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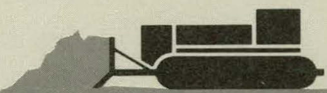
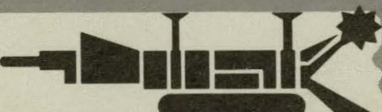


DESIGN, FABRICATION AND TESTING OF A LOW HEADROOM CONVEYOR TRANSFER CHUTE

Final Technical Report
Contractor—Foster-Miller Associates, Inc.

December 1980

Contract No. U.S.D.O.E. AC01-79ET-14256



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DESIGN, FABRICATION AND TESTING OF A LOW HEADROOM CONVEYOR TRANSFER CHUTE

Final Technical Report
as of
December 1980

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16. Abstract

This document contains the results of tests performed on eight one-sixth scale models of low headroom transfer chutes for underground belt conveyors. The models were evaluated using a methodology technique to select one chute for further full-scale testing in an underground mine. The study concludes that the slide chute should be tested in an underground 90-deg transfer point.

The report contains a state-of-the-art survey, a literature search, data from mine visits, test results, evaluation based on the methodology technique, and a set of guidelines for the design of low headroom transfer chutes. Also included are the preliminary designs of the slide and stone box chutes, scaled up from the designs used in the tests. Following the first phase of the program, the contract was terminated for the convenience of the government; therefore, the program did not progress to the Phase II full-scale chute fabrication or Phase III field testing.

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A special thanks is extended to Carbon Fuel of Chesapeake, WV and Mr. Joe Beam, Chief Industrial Engineer.

Following a visit to the underground operations at Carbon Fuel and the conclusion of our model chute test sequence, Carbon Fuel requested information on the best performing chute design. Mr. Beam supervised the fabrication and installation of the custom chute and has been instrumental in its successful application at a low headroom transfer point.

1.0 EXECUTIVE SUMMARY

1.1 Summary

The increased usage of belt conveyors in modern mines has provided higher levels of productivity than otherwise obtainable. It is generally recognized that most problems with belt conveyors occur at the loading and transfer points; it follows naturally, then, that for a high production operation, all belt conveyor transfer points must be designed, installed, and maintained with utmost care.

The U.S. Department of Energy (DOE) has determined that there is a need for a low headroom conveyor transfer chute. The use of such a chute would provide several benefits, noted below:

- The amount of roof required to be taken to provide sufficient vertical space for the transfer point is minimized. Benefits include less disruption to the normal production cycle and safer roof conditions.

- Less maintenance is required at the transfer. A good chute design produces less spillage, requires less adjustment, and operates satisfactorily under a wide range of material types and loading conditions.

- Performance is improved. Loads are centered, keeping the belts trained, and dust and noise generation is minimized, enhancing the work environment.

- Lower costs are incurred by the operator. The proper chute will wear out less frequently, will not damage the belt due to excessive impact of detraining tendencies, and will require less continual spillage maintenance. Of course, minimization of the boom hole will also permit more production hours.

This report describes the conceptual design efforts of Foster-Miller Associates, Inc. (FMA) to develop a low headroom conveyor transfer chute under DOE Contract No. DE-AC01-79ET-14256.

Testing was conducted on eight chute designs in a three conveyor system arranged to form a continuous loop (see Figure 1).

A 6-in. conveyor fed coal to an 8-in. conveyor with the belt-to-belt distance of 7 in. to model a 36 belt feeding a 48-in. belt with a belt-to-belt distance of 42 in. The 8-in. belt had 1/2-in. stripes painted down each side so that a 42-in. receiving belt could also be modeled.

The chutes were evaluated using a methodology technique which considered performance, cost, ease of fabrication, and maintainability in the mine.

Performance encompassed the ability of the chute to deposit the coal on the belt evenly and the tendency of the coal stream to detrain the belt. Considered also was the ability of the chute to handle large and small streams as well as wet and dry coal; the chutes were evaluated on their tendency to spill coal, be noisy, and cause wear.

