IM-EN-SM3-A

User Guide

SeedMaster for Multiparameter Sugar Crystallization Monitoring and Automatic Seeding

SM-3

VAISALA

SeedMaster

PUBLISHED BY
Vaisala Oyj
Vanha Nurmijärventie 21, FI-01670 Vantaa, Finland
P.O. Box 26, FI-00421 Helsinki, Finland
+358 9 8949 1

Visit our Internet pages at www.vaisala.com.

General safety considerations

The process medium may be hot or otherwise hazardous. Use **shields and protective clothing** adequate for the process medium - do not rely on avoidance of contact with the process medium.

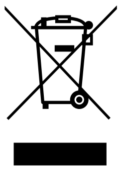
Precautions when removing a refractometer from the process line :

- Check first that the process line is depressurized and drained.
- Ensure you are clear of any possible spillage and you have a clear emergency escape path.

It is the user's responsibility to follow manufacturer's safety and operating instructions. The client's organization has the responsibility to develop and maintain occupational safety and create a safety culture where individuals are expected to follow safety instructions at all times. Any negligence towards safety instructions or failure to comply with safe practices should not be tolerated. It is the manufacturer's responsibility to produce goods that are safe to use when instructions are followed.

Disposal

When wishing to dispose of an obsolete refractometer or any parts of a refractometer, please observe local and national regulations and requirements for the disposal of electrical and electronic equipment.



Warranty

For standard warranty terms and conditions, see www.vaisala.com/warranty.

Please observe that any such warranty may not be valid in case of damage due to normal wear and tear, exceptional operating conditions, negligent handling or installation, or unauthorized modifications. Please see the applicable supply contract or Conditions of Sale for details of the warranty for each product.

Technical support

Contact Vaisala technical support at helpdesk@vaisala.com. Provide at least the following supporting information:

- Product name, model, and serial number
- Name and location of the installation site
- Name and contact information of a technical person who can provide further information of the problem

For more information, see www.vaisala.com/support.

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1 Introduction

Crystallization is a very important part of sugar manufacturing. Crystallization has a major effect on product quality, yield and cost of production. Modern control of crystallization should rely on reliable on-line measurement of those parameters that are critical in controlling the process by a local operator (manual control), or by an advanced automatic process control system.

SeedMaster SM-3 is a unique crystallization transmitter and seeding device to be used with the Vaisala K-PATENTS® process refractometer. The SM-3 allows for accurate in-line and real-time monitoring of supersaturation and crystal content over the complete process of crystallization, and implementation and control of automatic or manual seeding. The SM-3 can be connected to one or two Vaisala K-PATENTS process refractometers and to one or two crystallizers.

The SeedMaster SM-3 provides the following tasks:

1. Electronic data capture on massecuite parameters.
2. On-line calculation and transmission of massecuite parameters for the advanced control of sugar crystallization with control system.
3. Organization and storage of strike history data archive.
4. Advanced communication with the control system.
5. Automatic seeding of the vacuum pans.
6. Serves as user interface for the pan and control system operators.

2 The SeedMaster SM-3 system

2.1 The SeedMaster SM-3 device

SeedMaster SM-3 is a unique instrument designed to provide all of the important information needed for the advanced control of sugar crystallization.

The heart of SeedMaster 3 is a high performance computer specifically designed to receive some measured data and calculate, display and transmit all of the vital parameters characterizing sugar crystallization simultaneously for up to 2 crystallizers. Besides that it can perform *reliable automatic seeding* of the crystallizers as well. Both features require the input of some data measured on-line by 1 (or 2) Vaisala K-PATENTS process refractometer(s) and by some selected instrument(s) (providing on-line data on massecuite density or solids content). Input of a few laboratory data and status information are also required.

Based on these data the SeedMaster 3 is able to calculate 6 massecuite parameters per crystallizer in real time. **Supersaturation, the most important of these, should be used for the advanced control of crystallization.**

Some of the parameters (for example: crystal content, mother liquor purity, mean crystal size etc.) are also important ones and are rarely determined by the local laboratory. These, however, can provide important basis for the calculation of some production data (like tons of sugar produced per strike, day, month etc.).

2.2 On-line measurement of liquid concentration: the Vaisala K-PATENTS process refractometer

The SM-3 device was designed to calculate supersaturation on-line by taking into account all of the parameters governing it (see Eq. 1, page 41). *This needs reliable data on liquid (syrup or mother liquor) concentration selectively, that is undisturbed by the presence of crystals.* The Vaisala K-PATENTS process refractometers are able to cope with the task. The system consists of one or two refractometer sensors and an Indicating transmitter. They can be connected to a DCS by a 10 to 100 m long cable.

2.2.1 Mounting the sensor

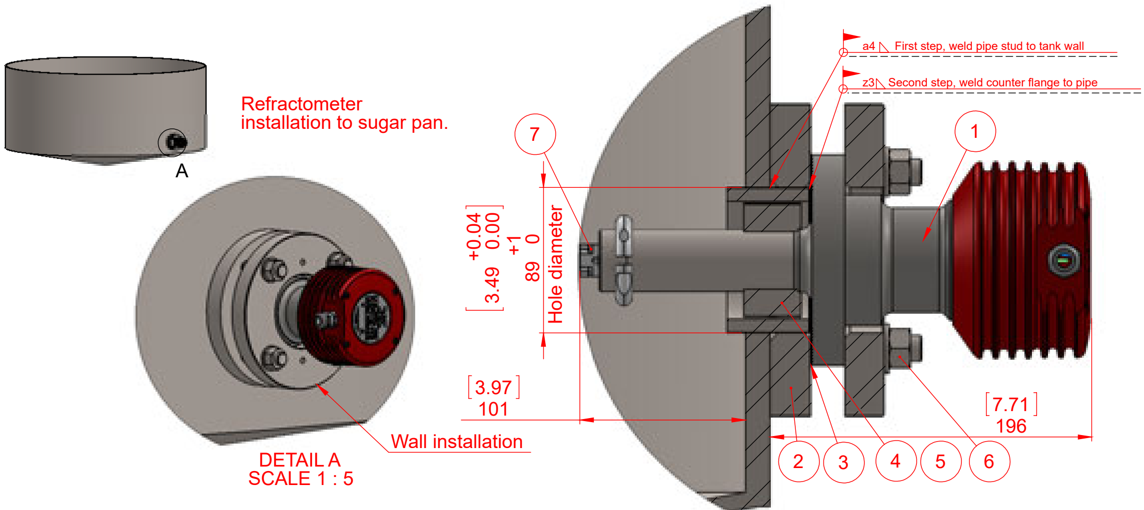
In crystallizer applications it is recommended to use a probe type sensor with insertion length 130 mm. The following considerations should be taken into account:

1. Select a location, where measured concentration is representative for the largest volume of the syrup or massecuite. This requirement means that locations close to the feed syrup entry and above the calandria should be avoided. Too short distance from the entry point results in misleading data valid for a diluted massecuite in a relatively small volume. A too fast drop of measured concentration after opening the feed valve is real cause for concern.

2. Supersaturation increases with decreasing temperature if syrup / mother liquor concentration is kept constant. This means that highest supersaturation is expected where temperature is the lowest. Temperature is the lowest at the surface of the massecuite, while it is the highest just above the calandria. Naturally, the rising surface cannot be followed with the sensor. In practice temperature in the pan bottom is fairly close to surface temperature.

Refractometer sensors should be located in the pan bottom or at the side of the calandria, but well below its surface.

NOTE:
The massecuite and solids content (brix) sensors should be located on the same level as the refractometer sensor and at least 0.5 m from each other in order not to disturb good circulation around them.



#	Sales codes	Description	Material	Supplied by	Pcs
1		PR-23-GP	Process connection AISI 316L	Vaisala	1
2		Counter flange for vacuum pan installation, ANSI/DIN/JIS, 3466	-	-	-
2.1	AP-ASS-W-100-NC	PR-11035, ANSI	AISI 316L	Vaisala	1
2.2	AP-DSS-W-100-NC	PR-11036, DIN	AISI 316L	Vaisala	1
2.3	AP-JSS-W-100-NC	PR-11033, JIS	AISI 316L	Vaisala	1
3		Flange gasket	as requested	Customer	1
4		PR-11034,Flange insert, 3669	AISI 316L	Vaisala	1
5		Screw DIN914 ISO 4027 M6x8	A4 - 70	Vaisala	1
6		Stud Bolt(DIN939 M16x65), Nut DIN934 M16 and washer (DIN125 M16)	A4 - 70	Vaisala	DIN 8+8 ANSI 4+4 JIS 8+8
7		11716, M3x8 DIN912	A4 - 70	Vaisala	2

Figure 2.1 Mounting the PR-23-GP sensor with Counter adapter -AP

2.2.2 Mounting the Indicating transmitter DTR

It is general practice to mount the Indicating transmitter close (but not too close to avoid radiated heat) to the vacuum pans. Specified maximum ambient temperature is 45°C. The DTR must not be exposed to rain or direct sunshine. Avoid vibration and steam when cleaning ("steaming out") the pan.

2.3 SeedMaster 3 configurations

2.3.1 SeedMaster 3: a control room device

The device is used in the control room of the plant. It has advanced digital communication features to

- send a large amount of acquired and calculated data on-line to a Process Control System, and
- to receive some laboratory data, status information etc.

The SeedMaster SM-3 is a computer with a large LCD touch-screen mounted in a robust flat enclosure. It has two Ethernet connectors. All process input and output (digital status, laboratory, measured and calculated) data, etc. are communicated directly between the SM-3 and the Control System via the Ethernet or Ethernet and Modbus. Analog or digital I/O channels can be added with an I/O unit.

2.3.2 Using SeedMaster 3 with I/O unit

A SM-3 I/O unit should be used when analog and/or digital I/O is required. With the I/O unit, SM-3 has:

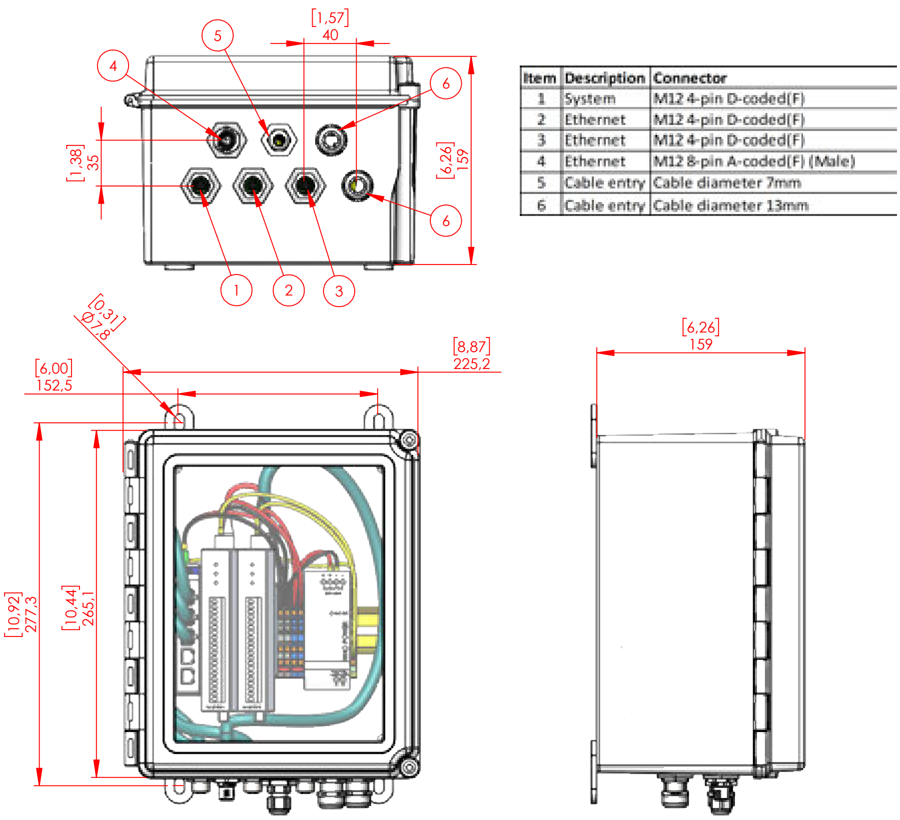
- 6 Digital Inputs
- 2 Digital Outputs
- 4 Analog Inputs (0-20 or 4-20 mA)
- 4 Analog Outputs (4-20 mA)

The unit contains the following items in a safe enclosure (For further details see Chapter 7):

- MOXA ioLogik E1241
- MOXA ioLogik E1242
- 5-port Ethernet switch
- power supply +24 V

The I/O unit is connected to SM-3 directly (see Figure 2.3). In this case both Ethernet connectors of the SM-3 are used. MOXA I/O units are connected to eth1 (marked as “ETHERNET” on the back). SM-3 will act as DHCP server on this connector, and will automatically set IP addresses for the modules.

The recommended installation location for the I/O unit is control room.



Item	Description	Connector
1	System	M12 4-pin D-coded(F)
2	Ethernet	M12 4-pin D-coded(F)
3	Ethernet	M12 4-pin D-coded(F)
4	Ethernet	M12 8-pin A-coded(F) (Male)
5	Cable entry	Cable diameter 7mm
6	Cable entry	Cable diameter 13mm

