NIR Moisture Meter

HK8

Operating Manual

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Content

1. Introduction into NIR-technology

History

In 1800 the English man William Herschel discovered the infra red region of the light, by accident. He tried to measure, what each spectral colour of the sun light contributes in heating a body exposed to sun light. He used a glass prism to produce a spectra, while he used a thermometer to measure the temperature for each colour. The sum of all temperature increases however was much lower than the temperature caused by the entire sun light.

By accident the thermometer moved outside the spectra, just next to the red band. Suddenly he saw a dramatically increase in temperature. He postulated, that there exists an invisible band of light beyond red. He called this band beyond red = latin infra red. This band starts at 700nm. The band up to 2500nm is called the near infra red band = NIR band.

Until end of the 1960s all IR measurements have been made in the band above 2800nm, because the fundamental bands of the organic compounds occur at 2800nm to 50000nm. The NIR band consists only of overtone bands and combination bands. End of the 1960s, however the potential of NIR measurements for agriculture products was discovered.

NIR instruments

In general a NIR instrument works as follows:

- The product is illuminated with a white lamp (i.e. the complete spectra of light is available).
- The product absorbs, depending on the chemical composition of the product, parts of the spectra.
- The light which is reflected by the product (when measuring in reflection), or the light which is transmitted through the product (when measuring in transmission) is filtered or divided into a spectra.
- The amplitude of the received light is measured and compared to a reference.
- From it a quantitative analysis of the chemical compounds of the product could be made.

Until a few years ago the main technologies for NIR instruments were filter instruments or spectrometers where the spectrum of the received light is produced by a moving diffraction grating.

A filter instrument needs for each constituent to be measured at least one optical filter to be installed in the instrument. This should be an optical filter narrow banded around the spectral line of the constituent. While measuring, these filters have to be moved into the received/transmitted light beam. This usually is done by a filter wheel. This is a relatively complex mechanic, as well as it needs maintenance.

The HK8

Notation convention: In the whole manual we use the term DIGITAL LIGHT UNIT DLU when we refer to the digital number which represents the absorption at a given wave length in the spectra.

The HK8 is a NIR moisture meter measuring at four specific wavelengths in the range of 900nm to 1900nm. The system is divided into an evaluation unit and into a sensor unit. Sensor and evaluation unit are interconnected by a standard 6 wire cable, which could be up to 50m in length. Both sensor and evaluation unit have a weight of only 2,5kg, which makes it easy to handle the system.

The HK8 has a unique new sensor design. The illumination light is produced by LED's at specific wavelengths. This has several advantages over the conventional filter instruments:

1. Very low power consumption
2. Up to 10 years live time of the illumination
3. No moving parts
4. Maintenance free

Simplified basics of spectral analysis

The goal of spectral analysis is to calculate, out of the measured spectra, the amount (concentration) of the unknown constituents of interest in a sample. As with all quantitative analysis it is assumed, that the measuring values (the spectra) are some how related to the concentration of the constituents of interest in the sample. The job is to create a calibration equation, which when applied to unknown data, can predict the concentration of the constituents of interest. This calibration equation is also called the calibration model.

One measure a set of spectra with know concentrations of the constituents of interest. The calibration model is applied to this spectra and delivers (hopefully) a set of constants which allows the prediction of the constituents of interest in an unknown spectra. With other words: The calibration procedure delivers a set of constants for the calibration equation, which when applied to an unknown spectra allows the calculation of the concentration of the constituents of interest.

The basic equation for calibrating a spectrometer is the Beer-Lambert-Law:

$A(l) = E(l) * D * C$

A(l): Absorption at wave length l
E(l): Absorption coefficient at wave length l
D: Measuring path
C: Concentration

This law shows a simple linear relationship between the absorption and the concentration of a constituent at a given wave length. In other words: When moving a sample into the beam of a

spectrometer, there is direct and linear relationship between the concentration of the constituents and the absorbed light.

2. User interface

The instrument is operated by menus. These menus can be accessed and operated by push buttons at the front panel of the instrument. The keys <SK1>, <SK2> and <SK3> have different functions depending on the actual menu.

2.1 Keyboard

<SK1>:
- Brach to sub-meues
- Entering numbers
- Viewing of options at certain entries

<SK2>:
- Branch to sub-meues
- Movement of cursor while entering numbers
- Brach back to main menu

<SK3>:
- Next option in dialouge

<Enter>:
- Confirmation of inputs
- Deletion of error messages
- In input fields with more than 1 parameters, selection of the next parameter

<Clear>:
- Clearance of new input and return to last known value

<Run>:
- Start and stop of measurement

The buttons <SK1>, <SK2> und <SK3> are located under the display. They are counted from the left to the right.

2.2 Dialogue structure

The dialogue is structured in sub-menus with the the following items. These sub-menus can be accesd from the main-menu.

