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FOUNDRY NOISE ANALYSIS AND ABATEMENT RECOMMENDATIONS

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The production of metallic products is a complex process, beginning in many cases with the casting of a part, followed by removal of defects, and then followed by final machining. Most of these steps take place in foundries, and they involve some degree of noise. The noise levels in foundries may exceed OSHA allowable levels, and a noise analysis is necessary to determine whether or not a problem exists. The noise analysis can also point the way to potential noise reduction steps, if it is conducted in a way that identifies the major noise sources and their special characteristics.

This paper describes the tests, test results, and noise control recommendations made at a non-ferrous melt foundry and a large casting foundry. In both cases an overall noise survey was conducted to determine local noise levels, thereby allowing identification of major noise sources. The survey was conducted using the A-weighted scale (dBA) of a Bruel-Kjaer Model 2209 sound level meter, since OSHA compliance is determined based on this scale. A Bruel-Kjaer model 4220 piston-phone calibrator was used before, during, and after these tests to ensure the accuracy of the readings.

The survey was followed by octave band analysis of the major noise sources, so that their spectral distribution and character could be identified. Noise control recommendations were then made based on the identified characteristics of the major noise sources. The implementation of some of these recommendations is now underway, and follow-up tests will be made to determine the actual noise reduction delivered at a later date.

Non-Ferrous Melt Foundry

Description. A visual inspection of the non-ferrous melt foundry identified a number of potential noise sources, including rocker-type electric arc furnaces, oil-fired pit furnaces, gas-fired preheat ladles, blowers, and fans. A 16-location grid was laid out on a 50 by 25 feet spacing over the foundry work area. A-weighted noise levels were recorded at these locations. Octave band data was also taken at two points.

During the course of testing, it was discovered that two different operating conditions existed during a typical shift. One operating condition, designated the AM operation, occurred during the morning and involved the operation of two electric arc furnaces and three pit furnaces. A second operating condition, designated PM operation, occurred during the afternoon and involved the operation of four pit furnaces without the electric arc furnaces. It is to be expected that these operating conditions could vary somewhat from day to day, but the conditions tested were judged to be typical by plant personnel. It is also possible that a future major change in workload could change the typical operating conditions, and in that case further testing would be necessary.

Results of the A-weighted Survey. The results of the A-weighted survey were used to construct a noise contour map of the foundry work area for the two

typical operating conditions. For the PM operation, the highest noise contour is 97 dBA, near the oil fired pit furnaces. A drop-off of noise with distance from the furnaces indicates that the furnaces are the major noise source during PM operation, and that the fans, blowers, and other equipment are lesser sources. The noise readings were linearly averaged to determine an approximate foundry area average, and the result was 92 dBA. A given worker may have greater or lesser exposure than this average, depending on where he spends his time during the day, but the average can be used to establish a preliminary target for noise reduction. Either a dosimeter measurement or a time and location study could be used to modify the noise reduction goal as needed.

During AM operation, the noise levels were greater than for PM operation due to the additional noise caused by the electric arc furnaces. The noise distribution changed from the AM operation, but it is still evident that the major noise sources are the furnaces rather than the auxiliary equipment. The maximum noise contour in this case is 101 dBA near the electric arc furnaces, and the overall area average is 95 dBA.

Results of the Octave Band Analysis. Octave band test data analysis is achieved by breaking up a noise signal into frequency ranges centered about 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 Hz. While the frequency ranges get rather coarse at the high end of the scale, a reasonable portrayal of the amount of energy present at different parts of the frequency spectrum becomes possible. Effective noise control depends on knowing whether the noise source contains several predominant frequencies or broad band noise, and whether the noise is high frequency or low frequency in character.

Therefore, after the electric arc and pit furnaces were identified as the major noise sources, an octave band analysis was performed near the furnaces. The PM operation showed a preponderance of energy at the 125 Hz band. In the AM operation two peaks are evident, one at 63 Hz and one at 4,000 Hz.

The low frequency peak at 125 Hz can be related to the pit furnace operation, since their operation caused a change from the background noise to the PM curve. The shift of this low frequency peak to 63 Hz during AM operation may have been due to the operation of the motors driving the rocking mechanism of the electric arc furnaces, or to operation of a different set of pit furnaces. These devices are similar to turbojets in their noise characteristics due to the turbulent mixing of the combustion gases and the atmospheric air at the exhaust boundary. The sound power radiated by such turbulent jets can be expressed as follows:

$$\text{Power} = \frac{K P_J^2 V^8}{P_0 C_0^5} d^2$$

Where K = a constant
P_J = density of the jet gases
P_0 = atmospheric density
C_0 = atmospheric sound velocity
d = jet nozzle diameter
V = jet velocity

The significance of the above equation is that the sound power varies with the eighth power of the jet velocity. Thus a 10 per cent reduction in jet velocity can more than halve the radiated acoustical energy.