Figure 2.2 I/O unit dimensions

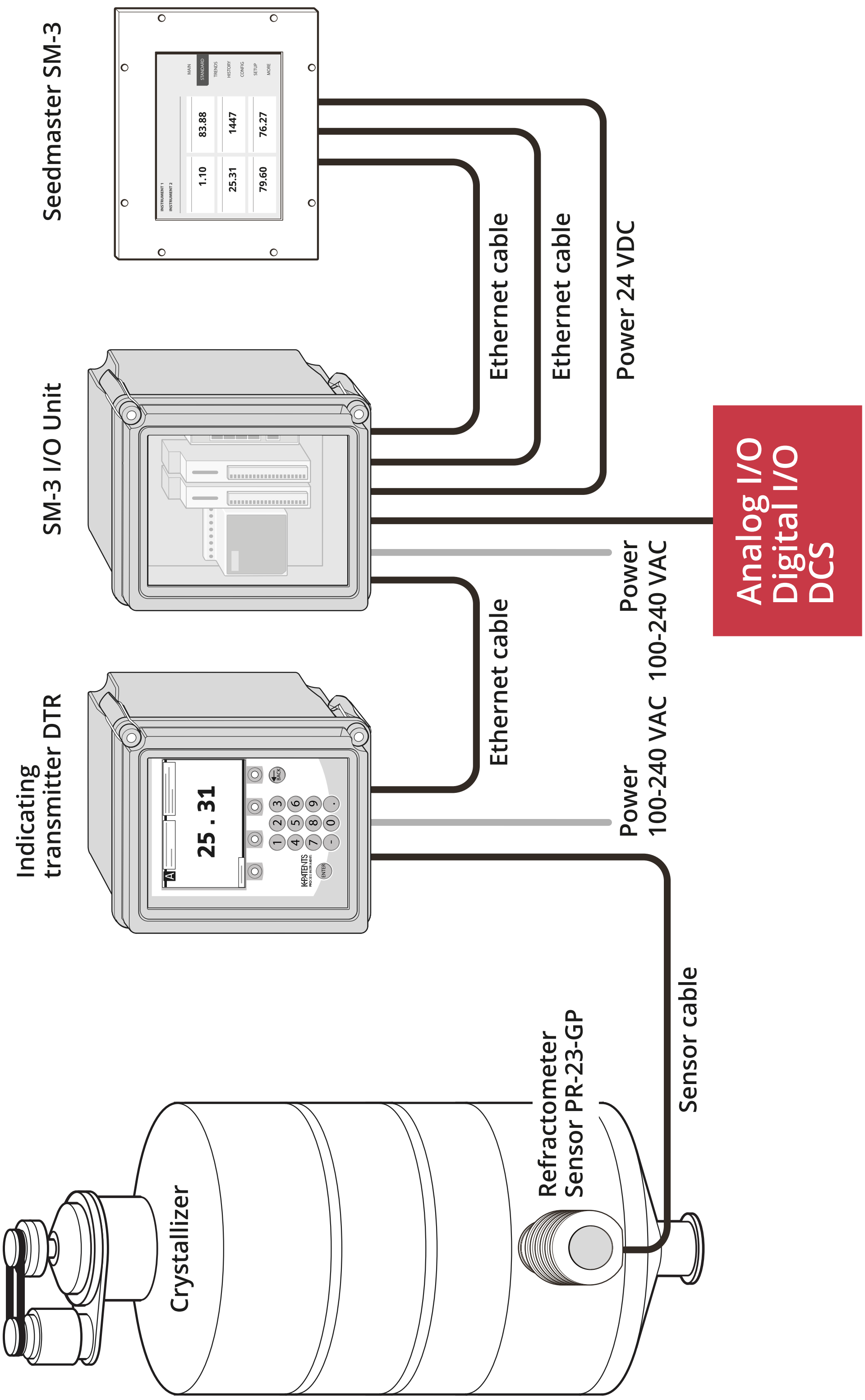


Figure 2.3 Using SeedMaster 3 with I/O unit

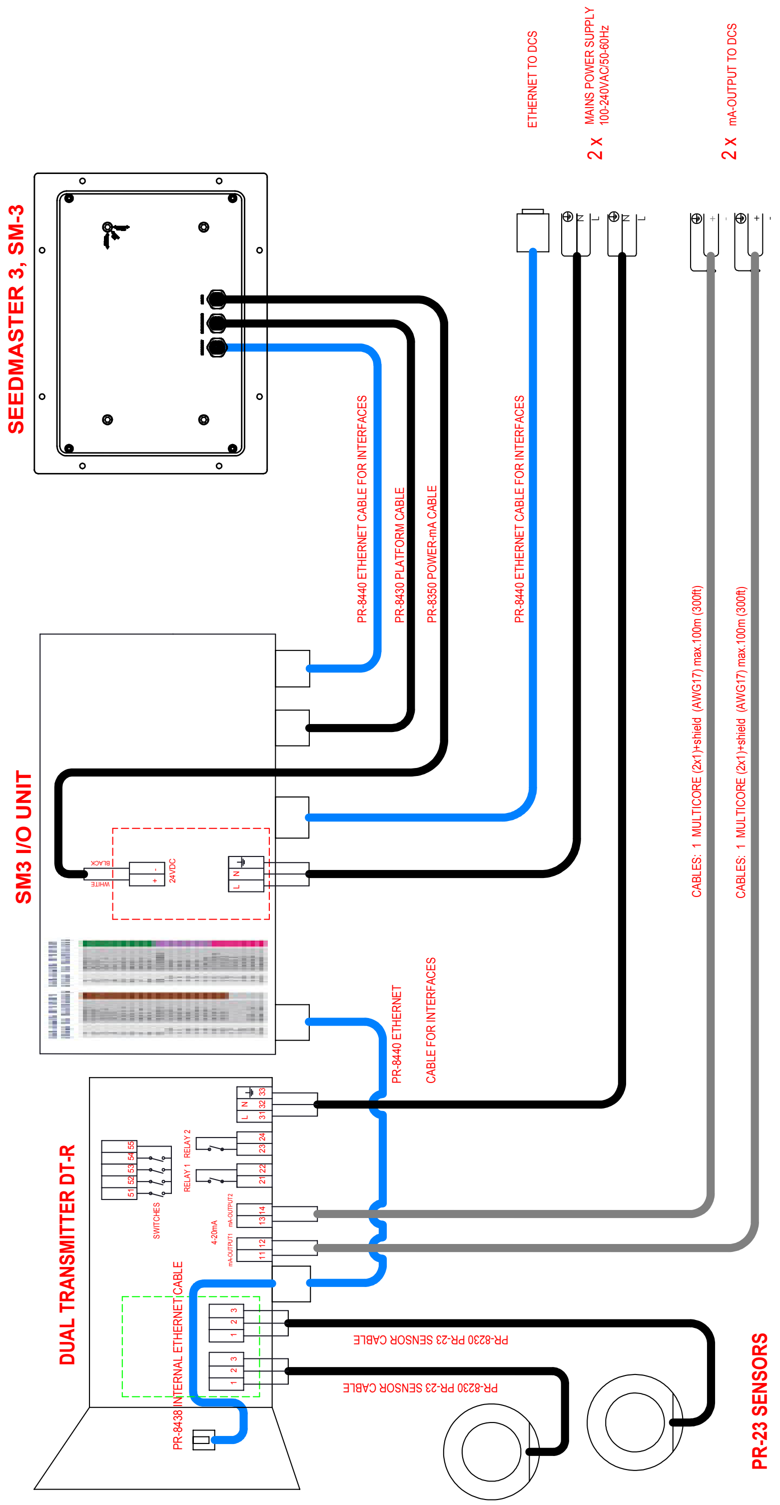


Figure 2.4 System wiring when I/O unit is used

2.3.3 Using SeedMaster 3 without I/O unit

SM-3 can be used without analog and digital I/O channels. In this case all communication is done via Ethernet. Three communication standards are supported:

- UDP/IP direct communication with Vaisala K-PATENTS refractometers
- Modbus/TCP communication for process I/O
- TCP/IP connection to PC for software updates and data downloads

When I/O unit is not used, only one of SM-3's Ethernet connectors is used. If multiple Ethernet cables have to be connected (eg. refractometer and DCS), an Ethernet switch can be used (see Figure 2.5).

Refractometer data

If connected to the same network, SM-3 can gather all required data from Vaisala K-PATENTS refractometers using the UDP/IP communication protocol described in the refractometer's manual.

Another possible solution is that refractometer data is directed to another system (DCS, etc.) and SeedMaster 3 gets the measured values from this system via Modbus/TCP. This solution means however that only concentration and temperature data are forwarded to SM-3. With the previous method other valuable data (refractometer status, slope, optical image, etc.) can be accessed on the SM-3 as well.

Inputs from other instruments, outputs

All other inputs can be forwarded to SM-3 via Modbus/TCP. SeedMaster 3 acts as a Modbus server. This means all data traffic has to be requested by a client (DCS, etc.). This can be:

- Writing data into SeedMaster's input registers
- Reading SeedMaster's output registers

For further details on Modbus, see Appendix B.

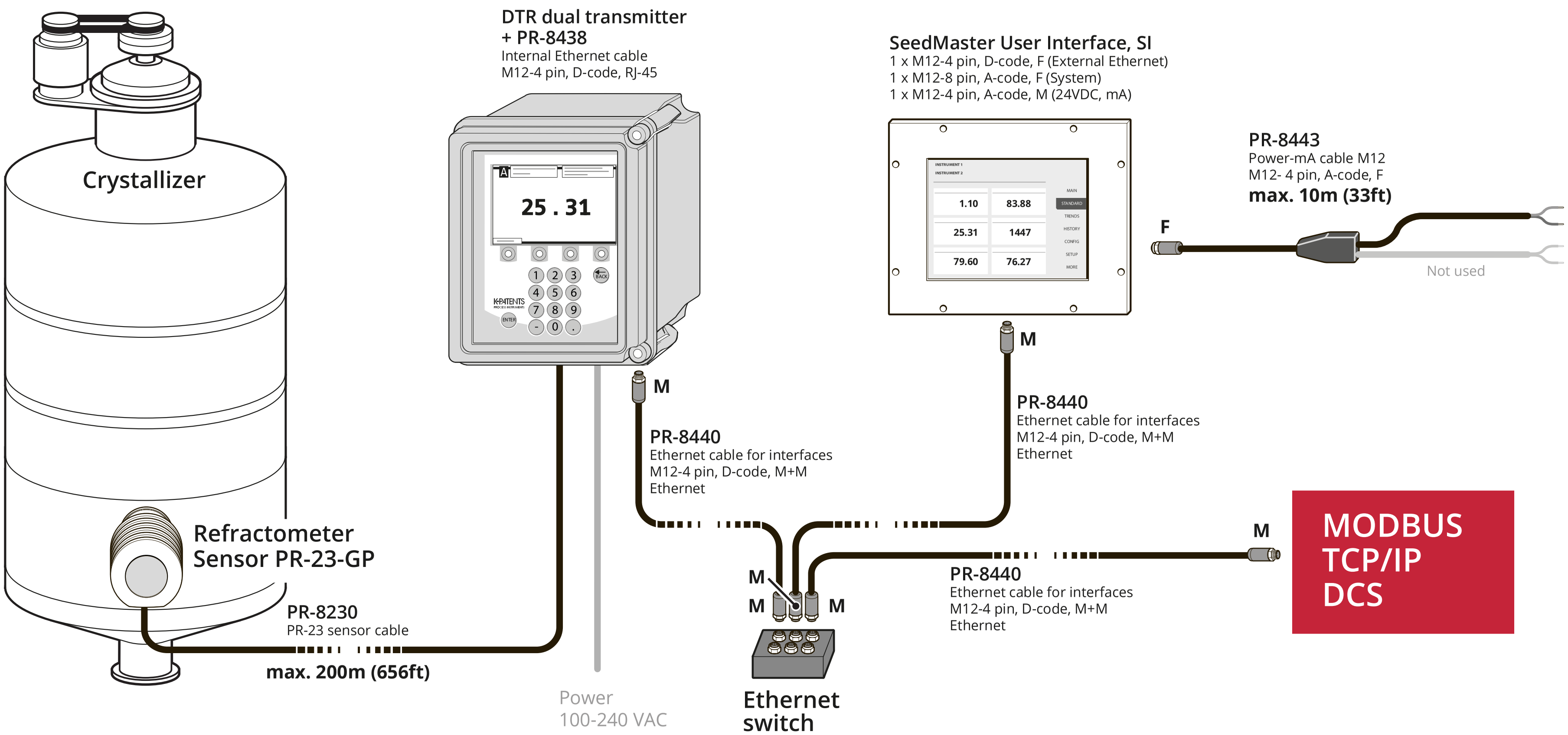


Figure 2.5 Using SeedMaster 3 without I/O unit

3 Principle of operation

The SeedMaster SM-3 was designed to provide information online on all of the parameters which are important for the up-to-date control of crystallization. The liquid concentration reading provided by a Vaisala K-PATENTS process refractometer, is an important part of the system. With a Vaisala K-PATENTS refractometer syrup/mother liquor concentration data are not disturbed by the presence of crystals, steam and vapor bubbles and the color of the liquid. At the same time the refractometer provides data on massecuite temperature as well. This means that data on C and T (concentration and temperature) in Equation 1, page 41, are directly provided by the refractometer. Besides these data information on mother liquor purity P is also required for the on-line calculation of supersaturation.

Mother liquor purity is equal to feed syrup purity only up to the point of seeding. When the crystals begin and continue to grow, mother syrup purity drops accordingly. It is therefore not constant during the strike, and should be calculated on-line together with changing crystal content. *This, however, needs the use of additional on-line data ("Third input") from some already existing sensor (massecuite density or massecuite solids content (brix))*.

Finally, it is well known that feed syrup quality, characterized by its "m", "b" and "c" parameters, can show considerable changes, which have to be taken into account when calculating the massecuite parameters. Syrup quality parameters should be determined by the local laboratory (see: Appendix A). If it is not possible, data typical for beet and cane syrups are available. Besides these some additional laboratory data are also required.

Based on the calculated data SeedMaster 3 can be programmed to carry out **automatic seeding** of the crystallizer on its own, when

- supersaturation, or
- massecuite density

becomes equal to the supersaturation or density set-point selected by the technologist or pan operator (supersaturation is preferred). Actual seeding is carried out by opening the seed valve (digital output) for a pre-set time interval.

NOTES:

1. **Automatic seeding is the only control operation which can be implemented by the SeedMaster 3.**
2. If seeding of the crystallizer is carried out not by SeedMaster 3, but by another device (a control system, for example), or by the operator, **SeedMaster 3 must be notified accordingly by a digital input, or via Modbus communication**.
3. All operations discussed above can be performed independently and simultaneously with two crystallizers at the same time.
4. "Strike cut" crystallization practice is not supported by the SM-3.

3.1 Calculated data

SeedMaster 3 carries out involved calculations on-line based on the information received. Calculated data and one or the other of the measured data used (density, solids contents, level) are combined providing information on 6 massecuite parameters (set of massecuite parameters) per crystallizer. These are:

1.	**supersaturation**	**(-)**
2.	**crystal content**	**(% by volume)**
3.	mother liquor purity	(%)

4. massecuite density (kg / m^3)
5. massecuite solids content (%)
6. mean crystal size (mm)

NOTES:

1. Any 4 out of the 12 (6 per crystallizer) listed above can be selected for transmission by analog (4-20 mA) current output.

2. All of these and some other data can be transmitted to a PCS via ethernet, or DCS via Modbus communication.

3. Mean crystal size data are approximate and valid only if full seeding is practiced and no dissolution of crystals or further nucleation takes place during crystallization.

3.2 On-line data inputs

The three on-line (real-time) data inputs required for the correct operation of the SeedMaster 3 are:

1. syrup / mother liquor concentration,
2. massecuite temperature,
3. massecuite solids content (%), OR massecuite density (kg / m^3).

NOTE:
If there is no instrument available to provide on-line data on massecuite solids content or density, laboratory data on the change of crystal content after seeding has been completed can be used. In this case, however, accuracy of the calculated data may suffer.

3.2.1 Receiving concentration data

Concentration is measured by a Vaisala K-PATENTS refractometer. The measured values can be transmitted to SeedMaster 3 in the following ways:

- UDP/IP Ethernet communication (if the refractometer can be accessed from SM-3 via Ethernet). This is the preferred method.
- Modbus/TCP, if concentration is transmitted from refractometer to another system, which sends the values to SM-3 via Modbus/TCP.
- Analog (0-20 or 4-20 mA) signal, if SM-3 I/O unit is available, and refractometer is equipped with analog output, or concentration is transmitted to a system which forwards it to SM-3 via analog output.

3.2.2 Receiving temperature data

Massecuite temperature is always measured by the sensor probe of the Vaisala K-PATENTS refractometer and may be available for transmission as standard current (4 – 20 mA) output (option). The Indicating transmitter of a PR-23-GP refractometer has (depending on the model used) two, or only a single current output.

Temperature can be transmitted to SM-3 in the following ways:

- UDP/IP Ethernet communication (if the refractometer can be accessed from SM-3 via Ethernet). This is the preferred method.
- Analog (0-20 or 4-20 mA) signal, if SM-3 I/O unit is available.

NOTES:

1. Due to the limited number of analog inputs (4) it is advised to use Ethernet communication to transfer data originating from the refractometer to the SeedMaster 3.

3.2.3 Selecting the “THIRD INPUT” transmitter

Whenever available, a “THIRD INPUT” transmitter should be used. The instrument should be carefully calibrated.

<u>Using laboratory data instead of “THIRD INPUT”</u>
It is always preferred to have real on-line feedback (that is: on-line information from one of the instruments listed). *However, if there is no instrument available to use as “THIRD INPUT”, laboratory data on crystal content (% by volume) at some selected intervals reflecting a typical strike can be used with batch vacuum pan applications. However, this will be only a rough approximation.* All features of SeedMaster 3 are available.

3.2.4 Optional data input

An optional LEVEL transmitter can be connected to one of the analogue input channels of SeedMaster 3. The level data may come from a DCS via Modbus communication, too. The use of level data is optional: if available, they are used to refine some of the calculations (for example: calculation of mean crystal size) and to implement a smooth transition from one feed syrup to another one, if feed syrups with different purities are used in the same batch strike. It can provide additional information on site for the pan operator, too. *If there is no on-line data on level, approximate level (%) versus time (measured from completed seeding) data will be generated and used by the SM-3.*

3.3 Digital inputs

The 2 digital inputs (per pan) are typically contact (relay or switch) types. An “ACTIVE” digital input can be configured either as an OPEN, or CLOSED relay (or switch) contact.

3.3.1 "STRIKE ACTIVE" digital input

SeedMaster 3 can be operated in “Stand-by”, or in “Active”. In Stand-by mode it waits for the start of a new strike (batch pans) and no calculations are performed.

The Active mode should be evoked by the start of a new strike (feeding syrup in the pan begins), and should usually end with the drop of the charge and motor switch OFF. In the time between two active strikes (SeedMaster 3 in Stand-by mode) the pan is usually washed and is under normal pressure. Temperature and concentration data can be quite far from their normal ranges.

Information on the “ACTIVE “status of a pan or crystallizer might come from 2 sources, namely:

- from a relay or switch contact (digital input), or
- from a DCS via Modbus communication.

STRIKE ACTIVE signal has to be active during the whole strike.

3.3.2 “SEEDED” digital input

In order to perform the calculations correctly SeedMaster 3 needs information on the seeding of the pan.

There is no need for this input if seeding of the pan is carried out by SeedMaster 3 itself, that is if

- AUTOMATIC SEEDING was configured, or
- the operator uses the “MANUAL SEEDING” feature regularly (not advised).

However, if seeding is carried out

- either by an independent process control system (PCS), or
- manually by the operator (pan-man) *without using the “MANUAL SEEDING”* feature of SeedMaster 3, *the device must be notified on the seeding of the pan by a digital input lasting for at least 20 seconds*. In this case information may come in the form of a digital input signal, or via Modbus communication from an independent control system (DCS). Figure 3.1 shows digital input signals versus time.

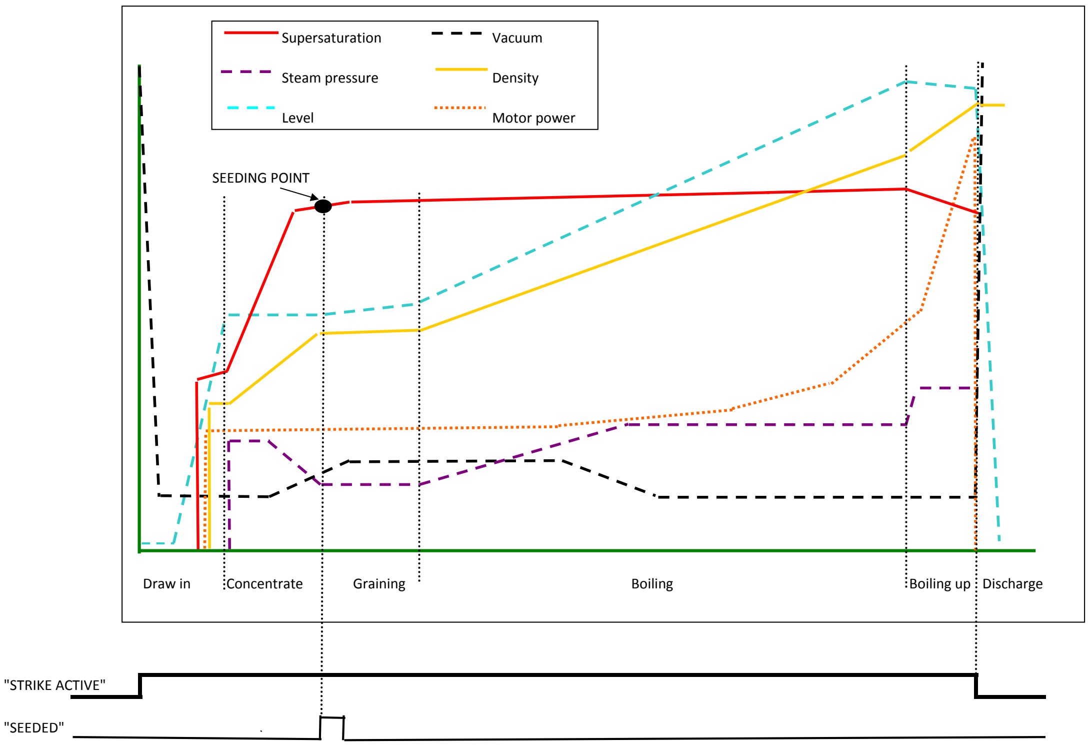


Figure 3.1 Digital inputs

NOTES:

1. **Failing to provide information on seeding when needed will result in erroneous operation.**
2. When SeedMaster 3 receives information from a PCS on seeding, it will operate the same way as it would if MANUAL SEEDING were configured, that is it will OPEN the seeding valve (if connected) for the configured time.

