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MINISTRY OF AVIATION

AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT

BOSCOMBE DOWN

EROSION AND NOISE ATTENUATION TESTS ON A 50 FT. CHALK TUNNEL USED AS A JET ENGINE NOISE MUFFLER

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Erosion and Noise Attenuation Tests on a 50 ft. Chalk Tunnel used as a Jet Engine Noise Muffler

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Summary

Tests were made on a small earth tunnel to check its resistance to erosion and to assess the noise reduction that may be expected when such a device is used to muffle the exhaust noise of a jet aircraft. Photographs taken before and after tests with a Hunter aircraft are given, and estimates made of the attenuations due to absorption of sound by the chalk walls, a 30° bend, and an exit which directs the efflux up into the air.

It is concluded that there will be no serious erosion problems in a chalk tunnel if the gas velocity is less than 800 ft./sec. and that the 50 ft. tunnel gave a maximum of 22 dB attenuation.

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1. Introduction

It has been suggested that with modern earth moving equipment an aircraft jet engine noise suppressor could be constructed in the ground comparatively cheaply, by digging a suitable trench and covering it with steel piling and then laying the spoil over the top. The efflux from the jet engine could then be ducted into the tunnel and discharged at the far end after the noise had been reduced by expansion, cooling and absorption along the tunnel walls.

A pilot tunnel was constructed at Boscombe Down, to test the resistance of the local chalk to erosion and the opportunity was taken to perform tests which would give an estimate of the absorption of the chalk, the attenuation due to a 30° bend in the tunnel as well as the effect of a vent at the end of the tunnel which directs the sound into the air.

2. Description of Tunnel

This was excavated out of the solid chalk subsoil and was 7'6" wide and 7'6" deep. The first section was 30 ft. long followed by a 30° corner and a further section of 20 ft. All but the last 8 ft. were covered with steel piling and the spoil from the trench heaped up on top. A 4' diameter steel pipe was positioned to accept the jet efflux from a Hunter aircraft and lead it down into the first section of the tunnel at an angle of 15°. Fig. 1 is a plan of the tunnel which gives dimensions and some of the test positions.

3. Method of Test

3.1 Wall Erosion

A Hunter aircraft was positioned so that the jet efflux from it entered the steel inlet tube and was directed into the tunnel. Photographs were taken of the walls and floor before and after the tests and visual observation of the exit was maintained during the tests for indications of excessive erosion. Infact the first run was stopped after two minutes because the size and quantity of chalk debris in the exhaust gas stream suggested that a substantial fall might have occurred. Local protection with Pierced Steel Planking (P.S.P.) was applied and a further run of ten minutes duration made.

3.2 Noise Aborption

The noise absorption due to the chalk walls was estimated for each of the mid frequencies of the standard octave bands by measuring the sound pressure levels (s.p.l. in dB reference 2 x 10^{-4} micro-bar) produced at various positions along the tunnel by a loudspeaker situated at its head and driven by a Bruel and Kjær oscillator. A warble tone was used, to prevent the formative of standing waves. The s.p.l. measurements were made with a Scott sound level meter at five foot intervals along the centre line of the tunnel as well as at one foot intervals across it at the positions before and after the 30° bend.

Sound pressure level measurements were also taken above ground level for positions about the tunnel exit laying on circles of radius 10', 20' and 30' and having angular separations of 45° one from the other. For these measurements two positions of the loudspeaker were tried. One set of results was obtained with the speaker at the 30° corner and another

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set with it lying on its back on the floor of the tunnel in line with the centre of the exit.

Sound pressure level measurements were also obtained while a Hunter aircraft engine was running into the tunnel. These measurements were taken at four positions lying on a 100 yds. radius circle centre just aft of the aircraft's tail at angles of 90^o, $112\frac{1}{2}^o$, 135^o and $157\frac{1}{2}^o$. Zero degrees being in the direction the aircraft was facing. A corresponding set of measurements was obtained with the aircraft away from the tunnel.

4. Results

4.1 Erosion

The erosion of the tunnel floor and walls may be estimated from the photographs in figs. 2 and 3 which show the inlet into the tunnel looking from the 30^o bend both before and after the test runs with the Hunter. Fig. 2 shows the erosion which occurred during the initial two minute run and it can be seen that the majority of the damage is confined to the lower portion of the walls and floor. Careful examination will reveal that it was the floor which sustained the greater damage and because of this P.S.P. was provided for the second run of ten minutes duration. The effect of this second test may be assessed from the pictures in fig. 3 to be only slight. In fact the loose debris found inside the tunnel was less than $\frac{1}{3}$ of that which had to be removed after the first test.

