

## A REDUCED-NOISE AUGER MINER CUTTING HEAD

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### ABSTRACT

After extensive laboratory and in-mine tests, a cost-effective, mineworthy, reduced-noise auger miner cutting head was designed, fabricated, and field tested by Wyle Laboratories, under Bureau of Mines contract H0188065. Compared with standard auger cutting heads, the new heads reduced noise by 10 dBA at the

jacksetter's position and 6 dBA at the operator's position. The reduced-noise heads were able to cut and load coal as effectively as the standard heads and are now being used successfully in several underground mines. Mine shops can easily modify the standard auger cutting heads to produce the reduced-noise design.

### INTRODUCTION

Auger-type continuous miners are designed to extract coal from thin seams, approximately 26 to 50 in. in height. Figure 1 shows one model of auger miner, the Fairchild (Wilcox) Mark 21.<sup>3</sup> The two rotating augers at the front of the miner cut the coal and move it to the chain conveyor at the center of the machine. The conveyor carries the coal to the rear of the machine and dumps it onto a bridge conveyor system. The bridge conveyor connects with a panel conveyor (panline), which removes the coal from the face area.

Figure 2 describes the cutting pattern of the auger-type continuous miner. Note in figure 2 that the "anchor jack" is

placed very close to the face before each arc-shaped cut is made. On the Mark 21 miner in figure 1, the hydraulic anchor jacks are emplaced remotely by the machine operator. However, on the older Mark 20 auger miner shown in figure 2, the anchor jacks are simple mechanical posts, emplaced manually by workers called jacksetters. In addition, both models of auger miners require the presence of timbermen and/or cleanup personnel in the immediate face area. Because of their close proximity to the cutting heads, the jacksetters, timbermen, and cleanup personnel on auger mining sections are exposed to more noise and dust than almost all other workers in underground coal mines.

### APPROACH TO AUGER MINER NOISE CONTROL

Noise levels in a typical auger mining section during coal cutting are approximately 106 to 108 dBA at the jacksetter's position and 102 dBA at the operator's position.<sup>4</sup> To comply with Federal noise

regulations, operating time per shift would have to be limited to less than 45 min for the jacksetter and about 1-1/2 h for the operator. For this reason, MSHA and the Bureau of Mines have investigated ways to reduce the noise associated with auger mining systems.

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<sup>3</sup>Reference to specific products does not imply endorsement by the Bureau of Mines.

<sup>4</sup>Bobick, T. G., and D. A. Giardino. Noise Environment of the Underground Coal Mines. MESA IR 1034, 1976, 26 pp.

The three major noise sources on standard auger miners are the cutting heads, the chain conveyor, and the hydraulic motors, in decreasing order of importance. The cutting process is by far the dominant noise source at the jacksetter's position; cutting noise is approximately equal to the sum of conveyor noise and

