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Addendum 1 to
Porton Technical Paper No. 336

Copy No. 92

Date= 3 FEB 1954

The Performance Testing of the E19R1 Mechanical Smoke Generator

by

K. Sinclair and R.B.E. Stubbs

SUMMARY

Details of the tests of efficiency of the E19R1 Mechanical Smoke Generator as compared with the Generator, Smoke, Mechanical, M.1. for use viewed horizontally, are reported in P.T.P. 336. Trials carried out determine the relative efficiency of the E19R1 Generator when the smoke produced are viewed from the air, show that the E19R1 Generator using G.P. Fog Oil gives a screen which is about 67% of that given by the M.1. Generator using the same amount of Fog Oil, and that the ratio falls to about 56% if Pool Diesel Oil is employed in the E19R1 Generator.

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Supt., Development Division.

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Addendum 1 to
Porton Technical Paper No. 336

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Date. 3 FEB 1954

The Performance Testing of the E19R1 Mechanical Smoke Generator

by

K. Sinclair and R.B.E. Stubbs

I. Introduction

Details of the horizontal screening lengths produced by the American E19R1 Mechanical Smoke Generator and of the efficiency of this generator when compared with the Generator, Smoke, Mechanical M.1, are reported in P.T.P. 336. The results of trials carried out to determine the relative efficiency and the length of the screens produced by the E19R1 Generator, when such screens are viewed from the air, are reported herein.

II Procedure

Four trials were carried out with each of the following smoke-producing oils:-

(a) General Purpose Fog Oil (to C.S. 2809A)

(b) Pool Diesel Oil (Pool 21, Diesel Fuel, 45 Cetane)

In all tests the M.1 Generator was operated on General Purpose Fog Oil, its output being adjusted (as far as possible) so that the screens produced by both generators were of a comparable length. For each smoke emission the generators were functioned simultaneously for a period of 45 minutes over the layout shown in Fig. 1. Observations on the lengths of the screens were made from a helicopter flying at a height of about 1000 feet, between 20 and 30, observations being made during each emission. Trials 1A,3A,4A and 8A were observed by one observer (DJH) and the remaining four trials by a second observer (GEL)

III. Mechanical Performance

The E19R1 Generator performed satisfactorily throughout the tests, with the exception of petal valve failures at the commencement and termination of Test No. 1A. The performance of the M.1 Generator was satisfactory for Tests Nos. 1A to 6A. During Tests Nos. 7A and 8A, however, the efficiency of the M.1. Generator fell to 78%*, due to an accumulation of rust and disintegrated lagging in the furnace chamber, which only became apparent when the Generator was examined at the conclusion of Test. No. 8A.

---

* The screening length reduced to standard conditions was found to have fallen from 550 yards to 430 yards.

IV. Results

Details of the smoke-oil used, the rate of consumption of oil, the relevant meteorological observations and the length of the screen produced in each test, are recorded in Appendix A.

Deacon has shown in PR 2734, para. 56, that for white oil smokes over land the horizontal screening length, SL, is given by the expression,

$$SL \propto (Q)^{0.6} \; u^{-0.6} \; (R-1)^{4.0} \; d^{0.4}$$

where
- Q = source strength
- u = 2 metre wind speed
- R = ratio of 2 metre to 1 metre wind speed.
- d = distance of smoke from the observer

The formula used for reducing the vertical screening length to standard conditions in this series of trials was

$$SL \propto (Q)^{0.6} \; u^{-0.6} \; (R-1)^{4.0}$$

since from a study of the screening lengths produced by the M.1. (G.P. Fog Oil in every case) this formula gave a better measure of agreement than other values of the indices. It will be observed that this formula is identical with that used for the horizontal assessments except that no correction is made for "d", the viewing distance.

For trials with G.P. Fog Oil in both Generators the standard screening lengths SL_s, have been calculated for Q_s = 4.7 lb/min. (the mean consumption rate of oil in the E19R1 Generator for trials 1A,6A,7A and 8A). For trials with Diesel Oil in the E19R1 Generator and G.P. Fog Oil in the M.1. Generator, a Q_s = 5.8 lb./min. (the mean consumption rate of oil in the E19R1 Generator for trials 2A,3A,4 A and 5A) has been used. The other standards used throughout the calculations were:- u_s = 10 m.p.h., and R_s = 1.14. The value of R in all cases has been calculated from the 2 metre wind speed and the 23 ft - 4 ft temperature gradient (P.R. 2572 and P.R. 2717) The standard screening lengths and relative efficiencies, so calculated, are recorded in Appendix A.

V. Discussion.

In terms of the standard screening lengths the resultsfor the M.1. are fairly consistent for each observer: but from a comparison of the results for the two observers, the screening length assessments are in the ratio of about 2:1. While this is no doubt due to a difference in eyesight or standard of vision the fact that no method of standardising observers for aerial viewing has yet been found possible, precludes adjustment of the results by means of a correction factor.

When the E19R1 Generator is considered the variation in results from one trial to another with the same oil and even with the same observer is disturbingly large. No explanation can be given for this (the Generator appeared to function normally throughout the tests) and the best that can be done is to report the average of the results for each oil.

In addition, and in order that the performance of the E19R1 Generator may be compared directly with that of the Apparatus, Oil Smoke, No.3,Mk 1, the relevant figures for efficiency when each Generator is compared with the Generator, Smoke, Mechanical, M.1, have been brought together in Table 1.

Table 1

Screening Efficiencies of the E19R1 and A.C.S. No. 3 Generators when compared (vertical viewing) with the M.1. Generator.

SMOKE OIL USED	SCREENING EFFICIENCY (%)	
	E19R1	A.C.S. No 3
G.P. FOG OIL	67	77
POOL DIESEL OIL	56	49

VI Conclusion

It is concluded from the results that the E19R1 Generator using G.P. Fog Oil gives a screen which is about 67% of that given by the M.1. Generator using the same amount of G.P. Fog Oil and that the ratio falls to about 56% if Pool Diesel Oil is employed in the E19R1 Generator.

VII Acknowledgement

The assistance afforded by J.I.P. Jones of the Meteorological Section is gratefully acknowledged.

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Appendix A

Results of the Screening Efficiency Tests (vertical viewing) performed on the E19R1 Mechanical Smoke Generator

Trial No.	Date	Zero (G.M.T.)	Generator	S.G. of Oil used at 60°F	Output (lb./min.)	Screening Length (yd.)	Wind Speed (m.p.h.)	Temperature Gradient (23'-4') (°F)	Ratio of 2 metre wind / 1 metre wind	Standard Screening Length (yd.)	SL_s. E19R1 / SL_s. M.1 (%)	Observer
G.P.Fog Oil in both Generators (Q_s = 4.7)					Q	SL	U_{2m}		R	SL_s		
1A	4.4.52	11.16	E19R1	0.932	4.5	150	9.0	-1.2	1.127	210	51	DJH
			M.1	0.932	3.6	260	9.0	-1.2	1.127			DJH
6A	16.10.52	14.29	E19R1	0.930	5.3	175	7.9	+0.2	1.147	120	63	GEL
			M.1	0.930	6.0	310	7.9	+0.2	1.147	190		GEL
7A	28. 1.53	14.44	E19R1	0.930	4.6	240	9.7	0.0	1.142	220	69	GEL
			M.1	0.930	5.6	295	9.7	0.0	1.142	320*		GEL
8A	24. 2.53	15.12	E19R1	0.930	4.5	455	9.2	-0.3	1.138	470	85	DJH
			M.1	0.930	5.0	440	9.2	-0.3	1.138	550*		DJH

*Corrected to 100% efficiency - see Section III.

Appendix A. (contd.)

Diesel Oil in E19R1: C.P.Fog Oil in M.1 (Qs = 5.8)												
2A	7. 7.52	10.25	E19R1	0.857	6.3	90	17.4	-1.5	1.134	140	64	GEL
			M.1	0.932	6.4	140	17.4	-1.5	1.134	220		GEL
3A	15. 9.52	14.32	E19R1	0.837	5.5	105	15.6	-0.6	1.137	160	31	DJH
			M.1	0.932	6.3	380	15.6	-0.6	1.137	510		DJH
4A	2.10.52	10.59	E19R1	0.852	5.7	350	12.7	-0.1	1.141	400	73	DJH
			M.1	0.930	5.9	500	12.7	-0.1	1.141	550		DJH
5A	16.10.52	13.30	E19R1	0.852	6.2	160	6.7	-0.1	1.142	120	55	GEL
			M.1	0.930	5.9	300	6.7	-0.1	1.142	220		GEL

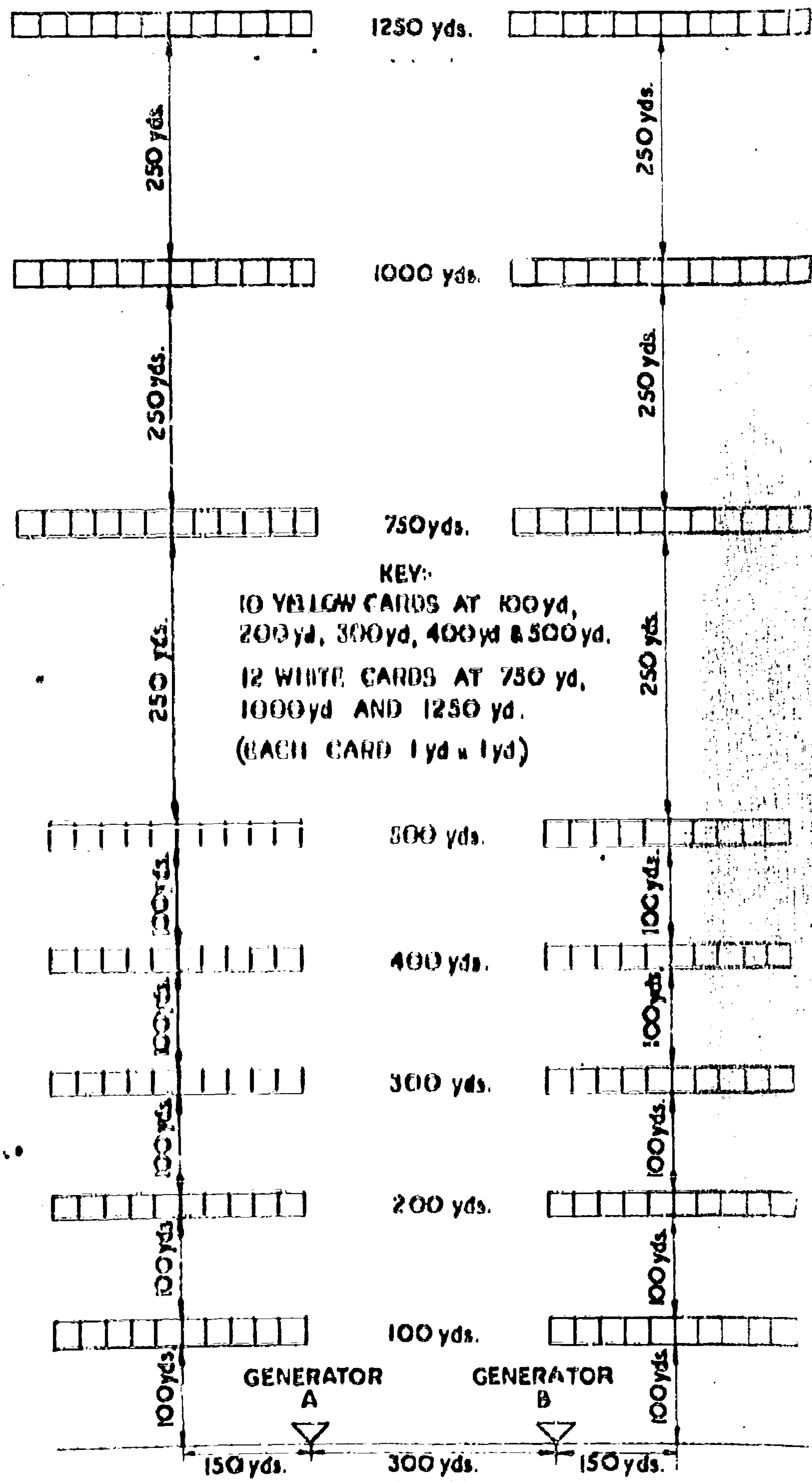

FIG.I. LAYOUT.

