MANUAL ON LABOR HYGIENE

ED. BY

25 NOVEMBER 1980 B. D. KARPOVA AND V. YE. KOVSHILO

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Translation

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MANUAL ON LABOR HYGIENE

Moscow SPRAVOCHNIK PO GIGIYENE TRUDA in Russian 1979 signed to press 19 Apr 79 pp 2, 42-72, 114-118, 445-446

[Annotation, table of contents, chapters on Electromagnetic Fields, Ionizing Radiation and Radioactive Substances, and Lasers from the book edited by B.D. Karpova, V.Ye Kovshilo, Izdatel'stvo "Meditsina", 30,000 copies, 447 pages, UDC 613.6(035)]

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ANNOTATION

[Text] This manual illuminates the pressing problems of labor hygiene and industrial sanitation rather fully on a modern scientific level. It presents the hygienic characteristics of the principal harmful production factors, and information on their biological action upon the body (occupational diseases), on hygienic standards, and on preventive measures. Material are given on labor hygiene in individual industrial sectors--coal, metallurgical, chemical, and so on, and in agriculture. The manual contains data pertaining to Soviet law concerning industrial sanitation inspection, labor hygiene applicable to women and adolescents, and morbidity of industrial workers. Sections pertaining to labor hygiene in production operations in which carcinogenic compounds, ultrasound, and infrasound are unfavorable factors have been included.

The second edition is supplemented by new data: Chapters are included on labor hygiene pertaining to water transportation and laser emissions; new recently approved public health rules, construction norms, and state standards are presented.

The "Manual on Labor Hygiene" is the most complete guide available, and it is intended for physicians working at epidemiological stations and in industrial enterprise medical units and public health points, as well as for hygienists of different specialties. It will doubtlessly be of interest to engineers concerned with safety in industrial enterprises, trade union technical inspectors and certified physicians, and laboratory and institute colleagues.

This edition contains 67 tables.

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ELECTROMAGNETIC FIELDS

Moscow SPRAVOCHNIK PO GIGIYENE TRUDA in Russian 1979 signed to press 19 Apr 79 pp 42-63

[Article by T. V. Kalyada]

[Text] Electromagnetic energy of frequencies varying from infralow to superhigh enjoys broad application in all areas of science and technology. It is used in industry for induction and dielectric heat-treatment of materials, and to place a substance into a plasma state. It is used in radio communication and radio broadcasting, in television, and in radar applications; it is employed in radiometeorology and astronomy, radio navigation, and medicine. Systems generating, transmitting, and using electromagnetic energy in production processes create electromagnetic fields in the environment.

Physical Characteristics of the Principal Parameters

An electromagnetic field propagates in the form of electromagnetic waves at a velocity close to the speed of light. The principal parameters of electromagnetic oscillations are: wavelength, oscillation frequency, and propagation rate, which are associated by the relationship:

$$\lambda = \frac{c}{f\sqrt{\varepsilon' \mu'}},$$

where λ is the wavelength, $c = 3 \cdot 10^3$ m/sec is the rate of propagation of light in a vacuum and, for practical purposes, in air, f is oscillation frequency, and ε' is dielectric and μ' is magnetic permeability in air, equal to 1.

The electromagnetic spectrum from infralow to superhigh frequencies is arbitrarily subdivided into bands depending on oscillation frequency or wavelength (Table 7).

The unit of oscillation frequency is the hertz--one complete cycle in 1 second. Multiple units are also employed: kilohertz (1 kHz = 10^3 Hz), megahertz (1 MHz = 10^6 Hz), and gigahertz (1 GHz = 10^9 Hz).

Table 7. Spectrum of Electromagnetic Oscillations From Infralow to Superhigh Frequencies

Frequency Band	Wave Band	Oscillation Frequency	Wavelength
Low frequencies (LF)	Infralow	0.003-0.3 Hz	$10^7 - 10^6$ km
	Low	0.03-3.0 Hz	$10^6 - 10^4$ km
	Industrial	3 Hz - 300 Hz	$10^4 - 10^2$ km
	Acoustic	300 Hz-30 kHz	$10^2 - 10$ km
High Frequencies (HF)	Long	30-300 kHz	10 - 1 km
	Medium	300 kHz-3 MHz	1 km - 100 m
	Short	3 - 30 MHz	
Ultrahigh Frequencies (UHF)	Ultrashort	30-300 MHz	10 - 1 m
Superhigh Frequencies (SHF)	Decimeter	300MHz-3 GHz	100 - 10 cm
	Centimeter	3 - 30 GHz	10 - 1 cm
	Milimeter	30-300 GHz	10 - 1 mm

An electromagnetic field can be described as a variable electric field and a magnetic field inseparably associated with it. Within the radiation zone, an electric and a magnetic field are mathematically associated by the relationship:

$$E=\sqrt{\frac{\mu_0}{\varepsilon_0}}\cdot H=377\cdot H,$$

where $\sqrt{\mu_0/\varepsilon_0}$ = 377 ohms; 377--number characterizing wave resistance of free space; H--field magnetic component; E--field electric component; ε_0--dielectric permeability; μ_0--magnetic permeability.

An electromagnetic field about any source of wave emissions is arbitrarily subdivided into three zones: near--induction zone, intermediate--interference zone, and far--wave zone, or radiation zone. If the geometric dimensions of the radiation source are less than the radiation wavelength (as in a point source), the boundaries of the zones may be defined as the following distances:

$R < \frac{\lambda}{2\pi}$ — Near Zone

$\frac{\lambda}{2\pi} < R < 2\pi\lambda$ — Intermediate Zone

$R > 2\pi\lambda$ — Far Zone

Therefore an induction field dominates when long, medium and, to a certain degree, short and ultrashort wave sources are present in a working building, while the intermediate zone and the radiation field dominate when microwaves are generated. The conditional distances of propagation from an induction field emitter are 160-500 m for long waves, 16-160 m for medium waves, 1.6-16 m for short waves, 16 cm-1.6 m for meter waves, 1.6-16 cm for decimeter waves, and 0.16-1.6 cm for centimeter waves.

There is no definite dependence between the electric and magnetic components of an electromagnetic induction field, and they may differ from each other by many orders of magnitude ($E \neq 377\ H$). In the induction zone, the intensities of the electric and magnetic components are 90° out of phase. When one of them attains its maximum, the other is at its minimum.

In the radiation zone, the intensities of both field components are in phase, and in any moment in time they are proportionately dependent. Therefore the mathematical dependence $E = 377\ H$ is valid only in relation to the radiation zone.

As we travel away from the emission source, electromagnetic fields weaken (attenuate) quickly. In the induction zone, the intensity of the field's electric component is inversely proportional to the cube of the distance, while the intensity of the field's magnetic component is inversely proportional to the square of the distance. In the radiation zone, electromagnetic field intensity diminishes in inverse proportion to the distance. When highly directional radiation sources (antennas) have dimensions significantly exceeding the emission wavelength, the boundary of the far zone is farther away. It depends in this case on the ratio between the antenna dimensions and the wavelength:

$$R \geqslant \frac{2D^2}{\lambda},$$

where D is the greatest geometric aperture of the emitting antenna and λ is emission wavelength. For practical purposes, meanwhile, where $D \gg R$, the boundary of the far zone may be significantly closer, down to several orders of magnitude of D, since the induction field attenuates rapidly with distance. When the radiation source consists of long slits, louvers, or openings in a screen, the formed field is for practical purposes several D . ng (in these cases D is the length of the radiating slit).

Inasmuch as electric and magnetic fields of different intensities exist within the induction zone, the intensity of low (LF), high (HF), and ultrahigh (UHF) radiation received by workers is evaluated separately, using different intensities for the electric and magnetic components of the field. The intensity of the electric field is measured in volts per meter (v/m), while the intensity of the magnetic field is measured in amperes per meter (a/m).

In the wave zone, which is the one that for practical purposes affects persons working with superhigh frequency (SHF) apparatus, field intensity is determined from the power flux density--that is, the quantity of energy falling upon a unit of surface area. In this case the power flux density (PFD) is expressed in watts per square meter, or in fractions of watts: milliwatts and microwatts per square centimeter (w/m^2, mw/cm^2, $\mu w/cm^2$).

In hygienic practice, we most often express PFD in mw/cm^2 or $\mu w/cm^2$.

PFD, E, and H are associated together in the wave zone by the relationships:

$$P\left[\frac{\text{мW}}{\text{cм}^2}\right] = \frac{E^2\,[\text{v/м}]}{3750} = 19 \cdot H^2\,[\text{A/м}],$$

$$\left[E\,\frac{\text{V}}{\text{м}}\right] = 86 \cdot \sqrt{P\,\frac{\text{мW}}{\text{cм}^2}}$$

$$H\left[\frac{\text{A}}{\text{м}}\right] = 0{,}23\,\sqrt{P\,\frac{\text{мW}}{\text{cм}^2}},$$

where P is power flux density, E is electric field intensity, and H is magnetic field intensity; the dimensions of the appropriate parameters are shown in brackets.

The PFD may also be determined at different distances from the source, when we know the emitted power:

$$P = \frac{W}{4\pi R^2},$$

where W is emitted power.

When directed radiation is involved, this value should be multiplied by the antenna gain, which depends on the emitter's parameters.

A complex pattern of direct and reflected waves arises in production buildings containing metallic equipment, and in shielded enclosed spaces. In such cases we may observe formation of standing waves and irradiation conditions similar to those found in the induction zone. Therefore power flux density (PFD) per unit surface would not adequately describe the intensity of irradiation. In order to arrive at a more accurate description of irradiation intensity, we use the density of electromagnetic energy (the quantity of field energy per unit volume), expressed in ergs per cubic centimeter (ergs/cm^3). In the wave zone, this value is associated with the field's E and H values or the PFD (P) by the relationship:

$$W = W_E + W_H$$

$$W_E \left[\frac{\text{ergs}}{\text{cm}^3}\right] = \frac{10^{-8}}{72} \cdot E^2 \cdot \left[\frac{\text{V}}{\text{M}}\right],$$

$$W_H \left[\frac{\text{ergs}}{\text{cm}^3}\right] = 2\pi \cdot 10^{-6} \cdot H^2 \left[\frac{\text{A}}{\text{M}}\right],$$

$$W \left[\frac{\text{ergs}}{\text{cm}^3}\right] = 3{,}3 \cdot 10^{-7} \cdot P \left[\frac{\text{MW}}{\text{cm}^2}\right],$$

where W is the density of electromagnetic energy in a unit of volume.

We can use the energy density of an electromagnetic field to determine the degree of irradiation by a field of any configuration: in the induction zone, in the wave zone, and complex fields resulting from simultaneous operation of several sources generating in the same band or at different frequencies.

Electromagnetic oscillations created by high frequency oscillators may be harmonic, where E and H vary according to a sine or cosine law, or modulated, where the amplitude, frequency, or phase varies according to a certain law. Pulse modulation pertains to complexly modulated oscillations. When oscillators operate in pulsed mode, electromagnetic pulses of a certain length follow one another periodically, and they are separated from one another by intervals of a given duration. The power of energy contained in a pulse is significantly higher than the mean radiation power, and the association between these values is expressed by the relationship:

$$P_p = \frac{P_m}{\sqrt{F \cdot \tau}},$$

where P_η is energy density per pulse, P_m is mean power, F is the pulse repetition frequency (expressed in Hz or pulses/sec), and τ is pulse duration, sec.

Electromagnetic waves are typified by polarization. If the three-dimensional orientation of the E and H vectors remains constant while the field moves, we are dealing with linear polarization; if the waves vary according to a certain law, then we are dealing with elliptical and circular polarization.

If we are to make a hygienic assessment of the radiation conditions experienced by workers, in addition to the physical parameters of the electromagnetic field we would need to know the nature of irradiation. The field's action may be constant or intermittent. Both periodicity and aperiodicity of irradiation, varying in intensity and exposure time, are typical of the latter. Concurrent physical and chemical factors of the production environment, produced both by the work of generator systems and by production processes making use of electromagnetic energy, have important hygienic significance.

Electromagnetic Field Sources

As power engineering and electrification undergo development, various electric devices working on high and superhigh voltage alternating current and intended for long-distance transmission and distribution of energy enjoy increasingly broader application. Electric power transmission lines carrying voltages of 100, 220, 330, 500, and 750 kv, outdoor distribution systems contained within switching apparatus, protective devices, automatic systems, measuring instruments, collecting and connecting bus bars, and auxiliary devices are sources of industrial frequency electric fields (IFEF). The size of the bias current and electric field passing through an individual present in an electric field while working on high-voltage substations and aerial transmission lines varies within broad limits, from 2 to 45 w/m and from 6 to 570 μa, and it depends on the nature of the emission source and the voltage. The greatest electric fields and current leakage are found with 500 and 750 kv power transmission lines and outdoor distribution systems. Minimum electric field intensities are found in enclosed spaces on the territory of an outdoor distribution system. Repairs are made on circuit breaker drives and switches, single circuits are tested, and other such jobs are performed directly on the equipment of outdoor distribution systems in places characterized by high electric field intensity. The time of exposure to electric fields of different intensities depends on the jobs being done, and it varies from several minutes to several hours in a work shift.

