An evaluation of the acoustic performance of No. 3 cell inlet silencer

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SUBJECT AN EVALUATION OF THE ACOUSTIC PERFORMANCE OF NO. 3 CELL INLET SILENCER

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ISSUED TO Internal

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AN EVALUATION OF THE ACOUSTIC PERFORMANCE OF NO. 3 CELL INLET SILENCER

1.0 INTRODUCTION

As part of a programme designed to reduce the jet noise emitted from the Engine Laboratory, a baffle-type silencer was installed in the inlet to No. 3 test cell. The purpose of this investigation was to evaluate the transmission loss across the silencer, as well as the resulting noise reduction at a point 30 feet in front of the inlet. Because there was no engine in the cell at the time of installation, the silencer was tested using an 1 1/8-inch-diameter air jet as noise source. Some time after completion however, a few rough over-all sound-pressure measurements were made with an Olympus engine in the cell.

2.0 DESCRIPTION OF INSTALLATION

2.1 The silencer is built up of a unit element consisting of two fibreglass panels (2" x 20½" x 41½") mounted in a wooden frame, as shown in Fig. 1. These elements are put together so as to form a group of staggered parallel passages three units deep (See Fig. 2). Four and a half of these groups make up the complete silencer (Fig. 3). The supporting structure is of plywood and designed so that the installation can be dismantled (with some difficulty) if necessary.

2.2 The particular type of silencer under test reduces noise transmission by two different methods. One, by reflection of some of the noise back towards the source. This is brought about by the bends. Two, by absorption of part of the acoustic power by the fibreglass lining on the baffles.

3.0 INSTRUMENTATION

3.1 Over-all sound-pressure levels (OA SPL) were measured using a Dawe Instruments Limited type 1408-B sound-level meter, whose range extends from 30 to 135 db above the standard reference level of 0.0002 dynes per sq. cm. at 1000 c/s. On the C scale, the instrument has a frequency response substantially flat from 40 to 6000 c/s.

3.2 An Ampex model 600tape recorder was used to record the noise for subsequent frequency analysis in the laboratory. The manufacturer gives the frequency response as 40 to 15,000 cps - 4 db at 15,000 cps. for this model, which had a 7.5 ips. tape speed.

3.3 A Bryl & Kjaer 1/3 octave audio-frequency spectrometer type 2109,connected to a Bryl & Kjaer high-speed-level recorder type 2304, was used for frequency analysis of the recorded noise. The pass bands

of the spectrometer had the following geometric mean frequencies in cycles per second:

50	315	2000
63	400	2500
80	500	3150
100	630	4000
125	800	5000
160	1000	6300
200	1250	8000
250	1600	10000

A weighing network with flat response (C scale) is also built into the spectrometer. The arrangement will permit traces to be made at each octave band as well as the OA SPL of the recorded noise.

4.0 TEST PROCEDURE

4.1 The test was carried out in two parts, one before and the other after the installation. Two imaginary planes that would later coincide with the inlet and outlet of the silencer, were selected for sound measurements, each plane being subdivided into twelve measuring stations arranged in two rows of six each. The layout is shown in Figs. 2 and 3. In both cases, over-all sound-pressure levels were taken at each station, while tape recordings were only recorded at stations 3 and 15.

4.2 Another station (No. 25) was established arbitrarily 30 feet in front of the inlet door, for the purpose of evaluating the noise reduction at a given point. Only tape recordings were taken at this station, one before and one after silencer installation.

4.3 The noise source consisted of a 1 1/8-inch-diameter air jet placed 14 feet away from the silencer, measured from the inside along a line passing through stations 15 and 3, but only about one foot off the floor. During both tests the air jet was operated at a pressure of 30 psig.

4.4 Some time after the installation was completed, a few rough OA SPL measurements were made as a check with an Olympus engine running at idle (2100 r.p.m.).