3.3.3 "CHANGE FEED SYRUP" digital input

If instead of a single one, 2 or 3 (maximum) feed syrups having different syrup purities are to be fed to the same batch strike the device must be informed on the execution of the change. One way to do it is to use a digital input.

In this case information on purity and pan level may come from a PCS or DCS via communication. The digital input has to be active for 15-25 seconds to notify SM-3 about feed syrup change. Three different purities can be set on SeedMaster 3, and when it receives the signal, it will jump to the next purity value. SM-3 can also be configured to consider feed syrup changed at certain levels. If there are no level data available, the SeedMaster 3 will use simulated level data.

3.4 On-line data outputs

3.4.1 Data available for transmission

There are 9 massecuite parameters per pan displayed on the LCD of SeedMaster 3. They are (except of level) available for transmission via communication to another device (DCS).

Set of massecuite parameters:

1.	Supersaturation	(-)
2.	Massecuite solids contents	(%)
3.	Crystal content	(% by volume)
4.	Mother liquor purity	(%)
5.	Massecuite density	(kg / m^3)
6.	Syrup / mother liquor concentration	(%)
7.	Temperature	(°C)
8.	Mean crystal size	(mm)
9.	Level	(%)

3.4.2 Standard current outputs

SeedMaster 3 hardware provides 4 standard current (4 – 20 mA) output channels. Any 4 out of the possible 16 (8 per crystallizer) parameters can be selected for transmission.

3.4.3 Digital (ON / OFF) outputs

There are 2 digital outputs available. These can be used to operate seeding valves, if SeedMaster 3 is in control of seeding.

<u>"SEEDING" output</u>
Actual seeding of the pan is carried out

1. directly by the control system (DCS), or
2. by turning the digital "SEEDING" output ON to open the seeding valve for a selected time interval (configurable, see chapter 7). This output will be operated in 3 cases:
   – when AUTOMATIC SEEDING by SeedMaster 3 was configured,
   – when MANUAL SEEDING by using SeedMaster 3 was carried out by the operator, and
   – when it receives a command for seeding via input, or Modbus communication.

This same output can be used also when crystal footing is being used for seeding.

4 User interface

When you power up the SeedMaster 3, it takes about a minute to start. Then it shows Main display with information on the measurement. The display is a touch-screen display. If you find it hard to use with your fingers, try tapping the display with your nail or the blunt end of a pen. The display works also when you have gloves on.

To get access to additional information and the settings, tap *Menu* in the upper right corner of Main display.

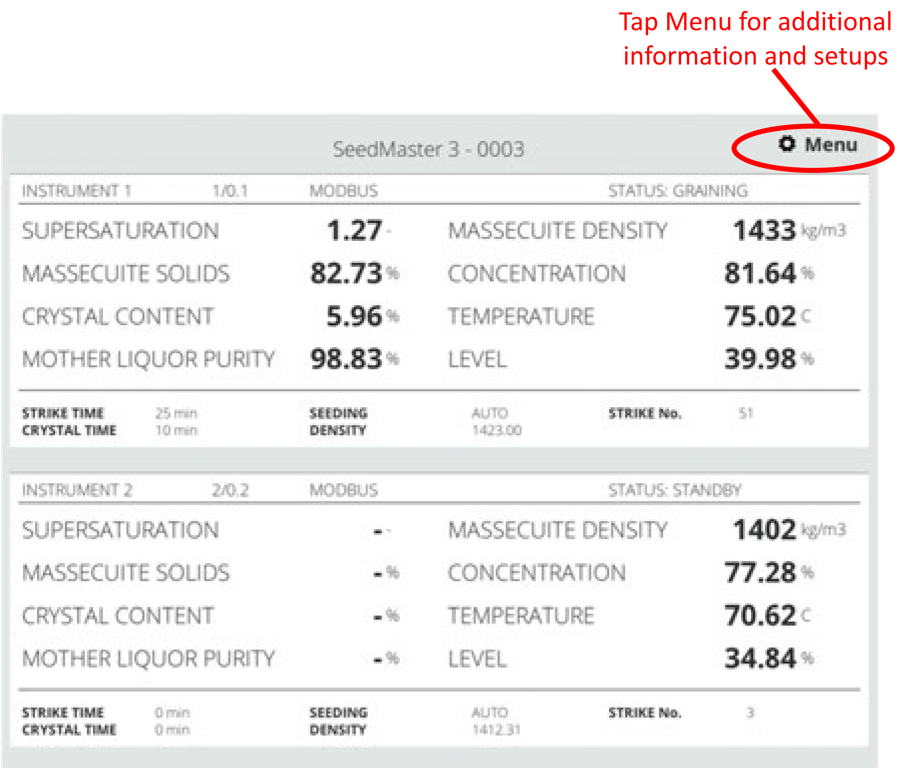


Figure 4.1 Main display

4.1 Configuring SeedMaster 3

To get to the Configuration menu, press *Menu*, then *Config*. There are 7 tabs under Config: General, AI+DI, Modbus in, Keyboard, Ao+Do, Range and IO map.

4.1.1 General

Go to *Menu->Config*, then tap *General* to access the general settings.

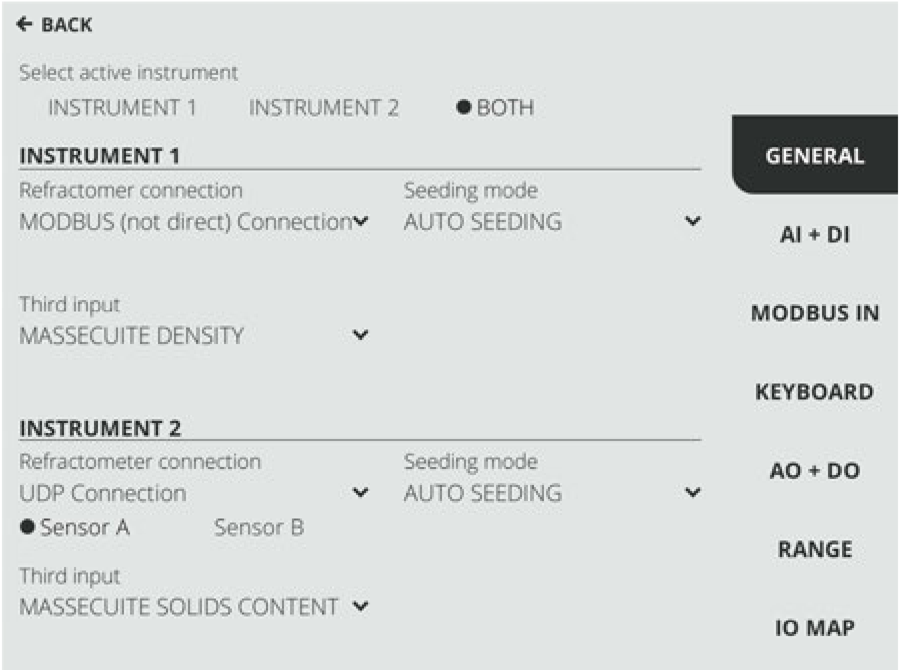


Figure 4.2 General tab in the Config menu

You can select active instrument in the first section. Below that part refractometer connection, seeding mode and third input can be selected for each active instrument.

Connection between refractometer and SM-3 can be direct via UDP. In this case the two devices have to be connected via Ethernet, and SeedMaster needs to know the IP address of the refractometer (See network settings in Section 4.2.3). When communicating via UDP, you have to select which sensor of the refractometer you want to use (when it is a PR-23 with 2 sensors).

If the connection is not direct via UDP, concentration and temperature data can be transmitted to SM-3 via analog signals or Modbus/TCP.

Third input can be either massecuite density or massecuite solids content. If none of those is available, third input can be "simulated". This means that crystal content versus time in 3 points has to be defined by the user under *Config->Keyboard*.

4.1.2 Analog and digital inputs

Go to *Menu->Config* and tap *AI+DI*.

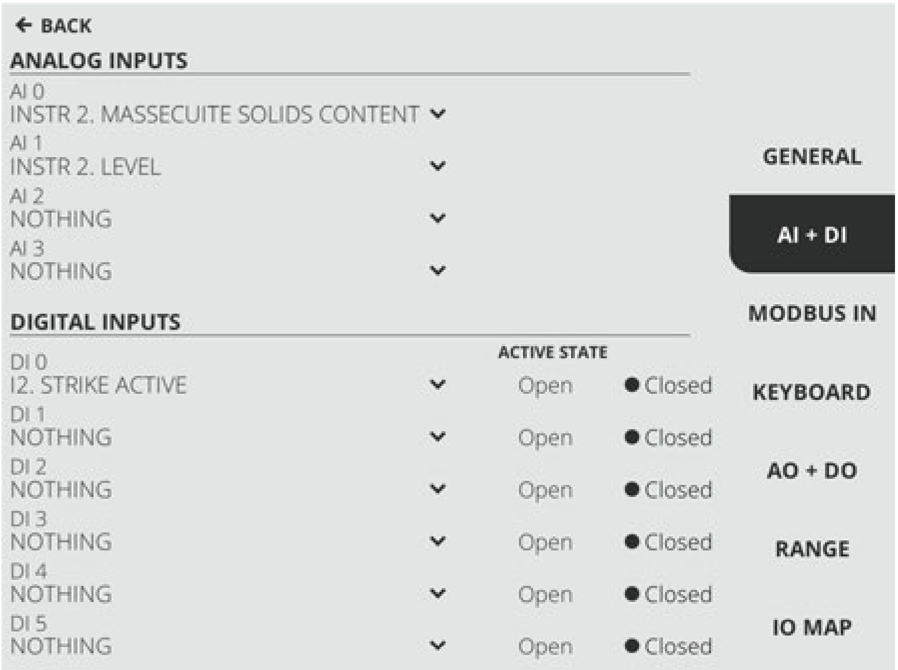


Figure 4.3 AI+DI tab in the Config menu

When the I/O unit is connected, SM-3 can use 4 analog and 6 digital inputs. Analog inputs can be used for:

- Concentration and temperature if refractometer connection is configured as analog
- Third input (density or solids content)
- Level

Analog inputs can be configured as 0-20mA or 4-20mA under *Config->Range*.

Digital inputs can be used for:

- STRIKE ACTIVE signal
- SEEDING signal
- FEED SYRUP CHANGE signal

Each digital input can be configured to be considered as active in open or closed state.

4.1.3 Modbus in

Go to *Menu->Config* and tap *Modbus in*.

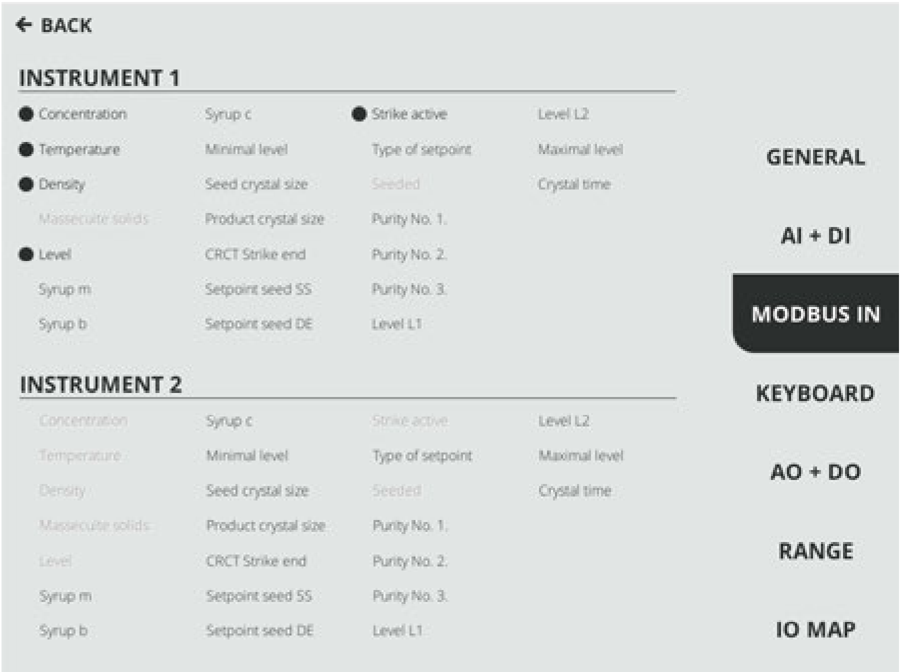


Figure 4.4 Modbus in tab in the Config menu

A lot of different parameters and measured data can be transmitted to SM-3 via Modbus. If refractometer connection is configured as MODBUS under *Config->General*, concentration and temperature are automatically selected here. If it is configured as UDP or analog, then concentration and temperature cannot be selected here (as it is seen under INSTRUMENT 2 on the above image).

If a signal is connected to the analog or digital inputs under *Config->AI+DI*, then it cannot be selected as a MODBUS input here.

4.1.4 Setting parameters with keyboard

Go to *Menu->Config* and tap *Keyboard*.

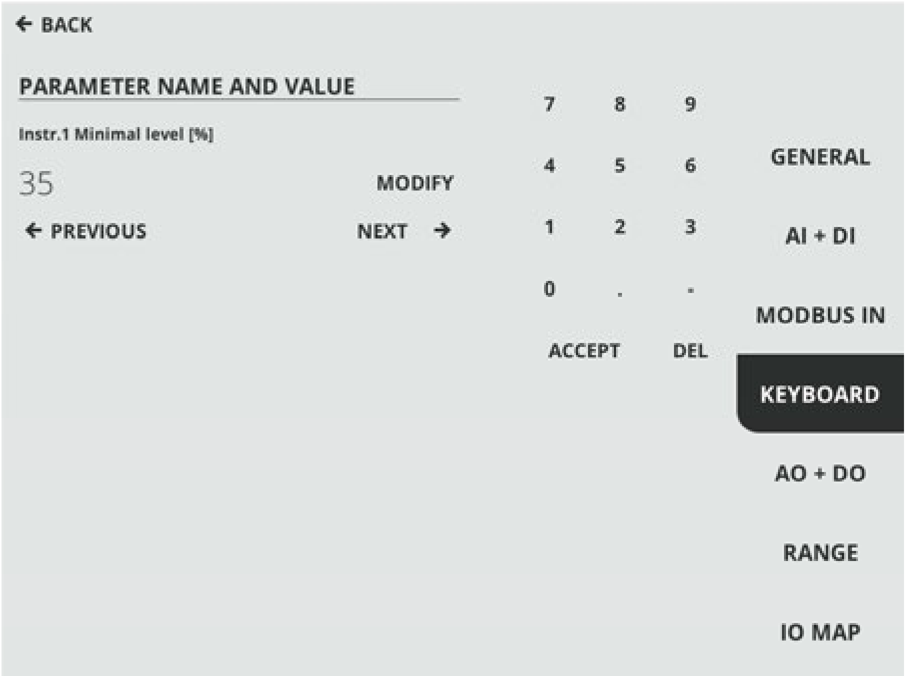


Figure 4.5 Keyboard tab in the Config menu

After "GENERAL", "AI+DI" and "MODBUS IN" are set, SeedMaster decides which parameters are still required for optimal operation. Those can be set here. Switch between parameters with the buttons *<- PREVIOUS* and *NEXT->*. To alter the value of a parameter press *MODIFY*, enter the new value on the numeric keyboard and press *ACCEPT*.

When the actually shown parameter is a syrup parameter (m, b or c), two buttons appear below. With those, typical cane or beet sugar m, b and c parameters can be given to these 3 (on calculating m, b and c, see Appendix A).

If third input is set as "SIMULATED" under "GENERAL", crystal content versus time has to be set in three points. This can also be done here.

4.1.5 Analog and digital outputs

Go to *Menu->Config* and tap *AO+DO*.

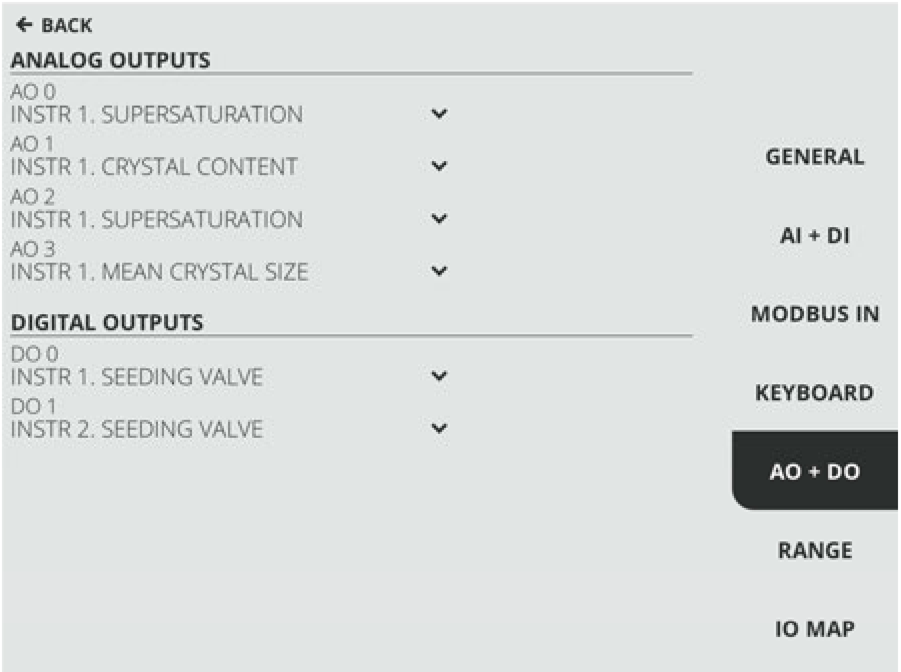


Figure 4.6 Output signals in the Config menu

Analog and digital output signals can be selected here. The 4 analog outputs can be configured to transmit the following signals of instrument 1 or 2:
- Supersaturation
- Concentration
- Temperature
- Density
- Massecuite solids content
- Mother liquor purity
- Crystal content
- Mean crystal size

Analog outputs are 4-20mA signals. Ranges can be set under *Config->Range*.

Digital outputs can be used to control seeding valves. Open times can be set under *Config->Keyboard*.

