INFRARED NAVIGATION DURING THE WAR

Lievin, Boris A., Moscow State University of Railway Engineering (MIIT), Moscow, Russia.
Kudriavtsev, Igor E., All-Russian Electrotechnical Institute (VEI), Moscow, Russia.
Ovcharov, Igor V., All-Russian Electrotechnical Institute (VEI), Moscow, Russia.

ABSTRACT

The first samples of domestic infrared (hereinafter-IR) navigation devices were created in the late 30-ies of XX century in NII-9 (Leningrad) and VEI (Moscow). Since the beginning of 1941 their production for the Navy and Air Force was organized, as the article describes in detail. After the war, the development of IR devices continued resulting in full coverage of the range of electromagnetic waves.

Keywords: infrared technology, navigation, photoelectronics, electron-optical converter.

Background. *The journal publications, due to efforts of domestic scientists successfully develop issues of transport geoinformatics, emerged at the intersection of geodesy, geoinformatics and navigation [1]. Of course, to find ways to further progress [3] of this research field is very useful to refer to its history in the year celebrating the 70th anniversary of the Victory over the Nazism.*

Objective. *The objective of the authors is to investigate issues concerning application of IR devices during the Great Patriotic War of 1941-1945 for the Navy and the Army.*

Methods. *The authors use general scientific methods, statistical method, historical retrospective method, comparative analysis.*

Results.

In all its «infra-glory»

Let's consider the emergence of Russian night military transport navigation in the Great Patriotic War. Such navigation was based on using infrared rays range from 0,8 to 1 µm [4].

In the prewar years, at the All-Union Electrotechnical Institute (VEI) a scientific direction formed in the field of photonics, which was headed by professor P. V. Timofeev. Domestic solar cells, television tubes, photomultiplier tubes, and other devices were developed. From VEI the country's first television broadcasts were transmitted. At the same time and no less fruitful Leningrad photonics school evolved and, a brilliant representative of which was the engineer of NII-9 V. I. Krasovsky [5].

An important step was the creation, almost simultaneously in VEI and NII-9 (now JSC «Research Institute of Television»), of domestic electro-optical converter (hereinafter – EOC). This device, invented by an employee of the company PHILIPS Kholst in 1934, allowed seeing in total darkness with backlight of IR rays.

Soon this theme disappeared from the open literature: pre-war competition of leading powers began in the field of night vision. P. V. Timofeev, and V. I. Arkhangelsky with the participation of V. I. Krasovsky offered an original, compact and technological design – EOC C-1 (basic model) and EOC C-2 (small-sized model). They were used until 1945 (Pic. 1).

In 1938, under the guidance of P. V. Timofeev was created a layout of a marine night vision device, later a set of instruments for marine navigation. With its help the following tasks were solved:

– Replacement of visible navigational and range lights with invisible infrared;

– Ensuring joint sailing of ships with full obscurement;

– Visual secret communication between ships and shore points.

For these purposes were developed and adopted for service in the Navy finder «Omega-VEI», binoculars «Gamma-K» and instruments for joint sailing «Fire». Even before the war they were met with great interest and understanding by the heads of the state. By the beginning of military operations the Black Sea Fleet had had 15 IR-finders «Omega-NII-9», in November 1941 another 18 were added. Ship night finder was designed for the detection and direction finding of hidden from the enemy, invisible to the naked eye navigation lights.

Below there is a brief description (Table 1) of the main types of night vision devices (hereinafter-NVD) for maritime and aeronautical navigation (Source: personal archive of V. I. Arkhangelsky).

*«***Omega NII-9».** *Ship finder for direction finding of infrared lights. Developed in NII-9 in 1939-1940. Adopted in 1940, but there was no mass production due to the outbreak of war. Devices of experimental series were*

Table 1

	«Omega NII-9»	«Omega VEI»	«Gamma VEI»	«Gamma-K»		«Delta»	«Bug»
				The first pipe	The second pipe		
Bearing accuracy	± 15′	± 15′					
The field of view	10º	10º	20º	20º	7º20′	22º	10º
Angular resolution	4′	3,5′	7′	7′	2,5′	10′	4′
Zoom	2.4^x	3.6^x	from 1,8^x to 3,6^x	1.8^x	4.9^x	1.1^x	2^x
EOC type	C-1-37 («Kholst glass»)	C-1	C-1	C-1		C-2	C-1
Autonomous power from the battery voltage	2.5 V	2.5 V	2.5 V	2,5 V		27 V (from the dry battery)	2 NKN-10
Weight of observation device			1.25 kg	1.25 kg		0.6 kg	
Weight of the device with a power supply			4.3 kg	4.3 kg		1.4 kg	2.23 kg
Exit pupil diameter							25 mm

used in the defense of Sevastopol. It had a device to be mounted on a magnetic compass and gyrocompass repeaters «Course P» and «GU».

