



Spector Sci-Tech LLC

IN-02 METAL STRESS SCANNER USER MANUAL

Russia – Ufa – 2020

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This operating manual allows you to acquaint you with the device and operation of the IN-02 metal mechanical stress scanner (hereinafter referred to as the stress scanner) and sets the rules for its operation, transportation and storage, compliance with which ensures that it is maintained in constant readiness for operation.

1. PURPOSE

1.1. The metal mechanical stress scanner IN-02 of the scanning type is designed for continuous monitoring of the value of the mechanical stress of the metal of a steel product, a metal structure made of structural steel, according to the distribution of the field strength of the residual magnetization of the metal.

1.2. The stress scanner can be used in field, workshop and laboratory conditions.

1.3. Sources of electromagnetic industrial interference must be removed from the stress scanner at a distance of at least 3 m.

1.4. Degree of protection against penetration of solids and water for the stress scanner IP41 according to GOST 14254-80.

1.5. Display of measurement results are digital in units of the measured value of the field strength of the residual magnetization of the metal (mT), or the mechanical stress of the metal (MPa).

1.6. Indication of readouts is liquid crystal graphic display with backlight for working in conditions the natural environment lighting is not enough.

1.7. According to the operating conditions, the stress scanner belongs to the type of climatic version of UHL 3.1 according to GOST 15150-69 and can work steadily when:

- ambient temperature from minus 20°C to plus 70°C,
- relative humidity up to 98 % at +25°C,
- atmospheric pressure from 84 kPa to 106.7 kPa.

2. TECHNICAL SPECIFICATIONS

2.1. The range of measurement of the field strength of the residual magnetization of the metal, mT: **- from 0 to 20.00**

2.2. Measuring range of mechanical stress of metal of steel products, metal structures, MPa: **- from 0 to σ_B**

where σ_B is the ultimate strength of the metal.

2.3. The limit of the allowed basic error in measuring the mechanical stress of the metal of a steel product or metal structure is determined by the formula:

$$0.5 + 0.05 \sigma_i \quad (2.1)$$

where σ_i is the stress scanner readout in MPa.

2.4. The metal stress scanner is powered by 3x18650 elements with total nominal electric voltage of 11.1V.

2.5. Electric current consumed from a freshly charged PP3 element, mA:

- when working without the display backlight **- 16 ± 0.5**
- when working with the display backlight **- 68 ± 0.5**

2.6. Operating time of stress scanner when powered from freshly charged element PP3, in hours, at least: **- 45**

2.7. Time to set the metal stress scanner's operating mode, s, not more than: **- 30**

2.8. Maximum speed of the inspection: **- 7 m/min**

2.9. Time of continuous operation of the stress scanner, h, not less than: **- 12**

2.10. Battery charge time, minutes, not more: **- 250**

2.11. The stress scanner has a memory card with a capacity of more than 60000 measurements.

2.12. The stress scanner has a standard output for transmitting measured information to a personal computer via a mini-USB connector.

2.13. Overall dimensions, mm, not more than:

- Electronic unit (length × width × thickness)

- 210×110×44

- Magnetic measuring unit (length × width × height)

- 260×150×30

- Magnetic measuring unit cable length **-1500±200**

2.14. Weight, g:

- Electronic unit with battery **- 550**

- Magnetic measuring unit **- 1300**

2.15. Average recovery time, h: **- 5**

2.16. Full average service life, years: **- 10**

2.17. Established service life, years: **- 2**

3. DEVICE AND PRINCIPLE OF OPERATION

3.1. The principle of operation of the metal stress scanner is based on the measurement of the magnetic field strength over the surface of the residual magnetized area of the metal (the field strength of the residual magnetization of the metal).

