NOISE CONTROL IN AIR SEPARATION PLANTS

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Noise in air separation plants is generated by the air and gas compressors and their drives, by expansion turbines and small high speed blowers, by the turbulent flow of air and gas in the process piping and by the blow-offs and vents. In small plants, i.e., those with production rates of 25 tons per day or less, noise from most of these sources is insignificant except during periods of plant starting or thawing. In larger plants, however, noise from any or all of these sources can be a hazard to plant safety either because of speech interference and operator fatigue; or because of potential employee hearing damage. Also, noise projected beyond the limits of the plant proper, may constitute a neighborhood nuisance.

Problems associated with noise produced in rotating and reciprocating machinery have been of particular concern in our "on-site" plant program. These problems have been attacked partly through the application of noise reduction techniques to existing equipment, and partly through the efforts of vendors in refining their designs. We have encouraged vendor action by development of a maximum noise level specification used in conjunction with our purchase specifications.

The study of acoustic noise—its causes, modes of transmission and methods of control—is a young science. It has only been in the last fifteen to twenty years that it has advanced from the status of a laboratory curiosity to a scientific discipline. Application of acoustic principles to the design of large mechanical equipment has only come within the past few years and may even now be considered in the early development stages. Compressors, gears, motors and similar mechanical equipment purchased as recently as five years ago, may very likely have been designed with little or no thought to acoustic noise generation.

Measurement and evaluation necessary

While measurement and evaluation of the many types of noises generated by air separation plant equipment are not simple, they must be accomplished before they can be dealt with to reduce the effect on the human ear. Since no single measurable quantity completely describes noise, methods have been devised to measure specific characteristics of noise which have been related through experimentation to the response of the human ear. This subject is covered in detail by others (1, 2, 3,). Briefly, the noise is measured using a microphone which converts the sound pressure wave signal to an electrical signal. This signal is then amplified, filtered and indicated on a meter on which the face is calibrated in terms of decibels. In this case, a decibel is defined as twenty times the logarithm of the ratio of sound pressure of the noise being measured to a standard pressure. The standard pressure for most noise measurements today is .0002 of a microbar. From a practical engineering point of view, the total noise that human beings hear can be considered to cover a frequency range from approximately 20 to 10,000 cycles per second. This audio range is subdivided into eight frequency bands called octave bands. They cover the range of frequency somewhat as the octaves on a piano cover the range of pitch. The frequency range for each octave band is shown in Figure 1.

Within the past several years, considerable work has been done by a number of authorities to establish allowable noise levels in industrial plants (2, 3, 5). Studies have resulted in the development of a number of criteria suggesting the effects of noise on human beings. We are primarily concerned with the hearing damage risk criterion of the sort that was originally suggested by Kryter (8) in his critical band concept and later developed by Beranek (2) in his tentative damage risk chart, Figure 2. Other criteria have been suggested by Hardy (10), McGrath (11) and others. These are discussed in a manual (3) published by the American Industrial Hygiene Association and in other similar publications. For our purposes we have assumed a criterion for in-plant noise which is almost identical to the Beranek criterion.

Centrifugal oxygen compressor

Figure 3 shows a typical noise profile plotted to show the noise level in decibels in each of the eight octave bands. Also shown is our criterion extended to

OCTAVE BAND	FREQUENCY RANGE
1	37.5 - 75
2	75 - 150
3	150 - 300
4	300 - 600
5	600 - 1200
6	1200 - 2400
7	2400 - 4800
8	4800 - 9600

Figure 1. Frequency range for each octave band.

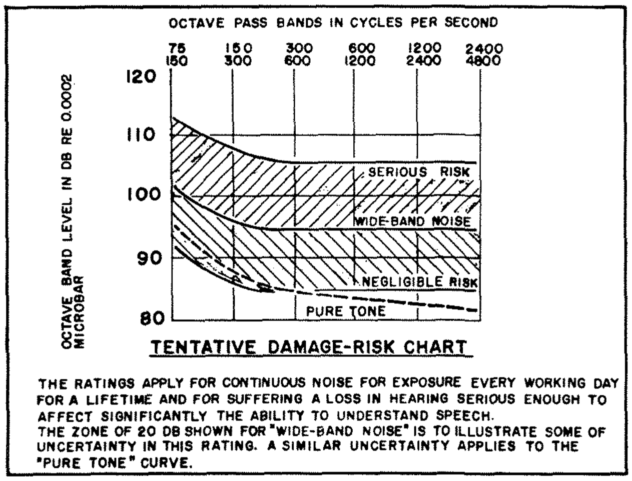

Figure 2. Beranek's tentative damage risk chart (2).

