Performance Capabilities of Non-Cooled IR-Imagers for Diagnostics of Energy Saturated Objects and Industrial Equipment

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Abstract. The principle of 2D thermal field distribution remote registration provides survey not only of the intensity and shape but collecting of additional information about dynamics of heat exchange between separate parts of energy saturated and other heat radiating objects.

IR-imaging systems are most efficient for detection of hidden heat and water leakages in buildings and heat supply pipes all around the clock and at any weather conditions. They also can be successfully used for location of overheat accident-sensitive and fire risk areas of equipment under load. Instruments provide shape and intensity visualization of critical places thermal fields, i.e. help to solve numerous tasks of industrial diagnostics by means of this NDT method.

Currently the use of portable IR-imagers became more and more popular for equipment and technical objects health monitoring as well as for location of damaged places and leaks on main oil and gas pipelines the breaking of which can cause catastrophic consequences. The portable IR-images based on non-cooled hybrid solid state matrixes are of special interest.

The latest tendency in development – multi channel performance, wide band spectra (range 0.35 to 13 μm) - significantly expand the area of instruments applications both in traditional machine building, energy, transport industries and in boundary industrial areas

Introduction

The principle of 2D thermal field distribution remote registration provides survey not only of the intensity and shape but collecting of additional information about dynamics of heat exchange between separate parts of energy saturated and other heat radiating objects. When talking about energy saturated objects two aspects can be discussed. One is technical diagnostics the other one – protection of these potentially hazardous facilities. In fact these two classes of tasks can be solved with the help of one type of equipment – non-cooled IR imagers.

In case of technical diagnostics the tasks also can be split in two groups. One group – necessity to evaluate the temperature of problem areas, the second one – detection of heat leaks.

1. Samples of available equipment

All mentioned above tasks can be solved with the help of various non-cooled IR-imagers developed by “Spectrum-RII” during years 2002-2006. The newly developed instruments

implement non-cooled 2D receivers of IR-radiation based on solid hybrid matrixes of large capacity and operating in spectral range 8-13 mcm.
These are:

- Portable IR-imager TN-4604MB based on ½” microbolometric matrix (160x120 pixels) and minimal detected temperature difference (MDTD) 0.15^0C with built in lens 25mm/1.0, Fig. 1a.
- Multifunctional IR-imager TN-4604MP based on 1” pyroelectric matrix (320x240 pixels) and MDTD 0.1^0C with built in lens 50mm/0.7, Fig. 1b.
- Portable IR-imager ”KATRAN” for surveys and search purposes (performance IP65), geometrical resolution 160x120 pixels, thermal sensitivity 0.12°C and FOV 19°x14° (Fig. 1c).
- New long-focus system TN-4604MP-100. It is mounted on tilt and additionally equipped with optic-electron channel designed for detection of optic instruments at distances up to 1000m and TV-channel with increased spectral sensitivity (operating range 0.38 to 1,7mcm) that provides selection of optical images in several intermediate ranges (Fig. 1d).

a) b) c) d)

Fig.1.

All above instruments provide all around the clock and in severe weather conditions efficient survey over objects of interest or protected areas; visualization of heat radiating objects and solution of wide range of tasks basic of which are:
Technogenic safety provision: buildings, installations with power electrical equipment and various transportation means diagnostics; location of leaks and oil- and heat pipeline breaks, hidden sources of fire, etc.
Conducting of search and survey diagnostic actions: search for remote objects (people. animals, cars, etc.; all around the day and at all weather conditions protection of perimeters of important strategic facilities; detection of hidden anomalies (fire dangerous places where overheating present, cavities, liquid accumulations etc.) in industrial buildings and other structures.
There are many other applications for non-cooled IR-imagers.

2. Peculiarities of use of 1” and ½” matrixes

It is necessary to note some principal important distinctive features of 1” and ½” matrixes use as they are directly dependent on thermal sensitivity and geometrical (spatial) resolution and some other parameters.

Without no doubt the IR-imager with 1” matrix in terms of the same FOV and distance to observed object has two times better spatial resolution within the plane where the object is located or in case if it has the same spatial resolution it is possible to see object at distance two times longer.

Nevertheless, if the instrument weight and size as well as power consumption and price are most important parameters and the user is satisfied with relative deterioration of thermal image quality, than in case of equal visualization scale and distance to the object the IR-image with ½” matrix is preferable. In imager with ½” matrix the focal length of IR lens will be two times less and hence it proportionally will have less size, weight and price. The price will be off due to the fact that capacities of these two matrixes are different, thus capacity of ½” matrix is 160 x 120 = 19200 pixels while for 1” matrix it is 320 x 240 = 76800 pixels.