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The Performance Testing of the E.19R1 Mechanical Smoke Generator

by

K. Sinclair and R.D.E. Stubbs

SUMMARY

The performance of the American E.19R1 Mechanical Smoke Generator has been assessed, with a view to determining to what degree it meets the War Office User Requirement for a mechanical oil smoke generator.

From the results of the trials carried out it may be concluded that the Generator fails to meet the War Office User Requirement in a number of important respects. It has failed to withstand both the mechanical performance and climatic cycle tests to which it has been submitted, and the screens produced when employing either General Purpose Fog Oil or Pool Diesel Oil are inferior in length to those produced by both the Generator Smoke Mechanical M.2 and the Apparatus Oil Smoke No.3, Mk.1.

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KS/RDES/PMF.

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PORTON TECHNICAL PAPER NO. 336
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The Performance Testing of the E.19R1 Mechanical Smoke Generator

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K. Sinclair and R.B.E. Stubbs

I. Introduction

In response to a request from the War Office the E.19R1 Mechanical Smoke Generator, an American equipment operating on the pulse jet principle has been subjected to tests with the object of determining to what degree its performance meets the War Office User Requirement for a mechanical oil smoke generator.

The results of the tests, which were designed to ascertain the operational, functional and mechanical reliability of the Generator and its efficiency as a smoke-producing unit, are reported herein.

II. Description and Mode of Operation

The E.19R1 unit is a pulse jet smoke generator, which is designed to operate at variable smoke outputs from 25-50 U.S. gal/hr. Its empty weight is approximately 137 lb., and its dimensions are length, 40", height, 23" and width, 16.5".

The complete unit is illustrated in Figs. 1, 2 and 3.

The unit consists of a petrol tank, pulse jet engine and exhaust assembly, ignition assembly, smoke oil assembly and air pump. The petrol tank, which has a capacity of 3½ U.S. gal., is mounted within a welded tubular frame (Fig.4). The engine and exhaust assembly are encased in an insulated cylindrical shell which is mounted below the petrol tank (Fig.5). This assembly comprises a combustion chamber and exhaust tube (Fig.6), and engine head unit (Fig.7). The ignition system consists of a foot operated switch, two 6-volt dry batteries and a coil and spark plug assembly.

To start the pulse jet engine a mixture of petrol (gravity fed from the petrol tank) and air (provided by the hand operated air pump) is injected into the combustion chamber and ignited by means of a spark.

The pressure developed by the subsequent explosion keeps the intake valve closed and causes the hot gases to seek escape via the exhaust tube. As the gases move toward the exhaust tube opening and away from the petals on the intake valve, the pressure is lowered and the petals are drawn open. A partial vacuum is developed near the petals, which induces atmospheric air to flow through the venturi on the engine head and over the flow ejector. As the air passes over the flow ejector, it draws another charge of petrol into the combustion chamber and a further explosion takes place. The igniting spark is required only for the initial explosion, succeeding charges being set off by the rolling or propagating of flame back and forth in the combustion chamber. The cycle or frequency of explosions is sixty per second. To stop the Generator it is first necessary to cut-off the oil supply and to allow the engine to race until smoke emission ceases. At this point the engine is stopped by momentarily squeezing the petrol supply pipe between the flow ejector and the engine head.

The smoke oil assembly consists of a quick-opening oil valve, oil flow needle valve, oil filter and hose, automatic shut-off valve and drum dip pipe. The dip pipe, to the outlet end of which a quick - opening oil valve is fitted, makes an air-tight connection when screwed into the smoke oil drum. A connecting tube between the top of the oil drum and the combustion chamber, ensures, once the engine has started, that the drum becomes pressurized to a gas pressure of about 10 lb./sq.in. The rate of flow of the smoke oil is regulated by a needle valve. In addition to this valve there are, in the smoke oil line, a quick-opening gate valve and an automatic shut-off valve, the latter closing when the engine stops. The automatic shut-off valve is of the pressure actuated diaphragm type. When operation ceases the pressure in the oil drum, being greater than the pressure in the combustion chamber, causes this valve to close automatically.

On being injected into the exhaust tube, the smoke oil is immediately vapourised by the heat from the combustion chamber. The vapour so produced then passes through the discharge manifold into the air, expands, gives up heat and finally condenses as minute droplets of oil. An example of the smoke cloud produced by the generator is illustrated in Fig.8.

III. Generators employed in the tests

Five E.19R1 Mechanical Smoke Generators, Serial Nos. 10, 41, 42, 43 and 44, were made available for the tests.

IV. Operational, Functional and Mechanical Performance Tests

The following tests have been carried out on one or other of the generators referred to in Section III.

A. Preliminary functioning test.

B. 100-hr. continuous functioning test.

C. Accelerated mechanical strength test.

D. Accelerated climatic cycle test.

A. Preliminary Functioning Test

The objects of this test were threefold:-

1. to provide the British operators with an opportunity of making themselves familiar with the layout of the E.19R1 Generator,

2. to enable the British operators to acquire the technique necessary to ensure operation of the generator at maximum efficiency, and

3. to determine the operational reliability of the generator when alternative smoke-producing oils are employed.

The test, which was performed on Generator Serial No.10, took the form of a period of 37 hours of discontinuous functioning during which, either General Purpose Fog Oil or Diesel Oil, was employed as the smoke-producing agent. A record of the occurrence and frequency of mechanical failures, the measures adopted to overcome these failures and the suggestions made for improvement in both the component parts of the generator and the tools provided for use with it, was maintained through the test. This record is reproduced in Appendix A.

The British operators found the Generator comparatively simple to operate at maximum efficiency and there would appear to be no reason why British troops who have been trained to operate the Apparatus, Oil Smoke, No.3, Mk.1, should not be able to operate the E.19R1 Generator, after a short period of instruction. The time from a cold start to emission of smoke was found, under good conditions (i.e. full drum of smoke oil of low viscosity) to be less than one minute. It was ascertained also that smoke production could be terminated within 20 seconds and restarted without any apparent effect on the generator. When set to maximum output the Generator functioned automatically until such time as the drum of smoke oil became empty. It will be appreciated that, due to the layout of the smoke oil feed system, it is necessary to shut the Generator down while the dip pipe and pressure line are transferred from the empty to the full drum. During the test it was observed that, on some occasions when the generator was closed down after a period of operation, flames appeared at the emission nozzles.

The Generator performed satisfactorily on both General Purpose Fog Oil and Pool Diesel Oil, the mean rates of consumption at the maximum setting being as follows:-

General Purpose Fog Oil	30 Imperial gal./hr.
Pool Diesel Oil	41 Imperial gal./hr.

Since the viscosity of G.P. Fog Oil at 60°F. is 1,112 Redwood Seconds and that of Pool Diesel Oil 42 Redwood Seconds, the low throughput recorded when the former oil is employed as the smoke-producing agent, is undoubtedly due to its more viscous nature. The mean consumption of petrol during the test was 2½ Imperial gal./hr. An attempt to employ Pool Fuel Oil as the smoke-producing agent failed completely. In the first test the resistance offered by the oil filter to the oil flow was such that the rate of consumption fell to a very low level. For the second test, therefore, the oil filter was by-passed. Even this test had to be abandoned after a short period, however, owing to the excessive amount of carbon deposited in the exhaust tube and the emission nozzles.

TABLE 1.

Results of the "Bump" Test (13.8.52)

Time From Zero min.	Results
Zero	Test commenced.
Z + 5	Flow meter became loose in its case (Fig. 20).
Z + 8	Pressure gauge needle dropped off its pivot (Fig.21).
Z + 13	Petrol tank sustained a fracture (Fig. 22) and contents drained out.
Z + ? (Stop watch failed).	Petrol pipe connection to float chamber broke off at the coupling (Fig. 23).
Z + 20	Test completed.

Since, owing to the failure of the petrol supply, it was not possible to function the Generator at the end of the test, it was dismantled and submitted to a thorough examination which revealed the following faults:-

1. The float bowl assembly had worked loose.

2. The flexible petrol pipe had developed a fracture.

3. The glasswool constituting the lining had settled into the lower portion of the shell (Fig. 24).

The loosening of the flow-meter in its case (see Table 1) could be readily overcome, by cementing the retaining screws in position.

D. Accelerated Climatic Cycle Test

The test, which was performed on Generator, Serial No. 44, consisted of submitting the unit to the following tests:-

(i) Visual Inspection and Performance.

(ii) Dry Heat (first test).

(iii) Damp Heat (first test).

(iv) Low Temperature.

(v) Damp Heat (second test).

(vi) Dry Heat (second test).

(vii) Damp Heat (third test).

(viii) Visual Inspection and Performance.

(ix) "Driving Rain" Test.

Owing to restrictions on the use of the climatic chambers available, it was not possible to make smoke during the exposure, and tests were confined to operation of the engine only, for short periods.

(i) Visual Inspection and Performance Test

In this test the Generator, following a visual inspection, was operated for ten minutes. The result was satisfactory and the unit appeared to be in normal running order.

(ii) Dry Heat (first test)

The Generator was stored in a Hot Chamber at a temperature of 55°C. ± 1°C. (131°F.) for a period of eight hours.

The engine was operated for three periods of three minutes each.

Operation on each occasion was satisfactory with the exception that engine pulsations were somewhat unsteady. It was also observed that during these brief periods of operation, a blue flame played round the petrol inlet to the engine head.

(iii) Damp Heat (first test)

The Generator was stored in a Hot Chamber, at a temperature of 40°C. ± 1°C. (104°F.) and a relative humidity of at least 95%, for a period of twelve hours. During this time the engine was operated for three periods of three minutes each. During the first period, which followed the charging of the petrol tank with petrol at normal temperature, the engine function satisfactorily. During the second and third periods of operation, however, when the petrol had reached the ambient temperature of the chamber, the uneven pulsation of the engine again became evident.

(iv) Low Temperature Test

As soon as Test (iii) had been completed the Generator was placed in a Cold Chamber, at a temperature of -40°C. ± 1°C.(-40°F.) for a period of twelve hours. During the exposure the engine was operated for three periods each of three minutes duration. At the first attempt the Generator failed to start for the following reasons:-

(a) The "snap-on" air connector would not clip on to its male connection.

(b) The batteries registered a voltage of only 3 volts.

(c) Ice collected on the earth button at the base of the "Stan-Test" coil, thus insulating this component from the frame.

In addition, the petrol, oil and air pipes had become hard and stiff. The petrol pipe, which is made of plastic material, had hardened to such an extent that it could not be removed from the petrol jet.

With regard to (c) above it should be pointed out that removal of the Generator from the damp atmosphere of the Hot Chamber directly into the Cold Chamber, may have given rise to conditions favouring the formation of ice on the earth button at the base of the "Stan-Test" coil.

After the old batteries had been replaced by new ones (an operation made difficult by virtue of the hardening of the plastic covered cables) the ice broken away from the earth button and a supply of warm air was made available in the region of the engine head. The engine of the Generator was then operated for three minutes during which period it functioned satisfactorily. It could only be stopped, however, by closing the petrol cock. During the second and third periods of operation, for both of which a supply of warm air to vapourise the petrol was made available, the engine functioned normally.

(v) Damp Heat (second test)

On the completion of Test No.4 the petrol was drained from the petrol tank and the Generator was returned to the Damp Heat Chamber for a period of 12 hours. The tank was then charged with petrol at normal temperature and the engine was functioned for a period of three minutes. An attempt to repeat this test failed and it was found necessary to remove the engine head and replace it by a new head before functioning could be recommenced. A photograph of the faulty head is reproduced in Figure 25. Following the fitting of the new head three, three minute periods of operation were carried out, during which uneven pulsation of the engine was again evident.