3.2. The block diagram of the stress scanner is shown in Fig.3.1.

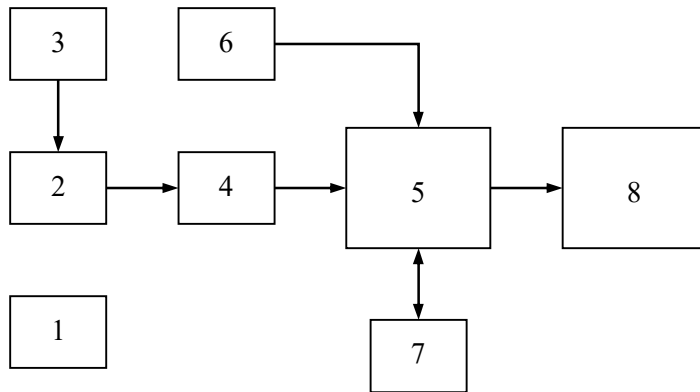


Fig.3.1. Block diagram of IN-02 the metal stress scanner

1 – magnetic measuring unit, 2 – integrated Hall effect sensor chip, 3 – pulse voltage stabilizer, 4 – scaling amplifier combined with a low-pass filter, 5 – microcontroller, 6 – travel distance sensor, 7 – memory card, 8 – liquid crystal display.

The stress scanner works as follows. Magnetization of the metal of a steel product or metal structure is carried out by a constant magnetic field in the process of translational movement of the magnetic measuring unit 1 along the inspected surface of the metal.

The sensor with the integrated sensor 2, which is located in the housing of the magnetic measuring unit 1, is

powered by a constant electric current from the pulse voltage stabilizer 3. The electrical voltage from the output of the sensor 2 is supplied via a scale amplifier combined with a low-pass filter 4 to the input of the analog-to-digital converter of microprocessor controller 5.

To tune out the effect of random changes in ambient temperature on the stress scanner readings, the amplifier 4 has an automatic gain control unit inspected by an electrical signal coming from the output of the temperature sensor, which is located inside the housing of the the sensor 2.

In the case of the magnetic measuring unit 1, a travel distance sensor 6 is installed, the output of which is connected to one of the logical inputs of the microprocessor controller 5.

One of the outputs of the microprocessor controller 5 is connected to the electronic memory card slot 7, the other output of the microprocessor controller 5 is connected to the input of the graphic liquid crystal screen 8.



Fig.3.2. Appearance of IN-02 the metal stress scanner
1 – magnetic measuring unit, 2 – electronic unit.

3.3. The appearance of the stress scanner with a magnetic measuring unit is shown in Fig.3.2.

3.3.1. The IN-02 stress scanner consists of a magnetic measuring unit 1 and an electronic unit 2, which are connected by a flexible cable.

3.3.2. On the front panel of the electronic unit 2 (Fig.3.3) there is a graphic liquid crystal screen 3, a power button 4, a screen backlight button 5, a button for switching the measurement mode 6, a button for recording measurements in electronic memory 7, and a button for holding measurements on the screen 8.

3.3.3. The battery cover is located on the back of the electronic unit 2 housing. In order to remove the batteries from the battery compartment, you need to slightly press the latch of the battery cover and pull it towards you.

3.3.4. In the upper part of the electronic unit housing, there is a panel of connectors (Fig.3.3).

3.3.4.1. Connector 9 is used to connect the magnetic measuring unit 1 to the electronic unit 2 of the IN-02 metal stress scanner.

3.3.4.2. Connector 10 is used to connect a memory card slot (uSD flash card) to the electronic unit of the IN-02 metal stress scanner.

3.3.4.3. The mini-USB 11 connector is used for transmitting measured data from the IN-02 stress scanner to a personal computer and receiving service information from the computer.

3.3.4.4. Connector 12 is used to connect the charger's power adapter to the electronic unit 2 for recharging the battery, which consists of 3x18650 batteries and is located under the cover on the back of the electronic unit 2.

