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Mar 15 1942

III #15

DIVISION B

NATIONAL DEFENSE RESEARCH COMMITTEE

of the

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

Screening Smokes

OSRD No. 436

Serial No. 197

Informal Copy

## Screening Smokes

by T.K.S. 3-5-42.

The investigations on screening smokes have been directed toward the development of suitable devices for the protection of industrial and military objectives against aircraft by the use of large quantites of smokes or fogs. The subject is referred to in English reports as "area screening". Because of the large areas of the industrial sites to protected, the amounts of material required for screening purposes are so great that the usual chemical smokes (such as white phosphorous, chlorsulfonic acid, etc.) cannot be employed.*

Although the principal purpose is the protection against aircraft by making aimed bombing impossible, it appears from British reports that the use of protective smokes has been an important factor in maintaining the morale of factory workers, especially in munitions plants.

## British and American Practice

The British appear to have concentrated on the use of two types of oil smoke generators, the "modified Tweedale" and the large truck-borne "Haslar".

The M.H.S. (Ministry of Home Security) Mk. I, the M.H.S. Mk. II, the "modified Tweedales", and the United States C.W.S. M-1 generators all consist of an oil container, an air port or vent, and a stack or flue. Figure 1 illustrates the M.H.S. Mk. I. The burning rates of the various English types is 2-10 Imp. gal. per hour, and the M-1 uses 12-15 U.S. g.p.h. The M.H.S. Mk. II burns 2 Imp. g.p.h. Apparently more than 200,000 of these small generators are in use in England, probably mostly Mk. II. These various devices appear to be developments of the Tweedale orchard heater used widely in California.

The "Haslar" (see Fig. 2) burns 50 times as much oil as the small units, i.e. about 100 Imp. g.p.h. The oil used is fuel oil rather than diesel oil, and a water spray is introduced part way up the stack. The smoke is lighter in color than in the small units, being light tan in place of dark gray or black. The labor involved is reduced, since the unit is operated by a driver and one attendant, whereas the small units require one attendant for 20 generators.

* A recent Intelligence report indicates that the smoke used by the Germans at Brest is a weak mixture of titanium tetrachloride and ammonium chloride. Generators are placed at a large number of points, including small boats in the harbor. The smoke has a detectable odor but does not cause breathing difficulty. It is best in a damp climate, as at Brest. The report states that smoke is used at Brest in the daytime as well as on moonlight nights.

In practice the target is protected by several thousand small units, usually spaced closely (intervals of 7yds.?) together along adjoining country roads. A much smaller number of Haslars on 3-ton trucks are used to give volume to the screen. Haslars are not used alone, since the smoke does not spread sidewise with sufficient rapidity to use only large sources. Use of the generators is not considered practical for general use in daylight, or at wind speeds above 10-12 m.p.h. The effectiveness of the screen in the moonlight is estimated to be 15-30 times as great as in daylight. The principal operational difficulties are (a) the large amount of imported oil required, (b) the incidence of flaming, especially at high wind speeds, and (c) the large man-power required.

An English report of January, 1941, includes the following summary: "A scheme for smoke screening back areas during moonlight nights has been developed. The equipment consists of low-cost generators. Fuel and labor costs are high. A large lorrymounted unit produces smoke to give bulk to the screens. Screening is practicable only at low wind velocities. The equipment and methods are reasonably well standardized and no immediate change is now anticipated." At the time this report was written no factory protected by smoke had been bombed. The same report carries the statement "Employees in some factories demand smoke as the price for continuing work at night".

## Screening Effectiveness as Expressed by the Factor $N_o$

English reports on both chemical and oil smokes employ a factor $N_o$ as a measure of the screening power of a particular smoke. Although it is not clear how this is measured in the field, it is clearly defined as the number of mg. per sq. m. between the observer and the object which are needed to just obtain obscuration. The viewing distance is nominally 1,000 yds. Observed values are corrected to a common basis of a wind velocity of 10 m.p.h., a relative humidity of 75%, and a value of r of 1.15. r is the ratio of wind speeds at 2m. and at 1m. above the ground. It would seem wise for U. S. measurements to be reported in these same units, rather than in lbs. per acre, etc. The conversion factors are:

$$\text{lbs./acre} = 0.0089\ N_o = \frac{N_o}{112}$$
$$\text{lbs./sq. mile} = 5.7\ N_o$$

Porton Report 1400 employs a factor B, defined as follows:

$$B = \frac{Q}{uN_o} \times 1000$$

where Q is the strength of the source in g./ (sec.) (m.), and u is the mean wind speed in m./sec. In order to have a basis for the estimation of oil rates, $N_o$ should refer to the oil used by the generator, rather than the oil existing in the cloud. It is evident that B must be greater than 1.0 in order to obtain any screening. If B is 1.05, the area screened effectively (over which the concentration is equal to or greater than $N_o$) is a rough triangle approximately as indicated by Fig. 3. If B is increased to 1.3, the area screened is much greater because the concentration $N_o$ is maintained for a very much greater distance downwind. The quantitative relations are not given in the reports studied, but it would appear that the area screened varies widely as B varies from 1.0 to 1.5 or 2.0. There is no advantage in operating at a B above perhaps 1.5, yet an adequate factor of safety is important, since variations in local wind velocity, source strength, or $N_o$, may cause B to drop below 1.0 and no screening would then be obtained.