4.1.6 Range

Go to *Menu->Config* and tap on *Range*.

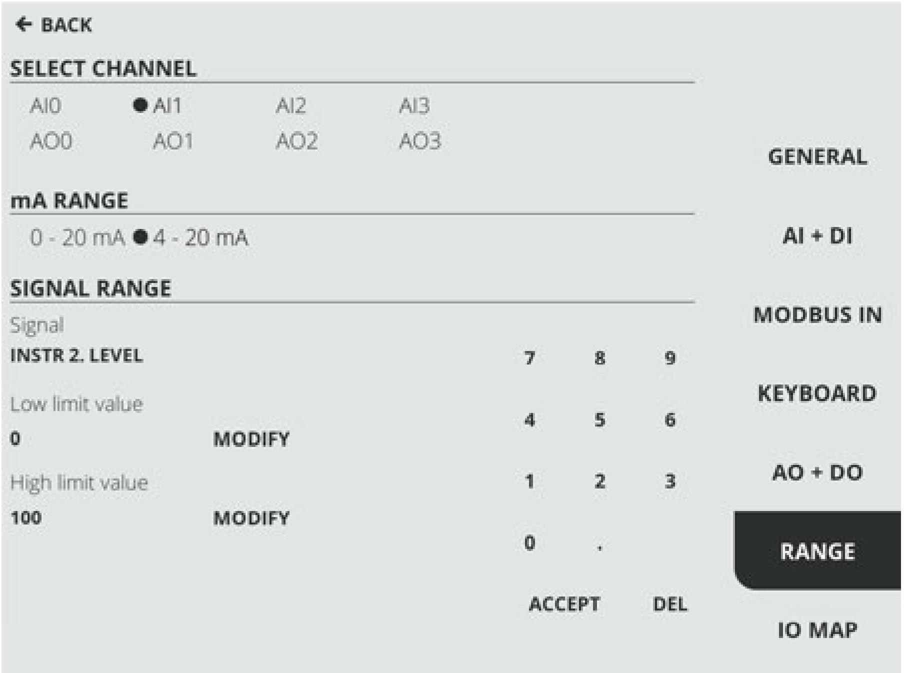


Figure 4.7 Range in the Config menu

Ranges for analog inputs and outputs can be set here. On the top of the screen you can select an analog channel. If there is a signal configured to this channel under *Config->AI+DI* or *Config->AO+DO*, range options will appear below. For inputs there is a mA range option in the middle of the screen (0-20 mA or 4- 20 mA). Outputs are always 4-20 mA.

In the “SIGNAL RANGE” part SeedMaster 3 shows, which signal is connected to this channel. Low and high limit values can be set by pressing *MODIFY*, entering the new value on the numeric keyboard and pressing *ACCEPT*.

4.1.7 IO map

The IO map shows all the inputs and outputs configured in the CONFIG menus. Go to *Menu->Config->IO map* to view the mapping.

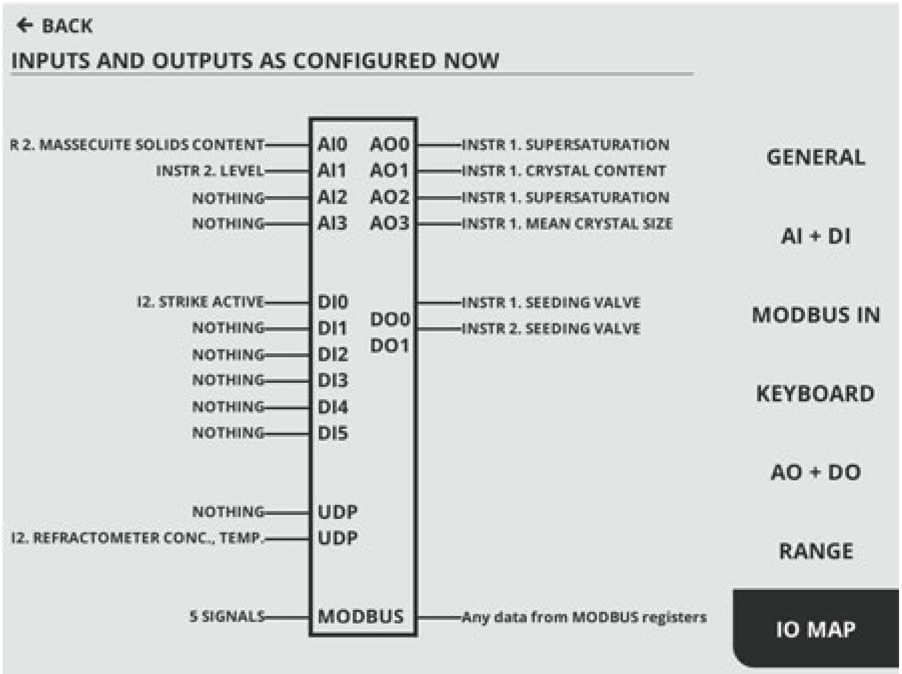


Figure 4.8 IO map in the Config menu

4.2 Set up SeedMaster SM-3

There are five tabs under *Menu* -> *Setup* where the basic properties of the device can be set.

4.2.1 Standard display setup

Go to *Menu->Setup* and tap *Standard* to get access to the Standard display settings, where you can choose the values shown in the Standard display.

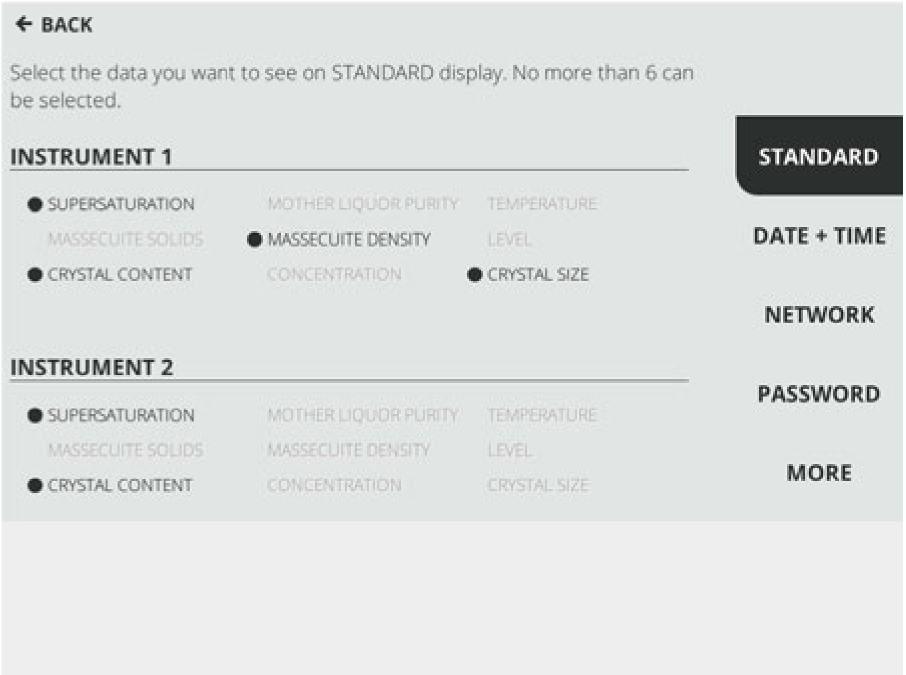


Figure 4.9 Standard tab in the Setup menu

Six values are shown in the Standard display (*Menu->Standard*). Under *Setup->Standard* you can select which 6 (or less) values you want to see in the Standard display (see Figure 4.19). The following can be chosen from Instrument 1 or 2:

- Supersaturation
- Massecuite solids content
- Crystal content
- Mother liquor purity
- Density
- Concentration
- Temperature
- Level
- Mean crystal size

4.2.2 Setting date+time

Go to *Menu->Setup* and tap *Date+time* to set instrument time.

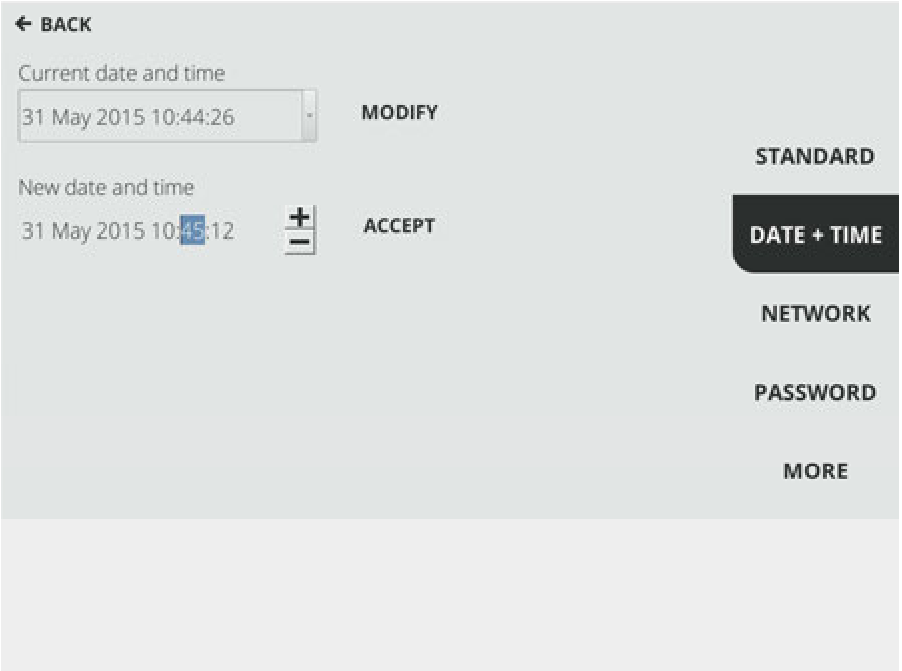


Figure 4.10 Setting date and time in the Setup menu

System date and time can be set here. Current date and time is shown on the top. If you want to alter it, *MODIFY* has to be pressed. A field to edit new date and time appears. You have to tap the part you want to modify (e.g. month – "May" on the above picture), and press the "+" or "-" buttons to increment or decrement. When satisfied, press *ACCEPT*.

4.2.3 Network

Go to *Menu->Setup* and tap *Network* to get access to the system network settings.

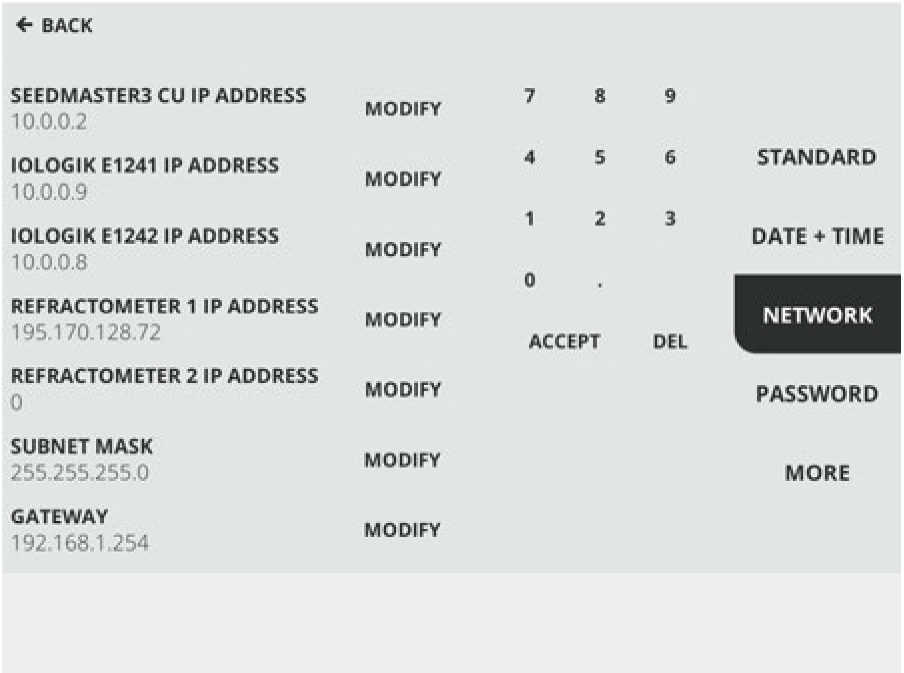


Figure 4.11 Network tab in the Setup menu

Network properties are set here. “SEEDMASTER3 CU IP ADDRESS” is the address of the central unit, SeedMaster 3 itself.

“REFRACTOMETER 1 IP ADDRESS” is the IP address of the refractometer used for instrument 1. This is used only when UDP communication is configured under *Config->General*. The same applies for the second refractometer. If there is one refractometer DTR with 2 sensor heads, the 2 IP addresses will be of course identical.

Subnet mask and gateway are also to be set here.

Below that the IP addresses of the I/O unit IO modules can be configured. When there is no I/O unit connected, “NO MODULE” has to be set. If the I/O unit is connected to eth1 Ethernet connector (marked as “ETHERNET” on the back) “DHCP” has to be selected.

4.2.4 Password

The password is needed only for manual seeding. Go to *Menu*-> *Setup* and tap *Password* to change the password.

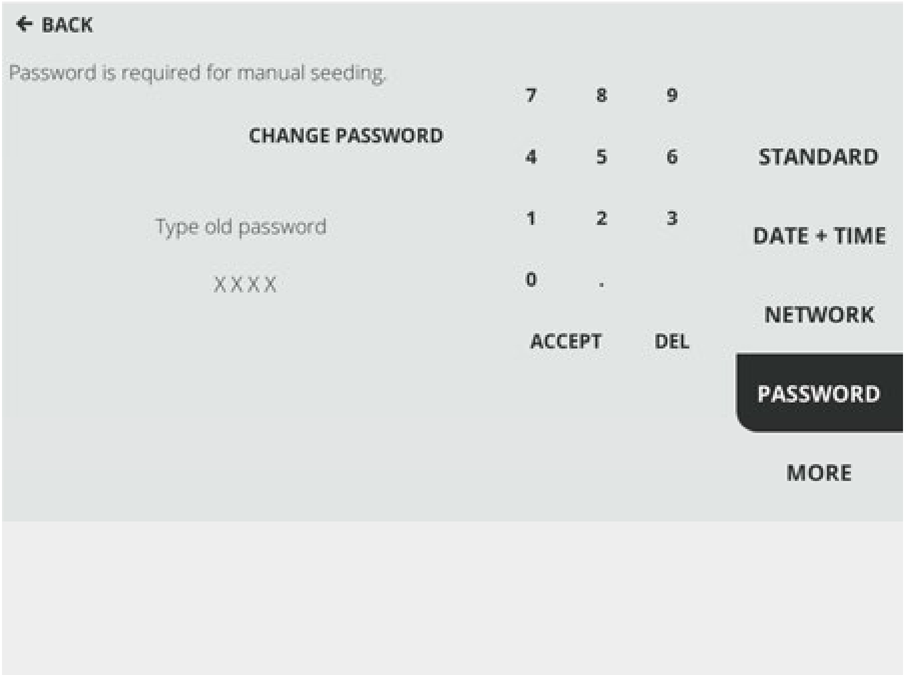


Figure 4.12 Password tab in the Setup menu

Note. “0000” as a default password will always be accepted.

4.2.5 More setups

Go to *Menu->Config* and tap *More*.

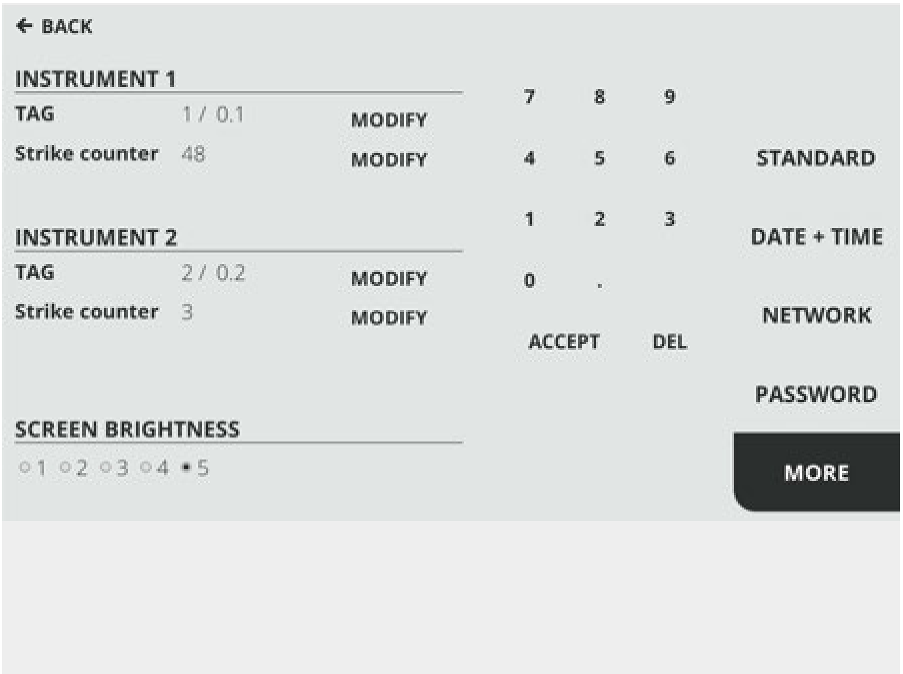


Figure 4.13 More tab in the Setup menu

Tag for both instruments can be set here. This can be (almost) whatever you want. Instrument tags are shown on Main and Standard displays.

Strike counter can also be set here. Strike counter is incremented every time a new strike starts. Screen brightness is also set here.

4.3 Further features

Under *Menu->More* the following functions can be reached: Test I/O, Modbus, Manual, Refractom(eters).

