DESIGN BUREAU "FIZELEKTRONPRIBOR"

OKP 42 1550

Moisture meters FIZEPR-SW100

Technical Description and Manual
operating instructions
VIGT.415210.100 RE

Part 2. Instructions for setting up moisture meters and software description
(ed. 1.07)

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CONTENT

1. Introduction

1.1. This technical description and operating manual are intended to familiarize you with the SWPro and SW100 software (hereinafter referred to as the programs) of the FIZEPR-SW100 moisture meters, as well as with the measurement principles and setup methods for these moisture meters.

1.2. The software is designed for setting up FIZEPR-SW100 moisture meters, diagnosing their operation, and displaying measurement results.

1.3. The software is installed on a computer (laptop) running Windows XP (or higher). To use the program, you need the files "SWPro.exe," "SWPro.ini," "SW100.exe," and "SW100.ini." The program does not require any installation and can be launched from any location (folder) to which these files are copied.

1.4. The computer communicates with the moisture meter via an RS-485 interface through an RS232 or a USB serial port. Standard USB-to-RS485 interface converters can be used for communication via the USB port, such as the "OWEN-AC4" from Owen, the "ACDR.426469.032" from NVP Bolid, and others.

1.5. This manual assumes use of SWPro and SW100 software versions 2.9 and higher and firmware version 35 and higher. These programs are not intended to be run from a CD. To use the programs correctly, they must be copied to a computer or flash drive.

2. SWPro software for working with FIZEPR-SW100 moisture meters

The SWPro program is designed for setting up and diagnosing the operation of FIZEPR-SW100 moisture meters, as well as for displaying measurement results.

The program's main window (see Fig. 1) can be divided into three sections. The top section contains the menu and quick-access buttons for controlling the moisture meter and software. The middle section is a field for plotting (displaying) signal graphs (spectra). The lower section displays communication parameters, the measurement data received from the moisture meter, and the main moisture meter settings.

The program can operate both in connection with a moisture meter and without one. These modes are called "Recieve" and "Analysis" respectively.

In "Receive" mode, the computer receives data from the moisture meter and displays it on the screen in real time. In this mode, you can also change the moisture meter's settings and operating modes.

The data obtained from the moisture meter can be saved using the “Save” button on the quick access toolbar or via the “File|Save…” menu item.

In "Analysis" mode, data is not received from the moisture meter, and commands cannot be sent to the moisture meter. In this mode, you can only view data already received or previously saved to a file.

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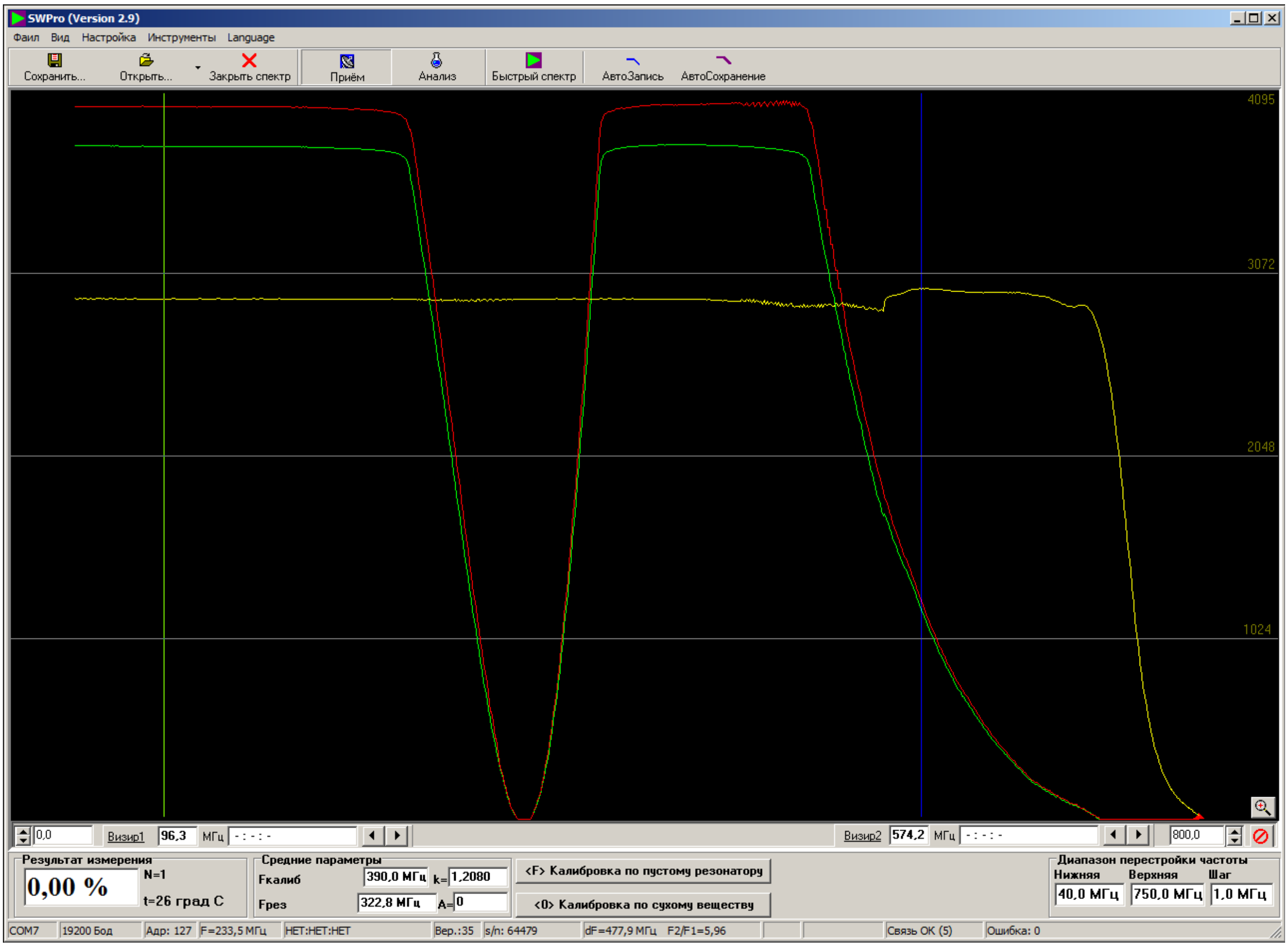

Fig. 1

Previously saved files can be opened using the "Open" button on the quick access toolbar, or using the "File|Open..." menu command.

Switching between these two modes is done using the buttons on the quick access toolbar with the corresponding names.

If you open a saved file in the "Receive" mode, the program automatically switches to the "Analysis" mode and data reception stops.

2.1. Software identification

In the main program window, the program icon, the name (program identifier) “SWPro” and the software version number are displayed in the upper left corner (see Fig. 1).

2.2. Moisture meter configuration files

As mentioned above, the data obtained from the moisture meter is not only displayed through the SWPro program interface, but can also be saved to a file.

The configuration is saved by selecting the menu item “File|Save…”.

The saved configuration files have the extension ".cfg".

The saved data contains all moisture meter settings, including the number of the currently used calibration table and the calibration table itself (see the chapter “Calibration tables”).

In addition, the moisture change graph is saved in the form in which it is currently displayed in the “Moisture graph…” window.

The configuration file "... .cfg" contains comprehensive information about the operation of the moisture meter and can be used for diagnostics of the operation of the moisture meter by the manufacturer or another person who has undergone training.

The configuration file can be used to remotely reconfigure the moisture meter or restore factory settings. To do this, load the file into the moisture meter using the "Setup|Load Configuration from File to Moisture Meter..." menu command.

It is important to distinguish between the commands “File|Open…” and “Settings|Load configuration from file to moisture meter…”.

The first command is used to view saved moisture meter parameters, as well as spectrum and moisture graphs. To do this, the program automatically switches to "Analysis" mode.

The second command reconfigures the moisture meter according to the parameters contained in the configuration file. Loading the configuration into the moisture meter is only possible in «Receive» mode and when a connection with the moisture meter is established.

2.3. Remote diagnostics of the moisture meter

As noted above, saved configuration files allow you to evaluate the moisture meter's performance, including remotely.

To do this, configuration files are sent by mail or other means to the moisture meter manufacturer or authorized dealer.

To send data, you should save several configuration files (3-5) at intervals of 1-2 minutes. Multiple configuration files allow you to evaluate how the moisture meter's state changes over time.

3. Setting up communication parameters

3.1. Description of moisture meter communication parameters

Receiving data from the moisture meter and configuring it is possible only in the «Receive» mode and only when the connection with the moisture meter has been successfully established.

Communication parameters are set in the settings window (Fig. 2), accessible from the menu item “Settings|Communication parameters…”.

