NOISE REDUCTION IN QUEENSLAND SUGAR MILLS

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ABSTRACT
A study of noise in Queensland sugar mills has been undertaken to evaluate the technical problems involved in satisfying the hearing conservation criteria which have emerged in recent years. Initial noise surveys have shown that many problems are common from mill to mill and that in most cases a noise reduction of about 10 db at the source would be acceptable. This paper describes some methods used to demonstrate working solutions to the most serious common problems. Satisfactory methods of noise reduction have been found for locomotives, cane preparation equipment, mill turbine reduction gearboxes, steam vents from low pressure exhaust and high pressure relief valves, vacuum pumps, and air compressors.

INTRODUCTION
Although it has been known for many years that permanent impairment of hearing can result from exposure to loud noise, there has only recently been a general awareness of the problems and concern shown about their solution. In recent years relationships have been established showing the nature of the problems and quantitative evaluations have led to generally accepted criteria relating the noise levels and exposure to loss of hearing.

The Sugar Research Institute, Mackay, has for some years measured and evaluated noise levels in Queensland sugar mills, located the most troublesome areas and set about obtaining satisfactory solutions. In common with other states and countries, Queensland is drafting legislation to limit occupational noise exposure. The Standards Association of Australia has adopted the criteria that the maximum allowable noise level for full-time exposure should be 85 dbA and that for every increase in level of 3 db the allowable time of exposure should be reduced by a factor of 2.

INITIAL NOISE SURVEYS
Noise surveys have been carried out in 10 mills and isolated problems examined from time to time in other mills. It has been found that within the main mill buildings, there are positions occupied by operators having average noise levels greater than 85 dbA, and a few have levels greater than 95 dbA. This demonstrated that the majority of noise problems within a typical mill can be overcome by a reduction at the source of 10 db or less.

It was apparent from the noise surveys that the problem was similar from mill to mill. Most of the major noise problems for any mill were contained within the following list of common sources:

Cane locomotives; preparation equipment; mill-drive gearboxes (primary reduction); hydraulic pumps; high-pressure fans; boiler feed pumps; steam valves, vents, and leaks; turboalternators; vacuum-breaking valves;
compressors; vacuum pumps; fugals; pneumatic tools; workshop and maintenance operations.

METHODS OF NOISE REDUCTION

Practical methods of engineering noise reduction are described in many standard texts (e.g. Beranek,2 Harris3) and will not be dealt with in detail here. The two methods which have found most widespread application in the treatment of the above list of problems are enclosure and absorption.

The reduction of noise by enclosure relies simply on the fact that airborne noise is usually greatly reduced when it passes through a solid barrier — the noise reduction increases with increasing barrier mass and sound frequency. Sound waves are absorbed by blankets of porous materials such as mineral wool or glass wool if the blanket is used in conjunction with a hard reflective backing surface. In simple applications the thickness of the absorbing layer must be of the same order as one quarter of the wavelength of the sound to be absorbed.

A third general method of noise reduction which is particularly applicable to impact noises is the damping of vibrating surfaces. This method, however, is only of value when resonant vibration is predominant.

Cane locomotives

Most of the cane is transported to Queensland mills by rail — there are some 3,000 km of narrow gauge rail line and more than 100 locomotives in operation. Locomotives represent one of the most serious noise problems for mills — the noise level is high, the exposure time is high, and a relatively large number of operators is involved. Typically, a noise reduction of 10 to 15 db is required in the cab.

It has been observed that the noise level inside a locomotive cab is invariably several decibels higher than that found when the sound level meter is held at arm’s length outside the open door. This is due to the repeated reflection of sound within the cab which has no capacity for sound absorption. In one locomotive a noise reduction in the cab of 6 db has been obtained simply by fixing a 50 mm thickness of mineral wool to all inner surfaces. Of course a perforated facing is required to protect the driver from skin irritation and to protect the absorptive blanket from mechanical damage.

Locomotives have invariably been supplied to mills with an inadequate engine exhaust silencer. A further noise reduction of 4 db was achieved in the cab of the locomotive described above by fitting an exhaust muffler of the

![FIGURE 1. Prototype locomotive exhaust muffler.](image-url)
design shown in Fig. 1. Note that the muffler is of the "straight-through" type, so the reduction in noise is not accompanied by high engine back-pressure and loss of power.

Due to its size, the muffler shown in Fig. 1 would be difficult to install as a permanent fixture without extensive modifications to the engine cowling and possible rearrangement of the fuel tank. A series of 4 smaller mufflers have been constructed and are under test.

