Russian Academy of Sciences

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Scientific technical report

on the Agreement 991-12 about research scientific work

“Research of the coat samples reflection in visible and infra-red bands”.

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Abstract

Measuring of the reflection coefficients values was done with the photometer FO-1 with absolute method, based on Taylor's method.

Research of specular reflection illumination of coat samples in visible band was done with the double-beam spectrometer Hitachi EPS-3.

There was done the measuring of diffuse and specular reflection coefficients of four SuperTerm coat samples and some comparison samples, for which values of total reflection coefficients in visible band were found. Measuring was done at room temperature.

It emerged that specular reflection coefficients for all SuperTerm coat samples and base material - galvanized iron – practically do not reflect the light specularly in all visible frequence band, whereas diffuse reflection of SuperTerm coat appeared to be very effective for diffusion of visible light falling on energy object.

Research objects and research methods:

Taylor method which is the basis of a photometer involves the following: a light beam of certain wave length is directed onto the side of an integrating sphere, where after multiple reflections a certain illumination E_1 is made. Then this beam is directed onto the surface of a measured sample, which is forced against the work port in the sphere. A light beam reflected from the surface gets back into the sphere and creates an illumination E_2. The illuminations ratio $\rho=E_2/E_1$ gives absolute reflectance of the measured sample. A photometer FO-1 allows to measure reflection coefficient of diffuse, specular-diffuse and specular surfaces. A photometer has 12 light filters (one for near ultraviolet band, 6 – for visible band, 4 – for near infra-red band, and one resolving light filter for making spectral sensitivity relevant for eye's visibility factor, which width corresponds to visible spectrum), using which one can define spectral characteristics of the diffuse reflection coefficient. The light filters parameters are given on Fig. 1 and 2.