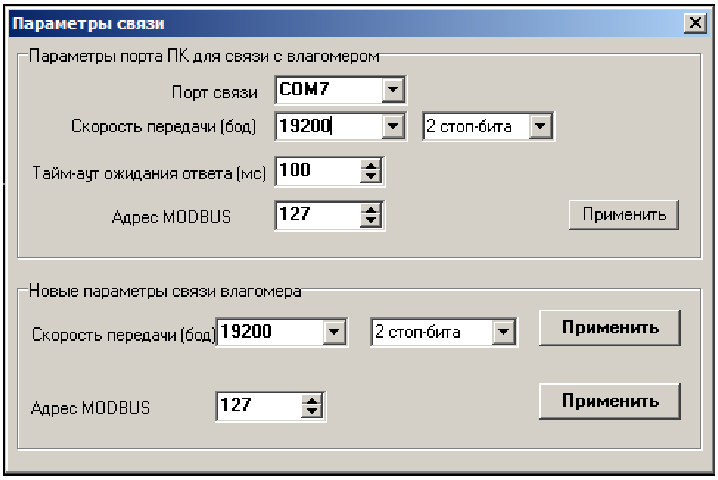

Fig. 2

All the necessary settings for establishing a connection are located at the top of the tab:

- **Communication port**– This is the port to which the moisture meter is connected. When using USB-RS485 interface converters (adapters), the operating system (Windows) automatically assigns a port number to each specific adapter. You can find the port number and access the adapter settings (if any) using the Windows Device Manager. The port number for USB-RS485 adapters must be between 3 and 9 inclusive. If this is not the case, you can change the port number using the Windows Device Manager.

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- **Data transfer rate**, the number of stop bits, and the MODBUS address are set to values known for the moisture meter. If this is a newly purchased moisture meter, the default values (specified in the moisture meter's data sheet) are used.
- The "Response Timeout" field specifies the time in milliseconds between requests sent to the moisture meter via the MODBUS protocol. The optimal timeout for a baud rate of 19200 is 100 ms. The recommended timeout is set automatically when a new baud rate is selected. However, if the connection is unstable due to additional OS delays, increasing the timeout is permissible. Increasing the timeout by more than 50% is not advisable, and the cause of the unstable connection should be sought elsewhere.

After selecting all the necessary parameters, you need to click the “Apply” button.

The currently set communication parameters, namely the selected COM port, speed, and MODBUS address, are displayed in the status bar at the bottom of the main program window (fields 1, 2, and 3, from left to right, respectively). If a nonexistent port or one occupied by another program was selected, a message appears stating that the port could not be initialized. The fields corresponding to the open port number and the set speed remain blank in this case.

If the COM port is selected correctly, the RS485 communication line is connected correctly, and the communication speed, number of stop bits, and MODBUS address are specified correctly, the second window on the right side of the status bar will display "Connection OK." Otherwise, the message "No connection" will appear.

3.2. Changing the moisture meter communication parameters

If you need to change the moisture meter's network address or baud rate, the "New Moisture Meter Communication Parameters" window contains fields for setting these parameters. After changing the parameter, click the "Set!" button.

If, when attempting to change the moisture meter parameters, the connection with the moisture meter is lost, then you should return the connection parameters to those that were in place before the change and restore the connection.

Note 1. Changing the moisture meter's communication settings is only possible (!) when a connection to the moisture meter is established.

Note 2. If the connection with the moisture meter cannot be established or its settings are unknown, you can reset the settings, after which the moisture meter will return to its default settings.

To reset the network settings and restore the moisture meter to its factory settings, press and hold the “Reset” button for at least 5 seconds, which is located on the right side of the lower board of the electronic unit under the cutout of the upper board (shown by the arrow in the photo in Appendix 1).

4. Measurement algorithms of FIZEPR-SW100 moisture meters

The coefficient of slowing down of an electromagnetic wave in a material k_{dec} calculated according to the formula:

$$k_{dec} = f0 / fM,$$

Where $f0$ – resonant frequency of an empty sensor (the sensor is filled with air);

fM – the resonant frequency of the sensor when it is filled with the controlled material.

It should be noted that the frequency $f0$ is determined once during sensor manufacturing (for bulk moisture meters, after the sensor is installed on the equipment) and is stored in the moisture meter's processor. This operation is called "empty resonator calibration."

The measurement process consists of periodically measuring the resonant frequency fM and calculating the value of the Deceleration factor k_{dec}.

The moisture content W of a material is determined by the measured k_{dec} value. Moisture content W is calculated using calibration tables, which are correspondence tables between the deceleration factor k_{dec}, moisture content, and temperature.

Thus, the main function of the moisture meter is to periodically search for the resonant frequency fM of the sensor, measure the temperature and calculate the Moisture based on these parameters.

4.1. Main parameters measured by a moisture meter, monitoring the operation of a moisture meter

As noted above, the moisture meter periodically measures the resonant frequency and temperature. All other parameters are calculated based on these measurements.

All main measured and calculated parameters are displayed at the bottom of the main window in the “Average parameters” and “Measurement result” panels (Fig. 3):

Fig. 3

Average parameters:

- F_{calib} – resonant frequency of the empty sensor ($f0$);
- F_{res} – the average resonant frequency measured by the moisture meter at a given moment$(fM);$
- **k** – the deceleration factor of an electromagnetic wave in a material ($k_{dec} = f0 / fM$);
- **A** – the level (voltage) of the output signal at the resonance point.

The “Measurement Result” window displays the moisture in percent, calculated using calibration tables, as well as the temperature (t = … degrees C) and the current measurement averaging parameter (N = …).

4.2. Algorithms for determining the resonant frequency

The search for the resonant frequency is carried out by reconfiguring the high-frequency generator and measuring the voltage U(f) of the signal at the sensor input.

The result is a voltage dependence (function) U(f) on frequency, which is represented in the moisture meter's processor as an array of value pairs (U, f). In the SWPro program, this dependence is displayed on the graph (spectrum) as a red line.

The generator frequency is adjusted from the minimum frequency Fmin to the maximum f_{max} with a step of ΔF.

The values of frequencies Fmin, f_{max} and ΔF are set in the dialog box “Settings|Frequency tuning range” (Fig. 4).

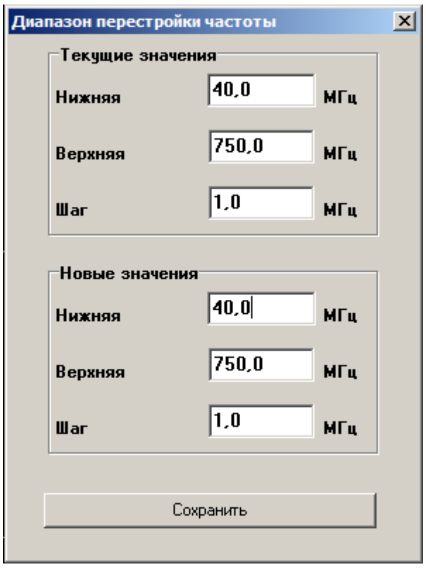

Fig. 4

By default, f_{min} = 40 MHz, f_{max} = 750 MHz, tuning step Δf = 1 MHz.

New values are entered at the bottom of the window and the "Save" button is clicked.

The moisture meter generates frequencies within the specified limits and with the specified step.

At each step, the moisture meter digitizes the voltage levels at the primary transducer input and the generator output and calculates their ratio. The SWPro program visualizes these voltages as graphs showing their dependence on frequency (the frequency spectrum of the signals). The voltage at the generator output is displayed as a yellow line, and the non-normalized voltage level at the primary transducer input is displayed as a green line.

Voltage U(f) (red line) is the voltage at the input of the primary converter, normalized to the voltage at the generator output.

There are several algorithms for searching for the resonant frequency based on the data of the above-mentioned array (U, f).

The algorithm is selected in the "Algorithm Settings" dialog box, menu "Settings|Algorithm settings" (Fig. 5).

Algorithm 0

The resonant frequency is taken to be equal to the frequency at which the voltage value U(f) has a minimum value in the given tuning range f_{min} - f_{max}.

The accuracy of determining the resonant frequency is equal to the tuning step Δf.