4.3.1 Test I/O

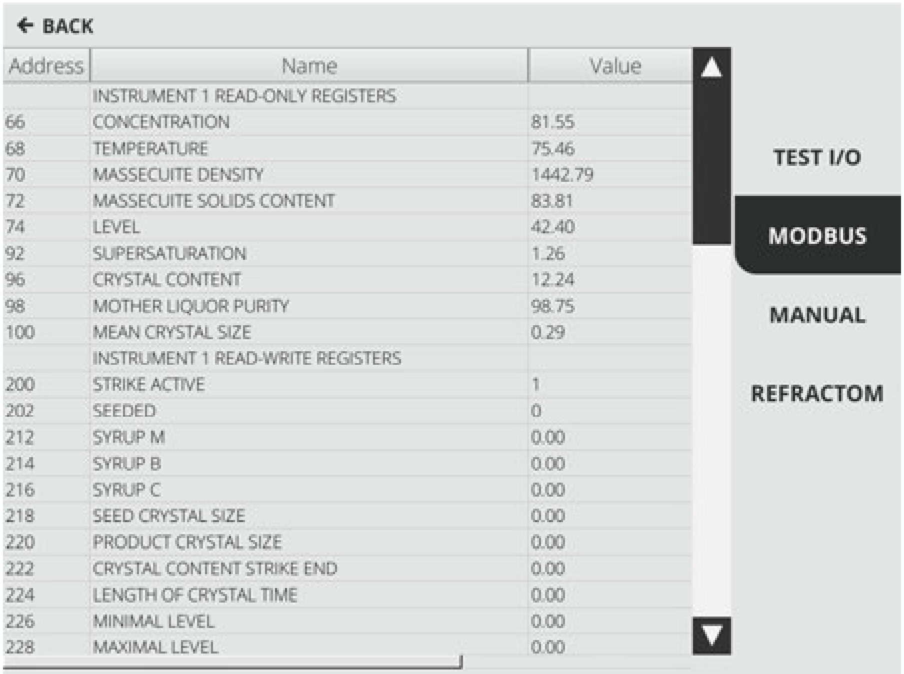
Go to *Menu->More* and tap *Test I/O*. Analog inputs and outputs can be tested here (if an I/O unit is connected).

In the upper part of the screen Input values are shown. In the lower part outputs are shown. You can open or close digital outputs. Analog outputs can get 2 different values.

Figure 4.14 Test I/O tab in the More menu

4.3.2 Modbus

Go to *Menu->More* and tap *Modbus* to view Modbus information. All Modbus input and output registers are listed here with address, name and value. This can be useful to test Modbus communication.



Address	Name	Value
	INSTRUMENT 1 READ-ONLY REGISTERS	
66	CONCENTRATION	81.55
68	TEMPERATURE	75.46
70	MASSECUITE DENSITY	1442.79
72	MASSECUITE SOLIDS CONTENT	83.81
74	LEVEL	42.40
92	SUPERSATURATION	1.26
96	CRYSTAL CONTENT	12.24
98	MOTHER LIQUOR PURITY	98.75
100	MEAN CRYSTAL SIZE	0.29
	INSTRUMENT 1 READ-WRITE REGISTERS	
200	STRIKE ACTIVE	1
202	SEEDED	0
212	SYRUP M	0.00
214	SYRUP B	0.00
216	SYRUP C	0.00
218	SEED CRYSTAL SIZE	0.00
220	PRODUCT CRYSTAL SIZE	0.00
222	CRYSTAL CONTENT STRIKE END	0.00
224	LENGTH OF CRYSTAL TIME	0.00
226	MINIMAL LEVEL	0.00
228	MAXIMAL LEVEL	0.00

Figure 4.15 Modbus tab in the More menu

4.3.3 Manual seeding

Go to *Menu->More* and tap *Manual*. Manual seeding can be performed here for any instrument where strike is active. Manual seeding can be done at any time, even when the strike is already seeded.

Password is required for manual seeding (see Section 4.2.4).

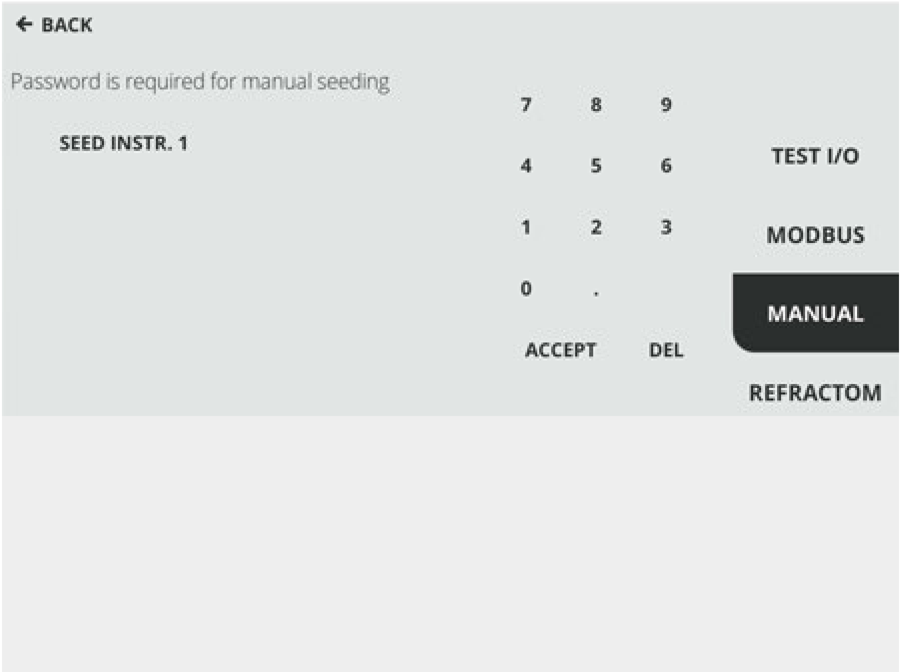


Figure 4.16 Manual (seeding) tab in the More menu

4.3.4 Refractometer information

Go to *Menu->More* and tap *Refractom* to access refractometer information. When a PR-23 refractometer is connected via Ethernet, SeedMaster 3 can show some vital parameters of it. This includes optical image, slope and several static and dynamic data. Refractometer IP address has to be set under *Setup->Network* to be able to get these data.

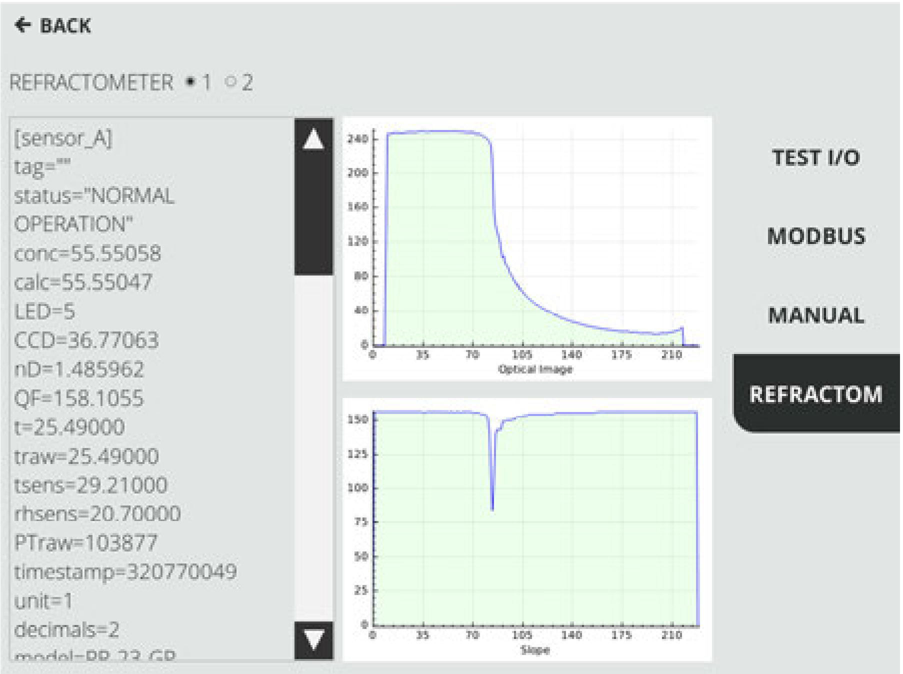


Figure 4.17 Refractometer info in the Refractom tab in More menu

4.4 Informational displays

4.4.1 Main display

When both instruments are active, 2 identical boxes are shown on the Main Display.

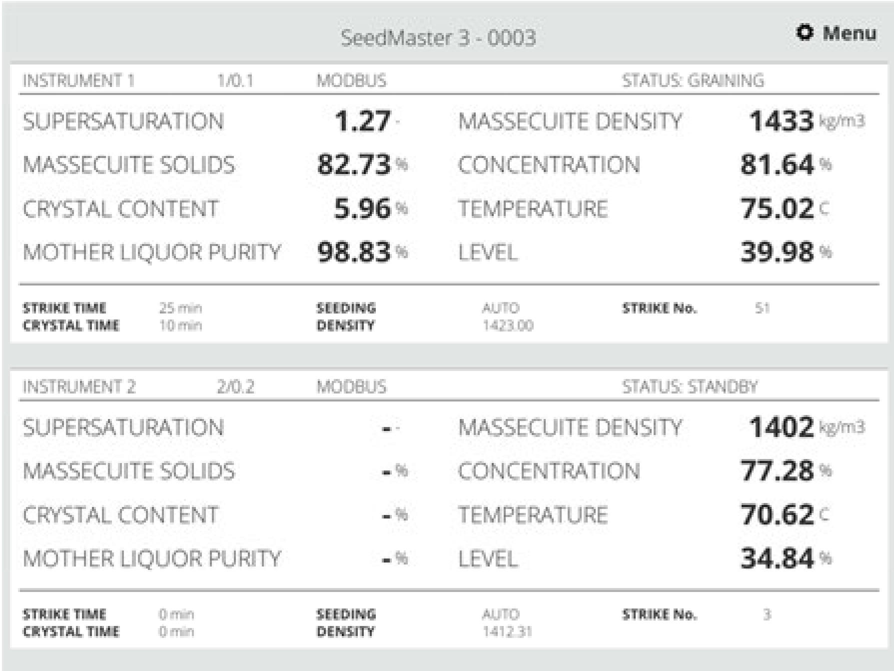


Figure 4.18 Main display

In the top row of an instrument box the followings are shown (from left to right):

- Name of the instrument
- Instrument tag
- Refractometer status (if connected via UDP) or mode of refractometer connection
- Strike status:
  - Standby – strike is not active
  - Active – strike is active but not seeded yet
  - Graining – seeded, crystal content is under 20%
  - Boiling – crystal content is over 20%

In the center of on instrument box measured and calculated data are shown:

1. Supersaturation
2. Massecuite solids [%]
3. Crystal content [%]
4. Mother liquor purity [%]
5. Massecuite density [kg/m^3]
6. Concentration [%]
7. Temperature [°C/°F]
   (unit of measurement can be set under *Config->Keyboard*)
8. Level [%]

Measured values are shown even when strike is not active (as seen on Instrument 2 on the picture).

At the bottom of an instrument box the followings are shown:
- Strike time [min] – time elapsed from strike activation
- Crystal time [min] – time elapsed from seeding
- Seeding mode – Automatic/Digital/MODBUS/Manual
- Seeding setpoint (if seeding is automatic) – Density or Supersaturation; setpoint value
- Strike number

4.4.2 Standard display

Go to *Menu->Standard* to switch to the Standard display. Six selected signals are shown on the Standard display.

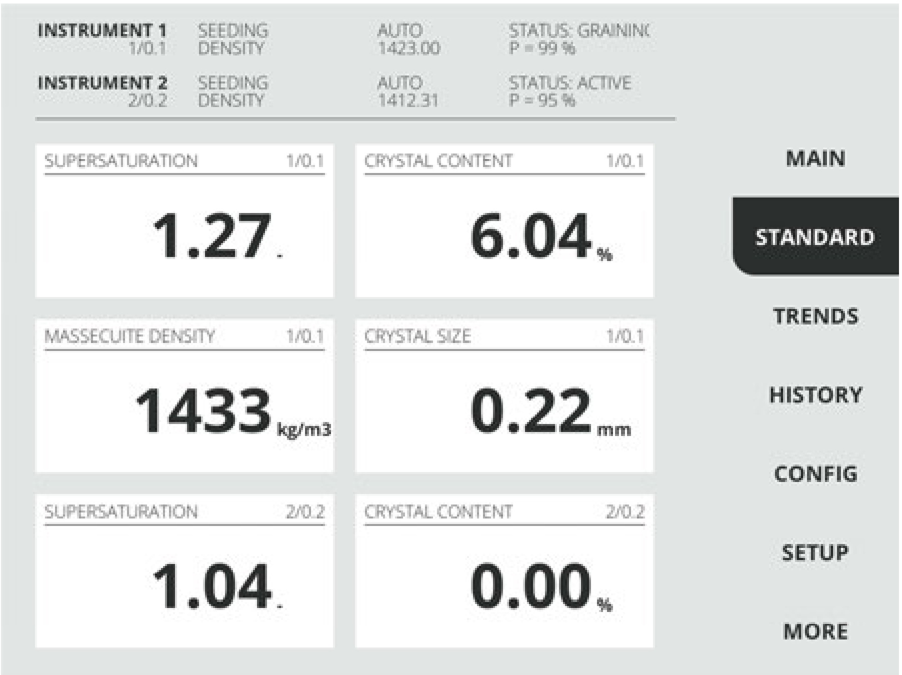


Figure 4.19 Standard display

At the top of the screen seeding mode, seeding setpoint, status and feed syrup purity data are shown. Below that there are 6 boxes showing 6 selected values (select under *Menu->Setup->Standard*), with name, value, unit of measurement and instrument tag (go to *Menu->Config->More* to change tags).

4.4.3 Trends display

Under *Menu->Trends* two real-time trends can be seen simultaneously.

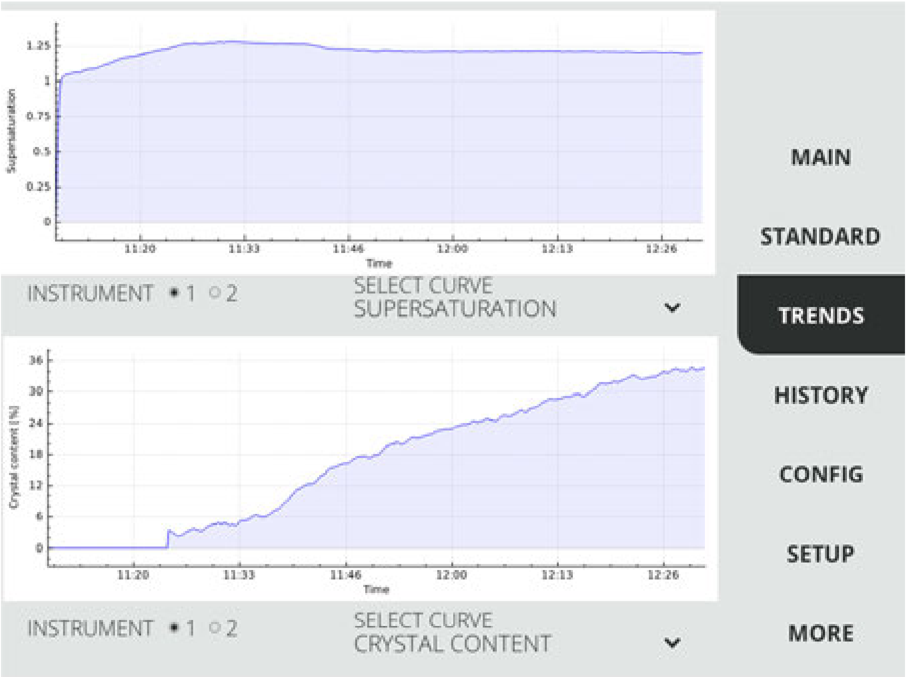


Figure 4.20 Trends display

The following trends can be chosen for Instrument 1 or 2:

- Supersaturation
- Massecuite solids content
- Crystal content
- Mother liquor purity
- Density
- Concentration
- Temperature
- Level
- Mean crystal size

The leftmost point of the graphs represents the moment when the strike started. The rightmost point is the actual time.

4.4.4 History display

When a strike is finished, all measured and calculated data gets stored in the device history. Under *Menu->History* data of the last 100 strikes can be examined.

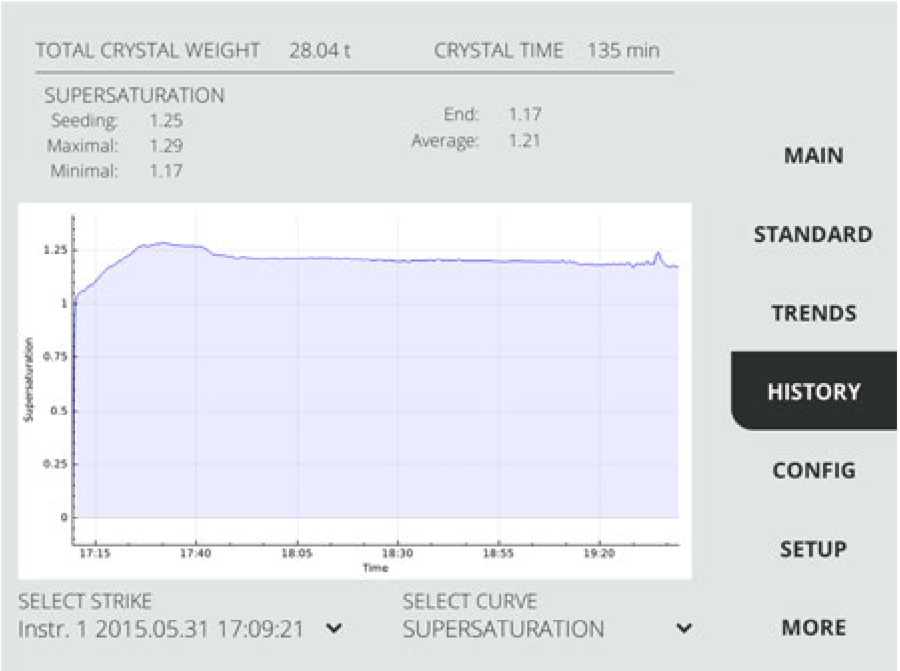


Figure 4.21 History display

Strikes can be selected at the bottom-left corner of the History screen by instrument and start time. At the bottom-right you can select a signal to be shown on the central graph. At the top of the screen total crystal weight, crystal time and some selected supersaturation values are displayed.

