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PRACTICAL REDUCTION OF NOISE FROM CHUTES AND SCREENS IN COAL CLEANING PLANTS

Prepared for

United States Department of the Interior
Bureau of Mines

by

Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, MA 02138

Final Report on
Contract No. H0144079

December 1976

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16. Abstract

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Design and installation recommendations are made for quieting chutes by means of dams, impact cushioning pads, impact shields, and damping materials, and for quieting screens by means of resilient decks, lined screen bottoms, drive mechanism enclosures, and side plate additions.

A brief account is appended of the wear and productivity performance of resilient materials observed in three coal cleaning plants.

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FOREWORD

This report was prepared by Bolt Beranek and Newman Inc., Cambridge, Massachusetts, under USBM Contract No. H0144079. The Contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of PM & SRC with Mr. Charles Summers and Dr. H. Kenneth Sacks acting as the Technical Project Officers. Ms. Elizabeth Rexroad was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period March 1976 to December 1976. This report was submitted by the authors on Decmeber 23, 1976.

TABLE OF CONTENTS

TABLE OF CONTENTS *(Cont.)*

LIST OF FIGURES AND TABLES

LIST OF FIGURES AND TABLES *(Cont.)*

INTRODUCTION

At many locations in coal cleaning plants the noise levels presently exceed those permitted by the Federal Coal Mine Health and Safety Act of 1969. Chutes and screens have been found to be among the most prevalent sources of noise in such plants, contributing to noise levels that sometimes reach 100 to 105 dBA. Therefore, quieting of chutes and screens is likely to be a major feature of any program for reducing the noise exposure of plant workers. It is the intent of the present report to provide plant personnel with definite practical guidelines for reducing chute and screen noise.

The first of the following sections provides some basic information about noise and suggests how one may decide what plant equipment needs quieting. The following sections discuss chute and screen quieting methods, generally in enough detail to permit plant personnel to implement them. The appendix discusses the experience two coal cleaning plants have had with the durability of some rubber chute linings and screen decks.

1. SOME FACTS ABOUT NOISE

1.1 What is Noise?

Noise (or unwanted sound) consists of small, rapid vibrations of air, which can be sensed by the human hearing system. Such air vibrations generally are caused by vibrations of a solid surface — for example, the bottom of a chute set into motion by coal impacts — or by unsteady air flows — for example, those produced by fan blades "chopping" the air.

A particular noise usually is made up of air vibrations at many different frequencies. "Frequency" refers to the number of back-and-forth motions (or "cycles") that occur in a second. Low-frequency noise, like the rumble of thunder, is low in pitch; high-frequency noise, like the whine of a siren, sounds high-pitched. Coal tumbling down a chute makes a different noise than an air jet because the two noises contain different mixtures of frequency components.

1.2 Measured and Permissible Noise Levels

The amount of noise that exists at a particular location can be measured by use of a "sound level meter," which gives a reading in "decibels." Some sound level meters are arranged so as to enable one to measure the noise components at various frequencies; others give a reading only for the total noise at all frequencies. The noise level meters in most common use for evaluation of industrial noise levels give "A-weighted" decibel values, usually abbreviated as "dBA", which are related to the perceived noisiness of sounds.

In order to provide some feeling for what numerical dBA values imply, Table 1 indicates some noises that typically correspond to various A-weighted noise levels, and Table 2 summarizes the presently permissible maximum noise exposures prescribed by the Coal Mine Health and Safety Act of 1969. From these tables one may find, for example, that a coal preparation plant worker is allowed to work no more than 1/2 hr per day near a machine that makes as much noise as a pneumatic pavement breaker (that is, 110 dBA).

1.3 Noise Levels Due to Combinations of Sources

If one listens to two identical machines (or other noise sources), one hears more noise than if only one machine is operating; however, two machines do not sound twice as noisy as one - rather, turning on the second machine increases the noisiness one perceives by only a little bit. Similarly, if one adds the noise of a third machine to that of two others, the perceived noisiness increases by only a very small amount. Because of the way we perceive and judge noise, and since the dBA values are related to perceived noisiness, the noise level (dBA) corresponding to two machines can not be obtained simply by adding together the two dBA values corresponding to the two individual machines. Instead, a special combination procedure applies, some features of which are described below.

Two equally noisy machines together produce a noise level that is 3 dBA higher than that due to a single machine. Three equally noisy machines result in a level that is 5 dBA higher than that from a single machine. Noise level increases due to more machines are given in Table 3. From this table one may observe that adding the noise from an additional machine to that from a considerable number of machines produces only a small increase in the noise level. Similarly, turning off only one of several machines results in only a small decrease in the noise level. For example, if the noise from a jackhammer is measured as 104 dBA, then the combined noise from 5 jackhammers amounts to 104 + 7 = 111 dBA; if one more jackhammer is added, the noise level goes up by one half (to 111.5 dBA), but if one is turned off, the noise drops by 1 to 110 dBA.

Table 4 indicates how two different noise levels combine. For example, if the noise level in a certain plant location is 100 dBA with the vibrating feeder there turned off, and if the feeder produces 103 dBA when the rest of the plant is not operating, one may estimate* that the noise level at the above-mentioned location, if the feeder is turned on while the plant is operating, will be 105 dBA.

1.4 Estimation of Noise Due to One of Several Sources

Table 4 also enables one to estimate the noise level produced by a given source by itself from the decrease in noise level that results when one turns off that source (or quiets it considerably). For example, if the noise level at a particular location is 98 dBA with all equipment operating, and if this level is 97 dBA when a nearby screen is turned off, one finds† that the screen by itself produces a noise level of 91 to 93 dBA. As another example,

---

*103 - 100 = 3 dBA. for a difference of 3 dBA, Table 4 indicates that one must add 2 dBA to the higher noise level to obtain the combined noise level.

†The combined noise level, 98 dBA, is 98 - 97 = 1 dBA above 97 dBA (which is due to everything but the screen). For a combined level that is 1 dBA more than the higher of two separate levels, Table 4 shows that the difference between the separate levels is between 5 and 7 dBA. Therefore, the screen noise level is between 98 - 7 = 91 dBA and 98 - 5 = 93 dBA.

if the noise level near a crusher is 90 dBA when the crusher is in operation and 84 dBA when the crusher is turned off, it is clear that the crusher contributes most of the noise. From Table 4 one finds* that the crusher by itself would produce a noise level of 89 dBA.

1.5 Effect of Quieting One of Several Sources

If one knows the noise produced by a given source (either from measuring the noise resulting when only that source is operating, or from use of the approach described in Section 1.4), one can employ Table 4 to determine how much reduction in total noise results from quieting the given source by a known amount. And if one knows how much noise reduction one obtains from various amounts of source quieting, one can determine how much quieting is useful.

Obviously, quieting a source that makes only a minor contribution to the total noise can produce only a minor reduction in that noise. E.g., since the screen in the first example of Sec. 1.4 contributes only 1 dBA to the total noise level, no amount of quieting of the screen can reduce the total noise by more than 1 dBA.

On the other hand, since the crusher in the second example makes a major contribution to the total noise, quieting of the

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*The combined level, 90 dBA, is 90 - 84 = 6 dBA above the lower level (due to everything other than the crusher). For this value of the difference between the combined noise level and the lower level, Table 4 shows that the difference between the separate noise levels is 5 dBA. Thus, the noise level due to the crusher itself is 84 + 5 = 89 dBA.

If the separate crusher noise level is 86 dBA and the noise level due to everything else is 84 dBA, the difference is 86 - 84 = 2 dBA, for which Table 4 shows that the combined level exceeds the higher of the two separate levels by 2 dBA. Therefore, the combined level is 86 + 2 = 88 dBA.

crusher results in significant noise reduction. By use of Table 4 one may determine that reducing the crusher noise in this example by 3 dBA (to 86 dBA) would result in a total noise level of 88 dBA; reducing the crusher noise by 5 dBA (to 84 dBA) would result in a total noise level of 87 dBA. However, if one leaves the crusher alone in this example and quiets only the rest of the plant, one could never achieve a noise level that is below the 89 dBA due to the crusher.

1.6 General Rules for Reducing Plant Noise

The foregoing examples illustrate some important facts pertaining to quieting:

1. Significant reduction in the noise due to several sources can be achieved only be reducing the noise due to the loudest contributing source.

2. Once the noise due to the loudest source has been reduced to a level that is 5 dBA below the noise due to the remaining sources, further quieting of this source produces no significant reduction in the total noise.

3. If many sources contribute to noise, a majority of these sources need to be quieted if a significant noise reduction is to be achieved.

1.7 Deciding on Whether Quieting is Worthwhile

In order to determine whether quieting of a particular chute or screen (or of any combination of equipment items) is likely to be useful, one needs to know whether these items make a significant contribution to the total noise at a location of interest.

One may evaluate this contribution by measuring the noise for any two of the following three conditions:

1. Item (or combination of items) under consideration operating by itself with no significant noise coming from the rest of the plant.

2. Item or combination under consideration not operating (making no noise); rest of plant operating normally.

3. Entire plant, including items under consideration, in operation.

By applying Table 4, one may then determine the magnitudes of the contributions made by the items under consideration. However, one need not carry out these calculations if one only wants to know whether quieting of these items will result in useful noise reductions. Instead, one may use as a rule of thumb that such quieting will be useful if any of the following statements hold true regarding the measurements for the conditions described above:

(a) The noise for condition (1) exceeds or is equal to that for condition (2).

(b) The noise for condition (3) exceeds that for condition (2) by *at least* 3 dBA.

(c) The noise for condition (3) exceeds that for condition (1) by *no more than* 3 dBA.

Many of the measurements discussed above do not require elaborate arrangements for separate operation of the various items of equipment whose noise is of concern. For example, short periods in which a given chute or screen (or combination) is not in use while the rest of the plant is in essentially full operation may be available just before or after start-up or shut-down of the processes served by those items of equipment.

In some instances, careful listening may be substituted for actual noise measurement, if one keeps in mind that a 3 dBA difference in noise level amounts to a small, but noticeable difference in perceived loudness. Thus, if one perceives a chute or screen (or combination) to be about as loud or louder than the rest of the plant, or if one judges the total noise without these items in operation to be less than the noise when they are in operation, then one may expect quieting of these items to be useful.

TABLE 1. TYPICAL NOISES CORRESPONDING TO dBA VALUES.

Noise Level (dBA)	Typical Noise
130	near military jet takeoff
120	near pile-driver; oxygen torch; chipping hammer
110	near pneumatic pavement breaker; rock-n-roll band
100	inside propeller aircraft; at edge of highway
90	near cement mixer; 25 ft from motor cycle
80	in automobile at high speed; near home garbage disposal
70	in busy department store
60	near home dishwasher
50	on quiet street in daytime
40	in private office
30	in quiet bedroom
20	in empty theater

TABLE 2. PERMISSIBLE NOISE EXPOSURES.

Exposure Duration (hr per day)	Maximum Permissible Noise Level (dBA)
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

TABLE 3. NOISE LEVELS FROM COMBINATIONS OF EQUALLY NOISY MACHINES*

Number of Equally Noisy Machines Operation	2	3	4	5	6	7	8	9	10
Increase in noise level (dBA) over single machine	3	5	6	7	8	8.5	9	9.5	10
Increase in noise level (dBA) due to adding one more machine	2	1	1	1	0.5	0.5	0.5	0.5	0.5
Decrease in noise level (dBA) due to turning off one machine	3	2	1	1	1	0.5	0.5	0.5	0.5

*All noise level increases and decreases shown here are rounded off to the nearest 0.5 dBA, which usually is the smallest practically significant difference.

TABLE 4. COMBINATION OF TWO NOISE LEVELS.*

Difference Between Separate Noise Levels	0	1	2	3	4	5	6	7	8	9	10	11	12	Over 12
Combined noise level is this much above higher separate level	3	2.5	2	2	1.5	1	1	1	0.5	0.5	0.5	0.5	0.5	0
Combined noise level is this much above lower separate level	3	3.5	4	4.5	5.5	6	7	8	8.5	9.5	10.5	11.5	12	same as difference

*All noise level values shown here are dBA values and are rounded off to the nearest half.

2. QUIETING OF CHUTES

2.1 Overview

Chutes make noise primarily because impacts of material on them set their bottom and side plates into vibration, and these vibrating plates then produce sound, much like loudspeakers. Noise reduction can best be achieved by reducing the noise-producing impacts. The most useful means for accomplishing this impact reduction are:

1. Dams that trap some material in the chute, so that more material falling onto the chute impacts against the trapped material, rather than against the chute metal.

2. Impact cushioning pads of rubber or similar materials.

3. Shields that keep falling material from impacting directly on the chute plates, thus reducing the impact forces.

Dams are inexpensive and easy to install. They can reduce chute noise by about 5 to 10 dBA. However, they cause material to collect in the chute, and thus may obstruct the flow of material. The material collected in the dam also adds weight to the chute, which may therefore require strengthening and added supports. Where the flow obstructions and weight additions produced by dams can be tolerated, dams generally constitute the most cost-effective means for chute noise reduction.

Impact Cushioning Pads or Liners may be expected to involve materials cost between $10 and $25 per square foot, but are very durable and protect the chute bottom steel from wear. Rubber chute liners can reduce chute noise at best by as much as 20 dBA. Materials sliding on rubber experience more friction than the same materials sliding on steel; material may collect on rubber liners in chutes with shallow slopes, and may obstruct flow.

Next to dams, rubber liners generally are the most cost-effective and reliable noise reduction means; however, they can not be used where they produce unacceptable flow obstructions.

Impact Shields cost about as much per square foot as chute liners. Such shields are most useful where material falls a long distance onto the chute and are best used in conjunction with chute liners. Shields can produce noise reductions of 5 to 15 dBA. Care must be taken in the design of such shields to prevent flow obstruction and material spillage.