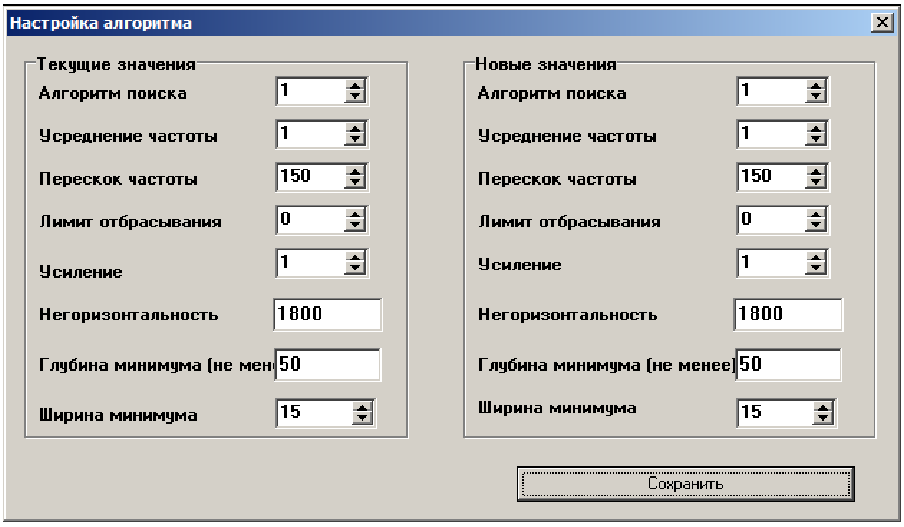

Fig. 5

Algorithm 1

The resonant frequency is the frequency at which the curve has a sufficiently deep signal minimum that satisfies the conditions specified in the search algorithm settings. If there are multiple minima, the one with the lowest frequency (the first minimum on the left) is selected.

The minimum is found by analyzing the U(f) levels over the frequency range $df = f2\text{-}f1$ (df is specified in the "Settings|Algorithm Settings|Minimum Width" menu). The value of df is expressed in frequency tuning steps Δf. The specified search frequency range is constructed sequentially from each point on the U(f) graph to the right.

The minimum is considered to be found if three conditions are met simultaneously on the next analyzed frequency interval f2-f1:

1)U(f1) ≤ U(f2). This condition means that only the df interval for which the graph point corresponding to the right end of the interval is higher than or equal to the point corresponding to the left end is taken into account for analysis (see Figure 1).

2)Dp > Dp0 , where Dp0 is specified by the "Minimum Depth" parameter, expressed in ADC counts (see the "Setup|Algorithm Setup|Minimum Depth" menu). "Minimum Depth" determines the degree of "convexity" of the minimum.

3)U(f2) - U(f1) < *Umax* , where *Umax* is set by the "Non-Horizontal" parameter in the "Setup|Algorithm Settings|Non-Horizontal" menu. This parameter allows you to filter out possible interfering spikes on the U(f) graph that have steep edges.

If the above conditions are met, then the resonant frequency ***fM*** is determined by the formula: ***fM*** = *(f1+f2)/2*.

The accuracy of determining the resonant frequency using this algorithm is 0.1 MHz.

If a minimum satisfying these conditions is not found, then the resonant frequency found using Algorithm 0 (absolute minimum) with an accuracy equal to the step Δf is taken as the minimum.

Algorithm 2

The frequency found using algorithm 1 is taken as the resonant frequency, but if the absolute minimum is below it in frequency by more than the frequency jump value (see section 4.4), then the frequency found using algorithm 0 is taken as the resonant frequency.

Algorithm 3

The resonant frequency is taken to be the frequency of the absolute minimum found in the frequency range that satisfies the same conditions as the range according to algorithm 1. In this case, the accuracy of its determination is equal to the tuning step.

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Fig. 6

Algorithm 4

The resonant frequency is taken to be the intersection point of the chords drawn through the intersection points of the main segment found by algorithm 1 and the intersection point of the segment drawn in the middle between the main segment and the absolute minimum point.

Algorithm 5

The resonant frequency is determined using the double fork method, thereby refining the minimum found using the standard fork method. That is, the frequency corresponding to the intersection point of the line drawn through the midpoints of the segments mentioned in Algorithm 4 and the line drawn at the absolute minimum.

4.3. Averaging measurement results

When measuring a real signal, the result is affected not only by the measured value itself, but also by external interfering factors, such as noise from the instrument's electronic circuits and process conditions. For a moisture meter, these factors may include:

- fluctuations in the properties of the measured medium, associated, for example, with the inclusion of gas bubbles or sediment in the liquid flow;
- stratification of liquid, uneven distribution of water in the volume of liquid.

As a result, the frequency measured by the moisture meter may vary from measurement to measurement, leading to fluctuations in the calculated moisture content. Averaging should be used to reduce the influence of these factors.

When frequency averaging, the average value of the last N measurements is used to calculate moisture, rather than the currently measured frequency value.

The N parameter – "Frequency averaging" is set in the "Algorithm settings" window.

The SW100 program has a tab called "Averaging" for this purpose (see section 9.4).

When the value of parameter N is set to 0 or 1, averaging is not performed.

Note. It should be remembered that the measurement time (the time it takes to establish a reliable measurement result) is directly proportional to the averaging constant and is approximately equal to three times the measurement period. For example, if the measurement period is 1 second, then the signal establishment time is 3 seconds.

4.4 Filtering outlier measurements

Outlier filtering eliminates values that deviate significantly from the average values over the averaging period. This type of filtering helps prevent the impact of sudden changes in the process.

Filtering is performed according to the following algorithm.

During each resonant frequency measurement, the average frequency is compared with the frequency just measured. If the difference is greater than the "Frequency Jump" parameter, the average value is substituted for the currently measured ("dropout") frequency. The measurement and averaging process continues as if there had been no jump.

The "Frequency hopping" parameter is set in the "Algorithm settings" window in tenths of MHz.

The filtering of outlier values is controlled by the "Discard limit" parameter in the "Algorithm settings" window.

If this parameter is zero, filtering is disabled.

If the parameter is equal to 1, then one random “dropped” measurement is discarded and averaging continues.

If the parameter is equal to 2, then two consecutive “dropped” measurements are allowed.

If the parameter is 3, then three, and so on.

If the "dropout" continues more times than specified in the setting, then the resonant frequency is considered to have changed and the averaging process starts over again, using the current measured values.

If filtering is disabled (“Discard Limit” = 0), then averaging starts over every time the next measured resonant frequency differs from the average by more than the “Frequency Jump” parameter specifies.

Filtering outliers only makes sense if averaging of measurement results is enabled (see section 4.3), since the decision to discard the next measurement is made by comparing it with the average value.

4.5 . Approximate assessment of measured parameters and correctness of operation

The spectrum graph provides a general overview of the moisture meter's operation and allows one to assess its accuracy. The resonant frequency when the sensor is filled with material can be determined from the spectrum—the shape of the resonance curve. The resonance curve of a functioning moisture meter should clearly show a signal minimum.

The frequency value at which the signal minimum is achieved can be determined using the “Visir” tool with an accuracy of up to several MHz.

SWPro has two such sights. You can turn the sights on and off using the menu item "View|Sight 1..." or "View|Sight 2...".

Each sighting device corresponds to a field (under the spectrum graph) indicating the frequency at which the sighting device is “located” and the signal amplitudes measured at this frequency.

The sighting devices are moved by left-clicking. To determine the frequency, move the sighting device to the desired point in the spectrum and read the frequency value in the window corresponding to the sighting device number.

If the frequency determined in this way, at which the minimum signal is achieved, is approximately equal (with an accuracy of several MHz) to the frequency measured by the moisture meter (Fres), then the moisture meter is configured correctly and is working properly.

4.6 Additional diagnostic information

To enable or disable additional information windows, double-click the panel to the left of the "Frequency Tuning Range" panel (in the lower right corner of the main window). This will replace the calibration buttons with windows containing additional parameters (Fig. 7).

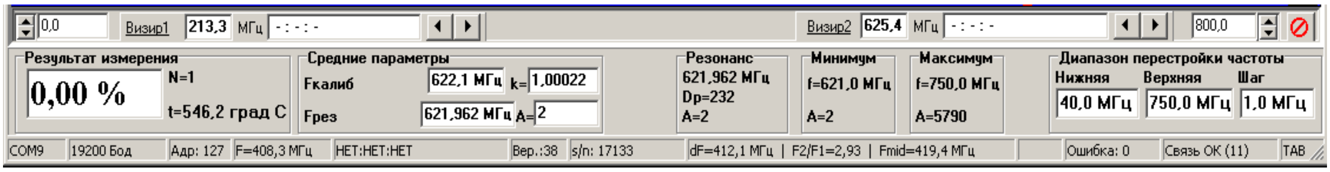

Fig. 7

The "Minimum" window displays the frequency f at which the sensor input voltage is at its minimum (searched using Algorithm 0). The signal magnitude at the minimum is displayed as the value A.

The Maximum window displays the frequency f at which the voltage at the sensor input has its maximum value, also designated by A.

The Resonance window contains the following information:

f is the resonant frequency determined by the currently selected algorithm.

A – signal level at the minimum point on the interval df (see Fig. 6).

Dp – “depth of minimum”, measured according to Algorithm 1 (see Fig. 6).

Note 1. The Dp value can be used to estimate the sensitivity margin when determining the resonant frequency using Algorithm 1. That is, for reliable operation of the device, the Dp value must have a value greater than Dp_0 specified in the settings.
"Settings|Algorithm settings|Minimum depth".

