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REQUIREMENTS FOR A GOOD ACOUSTIC LABORATORY

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INTRODUCTION
It is a well-known fact that the compressor manufacturer in the course of time has been obliged to show some interest in the noise caused by his products. The necessity becomes greater as the competition increases. It is becoming clear to the customer that noise is not absolutely necessary to achieve the primary object, namely refrigeration. At the same time the authorities are setting up rules stating how much noise we may produce in and outside our houses. For refrigeration compressors it is fortunately a question of annoyance, rather than a question of high noise levels. In the past a lot has been written about noise testing and noise evaluation methods, some usable, but also some so sophisticated that they were impossible to use in practice. In the last ten years a crystallization of the best of the methods has taken place, and within ISO usable standards and drafts are on their way (1), which is of great satisfaction. It would be gratifying if all those national standards could be replaced by international standards, thereby making it possible to speak the same language.

REQUIREMENTS
What is the requirements to a good acoustic laboratory from the point of view of a compressor manufacturer and his customer? The primary object must be to own "a tool" which facilitates the manufacturing of a silent compressor.
1. For that purpose we shall of course need people with sufficient education and imagination to handle the problems in the correct manner.
2. Furthermore we shall have to purchase special measuring equipment in order to carry out the necessary detail analysis of the various components and parameters influencing the noise level. Things like valve examination, muffler calculation and investigation, spring and discharge tube analysis, and compressor shell investigation can be mentioned.
3. We need measuring surroundings (test rooms) enabling us to carry out objective measuring with possibilities for sound power determination, with an accuracy as stated in international standards. The measuring room should also be acoustical adjusted (frequency independent reverberation time) so that it enables us to carry out a subjective evaluation of the noise character (pounding, discrete frequencies, time variation, etc). Such an "adjustment" will also facilitate tape recordings of diverse equipment during testing and replay in front of an audience for pronunciation.
4. The measuring procedure must be practicable in time as it is normally necessary to carry out measurements on several samples, and at more than one running condition. This is tantamount to measuring equipment with automatic data acquisition, which together with a digital computer admits an easy access for all desired calculating such as sound power level, noise evaluation, statistical tests, etc.

The following contains a review of the procedure with which we attempted to meet the requirements under points 3 and 4.

TYPES OF TEST ROOMS
It is commonly known that a reverberant room offers great advantages in regard to cost and test effort, compared with an anechoic room (2,3). The disadvantage is by and large limited to the problem of obtaining sufficient space averaging of the sound pressure when testing equipment whose spectra contains narrow bands of noise(4.5)
Our reverberent test rooms (two identical rooms, constructed in 1968) are of the conventional rectangular type with data in accordance with several standards and draft proposals (6.7). The room volume is 200m³. Further data for the rooms are stated at the top right corner of figure 5.
In order to be able to measure equipment with extremely low noise levels the rooms...
are built with double walls. The inside room is vibration insulated by means of rubber springs. Background noise levels (room + measuring instruments) are stated as function of frequency in figure 5 (in table).

Reverberation time adjustment and diffusing elements.
The room were constructed with inside surfaces as hard as possible to create a high reverberation time at the high frequencies. After the finishing of the building, regulation of the room absorption was made for two reasons:
1. To increase the bandwidth of the resonance curves of the normal modes of the room, particularly at the low frequencies.
2. By and large to obtain a frequency-independent reverberation time for the possibility of making an auditive evaluation of noise from the test object as mentioned (see figure 1).

Most of the absorbing elements are made of perforated and unperforated aluminium panels. The elements were placed at random and at various angels to the room surface to work as diffusers, also. A final regulation was carried out by means of "tuned membrane absorbers" suspended in the room. Further diffusion was made in the ceiling construction (see figure 2).

There are now revolvable or oscillating diffusers in the room. Space averaging is made by a traversing microphone which moves with a constant velocity (0.4m/sec) over a path of two metres.

![Fig. 2. Interior of test room.](image)

**Fig. 1.** Reverberation Time versus Frequency

a. Before regulation.
b. After regulation.

**INSTRUMENTATION**

Agmeasuring equipment are used a 1/3 octave band Real Time Analyser (B & K, type 3347) with continuous time averaging (RC-smoothing) with time constant equal to 20 seconds. The analyser is connected to a tape punch B&K type 5582). A Manual Data Extension Unit (B & K, type 5599) gives the possibility for information on sample type and number, running conditions, etc. (see figure 3).

The data measured can then be calculated in a digital computer.

**QUALIFICATION OF THE TEST FACILITIES**

To examine the quality of the room, various meaurings have been carried out on two different types of noise sources.
1. The conventionally used ILG-Reference Sound Source (broad band noise)
2. Selected compressor with narrow bands of noise and discrete frequencies.

