FTD-MT-24-426-69

FOREIGN TECHNOLOGY DIVISION

SMOKE AGENTS AND DEVICES AND SMOKE-PRODUCING SUBSTANCES

by

G. S. Zaytsev and A. Ya. Kuznetsov

99

FTD-MT- 24-426-69

EDITED MACHINE TRANSLATION

SMOKE AGENTS AND DEVICES AND SMOKE-PRODUCING SUBSTANCES

By: G. S. Zaytsev and A. Ya. Kuznetsov

English pages: Cover to 96

SOURCE: Dymovyye Sredstva i Dymoobrazuyushchiye Veshchestva. Voyennoye Izd-vo Ministerstva Oborony Soyuza SSR, Moscow, 1961, pp. 1-84.

This document is a Mark II machine aided translation, post-edited for technical accuracy by: Charles T. Ostertag.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

FTD-MT- 24-426-69 Date 21 Jan 1970

TABLE OF CONTENTS

U. S. Board on Geographic Names Transliteration System........ iii

Chapter I. Brief Historical Outline of the Development and Application of Smoke Agents........................... 1

Application of Smoke Agents During the First World War..... 2

Application of Smoke Agents During the Second World War and the Great Patriotic War........................ 4

Chapter II. General Information About Aerosols.............. 8

Smokes and Fogs. Peculiarities and Characteristics of an Aerosol State...................................... 8

Optical Phenomena in Smokes. Scattering and Absorption of Light. Attenuation Factor of Light................. 14

Concept of Smoke Cloud and Its Camouflaging Properties. Reasons for Invisibility of Objects.................... 21

Behavior of a Smoke Cloud in the Atmosphere. Stability of Smoke Clouds............................. 27

Chapter III. Smoke-Producing Substances..................... 35

Methods of Obtaining Aerosols. General Characteristics of Smoke-Producing Substances.......................... 35

Substances, Giving Off Smoke as a Result of the Reaction with Moisture of the Air...................... 38

Sulfuric Anhydride (Sulfur Trioxide)................... 39

Oleum.. 41

Chlorosulfonic Acid 41

Solutions of Sulfuric Anhydride in Chlorosulfonic Acid.. 43

Titanium Tetrachloride 44

Silicon Tetrachloride 45

Tin Tetrachloride (Stannic Chloride) 46

Substances Which Produce Smoke as a Result of Reactions with Oxygen of the Air 47

Pyrotechnic Smoke-Producing Compositions of Camouflaging Smokes 48

Smoke Mixtures on the Basis of Oil Products and Foam Plastics 53

Colored Signal Smokes 55

Chapter IV. Technical Means for Smoke Generation 58

Hand Smoke Grenades and Smoke Pots 59

Artillery Smoke Devices 64

Aerial Smoke Devices 67

Smoke Machines and Generators 71

Chapter V. Application of Camouflaging Smokes 76

Classification and Characteristics of Smoke Screens. Application of Smokes for Camouflaging the Combat Actions of Troops 76

Smoke Camouflage of Rear Objectives 80

Application of Smokes for Blinding Night Vision Devices and Camouflage in the Case of Artificial Illumination 83

Application of Smokes as Interferences in the Operation of Radar Installations 87

Use of Smoke Agents for Protecting the Troops from the Influence of Light Radiation of a Nuclear Explosion 88

Use of Smokes for Protection of Troops from Bacteriological Weapons 92

Conclusion 96

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

In two World Wars and a number of small wars smokes were used widely for camouflaging of troops and rear objects. The undisputable opinion exists that smoke agents will also find application in wars of the future.

In the book offered to the reader smoke agents and smoke-producing substances are examined which are found in the armament of different armies, and also methods and problems of their application. The authors allot special attention to new trends in the use of smoke.

The book is based on materials published in the foreign and Soviet press.

CHAPTER I

BRIEF HISTORICAL OUTLINE OF THE DEVELOPMENT AND APPLICATION OF SMOKE AGENTS

In world military history many examples are known when natural fog or powder smoke promoted the success of a battle to a considerable degree. However, in the distant past the use of camouflaging properties of smoke and fog was often accidental.

The first example of the conscious application of smoke in the interest of troops is the covering of a crossing over the Western Dvina by the Swedes in 1701. The Swedes set fire to wet straw, the smoke from which masked the concentration of their troops and preparation for the crossing. This fact is described by Voltaire thusly:

"The smoke became so thick that the Saxons in no way could find out if the Swedes were crossing the river or not. Meanwhile Karl ordered the crossing to begin. In a quarter of an hour he appeared on the other shore and immediately gave the order to ferry his artillery across and to form a combat formation. The enemy, blinded by smoke, could protect himself with only several shots fired at random. When the wind dispersed the smoke, the Saxons saw that Karl with his troops was already marching against them."

Later smoke screens were used in naval operations. Thus, according to Freys, during the Civil War of 1862 in America the black smoke screen found wide application. For producing such a curtain wood wi[illegible]h content of resin was burned in the ships' furnaces.

On the eve of the First World War, during maneuvers of the United States fleet, smoke screens were used with success for covering of ships.

The systematically conscious use of smokes for camouflaging the combat actions of troops, and also the development of methods of application of smoke began with the First World War.

Application of Smoke Agents During the First World War

Smoke screens with the use of special smoke agents were set up for the first time by ground forces of the Russian army in 1913 on maneuvers in Ust'-Izhor. In November 1914 Sannikov smoke pots (candles) were used successfully by Siberian riflemen in fights with the Germans at Ivangorod.

In March 1915 the English used smoke screens for camouflaging mine sweepers in the Dardanelles operation. In July of the same year rifle grenades equipped with a special mixture appeared in the English army.

In the period 1915-1916 wide dissemination was received by so-called "false smoke screens," and also the use of camouflaging smokes for expanding the front of cloud attack with toxic agents. Taking a false smoke screen for a gas attack, the enemy concentrated his fire on it and thereby weakened the defense. Furthermore, the application of neutral camouflaging smokes instead of poisonous gas permitted the infantry which was advancing behind the cloud to be at individual sections of the front without gas masks, whereas the enemy, expecting a gas attack, donned gasmasks, and this lowered his combat ability. The Kaiser troops practiced the consecutive launching of initially nontoxic smoke and then gas, and by this lulled the vigilance of allies, the troops of which encountering the second wave without gasmasks, received serious defeats.

The first smoke prescriptions, used during the First World War, produced smoke of a black color, which possessed insufficient camouflaging ability and was unstable. In connection with this extensive work was conducted on the brightening of clouds by means of changing the composition of smoke mixtures.

In the Russian army the Yershov mixture was used most extensively. Its composition included chlorous ammonium – 50%, napthalene – 20%, potassium chlorate – 20%, carbon (powder) – 10%. Another variety of Yershov mixture was composed for the purpose of obtaining a quick-burning mixture. For this some of the chlorous ammonium (10%) was replaced by an additional oxidizer – potassium nitrate.

In the English army a mixture of the following composition was used: potassium nitrate – 40%, coal tar – 29%, sulfur – 14%, carbon (powder) – 9%, borax – 8%.

In the French army Berger's mixture was used. It consisted of carbon – 41.1%, zinc dust – 32.2%, sodium hypochlorite – 14.6%, chlorous ammonium – 8.8%, and kieselguhr – 3.3%.

Such mixtures were used mainly in smoke candles, grenades, and pots.

The allies also found wide application for phosphorus, which, in addition to a high camouflaging ability, possessed an incendiary effect. Phosphorus was used in grenades, shells, and mortars.

As a smoke-producing substance the Germans used oleum, chlorosulfonic acid, and solutions of sulfuric anhydride in chlorosulfonic acid. Since the process of smoke generation of these substances consists of the transfer of a highly volatile substance – sulfuric anhydride, into the air, then the following method of application was developed. Unslaked lime CaO was placed in a special smoke generator and a smoke-producing substance was gradually added to it. As a result of the reaction between these two substances heat was liberated which was sufficient for evaporation of the smoke generator.

Along with smoke-producing substances during the years of the First World War the tactical application of smokes was also developed. Neutral smokes were used for covering an attack, blinding of strong points and observation posts, covering water crossings, flanks, retreating troops, etc. Specific value was gained by camouflaging smokes for covering the advance of tanks and their supporting infantry, ensuring the suddenness of the attack and decreasing the effectiveness of fire of antitank guns.

Thus, camouflaging smokes during the years of the First World War became a means for camouflaging the actions of troops. They were used extensively both on the offensive and also in defense. Means of smoke generation were smoke artillery shells and mortar shells, smoke hand and rifle grenades, smoke pots, and special smoke generators.

Application of Smoke Agents During the Second World War and the Great Patriotic War

During the years between the First and Second World Wars development continued of means of application of smokes and also views on their use.

According to views existing in the majority of foreign armies on the eve of the Second World War, smokes were regarded only as means for supporting of tactical missions; indications of the value of smokes in the carrying out of operations were completely absent in foreign armies. In the Soviet army views on the application of smokes amounted to the fact that they should be considered not only "protective cover for the troops," as this was done by foreign specialists, but also as a means of supporting active offensive actions. We have not considered smokes merely as tactical agents; problems on their application have included leading the enemy into error relative to the direction of the main strike and camouflaging of important military and rear area objectives.

Considering these properties of smokes, the Soviet Army began to use them from first months of the Great Patriotic War. It is true that in the first year of the war smokes were used for camouflaging the actions of small units. Small units of infantry and other arms used hand smoke grenades and smoke pots to support their own combat actions. With their help the infantry rapidly created smoke screens under any conditions of the combat situation. Furthermore, small tank units used smoke agents for covering combat maneuvers, camouflage of repair and evacuation of vehicles from the field of battle, and simulating the burning of tanks. However, in the course of war the application of smokes rapidly took on a wide scope. Already in 1942 on certain fronts smokes were used in army operations (smoke screening of army crossings), and beginning with the second half of 1943 they were used not only on an army scale, but also on the scale of army group. There, where smokes were used widely and in good time the troops had less losses in personnel and materiel and, as a rule, successfully fulfilled their combat missions.

Let us give such an example. In 1944 a major unit of a tank army used smokes with success in the forcing of the San River in the region of Vysoukho. In spite of intensive enemy air raids and artillery fire neither one of crossings was knocked out. It was characteristic that the release of smoke was carried out in the army on a centralized basis, by a single plan, and smoke screens were set up on a wide front. For confusing the enemy relative to the true crossings, false crossings were created and they were also covered by smokes. Smoke screens were also set up on sections of the river where there were no crossings at all.

Smoke agents were used also by major units of the army in the course of battle for extending bridgeheads on the opposite shore. Usually smokes covered the attacks of tanks and motorized infantry. Depending on direction and speed of wind, location of the enemy and his maneuvering, both flank and frontal smoke screens were used. Flank smoke screens were set up on the move and in place by means of dropping pots from tanks on one or both flanks. Here the crews of tanks, being covered by local terrain features or using folds in the terrain, moved their tanks to the flank of the subunit at a distance which made it possible to cover enemy weapons with a smoke screen and dropped off the pots. Then the tanks were joined with their own attacking subunits.

Smoke cover of combat actions of troops, and also rear objectives, was usually organized by rifle and tank subunits for the purpose of depriving the enemy of the possibility to conduct aimed fire and bombing, to make it difficult for him to conduct observation of the actions of troops on the field of battle, and to distract the attention and fire of the enemy from the direction of the main attack during offensive operations. For this smoke pots and grenades were used, and also special smoke machines (generators).

In the course of the Great Patriotic War wide application was also found for artillery smoke shells (mortars) and aerial smoke agents. Smoke shells and mortars were used mainly for blinding (smoke screen) of enemy observation posts and firing points. Aviation used smoke agents for the purpose of camouflaging the actions of troops during the development of combat in the depth of the enemy's defense for blinding of enemy firing systems, and blocking of enemy airfields.

Various infantry, artillery, and aerial smoke devices were used by all the armies participating in the Second World War. As smoke-producing substances in most cases they used phosphorus, solutions of sulfuric anhydride in chlorosulfonic acid, pyrotechnic smoke mixtures, and oil products.

The Second World War and the Great Patriotic War showed that the wide, bold, and tactically competent application of camouflaging smokes promotes the successful fulfillment of combat missions and considerably reduces loss in personnel and equipment. The application of various smoke-producing substances for the creation of smoke screens made it possible to camouflage the location and actions of our troops, to cover different objects from enemy observation, to blind the enemy for the purpose of hindering orientation, observation, etc. Thus, smokes were effective agents for supporting the combat actions of units and subunits during the carrying out of tactical missions and also a means of protected large-scale operations on an army and front scale.

The importance of smoke agents for supporting the combat actions of troops under contemporary conditions has not lessend it in the least; it is even acquiring new meaning, and smoke agents and smoke-producing substances require further improvement.

CHAPTER II

GENERAL INFORMATION ABOUT AEROSOLS

Smokes and Fogs. Peculiarities and Characteristics of an Aerosol State

Among the various colloidal systems a special place is occupied by aerosols, i.e., systems in which the dispersion medium is a gas (for the most part air), and the dispersed phase – solid or liquid bodies with a high degree of dispersion. Examples of aerosols can be the clouds observed in nature, fogs, fine dust, etc.

If the dispersed phase is a liquid, then the aerosol is called a fog; if the dispersed phase is a solid, the aerosol is called a smoke. Sometimes an aerosol can constitute smoke and fog simultaneously.

It is necessary to note, however, that, besides this classification based on aggregate state, there exists another classification of aerosols based on degree of dispersiveness.[1] Thus, in English literature the division of "smoke" and "fog" is made not by aggregate state, but by the size of collodial particles. Fog is an aerosol, consisting of larger particles (diameter 10^{-3}-10^{-5} cm), and smoke is an aerosol made up of finer particles (10^{-5}-10^{-7} cm).

---

[1]Degree of dispersion is only one of the principal characteristic criteria of a colloidal state, and many properties of these systems are a function of their degree of dispersion (see S. M. Lipatov, Physical chemistry of colloids. State Chemistry Publishing House, M.-L., 1938).

In military practice the concept of smokes and fogs is usually not differentiated and artificially created smokes and fogs, used for camouflage, are called smokes.

Dimensions of particles of various smokes and fogs are within the limits from $1 \cdot 10^{-3}$ to $1 \cdot 10^{-7}$ cm. Radius of particles of aerosols which are used for camouflaging smoke generation fluctuates in narrower limits, i.e., from $8 \cdot 10^{-5}$ to $2 \cdot 10^{-5}$ cm. Particles of fog (droplets) usually have the form of a sphere. The density of these droplets is equal to the density of the liquid from which the fog is made up. Particles of smoke do not have a geometrically regular form and are often made up of flaky formations of diverse structure. The density of smoke particles is much less than the density of the solid of which they are made up; sometimes the density of the substance is 5-10 times greater than the density of the smoke particles.

Transition of a solid or liquid substance into an aerosol state with the formation of smoke or fog is accompanied by a certain change in its properties. The aerosol state is characterized first of all by a large specific surface.[1] This causes an increase of activity of the substance and acceleration of physicochemical processes. Thus, aerosols absorb a certain quantity of gas ions and molecules.

Aerosols are characterized by degree of dispersion (dimension of particles in the dispersed phase) and concentration by weight, i.e., quantity of dispersed phase in unit of volume of aerosol (or partial concentration, i.e., number of particles of dispersed phase in unit of volume of aerosol). Concentration by weight of smokes, used for creation of a smoke screen, is usually expressed in tenth parts of a milligram per one liter, which corresponds to a content of several millions of smoke particles in 1 ml of air.

---

[1]In colloidal chemistry specific surface is understood to be the ratio of surface of a particle to its volume: surface/volume = S/V = = S_0. Specific surface of a particle is the value, characterizing the degree of breaking up of a given system; it most frequently is called degree of dispersion.

The most important peculiarity of aerosols is their instability. At the basis of change of properties of an aerosol in time lie the properties of the air as the dispersion medium. Particles of smoke or fog move continuously in the air and experience two kinds of movement simultaneously: movement under the impact of gravity and Brownian movement.

Movement under the impact of gravity forces the particles to drop downwards. The rate of fall of particles, the radius of which is less than $1 \cdot 10^{-3}$ cm, remains constant and can be calculated proceeding from gravity and from the resistance exerted on a moving particle by molecules of air.

Forces of gravity

$$F = \frac{4}{3} \cdot \pi r^3 g (\rho - \rho'),$$

where r – radius of particle in cm; g – acceleration due to gravity, equal to 981 cm/s^2; ρ – density of particle; ρ' – density of medium.

Resistance of a viscous medium to uniform movement of a particle is expressed by the Stokes formula:

$$W = 6\pi\eta r v,$$

where η – coefficient of viscosity of medium in pauses (for air $\eta = 1.81 \cdot 10^{-4}$ g/cm·s); r – radius of particle in cm; v – rate of fall of particle in cm/s.

From conditions of equality of gravity and resistance, exerted on movement by molecules of air, we find the rate of uniform settling:

$$\frac{4}{3} \cdot \pi r^3 g (\rho - \rho') = 6\pi\eta r v;$$

$$v = \frac{2}{9} \cdot r^2 g \frac{(\rho - \rho')^*}{\eta}.$$

---

*As it emanates from the law of Stokes, for particles of one size the rate of settling depends only on their density.

Value ρ' for air is so small that it is fully possible to take it equal to zero. Replacing $\frac{2}{9}\cdot\frac{g}{\eta}$ by constant value k, we obtain a formula in a simpler form:

$$v = kr^2\rho^*,$$

where $k = 1.2\cdot 10^6$ cm^2/g·s.

The path, covered by a particle under the impact of gravity during the time t, is calculated by the formula

$$S = kr^2\rho t.$$

The rate of uniform falling of particles under the impact of gravity is determined by dimensions and density of particles of the dispersed phase, and viscosity and density of the dispersion medium. The less the viscosity and density of the medium, the more rapidly settling takes place. Thus, for example, in an atmosphere of hydrogen ($\eta = 0.93\cdot 10^{-4}$ CGS) or water vapor ($\eta = 0.975\cdot 10^{-4}$ CGS) the falling of droplets should occur approximately 2 times more rapidly than in pure air ($\eta = 1.882\cdot 10^{-4}$ CGS).