4.2 Loudspeaker Tests

4.2.1 Absorption by the Chalk Walls

The results of tests using the loudspeaker as the sound source are given in table 1 and fig. 4 which show the overall attenuation to be about 13.5 dB or 0.34 dB per foot run. Assuming that the steel roof absorbed a negligible amount of sound energy this corresponds to an absorption co-efficient for chalk of around 1.5×10^{-2} dB/sq. ft. for sound pressure levels in the range 60 to 110 dB.

4.2.2 Attenuation due to the Bend

Fig. 4 gives no definite indication that the 30^o bend caused any increase in the attenuation over that due to the straight portion of the tunnel. Additional measurements taken about the bend adjacent to the wall screened from the noise source also failed to detect any appreciable attenuation due to the corner.

4.2.3 Effect of the Sound Coming from Below Ground Level

The results from the tests with the loudspeaker positioned firstly at the bend and secondly on the floor at the exit are given in table 2 while figs. 5 and 6 are samples of the graphs used in making up the table. In all cases the s.p.l. measurements were taken in and around the tunnel at positions along lines radiating from the centre of the exit at angles of 45^o to one another. The results are plotted in dB against the distance from the last microphone position inside the tunnel. Straight lines have been drawn through the points for the positions outside the tunnel and these have been extended to estimate the s.p.l. which would have been expected at the initial position if the tunnel had had a straight exhaust system. The difference between the estimated and actual values have been taken as a measure of the attenuation produced by the exit. These values

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are given in table 2 and show that the exit bend should contribute 14 dB, or about half the total attenuation of the tunnel. Further if the noise could be directed vertically upwards a further 6 dB of attenuation should be available.

4.2.4 Total Effect of Tunnel

The tests conducted with a low intensity sound source and without air flow through the tunnel show that a total of 28 dB of attenuation can be obtained.

4.2.5 Aircraft Noise Attenuation

The noise of the Hunter engine running-up into the tunnel and in the open is given in tables 3 and 4 while the attenuation due to the tunnel is shown in table 5.

5. Discussion of Results

An estimate of the gas velocity at various positions inside the tunnel has been made using the standard jet velocity of a Hunter and the cross-sectional area of the gas stream at the points considered. The maximum velocity of the jet impinging on the floor was calculated to be of the order 2,300 ft./sec. which caused considerable erosion of the chalk while the minimum velocity was estimated to be 800 ft./sec. which caused negligible erosion. The final gas velocity within the square section of the tunnel was also estimated to be about 800 ft./sec. which suggests that if the steel duct had been arranged to direct the exhaust gas along the tunnel instead of at the floor the erosion would have been very much less than was actually experienced.

The tunnel has been in existance for over a year and shows signs of deterioration which may be attributed to two causes:-

1. engine running which now totals 20 minutes around the full thrust region of a Hunter aircraft, and

2. weathering which although small compared to engine running damage is quite definite and detectable as a flaking away of the chalk walls at the exit end of the tunnel.

No tests were made to assess this damage quantitatively.

The mean attenuations given in table 1 was determined excluding the values of 24.6 dB at 450 cps and 18.8 dB at 7.2 kcs as these values are quite destinct from the rest of the results. An increase in the attenuation as the frequency increases is to be expected and the figure of 13.8 dB is probably quite genuine. However, a value of 24.6 dB at 450 cps would suggest that the chalk exhibits selective absorption about this frequency. However tests with the Hunter aircraft summarized in table 5 do not support this.

The tests made inside the tunnel with a low intensity noise source indicate that some 28 dB of attenuation should be available while tests with the Hunter realized a maximum of 22 dB. There are two major differences between these tests. One set was made in still air at relatively low sound intensities while the other was at high intensity and in a moving stream of air which should effectively shorten the tunnel. Sound travelling at 1100 ft./sec. would take 4.5×10^{-2} seconds to pass through the tunnel in still air, while the gas stream moving at about 800 ft./sec. would move

/36 ft. ...

36 ft. in the same time. Hence the effective length of the tunnel when reduced to still air conditions is only 14 ft. which represents about 5 dB of attenuation. When this is added to the estimated 14 dB due to the exit being below ground level we get better agreement between the two sets of results.

Although this is by no means conclusive it does lend some weight to the inference drawn from the still air tests that extra attenuation should be available if the noise could be directed vertically upward into the air when it leaves the tunnel instead of at an estimated 60° as in the present case.

6. Conclusions

(a) A tunnel of the type described may be used as a noise attenuator without serious erosion being encountered provided that the exhaust gas velocity is kept below 800 ft./sec. Higher velocities may be possible if the gases at the inlet end are directed along the tunnel rather than at the floor.