Heavy Materials added to chute bottoms reduce their vibrations and provide noise reduction. Concrete-like *cementitious liners* are particularly convenient for adding weight. They are relatively easy to apply and cost only about $3 per square foot; they also protect the steel surfaces to which they are applied. Their wear resistance under impact is uncertain, but they are easily and inexpensively repaired. No matter whether they are applied on the top (impacted) or bottom surface of a chute bottom, such liners can produce noise reductions between 5 and 10 dBA.

Damping Materials reduce the "ringing" of steel plates produced by each impact. They generally need to be applied to the outside surfaces of a chute. Typical material costs are $0.50 to $2.00 per square foot; application is relatively easy. Noise reductions are likely to be less than 5 dBA.

It is important to note that the noise reduction obtained by using two or more noise control methods simultaneously is *not* equal to the sum of the noise reductions one obtains by using the methods individually. Generally, simultaneous use of two or more noise control treatments produces only slightly more noise reduction than use of the best of the individual treatments.

A summary of the major features of these quieting methods appears in Table 5. Recommendations concerning their selection and installation are given in the following pages.

2.2 Dams

Dams consist of steel strips welded into a chute more or less perpendicular to the chute bottom (see Fig. 1), so as to trap some of the material in the impact region. The dams should be constructed in a manner that will result in falling material impacting on at least a 6-in. thickness of trapped material.

The angle of repose of bituminous coal - that is, the angle with the horizontal at which piled coal will stand - typically is about 45°; for anthracite, this angle is about 30°. (The angle at which coal slides freely down an inclines surface of bright steel is about 22°; for anthracite is is about 18°.) Therefore, one may expect a coal pile with a hump (Fig. 1a) to form above a dam in a chute that is inclined at less than 45° to the horizontal, whereas one may expect a smooth pile with slides at 45° from the horizontal (Fig. 1b) to form above a dam in a chute inclined at more than 45° to the horizontal.*

For the selection of dam configurations for specific installations, it is recommended that one use sketches (to scale) of the cross-sections, like those of Fig. 1, applying the angles of repose as in Fig. 1 to choose dam heights and locations so that adequate thickness (6 in. or more) of trapped material are

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*This statement and Fig. 1 apply for bituminous coal. They apply for anthracite if 30° is substituted wherever 45° appears. The values of all angles cited here are standard handbook values; e.g., see *Kent's Mechanical Engineers' Handbook,* Power Volume, John Wiley & Sons, Inc., New York, 12th Ed., p. 2-32. The actual values vary somewhat, depending on the size and shape of the material, its uniformity of size, and moisture content.

obtained in the impact region without obstructing the coal flow. For chutes at less than 45° from the horizontal, only one dam is needed; more are likely to obstruct the flow. For steep chutes, however, a second dam, and possibly even more dams may be required, because coal falling from the first dam onto the chute may still produce considerable noise. Extensions of the chute sides in the vicinity of the dam may be needed to avoid material spillage over the sides.

2.3 Impact Cushioning Pads and Liners

Cushioning pads generally consist of one or more layers of rubber placed on the chute bottom in the region where material impacts. In some cases a steel sheet is used atop the rubber to protect it from wear or to keep the friction small. For noise reduction, the rubber layers should be as soft and as thick as possible. However, durability (resistance to cutting, gouging, and abrasion) is also an important design consideration.

Although potentially useful cushioning materials are available from at least a dozen manufacturers, only three appear to supply materials that are soft enough for effective noise control and that have found wide acceptance in the coal industry. These are:

1. Linatex Corporation of America
   P.O. Box 65
   Stafford Springs, Conn. 06076
2. The Goodyear Tire and Rubber Company
   1144 East Market Street
   Industrial Products Division
   Akron, Ohio 44316
3. Trelleborg Rubber Company
   P.O. Box 39010
   Solon, Ohio 44139

Much of the information presented in the rest of this section has been gleaned from the experience and literature of these organizations.

The minimum chute angle (measured from the horizontal) at which coal slides on rubber is about 35°. Therefore, build-up of a coal pile on rubber impact pads should be expected on less steep chutes. This build-up produces an added noise reduction benefit, but may interfere with flow.

Rubber wears best if material impacts on it at 90° (i.e., if the direction of impacts makes a 90° angle with the surface); rubber wears very poorly for impact angles of less than about 50°. Therefore, simple rubber layers may be used for impact angles of 50° or more, whereas more elaborate configurations are needed if the impact angle is less than 50°.

Figure 2 illustrates some impact pad configurations suitable for impact angles over 50°. The simplest of these is a single layer of rubber. One may bond this layer directly to the chute bottom by use of adhesives available from the materials suppliers, but such field installations tend to be unreliable. It is preferable to hold the rubber pads via a clamp bar by a row of bolts near their tops. Instead of such a single pad installation (Fig. 2a), one may bolt into the chute a factory-bonded rubber/steel laminate (with the rubber side up). Such a laminate* may be more convenient to handle and easier to install,

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*For example, Goodyear's "Armabond," Linatex's "bolt-in wear plates," or "Metalbak."

but tends to be more expensive than rubber sheet by itself. The rubber layer should be an inch or more in thickness, and of the lowest durometer material available.*

Instead of a single rubber layer, one may often do well to use a double layer, even though installation is more difficult. With a double layer (Fig. 2b) one can obtain a greater thickness of resilient material at reasonable cost, and when the top layer is damaged or worn, one needs only to replace it. If two layers of tough resilient material are used, one gains some added resilience and gouging resistance by using strips (Fig. 2c) instead of continuous pads. However, since the layer between the top layer and the steel chute bottom is not exposed to direct impacts of material, this middle layer need not be of an especially tough rubber – any good commercial grade of sponge rubber sheet will suffice, and generally will provide more noise reduction than a middle layer of solid rubber.

Figure 3 illustrates some impact pad configurations that are useful for chutes where the impact angles are less than 50° – that is, where impacts occur more nearly tangent to the chute surface. The arrangement recommended here uses rubber pads whose surfaces make some angle with the chute bottom, so that

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*Of the available Goodyear materials, "Jade Green Armabond" is the one with the lowest durometer. Linatex appears to furnish only one type of pad material. Trelleborg recommends the Trellex 60 grade. For a one-inch thickness, one may expect about 20 dBA noise reduction; for a 1/2 inch thickness, about 16 dBA. (Also see Fig. 4).

Where manufacturers recommend greater thicknesses on the basis of wear and gouging considerations, these recommendations should be followed.

the impacts on the rubber surface occur at angles of more than 50°. Fig. 3a shows Linatex's "D-Section" impact pad, which employs members with a U-shaped cross-section (all of rubber) under a surface pad to support it at an angle to the chute bottom and to provide additional resilience. Figure 3b illustrates a steel plate with a rubber layer bonded to it, supported at an angle to the chute bottom by means of support brackets. Figure 3c illustrates a ribbed or "stepped" rubber pad, where the profile of the pad is arranged so that impacts on its surfaces occur at more than 50°.

Where near-tangent impact is unavoidable, unprotected rubber pads generally do not last long. In such cases, the rubber pads should be covered by a steel plate of about the same thickness as the chute bottom, as illustrated in Fig. 3d. The added steel plate generally will make the rubber pad about 2 or 3 dBA less effective for noise control - that is, withouth the steel plate, one may expect to obtain 2 or 3 dBA less chute noise than with the steel cover plate in place.

Figure 4 provides a means for estimating the noise reduction to be expected by use of resilient impact pads. (For a typical Linatex material, the stiffness per unit area is about 800 psi/in.)

2.4 Impact Shields

An impact shield is any configuration that slows falling material before it impacts on the chute. Of course, impact shields must be constructed so that material impacts on them produce less noise than impacts on the chute bottom. An impact shield need not use resilient materials, but it usually is quieter if it does.

A typical arrangement that is useful for reducing impacts from large drop-heights to short-drop impacts is shown schematically in Fig. 5. This illustration indicates rubber pads, which produce both noise reduction and wear protection. However, if one desires, one may generally devise similar arrangements that use heavy metal bars or plates or dammed-up material in place of the rubber. Of course, less complicated arrangements - perhaps using only one surface for catching/deflecting material - may be used for shorter drop-heights. In all cases, enough space must be provided to avoid blockage.

Some simple impact shield configurations are shown schematically in Fig. 6. These shields should not be supported from the chute bottom; they may be supported from a separate framework or from reinforcements (e.g., heavy angle irons) mounted to the chute sides. These impact shields usually will require side plates to prevent material missing the chute. Figure 7 indicates the noise reductions achievable by use of impact shields.

2.5 Cementitious Liners

Concrete-like chute lining materials are available from:

1. Duraline, Inc.
   615 Washington Road
   Pittsburg, PA 15228
2. Stonhard, Inc.
   Park Avenue
   Maple Shade, NJ 08052

These lining materials currently are used for abrasive wear protection, largely where the material to be handled is relatively fine. It is not known how well these lining materials stand up under impacts of large chunks of material. However, for noise control purposes, these materials may be applied on the outside of the chute – i.e., under the chute bottom – where they are not subjected to direct impacts.

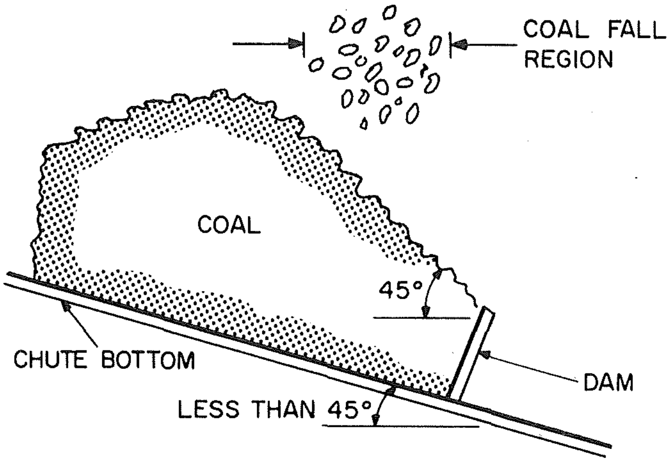
For effective noise control, the thickness of the cementitious material (no matter whether it is used outside or inside the chute) should be at least four times that of the chute bottom. Figure 8 permits one to estimate the achievable noise reduction.

Installation of the cementitious layer is done either over expanded metal (metal lath) which has been tack-welded to the area to be lined, or over a bonding agent. Because of the more intimate contact between the chute bottom and the added layer that results with the use of a bonding agent, this method of installation is generally preferable from the standpoint of noise control.

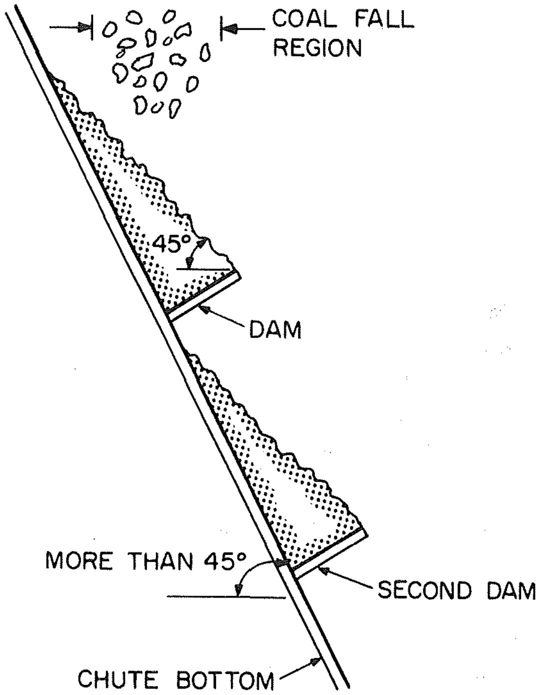
2.6 Damping Materials

Of the many commercially available materials, the ones listed in Table 6 appear to be most suited for coal processing plant applications, in view of their relatively low cost and ease of installation. All of the recommended materials may be applied by trowel, spray, or brush; all should be applied to the chute *exterior*, because of their limited wear resistance.

Use of damping materials in the amounts indicated in Table 6 may be expected to produce noise reduction of 1 to 4 dBA in general; using twice the amounts of damping material is likely to produce 1 or 2 dBA more reduction. The effectiveness of damping depends on how much a chute "rings" – keeps producing sound (like a gong) – when it is impacted; the more it rings, the more reduction can be achieved by means of damping materials.