It follows from the laws of settling that particle of smoke of all dimensions fall under the impact of gravity. The rate of settling is a value, depending on the radius of the particle and increasing with an increase of the latter. In a polydispersed smoke cloud the largest particles settle first. It is necessary to note that in most cases smokes and fogs are polydispersed systems, i.e., they contain particle of various dimensions.

Brownian movement of aerosol particles occurs under the influence of impacts of molecules of the environment. Comparatively large particles of smoke or fog are less sensitive to impacts of molecules, and their Brownian movement is minor. Under the impact of gravity such particles settle comparatively rapidly. Very fine particles with considerable Brownian movement are held in the

*The Stokes formula gives the greatest coincidence with experimental data for particles $r > 10^{-4}$ cm.

air for an extraordinarily long time without settling to earth. For particles with a radius of 10^{-7} cm the rate of Brownian movement is many times greater than the rate of settling under the impact of gravity.

Brownian movement of particles in an aerosol cloud occurs uniformly in all directions. The rate of Brownian movement is small and cannot essentially influence the course of change in concentration by weight.

Brownian movement of particles of smoke can be observed in an ultramicroscope: on the dark field of an ultramicroscope luminescent stars of chaotically shifting smoke particles are seen.

In aerosols, starting from the moment of their formation the phenomenon of coagulation is observed. Coagulation of aerosol is the term for consolidation (adhesion) of particles of smoke or fog. For smokes the process of coagulation is frequently called flocculation (from the English flocks – flakes).

Being found in Brownian movement, particles of an aerosol collide among themselves. As a result of this particles conglomerate, i.e., become larger. Droplets of fog can be enlarged also at the expense of evaporation of smaller droplets. As is known, vapor pressure over small droplets of fog is greater than over large ones, therefore "distillation" liquid from small drops on large is possible. Adhesion of particles occurs also under the influence of forces of attraction which are acting between particles.

The capacity of smokes for coagulation decreases in the presence of an analogous electrical charge on the particles; absence of a charge or especially the presence of an opposite charge on the particles facilitates coagulation of smokes. Particles of smoke can obtain their charge during friction against a gaseous environment due to dissociation of particles at the time of formation of smoke, and also by means of capturing gas ions from the dispersion medium.

Peculiarity of coagulation of particles of an aerosol is that it begins spontaneously and continues continuously during the entire "life" of the aerosol. This is explained by the low viscosity of air and the insignificant quantity of analogous electrical charges present in the air. The low viscosity of air promotes diffusion of particles, which in turn speeds up coagulation.

The rate of coagulation at every given moment of "life" of an aerosol is proportional to the square of their particle concentration. With a decrease in the number of particles the rate of coagulation drops sharply.

In addition to the properties of air, instability of an aerosol is also influenced by properties of the aerosol particles themselves: density of particles, their size, and degree of homogeneity of the aerosol on the whole. Instability of an aerosol increases with an increase of density and size of particles, and also with an increase of its polydispersion.

In initial period of "life" of an aerosol the particle concentration (i.e., number of particles in a unit of volume of air) is very great and, apparently, is close to the particle concentration of hydrosol, i.e., of an order of 10^{11}-10^{12} particles in 1 cm^3. Such a large particle concentration causes the rapid coagulation of particles, in consequence of which already in the second-third minute of "life" of the aerosol the particle concentration drops to 10^6-10^7 particles in 1 cm^3. With an increase of coagulation polydispersion of the aerosol is strengthened, which in turn accelerates the settling of particles.

Thus, from the moment of formation the aerosol acquires an unstable nature. Intensity of this process increases with an increase of degree of polydispersion during the formation of the aerosol. Along with the settling of large particles the aerosol becomes thinner and more uniform. This leads to an increase in the stability of the aerosol, since coagulation is slowed down. It has been experimentally proven that a nonuniform (polydispersed) aerosol coagulates more rapidly than uniform (monodispersed).

Optical Phenomena in Smokes. Scattering and Absorption of Light. Attenuation Factor of Light

We can see the world surrounding us only because it is illuminated.[1] Certain bodies emit inherent light (for example, the sun, incandescent bodies, flame); they are called light sources. The majority of bodies we see only when they are illuminated by some light source and send to our eye the reflected light of this source.

Light from any source in a uniform medium spreads in all sides rectilinearly; the path of propagation of light carries the name beam. Rectilinear propagation of light is one of the first laws of nature with which man became acquainted.

If a light beam which is spreading in the air encounters on its path any hard or liquid body, then it, upon reaching the surface of this body, is partially reflected from it at the same angle at which it is incident on the reflecting surface. Reflection of light is the reason for the visibility of objects which do not emit their own light. An example of light reflection can be the solar "light spot," which is the reflection of light of a brightly luminescent object from a mirror. If the surface is rough, it encounters a pencil of light which is incident on it at different angles and accordingly is reflected at different angles. Such reflection is called scattered. Diffused reflection is produced, for example, by frosted glass.

Aerosols are optically nonuniform media. In the case of passage of radiant energy through such media it is scattered by particles which are suspended in the air, and which have a refractive

---

[1]Energy of radiation of visible and invisible rays is called radiant energy. Radiation in the visible region of the spectrum (visible rays) is called light. In contemporary physics radiant energy is examined as a flow of material particles possessing wave and quantum properties simultaneously.

index which is greater than the refractive index of air. Presence in air (dispersion medium) of a solid or liquid dispersed phase lowers its penetrability relative to light.

The capacity of a smoke cloud to make objects invisible to an observer is explained by the optical phenomena occurring in smokes. A ray of light, passing through a smoke cloud, emerges from it less intense than at the entrance. In smokes light is partially reflected, is scattered, is absorbed by particles of smoke and only partially passes through the smoke without a change. Basic causes of attenuation of a light ray are scattering and absorption of light by smoke cloud.

By light scattering is understood the deflection of light rays by smoke particles to various sides during passage of a ray through smoke. Light scattering by a smoke cloud is caused by refraction of light in particles, by reflection from their surface, diffraction, and other causes.

Falling on the boundary of two media, light rays change their directions, in other words, are refracted. A very interesting natural phenomenon is the fact that the sun can be seen when it is already concealed beyond the horizon which is explained by refraction of solar rays in the atmosphere of the earth. The cause of refraction of light on the border of two media lies in the difference of propagation velocities of light in different media.

A ray of light, falling from the air into a liquid particle (droplet of fog), is refracted in it at the entrance (Fig. 1). Upon getting out of the particle into the air the ray is refracted a second time. The ray is partially reflected. Only the reflection of the light ray is observed from opaque smoke particles. Due to the fact that aerosol particles have various forms, refraction and reflection of light at various angles to the surface is the cause of scattering of radiant energy.

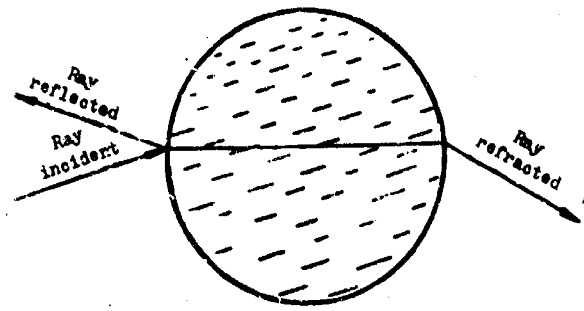


Fig. 1. Diagram of refraction and reflection of light by a droplet of fog.

If the dimensions of the particles are approximately equal to wavelength of passing light, then the cause of scattering is diffraction of light. The phenomenon of diffraction lies in the fact that light is deflected from a rectilinear direction.

A particle of smoke can be examined as a little screen. Rays of light, passing such a particle, are deflected from their own initial direction, which serves as the cause of diffractional scattering (Fig. 2). If the dimensions of the particles are less than the wavelength of light, scattering has a more complex nature and is connected with physical phenomena occurring inside the atoms.

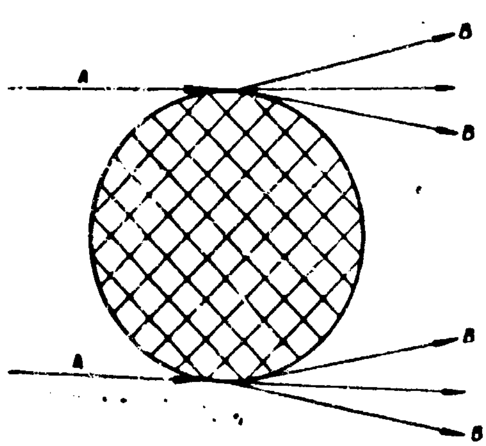


Fig. 2. Diagram of diffractional light scattering by particle of smoke: A) rays of incident light; B) rays of scattered light.

The main role in light scattering in camouflaging smokes is played by diffractional scattering.

The phenomenon of light scattering by particles of an aerosol has acquired the name of Tyndall effect. This phenomenon amounts to the following. If through the air, in which minute particles are found in a suspended state, a bright bundle of convergent rays is passed, then in the air a light cone will appear which is easily visible in a dark location. Formation of the cone is explained by the fact that each particle disperses the rays which are incident on it and is as if turned into a luminescent point, thanks to which entire path of rays in the air becomes visible.

In smokes, the dimensions of particles of which are greater than the wavelength of light, the intensity of scattered light is expressed by the formula[1]

$$I_s = k\frac{C}{r},$$

where k – proportionality factor; C – concentration by weight of aerosol; r – radius of particles of aerosol.

For particles of an aerosol, having dimensions considerably less than wavelength of light passing through it, the intensity of scattered light is expressed by the formula

$$I_s = kCr^3$$

and increases rapidly with an increase of dimensions of particles.

It was determined that the greatest light scattering, and consequently also the best camouflaging properties are held by aerosols, the particles of which have dimensions close to wavelengths of visible light, i.e., $1\cdot10^{-4}$–$1\cdot10^{-5}$ cm.

---

[1]G. Gurevich, G. Luchinskiy. Concerning the question of dependence of light scattering in aerosols on the size of particles and wavelengths of light. Journal of Physical Chemistry, [ZhFKh], vol. III, p. 151.

Intensity of light scattering is increased with a decrease of the length of its wave (this can be seen from the Rayleigh formula):

$$I_S = I_0 \frac{kCr^3}{\lambda^4},$$

where I_0 – intensity of incident light; k – proportionality factor; C – concentration by weight of aerosol; r – radius of particles of aerosol; λ – wavelength of incident light.

Smokes and fogs are able not only to scatter light, but also to partially absorb it. Absorption means weakening of light intensity, occurring in case of its passage through a physical body, due to transition of radiant energy into some other form of energy (for example, into thermal, chemical, or electrical). Theoretically all bodies, not being ideal insulators, and including various solutions, absorb radiant energy due to electrical conductivity.

Absorption of light by smoke or fog is composed of absorption of light by the dispersion medium (air) and the dispersed phase (substance which is found in an aerosol state). Absorption of light by air is much less than by particles of smoke or fog. Coefficient of transparency of atmosphere in case of a clear sky on the average is equal to 0.8. This means that around 80% of solar energy falling on the surface of the atmosphere reaches the earth's surface, and around 20% is held back due to absorption and scattering. The basic cause of absorption of light in pure air are its impurities.

Quantitative relationship between absorption of light by an aerosol, concentration of aerosol, and thickness of absorbed layer in the case of constant degree of dispersion of aerosol is expressed by the Lambert-Bouguer-Beer formula:

$$I = I_0 e^{-klC},$$

where I_0 – intensity of light entering the absorbing layer; e – base of natural logarithm; k – attenuation factor of light; C – concentration by weight of aerosol; l – thickness of layer of aerosol.

In smokes of different density, or in the case of different thickness of layer of smoke, attenuation of passing light will be unequal. For appraisal of the capacity of smoke to weaken light which is passing through it there is the attenuation factor of light which shows what share of light entering a cloud of smoke, is scattered and is absorbed on the way, equal to a unit of thickness of the cloud. Attenuation factor of light, in other words, determines by itself the so-called range of visibility, by which is understood the distance of the smoke cloud from the observer to the observed object under the condition that the latter becomes invisible.

Attenuation factor of light depends on the nature of the dispersed phase of the aerosol. For one and the same smoke-producing substance it is increased proportionally to the density of smoke, i.e., its concentration.

Attenuation factor of light is expressed in m^{-1} and is taken in each separate case depending upon concrete conditions. Absolute value of attenuation factor of light in camouflaging smokes comprises approximately 0.4-0.04 m^{-1}.

Attenuation factor of light can be determined by experimental means. For this purpose photometric light readings are taken from two lamps (Fig. 3), one of which is inside the smoke chamber, and the other outside of it. The lamp located inside the chamber is made stationary at distance l from the wall of the chamber; the outside lamp can be moved. When there is no smoke in the chamber, then during photometry the outside lamp will occupy a position at which the distance from the lamp to the photometer will be a. In the presence of smoke in the chamber, light which is arriving from the inside lamp, in the case of passage through the thickness of smoke, will be attenuated, therefore for leveling off of illuminance of photometer fields the outside lamp must be moved from the photometer by distance b. Distance b always should be greater than distance a.

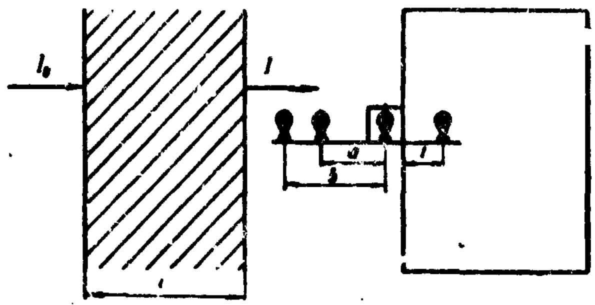


Fig. 3. Attenuation of light in a smoke cloud.

Since intensity of light for one and the same light source is inversely proportional to the square of distance, then for the test we will have:

in the absence of smoke in the chamber

$$I_0 = \frac{A}{a^2};$$

in the presence of smoke in the chamber

$$I = \frac{A}{b^2},$$

where A – luminous intensity of outside lamp; a and b – distance of this lamp from the photometer in the absence and in the presence of smoke in the chamber.

Dividing the first equation into the second, we obtain

$$\frac{I}{I_0} = \left(\frac{a}{b}\right)^2, \text{ or } I = I_0\left(\frac{a}{b}\right)^2.$$

But $I = I_0 e^{-klC}$, then $e^{-klC} = \left(\frac{a}{b}\right)^2$, from which

$$k = 4{,}606\,\frac{\lg\frac{b}{a}}{lC}.$$

Thus, camouflaging properties of an aerosol are conditioned mainly by attenuation of light coming from the observed object to the eye of the observer. Attenuation of light is composed of absorption, reflection, refraction, and light scattering by particles of an aerosol. For large particles there is greater meaning in absorption, refraction, and reflection, and for small particles – scattering (diffraction) of light. The presence of a solid (smoke) or liquid (fog) dispersed phase in the air lowers its penetrability relative to light.

Greater or lesser attenuation of light by smoke screens depends on thickness of the layer of smoke. Light of various brightness, when passed through the layer of smoke of identical thickness, is attenuated in it by an identical share of its own initial value. But light of identical brightness, when passed through smoke screens of different thickness, is attenuated all the more, the greater the thickness of the layer of smoke. Attenuation of light is also influenced by the density of the smoke screen. The denser the smoke, i.e., the greater its concentration, the more considerable is the attenuation of light which is passed through it.

Concept of Smoke Cloud and Its Camouflaging Properties. Reasons for Invisibility of Objects

A smoke cloud consists of minute particles of a smoke-producing substance which are found in an air in a suspended state.

The main requirements for a smoke cloud are high degree of camouflaging ability of the cloud and its stability, i.e., capacity to be held in an air for a prolonged time without settling and without being broken up.

The camouflaging properties of a smoke cloud are determined by two groups of phenomena: phenomena connected with optical properties of the dispersed phase (solid or liquid particles), and phenomena of an external order.

The basic optical phenomena in smoke which determine its camouflaging capacity are scattering, absorption, and reflection of light from the "border" of the smoke cloud with pure atmosphere. Thus, white, and sometimes black, smokes are used for camouflaging. Difference in color is explained by the unequal scattering and absorption of light in these smokes. In white smokes out of the total amount of scattered and absorbed light to the share of the latter belong only 10-30%, the remaining light is scattered. In black smokes, conversely, the share of absorbed light comprises up to 80%, and an insignificant share is scattered. Consequently, in smokes of white color the basic role in attenuation of light is played by scattering of it, and in smokes of a black color – by absorption of light.

Our eyes receive rays not only from the viewed object, but also from objects surrounding it (background), and this circumstance plays a decisive role in the problem of sharpness and clearness of visibility. A smoke cloud, located between the observer and the object leads to a decrease of contrast of brightness and color between the viewed object and background, and hence, to the impairment of visibility.

For appraisal of the camouflaging properties of smoke cloud the concept of distance of discernment (visual range), is used, i.e., distance, beyond the limits of which the human eye cannot ascertain the presence of an object. This concept is broken down into distance (range) of visibility, determined as the maximum distance with a still sufficiently clear visibility of contours and parts of an object, and distance of penetrability, or maximum distance, at which an already invisible object can be detected.

A graphic presentation of the difference between concept of visibility and penetrability is gained by a consideration of a bulb which is placed inside a frosted glass jar. If there is sufficient cloudiness and thickness of the shell of the jar, the bulb itself is not visible; its presence can be judged by the bright light emanating from the frosted shell.

In objects which do not have sources of natural light (buildings, trees, etc.), the distance of visibility and distance of penetrability almost coincide completely. For light sources, conversely, the difference between distance of visibility and distance of penetrability is expressed more strongly.

Artificial smoke screens, by sharply lowering the natural transparency of air, effect the visibility of objects by the fact that they decrease, to a considerably greater degree than natural smoke, the contrast between object and background. The more that light is scattered by a smoke screen, then the brighter it is and, consequently, the less the visibility of the object, since the brightness of the smoke cloud, being superimposed simultaneously on the brightness of the object and on the brightness of the background, as if equalizes them (the brighter the smoke cloud, the greater the effect).