(b) The maximum attenuation of Hunter engine noise produced by this tunnel was 22 dB.

(c) Most of the attenuation appeared to arise at the outlet from the tunnel which directs the gases and noise into the air.

(d) A 30° bend inside the tunnel is unlikely to have a significant effect upon the noise attenuation properties of the tunnel.

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Table 1

Noise attenuations obtained inside the tunnel under still air conditions for s.p.ls between 60 and 100 dB

Octave Band cps	37.5 75	75 150	150 300	300 600	600 1200	1200 2400	2400 4800	4800 9600
Attenuation in dB	14.1	13.2	13.2	24.6	12.7	14	13.6	18.8
					Mean attenuation excluding values 12.7 and 18.8.			13.5

Table 2

Estimated Noise attenuation for a noise source situated below ground level

	Octave Band cps	150 300	300 600	600 1200	1200 2400	mean attenuation
Attenuation in dB	Noise Source at 30° Bend	13	15	13	16	14
	Noise Source at foot of exit	19	19	20	22	20

Table 3

Sound pressure levels in dB measured at a distance of 100 yds from the aircraft and tunnel combination

Angle of Microphone to aircraft centre-line \ Frequency Band cps	37.5 75	75 150	150 300	300 600	600 1200	1200 2400	2400 4500	4800 9600	Overall
90°	96	92	89	88	87	88	88	84	97
112½°	95	91	86	90	91	86	83	79	96
135°	102	99	93	95	96	92	85	84	103
157½°	101	97	86	95	99	91	81	82	102

Table 4

Sound pressure levels in dB measured at a distance of a 100 yds from the aircraft alone

Angle of Microphone to aircraft Centre-line \ Frequency Band cps	37.5 75	75 150	150 300	300 600	600 1200	1200 2400	2400 4800	4800 9600	Overall
90°	111	111	107	110	109	111	108	108	119
112½°	116	113	111	110	112	109	110	101	118
135°	115	115	110	109	110	105	106	98	119
157½°	113	107	100	103	107	106	101	93	116

Table 5

Attenuation of jet engine noise in dB due to the chalk tunnel

Angle of microphone to aircraft Centre-line \ Frequency Band cps	37.5 75	75 150	150 300	300 600	600 1200	1200 2400	2400 4800	4800 9600	Overall
90°	15	19	18	22	22	23	20	24	22
112½°	21	22	25	20	21	23	27	22	22
135°	13	16	17	14	14	13	21	14	16
157½°	12	10	14	8	8	15	20	11	14

FIG. I.

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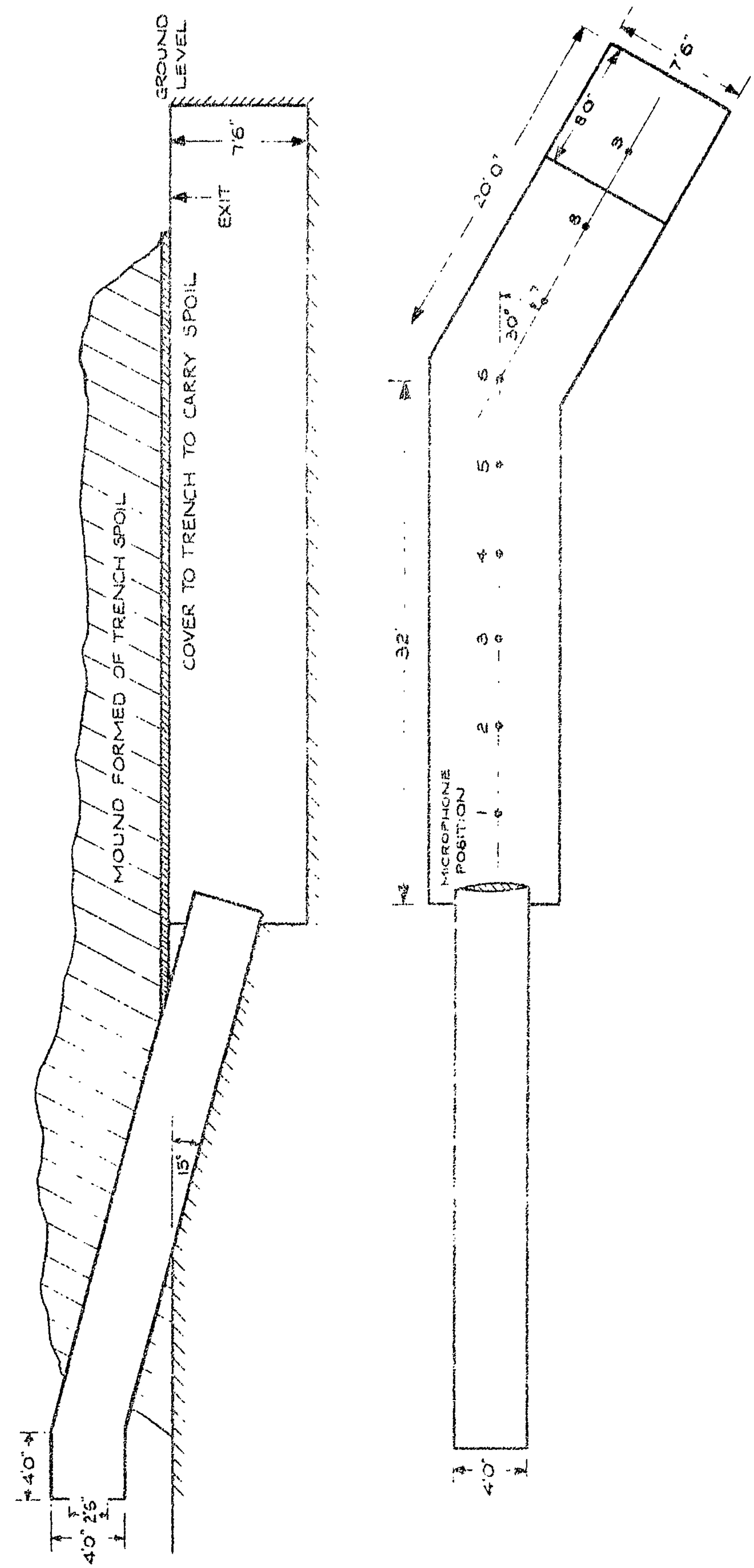