5 Technical data and specifications

SeedMaster 3 is based on the use of a high-power 32-bit microprocessor and a high capacity memory operating under a real-time operating system. This, together with the application program of the device, parameters, measured and calculated data are stored in memory. The real-time clock used in the device has its own lithium battery.

In order to increase reliability and to reduce servicing, *no potentiometers* are used in the instrument.

5.1 Main device features

1. On-line calculation, display and transmission of up to 9 massecuite parameters during sugar crystallization for up to 2 pans simultaneously.
2. Automatic seeding of vacuum pans based on calculated supersaturation or density set-point for seeding selected by the local technologist.
3. Collecting all calculated and measured data for the last 100 strikes in strike history archives, which can be displayed as trends with appropriate time data.
4. Advanced communication features including Ethernet.
5. Large LCD touch-screen display, robust design.

5.2 Data available for transmission

Set of massecuite parameters:

1.	Supersaturation	(-)
2.	Massecuite solids contents	(%)
3.	Crystal content	(% by volume)
4.	Mother liquor purity	(%)
5.	Massecuite density	(kg / m^3)
6.	Syrup / mother liquor concentration	(%)
7.	Temperature	(°C)
8.	Level	(%)
9.	Mean crystal size	(mm)

5.3 Inputs for calculation

5.3.1 Process inputs

1. Syrup / mother liquor concentration measured by Vaisala K-PATENTS refractometer(s)
2. Massecuite temperature measured by Vaisala K-PATENTS refractometer(s), or separate transmitter(s).
3. Third party transmitter measuring
   - density, OR
   - massecuite solids content.
4. Optional input: massecuite level (advised).

Digital (ON/OFF) inputs:
(depending on the selected mode of operation)
1. None (digital inputs are sent via Modbus/TCP by the PCS).
2. Maximum 3 (“Strike active”, “Seeded”, ”Change feed syrup”).

Laboratory data
1. Feed syrup purity/purities (%).
2. Syrup quality (“m”, “b”, “c”) parameters. Typical data and a description of a procedure to determine local parameters are provided (see: Appendix A).

NOTE:
All inputs and laboratory data can be also received via Modbus/TCP communication.

5.3.2 Calculated outputs

Analog (4–20 mA) outputs:
Any 2 of the 8 calculated / measured massecuite parameters (per pan).

NOTE:
All calculated and measured data can be also transmitted via Modbus/TCP.

5.3.3 Digital outputs

Digital (ON/OFF) output:
Opening the seeding valve(s) for a selected time interval.

5.4 Specifications

5.4.1 SeedMaster 3

Display and keypad:	10" color touch screen display 1024x768, 4-wire resistive
Power supply:	+24VDC±10%
Electrical classification:	General purpose, ordinary locations
Connections:	1xM12-4pin, D-coded, F(External Ethernet)
	1xM12-8pin, A-coded, F(System)
	1xM12-4pin, A-coded, M(24VDC, (mA))
Input/outputs:	Power, Ethernet (sensor and external)
Dimensions:	H 242mm x W 312mm x D 49mm
Materials:	Aluminum frame
IP classification:	IP 65, Nema 4X
Weight:	5 kg (11 lbs)
Mounting:	Panel mounting: 8pcs M5 screw, VESA 200x100: 4pcs M6 screws

5.4.2 Process I/O Unit

The Process I/O Unit is based on the use of ioLogik E1242 and E1241 type modules manufactured by MOXA Inc., USA.

Module ioLogik E1242 (Moxa)

Analog Inputs:	4 differential input channels
Resolution:	16 bits
Range:	0-10 VDC, 0-20 mA, 4-20 mA
Input impedance:	10M ohms; 120 ohms (current input)
Accuracy:	±0.1 % FSR @ 25 °C
	±0.3 % FSR @ -40…+75 °C
Digital Inputs:	4
Sensor type:	Wet Contact (NPN or PNP), Dry Contact
Wet Contact (DI to COM):	ON: 10 to 30 VDC
	OFF: 0 to 3 VDC
Dry Contact:	ON: short to GND
	OFF: open
Digital Outputs:	4 configurable DI/DO-s
Type:	sink
Overcurrent protection:	2.6 A (4 channels @ 650 mA)
Overvoltage protection:	45 VDC
Current rating:	200 mA per channel
Power consumption:	139 mA @ 24 VDC

Module ioLogik E1241 (Moxa)

Analog Outputs (total)	
Analog current:	4 channels
Resolution:	12 bits
Range:	0-10 VDC, 4-20 mA
Accuracy:	±0.1 % FSR @ 25 °C
	±0.3 % FSR @ -40…+75 °C
Power consumption:	194 mA @ 24 VDC

Common module specifications

Operating temperature:	- 10…+ 60 °C
Isolation:	3 kVDC or 2 kVrms
Communication:	2 switched 10/100 Mbps RJ45 ports
Protocols:	Modbus/TCP, TCP/IP, UDP…
Dimensions:	27.8x124x84 mm (1.09x4,88x3.30 in)
Mounting:	DIN rail or wall

Ethernet switch EDS-205A (Moxa)

Ports:	5 ports (unmanaged)
Dimensions:	30x115x70 mm; (1.2x4.5x2.8 in)
Power:	12 / 24 / 48 VDC (redundant)
Consumption:	0.1 A @ 24 V
Operating temperature:	- 10…+60 °C
Overload protection:	1.1 A
Mounting:	DIN rail or wall

Power supply DR-3524 (Moxa)

AC input voltage:	85-264 VAC
AC input current:	1.5 A (115 VAC), 0.75 A (230 VAC)
Output voltage:	24 VDC
Output current:	0 – 2 A
Operating temperature:	- 10…+ 50 °C
Cooling:	Built in EMI filter, free air cooling convection
Protection:	short circuit, overvoltage, overload, over temperature
Dimensions:	78x93x67 mm
Mounting:	Snap on for DIN rail mounting

NOTES:

1. There is no mains switch in the instrument! An external power switch should be used.
2. Check if your mains voltage specification and that of the instrument are identical before first switching on the instrument!
3. For more detailed / updated information on the Process I/O Unit hardware visit *http://www.moxa.com/*.

5.4.3 Interconnecting cables

Interconnecting cable between SM-3 and SM3-IO-UNIT

Cable: PR8430 = Platform 4 cable, M12-8pin, A-code F+M, Ethernet, mA, 24 V
Length: 10 m (33 ft) by default, maximum length 90 m (295 ft)

Interconnecting cable between SM-3 and Moxa ethernet switch / DTR Ethernet connection

Cable: PR-8440 = Ethernet cable for interfaces, M12-4 pin, D-code, M+M
Length: 10 m (33 ft) by default, maximum length 90 m (295 ft)

Power-mA cable

Cable: PR8443-001 = Power-mA cable, M12-4pin, A-code, F, mA, 24V, 1 meter
Cable: PR8443-010 = Power-mA cable, M12-4pin, A-code, F, mA, 24V, 10 meters

5.4.4 Refractometer sensor

Model and description	Model
PR-23 = Sensor	PR-23
Sensor model	
G = General	G
Sensor type	
P = Probe type for tank and large pipeline installation	-P
Refractive Index range limits	
-62 = R.I. 1.320-1.530 n_D (0-100 Brix)	-62
Process connection	
-A = ANSI-flange 150 lbs, 3 inch, insertion length 130 mm	-A
-D = DIN-flange 2656, PN25 DN80, insertion length 130 mm	-D
-J = JIS-flange 10k 80A, insertion length 130 mm	-J
Sensor wetted parts material	
SS = AISI 316 L	SS
Electrical classification	
-GP = General purpose	-GP
Sensor housing	
-AA = Anodized aluminium	-AA
Prism wash	
-WN = Integral wash nozzle	-WN

For example PR-23-GP-62-DSS-GP-AA-WN.

5.4.5 Counter flange adapter for vacuum pan installation

Model and description	Model
Adapter	
AP = Adapter for PR-23-GP	AP
Sensor type	
-A = ANSI-flange 150 lbs, 3 inch, insertion length 130 mm	-A
-D = DIN-flange 2656, PN25 DN80, insertion length 130 mm	-D
-J = JIS-flange 10k 80A, insertion length 130 mm	-J
Material of construction	
SS = AISI 316 L	SS
Process connection	
-W = Welded	-W
Prism wash option	
-NC = Nozzle connection **(A)**	-NC

Includes Counter flange, flange insert, 1 x screw and bolts
(A) Integral nozzle in PR-23-GP

For example: AP-DSS-W-NC

6 Maintenance

6.1 Battery replacement

A small lithium battery keeps time in the SM-3 when it isn't powered. Vaisala recommends that this battery is replaced every five years.

Note: Only instrument timekeeping is affected by the battery. Measurement is not affected.

To replace the battery, you need a Lithium CR2032, 3V battery and a Torx TX20 Screw driver.

1. Place the unit on a table face down.
2. Open the screws in the four corners of the backplate.
3. Carefully move the backplate away from you to expose the battery.
4. Replace the battery. + sign comes on top.
5. Move the backplate back in place. Make sure that all the cables are inside the backplate, then screw it on.
6. Turn on the SM-3, check time and adjust as needed in the instrument settings.

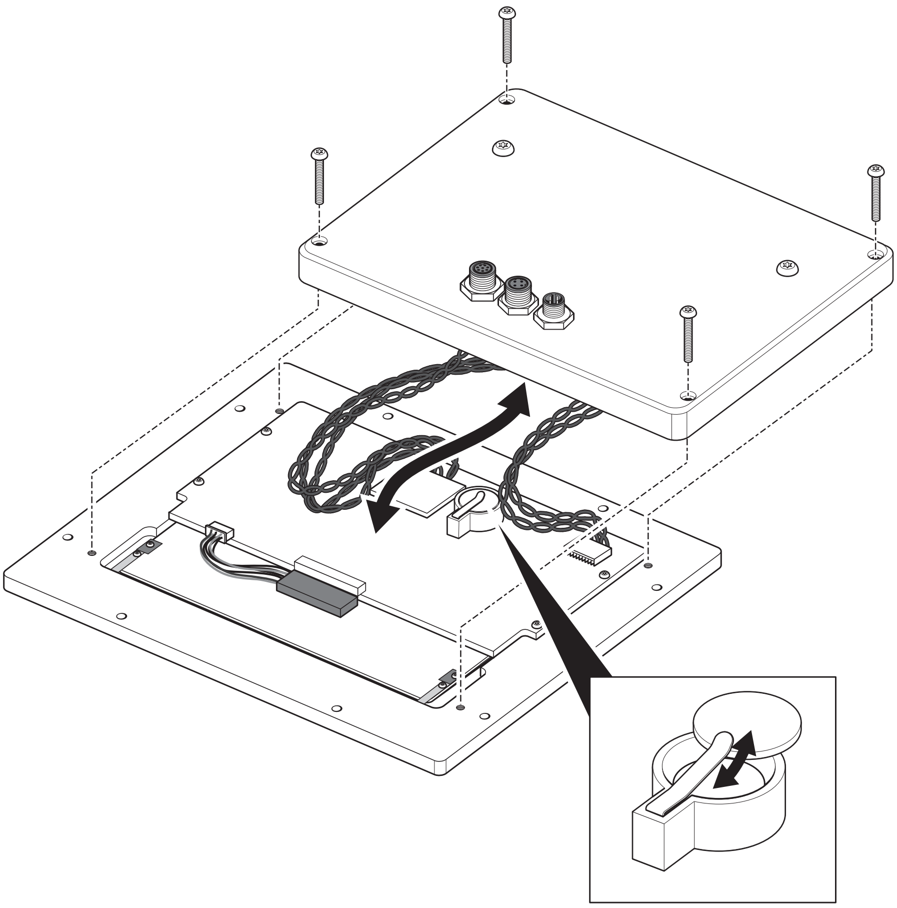


Figure 6.1 Battery replacement

7 Sugar crystallization in brief

7.1 The last step: crystallization

The main steps of sugar manufacturing are:
- sugar extraction (from cane or beet),
- juice purification and concentration, and
- crystallization.

SeedMaster 3 was designed to provide all the vital information required to control the process of sugar crystallization on an unprecedented level. It is therefore logical to concentrate further discussions on the process of crystallization.

Two methods to produce sugar crystals can be distinguished:
- cooling crystallization and
- evaporative crystallization.

Most of the sugar crystallized is produced in evaporative crystallization in batch or lately in continuous evaporative crystallizers, but the basic principles of operation are the same in both types of crystallization methods. Traditionally the vacuum pan operating in batch mode became the major piece of machinery and enjoys wide use all over the world.

Crystallization is a very important part of sugar manufacturing. This is a process which has a large influence on product quality and on the cost of production, both of which are very important when competitiveness is at stake.

During most of its long history the control of sugar crystallization in batch pans was the undisputed authority of the pan-men, who acquired their skill during a large number of years in practice. Working mostly without any real instruments, they used only their eyes and fingers to keep the process under control. No wonder, they still are being regarded as "artisans" of their profession. However, artisans can be quite different, and quite often tend to behave rather unpredictably, which is far from being compatible with the quality- and costconscious requirements of industrial mass production, so representative of our times.

Modern control of crystallization must rely on the reliable on-line measurement of the parameters which are vital in the control of the process performed by a local operator (manual control), or by an advanced automatic process control system (PCS).

7.2 Supersaturation: the driving force of crystallization

It is well known that crystallization can take place only in solutions which contain more solids in solution than required to saturation. In case of sugar solutions the same mass of water can dissolve different amounts of sugar depending on its temperature: the amount of sugar is larger, if temperature is higher. A saturated sugar solution therefore can be supersaturated either by decreasing its temperature (cooling), or by decreasing the mass of water (evaporation).

Supersaturation is defined as the amount of sugar dissolved divided by the amount of sugar required for saturation in the same amount of water at the same temperature. We have real supersaturation only if this ratio is larger than 1.0 (saturation).

Supersaturation is the driving force of crystallization: crystal growth (speed of crystallization) depends very much on this parameter. High supersaturation means faster crystal growth and vice-versa. There is no crystal growth if supersaturation is less than 1.0, in which case instead of growing, already existing crystals begin to dissolve. It is important to emphasize that supersaturation is a complex multivariable function of the liquid phase (mother liquor) parameters and should be calculated taking into account all of its governing parameters:

$$Supersaturation = f(C, P, T, m, b, c) \tag{1}$$

where:

C: syrup / mother liquor concentration (%)
P: syrup / mother liquor purity (%)
T: temperature (°C)
m, b, c: syrup quality parameters (-)

Syrup quality parameters are discussed in detail in Appendix A. It follows from its definition that, among others, concentration of the mother liquor should be measured online, *undisturbed by the presence of crystals* in the massecuite in order to be able to calculate it.

7.3 Seeding methods

Seeding is a very important step in the process of crystallization, which has a large influence on the quality of the product. When completed, the crystals begin to grow in size, if supersaturation is larger than 1,0. Shock seeding is the traditional way of seeding. It relies on the building up of high supersaturation in the solution, when a small amount of seed crystals entered into the pan results in the formation of new crystals (nucleation). The number of these crystals keeps growing as long as the value of supersaturation is above a “safe” (nucleation-free) limit. The final number depends very much

- on the actual value of supersaturation, and
- on the time (time of nucleation) spent in the region of high supersaturation above the “safe” limit.

There are at least 3 important parameters in this method of seeding:

1. The actual value of supersaturation maintained in the “seeding point” and during nucleation.
2. The time length of nucleation.
3. The limit value of supersaturation above which nucleation begins, if there are already crystals in the solution.

Point 1. calls for a reliable measurement of supersaturation.

Point 2. has some difficulties of its own, too. How to determine the correct length of nucleation? The method of trial and error (TAE) can only be used, if supersaturation was the same all over the trials, which again calls for its measurement. Even if it is known, in case of manual control of crystallization is it possible to ensure exactly the same time for nucleation from strike to strike (even during the night shift)?

Point 3. requires the knowledge of the *critical supersaturation*, above which nucleation begins in the presence of already existing (seed) crystals. There are not many reliable data on this limit. A recent publication (see below) provides data depending somewhat on syrup purity and temperature, too (the dependence on temperature is more pronounced with low-purity syrups). In case of high syrup purity (larger than 94 %) this supersaturation limit is about 1.12…1.13. *An important point is that the formation of new (often unwanted) crystals can begin any time when supersaturation exceeds the critical supersaturation limit.*

(This figure is based on the equation published in: *M.Saska: Boiling point elevation of technical sugar cane solutions and its use in automatic pan boiling. International Sugar Journal 2002, VOL. 104., No.1247., 500- 507*).

The next figure shows some of the trends typical of shock seeding. It is evident that shock seeding has quite a few uncertainties and consequences, which make its use in modern practice undesirable.