Note 2. The Dp value is only relevant when a minimum is found that satisfies the three conditions of Algorithm 1. In other cases, the displayed value is undefined and can be any.

Note 3. An indication that the minimum according to Algorithm 1 has not been found may be the absolute equality of frequencies in the “Minimum” and “Resonance” windows.

5. Calibration tables

According to its operating principle, a moisture meter is a dielectric constant meter.ε_r. Recalculation of dielectric constant (or ***kdec***) into moisture W is calculated by a processor based on calibration tables, which define the correspondence between the specified parameters. Generally, each type of material being monitored has its own functional relationship between permeability and moisture. Moreover, this functional relationship is tied to the specific temperature of the material.

The moisture meter can store up to 100 different calibrations. Calibrations can be switched using the calibration dialog box or via the MODBUS digital interface using the registers specified in Part 1, Section 12.

In some cases, when building automated systems, it's more convenient to convert permittivity to moisture content using the automated system itself rather than the moisture meter's processor. This solution can be useful when quickly changing calibrations during the process (for example, when dosing different types of materials), as it eliminates the need to program complex calibration switching algorithms via communication lines.

In this case, only the temperature and the Deceleration factor value are received from the moisture meter, which are converted into moisture in the external control system.

Each calibration is a table of correspondence between the Deceleration factor ***kdec*** (function of ***εr***) and moisture W. An example table is provided in Section 5.2.5 of this manual. There are four such tables for each material, each compiled for a specific temperature. The first table is compiled for the lowest temperature of the measured material, and the fourth for the highest.

Comment. Deceleration factor ***kdec*** – is the ratio of the resonant frequency of the sensor when filled with air to the resonant frequency when filled with the material being monitored. This coefficient is equal to the ratio of the velocity of an electromagnetic wave in a vacuum (in air) to the wave propagation velocity in the material (see Chapter 4). In technical literature, this parameter is also called the refractive index of the material. For low dissipative losses for an electromagnetic wave propagating in a material, the refractive index is related to the permittivity by the expression:

$$\varepsilon_r = k_{dec^2}$$

The calibration table is a set of 15 points (pairs of values ***kdec***, ***W***), which are used by the processor to set the function ***W = W (kdec)*** moisture W is calculated by the processor by linear interpolation of intermediate values of the Deceleration factor ***kdec*** on the corresponding segment of the function W = W***(kdec)***.

5.1. Window for working with calibrations

To access the tables in the main SWPro window, select "Setup|Calibration Tables..." from the menu. This will open a window (Fig. 9) titled "Calibration Tables," which contains the controls and display elements needed to view and edit the tables. This window is identical in appearance and functionality to the same window in the SW100 program (see Chapter 9 of this manual).

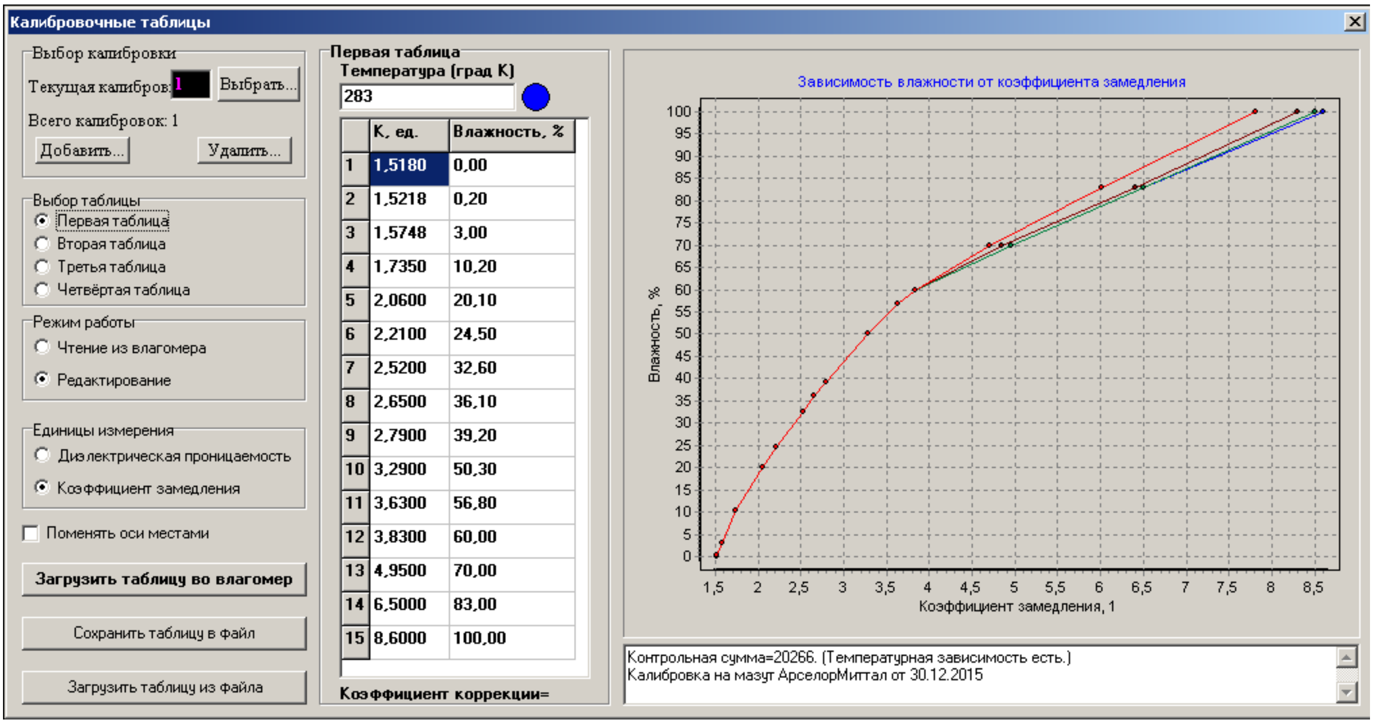

Fig. 8

The window can be conditionally divided into three parts:

- on the left side there are window controls;
- in the middle part – the current conversion table;
- on the right side – a graphical representation of tabular data.

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When this window is opened for the first time, the data from the first table located in the moisture meter memory is displayed (it is assumed that the connection with the moisture meter has already been established).

The table to display is selected by selecting the desired item in the "Table Selection" panel. The temperature corresponding to that table is displayed at the top of the table. The "Units" panel allows you to select the display of the measured value as a deceleration factor k_{dec} or relative permittivity εr.

The correction factor indicates whether the calibration offset calculated after the "Calibration by solids" operation (see Section 5.3 below) is used. For newly created or edited tables, the correction factor is zero.

There are two modes of working with tables: “Reading” and “Editing”, which can be switched in the corresponding “Working mode” field.

In the “Reading” mode (enabled by default), it is only possible to view tables stored in the moisture meter’s memory.

In the Edit mode, you can edit tables, write calibration to the moisture meter, save calibration to a file, and open calibration from a file.

Since each calibration consists of four tables, you must first select the calibration you're interested in. This is done in the upper left corner of the window by entering its number in the "Current calibration number" field.

The total number of calibrations recorded in the moisture meter is displayed below this field.

Note. It is necessary to take into account that the calibration selected in this way is saved in the moisture meter’s memory and further calculations in the operating mode will be performed according to it.

If you need to add another calibration or delete the current calibration, you must click the corresponding “Add” or “Delete” buttons.

For quick identification, the SWPro program (as well as the SW100 program) calculates the checksum of the current calibration and displays it in the field below the graph. When the moisture meter is delivered, the checksums of all calibrations stored in the meter are listed in the data sheet. This allows you to determine the integrity of the calibrations without comparing them line by line.

After selecting the calibration, you can begin working with the calibration tables.

5.2. Procedure for working with calibration tables

5.2.1. Writing tables from a file to a moisture meter

Recording calibration tables into the moisture meter is carried out in the following order:

1) establish a connection with the moisture meter;
2) open a window for working with calibration tables (Fig. 8);
3) go to the "Edit" mode;
4) click the “Open table from file…” button and select the desired file in the standard dialog box that appears;
5) After this, click the “Save table to moisture meter” button.

Note 1. When creating and editing tables, please note that a table with a lower number must correspond to a table for a lower temperature.

Note 2. If a temperature-independent characteristic is used for a given type of material being measured, the same data is recorded in all four tables of the moisture meter, but for each table, before recording in the moisture meter (step 5), the temperature must be manually specified in accordance with Note 1.

5.2.2. Saving calibration from a moisture meter to a file

To save the tables in the moisture meter's memory, you must perform the following steps:

1) go to the "Edit" mode;
2) click the “Save table to file…” button and in the standard dialog box that appears, specify the desired file name;

5.2.3. Adjusting existing tables

If during the operation of the moisture meter it becomes necessary to adjust the calibration characteristics, it is recommended to follow this procedure:

1) switch to Edit mode
2) save the tables in the moisture meter memory according to clause 5.2.2;
3) make the desired changes to the current table (or open a new one from a file);
4) record it in a moisture meter;
5) save the calibration to a file in accordance with paragraph 5.2.2.