The high frequency peak of the AM data appeared with the operation of the electric arc furnaces, and was therefore related to the crackling discharges of the electric arc furnaces. It was also noted that as much as a 10dB variation occurred in these higher octave noise levels, depending on whether the furnace spout was facing forward or rearward during the rocking cycle.

Noise control recommendations. A number of noise control techniques are possible, starting with simple administration measures. For example, the worst noise conditions occur when both types of furnaces are operating simultaneously. One possibility that should not be overlooked would be to schedule the electric arc furnaces for night shift operation, which would reduce daytime noise levels by 3dBA average. Plant management obviously must determine the applicability of this measure. Another administrative measure involves the location of the electric arc furnace operators desk, which is within the 101 dBA contour. Simply moving his desk to a quieter location would reduce the overall need for other noise control measures.

At the other end of the spectrum from administrative control lies source control. An obvious source control approach for the pit furnaces would be to reduce the flow rate or the flow velocity of the combustion jets. The equation presented previously shows that a 10 per cent reduction in velocity would more than halve the sound power of the furnaces. The simplest approach to reduction of flow velocity would be to reduce the flow rate to the furnaces through air flow valving. However, the reduced flow rate would increase melt time, and this approach would require management evaluation. An alternative would be to replace the present combustion jets with lower velocity jets that still maintain the same flow rate.

Other measures are possible through path control techniques, such as barrier-walls or sound absorptive wall lining materials. These measures are all more effective for high frequency noise, and therefore would be most useful for the electric arc furnace noise. However, these could also be useful for the low frequency pit furnace noise, since the pit furnace noise level is not as high as the electric arc furnaces.

The use of a wall would be the most effective technique, with 20-30 dBA reduction possible. However, the need for loading and unloading the furnaces would make a permanent, well-sealed wall impractical. A compromise would be to use a floor-to-ceiling movable curtain placed in front of the furnaces from one end of the pit furnace area to the other end. Typically, such curtains are made of lead-vinyl, and they can be lined with acoustical foam on the source side. While the approach may only achieve 10 dBA, due to inevitable noise leaks, such a reduction would be of the magnitude needed to achieve OSHA compliance.

The sound absorptive material approach would involve lining the walls and ceiling around the furnaces with an appropriate material. Acoustical energy leaves the furnaces traveling forward towards the foundry and rearward towards the wall. The rearward traveling energy is reflected and also reaches the foundry area. A perfectly absorbing material on the rear wall could therefore remove half of the acoustical energy from the foundry, a 3dBA reduction. The low frequency characteristic of the pit furnaces would require several feet thickness of material for this effect in general, but the presence of a vaulted ceiling over the furnace area causes multiple reflections. Therefore a two to four inch layer of material may be effective. A note of caution is necessary with this approach, since it is not clear how long these materials will withstand the heat and exhaust gases of the area above the pit furnaces before degrading in their performance.

Large Casting Foundry

Description. Our next test was of a large casting foundry. The actual casting operations do not take place in the building surveyed. Rather, it is used for the subsequent operations of chipping, grinding, repair welding, and touch-up machining. These operations take place at random times throughout the workshift, causing both temporal and spatial variations in noise levels. In light of this circumstance, it was decided that the average of a series of tests would be required for meaningful data. Fifty-one test points on a 40 by 50 feet grid were laid out, and six sets of noise survey test data was taken over a two-week period.

The process of chipping was noted to be a particularly loud noise source. However, the noise surveys never happened to encounter this source at close hand, due to the short duration of chipping. It was decided to take octave band and narrow band data of the chipping process, due to the apparent loudness of chipping work and the potential need for noise control techniques there. Chipping is used to remove zones of defects in the surfaces of large castings, prior to repair welding. The process consists of applying a pneumatically-driven cold chisel to the casting surface, thereby removing defective material. The repeated impact causes the casting to vibrate, emitting high intensity acoustical noise.

Results of the A-weighted Survey. In the A-weighted noise levels averaged over six tests, only two of the 51 test locations show noise levels above 90 dBA, and both of these points were within grinding areas where several workers were simultaneously grinding castings. This condition only occurred during the first test, and all subsequent tests had fewer workers grinding simultaneously and lower noise levels. The overall foundry average noise level was 87 dBA, well within OSHA criteria. On the basis of this data, it appeared that only a minimal change existed for an OSHA violation, and administrative controls on grinding could correct any such violation. However, a greater amount of test data would be required to insure that seasonal or work load variations do not significantly change these results. Furthermore, noise tests of the chipping process indicated noise levels above 100 dBA. Therefore, any worker spending a substantial portion of time chipping might require protection.

