U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON

LETTER CIRCULAR
LC-706
Supersedes
LC-685

OCTOBER 23, 1942

DEVICES FOR AIR RAID WARNINGS

As a result of the present war, civilian authorities are anxious to obtain information concerning devices suitable for air raid warnings. In response to many requests the Bureau has undertaken a study of such devices and has tried to collect as much information as possible about the most desirable type of signal.

This work is still incomplete, but as the need for information is urgent, all of the data which have been taken on available devices are presented in this letter circular.

To aid in deciding on the type of warning device that should be used in any locality, a number of facts are discussed under the following headings:

1. Frequency
2. Quality of sound
3. Signal strength
4. Ease of coding signal
5. Type of device
6. Effects of weather - loss of intensity with distance
7. Directional characteristics
8. Sound intensity measurements

1. Frequency

In deciding on the type of signal that is to be used for air raid warnings, one of the first considerations should be its frequency characteristics.

Experiments by Knudsen and others show a decided absorption of sound at frequencies above 1000 cycles per second, as a result of which these higher frequencies are attenuated quite rapidly. This would indicate that as the frequency is decreased the sound energy which is lost becomes smaller. Reasoning along these lines would indicate that the lower the frequency of the signal, the better would be its transmission.

However, the frequency of a warning signal should be such as to stimulate the nerve terminals in the ear. Work by Fletcher and many others has shown that the average ear has a maximum sensitivity between 3000 and 4000 cycles and becomes less sensitive at lower frequencies. Hence a signal having too low a frequency is not satisfactory.

For the above reasons it is necessary to compromise between loss due to air absorption and loss insensitivity of the ear.

Experimental work by this Bureau in cooperation with the former Bureau of Lighthouses indicated that the most desirable frequency range for warning signals lay between 200 and 500 cycles per second when it was desired that the signal be heard for a considerable distance. (A 200-cycle note is about 2 tones below middle C, and a 500-cycle note is about an octave above middle C). Surveys of signals in Boston and by the Northern Electric Company, Ltd., in Canada, confirm the Bureau's findings that signals in this frequency range carry better than those having frequencies outside this range.

When relatively small signaling devices are used and it is the intention that they should not be heard for distances much greater than a quarter of a mile, a signal having frequencies of 1000 to 1500 cycles seems to be quite effective for warning persons who are out-of-doors. The reasons for this are that the distance is not great enough to produce large losses by air absorption and a signal having these frequencies is not masked as much by the average noises as a signal having most of the energy in a much lower frequency band.

If it is desirable for the signal to penetrate the outer walls of building structures, a signal having most of the energy in the lower frequencies is desirable. Studies made by the Bureau on sound transmission through different types of building construction indicate that the average transmission loss of sound through such structures is about 8 decibels less at 200 cycles than at 1000 cycles.

The most desirable type of signal, from the standpoint of frequency, is, therefore, determined by conditions under which the signal is to be used. For instance, if it is desirable that the signal cover a large area and be heard inside buildings, a signal having most of the energy in the frequency band between 200 and 500 cycles is desirable. If it is the intention that the signal be heard for only a short distance, say a quarter of a mile and certainly not over half a mile, a signal having most of the energy in a frequency band of approximately 1000 to 1500 cycles might be most desirable.

2. <u>Quality of sound</u>

Having chosen the band of frequencies which is most likely to be heard, one should consider the quality of the tone; that is, should it be a pure tone or should it be a complex tone made up of inharmonic components. Tests again show that an inharmonic combination of tones or a pure tone which is being constantly varied in frequency arrests the attention more quickly than a pure tone or a tone with overtones which are exact harmonics of the fundamental. Also, a combination of tones which are separated by a half octave or more can be selected which will sound louder than a pure tone which has the same amount of energy. If, in addition to the use of two tones, these tones can be varied in frequency the signal becomes very distinctive.

The character of the signal should be also such that it cannot be confused with the signals used by fire trucks, ambulances, and other emergency equipment. Moreover, it should not be similar to surrounding noises since these would mask the warning signal.