GENERAL ARRANGEMENT OF CHALK TUNNEL NOISE SUPPRESSOR GIVING DIMENSIONS & MICROPHONE POSITIONS.

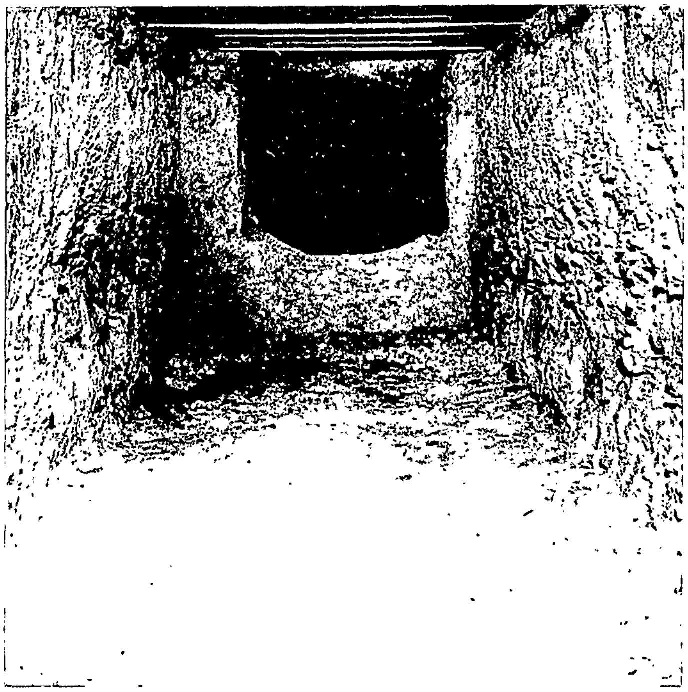


FIG. 2. THE CHALK TUNNEL BEFORE AND AFTER THE TWO (2) MINUTE ENGINE RUN WITH A HUNTER AIRCRAFT.