Mentioned above peculiarities used as basic criteria at the stage of selection of matrix dimensions (format) and type of required IR lens suitable for this or that specific application and solution of diagnostic tasks.

It is well known that limiting distance of survey reduced during rain, snowfall, fog or dust storm but at the same time, first of all, it is determined by technical performance of any IR-imager.

One more significant disturbing factor is presence within the view field of intensive heat radiating sources that make visualization of low contrast object rather poor.

In table 1 presented are field of view (FOV) angles of matrix modules depending on used standard germanium IR lenses.

Table 1. Relation between FOV angles and IR-lens focal length

<table>
<tr><th rowspan="2">Matrix format, pixels</th><th rowspan="2">IR-imager FOV</th><th colspan="6">Focal length of IR-lens, mm</th></tr>
<tr><th>9</th><th>18</th><th>25</th><th>50</th><th>100</th><th>150</th></tr>
<tr><td rowspan="3">320x240 (1”)</td><td>Maximal (along diagonal)</td><td>-</td><td>58°</td><td>44°</td><td>22°</td><td>11,5°</td><td>8°</td></tr>
<tr><td>Along horizontal / vertical</td><td>-</td><td>46°/35°</td><td>34°/26°</td><td>18°/13°</td><td>9°/6,8°</td><td>6°/4,5°</td></tr>
<tr><td>Instantaneous value</td><td>-</td><td>3,5mrad</td><td>2mrad</td><td>1mrad</td><td>0,5mrad</td><td>0,3mrad</td></tr>
<tr><td rowspan="3">160x120 (1/2”)</td><td>Maximal (along diagonal)</td><td>68°</td><td>-</td><td>23°</td><td>12°</td><td colspan="2" rowspan="3"><u>Note:</u> 1mili radian (mrad) equals ≈ 3,3 angular minutes</td></tr>
<tr><td>Along horizontal / vertical</td><td>54°/42°</td><td>-</td><td>19°/14°</td><td>9,5°/7°</td></tr>
<tr><td>Instantaneous value</td><td>7mrad</td><td>-</td><td>2mrad</td><td>1mrad</td></tr>
</table>

As an example two basic relations will be given below:

- in case of invariance of FOV and spatial resolution ability in plane of object location when IR lens focal length is increased the detection and recognition distance of heat radiating objects will be proportionally increasing,

– in case of fixed distance to observed object when the IR lens focal length is increased the FOV size is proportionally decreasing and correspondingly the spatial resolution is increasing in the plane of observed object location.

In table 2 presented are the sizes of FOV at different distances to observed object (for IR-imager with 1” matrix and two types of used IR lenses).

Table 2. Relation between FOV and distance to observed object

IR lens specification	Ground distance to the object, m					
	50	100	200	400	600	1000
$F^{/}$ = 50mm, $\alpha_1 \approx 20^0$ (tg α_1 = 0,364)	Along diagonal 18m	36	72	145	216	360
	Hor./Vert. 14.5/11m	29/22	58/44	116/88	172/128	290/216
Resolution in the plane of object location (lines/m)	22 (4,6cm/line)	11	5.5	2.7	1.7	1.1
$F^{/}$ = 100mm, $\alpha_2 \approx 10^0$ (tg α_2 = 0,176)	Along diagonal 8.8m	17.5	35	70	106	176
	Hor./Vert. 7/5.3m	14/10	28/21	56/42	84/64	140/106
Resolution in the plane of object location (lines/m)	44 (2.3cm/line)	22	11	5.5	3.6	2.2

When the area survey is performed in wide range of distances with the goal to detect and further to monitor the heat radiating objects (with additional option of detailed object examination, i.e. use of vast scale providing object recognition), the pancreatic lenses (transfocators) are applied. The last ones help smoothly change their own focal length in wide range (as well as image scale and spatial resolution within the plane of object location).

The IR- transfocators focal length variation is preformed mainly in the range of 20 – 100mm (i.e. 5x multiple scaling) or 50 – 150mm (correspond to 3x scaling). When using this type of lens additional technical solutions are taken: in the TV-channel of IR-imager installed is corresponding and matching small size transfocators operating in visible spectral range and matching the same range of FOV angles variations.

3. Some practical results

In Fig. 2 presented are practical results and images obtained with the help of IR-imager of TN-4604MP type with lens 50/0.7. In the figure presented are TV images of examined objects (left) and their thermal presentations (right).

The IR-imagers that were developed and produced by “Spectrum-RII” company in fact realize various performance concepts that made possible instruments use not only in traditional application areas (machine building, power industry, construction activity, transport, etc.) but in specific as well and hence create very promising area of future development line.