3. Signal strength

To be heard above other noises, it is necessary that the signal be sufficiently loud. There is very little information to indicate how loud a signal should be, but it would seem desirable that the loudness level of the signal should be at least equal to the loudness level of the noise at a point where the signal is to act as a warning. (In very quiet areas the signal, of course, should be louder than the surrounding noise.) In areas where there is considerable traffic the average noise level is 80 decibels or more. In a residential area, off arterial highways, the average noise level is approximately 60 to 70 decibels, although in some very quiet areas this level may be as low as 50 decibels.

If a signal level of 80 decibels is chosen as a minimum level for noisy locations and 70 decibels as the minimum level for residential districts, there will be a positive warning to persons out-of-doors and probably to any one located in an outer room with windows. It is unlikely, however, that such signals will penetrate rooms in the interior of a building.

To obtain signals of this level will require a considerable acoustic output, and it becomes necessary to consider the economic side of the question so as to decide whether a large number of small signals placed close together would be more economical than a few large signals spaced considerably farther apart. The answer to this question might be very different in different localities. This subject will be discussed further under parts 5 and 6.

It is the Bureau's belief that in a down-town section, where the buildings are continuous and high and the streets are narrow, relatively small signaling devices, placed at street intersections, might give the best coverage. The number of intersections between signaling devices would depend on the output of the signaling device, and whether locations could be worked out so as to give uniform sound coverage for all streets.

For other locations where a uniform coverage is desired in all directions, it is believed that a device which will give a signal level of approximately 110 decibels at 100 feet will give, on the average, a satisfactory warning signal up to a distance of one-quarter mile if the average noise level does not exceed 80 decibels, and up to one-half mile if the average noise level does not exceed 70 decibels. If the signal strength is 100 decibels at 100 feet, these distances will be about one-half as great, and for a level of 120 decibels at 100 feet the distances could be doubled. The uncertainty due to weather conditions will be somewhat greater at longer distances. To cover an area having a radius of 1 1/2 miles the signal level should not be less than 135 decibels at 100 ft. Under many conditions a signal of this strength will be heard 8 to 10 miles but under adverse conditions it will be weak at a distance of 1 1/2 miles. This point will be discussed further under part 6.

The above statements are rather general and may not apply exactly to any given location. The distribution of signaling devices in any city is an individual problem, and it may be necessary to make trial installations at some points before the best results can be obtained.

4. Ease of coding signals

A signaling device should be chosen which can be easily operated so as to give coded signals.

5. Type of device

In considering the type of device which should be used it is desirable to make a survey of existing facilities. An attempt should be made to lay out a warning system which will require the purchase of a minimum amount of new equipment and still give an efficient warning. For instance, if there are steam plants which have steam up all of the time, a steam whistle or steam siren might be used. In many cases a factory might have a whistle or siren, and it would not be necessary to purchase additional equipment for that locality. In many other locations it might be possible to use air horns, such as are listed in the report at the end of this circular. The necessary air might be obtained at a filling station or a bus terminal. A device which does not require more than 0.5 cu ft of free air per second and a pressure of 25 lb, can be operated by the equipment in the average filling station, which consists of a tank having a volume of 4 cu ft and a 1 1/2 hp compressor. If a greater amount of air is consumed it would be necessary to have more storage capacity or a larger compressor, or both. In any given city it may be possible to take advantage of other factors to lessen the amount of equipment which must be purchased.

6. Effects of weather -- loss of intensity with distance

One of the most important factors in the propagation of acoustic signals over large distances is the weather, or more specifically the humidity, wind, and temperature variations in the atmosphere. The amount of moisture in the air, the temperature, the direction and velocity of the wind, the presence of ascending or descending air currents, the existence or absence of stratified layers, all affect the transmission of sound through the air.