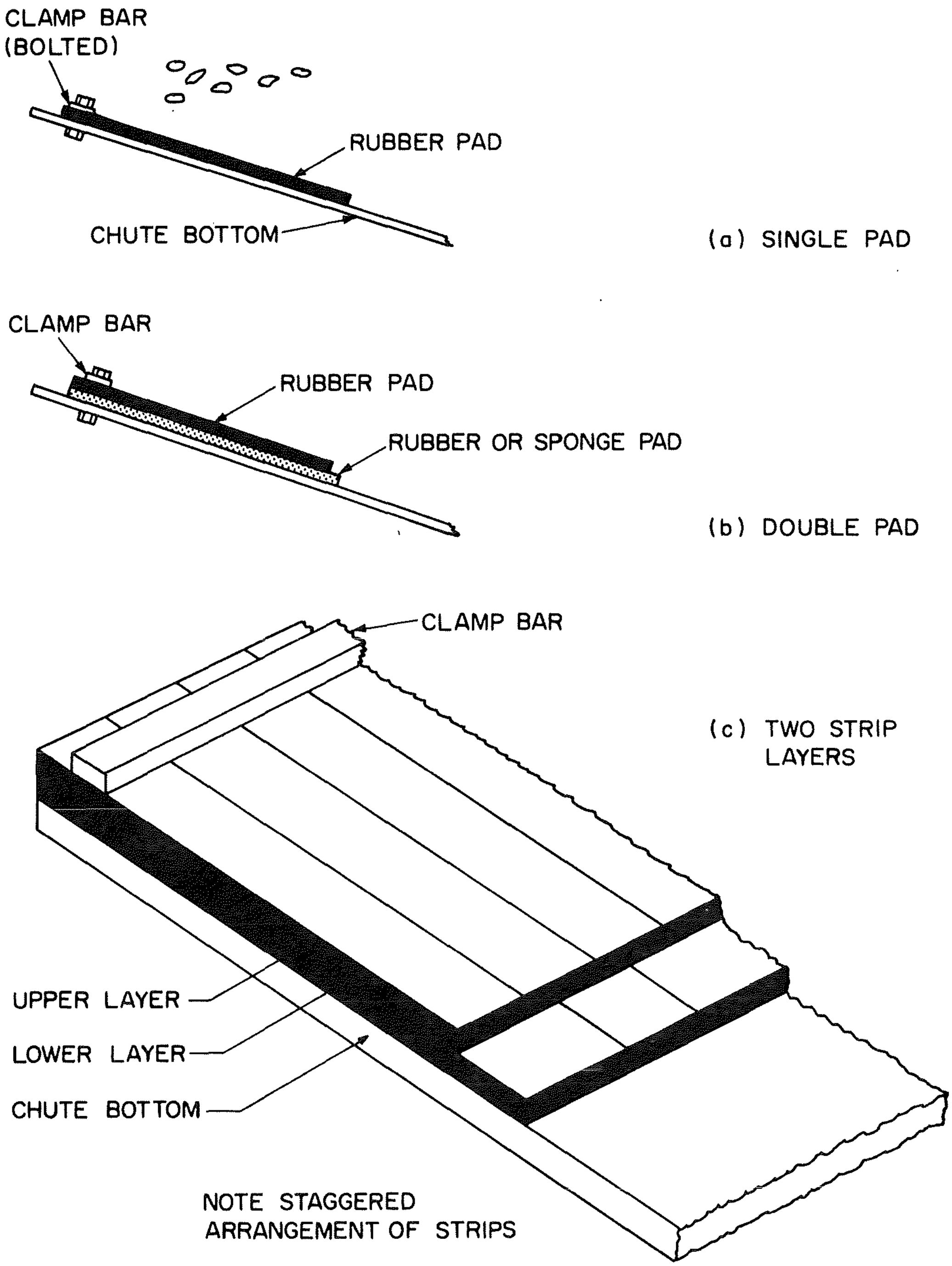


(a) CHUTE AT LESS THAN 45°



(b) CHUTE AT MORE THAN 45°

FIG. 1. SCHEMATIC SECTIONS OF CHUTES WITH DAMS.

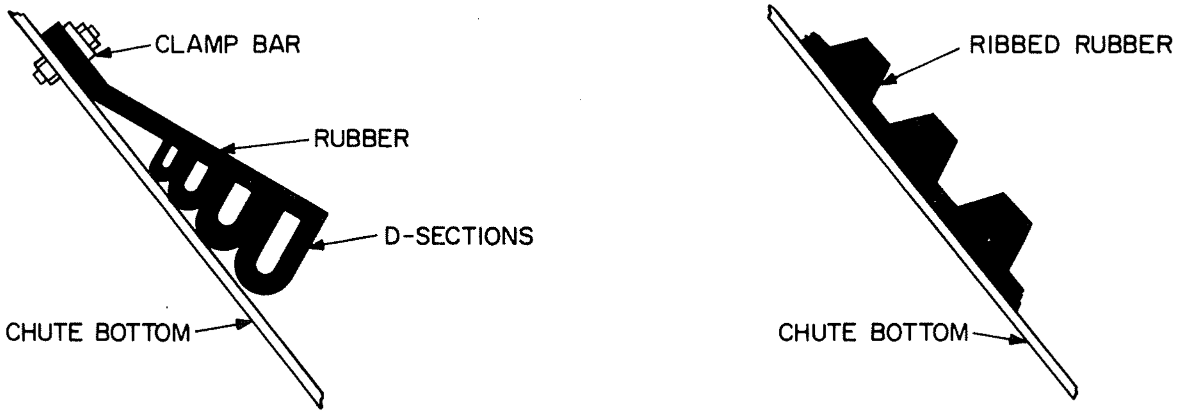


(a) SINGLE PAD

(b) DOUBLE PAD

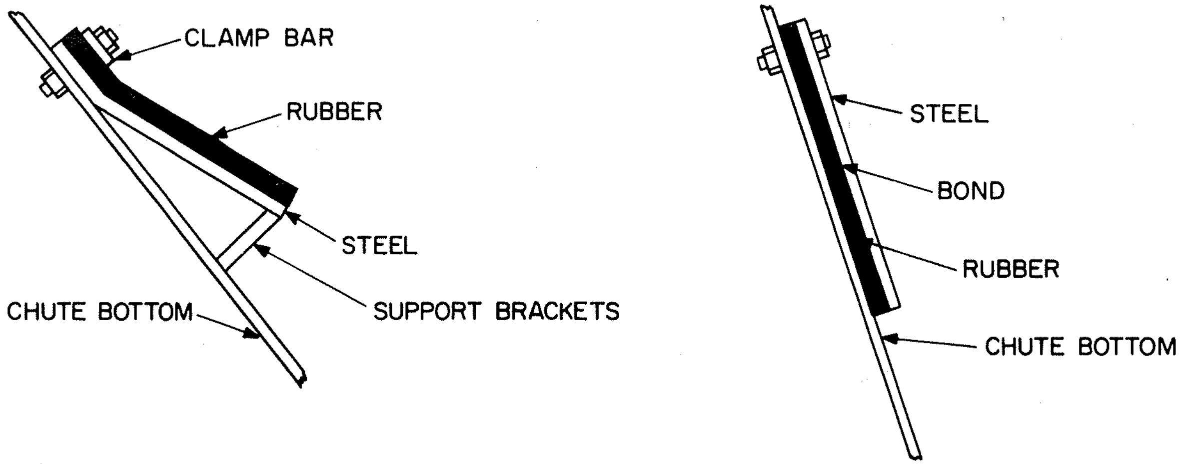
(c) TWO STRIP LAYERS

FIG. 2. RUBBER IMPACT PAD CONFIGURATIONS FOR CHUTES WHERE IMPACT ANGLES ARE OVER 50°.



(a) LINATEX D-SECTIONS
(FOR IMPACT ANGLES BETWEEN 30° and 50°)

(c) STEPPED LINER
(FOR IMPACT ANGLES BETWEEN 10° and 30°)



(b) RUBBER-STEEL SANDWICH
(FOR IMPACT ANGLES BETWEEN 30° and 50°)

(d) STEEL-RUBBER SANDWICH
(FOR IMPACT ANGLES LESS THAN 15°)

FIG. 3. RUBBER IMPACT PAD CONFIGURATIONS FOR CHUTES WHERE IMPACT ANGLES ARE LESS THAN 50°.

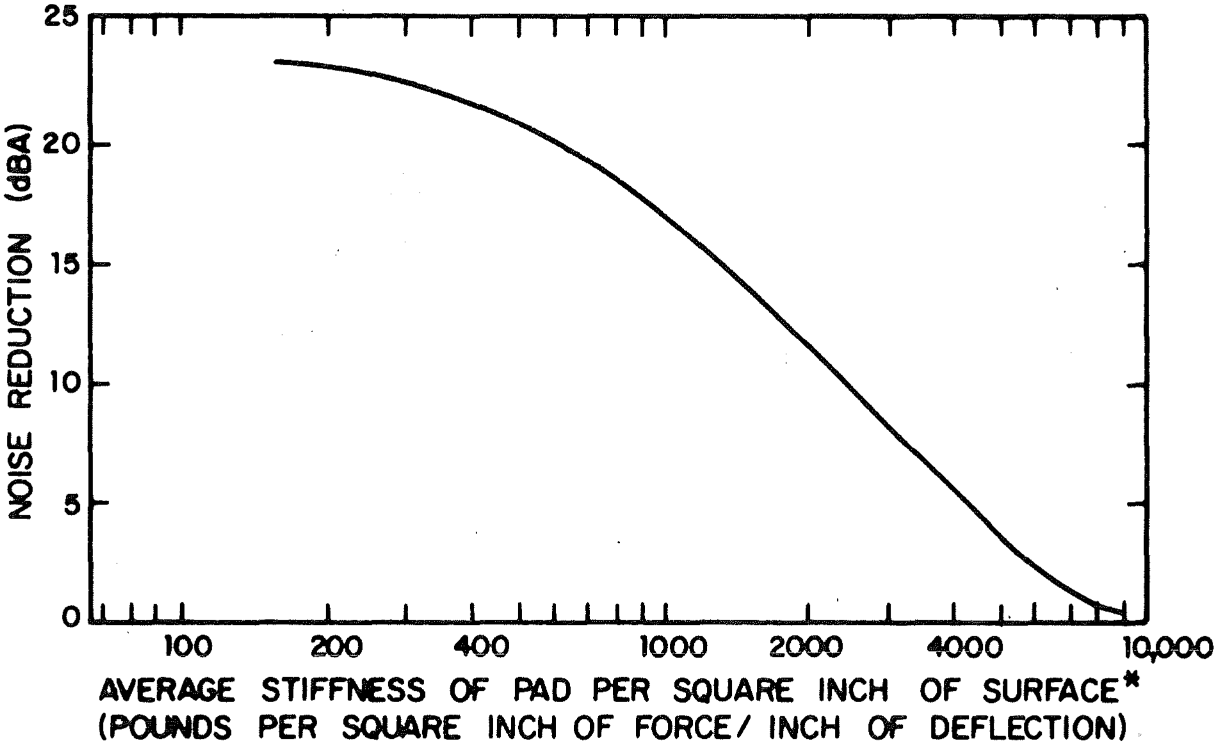


FIG. 4. TYPICAL CHUTE NOISE REDUCTION DUE TO USE OF RESILIENT PADS FOR IMPACT CUSHIONING. (IF STEEL COVER IS USED ATOP PAD, NOISE REDUCTION IS 3 TO 6 dBA LESS THAN THAT INDICATED.)

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*For simple rubber pad, this stiffness = E(psi)/h(in.), where E = modulus of elasticity, h = thickness of pad.

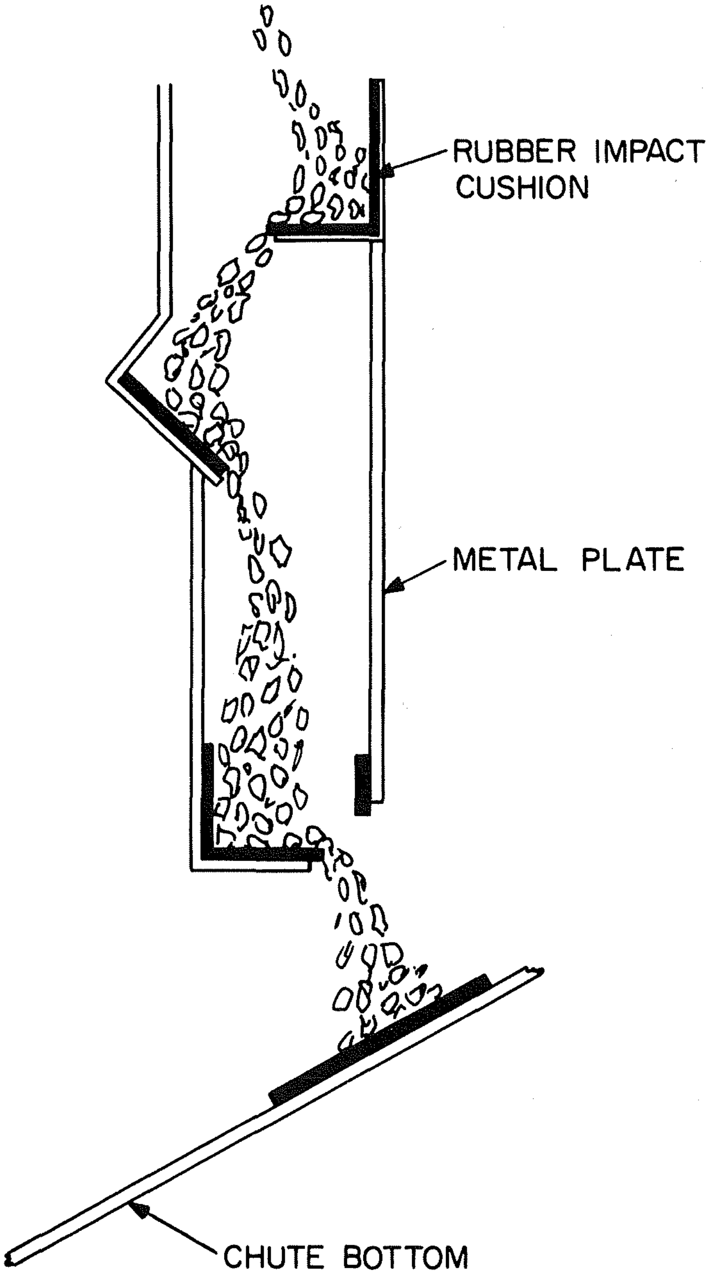
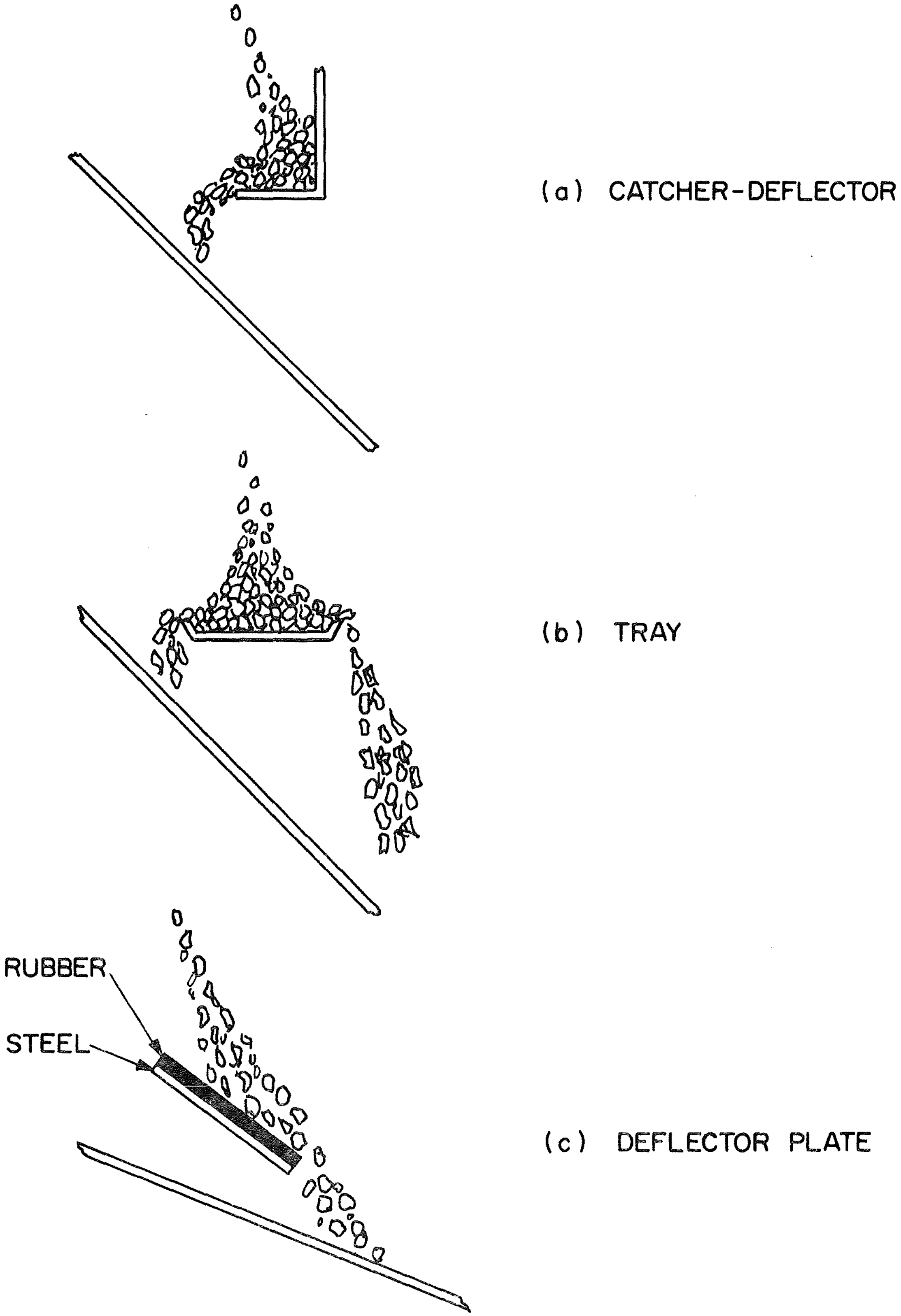