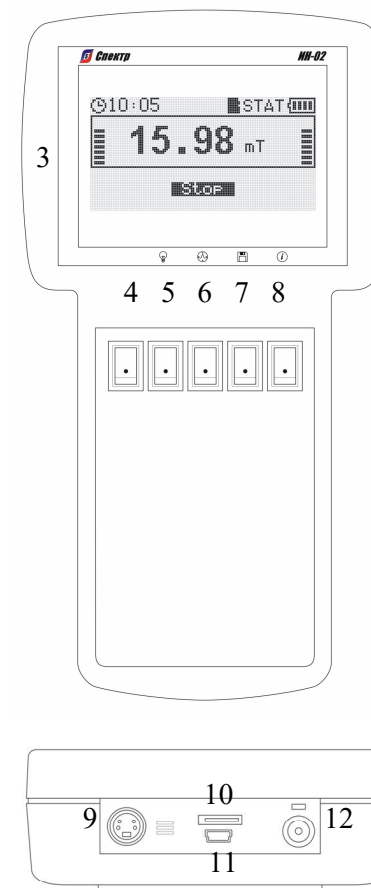


Fig.3.3. Location of controls and connectors of the electronic unit of IN-02 the metal stress scanner

3 – graphic liquid crystal display, 4 – power on button, 5 – screen backlight button, 6 – measurement mode switch button, 7 – measurement recording button, 8 – measurement hold on the screen button, 9 – connector for connecting the magnetic measuring unit, 10 – memory card slot, 11 – mini-USB connector, 12 – connector for charger network adapter.

3.4. Assignment of controls and indication

3.4.1. Graphic liquid crystal screen 3 is used to screen graphic and digital information during the operation of the metal stress scanner.

3.4.2. Button 4 is used to turn on the electric power of the metal stress scanner.

When you turn on button 4, the logo of Spector Sci-Tech LLC appears on the stress scanner screen for a short time with information about the type of stress scanner (Fig.3.4 a).

After setting the measurement mode, the stress scanner screen displays digital readings of the sensor output signal (in mT or MPa), time, battery charge level of the metal stress scanner, and service messages (Fig.3.4 b, c).

3.4.3. Button 5 is used to turn on the stress scanner screen backlight. When you turn on button 5, the screen is illuminated with additional light to improve the screen of digital readings.

3.4.4. Button 6 is used to switch the measurement mode of the metal stress scanner.

When button 6 is enabled, the stress scanner switches to dynamic measurement mode. In dynamic measurement mode, the stress scanner screen displays a digital reading and a graph of the change in the value of the sensor output signal during continuous scanning of the metal surface (in mT or MPa), the set measurement mode, the battery charge level, the current time and service messages (Fig.3.4 c).

When button 6 is turned off, the stress scanner switches to static measurement mode. In the static measurement mode, the stress scanner screen displays a digital indication of the sensor output signal value (in mT or MPa), measurement mode, battery charge level, the current time and service messages (Fig.3.4 b).