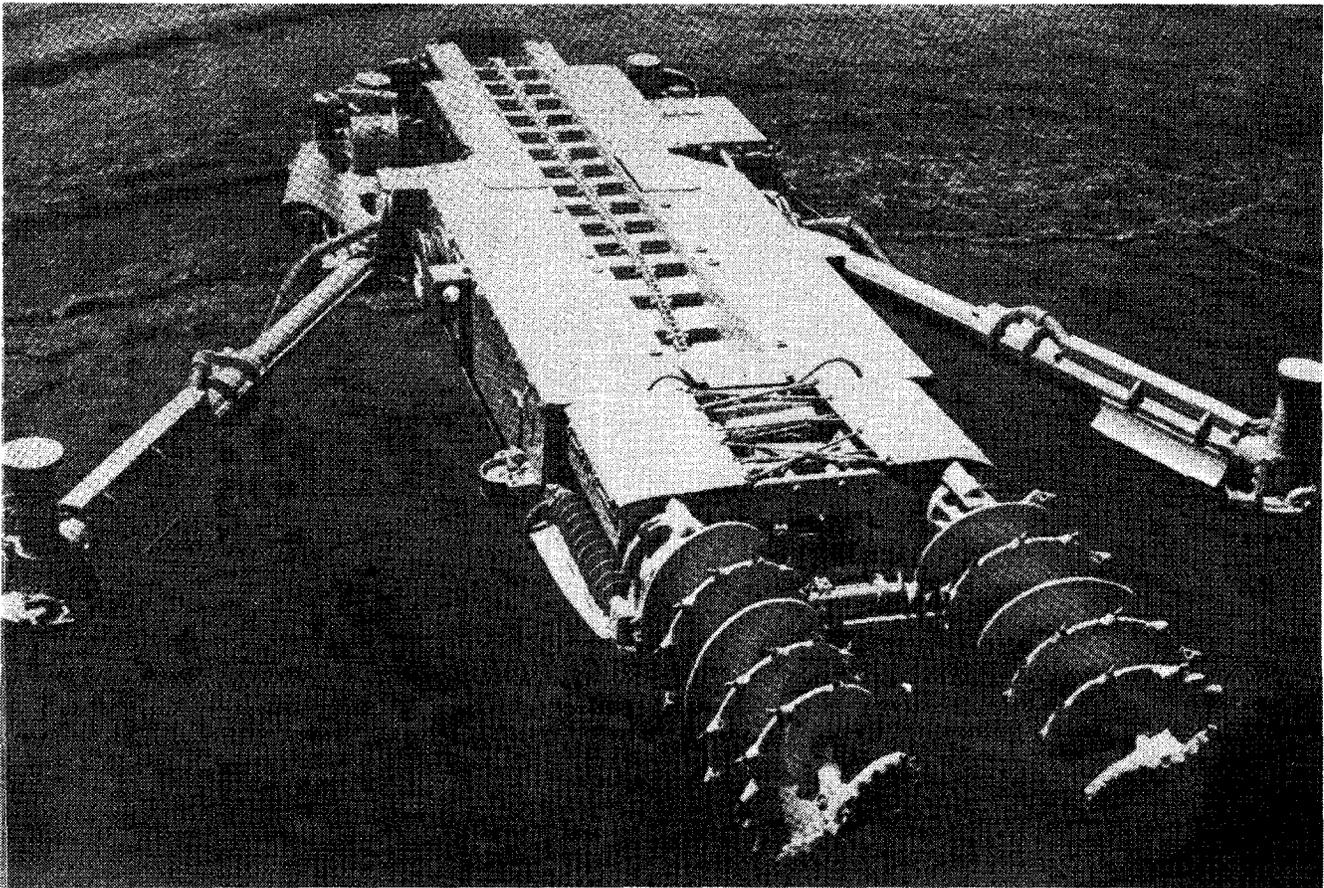
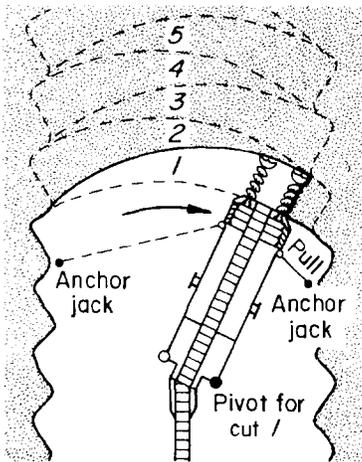
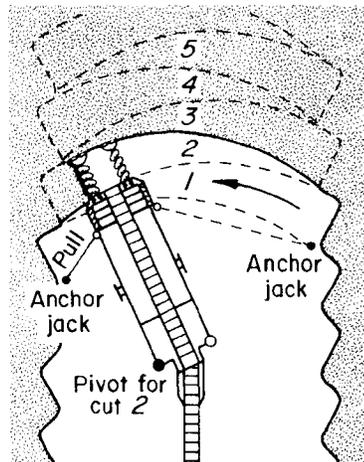


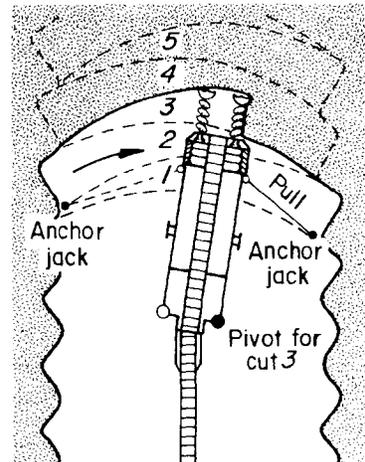
FIGURE 1. - Fairchild (Wilcox) Mark 21 auger miner.



Miner pivots on extended right pivot jack as it swings to right making cut 1. Retracted left pivot jack swings forward toward cut 2 pivot point.



