HOME OFFICE

SCIENTIFIC ADVISER'S BRANCH

CD 17071

Notes on Pneumatic Sirens for National Warnings for consultation with the Aerodynamics Division of the NPL

I. The Problem

The existing four to five H.P. electric sirens were installed at exposed sites before and during the last war. The metal rotors of some of these sirens have been found to be defective but it is not known how many replacements might be needed.

A total of 7,000 electric sirens were installed throughout the United Kingdom, a relatively small number, and entirely in built-up areas. During the war the warning coverage appears to have been adequate probably because petrol was rationed and air raids occurred mainly at night when background noise levels in residential areas were very low.

The effectiveness of these electric sirens, under present daytime, high background noise levels, in industrial cities, is not known with certainty because of the manifold increase, since the last war, in motor traffic and corresponding increase in noise levels and also because of the increasing proportion of very tall buildings and consequent increase in sound shadow effects.

The background noises in cities are not constant continuous levels but consist generally of high peaks lasting several seconds alternating with brief periods of much lower sound levels.

In judging a particular sound in relation to a background of about the same noise level, it is suggested that the significant criterion is whether or not the meaning of the particular sound can be recognised and comprehended by a listener with average hearing. The red warning, wailing note, is so simple and characteristic that it might be picked out and comprehended from an average background noise of considerably higher level, especially during a period of political tension. In this connection the duration of the warning signal may be of great importance e.g. two minutes or one minute.

A serious disadvantage of the electric siren system is that it depends on mains electric current which may fail during a nuclear attack, possibly before a red warning could be given and, very probably, before a black warning of imminent radioactive fall-out could be given over large areas of the United Kingdom.

This is an appropriate time therefore, for Civil Defence planning purposes, to consider the use of more powerful pneumatic sirens, independent of the electric mains power, particularly in outer suburbs and rural areas where the area coverage could be fifty to one hundred times as large as that of the electric sirens.

In 1938 the Committee on "Loud Noise" Air Raid Warning Signals reported the results of both objective and subjective trials, of a number of sirens, carried out with the assistance of NPL. In paragraph 45 of this report, the Committee expressed its preference for steam sirens where a steam supply was available, for the compressed air siren (then under consideration for use in Trinity House light vessels) where a supply of compressed air was or could be made available and elsewhere for the Gent four H.P. electric siren.

The difficulties of assessing siren performance, because of the complexities of sound distribution are referred to in detail in paragraphs 21, 22 and 25 of the report. These difficulties would now be greatly enhanced because of the much larger area of coverage of pneumatic sirens and the consequent higher probability of damping by topography, buildings and weather variations, particularly air temperature layering.

The importance of a two minute duration for the attack warning signal is mentioned in paragraph 41 of the report; "that a signal which continues for at least two minutes has opportunities of attracting attention over casual background noises, which give it a considerable value over a short signal".

The present summary notes contain:-

(i) An account of the performance claimed by the Pintsch-Bamag A.G. of Butzbach in Hessen, Federal German Republic, of their marketed compressed air sirens, designed either as pylon or roof top warning systems, together with the basis recommended by the P.B. Company for planning the distribution of these pneumatic sirens.

(ii) Some test results in the towns of Hanover and Nürnberg as well as in the rural area of Trauenstein, of the P.B. pneumatic sirens, carried out by the F.G. R. Physico-Technical Institute, Brunswick.

(iii) A general description of the sound producing siren head, controls, power and air compressor units and compressed air reservoir.

(iv) Tentative Home Office proposals for the installation, testing and performance evaluation of a pilot pneumatic siren system, possibly in Leeds and surroundings.

The advice and assistance of the NPL at this early stage would be greatly appreciated.

II. Performance claimed by the Pintsch Bamag Company for their Pneumatic Sirens and their Planning Recommendations

The performance specification laid down by the F.G.R. Ministry of the Interior, dated August 1967, for their acceptance of the pneumatic sirens includes the following Civil Defence warnings:-

(a) Red Warning

A (wailing) rising and falling note; frequency range 300 to 420 cycles per second (Herz units) ± 10 Hz: period two seconds for rise, two seconds for fall; duration of warning signal one minute.

