 25 Hz (slow counting), two are suitable for impulse counting up to a rate of 1 MHz (fast counting).

2.1 Analog input modules 5B31-03 (± 10 V)

The galvanically isolated 5B Series input modules from ANALOG DEVICES are single channel, plug-in signal conditioners that provide input protection, amplification and filtering, series output switching, and a high level analog output. Key specifications include: 1500V rms isolation, accuracy of $\pm 0,05$ %, $\pm 0,02$ % span nonlinearity and low drift of $\pm 1 \mu\text{V}/^\circ\text{C}$. All modules operate from a single $+ 5$ V supply with typical power consumption of 0.15 W. The modules are hard potted.

The 5B31 – 03 measures input signals of ± 10 V. The transfer function provided by the module is:

Input: ± 10 V

Output: ± 5 V.

The output signal is sent to the μ Mac-1050 and internally processed.

If a certain sensor does not provide a $0 - 10$ V signal but a $0 - 20$ mA or $4 - 20$ mA, a calibrated shunt (resistance) of 500Ω has to be connected across the poles of the input in order to transform the current signal into a voltage signal. The data acquisition is delivered with eight such shunts, so that each of the analog $0 - 10$ V input modules can be changed to accept a current signal. For that purpose a plug in connection for the shunts is provided on the board which holds the analog modules.

In order to access these plug connections, the lid of the data acquisition has to be removed.

WARNING! DISCONNECT THE DATA ACQUISITION FROM THE POWER SUPPLY BEFORE OPENING THE HOUSING!! DANGER OF ELECTRIFICATION !!

The data acquisition housing lid can easily be removed by unscrewing the four side screws of the lid (two on each side). Lift off the lid carefully (it is attached to a ground-wire).

In Figure 1 the open data acquisition is schematically shown from a top view with a close up of one of the modules and the plug connections for the shunts. The shunts can carefully be put into the corresponding holes on the board.

After you have put the shunt in place, make sure that the lid is closed before reconnecting to the power supply.

NEVER CONNECT THE DATA ACQUISITION TO POWER SUPPLY WHEN LID IS OPEN!!