It is noted that the screening effect is increased if the object is viewed at an oblique angle, i.e. as by an aircraft observer looking other than vertically down. The screening effect also increases with the distance from the cloud. It is estimated that $N_o$ would be reduced 40% by increasing the viewing altitude from 3,300 to 10,000 ft.

The values of $N_o$ reported by the British are obtained by field tests and presumably apply to conditions of actual use at night.

The following values are quoted in Porton Report 1400 (dated 1938):

| Smoke Material | $N_o$ - mg./m.$^2$ Rel. Hum. 40% | $N_o$ - mg./m.$^2$ Rel. Hum. 90% |
|---|---|---|
| H.C.E. | 600 | 275 |
| W.P. | 350 | 220 |
| C.S.A. | 700 | 400 |
| S.1. Smoke* | 1,100 | 1,100 |
| Fuel Oil* | 1,500 | 1,500 |

* No statement as to type of generators.

It is suggested that laboratory tests may be corrected to field values by correcting them in proportion to the corresponding ratio for one of the chemical smokes tabulated.

NDRC measurements of $N_o$, together with rough calculations of oil quantities needed for screening purposes are given in a later section of this report.

## Desirable Characteristics of Screening Smokes

In undertaking an investigation of screening smokes for the NDRC, the members of the section have considered the following as desiderata:

1. The smoke-forming material should be non-toxic. The danger of lipid pneumonia resulting from inhalation of oil vapors has been brought to our attention, and any evidence of such a hazard in English factories should be transmitted.

2. It should be non-corrosive.

3. It should be non-injurious to plant equipment (abrasive dusts could not be used).

4. It should be available in quantity (Note that special oils might be specified in the U.S. but might not be obtainable in England).

5. It should be capable of being readily dispersed.

6. It would be desirable to use a material which reacts with the atmosphere to add weight. (White phosphorus smoke is over twice the amount of the P used.)

7. The actual density of the material is not very important (Settling is no problem in smoke particles of proper size).

8. The smoke should have a suitable color. It has been stated but not confirmed that grey or tan smoke is more suitable for camouflage than white smoke. On the other hand, white smokes partially diluted are difficult to distinguish from natural haze. The variation $N_0$ with addition of carbon particles to white oil smoke is now being studied.

9. The smoke particles should be of the optimum size. This point is discussed below.

10. The smoke should be persistent. This point is also discussed below.

## Optimum Particle Size

The visibility of objects on the ground depends on the lighting of the object and on the contrast of light and dark as viewed from above. The presence of a smoke reduces visibility by three mechanisms: reduction of the illumination of the object; scattering of the reflected light from the object, reducing contrast; and glare, resulting from backward scattering of light from cloud to observer. For very small particles the intensity of the scattered light varies as the sixth power of the radius of the particle; for very large particles the scattering varies as the square of the radius. Since the number of particles per unit weight of material varies inversely as the cube of the radius, it is evident that there must be a particle size for which the scattering is greatest. This optimum radius corresponds to the point where the slope of the curve of scattering vs. radius has a slope of 3 on a graph having logarithmic coordinates.

The early calculations of Langmuir (letter to T. K. Sherwood dated August 27, 1941) indicated optimum particle diameters of 0.6--0.9 μ, and estimated a screening capacity of oil smokes which appeared practical. More recently LaMer (January 21, 1942) has reported tests and calculations relating to the question of optimum particle size. The angular distribution of intensity of scattered light from stearic acid smoke was found to follow closely the results of Engelhard and Friess (Koll.Z., 81, 129 (1937)). The absorption coefficient of stearic acid was found to be essentially zero. The total scattering (0 to 180°) per unit mass was found to be greatest at particle diameters of 0.6 μ. In the range of diameters 0.2 to 1.0 μ the backward scattering is almost independent of particle size and the predominant forward scattering almost identical with total scattering. Both water and stearic acid have essentially the same optimum particle size.