(b) All clear signal

A steady note of 420± 10 Hz of duration one minute.

(c) ABC (Atomic, Biological or Chemical) Warning Signal, which might include the 'fall-out imminent' warning required in the United Kingdom:

Three notes, rising and falling, each lasting twelve seconds separated by twelve second intervals: total duration of the warning signal one minute.

(d) Fire warning (peace time)

Three steady notes of twelve seconds, with twelve second intervals: total duration of warning signal, one minute.

Note

The Pintsch Bamag Company's apparent intention is that, normally, a single warning signal of one minute duration would be given, causing the air pressure in the compressed air reservoir to drop from 15.5 ats. gauge to 13.5 ats., when the engine and compressor would cut in automatically, to recharge the air reservoir, a process which would take nearly thirty minutes.

In emergency however, it would be possible with the air in the reservoir, to give four separate signals each lasting one minute thereby causing the pressure to drop about 9 ats. gauge from somewhere in the range between 15.5 and 13.5 ats. to within the range 6.5 to 4.5 ats. The fourth signal would be only about 5 dB lower than the first and it would then require about two hours to recharge the compressed air reservoir to 15.5 ats.

(e) P.B. Company planning recommendations

It is assumed that the pneumatic siren is mounted on a mast or pylon and that the sound producing element in the siren head is at least twenty metres (but never more than fifty metres) above the surrounding terrain and that, if it is a roof top type, it is mounted at least five metres above the roof ridge.

In the Pintsch Bamag pneumatic siren, the sound is issued through four exponential horns and the sound pressure level at thirty metres horizontal distance from the 420 Herz source is 122 dB (or 132 dB at ten metres), with reference to a basic sound pressure level of 2×10^{-4} microbars. Hence:- at any point, the relative sound pressure level in $dB = 20 \log_{10} \frac{P}{2 \times 10^{-4}}$ where P is the sound pressure in microbars at that point. The directional effect is claimed to be circular within $\pm$ 3 dB and the acoustic efficiency to be the "quintuple" of the normal 5 KW electric siren.

Pintsch Bamag recommend that planning should be based on a practical decrease of 7 dB relative sound pressure level (as compared with the theoretical decrease of 6 dB) for each doubling of the distance from the source, for unhindered sound propagation out to a distance of about 10 Km when the general damping effect of approximately 1 dB per Km becomes predominant.

Figure I is an extract from data supplied by the Pintsch Bamag Company. It shows the variation in relative sound pressure level with distance, in free air, on the assumption of a 7dB decrease for each doubling of the distance from the source: it also shows the three lines recommended by the firm for use in assessing the mean sound pressure levels as a function of distance in rural districts, in built-up areas where building heights do not exceed twenty metres and in cities.

Pintsch Bamag further recommend that 70 dB (60 dB inside a room with closed windows) be used as the limit for audibility range planning purposes. According to Figure I this level of audibility will be reached at the following ranges and area coverages:-

Cities 440 metres area coverage 0.61 Km^2

Built-up areas 1160 metres area coverage 4.24 Km^2
Rural areas 3 kilometres area coverage 28.3 Km^2
(Peripheral for 65 dB, outside 5 Km, area coverage 78.5 Km^2)

On this basis the firm estimated that, apart from a central 4.35 Km^2 in the City of Munich already covered by electric sirens, the number of pneumatic sirens needed to warn the 1¼ million inhabitants of Munich would be:

16 for 10 Km^2 of city area plus
66 for 280 Km^2 of residential area

or a total of eighty-two pneumatic sirens for 290 Km^2 (i.e. 113 square miles) averaging about 1.38 square miles coverage for each siren.