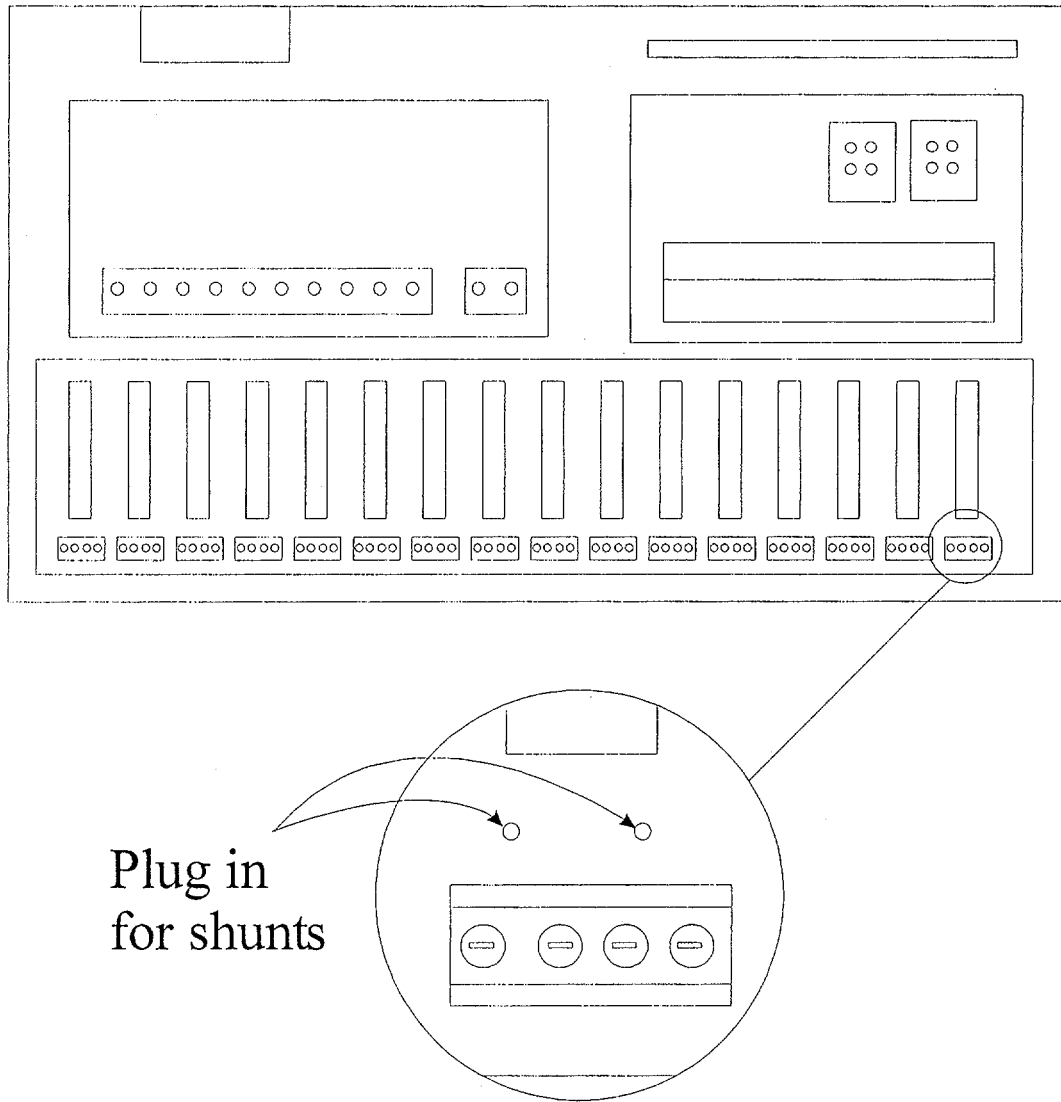


Figure 1: Plug in holes for shunts (change 5B analog modules to accept 0/4 – 20 mA signal)

2.2 Analog input modules 5B37-T-03 (Thermocouples Type T)

The 5B37 thermocouple conditioner provides cold junction compensation for the associated screw terminals as well as a bias current to give a predictable (upscale) response to an open thermocouple. Input protection allows safe operation even in the event of a 240 V rms power line being connected to the signal terminals.

2.3 Digital inputs

Six digital inputs are provided. One of the 25 Hz digital inputs and one of the 1 MHz digital inputs are internally connected to a 10 V TTL source, so that impulse counting can be achieved through these channels by connecting the poles of the corresponding ports (e.g. through a mercury switch). The remaining digital inputs have to be supplied externally with a 10 V TTL signal.

3 Front panel of the desktop housing

The above described components of the data acquisition system are mounted in a desktop type casing. The input connections are on the front panel of the desktop as shown in Figure 2.

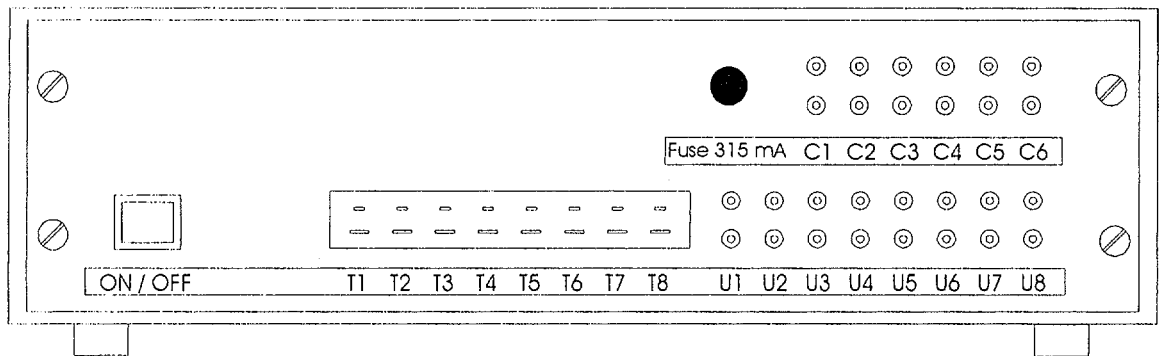


Figure 2: Casing front panel configuration

The ports T1 through T8 represent the connection to the thermocouple modules. The sockets are standard connectors for thermocouples and the corresponding male plugs are also supplied.

