Spector Sci-Tech LLC

IN-01m
METAL STRESS INDICATOR

USER MANUAL

Russia – Ufa – 2020

CONTENTS

Page

1. Purpose 4
2. Technical specifications 5
3. Device and principle of operation 7
4. Safety instructions 13
5. Preparing the metal stress indicator for work 13
6. Operating procedure 14
   6.1. Measuring the mechanical stress of metal of steel parts and metal structures 14
   6.2. Measuring the tension of steel studs and bolts 15
   6.3. Charging or replacing the battery 16
7. Maintenance service 19
8. Troubleshooting 20
9. Transportation and storage rules 22

Appendix. Mechanical and magnetic parameters of frequently arrived Russian grades of structural steels 23

This operating manual allows you to acquaint you with the device and operation of the IN-01m metal mechanical stress indicator (hereinafter referred to as the stress indicator) 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 IN-01m metal mechanical stress indicator is intended for indirect estimation of the value of the metal mechanical stress of a local section of a steel product or a metal structure made of structural steel by the value of the field strength of the residual magnetization of the metal.

1.2. The stress indicator can also be used to measure the tightening force of steel studs and bolts of housing equipment.

1.3. The stress indicator can be used in field, workshop and laboratory conditions.

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

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

1.6. 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).

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

1.8. According to the operating conditions, the stress indicator 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 20ºC to plus 70ºC,

- relative humidity up to 98 % at +25ºC,

- 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:

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

where σ_i is the stress indicator readout in MPa.

2.4. The metal stress indicator is powered by a PP3 element with nominal electric voltage of 9V.

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

- when working without the display backlight **- 7 ± 0.5**

- when working with the display backlight **- 16 ± 0.5**

2.6. Operating time of stress indicator when powered from freshly charged element PP3, in hours, at least: **- 20**

2.7. Time to set the metal stress indicator's operating mode, s, not more than: **- 10**

2.8. Time of one measurement, s, not more than: **- 5**

2.9. Time of continuous operation of the stress indicator, h, not less than: **- 16**

2.10. Battery charge time, minutes, not more: **- 80**

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

2.12. The stress indicator 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) **- 136×72×28**

- Sensor (diameter × length) **- 20×15**

- Sensor cable length **-950±50**

- Magnetizing device (diameter × length) **- 20×190**

2.14. Weight, g:

- Electronic unit with battery **- 200**

- Sensor with cable **- 40**

- Magnetizing device **- 300**

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 indicator 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 indicator is shown in Fig.3.1.

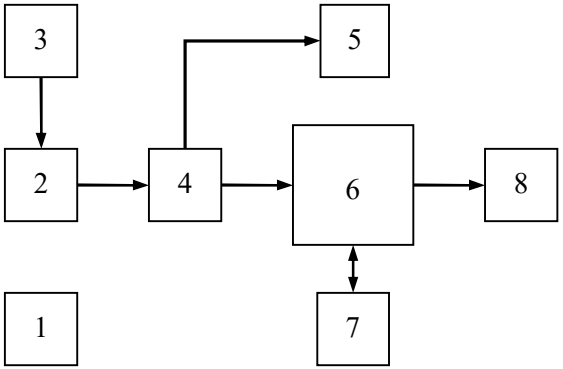

Fig.3.1. Block diagram of IN-01m the metal stress indicator

1 – magnetizing device, 2 – integrated Hall effect sensor chip, 3 – pulse voltage stabilizer, 4 – scaling amplifier combined with a low-pass filter, 5 – threshold indication unit, 6 – microcontroller, 7 – memory card, 8 – alphanumeric liquid crystal display.

The stress indicator works as follows. Magnetization of the metal of a steel product, metal structure is carried out by the magnetic field of a single-pole magnetizing device 1.