Main menu

The main menu has the following sub-menus:

Measurement, Measurement Parameters, Calibration, General, System, (Height)

- **Measurement**
  - : Measured moisture, averaged with the time constant

- **Measurement parameters**
  - **Time constant**: Time constant for process value averaging. Range 0 to 999s
  - **Current out #1 0/4mA**: Constituent #1 at 0/4 mA. Range 0 to 10000
  - **Current out #1 20mA**: Constituent #1 at 20 mA. Range 0 to 10000. This two inputs define the constituent #1 output span.
  - **Current out #2 0/4mA**: Constituent #2 at 0/4 mA. Range 0 to 10000
  - **Current out #2 20mA**: Constituent #2 at 20 mA. Range 0 to 10000. These two inputs define the constituent #2 output span.

  When the relay function to detect minimum or maximum threshold is selected, the submenu additionally displays:

  - **Threshold**: Process value at which the relay switches. Range: 0 – 10000
  - **Hysteresis**: Hysteresis used for MIN/MAX. Range: 0 – 100

- **Calibration**

  . Data
  - **A0/A1**: Option to enter coefficients for a linear correction of an existing calibration model formed by B0 to B4.
  - **Standardisation**: Option to define the raw data standardisation. Range T / 1. Derivative / Special
  - **B- 0**: Displays the calibration coefficients, calculated and transferred to the instrument by SPECTER8.

- **General**
  - **Lock keyboard**: Entering of a password to lock the keyboard. Range 0 to 999999.
  - **Unlock keyboard**: Entering of the password to unlock the keyboard. Range 0 to 999999.
  - **Language**: Selection of dialogue language. German / English / French / Czechoslovak
  - **Date**: Actual date and time setting
  - **Relay Function**: Definition of the relay functions: ERROR, MIN-THRESHOLD, MAX-THRESHOLD

- **System**

. User

- **COM2 Baud rate**: Baud rate for data transfer 19200, 38400 Baud
- **Print cycle**: Option to activate on COM2 a periodic data transfer of the measurement results. Range: OFF, 1s, 10s, 30s, 60s.
- **Average after HALT**: Option to define how the measuring value averaging should continue after a HALT condition. Options: Continue / Reset

. Current

- **Current Output**: Selection if current output if signal is 0-20mA or 4-20mA.
- **Test current**: Test value for curent output 1 and 2 Range 1-21. Where 1 equals to 0mA and 21 equals to 20mA
- **Output current during HALT**: Option to define the current output value during HALT. Options: Stay at last value before halted, 0mA, 4mA or 20mA.

. Protected

- **Password**: Option to enter the required password to access this menue.
- **Integration Time**: Input to select the light integration time. Range 12,5ms – 625ms.
- **MIN F1 F2**: Minimum of 1.wavelength and 2. wavelength
- **MIN F3 F4**: Minimum of 3.wavelength and 4. wavelength
- **Measurement Mode**: Option to select either continuous measurement or batch measurement
- **Reference Measurement**: Option to execute a reference measurement, to overwrite the factory set reference
- **Reference**: Display of the actual reference spectra.
- **Height Measurement**: Option to activate a product height measurement.

. Factory

- The factory menu is not accessible

. Height (Option)

- **Input Range**: Option to define the 0/4-20mA input span of an optional height measurement. Range 0 to 999999.
- **H-Act**: Display of the actual measured product height
- **H-Start**: Option to enter a height threshold to start and stop the measurement. If H<H-Start the measurement is halted.

2.3 Entering numbers

The instrument has no option to directly enter numbers. The entering of necessary numbers is done with the soft keys. When numbers can be entered the following is displayed:

SCROLL CURSOR NEXT

With the following functions:

SROLL: increment digit
CURSOR: move cursor
NEXT: next menu entry

The cursor (underscore) indicates the digit, which can be changed. With SCROLL the right value for the selected digit can be entered. After this the next digit can be selected by pressing CURSOR. This should be repeated until the total number has been entered. To make data entering easier the actual, by the cursor marked, digit is blinking. Confirmation of the complete number has must be done by pressing <Enter>.

Example: Lock keyboard by entering 268 as password

Display: LOCK KEYBOARD: _
SCROLL CURSOR NEXT

The cursor points to the last digit. With SCROLL the number 8 should be entered and after this, the next digit should be selected by pressing CURSOR.

Display: LOCK KEYBOARD: _8
SCROLL CURSOR NEXT

Now use SCROLL to enter 6 and and after this use CURSOR to move the curesor one position to the left.

Display: LOCK KEYBOARD: _68
SCROLL CURSOR NEXT

Use SCROLL to enter 2.

Display: LOCK KEYBOARD: _268
SCROLL CURSOR NEXT

Now the total number is entered. To confirm press <Enter>. The display stops blinking, use NEXT to move to the next menu entry.

2.4 Error messages

If the instrument discoveres an error, it display an error message. To delete an error message press <Enter>. The following error messages could appear:

ILLEGAL PASSWORD! PLEASE CORRECT!	Illegal password
VADLUE OUT OF RANGE!	Entered value out of range
ILLEGAL INPUT!	Illegal input (e.g. 2 decimal points entered)
LED(s) broken!	Illumination LED's are broken
NO SENSOR DATA! PLEASE CHECK SENSOR!	No communication with sensor.