It has been observed that under favorable atmospheric conditions a powerful signal may be heard many miles. Yet, as before stated, under unfavorable conditions, the same signal will be weak at 1 1/2 miles, and under the worst conditions may not be heard 1/4 mile away. The signal strengths which are given in this letter circular are valuable in comparing the acoustic output of different types of signaling devices, but fail to answer one important question: At what distance can these different signals be heard? In an attempt to answer this question, measurements of the sound levels were made at varying distances up to 2 1/2 miles and observations of the audibility of the signals have been made up to distances of over 8 miles. It was found, as stated above, that changes in weather changed the sound level of a signal by a marked amount. At 1/2 mile a reversal in direction of a breeze of 10 miles an hour or less changed the level of a signal 10 decibels or more. All of the data obtained in these tests have been compiled, and the form of an equation which seems to fit the data is as follows:

Loss in decibels from signal strength at 100 ft =
Loss due to distance (inverse square law) + the loss due to the sound passing through the air.

It was found that for signals having a fundamental less than 700 cycles per second the average loss due to the sound passing through the air is about 0.2 decibel per 100 feet for conditions of good transmission. Under unusual conditions this loss is occasionally smaller. Under the worst conditions encountered, on a warm day with a 20 mile per hour adverse wind, the loss was 1.0 decibel per 100 feet. Under some conditions this loss might be greater. Many cases are recorded by other observers where this factor must have been 2.0 decibels per 100 feet or more. A strong, gusty, adverse wind with low humidity appears to represent the worst conditions for the transmission of sound. Cloudy weather, a light mist, or even rain and snow, often represent good conditions.

Using the values 0.2 decibel and 1.0 decibel per 100 feet as representing the extremes which would ordinarily be encountered, the following table has been computed to show what the loss in signal level might be at different distances under the above conditions.

Loss in Decibels from Signal Strength at 100 feet

Distance	Loss due to distance (inverse square law)	Total loss for factor of 0.2 db per 100 ft	Total loss for factor of 1.0 db per 100 ft
1/2 mile	28	34	54
1 "	34	45	86
1 1/2 "	38	54	116
2 "	40	61	145
3 "	44	75	
4 "	46	88	
8 "	53	137	

Using the above table and the source strength, one can compute the probable limits for the signal level at a given distance under varying weather conditions.

It is believed that the losses indicated above apply to city areas as well as the country areas where the measurements were made. In city areas, however, additional losses are caused by buildings and other obstacles which create definite acoustic shadows. When a listener is within an acoustic shadow the additional loss in sound level may vary from a few decibels up to 20 decibels or more. Where powerful signaling devices are used, spaced relatively far apart, it may be necessary to use small supplementary devices where bad sound shadows are found.

7. Directional characteristics

The directional characteristics are given in the discussion of each device. Judging from the tests which have been made, a device can, for all practical purposes, be considered non-directional if the signal strength as determined at 100 ft does not vary more than 7 to 8 decibels when measured in a horizontal plane around the device. If this variation is 15 decibels or more, rotation is necessary to obtain a reasonable coverage in all directions.

8. Sound intensity measurements

Sound intensity measurements and a frequency band analysis have been made at a distance of 100 feet from the devices listed. The frequency band analysis was always made in the direction of the maximum acoustic output. All measurements were made in an open field with each device (with 2 exceptions) mounted about 20 ft above the ground. Many measurements have been made at greater distances to determine the attenuation with distance, but as the difference in attenuation of the signals from the various devices was less than the variation in attenuation due to varying weather conditions, these measurements are not given.

BENDIX-WESTINGHOUSE AUTOMOTIVE AIR BRAKE CO.
Elyria, Ohio.

Only an air-head (air-operated loudspeaker unit) and horn were furnished.

As there was no means supplied of generating a signal, the oscillator, amplifier and compressor furnished by the Dilks Sales Company were used.

With an air pressure of 27 pounds and 34 volts across the voice coil the signal strength at 100 ft was 106 decibels on the axis of the horn, 93 decibels 45° off the axis, and 86 decibels 90° off the axis.

The harmonic content of the signal was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	95
500 - 1000 " " "	102
1000 - 2000 " " "	100
2000 - 4000 " " "	98
4000 " " "	94

BUCKEYE IRON AND BRASS WORKS
Dayton, Ohio.