The Sensor with the integrated chip of the Hall effect sensor 2 is powered by a constant electric current from a stabilized pulse voltage source 3. Voltage from the output of the Hall effect sensor 2 via a scale amplifier combined with a

low-pass filter 4 to the input of the signal level exceeding light indication unit 5 and the input of the analog-to-digital converter of the microprocessor controller.

To detach from the influence of temperature changes the amplifier 4 has an automatic gain control unit controlled by an electrical signal coming from the output of the temperature sensor, which is located inside the housing of the Hall sensor integrated circuit 2.

The voltage from the output of the scale amplifier 4 is supplied to the comparator of the light indication unit 5 for exceeding the signal level corresponding to the metal yield point, and the input of the analog-to-digital converter of the microprocessor controller 6.

One of the outputs of the microprocessor controller 6 is connected to the electronic memory card 7, the other output of the microprocessor controller 6 is connected to the input of the alphanumeric liquid crystal display 8.

3.3. The appearance of the stress indicator with a Sensor and a magnetizing unit is shown in Fig.3.2.

Fig.3.2. Appearance of IN-01m the metal stress indicator
1 – magnetizing unit, 2 – electronic unit, 3 – sensor.

3.3.1. The stress indicator consists of a magnetizing device 1, an electronic unit 2, and a sensor 3 connected to the electronic unit via a connector.

3.3.2. On the front panel of the electronic unit, there is a digital liquid crystal display 4, a power button 5, a button for turning on the device's screen backlight 6, a button for recording the measurement in memory 7, and a button for displaying the current date and time 8 (Fig.3.3).

3.3.3. The battery cover is located on the back of the electronic unit housing. To remove the battery from the battery compartment, press the battery cover slightly and slide it down.

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 for connecting to the electronic unit of the Sensor.

3.3.4.2. Connector 10 is used for placing a memory card (flash card) in the electronic block.

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

3.3.4.4. Connector 12 is used to connect the charger's network adapter to the electronic unit for recharging the battery (battery).

3.4. The purpose of the controls of stress indicator

3.4.1. The liquid crystal display 4 is used to display information during the operation of the stress indicator.

3.4.2. Button 5 is used to turn on the electric power of the stress indicator.

When you turn on button 5 information about the type of stress indicator appears on its screen for a short time and its serial number (Fig.3.4 a).

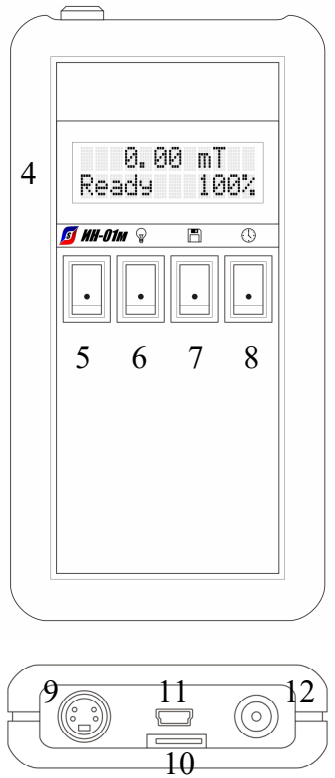

Fig.3.3. Location of controls and connectors of the electronic unit of IN-01m the metal stress indicator

4 – alphanumeric liquid crystal display, 5 – power button, 6 – screen backlight button, 7 – button to perform recording measurements in memory, 8 – button for displaying the date and time, 9 – sensor connector, 10 – memory card slot, 11 – mini-USB connector, 12 – connector for charger network adapter.

After setting the measurement mode, the stress indicator screen displays a digital indication of the output signal of the sensor (mT or MPa) the battery charge level of the stress indicator in % , and its ready state (Fig.3.4 b).

(a) *(b)*

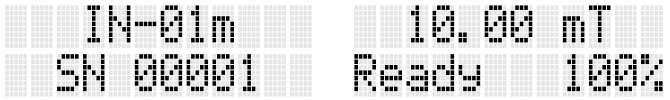

Fig.3.4. Displaying information on the IN-01m stress indicator screen when the power is turned on (a) and after the measurement mode is set (b)

3.4.3. Button 6 is used to turn on the stress indicator screen backlight. When you turn on button 6, the screen is illuminated with additional light to improve the display of digital stress indicator readouts.