1.2 Conclusions/Recommendations

Based on the model tests and the design methodology scoring, three chute designs have been ranked highest for use in a low headroom installation: the stone box, the deflector plate, and the "slide" chute; however, *from the standpoint of performance, the slide is the clear-cut preference.* Because the deflector is already in common usage in underground coal mines, the slide (see Figures 2 and 3) and stone box (see Figures 4 and 5) would be the

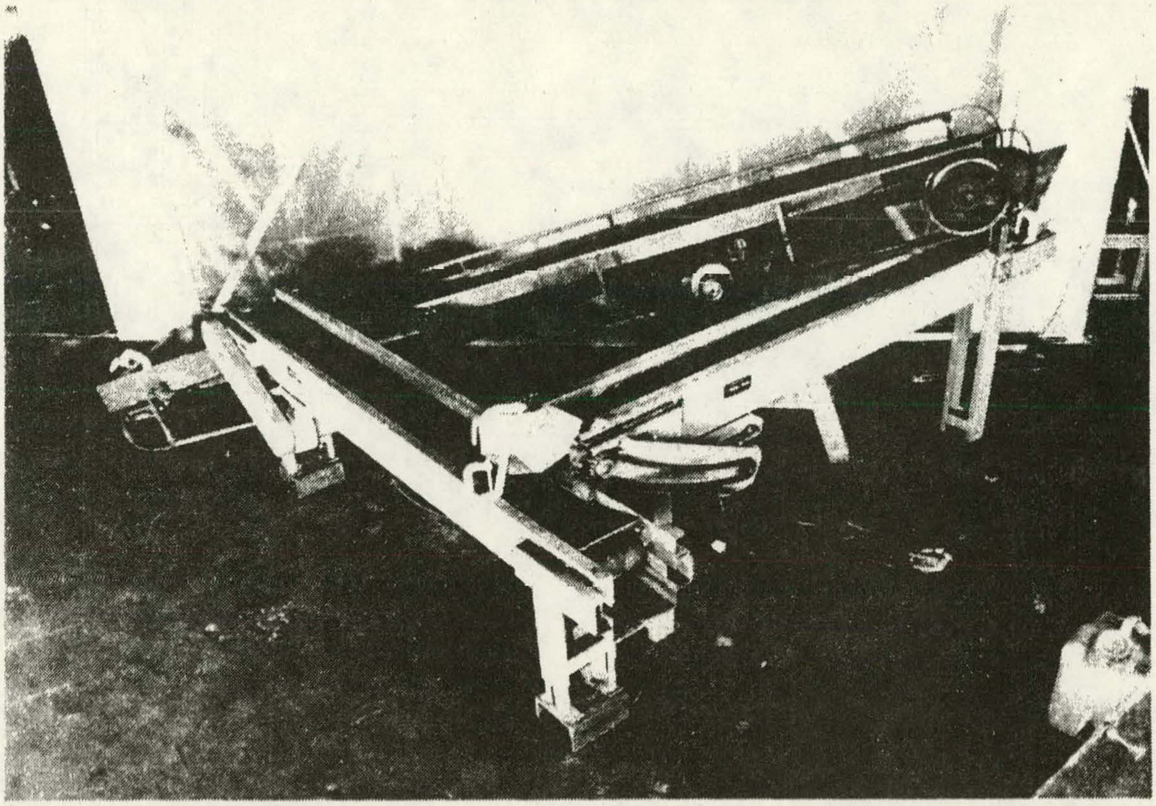

FIGURE 1. - Conveyor arrangement.