FIG. 5. SCHEMATIC CONFIGURATION FOR REDUCING IMPACTS DUE TO LARGE FALL HEIGHTS.



(a) CATCHER-DEFLECTOR

(b) TRAY

(c) DEFLECTOR PLATE

FIG. 6. SOME SIMPLE IMPACT SHIELDS.

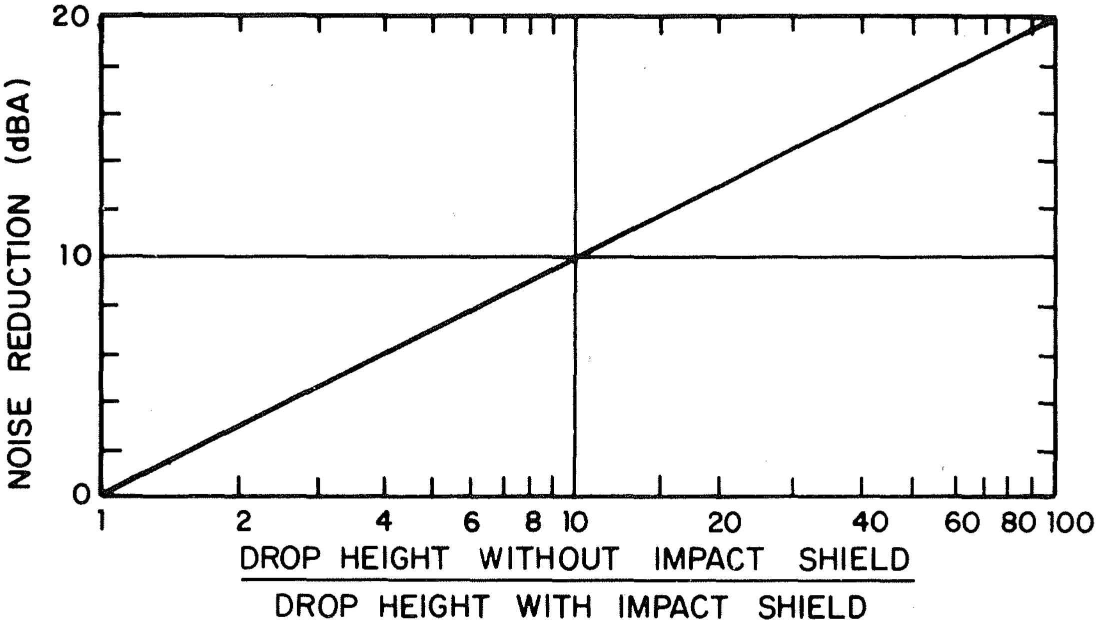


FIG. 7. NOISE REDUCTION EFFECT OF IMPACT SHIELDS DUE TO REDUCTIONS IN HEIGHT THROUGH WHICH COAL DROPS BEFORE IMPACTING ON CHUTE.*

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*Note: Additional noise reduction may be achieved by use of resilient chute liners. Noise reduction achievable is limited by noise of coal impacts onto impact shields.

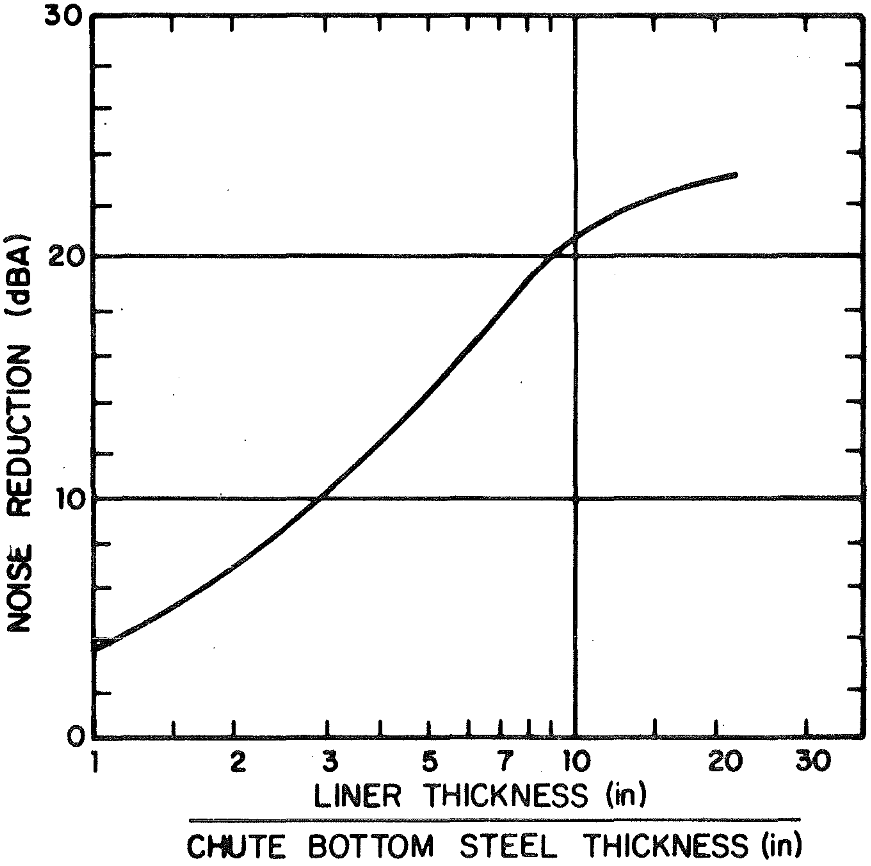

FIG. 8. NOISE REDUCTION DUE TO ADDITION OF CEMENTITIOUS LINERS.

TABLE 5. OVERVIEW OF CHUTE QUIETING METHODS

Noise Control Treatment	Noise Reduction	Typical Material Costs	Installation	Notes
Dams	5 to 10 dBA	$10 to $50	Welding	Must be designed to avoid spillage and flow obstruction. Reduce wear of steel bottoms.
Impact Cushioning Pads	10 to 20 dBA	$10 to $20 per sq. ft.	Bolting	Increased sliding friction may cause material buildup. Pads have good durability.
Impact Shields	5 to 15 dBA	$10 to $20 per sq. ft.	Welding, Bolting	Most useful for large drop heights. Can decrease wear at impact location.
Cementitious Liners	5 to 10 dBA	$3 per sq. ft.	Bonding	May be applied in or under chute. Protect steel and are easy to repair.
Damping Materials	1 to 5 dBA	$0.50 to $2 per sq. ft.	Spray, Troweling or Bonding	Applied outside of chute.

TABLE 6. DAMPING MATERIALS

Supplier/Location	Material Designation	Recommended Weight (lb/ft^2)	Approximate Cost ($\$/ft^2$)
Allforce Acoustics 1600 Peninsula Dr. Erie, PA 16512	Soundscreen Sprayable Damping	1.4	1.90
H.L. Blachford, Inc. 1855 Stephenson Highway Troy, MI 48084	Aquaplas F-80	1.0	0.90
Ferro Corporation 34 Smith Street Norwalk, CN 06852	Coustidamp A-FS	2.0	2.00
Korfund Dynamics Corp. P.O. Box 235 Westbury, NY 11590	Vibrodamper* Type 80-A	1.1	1.00
Quaker State Oil Refining Corp. P.O. Box 989 Oil City, PA 16301	Sound-off	2.8	0.50
Safety Aids, Inc. 4070 West Maple Road Birmingham, MI 48010	Soundown 727	1.0	0.70
Singer Partitions 444 N. Lakeshore Drive Chicago, IL 60611	Sound Stopper Vibration Damper	0.6	1.80
Soundcoat Co., Inc. 175 Pearl Street Brooklyn, NY 11201	Damping Compound* GP-1	1.7	0.45

*Where water is present, material surface must be protected with paint.

3. QUIETING OF SCREENS

3.1 What Parts Need Quieting?

The noise produced by a screen comes primarily from two sources: impacts of coal (or other material) against screen decks and bottom plates due to the agitating action of the screen, and the drive mechanism. In general, coal impact noise predominates in screens handling coarse coal, and drive mechanism noise predominates in screens handling finer coal. In some cases, additional noise results from rattling at loose connections.

The noise due to coal impacts comes primarily from the screen decks and bottoms on which the impacts occur. Noise due to a drive mechanism may come primarily through the mechanism housing or from the side plates to which the mechanism is mounted. (The drive mechanism tends to make these side plates vibrate at audible frequencies, and the plates then act somewhat like loudspeakers.)

In order to determine the contributions of coal impacts and of the drive mechanism to the total noise of a given screen, one should make noise measurements and listen carefully when the screen is operating empty and full of coal. By comparing the results measured under these two conditions, one may evaluate the contributions of the two sources, and one may determine the noise reduction to be expected due to quieting each source. (See Sections 1.3 and 1.4). Empty and full operation comparisons can often be made during start-up or shut-down of the process served by the screen. Of course, whether the screen is operated for experimental purposes or in regular production, care must be taken so that the observed noise is not contaminated by that from neighboring equipment.

Once one has determined the extent to which coal impacts and the drive mechanism contribute to the total noise of a screen with which one is concerned, one should pinpoint as far as possible from where the noise comes, so that one can select the best noise reduction approach. For coal impact noise, one should identify how much noise comes from each deck and from the bottom. For drive mechanism noise, one should determine how much comes from the housing and how much from the side plates.

The various impact noise contributions may be rank-ordered by careful listening. Their evaluation is likely to require some experimentation, with the screen artificially set up so that only one deck or only the bottom has material on it. One may sometimes obtain some idea of the relative magnitude of the noise coming from the drive mechanism housing and that coming from the side plates by measuring (or carefully listening to) the noise at about one foot to the side of the drive mechanism and at about one foot from the side plates at several locations at some distance (say, 10 ft or more) from the drive mechanism, with the screen operating without coal. Where this approach provides no clear-cut indication about which surface produces more noise, one may need to build a temporary acoustic enclosure* around the drive mechanism housing, and measure the noise of the screen with and without this housing in place.

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*This enclosure may be constructed most simply by wrapping two or three inches of soft fiberglass (or sponge rubber) around the mechanism housing, and then wrapping quarter-inch thick lead or leaded vinyl around the fiberglass. Care must be taken that the housing does not make direct contact anywhere with the external layer, and that there are no major air leaks in this layer. A wrapping of fabric tape usually is useful for holding the external layer in place and sealing it sufficiently.

The most practical means generally available for reducing the noise due to coal impacts are:

1. Use of resilient screen decks and resiliently lined screen bottoms.

2. Reduction of the screen throw (oscillatory motion), where such a reduction has no adverse effect on the screen productivity.