Спектральные характеристики стеклянных светофильтров

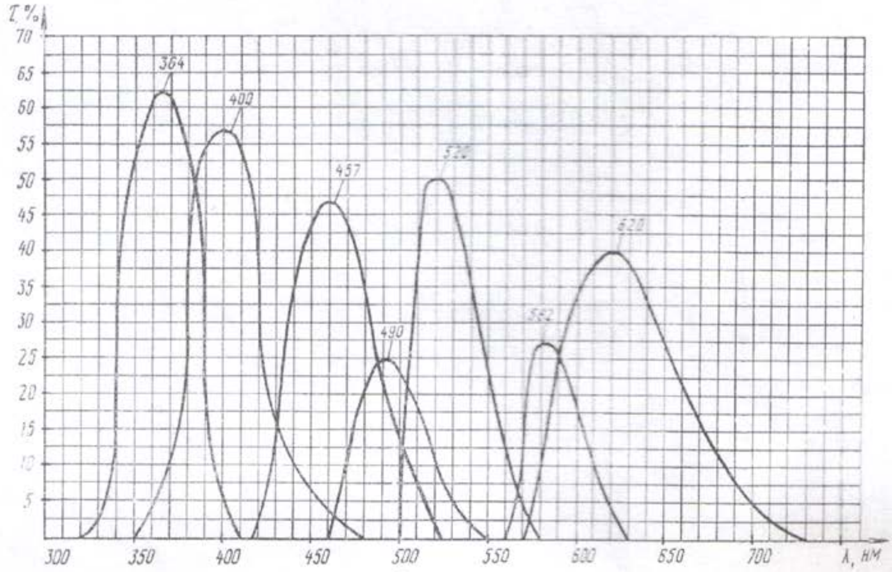

Рис. 1

Спектральные характеристики интерференционных светофильтров

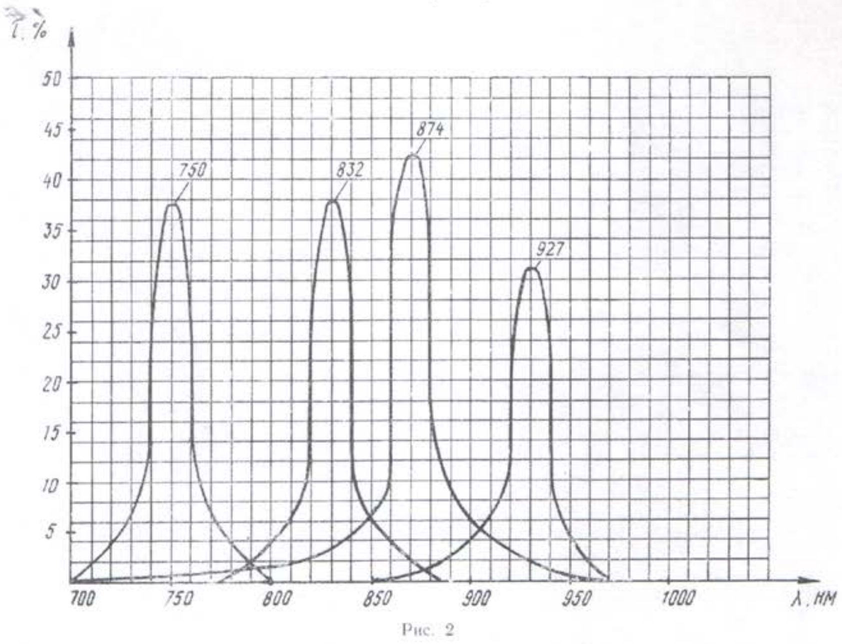

Рис. 2

Спектральные характеристики стеклянных светофильтров – Spectral characteristics of glass filters
Спектральные характеристики интерференционных светофильтров – Spectral characteristics of interference filters
Рис. – Fig.
нм – nm

Fig.3. Transmission characteristics of light filters for the whole frequence band.

Accuracy of measuring absolute reflectance with a photometer FO-1 (according to its passport data) equals 3%. The photometer optical schematic is given on Fig. 3.