The devices submitted consisted of 4 whistles marked as follows:

2" plain whistle
2" chime whistle
4" plain whistle
4" chime whistle

These whistles were operated with steam from a boiler used for heating purposes and blown on the roof of the building. The intention was to operate as nearly as possible at a pressure of 100 lb/in^2, but as there was no reducing valve and the load on the boiler varied, it was not possible to hold the pressure constant. Fortunately a change of 5 to 10 lb/in^2 in steam pressure did not change the acoustic output to an appreciable extent.

The signal strengths of these whistles at 100 feet and the fundamental frequency produced by each were as follows:

Whistle	Signal strength (decibels)	Fundamental frequency (cycles per second)
2" plain	99	780
2" chime	101	940, 1070, 1300
4" plain	109	450
4" chime	104	430, 510, 600

The harmonic contents of the signal produced by each of these devices were as follows:

Band	Level in decibels 2" plain	2" chime	4" plain	4" chime
0 - 125 cycles per second	-	-	-	-
125 - 250 " " "	-	-	-	-
250 - 500 " " "	-	-	104	100
500 - 1000 " " "	98	90	99	100
1000 - 2000 " " "	85	100	104	98
2000 - 4000 " " "	83	93	95	90
4000 " " "	78	82	83	84

E. D. BULLARD
275 Eighth St.,
San Francisco, California.

This siren had three heads and was driven by a standard automobile engine. When tested, the gears driving the three heads had the ratio values of 21, 24, and 27. The throttle on the engine was fixed so as to hole it approximately at a constant speed of 3400 rpm.

This device was directional. When the measurements were taken at a distance of 100 feet from the siren and on a line perpendicular to the face of the siren at its center, the level was 125 decibels. This level was approximately constant over an angle of 45° to either side of the perpendicular. For greater angles the level gradually decreased and was a trifle over 10 decibels lower at the rear of the siren than it was directly in front of it. The fundamental frequencies of the three heads were 490, 560, and 630 cycles per second.

The harmonic content of this signal was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	112
500 - 1000 " " "	122
1000 - 2000 " " "	119
2000 - 4000 " " "	114
4000 " " "	114

CHRYSLER CORPORATION
Detroit, Michigan.

The device submitted is known as the Chrysler-Bell siren. This siren had a single head and was supplied with air by a blower. The source of power was a standard Chrysler automobile engine. A short horn was attached to each port in the siren to increase the efficiency. The average signal strength at 100 feet in front of and on the axis of the horn was 137 when adjusted for maximum acoustic output. The sound level decreased about 6 decibels 45° off the axis, 12 decibels 90° off the axis, and 20 decibels 180° off the axis.

The fundamental frequency produced by this siren was 430 cycles per second.

The harmonic content of the signal was as follows, when the signal strength was 132 decibels.

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	130
500 - 1000 " " "	118
1000 - 2000 " " "	117
2000 - 4000 " " "	109
4000 " " "	116

CLARK COOPER COMPANY
1500 North Nascher St.,
Philadelphia, Pa.

The devices submitted consisted of 2 air horns marked as follows:

Clark Cooper Type 6
Clark Cooper Type 8

These horns were tested at an air pressure of 90 lb/in^2.

The signal strength of these horns at 100 feet, the air consumption in cubic feet of free air per second, and the fundamental frequency produced by each were as follows:

Horn	Signal strength (decibels)	Air consumption (cu ft/sec)	Fundamental frequency (cycles per second)
Type 6	109	2.0	275
Type 8	110	3.0	175

The harmonic contents of the signal produced by each of these devices were as follows:

Band	Level in decibels Type 6	Level in decibels Type 8
0 - 125 cycles per second	-	-
125 - 250 " " "	-	100
250 - 500 " " "	100	100
500 - 1000 " " "	104	106
1000 - 2000 " " "	102	103
2000 - 4000 " " "	99	100
4000 " " "	97	96

DEFIANCE ALLOYED PRODUCTS COMPANY
Defiance, Ohio.