(vi) Dry Heat (second test)

Repeat of Test No.2. The first three minute period of operation, during which petrol at normal temperature was used, was satisfactory. Further attempts to run the engine, failed, however, in that the engine would start and then stop. Since this was presumed to be due to the fact that by this time the petrol had reached the ambient temperature of the chamber, the generator was removed from the chamber, allowed to cool down and operate in the open air. Operation, under these conditions, was completely satisfactory.

(vii) Damp Heat (third test)

Repeat of Test No. 5. The first three minute period of operation, using petrol at normal temperature, was satisfactory. At the commencement of the second period, however, when the temperature of the petrol had reached the ambient temperature of the chamber, the engine fired back through the head and the petrol vapour from the float chamber vent caught fire. Before

the flames could be extinguished the leads to the flowmeter had ignited. Further attempts to run the engine failed, in that the engine would start and then stop immediately afterwards.

(viii) Visual Inspection and Performance

At the completion of Test No.7 the Generator was returned to the Dry Heat Chamber for a period sufficient to ensure that the machine would be thoroughly dried out. A visual inspection of the component parts of the unit was then made and the machine was operated in the open for a period of ten minutes. No fault could be found and the Generator operated satisfactorily. A photograph of the Generator as it appeared at the completion of tests (i) to (viii) is reproduced in Fig.26.

(ix) "Driving Rain" Test

The Generator was placed in a chamber fitted with eight water sprays arranged to simulate the effect of "driving rain". The machine was subjected to the test for 1 hour. Throughout this period the Generator was continuously rotated (at between 12 and 20 r.p.m.) about a vertical axis passing through the centre of the equipment and the centre of the chamber. At the end of the exposure period an attempt was made to operate the engine while still subjected to the "driving rain". Although the engine started satisfactorily it stopped again almost immediately. Since this was thought to be due to water entering the emission nozzles the "driving rain" playing on the emission nozzles was turned off and a further attempt was made to start the engine. Although the engine started readily it stopped again within one minute owing to water having percolated through the engine head cover.

V. Screening Efficiency Trials

1. Object

The object of the trials was to determine the relative efficiency of the E.19R1 Generator, as a smoke-producing unit, when compared with the Generator, Smoke, Mechanical M.1 (the "Esso").

2. Procedure

A number of trials were carried out with each of the following smoke-producing oils:-

(a) General Purpose Fog Oil (to C.S.2809A).

(b) Pool, Diesel Oil (Pool 21, Diesel Fuel, 45 Cetane).

In all tests the M.1 Generator was operated on General Purpose Fog Oil, its output being adjusted (as far as possible) so that the screens produced by both generators were of a comparable length. For each smoke emission, screening lengths were measured at half minute intervals over a period of about half an hour. Screen heights were measured by theodolite at two minute intervals. The observation points were at flank positions estimated to be about 1000 yards from the end of the screen and so placed that the end of the screen was viewed as near to the perpendicular as possible.

Ten trials were attempted between 18.2.52 and 12.10.52 of which eight were successful (trials 2 and 3 and 5 to 10). The screening lengths used in the results were all measured by the same observer and, except for trials 3 and 7, were all viewed from high ground against a fairly level background. Trials 3 and 7 were viewed from low ground against rising background. Wind speeds and directions at 2 metres were measured near the source of emission: the temperature gradients were obtained from the records at the Meteorological Station in C.D.E.E. During each emission the temperature of the smoke oil used in the E.19R1 was measured and recorded. These temperatures together with the corresponding oil viscosities are shewn in Appendix C.

3. General Observations

The significant points arising during individual trials are noted below: absence of comment indicates satisfactory functioning and satisfactory assessment of screening lengths.

Trial 1. The E.19R1 gave an above average screening length under good meteorological conditions. The M.1 developed a number of minor mechanical faults and as a result the screen produced was abnormal.

Trial 2. Rather large variations in screening lengths were observed throughout the trial, especially with the M.1. The wind was on the light side for good assessment.

Trial 4. In this trial there were large differences between the observer and the screen for the two screens and both screens were observed obliquely. The assessment was not included in the results.

Trial 6. Screen heights were above average due to the wind being lighter and the lapse stronger than normal for the series.

4. Results

Details of the lengths and heights of the screens produced, the smoke oil used, the rate of consumption of oil and the relevant Meteorological observations are given in Appendix D.

(a) Horizontal Screening Lengths

Deacon has shown in P.R.2734, para. 56, that for white oil smokes over land, the screening length, S.L. is given by the expression

$$SL \propto (Q)^{0.6}\ U^{-0.6}\ (R-1)^{4.0}\ d^{0.4}$$

where Q = source strength in lb./min.

U = 2 metre wind speed in m.p.h.

R = ratio of 2 metre to 1 metre wind speed.

d = distance of smoke from observer in yards.

For trials with G.P. Fog Oil in both generators the standard screening lengths SL_s, have been calculated for $Q_s = 4.7$ (the mean consumption rate of oil in the E.19R1 for trials 1 to 6). For trials with diesel oil in the E.19R1 and G.P. Fog Oil in the M.1, a Q_s of 5.8 (the mean consumption rate of oil in the E.19R1 for trials 7 to 10) has been used. The other standards used throughout in the calculations were:- $U_s = 10$; $R_s = 1.14$, and $d_s = 1000$.

The value of R in all cases has been calculated from the 2 metre wind speed and the 23 ft. - 4 ft. temperature gradient (P.R. 2572 and P.R. 2717).

(i) Standard Screening Lengths for the E.19R1 and M.2 operating on G.P. Fog Oil.

From five trials (1, 2, 3, 5 and 6) the mean SL_s for the E.19R1 at $Q_s = 4.7$ is 370 yards and from four trials (2, 3, 5 and 6) the mean SL_s for the M.1 for the same Q_s is 490 yards. Thus the efficiency of the E.19R1 relative to the M.1., both using G.P. Fog Oil is about 76%.

(ii) Standard Screening Lengths for the E.19R1 and M.2 operating on Pool Diesel Oil and G.P. Fog Oil, respectively.

From four trials (7 to 10) the mean SL_s for the E.19R1 is 270 yards and for the M.1 520 yards, both at $Q_s = 5.8$. Thus the efficiency of the E.19R1 using Pool Diesel Oil relative to the M.1 using G.P. Fog Oil, is about 52%.

[The mean SL_s for the M.1 for all trials included in the results, reduced to $Q_s = 15$ is 960 yards, a figure which is in agreement with that found in the comparative trials of the Apparatus, Oil Smoke, No.3, Mk.1 reported in P.T.P. No.232. In the latter trials the mean SL_s for the M.1 at $Q_s = 15$ was given as 940 yards.]

(b) Heights of Screens

Height measurements at estimated mid-points of the observed screens were made by theodolite from the observing positions. From these measurements and using Fig.11 of Monograph 9.208, the estimated heights at 100 yards and 200 yards have been calculated and recorded in Appendix D. The figures for the estimated heights at 100 yards from the source are not as reliable, except for trials 2 and 7, as those for 200 yards. The heights have not been standardised for output and meteorological conditions and the higher mean heights of series (i) below compared with series (ii) may be accounted for mainly by the generally higher winds in series (ii).

(i) Screen Heights for the E.19R1 and the M.1 operating on G.P. Fog Oil.

From the mean of trials 2, 3, 5 and 6 the height of the E.19R1 screen at a distance of 200 yards from the source is 48 ft. compared with 60 ft. for the M.1.

(ii) Screen Heights for the E.19R1 and the M.1 operating on Pool Diesel Oil and G.P. Fog Oil, respectively.

The mean height of the E.19R1 screen at a distance of 200 yards from the source is 34 ft. compared with 42 ft. for the M.1 generator.

5. Discussion

It will be appreciated from an examination of the measurements recorded in Appendix C that the difference in the mean throughputs when G.P. Fog Oil and Pool Diesel Oil are employed, is largely due to the more viscous nature of the former oil.

In order that the performance of the E.19R1 Generator may be compared directly with that of the Generator, Smoke, Mechanical, M.2 (Besler 50 U.S. gal.) and the Apparatus, Oil Smoke, No.3, Mk.1, the relevant figures for the screening lengths produced under standard conditions by each generator, have been brought together in Table 2.

TABLE 2.

Horizontal Screening Lengths produced, under standard conditions, by the M.2., E.19R1 and A.O.S. No.3, Mechanical Smoke Generators.

Smoke Oil used	Horizontal Screening Length yd.		
	M.2	E.19R1	A.O.S.No.3
G.P. Fog Oil	580	370	780
Pool Diesel Oil	*	270	400

* No reliable figure available.

6. Further Trials

Trials to determine the length of the screens produced by the E.19R1 when such screens are viewed vertically, are in hand. The results of these trials, when available, will be reported as an addendum to the present report.

VI. Performance of the E.19R1 in relation to the War Office User Requirement

An appraisal of the degree to which the performance of the E.19R1 Generator meets the War Office User Requirement for a mechanical oil smoke generator, is given in Appendix E.

VII. Conclusions

It is concluded from the results that the E.19R1 Generator fails to meet the War Office User Requirement for a mechanical oil smoke generator in a number of important respects. It has failed to withstand both the mechanical performance and climatic cycle tests to which it has been submitted and the screens produced when employing either General Purpose Fog Oil or Pool Diesel Oil are inferior in length to those produced by both the Generator, Smoke, Mechanical, M.2 and the Apparatus, Oil Smoke, No.3, Mk.1.

VIII. Acknowledgements

The assistance afforded by the staff of the Signals Research and Development Establishment, Christchurch and the Meteorological Section, C.D.E.E., is gratefully acknowledged.

(Sgd.) S.H. Fryer.,
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APPENDIX A.

Preliminary Functioning Test - Record Sheet

1. During the test three petal valves failed after working periods of 30 hours, 4 hours and $\frac{3}{4}$ hours, respectively.

2. The joint on the flow ejector, at that point where the air connection joins the petrol metering jet holder, fractured during the early stages of the test. A repair was effected by the application of brazing.

3. When operating the generator in the field great difficulty was experienced in removing the oil filter from its holder. The difficulty was due entirely to the inaccessibility of the filter holder.

4. On attempting to replace the filter cartridge in its holder, it was found that only with considerable difficulty could the large diameter spring on the end of the filter cartridge, be coaxed into the holder. It was also observed that the screw thread on the filter body tube, which is of a fine pitch, readily became cross-threaded during re-assembly operations.

5. It was observed, when functioning the generator, during a spell of cold weather, that ice formed in the pressurizing valve assembly. The provision of a wind shield is indicated.

6. Constant trouble was experienced with the smoke oil flowmeter due to both the breaking of the electrical leads and the condensation of moisture within the meter itself. It is recommended that a more robust meter be fitted.

7. During the test, information was received to the effect that the 10 m/m. sparking plug is to be replaced by a 14 m/m. plug. While endorsing this action it is recommended also that a more robust type of waterproof "snap-on" connection be fitted to the H.T. lead.

8. Difficulty was experienced in operating the two locking levers on the "Evertite" coupling on the dip pipe head, and it is recommended that these levers be lengthened.

9. It was observed that the brass ferrules on the neoprene connection between the float chamber and the metering jet, readily became detached. A more positive connection is desirable.

10. As a result of the test the following recommendations are made in respect of the tools supplied with the generator:-

    (a) that the bung wrench, which is inefficient be redesigned,

    (b) that the engine head wrench be replaced by two separate spanners; one for the head locking ring, the other for the head itself. The provision of two such spanners will enable the operator to ensure that the starting pump fitting is located in the "down" position when the engine head is locked.