3.4.4. Button 7 is used to save measurements to the electronic memory of the stress indicator. When the button 7 is turned on or off, the current transmitter reading displayed on the screen is recorded in the stress indicator memory.

3.4.5. When connecting a cable connected to the USB port of a personal computer to the mini-USB 11 connector, information about establishing a connection with the personal computer appears on the stress indicator screen (Fig. 3.5).

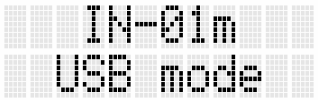

Fig.3.5. Displaying information on the IN-01m stress indicator screen when connected to a personal computer

Using of the IN-01m Connect software application pre-installed on a personal computer, the measured information from the stress indicator's electronic memory is transmitted over a cable and stored in the personal computer's memory.

3.4.6. Button 8 displays the current date and time of stress indicator on the screen.

3.5. Magnetizing unit

3.5.1. The magnetizing unit of the stress indicator is used for magnetizing the local metal section of a steel product or metal structure with a constant magnetic field, the intensity vector of which is directed perpendicular to the metal surface.

3.5.2. The magnetizing device is non-volatile, single-pole, rod type. It uses permanent magnets made from rare earth metals.

3.5.3. The pole of the magnetizing device is protected by an overlay to ensure convenience in the process, the handle of the magnetizing device is provided with a strap.

3.6. Sensor

3.6.1. The stress indicator sensor is designed to measure the field strength of the residual magnetization of metal over the surface of a local section of a steel product or metal structure.

3.6.2. The sensor contains a precision integrated Hall Effect sensor chip and a precision integrated temperature sensor chip with an analog signal output, which are located in a single housing.

3.6.3. The Hall sensor plane is located in the center of the transducer housing parallel to the working surface at a distance of 0.5 mm from it.

3.6.4. To measure the field strength of the residual magnetization of the metal, the center of the working surface of the stress indicator sensor is set in the middle of the residual magnetized area of the metal.

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 indicator.

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

4.3. When working with the stress indicator, 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 INDICATOR FOR WORK

Preparation for work includes preparation of the stress indicator, the magnetizing device and preparation of the inspected metal surface of a steel product, a metal structure.

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

5.1.2. Attach to the battery compartment freshly charged battery type PP3, with respect to the polarity of the contacts.

5.1.3. Connect the sensor to the electronic unit using the connector by inserting the cable part of the connector into the instrument part of the connector until it stops.

5.1.4. Turn on the stress indicator by pressing the power button. In this case, the stress indicator screen should light up, where the service information first appears, then the value of the measured signal of the Sensor is set (see section 3.4.2 of current document).

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

5.2. Preparation of the magnetizing unit consists in external inspection and cleaning of the surface of the magnetic pole from stuck metal particles and dirt. To do this, use a rag.

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

6. OPERATING PROCEDURE

6.1. Measuring the mechanical stress of metal of steel parts and metal structures

Measurement of the mechanical stress of the metal of a steel product or metal structure consists in preliminary magnetization of a local section of metal by a constant magnetic field of the magnetizing device and measurement of the field strength of the residual magnetization over this surface.

6.1.1. Install the pole of the magnetizing device on the local area of the metal surface of the steel product, metal structure and smoothly remove it from the magnetized surface in the vertical direction.

Note: lateral displacement of the magnetic pole of the magnetizing device is not allowed to reduce the accuracy of measurements.

If the magnetic pole is allowed to shift laterally on the metal surface when the magnetizing device is removed, repeat the magnetization operation in accordance with step 6.1.1.