They emphasise that each of these sirens reinforces the others so that for an audibility range of 70 dB the additional contribution* at any one siren location from the surrounding sirens would be:-

for 6 sirens	+7.9 dB
for 5 sirens	+7 dB
for 4 sirens	+6 dB
for 3 sirens	+4.6 dB

Hence if one of six sirens failed, the relative sound pressure level at that point would be (70+7) dB and at double the range for a 70 dB level outwards it would have fallen only to 70 dB.

In cities particularly, but also in densely built-up areas, Pintsch Bamag suggest that, where possible, individual pneumatic sirens should be located where the average background noise level is highest, usually at main traffic intersections so that the sound may be propagated more freely along the main traffic routes. In some locations the peak background noise levels may exceed 90 dB and supplementary electric sirens may be needed.

It is a requirement of the FGR Ministry of the Interior that these powerful pneumatic sirens should not be sited within 200 metres of hospitals, sanatoria, poultry or breeding farms and they should be at least 400 metres from railway stations and shunting yards and 1,500 metres from non barrier level crossings.

III. Tests of The Pintsch Bamag Pneumatic Sirens by Section V of the F.G.R. Physico-Technical Institute (Bundesanstalt) of Brunswick

The summary report dated 4th November 1966 by Dr. W. Kallenbach, senior scientist of the Institute is attached behind Figure 2 in this report. The same

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*Footnote

To get the combined relative sound level at any point from a number of sources it is necessary to convert the relative sound pressure level in dB for each source to the power level in watts at that point e.g. $dB = 10 \log W/10^{-13}$ watts where 10^{-13} watts is taken as the threshold for hearing. The power levels from each source are then added and converted back into dB relative sound pressure levels.

difficulties of assessing the performances of individual sirens were encountered as in the 1938 United Kingdom report, necessitating the averaging of sound level measurements taken at equal distances from the source over a geometrical pattern.

The cities of Hanover and Nürnberg where the trials were held are not very large (populations ca. 550,000 and 475,000 respectively) so that it may not appear surprising that little difference was noted between the averages of the recorded sound levels at equal distances in these towns and in the rural districts in Trauenstein (see Figure 2).

The findings of the Brunswick Institute indicate that for planning purposes, in such towns and rural areas, an average range of about 1,500 metres should be taken for an external relative sound pressure level of 70 dB and about three kilometres range for the 65 dB level. They also found that in locations of heavy traffic, the sound level which should have been audible was inadequate and that supplementary warning equipment would be advisable.

This leaves us with the problem of siren location and distribution in large cities where the sound blanketing effects of very tall buildings are serious.

IV. Description of the Pintsch Bamag Pneumatic Siren System

Two types are available, the Pylon type (tubular or lattice mast) and the Roof Top type. In both the siren head is identical but different arrangements are made for housing the power unit, the air compressor and the compressed air reservoir. All vital, exposed equipment is constructed of corrosion resistant metal.

(i) The Siren Head

This is 3.2 metres high and 1.2 metres in diameter. It has three sections, the bottom support and access section, the middle section with the four exponential sound issuing horns and the top section containing the sound generator and electric motor to drive it, together with the feed end of the compressed air supply line with the quick operating "Herion" magnetic valve.

The compressed air stream from this solenoid valve enters a guide tube which surrounds the twenty-four volt, 300 watt DC motor. The motor has a vertical shaft the lower end of which is connected by an elastic coupling with the spindle of a rotating disc which has four holes or ports at a fixed radius from the centre, and uniformly spaced from one another. This disc rotates between two fixed plates which also have corresponding ports at the same radius as the disc. The sound is generated by air passing through the ports as the disc rotates.

The speed of rotation of the disc (which can be varied if necessary) determines the frequency of the sound and the volume of air dictates the intensity. The warning signal is started by a remote control operating the solenoid valve and setting the DC motor in action.

The Herion solenoid valve (made in the Herion Werke, Stuttgart I) is a pilot controlled, membrane type, quick acting and secure closing device: a drawing of this valve is available in Home Office Files WMO/67 14/4/3 and SAG/68 17/7/1. The air delivery rate of the valve proposed by the Pintsch Bamag Company is 700 m^3 per hour or slightly less than 12 m^3 per minute at 1 at. gauge and 20°C.