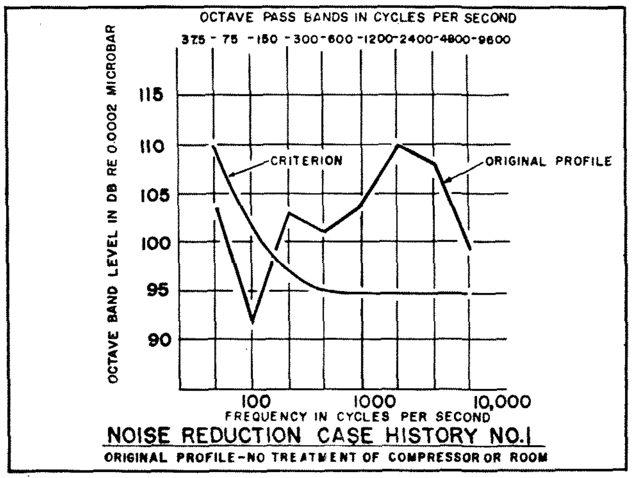

Figure 3. Typical noise profile plot.

include the first and eighth octaves. The profile is actually that of one of our large centrifugal oxygen compressors which was purchased before maximum noise levels were included as a part of our purchase specifications. When this machine was put into operation the excessively high noise level became apparent. It was found to result partly from the compressor and its drive and partly from the characteristics of the room in which it was located. After surveying and evaluating the problem, we decided on a program which included insulation of all gas piping, addition of a silencer to the motor cooling air exhaust and installation of an acoustic ceiling in the room. In Figure 4, profile 2 shows the new octave band noise levels. Even though the sound still exceeds our criterion significantly in the sixth octave band, the improvement was quite dramatic.

Another example of noise level around a centrifugal air compressor which was designed without particular attention being given to acoustic aspects is shown in Figure 5. We have several of these machines with essentially identical installation characteristics located in separate plants, and to gain experience in the application of noise reduction techniques, we tried several different treatments on these machines. Figure 6 shows the noise level profile after an inlet air silencer was installed and the walls of the room in which the compressor was located were sprayed with a sound absorbent material approximately one inch thick. The improvement was primarily in the third and fourth octave bands and resulted mostly from the addition of the suction silencer.

All of the piping for an identical compressor was acoustically insulated with the result shown in Figure 7. The degree of improvement obtained suggests that much of the noise from this compressor was being transmitted through the piping and was partly the result of air turbulence in the piping. However, a major portion of the noise generated within the compressor and reaching the operator's ear will usually be carried by the piping.

Speed increasing gear

Figure 8 shows the noise level in the vicinity of a speed increasing gear in the drive of an air compressor. We installed an acoustic shield over the gear case and coupling guards with the result shown in profile 2. The result here was notable, but a similar effect might have been gained by the gear manufacturer using design techniques which take noise generation into consideration. An example which illustrates this is shown in Figure 9. The first profile shows noise levels near a gear set which was designed and manufactured with no particular attention to noise generation. Several years after the survey was made the large gear cracked and both gears were replaced. The new gears were made by the same manufacturer for installation in the same casing to do the same job, but now the manufacturer had several years additional experience in dealing with

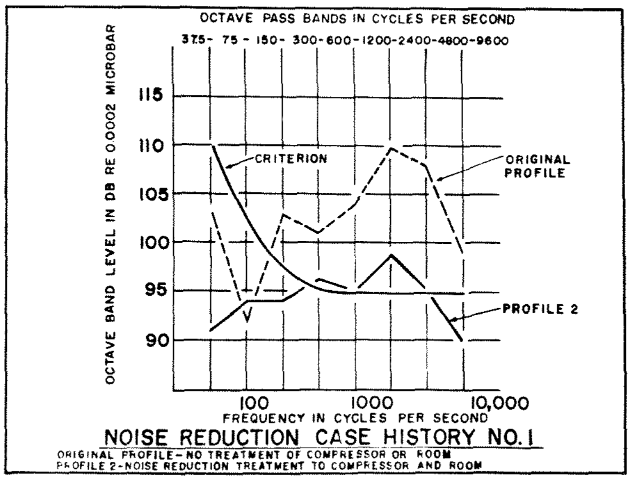

Figure 4. New octave band noise levels.