For camouflaging smokes the greatest interest lies in distance (range) of visibility. We will observe, for example, a man moving in the middle of a smoke cloud. As the man moves away from the observer, his visibility will worsen, and at some specific distance the man will be concealed from view. This distance is also taken as the distance of visibility. Distance of visibility is what is called the thickness of a layer of smoke, sufficient to conceal an object from the observer.

Establishment of distance of visibility depends both on subjective properties of the human eye, and also on the qualities of the observed object: nature of its surface, form, color, brightness, and reflecting capacity of separate parts of the object.

From psychophysical and optical laws it follows that for camouflaging a black object by smoke it is necessary to attenuate visible light by 82 times, which is expressed by the following formula:

$$S=\frac{4.4}{k}.$$

where 4.4 – optical density of smoke, equal to the logarithm of necessary value of attenuation of light; k – attenuation factor of light, m^{-1}.

Gray or white surfaces of objects which are located in a smoke cloud are less apparent than black, but in practice this difference is not so great that it is considered under field conditions. This is why the given formula can give a sufficiently complete idea of visual range of a smoke-blanketed object, which changes only depending on the attenuation factor of light.

The less the visual range, the better the camouflaging properties of a smoke cloud. Conversely, the greater the visual range, i.e., that distance at which it is possible to detect an object in a smoke cloud, the worse the camouflaging properties of the smoke cloud.

Visual range depends on properties of the smoke-producing substance, concentration of smoke in the cloud, significance of condition of illumination, brightness and color of observed object and surrounding objects (background), relative atmospheric humidity, and other causes. An increase of concentration of smoke in a smoke cloud leads to a decrease of range of visibility. If a white object is illuminated by direct solar rays, its range of visibility can become greater than the range of visibility of a black object. In the case of observation of an object against the background of its surrounding object through a cloud of black smoke the range of visibility will be greater than in the case of application of white smoke. This means that camouflaging properties of black smoke are inferior to white.

Range of visibility does not determine completely the qualities of a smoke-producing substance. For one and the same smoke-producing substance the range of visibility can be different in the case of different conditions for releasing the smoke. Thus, an increase of concentration of smoke in the smoke cloud leads to a decrease of range of visibility.

An important characteristic of smoke-producing substances is the value which is called camouflaging capacity. Camouflaging capacity (MC) is the attenuation factor of light by a smoke cloud, obtained with the expenditure of 1 g of smoke-producing substance for the production of 1 m^3 of smoke. This value is found by division of attenuation factor of light, obtained by experimental means, by concentration:

$$MC = \frac{k}{C},$$

where k – attenuation factor of light, m^{-1}; C – calculation concentration, equal to the ratio of weight of expended smoke-producing substance to volume of smoke obtained, g/m^3.

Camouflaging capacity depends on the degree of utilization of smoke-producing substance and relative atmospheric humidity.

In American literature it is possible to encounter the term "total obscurity power" (TOP), which means "complete camouflaging capacity." By this is implied the product of volume of smoke, obtained from a unit of weight of the smoke generator, by density of smoke:[1]

$$TOP = \frac{V}{S}\ [m^2/kg],$$

where V – volume of smoke in m^3, obtained from 1 kg of smoke-producing substance; S – range of visibility, m.

Physically complete camouflaging capacity signifies an area of 1 m^2 which can be closed by smoke, obtained from 1 kg smoke-producing substance, under the condition that through a layer of such smoke a 40 watt Mazda electric lamp cannot be overlooked.

[1]Here by density of smoke is understood the reverse value of range of visibility of standard Mazda electric lamp of 40 watts.

Smoke particles in the air are able to absorb from it the moisture which is contained in it in the form of vapor. The process of absorption of moisture has important practical significance. With an increase of relative atmospheric humidity absorption of moisture, as a rule, is increased, which leads to an increase of camouflaging capacity, since at the given calculation concentration the attenuation factor of light k is increased. High relative atmospheric humidity favors the use of smoke.

Knowing the camouflaging capacity it is possible to calculate the value of range of visibility. For this we will use formula $S = 4.4/k$, and from the formula $MC = k/C$ we find the value of k. Substituting the value of k in the formula for range of visibility, we obtain

$$S = \frac{4,4}{MC \cdot C}.$$

As a characteristic of smoke-producing substance camouflaging weight [MB] is also used. It constitutes the amount of smoke-producing substance, necessary for complete camouflage of an object with an area of 1 m^2. Numerically camouflaging weight is equal to product of range of visibility by calculation concentration:

$$MB = S \cdot C,$$

where S – range of visibility, m; C – calculation concentration, g/m^3.

The value of camouflaging weight is used during calculations of range of visibility:

$$S = \frac{MB}{C}.$$

It follows from the formula that the greater the camouflaging weight, then with those same conditions the greater the range of visibility, i.e., the worse the camouflaging properties of the smoke-producing substance.

Camouflaging weight of a smoke-producing substance depends on relative atmospheric humidity: the greater the relative humidity, the less the camouflaging weight, i.e., the less smoke-producing substance has to be expended for complete camouflaging of the object.

Behavior of a Smoke Cloud in the Atmosphere. Stability of Smoke Clouds

The examined causes of instability of an aerosol (coagulation, settling under the impact of gravity) essentially have an effect in expecially calm atmosphere. In other words, these factors affect the behavior of an aerosol in a closed system, for example, in a chamber. Under field conditions the behavior of a smoke wave will be determined wholly by the behavior of the atmosphere itself. Coagulation and settling of particles in this case will have secondary significance; particles can coagulate, for example, only at the time of formation of the aerosol, when particle concentration is very great.

Really, in the case of setting up smoke screens we observe the following picture. The cloud of smoke does not remain constant, but continuously changes; it is picked up by air currents and moves together with them, gradually increasing in volume. The concentration of smoke in the cloud decreases as it moves from its source, the cloud thins, range of visibility in it becomes greater, and its camouflaging properties are lowered. In separate cases the smoke cloud can change direction of movement or even rise upwards. A smoke cloud, introduced into the atmosphere, consequently becomes a component part of the latter and in its behavior obeys the basic laws determining the behavior of air.

The basic factors affecting the behavior of a smoke cloud are direction and speed of wind.

As is known, wind is the horizontal shifting of air. The cause of appearance of wind is primarily thermal (temperature) circulation of air, occurring continuously both in a vertical and also in a horizontal direction due to nonuniform heating of separate sections of the earth's surface. The appearance of wind also depends on difference in atmospheric pressure. The greater this difference, the stronger the wind. Moving air, furthermore, is influenced deflecting force of rotation of the earth and friction between moving layers of air and its uneven surface. Due to friction the rate of movement of air at the earth's surface is less than the rate at a certain distance from it.

Direction of movement of a smoke cloud is determined by the direction of the wind, which is designated by that side of the horizon from which the wind blows. In the case of setting up smoke screens the direction of the wind is usually determined relative to the frontline of our own troops. Based on this criterion we distinguish:

– frontal wind, rear (toward the enemy) or head (from the enemy), blowing perpendicular to the frontline or at an angle to it within limits of 60-90°;

– oblique wind (rear or head), blowing at an angle to the frontline;

– flanking (lateral) wind, blowing in parallel to the frontline or with a deflection from it up to 30°.

Depending on wind direction the problem of selection of means for setting up smoke screens is decided. For example, in the case of wind toward the enemy (frontal rear wind) the smoke screens can be created by any smoke devices, while in the case of wind from the enemy (frontal headwind) the main methods used will be those which make it possible to create smoke screens in the enemy's location.

Rate of movement of a smoke cloud is equal to windspeed, which is measured in meters per second. Windspeed exerts a great influence on duration of preservation and range of propagation of the smoke cloud. It has been established by experiments that the greater the windspeed, the more rapidly the scattering of the smoke cloud takes place, and the less the distance over which it spreads while preserving its camouflaging properties.

The most favorable wind for setting up smoke screens is one with a speed of 3-5 m/s. At high windspeeds the expenditure of smoke agents is increased. Wind with a speed greater than 9 m/s is unfavorable for creation of smoke screens, since it leads to the rapid scattering of the smoke cloud. Wind with a speed less than 1.5 m/s is also unfavorable for the release of smoke: such winds are unstable in direction and are characterized by sudden attenuation to a calm. They can be used only for setting up temporary screens.

If it is required to cover a given area with smoke with the help of a limited number of fixed sources, then it is desirable to have a windspeed which is constant in value and direction. In the case of too great a windspeed the satisfactory covering of an area will require an excessive expenditure of smoke; in the case of too low a windspeed the formation of a screen will occupy much time. If there is no wind, then a smoke screen can be formed only by means of releasing the smoke from moving vehicles.

Besides wind, the behavior of a smoke cloud is influenced by the degree of vertical stability of the air.

Three degrees of vertical stability of air are distinguished.

The first degree - *inversion* - is characterized by great vertical stability of air, caused by an increase of its temperature with height and strong cooling of the ground. It is known that heating and cooling of the earth takes place more rapidly than heating and cooling of the air. In the evening and at night following cooling of the earth there is the strongest drop in the temperature of layers of air which are nearest to it. The colder and, consequently, heavier air is below, and warmer above. During inversion the atmosphere preserves the stablest condition. With such an atmospheric state the local temperature circulation of air in it is almost ceased.

Inversion appears at night when there is a cloudless sky. In winter inversion is possible on clear frosty days.

The second degree – *isothermy* – is characterized by a state of indifferent vertical equilibrium of air, which is caused by an equality of air temperatures at all heights of the surface layer and soil.

Isothermy appears in the morning and evening hours during stable weather, but is most typical for overcast weather.

The third degree – *convection* – is characterized by great vertical instability of air, which is caused by a sharp drop in temperature of the air with height and strong heating of the soil. During convection thermal circulation and strong mixing of airmasses take place. The warm earth gives off heat to the lower layers of air; these layers, being heated and becoming lighter, rise upwards and are displaced by the colder and denser layers.

Convection is observed on clear summer days; it begins in approximately 2.5-3 hours after sunrise and is finished in approximately 2-2.5 hours prior to its setting.

The degree of vertical stability of the air is characterized by the value of the vertical temperature gradient. The vertical temperature gradient is the difference of temperatures of air (Δt), measured at two standard heights – 20 and 150 cm above the underlying surface of the earth, i.e.,

$$\Delta t = t_1 - t_2$$

where t_1 – temperature of air at a height of 20 cm; t_2 – temperature of air at a height of 150 cm.

A negative temperature gradient corresponds to inversion, zero – to isothermy, and positive – to convection.

In the case of inversion a smoke cloud scatters slowly and moves under the influence of wind directly at the underlying surface of the earth; during inversion the most favorable conditions for release of smoke are created. In the case of isothermy average conditions for the release of smoke are observed. The smoke cloud formed during convection, as a result of intense turbulent mixing, scatters rapidly, rising to the upper layers of air; convection is extremely unfavorable for release of smoke in the case of camouflage from a ground enemy, but promotes the best blanketing when camouflaging rear objects from aerial observation.

Due to turbulence of atmosphere and continuous mixing of smoke with the surrounding pure air, the smoke cloud is increased in volume as it moves away from the source of smoke and acquires approximately the form of a semicone with the summit at the point of release of the smoke. Views from above and from the side of a smoke cloud are shown in Fig. 4. Line *OX* is conditionally called the directrix of movement of the cloud.

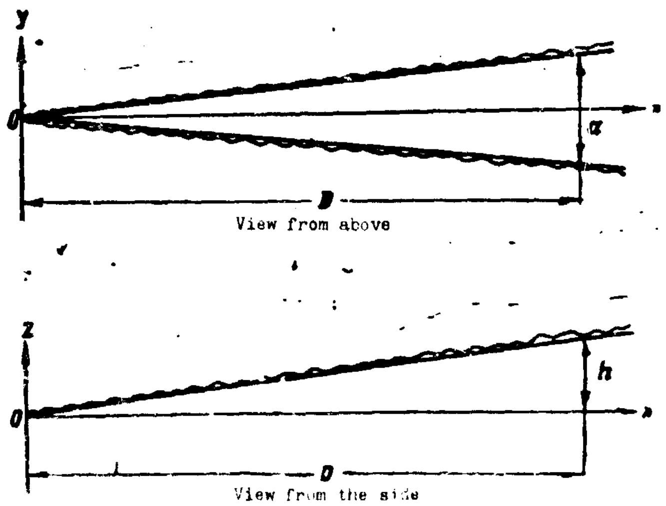


Fig. 4. Form of smoke cloud.

The width of a smoke cloud changes with distance; it can be determined by the formula

$$a = 2{,}9 \sqrt{D},$$

where D – distance from source of smoke, m.

Height of a smoke cloud h depends on degree of vertical stability of the air. Thus, during convection the height of a cloud is greater than during other degrees of stability, and is equal approximately to $0.1D$.

When the atmosphere is vertically unstable and there are ascending currents of air, the smoke cloud gradually shifts into the upper layers of air. At the same time the wind shifts the smoke in a horizontal direction. This ascending movement of the cloud leads at a certain distance from the point of release of the smoke to a breakaway of it from the earth and, consequently, to a loss of effectiveness of the smoke screen. The greater the speed of ascending currents and the slower the windspeed, then the more steeply the cloud will rise and the more rapidly it will break away.

Besides atmospheric conditions, the breakaway of a cloud is influenced by the temperature of the smoke in the process of smoke generation. Increase of temperature of smoke leads to intensification of convection phenomena in the smoke cloud and to a decrease of its stability.

The state of a smoke cloud is also influenced unfavorably by rain; when the drops fall they intensify turbulent mixing of the air, which in the end leads to more intense scattering of the smoke cloud. Besides this, rain attracts particles of smoke to the ground and promotes their settling. Drizzle, conversely, improves the camouflaging properties of smoke screens and decreases the range of visibility. Snowfall does not influence the use of smoke screens.

Relief of the terrain also renders an essential influence on the movement, behavior, and stability of a smoke cloud. Unevenness of terrain (high ground, ravines, hollow) promote the appearance of local winds, in consequence of which turbulent mixing is intensified and scattering of the smoke cloud is speeded up. Heights with steep slopes are by-passed on the sides by a smoke cloud; in this case the summits of the heights may not be covered by the smoke. At low windspeeds stagnation of smoke can form in hollows. At high windspeeds, conversely, in certain cases the smoke cloud passes over the ravine or hollow without filling them in.

Woods are by-passed on top by smoke clouds, where the cloud of smoke partially flows into them. The tops of trees promote intensive turbulent mixing of air, which leads to partial scattering of the smoke cloud; in woods stagnation of smoke will form.

From what was examined it is clear that weather and relief of terrain essentially affect the state of a smoke cloud. In connection with this the whole totality of these conditions is tentatively split into three groups: favorable, moderate, and unfavorable.

Favorable conditions: wind – stable in direction and speed, 3-5 m/s; degree of vertical stability of air – inversion or isothermy; terrain – level.

Moderate conditions: wind – 6-8 m/s; isothermy; terrain – moderately broken.

Unfavorable conditions: wind – up to 1.5 m/s and more than 8 m/s, turbulent; degree of vertical stability of air – convection; terrain – strongly broken.

Sea surface renders a unique influence on the behavior of a smoke screen. Water cools and is heated more slowly than land, and due to this during the hours of morning inversion or on cold nights the air over the water is warmer than that over the shore, and the convection currents which form carry the smoke cloud upwards. By day, conversely, air over the water is colder and the smoke screen is pressed to the water surface. Therefore, the most favorable time for setting up of smoke screens over a water surface is in daytime.

CHAPTER III

SMOKE-PRODUCING SUBSTANCES

Methods of Obtaining Aerosols. General Characteristics of Smoke-Producing Substances

Methods of obtaining aerosols are various, but usually they amount to two — dispersing and condensation. The basic difference between these methods is that in the case of the first method the specific surface of the initial system increases, and in the second it decreases.

Dispersion is carried out by mechanical means, for example, pulverizing of a solid on grinders, spraying of liquid (pulverization), destruction of solid or liquid bodies by an explosion. This method requires complex and bulky equipment and aerosols obtained by it are quite coarse, therefore it did not find wide application.

The essence of the condensation method of formation of aerosols lies in the fact that a substance, initially broken into separate molecules (most frequently transformed into vapor), is condensed, forming solid or liquid particles. The process of condensation goes on spontaneously and is accompanied by the release of energy. This is the most widespread method.

All condensation processes for the formation of aerosols can be divided into two stages — formation of supersaturated vapor and condensation itself.

Obtaining of supersaturated vapor is carried out by two methods – cooling of heated vapor (physical condensation) and as a result of the reaction between gaseous products of solid or liquid substances (chemical condensation).

It is known that for every substance the pressure of vapors, which are saturating space, for every temperature there is a fully specific value. If the temperature of air, which is saturated by vapors, drops, then there is a decrease in the value of elasticity of saturating vapors, and vapor which is surplus already supersaturates space. This is the essence of physical condensation. Supersaturated vapor is then readily condensed into fog (smoke).

A typical example of the formation of an aerosol using the phenomenon of physical condensation is the obtaining of smoke by the burning of smoke pots or grenades equipped with the so-called anthracene smoke mixture. As a result of burning of the mixture the smoke generator which is found in the mixture is sublimated, then in the cold air the formation of its supersaturated vapor takes place, and, finally, the formation of smoke.

Sublimation is carried out by several methods:

– by heating the substance to boiling or pouring the substance on a heated body; here the vapors of the substance, which are strongly heated, upon touching the mass of cold air are condensed into fog or smoke;

– by transmission of a stream of air through heated liquids, during which the air is heated and is saturated by vapors of the liquid; when the air emerges from the hot zone, vapors of the substance which are carried away by it are condensed and form an aerosol;

– by burning of a fuel mixture, in which a sublimable solid is found in a crushed state; during burning of the mixture heat is developed, due to which the substance evaporates and its vapors, coming in contact with the cold air, form a smoke.

It is clear from the enumerated methods of sublimation that for production of smokes and fogs in such a way the only substances which can be used are those which are chemically stable at high temperatures and slightly volatile. Boiling point of substances should be within the limits of from 150 to 500°C. In the case of low temperatures supersaturation may not set in; if the temperature is very high, then it is very difficult to vaporize a quantity of substance which is sufficient for the formation of smoke.