(ii) Compressed air reservoir

This is located in the bunker at the base of the installation and the compressed air is carried by pipe line up the mast or tower to the Herion valve in the siren head.

The volume of the air reservoir is 5.5 m^3 and it is normally charged to 15.5 ats gauge. As the pressure drops to 13.5 ats the automatic control system causes the engine to cut in and drive the air compressor to recharge the compressed air reservoir to 15.5 ats: this takes nearly 30 minutes.

(iii) Air compressor and power unit

An air-cooled 14 or 15 HP diesel engine drives an air compressor at 1800 rpm with an effective capacity of 25 m^3 per hour of air at 20°C and 1 at gauge. The suction pressure is 1 at and the delivery pressure 15.5 ats gauge.

(iv) Electric battery

This is located in the bunker chamber. The size of the battery is dictated by the capacity required to get the diesel engine and compressor unit started and also to supply power for the DC motor which drives the siren disc as well as for other electrical controls. Two types have been mentioned by Pintsch Bamag

24 volt 107 Amp. hour NiFe battery
24 volt 60 or 80 Amp. hour NiCd battery

The control panel has a 7-day clock switch and the battery provides the energy for all controls of the siren warning system at rest for one week without being recharged, while still leaving sufficient power for 3 engine starts each of 6 seconds duration at intervals of 30 seconds.

Recharging the battery is controlled by a transistor measuring relay which automatically starts the diesel engine and the Bosch generator when the lowest setting for the battery voltage is reached. The completion of charging is controlled by a minimum current relay. If the battery requires it, recharging takes place when the diesel-air compressor unit is switched on automatically to recharge the air reservoir from 13.5 to 15.5 ats gauge. The maximum charging current of the 3-phase Bosch generator is 35 amps: a current relay of the assembly monitors the generator charging current and terminates charging when the current drops below 10 amps, provided that no other control pulse is ordering the engine to keep running.

A rectifier is also provided for recharging the battery from the electric mains supply in peace time.

(v) Controls

The following controls are possible:-

(a) Push button control switch in the bunker at the base of the installation.

(b) Command transmission over Post Office lines operating a control relay outside the control cabinet.

(c) Manual control.

V Tentative Proposals for the Installation, Testing and Performance Evaluation of a Pilot Pneumatic Siren System possibly in Leeds and surroundings

In planning the distribution of pneumatic sirens and their individual locations, the greatest problems are encountered in cities. Here the following points require special consideration:

(i) Where sound shadowing effects by tall buildings and in narrow streets occur, it may be possible to retain existing electric sirens, especially in those districts which are effectively screened from all or most of the surrounding pneumatic sirens.

(ii) It is anticipated that a red warning can be given in advance of a nuclear strike so that the red warning can be given by both the pneumatic and the electric siren systems.

(iii) After the first strike it is probable that the electric mains supply would fail so that a subsequent black warning of imminent radioactive fall-out could be given only by the pneumatic sirens.

(iv) It is unlikely that fall-out will start or become heavy for at least half an hour in areas outside the range of serious damage.

(v) Since the public have been instructed to seek cover on hearing the red warning, normal heavy traffic would cease fairly quickly and consequently the high background noise level would be expected to drop substantially and result in a considerable increase in the combined audibility range of the pneumatic sirens giving a fall-out warning even in areas screened from several but not all surrounding sirens.

The National Physical Laboratory are invited to express agreement or comment on the uncertainties in the above statements and on the following proposed planning bases. Their assistance would be appreciated also in a subsequent tentative study in the Home Office of an effective warning system for the City of Leeds (population just over half a million) and surroundings using Pintsch Bamag pneumatic sirens, supplemented, where necessary, by existing electric sirens.

Basis for general planning over a large area

(i) A relative sound pressure level of 70 dB (with 60 dB inside a closed room) is a reasonable basis for audibility of a characteristic wailing note.