Pivoting on extended left pivot jack, miner swings to left through cut 2. Retracted right pivot jack advances toward cut 3 pivot point.



Again pivoting on extended right pivot jack, miner swings right, making cut 3. Retracted left pivot jack moves ahead toward cut 4 pivot point.

FIGURE 2. - Cutting sequence of auger-type continuous miners.

motor noise at the machine operator's position. By installing noise control treatments on the chain conveyor and motors of a Mark 20 auger miner, MSHA was able to reduce the noise level at the operator's position by 5 dBA (from 102 to 97 dBA).<sup>5</sup> Because cutting head noise was not addressed in this study, the Bureau contracted (H0188065) with Wyle Laboratories for development of a reduced-noise auger miner cutting head. This paper summarizes the research conducted under contract H0188065.<sup>6</sup>

Four major steps were involved in the development of the reduced-noise auger cutting head: (1) defining the forces that excite the cutting head (i.e., coal-cutting forces); (2) defining the vibrational response characteristics of the standard head; (3) developing new cutting head designs based on steps 1 and 2; and (4) building several new cutting heads and testing them in an underground coal mine to verify their noise-reducing capabilities and overall operational performance compared to standard auger cutting heads.

#### CUTTING HEAD EXCITATION (COAL CUTTING FORCES)

Basic research in coal-cutting mechanics<sup>7</sup> showed that coal (and rock) resists the advance of a cutting bit in a manner analogous to a spring. The cutting force of the bit increases until the tensile stress in the coal initiates a localized brittle fracture. This fracture propagates out from the point of force application for a small distance. The bit continues to advance through fractured coal, meeting relatively little resistance until it again contacts unfractured coal, when the process is repeated.

Figure 3 is a graph of coal cutting force versus time; it clearly shows the impulsive nature of the coal cutting process. Note that the initial impact force of the bit against the coal is no higher nor longer lasting than the subsequent fracture events. Extensive laboratory experiments showed that both the stress required to initiate fracture and the characteristic distance of fracture propagation are relatively independent of

cutting bit velocity. Thus, the peak force that initiates coal fracture and the total number of fracture events that occur in a given length of cut are statistical constants for a given type of coal, depth of cut, and bit configuration.

Figure 4 is a plot of cutting force (power spectral density) versus frequency, taken from the force-time history of figure 3. Note that the cutting force is relatively flat until the "cutoff frequency," after which it declines with frequency at a rate that is inversely proportional to the square of the frequency. The cutoff frequency is primarily a function of the coal type and the cutting bit velocity--the faster the cut, the higher the cutoff frequency. The standard auger miner produced a cutoff frequency of around 100 to 200 Hz; this was an important factor affecting the design of the reduced-noise cutting head.

<sup>5</sup>Giardino, D. A., T. G. Bobick, and L. C. Marraccini. Noise Control of an Underground Continuous Miner, Auger-Type. MESA IR 1056, 1977, 57 pp.

<sup>6</sup>Ongoing BuMines contract; for inf. contact W. W. Aljoe, TPO, BuMines, Pittsburgh, PA.

<sup>7</sup>Becker, R. S., and G. R. Anderson. An Investigation of the Mechanics and Noise Associated With Coal Cutting. Wyle Lab. Rep. TM 81-13, Nov. 1981, 107 pp.; available upon request from M. R. Pettitt, Wyle Lab., Huntsville, AL.