The existence of an optimum particle size for screening purposes is confirmed by laboratory screening tests carried out by Langmuir. These are best described by quoting extracts from a recent letter from Dr. Langmuir (to T. K. Sherwood, January 28, 1942):

"Work with Smoke Chamber. You will remember that the smoke chamber is a box 6' x 6' and 7' high. The top and sides down to a level 4' below the top are heated uniformly to about 60°C while the lower 3' and bottom are cooled to 10°C to 15°C by cold air circulating around the outside. When smoke is placed in the lower part the upper boundary is very sharply defined at a level 3' from the bottom. The smoke is thus contained in volume four cubic yards covering area of thirty-six square feet.

"We make smoke of very uniform particle size from a weighed amount of oleic acid. Tests show that the smoke is very evenly distributed in the lower 3' of the box. There is none above that level. The bottom of the box has a dull black reflecting surface of 10 per cent reflectivity, the sides up to 3' are white and the sides above the 3' level and the top are black. Four lamps in the top of the box give uniform illumination.

"We have measured the particle sizes by drawing samples of the smoke from the box and measuring the rate of fall by a microscope in our gravity fall cell and from this we calculate the particle diameter by Stoke's Law.

"In the box we have a card about 20 cm sq. of gray cardboard in the center of the larger sq. of black cardboard.

The black cardboard reflects 10 per cent and the gray reflects about 30 per cent. We consider that this degree of contrast is a fair representation of the contrast one can expect to find on the ground looking down from an airplane. The average reflectivity of the ground as seen from the air is about 10 per cent except under unusual conditions such as a snow covered surface.

"The black and gray cards are attached on a light frame which can be raised or lowered in the smoke. Smoke from a weighed amount of oleic acid is then put in the box, choosing the amount so that it is slightly greater than is needed to render the card invisible when the card is on the bottom and is viewed from directly above. The card is then raised until the gray and the black squares can just be distinguished. The weight of oleic acid in the smoke above the card is then calculated. The table summarizes the results to date.

| Particle Diameter, microns | Weight of oleic acid used for 36 sq. feet | N mg./m.$^2$ | Pounds per sq. mile |
|---|---|---|---|
| 1.10 | 4.09 grams | 1220 | 7000 |
| 1.04 | 2.61 | 780 | 4460 |
| 0.91 | 1.89 | 570 | 3270 |
| 0.73 | 1.60 | 480 | 2750 |
| 0.62 | 1.62 | 490 | 2780 |
| 0.55 | 1.90 | 570 | 3260 |

The minimum weight of 0.46 g. per sq. meter is obtained for a particle size of 0.68 microns. This corresponds to the weight of 6230 pounds per sq. mile, or 350 gal. oleic per sq. mile.

"The optimum particle size of 0.68 microns agrees excellently with the value of 0.6 microns which has been found recently by Dr. LaMer from the results of his measurements of the total integrated scattering per unit mass.

"We find that even 1/2 or 1/3 of this amount of smoke is very effective in decreasing the visibility of an object under the smoke and when viewing from an angle of 45° it is sufficient to completely obscure the object. I feel that this figure of about 350 gals per sq. mile can be used with a great deal of confidence as the amount that is needed of any practical oil with spherical particles when the particle size is chosen correctly. The foregoing results show a surprisingly large dependence on the particle size and emphasize a need of particles with diameters not greater than 0.8 microns.

"We have made experiments with a wide range of illumination and find that the obscuring power of the smoke is very nearly independent of the actual brightness of illumination. Undoubtedly with moonlight and starlight much smaller quantities of smoke would be effective. We plan to make further studies of these very low intensities of illumination.

"Schaefer is continuing measurements of the direct transmission of light measured by a photocell and the scattering of light as observed by the brightness of the top surface of the fog. I hope very soon to test out a theory by which we will be able to calculate the visibility of an object of any brightness which gives any degree of contrast with its surroundings under various thicknesses of fog."

## Persistence

Individual liquid particles evaporate rapidly when exposed to dry air. Using the Langmuir equation it is estimated, for example, that a 10 micron drop of oleic acid would have a life of 10 minutes in air. This is based on a large extrapolation of the vapor pressure curve for oleic acid leading to an estimate of 0.0002 m.m. for the vapor pressure at 20°C. (The extrapolation was made using the Cox chart shown on p. 1111 of the first edition of Perry's "Chemical Engineer's Handbook"). Individual particles of smaller size of more volatile substances may evaporate in a few seconds.

Since such fogs are known to be persistent, it seems clear that the air in the fog must be saturated with vapor. If the fog consists of a volatile liquid a large amount of material is required to saturate the air. If the liquid is non-volatile, the amount needed to saturate the air and so ensure persistence may be but a small fraction of the weight of the liquid droplets. A material having a molecular weight of 200 present in a concentration of 40 micrograms per litre need evaporate only to the extent of 10 per cent to saturate the air if its vapor pressure is 0.00037 m.m. Taking 0.001 m.m. as the maximum vapor pressure at 20°C. and again using the Cox chart for extrapolation, it appears that the material should have a boiling point in excess of 500°F.