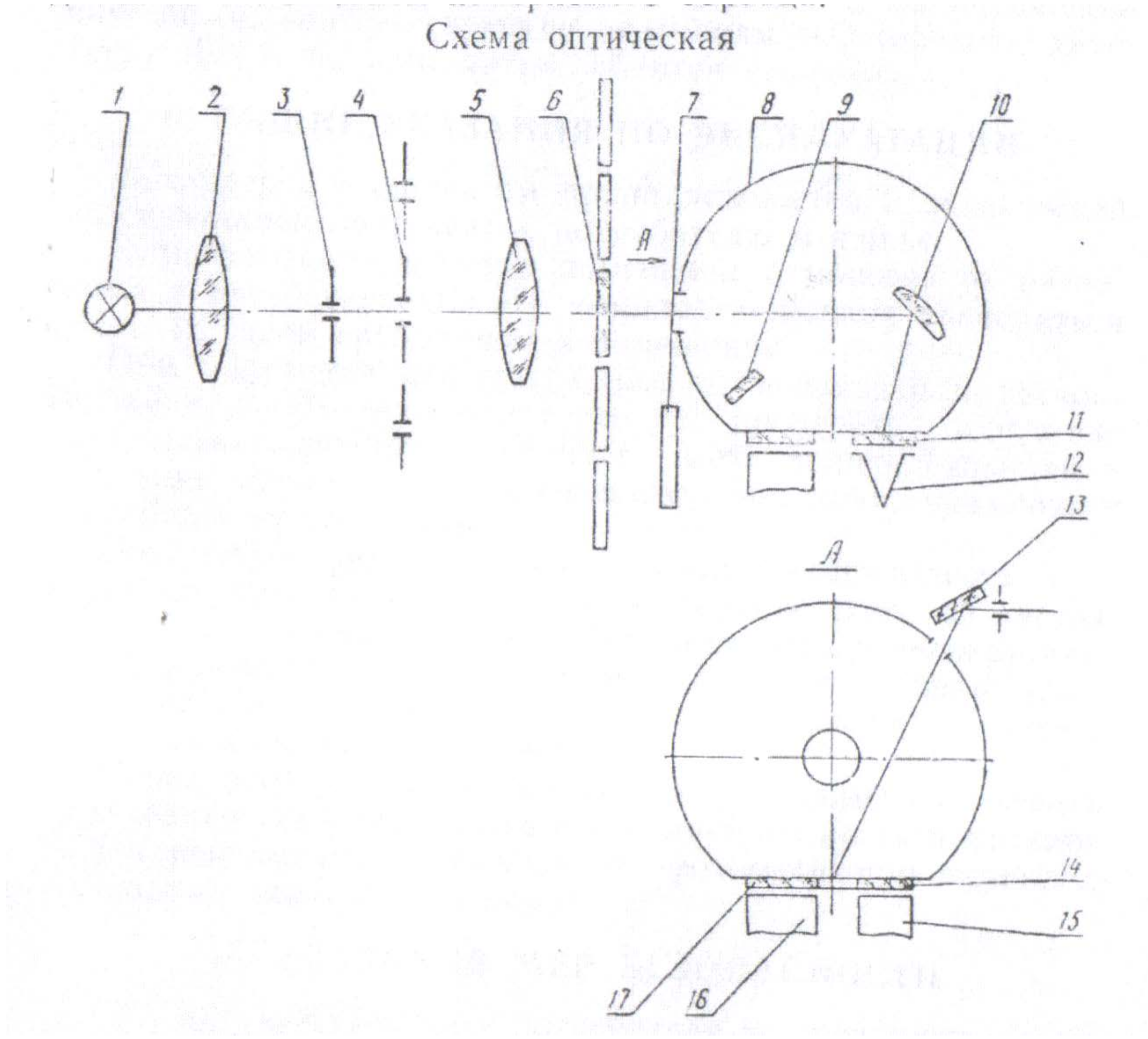

Схема оптическая – Optical schematic

Fig.3. Photometer optical schematic. 1 – light source, 2 – condenser, 3 – field stop, 4 – changeable stop, 5 – objective lens, 6 – light filters, 7 – transmission samples, 8 – integrating sphere, 9 – screen, 10 - tilting mirror, 11 – reflection samples, 12 – black trap, 13 – mirror for surveillance over sample, 14, 17 – milk glass, 15,16 – radiation receivers.

When measuring a coats reflection coefficient, 4 samples of such a coat, SuperTerm *("ST")*, applied to galvanized iron, were used. Three samples had a size of 20x20 mm, and one – 100x100 mm. For comparison of obtained results we measured the reflection coefficient of a special aluminum mirror on a polished glass basis 24 mm in diameter *(Al)* and of galvanized iron samples with a size of

20x20 mm, both fresh and oxygenated. Also similar measuring with duralumin samples *D16* took place.

Results of reflection coefficients measurement

In the course of the measurements it was defined that obtained reflection coefficients values do not depend on the size of samples used for measurements, and spread in values of the same type samples stays within the limit of a photometer accuracy.

The Table gives summary data of total reflection coefficients measurement with the use of a resolving light filter, i.e. in visible band.

Table. Absolute values of reflection coefficients of SuperTerm coat samples and comparison samples.

Reflection coefficient ρ (%)							
Mirror (*Al*)	*D16*	Fresh electro-zinc coating	Oxygenated electro-zinc coating	"*ST*" Sample 1	"*ST*" Sample 2	"*ST*" Sample 3	"*ST*" Sample 4
90.4	45.7	65.3	16.3	96.1	95.9	94.3	94.5

As you can see in the table, coat samples have much higher reflection coefficient in comparison with bottom layer made of galvanized iron (both fresh and oxygenated) and duralumin samples. And what is more, the coats reflection coefficient in visible band appeared to be a little higher than the aluminum mirror reflection coefficient too.

Specular reflection illumination in visible band

Specular reflection illumination was measured with a Hitachi device. This device is designed to measure the test samples light transmission spectrum in spectral range from 200 nm to 2.4 µm.

Hitachi EPS-3 spectrometer is a double-beam tool overlapping a spectral band from distant ultraviolet to infra-red light (185 nm – 2.5 μм).