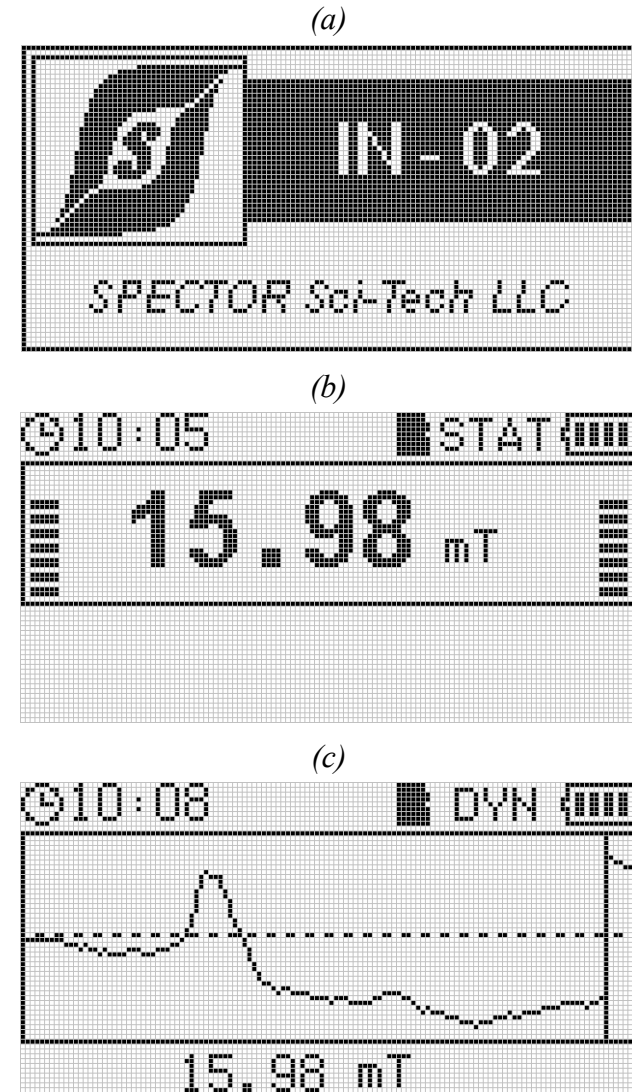


Fig.3.4. Displaying information on the IN-02 stress scanner screen when the electric power is turned on (a) and after the static (b) and dynamic measurement modes are set (b)

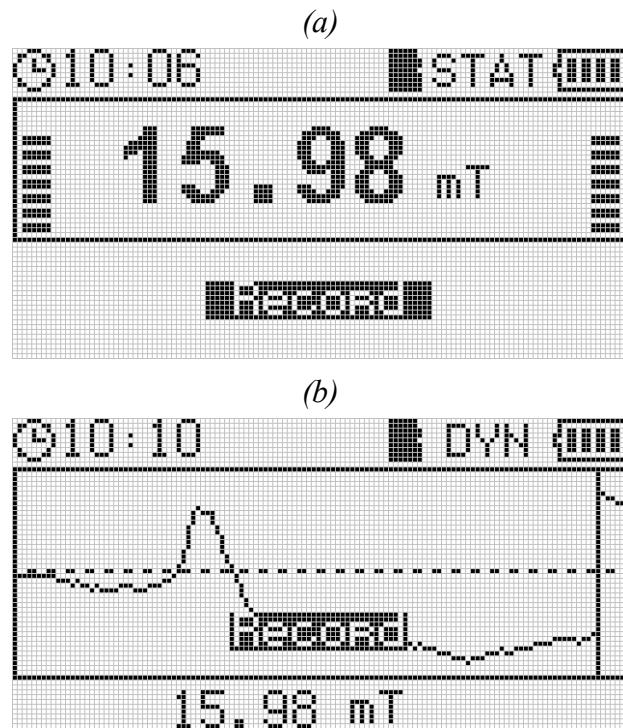


Fig.3.5. Displaying information on the IN-02 stress scanner screen when recording Sensor readings to the memory in static (a) and dynamic (b) modes

Note: in the static mode of the metal stress scanner, the electronic unit can be connected to the IN-01m stress scanner sensor instead of the magnetic measuring unit.

The connection of this Sensor expands the scope of the stress scanner due to the possibility of:

- magnetic inspection of the stressed state of metal of steel products and structures with a complex surface shape;
- inspection of the tightening force of steel studs and bolts in threaded connections;