Field tests with smoke generators have been made with oleic acid, No.3 fuel oil, and with Diol 55. The latter is typical of ordinary Coastal pale lubricating oils which are available in the United States in quantities of perhaps 100,000 barrels per day. It is a distillate lubricating fraction from a naphthenic crude, and sells for less than 10 cents per gallon. The Diol 55 has a mid-boiling point of about 680°F.

Smoke generator field tests have indicated that No. 3 fuel oil (mid-boiling point 480° F.) is just slightly too volatile to give adequate persistence.

Water and Aqueous Solutions

Late in 1940 Prof. W. G. Brown initiated a series of small-scale laboratory experiments for the purpose of exploring the possibilities of forming smoke or fog by the mechanical atomization of water or aqueous solutions. Small nozzles were found which were applicable for the purpose, at modest pressures, especially when the liquid was mixed with a quantity of air under pressure before entering the nozzle. Similar results were obtained with a high-pressure nozzle without air providing the pressure were raised to a above 3000 lbs./sq.in. Although no quantitative measurements of the fogs were made, the work served to direct further study along the line of very high pressure nozzles without air.

More recently, Prof. G. G. Brown has supervised the construction and test of a large truck-mounted unit capable of handling 13 gal. per min. at 6000 lbs. per sq. in. Although field tests have not so far indicated that this unit can compete with oil smoke generators, it has been used to study the effect of nozzle type, pressure, and character of solution. Most of the work has been done with solutions of NaCl, which are sprayed into a large box (1240 cu. ft.) in which is located a standard lamp and photo-cell spaced 3 ft. apart. The relation between light transmission, nozzle pressure, and salt concentration has been obtained for the H-466 nozzle using an 8% NaCl solution. Although the light transmission was reduced to 50% by concentrations of less than 150 mg. NaCl per cu.m. (at 5000 lbs. per sq. in.), the method so far appears impractical due to the fact that even the best nozzles show poor atomization, with less than 2% of the salt formed as a reasonably stable fog.

Although the pressures employed for direct atomization are high, the power requirement would not be excessive if satisfactory atomization were obtained. The experimental unit handling 13 g.p.m. at 5000 lbs. (equivalent in liquid volume dispersed to well over 1000 small Tweedales) has a theoretical power consumption of only 38 h.p.

Exploratory work has been started on chemical methods of stabilizing water fogs, but this has not uncovered anything of real promise.

## Solid Smokes

It has been suggested that various abundantly-available solid materials might be dispersed as reasonably stable smokes, and that some minerals, such as bentonite, might be obtainable as a sufficiently fine powder so that grinding would not be necessary. Certain natural clays and kaolins have also been suggested. (In this connection it may be noted that bentonite dusts have been found to have no serious influence on the operation of internal-combustion engines--see Div. B Progress Report Serial No. ).

It has been shown that a very small Micronizer has a large capacity for dispersing bentonite, but that compressed air in quantity is needed. These tests are being continued, together with tests on simple dispersion by means of a centrifugal fan.

Bentonite may be electrically charged by the use of a simple and rugged power-pak, and a distributing grid or screen placed over a bentonite vibrating feeder. The cloud has a uniform density and coagulation is definitely retarded. Negative charging produces better results than positive charging. Satisfactory field tests of this device have not been made.

## Oil Smokes

Three investigations of smoke-generating devices using oil are being sponsored by the section, and the devices developed appear to be definitely more promising than the results so far reported on aqueous solutions or solid smokes. The investigations involved are those of the Williams Oil-O-Matic Heating Corp., the Servel Co., and that of Dr. Langmuir of the General Electric Co.

The G. E. generator consists of a container in which the oil is boiled, a source of heat, and small nozzles through which the oil vapor issues under slight pressure into the atmosphere. In a jet of hot oil vapor the small particles tend to vaporize to produce a vapor which condenses on the larger particles, and the increase in average particle size is very rapid at the relatively high temperature of the oil vapor produced by boiling at essentially atmospheric pressure. If a smoke of fine particle size is to be produced by vaporization the vapor must be cooled very rapidly. Furthermore, a high concentration of particles results in rapid coagulation and resulting increase in particle size, even when the temperature and vapor pressure are very low. The G. E. device employs 1/8 in. nozzles with vapor at about 2 lbs. per sq. in. pressure to produce both the desired rapid cooling and the rapid dilution with air. Excellent white smokes of the desired particle size are produced both with oleic acid and with the Diol 55. The capacity is about 100 gm. per min. per nozzle.