The ports U1 through U8 represent the connection to the voltage input modules. The sockets are banana plug connectors and the corresponding plugs are also supplied. The upper row sockets, which are red, are the positive (+) connectors and the lower row black sockets are the negative (-) connector. If a source (e.g. from a pressure transducer or the flow meter transducer) is connected with the poles inverted, the data acquisition will read a negative value!

The ports C1 through C8 are the digital inputs. C1 through C4 are suited for impulse counting up to a rate of 25 Hz, C5 and C6 are suited for impulse counting up to a rate of 1 MHz. The ports C1 and C5 are internally connected to a 10 V TTL source, allowing to count impulses by connecting the circuit via a switch (e.g. mercury switch as on the calorimeter impulse generator).

The label of the individual channels underneath the sockets can be replaced, allowing to rename the channels on the front panel.

The digital input channels are protected by a 315mA fuse, which can easily be replaced from the front panel side by unscrewing the fixture.

Since the software MRS1 will be delivered pre-configured, it is important that the thermocouples, pressure transducers, power-, voltage- or current transducers, the flow meter and the impulse generator are being connected to the correct ports. The correct connections will be detailed in the following.

4 Electrical wiring

In Figure 3 the connections of the different sensors of the calorimeter set up to the data acquisition are schematically shown.

The port T1 has to be connected to the Type T thermocouple measuring the ambient temperature in the calorimeter room. The port T2 has to be connected to the thermocouple measuring the temperature of the refrigerant before the expansion valve. T3 has to be connected to the thermocouple monitoring the boiler temperature. The thermocouple measuring the temperature of the refrigerant leaving

the liquid accumulator has to be connected to port T4. The discharge temperature of the refrigerant is monitored through port T5 and the suction temperature through port T6. Port T7 has to be connected to compressor casing thermocouple and through port T8 the temperature of condenser half way is monitored.