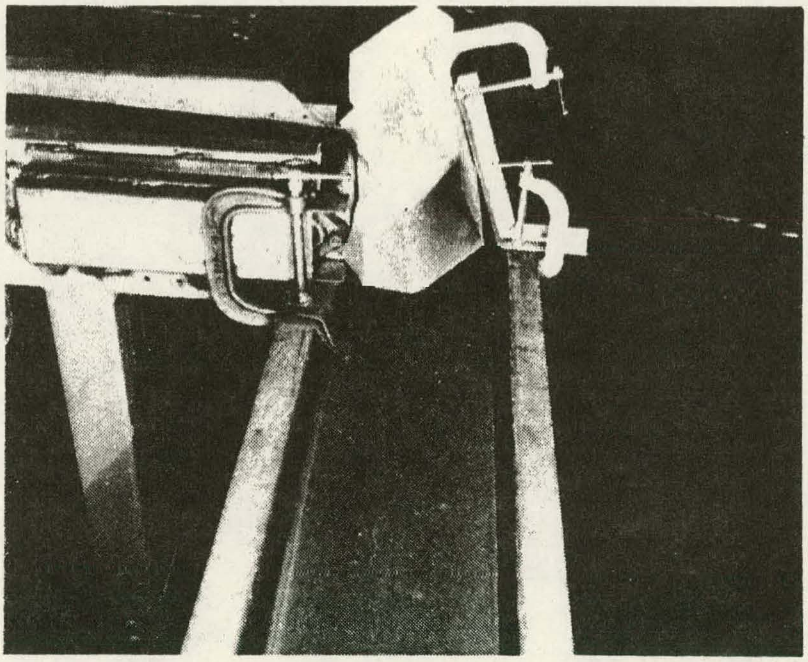

FIGURE 2. - Slide chute.