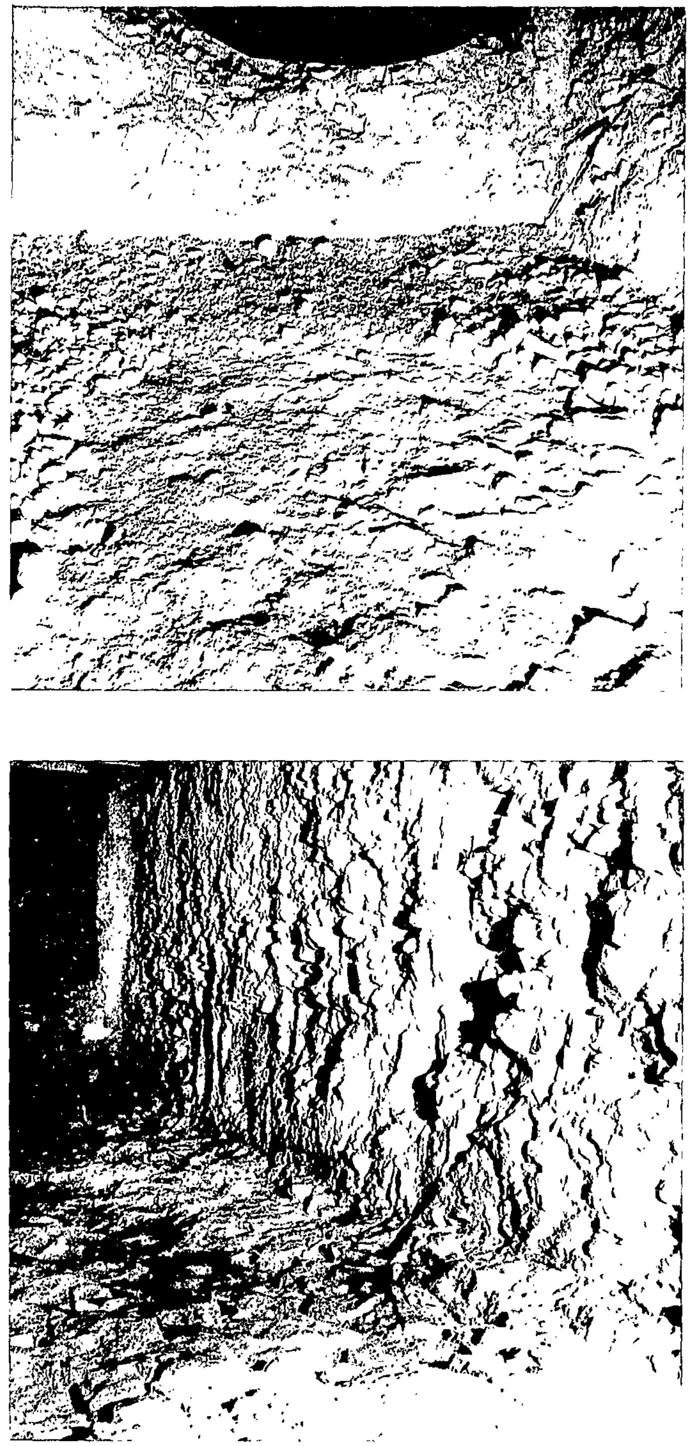


FIG. 2. (CONT.D).