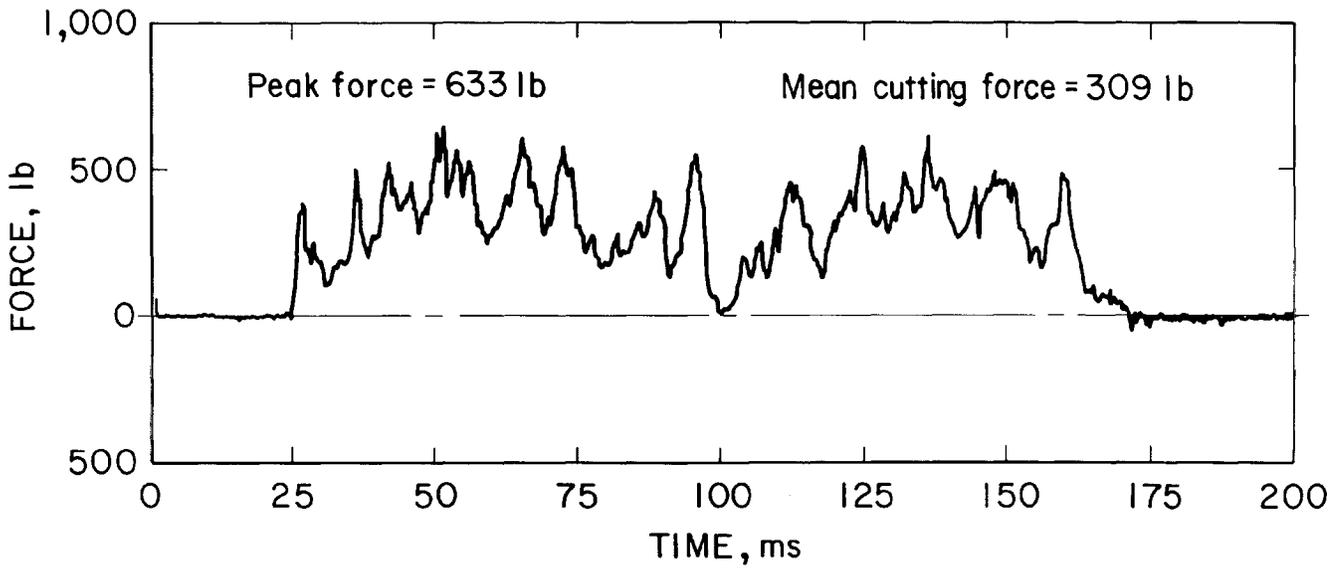


FIGURE 3. - Coal-cutting force versus time.