5.0 TEST RESULTS AND DISCUSSION

5.1.1 Over-all Sound-Pressure Levels from Dawe Sound-Level Meter

Station (Inside Plane)	1	2	3	4	5	6	7	8	9	10	11	12	Average
OA SPL Before Treatment	123	124	124	121	119	119	123	124	123	122	120	120	122
OA SPL After Treatment	117	116	117	120	116	119	121	120	121	120	119	118	119

Station (Outside Plane)	13	14	15	16	17	18	19	20	21	22	23	24	Average
OA SPL Before Treatment	122	122	122	121	121	120	120	123	122	121	119	120	121
OA SPL After Treatment	85	82	83	85	82	81	83	85	85	85	83	83	84

5.1.2 Over-all Sound-Pressure Levels from Analysis of Tape Recordings

Station	3	15	25
OA SPL Before Treatment	122	121	114
OA SPL After Treatment	116	84	78

The average OA SPL at the inside and outside planes agrees very well with the above data, except for station No. 3 after treatment. Because the average value of 119 db seems more representative, it will be used instead of 116 db, in the following calculations and graphs.

5.1.3 Over-all Transmission Loss with Air Jet Noise Source

The transmission loss TL has been evaluated by two different methods. One, the end difference method, where the TL equals the difference in SPL at the two planes of measurement. Two, the before-and-after method, where the TL equals the difference in SPL at the outside plane of measurement before and after treatment. From the above OA SPL data, the over-all transmission loss (OATL) was found to be:

OA TL (end difference method) = (119 - 84) = 35 db

OA TL (before-and-after method) = (121 - 84)-(3) = 34 db

A correction of 3 db has been applied in the last case, to correct for the difference in source intensity.

5.1.4 Over-all Transmission Loss with Olympus Engine as Source

The OA TL is not a good measure of the effectiveness of a noise suppressor, because it depends on the frequency characteristics at the noise source. It is therefore not surprising to find that OA TL is different with the Olympus replacing the air jet. With the engine idling (2100 r.p.m.), the OA SPL's were as follows:

Outside plane 103 db

Inside plane, station 2 132 db (in front of inlet duct)

Inside plane, stations 3,4 & 5 125 db

This gives OA TL of 29 db and 22 db respectively. It is interesting to note that the noise intensity distribution over the outside plane

is uniform in spite of the non-uniformity on the inside. This may be so because station 2 is mostly exposed to high-frequency compressor whine, for which the silencer is more effective than it is for lower frequency noise reaching the other stations from the exhaust end.

5.1.5 Transmission Loss in Bands

The true performance of the silencer can only be represented as in Fig. 4, where the TL is plotted vs frequency band. The top experimental curve is evaluated using the end difference method, and the other by the before-and-after method. In the last case, corrections were applied to the TL for each band to take care of difference in source intensity. The graph shows the two curves to be in good agreement, as well as the fact that the silencer is most efficient between about 600 and 4000 c/s where the TL in band is about 40 db. Unlike the OA TL, the TL in each band is independent of the frequency characteristics of the test source. Fig. 4 may therefore be used to calculate the noise level at the outside plane for any engine, provided the engine noise spectrum is known. The smooth curve is included for comparison. It shows the theoretical TL offered by nine feet of 4-inch fibreglass baffles spaced at 12-inch cts.

5.1.6 Noise Reduction

The over-all noise reduction (OA NR) at station 25 was found to be 33 db, while the corresponding NR per band is plotted in Fig. 5. The fact that the OA NR is of the same order of magnitude as the OA TL suggests that the directivity pattern of the emitted noise has not been altered by the silencer installation. However, it must be remembered that as in the case of OA TL, the OA NR depends on the frequency characteristics of the source, and as a result it may be somewhat lower with a jet engine in operation.

A comparison of Figs. 4 and 5 shows the curves to be similar in shape, but the NR levels are generally lower than the TL, which is impossible. This suggests that the results in Fig. 5 may have been affected by background noise. Unfortunately, the two background noise recordings had to be discarded because of faulty recording technique. Hence the theory cannot be verified.