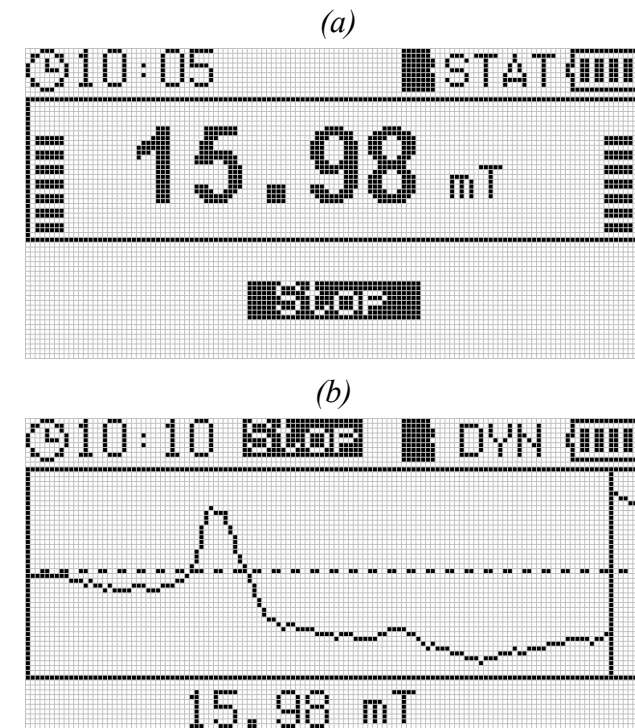


Fig.3.6. Displaying information on the IN-02 stress scanner screen when the measurement hold button is pressed in the static (a) and dynamic (b) modes

- determination of the group of structural steels that make up metal structures (ordinary quality steel, high-quality steel, alloy steel, etc.);

- operational evaluation of the structural steel grade of the metal structure.

3.4.5. Button 7 is used to save measurements in the metal stress scanner's electronic memory.

3.4.5.1. A single on-off button 7 in static measurements (off button 6) in the electronic memory of the stress scanner is

recorded on screen digital indication value captured from sensor (Fig.3.5 a).

3.4.5.2. When the button 7 is turned on in the dynamic measurement mode (when the button 6 is turned on), the electronic memory of the stress scanner continuously records the readings obtained when scanning the metal surface and displayed on the stress scanner screen as a graph (Fig.3.5 b).

After the button 7 is turned off, the recording of the transmitter readings in the electronic memory of the stress scanner stops.

3.4.6. Button 8 is used to hold the measurements on the screen. When the button 8 is turned on, the continuous measurement of the Sensor signal is stopped, and the "Stop" message appears on the stress scanner screen (Fig.3.6). When the button 8 is turned off, the continuous measurement starts again, and the "Stop" sign on the screen disappears.

3.4.7. When USB data cable connected to the USB port of a personal computer to the mini-USB 11 connector, information about establishing a connection between the IN-02 metal stress scanner and the personal computer appears on the screen (Fig.3.7).



Fig.3.7. Displaying information on the IN-02 stress scanner screen when connected to personal computer

Using the IN-01M CONNECT application pre-installed on a personal computer, the measured information from the metal stress scanner's memory is transmitted via a cable and stored in the personal computer's memory.

3.4.8. When the charger's network adapter is connected to connector 12 of the electronic unit, the stress scanner screen displays graphical information about the process of charging the battery (Fig.3.8).



Fig.3.8. Indication of the battery charge process on the IN-02 stress scanner screen

When the battery is charged, the stress scanner screen will screen "Charging completed", which means that the network adapter can be disconnected from the metal stress scanner.

3.5. Magnetic measuring unit

3.5.1. The magnetic measuring unit of the stress scanner is used for magnetizing the inspected section of metal of a steel product or metal structure with a constant magnetic field in the process of translational movement along the inspected surface of the metal.

3.5.2. The magnetizing unit of the magnetic measuring unit of the stress scanner is non-volatile and is a system of

permanent magnets made of ferrite iron and having high magnetic energy. The magnetic poles of the magnetic measuring unit are protected by a non-magnetic overlay made of "Melchior" type alloy.

3.5.3. The Hall effect sensor is located in the housing of the magnetic measuring unit next to the magnetizing system and measures the field strength of the residual magnetization above the metal surface.

The output of the Hall effect sensor is connected to a flexible electrical cable that has a connector for connecting to the electronic unit of the metal mechanical stress scanner.

3.5.4. To bring the magnetic measuring unit of the stress scanner into forward motion, the housing is equipped with a handle.

4. SAFETY INSTRUCTIONS

4.1. Persons who have studied sections 2-5 of this operating manual, as well as those who have received instructions on safety and fire safety when working with electrical installations, are allowed to operate, maintain and repair the stress scanner.