3. Basic parameter settings

The following installation steps are recommended:

- Set instrument configuration
- Enter measurement parameters
- Calibration
- Start measurement

3.1 Setting of system configuration

3.1.1 Language

Select the sub-menu 'GENERAL' in the main menu. Use NEXT to move the dialogue until the display for the language selection appears.

```
LANGUAGE: _ENGLISH
SCROLL   MAIN      NEXT
```

Use SCROLL to select the desired language (german, english, french, czechoslovak) and confirm by pressing <Enter>.

3.1.2 Current output signal

Select the sub-menu 'SYSTEM' in the main menu. In this sub-menu select the sub-menu 'CURRENT'. The first entry in this sub-menu is the display for the current output selection.

```
CURRENT OUTPUT:  _0-20mA
SCROLL     MAIN         NEXT
```

Use SCROLL to select the current output (0-20 mA or 4-20 mA) and confirm by pressing <Enter>.

3.1.3 Relay function

The relay can be assigned to three different tasks. The choice of the relay function is done in the menu “GENERAL“.

ERROR:	If an error occurs, the relay switches (error messages 2.4).
MIN THRESH.:	The relay switches when the minimum threshold is reached. The definition of the threshold value is done in the menu "MEAS.PAR.". (see chapter 5)
MAX THRESH.:	The relay switches when the maximum threshold is reached. The definition of the threshold value is done in the menu "MEAS.PAR.". (see chapter 5)

3.2 Measurement parameters

The parameters which influence the display and the output of the measurement value are summarized in the sub-menu 'MEAS.PAR.'.

3.2.1 Time constant

The instrument determines a measurement value each 1000 ms. To minimize short-therm variations, it is possible to use a linear filter. The averaged measurement value will be displayed and will be available through the current output. The time constant is entered in number of measurement cycles.

e.g.:

AVERAGE: 30 M-CYCLES
SCROLL CURSOR NEXT

3.2.2 Current Output Span

The measured moisture is available as a current output signal. The current output signal will be defined by two values: one for lower limt (0/4 mA) and one for the upper limit (20 mA). These can be defined freely, depending on the range of interrest of the measuring value.

e.g.:

IOUT1(0/4mA)= 5%H2O
IOUT1(20mA) 15%H2O

This means that a current output of 0/4 mA is eaqual to 5%H2O and 20 mA is equal to H2O%Ts. If the measurement exeeds 15%H2O the current output is kept at 20mA and if the measurement is below 5%H2O the current output is will stay at 0/4 mA.

4. Calibration

The calibration of an instrument requires four steps:

- Adjustment of integration time
- (Reference measurement) normally not necessary
- Sample spectra acquirement
- Calibration fit
- Transfer of calibration model to the instrument

For further explanations please also refer to paragraph 7, to appendix1 and to the SPECTER8 manual.

4.1 Integration time adjustment

Take one representative sample spectra with the SPECTER software. Look if the peak value of the acquired spectra is about 15.000DLU. If the peak is below 15.000DLU increase the integration time and repeat the procedure until the peak is at about 15.000DLU. If the spectrum shows any value above 16.000DLU (usually 16.384DLU) then one **must** decrease the integration time until the maximum is around 15.000DLU

Note: A spectra must not have any value above 16.000DLU. If this happens, the integration time is too long. The integration time could be varied from 6,25ms up to 625ms.

4.2 Sampling

Take at least ten samples spectra, well distributed over the whole measuring range. The samples must cover the whole measuring range, because CLS Regression, what is used for calibration, is not able to extrapolate. I.e. the predictive quality of the calibration model beyond the calibration range could be very bad.

4.3 Calibration fit

The moisture concentration is calculated with a linear calibration model:
$C = B_0 + SUM(B_i * X_i)$

With B_0: Intercept
B_i: coefficient, i= 1 to 4
X_i: actual spectral absorbance, I=1 to 4

For a detailed description of the calibration procedure please refer to the SPECTER manual.

4.4 Transfer of calibration model to the instrument

Once calibration with SPECTER is done the results should be transferred to the instrument. Although it is possible to enter all calibration data by hand, it recommended to transfer the calibration data via RS232 from the PC to the HK8.

5. Start measurement

The measurement will be started by pressing the <Run> button. When the instrument is started, the display will automatically swith to the 'MEASURE' sub-menu and the actaul measured process value will be shown. The message RUN is shown in the display to indicate, that the measurement is running. . If the instrument detects any error or if any threshold, entered by the user, is crossed the instrument display RNx instead of RUN. The various meanings are:

RUN:	everything ok, measurement in process.
RN1:	communication error between evaluation unit and HK8 sensor.
RN2:	spectrum has crossed the maximum value of 16000DLU and the actual measuring value is rejected and the current output is clamped on the last valid value.
RN4:	The measured value has crossed the min. threshold of the valid measuring range. The actual measured value is rejected and the output holds the last valid value.
RN5:	The measured value has crossed the max. threshold of the valid measuring range. The actual measured value is rejected and the output holds the last valid value.
RN6:	spectrum has crossed the min. threshold. The actual measuring value is rejected and the current output is clamped on the last valid value.
RN7:	there is not enough material on the conveyer belt. The actual measuring value is rejected and the current output is clamped on the last valid value.
RN9:	the measurement is stopped via external Start/Stop signal (switch).