Results of the Octave and Narrow Band Analysis. After the identification of chipping as a potentially serious noise source, octave band data was taken of the noise produced by the chipping of two different castings. While there are differences in the noise spectra for the two castings, both castings show a rather broad band high frequency noise energy content. The broad band nature of the results suggests that many vibration modes are involved in noise generation, rather than one or two predominant frequencies.

Since noise control techniques depend on the noise characteristics, a narrow band noise analysis was also performed. This test consists of tape recording the chipping noise signal, and then playing the taped data into a Fourier analyzer to obtain the noise energy at various frequencies. The energy is expressed in terms of power spectral density, or PSD, versus frequency. Conceptually, a narrow band analysis is similar to an octave band analysis, except that a greatly refined picture of the noise characteristics are obtained.

In the narrow band data taken during chipping of a valve casting, the presence of the many peaks throughout the spectrum indicates that many vibration modes are contributing to the observed noise. Therefore it would do little good to attempt to restrain the casting so as to eliminate one particular mode of vibration, since other vibration modes would still be radiating acoustical energy.

Noise Control Recommendations. The most effective means of dealing with a broad band noise source such as the vibrating casting is through the introduction of damping. Damping, if effectively applied, will cause the impact-induced vibrations to decay quickly, thus preventing the buildup of high noise levels. The vibrational energy would then be dissipated as heat rather than being radiated into the environment as acoustical energy.

Due to the irregular geometry of the castings, it is not easy to achieve effective damping. One approach could be to apply a layer of damping material to a part of the casting surface, and then back this layer with a stiff constraining layer that is firmly attached to the casting. The constraining layer is important to achieving effective damping, and it should be roughly 10 per cent or more of the casting thickness. It may be possible to either tack-weld or clamp this layer to the casting.

Another noise control technique would be to lubricate the chisel tip before and during chipping. The lubricant will reduce the amount of energy absorbed by friction during chipping. Such energy loss prolongs the process, thereby increasing worker noise exposure.

A final step would be to drape a noise barrier material over the casting to contain some of the noise energy generated by chipping. Since the duration of chipping is not very long (a minute or so is required to remove a three-inch long piece of metal as wide as the chisel), even a 5dBA reduction could be enough to insure OSHA compliance.

Conclusions

Acoustical noise surveys were performed at two foundries engaged in a broad spectrum of operations. The nonferrous melt foundry was found to exceed OSHA allowable noise levels, and the furnaces were identified as the major sources. A number of steps ranging from administrative to source control were suggested, and these are currently under evaluation. The large casting foundry was found to generally meet OSHA allowable noise levels. The chipping process was singled out as a potentially serious noise problem, and several recommendations for noise reduction were made. These can be implemented when and if they are necessary.

SUCCESS/FAILURE OF OSHA, NEP PROGRAM

By ED KELLY
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When we first heard about the NEP Program, and that our foundry industry was to be a target, every one of us became apprehensive. After all, no one wants to be targeted, particularly in view of the failures of the previous OSHA. However, as the NEP Program unfolded and I attended many of the committee meetings, there appeared on the horizon a promise that if, in fact, the NEP Program could be implemented, it could be good for our industry. At least it had the tone that everything would proceed in an orderly fashion and that by participating in the committee work of drawing up documents, we were at least being heard. At one point in the operation committee work, the compliance committee members became disheartened because they did not have the feeling that their input was being heard; however, after much vocal activity and press releases and publicity, Washington did respond and in the preparation of the final draft acknowledge the industry's input by incorporating it into the final draft of the compliance committee. This was indeed gratifying.

In reporting back to my associates at AFS headquarters and, as well, to our membership, I always assumed the position that if we had to have the NEP Program, I was at least satisfied with what I had heard, but I was concerned that it wasn't coming from the man in charge. At one committee meeting last January I made it a matter of record that where everything that was being said was promising, I wondered why Dr. Corn did not come out and publicly voice it so that the whole program would have a degree of credibility.

In the April 5 issue of *Iron Age*, Dr. Corn granted an exclusive interview, and he did finally come out and say it, and he said it well. Some of the highlights of this interview that we have been seeking for many months are such statements from the man in charge: "Higher technical competence of inspectors; zeroing in on serious hazards and deemphasizing others; increasing the quality and quantity of OSHA standards; and increasing the dialogue between OSHA and the public." Certainly we all recognize that we need higher technical competence of inspectors—this is good. We agree that the quality of OSHA standards must be more directional to our industry; this is why we developed the ANSI Standard Z241.1-1975. And we do not believe that the quantity of OSHA standards needs improvement.