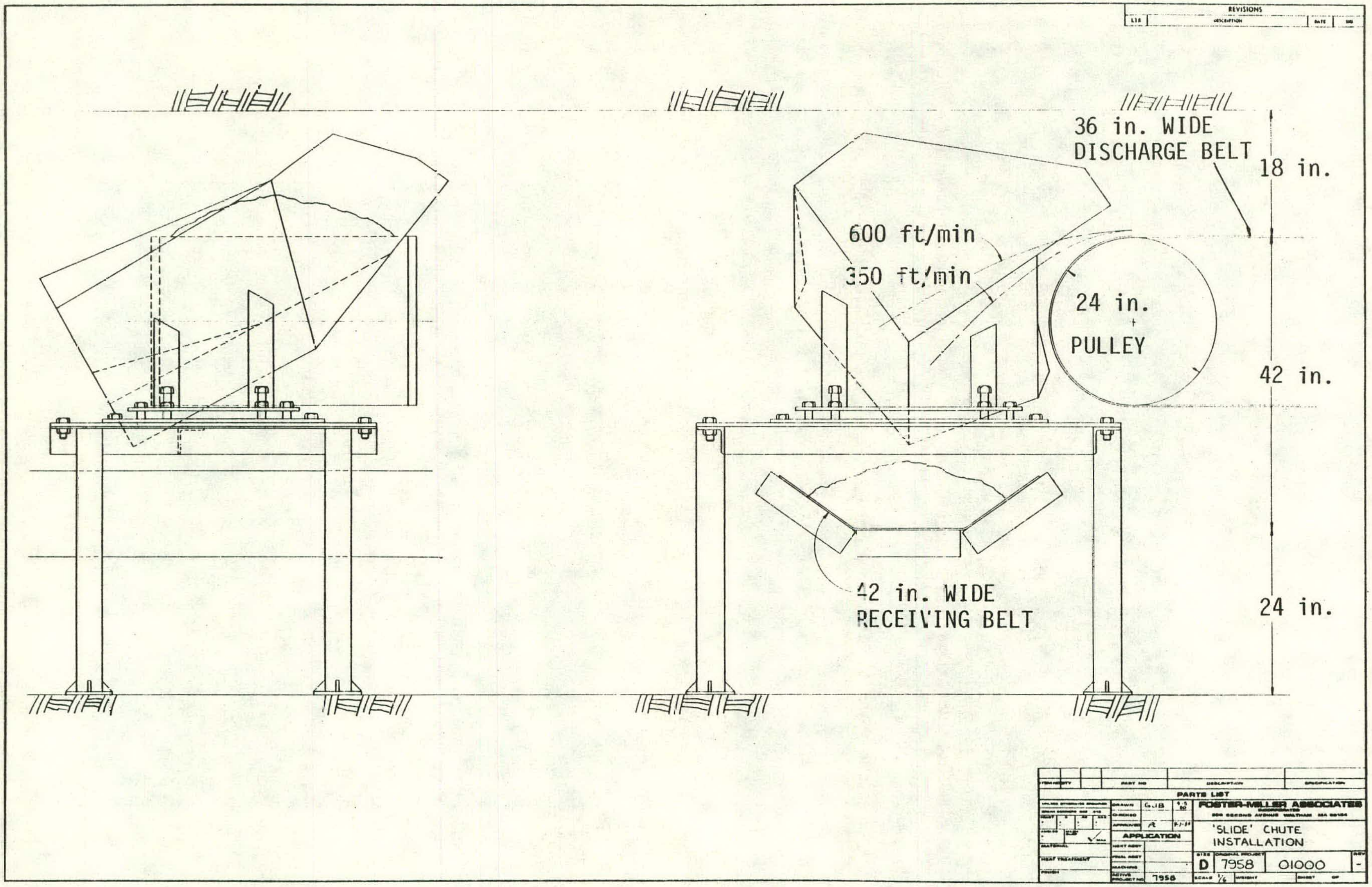

FIGURE 3. - Slide chute installation.

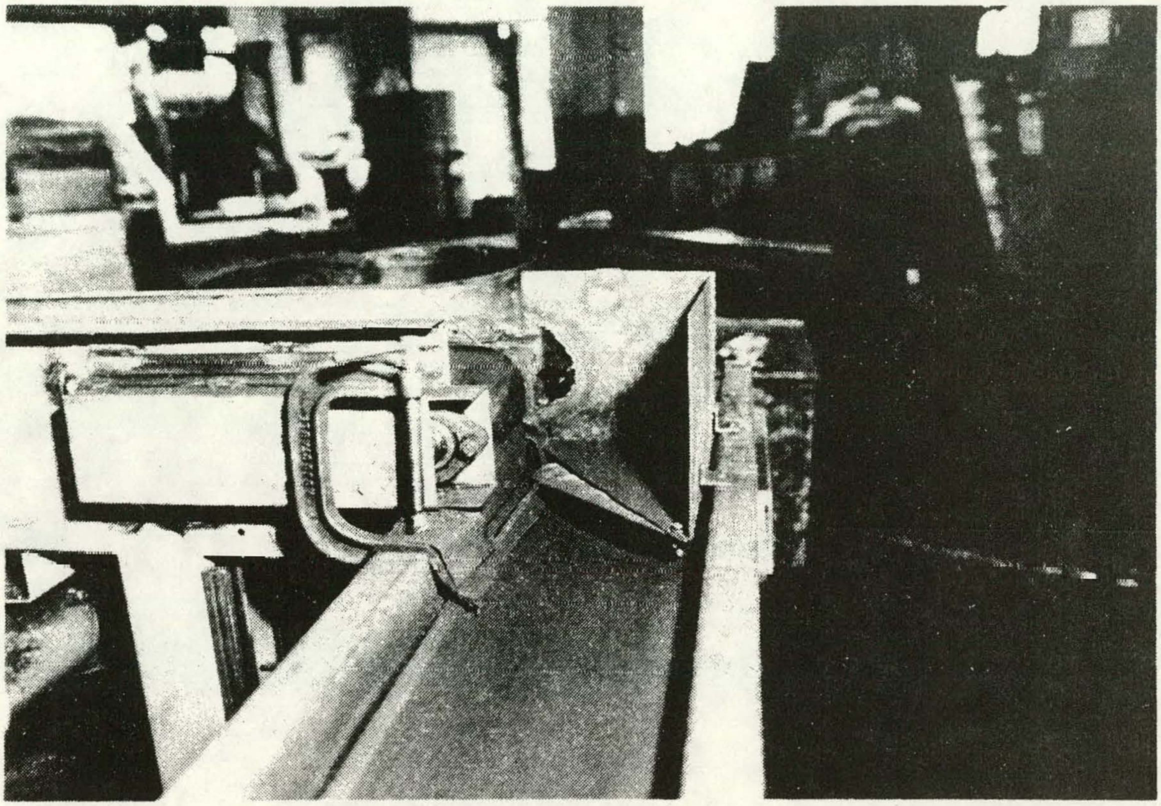

FIGURE 4. - Stone box - side view.