6. Miscellaneous

6.1 Test current

Located in the system sub-menu CURRENT.

To test the fuction of the current output loop it is possible to to set a constant current. The following values are availabel:

Input: 0 = Test current off
1 = Current output = 0 mA
2 = Current output = 1 mA
21 = Current output = 20mA

Remark: The test function operates only when the measurement is switched off!

6.2 Keyboard lock

The keybord can be locked with a password, which is a number in the range of 0 to 999999. The following procedure has to be done:

- Select 'GENERAL' from the main menu
- The display shows:

  LOCK KEYBOARD:
  SCROLL CURSOR NEXT

  The value of the password is not displayed

- Enter the preferred password and confirm with <Enter>. (See also paragraph 2.3).

When the keyboard is locked, only the menu item 'unlock keyboard' will be accessable. All other options can not be reached. The values of the parameters however can still be observed. Also the key <Run> will be locked. To indicate the locked keyboard the message LOCKED will be displayed.

6.3 Keyboard unlock

The following proceure has to be done to unlock the keyboard:

- Selct 'GENERAL' from the main menu and press NEXT until the following display appears.

  UNLOCK KEYBOARD:
  SCROLL CURSOR NEXT

- Enter the password and confirm with <Enter> .

If the correct password is entered the message LOCKED dissapeares from the display. If a wrong password is entered, an error message ILLEGAL PASSWORD! PLEASE CORRECT! Is displayed and the entering of the password has be repeated.

7. The system menue 'PROTECTED'

This menue contains data which should only be changed by the advanced users of the instrument. Any change in this menue modifies the operating mode of the instrument, and some changes even require a new calibration of the instrument. This is why the instrument is protected by a password. The password which allowes access to this menue is 911 and should only be nown by authorized persons.

7.1 Integration time

The measurement done by the instrument is basically a measurement of light intensity. This is, simplified, done as follows:

- accumulate the electrical charge, caused by the light, with a light detector for a certain time
- convert this charge into a voltage
- convert this voltage with a ADC into a digital number

Depending on the optical properties of the product arrives more or less light at the detector. E.g. from a white surface there is much more light reflected than from a dark one. To equalise this effect it is possible (and necessary) to adjust the accumulation time. This time is the INTEGRATION TIME.

Adjusting the integration time is an iterative process, where one has to take into account not to overload the ADC and on the other hand to have the highest possible signal amplitude to get best accuracy of the measurement.

For more details, please refer to the SPECTER software operating manual.

7.2 Measurement mode

The HK8 has two measurement modes. One is continuous measurement, the other is discontinuous measurement.

In continuous mode the HK8 calculates for each measuring cycle the actual moisture and it calculates, based on the time constant, a moving average of the measured moisture. The moving average is displayed at the HK8 display and it is available at the 4-20mA, as well as at the serial interface. The continuous measurement starts as soon as the Run button is pressed.

In discontinuous measurement mode (Start/Stop) the measurement is started by closing the external start/stop contact (see also the connection diagram, page 20). When the measurement is started the HK8 calculates for each measuring cycle the actual moisture. With the actual measuring value an arithmetic average over the, since started, elapsed time is calculated. This average is displayed and it is available at the 4-20mA output as well as at the serial interface.

Measurement and averaging continue until the start/stop contact is opened again. After stop the measuring value is hold until the start/stop contact is closed again.

To change the measuring mode, please move to the SYSTEM-PROTECTED menu. Use next until the following display appears:

MEASURE: CONTINUOUS
SCROLL NEXT

Use SCROLL to select CONTINUOUS or START/STOP and confirm with Enter.

Note:

Continuous mode: When the measurement is running the run indicator shows RUN. If the measurement is halted ether by the closed start/stop contact, or by the height measurement the run indicator shows RN9

Start/Stop mode: When the measurement is started by closing the start/contact the run indicator shows RUN. If the measurement is stopped by opening the start/stop contact the run indicator shows RN9

7.3 The height measurement

As the HK8 measures across a belt, it might be necessary to detect the presence of material, or not, to prevent false measurements If the process is not able to deliver this signal to the HK8 start/stop input, it is possible to connect a height measurement to the HK8. This height measurement enables the HK8 to determine if there is enough material on the conveyer belt, or not.

To activate the height measurement, please move to the SYSTEM-PROTECED menu. Use next until the following display appears:

HEIGHT MEASUREMENT: OFF
SCROLL NEXT

Use SCROLL to select ON and confirm with Enter.

Now, in the main menu, the HEIGHT menu is accessible.