Induction Heating

Low frequency electromagnetic energy (1-12 kHz) is broadly employed in industry to harden, melt, and heat metal. Induction coils and certain parts of the feeder lines of machinery producing power of up to 500 kw do not possess shielding devices, and they serve as sources of electromagnetic energy. When metal is subjected to heat treatment, the intensity of the magnetic field produced is 500-750 a/m; steel smelters and furnace operators are subjected to the combined action of magnetic fields, noise with an intensity of 80-90 db, and radiant energy of up to 3-4 $cal/cm^2 \cdot min$.

The use of the energy of a pulsed low frequency electromagnetic field for stamping, pressing, for the joining of various materials, for casting, for directed changes in metal structure, and for other production processes is accompanied by formation of equal-frequency electromagnetic fields.

When we operate magnetopulse devices (MIU-6, MIU-20, etc.) and Iskra hydroelectric devices, although the variations in the design of the power production and support systems is insignificant, the intensities of the magnetic component of the field experienced at the control console vary from 2 to 600 a/m for MIU devices and from 58 to 565 a/m for EGU [hydroelectric] devices. Field intensity at operator working places near the equipment varies from 20 to 3500 a/m (MIU) and from 170 to 2850 a/m (EGU).

The highest magnetic field intensities are recorded near an MIU-20 inductor when crushing parts located within the inductor. In a metal "dispensing" operation the intensity of the magnetic field is not great (20-560 a/m), since the radiation source--the inductor--is within the semifinished product, which serves as a shield.

The intensity of a pulsed electric field experienced by people working with an MIU and an EGU is insignificant, since these devices possess electric shielding.

Tube-type oscillators are sources of high and ultrahigh frequency energy. Oscillators used for industrial heating of metals and dielectric materials do not differ in principle from those of radio transmitting devices. Tube-type oscillators used in high frequency heating are usually single-circuit or double-circuit oscillators. In a single-circuit system, the oscillating circuit consists of the capacitance of a capacitor and an inductance coil (which is simultaneously the primary winding of a high frequency transformer). The inductor (the second one) serves as the secondary winding of the transformer, to the leads of which the working inductor are connected. In double-circuit systems, one circuit is connected to the anode circuit of the oscillator tube (the anode circuit), and the second is connected by induction to the first (the load circuit). The working element used in induction heating is a melting or heating circuit (the inductor), while with dielectric heating the working element consists of the capacitor plates. Induction heating is used for high frequency melting of metal and for heat treatment of semifinished parts, articles, electronic instrument components, and metallic articles. An inductor's EMF [electromagnetic field] energy is used to excite substances into a plasma state. The power produced by such devices varies, and the frequency band has limits from 60 kHz to 20 MHz. The working elements of high frequency devices may serve as electromagnetic wave emission sources in a production building: melting or heating inductors, bus bars carrying HF energy, HF transformers, and various oscillator components in high frequency circuits (the inductance coils of oscillating circuits, feedback coils, capacitor batteries, anode choke coils, tube anodes, some measuring instruments.

G-4-42, GLZ-61A, GZ-46, and GL devices may possess an ineffectively shielded oscillator box or oscillator circuit containing capacitor batteries. The intensity of radiation experienced by persons working with such devices may vary from hundreds to thousands of v/m, and up to hundreds of a/m. LGZ-100, LGPZ-30, LG-68, and GZ-46 devices, which are used for melting, hardening, and heating metal, can also possess unshielded parts: a matching HF transformer, and capacitor batteries contained in the oscillating circuit. LZ-107 and LZ-207 devices, which operate at the frequencies of 60-70 kHz, do not have shielding around the main working element and the matching transformer. The intensities of the electric and magnetic fields near the emitting element may be within several tens of v/m and units of a/m.

LG-3-100-53, LPZ-100, LGZ-200, LGZ-10, LPZ-10A, LG-7, LG-3, LZ-37, LP-67 and other such devices have only the working element exposed, taking the form of various configurations of inductors. The intensity of radiation experienced by persons working with these devices does not exceed several dozen v/m and a/m (at distances not greater than 0.5 m from the radiation sources). Inasmuch as metal cabinets (shields around HF devices) have louvers, peepholes, openings for attachment of measuring instruments, and holes that degrade the shielding properties, emissions from an oscillator cabinet may exceed the maximum permissible level in relation to the electric and magnetic components.

High EMF intensities are created by components of high frequency systems used in electronic tube industry to heat tube anodes and cathodes during evacuation. If the inductors can be moved outside the oscillator cabinet, the length of the line transmitting high frequency energy increases. Such components are not shielded as a rule. Batteries of air capacitors in the oscillator cabinet may also not be shielded. Field intensities at workplaces may vary from units to 250 v/m for the electric field and up to 50 a/m for the magnetic field. When electronic tubes are aged, roentgen radiation of moderate strength, representing one-third to one-fifth of the maximum permissible physical dose for a 6-hour workday, may arise after degassing at high voltage.

Electromagnetic energy may be radiated by an unshielded working element when exciting a substance in the magnetic field of an inductor into its plasma state, and the amount of energy depends on the degree of shielding and the power generated.

The nature of the field's spread through a production building is affected by the shielding within the building and the locations of metallic objects, metallic semifinished articles, and the electric circuits within it. High frequency currents induced within them by the external field makes them sources of secondary emissions, which may superimpose themselves over the field excited by the principal emitter. Liberated heat may have an influence on the temperature conditions of the building when HF energy is used for industrial heat treatment. Unsensible shielding of the entire building would sharply worsen the meteorological conditions. When the production processes indicated here are involved, we may witness the combined action of factors of the production environment such as EMF's, roentgen and infrared emissions of low intensity, and high air temperature.

Dielectric Heating

Devices operating in a frequency range from 3 to 150 MHz and in a power range from 1 to 30 kw are used for dielectric heating (drying of moist materials, gluing of wood, heating, welding, thermal stabilization, and melting of thermoreactive materials, including plastics). Working elements (capacitors) of GS-48, GS-46, and GLE-61A devices used to dry moist materials, wood, and yarn are mounted within metallic shielding chambers outside the building in which the oscillator is located. The intensity of the electric component of the field near the peepholes of drying chambers may be within dozens of v/m, while the magnetic component may be insignificant (0.5 a/m). Intense radiation (more than 100 v/m) would be detected in the building in which the oscillator is located (when bus bars, batteries of oscillating circuit capacitors, and inductance coils are not shielded). Devices used for heat treatment of thermoreactive materials, such as the UKV-3, DKV-2, LGS-0.2, LGYe-1, LGYe-3B, LGS-1.5, LGD-LD-1-4, etc., operate in a 10-40 MHz range, the oscillation power being from 80 w to 3 kw. UHF devices have working electrodes taking the form of flat or shaped capacitors or rollers. Emission sources may include unshielded working electrodes, feeder lines (when the oscillator is mismatched), tunable capacitors, and shielding irregularities (openings, slits in the oscillator housing, and in the welding press).

Electric field intensities of significant values (up to 150 v/m) are detected at the workplaces of operators performing spot welding with DKV-2 devices located in shielded cabinets.

Electric fields with an intensity up to 100 v/m are created up to 0.3 m from the radiation source when using devices such as the MST-3, which welds plastic articles with roller capacitors. Devices such as the LGYe-3B, used to glue wooden articles together, create an EMF due to ineffectively shielded capacitor plates and feeder lines. The intensity of the electric field at operator workplaces may attain 30 v/m. Oscillators built in recent years are fully shielded, and their emissions total units of v/m.

When ventilation in production buildings containing dielectric heating devices is ineffective, we may exceed the maximum permissible concentration of hydrocarbons when welding plastic materials, and of phenol and formaldehyde when molding and pelletizing plastics with presses employing HF devices as heaters; the maximum permissible limits for air temperature may be exceeded as well.

Testing Tube-Type UHF Instruments

When we manufacture tube-type instruments, we must check the characteristics of the electronic tubes, testing them in different modes. Radiation sources in the dynamic testing circuits may include: the self-oscillator, operating as a self-oscillating tube (of the sort used in a GU-33B, GU-34B, GU-15), the power amplifier (the tube being tested), the anode circuit, and the load. The intensity of emissions depends on the output power of the device and the shielding afforded to individual HF components. Field intensity is up to 10 v/m at the workplace (assuming general irradiation) and 10-60 v/m locally (around the hands).

Designing and Experimentally Operating Radio Transmitting Devices

When we design and experimentally operate radio transmitting devices (when we test models of UHF transmitters and their blocks, when we conduct experiments), we form electromagnetic fields. When tests are performed on an exposed circuit, the field intensity at the workplaces may attain 200 v/m. When transmitter models are adjusted and tuned, radiation may be produced through slits and gaps in the oscillator housing, and by wires leading into and out of the transmitter (carrying UHF energy); radiation may also be produced owing to absence of blocking capacitors or choke coils, and due to unshielded feeder lines. The hands of the workers are exposed to the greatest amount of radiation (150-200 v/m). When general irradiation is involved, the field intensity varies from units to several tens of v/m. The processing and testing of blocks, cascades, and circuits in HF (longwave, medium-wave, shortwave) radio apparatus in a design office and in scientific research institutes is typified by high variability in radiation intensity. The intensity of the field produced depends on the degree to which the HF components are shielded, the types of transmitters and antennas employed, the extent to which the power transmission lines are matched, and the work of the transmitter at equivalent power. From a hygienic point of view the latter is the most favorable variant. The working conditions are significantly worse when transmitters are outfitted with asymmetrical antennas. In the former case the field intensity varies from units to 65 v/m, while in the second it varies from 35 to 600 v/m. When several transmitters are tested simultaneously, the field intensity rises significantly (due to summation of power).

Operation of Transmitters at Radio and Television Transmitting Centers

Up to 20 transmitters operating in different bands and power ranges may be installed in the generator buildings of radio and television transmitting centers. Ineffectively shielded high frequency components in transmitter blocks (power summation systems, separation filters, etc.) and unshielded feeder lines and switching devices are the principal sources of electromagnetic energy. Antenna systems are also a source of EMF's, both within the territory of the antenna field and possibly in production buildings.

The intensities of EMF's produced by operating HF transmitters vary from 5 to 250 v/m. In portions of the antenna field in which personnel may be adjusting and repairing antenna-feeder devices, the intensities of the HF field may be from 60 to 200 v/m.

UHF electromagnetic field levels present in the instrument rooms of television centers depend on the type of transmitting devices. Older radio-television centers create EMF's with intensities from 6 to 150 v/m in production buildings, while modern transmitters produce from units to 12 v/m. The intensity of the magnetic field is found to be from 0.2 to 2.0 a/m. EMF's within the antenna field vary from 2.0 to 9.5 v/m, while on the television antenna tower the EMF will vary from 9 to 450 v/m at different elevations above the ground.

Transmitters (HF and UHF) contained in radio transmitting centers (marine, fishing, river fleet) create electromagnetic fields varying in intensity from tens to several hundreds of v/m. When several transmitters operate simultaneously, the intensity of the field rises significantly.

The intensity of magnetic fields produced in the buildings of civil air fleet radio transmitting centers (when shortwave and ultrashort-wave transmitters are operating) varies within rather broad limits (from units to several hundreds of v/m). The greatest intensities are detected by feeder lines (when they are used in ring arrangement), and when they are inadequately matched and asymmetrical. Meteorological conditions are not always favorable at workplaces; higher air temperature and low relative humidity are detected. Acoustic pressure in the medium frequency band may attain 90 db. Shipboard radio sets make extensive use of shortwave and medium-wave transmitters located in a radio compartment. These transmitters create electromagnetic fields varying in intensity from several tens to 1,500 v/m. Shielding of the radio compartment creates the conditions for concentration of radio waves within a small space owing to their reflection from the compartment's walls. Unshielded feeder lines, antenna switches, and switching devices serve as the sources of radiant energy. The intensity of EMF's produced by operating Brig, Korvet, and Musson sets is below or near the limit of the maximum permissible level.

When a radio set is operating, the deck and the superstructure are within the zone of action of electromagnetic fields emitted by the antenna, and they serve as sources of secondary emissions (metallic structures, cables, nonworking antennas). The nature of radiation exposure of the crew depends on the height and location of the antenna, the radiating power and frequency and the extent of wave reflection from metallic structures. The highest field values (hundreds of v/m) are recorded on the compass platform, and near stays, shafts, navigation instruments, metallic barriers, and pipes. The field's magnetic component does not exceed units of a/m. On the boat deck, an electromagnetic field would have an intensity of units of v/m.

Physiotherapeutic Offices

Physiotherapeutic offices perform diathermy and inductothermy with UDL-200M, UDL-300M, DKV-1 and DKV-2 high frequency oscillators, apparatus such as the UVCh-2M, UVCh-200, UVCh-4, and UVCh-300 for UHF therapy, and Luch-58, Luch-2, Mikroterm, Volna superhigh-frequency apparatus for microwave therapy. These devices operate in a frequency band from 1.6 to 2,450 MHz, and their output power is from 20 to 350 w. The principal sources of electromagnetic fields from operating high frequency apparatus include electrodes, feeders, and emitters of various types.