President Ford has even contributed in that he has stated that he wants the people who are carrying out the law to come to our foundries with the point of view of being helpful and not coming in trying to beat somebody down.

Dr. Corn also is admissive that their people can walk onto our premises and inspect and cite for violations, and that power must be appropriately handled, moderated. Dr. Corn further, in the interview, in not so many words but certainly the intent is well-spoken, said that he agrees with the AFS method of training which was tried early in January for Region V. He is admissive of the problem of taking a compliance officer into a workplace where, when even in the training mode, he must issue citations. Dr. Corn recognizes that this obviates this form of training. However, it is my belief that where Congress has given Dr. Corn the responsibility he must also be given the authority, and by this is meant he should have the authority to issue a field directive that this would be the case when an officer of the government is being trained in a workplace. If this is by consensus the better form of education, then certainly Congress can have no quarrel with Dr. Corn making such a decision. Certainly they could not criticize when Dr. Corn is striving for perfection.

To quote Dr. Corn, "We think we would have better professionals if, during an educational period, they could have access to, in a training capacity, the private sector." This we have believed for a long time and demonstrated it early in January with a group of compliance officers.

He has further said that OSHA will begin to screen out standards which were adopted from consensus standards that are no longer relevant or which constitute "nuisance" standards. He has further paid recognition to the fact that people cause accidents. By stating that given equal weight with spotting a physical violation will be a closer look at unsafe acts.

To all of this which we have read and that which we have heard, we agree. However, there is one last remaining question: When?

The National Emphasis Program was implemented by OSHA last December. At a meeting held at AFS headquarters, a group of government officials visited with AFS personnel and industry personnel and outlined the mechanics and operations of the program. What we heard impressed us because it was so different from the previous OSHA programs that had failed so miserably. However, we assumed a "wait and see" attitude, but a participating attitude, in that they structured seven committees (Training , Compliance, Evaluation, Consultation, Small Business, Education, Audit) and later, at a suggestion from AFS, they established the TAC Committee.

Of these committees, the most important to bring you up-to-date on are Training, Compliance, and TAC, which when translated from government initials is the Technical Advisory Center. Discussions of the other committees would preclude getting as much information to you as possible. This is why a discussion will be had about those three committees mentioned.

AFS personnel and about 60 people from industry participated in this committee work which was structured to provide strategems for the operation of this particular need of the NEP program. The Training Committee focused its intent on the training of compliance officers, area directors, consultants, and industrial hygienists. Incorporated into the final training paper were the AFS training methods that were used in January to train certain Region V compliance officers. This program was spectacularly successful; however, should the NEP fail it will be because of the OSHA solicitor making the decision that this type of training could not be conducted on site without the compliance officer issuing citations if he saw a violation. In the AFS training mode, the Region V administrator lifted the credentials of the compliance officers such that on-site training was made in four foundries in Milwaukee. This training contributed to the success of the total program at that time; however, as stated above, should NEP fail it will be because of inadequate training of the people to know our industry and our operations.

The Compliance Committee paper received the most criticism from industry participants in that the industry people felt that their input was not being heard. Their main feeling was that in order to reduce accidents and injuries you must first find out where accidents and injuries are happening, and they wanted a preaudit of such data prior to an inspection such that an inspector could go directly to the area of cause. Only through press releases and published criticism of the Washington action did we finally succeed and get this com-

pliance paper turned around. All is yet not clear; however, Washington did condescend to at least listen to industry's input in this particular circumstance. The Technical Advisory Center (TAC), if it works as the initial concepts have been laid out, will be of great advantage to the whole program. This will work out of Rosemont, Illinois with a group of possibly six government people and people from industry who will preaudit citations in the field and, as well, postaudit penalties involved such that they can bring about uniformity throughout the nation on what the compliance officers are doing. Further, it will provide interpretive needs of a compliance officer who may not have sufficient skill to recognize what he is looking at. AFS and its facilities, including its library and recall sources, hope to participate in this activity to a great extent for the benefit of its membership.

If the training fails, and this includes training of area directors, compliance officers, consultants, and industrial hygienists, then OSHA will again be subject to criticism, because without trained professionals interpreting our industry, the inspections are pretty close to meaningless and will take on the tone of again being nuisance activities.

Consensus has it that our activities in the program should continue even if we only get a small percentage of our input acceptable. At least, by a continuity of participation we will know what to expect when the program finally gets under way and, hopefully, we at AFS will be able to alert you so that the surprises out of the paper bag are not big ones.