Obtaining of supersaturated vapor as a result of chemical reactions in a gaseous environment is the direct result of preliminary saturation of air by vapors of products which are found in it. As a result of the reaction between two such gases the product formed supersaturates space in the case when it is in a concentration exceeding a concentration corresponding to its normal vapor pressure. The process of formation of aerosols in this case is the same as in the case of physical condensation - condensation of supersaturated vapor.

An example of the reaction of two gases with the formation of an aerosol is the reaction between ammonia and hydrogen chloride, as a result of which the white smoke of ammonium chloride is formed:

$$NH_3 + HCl \rightarrow NH_4Cl.$$

In the practice of camouflaging smoke generation chemical reactions in a gaseous environment are used quite extensively. As the gaseous environment elements of the atmosphere are used - water vapor or oxygen.

In certain cases for obtaining of smokes or fogs it is possible to use dispersion and condensation simultaneously which can be called a combined method for obtaining aerosols.

The examined methods of formation of aerosols are the basis of obtaining camouflaging smokes.

Based on the method of smoke generation, smoke producing substances, used for the production of camouflaging smokes can be conditionally divided into four groups:

- substances, forming fogs during atomization or evaporation as a result of chemical interaction with moisture of the air; this group of substances includes: sulfuric anhydride, oleum, chlorosulfonic acid, solutions of sulfuric anhydride in chlorosulfonic acid, titanium tetrachloride, silicon tetrachloride, and others;

- substances, giving off smoke during burning as a result of the interaction with oxygen of the air (the most typical representative - phosphorus);

- substances, forming smoke during their sublimation or from products, given off in the course of a thermal process (pyrotechnic mixtures);

- substances, forming smoke during evaporation under the impact of high temperature (oil products).

Substances, Giving Off Smoke as a Result of the Reaction with Moisture of the Air

Substances, giving off smoke as a result of reaction with moisture of the air, have a quite sharply expressed anhydride nature. Being quite volatile, they smoke in air spontaneously.

The process of smoke generation of these substances proceeds in the following stages:

- with the atomization of smoke-producing substance (mixture) into small drops;

- with evaporation of a substance (mixture);

- with the chemical reaction of vapors of a substance (mixture) with water vapors in the atmosphere and with condensation;

- with absorption of moisture.

The division of the process of smoke generation into stages is conditional, inasmuch as the process is indivisible and all the accompanying phenomena occur practically simultaneously.

Thorough atomization of a substance (mixture) is a necessary condition, ensuring intensive flow of the process of smoke generation, since here the surface of evaporation is increased. Intensity of evaporation is ensured by high vapor pressure of the substance (mixture); in the summer vapor pressure is considerably greater than in winter, in consequence of which under winter conditions it is more difficult to obtain a good smoke screen. In the summer, under conditions of increased temperature, the reaction of vapors of a substance (mixture) with vapors of water proceeds more intensively.

It is clear from the cited arrangement of the process of smoke generation that the camouflaging properties of smoke, obtained from the examined substances, are improved with a rise in air temperature, with an increase of its relative humidity, and with an increase in the degree of atomization of the smoke-producing substance.

Sulfuric Anhydride (Sulfur Trioxide)

Pure sulfuric anhydride is a colorless, slightly mobile liquid, the specific gravity of which is 1.92 and boiling point 44.6°. Technical sulfuric anhydride is solid, white, with a needle-shaped structure of mass, and with a content of from 96 to 100% of basic product. During storage, especially if there are traces of moisture, this substance is modified being converted into long silky crystals, which at 50°, without being melted, are sublimated. Vapor pressure of sulfuric anhydride at 24° is 240 mm Hg.

Parent substance for the production of sulfuric anhydride is sulfur dioxide, which is obtained by burning of sulfurous metals, mainly iron pyrite FeS_2, in special furnaces with the admission of air. Natural sulfur is used also for the production of sulfur dioxide.

Characteristic properties of sulfuric anhydride are its high volatility and extraordinary hygroscopicity. These properties also determine its smoke-producing capacity, since the vapors of sulfuric anhydride, when introduced into the air, react with moisture, forming a fog which is made up of particles of sulfuric acid suspended in the air. The reaction proceeds with the liberation of a large amount of heat:

$$SO_3 + H_2O \rightarrow H_2SO_4 + 21\,000 \text{ cal.}$$

Schematically the process of smoke generation of sulfuric anhydride can be presented as follows:

$$SO_3 \text{ (solid)} \xrightarrow{\text{crushing}} SO_3 \text{ (solid)} \xrightarrow{\text{evaporation}} SO_3 \text{ (vapor)} \rightarrow$$

$$\xrightarrow[\text{reaction with } H_2O]{\text{chemical}} H_2SO_4 \text{ (vapor)} \xrightarrow[\text{(boiling 338°)}]{\text{condensation}} H_2SO_4 \text{ (fog)} \rightarrow$$

$$\xrightarrow[\text{from the air}]{\text{absorbtion of moisture}} H_2SO_4 \text{ (fog with larger drops of diluted } H_2SO_4\text{),}$$

i.e., sulfuric anhydride is crushed, evaporates, then reacts with moisture of the air; the sulfuric acid formed is condensed and is diluted by moisture of the air.

Effectiveness of smoke generation of sulfuric anhydride depends on the method of application (fineness of crushing SO_3), on temperature (intensity of evaporation of SO_3), and on relative atmospheric humidity (degree of dilution of H_2SO_4 with vapors of water).

Sulfuric anhydride possesses the qualities of a good smoke generator; it itself is volatile and, by reacting with moisture of the air, gives a hygroscopic product of low volatility (sulfuric acid), as a result of which a stable fog is obtained. However, it has not received wide independent application due to the solid aggregate state at ordinary temperatures, which prevents it from being used with the help of the spraying method.

In the First World War sulfuric anhydride was used in smoke shells and aerial bombs in the form of an impregnation of a porous base (pumice, diatomite).

Oleum

Oleum is the name for a solution of sulfuric anhydride in sulfuric acid. Depending on the content of sulfuric anhydride, oleum at ordinary temperatures can be a liquid or in a crystal state; density of oleum is increased with an increase in the content of sulfuric anhydride.

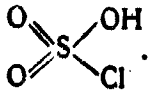
Technical oleum is a heavy oily liquid of a yellowish or brown color. Content of free sulfuric anhydride is from 18 to 19%.

The smoke-producing capacity of oleum is based on the fact that sulfuric anhydride evaporates from it easily, and when it combines with moisture a drop of sulfuric acid is formed. Sulfuric acid, as was already indicated, being a substance which is extremely hygroscopic, avidly attracts the moisture of the air, thus forming a thick, stable fog.

The high viscosity of oleum and capacity to solidify at low temperatures narrow the possibilities of its application as a smoke-producing substance.

Chlorosulfonic Acid

During the First World War for the purpose of camouflaging smoke generation chlorosulfonic acid was used — it is an incomplete acid chloride of sulfuric acid:

SO_2OHCl or .

At ordinary temperature technical chlorosulfonic acid is a heavy liquid, of different colors – from yellow to brown – which fumes in the air. Its specific gravity at a temperature of 20° is 1.720-1.770, boiling point within the limits of 150-152°, and freezing point -80°.

Chlorosulfonic acid is obtained from sulfuric anhydride and phosphorus chloride.

The process of smoke generation of chlorosulfonic acid is based on the fact that its vapors, which are obtained in the air when it is sprayed from devices, react with moisture of the air with the formation of sulfuric acid and hydrogen chloride:

$$SO_2OHCl + H_2O \rightarrow H_2SO_4 + HCl.$$

For the best smoke generation and best evaporation of chlorosulfonic acid, prior to launching in the air it is heated or sprayed with superheated vapor.

Chlorosulfonic acid gives a fog which has good camouflaging properties. It is comparatively inexpensive, however, its smoke possesses an irritating property; liquid chlorosulfonic acid carbonizes animal and plant tissues and acts on metals.

Chlorosulfonic acid, as compared to sulfuric, has lesser viscosity, considerably greater volatility, and a lower freezing point. These properties determined its application as solvent for sulfuric anhydride.

Solutions of Sulfuric Anhydride in Chlorosulfonic Acid

Chlorosulfonic acid, as compared to sulfuric anhydride, produces a smoke with a lesser camouflaging capacity. Solutions of sulfuric anhydride in chlorosulfonic acid produce a stabler smoke with a high camouflaging capacity. Therefore such solutions have received wide application. During the Second World War they were applied by means of spraying from smoke machines and devices.

The process of smoke generation of a smoke mixture on a base of a solution of sulfuric anhydride in chlorosulfonic acid is analogous to the process of smoke generation of sulfuric anhydride and chlorosulfonic acid separately. In view of the great difference in the boiling points of components of the mixture (for sulfuric anhydride 44.6°, for chlorosulfonic acid 151°) the process of evaporation proceeds basically with the formation of vapors of sulfuric anhydride as the most volatile. Evaporation of chlorosulfonic acid proceeds slowly even in the summer.

The basic smoke generator in mixtures on a base of sulfuric anhydride and chlorosulfonic acid is sulfuric anhydride, therefore it is expedient to use solutions of it for smoke generation as concentrated as possible. However, increase of concentration of sulfuric anhydride is limited by the high freezing point of mixtures containing very large quantities of SO_3.

The widest use has been made of solutions of sulfuric anhydride in chlorosulfonic acid of the following compositions: 40% (by weight) sulfuric anhydride and 60% chlorosulfonic acid; 60% sulfuric anhydride and 40% chlorosulfonic acid. According to reports in the American press, the United States has a "FS" mixture containing 55% sulfuric anhydride and 45% chlorosulfonic acid. This mixture does not freeze at -30°C. It is considered that as smoke mixtures it is possible to use solutions containing up to 70% sulfuric anhydride.

The examined mixtures along with sulfuric anhydride and chlorosulfonic acid contain sulfuric acid. The presence of sulfuric acid in the mixture at low temperatures leads to the formation of an insoluble precipitate which prevents its effective application under winter conditions (obstruction of pipelines and sprayers, lowering of volatility, raising of freezing point). This is the deficiency of such mixtures.

Another significant deficiency of smoke mixtures on a base of sulfuric anhydride and chlorosulfonic acid is the low utilization factor of mixtures. This coefficient does not exceed 30% in the summer and is considerably less in the winter.

The smoke of mixtures of sulfuric anhydride and chlorosulfonic acid is not dangerous for man, but irritates the upper respiratory tract, and when it settles on equipment, weapons and radio equipment it causes rusting of unpainted metallic surfaces.

Titanium Tetrachloride

Pure titanium tetrachloride is a colorless liquid which smokes in the air. Its boiling point is 135.8°, melting point -23°, and specific gravity at 10° is 1.7446. Technical titanium tetrachloride is a liquid, which to a greater or lesser degree is colored yellow and which contains various impurities.

For production of titanium tetrachloride they use either pure titanium oxide or titanium containing ore (rutile, ilmenite, and titanomagnetite).

Principle of smoke generation of titanium tetrachloride amounts to the following. Vapors of titanium tetrachloride which appear when it is sprayed react with moisture of the air when they enter the atmosphere and form smoke particles consisting of products with a various degree of hydrolysis of titanium tetrachloride. In the end the particles of smoke, obtained as a result of application of titanium tetrachloride, consist of hydrated titanium acid with a low content of hydrogen chloride.

Usual field concentrations of smoke which is formed by titanium tetrachloride slightly irritate the nasopharynx. In the interaction with metals the smoke of this smoke generator causes corrosion.

Titanium tetrachloride reacts rapidly with moisture in the air, forming a solid substance. Due to this its application with the help of spraying equipment is hampered; for use in spraying equipment it finds lesser application that a solution of sulfuric anhydride in chlorosulfonic acid. According to the press, titanium tetrachloride is included in the inventory of the United States Army as a smoke-producing substance for use in artillery smoke shells (mortars).

Smoke-producing action of titanium tetrachloride is strengthened considerably in the case of the simultaneous release of titanium tetrachloride and ammonia from smoke devices.

Silicon Tetrachloride

Silicon tetrachloride is a colorless liquid which fumes strongly in the air and possesses a sharp odor. Its boiling point is 57.02°, melting point -70°, and specific gravity 1.483.

The process of smoke generation of silicon tetrachloride amounts to the following. Being sprayed in the atmosphere, it evaporates rapidly and is subjected to hydrolysis by moisture of the air with the formation of smoke consisting of particles of silicon acid:

$$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl.$$

In case of the simultaneous release of ammonia the hydrogen chloride which is formed participates in the process of smoke generation and together with ammonia produces particles of ammonium chloride.

Field concentrations of smoke which contains hydrogen chloride and which was formed by silicon tetrachloride possess an irritating effect and cause the corrosion of metals.

The formation of smoke from silicon tetrachloride can be achieved both by means of spraying it from devices and also by means of spraying during the bursting of artillery smoke shells. Silicon tetrachloride as a very volatile substance evaporates completely.

Tin Tetrachloride (Stannic Chloride)

Stannic chloride can be examined as a full acid chloride of ortho-stannic acid $Sn(OH)_4$. It is a transparent, colorless, heavy liquid which fumes intensively in the air. Boiling point is 144°, melting point -33°, and specific gravity 2.226.

Stannic chloride can be used independently as a smoke-producing substance and jointly with ammonia. The process of smoke generation is based on the interaction of vapors of stannic chloride with moisture of the air, where in the air initially smoke particles of hydrates $SnCl_4 \cdot 3H_2O$, $SnCl_4 \cdot 5H_2O$ are formed. By hydrolyzing, these gradually yield ortho-stannic acid:

$$SnCl_4 + 4H_2O \rightarrow Sn(OH)_4 + 4HCl.$$

In the presence of ammonia, hydrogen chloride, which is obtained as a result of the hydrolysis of stannic chloride, enters into an interaction with ammonia and serves as an additional source of smoke generation.

When vapors of stannic chloride get into the air they react with water vapors. Here there is the possibility of hydration and hydrolysis of stannic chloride, and due to this the dispersed phase of the smoke which forms can consist of solid particles of hydrates, ortho-stannic acid, and incomplete acid chlorides of ortho-stannic acid.

Smoke formed by stannic chloride is irritating to the organs of breathing and sight, however, it does not present a great danger for man.

The formation of smoke from stannic chloride can be achieved both by spraying of stannic chloride from various devices and also by spraying during the bursting of artillery smoke shells.

Substances Which Produce Smoke as a Result of Reactions with Oxygen of the Air

Phosphorus is one of the substances which produce smoke as a result of reactions with oxygen of the air.

Elementary phosphorus exists in several allotropic modifications. The most well-known and studied are two varieties of it — white (or yellow) phosphorus and red phosphorus. Only white phosphorus is used as a smoke generator; red phosphorus is sometimes used in a mixture with white phosphorus for the purpose of a more uniform and prolonged smoke generation of the latter.

White phosphorus is a transparent mass of crystalline structure which is colorless or with a yellowish shade. Its melting point is 44.3°, boiling point 280.1°, and specific gravity 1.83.

In the air white phosphorus which is heated to 45-60° ignites. Spontaneous ignition of phosphorus in the air is also possible at lower temperatures as a result of its oxidation by oxygen of the air.

Process of smoke generation of phosphorus consists of the following.

In the case of the interaction of phosphorus with oxygen of the air phosphoric anhydride is formed:

$$4P + 5O_2 \rightarrow 2P_2O_5.$$

It is a very volatile and hygroscopic substance. As a result of reaction with water vapors of the air, phosphoric anhydride forms orthophosphoric acid:

$$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4.$$

Vapors of orthophosphoric acid are also hygroscopic and in turn absorb moisture of the air:

$$H_3PO_4 + nH_2O \rightarrow H_3PO_4 \cdot nH_2O.$$

In the end the smoke formed by phosphorus constitutes a fog which consists of the smallest droplets of a solution of orthophosphoric acid in water.

Absorption of moisture of the atmosphere by droplets of orthophosphoric acid occurs as long as pressure of water vapor over the drop is not equal to vapor pressure in the atmosphere. This makes it possible with one part by weight of phosphorus to obtain five and more parts by weight of the dispersed phase, which makes phosphorus one of the best smoke generators.

A phosphorous fog is not poisonous, but when it is inhaled it irritates the throat slightly causing a cough; furthermore, it has a destructive action on metals. A phosphorous fog is formed by the bursting of shells, mortars, and aerial bombs which are loaded with phosphorus.

Phosphorus belongs to the ranks of quite widespread elements and comprises around 0.06% of the entire mass of the earth's crust. In nature it is encountered only in an oxidized state in the form of various kinds of salts of phosphoric acid (phosphorites, apatites, and others).

Pyrotechnic Smoke-Producing Compositions of Camouflaging Smokes

Pyrotechnic smoke-producing compositions of camouflaging smokes are divided into two groups. The first group includes compositions which have one of the components of the smoke generator ready for use, and which during burning of the composition is sublimated and upon entry into the atmosphere produces a cloud of smoke. The second group includes compositions which produce smoke as a result of the chemical reaction of components during their burning.

Pyrotechnic smoke-producing compositions which produce smoke as a result of sublimation are simple and contain the smoke-producing substance, a combustible, and an oxidizer.

As smoke-producing substances in these compositions they use readily sublimable substances — ammonium chloride, aromatic hydrocarbons (napthalene, anthracene, phenanthrene, carbazole) and hydrocarbons of aliphatic series (spindle, machine, cylinder oil). These substances possess high volatility at the temperature of sublimation, chemical invariability at high temperatures, and low volatility at ordinary temperatures.

The combustible in the mixtures is the source of heat, due to which sublimation of the smoke generator takes place. Charcoal, starch, sulfur, and milk sugar are used as fuel, i.e., substances which oxidize at low temperatures and during oxidation produce a large thermal effect.

Since the process of burning of smoke-producing mixtures usually takes place in a closed volume, without the access of air, then to ensure this process an oxidizer is introduced into the mixture. Most frequently oxygen compounds are used as oxidizers, potassium chlorate for example.

Besides the three basic components (smoke-producing substance, combustible, and oxidizer), pyrotechnic smoke-producing compositions with the smoke-producer in a prepared form can also contain auxiliary components — stabilizers, looseners, flash reducers. These components are introduced in small quantities, so that the pyrotechnic composition can be used most effectively.