The most practical means for reducing the noise due to the drive mechanism, depending on what generates most of the noise, involve:

1. Enclosing the drive mechanism

2. Adding heavy layers to the side plates.

Of course, if noise due to rattling is observed, this rattling should be eliminated by tightening or adding bolts, or adding welds.

The noise reduction methods mentioned above are described in the following pages.

3.2 Resilient Screen Decks

Decks that are made entirely of a resilient material, such as rubber, produce relatively little noise due to coal impacts. The same is true of rubber-clad steel decks.

Resiliently-clad steel decks or decks made entirely of resilient materials are available from:

1. A-S-H Pump
P.O. Box 635
Division of Envirotech Corp.
Paoli, PA 19301

2. Hendrick Manufacturing Co.
   Carbondale, PA 18407
3. Linatex Corporation of America
   P.O. Box 65
   Stafford Springs, CN 06078
4. McBride Industries
   P.O. Box 94
   St. Albans, WV 25177
5. Trelleborg Rubber Co.
   P.O. Box 39010
   Solon, OH 44139

Resilient screen decks typically reduce the noise due to coal impact on decks by about 5 to 15 dBA, with the greater amounts of noise reduction pertaining to larger material sizes.

All-rubber or rubber-clad decks have a greater tendency to blind than steel decks with the same perforations; the use of resilient decks therefore reduces productivity to some extent.

Resilient or resiliently clad screen decks cost between $20 and $30 per square foot; rubber-clad steel decks typically are less costly than all-rubber decks, but also produce less quieting. Resilient decks tend to wear about twice as long as steel decks, if properly selected. However, decks made entirely of rubber have a tendency to sag, may accumulate material in the sagging areas, and may tear through. In order to avoid such tearing, such decks must be supported, usually by several longitudinal and lateral support beams.

3.3 Reduction of Screen Throw

Most screens that are in use oscillate more than necessary to accomplish what they need to do, and slowing them down (having them operate with fewer back-and-forth motions per minute) or reducing the extent of each back-and-forth motion may have no significant effect on their productivity. Screen throw reduction has two advantages: it reduces impact noise everywhere, and it can be obtained relatively simply and inexpensively, without introducing increased maintenance requirements. Unfortunately, the effect on productivity can not be predicted, and quite considerable throw reductions may be needed to achieve significant quieting.

Reducing the speed of the eccentric-weight drive of a screen, as can be accomplished most easily by changing the belt-pulleys on the motor and drive mechanism shafts, reduces both the speed and the extent of the oscillations. A 25% reduction in the drive mechanism speed is needed to reduce the impact noise by 3 dBA. Lesser speed reductions may be expected to produce only minor effects on impact noise, whereas a (usually unacceptable) 50% reduction in speed would reduce impact noise by about 6 dBA.

3.4 Resiliently Lined Screen Bottoms

Where coal impacts against a screen bottom are found to make a significant noise contribution, this contribution can be reduced by 3 to 6 dBA by adding a resilient lining to the screen bottom. Solid rubber pads of one-half inch thickness or more are recommended; tough, relatively soft, resilient materials as discussed in Sec. 2.3 should be used.

Single layers, bonded into place, may be expected to work well, if this bonding can be accomplished adequately in the plant. Otherwise, metal plates with factory-bonded rubber layers attached (also described in Sec. 2.3) may be bolted to the screen bottoms.

3.5 Drive Mechanism Enclosures

In those cases where drive mechanism noise comes primarily from the mechanism housing, one may reduce this noise most simply by providing an enclosure around this housing. An effective noise-reducing enclosure should be made of heavy material, should be reasonably airtight, should include some fiberglass or other sound-absorbing material, and should not make contact with the vibrating housing surfaces from where the noise comes.

A typical acoustical enclosure consists of a box of 1/8 in. or thicker steel that fits around the drive mechanism with about a two-inch air gap between the inside of the box and the nearest surface on the drive mechanism housing, and with one inch of the air gap taken up by glued-in fiberglass pads or mats (over 75% or more of the available surface). This box should not be attached to the drive mechanism housing, but should be attached separately to the screen structure. Any openings required in this box - e.g., for access of belts or cooling air - should be kept as small as possible. Openings that exceed an inch in diameter should be provided with "lined ducts"; these consist of tubes that extend at least five diameters from the box surface and that are lined with as much fiberglass as possible.

Figure 9 shows schematically the aforementioned major features of noise control enclosures for drive mechanisms. Also indicated in this figure is a gasket between the shell of the enclosure and its support, included primarily in order to eliminate possible rattling.

In cases where an installed enclosure provides insufficient noise reduction, one needs to determine by closing off such openings as the belt admission holes (by use of fiberglass pads that fit fairly snugly around the belt) whether the noise from the enclosure comes primarily from the enclosure shell or from the openings. If it comes mostly from the shell surfaces, one can reduce it most simply by adding mass to these surfaces - e.g., by gluing on leaded vinyl sheeting. To be effective, the added mass (per unit surface area) must be at least equal to that of the enclosure shell. If the noise comes mostly from the holes, the ducts should be made longer and lined more fully, and the openings should be made smaller, if possible.

A well-built and carefully installed enclosure, used under conditions where the noise comes directly from the drive mechanism housing, may be expected to reduce this noise by 10 to 15 dBA.

3.6 Mass Addition to Side Panels

In those cases where the noise due to the drive mechanism comes primarily from the side plates of the screen, noise control treatment of the side plates is required. The best such treatment consists simply of increasing the mass of the side plates.

Such mass increases can be obtained by bolting or welding additional steel plates to the side plates (taking care to avoid the possibility of rattling) or by covering the outsides of the side plates with damping materials or cementitious liner materials of the type described in Sections 2.4 and 2.5. The added mass per unit area should be at least equal to that of the side plates themselves; the corresponding reduction in the noise coming from the side panels then may be expected to be about 6 dBA.

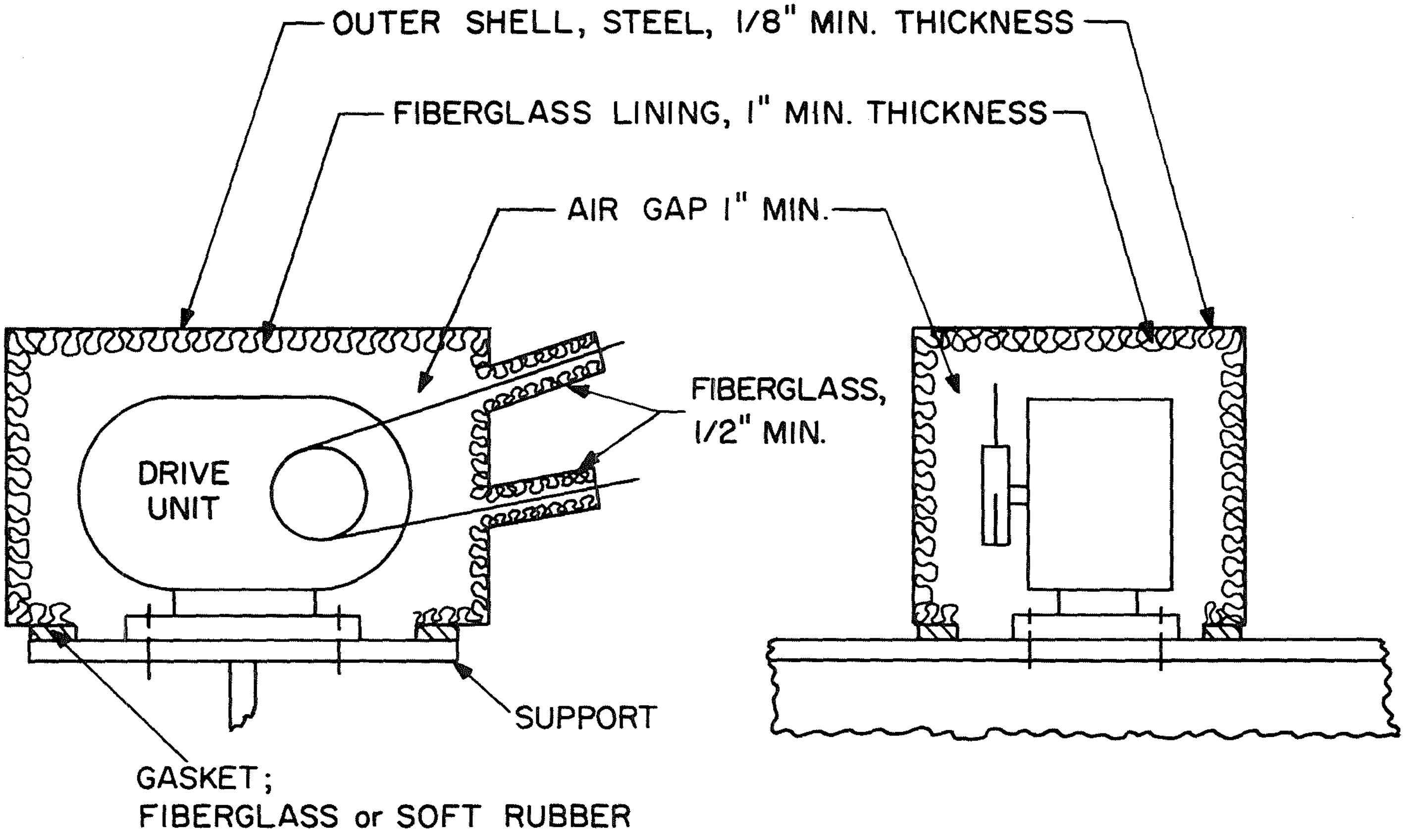

FIG. 9. SCHEMATIC SECTIONS THROUGH TYPICAL NOISE CONTROL ENCLOSURES FOR DRIVE UNIT.

APPENDIX – SOME REPORTED EXPERIENCE WITH RESILIENT MATERIALS IN COAL CLEANING PLANTS

A. Meadow River Tipple, Sewell Coal Co., Charleston, West Virginia*

This preparation plant is relatively new (about 3 years old) and was designed to process 400 tons per hour. However, the plant receives coal from only one mine, which works one shift, and the tipple works at most one shift per day.

Resilient screen decks and chute treatments are installed at several locations in this plant. These locations and the noise levels measured near these installations are indicated in Figs. A1 and A2.

A.1 Screens

The plant's entire flow runs across two raw coal screens. These are double-deck vibrators with Trelleborg decks having 1-in. diameter holes on the top, and with profile wire below. (These Trelleborg decks are made entirely of rubber, with no steel backing.) Figures A3 - A5 show middle and discharge-end portions of these rubber decks, which have been in use for about a year. Although some rounding of the bridging is evident, the decks may be seen to be in good shape.

However, at the infeed end of the two screens, the rubber decks tore after about 10 months' use and were replaced by conventional steel decks. Figure A6 shows one of the decks that was replaced; the deck essentially tore in the impact area, without showing significant wear elsewhere. It is likely that

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*Results of interviews with plant personnel during visits to plants in April 1976.

excessive wear occurred because (unlike at the Moss No. 3 plant, see next section of this appendix) there was no provision for slowing the impact of the infeed material; the bridging between the holes became rounded and worn until it finally gave way.

Steel decks were used on the raw coal screens for about a year before the rubber decks were installed. At that time, the steel decks showed some wear, but were still quite useable. (However, during the year that the steel decks were in use, production was 10 to 15% lower than during the past year.)

Trelleborg decks were also tried on the pre-wet screen in this plant. However, they were found to cause a flow backup and were replaced by conventional steel decks after a single shift.

A.2 Chutes

Profile Trelleborg rubber, installed at the impact locations near the tops of the chutes at the discharge end of the raw coal screens showed only minor rounding of the sawtooth-like cross section after a year's use.

Similar profile material is also used in chutes fed by the heavy media bath, refuse and clean coal dewatering screens, and is surviving well; see Figs. A7 - A9.

Clean coal and refuse chutes were constructed with sidewalls of flat Trelleborg, with bottoms made of sheet steel covered by flat Trelleborg material, and with profiled Trelleborg rubber at the impact locations (see Fig. A10). Only two replacements of the rubber were needed during a year's operation: one was in an impact area (where flat material was used instead of the better suited profiled type); the other was caused from the outside by an accident. Previously, it had been necessary to replace portions of the steel chutes every five to six months. This rubber material costs between $12 and $15 per square foot, but was found to outlast steel. (Half-inch thick mild steel plate typically costs $2.70 per square foot.)