Full seeding is the advanced mode of seeding. In ideal case there are no new crystals formed during seeding: the full required crystal crop is supplied during seeding in the form of well-prepared *slurry*. It is assumed that *only crystal growth and no nucleation* will take place during

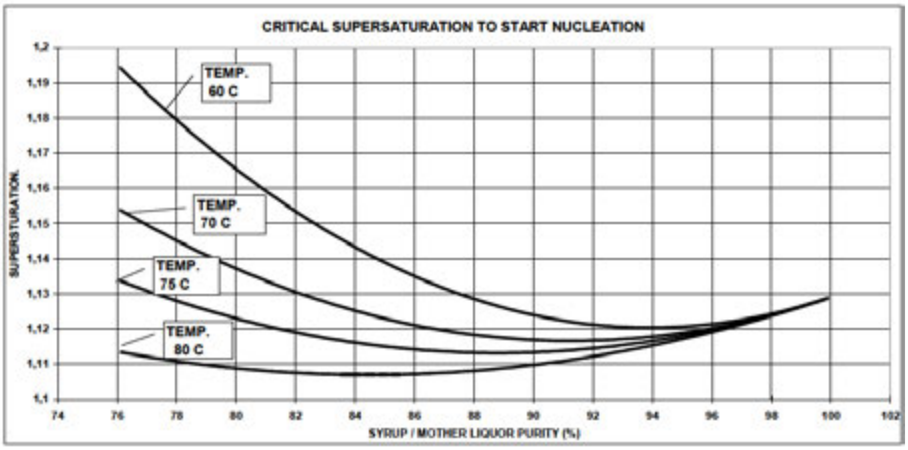


Figure 7.1 Critical supersaturation to start nucleation

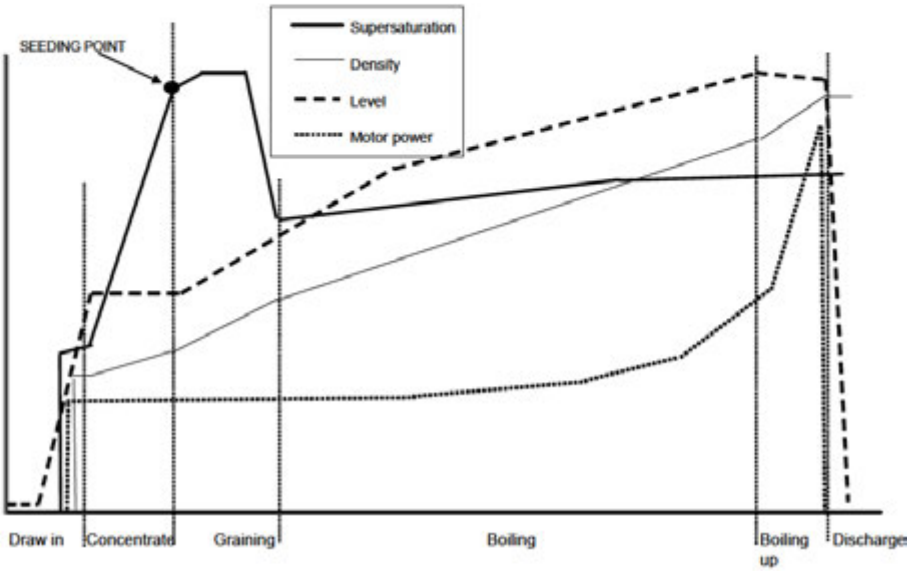


Figure 7.2 Typical shock seeding

the complete length of crystallization (during a strike in batch pans) that is the number of crystals in the end product is in ideal case equal to the one of the seeding material.

Besides using slurry, full seeding can be implemented by using the right amount of crystal footing (magma), too. It follows from the above that in case of full seeding and during the complete crystallization *supersaturation must not exceed its limit value*. This requirement may result in somewhat longer times of crystallization than accustomed, but will result in better sugar quality and less recycled fines and conglomerates.

NOTE:
The use of slurry (or crystal footing) alone is no guarantee for correct full seeding. Besides the right amount of slurry or footing (with the right number of crystals in it) *supersaturation must not exceed its limit value*.

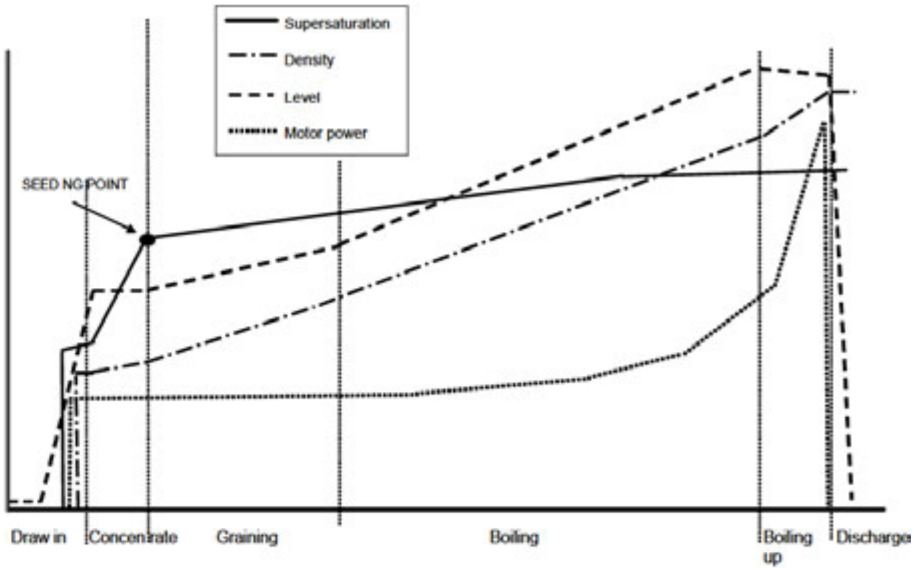


Figure 7.3 Typical full seeding

7.4 Crystal content

Good control of the process of crystallization requires some information on the crystal content of the massecuite, too. The amount of sugar needed to feed the growth of crystals increases as the surface area of the crystal mass increases. Feed syrup is supplied to fill the need.

The control of crystallization in a vacuum pan, for example, should be a coordinated process. Control parameters, like vacuum, heating steam (vapour) pressure or flow, feed syrup flow are connected in a complex way to the massecuite parameters. The actual value of supersaturation depends on quite a few parameters (see Equation 1). From these, concentration depends on the rate of evaporation and syrup feed, while temperature is basically determined by the absolute pressure above the massecuite.

In batch crystallization some indirect measure of crystal content is being used to signal the end of the strike (massecuite brix, density, or stirrer motor power / current consumption).

Product quality and supersaturation

The importance of supersaturation in product quality and cost of production cannot be overstated. Its role in seeding has already been discussed, while Figure 7.4 3 (scale: 1 by 1 mm) proves its effect all over the strike. In this figure a fairly wide crystal size (from 1 mm to perhaps 0,05 mm) distribution can be observed. Most probably there were much smaller size crystals, too, but they had escaped through the screen of the centrifuge only to increase the amount of crystallized and recycled sugar in the green syrup (Figure 7.6). It is evident that the smaller crystals (the "young generation") are due to *spontaneous nucleation in the later phases of the strike*. These crystals therefore did not have time enough to grow to a larger size till the end of the strike (it is assumed that the size of the seed crystals [the "old ones"] was fairly equal).

In Figure 7.5 (scale: 1 by 1 mm) among well-developed crystals quite a few conglomerates (a cluster of mutually intergrown crystals) of different sizes can be observed.

It has been proved that formation of conglomerates mostly happens when the size of the crystals is in the 40 to 250 micron range. *This means that the formation of conglomerates in the early phase of crystallization (not long after seeding) results in large conglomerates at the end of the strike, while smaller conglomerates in the end product are due to unwanted nucleation*

Figure 7.4

Figure 7.5

(because of too high supersaturation) in the later phases of the strike. Bad circulation, probably resulting in high local supersaturation in some parts of the pan also contributes to the formation of conglomerates.

It is quite common nowadays that special products require well defined crystal sizes, which call for a tight crystal size distribution. This can be achieved by good boiling control (including, of course, good control of supersaturation), or by screening of the product, if it has a wide size distribution. This later method, however, requires additional machinery, time and energy, results in lower product yield and naturally increases the cost of production.

Besides wide crystal size distribution conglomerate content also contributes to poor product quality. It is well known that the color of the product has strong correlation with conglomerate content, because intergrown crystals are more likely to retain some of the mother liquor during centrifuging. If conglomerate content is high, product color can only be improved with the excessive use of water in the centrifuges, which will result – because of dissolution - in considerable loss of the crystal mass.

7.5 Cost of production and the major parameters

It has been demonstrated that wide crystal size distribution and conglomerates of varying sizes in the end product are due to excessive supersaturation, which, if not controlled properly, can be present during the complete course of crystallization (Figures 7.4 and 7.5). This proves that *statements on the decreasing importance of supersaturation after seeding has been completed are totally unfounded and false*. Conglomerate and fines contents have very important effect on the cost of production. Too high fines content makes centrifuging difficult and results in considerable loss of already crystallized sugar through the screen baskets of the centrifuges. It is difficult to determine the amount of this loss and quite often it is neglected. It should be realized, that *the number of strikes per shift, often used in practice, is not a correct measure of the rate of production*. Fines and conglomerates result in recycled sugar only to be melted, concentrated and crystallized again, the end result of which is

- waste of time and energy,
- decreased effective yield of product sugar per strike and shift,
- increased use of water and
- increased cost of production.

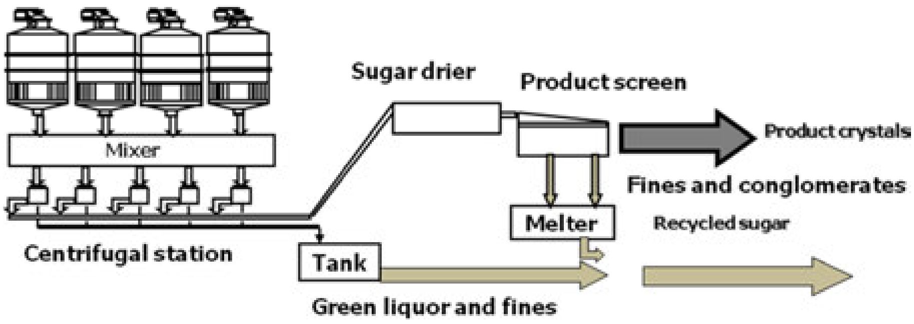


Figure 7.6

It is well known that the speed of crystallization is higher if supersaturation is higher, that is the rate of production increases with increasing supersaturation. It is therefore tempting to push production by maintaining high supersaturation, but exceeding the safe limit, where spontaneous nucleation begins and the risk of conglomeration increases is accompanied with the unpleasant consequences discussed above. *Selecting the correct supersaturation set point trajectory for a strike is therefore a kind of compromise (or optimization). However, any type of supersaturation control is unconceivable without the correct on-line measurement of supersaturation.*

7.6 Common instruments in use for crystallization control

There are two major types of data needed for good control of crystallization:

1. supersaturation, and
2. information related to crystal content.

The basic requirements concerning the sources of these data are: <u>*accuracy:*</u>

supersaturation : fairly high,
crystal content : modest;

<u>*in - and on-line instruments:*</u>

should provide reliable data in real time during the full course of crystallization;

<u>*long-term stability:*</u>

it is a basic requirement.

Besides instruments providing data on vacuum, massecuite temperature, level and vapor pressure or flow in the calandria, common instruments in use for boiling control measure

- electrical parameters of the massecuite (conductivity, conductivity and capacitance RF sensors),
- viscosity / consistency,
- stirrer motor consumption,
- density / solids content (nuclear),
- density / solids content (microwave),
- boiling point rise and
- refractive index.

None of these instruments provide reliable and quantitative data neither on supersaturation, nor on crystal content, the real massecuite parameters that matter.

Conductivity is due to the presence of different types of ions in the syrup or mother liquor. It depends on several parameters like concentration, composition and amount of non-sugars present, crystal content and temperature. It certainly has (through syrup / mother liquor concentration) some correlation with supersaturation (see Eq. 1), but due to changes in other parameters governing it, *it is far from being able to provide reliable information on supersaturation*.

Capacitance (RF sensors) depends mostly on the water content of syrup / mother liquor in a unit volume of massecuite, therefore, besides concentration *it shows strong dependence on crystal content*.

Viscosity of the syrup / mother liquor depends on their concentration and temperature.
Consistency is the property of the liquid / solids (mother liquor / crystals) mixture. Viscosity / consistency are measured in crystallization control practice by the same instrument. Consistency, however, *sharply increases with increasing crystal content*. At the end of a strike consistency can be 20-30 times larger than the viscosity of the mother liquor alone.

Stirrer motor current or power consumption provide data on viscosity / consistency in a different form.

Density of the massecuite comes from two sources: density of the mother liquor and that of the solid crystals. Besides these the crystal to mother liquor ratio in the massecuite will determine its value.

Solids content of the massecuite is similarly determined by the solids content of the mother liquor, that of the crystals and by the crystal to mother liquor ratio.

The common features of all instrument types discussed above are:

1. None of them is able to provide selective and accurate enough information on mother liquor concentration in the presence of crystals; therefore they are unfit to give even approximate, indirect information on supersaturation all over a strike (see Eq. 1).

2. Having completed seeding all instruments discussed above provides data which are more and more governed by the increasing crystal content. It is logical therefore that these instruments can be put to good use only to provide – though indirect and only approximate - information on crystal content.

There are only two principles of measurement which can be used to measure syrup concentration selectively even in the presence of sugar crystals.

Boiling point rise of a solution depends – among others – on its concentration, therefore it is correlated to supersaturation. Supersaturation, however, is a multivariable function of several parameters. On the other hand: boiling point rise depends on syrup / mother liquor purity and non-sugar composition, too. Boiling point rise is small (a few degrees Celsius) and therefore requires very accurate measurement. Due to these problems its use in the determination of supersaturation with the required accuracy and stability is very questionable.

Refractive index **of a solution has very strong and well-known correlation to its concentration. The principle of measurement is in use all over the world since over one and a half century in**

laboratory, and nowadays in process refractometer types, too. The data provided meet the requirements stated earlier regarding its use in the calculation of supersaturation.

Summing up:

1. Supersaturation is the most important parameter of crystallization.
2. Supersaturation is a multivariable function of several syrup / mother liquor parameters (see Eq. 1).
3. Common instruments in use measure only a single parameter of the syrup or massecuite, therefore they are unable to provide real quantitative data on supersaturation.
4. Supersaturation can only be calculated on-line by taking into account all of the parameters that govern it. It is therefore logical that reliable and accurate on-line data on syrup / mother liquor concentration are required. *The only way to get them is by the use of a reliable process refractometer.*
5. Information on supersaturation and on crystal content (even in indirect form) is required for advanced boiling control.

A Procedure to evaluate the "m", "b" and "c" coefficients of the wiklund-vavrinecz saturation function

Introducing the solubility coefficient

By analyzing a large amount of data on sugar solubility in beet sugar molasses collected by different researchers, Wiklund and Vavrinecz developed an equation (saturation function) for the calculation of the *solubility (or saturation) coefficient*.

The solubility coefficient is defined by the ratio

$$C = \frac{Z'}{Z}$$

where:

Z': sugar in solution in the impure sugar solution at saturation, g / 100 g water.
Z: sugar in solution at saturation in the pure sugar solution at the same temperature, g /100 g water

The solubility coefficient can be calculated by the saturation function as

$$Fsat = C = \frac{m.NS}{W} + b + (1-b)^{\frac{C.NS}{W}}$$

where:

NS/W: non-sugar to water ration m,b,c: syrup quality parameters to be determined by the local laboratory

NOTE:
The syrup quality parameters depend only on the composition of the non-sugars. They do not depend on the temperature or on the amount of non-sugars.

Solubility coefficient versus nonsugar to water (N/W) ratio

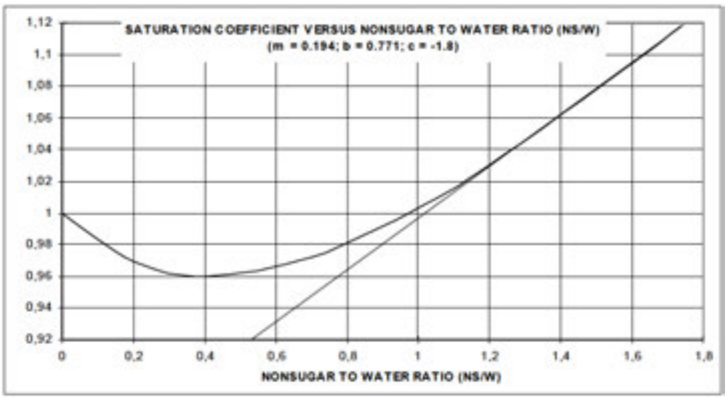


Figure A.1

Figure A.1 shows the saturation function with parameters typical for beet sugar molasses.

It can be seen (and proved, too), that above some $\frac{NS}{W}$ ratio (in this case about 1.2) the function can be represented by a straight line with a slope equal to "m". Below this $\frac{NS}{W}$ value the function is more and more represented by the exponential part.

One of the several possible ways to determine the local syrup quality parameters in the laboratory is described below.

Determining the local syrup parameters

Sample preparation for the saturation test

A) Take 7-10 samples 100 g each from the same low-purity final molasses (green syrup) and determine concentration, sugar content and purity data in the lab. Calculate non-sugar and water content, too. Put the samples in vessels which can be well sealed later on in order to prevent evaporation or leakage.

Example:

ORIGINAL SAMPLES:

	SOL (g)	S (g)	Q (%)	NS (g)	W (g)	Gsample (g)
1	83,22	51,37	61,73	31,85	16,78	100,00
2	83,22	51,37	61,73	31,85	16,78	100,00
3	83,22	51,37	61,73	31,85	16,78	100,00
4	83,22	51,37	61,73	31,85	16,78	100,00
5	83,22	51,37	61,73	31,85	16,78	100,00
6	83,22	51,37	61,73	31,85	16,78	100,00
7	83,22	51,37	61,73	31,85	16,78	100,00

where:

SOL	(%,g):	solids content (concentration)
S	(%,g):	sugar content
Q	(%):	purity = $\frac{100S}{SOL}$
NS	(g):	non-sugar content = $SOL - S$
W	(g):	water content = $Gsample - SOL$

B) Calculate the non-sugar to water ratio (NS/W) and enter it for sample No.1, which from now on will represent the original sample with its original NS/W ratio. Select $(NS/W)*$ values which will result in well distributed data in the complete range from $(NS/W)* = 0$ to the original one.

Using the selected $(NS/W)*$ and the original water content W calculate new water content $(W*)$ and water to add $(Wadd)$ data for samples No.2-No.7.

NOTE:
when $(NS/W) = 0$, the saturation coefficient is always equal to 1.0.*

$$\frac{NS}{W} = \frac{SOL.(100 - Q)}{100.(100 - SOL)}$$

$$W* = \frac{NS}{(NS/W)}(g)$$

$$Wadd = W * -W(g)$$

Example (continued):

	Selected range: (NS/W)*	Calculated water: W* (g)	Wadd (g)
1	1,90	16,78	0,00
2	1,6	19,91	3,13
3	1,2	26,54	9,76
4	1	31,85	15,07
5	0,7	45,50	28,72
6	0,4	19,63	62,85
7	0,2	159,25	142,47
8	0		

Add the listed amount (Wadd) of pure water to each sample. Sample preparation is now complete.