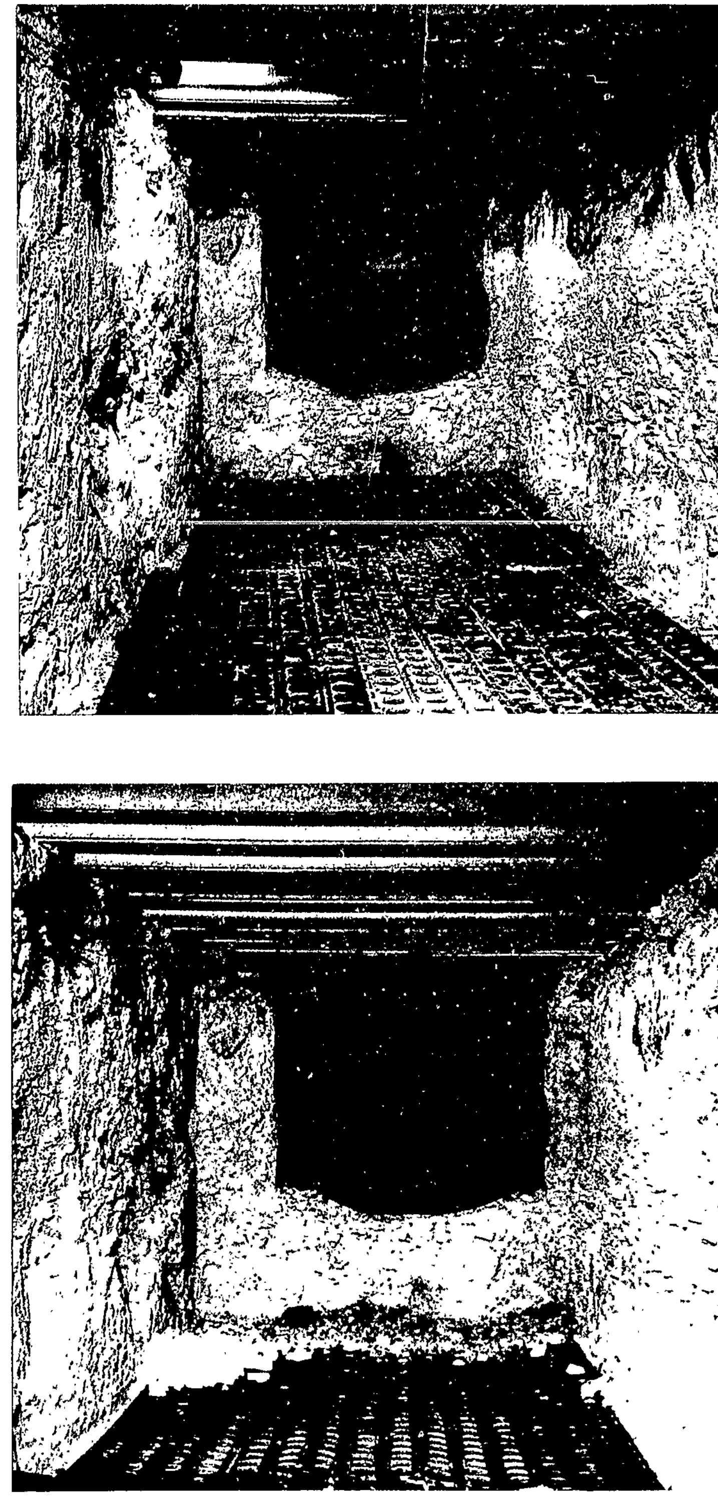
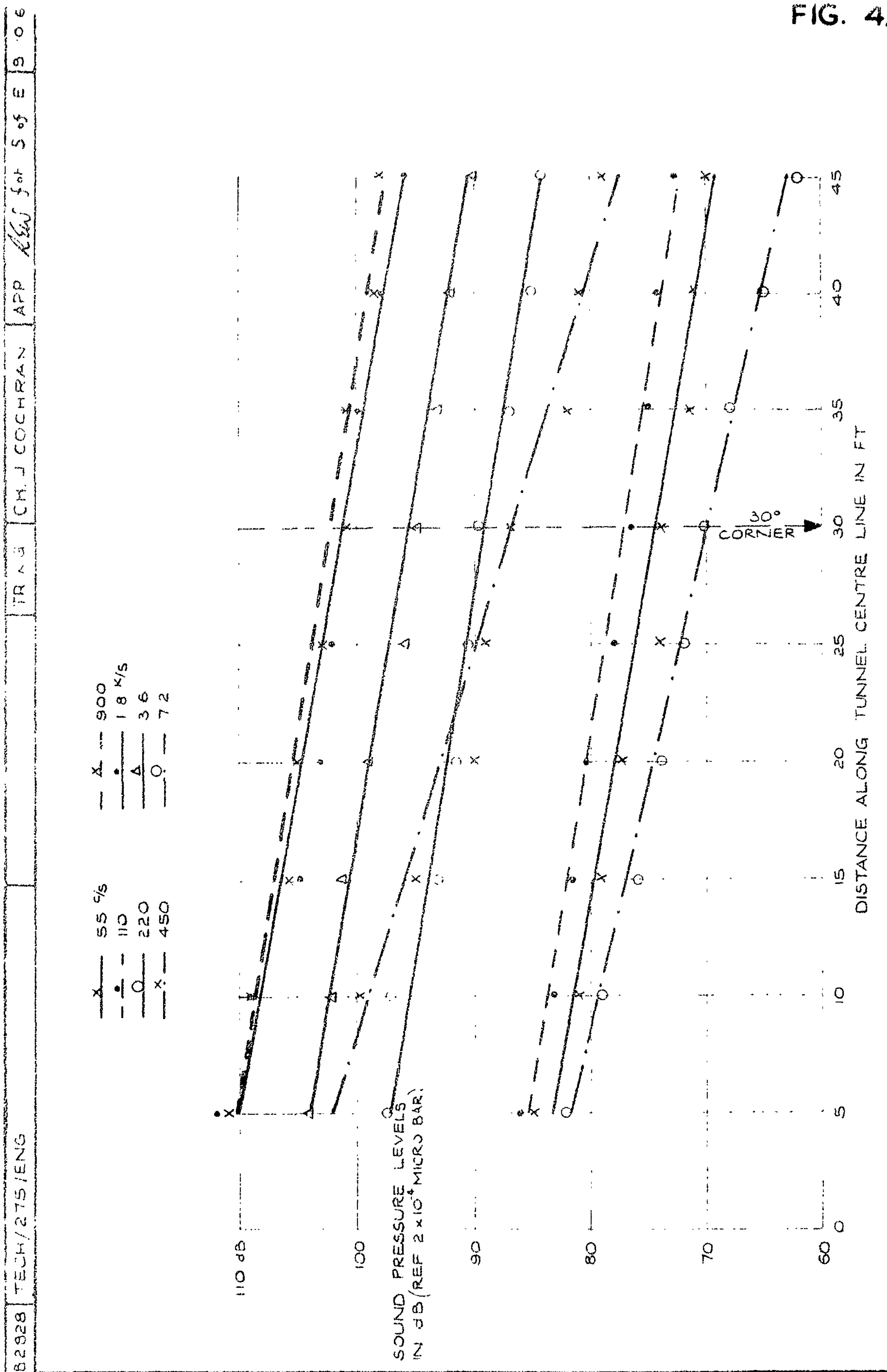