4.2. Replacement of elements of the electrical diagram of the stress scanner at the setup stage should be carried out when the power supply voltage is switched off.

4.3. When working with the stress scanner, the requirements of the *Rules of technical operation of electrical installations of PTE-84 consumers* and *Safety rules for the operation of electrical installations of PTB-84 consumers* must be met.

5. PREPARING THE METAL STRESS SCANNER FOR WORK

Preparation of the stress scanner for work includes preparation of the electronic unit, magnetic measuring unit and preparation of the inspected metal surface of the steel products and structures.

5.1. Before turning on the stress scanner after transporting it in cold weather, keep the stress scanner under normal conditions of use for at least 2 hours.

5.1.2. Insert freshly charged 18650 batteries into the battery compartment of the electronic unit, observing the polarity of the contacts.

5.1.3. Connect the magnetic measuring unit to the electronic unit of the IN-02 stress scanner using the connector, inserting the cable part of the connector into the instrument part of the connector until it stops.

5.1.4. Turn on the IN-02 metal mechanical stress scanner by pressing the power button. In this case, the screen should light up, where the service information appears and the value of the measured signal is set (see section 3.4.2).

5.1.5. In low light conditions, to improve the visibility of the readings, turn on the screen backlight button.

5.2. Preparation of the magnetic measuring unit consists in external inspection and cleaning of the surface of the magnetic poles, Hall effect sensor from stuck metal particles and dirt. To do this, use a rag.

5.3. Preparation of the inspected metal surface of a steel product or metal structure consists in pre-cleaning it from the remnants of insulation, dirt, oil and metal particles. To do this, use an appropriate tool, rag, sandpaper, or file.

6. OPERATION PROCEDURE

6.1. Measurement of mechanical stress of metal of steel products, metal structures

Measurement of the mechanical stress of the metal of a steel product or metal structure consists in magnetizing the inspected area of the metal with a constant magnetic field, measuring the strength of the field of residual magnetization over this surface, and evaluating the mechanical stress of the metal.

Note: the dynamic measurement mode of the stress scanner is the main mode of operation for continuous monitoring of the stress-strain state of the metal of extended steel products and structures.

The static measurement mode of the stress scanner is auxiliary and is used mainly to refine location, verify and confirm the surface of a steel product or structure where an area with an increased stressed state of the metal is detected.

6.1.1. Enable the dynamic measurement mode of the metal stress scanner. Install the magnetic measuring unit at the beginning of the inspected area of the metal surface of the steel product, metal structure and smoothly bring it into translational motion along the inspected surface.

6.1.2. Measure the values and get a graph on the stress scanner screen of the distribution of the field strength of the residual magnetization of the metal (in mT) on the inspected surface of the steel product, metal structure.

6.1.3. Based on the analysis of the graph of the distribution of the residual magnetic field strength of the metal on the inspected surface of the steel product, structure:

- presence of areas with increased stressed state of the metal;

- coordinates of the location of areas with increased stressed state of metal on steel products, metal structures;

- actual mechanical stress value in the area with increased stressed state of the metal.

6.1.3.1. The stress scanner readings in the area with increased stress-strain state of the metal will have the highest values.

6.1.3.2. The location of the amplitude on the graph of field strength distribution of the residual magnetization of metal will correspond to the location of the region with the greatest mechanical stress of the metal on the surface of steel products, steel structures.

6.1.3.3. To estimate the value of mechanical stress in an area with an increased stress-strain state of the metal:

- determine the value of the signal amplitude according to the graph on the stress scanner screen corresponding to the area with an increased stressed state of the metal;

- set the value of the mechanical stress of the metal (in MPa) for the received signal amplitude in the area with an increased stressed state of the metal. For this purpose, the curves of the dependence of the field strength of the residual magnetization on the value of the mechanical stress of the metal, previously obtained on standard samples of structural steels, are used.