6.0 SUMMARY

The acoustical test on the baffle-type silencer installed in the inlet to No. 3 test cell shows:

1. Over-all transmission loss across the silencer, with air jet as noise source, ranged from 34 to 35 db.

2. Over-all transmission loss across the silencer, with Olympus as noise source, ranged from 22 to 29 db.

3. Over-all noise reduction at a point 30 feet in front of inlet was 33 db., with air jet as noise source.

4. Note that over-all transmission loss and over-all noise reduction depends on the frequency spectrum of the noise source.

5. On the other hand, the silencer performance as represented by Fig. 4 is independent of the frequency spectrum of the noise source.

6. The silencer is more efficient for high- than for low-frequency (Fig. 4). Between 600 and 4000 c/s, the transmission loss is in excess of 36 db.

A P P E N D I X

Two different criteria are of interest when sound-control systems are evaluated. The first one is the transmission loss (TL), which is a measure of the reduction in total transmitted acoustic power obtained by the use of a given silencer. In other words, it is a measure of the effectiveness of the sound absorbing device. The second kind is expressed as noise reduction (NR), and it is a measure of the reduction in sound-pressure level obtained at a given point when a sound-control treatment is installed. A reduction in sound-pressure level at a designated location may be brought about by changing the distribution pattern from the noise source (by reflectors, relocation, etc.) or by absorbing some of the transmitted power. A sound-control device of the first type will obviously have zero TL because no power is absorbed, but it may still be as effective in reducing the noise at the selected point, as a device of the second type.

By definition TL may be written as:

$$TL = 10 \log P_{in}/P_{out} \qquad (1)$$

where Pin and Pout is the acoustic power entering and leaving the sound-control device. But if it is assumed that reflection is negligible, the power may be computed from the expression:

$$P = S(p^2)av/pc^2 \qquad (2)$$

where S is the area through which the noise is transmitted, $(p^2)av$ is the pressure squared average over the opening, and pc is the specific impedance of the air under the prevailing conditions.

The average sound pressure level $(SPL)_{av}$ is the average of the SPL measurements taken over the whole area.

$$(SPL)_{av} = 1/n\{SPL_1 + SPL_2 + \cdots + SPL_n\} = 10 \log \left\{\frac{P_1 \times P_2 \times \cdots \times P_n}{P_{Ref.}^n}\right\}^{2/n} = 10 \log \left\{P/P_{Ref.}\right\}^2_{av} \qquad (3)$$

because

$$SPL = 20 \log \{P/P_{Ref}\} = 10 \log \{P/P_{Ref}\}^2 \qquad (4)$$

In the particular case where the areas and the impedances are the same at both the inlet and outlet end, equations (1), (2) and (3) give:

$$TL = 10 \log \{P_{in}^2/P_{out}^2\}_{av} = 10 \log \left\{\frac{(P_{IN}/P_{Ref})^2}{(P_{OUT}/P_{Ref})^2}\right\}_{av} = (SPL_{IN})_{av} - (SPL_{OUT})_{av}$$

In other words, in the special case the TL equals the difference of the average SPL at inlet and outlet to the sound-control device.