Fig. 3. The Chalk Tunnel Before and After the Ten (10) Minute Engine Run with a HUNTER Aircraft.

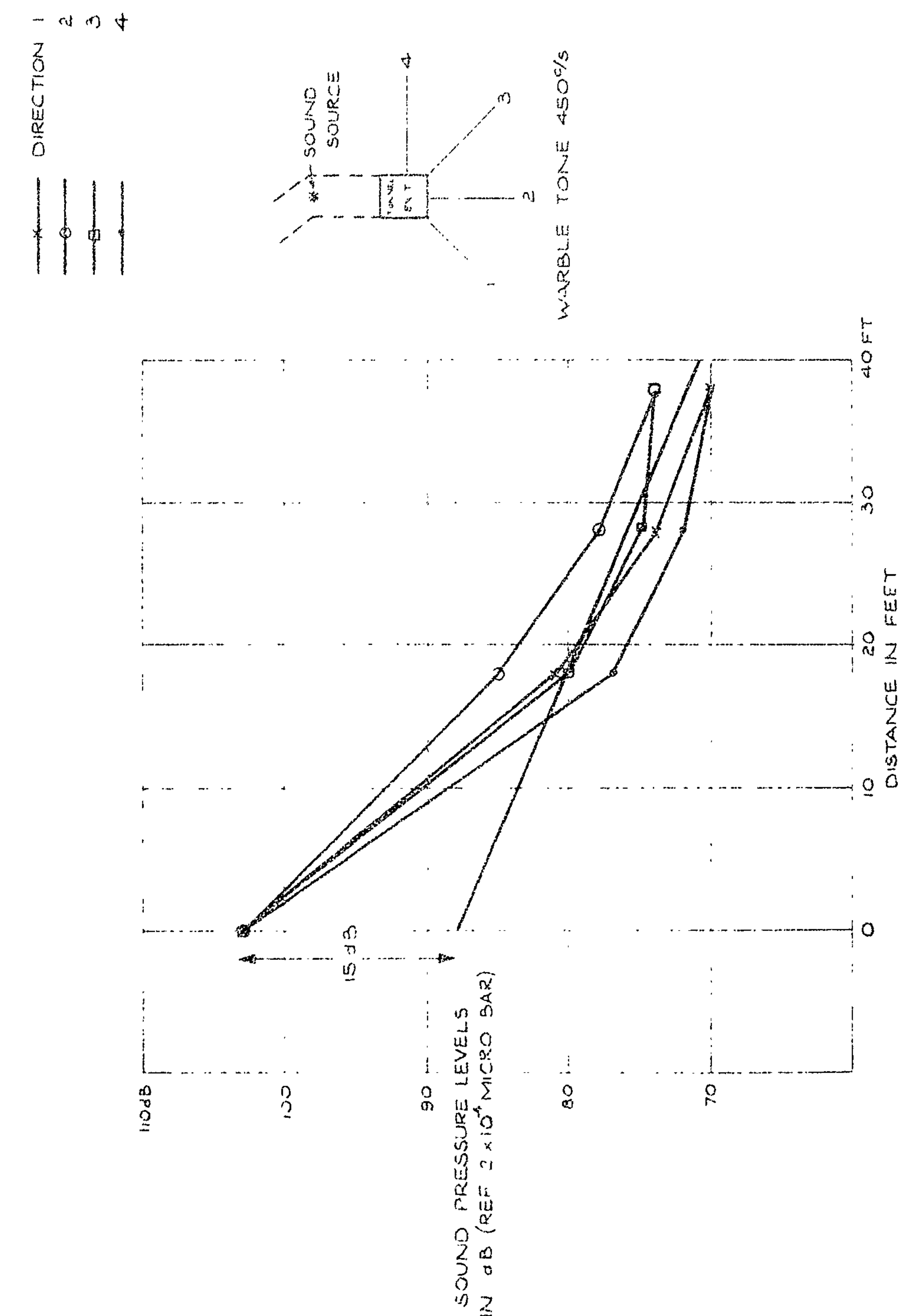
A. & A. E.E. 16891.