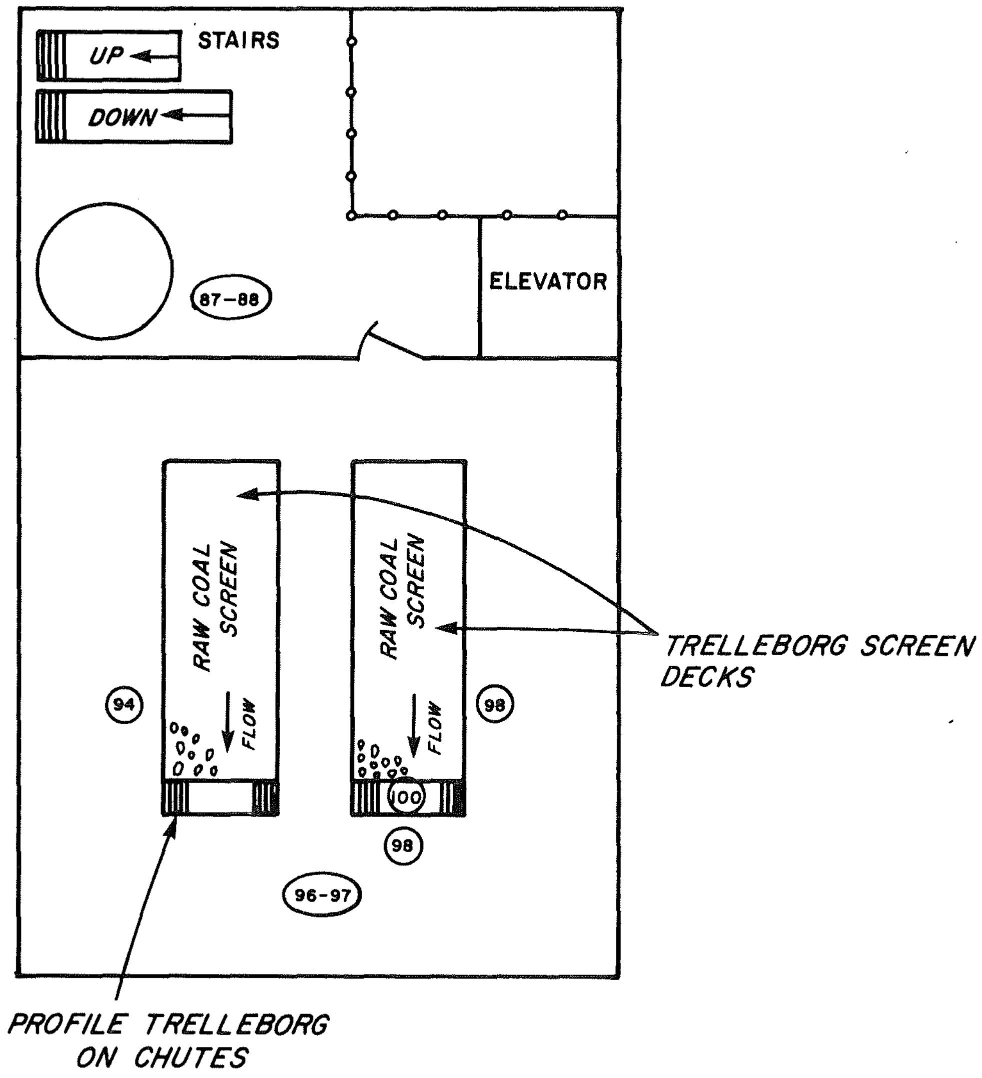

FIG. A.1. LEVEL 7 AT MEADOW RIVER PLANT. (NUMBERS SHOW NOISE LEVELS, dBA, AT THE INDICATED LOCATIONS.)

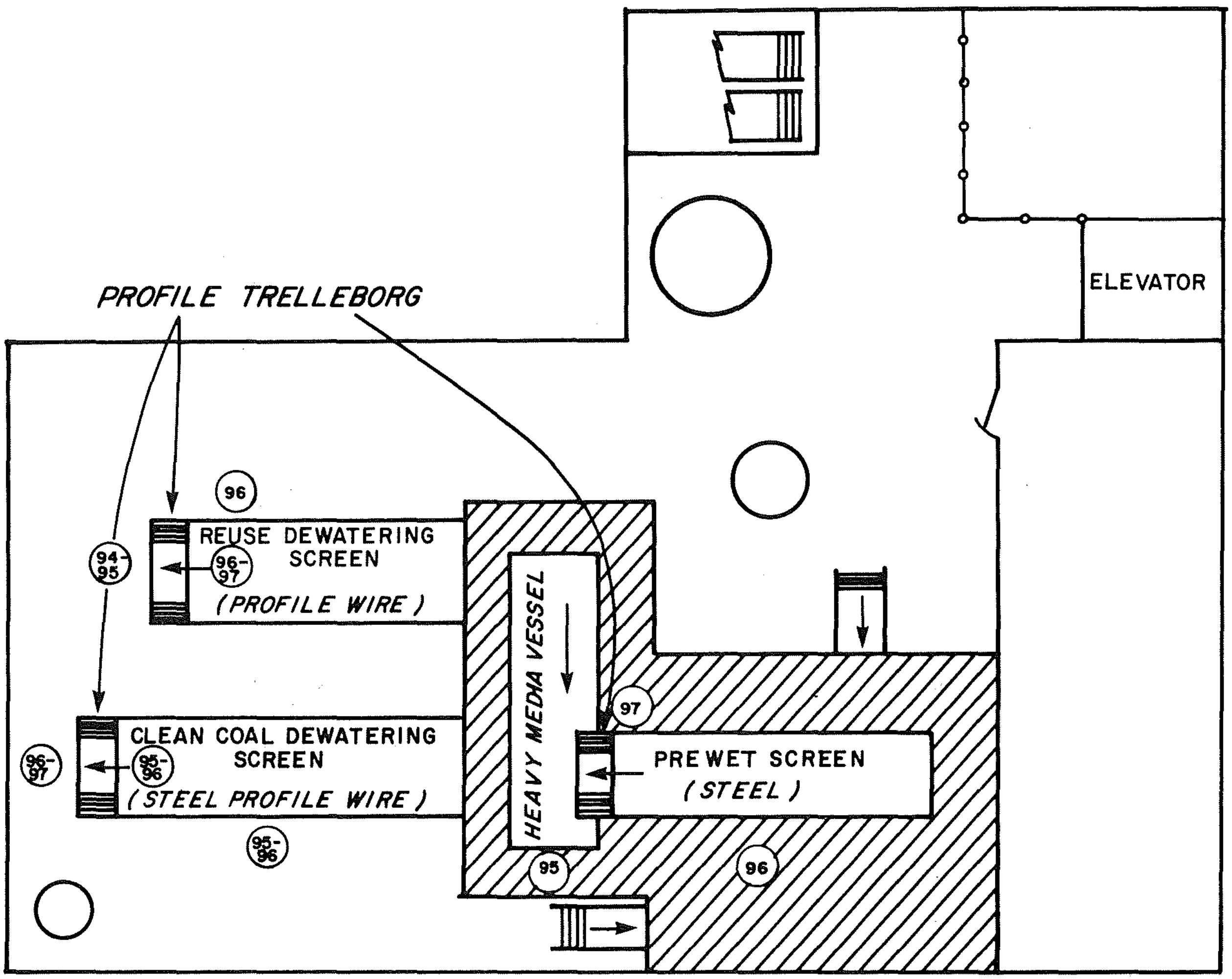

FIG. A.2. LEVEL 6 AT MEADOW RIVER PLANT. (NUMBERS SHOW NOISE LEVELS, dBA, AT THE INDICATED LOCATIONS.)

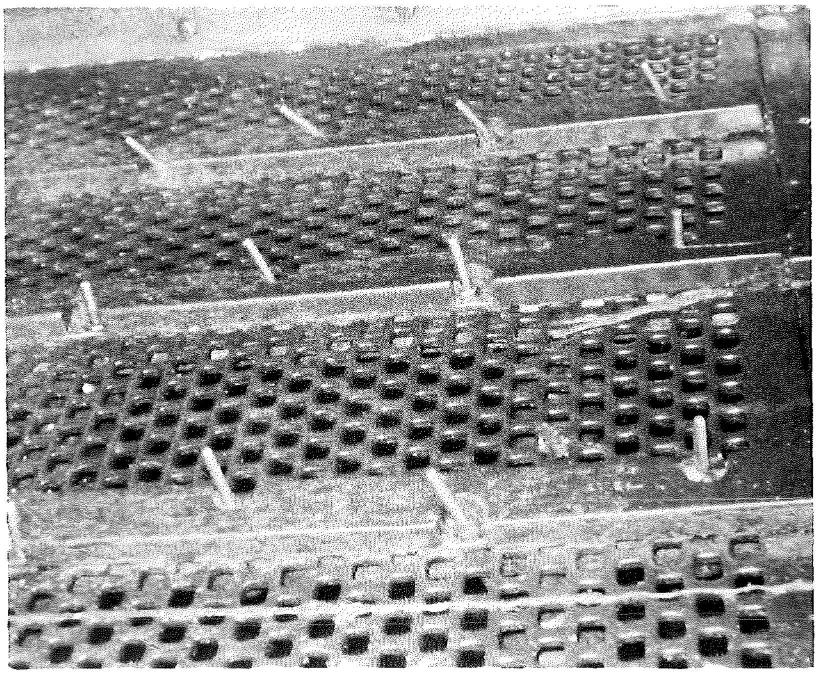

FIG. A.3. CENTER SECTION OF RIGHT-HAND RAW COAL SCREEN: MEADOW RIVER. (NOTE ROUNDED BRIDGING OF RUBBER DECK AFTER ONE YEAR OF USE.)

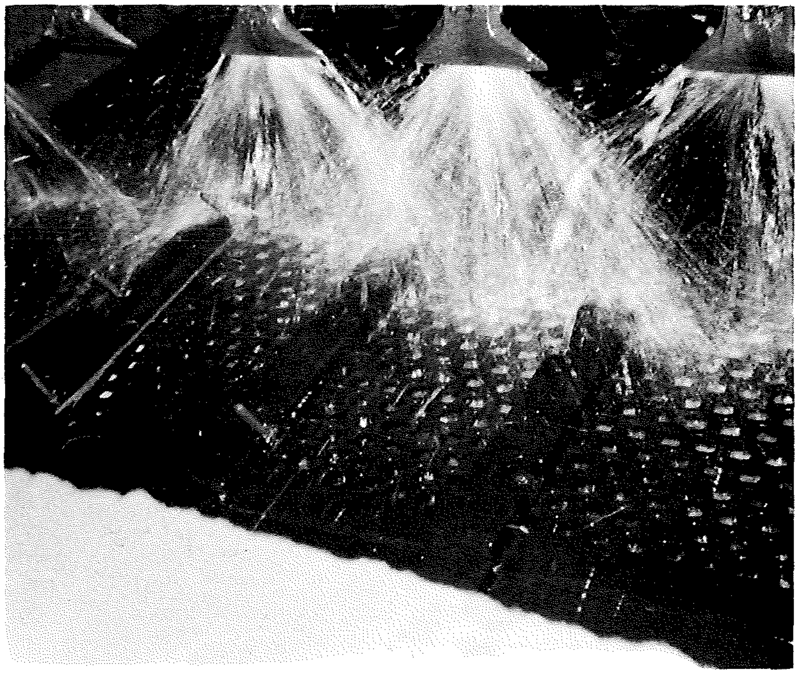

FIG. A.4. MIDDLE SPRAY AREA, RIGHT-HAND RAW COAL SCREEN: MEADOW RIVER.

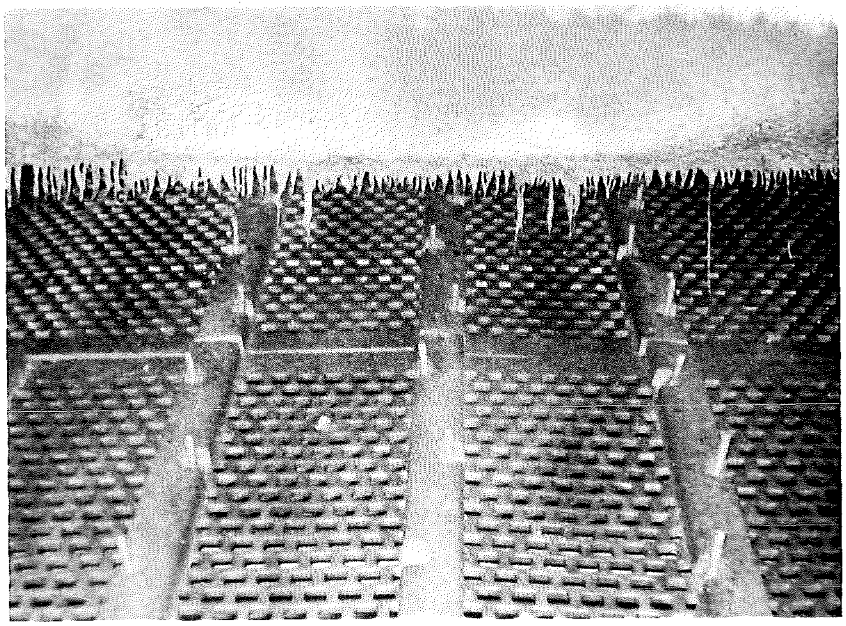

FIG. A.5. DISCHARGE END, LEFT-HAND RAW COAL SCREEN: MEADOW RIVER. (NOTE ROUNDED BRIDGING BETWEEN HOLES OF RUBBER DECK AFTER ONE YEAR OF USE.)

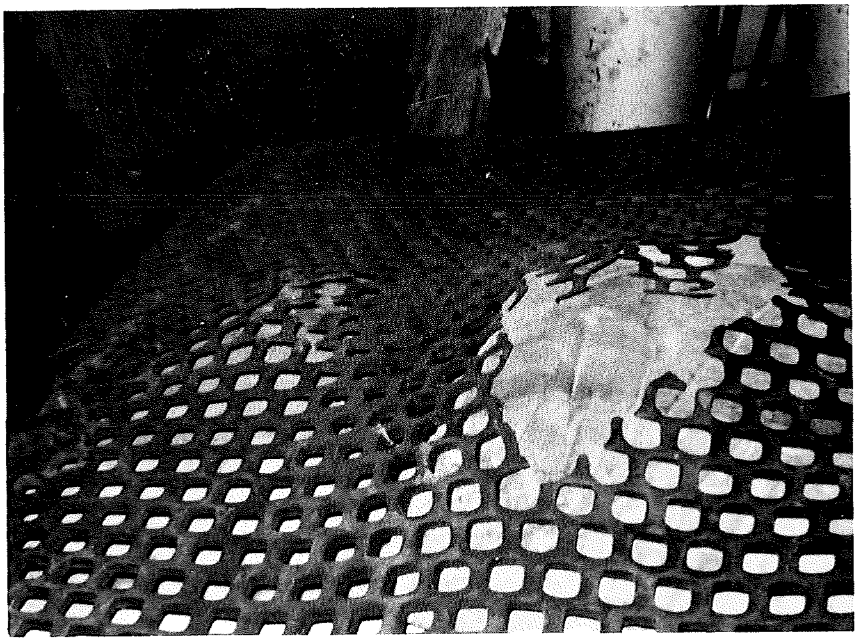

FIG. A.6. TORN RUBBER DECK FROM INFEED USE OF RAW COAL SCREEN: MEADOW RIVER. (REMOVED AFTER ABOUT 10 MONTHS' USE.)