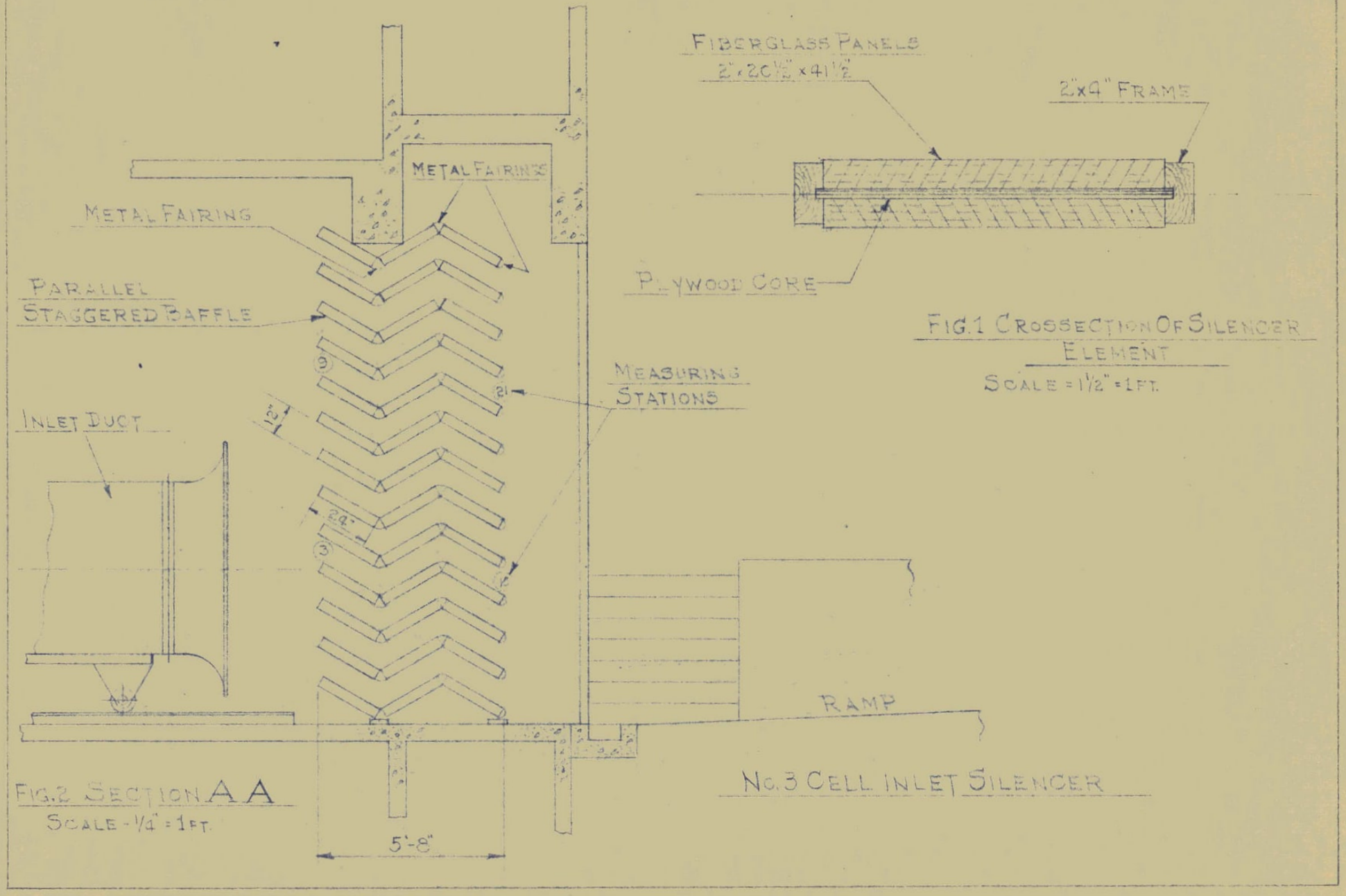


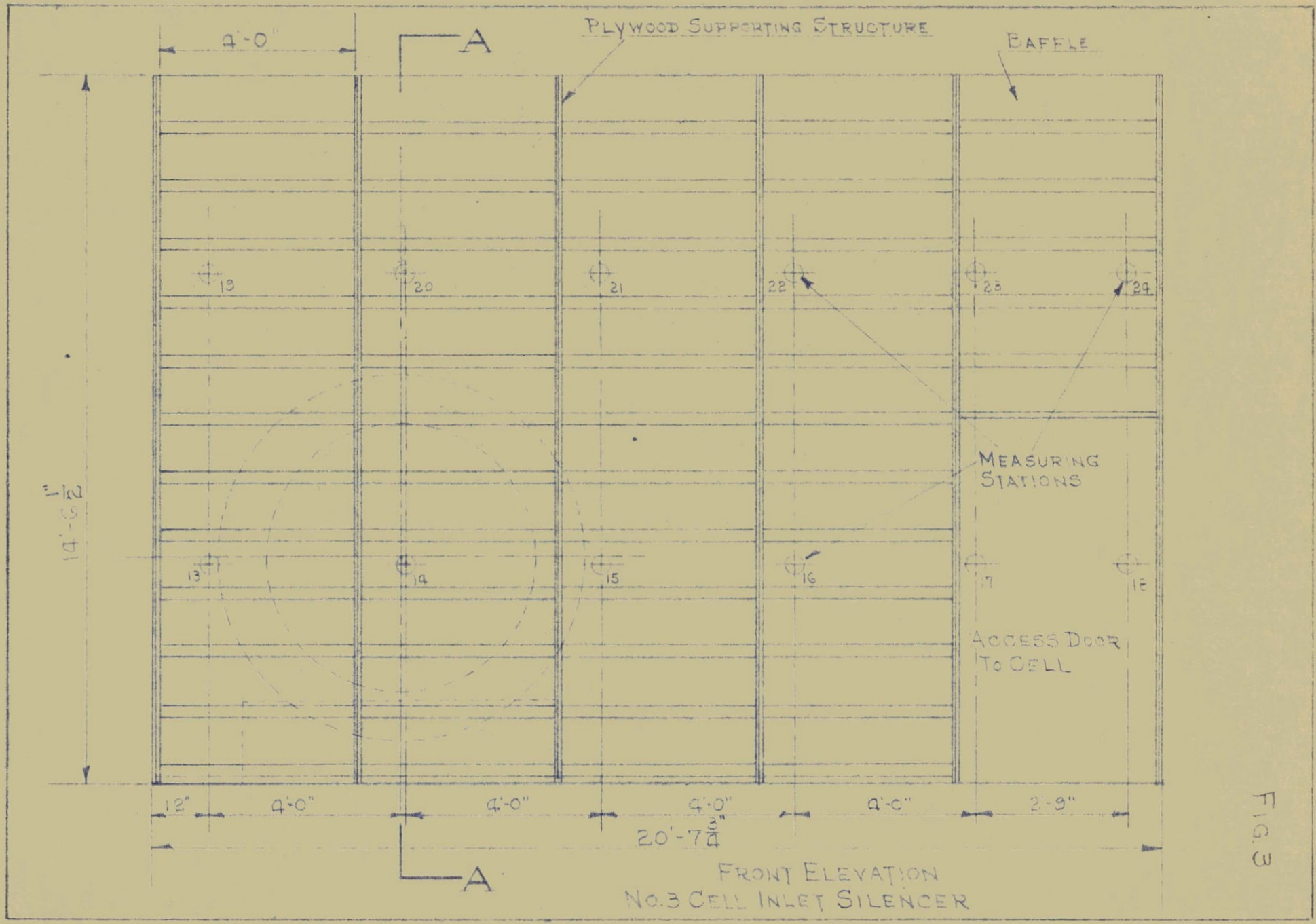
FIG. 1 CROSSECTION OF SILENCER ELEMENT

SCALE = 1½" = 1 FT.

FIG. 2 SECTION A A

SCALE - ¼" = 1 FT.