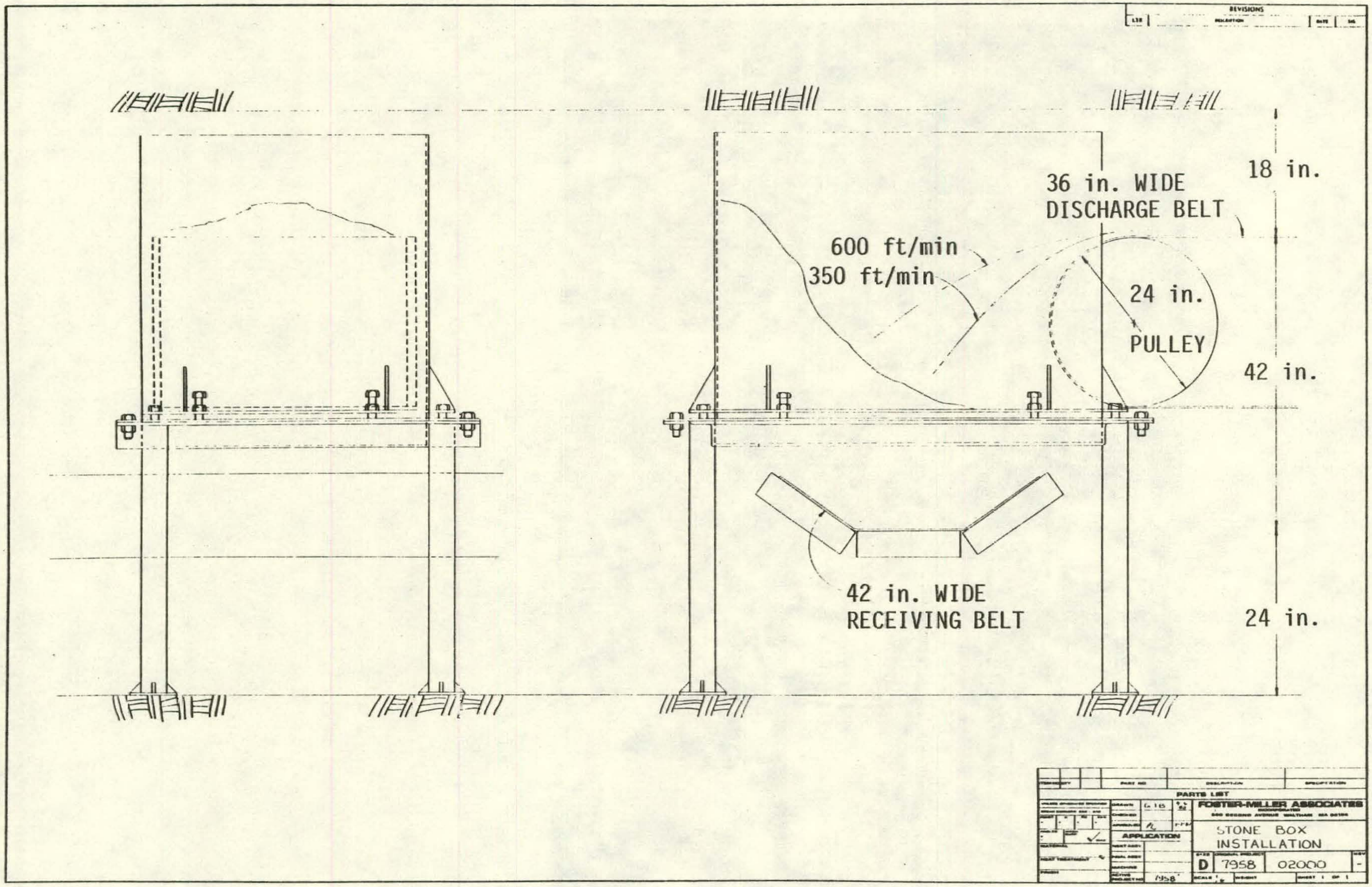

FIGURE 5. - Stone box installation.

designs worthy of further consideration. Due to the promise of far superior performance while obtaining the goal of low headroom, the slide design is the one recommended.