Several on ground an in air trials, when new instruments were used for diagnostics and surveys of municipal heat pipelines, long oil pipelines, airports runways, hydraulic works, heating and power plants, nuclear power plants and houses apartments, proved their efficiency especially for detection of newly occurred (previously absent) thermal anomalies .

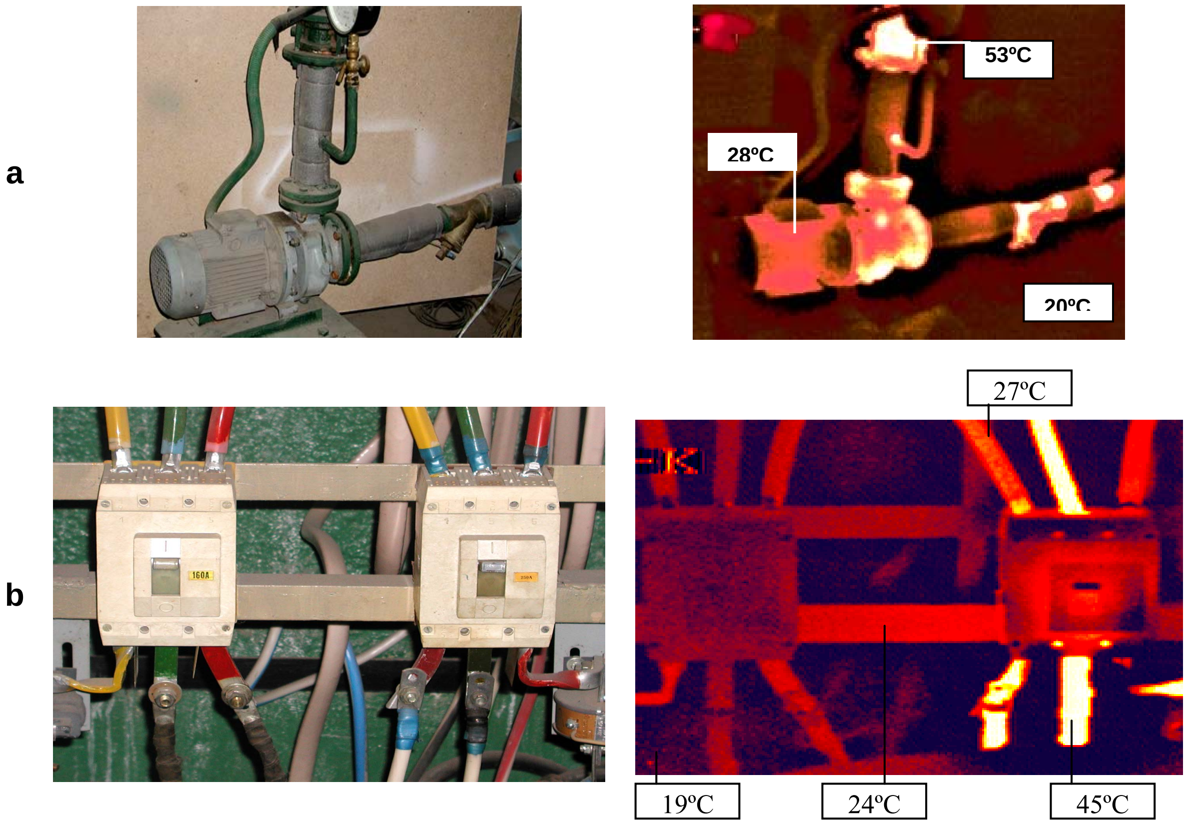

Fig. 2. TV and thermal images obtained by means of TN-4604MP
Heating water converter with overheated flange;
Power electrical control unit

In the near future “Spectrum-RII” plans to develop non-cooled imagers based on cameras with increased capacity (640 x 480 = 307200 pixels and more) and improved thermal sensitivity (not less than 0.05^0C (50mK)).

Conclusions

The use of non-cooled thermal imaging systems in airspace, petrochemical and defense industries is increasing continuously. This can be explained by appearing of newly developed computerized non-cooled IR-imagers with high spatial and thermal resolution making it possible to perform surveys and thermal diagnostics at high quality level.
Currently active works are conducted and efforts are made to improve weight-size parameters and reduce power consumption of newly developed instruments with the goal to make IR-imagers practically miniature and keep the quality of obtained images as good as in big ones or even better.
With further increase of thermal sensitivity in the future it will be possible to make qualitatively new transition from visualization of radiation (heat) sources to ability see in presence of thermal rays of reflection factor changes and differences in object emissivity.
At the same time it is necessary to note that new problems will face engineers, for instance, requirement to compensate the background thermal disturbances that necessitate strict thermostating of input germanium windows and IR matrix detectors as well as solution of other scientific and attendant engineering tasks.