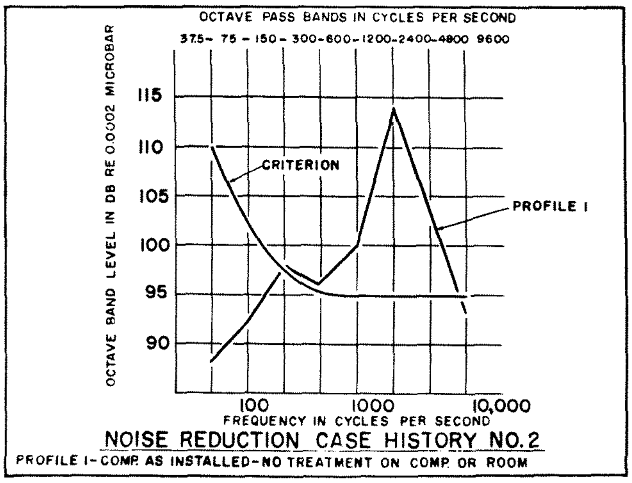

Figure 5. Noise level around centrifugal compressor.

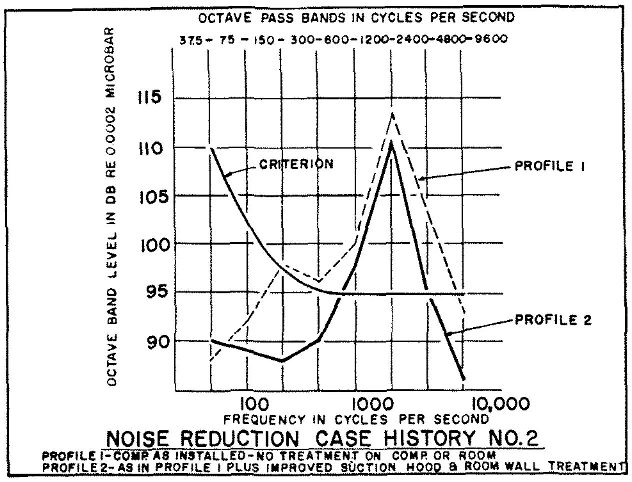

Figure 6. Noise level after improvements (see Figure 5).

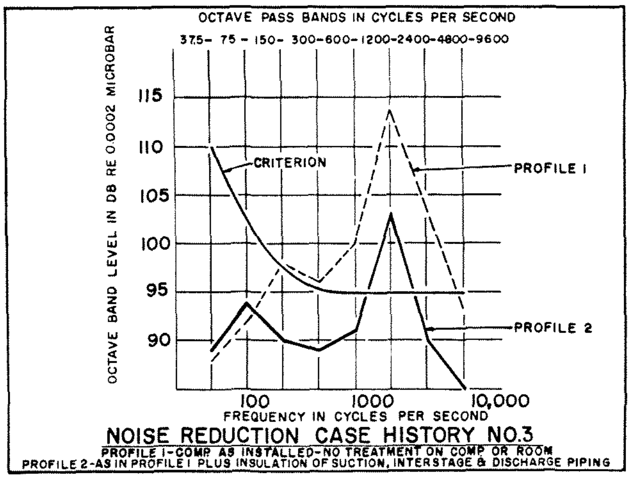

Figure 7. Noise level with piping insulated.