The slide chute is superior in its ability to center the coal on the receiving belt and to feed the coal in the direction of the receiving belt. It handles variation in load, velocity of flow, and moisture content very well. With proper alignment, the design of the chute provides for depositing the coal on the receiving belt centrally and in the direction of the belt for a wide variation of feed belt speeds, moisture content, and quantity of coal flowing so that the receiving belt does not tend to detrain.

2.0 STATE-OF-THE-ART SURVEY

A telephone survey was made of more than a dozen operators in the eastern United States to determine the present state of the art in transfer point technology. In general, there was interest in the low headroom design problem, which seems to be common to most mines. The information obtained is summarized in the following listing:

- Belt widths used range from 36 to 60 in. The most common transfer is a 36 in. section belt onto a 42-in. mainline belt; as more longwall faces come on stream, the belt sizes are being pushed upward to 48 and 54 in. mainline belts.

- Belt speeds range from 250 to 700 ft/min; the lower speeds correspond to low production, low headroom, or direct impingement conveyor systems.

- The installed belt-to-belt distance at transfer points varies from 24 to 72 in. with 48 in. typical. In general, the height of the installation increases in direct proportion to its complexity and the volume of material passing through the discharge.

- The amount of headroom considered acceptable at a transfer point varies at different mines, depending on the throughput and the required performance level. The amount of headroom (floor-to-roof) required for a transfer ranged from 48 to 84 to 120 in. at three typical mines.

- The most heavily loaded conveyor systems, the ones requiring chutes, are found handling longwall tonnages.

- The continuous miner sections tend to have a more uniform material consistency and even deposition across the belt width due to the normal inclusion of a feeder breaker ahead of the conveyor system. With little chance of blocky material on the belt, intermediate transfer points are constructed with adequate clearance between the chute and incoming material and then welded in place; no hinges are required.

- The two major problems at transfer points are material spillage and belt detraining. Spillage is a maintenance nuisance, whereas detraining can be catastrophic and very costly; depending on the frequency or magnitude of either problem, it normally proves to be the factor which justifies progressing to a more complex chute design. Spillage is a safety problem and can warrant an MSHA citation. Excessive buildup can jam idlers and damage belts. A detrained belt can cut up the edge of the belt, damage conveyor idlers, and cause spillage itself.

- Dust is a secondary problem, mainly because it has become customary to wet the material sufficiently to eliminate excessive dust. Water sprays are installed wherever necessary.

- Noise is not considered a problem because men work at transfer points only periodically.

- Chute wear is minimized through the use of abrasion resistant steel on sliding surfaces. Occasionally a permanent installation will justify stainless steel liners; one mine has settled on 310 stainless throughout their operations due to its superior polishing, antifriction characteristics.

- Intermediate transfer points, depositing onto a previously loaded belt, have more spillage problems and fewer training problems than a tail end transfer.

- Chute slope angles average 30 deg to the horizontal in line with the receiving belt centerline and 60 deg to the horizontal on chute surfaces sloping laterally toward the belt centerline.

- The operators feel that there is an advantage to minimizing the headroom requirement; total elimination is not required in order to justify a more complex design. In other words, there is a desire to save the production lost due to construction of boom holes.

3.0 LITERATURE SURVEY

A computerized review was made to determine if any literature has recently been published or research has been performed which is pertinent to the low headroom goals of this program. Although some general background information was available, the only reference that concerned itself with headroom was the prior work by Fairchild Space and Electronics on DOE Contract No. USDOE ET-78-X-01-2415. A careful review was made of this work, which concluded by recommending a toroidal geometry which did not, in fact, reduce headroom.