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OCT. 17 - OCT. 20, 1977 / CONRAD HILTON HOTEL, CHICAGO

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March 21, 2001

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SUCCESS/FAILURE OF OSHA, NEP PROGRAM

By ED KELLY
Safety Director, American Foundrymen's Society,
Des Plaines, IL

When we first heard about the NEP Program, and that our foundry industry was to be a target, every one of us became apprehensive. After all, no one wants to be targeted, particularly in view of the failures of the previous OSHA. However, as the NEP Program unfolded and I attended many of the committee meetings, there appeared on the horizon a promise that if, in fact, the NEP Program could be implemented, it could be good for our industry. At least it had the tone that everything would proceed in an orderly fashion and that by participating in the committee work of drawing up documents, we were at least being heard. At one point in the operation committee work, the compliance committee members became disheartened because they did not have the feeling that their input was being heard; however, after much vocal activity and press releases and publicity, Washington did respond and in the preparation of the final draft acknowledge the industry's input by incorporating it into the final draft of the compliance committee. This was indeed gratifying.

In reporting back to my associates at AFS headquarters and, as well, to our membership, I always assumed the position that if we had to have the NEP Program, I was at least satisfied with what I had heard, but I was concerned that it wasn't coming from the man in charge. At one committee meeting last January I made it a matter of record that where everything that was being said was promising, I wondered why Dr. Corn did not come out and publicly voice it so that the whole program would have a degree of credibility.

In the April 5 issue of *Iron Age*, Dr. Corn granted an exclusive interview, and he did finally come out and say it, and he said it well. Some of the highlights of this interview that we have been seeking for many months are such statements from the man in charge: "Higher technical competence of inspectors; zeroing in on serious hazards and deemphasizing others; increasing the quality and quantity of OSHA standards; and increasing the dialogue between OSHA and the public." Certainly we all recognize that we need higher technical competence of inspectors—this is good. We agree that the quality of OSHA standards must be more directional to our industry; this is why we developed the ANSI Standard Z241.1-1975. And we do not believe that the quantity of OSHA standards needs improvement.

President Ford has even contributed in that he has stated that he wants the people who are carrying out the law to come to our foundries with the point of view of being helpful and not coming in trying to beat somebody down.

Dr. Corn also is admissive that their people can walk onto our premises and inspect and cite for violations, and that power must be appropriately handled, moderated. Dr. Corn further, in the interview, in not so many words but certainly the intent is well-spoken, said that he agrees with the AFS method of training which was tried early in January for Region V. He is admissive of the problem of taking a compliance officer into a workplace where, when even in the training mode, he must issue citations. Dr. Corn recognizes that this obviates this form of training. However, it is my belief that where Congress has given Dr. Corn the responsibility he must also be given the authority, and by this is meant he should have the authority to issue a field directive that this would be the case when an officer of the government is being trained in a workplace. If this is by consensus the better form of education, then certainly Congress can have no quarrel with Dr. Corn making such a decision. Certainly they could not criticize when Dr. Corn is striving for perfection.

To quote Dr. Corn, "We think we would have better professionals if, during an educational period, they could have access to, in a training capacity, the private sector." This we have believed for a long time and demonstrated it early in January with a group of compliance officers.

He has further said that OSHA will begin to screen out standards which were adopted from consensus standards that are no longer relevant or which constitute "nuisance" standards. He has further paid recognition to the fact that people cause accidents. By stating that given equal weight with spotting a physical violation will be a closer look at unsafe acts.

To all of this which we have read and that which we have heard, we agree. However, there is one last remaining question: When?

The National Emphasis Program was implemented by OSHA last December. At a meeting held at AFS headquarters, a group of government officials visited with AFS personnel and industry personnel and outlined the mechanics and operations of the program. What we heard impressed us because it was so different from the previous OSHA programs that had failed so miserably. However, we assumed a "wait and see" attitude, but a participating attitude, in that they structured seven committees (Training , Compliance, Evaluation, Consultation, Small Business, Education, Audit) and later, at a suggestion from AFS, they established the TAC Committee.

Of these committees, the most important to bring you up-to-date on are Training, Compliance, and TAC, which when translated from government initials is the Technical Advisory Center. Discussions of the other committees would preclude getting as much information to you as possible. This is why a discussion will be had about those three committees mentioned.

AFS personnel and about 60 people from industry participated in this committee work which was structured to provide strategems for the operation of this particular need of the NEP program. The Training Committee focused its intent on the training of compliance officers, area directors, consultants, and industrial hygienists. Incorporated into the final training paper were the AFS training methods that were used in January to train certain Region V compliance officers. This program was spectacularly successful; however, should the NEP fail it will be because of the OSHA solicitor making the decision that this type of training could not be conducted on site without the compliance officer issuing citations if he saw a violation. In the AFS training mode, the Region V administrator lifted the credentials of the compliance officers such that on-site training was made in four foundries in Milwaukee. This training contributed to the success of the total program at that time; however, as stated above, should NEP fail it will be because of inadequate training of the people to know our industry and our operations.