The intensity of the field near the electrodes of an operating UDL apparatus attains 20 v/m, while around a DKV apparatus it reaches 30-80 v/m. Operating UHF apparatus produces radiation of the greatest intensity and duration. The intensity of the electric field may reach hundreds of v/m. Persons servicing permanently installed microwave apparatus may experience a power flux density of 300-600 $\mu w/cm^2$. Persons operating portable apparatus experience a radiation intensity of not more than 23 $\mu w/cm^2$. The intensity of radiation to which medical personnel are exposed depends on a number of conditions: the power of the apparatus, the diameter of the electrodes and the distance between them, the method of their application, the shape and diameter of the microwave emitter, the method of irradiation, and the quantity of simultaneously operating apparatus.

Radio Engineering Devices (SHF Band)

Use of superhigh frequency energy in radar, radio navigation, meteorology and astronomy, radiospectroscopy, geodesy, and nuclear physics has led to extensive development of an industry producing SHF oscillators.

Personnel processing and testing the blocks and units of radar set models in design offices and scientific research institutes may be exposed to SHF radiation produced by components in exposed blocks and units, and by ineffectively shielded radar set models. In these conditions the intensity of irradiation varies from tens to several hundreds of $\mu w/cm^2$. A complex of radar sets is tested (with antennas operating) in conditions close to those of real operation, meaning that the PFD may attain tens of $\mu w/cm^2$ at the workplaces. Personnel adjusting, tuning, and testing radar sets in the final testing shops of plants and in repair shops experience highly variable radiation intensities. The principal sources of radiation in a plant shop are the antenna systems. Exposed antenna systems may create radiation intensities of up to 10 mw/cm^2 at the workplaces. Antenna system fitter-installers and bridge crane operators may find themselves in especially unfavorable conditions when radar sets are operated with a live antenna. They may be subjected to radiation intensities from 500 $\mu w/cm^2$ to 10 mw/cm^2. When the antenna rotates and scans, all shop personnel may be subjected to microwaves. An increase in the PFD is noted when several radar sets are operated simultaneously.

Unfavorable conditions typified by high irradiation (1 mw/cm^2 and higher) by several radar sets operating simultaneously are created during the repair of radar apparatus in workshops.

The working conditions of personnel testing radar sets in testing ranges depend on the area of the testing range and the number of operating sets. Operators find themselves in better conditions, since for the bulk of their work time they are within buildings or inside special shielded compartments.

The intensity of radiation experienced by personnel inside buildings may be from tens to hundreds of μw/cm^2. Testing ranges located on plant territory have a relatively small area, in which several radar sets may be located. This creates conditions for summation of the power flux densities, meaning that the flux intensity may be higher than 500 μw/cm^2.

The working conditions of personnel adjusting, tuning, testing, and inspecting individual components of units and instruments contained within UHF apparatus in a production situation depend on the nature of the work they are doing (testing an antenna-waveguide tract for electric strength, testing and aging oscillator tubes and entire devices). Emission sources may include the cathode leads of magnetrons, points of access of pistons used to tune oscillator grid and anode circuits, rotating junctions, waveguide-coaxial junctions, flange joints, transceivers, phase shifters, matching devices, antenna equivalents in the case of incomplete energy absorption, exposed waveguide tracts, breaks within them, and couplers. When low-power circuits are tested and aged, the power flux density varies from units to tens of μw/cm^2, and it may attain 1 mw/cm^2 in the presence of operating high-power emitters.

Donets, Don, Neptun, Okean, and Mius longe range and short range radar sets are used for navigational purposes aboard various classes of ships (passenger, transport, fishing, technical, scientific research, and so on). These sets operate in pulsed generation mode with a pulse power varying from 15 to 100 kw, and in circular scanning mode with an RPM from 14 to 24. Radar set generators are located either in a special compartment of the machine room or in the chart room or wheelhouse. Antenna systems are installed on the compass platform. Various types of antennas (slot aerials, parabolic antennas, etc.) serve as SHF energy sources on decks and superstructures. The intensity of ship crew irradiation varies within broad limits--from units to hundreds of μw/cm^2, and it depends on the height at which the antennas are installed, their type, their emitted power, the antenna gain, the architecture of the ship, and the nature of reflection of waves from the ship's metallic structures. The highest radiation levels exist along the axis of the main lobe of the polar diagram. The PFD is lower by a factor of 10 in the zone of the rear and side lobes, both in the horizontal and vertical planes. The intensity of radiation on decks and superstructures within the zone of action of antennas depends on the operating tilt angle of the radar set antenna's electric axis (its angle of sight). With negative values of this angle the SHF radiation level grows, and as the antenna angle of sight increases the intensity of irradiation drops. Personnel making repairs on and preventive inspections of radar sets while at sea may be exposed to SHF energy of up to tens of $\mu w/cm^2$ when tuning and adjusting exposed blocks; at such times they are subjected to radiation from the cathode leads of magnetrons, flange joints of waveguide lines, and exposed tracts.

The ground radar equipment used by civil aviation includes various types of radar (surveillance, landing control, air traffic control, weather). The antenna arrays of ground radar sets are powerful sources of microwave emissions.

Other emission sources are airplane antennas undergoing system checks. The radiation is characterized by variability in intensity and nature. Power flux densities vary from tens to thousands of $\mu w/cm^2$, and they depend on the power of the radar devices, the height of antenna installation, scanning height, the direction of emissions, and the distance from the source.

Centimeter and millimeter waveband radar resources are used by the hydrometeorological service to detect, observe, and determine the location of cloud systems and centers of thunder activity. Antennas are the main sources of radiation to which workplaces and persons occupationally not involved with radar operation are subjected. The intensity of irradiation depends on variations in the tilt angle of the axis of the main lobe, the height at which the antenna is installed, and the distance from the emission source, and it varies from tens of $\mu w/cm^2$ to 1 mw/cm^2.

Accompanying unfavorable environmental factors personnel tuning, adjusting, and repairing radar set blocks may experience could include: soft roentgen emissions generated by tube-type instruments carrying a high anode voltage (up to 20 kev), higher temperature in compartments, high frequency noise, and air ozonization.

The microwave band is used in radio relay communication. The apparatus of radio relay lines includes cermet triodes, klystrons, traveling wave tubes, and oscillating circuits taking the form of resonators or segments of short-ciruited concentric lines, which are the principal sources of SHF emissions. SHF energy may penetrate into buildings from reflectors and loudspeakers. Station construction insures sufficient shielding, and the intensity of irradiation is within permissible values (below 10 $\mu w/cm^2$). The irradiation intensity may be 18-44 $\mu w/cm^2$ in emergency repair operations.

Plasma Research Devices

SHF devices used to study plasmas and to obtain them usually create electromagnetic fields with a PFD from 0.3 to 20 $\mu w/cm^2$. Leaks in the joints of waveguide tracts and emissions from the plasma itself may serve as radiation sources.

Action Upon the Body

The biological action of electromagnetic fields depends on the frequency band, the intensity of the operating factor, the time of exposure, the nature of radiation (continuous, modulated), and the irradiation pattern (constant, aperiodic, intermittent).

A 50 Hz electric field may produce painful sensations if electric discharges occur when the current leakage is more than 50 μa. Chronic exposure to a low frequency electric field manifests itself as both subjective disturbances taking the form of neurological complaints (headache, sluggishness, sleepiness, insomnia, irritability, pains in the vicinity of the heart), and functional disorders of the central nervous system, the cardiovascular system, and peripheral blood. Autonomic dysfunction proceeds as the neurasthenic hypersthenic syndrome coupled with a vascular component--hypertension, sinus tachycardia, and disturbed intraventricular conduction (EKG). The lability of peripheral blood indicators depends on the intensity of the electric field and the time of action. When a high intensity electric field is involved, red blood (erythrocyte, reticulocyte, hemoglobin) indicators are high, and a high percentage of neutrophils exhibiting pathological graininess can be noted; the early stage may be typified by moderate leukocytosis, followed by leukopenia.

The mechanism behind the biological action of radio frequency electromagnetic fields is associated with their thermal and athermal effects. The thermal action of an electromagnetic field is typified by growth in body temperature and local selective heating of tissues, organs, and cells owing to transformation of electromagnitic energy into thermal energy due to dielectric losses in these tissues. Dielectric losses in tissues increase as the oscillation frequency rises. The thermal effect depends on the radiation intensity. The threshold intensities for the thermal action of electromagnetic waves upon the animal body are typified by the following parameters: medium waveband--800 v/m; short--2,250 v/m; ultra-short--150 v/m; decimeter--40 mw/cm^2; centimeter--10 mw/cm^2; millimeter--7 mw/cm^2. Radiation intensity parameters below these values (and eliciting a thermal effect) are not neutral to the body. According to the theory of molecular polarization and the ionic theory, as well as the conception of information interaction between electromagnetic fields and living objects, low intensity electromagnetic fields have extrathermal action. A cumulative biological effect is typical of radio frequency electric fields of multiply repeating action. Experimental data also show that a disadapting action is inherent to SHF emissions.

High intensity radio frequency radiation may cause destructive changes in tissues and organs. Acute injuries may be severe, moderate, and light. These forms are encountered extremely rarely, and they may arise in accident situations, and when safety rules are violated. The degree to which the autonomic syndrome manifests itself in response to moderate and light injuries may vary from diffuse to pronounced form. Disturbances in the cardiovascular system in moderate cases may manifest themselves immediately after irradiation as diencephalic crises and as attacks of paroxysmal tachycardia. Later, we observe changes caused by a symptom complex typical of vascular hypotension; however, cases of hypertension are possible as well. Blood system disorders boil down basically to development of moderate neutrophilic leukocytosis.

Clinical research data permit distinction of three typical syndromes in response to the action of radio frequency emissions: asthenic, asthenic-autonomic, and diencephalic. The clinical pattern of the chronic action of radio frequency electromagnetic fields of nonthermal intensities develops on the background of growing neurasthenic symptoms. In the early stages of the factor's action, complaints of headache, higher tiring, irritability, sleep disturbances, and pains in the vicinity of the heart are typical. An expressed asthenic-autonomic syndrome often proceeds as a hypotonic type (hypotension, bradycardia, a highpeaked T spike).

In a more pronounced stage, the asthenic (neurasthenic) syndrome, and its accompanying autonomic-vascular dysfunction, develops as the hypertonic type, sometimes together with cerebral crises of sympathoadrenal nature. Complaints become more intense--easy excitability, disturbed sleep, reduced memory, seizure-like headaches, possible dizziness, passing out, gripping pains in the vicinity of the heart, lability of pulse, hypertension, and angiospastic reactions--constriction of arteries in the retina. At the moment of an attack the patient exhibits tremor, paling or reddening of the face, general hyperhydrosis, pronounced weakness, frequently higher body temperature, and growth in arterial pressure.

Cataracts may develop in response to SHF radiation, with both short-term irradiation and lengthy exposure to low PFD's.

Blood alterations are typified by polymorphism, and for the most part we note lability in the number of leukocytes and, more frequently, a tendency toward leukocytosis. With pronounced forms of the disease, leukopenia, lymphopenia more rarely, monocytosis, reticulocytosis, and moderate thrombocytopenia develop, and changes in bone marrow are possible. We note changes in protein fractions and a higher histamine concentration, the sugar curve undergoes alteration, and the concentration of phosphorus, potassium, and sodium in the blood changes. Disturbances are possible on the part of the endocrine system (thyroid hyperfunction, stimulation of the hypophyseocortical system, disturbance of sex gland function). The research done on the unique features in development of the symptoms and the successiveness of their formation within the bounds of clearly distinguishable clinical syndromes typical of chronic exposure to EMF's permit us to consider the question of distinguishing radiowave disease as an independent nosological form of occupational disease.

Setting the Hygienic Standards

According to the "Labor Protection Norms and Rules Applicable to Jobs at 400, 500, and 750 kv Alternating Current Industrial Frequency Electric Power Substations and Aerial Transmission Lines," approved by Order No 868-70 of the USSR Ministry of Public Health, 29 October 1976, exposure to electric fields is regulated in relation to both intensity and time of action. The permissible time that workers may remain within an electric field without protective resources and the electric field intensities are shown in Table 8.

Table 8. Permissible Time of Presence in an Electric Field Without Protective Resources

Paragraph Number	Electric Field Intensity kv/m	Total Daily Permissible Time of Presence of an Individual in an Electric Field, Min	Remarks
1	5	No limit	—
2	10	180	The standards of paragraphs 2, 3, 4, 5 apply on the condition that: a) During the rest of the workday the individual is located in places where electric field intensity is less than or equal to 5 kv/m; b) There is no chance that the person's body would be exposed to electric discharges
3	15	90	
4	20	10	
5	25	5	

When the intensity of the electric field is more than 25 kv/m at the workplace and when time within the electric field is beyond the norms, the work must be done while wearing protective resources. The intensities of radio frequency electromagnetic fields at workplaces must correspond to GOST [All-Union State Standard] 12.1.006-76. The maximum permissible intensity of a 60 kHz-300 MHz EMF at workplaces and in places where personnel occupationally involved with EMF's may be present must not ex ed the following during the work day:

Electric Component, v/m:

50--for frequencies from 60 kHz to 3 MHz;
20--for frequencies from 3 MHz to 30 MHz;
10--for frequencies from 30 MHz to 50 MHz;
5--for frequencies from 50 MHz to 300 MHz;

Magnetic Component, a/m:

5--for frequencies from 60 kHz to 1.5 MHz;
0.3--for frequencies from 30 MHz to 50 MHz.