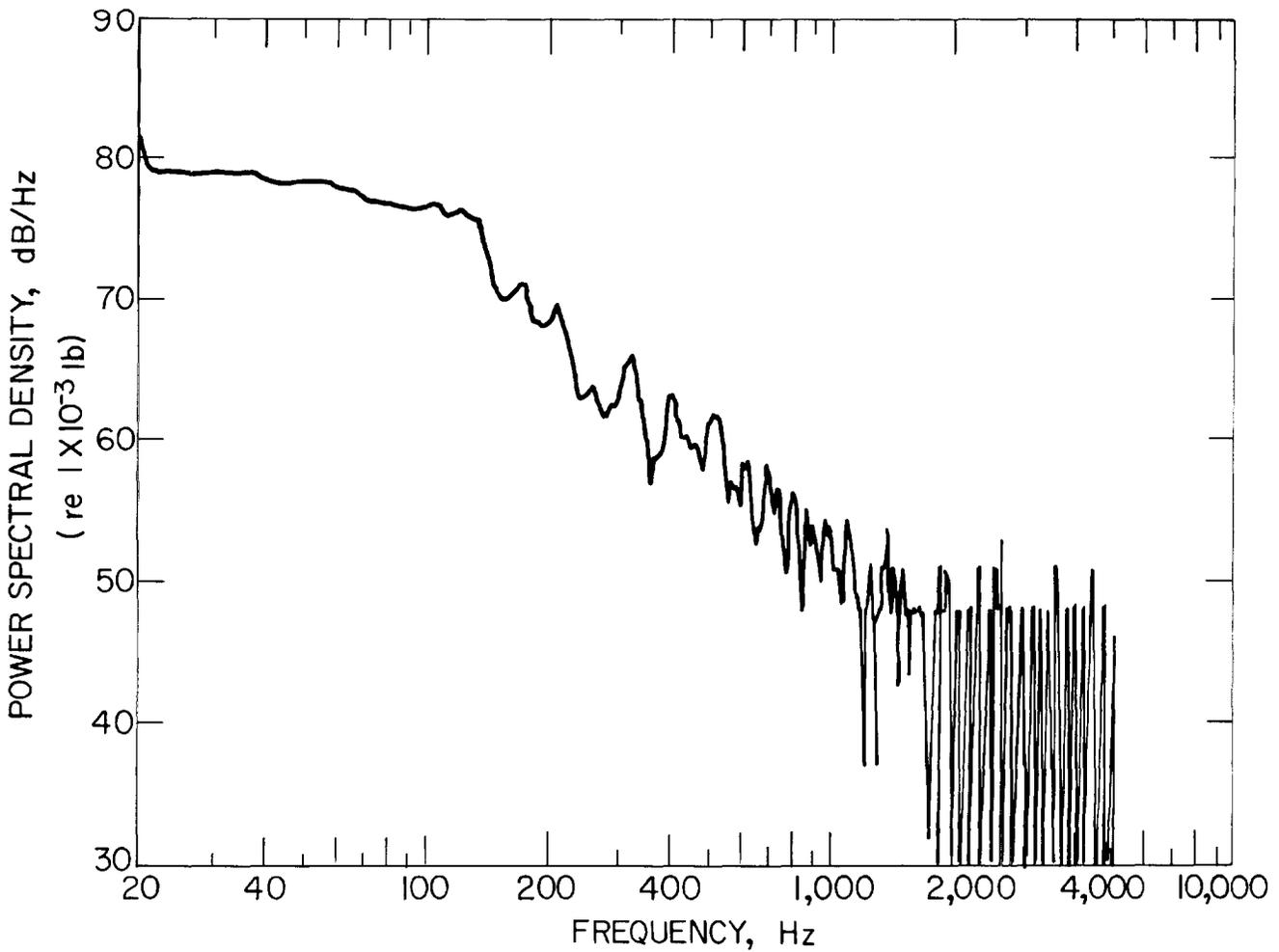


FIGURE 4. - Coal-cutting force (power spectral density) versus frequency.

CUTTING HEAD VIBRATION CHARACTERISTICS

The standard auger cutting head (fig. 5) consists of three major structural elements--a cylindrical core surrounded by two spiral, cantilevered plates called helixes. (The "head casting" at the front of the auger contains both a cylindrical core portion and two cantilevered helix portions.) When a simulated cutting force was applied to the cutting bits, it was found that the vibrational response of the helixes was much greater than the response of the core. Therefore, control of helix vibration was identified as the key to controlling cutting head noise.

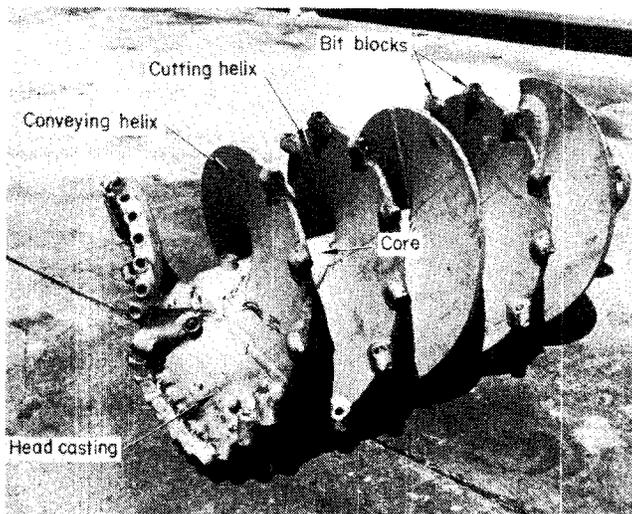


FIGURE 5. - Standard auger miner cutting head.