The Compliance Committee paper received the most criticism from industry participants in that the industry people felt that their input was not being heard. Their main feeling was that in order to reduce accidents and injuries you must first find out where accidents and injuries are happening, and they wanted a preaudit of such data prior to an inspection such that an inspector could go directly to the area of cause. Only through press releases and published criticism of the Washington action did we finally succeed and get this com-

pliance paper turned around. All is yet not clear; however, Washington did condescend to at least listen to industry's input in this particular circumstance. The Technical Advisory Center (TAC), if it works as the initial concepts have been laid out, will be of great advantage to the whole program. This will work out of Rosemont, Illinois with a group of possibly six government people and people from industry who will preaudit citations in the field and, as well, postaudit penalties involved such that they can bring about uniformity throughout the nation on what the compliance officers are doing. Further, it will provide interpretive needs of a compliance officer who may not have sufficient skill to recognize what he is looking at. AFS and its facilities, including its library and recall sources, hope to participate in this activity to a great extent for the benefit of its membership.

If the training fails, and this includes training of area directors, compliance officers, consultants, and industrial hygienists, then OSHA will again be subject to criticism, because without trained professionals interpreting our industry, the inspections are pretty close to meaningless and will take on the tone of again being nuisance activities.

Consensus has it that our activities in the program should continue even if we only get a small percentage of our input acceptable. At least, by a continuity of participation we will know what to expect when the program finally gets under way and, hopefully, we at AFS will be able to alert you so that the surprises out of the paper bag are not big ones.

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typical operating conditions. For the PM operation, the highest noise contour is 97 dBA, near the oil fired pit furnaces. A drop-off of noise with distance from the furnaces indicates that the furnaces are the major noise source during PM operation, and that the fans, blowers, and other equipment are lesser sources. The noise readings were linearly averaged to determine an approximate foundry area average, and the result was 92 dBA. A given worker may have greater or lesser exposure than this average, depending on where he spends his time during the day, but the average can be used to establish a preliminary target for noise reduction. Either a dosimeter measurement or a time and location study could be used to modify the noise reduction goal as needed.

During AM operation, the noise levels were greater than for PM operation due to the additional noise caused by the electric arc furnaces. The noise distribution changed from the AM operation, but it is still evident that the major noise sources are the furnaces rather than the auxiliary equipment. The maximum noise contour in this case is 101 dBA near the electric arc furnaces, and the overall area average is 95 dBA.

Results of the Octave Band Analysis. Octave band test data analysis is achieved by breaking up a noise signal into frequency ranges centered about 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 Hz. While the frequency ranges get rather coarse at the high end of the scale, a reasonable portrayal of the amount of energy present at different parts of the frequency spectrum becomes possible. Effective noise control depends on knowing whether the noise source contains several predominant frequencies or broad band noise, and whether the noise is high frequency or low frequency in character.

Therefore, after the electric arc and pit furnaces were identified as the major noise sources, an octave band analysis was performed near the furnaces. The PM operation showed a preponderance of energy at the 125 Hz band. In the AM operation two peaks are evident, one at 63 Hz and one at 4,000 Hz.

The low frequency peak at 125 Hz can be related to the pit furnace operation, since their operation caused a change from the background noise to the PM curve. The shift of this low frequency peak to 63 Hz during AM operation may have been due to the operation of the motors driving the rocking mechanism of the electric arc furnaces, or to operation of a different set of pit furnaces. These devices are similar to turbojets in their noise characteristics due to the turbulent mixing of the combustion gases and the atmospheric air at the exhaust boundary. The sound power radiated by such turbulent jets can be expressed as follows:

$$\text{Power} = \frac{K P_1^2 V^8}{P_0 C_0^5} d^2$$

Where K = a constant
P_1 = density of the jet gases
P_0 = atmospheric density
C_0 = atmospheric sound velocity
d = jet nozzle diameter
V = jet velocity

The significance of the above equation is that the sound power varies with the eighth power of the jet velocity. Thus a 10 per cent reduction in jet velocity can more than halve the radiated acoustical energy.

The high frequency peak of the AM data appeared with the operation of the electric arc furnaces, and was therefore related to the crackling discharges of the electric arc furnaces. It was also noted that as much as a 10dB variation occurred in these higher octave noise levels, depending on whether the furnace spout was facing forward or rearward during the rocking cycle.