    (c) that two "positioning" holes be drilled in the engine head and a two-pin spanner be provided, so that the petal valve can be properly located before being locked in position.

APPENDIX B.

Operator's Log Sheet for the 100 hours Continuous Functioning Test.

Date	Time from Zero(hr.)	Fault	Action Taken	REMARKS
28.7.52	Zero			Test commenced at 11.00 hrs.
29.7.52	39¼	Generator stopped. Flames seen round the engine head cover and under one side of the generator.	Fire extinguished. Petrol valve, which had failed, replaced.	Generator out of commission for 5 minutes.
29.7.52	55¼	Generator stopped.	Engine head removed; no fault apparent but generator would not start. New engine head fitted.	Small quantity of carbon removed from the emission nozzles. Generator out of commission for 10 minutes.
30.7.52	54	Generator shut-down.	Instructed to change the site of the trial.	Generator shut-down for 30 minutes.
31.7.52	76	Generator stopped.	Petal valve failed; new valve fitted.	Generator out of commission for 5 minutes.
31.7.52	79½	Generator stopped.	Petal valve failed; new valve fitted.	Generator out of commission for 5 minutes.
1.8.52	95	Generator shut-down.	Smoke interfering with another trial: enforced shut-down.	Generator shut-down for 30 minutes.
1.8.52	101¼	Generator shut-down.		Test completed. Total time of operation - 100 hr.

APPENDIX C.

Screening Efficiency Tests on the E.19R1 Mechanical Smoke Generator.

Temperature and Viscosity of the Smoke Oil used in each Test

Trial No.	Smoke Oil Used	Mean Rate of Consumption.		Temperature °F.	Viscosity Redwood Seconds
		lb./min.	Imperial gal./hr.		
1	General Purpose Fog Oil.	5.1	33	42	2,910
2	General Purpose Fog Oil.	4.5	29	41	3,060
3	General Purpose Fog Oil.	4.7	31	40	3,220
5	General Purpose Fog Oil.	4.4	28	52	1,710
6	General Purpose Fog Oil.	5.5	35	77	540
7	Pool Diesel Oil	6.0	42	73	38.5
8	Pool Diesel Oil	5.6	39	63	41.0
9	" " "	5.8	41	58	42.5
10	" " "	5.7	40	50	45.0

APPENDIX D.

Results of the Screening Efficiency Tests performed on the E.19R1 Mechanical Smoke Generator.

Trial No.	Date	Zero (G.M.T.)	Generator.	S.G. at 60°F.	Output (lbs./min.)	Screen Length (yds.)	Wind Speed (m.p.h.)	T.G. 23' - 4' (°F.)		Observing distance (yds.)	Standard SL.	$\frac{SL_S\ E.19R1}{SL_S\ M.1}$ %	Distance along screen (yds.)	Height at distance d_h (ft.)	Estimated height at 100 yds. (ft.)	Estimated height at 200 yds. (ft.)
	G.P. Fog Oil in both generators				Q	$S.L._s$	U_{2m}		R	d	SL_S		d_h	h_d	h_{100}	h_{200}
1.	18. 2.52	1058	E.19R1	0.932	5.1	450	9.9	-0.5	1.136	1400	420	-	160	47	35	54
		1120	M.1	0.932	-	-	-	-	-	-	-	-	-	-	-	-
2.	26. 2.52	1052	E.19R1	0.932	4.5	330	6.9	-0.4	1.134	1260	295	78	120	30	27	41
		1138	M.1	0.932	5.3	430	6.9	-0.4	1.131	1270	380	-	120	41	37	56
3.	14. 3.52	1106	E.19R1	0.932	4.7	360	12.0	-0.7	1.135	930	470	74	200	50	29	50
		1149	M.1	0.932	7.5	610	12.8	-0.8	1.135	900	640	-	200	66	38	66
5.	7. 4.52	1030	E.19R1	0.932	4.4	240	14.6	-0.7	1.136	760	390	69	135	34	26	42
		1122	M.1	0.932	7.6	390	14.9	-1.6	1.130	720	570	-	225	48	30	45
6.	5. 6.52	0942	E.19R1	0.932	5.5	210	8.2	-1.2	1.126	830	280	76	170	51	37	57
		1035	M.1	0.932	6.3	300	9.1	-1.0	1.129	780	370	-	160	63	47	72
	Pool Diesel Oil in E.19R1; C.P. Fog Oil in M.1															
7.	7. 7.52	1143	E.19R1	0.852	6.0	130	17.1	-1.4	1.133	640	260	44	70	20	26	40
		1108	M.1	0.932	6.6	290	16.6	-1.7	1.131	610	600	-	120	30	27	42
8.	15. 9.52	1120	E.19R1	0.852	5.6	180	13.1	-0.5	1.137	900	250	54	170	33	24	37
		1030	M.1	0.932	5.9	350	12.6	-0.4	1.138	830	460	-	350	61	31	46
9.	24. 9.52	1305	E.19R1	0.852	5.8	220	17.5	-0.2	1.140	900	320	57	210	32	21	31
		1350	M.1	0.932	6.6	380	19.7	-0.1	1.140	870	560	-	210	41	27	40
10.	2.10.52	0943	E.19R1	0.852	5.7	270	10.2	0.0	1.142	1100	250	54	250	29	17	26
		1023	M.1	0.932	5.6	460	11.4	0.0	1.142	1100	460	-	260	43	25	38

APPENDIX E.

Degree to which the E.19R1 Mechanical Smoke Generator meets the War Office User Requirement for a Mechanical Oil Smoke Generator

W.O. User Requirement	Degree to which the E.19R1 meets the Requirement
1. Size In size and weight the generator should not exceed the following dimensions:- Height 36 inches Width 20 inches Length 30 inches Weight (empty 230 lb.) Small variations from these dimensions may be accepted.	Height 23 inches Width 16.5 inches Length 40 inches Weight 137 lb. dry

2. Consumption

The consumption of fog oil will be the minimum necessary to produce a volume of smoke equal to or greater than the present equipment [M] but in no case will exceed 100 gallons per hour.

[M] Generator, Smoke, Mechanical, M.2 which has a consumption rate (maximum) of 42 Imperial gal./hr. and produces, when General Purpose Fog Oil is employed, a screening length of 580 yards.

	Oil	Consumption Imp. gal./hr.	Screening Length under Standard Conditions yds.
Present Equipment:- Generator Smoke Mech. M.2	G.P. Fog Oil.	42	580
	Pool Diesel Oil.	[M]	[M]
A.C.S. No.3, Mk.1	G.P. Fog Oil	100	780
	Pool Diesel Oil.	100	400
E.19R1.	G.P. Fog Oil	30	370
	Pool Diesel Oil.	41	270

[M] No reliable results available.

APPENDIX E.(CONTD.)

W.O. User Requirement	Degree to which the E.19R1 meets the Requirement
3. Performance	
The generator shall be capable as a short term policy of 24 hours continuous emission and at least 50 hours discontinuous emission without requiring mechanical replacements. 72 hours and 500 hours respectively should be aimed at as the long term policy.	During discontinuous operation for a period of 37 hours, three petal valves failed after working periods of 30 hours, 4 hours and $\frac{3}{4}$ hour, respectively. In addition a number of minor faults occurred. During the 100-hour continuous functioning test three petal valves failed after working periods of $30\frac{1}{4}$ hours, 42 hours and $3\frac{1}{2}$ hours, respectively. An examination of the generator at the completion of the 100-hour test indicated that carbon had been deposited on various components to varying degrees.
The time from cold start to emission of smoke should be a maximum of one minute.	The time from a cold start to emission of smoke is, under good conditions, less than one minute.
It should be possible to stop smoke emission within 20 sec. without prejudicing further smoke making or harming the generator.	Smoke production can be terminated within 20 sec. and restarted without any apparent effect on the generator.
The generator must function automatically when set to a certain rate of emission. The rate of emission must be variable so that it can be adjusted to certain fractions of the maximum as, say, one half and three quarters maximum output. The automatic functioning should not be achieved at the expense of simple maintenance by complicating the machine.	The generator functions automatically when set to maximum output. It is reputed to be capable of operation at outputs from 25-50 U.S. gal./hr., but no tests have been carried out at throughputs lower than the maximum.
4. Mount	
The generator must be a self-contained unit capable of being mounted in standard post-war vehicles including the jeep and jeep-trailer. It must be able to operate from a vehicle or from the ground.	The unit is self-contained and can be operated from a vehicle or from the ground. No tests to determine whether or not it can be mounted in Army vehicles, have been carried out.

W.O. User Requirement	Degree to which the E.19R1 meets the Requirement
5. Fuel The generator shall be capable of operation with any moderately heavy oil in standard supply. The generator shall include sufficient tank space to hold all fuel and water necessary for an hour's functioning, except for fog oil which the generator must be capable of drawing from another container whilst in action.	The generator can be operated on G.P. Fog Oil and Diesel Oil but will <u>not</u> operate on Pool Fuel Oil. The petrol tank has sufficient capacity for one hour's operation. Water is not used. Fog oil is discharged under pressure from a drum and it is necessary for smoke emission to cease during the period when an empty drum is replaced by a full drum.
6. Robustness The generator must be of robust construction to withstand normal rough usage and in particular it must be safeguarded against the jolting occurring whilst being deployed over bad ground so as to require a minimum of inspection and adjustment before going into action.	During the accelerated mechanical strength test (the "bump" test) the following faults occurred:- (1) Flow meter became loose in its case. (2) Pressure gauge needle dropped off its pivot. (3) Petrol tank sustained a fracture which allowed the petrol to drain out. (4) Petrol pipe to float chamber broke off completely. (5) Float bowl assembly became loose. (6) Flexible petrol pipe developed a fracture. (7) Glass wool lining settled into the lower portion of the shell. Owing to the fracture in the petrol tank reported at (3) above it was not possible to operate the generator at the completion of the test.

APPENDIX E.(CONTD.)

W.O. User Requirement	Degree to which the E.19R1 meets the Requirement
7. Operation The generator must be simple to operate and must be capable of being operated by one man and carried over short distances by two. The generator must be capable of being operated by native troops.	The generator is simple to operate, can be operated by one man and carried over short distances by two. Not tested.
8. Glow "Glow" or illumination when operating at night must be kept to a minimum.	During the 100-hour continuous functioning test the generator caught fire (petal valve failure) and flames appeared at two points. After the generator has been operated and shut off, flames occasionally appear at the nozzles.
9. Climatic Range The generator must be tropic designed and capable of functioning under conditions laid down in War Office Policy Statements Nos. 61 and 70 for normal equipment.	During the initial dry heat and damp heat tests undertaken by C.D.E.E., an uneven pulsation in the engine "beat" was evident. During the final dry heat and damp heat tests the generator failed to function. When these tests had been completed the generator was allowed to cool down to atmospheric temperature. When cool the generator functioned satisfactorily. That the generator failed to function in simulated tropical conditions appeared to be due to the instability of the petrol/air mixture in the flowjector at high temperatures. The following difficulties were experienced when attempting to operate the generator at -40°C.

APPENDIX E.(CONTD.)

W.C. User Requirement	Degree to which the E.19R1 meets the Requirement
9. Climatic Range (Contd.)	(1) The oil and air pipes hardened and were difficult to handle. (2) The "snap-on" air connector would not clip on to its male connection. (3) The batteries registered a voltage of 3 volts. (4) Ice collected on the earth button at the base of the "Stan-Test" coil, thus insulating it from the frame. (5) The plastic petrol pipe hardened and could not be removed from the petrol jet. It was not possible to operate the generator at -4.0°C. until new batteries had been fitted, the ice had been broken away from the earth button and a heater to supply warm air to the engine head, had been provided. When subjected to the "driving rain" test the generator failed to operate due to water entering the emission nozzles and the engine head of the unit.
10. Waterproofing and 11. Air Dropping.	Not tested.
12. Radio Interference Suppressors should be fitted.	Suppressors are not required.

