ENERGY SAVING

7.4. Thermal imaging diagnostics of energy equipment

7.4.3. State-of-the-art of infrared imaging technique

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Recording of the intensity change of thermal radiation is necessary for determination of the state of energy objects and communications. As it was written before, the pyrometers, infrared imagers and thermal scanners are used as the devices for recording the thermal radiation. The infrared receivers of thermal radiation usually work in the spectral ranges of 3…5.5 or 8…14 μm. Photon heat absorbers usually work with cryogenic cooling of sensors (for example, with liquid nitrogen having a temperature T = 77 K). It strongly reduces the thermal noise, not removed in the other way, and improves correspondingly the threshold sensitivity. Application of microprocessor or thermoelectric cooling systems under the higher temperatures deteriorates these parameters. Nevertheless, the sensitivity of thermal imaging devices achieves, as a rule, of 0.1°C.

The pyrometers perceive the thermal radiation from the heated area within the comparatively small spatial angle. By means of optical system it directs the radiation to the thermoelectric converters and fulfils the registration of electric signals by the indicating measuring converters, calibrated in the temperature indicators.

The direct reproduction of "thermal portraits" became possible only with appearance of **infrared imagers** — two-dimensional image converters of medium-wave infrared range in the image apparent on the screen of thermal-imagine monitor. The most significant successes in infrared imaging technique were achieved in the last years in the area of autonomous portable searching and diagnostic thermal-imaging systems with the cooled and not cooled radiation detectors. The **infrared imagers** with a single detector **(scanner)** contain the high-precision system of optical-mechanical scanning (OMS) of the space under observation with the consequentc reproduction of the obtained signals in the form of a frame.

Visualization of the objects in motion demands the quick frame change and is carried out by means of **infrared imaging high-speed camera**. For high-speed fast camera the preference is given to the receiver with quantum mechanism of reaction on the infrared radiation, because the operation speed of photon detectors constitutes about 1 μs. Because of difficulties of creating the fast-acting systems OMS, such infrared imagers work in the low-frame-rate regime, they use extensive rules of identical detectors. The expensive matrix (up to 10^6 elements) quantum detectors are used in some cases that allow excluding OMS in the observation systems.

The pyrometers are currently accessible temperature recorders for the separate elements and units of the object. The pyrometers provides temperature measurement in a wide range of –40 to +300 °C, while the special filters allow to widen the range of measurement up to 1500°C. The modern pyrometers are additionally equipped with the arrangements, forming the laser marks, which show an area, the temperature of which is averaged by recording digital indicator of device.

A principle of transforming the radiant infrared flux from the object, accepted by a sensitive element, into electrical signal proportional to the thermal spectral power of radiant flux, underlies in the base of infrared imager and thermal scanner operation. The infrared imagers and thermal scanners form the image of object on the detecting screen. Each point of the object is fixed with its temperature, while the level of temperature in each point is specified by different color. More often the infrared image of the object is substantially differed from the image in a visible color spectrum. Therefore, the separate thermal imaging devices are additionally equipped with the usual TV cameras, the image from which is also reflected on the screen. In linear measuring scanners the infrared radiation is registered along the line of sighting and is output in the form of graph of radiant temperature on the embedded color monitor of the device.

A block diagram of the mentioned television devices is presented in Fig. 7.29.

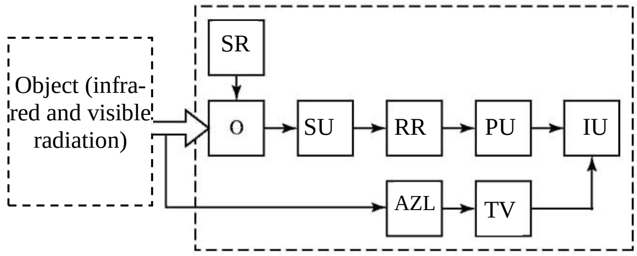

Fig. 7.29. A block diagram of infrared imager (scanner)

The flux of infrared radiation from the object falls in the lens *O*, is reflected by the mirror of scanning unit *SU* (this unit is absent in infrared imager) and falls on the radiation detector *RR*. The radiation detector for infrared imager is the infrared-sense matrix, while the thermal imaging scanner шы the point detector. The radiation receiver *RR* transforms the energy of incident flux of infrared radiation into electric voltage. The processing unit *PU* transforms the signal from the radiation detector *RD* in the array of radiation temperature values in accordance with the individual calibrated characteristics of device, which are kept in energy-independent memory, and the indications of internal sensors of temperature and images this array at the color liquid-crystal display.

Simultaneously with output of radiant temperature, distribution graph in the indication unit *IU*, the image of object is coming in visible spectral range. It is formed by television channel consisting of miniature TV camera with auto-zoom lens *AZL*.

The software makes the output of temperature at monitor in the form of digital value. The temperature could be corrected taking into account the coefficient of object's radiation and the background (environmental) temperature.

The largest distribution among foreign and domestic developments of infrared imagers with cooled single or matrix quantum detectors of infrared radiation had the devices securing the accuracy of measurements 1…2°C and presented in Table 7.11.

The pointed devices have the large set of servicing operations and special software.

Up to now the infrared imaging inspection was not quantity-used because of its large cost. After the appearance at market of Russian and foreign infrared scanners of different models, the infrared imaging diagnostics ceased to be the monopoly of large companies. It seems to be practically available for auditing services and product companies. The infrared scanners have the minimal price/quality ratio in comparison with the device of other types used for thermal imaging inspections of different objects.

The comparative characteristics of the most spread in Russia IRS's of Russian and foreign production are presented in Table 7.12.