Noise control recommendations. A number of noise control techniques are possible, starting with simple administration measures. For example, the worst noise conditions occur when both types of furnaces are operating simultaneously. One possibility that should not be overlooked would be to schedule the electric arc furnaces for night shift operation, which would reduce daytime noise levels by 3dBA average. Plant management obviously must determine the applicability of this measure. Another administrative measure involves the location of the electric arc furnace operators desk, which is within the 101 dBA contour. Simply moving his desk to a quieter location would reduce the overall need for other noise control measures.

At the other end of the spectrum from administrative control lies source control. An obvious source control approach for the pit furnaces would be to reduce the flow rate or the flow velocity of the combustion jets. The equation presented previously shows that a 10 per cent reduction in velocity would more than halve the sound power of the furnaces. The simplest approach to reduction of flow velocity would be to reduce the flow rate to the furnaces through air flow valving. However, the reduced flow rate would increase melt time, and this approach would require management evaluation. An alternative would be to replace the present combustion jets with lower velocity jets that still maintain the same flow rate.

Other measures are possible through path control techniques, such as barrier-walls or sound absorptive wall lining materials. These measures are all more effective for high frequency noise, and therefore would be most useful for the electric arc furnace noise. However, these could also be useful for the low frequency pit furnace noise, since the pit furnace noise level is not as high as the electric arc furnaces.

The use of a wall would be the most effective technique, with 20-30 dBA reduction possible. However, the need for loading and unloading the furnaces would make a permanent, well-sealed wall impractical. A compromise would be to use a floor-to-ceiling movable curtain placed in front of the furnaces from one end of the pit furnace area to the other end. Typically, such curtains are made of lead-vinyl, and they can be lined with acoustical foam on the source side. While the approach may only achieve 10 dBA, due to inevitable noise leaks, such a reduction would be of the magnitude needed to achieve OSHA compliance.

The sound absorptive material approach would involve lining the walls and ceiling around the furnaces with an appropriate material. Acoustical energy leaves the furnaces traveling forward towards the foundry and rearward towards the wall. The rearward traveling energy is reflected and also reaches the foundry area. A perfectly absorbing material on the rear wall could therefore remove half of the acoustical energy from the foundry, a 3dBA reduction. The low frequency characteristic of the pit furnaces would require several feet thickness of material for this effect in general, but the presence of a vaulted ceiling over the furnace area causes multiple reflections. Therefore a two to four inch layer of material may be effective. A note of caution is necessary with this approach, since it is not clear how long these materials will withstand the heat and exhaust gases of the area above the pit furnaces before degrading in their performance.

Large Casting Foundry

Description. Our next test was of a large casting foundry. The actual casting operations do not take place in the building surveyed. Rather, it is used for the subsequent operations of chipping, grinding, repair welding, and touch-up machining. These operations take place at random times throughout the workshift, causing both temporal and spatial variations in noise levels. In light of this circumstance, it was decided that the average of a series of tests would be required for meaningful data. Fifty-one test points on a 40 by 50 feet grid were laid out, and six sets of noise survey test data was taken over a two-week period.

The process of chipping was noted to be a particularly loud noise source. However, the noise surveys never happened to encounter this source at close hand, due to the short duration of chipping. It was decided to take octave band and narrow band data of the chipping process, due to the apparent loudness of chipping work and the potential need for noise control techniques there. Chipping is used to remove zones of defects in the surfaces of large castings, prior to repair welding. The process consists of applying a pneumatically-driven cold chisel to the casting surface, thereby removing defective material. The repeated impact causes the casting to vibrate, emitting high intensity acoustical noise.

Results of the A-weighted Survey. In the A-weighted noise levels averaged over six tests, only two of the 51 test locations show noise levels above 90 dBA, and both of these points were within grinding areas where several workers were simultaneously grinding castings. This condition only occurred during the first test, and all subsequent tests had fewer workers grinding simultaneously and lower noise levels. The overall foundry average noise level was 87 dBA, well within OSHA criteria. On the basis of this data, it appeared that only a minimal change existed for an OSHA violation, and administrative controls on grinding could correct any such violation. However, a greater amount of test data would be required to insure that seasonal or work load variations do not significantly change these results. Furthermore, noise tests of the chipping process indicated noise levels above 100 dBA. Therefore, any worker spending a substantial portion of time chipping might require protection.

Results of the Octave and Narrow Band Analysis. After the identification of chipping as a potentially serious noise source, octave band data was taken of the noise produced by the chipping of two different castings. While there are differences in the noise spectra for the two castings, both castings show a rather broad band high frequency noise energy content. The broad band nature of the results suggests that many vibration modes are involved in noise generation, rather than one or two predominant frequencies.