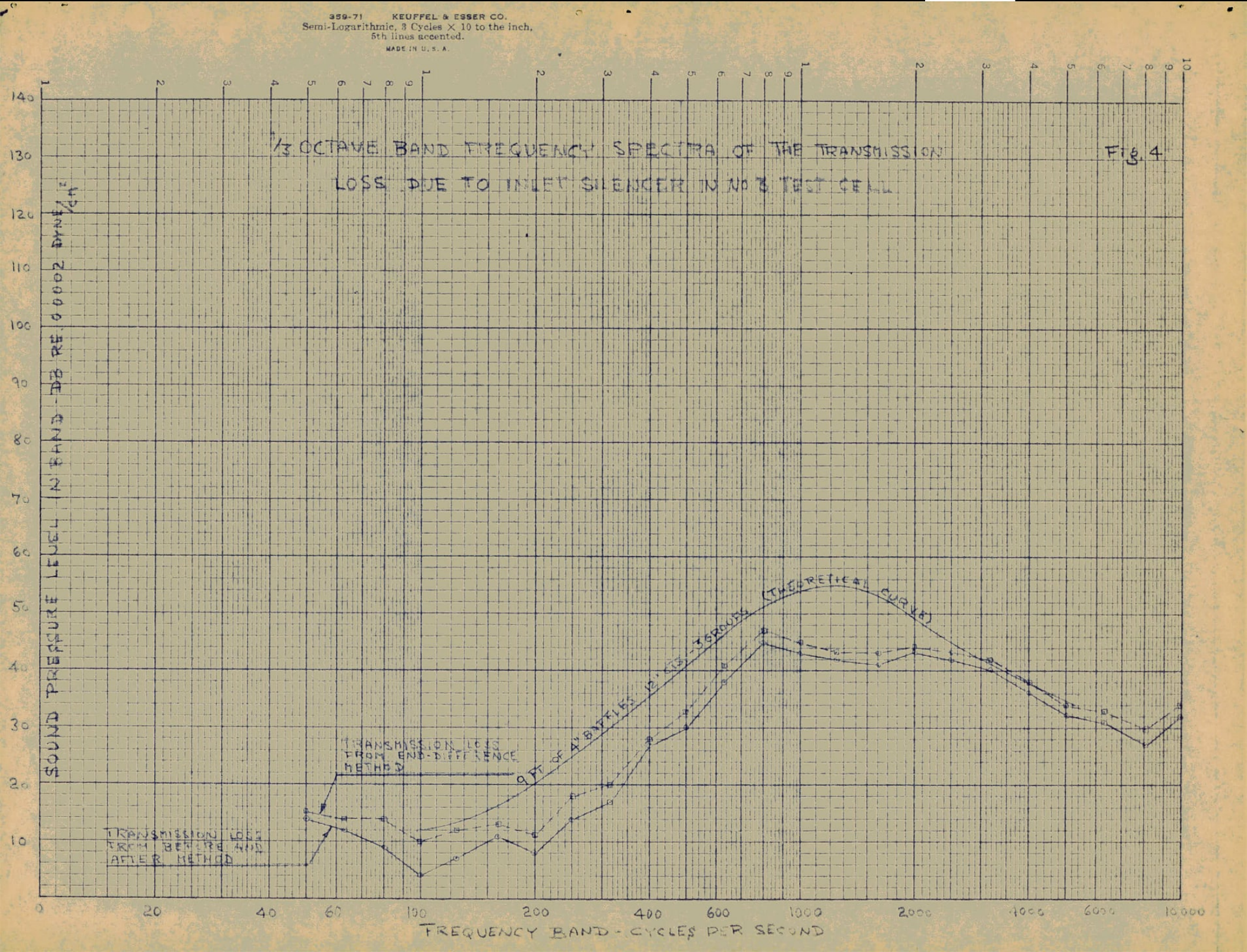
NO. 3 CELL INLET SILENCER



FRONT ELEVATION
NO.3 CELL INLET SILENCER

FIG. 3

359-71 KEUFFEL & ESSER CO.
Semi-Logarithmic, 3 Cycles × 10 to the inch,
5th lines accented.
MADE IN U. S. A.



359-71 KEUFFEL & ESSER CO.
Semi-Logarithmic, 3 Cycles × 10 to the Inch,
5th lines accented.
MADE IN U.S.A.