(ii) The planning ranges suggested by the Pintsch Bamag Company to give a 70 dB level from individual pneumatic sirens are acceptable, viz. 3 to 5 kms in farming and other open areas, 1200 metres in residential and town areas where buildings do not exceed 20 metres in height and 440 metres in city areas, provided that in cities the predominant criterion will be the positioning requirement of the individual siren in relation to heavy traffic intersections and in relation to the screening effects of very tall buildings (say, exceeding 10 storeys above ground level).

(iii) In cities it will be necessary to take into consideration the geometry of areas screened from one or more surrounding pneumatic sirens and the combined warning sound levels reached in these areas from the remaining sirens within an unhindered 1200 metre range.

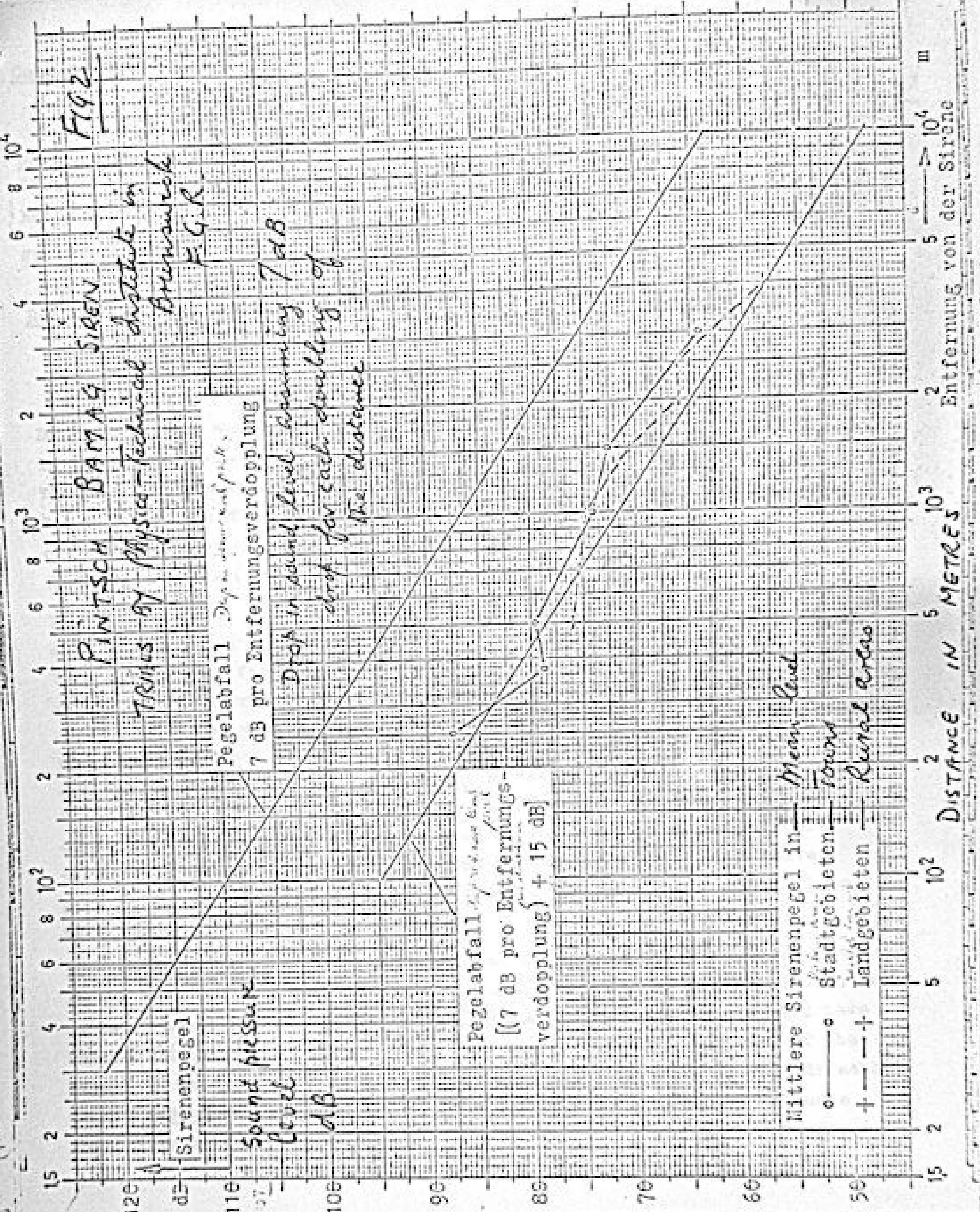
Figure 3 has been taken from an earlier Home Office file CDA/61 57/1/2 doc. 8 as a rough guide to the sound level-distance relationships which have been estimated or found with existing electric and hand-operated sirens, in comparison with the earlier estimates (1960) for the Pintsch Bamag compressed air siren.