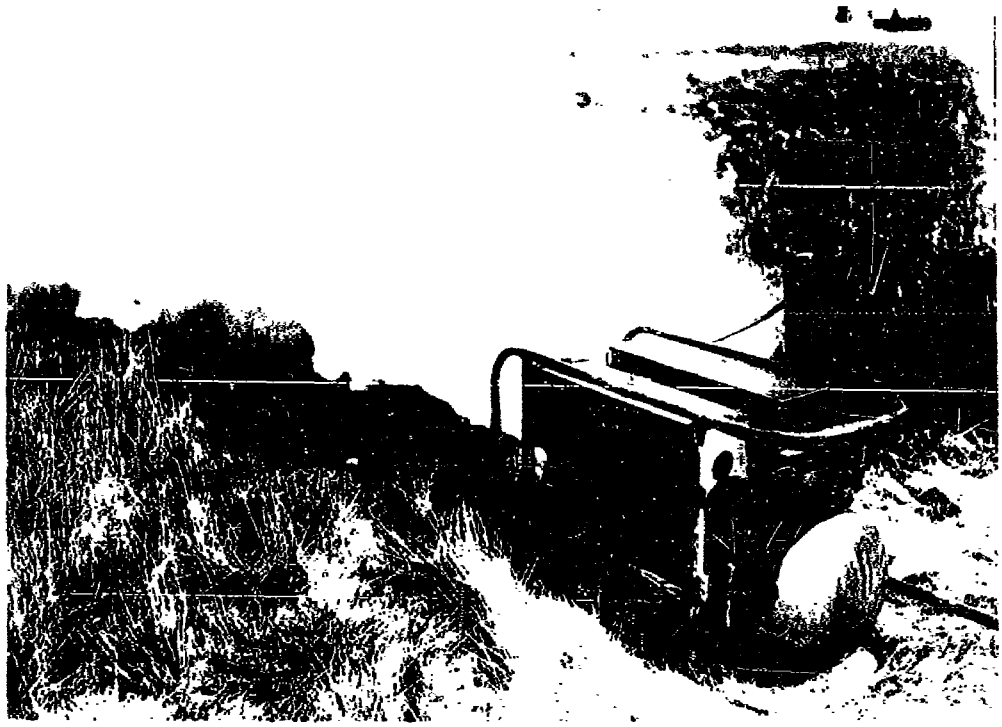

FIG 1 E 19 R1 MECHANICAL SMOKE GENERATOR
- END VIEW

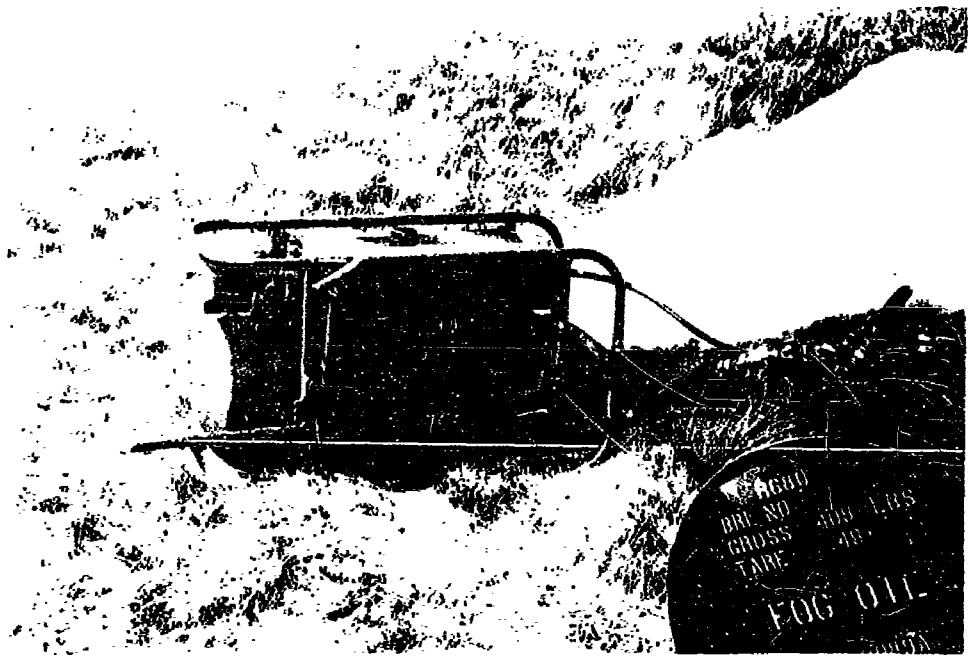

FIG 2 E 19 R1 MECHANICAL SMOKE GENERATOR
- SIDE VIEW

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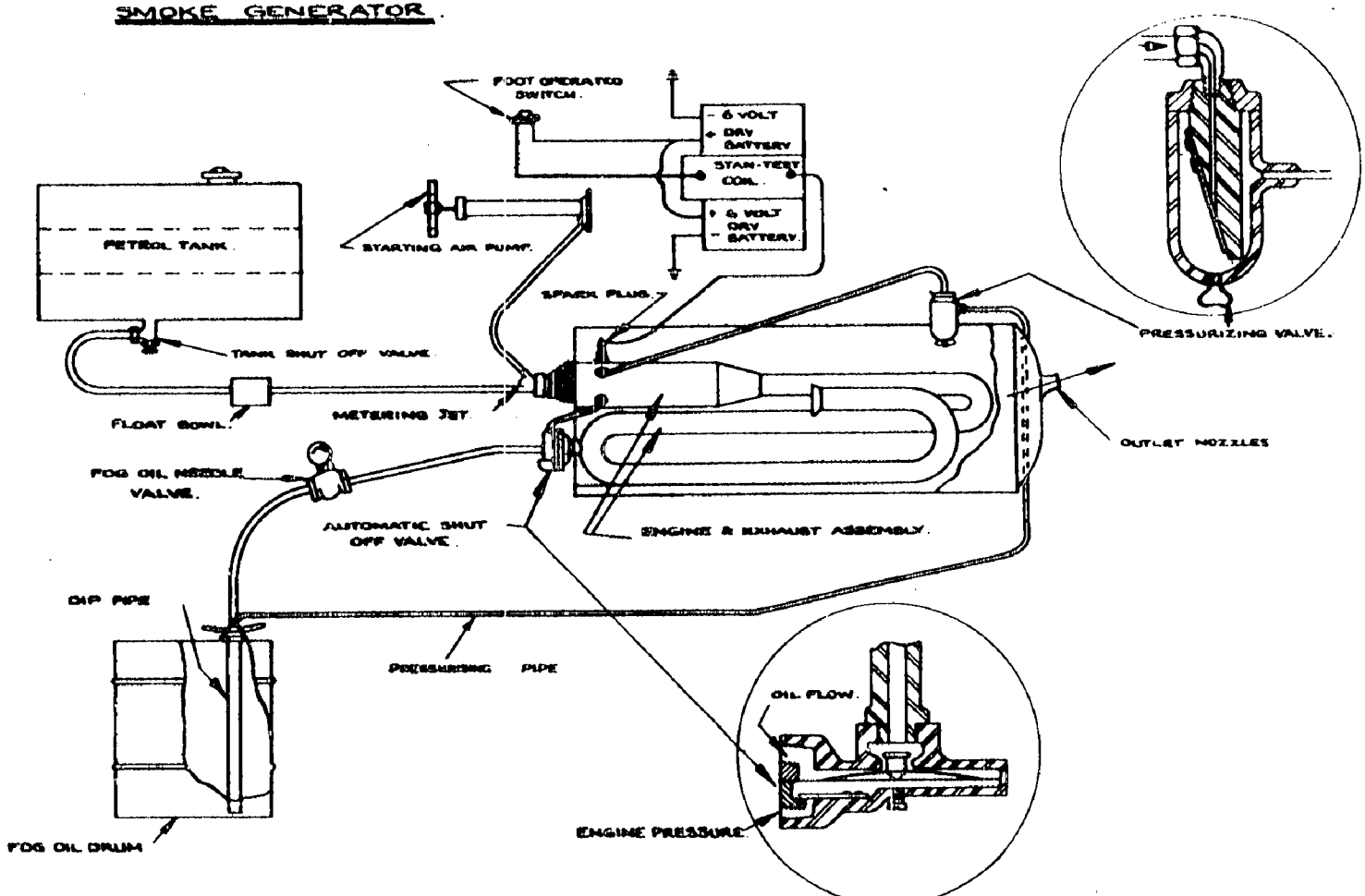
FIG.3. FLOW DIAGRAM OF E19R1 MECHANICAL SMOKE GENERATOR.



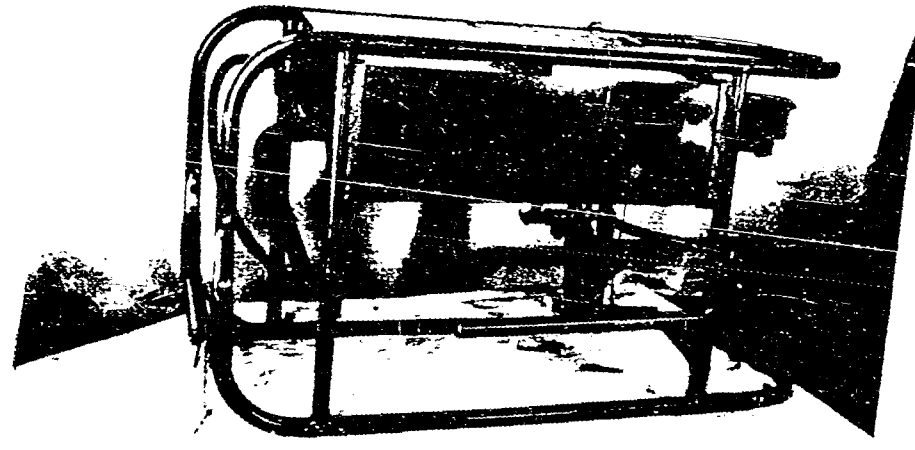


FIG. 4. E 19 R1 MECHANICAL SMOKE GENERATOR - FRAME AND PETROL TANK.

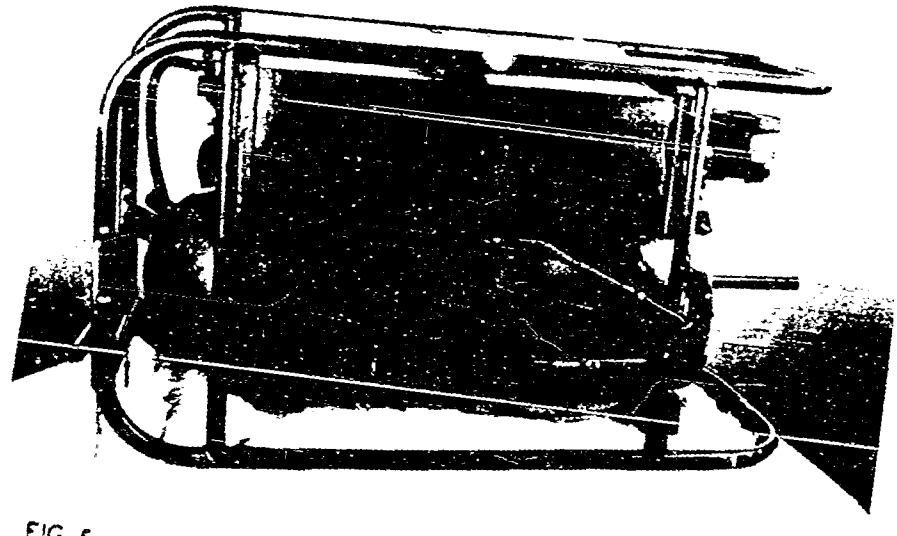


FIG. 5. E19 R1 MECHANICAL SMOKE GENERATOR - FRAME, PETROL TANK AND SHELL HOUSING THE ENGINE AND EXHAUST ASSEMBLY.