Stabilizers are substances which prevent a too vigorous and rapid burning of the mixture. The process of stabilization is based on the fact that stabilizers absorb a large quantity of heat, which ensures an even and calm burning of the mixture. The most widespread stabilizers are ammonium salts and oxalic acid.

Loosenerers are substances which loosen the mixture and make it more uniform, as a result of which free yield of gaseous products into the atmosphere and stable smoke generation are ensured. Most frequently kieselguhr (infusorial earth), zinc oxide, and magnesium carbonate are used as looseners.

During combustion pyrotechnic smoke compositions sometimes give off a flash; uniformity of burning of the mixture is disturbed by this, the amount of smoke liberated decreases sharply, and the smoke acquires a grayish shade. To avoid the phenomenon of inflammation flash reducers are added to the mixture. The best of these are soda, chalk, and magnesium carbonate. During their own decomposition these salts give off carbon dioxide, which dilutes the gaseous products of burning of smoke compositions which are capable of inflammation and thereby prevents their ignition.

Smoke mixtures of the type examined were used extensively during the First and Second World Wars. During the period of the world war in 1914-1918, for example, the Yershov mixture which was already mentioned was used. In this mixture ammonium chloride was the basic smoke-producer and napthalene the fuel, and at the same time an additional smoke-producer, since during burning of the mixture some of it sublimates and when it leaves the shell it produces additional smoke particles; potassium chlorate and potassium saltpeter served as the oxidizer, and birch carbon as a loosener and fuel.

The most widely used mixture during the years of the Second World War was a mixture consisting of anthracene, ammonium chloride, and potassium chlorate. This mixture, which was frequently called anthracene, remains in the armament of armies of a number of countries even at present. In it anthracene serves as a fuel and smoke-producer, ammonium chloride as a smoke-producer, and potassium chlorate as the oxidizer. Combustion temperature of anthracene mixture reaches 350-400°.

According to patent data (patent 2,842,502) in the army of the United States smoke mixtures analogous to anthracene have been developed on the basis of sulfamic acid: 65% sulfamic acid and 35% potassium perchlorate; 58% sulfamic acid and 42% ammonium perchlorate. Sulfamic acid is the smoke-producer, and potassium and ammonium perchlorates — the fuel and oxidizer.

Pyrotechnic smoke compositions of the anthracene type are used mainly for filling smoke pots and hand smoke grenades.

The process of smoke generation of such mixtures, used in smoke pots and hand smoke grenades, consists of the following. The oxidizer as a result of the action of heat which is liberated during burning of the igniting fuse of the pot or grenade, is decomposed with the liberation of oxygen. Under the action of heat and oxygen some of the fuel burns, and a portion is melted and passes into a vaporous state. The smoke-producing substance as a result of the action of a large amount of heat, obtained during combustion of the fuel, is decomposed with the liberation of gaseous products. The heated gaseous products emerge from the shell into the atmosphere, where, being cooled, are turned into the smallest solid particles, i.e., into smoke, and then, spreading in the direction of the wind and attracting moisture from the air on the force of their own hygroscopicity, will form liquid particles of fog.

Pyrotechnic smoke-producing compositions, in which smoke is obtained as a result of the reaction of burning, constitute the so-called metal-chloride smoke mixtures, i.e., solid mixtures made on the basis of powdery oxides of metals, serving as the fuel, and various organic halogen derivatives serving as the oxidizer.

A typical representative of metal-chloride smoke compositions is the previously mentioned Berger mixture which was used widely during the years of the First World War. In this mixture carbon tetrachloride is the oxidizer and zinc dust the fuel. Smoke is formed by the burning of the mixture due to reduction of carbon tetrachloride by zinc:

$$CCl_4 + 2Zn \rightarrow C + 2ZnCl_2.$$

Vapors of zinc chloride obtained as a result of the reaction are condensed in the atmosphere into white particles, making up the basic mass of the smoke cloud. However, the cloud has a gray color, since along with particles of zinc chloride there are black particles of carbon in it.

Besides the basic components (oxidizer and fuel), metal-chloride smoke mixtures frequently contain a number of components which have an auxiliary value. For example, mixtures containing carbon tetrachloride have in their composition an absorber of this liquid. The absorber (usually kieselguhr) prevents stratification of mixture. Sometimes additional oxidizers are added to the mixture, and also smoke-producers. Additional oxidizers promote the oxidation of carbon which is liberated during burning of the mixture, as a result of which whiter smoke is obtained and burning rate of mixtures is increased. The smoke generator, usually producing a white smoke, also strengthens the whiteness of the smoke cloud.

A variant of the metal-chloride smoke mixture, distinguished from the Berger mixture by a greater burning rate, has, for instance, the following composition: carbon tetrachloride – 40.8%, zinc dust – 34.6%, sodium chlorate – 9.3%, magnesium carbonate – 8.3%, and potassium nitrate – 7.0%.

During the years of the Second World War in metal-chloride smoke mixtures the liquid chlorine-containing components, carbon tetrachloride began to be replaced by solid organic chlorine compounds – hexachlorethane, octachlorpropane, hexachlorcyclohexane, and others. An example of a metal-chloride smoke mixture, consisting only of solid components, is a mixture, used during the Second World War in German smoke pots (NbK-39) and hand smoke grenades (NbHgr-39). This mixture contained hexachlorethane – 47.5%, zinc – 47.5% and zinc oxide – 5.0%.

Besides zinc and its oxides, as a combustible in metal-chloride smoke mixtures it is possible to use powders of calcium silicide, aluminum and iron.

Combustion temperature of metal-chloride smoke mixtures reaches 1000°.

The process of smoke generation of metal-chloride smoke mixtures amounts to the following. Under the action of heat, liberated during burning of the fuse of the smoke pot or hand smoke grenade, in which metal-chloride mixtures are basically used, and then the fuel, components of the mixture react between each other and will form chlorides of metals, for example:

$$CCl_4 + 2Zn \rightarrow C + 2ZnCl_2;$$
$$C_2Cl_6 + 2Al \rightarrow 2C + 2AlCl_3;$$
$$C_2Cl_6 + 2Fe \rightarrow 2C + 2FeCl_3.$$

Vapors of chlorides emerge outside through holes in the diaphragm of the pot or grenade and are cooled rapidly, being turned into minute solid particles. Then the particles of chlorides of metals react with moisture of the air, producing hydrates, which in turn attract moisture, are dissolved in it and form the minute droplets of the solution.

Thus, smoke, obtained during the burning metal-chloride mixtures, constitutes a fog, consisting of minute droplets of a solution of hydrates of chlorides of metals.

Smoke Mixtures on the Basis of Oil Products and Foam Plastics

In the foreign military press it is pointed out that for setting up of smoke screens it is possible to use oil products, which initially are vaporized in the stream of hot gases of special smoke pots or machines, and then upon entering the atmosphere are condensed, forming a cloud of smoke.

For best smoke generation mixtures are prepared from oil products. As components of mixtures those products are taken which evaporate completely at temperatures of sublimation and are readily condensed at ordinary temperatures in the atmosphere (diesel fuel, mazut, solar oil, and others).

Smoke mixtures on the basis of oil products are the most inexpensive and accessible of all the presently existing liquid and solid smoke mixtures. Smoke formed by them is harmless for man and does not cause corrosion of metals.

In recent years in a number of foreign armies the possibility of using foam plastics as smoke-producing substances was investigated. For the production of smoke foaming resins are injected into a stream of gases, the temperature of which is higher than the temperature of formation of the foam plastics themselves. Droplets of resin in the stream of hot gases which are escaping at a high speed acquire a porous structure and harden, forming the particles of smoke.

The low density of a smoke cloud, formed from foam plastics, results in the fact that the smoke remains in a suspended state in air considerably longer than smokes obtained by other methods. The density of smoke from foam plastics comprises 0.0012 g/m^3.

For formation of a smoke cloud it is possible to use almost all plastic materials to which a porous structure can be assigned. Considered as most promising are polyurethanes on the basis of polyester, and also phenol-formaldehyde and epoxy resins.

Sources of hot gases, into which foaming resins are injected, can be gas turbines, internal-combustion engines, and turbojet and jet engines.

If one were to consider that foam plastics make up one of the rapidly growing branches of the chemical industry, it is possible to assume that in future they will find wide application as smoke-producing substances.

Colored Signal Smokes

Colored smokes are frequently used for daytime signalling. Usually smokes of red, yellow, green, blue, and black colors are used.

The conditions of observation of a colored smoke cloud are influenced by its form and dimensions, brightness and color of background on which the smoke signal is projected, speed of wind and atmospheric precipitation (snowfall, rain, fog), height of sun above the horizon, and position of the observer relative to the sun and smoke cloud.

It has been established by experiments that colored smoke clouds have the best visibility and discernability in clear summer weather at a wind speed of no more than 2-3 m/s; at higher wind speeds the smoke cloud disperses rapidly. Good conditions for observation of the color of a cloud are those when the angle formed by the sun, the smoke cloud and the eyes of the observer is within the limits of 45-135°. The color of a smoke cloud is perceived most poorly in that case when the cloud is on a direct line between the sun and the eyes of the observer; during observation under such conditions many colored clouds seem almost white. In that case when the sun is behind the observer a colored cloud acquires a dark color.

Colored smoke mixtures constitute pyrotechnic solid mixtures containing fuel, an oxidizer, and an organic dye. Smokes can be obtained from them analogous to camoflaging – by dispersion and condensation. However, the best quality of smokes of all colors is obtained in the case of sublimation of organic dyes.

The colored smoke mixture should give off that amount of heat which is necessary for transition of the dye into a vaporous state, but during burning the temperature should not be so high that it causes decomposition of the dye. Furthermore, during burning the mixture should give off a considerable quantity of gaseous reaction products, which would promote the rapid removal of vapors of the sublimated dye from the sphere of burning of the mixture. The most suitable fuels for this are milk or beet sugar, starch, and sawdust.

As oxidizer in compositions of colored smokes they use potassium perchlorate, potassium and sodium nitrates and potassium permanganate.

Compositions of colored smokes also include a stabilizer and flash reducer (usually bicarbonate of sodium $NaHCO_3$).

Sometimes granulation of colored smoke mixtures is carried out. This is done in order to increase the burning surface of the composition and thereby decrease the overall time of smoke generation and increase the intensity of the smoke. For the purpose of granulation a cementing agent is introduced into the mixture.

Listed in the table below are several formulas of chlorate compositions of colored signal smokes.

Table. Formulas of chlorate compositions of colored signal smokes

Designation of components	Color of smoke, formed during burning of the composition								
	red		yellow		green		blue		
	1	2	3	4	5	6	7	8	9
Sugar milk	—	25	20	25	25	25	25	5	20
Beet sugar	28	—	—	—	—	—	—	—	—
Potassium perchlorate	30	35	30	34	34	35	25	35	30
Paratoner	3[illegible]	—	—	—	—	—	—	—	—
Rhodamine B	11	40	—	—	—	—	—	—	—
Auramine	—	—	40	41	27	12	—	—	—
Chrysoindine	—	—	10	—	—	—	—	—	—
Methylene blue	—	—	—	—	—	—	—	60	—
Indigo	—	—	—	—	14	28	—	—	—
1,4-dimethylamineanthraquinone	—	—	—	—	—	—	50	—	—
Sudan blue C	—	—	—	—	—	—	—	—	50

Smoke of a black color can be obtained during the burning of metal-chloride smoke mixtures which contain, besides halogen derivatives and metals, napthalene, anthracene, and other hydrocarbon compounds.

CHAPTER IV

TECHNICAL MEANS FOR SMOKE GENERATION

Modern means of camouflaging smoke generation can be conditionally split into four groups:

- means, in which combustible pyrotechnic smoke mixtures are used (hand smoke grenades and smoke pots);

- means, in which white phosphorus is used (artillery and aerial smoke ammunition);

- equipment for application of liquid smoke-producing substances, the vapors of which react with moisture of the air (smoke generators);

- means of smoke generation, in which various oil products are used (smoke machines).

As also for other types of military equipment, smoke equipment is continuously being developed and improved in close conjunction with the general development of science and technology. Considerable qualitative and quantitative changes in all these devices took place in particular during the Second World War and the postwar period.

In the opinion of foreign specialists, due to the peculiarities of smoke camouflaging of troops and objects under contemporary conditions new requirements are presented for smoke equipment. Under contemporary conditions, for example, especially great importance has been assigned the speed of screening the covered object. It is known that spreading of the smoke wave, created with the help of smoke machines and pots, and also the speed of covering the object with smoke, depend on speed of wind and distance between smoke points (boundaries). Usually screening of an object during a moderate wind occurs in 8-10 min; in the case of weak winds this time is increased considerably. Now such speed of screening is clearly insufficient. Therefore in the foreign military press it is pointed out that contemporary equipment for the release of smoke and the system of screening and control over it should ensure screening of the objective in a maximum of 2-3 min. Proceeding from this new smoke equipment is being developed.

Hand Smoke Grenades and Smoke Pots

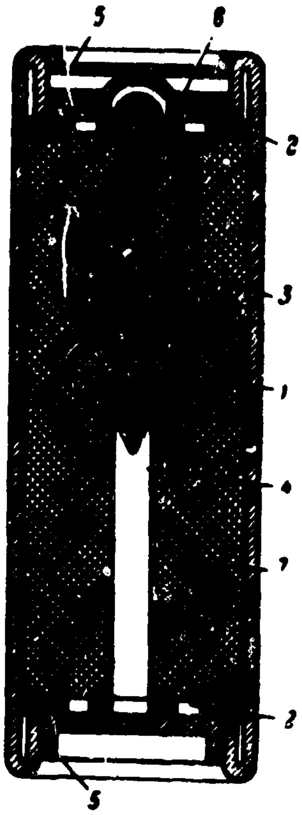
Hand smoke grenades and smoke pots are intended for setting up of smoke screens mainly by small subunits.

Hand smoke grenades (Fig. 5) usually have a cardboard cylinder as the shell. It is filled with the smoke mixture and is closed by cardboard diaphragms with holes for the exit of smoke. On one end of the grenade in the central hole of the diaphragm an igniting fuse is inserted which is intended for ignition of the grenade, and on the other end there is a paper tube. Both ends of the shell are hermetically sealed by cardboard covers with tape. Under cover, where the igniting head of the fuse is located, a grater is placed.

In Fig. 6 is shown an improved hand smoke grenade. It is ignited with the help of an igniting star and wire grater and this can be carried out in the process of throwing the grenade.

Hand smoke grenades weigh 0.5-0.6 kg, and duration of intense smoke generation of the grenades is 1-1.5 min.

In the application of smoke grenades it is necessary to consider that the smoke mixture in them inflames very rapidly, therefore to avoid burns the grenade should be thrown in the first seconds of burning of the mixture.



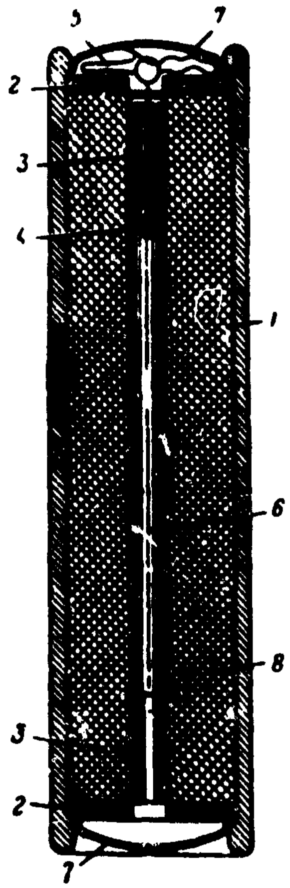


Fig. 5.　　　　　　Fig. 6.

Fig. 5. Hand smoke grenade: 1 - cardboard cylinder; 2 - diaphragm; 3 - igniting fuse; 4 - paper tube; 5 - cover; 6 - grater; 7 - smoke mixture.

Fig. 6. Hand smoke grenade (improved): 1 - cardboard cylinder; 2 - diaphragm; 3 - igniting star; 4 - wire grater; 5 - tape; 6 - tube; 7 - cover; 8 - smoke mixture.

The armament of the army of the United States includes the E16 hand and rifle smoke grenade (Fig. 7). It has a steel body and is equipped with a delay fuze. Its diameter is around 6 cm, length 11.5 cm, and weight of the smoke mixture with which the grenade is filled is around 350 g.

The chemical corps of the United States Army recently developed a hand smoke grenade which serves for the production of colored smoke.

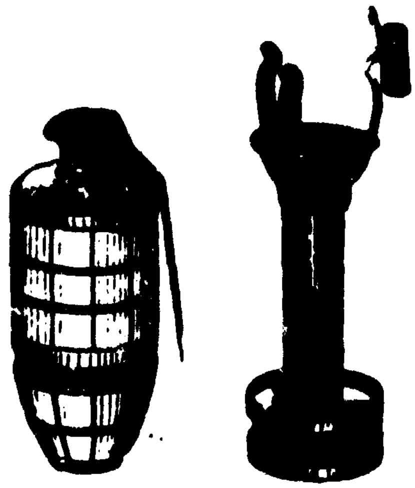


Fig. 7. American hand and rifle smoke grenade E16 (left) and M1A2 grenade launcher stabilizing device.

The weight of the grenade is less than 570 g. In dimensions and form it calls to mind a canned food container. The grenade can be filled with five different mixtures for obtaining green, red, violet, white, and yellow smoke. With the help of smoke created by such a grenade it is possible to indicate a landing site or areas for concentration of personnel and materiel. This grenade is intended for use by airborne troops.

Smoke pots (Fig. 8) are metallic case, usually of a cylindrical form, filled with a smoke mixture and equipped with a diaphragm and cover. While the pots are in storage for the purpose of protecting the smoke mixture from moistening the site of connection of the cover with the case is taped with insulating tape. Ignition of the pot is done with the help of an ignition attachment.