6.1.2. Install the stress indicator sensor in the middle of the magnetized area of the metal surface.

6.1.3. To measure the field strength of the residual magnetization on the surface (in mT) and to assess the value of the mechanical stress of the metal based on the dependence of the field strength of the residual magnetization on the magnitude of mechanical stress of the metal (see the Appendix), appropriate to the grade of steel.

If the calibration constants programmed into the memory of the stress indicator in manufacture, the display on the stress indicator screen will correspond to the value of the mechanical stress of the metal for this steel grade (in MPa).

6.1.4. To measure the mechanical stress of the metal on another section of the steel product, the metal structure should repeat the operation according to steps 6.1.1-6.1.3.

6.2. Measuring the tension of steel studs and bolts

Measuring the tension of steel studs and bolts of threaded connections consists in pre-magnetizing their end surface with a constant magnetic field of the magnetizing device and measuring the field strength of the residual magnetization of the metal above it.

6.2.1. Install the magnetizing device on the end surface of the steel stud or bolt and smoothly remove it from the magnetized surface in a perpendicular direction.

Note: lateral displacement of the magnetic pole of the magnetizing device is not allowed to reduce the accuracy of measurements.

If the magnetic pole is allowed to shift laterally on the metal surface when the magnetizing device is removed, repeat the magnetization operation according to step 6.2.1.

6.2.2. Install the stress indicator sensor in the middle area of the magnetized end surface of the steel stud or bolt.

6.2.3. To measure the field strength of the residual magnetization on the surface (in mT) and to assess the value of the mechanical stress of the metal (torque) on the basis of dependence of the field strength of the residual magnetization

on the magnitude of mechanical stress of the metal (see the Appendix) for the corresponding grades of steel studs, bolts.

6.2.4. When checking a large number of steel studs, bolts located on a separate unit of the body product, the operations according to steps 6.2.1-6.2.3 should be performed for each steel stud, bolt.

Note: uniformity of the tightening force of all steel studs, bolts is achieved when the stress indicator readouts on all controlled studs, bolts have approximately the same value within the measurement error.

6.3. Charging or replacing the battery

6.3.1. As the resource of the PP3 type battery is used up, the stress indicator screen in the zone indicating the battery charge level (see Fig.3.4 b) set the current charging level in %.

6.3.2. When the battery charge level decreases relative to the allowed threshold value, the stress indicator screen will display a flashing message *Recharge battery!* (Fig.6.1).

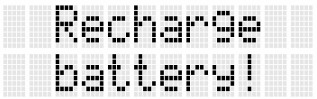

Fig.6.1. Message on IN-01m the stress indicator about the need to charge or replace the battery

When you reach that level you need to charge the battery, which in the electronic connector block to connect the power adapter cable of the charger and connect it to the network voltage of 220V, 50 Hz.

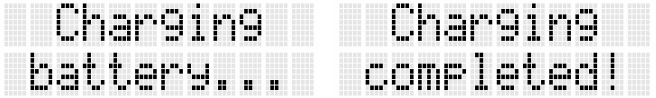

Fig.6.2. Indication of the battery charge process on the IN-01m stress indicator screen

6.3.3. If it is necessary to completely replace the battery, turn off the power of, open the battery cover of the electronic unit and remove the used PP3 battery.

Insert a freshly charged battery, observing the polarity of the contacts, and close the battery cover of metal stress indicator.

6.4. Working with metal stress indicator memory

6.4.1. The stress indicator 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 indicator.

6.4.2. To record the measured signal reading displayed on the screen into the stress indicator memory is switched on and off once (see Fig.3.3). In the process of recording the stress indicator readings in electronic memory, the stress indicator screen displays the inscription *Writing*.

The measured data is saved to the built-in memory card of the IN-01m metal mechanical stress indicator 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.

Structure of IN-01m stress indicator data files Table 6.1

Beginning of file	
Measurement time 1	Measurement 1
Measurement time 2	Measurement 2
…	…
Measurement time N	Measurement N
End of file	

The data file represents sequentially recorded measurement results (see table 6.1).