The views of NPL would be particularly welcome on the problem of the recognition and comprehension of the simple but very characteristic red warning signal in a rapidly fluctuating background noise of considerably higher average sound pressure level than that of the warning signal. Related to this are the questions of the optimum duration of the red warning signal and the proportion of people (with sharper hearing) in any group at the same location needed to secure group action on the signal: it might be considered adequate for example if 1 in 2 or 1 in 3 recognised the warning signal and also advised the others to take the necessary protective action.

Finally the problem of lack of synchronisation of the rising and falling red warning notes from different sirens require consideration as possible cause of confusion in comprehending the warnings.

J. McAulay

July 1968



Dienststelle		Name	Datum
P T B V/K	Ergebnisse der Schallausbreitungsmessungen an Pressluftsirenen		28.10.66
		Aktenzeichen Zeichnungsnummer	
		28351.66 V/K	

Copy of translation

ATTACHMENT TO FIG 2.

Physico-Technical Department
Section V

33 Brunswick

Reference: 28351.66 V/K

4/11/66

TO: Federal Civil Defence Department,
532 Bad Godesberg.

Re: Research into sound distribution of siren signals in urban and rural areas - your letter of 8/6/65 I.2-02-21-75-49e

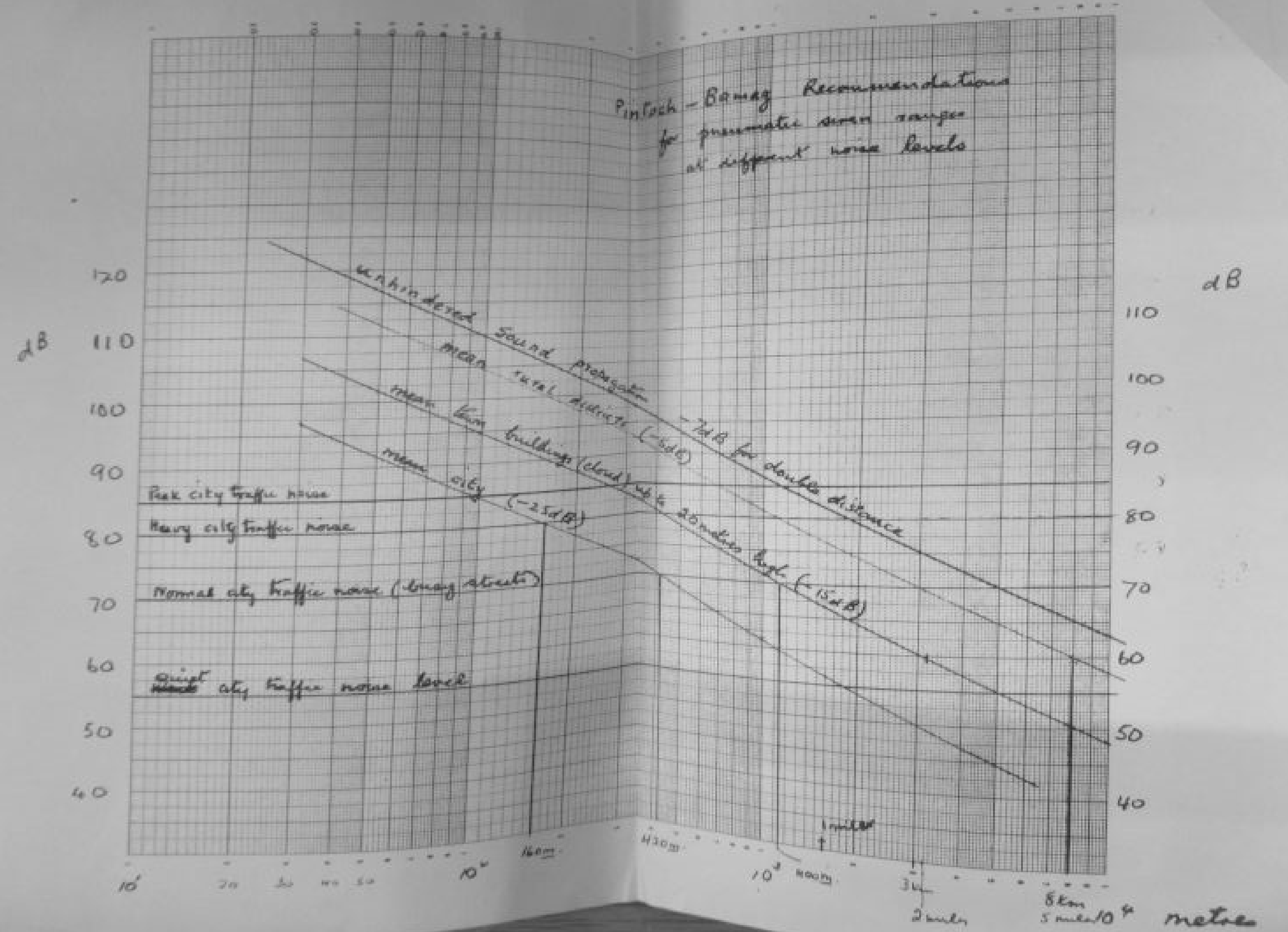
Within the scope of the above cited research project, the Federal Department took measurements of the sound intensity of compressed air sirens in the towns Nurnberg and Hanover as well as in the Northern Section of the ?Landkreis Traunstein. The evaluation of the results has now been completed. Since the preparation of the final reports will still take some time the enclosed relevant figures and particulars are given to serve as a basis for future planning. (See Fig 2)