«**Omega VEI**». *Ship finder for direction finding on the shore infrared lights. Developed in SDB in VEI in 1941-1942. It was adopted in the Navy. It had a device to be mounted on a magnetic compass and gyrocompass repeaters of different types (Pic. 2).*

«**Gamma VEI**». *Hand binoculars to search for and monitor infrared lights. Developed in SDB in VEI in 1941-1942. It was adopted in the Navy. As an experimental instrument used in engineering and air forces.*

«**Gamma-K**». *Hand combined binoculars to determine the alignment of infrared lights. Developed in SDB in VEI in 1944. It was adopted in the Navy. It had two pipes. One was used for the search for lights and keeping them in sight. The second pipe was used to determine on alignment.*

«**Delta**». *Head-mounted infrared binoculars device for a pilot. Developed in SDB in VEI in 1944-1945.*

«**Bug**». *The purpose of the device: detection of an aircraft in the air by the infrared radiation of motor branch tubes and aiming according to it. Intended for fighter aircraft.*

«**Fire-K**». *The equipment for the joint sailing of boats under full obscurement. Developed in SDB in VEI in 1945. Adopted in the Navy. It made it possible to monitor the neighboring boat and determine the distance to it. Set of equipment installed on the boat consisted of two lights located at a height of 3 m, one above the other.*

«**Soldiers of invisible front**»

In December 1941, a number of specialists from NII-9 and the factory «Svetlana», headed by V. I. Krasovsky were evacuated from Leningrad and sent to VEI and Moscow Electric-bulb Plant.

By order of the State Defense Committee on May 15, 1942 № 1755cc in the capital was established Special Design Bureau (SDB-1), headed by V. G. Biryukov. P. Timofeev was appointed a chief engineer. The objectives of SDB-1 included the construction of specialized electrovacuum devices and equipment, research and development on lighting technology, cathode ray tubes, searchlight equipment.

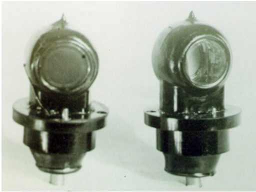
In 1943, when a quite solid scientific, technological and industrial base appeared, and devices were obtained in the required quantity, the command of the Navy recognized IR lights as primary means of enclosure. Their application allowed making fairways invisible to the enemy. It was noted that no one fired at the channel when there were infrared lights.

Significant results were achieved in night mining and demining using infrared devices, they found the experimental use in aviation, armored troops, small arms [6, 15].

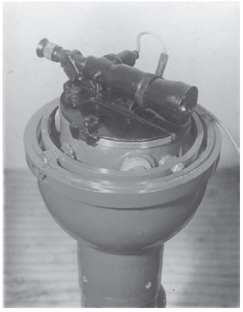
Here are materials of research and development of SDB-1 in 1944-1945, which demonstrate, at what high scientific and technical level, they were conducted.

The leading authors of the research were V. G. Biryukov, P. V. Timofeev, V. I. Arkhangelsky, V. I. Krasovsky, E. S. Ratner, M. M. Cheskis (winners of the Stalin Prize in 1946 for the creation of infrared devices), and V. V. Sorokina, M. M. Butslov, M. S. Yurov, P. R. Smirnov, K. A. Yumatov, S. V. Yudkevich, G. M. Topchiev, E. G. Kormakova, I. N. Zaidel and many others [15].

• «A laboratory power supply circuit for EOC with voltage of 25 kV was developed, assembled and tested. A focusing system for EOC, operating at high voltages, was designed and manufactured. Work has begun on the test of EOC with different scales of an electronic image. Manufacturing a stable power supply for EOC was started».



Pic. 1. EOC of type C-1. 1942 year.



Pic. 2. Marine IR finder «Omega-VEI» on gyrocompass repeater. 1942 year.

• «A sample of advanced infrared binoculars type «Gamma» with built-in power supply and improved parameters was developed, designed and manufactured. A sample of an individual light night vision device designed for short-range night reconnaissance and equipped with its own lighter was designed and manufactured. A model of a portable long-range vision device with its own illuminator was designed and manufactured. An infrared finder for navigation service of the Navy was developed, designed and built, the field of view of more than twice surpassing an existing device «Omega». A new device will replace at the same time devices «Omega» and «Gamma» at the ships of the Navy».