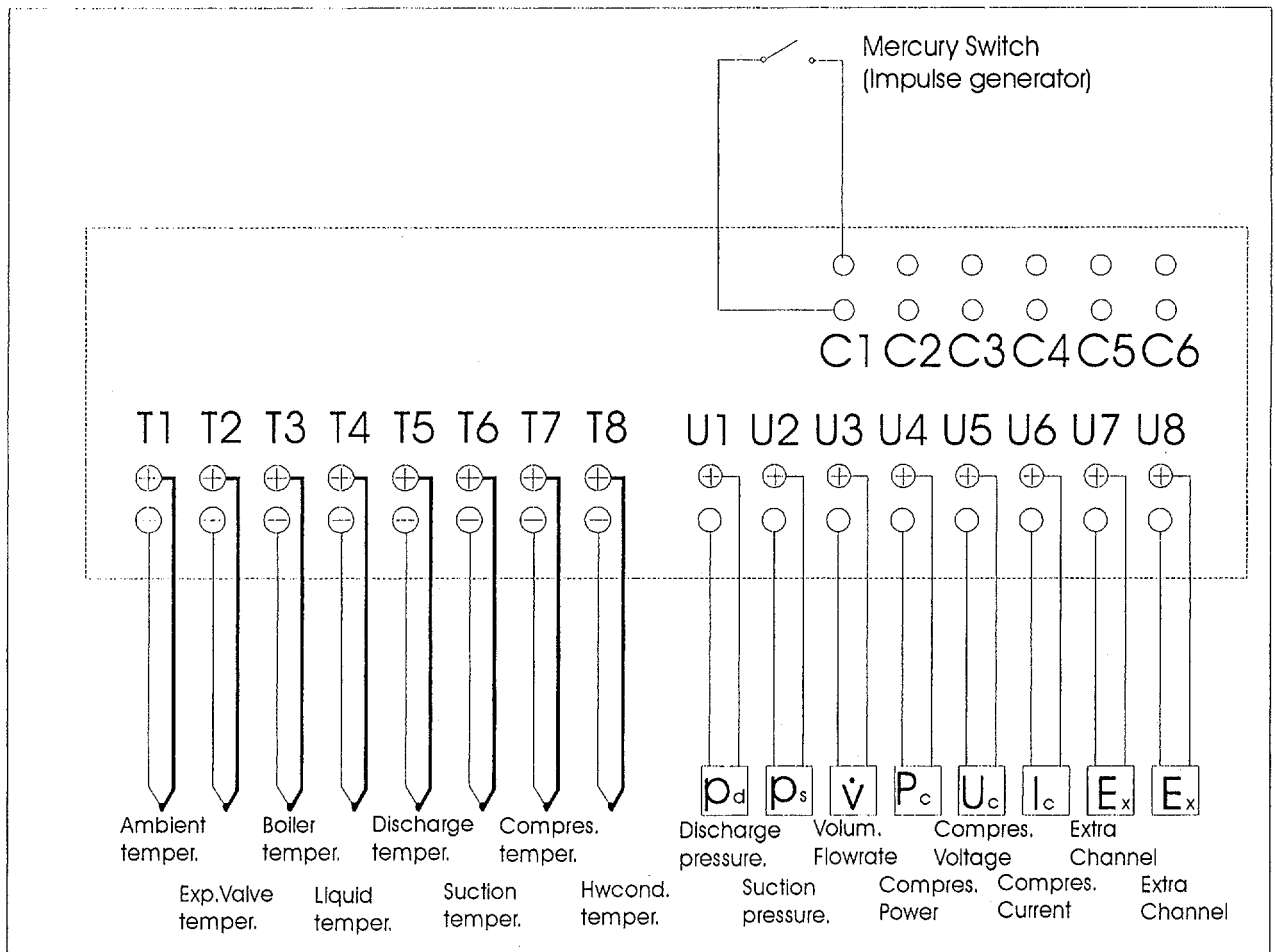


Figure 3: Sensor connections to the data acquisition front panel (schematic)

The sensor measuring the discharge pressure of the refrigerant has to be connected to port U1 and the sensor measuring the suction pressure needs to be connected to port U2. The signal coming from the flow meter transducer ATM 1613 (see manual "Flow meter") has to be fed to port U3. The signals coming from the power-, voltage and current transducers have to go to ports U4, U5 and U6, respectively. Ports U7 and U8 are extra ports for ± 10 V signals and are available for extra measurement.

The digital input C1 is the impulse counter for the impulse generator (rotating disk and mercury switch). The mercury switch has to be connected between the two poles of the C1 port as shown in the schematic. It does not require an extra voltage or current source to create the impulse signal because a 10 V TTL is already connected to the C1 port internally of the data acquisition.

The remaining digital input channels are available for extra measurements. However, in the software MSR1 these channels have not been configured yet (see manual "MSR1").

In

Table 1 the connections are once more summerized.

Port	Sensor	Signal	Location
T1	Type T Thermocouple	mV	Ambient Temperature
T2	Type T Thermocouple	mV	Expansion Valve Temperature
T3	Type T Thermocouple	mV	Boiler Temperature
T4	Type T Thermocouple	mV	Liquid Subcooling Temperature
T5	Type T Thermocouple	mV	Discharge Temperature
T6	Type T Thermocouple	mV	Suction Temperature
T7	Type T Thermocouple	mV	Compressor Encl. Temperature
T8	Type T Thermocouple	mV	Halfway Condenser Temperature
U1	Pressure Transducer	0 - 10 V or 0/4 - 20 mA	Discharge Pressure
U2	Pressure Transducer	0 - 10 V or 0/4 - 20 mA	Suction Pressure
U3	Flow-meter	0 - 10 V or 0/4 - 20 mA	Turbine Flow meter
U4	Power Transducer	0 - 10 V or 0/4 - 20 mA	Compressor Power
U5	Voltage Transducer	0 - 10 V or 0/4 - 20 mA	Compressor Voltage
U6	Current Transducer	0 - 10 V or 0/4 - 20 mA	Compressor Amperage
U7		0 - 10 V or 0/4 - 20 mA	Extra channel
U8		0 - 10 V or 0/4 - 20 mA	Extra channel
C1	Impulse counter	10 V / 25 Hz	From impulse generator (mercury switch)
C2	Impulse counter	25 Hz	Extra channel
C3	Impulse counter	25 Hz	Extra channel
C4	Impulse counter	25 Hz	Extra channel
C5	Impulse counter	1 MHz	Extra channel
C6	Impulse counter	1 MHz	Extra channel