This device consisted of a 4-horn unit, the horns being 90° apart in a horizontal plane, having a fundamental frequency of about 225 cycles per second. The signal strength at 100 feet was 99 decibels, when the air pressure was 35 lb per sq in. and the air consumption 0.5 cu ft of free air per second. This device was non-directional. The fundamental frequency of these horns was 225 cycles per second.

The harmonic content of this signal was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	83
250 - 500 " " "	83
500 - 1000 " " "	96
1000 - 2000 " " "	95
2000 - 4000 " " "	93
4000 " " "	87

DILKS SALES COMPANY
South Norwalk, Conn.

This device consisted of an air-head (air-operated loudspeaker unit), horn, amplifier, oscillator, and a small air compressor. When tested, the oscillator gave a tone which was constantly shifting from about 435 to 660 cycles per second.

With an air pressure of 22 pounds and 37 volts across the voice coil the signal strength at 100 feet was 107 decibels on the axis of the horn, 99 decibels 45° off the axis, and 90 decibels 90° off the axis.

The harmonic content of the signal was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	95
500 - 1000 " " "	102
1000 - 2000 " " "	100
2000 - 4000 " " "	98
4000 " " "	94

DORAN COMPANY
75 Horton Street,
Seattle, Washington.

The devices submitted by this company consisted of two horns marked as follows:

Doran-Cunningham Whistle Size 3A
Cunningham Whistle Size 4

These horns were tested at an air pressure of 80 lb per sq in.

The signal strengths of these horns at 100 feet, the air consumption in cu ft of free air per second, and the fundamental frequency produced by each were as follows:

Horn	Signal strength (decibels)	Air consumption (cu ft/sec)	Fundamental frequency (cycles per second)
Size 3A	106	0.53	320
Size 4	113	.73	240

The harmonic contents of the signal produced by each of these horns were as follows:

Band	Level in decibels Size 3A	Size 4
0 - 125 cycles per second	-	-
125 - 250 " " "	-	102
250 - 500 " " "	102	99
500 - 1000 " " "	97	107
1000 - 2000 " " "	93	106
2000 - 4000 " " "	89	103
4000 " " "	76	99

FEDERAL ELECTRIC COMPANY
8706 South State St.
Chicago, Ill.

This device was a 2 horsepower vertical electric siren submitted by the District of Columbia. The fundamental tone was about 550 cycles per second. The power consumption was 2.8 hp. The signal strength at 100 feet was 98 decibels. This device was non-directional.

The harmonic content of the signal was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	-
500 - 1000 " " "	94
1000 - 2000 " " "	90
2000 - 4000 " " "	92
4000 " " "	88

FOSTER ENGINEERING CO.
Newark, N. J.

The devices submitted by this company consisted of two steam sirens marked as follows:

Type 45 steam siren (No. 4 brake shoes)
" 45 " " (No. 3 " ")
" 30 " "

These sirens were operated from the same boiler as the steam whistles. Owing to the quantity of steam used for the type 45 siren, the drop in the pipe line to the roof was such that the average pressure at the siren when blowing was 90 lb/in^2. The average steam pressure for the small siren was 100 lb/in^2.

The signal strength of these sirens at 100 feet and the fundamental frequency of each were as follows:

Type of siren	Signal strength (decibels)	Fundamental frequency (cycles per second)
Type 45 (No. 4 brake shoes)	125	215
" 45 (No. 3 " ")	127	310
" 30 (1/8" valve opening)	116	890
" 30 (1/4" " ")	120	1170

The harmonic contents of the signal produced by each of these devices were as follows:

Band (cycles per second)	Level in decibels			
	Type 45 (No.4 shoes)	Type 45 (No.3 shoes)	Type 30 1/8" Valve Opening	Type 30 1/4" Valve Opening
0 - 125	-	-	-	-
125 - 250	118	-	-	-
250 - 500	122	124	-	-
500 - 1000	114	122	115	-
1000 - 2000	112	116	105	120
2000 - 4000	*	105	97	106
4000	*	*	98	111

*The energy at these frequencies was so small that it was not measured.