5.2.4. Creating calibration tables

To create a new calibration characteristic, it is much more convenient to prepare a table using some specialized, well-known program (for example, MS Excel) and save it in a format suitable for recording in a moisture meter using the SW100 or SWPro program.

To record and save tables, the specified programs use the standard CSV (comma-separated values) format, which is supported, in particular, by the MS Excel spreadsheet editor.

5.2.5. Format of calibration tables

The moisture meter calibration datasheet is a set of four tables in a CSV or Excel file. Each table consists of fifteen rows, specifying the correspondence between the deceleration factor k_{dec} and moisture W.

Below is what the table should look like in Excel format:

F	**283**	
1	1.57	0
2	1.76	8.44
3	1.94	15.5
4	2.06	20.1
5	2.21	24.5
6	2.52	32.6
7	2.65	36.1
8	2.79	39.2
9	3.04	44.8
10	3.29	50.3
11	3.63	56.8
12	3.83	60
13	4.95	70
14	6.75	83
15	9.15	100
F	**298**	
1	1.57	0
2	1.76	8.44
3	1.94	15.5
4	2.06	20.1
5	2.21	24.5
6	2.52	32.6
7	2.65	36.1
8	2.79	39.2
9	3.04	44.8
10	3.29	50.3
11	3.63	56.8

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12	3.83	60
13	4.95	70
14	6.75	83
15	9.15	100
F	**308**	
1	1.57	0
2	1.76	8.44
3	1.94	15.5
4	2.06	20.1
5	2.21	24.5
6	2.52	32.6
7	2.65	36.1
8	2.79	39.2
9	3.04	44.8
10	3.29	50.3
11	3.63	56.8
12	3.83	60
13	4.95	70
14	6.75	83
15	9.15	100
F	**318**	
1	1.57	0
2	1.76	8.44
3	1.94	15.5
4	2.06	20.1
5	2.21	24.5
6	2.52	32.6
7	2.65	36.1
8	2.79	39.2
9	3.04	44.8
10	3.29	50.3
11	3.63	56.8
12	3.83	60
13	4.95	70
14	6.75	83
15	9.15	100

The calibration table is compiled in compliance with a number of rules.

The first row specifies the temperature (in degrees Kelvin) to which this table corresponds. The first cell must contain the service symbol F (a Latin letter). The second cell contains the temperature value in degrees Kelvin. The third cell is blank.

All subsequent rows represent the reference points of the calibration curve. Each row consists of three columns. The first column contains the point's serial number (from 1 to 15). The second column contains the material's *Deceleration factor* value. The third cell contains the corresponding moisture content value in percent. The table should be arranged so that the cell with the lower serial number corresponds to the point with the lower *Deceleration factor* value.

When compiling tables, the Deceleration factor should be indicated with no more than four decimal places, and moisture - with no more than two decimal places.

Note 1. The table should not contain deceleration factors less than 1.

Note 2. If the calibration table contains at least one deceleration factor greater than 13, the precision of the factor is automatically reduced to 2 decimal places, with previously entered values rounded accordingly. In this case, the value of the smallest deceleration factor used in the table must be less than 50.

Note 3. Each table must contain 15 calibration points. If there are fewer than fifteen calibration points, all available points are entered into the table according to the rules specified above, and the missing rows are formed by copying (duplicating) the row with the highest deceleration factor for the given table.

An Excel table created according to these rules is saved in CSV format. The table is then ready for use with SW100 and SWPro.

5.3. Dry matter calibration

Dry matter calibration may be required to adjust the calibration curve when the properties of the controlled material change slightly, for example, when changing the grade of oil.

The essence of dry matter calibration is that the moisture meter automatically adds a certain value (correction factor) to the measured deceleration factor without changing the calibration table, i.e., it actually produces a parallel shift of the calibration dependence graph along the abscissa axis (see Fig. 8).

The value of the correction factor k_{corr} to clarify the deceleration factor Calculated automatically when you click the "Dry Matter Calibration" button. The moisture meter calculates using the following formula:

$$k_{corr}=k_{dec}. \, tab - k_{dec}, \, meas$$

Where k_{corr} – correction factor (the magnitude of the shift in the Deceleration factor);

$kdec, \, tab.$ – the deceleration factor from the first term of the first temperature tables of current calibration;

$kdec,meas$ – the correction factor measured at the time of calibration.

Important! To perform dry matter calibration, the material being calibrated must be moisture-free.

After completing the calibration for dry matter in the moisture meter to the measured deceleration factor $k_{dec}, \, meas$ the value will always increase k_{corr}:

$$k_{dec,corr} = k_{dec,meas} + kcorr,$$

Where $k_{dec.corr}$ – the adjusted Deceleration factor, according to which the moisture will be calculated from the calibration tables.

The value of the correction factor k_{corr} can be either positive or negative. The correction factor is absolute K_{corr} should not be greater than 0.32767. The value of the correction factor can be seen in the "Calibration Tables" window directly below the calibration table (Fig. 8).

Note 1. The correction factor value is too large. k_{corr} (more than 0.01...0.02) may indicate that its use for this material is not advisable; instead of calibration based on dry matter, it is necessary to perform a full calibration on a new material in accordance with Section 6 of this instruction.

Note 2. To reset (zero) the correction factor k_{corr} It is necessary to reload the original calibration table using the “Calibration Tables” window (Fig. 8).

6. Calibrating the moisture meter

For each type of material being measured, a calibration table must be stored in the moisture meter. This table relates the measured permittivity (deceleration factor) of the material to its water content. Moisture meter calibration involves entering data into the calibration table or adjusting it based on the comparison of the moisture meter readings with reference (laboratory) water content measurements. For bulk materials, the gravimetric (drying) method is the reference moisture measurement method. For liquid materials, the Karl Fischer titration method is used, but in some cases, the Dean-Stark method according to GOST 2477-2014 can also be used.

Moisture meters undergo preliminary calibration at the manufacturer's facility. This preliminary calibration uses existing material samples or samples of the measured material provided by the customer. To improve measurement accuracy, it is recommended to perform a final calibration of the moisture meter when commissioning the moisture meter. This allows for a more accurate accounting of the properties of the material being monitored and the specific application of the moisture meter sensor. For example, final calibration of oil moisture meters adjusts the calibration characteristics for a specific oil grade and its hydrocarbon composition. During the final calibration of bulk material moisture meters, such as wheat grain, adjustments are made for the specific wheat grade and, most importantly, for the bulk density of the bulk material at the location where the moisture meter sensor is installed.

Requirements for carrying out measurements, including during calibration, and the procedure for their implementation are described in Section 12 of the Technical Description and Operating Manual VIGT.415210.100-01 RE (TO-RE), Part 1.

6.1. Preparing the moisture meter for calibration

After installing a bulk moisture meter sensor at an industrial facility (bin, conveyor), a so-called "empty resonator calibration" should be performed before filling the sensor with the material being monitored. For liquid moisture meters, the "empty resonator calibration" performed at the manufacturer's facility is typically left unchanged.

In "empty resonator calibration" the resonant frequency of the empty sensor is determined - $f0$. This frequency is determined once either during sensor manufacturing (for liquid materials) or after sensor installation on the equipment (for bulk material moisture meters). The specified frequency $f0$ is called the calibration frequency of the moisture meter, it is stored in the internal memory of the device. Thus, the calibration frequency $f0$ is stored in the moisture meter's memory upon user command when the moisture meter's sensor is empty (not filled with the measured material).

Calibration can be done in two ways:

Method 1. By pressing the "Empty Resonator Calibration" button, the moisture meter stores the current measured frequency in its internal memory.

Method 2. By directly entering the frequency value (accurate to tenths of a MHz). To do this, select the "Setup|Calibration Frequency..." menu item and, in the window that appears (Fig. 9), enter the desired value, obtained based on the frequency measured by the moisture meter, the specified value for this parameter, or another value determined (for example, if the sensor's resonant frequency is outside the moisture meter's frequency tuning range).

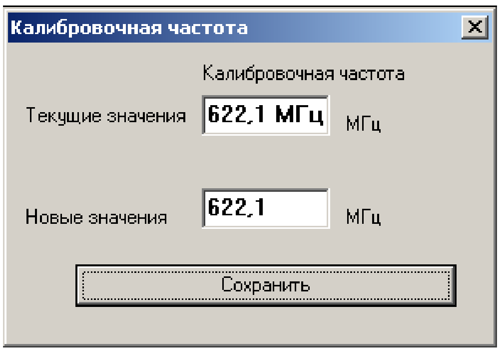

Fig. 9

For this calibration, the liquid moisture meter sensor is washed with an organic solvent or alcohol and thoroughly dried. Calibration is performed only on a clean and dry sensor.