Table 1: Port connections of the data acquisition

5 Connection of the data acquisition to power supply

The data acquisition needs a 220 V 50/60 Hz source for power supply. The system is delivered to Elgin Maquinas with a German standard plug. A plug suitable for Brazil was not available. Therefore the plug might have to be changed. The German plug can be cut off from the cable and a Brazilian type plug can be attached.

WHEN EXCHANGING THE PLUG, TAKE ALL NECESSARY PRECAUTIONS TO PREVENT AN ACCIDENT THROUGH ELECTRIFICATION!!

6 Connection of the data acquisition to host computer

The host computer used to run the data acquisition and associated software should fulfill the following requirements:

- PC-Type computer (from 80386DX with 4 MB RAM, but no PENTIUM II)
- 1 parallel port
- 2 serial port
- 1 VGA Graphic-card (512 kB) 640*480 Pixel
- 1 Monitor VGA
- 1 Keyboard
- 1 Printer
- 1 Hard Disk Drive at least 10 MB free storage

The data acquisition connects to the host computer via the serial port on the computer. When started, the software MSR1 will automatically look for a connected μ Mac-1050 at port COM 1. Therefore it is recommended to connect the data acquisition to port COM 1.

If not possible and if the data acquisition has to be connected to port COM 2, the software has to be started with an additional command <port=2>. It is recommended to start the software in that case from a batch file (the batch-file is also supplied with the software and is called msr1.bat).

The necessary cables are already connected to the data acquisition and adapters to connect to the host computer ports are provided.

Manual for

Flow meter FT 4-8

Frequency Sensor LFA 355

Transducer ATM 1613

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1 Introduction

For the old Linde calorimeter at Elgin Maquinas a turbine flow meter with suitable sensors and signal transducers was selected. The entire set up consists of three elements:

- Turbine flow meter FT 4-8;
- Carrier frequency sensor LFA 355;
- Signal transducer ATM 1613.

The individual components and the requirements to install and run the equipment are detailed in the following.

2 Description of Hardware Components

2.1 Turbine flow meter FT 4-8

The Standard Line Turbine Flow meter FT 4-8 is a volumetric flow measuring instrument. The flow sensing element is a freely suspended, bladed rotor positioned axially in the flow stream with flowing fluid pushing against the blades. The rotational speed of the rotor is proportional to the velocity of the fluid. Since the flow passage is fixed, the turbine rotors rotational speed is also a true representation of the volume of fluid flowing through the flow meter. The rotation of the turbine rotor generates electrical pulses in the pick-off which is attached to the flow meter housing in close proximity to the turning rotor. Each one of the pulses represent a discrete volume of fluid. The frequency or pulse repetition rate represents the volumetric flow rate and the accumulated pulse total represents the total volume measured. Meters provided for liquid applications are not interchangeable with meters provided for gas applications.

Specifications:

Measuring range:	0,003...0,1 l/s
Maximum value:	0,16 l/s
Medium:	Refrigerant
	Temperature °C: 30...50
	Density kg/m ³ : 800
	Viscosity cSt: 0,8
	Opera. pressure bar: 35
Nominal pressure:	500 bar
Casing:	Steel 1.4401
Vane:	Steel 1.4104
Bearing:	Ball bearing 440C SS
Bearing shaft:	Steel 1.4300
Connections:	½" AN thread
Linearity:	± 0,5 % of max. value at standard range and 1,2 cSt
Reccurence:	0,05 % of measured value

2.2 Frequency Sensor LFA 355

Attached to the flow meter turbine is a carrier-frequency sensor, representing the coil of a resonant circuit. The resonant circuit is tuned to about 50 Hz. If one of the blades of the turbine impeller runs through, the carrier is modulated by field disturbance.