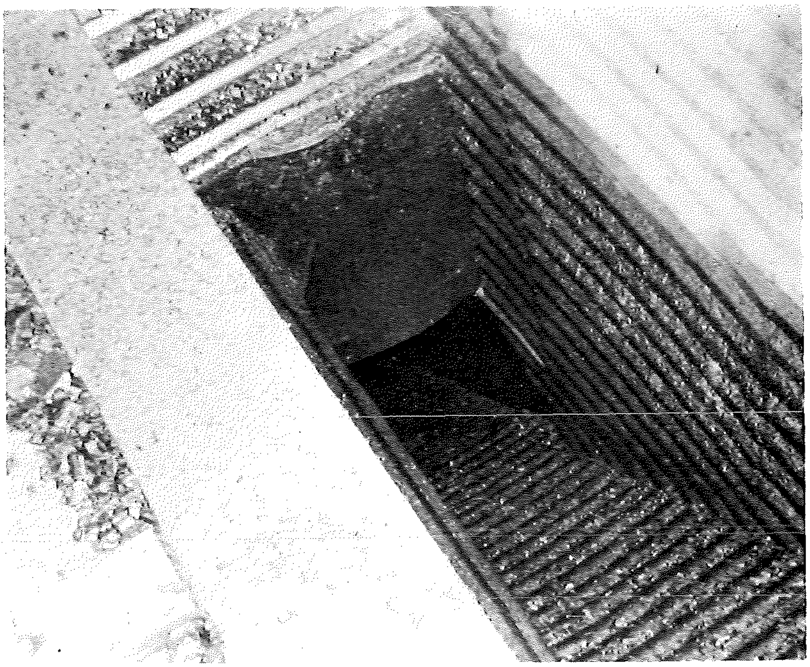

FIG. A.7. REFUSE DEWATERING SCREEN DISCHARGE CHUTE LINED WITH PROFILE RUBBER: MEADOW RIVER. (NOTE MINOR ROUNDING OF RUBBER EDGES AFTER ONE YEAR'S USE.)

FIG. A.8. REFUSE DEWATERING SCREEN DISCHARGE CHUTE LINED WITH PROFILE RUBBER: MEADOW RIVER. (NOTE ROUNDING OF RUBBER AFTER ONE YEAR'S USE.)

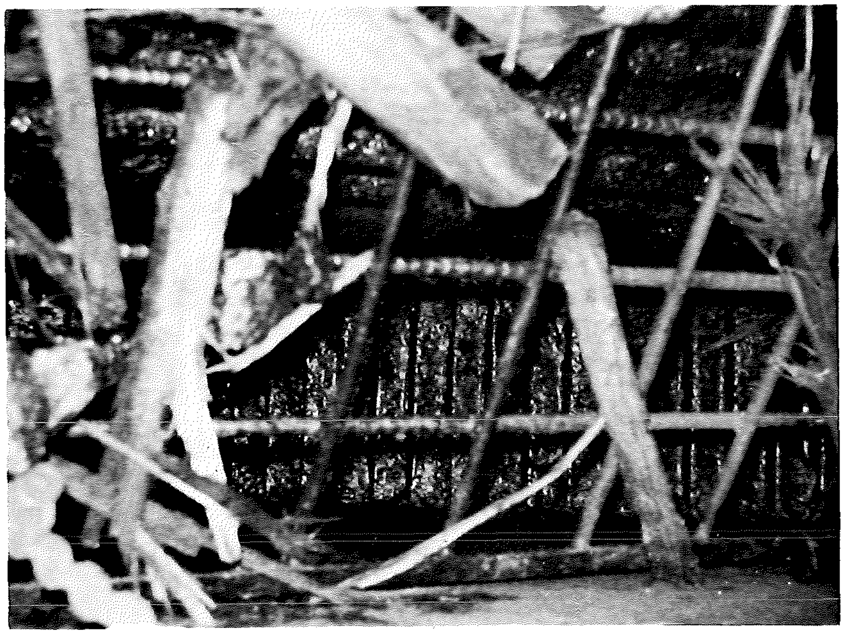

FIG. A.9. CLEAN COAL DEWATERING SCREEN DISCHARGE CHUTE, LINED WITH PROFILE RUBBER: MEADOW RIVER.

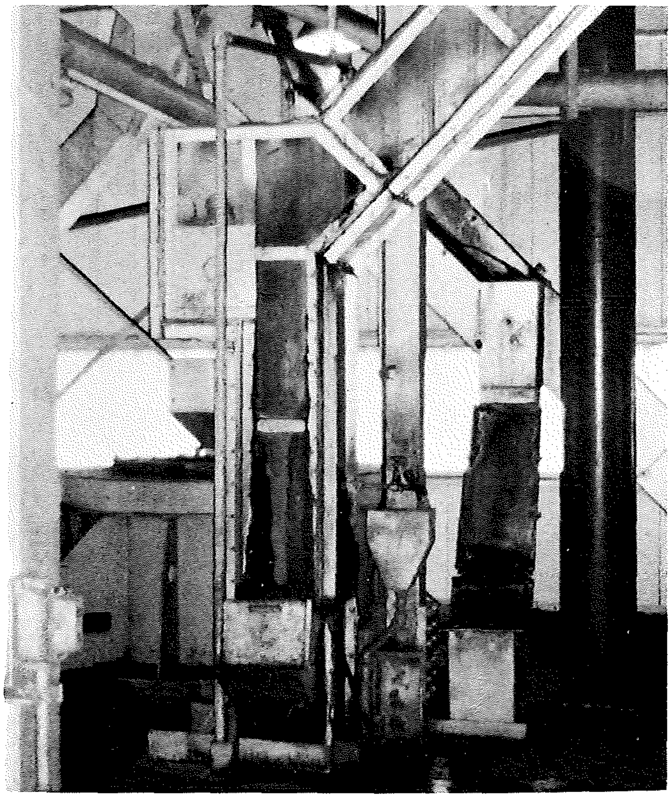

FIG. A.10. MAIN REFUSE CHUTE WITH RUBBER SIDEWALLS AND BOTTOMS: MEADOW RIVER.

B. Moss No. 3, Pittston Coal Company, Lebanon, Virginia*

This plant processes about 18,000 tons per day, with 48% of the material handled being refuse. The plant consists of four individual processing circuits, each with two raw coal prewet screens, two chutes to a primary heavy media bath, and one refuse dewatering screen. Thus, the flow across each raw coal screen amounts to about 2250 tons per day. About 60% of this flow is 1/4 x 0 in. and is sifted out; about 48% of the remainder (900 tons per day) is refuse and winds up on the final refuse screen for the circuit.

Resilient chute and screen treatments have been in use at several locations. Because of a plant shut-down, most of these had been removed; thus, only the limited noise data (indicated in Figs. B1 and B2) could be obtained.

B.1 Screens

Four 3/4-in. thick Trelleborg decks had been installed on each dewatering vibrator (see Fig. B3), with only one steel brace down the center of each screen. The decks had a slight crown when they were installed, but some sag was noticeable (beginning at the infeed ends) within three or four weeks' use. This sag slowed the flow somewhat. As time progressed, the sag increased, causing more material to remain on the decks and producing increasing up-and-down motion that led to the decks "beating themselves to death".

The aforementioned sagging and material accumulation resulted in failures of the airmounts supporting the screens. These airmounts carried excessive loads; they were compressed more than their design allowed, so that the associated radial expansion caused the bellows to rub against the structure and eventually

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*Results of interviews with plant personnel during visits to plants in April 1976.

to tear. This airmount problem was overcome by replacing these mounts with springs. A single-coil spring mounting was selected, because of prior experience indicating that the inner coil of concentric dual-coil systems has a tendency to break and interfere with the outer coil.

The original Trelleborg decks had no provision for increasing the tension as the decks stretched. However, the replacement decks which are about to be installed will have such provisions; it is expected that this will increase the life of these decks. In addition, the new decks will have two brace bars running down the length of the screen, instead of the single one running down the center of the previous installations.

As the original rubber decks wore out, they were replaced with steel decks. Prior to the June-July 1976 planned shut-down, only one rubber deck remained on the raw coal prewet screens. Comparison of noise measurements made near the steel decks and the remaining rubber decks (Fig. B1) shows the noise near the rubber deck to be 1 to 3 dBA lower than that near the steel deck. (The steel decks are 3/8 in. thick plates with 1 in. holes.)

Installation of rubber decks is no more complex than that of steel decks. However, it was found that rubber decks can be damaged seriously if a brace loosens and vibrates against the rubber. Thus, greater care is required for installation of rubber decks.

The materials cost for four Trelleborg decks was about $4200 (including side clamps and center bars); this is more than twice the approximately $2000 that the original steel decks had cost.

B.2 Chutes

The eight chutes from the prewet screens and the four chutes from the refuse screens were lined with flat Trelleborg rubber on the slopes and with profiled rubber in the impact locations; see Fig. B4. Some wear was evident, but all rubber material seemed quite serviceable. Moss No. 3 had no unusual problems with plugged up chutes (lined or unlined), probably because all chutes were made as large as possible to begin with. Also, care was taken to have no butt seams running across the direction of flow.

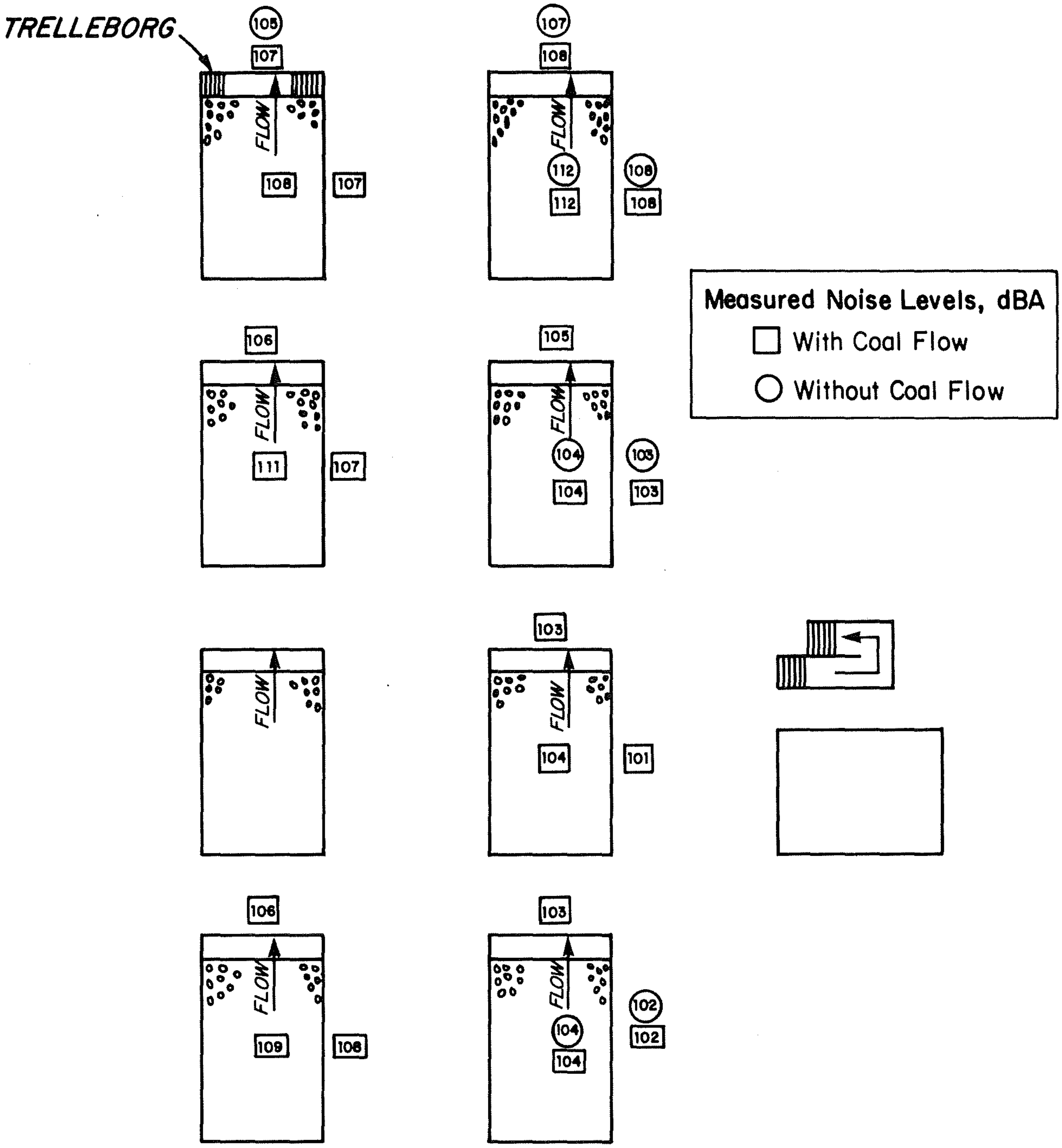

FIG. B.1. RAW COAL PREWET SCREENS (8 ft x 16 ft): MOSS NO. 3.