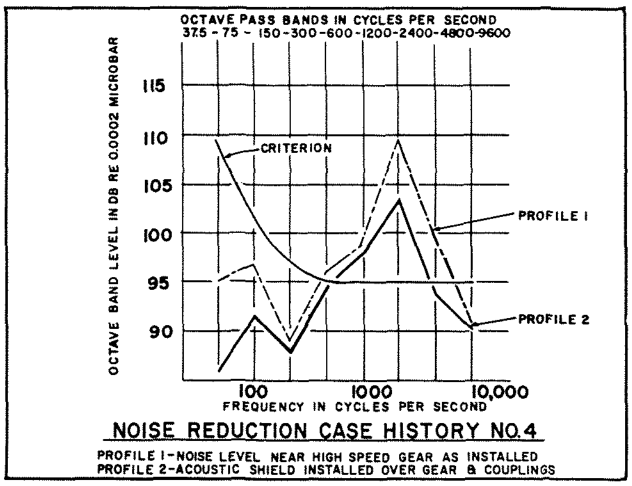

Figure 8. Noise level near speed increasing gear.

noise problems. Profile 2 shows noise levels in the vicinity of the new gears.

The Linde Equipment Noise Specification was developed about four years ago. It was modeled after the American Standards Association "Test for Apparatus Noise Measurement" Z24.7-1950 (6), and while it has undergone several modifications, its basic form and content have not been changed. A similar sample specification is included in the American Industrial Hygiene Association handbook (3). The specification was first applied to the purchase of large plant air compressors. Since then it has been extended to cover gas compressors of all sizes, gears, motors, engines, pumps and cooling towers.

Using Linde specifications

In using the specification, we have discussed its provisions with vendors prior to the purchase of new equipment. Where it is known that sufficient noise control information is available to meet our criterion, a guarantee of performance has been required. Generally, vendors have shown a great deal of initiative in this regard and have willingly taken responsibility for noise control. Some vendors have actually spent considerable development effort on methods for eliminating excessive noise from their products. In several instances where knowledge of effective noise control methods is limited we have worked with the vendors to find the best method of reducing noise after a piece of equipment has gone into service.

That our insistence on noise control through design has proved effective, is shown by the following examples of noise level profiles made on equipment which we have recently purchased. Figure 10 shows the profile of a 2,500 h.p. motor driven centrifugal air

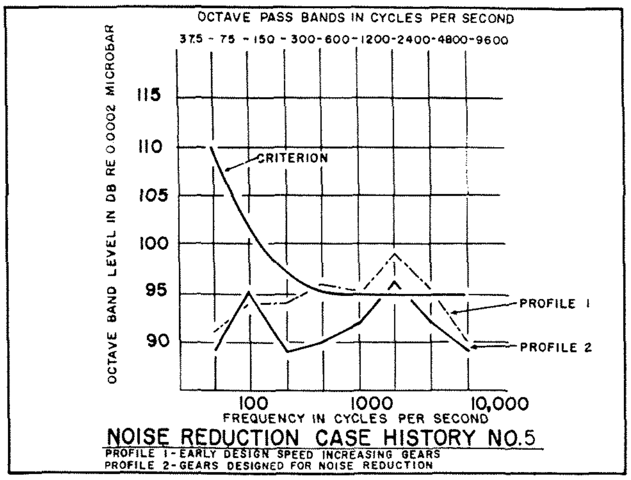

Figure 9. Improved design techniques lower noise levels.

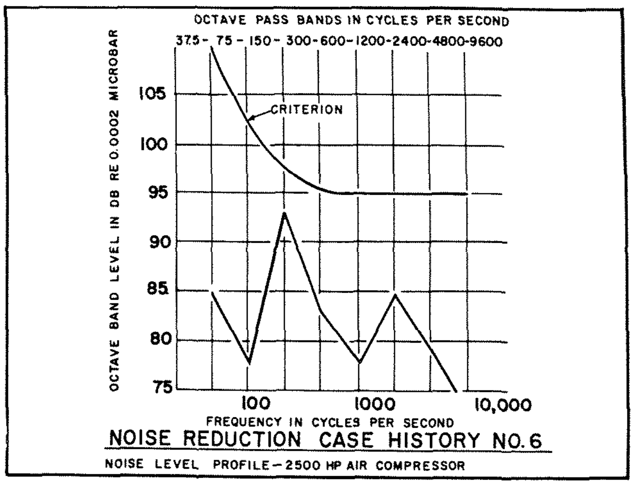

Figure 10. Profile of 2,500 h.p. centrifugal air compressor.

compressor. This machine includes a suction silencer, but there is no other acoustic insulation used on the casings or piping. The manufacturer guaranteed noise levels around this compressor not to exceed our criterion, and as the figure shows it was bettered in each octave.