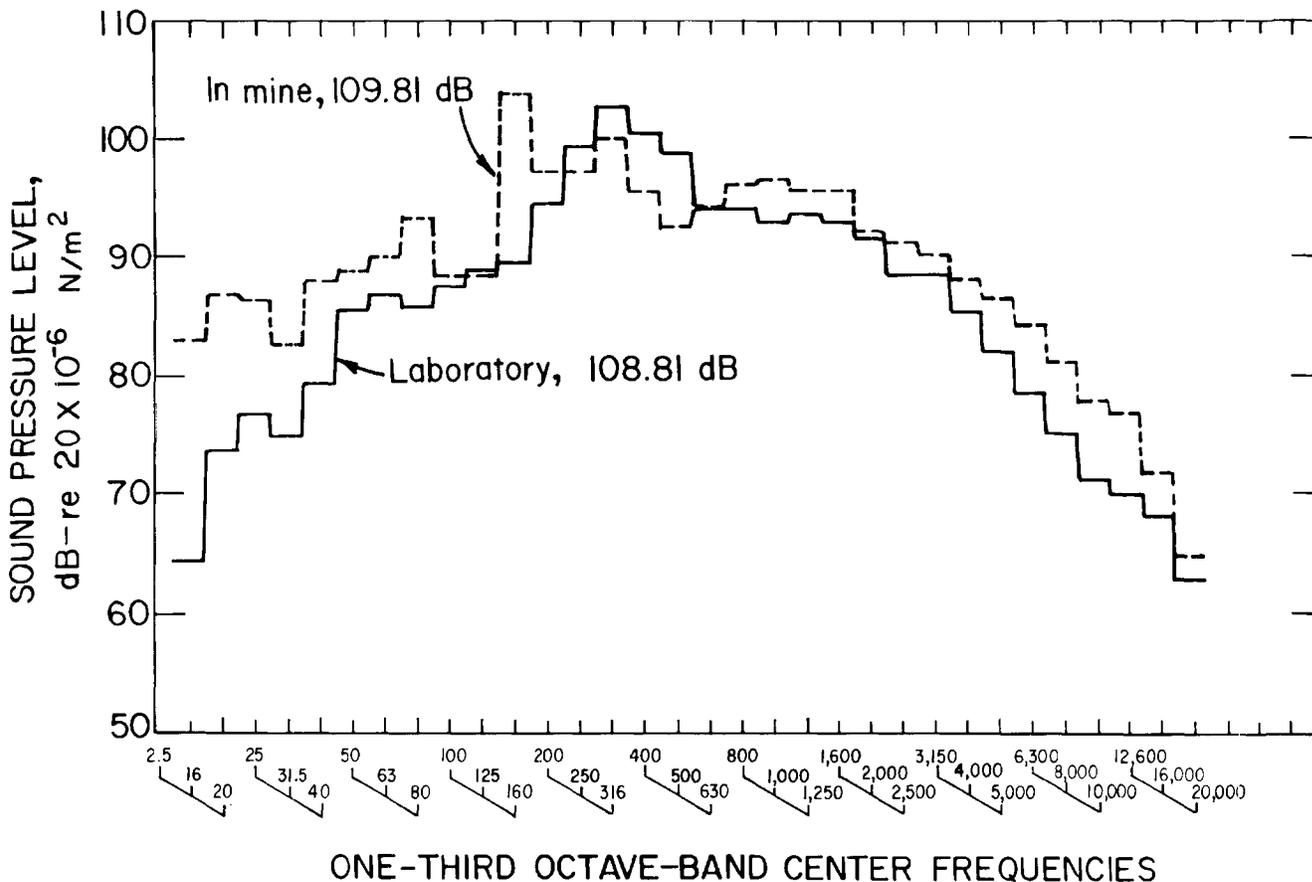


FIGURE 6. - Noise produced by standard auger cutting head.

vibrational response to coal-cutting excitation forces. The first natural vibration frequency of the standard helix was found to be about 200 Hz. Below this frequency, mass and stiffness of the helix determine its vibrational response; above 200 Hz, the amount of damping at its higher "resonant" vibration frequencies controls its ability to vibrate.

Radiation efficiency is a measure of a structure's ability to convert vibration into airborne noise. Laboratory analysis of the vibration of the auger helix showed that radiation efficiency

increased with increasing frequency; below 300 Hz the energy transfer was very inefficient. Although the coal-cutting forces exciting the auger were predominantly low frequency (fig. 4), significant noise was produced at higher frequencies because of the resonant vibration modes of the helix and the greater radiation efficiency. A plot of noise versus frequency obtained during laboratory and in-mine cutting tests (fig. 6) showed that the standard auger cutting head produced both low- and high-frequency noise.

#### DESIGN OF REDUCED-NOISE AUGERS

The design of the reduced-noise augers was governed by the need to reduce their vibrational response to coal cutting forces. This was accomplished in two ways: (1) increasing the first natural frequency of the helix; and (2) increasing the amount of damping at the helix resonant frequencies. Because the coal cutting forces were predominantly low frequency (see figure 4), they would only weakly excite a helix with a high first natural frequency. In addition, such a helix would also have fewer resonant frequencies in the excitation range. The simplest way to increase the first natural frequency of the helix was to make it stiffer and heavier. Damping materials were then added to attenuate its vibration at its higher resonant frequencies.