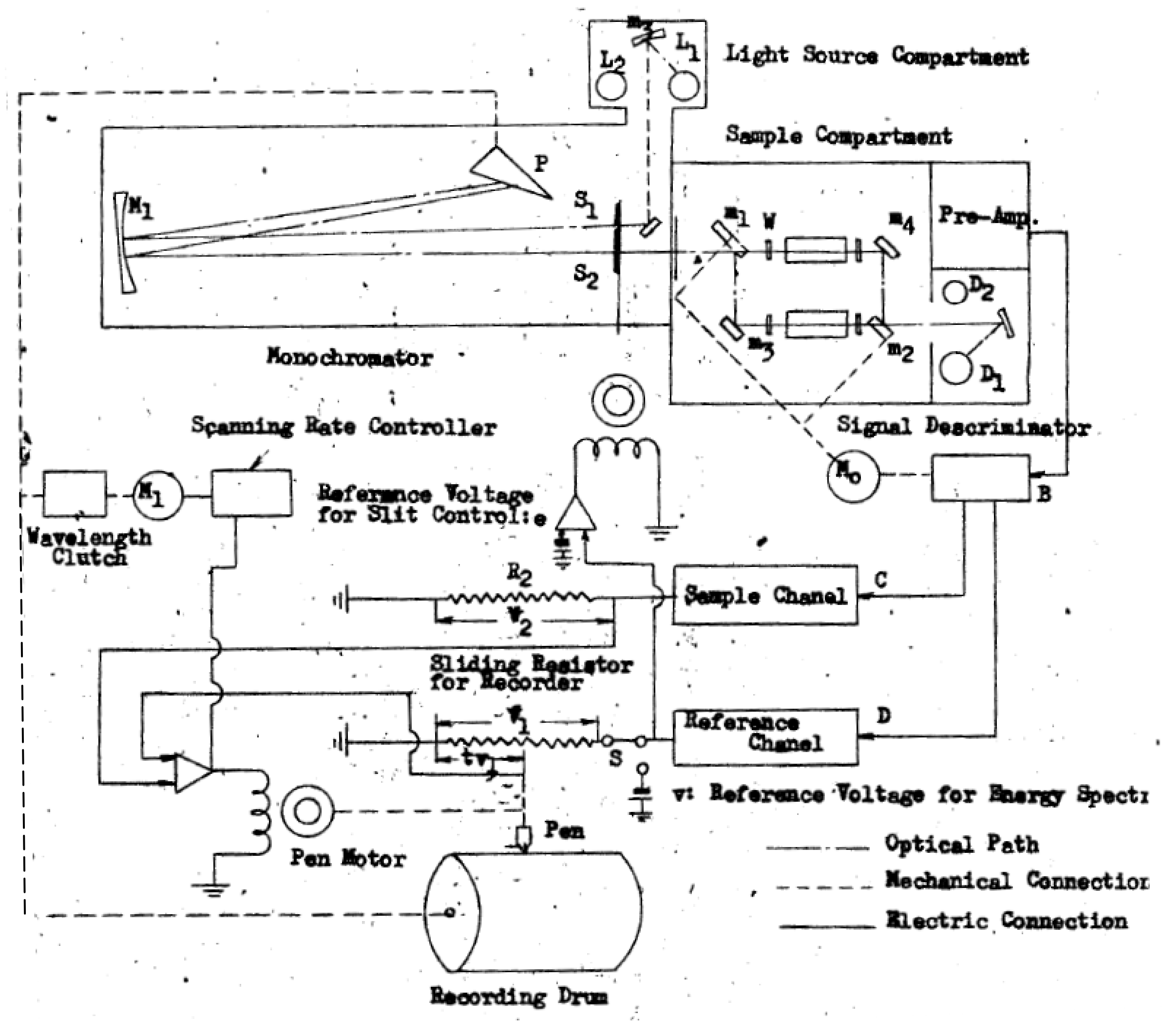

Fig. 4. Measuring circuit of Hitachi EPS-3 spectrometer.

EPS-3 operating principle is based on a dual-beam scheme allowing to measure radiation intensity ratio in two beams. If the light passes only in one beam, you can measure intensity of the light source radiant energy, while double-beam measuring scheme method allows to define coefficients of the light transmission through a sample or coefficients of reflection from an object on different wave lengths in relation to the intensity of a source or a standard sample.

The principle diagram of the device is given on fig. 4.

Light beam of a tungsten filament lamp *L1* or a hydrogen discharging tube *L2* depending on the necessary wave length band passes through a monochromator, reflects from a mirror *Mi*, deflects and reflects from a quartz prism *P*, angular location of which defines light wave length chosen by a monochromator. Input and output collimators *S1* and *S2* define the monochromator tuning precision and intensity of light coming out of the monochromator.

After the monochromator the light of the set wave length gets into section of a sample, where two tilting mirrors *m1* and *m2* alternately direct a light beam either on a sample or on a standard sample (for example, on an empty cell) to obtain the ratio of coefficients of transmission through a sample in comparison with a standard (lower and upper ways are given on fig.4).