Saturation test

A) Use increasing amounts of icing sugar and during continuous mixing add them to the samples. The weight of sugar to add should be a little more than enough to saturate the sample. Having added the sugar, close the sample containers carefully and put them in a common temperature controlled bath, where they should be kept at constant temperature and well mixed for several hours.
Select the temperature of the bath to equal for example 60 °C. The actual value is not critical, it can be in the 40- 70 °C range, but it should be kept constant by a temperature controller at its set-point.

B) Saturation of the samples with sugar needs good mixing and even so may take several hours. It can be regarded as complete when the change in the concentration of the sample liquid becomes negligible.

Evaluation

A) When the saturation test is complete, remove undissolved crystal sugar from the samples and determine concentration, sugar content and purity data for each sample in the laboratory. Calculate the S/W (sugar to water) ratio for each sample and by using the pure sugar solubility data valid for the selected sample temperature calculate the solubility coefficient for the samples.

$$\frac{S}{W} = \frac{SOL.Q}{(100 - SOL)}(\frac{g\ sugar}{100\ g\ water})$$

Use look-up tables (collected by Grut, or Wavrinecz) to get data valid for pure sugar solubility at the selected saturation temperature. For completeness some of these data are presented here:

Sugar solubility data (g/100 g water) for pure solutions according to Grut and Vavrinecz:

Temperature (C)	Grut (SG)	Wavrinecz (SV)
50	262.0	258.63
55	277.0	272.81
60	293.0	288.56
65	311.0	305.96
70	331.0	325.15

$$SAT.COEFF = \frac{S/W}{SV}$$

or

$$SAT.COEFF = \frac{S/W}{SG}$$

Example (continued): (In this example SV is being used.)

	MEASURED AND CALCULATED DATA AT SATURATION				
	SOL (%)	S (%)	Q (%)	S/W	SAT. COEFF.
1	83,71	54,00	64,51	331,49	1,149
2	82,50	54,70	66,30	312,57	1,083
3	80,50	57,46	71,38	294,67	1,021
4	79,30	59,20	74,65	285,99	0,991
5	77,90	62,20	79,85	281,45	0,975
6	76,20	66,30	87,01	278,57	0,965
7	75,10	70,10	93,34	281,53	0,976
8					1,000

B) Calculate the final non-sugar to water ratios $(NS/W)**$ of the samples based on the laboratory data, then draw the Saturation Coefficient versus $(NS/W)*^{*})$ chart using Excel.

Example (continued):

	$(NS/W)^{**}$	SAT.COEFF
1	1,824	1,149
2	1,589	1,083
3	1,182	1,021
4	0,971	0,991
5	0,710	0,975
6	0,416	0,965
7	0,201	0,976
8	0	1,000

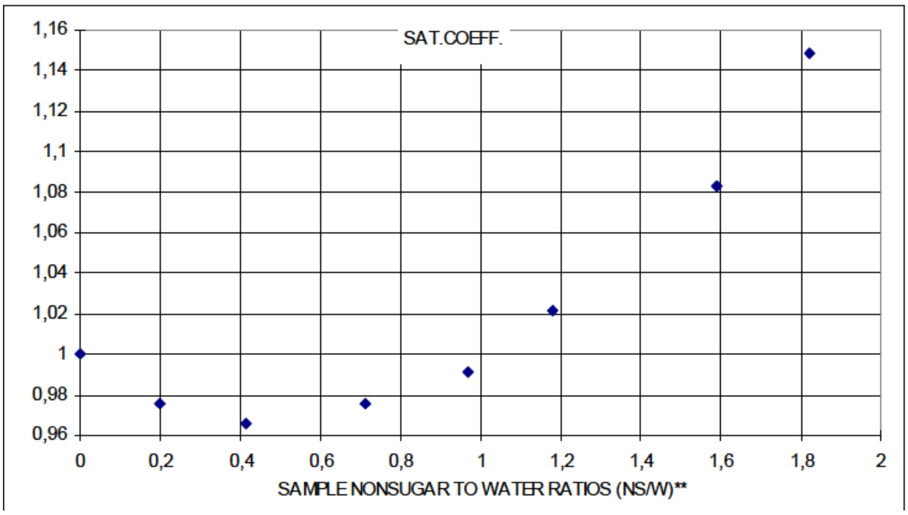


Figure A.2

It can be seen in Figure A.2 that the linear part of the chart starts at about $(NS/W)** = 1.2$. This belongs to sample numbers 1, 2 and 3. Separate these date on another chart and do the linear least square calculation in Excel (Figure A.3):

Now we already have the *"m"* and *"b"* parameters:

$$m = 0.194$$
$$b = 0.788$$

Let us continue with the part of the chart valid for lower non-sugar to water ratios (sample numbers 4, 5, 6, 7). Calculate

$$SAT.COEFF - m.(NS/W) ** - b$$

data for these samples and do again a least squares fit in Excel for these data using 1-b as Y axis intercept:

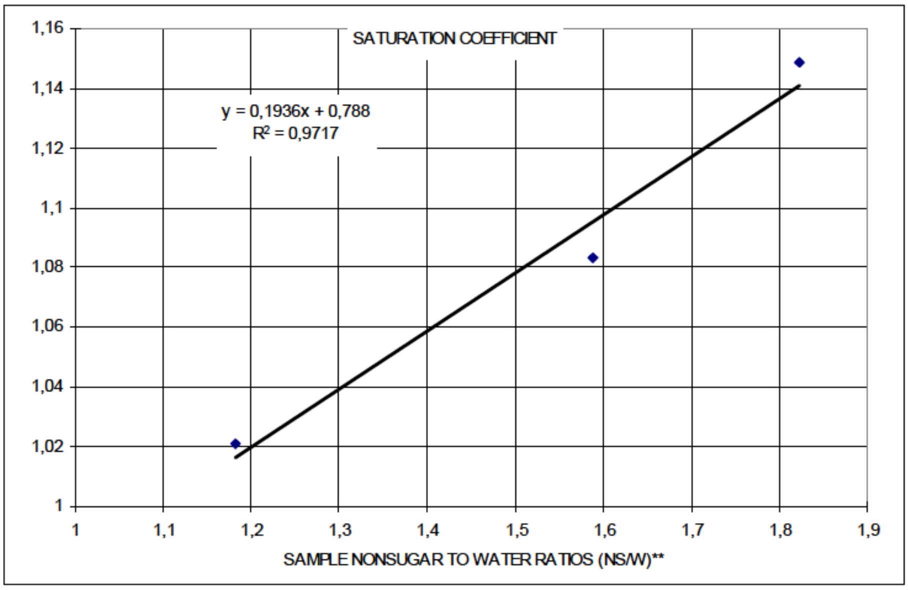


Figure A.3

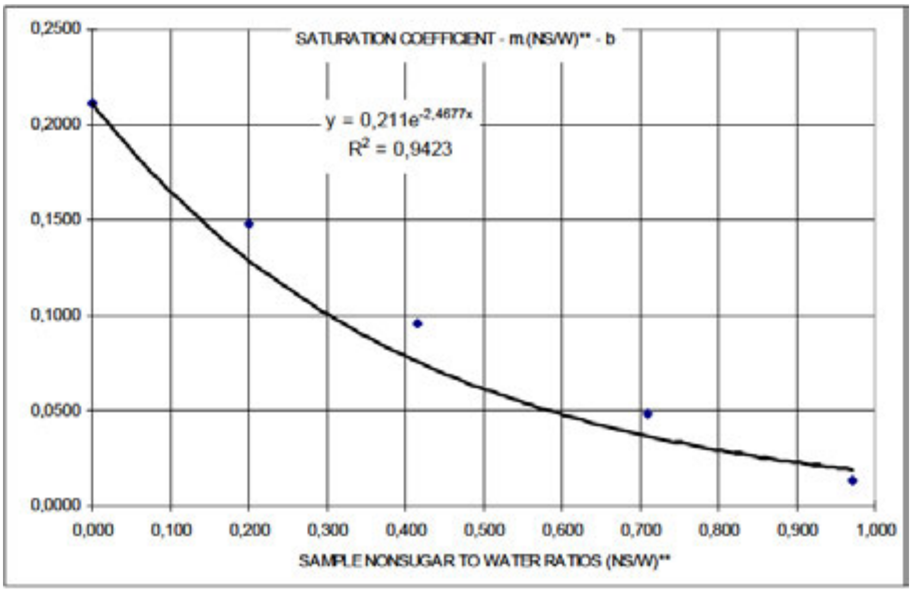


Figure A.4

	(NS/W)**	SAT.COEFF.	S.C.-m.(N/W)**-b
1	1,824	1,150	
2	1,589	1,085	
3	1,182	1,022	
4	0,971	0,992	0,0150
5	0,710	0,977	0,0498
6	0,416	0,967	0,0969
7	0,201	0,977	0,1489
8	0,000	1,000	0,2110

Now we have completed the task by finding from the data fit:

$$c = -2.47$$

The complete set of parameters is:

$$m = 0.194$$
$$b = 0.788$$
$$c = -2.47$$

Figure A.5 shows the sample data on the saturation coefficient and the value of the saturation function using the above set of quality parameters.

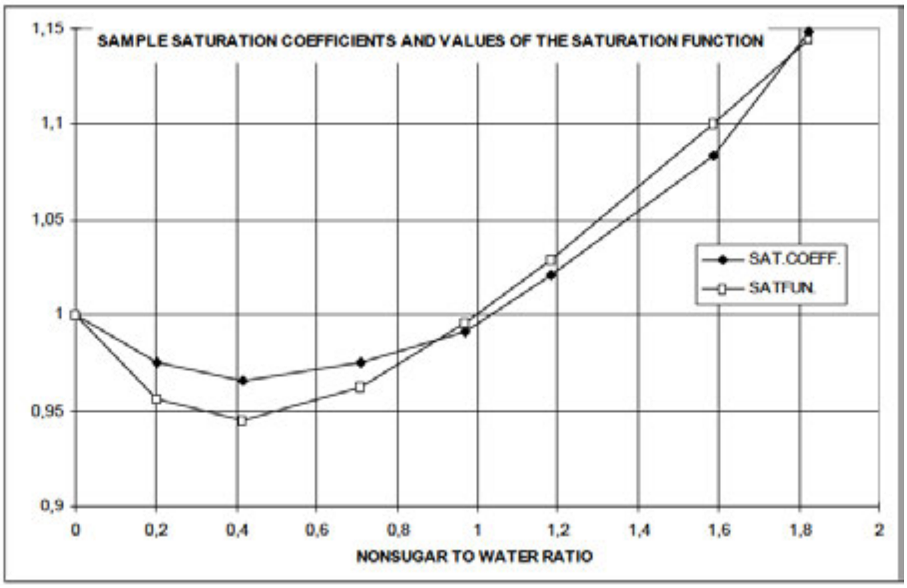


Figure A.5

NOTES:

1. The Wiklund-Vavrinecz saturation function is the result of extensive research on sugar solubility in beet sugar molasses. Unfortunately, there are very few similar data on cane sugar molasses. However, there seems to be no reason why the basic equation could not be used with cane sugar molasses. Some of the scarce data available indicates that the "m", "b" and "c" parameters can differ significantly from those valid for beet sugar. The result of these differences is more pronounced with low purity syrups. Based on data collected by Thieme on cane syrups the parameters have been determined (L.Rózsa: Sucrose solubility in impure cane sugar solutions, INTERNATIONAL SUGAR JOURNAL, 2000, VOL. 102, 230-235):

$$m = -0,06256$$
$$b = 0,982$$
$$c = -2,1$$

2. It is important to do the saturation test starting with low purity (C product) sample ("original sample"), in order to get fairly accurate linear equation on the linear part of the function. Accuracy can be improved by using more samples, too.

3. The first (exponential) part of the saturation function can quite often be well represented by a constant "c" usually equal to -2.1, or -1.8.

4. How often should the syrup quality parameters be determined depends on several factors, like type of the sugar beet or cane processed, fertilizer being used by the farmers, storage temperature etc. and has to be determined based on local experience.

B Modbus communication

Measured and calculated data, parameters and digital (ON/OFF) data can be transmitted in both directions between SeedMaster 3 and a computer, or a DCS.

Communication is based on the use of the MODBUS/TCP protocol. This is a client/server type communication among devices connected in an Ethernet TCP/IP network.

TCP:502 port is reserved for the communication. Playing the role of a MODBUS server SeedMaster 3 is waiting for requests from clients. Data to be transmitted are stored in register tables in the server. The MODBUS client asks for the transmission of these data. The communication structure is of the request/answer type, that is the client asks for data from the server, which responds by sending them.

For further information regarding MODBUS see the official descriptions.

In SeedMaster 3 two function codes are supported:
Read registers (Function code 3)
Write registers (Function code 16)

All MODBUS registers of SeedMaster 3 are 2 bytes long. All values are 4 byte floats. This means that each value takes 2 registers.

Values are transmitted in reverse word order. An example:

User wants to send concentration value 85.43% to instrument 1. Register address is 266 (decimal).
85.43 in floating point format (IEEE754 Single precision 32-bit): 42 AA DC 29 (hexadecimal).
These 2 words will be switched: DC 29 42 AA.
The function code for writing registers is 16, which is 0x10 in hexadecimal.
The request will look like: 25 00 00 00 00 0B 15 10 01 0A 00 02 04 DC 29 42 AA
The following 2 bytes (bytes 4-5) give the request length (number of bytes following). In our example 11 bytes will follow these 2 so they will be 00 0B.
The next byte (byte 6) is device ID, SeedMaster 3 does not care about it, this will be echoed. Here it is 0x15.
Byte 7 is function code, which is 16 in decimal, and 0x10 in hexadecimal.
Bytes 8-9 are first register base address. For register 266 the hexadecimal value is 01 0A.
Bytes 10-11 hold the number of registers to be written, here 00 02.
Byte 12 shows the number of data bytes. Here it is 04.
At the end comes the data on 4 bytes, reversed word order.

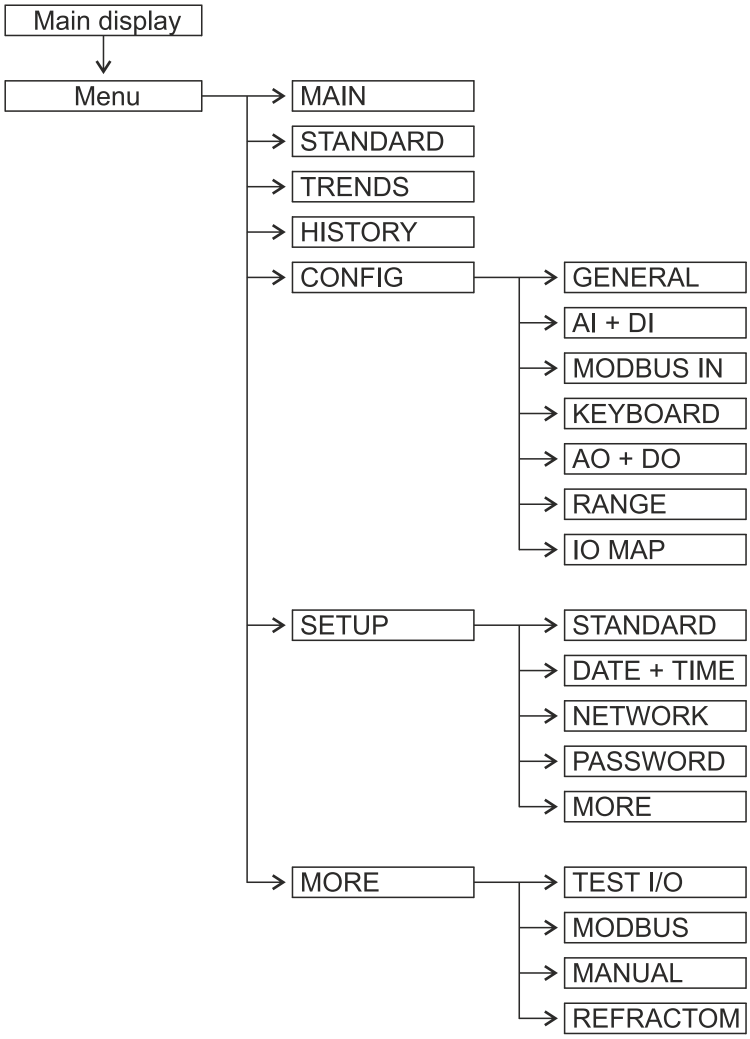
Please note that SeedMaster 3 performs its calculations once in every 10 seconds. There is no need for updating MODBUS registers faster than that. Too frequent MODBUS requests (e.g. 50 requests/second) can however lead to communication errors.

The following registers are used in SeedMaster 3:

	INSTRUMENT 1		INSTRUMENT 2	
	RO	RW	RO	RW
STRIKE ACTIVE		200		600
SEEDING		202		602
SYRUP M		212		612
SYRUP B		214		614
SYRUP C		216		616
SEED CRYSTAL SIZE		218		618
PRODUCT CRYSTAL SIZE		220		620
CRYSTAL CONTENT STRIKE END		222		622
LENGTH OF CRYSTAL TIME		224		624
MINIMAL LEVEL		226		626
MAXIMAL LEVEL		228		628
LEVEL L1.		230		630
LEVEL L2.		232		632
PURITY NO. 1.		234		634
PURITY NO. 2.		236		636
PURITY NO. 3.		238		638
TYPE OF SEEDING SETPOINT		240		640
SETPOINT SEEDING SUPERSATURATION		242		642
SETPOINT SEEDING DENSITY		244		644
CONCENTRATION	66	266	466	666
TEMPERATURE	68	268	468	668
MASSECUITE DENSITY	70	270	470	670
MASSECUITE SOLIDS CONTENT	72	272	472	672
LEVEL	74	274	474	674
SUPERSATURATION	92		492	
CRYSTAL CONTENT	96		496	
MOTHER LIQUOR PURITY	98		498	
MEAN CRYSTAL SIZE	100		500	

Strike active and seeding: send float 0 for false and float 1 for true values.

C Command selection tree



VAISALA