HENRY FREUND
314 Hunt Street,
Houston, Texas.

This device was similar to some of the exhaust whistles installed on automobiles. Since the operating pressure was not specified it was tested at several pressures.

The signal strengths at 100 feet for the different air pressures were as follows:

Air pressure (lb/sq in.)	Signal strength (decibels)
10	65
15	85
30	89
40	91

Since this whistle was rather inefficient and not loud enough to be of value as an out-of-door warning signal, measurements were not taken to determine the air consumption of the whistle or the frequency characteristics of the signal.

THE GAMEWELL COMPANY
Newton Upper Falls, Mass.

This device was a Type B diaphone with an aluminum piston. The device was operated at an air pressure of 35 lb per sq in. The air consumption was 1.2 cu ft of free air per second and the signal strength at 100 feet was 114 decibels. For all practical purposes this device was non-directional.

The fundamental frequency produced by this device was about 260 cycles per second.

The harmonic content of this signal was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	92
500 - 1000 " " "	106
1000 - 2000 " " "	111
2000 - 4000 " " "	106
4000 " " "	99

H.O.R. COMPANY, INC.
6-8-10 Broad St.,
Stapleton, S.I. N.Y.

This device was a 5 horsepower vertical electric siren. The fundamental frequency was about 500 cycles per second. The power consumption was 6.6 horsepower. The signal strength at 100 feet was 102 decibels. This device was non-directional.

The harmonic content was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	-
500 - 1000 " " "	101
1000 - 2000 " " "	91
2000 - 4000 " " "	83
4000 " " "	85

KEYSTONE GRINDER AND MANUFACTURING CO.
Wharton and Twentieth Streets,
Pittsburgh, Pa.

The device submitted by this company consisted of an air horn having a steel diaphragm .031" thick. This horn was tested at an air pressure of 15 lb per sq in. The signal strength at 100 feet was 108 decibels on the axis of the horn and the air consumption was 0.45 cu ft of free air per second.

The fundamental frequency produced by this horn was 960 cycles per second.

The harmonic content was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	-
500 - 1000 " " "	107
1000 - 2000 " " "	93
2000 - 4000 " " "	88
4000 " " "	86

Later tests using Apollo metal and American Nickeloid .018" thick for diaphragms gave approximately the same acoustic output.

This device was slightly directional, but not enough so to make it worth while to rotate the horn. When the sound level was measured around the horn in a horizontal direction at a distance of 100 ft from the horn, the maximum decrease in level from the measurement on the axis was 7 decibels.

KIEL LABORATORY
23-27 South Jefferson St.,
Chicago, Illinois.

The devices submitted were as follows:

1 Mogul 7 1/2 volt electric horn
1 Kodaire 24 volt d-c electric horn
1 Carl air horn (220 c/s)
1 " " " (275 c/s)
2 Air horns (no identifying marks)
1 Signalphone air horn

The two air horns which had no identifying marks differed only in the length of the horn. For the purposes of this report they will be termed long horn and short horn.

The signal strengths of these devices at 100 feet and on the axis of the horns, the air pressure in lb/in^2, the air consumption in cubic feet of free air per second, and the fundamental frequency produced by each were as follows:

Type of horn	Signal strength (decibels)	Air pressure (lb/in^2)	Air consumption cu ft/sec	Fundamental fre (cycles per se
Mogul	77	-	-	400
Kodaire	85	-	-	300
Carl Horn (220 c/s)	101	30	0.23	220
Carl Horn (275 c/s)	105	30	.23	275
Long Horn	100	30	-	325
Short Horn	100	30	-	440
Signalphone	110	15	.59	960

The harmonic contents of the signals from each electric horn were as follows:

Band	Level in decibels	
	Mogul	Kodaire
0 - 125 cycles per second	-	-
125 - 250 " " "	-	-
250 - 500 " " "	55	64
500 - 1000 " " "	70	80
1000 - 2000 " " "	75	80
2000 - 4000 " " "	68	76
4000 " " "	71	73

The harmonic contents of the signals from each of the air horns were as follows:

Band	Level in decibels			
	Carl horn (220 c/s)	Carl horn (275 c/s)	Long horn	Short horn
0 - 125 cycles per sec.	-	-	-	-
125 - 250 " " "	86	-	-	-
250 - 500 " " "	89	92	84	87
500 - 1000 " " "	97	101	93	87
1000 - 2000 " " "	97	101	93	93
2000 - 4000 " " "	89	91	94	93
4000 " " "	85	90	97	97

The harmonic content of the Signalphone air horn was not measured carefully, but it was approximately the same as that for the Signalphone horn listed under Keystone Grinder and Manufacturing Co.

LINE MATERIAL COMPANY
E. Stroudsburg, Pa.

This device was a 5 horsepower 2-tone horizontal electric siren. The fundamental tones were about 530 and 636 cycles per second when the steady tone was used. It also had a device to switch the current off and on, thus producing a warble tone. The power consumption on the steady tone was 12.2 horsepower. The average signal strength at 100 feet was 104 decibels. This device was slightly directional. The sound level varied about ± 2 decibels when measured around the siren in a horizontal direction, the maximum being in the direction of the shaft. When the warble was used this strength varied about ± 5 decibels, giving a signal strength varying from 99 to 109 decibels.

The harmonic content was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	-
500 - 1000 " " "	103
1000 - 2000 " " "	93
2000 - 4000 " " "	72
4000 " " "	70

LARGE SIREN DEVELOPED BY N.D.R.C.

This siren had a single head and was supplied with air by a blower. The source of power was a gasoline engine. A short horn was used to increase the efficiency, and this made the device directional. The average signal strength at 100 feet was found to be 133 decibels when measured in front of and on the axis of the horn. The sound level decreased about 6 decibels 45° off the axis, 23 decibels 90° off the axis, and 21 decibels 180° off the axis.

The fundamental frequency produced by this siren was 460 cycles per second.

The harmonic content of the signal was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	124
500 - 1000 " " "	129
1000 - 2000 " " "	118
2000 - 4000 " " "	114
4000 " " "	115

ST. HELENS WELDING AND MACHINE WORKS
St. Helens, Oregon

The device submitted was a "Skyrade" air horn. It consisted of a 3-horn unit, the horns being 120° apart in a horizontal plane. The manufacturer stated that the most efficient pressure was 75 lb but that it would operate satisfactorily at lower pressures. The signal strength at 100 ft and air consumption in cubic feet of free air per second were determined for four different pressures and were as follows:

Pressure (lb/in^2)	Signal strength (decibels)	Air consumption (cu ft/sec)
25	102	0.50
35	103	.67
50	105	.85
75	106	1.17

The fundamental frequency produced by these horns was 300 cycles per second.

The harmonic content of the signal when produced with 50 lb air pressure was as follows:

Band	Level in decibels
0 - 125 cycles per second	-
125 - 250 " " "	-
250 - 500 " " "	100
500 - 1000 " " "	99
1000 - 2000 " " "	97
2000 - 4000 " " "	97
4000	92

WESTINGHOUSE AIR BRAKE CO.
Wilmerding, Pa.

The devices submitted by this company consisted of two air horns marked as follows:

Type A-2 horn
Type E-44 horn

The Type A-2 horn was tested at an air pressure of 80 lb/in^2 and Type E-44 at an air pressure of 60 lb/in^2.

The signal strength of these horns at 100 feet, the air consumption in cubic feet of free air per second, and the fundamental frequency produced by each were as follows:

Horn	Signal strength (decibels)	Air consumption (cu ft/sec)	Fundamental frequency
Type A-2	101	0.22	298
Type E-44	108	.72	470

The harmonic contents of the signal produced by each of these devices were as follows:

Band	Level in decibels Type A-2	Type E-44
0 - 125 cycles per second	-	-
125 - 250 " " "	-	-
250 - 500 " " "	95	103
500 - 1000 " " "	91	101
1000 - 2000 " " "	92	94
2000 - 4000 " " "	96	101
4000 " " "	92	100