Based on the physical meaning of calibration, the Deceleration factor measured by the moisture meter k_{dec} after calibration should be equal k_{dec} = 1±0.0002 for moisture meters of liquid materials, and k_{dec} = 1±0.002 for bulk material moisture meters.

If the retarding coefficient is measured again with a moisture meter k_{dec} goes beyond the specified limits (provided that the sensor is empty), then this may be a consequence of insufficient cleaning of the inner surface of the moisture meter.

6.2. Performing operational calibration of the bulk material moisture meter

Once the "empty resonator calibration" is complete, the sensor should be filled with the material to be measured. The volume of space the sensor covers during measurements must be filled with the material to be measured. If this volume contains foreign objects or is partially filled with air, accurate measurements will be impossible, as the moisture meter measures the amount of water that is present in the volume being measured by the sensor.

If the FIZEPR0SW100.10.4x sensor installed in a hopper is being calibrated, it is necessary to ensure that the monitored material completely fills the entire space in the hopper around the sensor, ensuring that the material covers the sensor from above with a layer at least 0.5 m thick and that there are no voids beneath the sensor. The monitored material must be free of foreign inclusions.

If the FIZEPR-SW100.10.5x sensor installed above a conveyor belt is being calibrated, it is necessary to ensure that the monitored material completely fills the entire space around the sensor so that the layer of material at a distance of up to 15 cm around the sensor has a thickness of at least 10 cm and this layer rises several centimeters above the surface of the sensor shield.

When performing operational calibration, it is necessary to ensure that the monitored material has a stable moisture content (moisture is uniformly distributed throughout the measured volume) and that a representative sample is taken for laboratory analysis. To do this, take a series of samples (at least 8-10 samples are recommended) from different parts of the material volume monitored by the sensor and measure the moisture content of each sample gravimetrically. Using standard methods (GOST R8.736-2011), calculate the root mean square error from the obtained moisture content of the samples and determine the permissible measurement error for the moisture meter's intended application.

Note. The moisture meter's rated error is provided in Section 3.2 of the Technical Specifications, Part 1. The rated error values are established in accordance with the measurement method specified in verification procedure MP242-1715-2014. This procedure uses liquids (oil-water mixtures) as the reference material. This allowed us to eliminate the influence of bulk material bulk density and non-uniform moisture distribution within the measured volume when determining the moisture meter's rated error. Under real-world operating conditions, these factors can significantly impact measurement results, making it crucial to perform a working calibration that takes into account all factors affecting measurements.

After completing the above preparatory steps, measurements should be taken, and the measurement results should be read from an indicator device (computer screen, SWPro software). These data are recorded in a measurement report, which also includes laboratory measurement data, indicating

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the sampling date and material temperature. A sample report is provided in Appendix 23 of the Technical Operation Manual, Part 1.

When a sample is collected for laboratory measurements of the controlled material, moisture meter readings are recorded in the protocol. After the laboratory analysis is completed, the results are entered in the appropriate line. The difference between the obtained values is calculated, taking into account the sign. To make adjustments to the calibration table, sufficient statistics must be collected. The required volume of statistical data is determined according to GOST R8.736-2011, with the criterion being achieving convergence of measurement results.

7. Setting the current output

To configure the current output parameters (4–20 mA current loop) of the moisture meter, select the menu item “Setup|Current output…”.

After this, the corresponding dialog box will appear, shown in Fig. 10.

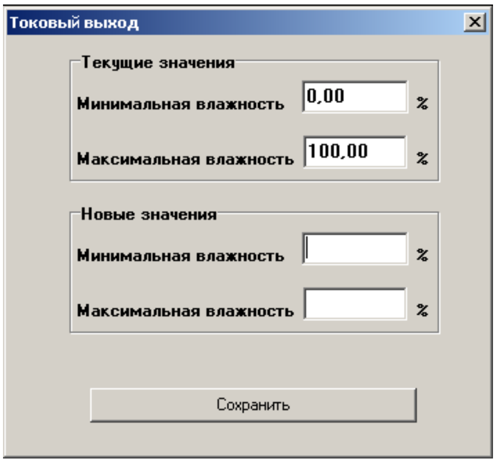

Fig. 10

This window shows the actual current output settings at the top. New settings can be entered at the bottom.

In this case, the minimum moisture corresponds to an output current of 4 ma, and the maximum moisture corresponds to a current of 20 mA. In order for the newly entered values to take effect, you must click the "Save" button.

Note. The settings of the current output parameters do not affect the measurement range and moisture values transmitted via the MODBUS interface and displayed in the corresponding windows of the SW100 and SWPro programs (Fig. 1, 13 and 15).

8. Options for automatic saving of measurement results

8.1 Automatic saving of spectra

When researching new materials or troubleshooting a moisture meter, it may be necessary to automatically save moisture meter configuration files without operator intervention. For this purpose, the SWPro program features an automatic configuration file saving mode (configuration files are saved along with the last measured spectrum).

The automatic saving mode is controlled using a special dialog box (Fig. 11), accessible through the “Tools|Autosave…” menu.

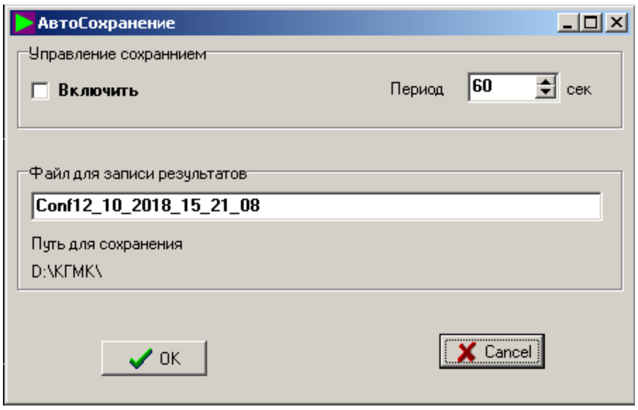

Fig. 11

In this window you can enable/disable autosave and set the saving period.

In the "File for saving results" field, you can control the path to which the results will be saved and the current template for the name of the saved .cfg file.

You can quickly turn the autosave mode on/off using the "Autosave" button in the main program window.

Note. The path for saving files is the same as the path of the last saved configuration file, so to change the save path you need to save the spectrum manually using the "File|Save..." menu.

8.2. Automatic saving of measurement results

Moisture meters do not contain an internal archive of measurement results. However, the SWPro program allows automatic recording of measurement results as a comma-separated value (CSV) text file. This format is fully supported by the MS Excel spreadsheet program.

To control automatic recording, use the dialog box (Fig. 12), accessible through the menu “Tools|Auto-Record…”.

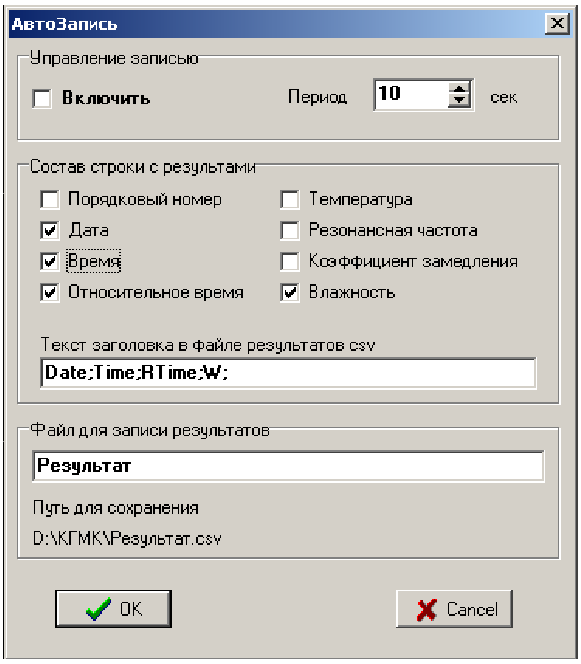

Fig. 12

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The recording of measurement results into a file is performed line by line with the period specified in the corresponding field.

The presence and purpose of individual columns are specified in the "Results Row Contents" field. The file may contain the following parameters, written in the corresponding columns:

Data (column)	Description	Unit of measurement	Symbol in the title line
Serial number	The serial number of the measurement from the moment the mode was turned on	-	N
Date	Date of measurement according to the computer clock	Year, month, day	Date
Time	Computer clock time	Hours, minutes, seconds	Time
Relative time	Time since recording mode was turned on	Seconds	RTime
Temperature	Temperature measured by a moisture meter	Degrees Celsius	T
Resonant frequency	Resonant frequency measured by a moisture meter	MHz	F
Deceleration factor	Deceleration factor	-	K
Moisture	Calculated moisture	%	W

The text in the line "Header text in the results file" is written as the first line so that the composition of the data in the file can be determined later.

In the "File for saving results" field, enter the file name (without extension). The .csv extension will be added automatically.