The Servel Co. has undertaken a development program directed toward the production of an oil smoke generator suitable for largescale manufacture. Starting with the basic idea (suggested by Dr. Langmuir) they have built and tested over 20 generators of various designs, of which only one will be described. This is their apparatus No. 7, shown diagrammatically in Fig. 5, and pictured in Figs. 6 and 7. It consists of a double shell supported vertically, with a burner providing a flame at the top of the outer anular space and an oil spray attached at the bottom of the central flue. The oil atomized by the spray is completely vaporized by the hot products of combustion and smoke is not formed until the gas-oil mixture mixes with air as it leaves the top of the central flue. The experimental model shown on the truck employs a small Willys engine of which two cylinders supply power and two cylinders produce compressed air to operate the oil spray. This unit uses liquid butane as a fuel, and has a capacity of 20-25 gal. oil per hour. It produces large quantities of white smoke. Small particle size is indicated by the marked red scattering of sunlight and by the violet color of the sun viewed directly through the smoke. Operated on a cold sunny day with about a 6 m.p.hr. wind it gave a dense smoke which persisted for about 0.5 miles downwind and a marked haze for over one mile. Very approximately, the area screened in this daylight test was perhaps 35000 sq. yds.

The device just described is similar in principle to the Williams unit described below, and the Williams unit has one advantage in that the same oil is employed for fuel and for smoke. Since the C.W.S. has emphasized the advantages of large numbers of smaller units without power, the Servel Co. is now concentrating their efforts on improving the design of small unit to be employed in the same way as are the Tweedales and M-1's.

The Williams unit is illustrated diagrammatically in Fig. 8. It consists of two domestic oil burner pumps and two oil burner nozzles of standard design. Oil is burned at one end of the large cylinder, the gases are cooled by admixture with air, and the mixed gases at 800°F. used to vaporize oil issuing from a second nozzle placed ahead of a refractory shield. Air is supplied to the first burner and to the hot gases by a small fan. The two oil pumps and the fan are on a common shaft driven by a 1.0 h.p. Briggs and Stratton utility gasoline engine. The capacity is about 20 g.p.hr. and the oil burned is only about 15% of the total.

Although the various units have not been compared by operating them simultaneously, it would appear that the performance (per unit of oil consumed) is about the same for the G.E., the Servel, and the Williams generators. In each case the smoke is white and apparently of sufficiently small particle size. Those who have viewed these units and the M-1 generator agree that the three units described produce several times as much smoke per gallon of oil as does the M-1. It is hoped that this guess may be checked by comparative tests in the near future.

Although no data exist, it would appear that the M-1 operates with perhaps 20% or less vaporization of the oil and upwards of 80% combustion. Some carbon is produced but this is probably small in actual amount. Improvement in performance of the M-1 should be possible if the per cent vaporization could be increased, and it appears that this might be possible. The rate of combustion is determined by the air admitted, since the stack gases leave with an insufficiency of oxygen. The vaporization rate, on the other hand, is determined by the rate of heat transfer to the oil pool principally by radiation from the hot metal above and by radiation from the luminous flame. It should be possible to increase the heat transfer by using a shallower gas passage and metal conductors to carry heat into the liquid oil. Furthermore, it would appear that some oil refluxes down the walls of the stack, and that this might be avoided by using proper stack insulation. This correction would also tend to eliminate the excessive soot deposited on the inside of the stack by thermal diffusion.

## Estimate of Oil Consumption for Typical Industrial Screening Project

No data are available which may be employed as a basis for estimating oil requirements with any assurance. British reports give values of $N_o$ of 1000 to 4000 for the Tweedales under field conditions, but it is not clear whether these refer to the daylight ground tests or to moonlight requirements and viewing from aircraft. For illustrative purposes, consider smoke to be released on a one-mile front with a 10 m.p.h. wind, and assume $N_o$ to be 2500. Using 30% excess smoke (B = 1.3), the required oil rate is

$$10 \times 1.3 \times 1610 \times 1610 \frac{\times 2.5}{454} = 185{,}000 \text{ lbs. per hour}$$

or about 28000 gal. p. hour. The area screened would be parhaps 4 sq. miles (see Fig.4). Using Langmuir's value for optimum particle size the rate would be reduced to 5600 g.p.h. If moonlight screening permits values of $N_o$ as low as 5% of the assumed daylight value of 2500, then the oil rate would be 1400 g.p.h. It is evident that no reasonable estimate of oil rates can be made until considerable field test data have been colected and analyzed.

In any case, it is evident that the cost of oil smoke screening will not be low, though it is clearly cheaper than the use of the less available chemical smokes.

## Conclusions

1. A promising oil smoke generator handling 20-25 g.p.h. oil has been developed. This is suitable for mass production, and involves only the assembly of parts now made in quantity or easily constructed.