6.4.3. Transfer of data recorded in the stress indicator's electronic memory to a personal computer.

6.4.3.1. Turn on IN-01m the metal stress indicator power with button 5.

6.4.3.2. Turn on the personal computer and launch the pre-installed software application IN-01m.

6.4.3.3. Insert a connecting cable into the mini-USB connector of the stress indicator's electronic unit and connect it to the corresponding connector of the personal computer. A message appears on the stress indicator screen about establishing a communication channel with the personal computer via the mini-USB connector of the electronic unit of the stress indicator (Fig.6.3).

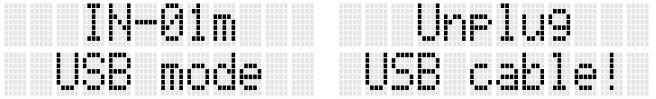

Fig.6.3. Indication of data exchange of the IN-01m metal stress indicator with a personal computer via USB

6.4.3.4. In the IN-01m CONNECT software application, open the *File* menu and select *Receive data*. After receiving information from the electronic memory of the stress indicator, a graph of the distribution of the measured values of the Sensor in the Cartesian coordinate system appears on the screen of the personal computer.

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

6.4.3.6. To stop transmitting data from the metal mechanical stress indicator to the personal computer,

disconnect the cable from the mini-USB connector of the electronic indicator unit.

7. MAINTENANCE SERVICE

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

7.2. Maintenance of the stress indicator 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 indicator, 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 indicator. In the event of failure of the electronic components of the stress indicator, they must be replaced.

7.5. Current repairs are made during the operation of the stress indicator. At the same time, faults detected during routine inspection are eliminated by replacing or restoring individual parts of the stress indicator (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 stress indicator screen	1. The battery is low. 2. Poor contact in the power supply circuit.	Charge the battery. Replace the battery. Clean the contacts in the battery compartment.
When metal stress indicator is powered on, the message "FAT32!"	The file system of the memory card is different	Remove the memory card and format its file system on the computer.
When the power is turned on, the message "SD error"	Appears on the screen if memory card is Faulty	Replace the memory card.
When the power is turned on, "No 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 measurement button, the message "Error!" appears	Faulty memory card	Replace the memory card.

Possible malfunction	Probable cause	Remedy
When installing the sensor on a metal surface, stress indicator reading does not change	There is a break in the connection of the cable to the sensor. The sensor is faulty.	Find the place of the break and, if possible, fix it. Replace the sensor.

9. TRANSPORTATION AND STORAGE RULES

9.1. The stress indicator must be transported in a package with the battery disconnected from the electronic unit.

9.2. Transportation of the packed stress indicator can be performed in closed railway cars or containers, on motor vehicles, as well as in heated compartments of aircraft.

9.3. The packed metal stress indicator must be fixed in vehicles, and when using open vehicles, in case of short-term transportation, it must be protected from the effects of precipitation and water.

9.4. Placement and attachment of the packed stress indicator in vehicles must ensure their stable position, exclude the possibility of collision with other objects, as well as against the walls of the vehicle.

9.5. Conditions of transportation:

- temperature, ºC **- from minus 30 to plus 80**
- relative humidity at a temperature of +35ºC, % **- 95**

9.6. The stress indicator in the transport package can withstand shaking with an acceleration of 15 m/s^2 at from 10 to 120 beats per minute or 7500 beats with the same acceleration.

9.7. The packed stress indicator with the battery disconnected from the electronic unit should be stored on racks in a dry room in the absence of acid vapors, alkalis and other aggressive impurities in the air.

9.8. Storage conditions in terms of the impact of climatic factors should correspond to the requirements of the *Appendix L* of *GOST 15150-69*.

9.9. The location of the stress indicator in storage should ensure its free movement and access to it.

9.10. If the stress indicator is stored for more than 6 months, it should be released from the transport package and kept in accordance with the above storage conditions in consumer packaging.

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
10ХСНД	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
10ХСНД	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).