• «A systematic monitoring of the operation of devices «Omega», «Gamma» and «Fire 44» was carried out on ships and in units of the Black Sea Fleet. At the same time one representative of SDB was at sea constantly and at the same time consulted when necessary personnel of ships on the use of these devices.

On the basis of these studies a group of instructional materials has been developed: temporary regulations to use the equipment «Fire-44», «Fire-K» and «Fire-M» were made up, together with the Directorate General of the Navy «Rules of navigation service» were written for equipment of joint sailing «Fire». In the Baltic Fleet classes were held for commanders of the ships of the squadron. Assistance was provided to the Research Hydrographic Navigator Institute in equipment of training navigator office with IR technique».

We see a clear systematic approach to the problem of night navigation: scientific bases – production technology of the most important components – mass production – user training.

• «Devices for joint sailing of boats and small ships were developed, sea tests of these devices at the facilities of two types were conducted, during which the conditions of use of IR technology for this purpose were studied. Based on obtained materials designs of serial samples of devices and requests for proposals were developed, agreed with workers of Research Hydrographic Navigator Institute (hereinafter – NIGSHI) and Directorate General of the Navy».

Experiments have been conducted to EOC with radioactive power. Special instrumentation was created. Based on theoretical calculations a minimum amount of radioactive substances was determined, required to build a power supply for EOC. Fortunately, there was no further development of these works.

In the Navy to work with the instruments «Gamma» and «Omega» were used the existing at the fleet in-built tools of navigation equipment: lighthouses, acetylene and kerosene-incandescent lights and other sources. IR filters were made of glass KC-13, which was produced according to technical conditions developed by SDB. Glass had three classes on the transmission, from 0,22 to 0,39. The visibility range of these lights in devices «Gamma» and «Omega» was 4-10 km for acetylene lamps, 20-25 km for class lighthouses and 30-35 km at the desired tactical conditions for degree of masking of visible light.

• «Portable infrared photometers for photometry of IR lighting means and measuring the transmission effectiveness of blackout filters were produced, adjusted and calibrated. A copy of this photometer was transferred to the plant № 686, where measurements were organized. A special photometer of low brightness, designed for photometry of screens of EOC of different types, was developed, designed and manufactured. Measurements of constants of the optical glass used in optics of optoelectronic devices were established».

• «The spectral characteristics of the infrared filters of all types were studied and average values of the spectral sensitivity of EOC of domestic mass production were experimentally obtained. Using the above data masking abilities and effective transmission of IR filters were set for studying incandescent lamps of different types and different color temperatures as well as arc and other sources of infrared rays. A method for determining optimal parameters of the sources of infrared rays for infrared lighting and alarm devices was developed, depending on tactical and technical requirements. Types of lighting and alarm devices and materials for their construction were studied. The necessary data to calculate IR lighting devices with optimal use of weights and dimensions for given values of range and masking were obtained».

• «On the basis of the military trials of equipment «Fire», held on the Black Sea Fleet on the orders of the People's Commissar of the Navy, in connection with the subsequent request for a large series of this equipment serial devices working drawings of equipment were designed, agreed with the Pilot plant of VEI and supplier plants, manufacturing separate elements of devices in cooperation. All changes recommended by the commission of military trials were made in drawings of equipment.

On the basis of the results of the test of models of photometers in the Caspian expedition of NIGSHI in 1944 specifications for the sample were developed. A photometer was developed, designed and calculated able to measure light intensity of navigation equipment and measurement of atmospheric transmittance as in the infrared part of the spectrum, and in some areas of the visible spectrum. A part of these photometers in quantities of five pieces was manufactured for NIGSHI. A method for measuring the transparency of the atmosphere with the help of these photometers was developed and prepared the production of standard lights for this purpose. Organization of the photometric station on the Black Sea was launched near the city of Batumi».

• «The study of field (cold) emission of electrons from the oxygen-cesium cathode was conducted and constructed samples of electronic rectifiers were built on 18-20 kV».

• «EOC was developed with electrostatic focusing. Maximum resolution is 25-50 strokes per 1 mm, and the threshold (for light device «Mira» 1,5 lux) 10-15 strokes per 1 mm. The technological process of serial production of these EOC was developed. equipment for experimental mass production of EOC experienced was designed, constructed and assembled (collected five exhausts posts, sealing-in machines and other equipment). The first samples of EOC with electrostatic focusing were manufactured and studied».