1. The measured sound levels were arranged according to distance from the site of the siren and measurements taken at equal distances were averaged. This gave curves for both urban and rural areas as shown in the attached graph. Also entered on the graph is a line drawn through the point 122 dB at 30m. distance with a 7dB drop per doubled distance as well as the present planning curve 15dB below that line. The graph shows that the curves of actual measurement move back and forth across the planning curve at mean distances (up to 1,000m.) and at greater distances above it. The small variations between urban and rural area curves result from unavoidable variation in statistic measurements and are not relevant. Both curves provide satisfactory confirmation of the present planning curve which has to date largely been used in planning.

2. Both the results obtained as well as subjective observation in towns showed that the peak siren sound level was occasionally insufficient in areas of heavy traffic although the distance from the nearest siren should have ensured adequate audibility. The cause is clearly the blanketing of the signal by heavy traffic noise. Where this occurs it would appear advisable to fit additional equipment, e.g. an electric siren, to ensure adequate audibility in such localities.

Dr. W. Kallenbach
Oberregierungsrat

Fig 1



Pintsch - Bamag Recommendations
for pneumatic siren ranges
at different noise levels
dB
120
110
100
90
80
70
60
50
40
unhindered sound propagation -7dB for double distance
mean rural districts (-5dB)
mean low buildings (closed) up to 20 metres high (-15dB)
mean city (-25dB)
Peak city traffic noise
Heavy city traffic noise
Normal city traffic noise (busy streets)
Quiet city traffic noise level
10
20
30
40
50
10^2
160m
430m
10^3
800m
1 mile
3k
2 miles
8km
5 miles
10^4
metres

~~Appendix E~~

Fig 3

Extract from Doc 8 (June 1965)
File CDA/61/57/1/2