Cane-preparation knives

One of the most serious sources of noise around the carrier is caused by the hammering of pieces of cane on the inside of the carrier enclosure. Since the tip speed of the knives may be 50 m/sec, pieces of cane are likely to strike the inside of the casing at this speed. In one mill a noise reduction of 4 db over the entire area surrounding the carrier has been obtained by fitting a double-sheet sand-filled casing to the primary impact regions. It is expected that a further noise reduction will be gained by extending this treatment. The dry sand filling provides damping due to the interparticle friction and consequently suppresses the natural frequencies of vibration of the inner plate. The outer plate, of course, acts as an additional damped noise barrier.

Shredders

The problem of shredder noise is growing more serious as mills install machines of higher speed and greater capacity. The noise contains strong low-frequency components which are propagated readily throughout the entire mill building.

It has been found that the dominant feature of shredder noise is the presence of a component at hammer-passing frequency — usually 100 to 200 Hz. It would therefore seem reasonable to attack the problem by spreading the hammers over the whole rotor periphery rather than in 6 or 8 axial rows as is current practice. A full-diameter, partial-width, experimental shredder operated by the Sugar Research Institute at a Mackay mill has been modified to test the effect on noise of spreading the hammer complement over 24 pivot pins rather than 8. As a result of this modification the noise was reduced by 7 dbA and the dominant frequencies were changed from the 125 Hz and 250 Hz octave bands to the 500 Hz and 1000 Hz bands. It is well known that higher frequency noise is easier to control by the standard techniques of enclosure and absorption. The staggered hammer arrangements had no adverse effect on the preparation obtained with the shredder or on the ability to accept cane at the intake.

Shredder noise appears to be transmitted from the inside of the machine to surrounding areas via airborne paths rather than through vibration of the shredder casing itself. Several mills have made a significant reduction in noise by placing a cover over the elevator from the shredder delivery.

Mill-drive gearboxes

Some high-speed mill-drive gearboxes, particularly those with fabricated rather than cast casings, generate a loud piercing noise at a single frequency equal to the tooth contact frequency of the primary reduction. This frequency
is typically about 1000 Hz. Criteria for occupational noise exposure are always intended for broad-band noise for which the sound energy is distributed over a wide frequency range. When a noise contains prominent tonal components, the allowable noise limit should be reduced — 10 db is a commonly accepted adjustment. For this reason, a reduction of 20 db was considered necessary for the tooth-contact tone of the gearboxes in question.

Three types of noise-reducing enclosures have been demonstrated for gearboxes. The first consisted of an arrangement of sheet lead (20 kg/m²) supported on a steel frame which was isolated from gearbox vibration and supported on coil springs. A lining of mineral wool (30 kg/m³) was used on the inside of the enclosure to prevent a build-up of noise. The bearings on the input shaft had a history of overheating and were left exposed. The noise reduction through the sheet lead was expected to be 40 db, but the actual noise reduction obtained was only 22 db, due to the radiation of noise from the bearing covers.

On another gearbox, sheet lead was attached to the panels of the casing rather than on a vibration-isolated frame. A layer of felt (10 mm thickness) was interposed between the casing and the lead to prevent direct transmission of vibration and the lead was fixed to the edges of the panels where the amplitude of vibration was expected to be small. A noise measurement was not made before treatment, but the enclosure was generally considered to be successful.

An objection is often raised to the enclosure of gearboxes on the grounds of possible overheating. For this reason an enclosure was constructed with an incorporated cooling fan and acoustically lined air inlet and outlet ducts. The noise of this gearbox was reduced to a level well below the background noise in the mill.

In an effort to overcome noise in the design stage, discussions were held with a manufacturer prior to the supply of 3 new gearboxes to a Mackay mill. It was decided to improve the accuracy of tooth form and uniformity of pitch

![FIGURE 2. General arrangement of steam vent silencers.](image-url)
by grinding the high speed pinion and shaving the wheel. The casing thickness was increased to 25 mm, additional rib-stiffening was used, and the hollow sides of the casing below the parting line were damped by filling with dry sand. As a result the characteristic whine of these gearboxes has been eliminated. Unfortunately it is not possible to say which design change produced the result. However, it was found that regrinding of the high speed wheel and pinion in another similar gearbox had virtually no effect on noise.

**Steam vents**

Atmospheric venting of steam from main exhaust lines, boiler safety valves, and small vents and drains, is the most widespread single source of noise in mills. Low pressure venting can be expected for prolonged periods at the beginning and end of the week and whenever operational difficulties occur or the steam system becomes unbalanced.