Before a stiffening-and-damping treatment could be applied to the standard auger cutting head, the bitless ("conveying") helix shown in figure 5 had to be removed. Although laboratory tests showed that this helix did not vibrate as much as the bit-carrying ("cutting") helix, its removal reduced the auger's vibrating surface area by about one-half. Removal of the conveying helix also provided room on the auger and reduced its weight, facilitating the addition of the stiffening and damping treatment described below. Subsequent underground

tests showed that the "conveying" helix was not needed for effective loading and cleanup.

In order to reduce the vibration of the remaining helix, the original 6-1/2-in core diameter of the standard auger was enlarged. Then, a unique stiffening and damping treatment was applied to form a simple, aesthetically pleasing package. As shown in figure 7, a hollow helix was created by welding a series of "stiffener segments" (3/8-in-thick plates) to the

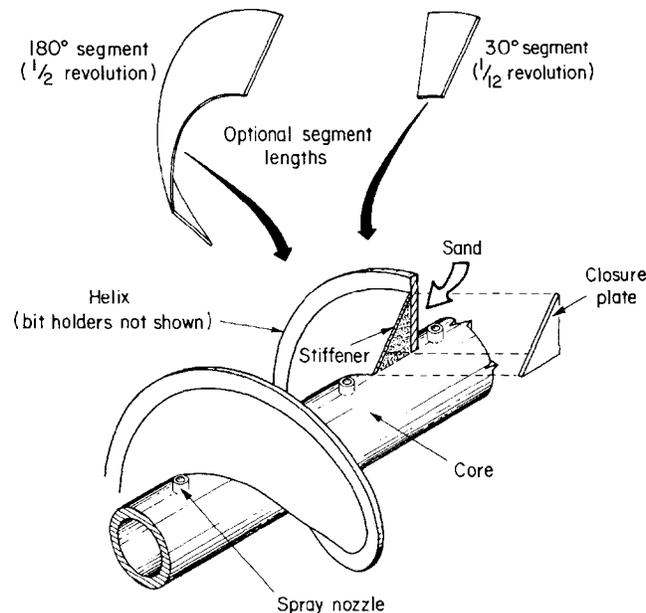


FIGURE 7. - Sand-filled auger fabrication technique.

core and helix, thereby forming a cavity of triangular cross section. The triangular cavity was then filled with sand and sealed. The stiffeners increased the first natural frequency of the helix, while the sand added mass and damping. Three separate sand cavities were needed to completely cover the auger cutting head; the largest of these was on the nonconveying side of the helix (fig. 8A). Because of space constraints, the two smaller sand cavities were on the conveying side of the helix (fig. 8B), but in-mine tests showed that they did not affect the coal-carrying capability of the auger.

As shown in table 1, two different versions of the reduced-noise auger were fabricated. The purpose of the "conservative" version (fig. 8) was to achieve a significant noise reduction while staying well within the normal conveying capacity of the standard auger. The purpose of the "aggressive" version (see table 1) was to achieve the largest noise reduction possible by reducing the conveying

TABLE 1. - Conservative versus aggressive reduced-noise auger designs

|                                       | Conservative | Aggressive |
|---------------------------------------|--------------|------------|
| Core diameter.....in..                | 9.5          | 14.0       |
| Stiffener angle (to helix).....deg..  | 30           | 45         |
| 1st natural helix frequency.....Hz..  | 800          | 1,200      |
| Frequency <sup>1</sup> .....pct..     | 400          | 600        |
| Damping treatment.....                | Sand         | Sand       |
| Damping increase <sup>1</sup> ..pct.. | 400          | 400        |

<sup>1</sup>Change from standard.

#### UNDERGROUND TESTS OF REDUCED-NOISE AUGERS

The operational performance--noise reduction, cutting and loading characteristics, and durability--of the two reduced-noise augers described in table 1 was evaluated by testing them in an underground coal mine for a 6-month period. The miners were initially very skeptical about the new auger designs, especially the cleanup capabilities of the aggressive (larger core) version. However, the