2. The attention of the section should now be directed to the development of simple small units not requiring power.

3. Data on field tests with large numbers of generators are urgently needed as a basis for the calculation of oil rates for typical screening projects.

## APPENDIX

### List of British Reports Available

1. Porton Report 1400 (Sept. 9, 1935.)
Summary of basic principles of the use of smoke screens, with comparative values of $N_0$ for standard smokes.

2. Porton Report 1491 (Feb. 14, 1936).
Wind tunnel nephelometer tests of smokes from generators using chemical smokes.

3. Porton Report 1520 (April 3, 1936).
Comparison of optical density measurements with screening lengths for chemical smoke generators.

4. Porton Report 1521. (April 3, 1936).
Functioning characteristics of Generator No. 5 Mk. I (zinc-calcium silicide), as measured in the wind tunnel.

5. Porton Report 2190 (March 8, 1941).
Effect of various modifications in the design of the Tweedale oil smoke generator.

6. Porton Report 2239. (July 15, 1941).
Daylight tests comparing the Tweedale with the M.H.S. Mk.I oil smoke generators.

7. Military Attache (London) Report 42124. The methods of use of Tweedale and the large Haslar generators, with a drawing of the former and photographs of both types in operation.

**List of NDRC Investigations Relating to Screening Smokes**

V. K. LaMer, Columbia University, New York City.

E. P. Stevenson, A. D. Little, Inc., Cambridge, Mass.

I. Langmuir, General Electric Co., Schenectady, N. Y.

W. G. Brown, University of Chicago, Chicago, Ill.

G. G. Brown, University of Michigan, Ann Arbor, Michigan.

W. R. Hainsworth, Servel, Inc., Evansville, Indiana.

A. R. Olson, University of California, Berkeley, California.

Games Slayter, Slayter Electronics Corp., Newark, Ohio.

W. A. Matheson, Williams Oil-O-Matic Heating Corp., Bloomington, Ill.

SECRET

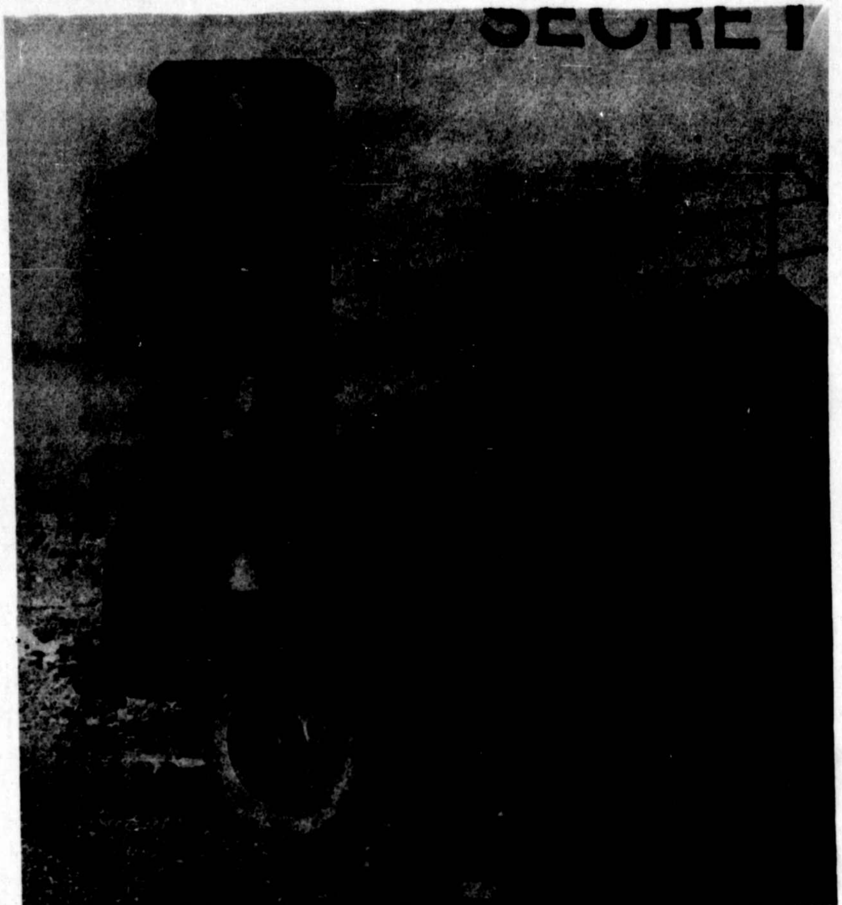


Fig. 2.