The maximum permissible electric field power flux densities (w/m^2, $\mu w/cm^2$) in the 300 MHz to 300 GHz bands and the permissible time of presence at workplaces and in places where personnel occupationally involved with EMF's may be present (with the exception of irradiation caused by rotating and scanning antennas) are presented in Table 9. Interpolation is not permitted with this table.

Table 9. Maximum Permissible Electromagnetic Field Power Flux Densities

Power Flux Density		Time of Presence	Remarks
w/m^2	$\mu w/cm^2$		
up to 0.1	up to 100	Work day	—
From 0.1 to 1.0	From 10 to 100	Not more than 2 hrs	For the rest of the working time, the power flux density must not exceed 10 $\mu w/cm^2$
From 1.0 to 10.0	From 100 to 1000	Not more than 20 min	On the condition that safety goggles are used. For the rest of the working time, the power flux density must not exceed 10 $\mu w/cm^2$

The maximum permissible EMF power flux density within a frequency band from 300 MHz to 300 GHz and the time of presence at workplaces and in places of possible presence of personnel associated occupationally with EMF's produced by rotating and scanning antennas are presented in tables 9 and 10. Interpolation is not permitted in these tables.

Table 10. Maximum Permissible Power Flux Densities of EMF's Produced by Rotating and Scanning Antennas

Power Flux Density		Time of Presence	Remarks
w/m^2	$\mu w/cm^2$		
up to 1.0	up to 100	Work day	—
From 1.0 to 10.0	From 100 to 1000	Not more than 2 hrs	For the rest of the working time, the power flux density must not exceed 100 $\mu w/cm^2$

When roentgen radiation is present in the building or if the air temperature is high (above 28°C), the PFD must not exceed:

0.1 w/m^2 (10 $\mu w/cm^2$)--during the work day;

1.0 w/m^2 (100 $\mu w/cm^2$)--in 2 hours of the work day.

For the rest of the working time the maximum permissible EMF power flux density must not exceed 0.1 w/m^2 (10 $\mu w/cm^2$). The dose of roentgen radiation experienced by personnel must not exceed the values set by radiation safety norms NRB-76 approved by the USSR Ministry of Public Health.

Measuring the Intensity of LF, HF, and UHF Electromagnetic Fields, and SHF Power Flux Density

A PZ-1 instrument is used to measure the effective electric field intensity in the near zone (induction zone) within the industrial frequency band (50 Hz). The measuring limits for electric field intensity are from 1 to 60 kv/m. A PZ-2 instrument may be used to measure the intensities of the electric and magnetic components of a field produced by continuous and pulse-modulated oscillations in the band from 200 kHz to 300 MHz. The limits of measuring effective field intensities for the electric component of continuous and modulated oscillations are 0.5-3,000 v/m, and they are 0.06-500 a/m for the magnetic component; the corresponding figures for pulse-modulated oscillations are 200-10,000 v/m and 2.0-2,500 a/m.

The electric and magnetic components of HF and UHF fields are also measured by the IEMP-1 instrument, which is designed to measure effective electric field intensities from 4 to 1,500 v/m in the 100 kHz to 30 MHz frequency band and from 1 to 600 v/m in the 200-300 MHz band, as well as magnetic field intensities within 0.5 and 300 a/m in the frequency band from 100 kHz to 1.5 MHz in production buildings neighboring directly upon high frequency facilities (within the induction zone) operating in continuous emission mode.

The IEMP-T electric amd magnetic field measuring instrument may be used to measure the intensity of an HF field. The sensitivity of the IEMP-T is greater, and its weight and overall dimensions are lower due to substitution of tubes by semiconductors. A small number of controls makes it easy to operate and reduces the probability that the instrument would break down due to incorrect connection. Measurements may be made in the 60-100 kHz frequency band following additional calibration of an IEMP-1 and IEMP-T.

The intensity of the electric component of an EMF may be measured with an NFM-1 instrument (produced in the GDR) in the 0.06-30 MHz and 10-350 MHz frequency bands; the measuring limits are 3-2,500 v/m and 1.5-1,250 v/m respectively.

PZ-13 and PZ-9 instruments are used to measure power flux density (PFD) in the SHF band. These instruments can make measurements in the 150-16,700 MHz range. The limits of the measured power flux density are 0.02-316 mw/cm^2.

A P2-2 SHF oscillation PFD indicator (signaling device) may be used to monitor excessive SHF radiation levels.

Radiation intensity measurements must be made not less than once a year at workplaces in which personnel regularly exposed to radiation may be located. The measurements should be made at the maximum utilized emitted power. Worker irradiation intensity measurements must also be made when new devices generating electromagnetic energy are put into operation, after repairs on them, in association with every change in the production process, and in connection with changes in the design of protective resources. Measurements of PFD's from rotating and scanning antennas should be measured at workplaces, and in places where personnel may be present, with the antenna motionless, both on the axis of the main beam and within the lateral lobes. Measurements are taken by persons specially trained and appointed by the enterprise administration, in the presence of representatives from the safety service and the trade union organization.

The measurements are recorded in a special log and brought to the awareness of the administration (GOST 12.1.006-76). Instrumental methods for evaluating irradiation intensity may be supplemented by determination of field intensity and PFD by computation. Use of computation methods is especially important in preventive public health inspection. When new facilities are put into operation, danger zones may occupy tens and hundreds of square kilometers, and the computer data for field intensities would serve for tentative protection measures, for organization of safety zones, and for the planning of the work of inspection services. Therefore public health inspection organs must have facility with the mathematical methods for computing EMF and PFD values, and for using computed data as the basis of hygienic assessments to be employed in selection of the optimum conditions for construction of facilities such as radio transmitting stations, television centers, retranslating stations, and various types of radar facilities. The following computation methods are recommended. EMF intensities may be computed in the HF (longwave, medium-wave, shortwave) band for the wave zone (radiation zone) when $d \geqslant 2L^2/\lambda$, d being the distance from the antenna to the measuring point, in kilometers, and L being the maximum antenna dimensions.

As a rule the intensity of the electric component of a field (E) is computed using the Shuleykin-(Van-der-Pol') formula:

$$E = \frac{245\sqrt{P_{\text{kW}} G_a}}{d} \cdot F \, \frac{\text{mV}}{\text{m}},$$

$$E = \frac{7750\sqrt{P_{\text{W}} \cdot G_a}}{d} \cdot F \left(\frac{\mu\text{V}}{\text{m}}\right),$$

where E--intensity of the field's electric component; P--transmitter power; G_a--antenna gain; d--distance from antenna to point of measurement, km; F--attenuation factor, used to determine losses of electromagnetic energy in soil. The latter is determined with the following approximation formula:

$$F = 1{,}41 \frac{2 + 0{,}3x}{2 + x + 0{,}6x^2},$$

where x is the so-called "numerical distance." Within the range of long and medium waves, in which the condition $60\lambda \gg \varepsilon'$ is satisfied, it is determined with the formula:

$$x = \frac{\pi \cdot d}{60\lambda^2\sigma} = \frac{100\pi d}{6\lambda\sigma},$$

while in the shortwave band we use the formula:

$$x = \frac{\pi d\ (\text{m})}{\lambda\ (\text{m})} \cdot \frac{1}{\sqrt{(\varepsilon')^2 + (60\lambda\sigma)^2}},$$

where λ--wavelength, meters; ε'--relative dielectric permeability; δ--radioconductivity of the soil over which the radiowave propagates. The values of ε' and δ corresponding to different surfaces and soils are presented in Table 11.

Table 11. Basic Soil Parameters

Вид поверхности (1)	ε'	σ, 1/Ом·м (2)	σ (СГСЕ) (3)
(4) Влажная почва, ровная поверхность	5—15	$3 \cdot 10^{-3}$	$2(10^4-10^8)$
(5) Влажная почва с низкой растительностью	4	10^{-2}	$2(10^7-10^8)$
(6) Сухая почва, песок	2—10 (4)	10^{-3}	$2(10^6-10^7)$
(7) Почва, покрытая большим сплошным лесом	4	10^{-3}	—
(8) Крупные города	3—5	$7{,}5 \cdot 10^{-4}$	—

Key:
1. Type surface
2. Ohms·m
3. (SGSYe)
4. Moist soil, even surface
5. Moist soil with low vegetation
6. Dry soil, sand
7. Soil covered by large continuous forest
8. Large cities

This method of determining field intensity is suited to emissions having a 360° polar diagram and to the direction of maximum radiation of the main lobe of a diagram.

When computing field intensity in the UHF band, determination of the intensity of the field created by each transmitter is recommended. The following formula is employed:

$$E\left(\frac{\text{v}}{\text{м}}\right) = \sqrt{30PG_a} \cdot \frac{F(\Delta^\circ)}{R_{(\text{м})}} K,$$

where P(w)--power fed to the antenna; G_a--antenna directive gain.

The latter is determined with the formula:

$$G_a = \varepsilon \cdot 1.64,$$

where ε--antenna gain relative to a half-wave vibrator (in multiples); $(F\Delta^0)$--normalized multiplier determined from the polar diagram of a typical antenna in the vertical plane for the corresponding band; k--coefficient accounting for irregularities in the horizontal antenna polar diagram, equal to 1.41; R (m)--distance from the phase center of the antenna to the given point.

The latter is determined with the formula:

$$R_{(\text{м})} = \frac{H}{\sin \Delta^\circ} = \frac{r}{\cos \Delta^\circ},$$

where H is the height of the antenna's phase center above the given point, r is the distance from the base of the television center's tower to the given point, and $\Delta°$ is the antenna's angle of emission toward the given point (reckoned from the horizon).

It is also recommended that the peak power of the television facility, which corresponds to the level of syncrosignal transmission, be accounted for in the computations.

The total intensity of the field created by all transmitters is determined with the formula:

$$E_{\text{сумм.}} = \sqrt{E_1^2 + E_2^2 + \ldots + E_n^2},$$

where E_1, E_2, E_n are the intensities of the fields created by the individual transmitters at the same point.

One shortcoming of the methods described here is that the computations do not account for reflection from the ground and buildings, which sometimes increases the field's intensity. However, the error is not so great, since the computations are made with peak power.

A PFD may be calculated in the SHF band with the formula:

$$\text{PFD} = \text{PFD}_0 F k_1 k_2 \ (\mu\text{w/cm}^2),$$

where PFD_0--power flux density for an unobstructed trajectory--that is, without accounting for energy absorption and reflection; F--attenuation factor accounting for radiowave reflection from ground surface; k_1--coefficient accounting for the pulsed nature of emissions (fill-in factor); k_2--coefficient accounting for the antenna's polar diagram in the vertical plane, the emission angle, and the height at which the antenna is installed.

PFD_0 may be determined with the formula:

$$\text{PFD}_0 = \frac{100 P_p S c}{d^2 \lambda^2},$$

where P_p--transmitter pulse power, watts; c--antenna use factor, which in most cases is 0.6 ± 0.8; S--antenna aperture, m^2; d--distance from antenna to the point of PFD determination, m; λ--wavelength, m.

Given an even surface along the trajectory for a distance $d \leqslant 5.1(h_1 h_2/\lambda)$, the attenuation factor is conditionally set at 1.6; in the formula, h_1 is the height of the antenna center above ground surface and h_2 is the height of the point at which the PFD is determined, meters.

When $d > 6.0 \cdot (h_1 h_2/\lambda)$, attenuation factor $F = 1$.

At distances $6.0 \cdot (h_1 h_2/\lambda) > d > 5.1(h_1 h_2/\lambda)$, the value of the attenuation factor varies (Table 12).

Table 12. Attenuation Factor F for Different Distances

$$\left(d = k\frac{h_1 h_2}{\lambda}\right)$$

K	F	K	F
5,1	1,6	5,6	1,2
5,2	1,5	5,7	1,2
5,3	1,4	5,8	1,1
5,4	1,35	5,9	1,1
5,5	1,3	6,0	1,0

Coefficient k_1 is determined with the relationship:

$$K_1 = \frac{\tau}{T} = \tau \cdot F,$$

where τ--pulse duration; T--pulse repetition period; F--pulse repetition frequency. Usually k_1 is 0.02-0.005.

The values of k_2 are found using the antenna polar diagram in the vertical plane.

However, the precision of computations in each concrete point is relatively low owing to the considerable influence of many factors that are difficult to account for.

Preventive Measures

In order to insure safety in work with devices emitting electromagnetic energy, and compliance with the maximum permissible radiation levels, we need to utilize a complex of protective resources and methods. All protective resources and methods are arbitrarily subdivided into three groups: organizational, engineering-technical, and therapeutic-preventive. Organizational measures foresee, both during planning and at operating facilities, optimum mutual location of radiating and irradiated objects, and development of a work-rest schedule permitting minimization of the time people are exposed to radiation and prevention of their entry into zones containing high intensity EMF's. Creation of safety zones about antenna structures of various types is an important hygienic measure.

The general principles at the basis of engineering-technical protection boil down to the following: electric sealing of circuit components, blocks, units, and the device as a whole with the purpose of reducing or eliminating electromagnetic emissions; protection of the workplace against radiation, or its removal to a safe distance away from the emission source; use of personal protective resources. One of these principles of protection or a combination of them may be used depending on the type of emitting source, its power, and its purpose.