Rostekhnadzor (Russian engineering supervision) of Moscow carried out the joint testing in natural conditions of thermal imaging device "Vision AGEMA" (Thermovision 550 — Sweden), thermal imaging device "Inframetrics-750" (USA) and IRS "Aurora" (Russia). The comparative tests showed the identity of fulfilled measurements of temperature fields.

It should be noted that rather often the foreign devices, suggested for using in Russia, were not certified by Gosstandard of Russia. The infrared scanner "Aurora" was registered by VNII-standard (TU 4276-001-49881450-01) and certified by the Russian Gosstandard as the measuring device (certificate RU.C.32.010.A № 8157). The presented data testifies that the device IRS "Aurora" has the better price-quality ratio in comparison with other presented devices. In addition, this device proved itself to be good in auditing the energy objects.

The infrared linear scanner "Aurora" has two main operating regimes:

• regime of building-up the thermal profile with reflecting the values of minimal, maximum and average temperature along the scanning line;

• regime of building-up the thermal imaging frame allowing to obtain the thermal frame similar to the image obtaining by means of infrared imager. The TV image of object under study, its thermal image and colorful scale of temperatures have the output at the screen of monitor in this regime.

The alignment of television image with the scanning line and thermal frame allows identifying the value of measured temperature with visible image of object under observation. A temperature in the specified point and temperature distribution along arbitrary line of the scanning field are reproduced at the frame. It is possible to carry out the continuous inspection of thermal field with fixing the minimal and maximum temperatures.

The infrared IRS "Aurora" proved itself to be good in conducting thermal imaging inspections of power installations of Intersystem Electric Grids of Center of FGC of the Open JSC RAO "UES of Russia", Eastern electrical grid company of the Open JSC "Mosenergo", Vladimirskaya substation (SS) of 750 kV, SS of 500 kV "Bely Rast" (Moscow Region), Moscow Power Engineering Institute, Moscow petroleum refinery, a complete set of buildings of Moscow mayor's office, Likhachev factory (ZIL, Moscow), JSC "Sport complex "Olimpiysky" (Moscow), building and industrial enterprises of Kaluga Region, JSC "SPE of Electrohydrodynamic aggregates" (Moscow) etc. Besides, IRS "Aurora" was actively used in Krasnodarsky Center of Energy Saving in thermal imaging inspections of industrial enterprises and municipal-housing sector.

Table 7.11. **Characteristics of most spread infrared imagers**

Device, manufacturing company, country	Characteristics				
	Range of the measured temperatures, °C	Accuracy of temperature measurement, °C	Operating spectral range, µm Cooling	Focal matrix (elements)	Overall dimensions of the chamber, mm Weight of device, kg
Thermovision R 550, AGEMA, Sweden	-20…+450	±2	3.6...5.0 Liquid nitrogen	320x240	220x132x140 4.7
ThermaCAM SC1000, Inframetrix, USA	-20…+450	±1	3,4...5 Liquid nitrogen	256x256	210x114x90 2.7
Model 760 Inframetrix, USA	-10...+250	±1	8...14 Thermoelectric	194	216x127x180 3.0
Thermo Tracer TH5104, NEC, Japan	-10...+800	±1	3.0...5.3 Thermoelectric	233x256	198x93x210 2.5
Prism DS FLIR Systems Ins., USA	-20…+450	±1	3.6...5.0 Thermoelectric	320x244	222x127x140 3.0
Thermograph "IRTIS-2000", "IRTIS" Co Ltd, Russia	-20…+200	±1	3.0...5.0 Liquid nitrogen	256x256	100x140x210 1.8

Table 7.12. **Characteristics of the most spread infrared scanner**

Engineering data	Compact IRS Varioscan-3022	Computer thermograph "IRTIS-2000"	IRS "Aurora"
Producer	"InterEng Mebtechnik GmbH"	"IRTIS" Co Ltd	SPC "Euroservice-XXI century"
Country	Germany	Russia	Russia
Spectral range, µm	2...5	3...5	3…5 Visible range *
Type of the sensor	HgCdTe	HgCdTe	HgCdTe
Cooling	Thermoelectric	Liquid nitrogen[2*]	Thermoelectric
Framing time, s	1.2[3*]	2[3*]	1.5
Temperature resolution at 30 °C, °C	0.12	0.05	0.05
Range of measurements, °C	—40...+1200	-20...+200	-20...+200
Geometric resolution, mrad	3.0	2.0	5.0
Field of vision, grad	30x20	25x20	Variable: 45×33, 38×28, 32×24, 25×18
Minimal remoteness from object, m	0.2	0.2	0.3
Operating temperature, °C	-10...+40	-10...+40	-20...+40
Storage temperature, °C	-25...+70	No data	-25...+70
Power consumption, W	12	12	18
Weight, kg	4.6 (without storage battery and tripod)	1.8 (without storage battery, tripod, notebook and thermos)	1.4 (without storage battery)
Overall dimensions, mm	240x192x200	200x140x100	120x102x103
Display	11.5 cm color LCD	No	6.2 cm color LCD
Inner storage block, a number of thermograms	25	Notebook	30
Interfaces	RS 232	RS232	RS432
System software	With intrinsic function for analyzing thermograms	With intrinsic function for analyzing thermograms	With intrinsic function for analyzing thermograms [4*]
Guiding price in the RF territory , thous. US $	50.0	19.0	15.0

*The availability of visible image of the object totally corresponding to the infrared image, substantially simplifies the decoding of the infrared images and doesn't demand the application of additional detection equipment (video cameras, camera devices, dictaphones).

[2*] It is necessary to have the special equipment for production and storage of liquid nitrogen. The complete set of device must include the thermos filled by liquid nitrogen. The cost of maintenance is increased by the cost of liquid nitrogen.

[3*] The taking pictures is carried out only with tripod.

[4*] The reports generated by software foresee the total compatibility with files of medium Windows-95 and higher.