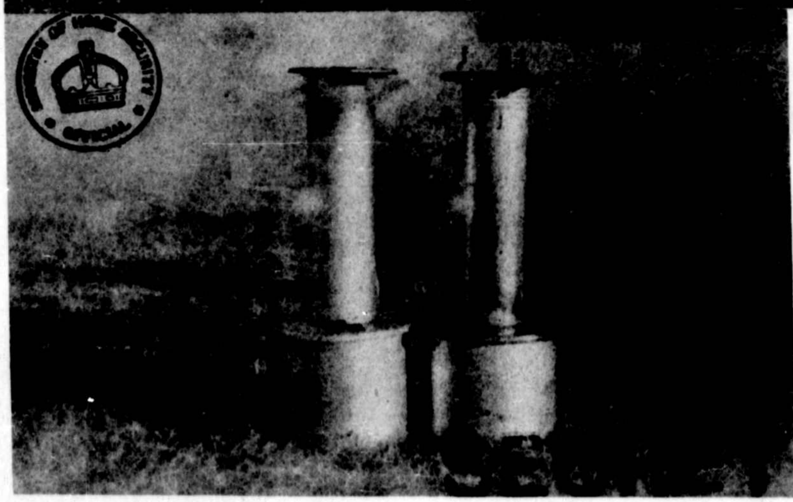
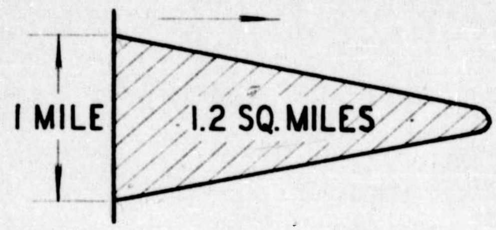


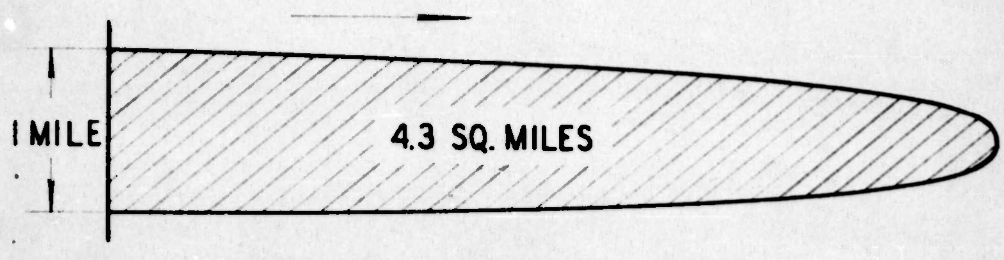

Fig. 1.

FIG. 3




B= 1.03

FIG. 4

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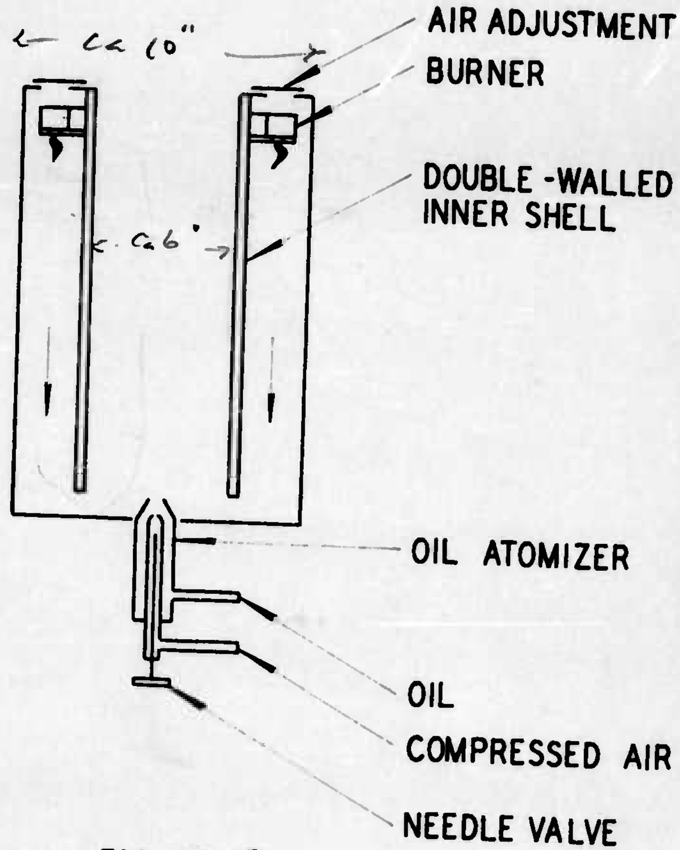


FIG. 5

SERVEL UNIT NO. 7

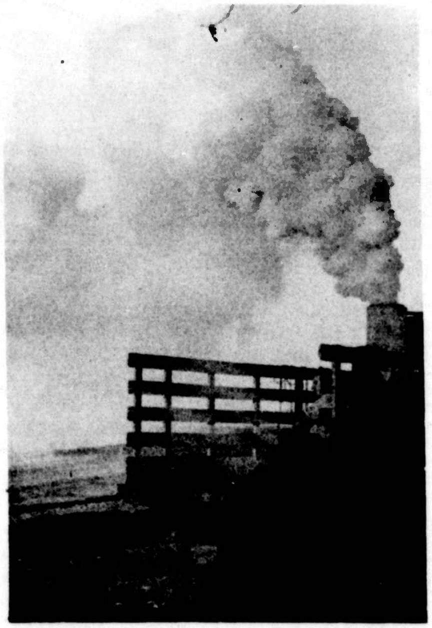

Fig. 6.