Permanent and moveable shielding devices and individual shielding clothing may be used as protection against a 50 Hz electric field. Permanently installed devices may take the form of deflectors, awnings, and partitions. Metallic mesh deflectors are mounted above the workplace near equipment cabinets, aerial circuit breaker control cabinets, near terminal assembly and cut-out switch drive boxes, near power distribution boxes, near contact filters, and so on. Awnings made of steel cables, wires, and reinforcement metal are installed over distribution device accessways and in places affording access for equipment inspection. Partitions made of metallic conductors are set up vertically between neighboring cells.

Moveable shielding devices may take the form of awnings, tents, partitions, panels, and so on. Moveable panels would best be used as removeable side screens on scaffolding when working on aerial circuit breakers, around the baskets of telescopic towers and hydraulic lifts, and so on.

The shielding devices must be grounded by connecting them to a grounding circuit or to grounded objects; the leads should be connected by welding, or with bolts (for permanent devices) or special terminals and conductors (moveable devices).

The personal protective outfit, which consists of protective overalls, shielding headwear, and special footwear with conducting soles or made entirely of conducting rubber, are prohibited when contact with current-carrying parts is possible--in particular when working on panels, electric drives, assemblies, and circuits carrying up to 1,000 volts, when testing equipment, and when doing electric welding jobs within the zone of action of an electric field. All elements of the shielding outfit must be connected to one another dependably by conductors, and additionally grounded if ground conductivity is low, as well as when the outfit is isolated from "ground." Machinery and mechanisms traveling on rubber wheels, and attachments and equipment (suspended) are also grounded dependably.

Electromagnetic shielding is one of the principal methods of affording protection against low frequency and radio emissions. Shielding may be complete or partial. Electromagnetic shielding involves the use mainly of materials typified by high conductivity (copper, brass, aluminum and its alloys, sheet steel, metallic mesh).

The main characteristic of a screen is its shielding effectiveness--that is, the degree to which it attenuates the electromagnetic field. Shielding effectiveness depends on the magnetic permeability of the material, its thickness, its specific resistance, and the frequency of the electromagnetic field. A material to be used in a screen should be evaluated on the basis of the extent to which it attenuates an EMF (Table 13).

Table 13. Shielding Effectiveness Data (Sanitary Norms and Rules No 848-70)

1) Данные эффективности экранирования
(Санитарные нормы и правила № 848—70)

Вид экрана	2) Материал экрана	3) Частота, кГц				
		10	100	1000	10 000	100 000
4) Металлические листы толщиной 0,5 мм	Сталь 5)	$2.5\cdot10^6$	$5\cdot10^8$	$>10^{11}$	$>10^{12}$	$>10^{12}$
	Медь 6)	$5\cdot10^6$	10^7	$6\cdot10^9$	$>10^{12}$	$>10^{12}$
	Алюминий 7)	$3\cdot10^6$	$4\cdot10^6$	10^8	$>10^{12}$	$>10^{12}$
8) Металлические сетки	Медь, проволока 0,1 мм, ячейки 1×1 мм 9)	$3.5\cdot10^3$	$3.5\cdot10^3$	10^3	$1.5\cdot10^4$	$1.5\cdot10^5$
	Медь, проволока 1 мм, ячейки 10×10 мм 10)	10^6	10^5	$1.5\cdot10^4$	$1.5\cdot10^3$	$1.5\cdot10^3$
	Сталь, проволока 0,1 мм, ячейки 1×1 мм 11	$6\cdot10^4$	$5\cdot10^4$	$1.5\cdot10^4$	$4\cdot10^3$	$9\cdot10^3$
	Сталь, проволока 1 мм, ячейки 10×10 мм 12)	$2\cdot10^5$	$5\cdot10^4$	$2\cdot10^4$	$1.5\cdot10^3$	$1.5\cdot10^3$

Key:

1. Type screen
2. Screen material
3. Frequency, kHz
4. Metallic sheets 0.5 mm thick
5. Steel
6. Copper
7. Aluminum
8. Metallic mesh
9. 0.1 mm Copper wire, 1 × 1 mm mesh
10. 1 mm Copper wire, 10 × 10 mm mesh
11. 0.1 mm Steel, 1 × 1 mm mesh
12. 1 mm Steel, 10 × 10 mm mesh

Shielding effectiveness grows depending on oscillation frequency, and it hardly changes with a continuous mesh screen. Sufficiently high shielding effectiveness is attained by eliminating the possibilities of energy radiation through gaps, slots, and holes in the screen (peepholes, louvers, and so on). Thus when we design screens we should mandatorily impose the requirement that electric contact be continuous along the perimeters of all interconnecting parts of the metallic housing. The general requirements on screens for high frequency devices, recommendations on shielding improvement, and the technical concepts used in the design of screens for individual units (inductors, working capacitors, feeder lines, and sc on), blocks, and entire devices may be found in special documents.* The distribution of electromagnetic field intensities in buildings containing HF and UHF oscillators may be complex due to secondary emissions, which may also arise in neighboring buildings. Conductors of the lighting and telephone circuits may in this case serve as radio frequency energy conductors. In order to block propagation of radio frequency energy by the lighting, power, and telephone circuits and in places where leads emerge from HF device screens, we use electric filters of different designs.

Screens must be grounded. The grounding conductor must be as short as possible and have the least inductance possible; thus it would take the form of a bus bar with a large cross section. Use of the screen as a neutral conductor is not permitted, since in this case the screen itself becomes a radiation source.

When designing shielding devices against SHF radiation, we must account for the parameters of the emitted energy and the nature of the production process. The form, dimensions, and material of the shielding devices depend on the emitted power, the frequency band, and presence or absence of directive or parasitic, and continuous or pulsed emissions. The shielding material is characterized by radiophysical principles of electromagnetic energy reflection or absorption. Total reflection of electromagnetic waves is achieved with materials having high conductivity (metals); partial absorption is inherent to materials with poor conductivity (semiconductors, dielectrics). Special materials used to manufacture resources offering protection against SHF radiation are described in Table 14.

Shielding and radioabsorptive materials are intended for a broad range of wavelengths (for 0.8 to 200 cm) and a high percentage of attenuation. When directed emissions are involved, power absorbers or antenna equivalents may be used to exclude a powerful source of radiation. These devices must correspond to the power and frequency band of the emitting system. To reduce the intensity of irradiation caused by directed emissions in

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* "Metodika rascheta ekranov dlya rabochikh induktorov i dlya soglasuyushchikh transformatorov plavil'no-zakalochnykh vysokochastotnykh ustanovok" [Methods for Designing Screens for Working Inductors and Matching Transformers of Melting-Heating High Frequency Devices], Leningrad, 1962; "Ekranirovaniye ustanovok vysokochastotnogo nagreva" [Shielding of High Frequency Heating Devices], Leningrad, 1965; "Rekomendatsii po snizheniyu napryazhennosti elektromagnitnogo polya na rabochikh mestakh obsluzhivayushchego personala televizionnykh i UKV ChM-stantsiy" [Recommendations on Reducing Electromagnetic Field Intensity at the Workplaces of Television and Ultrashort-Wave FM Station Maintenance Personnel], Moscow, 1972; All-Union Standard 5.8482-77, "Radio Communication Apparatus. Methods for Evaluating Electromagnetic Fields and Resources Protecting People From Radiation," Moscow, 1977.

Table 14. Special Materials Used to Manufacture Resources Offering Protection Against Radiated SHF Energy (Sanitary Norms and Rules No 848-70)

Material	Type, Brand	Unit of Measurement	Material Weight per m^2, kg	Dimensions (Length, Width), mm	Working Waveband, cm	Power Reflection Factor, %
Radio-absorptive and shielding materials						
Rubber mats	V2 - F2 V2 - F3 VKF - 1	kg	4 - 5 4 - 5 3.5-4	345 × 345, thickness 11-14 (including bus bars)	0.8 - 4 0.8 - 4 0.8 - 4	2 2 2
Magnetodielectric plates	KhV-0.8 -2.0, -3.2, -4.4, -6.2, -8.5, -10.6		3 - 9	345 × 400, thickness 1 - 3	0.8 2.0, 3.2, 4.4, 6.2, 8.5, 10.6	2
Ferrite plates	SVCh-068	m^2	18 - 20	100 × 100 × 4	30 - 200	3-4
Luch absorptive material	LUCh - 50 LUCh - 100 LUCh - 150	m^2	11 - 12 22 - 24 33 - 36	1750 × 1000 1750 × 1000 1750 × 1000	0.8 - 20 0.8 - 40 0.8 - 65	3 3 3
Porolon-based absorptive coatings	VRPM - 330		—	—	—	—
Boloto absorptive material	B - 2 B - 3 BR - 3	m^2	— — —	— — —	0.8 28.0 40.0	2 2 2
Radioprotective glass with metallic oxide film	VTU RZ-GIS-1.65		—	From 300 x 500 to 2000 x 2000 thickness 4, 5, 6	0.8 - 150	—
Cotton fabric containing microconductors	Art. 7289 STU - 36 - 12-199 - 63	linear meters	—	width 900 - 1000	0.8 - 100	—

production conditions, use of waveguide couplers, power dividers, and attenuaters making it possible to reduce emissions above the antenna system is recommended.

Use of different types of screens is recommended as a means for shielding a workplace: reflecting, mesh, elastic, absorptive. The following shielding devices are employed: fully enclosing (chambers) or partially enclosing (panels, U shapes, hemispheres, screens, awnings, wall coatings). The shapes, dimensions, and nature of the material of a partially enclosing screen must satisfy certain requirements, and in each specific case they must insure an irradiation intensity in the building that does not exceed the permissible value. In this case we should consider the number of radiation sources and their distribution within the building relative to the workplaces. Walls, floors, and ceilings should be covered by energy absorbing materials in order to reduce reflected energy in shielded buildings. Special protective goggles are recommended as individual resources for protecting the eyes against the action of SHF emissions (when the PFD is 1,000 $\mu w/cm^2$ and higher). ORZ-5 goggles, the glasses of which are covered with a layer of semiconducting tin oxide, weaken emission power by not less than 30 db (1,000 times) in the 0.8-150 cm waveband.

Protective clothing is manufactured from metallized fabric (Article 7289), and it takes the form of overalls, smocks, aprons, and hooded jackets with built-in protective goggles. The latter are needed for jobs of short duration performed in the presence of emissions of more than 1,000 $\mu w/cm^2$. Exclusion of contact with high voltage sources is a mandatory prerequisite of electrical safety when using such clothing.

Early detection of disturbances in the health of workers, which may arise in response to chronic lengthy exposure to radiowaves, is extremely significant to the prevention of occupational diseases. According to Order No 400 of the USSR Minister of Public Health, 30 May 1969, persons working with radio frequency electromagnetic radiation sources must be subjected to preliminary and periodic medical examinations. According to Attachment 1, Paragraph 51 of this order, workers exposed to superhigh frequencies--SHF, ultrahigh frequencies--UHF, and high frequencies--HF (shortwaves) must undergo periodic medical examinations once every 12 months; workers exposed to high frequencies--HF (medium and longwaves) must be examined every 24 months.

When symptoms typical of radio frequency irradiation are present, outpatient and inpatient examination and treatment (symptomatic, at a sanitarium or health resort) are recommended. It is known that in the initial stage, the clinical manifestations of exposure to radio frequency electromagnetic fields are reversible, and therefore temporary transfer to work not involving EMF irradiation is indicated when the initial form of radiowave disease is established. Women should also be transferred to other jobs within the enterprise during pregnancy and nursing. Persons below 18 years old are not permitted to work with radio frequency generators.

Persons having contact with SHF and UHF radiation sources are given additional leave, and they work a shorter day.* Workers enjoy the following additional privileges if their jobs entail adjusting, tuning, testing, and servicing centimeter and decimeter waveband oscillators, work on measuring oscillators necessitating exposure to unshielded emitting systems of the same wavebands (from 1 mm to 100 cm inclusively), and work necessitating the individual's presence within the radiation zone in a building containing oscillators:

a) an additional leave of 12 work days when the intensity of irradiation is up to 10 $\mu w/cm^2$;

b) an additional leave of 12 work days and a reduced work day of 6 hours when the irradiation intensity is above 10 $\mu w/cm^2$.

Workers directly involved in the testing of UHF oscillators and apparatus are given an additional leave of 12 work days.

So-called accompanying unfavorable factors of the production environment must be accounted for in a hygienic assessment of the working conditions of laborers coming in contact with radio frequency radiation sources. Such factors include acoustic noise, an uncomfortable microclimate, roentgen radiation, air ionization, ultraviolet and visible emissions, electrostatic fields, laser emissions, and air contamination by toxic substances.

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* As per the "Spisku proizvodstv, tsekhov, professiy i dolzhnostey s vrednymi usloviyami truda, rabota kotorykh dayet pravo na dopolnitel'nyy otpusk i sokrashchennyy rabochiy den'" [List of Production Operations, Shops, Occupations, and Positions Offering Harmful Working Conditions Entitling the Worker to an Additional Leave and a Reduced Work Day], Moscow, 1976.

IONIZING RADIATION AND RADIOACTIVE SUBSTANCES

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[Article by V. P. Gerasimova]

[Text] Many promising directions have now been developed for the use of atomic energy for peaceful purposes. A vast range of areas of application of radioactive substances and ionizing radiation has come into being.

The discovery of atomic energy led to development of reactor design, and construction of atomic electric power plants utilizing uranium and thorium.