Note: if the calibration constants previously obtained for structural steels of different grades are stored in the electronic memory of the stress scanner during its manufacture (see Appendix), the readout the stress scanner screen will correspond to the value of the mechanical stress of the metal for this steel grade (in MPa).

6.1.4. The value of the signal amplitude in an area with an increased stressed state of the metal can also be estimated in the static measurement mode of the metal stress scanner.

6.1.4.1. To enable the static measurement mode of the metal stress scanner. Re-install the magnetic measuring unit on the metal surface of a steel product or metal structure in an area with an increased stressed state of the metal and smoothly bring it into translational motion along the inspected surface.

6.1.4.2. Above the surface with the highest mechanical stress of the metal, the digital readings on the stress scanner screen take the highest values.

On the basis of these values, according to step 6.1.3, the value of the mechanical stress of the metal in this area of the surface of the steel product, metal structure is estimated.

6.1.5. To measure the mechanical stress of the metal on another section of the steel product, the metal structure should repeat the operations prescribed in steps 6.1.1-6.1.4.

6.2. Charging or replacing batteries

6.2.1. As the charge of batteries decreases, in the charge level screen area (see Fig.3.5) the current charge level is set, and if it is lowered relative to the acceptable threshold value, the *Recharge battery!* message appears on the screen. When you reach that level you need to charge batteries, which in the electronic connector block to connect the power adapter cable of the charger and connect it to the network.

6.2.2. If it is necessary to completely replace the batteries, turn off the power of the metal stress scanner, open the battery cover of the electronic unit and remove the batteries that have used up their life.

Insert freshly charged batteries, observing the polarity of the contacts, and close the battery cover.

6.3. Working with metal stress scanner memory

6.3.1. The stress scanner is equipped with a memory card to quickly save the results of a large number of measurements. The measured values of the output signal of the Sensor are sequentially recorded in the electronic memory of the stress scanner.

6.3.2. To record the measured signal reading displayed on the screen into the stress scanner memory is switched on and off once (see Fig.3.3). In the process of recording the stress scanner readings in electronic memory, the stress scanner screen displays the inscription *Record*. After the button 7 is turned off, the recording of readings in the electronic memory of the stress scanner stops.

6.3.3. To record the measured signal readings displayed on the screen in dynamic measurement mode (when the button 6 is enabled) to the memory card, the recording button is enabled in memory 7 (see Fig.3.3). In the process of recording stress scanner readings in electronic memory, the stress scanner screen displays the inscription *Record* (Fig.3.5 b)

The measured data is saved to the built-in memory card of the IN-01m metal mechanical stress scanner in files of the DDMMYYYY type CSV, where DD is the current day, MM is the month, and YYYY is the year.

The CSV (Comma Separated Values) format is a common standard supported by MS Excel and compatible with any text editor.

The data file consists of several series of measurements that represent a sequence of records of measurement results made continuously in a single pass (see table 6.1).

6.3.4. Transfer of data recorded in the metal stress scanner electronic memory to a personal computer.

6.3.4.1. Turn on the stress scanner power with button 4.

Structure of IN-02 stress scanner data files

Table 6.1

Beginning of file		
Measurement series 1	Measurement time 1	Measurement 1
	Measurement time 2	Measurement 2
	...	...
	Measurement time N	Measurement N
Record separator (empty string)		
Measurement series 2	Measurement time (N+1)	Measurement (N+1)
	Measurement time (N+2)	Измерение (N+2)
	...	...
	Measurement time (N+M)	Measurement (N+M)
Record separator (empty string)		
...	...	...
End of file		

6.3.4.2. Turn on the personal computer and launch the IN-01m CONNECT application.

6.3.4.3. Insert the connection cable into the mini-USB connector of the electronic unit and connect it to the corresponding connector of the personal computer, while the stress scanner screen displays a message about establishing a communication channel with the personal computer through the mini-USB connector of the electronic unit (Fig.3.7).