Figure 11 includes the profile for a 4,000 h.p. gas engine which provides the drive for a centrifugal air compressor. The engine required air intake and exhaust silencers, but no other acoustic insulation beyond that supplied by the manufacturer as a part of his design. Figure 12 shows the profile of a 7,000 h.p. open fan-cooled synchronous motor. By careful design the manufacturer was able to eliminate the single high frequency fan noise which usually characterizes this type machine. Figure 13 is the profile of noise near a 7,000 h.p. speed increasing gear in the train driving a centrifugal air compressor. This unit was purchased with a maximum noise level guarantee which initially appeared to be exceeded. However, analysis showed that noise generated in the air compressor suction line was responsible. Insulation of the suction line reduced noise and eliminated the doubt.

Great improvement possible

A situation that shows graphically the degree of noise reduction that can be accomplished through design improvement is shown in Figure 14. Profile 1

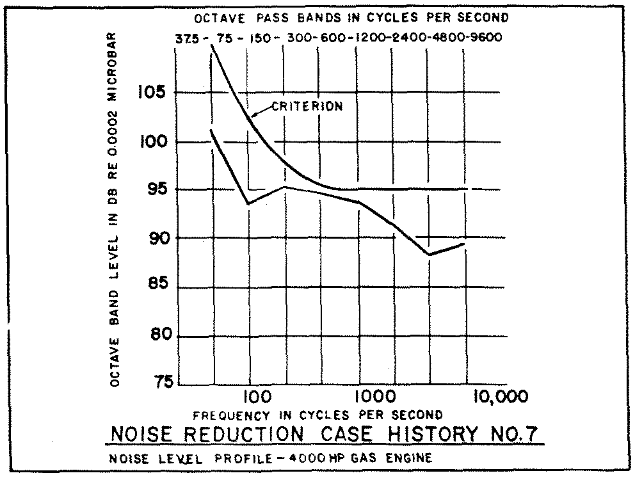

Figure 11. Profile of 4,000 h.p. gas engine.

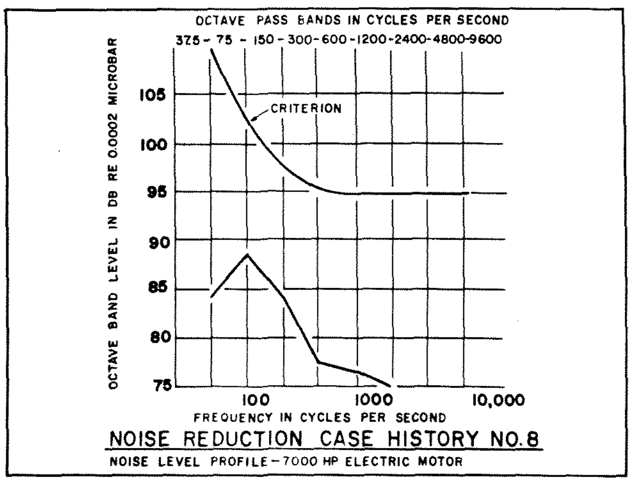

Figure 12. Profile of 7,000 h.p. synchronous motor.

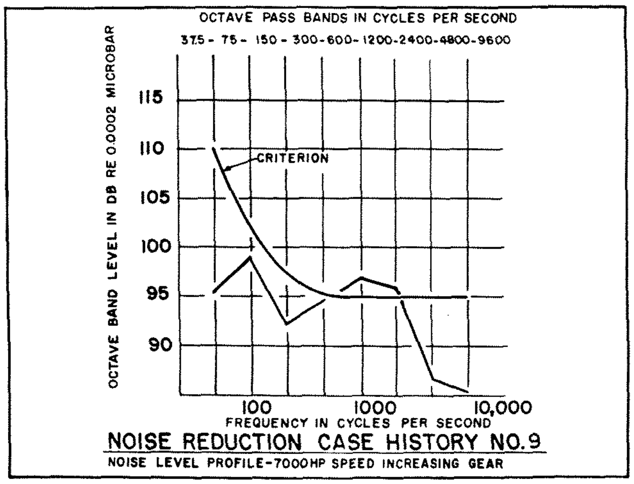

Figure 13. Profile near 7,000 h.p. speed increasing gear.