Since noise control techniques depend on the noise characteristics, a narrow band noise analysis was also performed. This test consists of tape recording the chipping noise signal, and then playing the taped data into a Fourier analyzer to obtain the noise energy at various frequencies. The energy is expressed in terms of power spectral density, or PSD, versus frequency. Conceptually, a narrow band analysis is similar to an octave band analysis, except that a greatly refined picture of the noise characteristics are obtained.

In the narrow band data taken during chipping of a valve casting, the presence of the many peaks throughout the spectrum indicates that many vibration modes are contributing to the observed noise. Therefore it would do little good to attempt to restrain the casting so as to eliminate one particular mode of vibration, since other vibration modes would still be radiating acoustical energy.

Noise Control Recommendations. The most effective means of dealing with a broad band noise source such as the vibrating casting is through the introduction of damping. Damping, if effectively applied, will cause the impact-induced vibrations to decay quickly, thus preventing the buildup of high noise levels. The vibrational energy would then be dissipated as heat rather than being radiated into the environment as acoustical energy.

Due to the irregular geometry of the castings, it is not easy to achieve effective damping. One approach could be to apply a layer of damping material to a part of the casting surface, and then back this layer with a stiff constraining layer that is firmly attached to the casting. The constraining layer is important to achieving effective damping, and it should be roughly 10 per cent or more of the casting thickness. It may be possible to either tack-weld or clamp this layer to the casting.

Another noise control technique would be to lubricate the chisel tip before and during chipping. The lubricant will reduce the amount of energy absorbed by friction during chipping. Such energy loss prolongs the process, thereby increasing worker noise exposure.

A final step would be to drape a noise barrier material over the casting to contain some of the noise energy generated by chipping. Since the duration of chipping is not very long (a minute or so is required to remove a three-inch long piece of metal as wide as the chisel), even a 5dBA reduction could be enough to insure OSHA compliance.

Conclusions

Acoustical noise surveys were performed at two foundries engaged in a broad spectrum of operations. The nonferrous melt foundry was found to exceed OSHA allowable noise levels, and the furnaces were identified as the major sources. A number of steps ranging from administrative to source control were suggested, and these are currently under evaluation. The large casting foundry was found to generally meet OSHA allowable noise levels. The chipping process was singled out as a potentially serious noise problem, and several recommendations for noise reduction were made. These can be implemented when and if they are necessary.

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FOUNDRY NOISE ANALYSIS AND ABATEMENT RECOMMENDATIONS

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The production of metallic products is a complex process, beginning in many cases with the casting of a part, followed by removal of defects, and then followed by final machining. Most of these steps take place in foundries, and they involve some degree of noise. The noise levels in foundries may exceed OSHA allowable levels, and a noise analysis is necessary to determine whether or not a problem exists. The noise analysis can also point the way to potential noise reduction steps, if it is conducted in a way that identifies the major noise sources and their special characteristics.

This paper describes the tests, test results, and noise control recommendations made at a non-ferrous melt foundry and a large casting foundry. In both cases an overall noise survey was conducted to determine local noise levels, thereby allowing identification of major noise sources. The survey was conducted using the A-weighted scale (dBA) of a Bruel-Kjaer Model 2209 sound level meter, since OSHA compliance is determined based on this scale. A Bruel-Kjaer model 4220 piston-phone calibrator was used before, during, and after these tests to ensure the accuracy of the readings.

The survey was followed by octave band analysis of the major noise sources, so that their spectral distribution and character could be identified. Noise control recommendations were then made based on the identified characteristics of the major noise sources. The implementation of some of these recommendations is now underway, and follow-up tests will be made to determine the actual noise reduction delivered at a later date.

Non-Ferrous Melt Foundry

Description. A visual inspection of the non-ferrous melt foundry identified a number of potential noise sources, including rocker-type electric arc furnaces, oil-fired pit furnaces, gas-fired preheat ladles, blowers, and fans. A 16-location grid was laid out on a 50 by 25 feet spacing over the foundry work area. A-weighted noise levels were recorded at these locations. Octave band data was also taken at two points.

During the course of testing, it was discovered that two different operating conditions existed during a typical shift. One operating condition, designated the AM operation, occurred during the morning and involved the operation of two electric arc furnaces and three pit furnaces. A second operating condition, designated PM operation, occurred during the afternoon and involved the operation of four pit furnaces without the electric arc furnaces. It is to be expected that these operating conditions could vary somewhat from day to day, but the conditions tested were judged to be typical by plant personnel. It is also possible that a future major change in workload could change the typical operating conditions, and in that case further testing would be necessary.

Results of the A-weighted Survey. The results of the A-weighted survey were used to construct a noise contour map of the foundry work area for the two