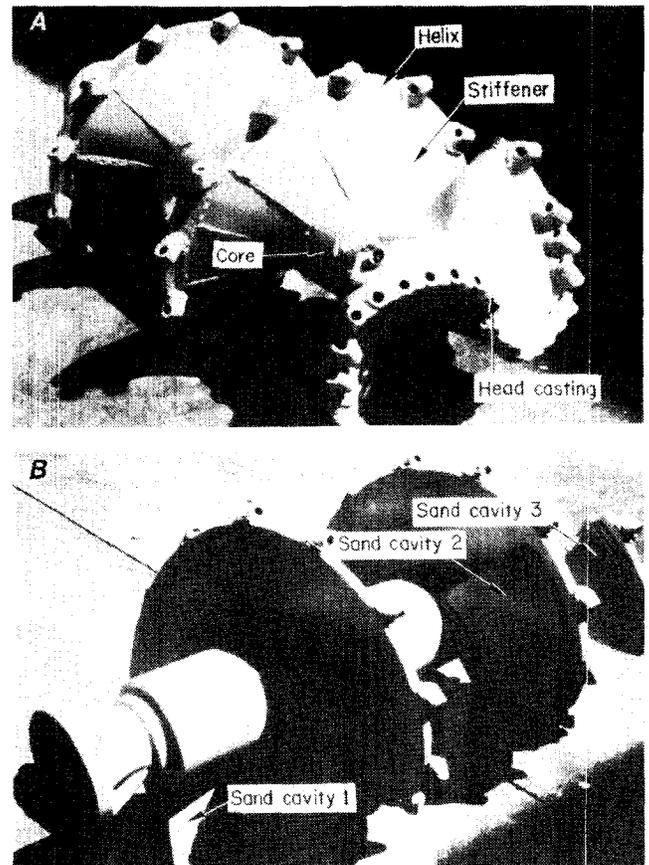


FIGURE 8. - Sand-filled auger, conservative version. A, Nonconveying side of helix; B, conveying side of helix.

capacity (helix height) to its lowest limit. The basic difference between the two versions was the auger core diameter; table 1 lists the other differences. Laboratory tests predicted that the reduced-noise augers would be capable of achieving noise reductions of 8 to 10 dBA.

miners were completely satisfied with the performance of both auger designs because they were almost identical to the standard augers in terms of cutting, loading, and cleanup.

More importantly, as shown in table 2, both auger designs resulted in significant noise reductions at both the jack-setter and the operator positions.

Because the jacksetter position was very close to the cutting heads, the initial (standard auger) noise level was higher (106 dBA) and the noise reduction was larger (8 to 10 dBA) than at the operator's position. Conveyor and motor noise played an important role in the initial noise level at the operator's position (96 dBA by themselves); therefore, the addition of the reduced-noise augers resulted in a lesser noise reduction (6 dBA) but virtually eliminated cutting noise as a contributor to overall operator noise. At the jacksetter's position, cutting noise was reduced to the point where its contribution was almost equivalent to the sum of the remaining noise sources on the miner.

#### CONCLUSIONS AND RECOMMENDATIONS

Although both reduced-noise auger designs resulted in substantial underground noise reductions, the conservative version was the design most readily accepted by mine operators. In practice, however, the best approach would be to install the helix-stiffening and sand-filling treatments without modifying the 6-1/2-in-diameter core of the standard auger. The major reasons for this recommendation are (1) the larger core does not increase helix stiffness nearly as much as the addition of the stiffener plates; and (2) fabrication of the large core is rather expensive and would be difficult to perform in a typical mine rebuild shop.

TABLE 2. - Noise reductions produced by sand-filled, reduced-noise augers in underground tests, decibels (A-weighted)

| Test condition               | Jacksetter  |           | Operator    |           |
|------------------------------|-------------|-----------|-------------|-----------|
|                              | Noise level | Reduction | Noise level | Reduction |
| Background <sup>1</sup> .... | 93          | Nap       | 96          | Nap       |
| Standard auger.              | 106         | Nap       | 102         | Nap       |
| Reduced-noise auger:         |             |           |             |           |
| Conservative.                | 97          | 9         | 96          | 6         |
| Aggressive...                | 96          | 10        | 96          | 6         |

Nap - Not applicable.

<sup>1</sup>All motors and conveyors operating; conveyor empty; cutting heads spinning in air.

Instructions for converting a standard, two-helix auger into a sand-filled, single-helix, reduced-noise auger are now available upon request from the Bureau of Mines and/or MSHA. Although the overall diameter of the augers in the experimental program was 28 in, the same procedure can be used to modify standard augers with diameters of 22 to 32 in. In the near future, the Bureau will publish a report containing these instructions in concise form, including all engineering drawings and data needed for modification. Additional information on the research program described in this paper is also available from the Bureau.

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