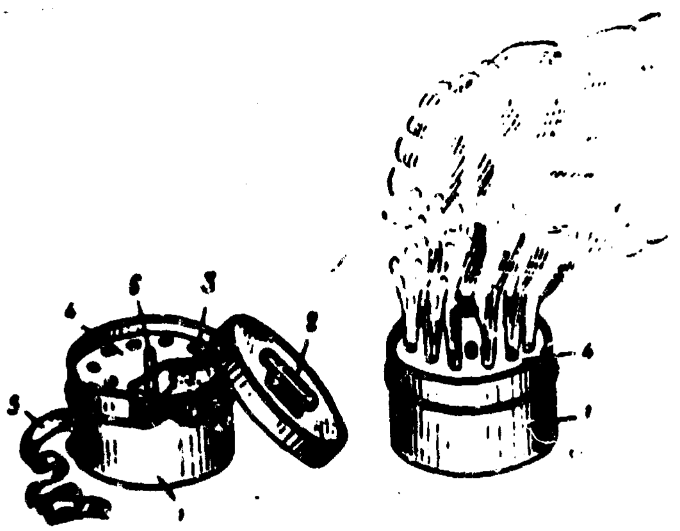


Fig. 8. Smoke pot: 1 – case; 2 – cover; 3 – smoke mixture; 4 – diaphragm; 5 – insulating tape; 6 – igniter.

In the Russian army the first samples of smoke pots were developed in 1913 by the engineer Sannikov.

All smoke pots are conditionally subdivided into small, medium, and large.

Small and medium smoke pots are used by all branches of service for the purpose of setting up smoke screens in all types of combat. Sometimes they can be used for camouflaging of rear objectives.

Small smoke pots have a weight up to 3 kg and duration of intense smoke generation of 5-7 min. Length of screening by a smoke screen in the case of burning of such a pot under moderate meteorological conditions is up to 50-70 m.

Medium smoke pots weigh up to 7.5 kg and duration of intense smoke generation is up to 15 min. Length of screening by a smoke screen in the case of burning of medium pots under moderate meteorological conditions is up to 70-100 m.

Large smoke pots are used for setting up powerful smoke screens on land and on water. They weigh up to 40-50 kg and duration of intense smoke generation is 5-20 min. Length of screening by a smoke screen in the case of burning of such charges under moderate meteorological conditions is 100-150 m.

The large smoke pot (Fig. 9) is a metallic body consisting of an outer cylinder and bottom and cover which are hermetically joined to it, and also an inner reticulated cylinder which is filled with the smoke mixture. The pot is put into action with the help of an electric igniter or percussion ignition cartridge.

Hand smoke grenades and smoke pots are filled with pyrotechnic smoke mixtures (chiefly anthracene and metal-chloride). During burning the white smoke with the yellow shade or yellow-brown smoke is given off, and as it moves away from the pots it changes to white. Smoke grenades can be filled with the mixture which gives off a

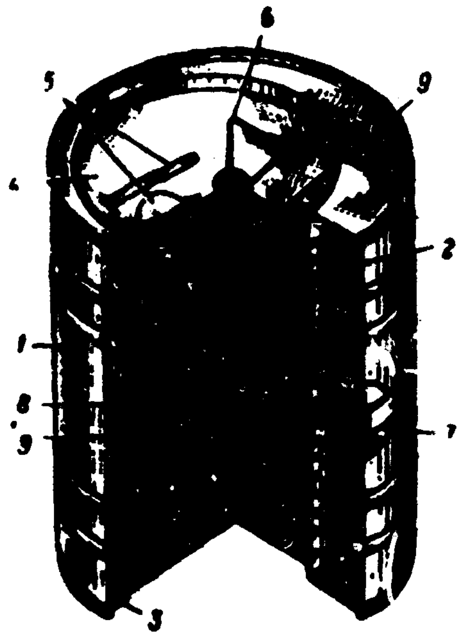


Fig. 9. Large smoke pot: 1 – outer cylinder; 2 – inner reticulated cylinder; 3 – bottom; 4 – cover; 5 – igniter; 6 – handle; 7 – valve of smoke outlet hole; 8 – main smoke mixture; 9 – transition smoke mixture.

black smoke. The possibility of using pots of oil products as smoke-producing substance is not excluded.

Hand smoke grenades and smoke pots are used for the creation of camouflaging smoke screens. Here the basic means of smoke release are the pots, and grenades are used for the rapid elimination of breaks in the smoke screen during the process of formation and supporting it in time.

In the organization of a smoke screen the intervals between smoke points on the boundary for release of smoke are established stemming from the direction of the wind. Thus, in the case of frontal wind the intervals are accepted as 30-40 m, in the case of an oblique wind as 40-60 m, and in the case of a flanking wind up to 100 m. In accordance with the accepted intervals a calculation is made of the number of smoke points, for which the length of the smoke release line is divided into intervals.

The necessary number of smoke pots for creation of a smoke screen is determined in each separate case depending on the duration of smoke release, screening line, and other conditions. Calculation is conducted by the formula

$$M = NLT,$$

where M – number of charges, pieces; N – norm of expenditure of pots per kilometer of front per hour; L – length of smoke release line, km; T – duration of smoke release, hours.

Knowing the total number of pots and the number of smoke points, it is possible to establish how many pots will be required for each point for the entire time of smoke release, and the number of salvos for the same period can be determined as the quotient from the division of time of smoke release by the time of smoke generation of the pot.

Artillery Smoke Devices

During the Second World War wide application was found for artillery smoke devices. The value of these devices lies in the fact that they make it possible to obtain smoke directly on the enemy's position. In this way more effective blinding of the enemy is achieved and difficulties are not created for the combat actions of our forces.

Artillery smoke devices include smoke shells and mortars. These rounds (Fig. 10) differ little in design and action from ordinary fragmentation high-explosive shells and mortars. The only difference lies in the fact that their casing is not filled with explosive, but a smoke-producing substance; a small amount of explosive is placed in the booster casing.

As smoke-producing substances in artillery smoke ammunition they use white phosphorus, sulfuric anhydride, stannic chloride, and other solid and liquid smoke-producing mixtures.

Smoke ammunition acts on a target in the same manner as fragmentation high-explosive. When a barrier is encountered there is an explosion of the explosive of the main charge, causing the

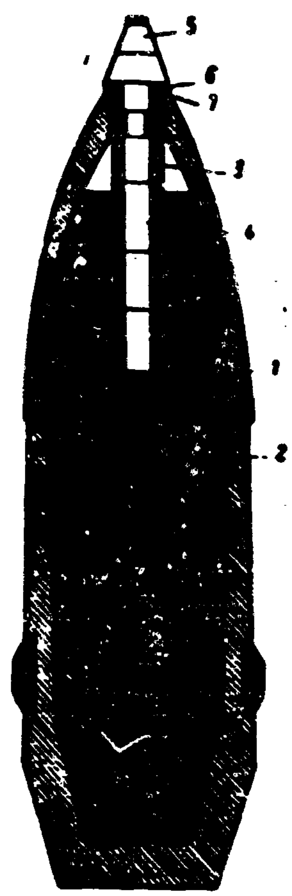


Fig. 10. Percussion smoke shell: 1 – body of shell; 2 – smoke-producing substance; 3 – booster casing; 4 – charge of explosive; 5 – fuse; 6 – flange of booster casing; 7 – lining.

splitting of the booster casing, jacket of the shell (mortar), and smoke-producing substance.

Thus, for a phosphorus smoke shell the following picture of bursting is observed. At the moment of bursting of the shell the phosphorus is crushed, scattered, and ignited. The phosphoric anhydride obtained as a result of the interaction of phosphorus with oxygen of the air actively absorbs moisture from the atmosphere, and in 1-3 seconds at the site of impact of the shell a screening cloud of white smoke will be formed. Depending on the caliber of the shell, the cloud is held for 10-30 seconds.

Effectiveness of smoke ammunition is determined successfully first of all by the explosive charge selected. The amount of explosive in the ammunition is usually low and makes up around 1% of the total weight of the shell. The main assignment of the explosive charge is to burst the body of the shell and to scatter the smoke-producing substance. Fragmentation effect of smoke ammunition is insignificant and comprises 5-15% of the fragmentation effect of ordinary ammunition.

Effectiveness of action of smoke ammunition is also determined by the terrain in the area of the target. Smoke ammunition is unsuitable for use on soft and swampy ground, and also in the case of a deep snow cover, since the ammunition will enter the ground (snow) and a considerable share of smoke-producing substance, being mixed with the ground (snow), does not take part in smoke generation.

For the most complete utilization of the smoke-producing substance, in addition to hard ground the proper fuze setting is necessary. In smoke ammunition ordinary detonators are used, but firing is conducted with their obligatory setting for fragmentation (instantaneous) action.

The greatest effect is achieved by surprise firing of smoke ammunition, therefore fire adjustment is conducted on the line usually with single rounds of fragmentation shells (mortars), after which firing for screening begins with firing by more than one weapon.

Dimensions of the smoke cloud, formed by the bursting of artillery smoke ammunition, are very dependent on meteorological conditions. The most favorable meteorological conditions for application of smoke shells and mortars are considered a calm or wind with a speed no greater than 5 m/s, direction of wind parallel to the front of the sector to be screened, and also the absence of convection.

Approximate dimensions of a smoke cloud, obtained in 2-3 s after the bursting of one smoke round during moderate meteorological conditions, comprise 10-40 m perpendicular to the direction of the wind and 2-9 m in height.

Norms of expenditure of smoke ammunition depend on meteorological conditions and state of terrain in the target area. Determining factors for norm of expenditure are speed and direction of wind.

Smoke shells (mortars) possess a number of advantages over other smoke devices, namely: their application depends less on meteorological conditions than the application of other ground smoke devices; the smoke screen is created in the enemy's position, the smoke blinds his observation posts and firing points, which to the greatest degree hampers observation and aimed fire; smoke screens are created suddenly and at any ranges of artillery-mortar fire.

Deficiencies of smoke shells (mortars) are low density of filler (ratio of weight of smoke-producing substance to weight of shell composes up to 0.2) and low coefficient of combat use of smoke-producing substance, in connection with which during the setting up of smoke screens a great expenditure of smoke shells (mortars) is required.

Aerial Smoke Devices

Aerial smoke devices are subdivided into aerial smoke bombs and airplane smoke tanks.

Aerial smoke bombs (Fig. 11) differ in their arrangement from ordinary fragmentation high-explosive bombs by the fact that their body is filled with smoke-producing substance and the explosive (explosive charge) is placed in the booster casing. As the smoke-producing substance in bombs they use mainly phosphorus, with which the bomb is filled under plant conditions.

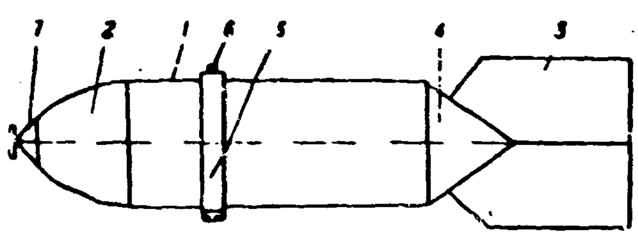


Fig. 11. Aerial smoke bomb: 1 – body; 2 – head; 3 – stabilizer; 4 – tail section; 5 – strap; 6 – lug; 7 – detonator.

Bombs can be suspended either inside the aircraft, in special bomb bays, or on the outside, under the wings or fuselage of the aircraft.

When the bomb encounters a barrier the firing mechanism and percussion cap are tripped. Action of the capsule causes detonation of the explosive in the explosive charge, in consequence of which the bomb explodes. The smoke-producing substance is crushed, ignites, and is scattered to the sides from the area of impact of the bomb, giving off a dense white cloud of smoke.

In the case of explosion of the bomb in the ground a funnel is formed, the depth and diameter of which depend on the construction of the bomb, its rate of fall, and density of the ground. A certain portion of smoke-forming substance reamins always in the funnel.

A smoke screen, obtained as the result of explosion of a smoke bomb, in the case of moderate meteorological conditions preserves camouflaging properties for 20-30 minutes. Immediately after explosion of the bomb the smoke cloud has a radius of 30-40 m and height of 10-15 m. The smoke screen from one bomb spreads in the direction of the wind for 1-1.5 km, increasing its width up to 50 m and height to 80 m.

It is most suitable to use smoke bombs in the case when the course of the aircraft coincides with the direction of the wind. Here the smoke wave from separate bombs overlap, increasing the density of the smoke and, consequently, improving the camouflaging properties of the smoke screen.

The basic assignment of airplane smoke tanks is laying of vertical smoke screens for the purpose of camouflaging troops from fire and ground observation of the enemy. Furthermore smoke tanks, based on experience of the Second World War, can be used for direct blinding of firing and observation points of the enemy.

Airplane smoke tanks are vessels of various construction and capacities filled with liquid smoke-producing substances. At the required moment the tanks are uncovered and smoke-producing substances pours from them by gravity flow.

Figure 12 shows an aircraft laying a vertical smoke screen with the help of an airplane smoke tank.

Fig. 12. Aircraft setting up a vertical smoke screen with the help of an airplane smoke tank.

Airplane smoke tanks can be used only at alitutdes of 50-100 m. At greater altitudes for discharging of smoke-producing substances the lower part of the smoke screen does not reach the ground, i.e., an opening is formed between the surface of the earths and the lower edge of the curtain.

A smoke screen, laid from an airplane smoke tank during moderate meteorological conditions, preserves camouflaging properties for 10-15 minutes. Length of the smoke screen reaches 250-300 m and its width on the ground reaches 15-30 m.

During the Second World War aerial smoke generators were used for blinding the fire system of the enemy and concealing the maneuvers of advancing troops while seizing strong points and pockets of enemy resistance, for camouflaging troops during the forcing of water barriers, and for camouflaging the actions of troops in the case of development of combat in the depths of the enemy defense. As a rule smoke screens were laid by groups of aircraft.

Speeds of contemporary aircraft considerably exceed the speeds of aircraft which used airplane smoke tanks during the Second World War. Experience shows that application of old models of smoke generators on contemporary aircraft has become ineffective. In connection with this new models of smoke generators are geing developed.

In the United States, for example, they have already developed a smoke generator which makes it possible to lay vertical smoke screens from jet aircraft from a height of 500 feet (160 m). The generator is equipped with small vessels filled with smoke-producing substance of the type of a solution of sulfuric anhydride in chlorosulfonic acid. After equipping the device with such vessels the "dead" space inside it is filled with smoke-producing substance. During operation of the device two processes take place simultaneously: smoke-producing substance, flooded in the "dead" space of the device, immediately form a smoke cloud in the air, and the vessels, falling to the earth. introduce into the atmosphere through a system of holes a portion of smoke-producing substance, which creates a smoke screen down to the ground.

In the opinion of foreign specialists, in contemporary combat aerial smoke devices will find application for the purpose of blinding the observation posts and weapons of the enemy. Smoke screens, created by these devices, can be used at a considerable depth and they have the great extent (up to 8-10 km), therefore they can fulfill more complex missions, for example, supporting the combat actions of airborne landings.

Smoke Machines and Generators

During the years of the First World War special smoke generators were used which were designed for spraying of self-smoking smoke-producing substances of the chlorosulfonic acid type. These were the so-called portable smoke generators (Fig. 13). Later conveyed smoke generators appeared (Fig. 14). These were used mainly for laying fixed smoke screens, in particular for covering crossings and rear objectives. They had a volume from 40 to 60 liters and lasted from 10 to 40 minutes.

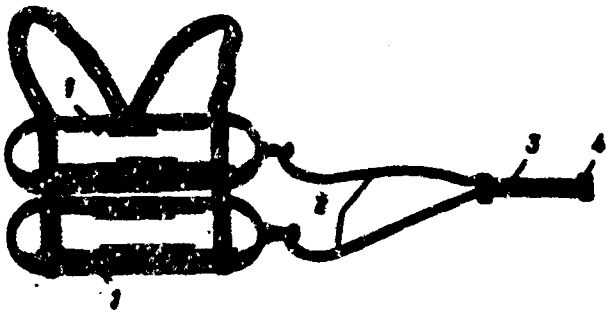


Fig. 13. Portable smoke generator; 1 – tanks filled with smoke-producing substance; 2 – rubber hoses; 3 – metallic tube; 4 – sprayers.

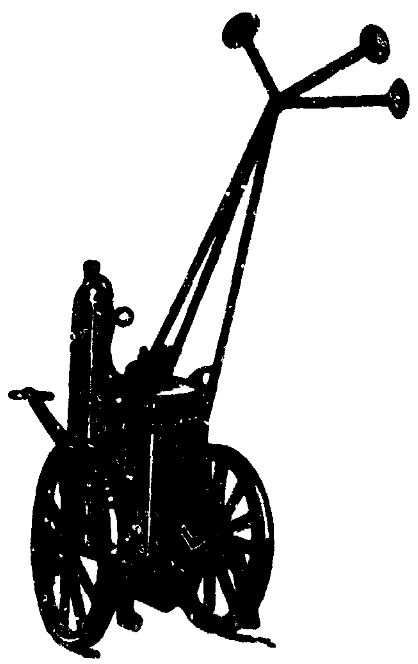


Fig. 14. Conveyed smoke generator.

In the period between the first and second world wars smoke generators were improved considerably and various smoke machines entered the armament of armies. Such generators and machines constituted reservoirs, the volume of which varied from 100 to 1000 liters. The reservoir was equipped with outlet pipes with sprayers, through which the smoke-producing substance was ejected into the atmosphere with the help of compressed air.

A schematic diagram of the arrangement of a smoke machine is shown in Fig. 15.

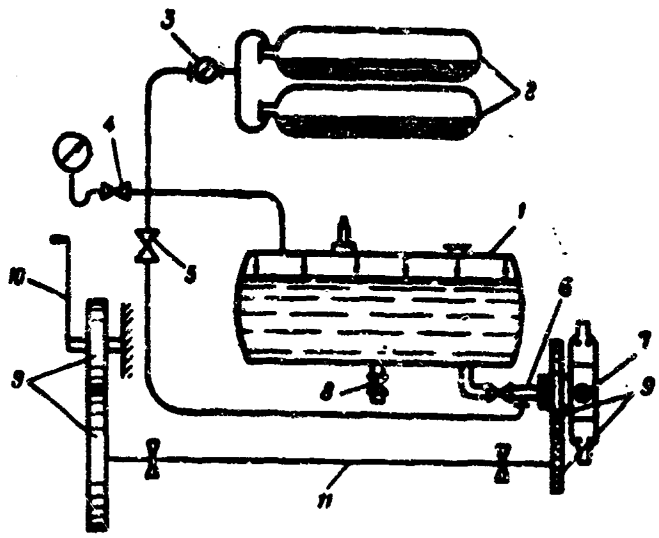


Fig. 15. Schematic diagram of smoke machine: 1 – reservoir; 2 – tanks with compressed air; 3 – reduction gear; 4 – air valve; 5 – valve of sprayer; 6 – pipeline; 7 – sprayer; 8 – drain cock; 9 – gear; 10 – handle of drive; 11 – shaft of drive.