6.3.4.4. In the IN-01m CONNECT application, open the File menu and select *Receive data*.

After receiving information from the electronic memory of the metal stress scanner, a graph of the distribution of the measured values in the Cartesian coordinate system appears on the screen of the personal computer.

6.3.4.5. To select the type of graphical screen of the measured stress scanner values and to save them on a personal computer, use the corresponding menu items of the IN-01m CONNECT application, which are described in the program's user guide.

6.3.5. To disconnect the stress scanner from the personal computer, disconnect the cable from the mini-USB connector of the electronic unit.

7. MAINTENANCE SERVICE

7.1. Maintenance of the stress scanner is performed by technical personnel from the departments of the control and measuring devices service (KIP) or similar.

7.2. Maintenance of the stress scanner consists of a preventive inspection, scheduled maintenance, and routine maintenance.

7.3. The frequency of planned inspections is set depending on the production conditions, but at least once a month. During a routine inspection, the fastening of all components, the condition of controls and paint coatings, and the integrity of the measuring transducer are checked.

7.4. Scheduled maintenance is performed after the warranty period expires and then at least once a year.

Repairs include visual inspection of the stress scanner, inspection of the internal state of the installation, verification of the reliability of the contact connections, and removal of dust and dirt. At the same time, all types of work are performed, the need for which was identified during the preventive inspection of the stress scanner. In the event of failure of the electronic components of the stress scanner, they must be replaced.

7.5. Current repairs are made during the operation of the stress scanner. At the same time, faults detected during routine inspection are eliminated by replacing or restoring individual parts of the stress scanner (replacing radio elements, restoring broken electrical connections, etc.).

8. TROUBLESHOOTING

8.1. Possible malfunctions and ways to fix them are shown in table 8.1.

Table 8.1.

Possible malfunction	Probable cause	Remedy
When the power is turned on, there is no information on the screen	1. The battery is low.	Charge the battery. Replace the battery.
	2. Poor contact in the power supply circuit.	Clean the contacts in the battery compartment.
When the stress scanner is powered on, the FAT32 error status occurred 	The file system of the memory card slot is different	Remove the memory card from slot and format its file system on the computer.
When the power is turned on, the undefined card status occurred 	Appears on the screen if memory card is Faulty	Replace the memory card.
When the power is turned on, "No memory card"	Appears on the screen if no card presented inside of the slot 10	Insert a memory card into slot 10.
When you click the record measurements button, the message "Error!" appears	Faulty memory card	Replace the memory card.

Appendix. Mechanical and magnetic parameters of frequently arrived Russian grades of structural steels

Table A.1

Steel grade	σ_B , MPa	σ_Y , MPa	H_c , A/cm		
			$\sigma=0$	$\sigma=\sigma_Y$	$\sigma=\sigma_B$
Ст 3	350	210	1.7	5.0	6.0
09Г2С	470	325	3.0-4.0	7.5-7.8	9.5
17Г1С	520	350	4.0	10	11
Steel 20	420	230	3.8-4.5	8.0-10.5	12.0-13.5
10XCHД	540	400	4-5	11.0-11.5	12-14.5
Ст Дс	650	400	5-6	8.0-8.5	10-11

Table A.2

Steel grade	σ_B , MPa	σ_Y , MPa	H_r , mT		
			$\sigma=0$	$\sigma=\sigma_Y$	$\sigma=\sigma_B$
Ст 3	350	210	0.62	1.69	2.0
09Г2С	470	325	1.06-1.38	2.43-2.79	2.98
17Г1С	520	350	1.38	3.12	4.12
Steel 20	420	230	1.32-1.54	2.57-3.25	3.63-4.0
10XCHД	540	400	1.38-1.7	3.38-3.5	3.63-4.24
Ст Дс	650	400	1.7-2.0	2.57-2.71	3.12-3.38

Accepted designations:

σ_Y – metal yield limit (MPa),

σ_B – the strength limit of the metal (MPa),

H_c – coercive force of the metal (A/cm),

H_r – the field strength of the residual magnetization of the metal (mT).