8 The height menu

The height menu has three entries:

- Current input span definition
- Display of actual measured height
- Start height (threshold)

8.1 Current input span definition

0/4mA: 0.00 20mA: 0.00
SCROLL NEXT

Use SCROLL and CURSOR to enter the height at 0/4mA and confirm with Enter. Now the cursor moves to the input field for 20mA. Use SCROLL and CURSOR to enter the height at 20mA and confirm with Enter. Now the current input span is set and after pressing NEXT the display shows the actual measured height of the product.

8.2 H-START

The measured height is an indication, if there is enough material on the conveyer belt for an accurate measurement. The threshold for enough material is defined by H-START.

H-START: 0.00 mm
SCROLL NEXT

Use SCROLL and CURSOR to enter H-START and confirm with Enter. Now the function of the instrument is as follows:

IF H > H-START the instrument is measuring and the measured moisture is available at the display, at the current output and at the RS232 interface. The display shows the normal RUN indicator.

IF H ≤ H-START the measurement is halted and the display is kept at the last measured value. The RUN indicator changes from RUN to RN9, which indicates HALT.

Depending on the selected mode (see SYSTEM-CURRENT) the current output is either kept on the last value, or is set 0, 4 or 20mA.

The HK8 delivers all necessary signals and supplies for a standard height sensor with 4-20mA output. The height sensor should be able to operate at 15VDC and it must not draw more than 100mA.

9. Technical data

Evaluation Unit

System:	Microprocessor with NV-memeory
Housing:	Aluminium, IP65 HxBxD = 180x180x100mm
Weight:	about 2,5kg
Volatage:	85 - 260VAC 47 - 65Hz
Power consumption:	50VA
Current output:	0/4 - 20mA isolated, max. laod 500 Ohm
RS232 interface:	19200, 38400 Baud, 8 data bit, 1 stop bit, no paritity
Display:	2x24 character LCD, LED-backlight
Operating temperature:	-20 - 50 °C
Storage temperature:	-30 - 95 °C
Radiation:	EN55011 Part B
Noise immunity:	EN50082/1
Safety:	IEC1010-1
Spectrometer:	940, 1200, 1440, 1550nm

Reflection sensor

Housing:	Aluminium, IP65 HxBxD = 180x180x100mm
Weight:	about 2,5kg
Illumination:	LED’s
Operating temperature:	-20 - 50 °C
Storage temperature:	-30 - 95 °C

Note: All current output signals are active outputs!

Appendix 1

Getting started

Before doing anything, the instrument and the sensor should warm up for one hour to one and a half hours.

Notation convention: In the whole manual we use the term DIGITAL LIGHT UNIT DLU when we refer to the digital number which represents the absorption at a given wave length in the spectra.

1. Optimising the integration time

The goal of optimising the integration time is to increase the signal to noise ratio of the instrument to its maximum. One can imagine that at a given light power, by the illumination, the received portion of light is depending on the optical properties of the product and of the properties of the measuring site (distance, sensor type). E.g. when measuring in transmission it is a big difference in received light, transmitting through a transparent sample or through a semitransparent sample. Or when measuring in reflection there is also a big difference between a light sample and a dark sample.