Although most of the noise is radiated from the vent the source is at the control valve where the flow is usually sonic. It has been shown that this noise can be controlled simply by installing a sound-absorbing device, such as that shown in Fig. 2, between the valve and the outlet. The silencer is nothing more than a section of duct lined with mineral wool or fibreglass. The amount of noise reduction is determined by the thickness of the lining, its absorption characteristics, and the area facing the flow. Means are available for determining these parameters given the temperature and pressure upstream from the control valve and the maximum flow rate. For high-pressure exhaust a "pepper-pot" diffuser is placed before the absorptive section to change the noise spectrum from low to high frequency. An elaborate facing on the absorptive material is required to prevent erosion by the steam flow.

This method of reducing steam vent noise has found wide acceptance in Queensland sugar mills for major vents. In any mill, however, there is a multitude of small vents whose combined effect is probably far more significant than that of the major vents. Small vents can be dealt with economically with a simple rule-of-thumb design — for example by using an absorptive section whose thickness is greater than 1/4 pipe diameter and whose length is greater than 10 pipe diameters.

Absorptive vent silencers are equally effective on air lines cooling bearings or vacuum breaking valve inlets on pans.

**Valves**

Although most of the noise generated at a valve travels down the line as fluid-borne noise, a significant amount is radiated by the valve body and downstream pipework. A simple enclosure will overcome this problem. When noise travelling down the pipe is a problem, an inline muffler, similar in principle to those described in the previous section, may be used.

**Compressors and vacuum pumps**

The main source of noise for a compressor is usually the intake, and for a vacuum pump the exhaust. It has been found that this noise can be controlled effectively with a muffler similar to the dissipative steam vent silencers previously described.
DISCUSSION

The role of the Sugar Research Institute in the problem of noise reduction is necessarily limited to the demonstration of solutions to the most significant common problems. It would be impossible to examine every problem in each of the 27 member mills in Queensland. The detailed engineering effort must inevitably be undertaken by mill staff. And yet the successful solution to a noise problem requires both an intimate knowledge of the plant and process, and an appreciation of the fundamental methods of noise reduction — enclosure, absorption, damping, and so on. Many sad failures can be attributed to ignorance of the plant operation or to ignorance of the fundamental acoustics.

There is a trend in Queensland sugar mills towards the appointment of chemical engineers with formal qualifications, whose duties are removed from the urgent day-to-day problems of running the mill. Most formal engineering courses would give an adequate background for a short training course in noise reduction. Some Universities and Institutes of Technology in Australia already provide such courses.

Detailed engineering effort and the acquisition of expertise by mills is of course only one aspect of the problem. It is equally important to prevent the installation of new noise problems. In recent years, due to the specification of maximum noise levels on orders for new equipment, there has been a remarkable increase in interest shown by suppliers of equipment in competitive fields, notably locomotives, mill-drive gearboxes, and hydraulic pumps. Wherever possible, the noise problem should be solved by manufacturers, who can spread the cost of research and development over a large number of units.

There is a need for more research on noise reduction. In order to achieve our objective of demonstrating working solutions to the common problems referred to previously, Sugar Research cannot afford to examine any one problem in great depth. Such problems as the absorption of low frequency sound by Helmholtz resonators, the transmission of gearbox vibrations between the teeth and the casing, and so on, could well form the basis of higher-degree projects in Universities.

The implementation of a noise reduction program in an industrial plant should be accompanied by some means of judging its success. Since the main purpose of noise reduction in sugar mills is hearing conservation, it follows that the best means of measuring the result is by regular monitoring audiometry. Furthermore, the 85 dbA criterion does not ensure absolute safety for all employees — there is a small percentage who are particularly susceptible to noise-induced hearing loss. By monitoring hearing at regular intervals this small percentage could be identified and protected.

Of all the factors involved in the elimination of the noise problem in sugar mills, the attitude and motivation of the entire staff, from the highest levels of management to the most menial plant operators, is most important. Unless the management appreciates the extent of the problem no action will be taken, but unless the operators understand the reasons for a noise reduction program, they can effectively obstruct its implementation.

REFERENCES

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RESUMEN

Un estudio sobre ruido ha sido iniciado en los ingenios de Queensland para evaluar los problemas técnicos envueltos en satisfacer los criterios de conservación del sistema auditivo que han surgido en los últimos años. Ensayos de ruidos iniciales han demostrado que muchos problemas son comunes de ingenio a ingenio y que en la mayoría de los casos una reducción en el ruido de alrededor de 10 decibeles en la fuente, sería aceptable. Este artículo describe algunos métodos usados como soluciones funcionales aplicables a los más serios problemas comunes. Métodos satisfactorios de reducción de ruido han sido encontrados para locomotoras, equipos de preparación de caña, reductores de velocidad en los molinos, desalojos de escapes a baja y alta presión, bombas de vacío y compresores de aire.