You can quickly turn the auto-recording mode on/off using the “Auto-recording” button in the main program window (Fig. 1).

Note 1. The file save path is the same as the folder where the configuration file was last saved. Therefore, to change the save path, you must save the spectrum manually using the "File|Save..." menu.

Note 2. After stopping recording, carefully monitor the column composition. Accidentally changing them can cause data confusion. The solution is to specify a new file name to continue recording.

Note 3. When you check the "Enable" box in the control window (Fig. 12) and click the "OK" button, a new file is created with the name specified in the window. This may result in the loss of previously recorded data. Therefore, to continue recording, you must specify a new file name for the newly recorded data.

Note 4. It is not recommended to open a file being recorded to while auto-recording is enabled. This may result in an access error and program crash.

9. SW100 program for working with FIZEPR-SW100 moisture meters

Software "SW100" provides the following functions:

– displaying the current moisture value in digital form on the computer screen;
– displaying the measured moisture on the computer screen in the form of a graph, which shows the current moisture value and its change over time;
– control of the moisture meter, setting some of its operating modes.

The program consists of a main window, which displays the current moisture value in digital form and the current moisture meter settings, as well as an additional window, which displays a graph of the technological process (Fig. 13).

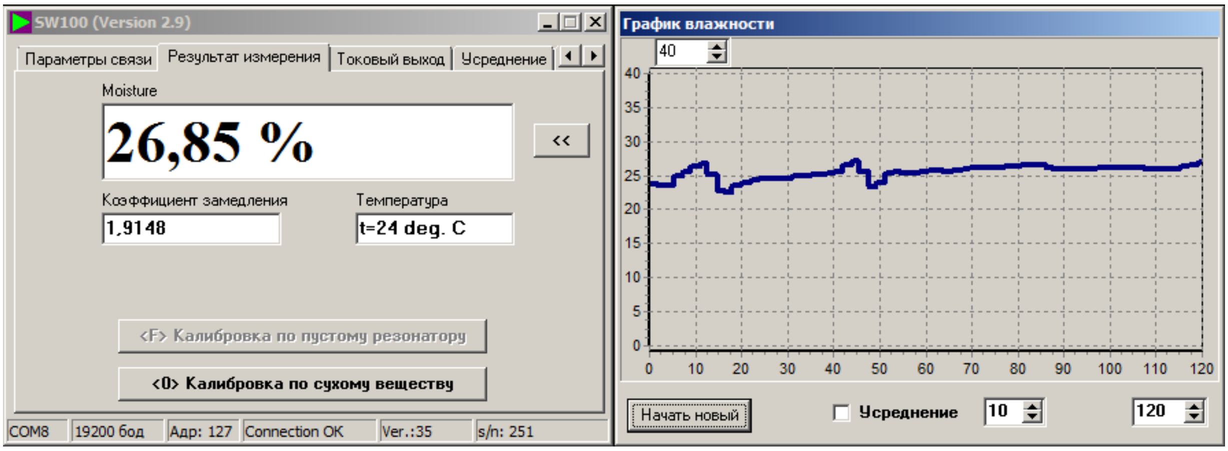

Fig. 13

In the main program window, there are 6 tabs at the top that allow you to control the moisture meter's operating modes and configure it.

At the very bottom of the main window is a status bar for displaying service information. It is divided into six fields:

1) The first field displays the name of the serial port to which the moisture meter should be connected;
2) in the second – the set port operating speed in baud (bits/s);
3) in the third – the address of the moisture meter in the MODBUS network;
4) in the fourth – a message about the status of data exchange over the network: "Connection OK" – there is a connection, "No connection" – there is no connection; if this field is left empty, then the serial port is not selected;
5) in the fifth – the version number of the internal software of the moisture meter (the "firmware" of the moisture meter);
6) The sixth field displays the serial number of the moisture meter.

9.1. Software identification

In the main program window, in the upper left corner, the program icon, the name (program identifier) "SW100" and the software version number are displayed (see Fig. 14).

9.2. Establishing communication with the moisture meter

To receive data from the moisture meter or make any changes to its settings, you need to establish a connection with the moisture meter.

Communication parameters are configured on the "Communication parameters" tab (Fig. 14).

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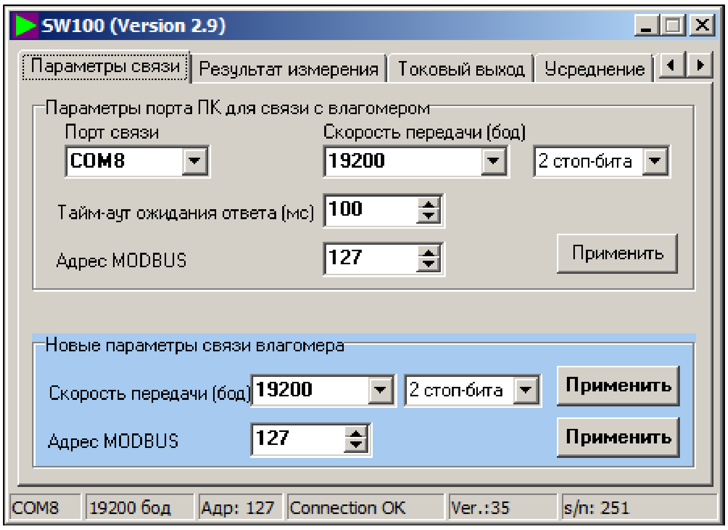

Fig. 14

All necessary settings for establishing a connection are located at the top of the tab. After selecting all the required parameters, click the "Apply" button.

The successful establishment of the connection will be indicated by the message “Connection OK” in the status bar at the bottom of the window.

To change the moisture meter's network address or baud rate, the "New Moisture Meter Communication Parameters" window (shown in blue) contains fields for setting these parameters. After changing the parameters, click the "Apply" button.

A detailed description of the communication settings is given in Chapter 3 of this description.

9.3. The "Measurement Result" tab

This tab (Fig. 15) contains fields that display directly measured parameters: “Moisture”, “*Deceleration factor*” and “Temperature”.

Double-clicking the left mouse button on the "*Deceleration factor*" field allows you to display the permittivity of the material being tested.

The >> button allows you to turn on an additional window with a moisture graph, in which you can see a graph of moisture changes over time.

The "Empty Resonator Calibration" button allows you to fine-tune the moisture meter after installation at the customer's site. For bulk moisture meters of the FIZEPR-SW100.10.4 and similar models, this calibration is mandatory. For more information, see Chapter 5 of this description.

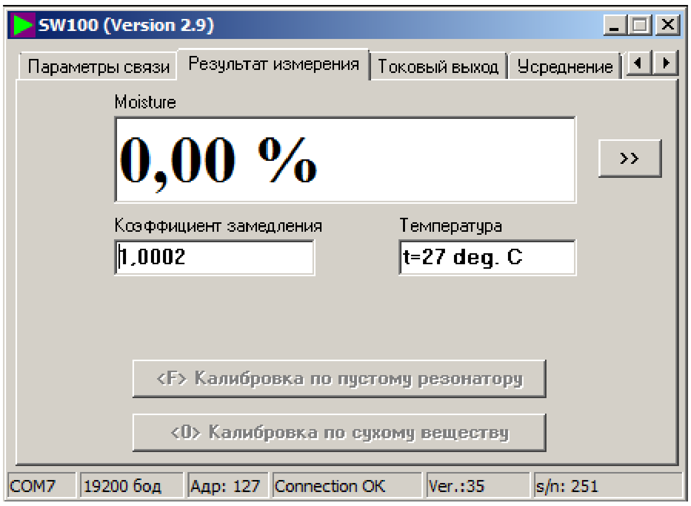

Fig. 15

The "Dry Matter Calibration" button allows you to shift the moisture meter's performance curve without creating a new calibration. This may be necessary when the material being tested doesn't fully match the manufacturer's calibration, but the differences are minor. This calibration requires that the "dry" substance used for calibration be moisture-free. For more details, see section 6.3.

After calibration using dehydrated material, the moisture meter will remember the characteristic shift and will operate accordingly. The calibration tables themselves remain unchanged.

To return the calibration characteristic to its original form (remove the shift), it is necessary to rewrite the calibration tables in accordance with section 6.2.

Calibration using an empty sensor or a “dry” substance should only be performed if you are confident that you are doing it correctly.

The "Empty Resonator Calibration" and "Dry Material Calibration" buttons are only available after entering "Verification Mode." Switching to Verification Mode is done on the "Metrology" tab (see Section 9.5 below, Fig. 18).

9.4. Setting up the current output

This tab (Fig. 16) shows the calibration coefficients of the 4–20 mA current loop: the minimum moisture corresponding to a current of 4 mA, and the maximum corresponding to a current of 20 mA.

To change the scale of the current output, you need to set new values for the minimum and maximum moisture in the “New Values” field and click the “Save” button.