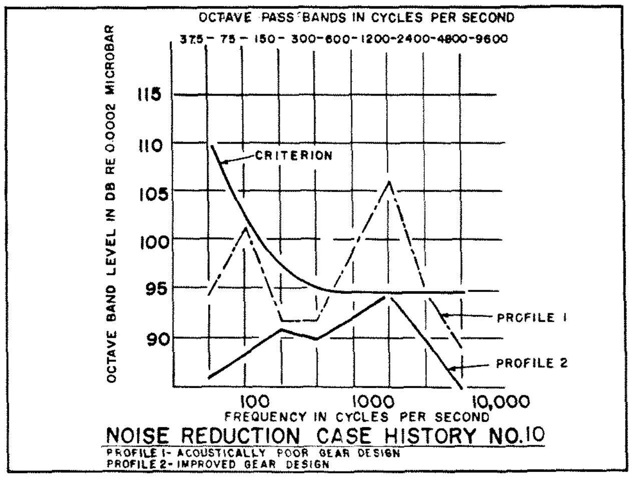

Figure 14. Design improvement can drastically reduce noise level.

shows noise levels around a 2500 horsepower speed increasing gear which was purchased with partial acceptance of the noise specifications. At the time of manufacture, the vendor used good design by AGMA standards. Resulting noise level was well above our criterion, and it was particularly annoying because of a high level narrow band noise at tooth contact frequency. Shortly after this gear was put in operation, spare gears were ordered and the vendor was encouraged to improve tooth contour for noise reduction. These new gears were installed and Profile 2 shows that the resulting noise level is well within the requirements of our noise specification. Since that time the vendor has been able to improve the original gears in the same way at relatively small cost.

Since development of our noise specifications, we have obtained acceptance of its provisions by vendors of all types of mechanical equipment used in our air separation plants. The results have been to encourage manufacturers to place more emphasis on design to reduce noise, and to create better acoustic environments for operating personnel within our plants. Present requirements must be maintained even though air separation plants continue to increase in size requiring larger compression equipment and drives. However, our experiences have shown us that most equipment vendors are concerned about noise in their machines, and are placing more and more emphasis on noise reduction design techniques. With encouragement from users we are convinced that effective noise control can be achieved and maintained.

Questions and answers

HOFMAIER—American Cyanamid. I wonder if Mr. Procter would care to comment on some specific changes which were made in the equipment and then also, I'd like to comment on some changes we made in our compressor building in New Orleans, which gave us a reduction from the neighborhood of 112 decibels up in the high frequency range down to about 95 decibels. First of all if you would make some comments on what changes were made and then I'd be happy to make some comments on our changes.

PROCTOR—Linde Division. I included a number of examples in my paper in order to suggest noise reduction treatment of a variety of types. Perhaps you are most interested in the first example in which we made some rather substantial improvements in the characteristics of a compressor room. This amounted to the installation of an acoustical ceiling. Standards of performance of the various acoustical ceiling materials and recommended methods of installation for such ceilings are available. We followed these recommendations for a suspended ceiling. The ceiling was dropped about 7-inches and suspended on hangers.

The main ceiling in this room consists of preformed concrete slabs supported on 6-inch I beams which are in turn supported on 14-inch I beams. Room lighting is suspended within the roof structure. A traveling crane is located immediately below the large I beams and some service piping and equipment is located near the ceiling. We had to take all of these aspects into consideration in installing this ceiling. I would like to have dropped the ceiling down below the 14-inch beams but that would have interfered with the crane and lighting. We compromised and located the acoustic ceiling in the spaces between the large beams. Even so we got a fairly substantial improvement in room performance.

By improvement I mean, that although the noise level in the room was reduced only slightly, room reverberation was reduced considerably. Before the ceiling was installed, the room surfaces were acoustically reflective. In this condition there were many standing waves of noise in the room. These were very obvious and extremely disturbing. In making noise measurements, of course, we avoided the peaks, or nodes, so we were not actually measuring the highest noise levels in the room before the ceiling was applied.

After the ceiling was installed the standing waves were reduced considerably. There were only several small areas where additional equipment insulation was required.

In addition to the work on the ceiling we insulated all of the gas piping in the room including the compressor suction which is a 24-inch line, the interstage piping and the discharge piping. There are three intercoolers and one aftercooler associated with the machine. All of the interstage piping up to and including the heads of the coolers was insulated plus the discharge piping from the machine.