The signal is demodulated and enhanced by the LFA 355. Processing of the signal is fail safe due to the close proximity of the sensor to the turbine. A high voltage level is provided for passing on the signal in form of a frequency.

Specifications:

Type of sensor:	Carrier frequency sensor
Signal:	Pulse larger 5 Vss from TF-Electronic
Power supply:	11-30 V dc

2.3 Transducer ATM 1613

The transducer ATM 1613 permits the measurement of process variables which have been transformed into a frequency by suitable sensors (e.g. by the LFA 355).

The measuring method is based on the multiple period duration principle. The frequency is determined by taking the reciprocal of the measured period duration. The number of periods which are accounted for while evaluating the measured value depend on the setting of the measurement duration and the value of the input frequency. If the duration of the period of the input signal (input frequency) is smaller than the measurement duration the frequency mean value is averaged over all periods within that interval. If the duration of the input signal is larger than the measurement duration the frequency is evaluated from the last recorded period.

The frequency thus evaluated is scaled to a adjustable end value and via a 12-Bit D/A transformer send to the output. The measurement duration is 5 ms and is therefore suitable for fast signal processing.

Specifications:

Measuring range:	0,02...20 kHz
Input signal:	50 mV...80Veff.
Linearity:	0,05 % of max. value
Output signal:	4 – 20 mA or 0 – 10 V
Power supply:	12...30 Vdc

3 Installation of the flow meter

The turbine flow meter FT 4-8 is suitable for measuring liquid flow. It is not suitable for measuring vapor or two phase flow. Therefore, it is important that the flow meter is installed at a location in your system where liquid flow is guaranteed. For the calorimeter, liquid flow can be guaranteed if the

turbine flow meter is installed between the liquid accumulator and the expansion valve (see Figure 1).