We know of over 900 manmade radioactive isotopes used in metal flaw detection, in analysis of the structure and wear of materials, in separation of substances and synthesis of chemical compounds, in apparatus and instruments performing monitoring and signaling functions, in medical pratice, and elsewhere.

Radioactivity is defined as spontaneous transformation of atomic nuclei accompanied by emission of energy quanta or ejection of particles. As they undergo radioactive decay, atomic nuclei emit radiation of corpuscular nature, and electromagnetic radiation. Radioactive transformations are accompanied by ionization, which causes formation of electric charges of different kinds.

Basic Forms of Ionizing Radiation

Alpha-particles are helium atom nuclei carrying a double positive charge and having a mass equal to 4. Alpha-particles travel linearly in mediums, creating areas of high ionization intensity along their paths. This form of radiation is observed predominantly with natural radioactive elements (radium, thorium, uranium, polonium, etc.).

Alpha-particles do not travel far--2-11 cm in air, 30-150 mm in biological tissues, and 10-69 mm in aluminum.

H vy particles include protons and neutrons, which interact with the substance, creating areas of high ionization intensity within it.

Beta-particles are a flow of electrons or positrons. Beta-particles carry different amounts of energy--from several kiloelectron volts to 3 Mev. Penetrability depends on particle energy; however, it is less than that of gamma-rays. Given average energy levels, the path of beta-particles in air is several meters long, and it is about 1 cm in human tissues and 1 mm in metals. As they pass through a substance, beta-particles interact with both electrons and atomic nuclei.

Energy lost by electrons as they pass through a substance is expended in excitation and ionization, as well as in the formation of braking radiation. The latter is an electromagnetic form of radiation.

The specific ionizing capability of beta-particles is lower than that of alpha-particles but higher than that of gamma-rays. Secondary processes--luminescence, photochemical reactions, formation of chemically active radicals--occur in some mediums as a result of ionization.

The effect of beta-particles upon the body may manifests itself either with external irradiation or with internal irradiation--when beta-particles get inside the body.

Gamma-rays are electromagnetic radiation, and they represent a flow of energy quanta. Their wavelengths are shorter than those of roentgen rays. The energy of gamma rays varies within broad limits--from 0.01 to 10 Mev and more. We can arbitrarily subdivide gamma-rays depending upon their energy into soft (0.1-0.2 Mev), moderately hard (0.2-1 Mev), hard (1-10 Mev), and superhard (over 10 Mev).

The penetrability of gamma-rays depends on their energy. Gamma-rays pass through the human body and other materials without noticeable attenuation. Gamma-rays propagate linearly, their path in air is long, and they may cause secondary and scattered emissions in the mediums through which they pass.

Neutrons do not have an electric charge. Neutrons are arbitrarily subdivided depending upon kinetic energy into fast (up to 10 Mev), ultrafast, intermediate, slow, and thermal. Neutron radiation has higher penetrability. Slow and thermal neutrons enter into nuclear reactions, which may result in the formation of stable or radioactive isotopes.

Roentgen rays are electromagnetic radiation with a very short wavelength (0.006-2 nm). Roentgen radiation is distinguished from gamma-rays by having a lower oscillation frequency and greater wavelength parameters. It propagates at the speed of light. High penetrability is the most important property of roentgen radiation.

The shorter the wavelength, the greater is the possibility of penetration by rays. The ionizing action of roentgen rays is extremely insignificant. When a beam of roentgen rays strikes a substance, secondary and scattered emissions arise.

Natural radioactive elements include those in the thorium series, the uranium series, and the actinium series. As they decay, they form a large number of new radioactive elements, which is accompanied by the release of alpha- and beta-particles as well as gamma-radiation.

The unit of activity is 1 curie (Ci)--the activity of a preparation of the given isotope in which $3.7 \cdot 10^{10}$ decay events occur in 1 second. The activity of 1 gm of pure radium is about 1 Ci. Other established units are millicuries ($1 \cdot 10^{-3}$ Ci) and microcuries ($1 \cdot 10^{-6}$ Ci).

Specific radioactivity is unit activity per unit mass--Ci/gm, and so on. Active concentration is expressed as units of Ci/liter and its fractions.

The gamma-equivalent is used to compare radioactive preparations on the basis of their gamma-radiation. The basic unit is the milligram-equivalent of radium (Mg-e radium).

The radiation dose depends on ionizing capability. The roentgen is the unit dose of roentgen and gamma-radiation. Fractions of the roentgen include milliroentgens and microroentgens. Radiation dose per unit time is the dose rate (1 r/hr, 1 μr/sec, etc.). The absorbed dose is the amount of energy absorbed from any ionizing radiation, per unit mass of the medium. The rad is the unit of absorbed energy. Given equal absorbed doses, different forms of emissions produce different biological effects.

The biological equivalent dose, measured in biological equivalents roentgen--ber, is used to assess the action of one of the components of mixed radiation.

Sources of Ionizing Radiation

Work with unshielded radioactive substances may be accompanied by contamination of air, equipment, the building, special clothing, and exposed skin of workers by radioactive aerosols, gases, vapors, and solutions. Aerosols may be liberated during mechanical and chemical processing of radioactive materials and ores, processing of irradiated substances, processing of radioactive wastes, and during many processes involving pulverization, bulk transfer, distillation, and abrasion. The concentration and composition of radioactive aerosols and the dimensions and shapes of the particles are subject to significant variation depending on the place and time of their formation.

Radioactive gases may form in a number of production processes (in the operation of reactors and accelerators, when mining and processing ores and minerals containing natural radioactive substances, and so on). When uranium is split in reactors, radioactive xenon, krypton, and argon are liberated; When thorium and uranium ore is processed, gaseous emanations f[illegible]m--thoron and radon. We may observe contamination of the air by radon when radon sources are utilized, when radium and radon containers are opened, and when other operations are performed with radioactive substances.

Building structures and trim materials may absorb radioactive substances, creating secondary sources of the latter in production or laboratory buildings.

The most widespread use of radioactive substances in shielded form is gamma-defectoscopy, in which we capitalize directly upon the capability gamma-rays have for penetrating through materials and exposing photographic film, thus recording defects in materials.

Gamma-defectoscopy has enjoyed widespread use in many sectors of industry: in machine building, ship building, construction of bridges and other structures, metallurgy, and so on. Artificial radioactive isotopes are used as the gamma-radiation source (cobalt--Co^{60}, selenium--Se^{75}, silver--Ag^{110}, etc.). Co^{60}, which has a half-life of 5.3 years, is used most often. The radioactivity of emission sources may be from 0.5 to 20.0 gm-e radium.

Gamma-defectoscopy may be performed with portable or permanent instruments--that is, the analyses are performed either right at the production operation or in the laboratory. Apparatus using Co^{60} (GUP) is used most often for gamma-defectoscopy in permanent conditions. Depending on the radioactivity of the source, the apparatus is placed either in isolated buildings (furnished with a remote control panel) or in the laboratory itself. The principal elements of its design include a container for the radioactive source, a conducting hose through which the isotope container moves and a device holding the article to be inspected and the photographic film. Permanently installed devices include the GUP-SO-O, the 5-U, the GUP-SO-50, and so on. These devices have two containers, one holding the Co^{60} preparation and the other serving as the working container. The most dangerous moment of work with a GUP is when the ampule containing the radioactive source moves along the hose from the storage container into the working container; gamma-radiation may be at its greatest at this moment.

We must consider irradiation by both the initial beam of gamma-rays and scattered gamma-radiation; in this case emissions from an object which is struck by a beam of gamma-rays at a 90° angle is the most dangerous.

Portable radioactive isotope containers are used for gamma-defectoscopy in the shop or at a production facility. The containers are made from lead of varying thickness depending on the radioactivity of the source. At the place of work, the containers are moved either on special carts or with the help of long handles. For illumination, a window is opened in the container, photographic film is placed on the other side of the article, and an image of the illuminated part is obtained on the film.

The most dangerous operations during gamma-defectoscopy are: transportation of isotope containers from the storage point to the place of work and back, placement of the container at the place of work for exposure, opening of the container window for illumination, illumination itself, and repair and recharging of the containers.

Special storage points consist of the storehouse itself, a recharging and repair shop, and the attendant's work area. Ampule containers are stored in special covered pits.

Nuclear reactors are installed at atomic electric power plants, and they are used for experimental purposes. The main part of the reactor is the active zone, in which the chain reaction proceeds. The fuel element, which contains the nuclear fuel, is in the active zone. The fuel consists of U^{235}, U^{239}, Pu^{233}, etc. When a chain reaction occurs, we observe release of a large quantity of neutrons and gamma-rays, accompanied by liberation of significant quantities of heat. Numerous decay products--sources of alpha-, beta-, and gamma-radiation--form as a result of uraniums's decay.

Special moderators (ordinary water, heavy water, graphite, beryllium) are introduced into the reactor to reduce the energy of fast neutrons down to that of thermal neutrons. Various heat carriers are used to remove the heat (ordinary and heavy water, graphite, mercury, air, carbon dioxide, and other substances).

The type of reactor, moderator, and heat carrier basically predetermines the working conditions of the personnel of atomic electric power plants and laboratories.

Work at atomic power plants and experimental reactors may involve both external irradiation (gamma- and beta-rays, neutrons) and internal irradiation (entrance of radioactive aerosols and gases into the body). The active zone and its equipment as well as radioactive gases formed (Ar^{41}, Xe^{133}, Kr^{89}) are the source of gamma-radiation and neutrons.

Structures, parts, and instruments possessing induced radioactivity may serve as sources of gamma-radiation. Sources of beta-emissions may include decay products, the heat carrier, and corrosion elements. Building structures and equipment may become superficially contaminated during operation.

The danger of irradiation of workers by gamma-rays may arise during work with gamma-radiation sources. As an example nuclear reactions are accompanied by the release of gamma-rays with 10-12 Mev energy, and the decay of a number of manmade and natural radioactive substances is also accompanied by the release of gamma-radiation.

Flows of thermal and fast neutrons form when reactors and accelerators operate. Through so-called induced activity, intense flows of neutrons produce secondary sources of beta- and gamma-radiation, and they activate equipment, air, and building structures.

Gamma-radiation is most dangerous when external irradiation is involved, while alpha- and beta-emissions present the greatest danger with internal irradiation. Alpha-emitters, which have considerable ionizing capability, are the most dangerous.

Beta-emitters are less dangerous, but they do have ionizing capability as well.

Gaseous emanations--radon, thoron, and actinon, which are chemically inert gases, cause irradiation by alpha-particles when they get inside the body. The solid decay products are alpha- and beta-emitters.

Radioactive inert gases--krypton, argon, xenon--are beta-emitters.

Roentgen rays are used in industry for defectoscopy of metallic articles, and for roentgen structural and spectral analysis. Roentgen devices are used in medical practice for x-ray diagnosis and x-ray therapy.

The voltage applied to the apparatus may vary depending on its purpose: from 30 to 70 kv for apparatus used in structural analysis and x-ray diagnosis, and up to 100-400 kv and more for apparatus used in roentgenoscopy and x-ray therapy.

The principal unfavorable factor accompanying work with roentgen devices is external irradiation of service personnel (local and general), as well as of persons in neighboring spaces located above or below the work area. Some operations involved in roentgen structural analysis (setting up the chamber, centering the samples, and so on), in work with portable roentgen apparatus in medical practice, and in x-ray diagnosis associated with investigation of internal organs offer the greatest danger from the standpoint of irradiation.

Action Upon the Body

Pathological processes elicited by ionizing radiation may manifest themselves as acute or chronic radiation sickness depending on the degree of injury. Chronic forms are observed in response to long-term exposure to doses exceeding maximally permissible levels. The remote consequences of radiation injury may manifest themselves as radiation cataracts, malignant tumors, and other pathological alterations.

The initial phase of the biological action of radiation consists of ionization of the atoms and molecules of living matter, ionization of water molecules in organs and tissues in particular.

This results in the formation of free radicals (atomic hydrogen--H), hydroxyl (OH), hydroxide (HO), and hydrogen peroxide (H_2O_2), which may react with substances capable of being oxidized and reduced. Reacting with the active structures of enzyme systems, free radicals inactivate these enzymes, thus disturbing the catalytic activity of thiol enzyme systems participating in the synthesis of nucleoproteins and nucleic acids. The quantity of the latter decreases dramatically in tissues and in cell nuclei in response to irradiation.

Changes occurring in the central nervous system in response to radiation lead to neurotrophic disorders.

Radioactive substances distribute themselves within the body depending on their physicochemical properties and the functional state of the body. As an example radioactive iodine (I^{131}) accumulates in the thyroid, while strontium (Sr^{90}) accumulates in bones. A number of radioactive isotopes may distribute themselves uniformly within the body.

Radioactive substances are released from the body through the gastrointestinal tract, the kidneys, the respiratory tract, the skin, and the mammary glands. Depending on the biological half-life of these substances (that is, the time during which half of the radioactive substance in the body is eliminated from it), some substances are eliminated quickly while others disappear slowly, forming deposition sites in a number of tissues and organs.

Hygienic Standardization

Public health rules concerned with work with radioactive substances and other sources of ionizing radiation (OSP-72) and the radiation safety norms are based upon maximum permissible doses of irradiation, and maximum permissible levels of radioactive contamination.