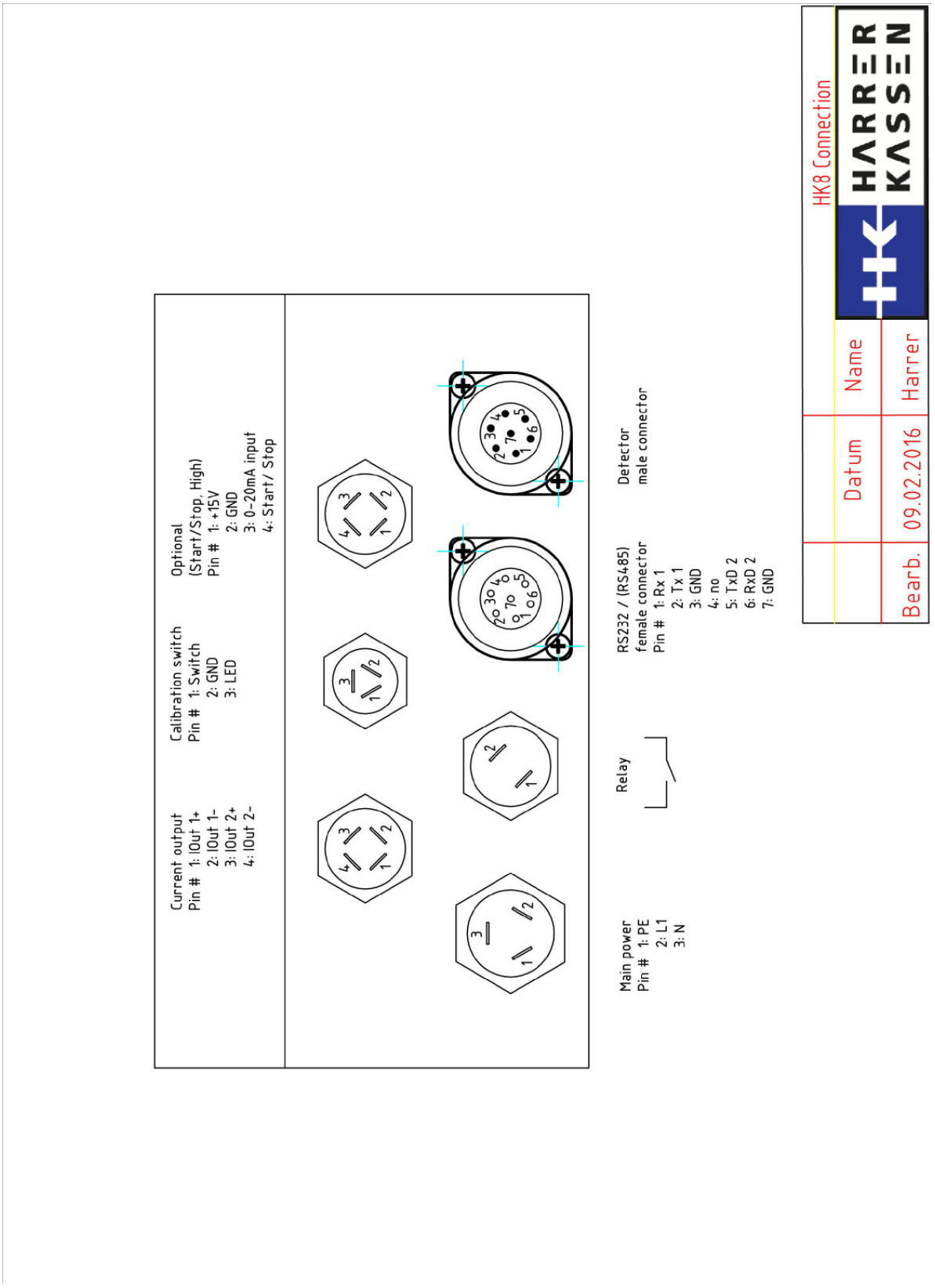
Take one representative sample spectra with the SPECTER8 software. Look if the peak value of the acquired spectra is about 15.000DLU. If the peak is far below 15.000DLU increase the integration time and repeat the procedure until the peak is at about 15.000DLU. If the spectra shows any value above 16.000 DLU (usually 16.384 DLU) then one **must** decrease the integration time until the maximum is around 15.000DLU.

2. Taking sample spectra