• «The design and method of serial production of EOC with magnetically focused electrons were developed. Models of devices with these EOC were built. Leader of works in this area was then a young scientist G. M. Topchiev. It should be noted that such devices were too bulky for military applications».

«According to agreements with Main Engineer Department of Red Army were designed and manufactured 12 infrared vision devices with EOC with electrostatic focusing of four different types:

device «Mira» (glasses for soldiers) – 3 pcs;
device «Mira» (commander binoculars) – 3 pcs;
device «Vega 1» –3 pcs;
device «Vega 2» –3 pcs.

Devices «Vega 1» and «Vega 2»were intended to replace the devices of the «Alpha» type.

The research on antimony-cesium cathode was conducted and built the first samples of EOC with them were built. A detailed study of oxygen-cesium cathodes was conducted, whereby the dependence was obtained of sensitivity, dark current and other parameters of the thickness of the films constituting the cathode, and a method for their application. Established A technique of mass production and control over oxygen-cesium cathode was set».

• «Sulfide phosphors for EOC were designed and manufactured. Brightness of sulfide phosphors exceeds the brightness of willemite, and their inertia is much lower. Phosphors provide a resolution of at least 10 strokes per screen».

During the war, according to various estimates, it was produced and delivered to the Navy and the Army from 2 to 7 thousand different infrared devices. Participants of works were awarded orders and medals, diplomas. Created instruments have been praised by admirals Kuznetsov and Haller, generals Shtemenko and Nedelin, academics Vavilov (Pic. 3) and Lebedev [6].

In 1945, scientists from SDB-1 examined places of development and manufacture of IR technology devices in Germany. They studied system of work organization, equipment nomenclature, supplied to various combat arms of the German armed forces, revealed the characteristic features of the German infrared technology. A big confidential archive was collected on a variety of topics and areas of research. According to the documents, as well as through the interrogation of German experts was obtained information about the combat use of the equipment, as well as on the planned new developments.

Transferred to Moscow, captured numerous samples were assembled, mounted, adjusted and tested on laboratory base of VEI. Preliminary laboratory tests of German filters, optics, EOC, power supply units and their individual components, as well as a number of devices were conducted. Check calculations of the German optics were performed and the ability to reproduce the most interesting objects on the domestic optical glass was set. The parameters of some of the captured equipment were tested in the field.

It was the official conclusion that infrared technology, developed by SDB-1, VEI, is not inferior to the German [6, 15]. This is confirmed by other sources [7, 8]. At the same time with scientific objectivity it was stressed that «the quality of German materials and the culture of production of individual parts and devices are in general significantly higher than those of the Soviet equipment.

Pic. 3. Discussion of the scientific issues of night vision.
Pictured (left to right): N. G. Tager, S. I. Vavilov, P. V. Timofeev, Ya.M. Goldovsky.

Pic. 4. Night vision devices of SDB-1, manufactured by Experimental Electromechanical Plant of VEI. 1942-1945 years.

Special attention should be paid to the high quality of the German glass, insulation materials and selenium rectifiers».

Conclusion. *In the postwar period, V. I. Krasovsky founded a new scientific direction – the use of EOC in astronomy. P. V. Timofeev, and V. I. Arkhangelsky until death worked in VEI, developing both military and civil infrared technique [9]. Their followers, scientists of VEI V. I. Perevodchikov, V. I. Eremin, G. G. Carlsen, O. I. Abramov, I. V. Ovcharov contributed to the development of electron beam, laser technology, hydrooptics, heating, radio, fluorovision [10].*

In the context of new areas of interest is a general study of the history of imaging systems of electromagnetic fields (ISEF) in the range of gamma rays [11] to radio spectrum. Building ISEF of different spectral ranges often has a lot in common and long-term [12]. Subject is promising, in particular for use in unmanned aerial vehicles [13, 14]. With this in mind, researchers of VEI are developing devices, providing reliable protection against unauthorized access to critical facilities.

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Information about the authors:
Lievin, Boris A. – D.Sc. (Eng.), professor, rector of Moscow State University of Railway Engineering (MIIT), Moscow, Russia, tu@miit.ru.
Kudriavtsev, Igor E. – Ph.D. (Eng.), the first deputy director of All-Russian Electrotechnical Institute (VEI), Moscow, Russia, commers@vei.ru.
Ovcharov, Igor V. – Ph.D. (Eng.), head of scientific and technical information department of All-Russian Electrotechnical Institute (VEI), Moscow, Russia, igor49-10@rambler.ru.

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