The piping insulation consists of glass fiber sound absorbing material covered with a sound impermeable aluminum sheet covering. Care was taken during the installation to see that all joints in the aluminum shield were well sealed and that there were no air passages for noise to leak through.

The suction line leading to the compressor room is quite long and includes two automatic flow control valves located about 100-feet from the compressor room wall. Since there is a fair amount of turbulence in these valves, we insulated the valves and the suction line from the valves to the compressor.

In accomplishing our goal we considered many other possible modifications. This machine is installed on a fabricated steel base which is subject to vibration. We considered methods for silencing the base. After careful evaluation, we decided that this was not necessary. We also suspected that the speed increasing gear was contributing to the noise problem. We built an acoustic insulating shield for the gear but later found that it was not necessary. The motor also was suspected. We considered running acoustical ducts to and from the motor to handle the motor cooling air, but we established that this was not required.

HOFMAIER—I might just comment briefly that we did much of the same things. We insulated coupling guards on a lot of these machines. We found that one of our particular offenders was the expansion joint up against the machine. Being rather light, it tended to generate a lot of sound. The expansion joints on all these machines were insulated with fiberglass blankets. We also put acoustical insulation on our air filter box, and since this happened to be a group of air machines for our air plant this helped quite a bit. We also went to the fiberglass blanket suspension, actually suspending blankets in a vertical plane, hanging down from the ceiling. This helped the situation measurably.

PROCTOR—We have been able to improve noise levels to some extent during plant deriming or thawing. We install silencers in the plants to handle air blowdown from the regenerators, waste nitrogen venting, and air and product compressor venting. We have arranged some of the larger vents that are used during deriming to vent into these permanent silencers. However, even with these provisions noise levels during deriming are high.

Fortunately, the deriming operation is of relatively short duration. Hearing damage is unlikely to occur unless the noise levels are considerably above our stated criterion. Where a noise may exist for several hours or even several days men required to be in the vicinity should be supplied with ear protection for comfort, but we believe the chance of incurring permanent damage is extremely small.

Q. To what degree are noises from adjacent machines in the same room cumulative? It occurred to me that if you had every piece of equipment bought on a noise specification, that the cumulative effect of all of them might be above your criteria.

PROCTOR—That is exactly right. The noise criterion shown in my paper calls for a maximum of 95 decibels above 300 cycles per second. This is, of course, total plant noise. For the purchase of any one piece of equipment such as a compressor our specifications call for 89 decibels maximum noise level in the frequency span above 300 cycles per second.

The criterion curve for a single piece of equipment has the same shape as the curve for total plant noise, but it is 6 decibels lower. The reason for this is that the sum of two equal noises causes an increase in noise level of 3 decibels. Consequently, if the compressor and gear both operate with a noise level of 89 decibels, when the two are put together the resultant noise level is 92 decibels. Then when the complete air compressor assembly and the complete oxygen compressor assembly both operating at 92 decibels are added together, we get a plant noise level of 95 decibels.

BOLLEN—Dow Chemical of Canada. Our present Air Separation and Ammonia plants have been in operation since 1955. During this period we were not aware of any noise level problems. Recently, however, we noticed one of the operators working with cotton batten stuffed in his ears. The supervisor asked him if he had ear trouble and the operator told him that the noise in the plant bothered him. He said that it made him irritable and also gave him headaches.

We thought that this might be just an isolated case but never-the-less made enquiries to see whether anyone else had experienced similar problems. The initial indications were that all the operators were bothered to some degree by the noise.

At the time of the Denver symposium we reported that we were carrying out a noise level survey to determine whether or not we had a health hazard. Since that time we have completed two such surveys. The initial survey was carried out by the Biochemical Research Lab. of Dow Chemical Co., Midland. The second survey was carried out by the Dept. of Health for the Province of Ontario. Both surveys were essentially the same and indicated that the noise level was not high enough, at any location in or around the plant, to constitute a health hazard of any degree.

Recognizing, however, that a continuous noise level, which might be too low to have an effect on hearing, could still be bothersome to some individuals the Company has made ear plugs and ear muffs available for those that wish to wear them.

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