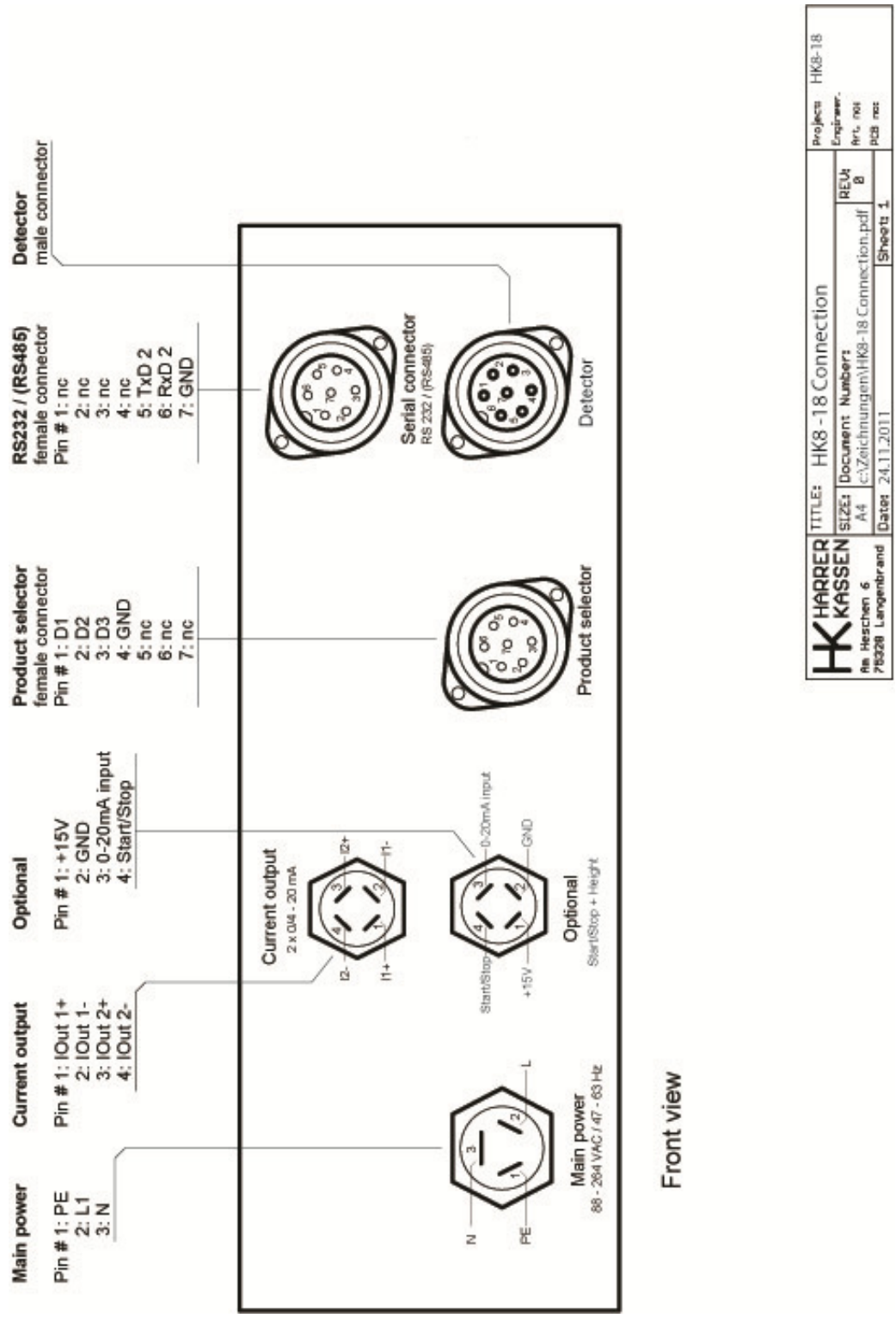
The HK8 continuously averages the measured spectra over the time constant. Therefore, before starting the calibration procedure, the time constant should be adjusted to the product surface properties. That means for a very smooth product, like sand, the time constant could be short and for a product with a rough surface, like wood chips, the time constant should be longer. The averaging of the spectra makes the spectra statistically more representative for a given sample.