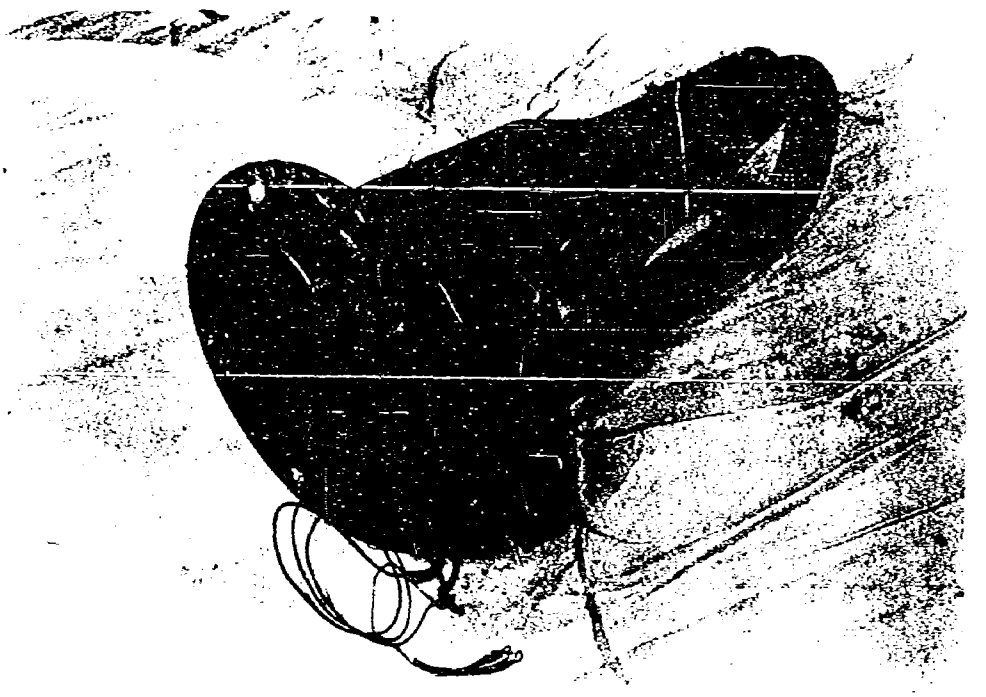


FIG. 6. E 19 R1 MECHANICAL SMOKE GENERATOR
– COMBUSTION CHAMBER AND EXHAUST TUBE.

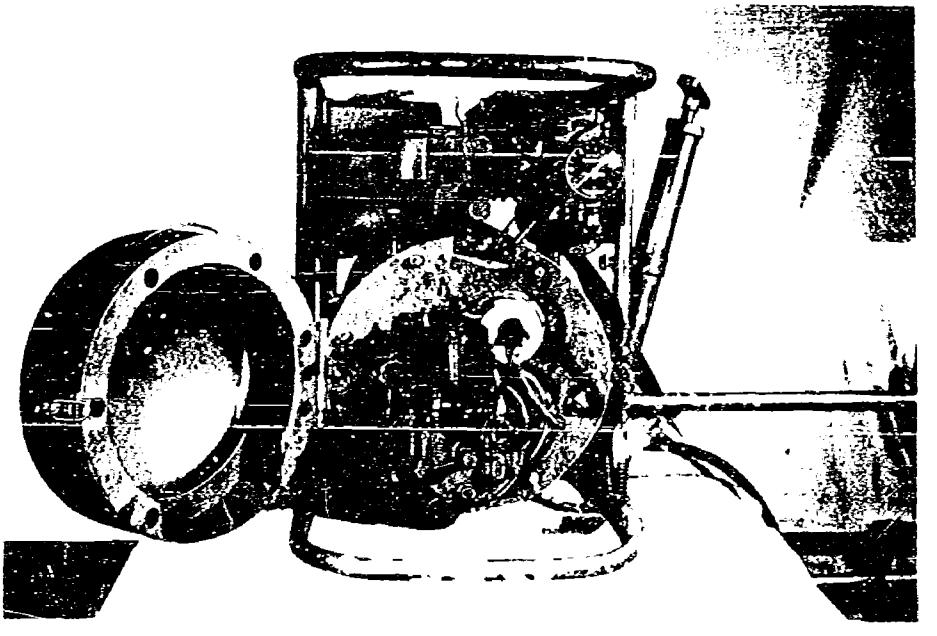


FIG. 7 E 19 R1 MECHANICAL SMOKE GENERATOR
– ENGINE HEAD UNIT

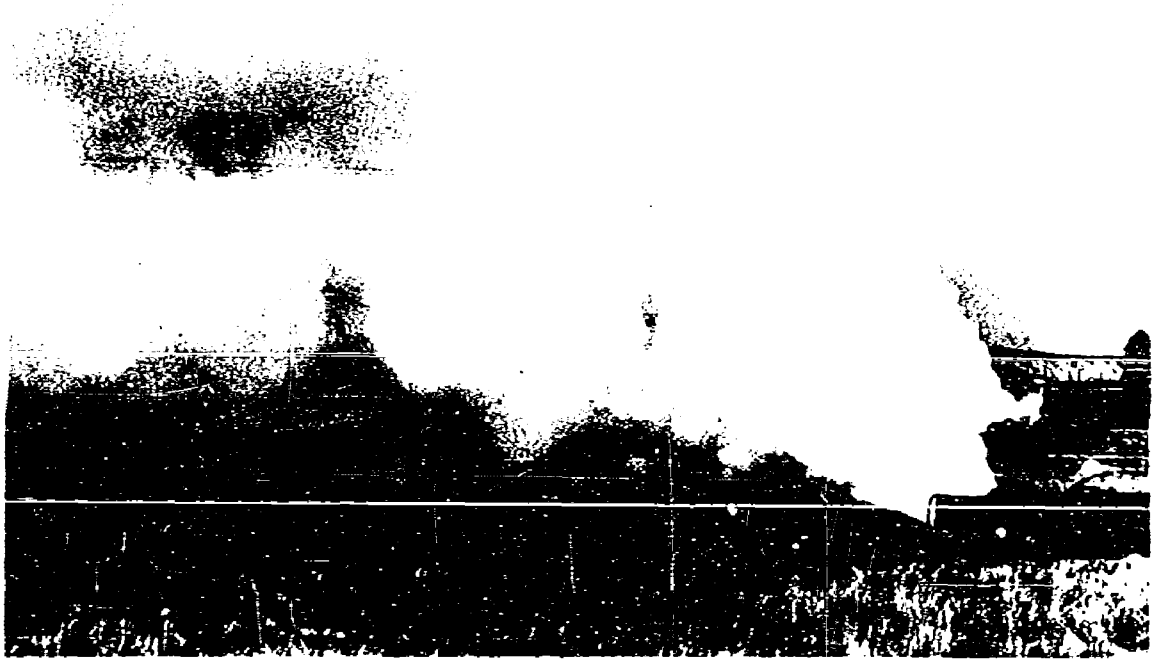


FIG. 8 E19R1 MECHANICAL SMOKE GENERATOR – TYPICAL SMOKE SCREEN.

T805

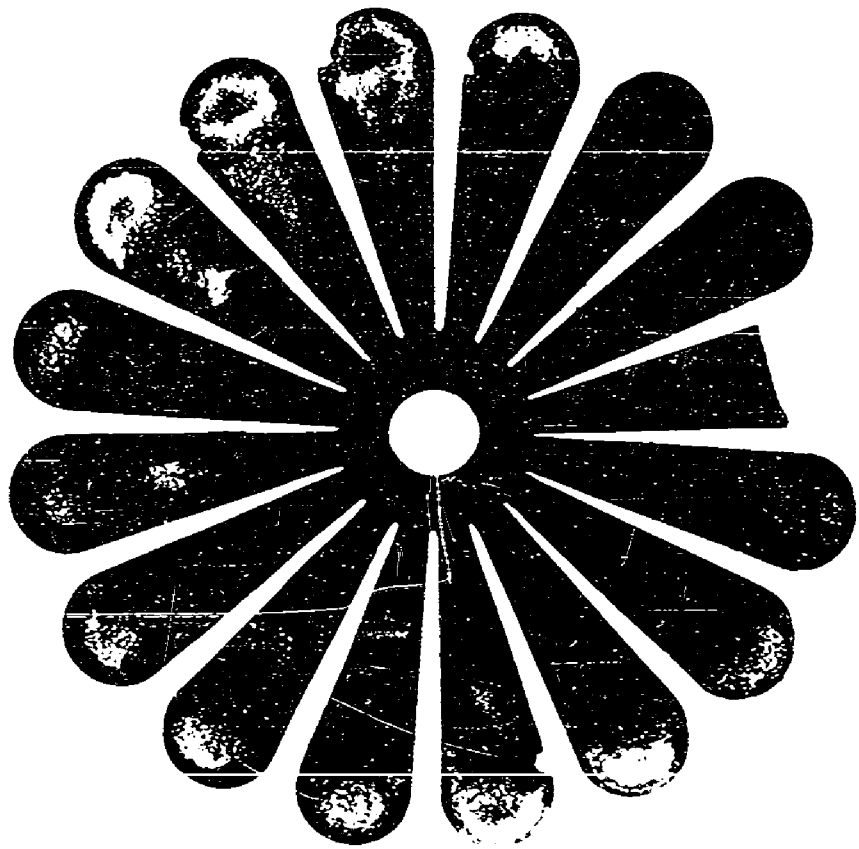


FIG. 9. E19R1 MECHANICAL SMOKE GENERATOR — PETAL VALVE WHICH FAILED AFTER A WORKING PERIOD OF 30 1/4 HOURS

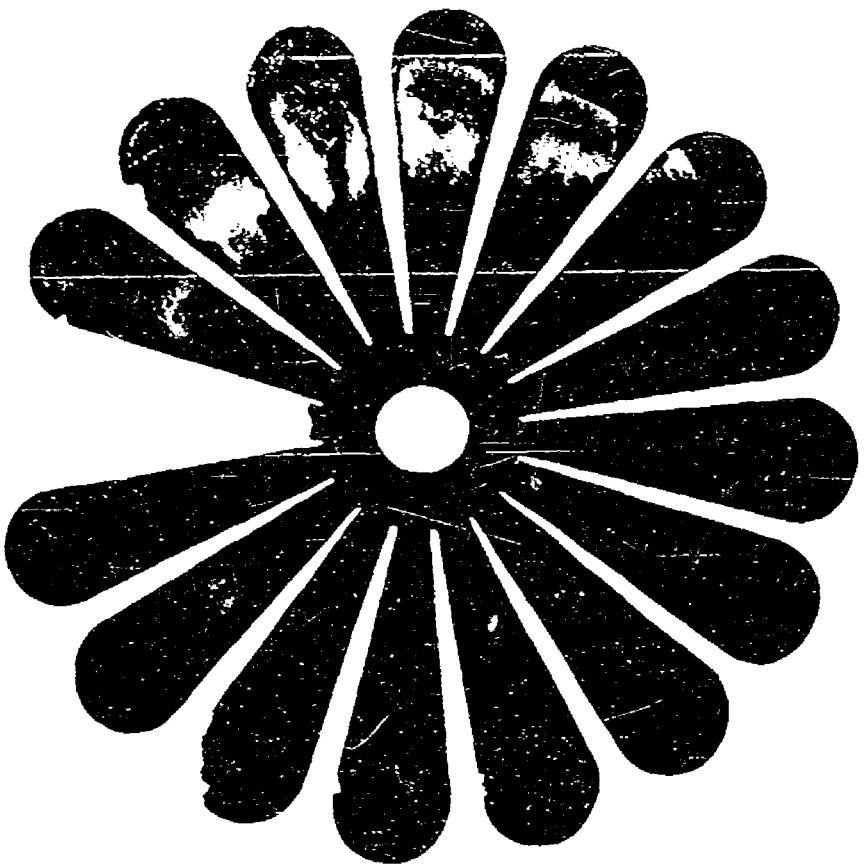


FIG. 10. E 19 R1 MECHANICAL SMOKE GENERATOR – PETAL VALVE WHICH FAILED AFTER A WORKING PERIOD OF 42 HOURS.