Operational experience with smoke machines showed that it is necessary to develop a machine on a caterpillar drive and with armor, just as for a tank, so that their passability, maneuverability, and hardiness would make it possible to move them on the field of battle together with tanks. So various smoke tanks and tank smoke generators appeared, and later – special smoke trailers.

During the years of the Second World War smoke generators on the basis of barrels equipped with a set of special equipment were widely used (Fig. 16). The equipment made it possible to release smoke both simultaneously from the whole set of barrels, and also in series from each barrel.

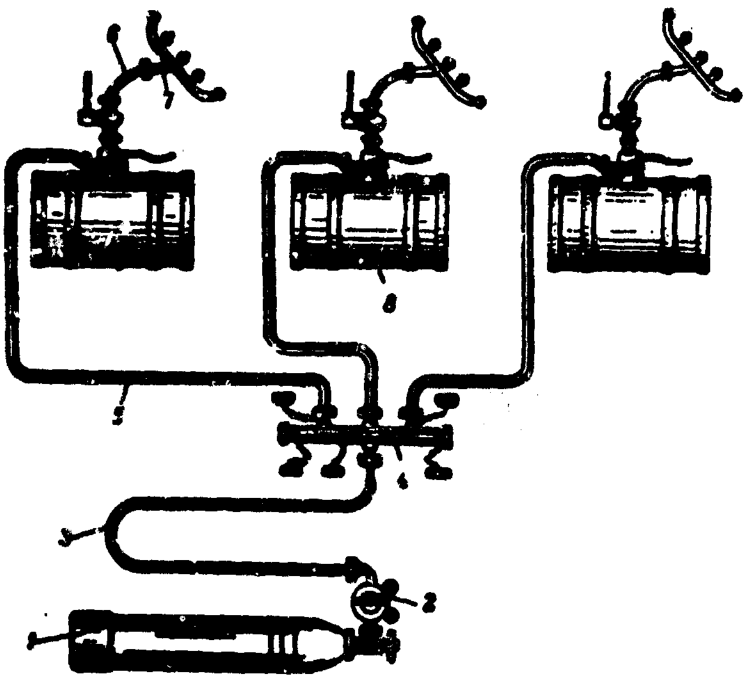


Fig. 16. Smoke outfit made from barrels: 1 – tank with compressed air; 2 – reduction gear; 3 – hose; 4 – air collector; 5 – hose; 6 – siphon; 7 – liquid collector with sprayer; 8 – barrel.

The principle of action of such smoke generators lies in the fact that compressed air, supplied to the barrel, presses on the surface of the smoke mixture and forces it to rise along the pipe of the siphon. Upon opening of the spigot the smoke mixture proceeds through a collector to the sprayers, from which it is ejected into the atmosphere in the form of small drops.

As smoke-producing substances in the case of releasing smokes from generators on the basis of barrels solutions of sulfuric anhydride in chlorosulfonic acid were used.

Recently in the United States Army wide dissemination has been gained by the so-called thermal smoke machines (Fig. 17). These machines work on the principle of evaporation and condensation of high-boiling oil products (oil, coke distillate, diesel fuel). They can be used from the ground, a trailer, or a truck. In Fig. 18 one of such machines is shown in action.

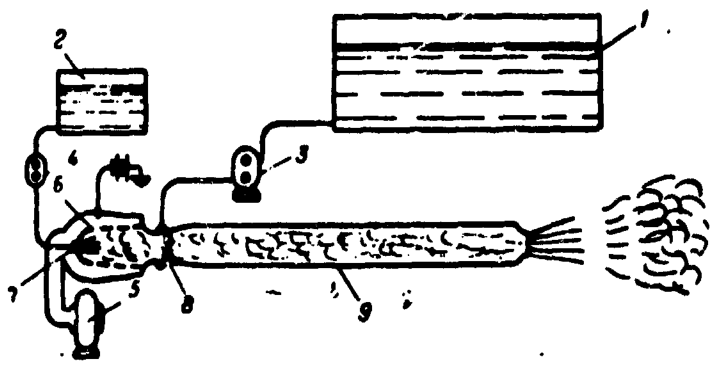


Fig. 17. Schematic diagram of thermal smoke machine (equipment): 1 – vessel for smoke-producing substance; 2 – vessel for fuel; 3 – pump for smoke-producing substance; 4 – pump for fuel; 5 – blower; 6 – combustion chamber; 7 – fuel spray nozzle; 8 – injector for oil-forming substance; 9 – evaporator.

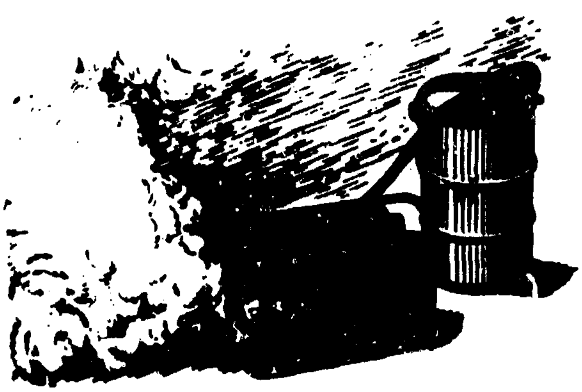


Fig. 18. American thermal smoke equipment in action.

The principle of action of the thermal smoke machine amounts to the following. By operation of a hand pump gasoline is sucked up from a floating chamber and enters the head of the engine through an apportioning nozzle. Simultaneously with this a stream of air from the air tube passes under the spraying holes. The gasoline is mixed with the air. The gasoline-air mixture which is formed enters the combustion chamber, fills it, and is ignited with the help of a spark plug. As a result of combustion of the mixture in the chamber a great quantity of heat is given off and pressure is increased. Some of the gaseous products of combustion from chamber, by way of the valve and hose, enters the vessel with the smoke-producing substance, as a result of which in it during operation of the engine the pressure necessary for supply of this substance to the evaporator is maintained constantly. The remaining share of hot gaseous products of combustion enters the tube of the engine and the evaporator. The mixture of vapors of oil products and products of combustion of the gasoline-air mixture from evaporator proceeds under the housing and is ejected under pressure into the atmosphere. When the vapors of oil products enter the atmosphere they are cooled rapidly and condense with the formation of white smoke, consisting of minute droplets of the oil product.

CHAPTER V

APPLICATION OF CAMOUFLAGING SMOKES

The Second World War showed that the successful carrying out of any operation is inconceivable without the realization of measures for camouflaging of troops and rear objectives. Among these measures a large role belonged to the application of smoke agents.

Wide and skillful application of smokes under combat conditions promoted the successful fulfillment of combat missions and reduced losses from enemy fire. Smokes hampered enemy observation and the carrying out of aimed fire and bombing. Smoke devices entered solidly in the combat practice of troops and in the system of antiaircraft defense.

Classification and Characteristics of Smoke Screens. Application of Smokes for Camouflaging the Combat Actions of Troops

A smoke screen is the artificially formed cloud of smoke or fog, which prevents the enemy from conducting observation, aimed fire, or bombing and conceals the actions of our forces.

All smoke screens are subdivided and are characterized depending on their assignment, location, and method of setting up.

Based on assignment smoke sceens can be blinding and camouflaging.

A blinding smoke screen is created directly on the enemy position, when the smoke, by covering observation posts and firing points, hinders enemy observation of the field of battle, and also the conduct of aimed fire. In the case of a blinding smoke screen our troops operate outside the smoke.

As a rule, blinding smoke screens are created by artillery and aerial smoke devices.

Camouflaging smoke screens are created for the purpose of camouflaging the actions of our troops. They are set up in our own positions or between our troops and the enemy. For creation of camouflaging smoke screens smoke machines and generators, smoke pots, and hand smoke grenades are used.

Number, location, and sequence of operation of smoke machines for the creation of camouflaging smoke screens are established in each separate case depending on the mission on hand, nature of terrain, and meteorological conditions.

Based on its position relative to the combat formation of the troops smoke screens are subdivided into frontal, flanking, rear, and false directions.

Frontal smoke screens are those which are created in front of our troops and cover the latter from the front. These curtains can be placed in the enemy position, between the enemy and our forces, and directly in front of our troops. As a rule, such smoke screens are placed on a line which is greater than the front of combat actions of the covered troops.

Flanking smoke screens are considered those which are created on flanks of a combat formation for the purpose of covering our troops from observation and flanking fire of the enemy. They are set up both in the enemy position and also between the enemy and our troops.

A flanking smoke screen, created in the enemy position and dissecting his combat formation, is called a box smoke barrage.

Rear are those smoke screens which are set up in the rear of the combat formation of our troops for the purpose of camouflaging rear units and the movements of troops.

Smoke screens in false directions are those which are placed outside the combat formation of our troops for the purpose of leading the enemy into error relative to the direction of the main strike, the site of a river crossing, or other concealed object.

Based on the method of fulfillment smoke screens are subdivided into fixed and mobile.

A fixed smoke screen is one created on a line which remains fixed during the entire time of release of smoke.

Accepted as mobile is a smoke screen, the boundary of which shifts as a result of movement of the smoke devices (machines) or shifting of fire by artillery smoke devices.

For covering the combat actions of troops the smoke agents are usually disposed linearly. A line on the terrain, where smoke devices are disposed and put into operation, is called the smoke release line.

Based on the experience of past wars, smokes for camouflaging the actions of troops can be used under any conditions of the combat situation.

In offensive combat, based on experience of the Second World War, the basic missions for the application of smokes are:

- camouflaging the movement of troops to the initial position for an offensive and deployment of the combat formation at a distance from the enemy which ensures the most advantageous conditions for entry into battle;

- camouflaging the making of passages in barriers, especially before the enemy's main line of resistance;

- camouflaging the buildup in the initial position for an attack by subunits of infantry which are operating on open terrain, and also the movement of launching the attack;

- camouflaging a wide envelopment, infiltration through intervals in the enemy's defense position for a strike on the flank and in the rear;

- securing the forcing of water barriers and camouflaging the crossings;

- blinding the enemy system of observation and separate firing points, especially those conducting fire from the flanks.

Smoke acquires specific value in the case of attacking a fortified defense zone, flanking positions of enemy which are sticking out forward of bent inwards, fortified heights and woods, stone structures, and reinforced concrete pillboxes.

In defensive combat smoke can be useful:

- for blinding of one group of enemy, which has broken inside the defense, so that all his forces and fire are concentrated on another group, which is counterattacked;

- for blinding enemy tanks which have broken into the depths of defense so that they can be approached secretly and destroyed by grenades and other weapons;

- for blinding enemy observation posts in order to deprive him of the possibility of fire adjustment.

In the depth of a defensive zone smokes are used at a distance of no less than 500 m from the main line of resistance in order not to hinder the actions of our units which are holding the line. In all cases of application of smokes in the defense they are used with the permission of the senior commander and in coordination with artillery and neighboring units.

Furthermore smokes can find application for camouflaging the actions of reconnaissance units, for camouflaging troops when they are pulling out of battle, and in a number of other cases.

The appearance of weapons of mass destruction, development of means of radar reconnaissance, devices for night vision, and means of artificial illumination have introduced peculiarities in problems and methods of smoke camouflaging of troops. These peculiarities, according to views of the American specialists, amount to the following:

- smokes have become important as means of camouflaging troops and objectives not only during the day, but also under night conditions;

- smoke camouflage of troops should be combined with antiradar camouflage;

- smokes can be means of protection from certain types or harmful factors of weapons of mass destruction.

Questions connected with these peculiarities of smoke camouflage of troops are examined below, in special divisions of this chapter.

Smoke Camouflage of Rear Objectives

During the Second World War a considerable role was played by smoke camouflage of various rear and industrial objectives (crossings, railroad stations, industrial enterprises, etc.). Smoke camouflage served as a means for strengthening the antiaircraft defense of such objects and was used regardless of the number of active means available in the defense system of the objective.

The basic purpose for screening rear objectives is to exclude or hamper the possibility of pinpoint bombing by enemy aircraft, if the latter penetrate to the objective through the barrage fire of antiaircraft artillery. During the Great Patriotic War there were many cases when enemy aviation, in carrying out raids on objectives covered by smoke could not conduct bombing. For example, out of fourteen raids by German aircraft on Kiev in nine cases they did not find targets in the smoke and flew away without dropping bombs.

Let us consider the peculiarities of smoke camouflage of rear objectives.

Smoke screens as a rule are easily seen from great distances and heights, which can permit the enemy to comparatively easily detect the region of location of the object being camouflaged. Therefore in the organization of smoke camouflage of rear objects the area of screening should exceed the true dimensions of the objective by several times. In the past war for reliable covering of an objective it was considered necessary to smoke an area, exceeding the dimensions of the objective by no less than 5 times.

The smoke should mask not only the objective itself, but also the nearest terrain features which can serve as reference points for the enemy for determining the site of location of the objective. The camouflaged object should not be located in the center of the smoked area.

Determining the moment for the smoke screen will depend on the situation. It is expedient to put out smoke screens every time enemy aircraft are detected on a course which lies on an objective in question. The smoke screen can be started on the signal of an atomic alarm.

Because of contemporary means of guiding aircraft onto a target great meaning has been acquired ~~by~~ camouflaging of objectives not only in the case of raids by bomber aircraft or aircraft which are carriers of nuclear bombs, but also in the case of overflights of enemy reconnaissance aircraft. In the absence of camouflage a reconnaissance plane can establish where the true targets are and guide the bombers onto them.

Screening of rear objectives should be used not only in the light time of day, but also at night, since the enemy, using illuminating equipment and infrared devices, can see objects without sufficient natural illumination.

In the case of screening rear objectives there is a great deal of value in the calculation of height, since depending on this it is necessary to move away or to close in the smoke release line to the objectives. It is known that with removal from the source of smoke release the height of the smoke wave is increased. Consequently, the higher the objective the further from it it is necessary to dispose the smoke release line.

During screening of an objective it is necessary to aspire to creation of a smoke screen without openings, which could facilitate exposure of the exact position of the objective to the air enemy. Here one should not try to obtain too thick a smoke, thus requiring a great expenditure of smoke agents. In the case of camouflaging rear objectives from the air enemy it is sufficient to obtain a solid smoke mist.

Camouflaging of rear objectives with smokes is carried out as a rule with the help of smoke machines, a set of barrels with smoke equipment, and large smoke pots.

During screening of objectives the smoke devices are most rationally disposed in arrangements which have the names "area," "circular," and "combined."

Order of distribution of smoke devices by "area" amounts to the fact that the devices utilized are disposed comparatively uniformly over sectors into which the entire area subject to screening was split beforehand. The arrangement by "area" is used usually in the case of screening a sector with dimensions no less than 10-20 km^2.

The "circular" arrangement of distribution of smoke devices results in the fact that they are disposed around the camouflaged object in one, two, or three rings, forming smoke release lines in the form of concentric circumferences, ensuring complete coverage of the objective by smoke regardless of wind direction.

The "combined" arrangement of distribution of smoke devices amounts to the fact that each camouflaged object individually is covered by a "circular" arrangement, and the terrain in the area of distribution of the objectives – by the "area" arrangement.

Of all the examined arrangements for distribution of smoke devices the most economical is the "area" arrangement.

Norms of expenditure of smoke agents in the case of screening of rear objectives depend on the size of the smoked area and time of screening.

Application of Smokes for Blinding Night Vision Devices and Camouflage in the Case of Artificial Illumination

In recent years in various fields of military technology all the more application has been found by infrared rays – invisible rays, occupying in the spectrum of electromagnetic fluctuations a sector between visible rays of maximum wavelength (0.76 microns, red) and the shortest radio waves (300 microns).

A study of infrared rays showed that their properties are basically no different from the properties of visible light. However, there are differences. One of them is the fact that infrared rays pass readily through certain materials which are impenetrable for light (for example, through dark tissue, thin plywood, sheet ebonite). Infrared rays also pass more readily tha visible light through the atmosphere in rain, snowfall, and li fog.

The source of infrared rays can be any body. The source of infrared radiations are vibrations of electrons and ions in bodies. Intensity of radiations depends to a considerable degree on the temperature of the bodies: with an increase of temperature radiation is amplified.

Objects having temperatures of tens and hundreds of degrees are powerful sources of infrared (thermal) radiations. Receiving the radiation of these objects with the help of the corresponding device, it is possible to detect them. Devices, perceiving infrared radiations of heated objects, are called thermal direction finders. These were used widely in foreign fleets during the Second World War, in particular for the navigation of ships in a fog.

For observation of objects which do not possess infrared radiation sufficient for perception by an instrument of the thermal direction finder type, the capacity of objects to reflect infrared rays is used. Instruments working on this principle are called night vision devices.

In Fig. 19 the principle of action of night vision devices is shown. Infrared rays, radiated by a searchlight, are directed on the object; rays reflected from the object are perceived by an image converter, as a result of which the image of the object found in front of it appears visible to the observer.

For military purposes the following night vision devices are used: infrared devices for signal purposes, infrared devices for firing and reconnaissance, and also infrared devices for driving.

However, infrared devices possess a number of deficiencies. The main one of them is dependence of range on atmospheric conditions.

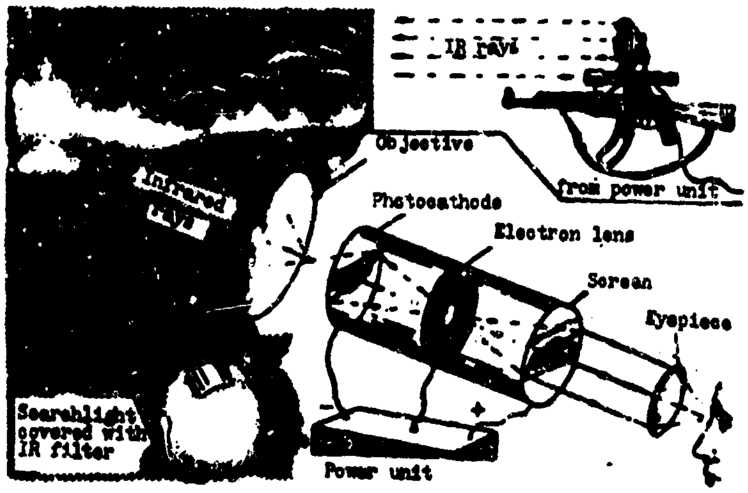


Fig. 19. Principle of operation of a night vision device.