Dosimetric Monitoring

Various types of dosimeters are used for dosimetric monitoring. DK-02 pocket dosimeters (gamma- and roentgen radiation), IFKU film dosimeters (beta-radiation, thermalneutrons), and KID-2 dosimeters (gamma- and roentgen radiation) are used for individual dosimetry. Roentgen and gamma-radiation dose rates are measured by the SPG-1 (4 Kura), DIM-60, DRGZ-02 (Argun'), and the DRGZ-01 (Araks) dosimeters, MRM-2 and MRM-3 microroentgenometers, and others. A number of dosimeters are used as ionizing radiation indicators: the Solovey-2 pocket indicator (gamma-radiation, hard beta-radiation, neutrons), and the SRM-2 detecting radiometer (gamma-radiation). The degree to which clothing and hands are contaminated by radioactive substances is measured by the RUP-1 general-purpose radiometer (alpha- and beta-active substances), the TISS general-purposes radiometer (alpha- and beta-active substances), the portable Kran-1 radiometer (alpha-active substances), and the IZV-1 instrument (Oleandr), used to detect short-lived radon decay products.

Preventive Measures

The use of unshielded radioactive substances requires implementation of a complex of measures to provide protection from both external and internal irradiation. The requirements imposed on the layout of laboratory and enterprise spaces depend on the class of radiation danger (Table 15).

Table 15. Job Class, Set Depending on the Radiotoxicity Group of the Radioactive Isotope and its Actual Quantity (Activity) at the Workplace (From OSP-2)

1) Группа радиотоксичности	2) Предельно допустимая на рабочем месте активность, не требующая разрешения санитарно-эпидемиологической службы, мКи	Активность на рабочем месте, мкКи 3)		
		Класс работ 4)		
		I	II	III
А	0,1	Более 10^4	От 10 до 10^4	От 0,1 до 10
Б	1,0	» 10^5	От 100 до 10^5	От 1 до 100
В	10,0	» 10^6	От 10^3 до 10^6	От 10 до 10^3
Г	100,0	» 10^7	От 10^4 до 10^7	От 10^2 до 10^4
Д	1000,0	» 10^8	От 10^5 до 10^8	От 10^3 до 10^5

Key:
1. Radiotoxicity group
2. Maximum permissible activity at workplace not requiring permission of the sanitary-epidemiological service, mCi
3. Activity at workplace,
4. Job class
5. More than
6. From
7. To

According to the public health rules, class III jobs may be permitted in the common spaces of laboratories at specially equipped places.

Class II jobs must be performed in specially equipped isolated spaces. A building or room (with a separate entrance) completely isolated from other spaces must be allocated for a class I job.

The protective measures associated with work with unshielded radioactive substances require that the work spaces be laid out and planned specially. Special requirements are imposed on the equipment, on the heating and ventilation systems, on the water supply and sewage systems, on personal hygiene, and so on. All protective measures are aimed at preventing the possibility of contamination of air, equipment, special clothing, and hands by radioactive aerosols, gases, and vapors.

The particular protective measures employed are spelled out for each concrete case of the use of unshielded radioactive substances depending on that nature of the production processes.

Spaces intended for class I jobs are planned as three zones: zone one (clean)--operator and auxiliary spaces containing no active contaminants;

zone two (dirty)--area in which work with radioactive substances is done; zone three (dirty)--repair and transportation; communication between the clean and dirty zone is mediated by a medical checkpoint or an air lock.

Certain requirements are imposed on trim materials in the work area depending on the class of radiation danger.

The finishing materials used on walls, ceilings, and floors must not absorb radioactive substances, and they should permit easy wet mopping. Stable paints (epoxy, nitrated enamel, polychlorvinyl, and so on) may be used to finish walls and ceilings. The floors are covered with linoleum and special plastics. To the extent possible, furniture and equipment should be made from nonporous materials, surfaces should be smooth, and legs should be high.

Installation of local exhaust ventilation taking the form of exhaust cabinets, boxes, and chambers, as well as universal balanced ventilation, is foreseen as a way to prevent contamination of air in spaces used for work with unshielded radioactive substances. Air removed from such spaces by local and general exhaust ventilation must be purified.

Lead shields of various thicknesses and designs are used as protection against gamma-radiation. Aluminum or plastic shields are sufficient for protection against beta-emissions.

Remote-controlled manipulators and devices, which are used for the performance of various operations from a remote site, are employed in jobs involving extraction of ampules and the unpackaging of powders and solutions.

Water supply lines and sewage lines must be installed in areas of work with unshielded radioactive substances. Wash basins should be supplied with hot water taps. Waste water must be purified and decontaminated. All waste, both solid and liquid, must be collected in special containers and removed in accordance with the rules to specific places reserved for the burying of radioactive wastes.

Individual protective measures and personal hygiene are foreseen depending on the job class. These measures include providing special clothing, footwear, airtight overalls, gloves, Lepestok respirators, the equipment of medical checkpoints, and so on. Special laundries must be set up to wash special clothing.

Food storage, eating, smoking, and drinking of water are not permitted in work areas.

Radiometric control must be organized over the degree of radioactive contamination and over the sufficiency of protection afforded against gamma-radiation.

A large number of measures are implemented to protect personnel against radiation while working at permanent facilities. The layout of areas containing permanently installed devices for defectoscopy has important hygienic significance. This is why GUP's must be located as a rule in isolated spaces and furnished with remote control panels.

In a number of cases spaces are laid out as a maze, so as to prevent exposure to direct radioactive beams. The walls of spaces in which GUP's are to be installed must be made of reinforced concrete or concrete, and they should be plastered (barium is added to the plaster) and painted. The doors should be covered with sheet lead (the thickness of the lead lining is computed on the basis of the activity of the gamma-source.

Special spaces are foreseen for repair of apparatus, recharging of containers, processing of photographic film, and personal needs.

The equipment contained in storehouses must correspond to special requirements spelled out in the regulations (OSP-72).

Constant dosimetric control must be performed during gamma-defectoscopy. Permanently operating instruments are installed in storehouses to monitor the background radiation level. Persons working in storehouses during gamma-defectoscopy are supplied with individual dosimetric resources.

The principal protective measure is that of reducing irradiation time and increasing the distance from the source to the worker. The zone within which radiation exceeds the permissible level must be marked or barricaded off in appropriate fashion. When gamma-defectoscopy must proceed constantly, the ampules should be carried by persons not directly involved with the illumination process.

All persons working with gamma-sources must undergo a production hygiene briefing before work.

Conditions that would exclude the possibility of overexposing working personnel and the surrounding population must be created when building and operating atomic power plants and experimental reactors. To avoid disasters, safety zones should be created.

Preventive measures aimed at insuring radiation safety may be arbitrarily subdivided into two basic groups: the first group--biological protection against penetrating radiation; the second--measures aimed at preventing contamination of air in production buildings, equipment, and the clothing and skin of workers.

Permanent biological protection is afforded against penetrating radiation. Biological protection entails installation of layers of heavy substances (concrete, boron-containing substances, and so on). A certain margin of safety is added to the thickness of the material, and maximum permissible radiation doses are set for the personnel depending on the nature of their work and the time they remain within the production spaces. Strict requirements are imposed on the quality of the protective material, so as to preclude escape of radiation from the active zone into other areas; this is achieved by sealing the spaces between the protective material and supply system by plugging up seams, and so on.

The second group of measures entails correct, from the standpoint of labor hygiene, location of the "dirty" zone (the reactor, treatment facilities, ventilation chambers, and so on) and the "clean" zone (generator room, administrative building, dining hall, public health station, medical unit, and so on) in the territory.

The hygienic requirements call for a number of measures: 1) Sensible planning and trimming of work spaces; 2) remote devices to monitor and regulate processes in the reactors; 3) installation of effective balanced ventilation coupled with subsequent treatment of spent air; 4) installation of personnel medical treatment spaces (medical checkpoints and a dosimetric monitoring system); 5) provision of individual protective resources (protective overalls, special clothing and footwear, gloves, underwear, respirators, and so on); 6) proper organization of the storage and transportation of irradiated fuel cells and radioactive wastes.

Steps must be taken during repair operations in the radioactive zone to reduce the time workers remain within the zone, and to subject equipment and instruments to be repaired to preliminary decontamination.

Dosimetric and hygienic monitoring of gamma-, beta-, and neutron radiation fields, of the levels of superficial contamination, and of the condition of the aerial environment is an important part of the radiation safety system, as is individual dosimetric monitoring.

All rooms intended for x-ray operations must be well ventilated and furnished with natural illumination. When determining the sort of protection to be afforded to the apparatus and to the work spaces, we must consider the possibility that direct and scattered x-rays may penetrate into neighboring spaces, as well as into ones located above and below the work space. Protective shields taking the form of booths, movable screens, and so on are used to protect personnel who by the nature of their work must remain in spaces containing roentgen apparatus (this pertains to roentgenography of heavy and cumbersome objects using movable roentgen apparatus, x-ray diagnosis, and so on).

Observation windows and the windows of protective booths or screens in x-ray rooms must be made from leaded glass of various thickness. Acoustic or light warning systems are built into the high-voltage circuit of the x-ray tube. All work associated with x-ray structural and spectral a. lysis must be performed in a shielded room or booth. Lead discs and automatic devices that keep beams from striking the eyes and fingers of workers are foreseen.

Protection against exposure of personnel working with medical x-ray apparatus requires special protective resources, which include sensible distribution of workplaces, installation of apertures to control the size of the x-ray beam, installation of protective booths or screens for x-ray technicians, provision of movable screens to protect the physician's legs and body, and installation of leaded glass behind the fluorescent screen.

Attention should be turned to the collection of apparatus working characteristics (current direction and intensity).

The screens must be sufficiently movable, which would help to reduce irradiation time. Chest aprons and special mittens are used for individual protection.

Work with x-ray devices requires organization of dosimetric monitoring with the purpose of both determining the roentgen radiation levels at workplaces and the doses received by the personnel on one hand, and testing the adequacy of protective fixtures on the other.

According to Order No 400 of the USSR minister of public health, 30 May 1969, workers involved in all types of jobs associated with radioactive substances and sources of ionizing radiation are subject to preliminary and periodic medical examinations once every 12 months. Persons working directly with radioactive substances and other sources of ionizing radiation cannot be less than 18 years old.

Women must be released from work involving the use of radioactive substances and other sources of ionizing radiation throughout the entire term of pregnancy; women working with unshielded radioactive substances must also be released from such work during the nursing period.

LASERS

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[Article by I. N. Ushkova]

[Text] Lasers are enjoying increasingly broader application in industry, in scientific research, and in medicine. Lasers are used to weld ultrathin metallic parts, to work hard alloys, to drill holes in rubies at watch industry enterprises, and to assist in airplane landing. Lasers enjoy broad use in medicine: Laser beams are used to perform operations on the retina, functioning as a scalpel. Lasers may enjoy application in the control of chemical processes, and in alteration of molecular structures and chemical bonds.

General and Hygienic Characteristics of Lasers

The word "laser" is an abbreviation consisting of the initials of the words of the English phrase "light amplification by stimulated emission of radiation." The principal components of all lasers are: the working substance (a monocrystal, glass containing active additives), an optic resonator consisting of parallel mirrors, and a pumping energy source (bright flash lamps for a solid working substance, and a constant or variable electric field for gaseous substances). The principle of operation entails the use of induced (stimulated) electromagnetic radiation produced by the working substance. Planck and Bohr showed that electromagnetic waves are emitted and absorbed not continuously but as isolated fractions, or quanta, called photons. Emission and absorption of quanta is discontinuous. An atom consists of a nucleus surrounded by electrons, which revolve about the former in different orbits. The farther away the electron's orbit is from the nucleus, the higher is the electron's energy. An atom always exists in a particular energy state. Its transition from one state to another is accompanied either by an increase in energy or by its loss upon interaction with an electromagnetic wave or upon collision with other atoms. An atom may drop spontaneously to a lower energy level by emitting a proton. Transition to a higher level may occur only in the event that the frequency of the interacting electromagnetic radiation is equal to the difference of energies of two states separated by Planck's constant.

$$V = \frac{E_2 - E_1}{h},$$

where V--emission frequency; E_2--energy at the higher level; E_1--energy at the lower level; $h = 6.7 \cdot 10^{-27}$ ergs/sec--Planck's constant.

An atom may absorb the energy carried by an electromagnetic wave. Conversely, when an atom releases energy, this energy is added to the energy of the electromagnetic wave. The increment in emission energy manifests itself as formation of a photon coherent with the acting wave. This phenomenon is what we call stimulated emission.

The work cycle of a solid-state laser consists of the following stages:

1. Charge accumulation by capacitors supplying power to the flashbulbs intended for optical pumping.

2. Discharge of the capacitor battery through the flashbulbs.

3. Inertia, and emission, beyond the limits of the resonator, of a pulse of coherent monochromatic light.

There are many modifications of lasers today, each differing significantly from the next. Depending on the classification system employed, lasers may be subdivided in the following ways:

1. In relation to the active element in which pumping power is transformed into emissions--gas, liquid, semiconductor, solid-state.

2. In relation to the method of excitation (pumping)--passing a constant, a pulsed, or a high frequency current through continuous or pulsed gas or light (in particular, light flashes of a pulsating lamp used in solid-state and liquid lasers).