T866/6

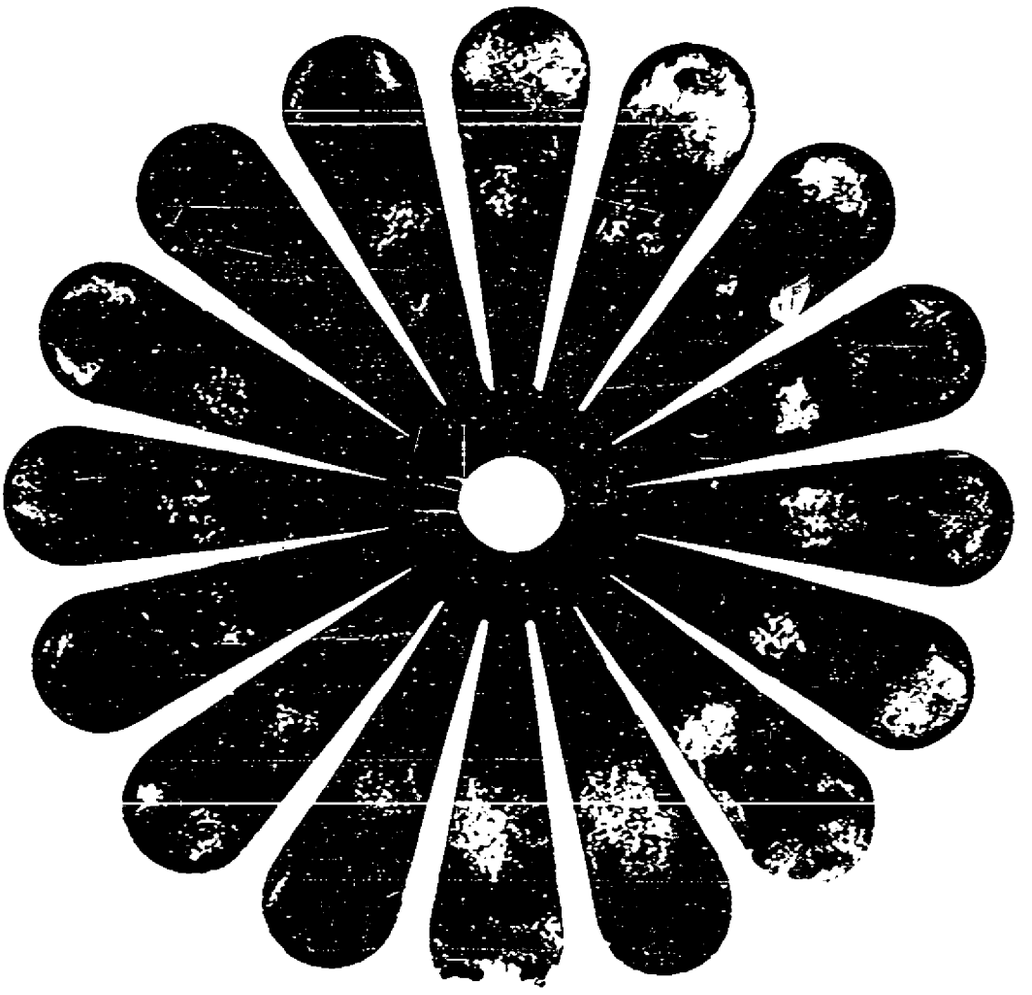


FIG. 11 E19R1 MECHANICAL SMOKE GENERATOR — PETAL VALVE WHICH FAILED AFTER A WORKING PERIOD OF 3 1/2 HOURS.

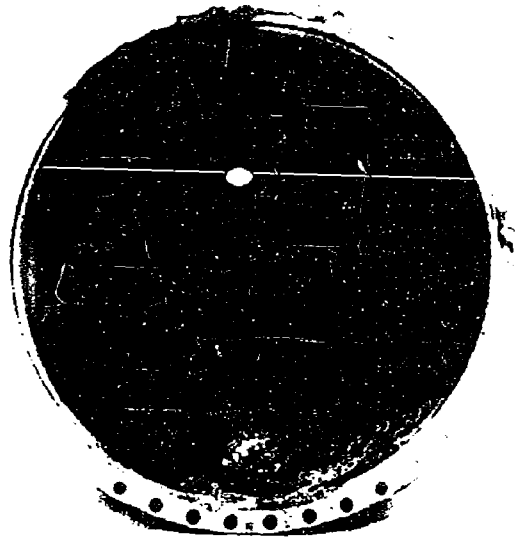


FIG 12. DEPOSITION OF CARBON INSIDE THE SHELL END-PLATE.

FIG. 13 DEPOSITION OF CARBON INSIDE THE SHELL

FIG. 14. EI9RI MECHANICAL SMOKE GENERATOR – DEPOSITION OF CARBON INSIDE THE EXHAUST TUBE. (⟶)

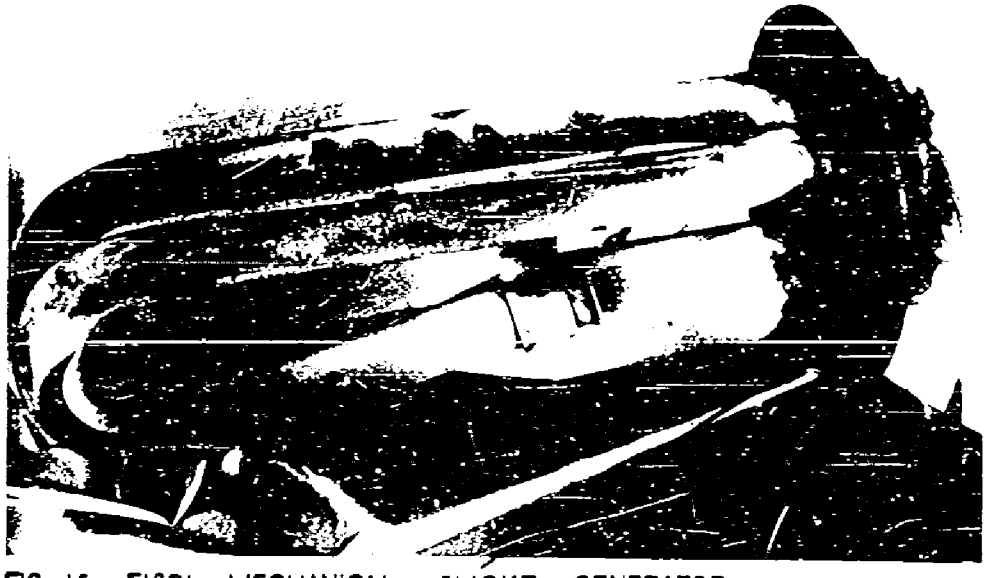


FIG. 15 EI9RI MECHANICAL SMOKE GENERATOR – DEPOSITION OF CARBON ON THE INSIDE OF THE ENGINE HEAD (⟶)

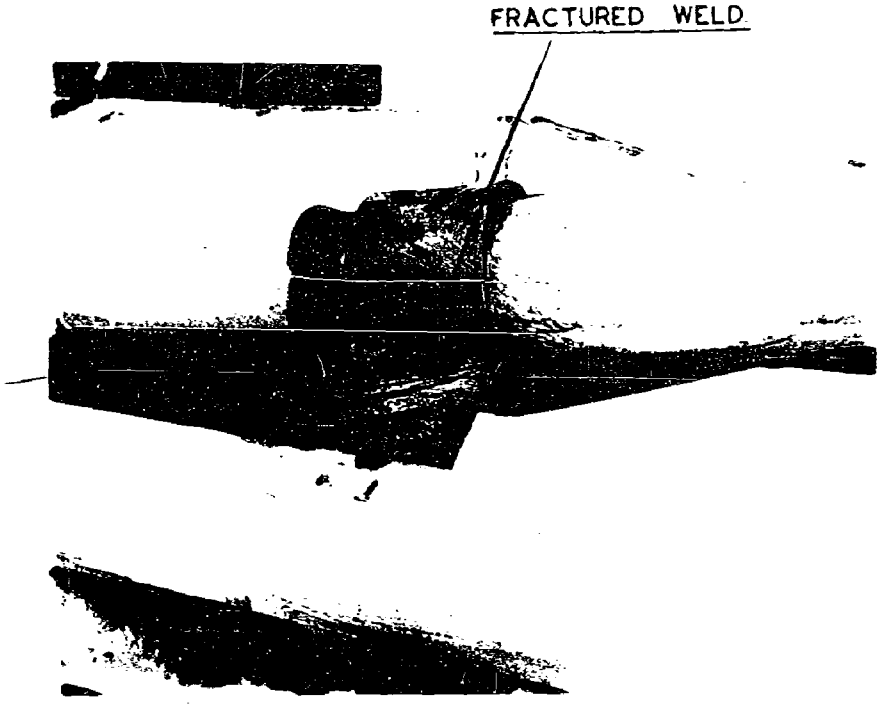


FIG 16. E 19 R1 MECHANICAL SMOKE GENERATOR - DEPOSITION OF CARBON ON THE OUTSIDE OF THE EXHAUST TUBE (⟶)