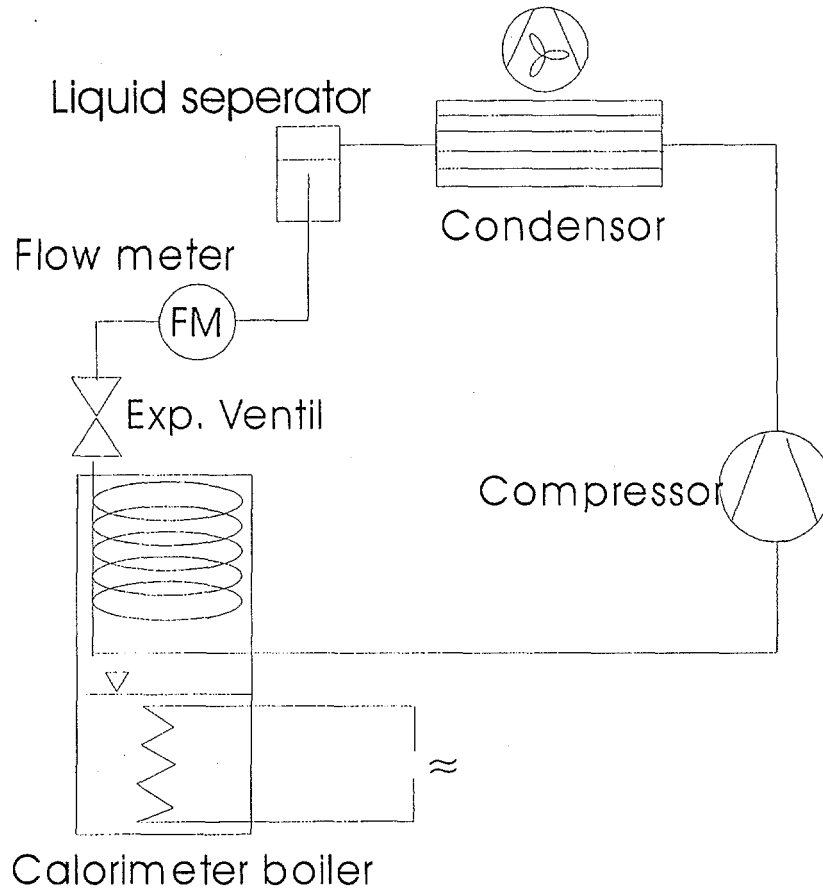


Figure 1: Location of turbine flow meter in calorimeter cycle

The turbine flow meter is sensitive to velocity profile disturbances in the flow stream. For optimizing the velocity profile it is recommended that a straight run of constant diameter piping with length of at least 10 diameters upstream of the meter and at least 5 diameters downstream be provided. The upstream section should have straightening vanes or other flow conditioners.

Therefore, the flow meter is delivered with two flow straightening sections, one for upstream and one for downstream. The upstream straightening section is equipped with vanes on the inside of the piece of pipe. The straightening sections are equipped with 1/2" AN nuts for flared pipe endings. The turbine flow meter is equipped with corresponding 1/2" AN threaded connections. The pipe ends upstream and downstream also have to be equipped with 1/2" AN threaded connections (see Figure 2).

The carrier frequency sensor LFA 355 is attached to the flow meter and needs to be connected through appropriate wiring to the transducer ATM 1613. The correct wiring will be detailed in the following.

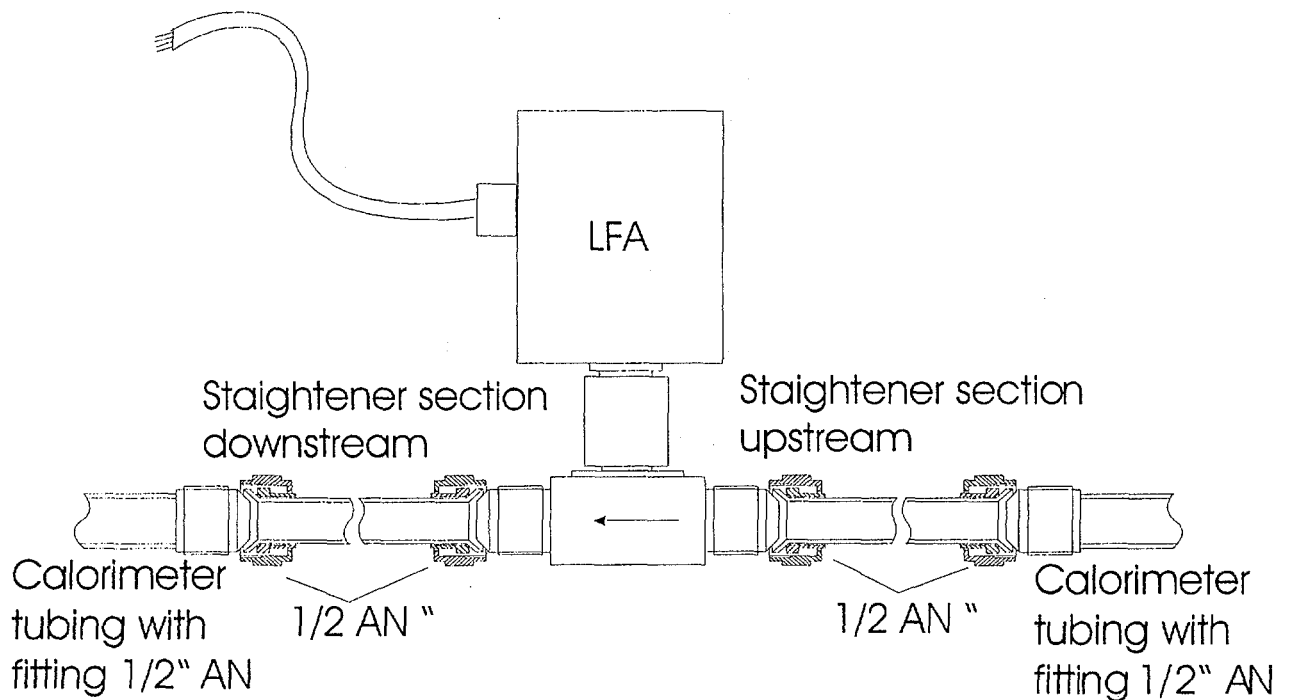


Figure 2: Straightening sections of flow meter and connection to calorimeter cycle

4 Electrical wiring

The LFA 355 and the transducer ATM 1613 have to be connected through correct wiring. In Figure 3 the connections are shown.