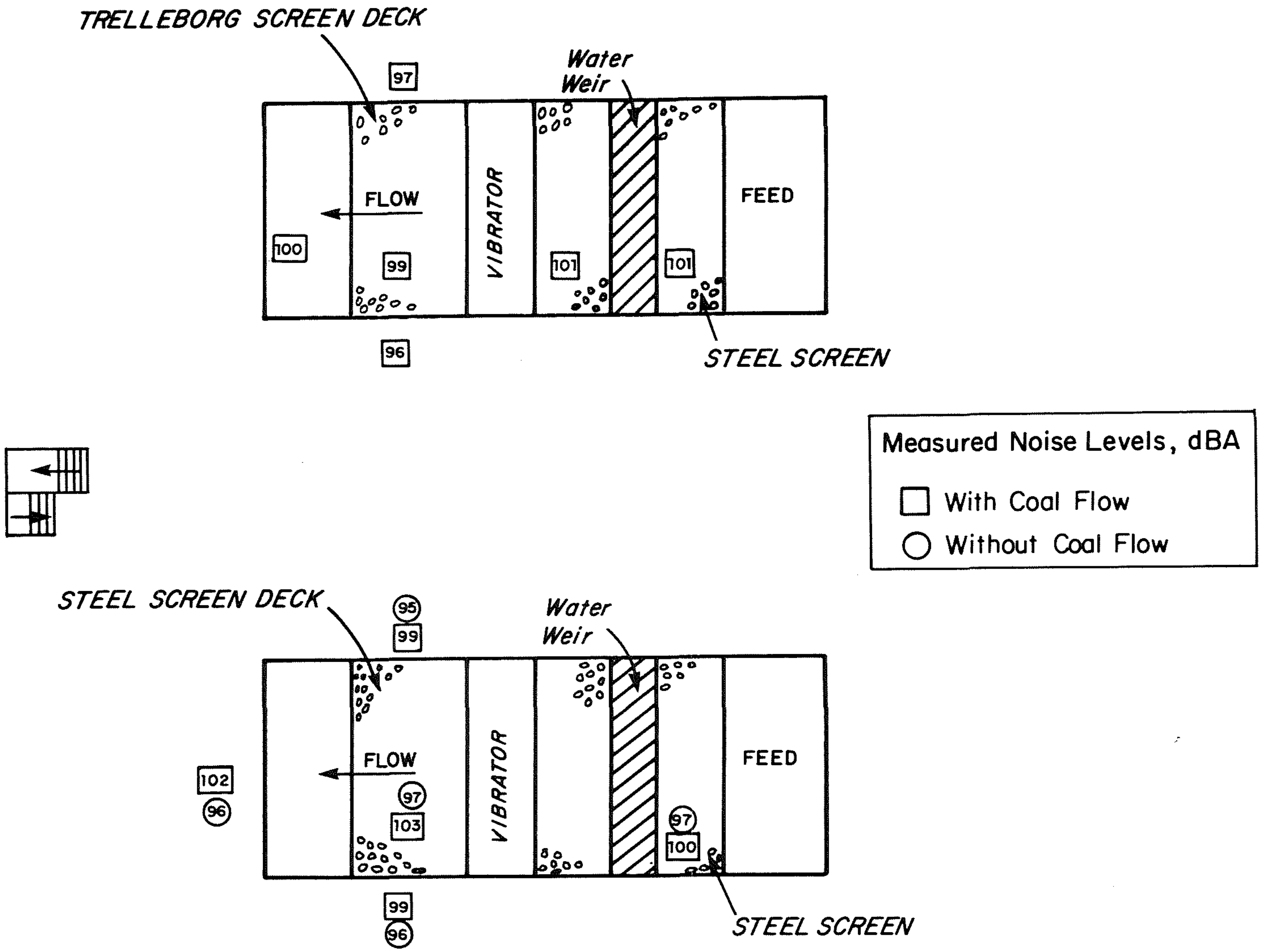

FIG. B.2. FINAL REFUSE SCREENS: MOSS NO. 3.

FIG. B.3. RESILIENT DECK AT DISCHARGE END OF "B" REFUSE DEWATERING SCREEN: MOSS NO. 3.

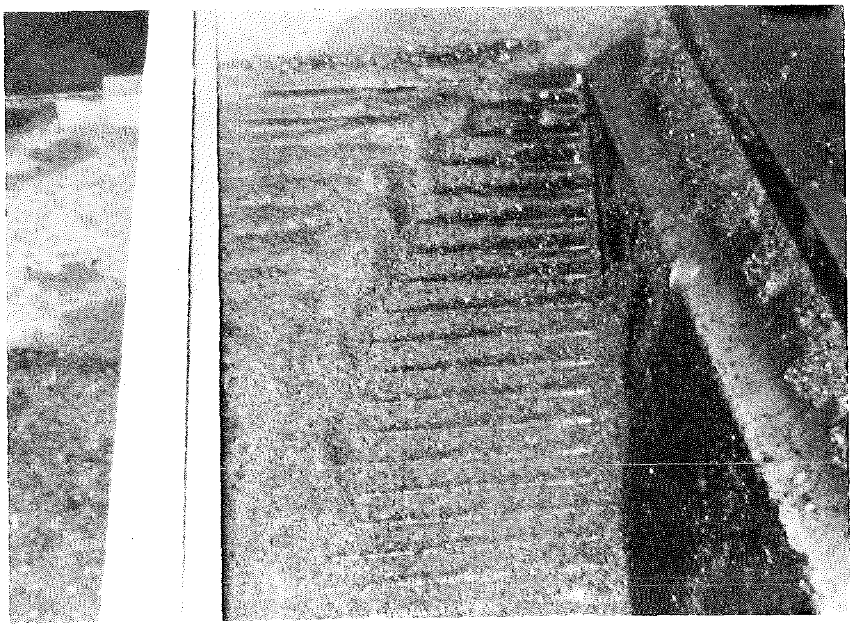

FIG. B.4. PROFILE RUBBER AT IMPACT LOCATION IN CHUTE AT DISCHARGE OF A1 PREWET SCREEN: MOSS NO. 3. (NOTE SOME ROUNDINGS OF RUBBER PROFILE AFTER 1-1/2 YEARS' USE.)

C. Georgetown Preparation Plant, Hanna Coal Co., Cadiz, Ohio

This large plant, which is about 25 years old, processes roughly 1600 tons of raw coal per hour. It uses three distinct coal circuits employing different types of equipment. This plant presently is cooperating in an investigation in which the costs, productivity effects and noise reductions resulting from use of various noise reduction techniques applicable to coal preparation plants are to be evaluated. This investigation is still in progress; some preliminary findings are presented here.

C.1 Screens

Secondary Sizing Screens

Each of these screens handles about 1600 ton/hour of 1/4" x 7" raw coal. Two Hendrick "Rubber Clad" deck panels, measuring 95" x 40", with 1-1/4" diameter holes on staggered centers were installed on 22 January, 1976. These decks consist of 3/8" of 60 durometer rubber, bonded atop 3/16" perforated steel plate. At $21.50 per sq ft, these decks cost about 3.4 times as much as ordinary steel decks. Initial installation required about twice as much labor time as normal replacement of steel decks, because the support brackets had to be lowered to accomodate the greater thickness of the resilient decks. Subsequent replacement of resilient decks with similar ones is expected to require no more effort than replacement of steel decks with new steel decks.

After about seven months of use, there was observed along the leading edge of one of the decks some separation of the rubber from its steel backing and a small patch of rubber had been worn through to the steel. This deck was then reversed. As of December 1976, these resilient decks are still in service, but are beginning to show additional deterioration after about a year of use. Steel decks on these screens typically last between 12 and 15 months.

The rubber-clad decks were observed to blind about 10%. No noise reduction data are available at present.

On the #2 screen, a panel of a Trelleborg all-rubber deck was installed on 18 November, 1975. This deck was 3/4" thick, with a top surface of "Trellex 60" abrasion-resistant rubber bonded to a high-durometer rubber supporting layer, and with 1-1/4" diameter holes on staggered centers. This deck cost about $33 per square foot, or roughly 5.3 times as much as the steel deck it replaced.

Severe blinding (about 50%) occured, and the deck was removed on 31 November. The deck was reinstalled on 13 January, 1976, with a clamping system that was modified with the intent of reducing blinding. However, the blinding problem persisted and the deck was removed on 20 January. No noise reduction data was obtained.

Classifying Screens

Seven panels of Hendrick "Rubber Clad" screen decks, each measuring 95" x 48", were installed on December 9, 1976 in place of the original screen decks. The rubber and steel thicknesses of these panels were the same as those of the deck panels employed on the secondary sizing screens, but here the holes in the steel plate were 1-3/4" in diameter and were 1/4" larger than those in the rubber (in order to reduce the potential for blinding). As yet, there is no conclusive evidence on the effect of this configuration for blinding reduction, and it is still too early to judge the durability of this installation.

These deck panels cost $16.30 per square foot. Installation here presented the same initial problem as indicated for the above-mentioned sizing screens.

The noise measured at 1 ft above these resilient decks was 101 dBA, which is 8 dBA less than that measured at the same location above corresponding conventional steel decks.

Primary Scalping Screens

Four 60" x 48" panels of Hewitt-Robbins "Tuffguard" decks were installed in mid-July, 1976 on a primary screen that handles about 1650 tons of raw coal per hour. These panels are made of 3/16" steel, covered with 1/4" of polyurethane, and have 6" diameter holes.

These deck panels cost $32.50 per square foot, or about 2.3 times as much as the steel panels they replaced. Initial installation required about twice the usual labor (about 8 man-hours), because the support brackets had to be repositioned; subsequent replacement is expected to require no more effort than usual replacement of conventional steel panels.

After about three months' use, the rubber at the leading edges of many of the holes had begun to separate from the steel backing plate. The Tuffguard panels were removed in November 1976, because this separation interfered with coal flow. Conventional steel decks here typically last between 1-1/2 and 2 years.

Noise measurements made at 3 ft to the side of the screen indicated that the resiliently covered decks resulted in a noise reduction of about 3 dBA (from 94 to 91 dBA).

Ripl-Flo Screens

Seven panels of Hewitt-Robbins "Tuffguard" decks were installed in two different screens in mid-September, 1976. These panels measure 59" x 42" and 46" x 41", have the same steel and polyurethane thicknesses as indicated above, but have 1-1/8" hexagonal holes.

These resiliently covered panels cost $26.40 per square foot, which is about 3.7 times as much as conventional steel decks. The installation effort here was the same as for steel decks; no adjustment of the holddown brackets was necessary.

As of December, 1976, the panels are still in good condition. They are deemed to do a good job of screening in general, although they blind 10 to 15% occasionally, when the flow is unevenly distributed over their surface.

At 6" above the screen decks, the noise measured with the Tuffguard screens is about 6 to 7 dBA less than that measured above similar all-steel screens.

C.2 Chutes

Profile Rubber

Thick panals of ribbed rubber (Trelleborg profile rubber) have been installed in several chutes throughout the plant, to cushion impacts of both large (+7") and small (-2") material against chute walls. Such panels are used on vertical or near-vertical surfaces, where there exists little potential for blocking of the material flow.

For 2.2" thick pads of type VP (which have steel channels molded into their smooth sides to facilitate installation), costs can run up to $50 or $75 per square foot - as compared to $2.70 per square foot for 1/2" mild steel plate. Pad installation effort varies substantially, depending on accessibility of the installation and the size of the pad; typical effort requirements range from one to two times the effort needed for a steel plate installation. It has been necessary to order the pads in the desired sizes, rather than cutting them to size at the site. In some cases, several smaller pieces were supplied instead of a single larger one, thus slightly complicating installation.

The preferred method of installation consists of pre-mounting a set of T-bolts into the existing chute wall, sliding the panels over the bolt heads, and then tightening the bolts.

Two 2.2" thick pads of Trelleborg profile rubber were installed at the infeed to a McLanahan rock crusher that handles +7" material, one on 4 September and one on 30 November 1976. Installation of each pad took two men three hours. One-half-inch thick steel plate lasts about two years in this location. It is still too early to judge the endurance of the rubber pads in this location, but the pads so far seem to be doing an excellent job.

Two Trelleborg profile rubber pads were installed on the vertical chute walls, at impact locations of refuse discharged from baskets of the refuse elevators at the McNally Baum jigs. One pad was installed on 18 October 1975, the other on 19 June 1976; as of November 1976 both were still serviceable, whereas 1/2" mild steel here lasts only about 5 months. Installation of each pad required 2 men for 1 shift, compared to 2 men for 1/2 shift for steel plate.

Abrasion-resistant Plastic

"Minaloy", a high molecular weight plastic intended for use as a long-wearing chute liner, was installed at several locations.

The #2 refuse chute for the McNally Baum jigs was lined with 1/2" of minaloy on 18 December, 1975. The material cost was about $9.00 per square foot, compared to $2.70 per square foot for 1/2" mild steel plate. Installation involved countersinking holes in the minaloy sheets, bolting them into the existing chute, and burning off the portions of the bolts protruding above the minaloy surface. For this 26 ft long, 1-1/4 ft wide chute, installation required two men for one shift - about twice as long as installation of steel plate. The minaloy was removed on 20 February, 1976, because it showed severe wear - possibly because this liner is useful only where the material slides, rather than bounces (and produces gouging). Steel here typically lasts six to eight months.

At other locations, where the material is relatively fine and where only sliding occurs, the minaloy appears to be performing better, but it is too early for definitive evaluation.

Ceramic Chute Liner

"Durafax" chute liner consists of 1/2" thick tiles, 4-1/2" square, of dense sintered alumina, which typically are welded to the existing steel chute via a central hole, by a metal gromet system. (The hole can then be sealed by a ceramic plug.)

Installation of such a liner on both jig refuse chutes required two men for 1-1/2 shifts - about three times as long as steel plate replacement. The liner itself cost about $10 per square foot, compared to $2.70 per square foot of 1/2" thick mild steel. Tiles installed on 21 February 1976 were still in good condition after ten months' use, although they did exhibit some minor cracks. Steel liners here normally require replacement after 6 to 8 months.