It is known that radiant energy is scattered in the atmosphere by molecules of different atmospheric gases, and also by particles of dust. According to theoretical research the scattering of radiant energy by particles, the dimensions of which are small compared to its wavelength, is inversely proportional to the fourth degree of wavelength. With a decrease of wavelength scattering is increased.

Infrared rays, possessing comparatively great wavelength (microns-tens of microns), are scattered in ordinary atmosphere and, consequently, are weakened insignificantly. Thus, for example, at a distance of 10 km the weakening of rays with a wavelength of 3 micron comprises no more than 0.013%. In the case of a haze, under conditions of which visibility does not exceed 1 km, the use of infrared rays gives a gain in range of approximately 2-4 times as compared to visible rays.

Quite differently is the matter with propagation of infrared rays in a fog. In this case the size of the particles suspended in the air becomes commensurable with the wavelengths of passing infrared rays or considerably exceeds them. As a result considerable scattering of infrared rays and weakening of visibility are observed.

Investigations of the passage of infrared rays in a fog made it possible to derive a formula for determination of brightness of rays, passing through a layer with thickness x, and scattering coefficient of rays depending on the radius of drops in the fog. Thus, if the initial intensity of the ray is equal to I_0, then after passage of the ray through the fog it decreases to a value

$$I = I_0 e^{-\pi N \rho^2 k' x},$$

where e — base of natural logarithms; N — number of drops in 1 cm^3 of fog; ρ — radius of drops; x — function, depending on radius of drops and on wavelength.

If the index of refraction of the medium $n = 1$, then value k' is proportional to scattering coefficient:

$$s = 2\pi\rho^2 k,$$

from where

$$k = k' = \frac{s}{2\pi\rho^2}.$$

Consequently, in the case of passage of infrared rays through an atmosphere with lowered transparency the deciding factor is the size of drops of the fog (large drops scatter infrared rays more strongly).

The presence in the fog of small particles along with the large particles determines its better transparency for infrared rays as compared to visible.

From what was said it becomes clear, why in foreign armies all the greater attention is allotted to questions of the use of smokes as means of camouflaging troops under night conditions. Smokes are capable of scattering infrared rays and thereby hamper the use of night vision devices.

In the opinion of foreign specialists, smokes can be used widely for the purpose of camouflaging troops and objectives under conditions of artificial illumination at night.

Methods and equipment for the application of smokes for the purpose of blinding night vision devices and camouflaging troops under conditions of artificial illumination do not differ from methods and equipment for the application of smokes in the case of camouflaging under conditions of daylight.

Application of Smokes as Interferences in the Operation of Radar Installations

In the armies of a number of countries a great deal of attention is allotted to searching for measures for combatting radar devices. During the Second World War one of such measures was use of metallized paper strips, which served as interference in the case of detection of aerial targets by radar. Metallized strips were dropped in large quantities from aircraft, were held for a certain time in the air, and created false targets on radar screens which were difficult to distinguish from the real.

In the opinion of American specialists, analogous to the metallized paper strips for interference of radar installations, it is possible to develop smokes which consist of metallized particles. The smoke generators of such smokes can be foaming high-molecular substances of type of epoxy, phenol, polyethylene, silicone, and urethane resins.

For production of smoke from these resins the Americans used the principle of spraying of resin in a current of hot gases, polymerization of their vapors in the cold air, and formation of foam plastic in the air in a suspended form.

Particles of smokes of foam plastics have a spherical form with a cellular structure. Diameter of particles fluctuates from 1 to 100 microns depending on the composition of the foaming components. This ensures a low density of smoke, thanks to which its rate of settling is insignificant.

Application of smokes on the basis of foam plastics as the means for combatting radar is based on the fact that the signal which is visible on the radar screen bears a false nature and comes not from the real target, but from particles of the smoke screen. Furthermore, for radars working on a wavelength less than 1 cm absorption of radar waves by the smoke screen takes place.

Ordinary smokes are not an interference to radar observation. However, their application in combination with antiradar camouflage can give a good result. Thus, false regions of troop concentrations, simulated with the help of various reflectors, in the opinion of foreign specialists are expediently covered by smokes. It is necessary to combine this camouflage with camouflage of the actual areas of troop concentrations. This will achieve the basic goal - to lead the enemy into error relative to true intentions.

Use of Smoke Agents for Protecting the Troops from the Influence of Light Radiation of a Nuclear Explosion

It is known that in the case of an explosion of an atomic or hydrogen bomb the effective casualty radius by light radiation is considerably greater than the effective casualty radius due to shock wave and penetrating radiation. With an increase of power of nuclear ammunition the effective casualty radius by light radiation is increased considerably more rapidly than other damaging factors. Therefore protection from light radiation acquires all the greater importance.

The question arises, is it possible to decrease the damaging action of light radiation, and also to reduce the area over which burns can be caused in man and objects set afire?

The basic characteristic, determining the damaging action of light radiation of nuclear explosion, is the amount of light energy, falling on one square centimeter of illuminated surface, perpendicular to the direction of propagation of radiation during the entire time of glow of the fireball. This quantity of light energy is called light pulse.

The value of light pulse depends on quantity of light energy, radiated by the fireball during the entire time of its glow, on the distance between the illuminated surface and the center of the nuclear explosion, and on atmospheric conditions at the time of the explosion.

Light radiation from the luminescent region spreads rectilinearly. If around the luminescent region of an air nuclear explosion a sphere of radius R is described (Fig. 20), then the energy, radiated by the luminescent region during the entire time of its glow $E_{изл.}$, if weakening of energy in atmosphere is absent, will completely pass through the surface of the sphere

$$S = 4\pi R^2 [см^2].$$

Hence per 1 cm^2 of this surface there will be the energy

$$H = \frac{E_{изл}}{4\pi R^2}\left[\frac{cal}{см^2}\right].$$

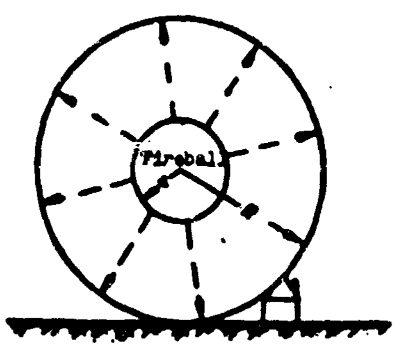


Fig. 20. Propagation of energy, radiated by the fireball in the atmosphere.

This energy content is also called light pulse.

In an atmosphere saturated with dust, in fog, snowfall, or rain the radius of damaging action of flight radiation decreases. The fact is that dust particles, water droplets, and snow prevent the propagation of radiation by scattering and absorbing it. For the purpose of calculating the attenuation of light radiation during passage through the atmosphere the correction factor $e^{-k(R-r)}$ is introduced into the formula for calculation of light pulse. Here e – base of natural logarithms; k – average attenuation factor of radiation for the whole range of wavelengths; R – distance from center of luminescent region to place where radiation is measured, km; r – average radius of luminescent region, km.

With this factor the formula for calculation of light pulse will have the following form:

$$H = \frac{E_{\text{св}}}{4\pi R^2} e^{-k(R-r)}.$$

For a comparatively narrow pencil of rays (when rays which left the pencil at the expense of scattering do not return back to it) the attenuation factor for various atmospheric conditions can be found approximately from the expression

$$k \approx \frac{4}{D}\left[\frac{1}{\text{км}}\right],$$

where D – meteorological visual range,[1] measured in a horizontal direction, km.

For pure air the meteorological visual range comprises around 40 km; average attenuation factor will be equal to $0.1 \frac{1}{\text{km}}$. In the case of moderate cleanness of air (visual range around 20 km) the attenuation factor is equal to $0.2 \frac{1}{\text{km}}$.

[1]Meteorological visual range is understood as the maximum distance, which in the daytime against the background of the sky at the horizon it is possible to distinguish the outline of large dark objects.

Smoke screens, just as natural fogs, will weaken the light radiation of a nuclear explosion. In known limits the attenuation factor will be directly proportional to concentration by weight of smoke, measured in mg/l or in g/m^3. Absolute value of attenuation factor for a narrow parallel pencil of light in camouflaging smokes comprises approximately 0.4-0.004 $\frac{1}{m}$ or 400-40 $\frac{1}{km}$. From these figures it is clear that the attenuation factor for smoke screens is sufficiently great and corresponds to attenuation in dense natural fogs for a narrow pencil of rays.

In connection with this in the United States experiments were conducted on the creation of smoke screens, capable of decreasing the damaging action of light radiation of a nuclear explosion on personnel, military equipment, and inhabited localities. Thus, in 1954-1955 during the "Knothole" and "Teapot" nuclear explosions smoke screens (oil mists) were laid out with the help of smoke machines, adapted for remote control. Smoke was released for 10 min prior to the explosion. The smoke screen weakened the influence of light radiation of the nuclear explosion by 65-90% depending on the distance to the epicenter of the explosion. In the opinion of American specialists, such attenuation promotes a lowering of light pulse to 3 cal/cm^2 in the zone where the maximum value of excess pressure of the shock wave reaches a considerable value – 0.63 kg/cm^2. Light pulse, equal to 3 cal/cm^2, is the threshold of ignition of combustible materials and moderate severity of burns on exposed parts of the body. Density of the smoke screen here corresponded to the density obtained with an expenditure of oil of 440-620 liters per square kilometer of area. Approximately the same densities of smoke screens are used for purposes of camouflage.

Work was also conducted on a study of the influence of different forms of smokes on lowering the influence of light radiation. The tests showed that other smokes not only are not inferior, but in a number of cases exceed oil mists. Thus, industrial smoke which reduces atmospheric visibility, can successfully weaken the damaging influence of light radiation of nuclear explosions.

In the opinion of American specialists, in the organization of rotection from light radiation with help of smokes it is necessary to originate from the necessity of protecting the so-called peripheral regions, and not the region of the epicenter of the explosion, which is subjected, furthermore, to the strong influence of penetrating radiation and shock wave. Laying out of smoke should be carried out with smoke machines, controlled at distance by wires or by radio.

Protection from the light radiation of nuclear explosion with the help of smokes will demand the screening of considerable territories. Furthermore, as tests show, for sufficiently effective attenuation of light radiation the concentration of smoke should be increased by 1.5-2 times in comparison with the concentration which provides camouflage from visual observation. All of this requires the expenditure of a huge quantity of smoke agents and time.

Consequently, to solve the problem of covering objects from nuclear blows only by means of screening them is very difficult; smoke screens have to be used in complex with other measures of protection.

Use of Smokes for Protection of Troops from Bacteriological Weapons

In the postwar period in the imperialistic countries, along with improvement of nuclear and chemical weapons such means of mass destruction as bacteriological weapons have been developed. It is true, the rapid development of means of nuclear destruction moved to second place the problems connected with bacteriological warfare. However, it does not follow from this that bacteriological weapons and protection from them ceased to be urgent. Scientists have ascertained with great alarm that during the last 10-15 years the potential power of bacteriological weapons has increased immeasurably. It is also significant that the peaceful industry dealing with development of means for combatting pests of plants (insecticides), which is widely developed in many countries, perhaps can be switched without great difficulties to the manufacture of deadly microbes and toxins.

In measures for protection from bacteriological weapons a definite place, in the opinion of foreign specialists, can probably be assigned to smokes. It is known, for example, that one of the methods of application of bacteriological weapons is the propagation of insects which are infected with pathogenic microbes. So-called insecticide smokes can be used successfully for the destruction of insects.

Certain experience in the use of such smokes already exist. During the Second World War in the jungles of Burma and on the islands of the Pacific Ocean containers were used which were filled with a mixture of freon and DDT for protecting the troops from harmful insects. During the war in Korea infected insects were destroyed very effectively by means of spraying exterminating agents, primarily emulsions of DDT.

During the last few years a great deal of attention has been given to a new method of application of chemical poisons – conversion of a liquid chemical poison or a solution of it in some liquid into an aerosol state. Such a method is very effective and finds wide application for combatting insects, ticks, fungus diseases, etc.

Development of aerosol methods for the treatment of objects led to the development of a number of designs of aerosol generators. Let us point out two of the most widespread types of generators: generators, forming an insecticide fog with the help of superheated steam (Bes-Kil generator), and generators, for which for formation of fog heated air is used (Tayfa generator). The first one expends 141 liters of insecticide per hour, the second – from 75 to 242 liters per hour. In both generators the size of aerosol particles is regulated.

As insecticides in fog generators they use DDT, hexachloran, chlorindan, and toxaphene; as solvents – kerosene, diesel fuel, and oil.

The design of fog generators provides for a minimum duration of heating of the insecticide, however, even under these conditions decomposition of a certain share of it can take place.

For combatting harmful insects, ticks, etc., insecticide smoke pots are also used. Principle of action of these charges amounts to the application of exothermal chemical reactions, during which a sufficient quantity of heat is liberated for the evaporation of organic insecticides and creation of a smoke stream. DDT, chlorindan, methoxychlor, and hexachlorobenzene are used as insecticides in the charges.

The arrangement of a low-temperature insecticide smoke pot is shown in Fig. 21. A powdery mixture of insecticide and thermal reagents is placed in the charge. After ignition of the charge with the help of an actuating device, which operates on the principle of friction match, a chemical reaction occurs during which the insecticide at first is softened and then is ejected together with the liberated steam. In atmosphere condensation of steam and insecticide occurs; the drops which form contain a mixture of water and insecticide and have a diameter of around 5 microns. Then the drops are enlarged and reach a diameter of 10-50 microns.

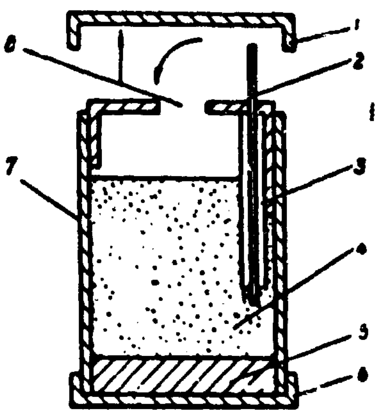


Fig. 21. Diagram of insecticide smoke pot: 1 – upper protective cover; 2 – friction actuating band; 3 – actuating mechanism; 4 – mixture of insecticide and chemical reagents; 5 – thermal insulation disks made from corrugated cardboard; 6 – lower protective cover; 7 – cylindrical cardboard box; 8 – hole for exit of dry aerosol.

After settling of the particles of aerosol on the surface objects the growth of crystals of insecticide occurs. For DDT the crystals reach a length of 200 microns.

Insecticide smoke pots are intended for treatment of closed locations.

CONCLUSION

Experience of two world and a number of small wars shows that the value of smokes as a means for camouflaging the combat actions of troops is still increasing. At the same time in recent years it has been established that smokes can be used as the means of protection from certain types of harmful factors of weapons of mass destruction, and also as interferences in the operation of radar installations and night vision devices.

The armament of a number of foreign armies, as this is shown in the book, includes various smoke agents which have passed comprehensive tests and smoke-producing substances. These devices and substances are continuously being improved and developed, and the possibility of appearance of new forms is not excluded.

Improvement and development of smoke devices is proceeding along the line of reducing the weight of smoke generators and machines, increasing their economy, obtaining smoke with an assigned degree of dispersion, and also along the line of developing special automatic equipment, requiring a minimum number of personnel for service.

The search for new smoke-producing substances includes the problem that the smoke has a lower settling rate and is less harmful for man and equipment. It is considered that for these goals it is possible to use smoke generators on the basis of foam plastics, which make it possible to obtain smoke of low density.

DATA HANDLING PAGE

01-ACCESSION NO.	TM0500182
98-DOCUMENT LOC	
39-TOPIC TAGS	screening smoke, radar screening smoke, smoke bomb, smoke gas, smoke generator, aerosol, IR screening smoke, nuclear explosion, nuclear explosion protection, acid smoke
09-TITLE	SMOKE AGENTS AND DEVICES AND SMOKE PRODUCING SUBSTANCES -U-
47-SUBJECT AREA	07, 15, 17
42-AUTHOR CO-AUTHORS	ZAYTSEV, G. S. ; 16-KUZNETSOV, A. Ya.
10-DATE OF INFO	-----61
43-SOURCE	DYMOVYYE SREDSTVA I DYMOOBRAZUYUSHCHIYE VESHCHESTVA, MOSCOW, VOYENNOYE IZD-VO MINISTERSTVA OBORONY SOYUZA SSR (RUSSIAN)
68-DOCUMENT NO.	FTD-MT-24-426-69
69-PROJECT NO.	72302-82
63-SECURITY AND DOWNGRADING INFORMATION	UNCL. 0
64-CONTROL MARKINGS	NONE
97-HEADER CLASN	UNCL

76-REEL/FRAME NO.	77-SUPERSEDES	78-CHANGES	40-GEOGRAPHICAL AREA	NO. OF PAGES
1891 0774			UR	96

CONTRACT NO.	X REF ACC. NO.	PUBLISHING DATE	TYPE PRODUCT	REVISION FREQ
	65-	94-	TRANSLATION	NONE

STEP NO.
02-UR/0000/61/000/000/0001/0084

ABSTRACT

(U) The author deals with the history and development of smoke agents and smoke generating devices. The book is based extensively on agents and equipment of World War II vintage. Reference is made to aerial spraying and laying of smoke screens from ships, but the emphasis is on the use of smoke by the ground forces. Chapter I gives a brief history of the use of smoke since the First World War. Chapters II and III go into the properties of aerosols as used in smoke screens and fogs and the chemical nature of various smoke-producing substances. Chapter IV deals with smoke generating equipment: hand grenades, smoke pots, artillery and motor shells, aerial bombs, and smoke machines and generators. Chapter V covers the tactical application of smoke with special sections on the use of smoke in connection with night vision devices, interference of radar stations, protection from light radiation of a nuclear explosion, and protection from bacteriological weapons.