Re.1. Figure 4 shows the sound pressure levels for the sound source (RSS) versus distance to microphone. From 125 Hz and up to 8 kHz we have very smooth sound pressure levels over a long distance except at 250 Hz. Qualification test for broad band noise
measurements in accordance with the new ISO draft (7) are shown in figure 5a and 5b. The requirements are more than satisfied except the 100 Hz 1/3 octave band.

Other measurements (not shown here) show that one source location and the microphone traversed with constant velocity over a path of two metres, gives measuring uncertainty which is less than that mentioned in the new ISO-draft (7).

With a carefully selected fixed microphone location, the uncertainty will only be slightly increased, which is important when recording on tape recorders.

Re 2. When measuring sources with narrow bands of noise and discrete frequency, one must be more careful. Figure 6 shows measurements on a compressor, which, after the definitions in the ISO (7) part II, have narrow bands of noise with 315, 400, 800, 1600 and 2000 Hz and discrete frequencies with 500 and 1000 Hz.

Figure 7 shows measurements and statistical test with the compressor location moved 0.7 metres from the above mentioned. There were only significant deviations in a very few 1/3 octave bands.

Finally, figure 8 shows a statistical test between the measurements from figure 6 and ten measuredings taken at intervals of one minute on the same compressor, but with fixed microphone located in the centre of the microphone path.

As expected there are significant differences between several frequency bands, but the deviations are modest.

PRESENTATION OF MEASURED AND CALCULATED DATA

Figure 5 to 8 also shows clear examples of how to present the measured sound pressure levels, calculated sound power levels and statistical test.

The applied equation for sound power level calculation

$$L_w = L_p + \left[ 10 \log_{10} V - 10 \log_{10} T - 14 \right] dB$$

to account for the effect of the interference pattern formed near the room surfaces, ISO part II (7).

FINALLY COMMENTS

Mentioned here are some of the most important requirements for a good acoustic laboratory, without, however, all the details.
Of the factors which are significant for the sound power calculations are things like accuracy when adjusting the measuring equipment and the determination of reverberation time. Oscillating or rotating diffusers are often used in reverberant test rooms, but one of the factors connected with this must be made clear. Such diffusers cannot operate during tape recordings, since space variations of the sound pressure level in the test room will be conceived as time variation of the test object.

The length of the microphone path we use is much less than demanded by the measuring method, in order, the length of the microphone path we use is made clear.

The measurement of whether this point is still too sophisticated or not, it must be better having the other facilities in order, with the possibility to make compressors without pure tones than being able to measure with the utmost precision on a bad product.

REFERENCES


Fig. 5a.
MEAN SOUND PRESSURE LEVEL, STANDARD DEVIATION AND SPECTROGRAM FOR

THRU OBJECT: 1 LG + RPS + 220 VOLT \* ROOM TEMP. 20 C \* " MF, DATE \* CODE 1
13 HZ+POS 1150+HPS \* 50 HZ \* 60% REL. HUM. \* ME 8 \* 03-06-72

LP*10 NO 14 NO 21 NO 32 NO 41 NO 52 NO 61 NO 72 NO 81 NO 92 NO 100
250 315 400 500 630 800 1K 1.2 1.6 2K 2.5 3.2 4K 5K 6.3 8K 10K 12K DBA

SPECTROGRAM FOR CALCULATED MEAN SOUND PRESSURE LEVEL AND + 2 TIMES THE STD DEV

LP 010 20 30 40 50 60 70 80 90 100
125 160 200 250 315 400 500 630 800 1K 1.2 1.6 2K 2.5 3.2 4K 5K 6.3 8K 10K 12K DBA

Fig. 5 b
F- AND T-TEST FOR NOISE MEASUREMENTS. "-'-04 TEKNIK EDB; DANFOSS, NORDborg. PROGRAM M3062 "-04".

1) MEDIUM VOLT = 220 VOLt • EVAPORATING TEMP. = 25 C • MF. DATE • CODE 6
2) MEDIUM VOLT = -55 C • MEAS. • CODE 03.0672 • (REFERENCE)

| LP | 193 | 143 | 139 | 120 | 130 | 125 | 135 | 148 | 157 | 251 | 122 | 121 | 100 | 118 | 273 | 204 | 169 | 137 | 120 | 116 | 96 | 96 | 111 |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| T-100 | 193 | 143 | 139 | 120 | 130 | 125 | 135 | 148 | 157 | 251 | 122 | 121 | 100 | 118 | 273 | 204 | 169 | 137 | 120 | 116 | 96 | 96 | 111 |
| S | 1.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 1.4 | 1.8 | 2.1 | 2.4 | 2.6 | 2.9 | 3.2 | 3.4 | 3.7 | 4.9 | 5.2 | 5.5 | 5.7 | 6.0 | 6.3 | 6.6 | 6.9 |

**NOTE:** FOR CALCULATED LP=MEAN = -95 PCT, **-99 PCT AND **-99.9 PCT SIGNIFICANT. F ONLY 95 PCT TESTED.

**Fig. 7.**

**Fig. 8.**