The power supply to the ATM 1613 has to be 12 – 30 V dc. The connections are port 1 (L1) and port 2 (N).

The output signal (0 –10 V) comes from connections 7 (U-) and 8 (U+) and need to be connected to the corresponding input channel of the data acquisition (see manual ‘Data Acquisition’).

The LFA has to be connected to ports 16 (+U), 18 (⊥) and 20 (V) such that the brown wire goes to 16, black, green and white go to 18 and the yellow wire has to be attached to port 20.

The LFA and ATM are already connected with 3 m long cable. The ATM can be located inside the calorimeter room or, if the length of the cable permits, outside of the room. The connection from the output ports of the ATM to the data acquisition should be kept as short as possible.

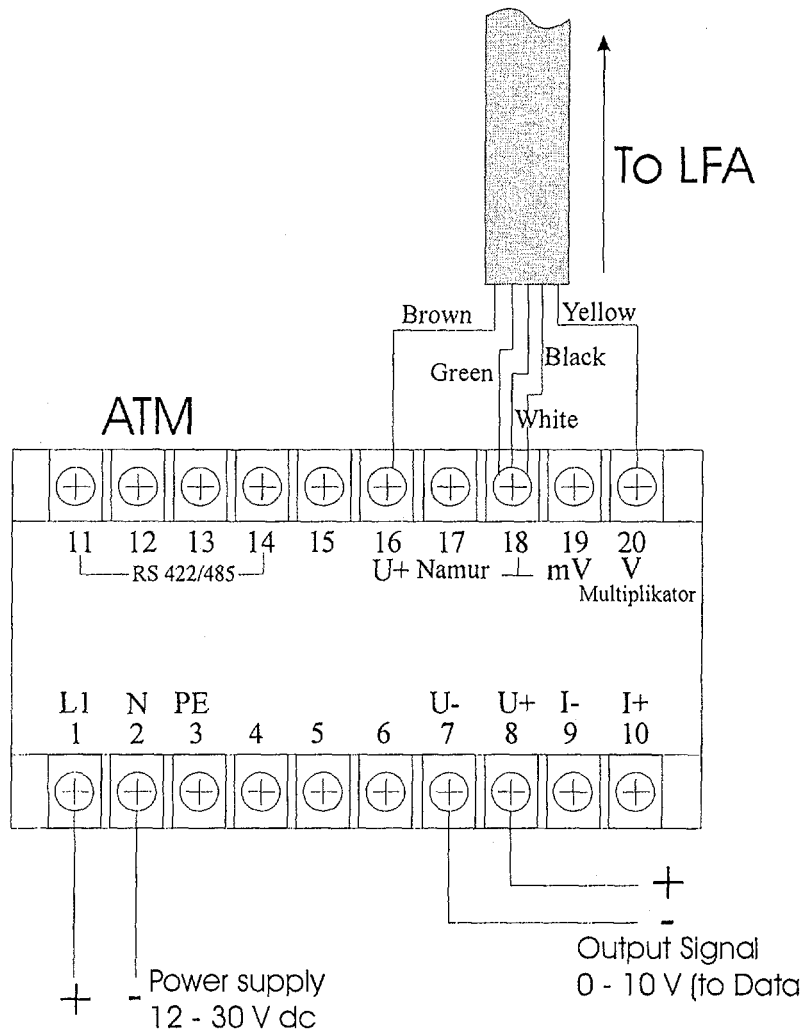


Figure 3: Wiring diagram for connecting LFA 355 and ATM 1613