Always take the product samples at the place where sensor is installed, to ensure, that the moisture is close related to the measured spectra.

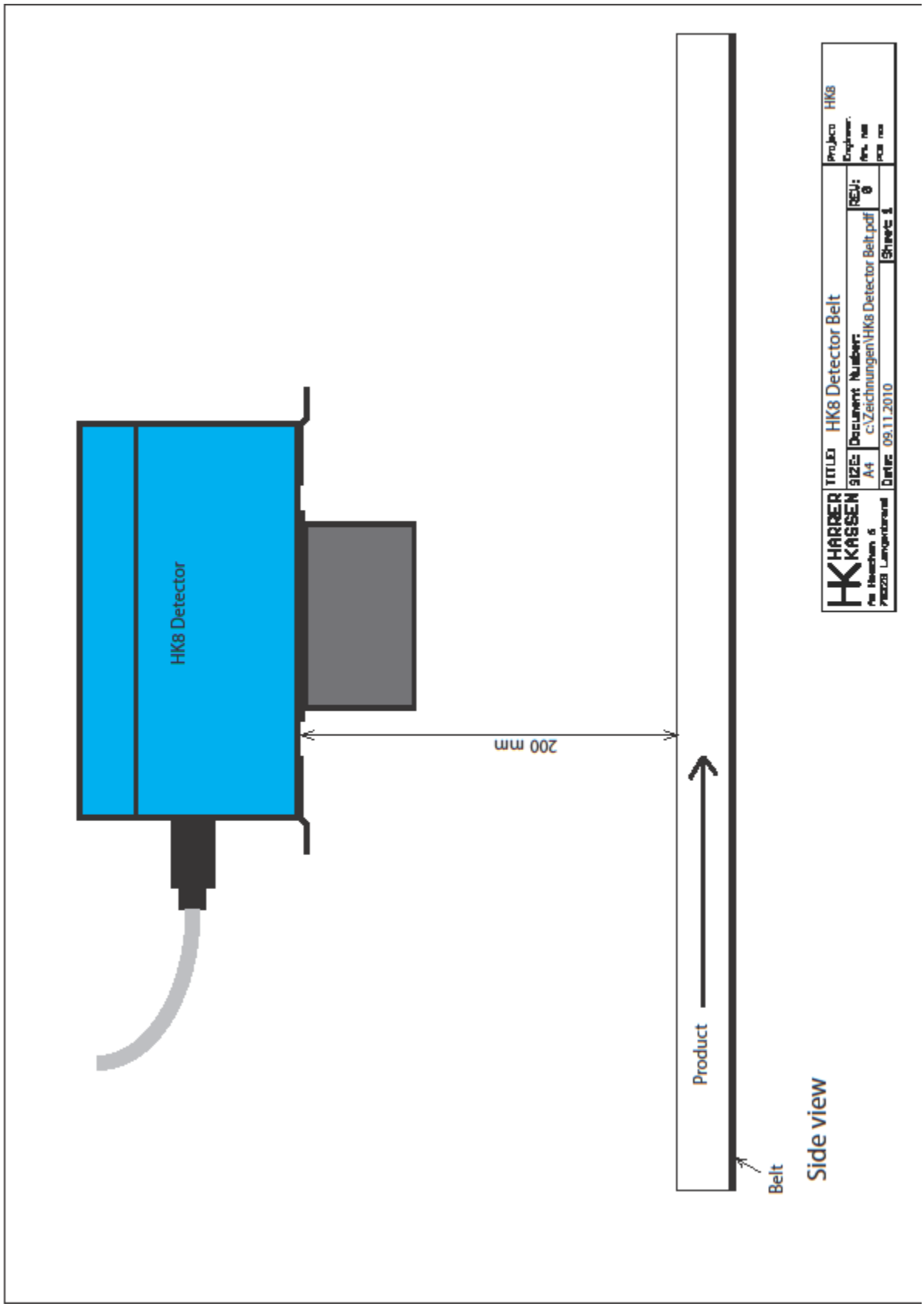
Connection diagram



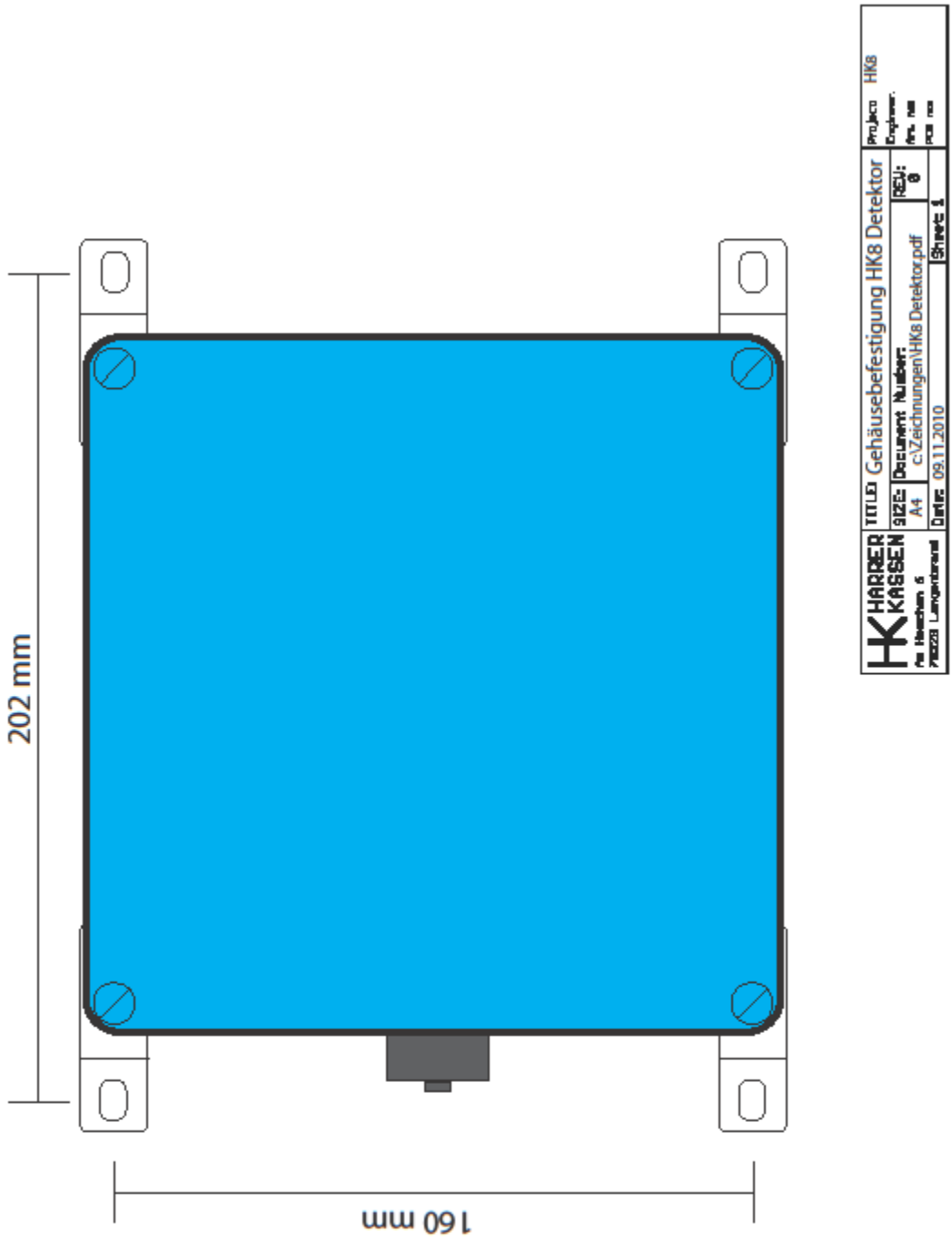
Connection diagram HK8-8



Sensor installation



Sensor and evaluation unit mounting dimensions



Declaration of Conformity

Herewith we declare, that the moisture meter

HK8

is in conformity with the requirements 89/336/EWG and 73/23/EWG.

The instrument is developed and manufactured by applying the following harmonised standards:

- EN 61000-6-2	Generic Immunity Standard Part 6-2 for Industrial Environment
- EN 61000-6-4	Generic Emission Standard Part 6-4 for Industrial Environment
- EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use

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18.11.2010

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