FIG. 4.



SOUND PRESSURE LEVELS OBTAINED AT FIVE FOOT INTERVALS ALONG THE TUNNEL FOR VARIOUS WARBLE TONES.

FIG. 5.



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A TYPICAL GRAPH USED TO ESTIMATE THE ATTENUATION OF A NOISE COMING FROM BELOW GROUND LEVEL WHEN THE SOURCE IS AT THE TUNNEL BEND.

FIG. 6.

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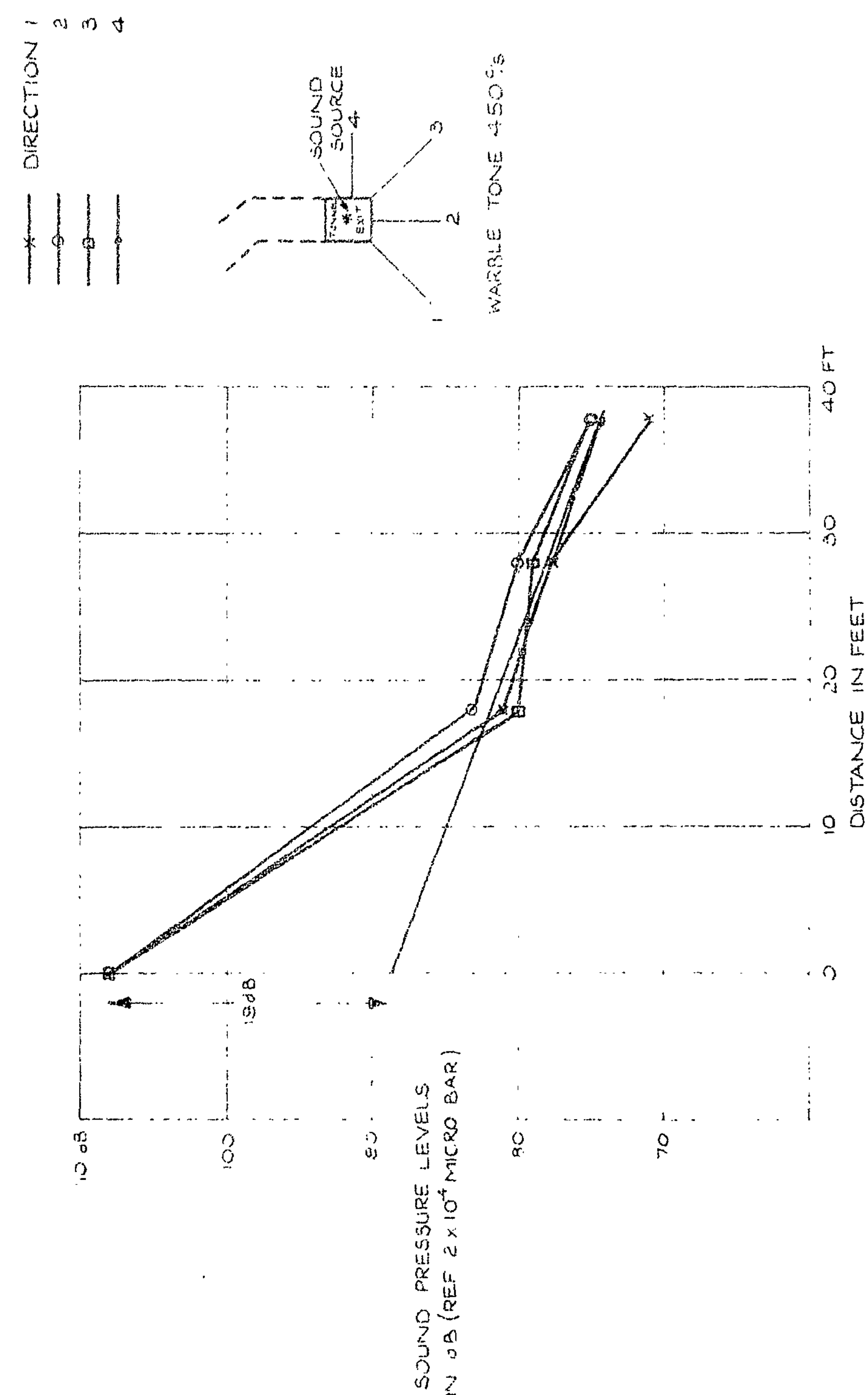

A TYPICAL GRAPH USED TO ESTIMATE THE ATTENUATION OF A NOISE COMING FROM BELOW GROUND LEVEL WHEN THE SOURCE IS AT THE FOOT OF THE TUNNEL EXIT.

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