3. In relation to the generated light wavelength--ultraviolet, visible, and infrared.

4. In relation to the operating mode--operating continuously, in simple pulses, and in modulated fractions of pulses.

5. In relation to the means for removing heat from the laser--naturally cooled and forced-air or liquid cooled.

The principal parameters of laser emissions are: wavelength (μ), emission power (w), power flux density (w/cm^2), radiation energy (j), energy flux density (j/cm^2), and beam divergent angle (angular minutes).

The operating modes are: continuous (sec), free oscillation (Hz), modulated fractions (Hz), pulse duration (sec). The principal properties of laser emissions are: monochromatic coherent electromagnetic radiation in different portions of the spectrum--that is, laser emission is characterized by a particular wavelength and is strictly ordered in time and in space. The wavelength band embraces the visible spectrum, and it extends into the infrared and ultraviolet regions.

Operation of different types of lasers is accompanied by:

1. Presence of high-voltage charging devices powering the capacitor batteries. They may retain a high-potential electric charge following discharge of the pulse capacitors into the flash lamps.

2. Blinding light produced by the pumping lamps. The total energy carried by the signal of a pumping lamp may attain 20 j, and the brilliance of a flash from a xenon lamp is $4 \cdot 10^8$ nits at a pulse duration of 1-90 msec.

3. Toxic chemical impurities in the air of work spaces, formed when pulsating pumping lamps discharge (ozone, nitrogen oxides), and as a result of vaporization of the target materials (carbon monoxide, lead, mercury, and so on).

4. Intense noise arising during the work of some lasers.

Noise may attain 70-80 db in the medium-frequency spectrum, and 95-120 db at frequencies of 1000-1250 Hz. High noise levels arise when tuning a laser possessing mechanical shutters used to control the emission pulse duration.

5. Ultraviolet emissions from pulsating lamps and gas-discharge tubes.

6. The effect of an HF or UHF electromagnetic field.

Action Upon the Body

The biological action of laser emissions depends on the emission power, wavelength, nature of the pulse, the pulse repetition frequency, time of irradiation, the size of the irradiated surface, and the anatomical and functional features of the irradiated tissues. A distinction must be made between thermal and nonthermal and between local and general action of emissions. The thermal action of emissions from continous-action lasers has much in common with ordinary heating. Pulsed lasers have certain unique features. Pulsed laser emissions cause irradiated tissues to heat up quickly, and water to boil instantaneously, owing to which pressure rises sharply, a shock wave arises, and in the end, mechanical injury occurs to tissues. A distinguishing feature of a laser burn is sharp delimitation of the injured area from the intact area surrounding it. Nonthermal action stems mainly from processes arising as a result of selective absorption of the electromagnetic energy by tissues, as well as due to electric and photochemical effects. Local action may express itself as injury to various portions of the eyes and skin. The human eye distinguishes light in the visible spectrum from 0.40μ to 0.76μ. The optical mediums of the eye are transparent to radiation in broader limits of the spectrum--from 0.40 to 1.40μ. Emissions with wavelengths from 0.40 to 0.90μ pass especially well through the eye's optical mediums. Emissions from the most widespread lasers--ruby ($\lambda = 0.69\mu$), neodynium ($\lambda = 1.06\mu$), and helium-neon ($\lambda = 0.63\ \mu$)--pass through the eye's optical mediums with almost no losses at all, and practically all of their energy reaches the most sensitive part of the eye--the retina, which is especially important to the visual function. Because laser beams are highly parallel, the eye's optical system can focus them, owing to which a high local energy density is created on the retina. On reaching the floor of the eye, the laser emissions act upon visual elements of the retina and upon other formations, being absorbed mainly by the pigmented formations of the retina. The amount of laser energy absorbed depends on the extent of pigmentation of the floor of the eye, and it varies significantly. On entering the eye, laser energy is absorbed by the pigmented epithelium, and within a very short time it raises its temperature to high levels, eliciting thermocoagulation of contiguous tissues--choreoretinal burn. Depending on the nature of modulation, thermal injury occurring in this case is accompanied by more or less pronounced injury to the retina. Emissions may also be absorbed by other elements within the eye, particularly by the choroid, though to a lesser degree. A portion of the energy entering the eye, meanwhile, reflects in multiples from the eye's inner walls, and thus the retina is subjected to laser action over a significant surface area, which causes functional changes within it. Injury to the foveal region of the retina is especially dangerous, since it is highly important in functional respects. Injury of this area may result in profound and persistent disturbances of central vision. Eye injury may arise not only in response to direct emissions from a laser but also reflected emissions, even if the reflecting surface is not mirror-smooth. Lasers exist today which produce emissions which are completely absorbed by the eye's transparent mediums, which contain large quantities of liquid (the cornea, the aqueous humor). The injurious action of these emissions is mainly the product of a pronounced thermaleffect, owing to which the transparency of the cornea is decreased at the place of injury. Laser emissions may cause skin injuries. The degree of injury depends on both the parameters of the laser emissions on one hand and the degree of pigmentation of the skin and the state of circulation on the other. Pigmented skin absorbs laser rays much more significantly than does light skin. However, absence of pigmentation promotes deeper penetration of laser rays into the skin and beneath the skin, owing to which injuries may be more pronounced. Skin injuries recall thermal burns having clear outlines surrounded by a narrow zone of redder skin. The overall action of laser emissions upon the worker's body is also associated with the parameters of the laser emissions.

In this case functional disturbances in the activity of the central nervous and cardiovascular systems, asthenic neurosis, and pathology of the autonomic vascular system, taking the form of autonomic vascular dysfunction and asthenic-autonomic syndromes, are possible. Cardiovascular disturbances may manifest themselves as vascular dystonia of the hypotonic or hypertonic type, and disturbance of cerebral circulation. Changes in peripheral blood involve mainly the primary erythrocytes and the blood coagulation system. An insignificant decline in the hemoglobin concentration, a rise in the quantity of erythrocytes, and growth in the abundance of young forms of erythrocytes--reticulocytes--is possible in this case. Changes in the coagulation system may manifest themselves as a decline in the quantity of thrombocytes. Changes are also possible in lipid, carbohydrate, and protein metabolism, as is a decline in norepinephrine excretion.

Hygienic Standardization

Temporarily, until such time that maximum permissible norms are approved, the "Interim Public Health Rules Governing Work With Lasers" (approved by the USSR minister of public health on 24 August 1972) may be recommended as the principal legal document to be followed in evaluating the working conditions of laser operators. The principal data of this document are presented in Table 22.

Table 22. Safe Corneal Energy Densities for Pulsed Laser Emissions (j/cm^2)

1) Длина волны, мкм	2) Длительность импульса, с	3) Диаметр зрачка 8 мм		5) Диаметр зрачка 4 мм	
		4) Угол расхождения луча, угл. мин *		4) Угол расхождения луча, угл. мин *	
		20	1	20	1
0,53	2×10^{-8}	9×10^{-7}	$1,5\times10^{7}$	$2,0\times10^{-6}$	$2,5\times10^{-7}$
0,69	10^{-3}	$7,5\times10^{-6}$	$1,5\times10^{-6}$	$2,0\times10^{-5}$	$2,0\times10^{-6}$
	4×10^{-8}	$1,5\times10^{-6}$	$3,5\times10^{-7}$	$4,0\times10^{-6}$	$4,0\times10^{-7}$
1,06	10^{-3}	$6,5\times10^{-5}$	$3,0\times10^{-6}$	$1,5\times10^{-4}$	$4,0\times10^{-5}$
	4×10^{-8}	$2,5\times10^{-5}$	$1,0\times10^{-5}$	$5,0\times10^{-5}$	$1,0\times10^{-5}$

* A divergence angle of 20' for laboratory conditions, defined as the divergence of the beam at the oscillator output. A divergence angle of 1' in the field, when the conditions $L \geqslant d \cdot 3.5$ is satisfied, where L is the distance from the eye to the emitter, meters, and d is the diameter of the beam at the oscillator output, mm.

Key:
1. Wavelength, μ
2. Pulse duration, sec
3. Pupil diameter 8 mm
4. Beam divergence angle, angular minutes *
5. Pupil diameter 4 mm

For laser emissions with wavelength 10.6 μ, the safe energy level in relation to the retina must not exceed 0.2 w/cm^2 when the exposure time is greater than 1 sec, and 2.0 w/cm^2 when exposure time is 0.15 sec.

When working with an argon (0.49 μ) or a helium-neon (0.63 μ) laser, the safe power density experienced by the retina must not exceed 10^{-5} w/cm^2 at an exposure time of 0.15 sec. Before determining the safe zones about a laser device, we would have to take energy density measurements at certain points, or perform calculations (see the "Interim Public Health Rules Governing Work With Lasers").

Measurement of Emission Intensity

The intensity of laser emissions may be measured with laser power and energy measuring instruments such as the IMO-2 (measures mean power and energy of laser pulses) and the IKT-1M (calorimetric solid-state measuring instrument). In addition use of the following instruments is possible in relation to pulsed lasers in the 0.38 to 1.1 μ waveband:

The ELU-FT photoelectric multiplier, the S1-39 oscillograph, and the VS-23 rectifier. When pulse duration varies from units of nanoseconds to 2 μ sec, the SI-39 oscillograph may be substituted by the I2-7 oscillograph, and by the S1-31 oscillograph in the case of a free pulse generation laser.

When the continuous operating mode and wavelengths from 0.4 to 1.2 μ are involved, a FD-7k photodiode, an OKG mechanical beam modulator (any type), and an SD-1 (K3.2) synchronous detector with a U2-6 amplifier or a V6-4 selective microvoltmeter may be used; an MZ-18 bolometric power measuring instrument may be used with a wavelength band from 0.4 to 3.5 μ (when measuring power flux densities greater than 10^{-3} w/cm^2).

The apparatus must be graduated in units of irradiation intensity.

Preventive Measures

Safety measures protecting the worker from the following list of factors must be foreseen first of all when planning and locating the equipment with the goal of insuring safety of work with lasers:

1) Irradiation by coherent laser light;

2) Irradiation by light from pulsating pumping lamps and ultraviolet emissions produced by gas discharges;

3) The effects of toxic substances;

4) Injury by electric current;

5) Noise;

6) The effect of HF or UHF electromagnetic fields.

Construction, fire prevention, and public health norms and rules governing installation of electric devices must be followed in this case.

Operating lasers may be located only in specially outfitted rooms. The area of such rooms must satisfy the requirements of SN-245-71 and insure safe servicing of the devices. The rooms should be furnished with combined lighting. The floors and ceilings are painted a matte finish with a low reflecting capacity. Dark paint having a high absorption coefficient is recommended behind the target, and a light color is recommended for the surrounding area. Objects within the room must not have mirror-smooth surfaces, with the exception of special apparatus. When several lasers are operated in the same room, they must be located in such a way as to exclude the possibility of radiation striking personnel and the workplaces. Illuminated warning signs must be installed at doors leading to rooms in which lasers are located: "Work in Progress!", "Danger!", "Do Not Enter!". A high emission energy density zone is marked off in open areas where lasers are located, and shields preventing the spread of laser emissions beyond this area are set up. Barriers precluding the possibility that laser beams would stray beyond a shielded device or the possibility that a person may enter the beam path are foreseen as a means for preventing injury by direct or reflected laser beams. Blocking systems or shutters are used to protect the eyes of a worker operating a device in which the observation system is combined with the optical system; safety goggles are worn in addition.

It is recommended that light filters be made from the brands of glass shown in Table 23.

Table 23. Glass Brands (GOST 9411-66) Recommended for Use in Safety Goggle Light Filters

Range of Wavelengths Absorbed by Glass, nm	Glass Type	Glass Brand
Less than 350	ZHS--yellow glass	ZHS-10, ZHS-11
" " 450	ZHS--yellow glass	ZHS-17, ZHS-18
" " 540	OS--orange glass	OS-11, OS-12
" " 320		
From 600 to 1500 and more than 3000	SZS--bluegreen glass	SZS-22
More than 5000	BS--colorless glass	BS-15

The paperwork accompanying the goggles must indicate the wavelength range for which the goggles are designed, and the optical density of the light filter. To preclude possible action of the blinding light of pumping lamps upon the worker, such lamps are covered with opaque hoods.

The maximum permissible concentrations of poisonous gases, vapors, and dust in the air about the work zone of the room must not exceed the levels established by GOST 12.1.005-76. For this purpose mechanically activated balanced ventilation is installed in rooms containing laser devices; such ventilation must satisfy the air exchange norms. When work with volatile liquids is involved, exhaust cabinets are installed. When work with lasers is accompanied by formation of toxic gases and vapors in concentrations above those permissible, the laser devices must be outfitted with local suction devices intended to contain and remove contaminated air.

Various remote controls, blocking systems, automatic circuit breakers, mechanical grounds, warning systems, and protective resources are used to protect workers from injury by electric current. All components of powered laser devices must be shielded, and metallic housings must be grounded. The means for protecting personnel from electromagnetic fields and noise, and the permissible public health norm, measuring schedules, and the instruments and methods used in such measurements are indicated in the appropriate sections of the manual.

Work with lasers is limited to persons at least 18 years old who underwent a preliminary medical examination when first employed, and who are examined once every 12 months by a therapist and a neuropathologist, and once every 3 months by an oculist, in accordance with Order No 400 of the USSR minister of public health dated 30 May 1969. In addition applicants for work must take a special training course, obtain the appropriate qualifications, and pass a technical qualifying examination on work safety rules. [11004-8144/0555]

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