Fig. 7 - Servel Unit

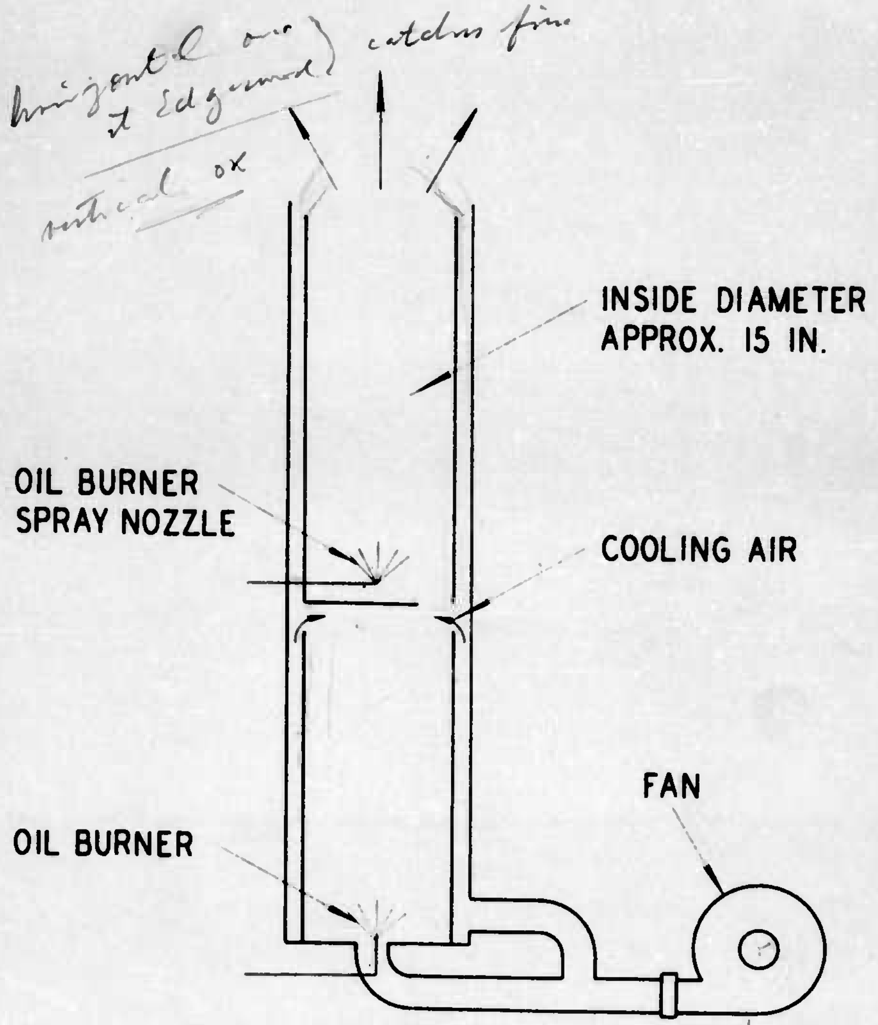


FIG. 18
WILLIAMS UNIT
(FAN AND TWO OIL PUMPS OPERATED ON
ONE SHAFT DRIVEN BY 1 H.P. GASOLINE MOTOR)

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A.T.I.

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(23) & Smoke Screens

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AUTHOR(S): (Not known)
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| DATE | DOC. CLASS. | COUNTRY | LANGUAGE | PAGES | ILLUSTRATIONS |
|---|---|---|---|---|---|
| March '42 | Unclass. | U.S. | Eng. | 20 | photos, tables, diagrs |


ABSTRACT:

Screening smokes were investigated with the aim of developing methods of protecting industrial and military objectives against aircraft by use of large quantities of smoke or fog. Water or aqueous solution mechanical atomizers, operating at a pressure of 6000 psi for fog and smoke generating devices using oil, have been developed. The results obtained with oil smoke generating devices appear to be definitely more promising than results so far obtained with aqueous solutions or solid smokes. The operational cost of oil smoke screening devices is much less than that of chemical smokes.


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