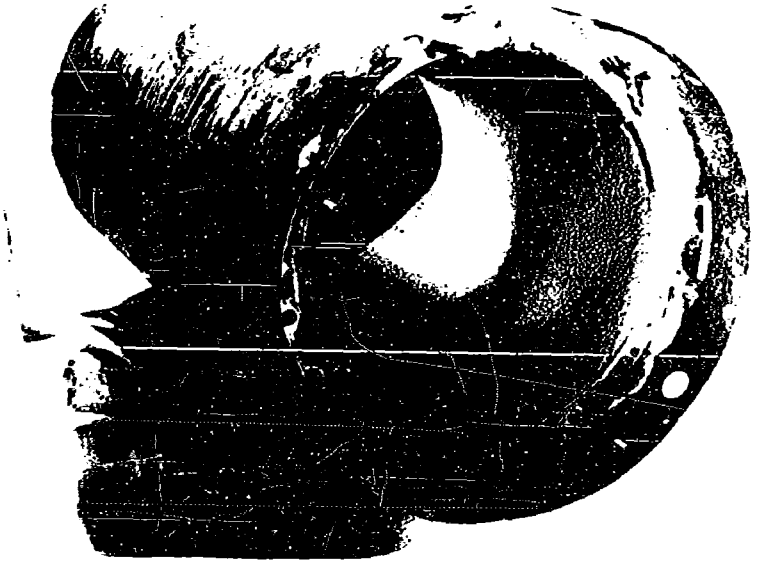


FIG 17 E 19 R1 MECHANICAL SMOKE GENERATOR - DEPOSITION OF CARBON INSIDE THE SHELL

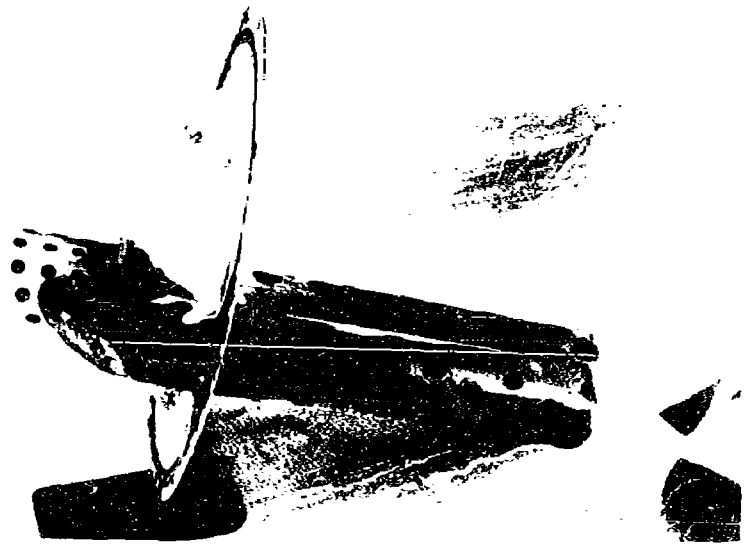


FIG. 18 E19R1 MECHANICAL SMOKE GENERATOR
-DEPOSITION OF CARBON ON THE SILENCER

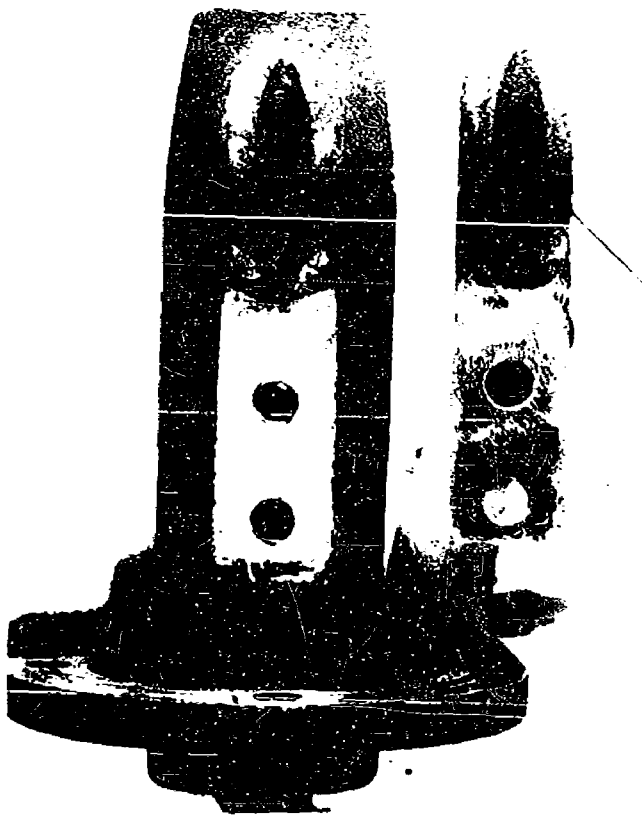


FIG. 19 E19R1 MECHANICAL SMOKE GENERATOR
-DEPOSITION OF CARBON IN THE PRESSURIZING VALVE.

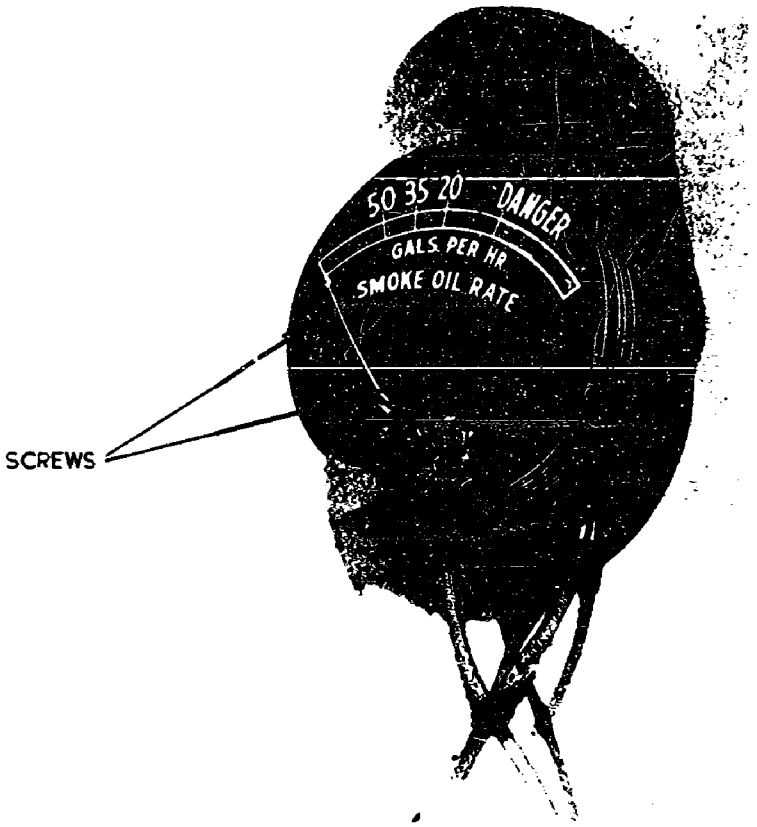


FIG. 20 E19R1 MECHANICAL SMOKE GENERATOR — FLOWMETER AFTER "BUMP" TEST. (NOTE THE SCREWS.)

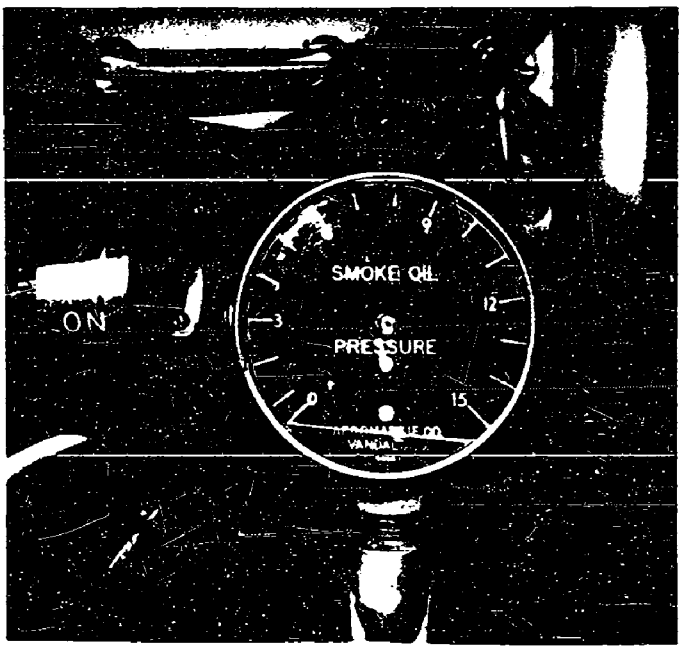


FIG. 21 E19R1 MECHANICAL SMOKE GENERATOR — PRESSURE GAUGE AFTER "BUMP" TEST

FIG 22 E19RI MECHANICAL SMOKE GENERATOR - PETROL TANK FRACTURED DURING BUMP TEST

FIG 23 E 19 RI MECHANICAL SMOKE GENERATOR - PETROL PIPE FRACTURED DURING BUMP TEST

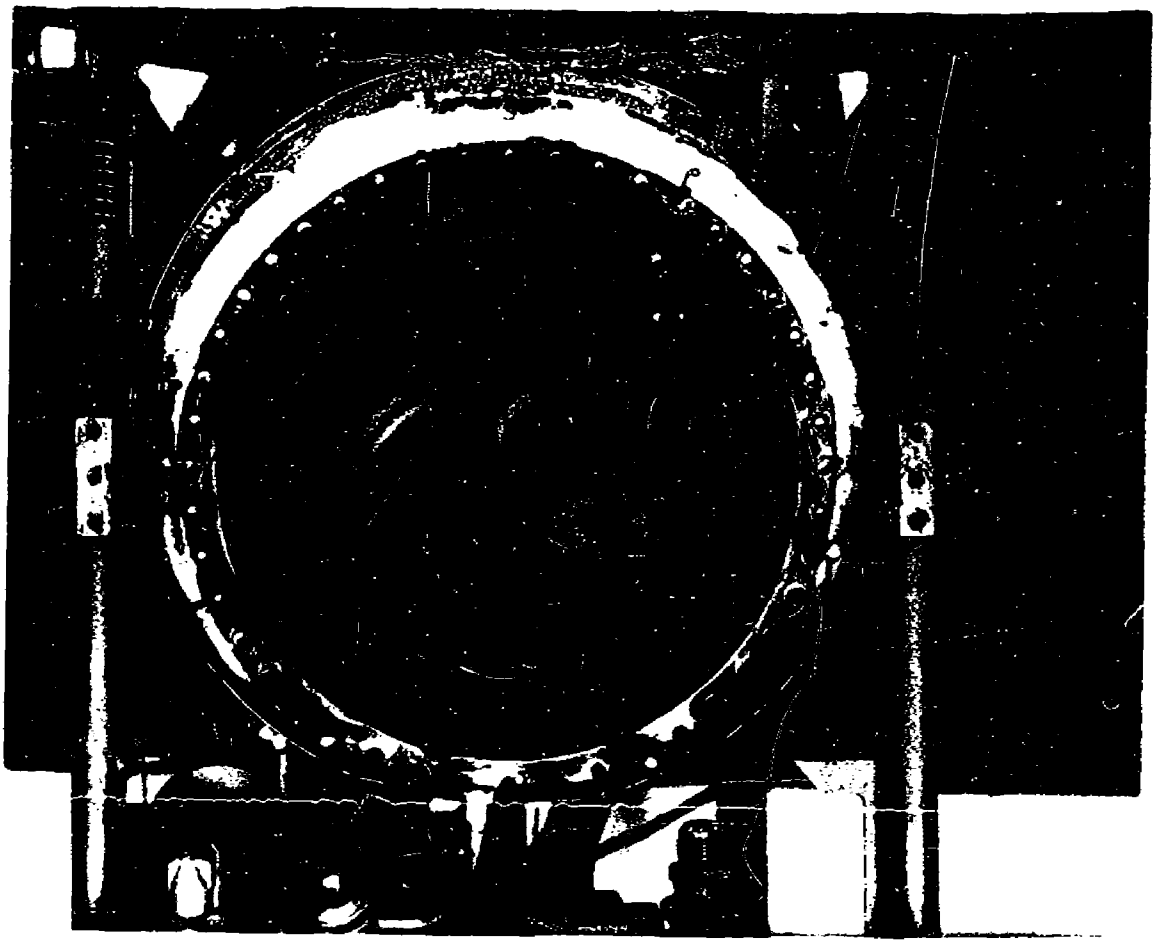


FIG. 24. E19R1 MECHANICAL SMOKE GENERATOR — POSITION OF GLASS WOOL LINING AT THE COMPLETION OF THE "BUMP" TEST.

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FIG. 25. E19R1 MECHANICAL SMOKE GENERATOR FAULTY ENGINE HEAD EX TEST N° 5 (⟶)

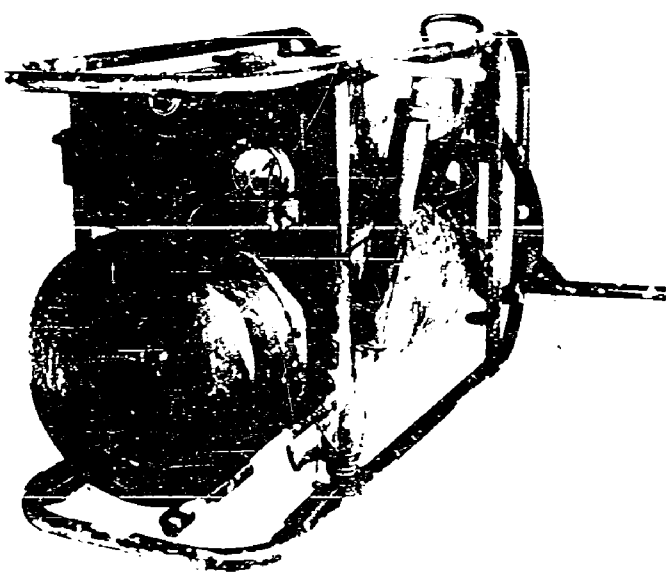

FIG. 26. E19R1 MECHANICAL SMOKE GENERATOR – APPEARANCE AT THE END OF THE CLIMATIC CYCLE TESTS.

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