Then the beam gets on a detector and intensifies, the device analytical part calculates ratio of signals of light passed through a sample and a standard sample.

The device is designed to study the light passing through liquid and gaseous samples, which are put into cells, and also through solid bodies. Substitution of one of the mirrors *m3* or *m4* for the object being studied allows to explore specular reflection from samples in a broad wave length band.

Wave lengths of a spectrometer

Measuring range	Wave lengths	Light source	Detector
Distant ultraviolet	185-220 nm	Hydrogen tube	Photomultiplier to 650 nm
Ultraviolet	210-360 nm	Hydrogen tube	Photomultiplier
Visible light	340 -700 nm	W filament lamp	Photomultiplier, from 600 nm

			photoresistance
Near infra-red light	600-2000 nm	Filament lamp	Photoresistance (PbS)

Measurements of the specular reflection from SuperTerm coat samples and samples of galvanized iron surfaces, used for coating with SuperTerm.

Отражение, отн. ед. – Reflection, relative unit

Длина волны, нм – Wave length, nm

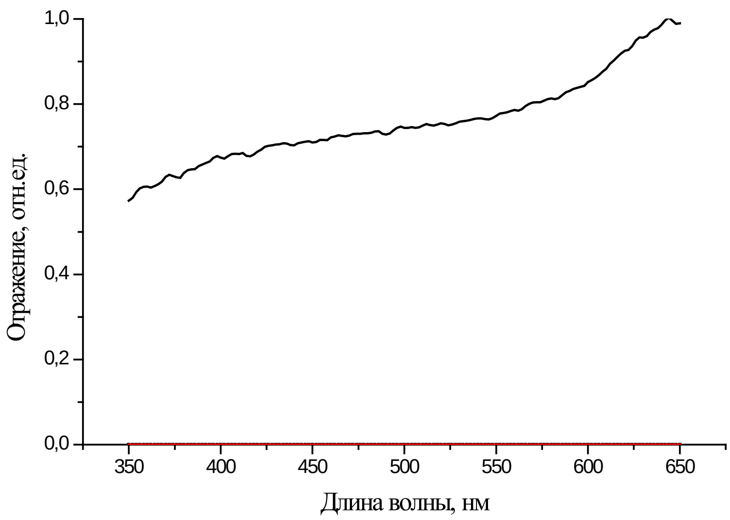

Fig.5. Spectra of specular reflection of an *Al* mirror (upper line with reflection coefficient about 0.6-1.0), coats of *SuperTerm* and galvanized iron (two lines with reflection coefficient ~ 0 on the whole visible band)

Fig.5 shows the results of the measurements of coefficients of specular reflection from the surfaces being studied. The measurements revealed that both fresh galvanized iron and galvanized iron coated with SuperTerm do not reflect light specularly (spectra lies on the axis y=0), as distinguished from the glass coated with aluminum film – technical mirror.

For Hitachi EPS-3 spectrometer the device was made, that can measure light reflection spectra. This device cannot measure exact absolute value of the light reflection coefficient, but using IFS 113v Fourier spectrometer (production of the firm Bruker, Germany) we can define absolute value of the light reflection coefficient by measuring reflection spectra on the whole spectral range 5000 cm^{-1}

(2 µm) - 400 cm^{-1} (25 µm), and that is what is planned to be made during the work as prescribed by the second stage of the agreement (in September 2012).

Fourier spectrometer will give an opportunity to measure not only specular reflection illumination spectra in the band of 2-25 µm, but perhaps also diffuse reflection spectra in this IR band of the spectrum.

Conclusion

Reflection from SuperTerm samples as well as from technical metal (galvanized iron) samples is only diffuse, there is no specular reflection. Total coefficients of diffuse light reflection for SuperTerm coat samples in visible band are consistent with (and even several percents higher) aluminum mirror reflection coefficient, and are substantially higher than reflection coefficients of galvanized iron and duralumin. In summary, the measurements revealed that coating of objects with SuperTerm makes absorbing ability of this surface in visible-light spectrum circa 20 times less in comparison with absorbing ability of an absolute black body, and also makes heat input through the surface several times weaker in comparison with the surface made of fresh galvanized iron. Absorbing ability of oxygenated galvanized iron is close to such of an absolute black body.

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