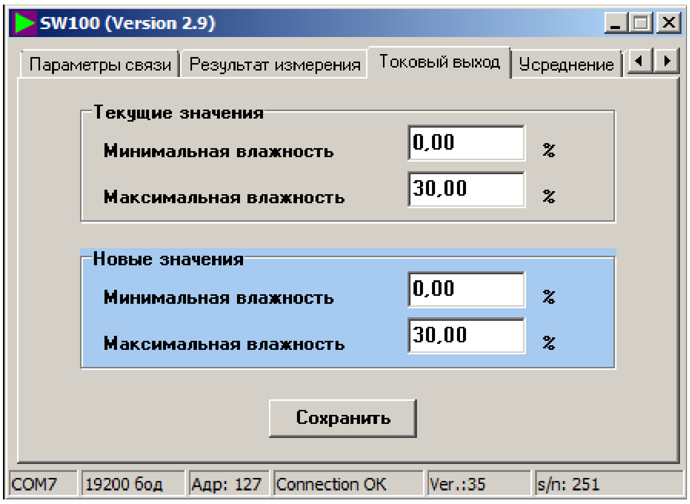

Fig. 16

Note. The settings of the current output parameters do not affect the measurement range and moisture values transmitted via the MODBUS interface and displayed in the corresponding windows of the SW100 and SWPro programs (Fig. 1, 13 and 15).

9.5. The Averaging Tab

On the Averaging tab (Fig. 17), you can change the averaging constant, which specifies the number of measurements used to calculate the average moisture value.

It should be remembered that the measurement time (the time to obtain the most reliable result) is directly proportional to the value of the averaging constant.

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For more details see section 4.3.

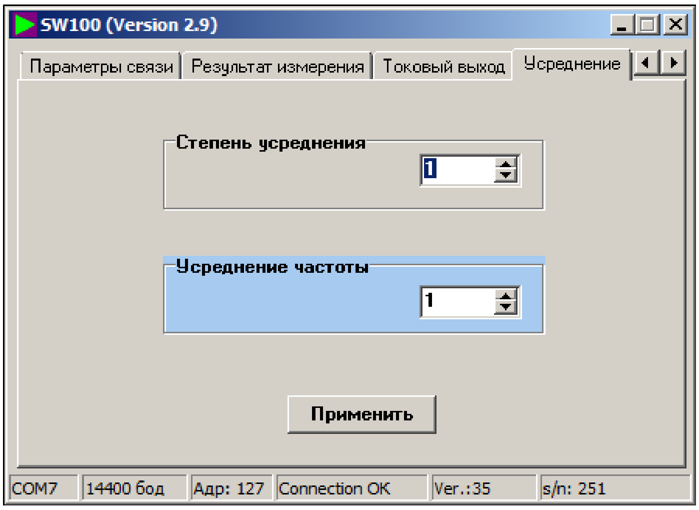


Fig. 17

9.6. Metrology Tab

The “Metrology” tab (Fig. 18) contains four buttons: “Calibration tables”, “Load configuration to device”, “Save device configuration to file”, “Verification mode”.

If you need to change the calibration tables, click on the “Calibration tables” button, which will open a window with the corresponding name (see Chapter 6).

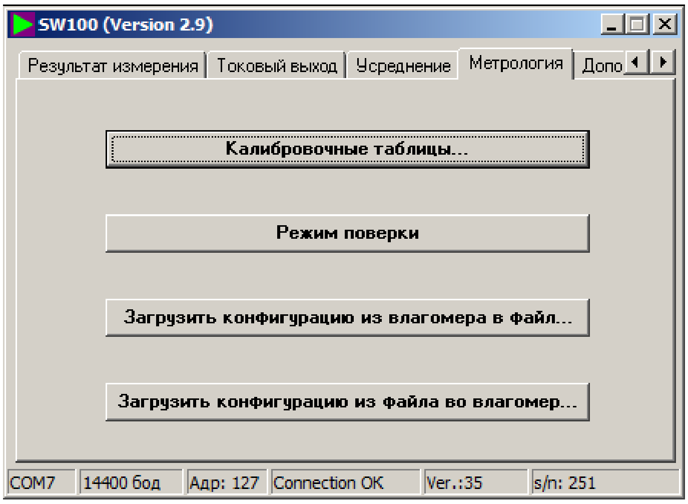


Fig. 18

The "Load Configuration from Moisture Meter to File" button saves the current configuration to a .cfg file, which is used for monitoring and diagnosing the moisture meter's operation. Clicking this button opens a dialog box where you can specify the file name and save location. This file can be sent to the manufacturer for diagnosing the moisture meter's operation. This file also saves the spectrum and moisture change graph, as currently displayed in the corresponding window.

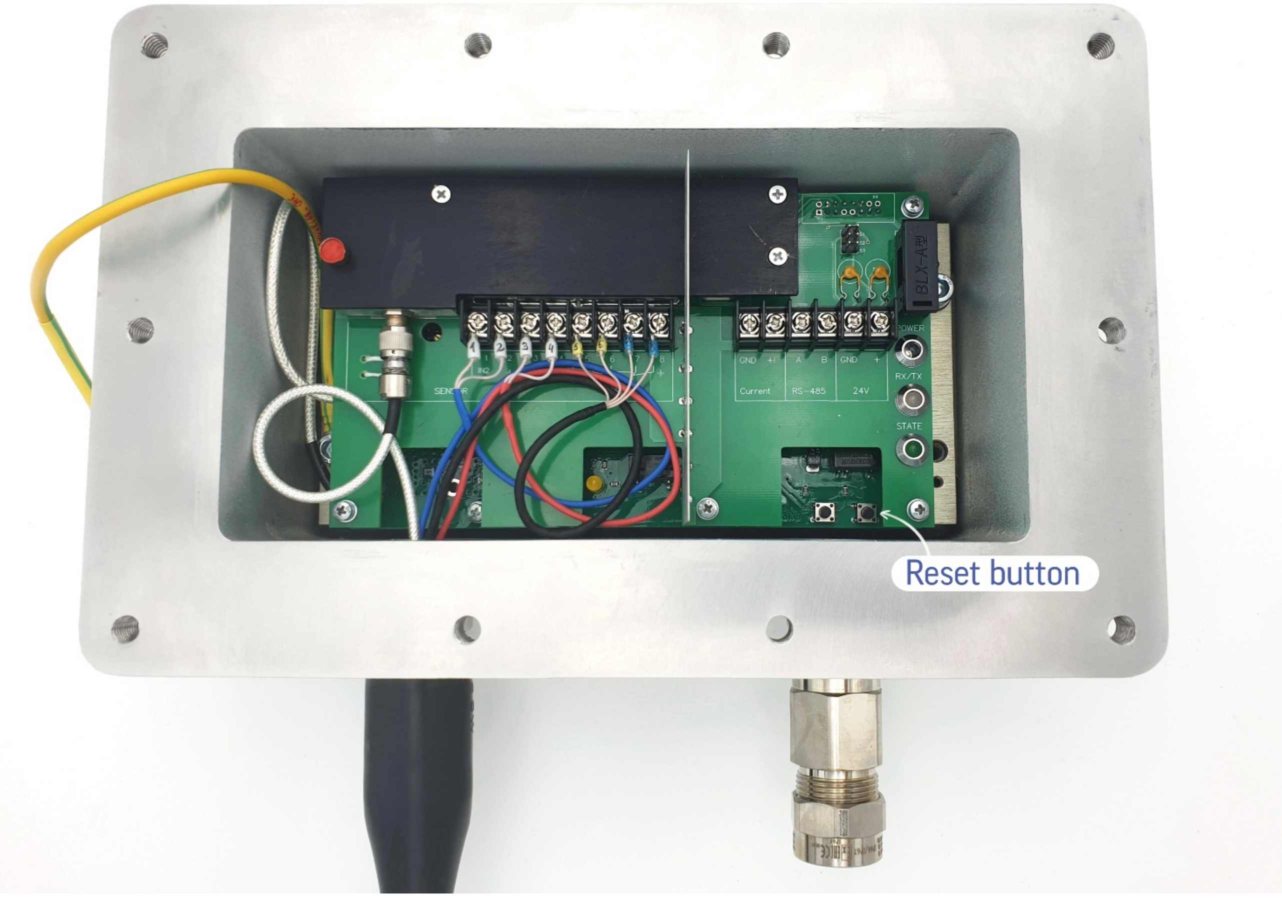
The "Load configuration from file to moisture meter" button is used to load a calibration table into the moisture meter in the form of a file with the ".cfg" extension.

This option can be used to quickly reconfigure the moisture meter, for example, to adjust the calibration to match laboratory analysis results for the material being monitored. For more details, see Chapters 5 and 6.

10. Appendices

Appendix 1

Electronic unit type VIGT.415210.101-02 (explosion-proof design)
with the top cover removed



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