The articles of interest that were discovered through the organized search are listed in the bibliography. The following is a brief discussion of the background information obtained.

Colijn (4) provides an excellent overview of various design considerations important for any transfer point. In particular, he has collected information on:

- The impact absorbing characteristics of the receiving belt and impact idlers
- The radius required in a transfer chute to maintain any material speed
- The length of skirtboards to ensure that material has reached the speed of the receiving belt.

Roberts (25) describes the chute cutoff angle that is optimum in a curved geometry as the one at which the material speed is maximum. For values typical for a coal installation, a cutoff angle of 20 to 25 deg to the horizontal is determined (4). Roberts investigated the performance of cycloidal and parabolic chute curves and found them to offer no advantages over circular chutes.

Stone boxes were discussed by both Jones (18) and Schmitz (26). Jones was interested in the stone box to minimize degradation of brittle sinter in a very abrasive application. He concluded the following:

- The stone box produced *less* degradation than a torus shape

- When the bulk material contained 23 percent fines, degradation was reduced by half

- Covering the steady-state stone box material curvature with a tarpaulin increased degradation.

Degradation is a measure of flow turbulence and dust generation. Schmitz addressed the use of stone boxes where large lumps are being handled. He has concluded that for blocky material the most important factor affecting belt life is the relative speed between the lump and the receiving belt upon impact. A large vertical drop can be accommodated if the material does not tear the belt as it is being accelerated.

Water sprays used for dust control are less apt to clog due to corrosion and contamination if they are set up to produce a coarse droplet size (21).

Johanson (16) details the material properties that must be correctly scaled or simulated for proper modeling of bulk materials behavior. For dynamic tests, as with transfer chutes, the effective angle of internal friction and the kinetic angle of friction must be duplicated for the material of interest. By using the same material, duplication is automatically ensured.

4.0 MINE VISITS

Four mines were visited to observe and obtain data on the chutes used at their transfer. The visits to the four mines clearly illustrate that there is no established design for 90 deg transfer points. Some curved chutes have been initially tried but circumvented by welding in flat impact sheets. The mine operators install what is expedient at the time.

The information obtained also clearly indicates that for transfer chute designs to be used underground and to maintain their configuration, it is essential that maintenance of these chutes be relatively simple and easy.

At all mines visited, belts were replaced for reasons other than belt carcass wear. Edge tearing, carcass rotting, or tearing out of the splices were the primary reasons for replacement of the belt.

Introduction of moisture to the coal, either at the miner or at the transfer point, makes some room for compromises between turning the coal with the least amount of turbulence (or dust generation) and providing a practical maintainable chute. Also, assuming that belt carcass wear is not an item of strong consideration, *relaxation of the requirement for depositing the coal on the receiving belt at the receiving belt speed may be instrumental in developing a practical maintainable design.*

Trip reports for each of the mine visits are included in Appendix A.

5.0 CONCEPTUAL CHUTE DESIGN

In the conceptual design phase of the program, several chute concepts were generated, as follows:

- Deflector plate
- Stone box
- Jay chute
- Loop chute
- Can chute
- Slide chute
- Hopper chute
- Catenary chute.

Each of these chutes was modeled and tested in a one-sixth scale conveyor test loop. Descriptions of each of these chute geometries are included in Appendix B, which also details the model tests themselves.

Following the model tests, each chute was evaluated using a methodology scorecard. The methodology used to evaluate and rank the chutes is described in Appendix C.

Of the chute designs tested and evaluated, the *slide chute* shows the greatest promise for successfully transferring coal between belts perpendicular to each other in the least amount of vertical space. Although the deflector plate and stone box also scored well overall, the slide chute had superior performance.

5.1 Description of the Slide Chute

As shown in Figure 6, the slide chute is comprised primarily of three flat plates. The flat plates serve to approximate the theoretically ideal flow characteristics of a curved geometry.

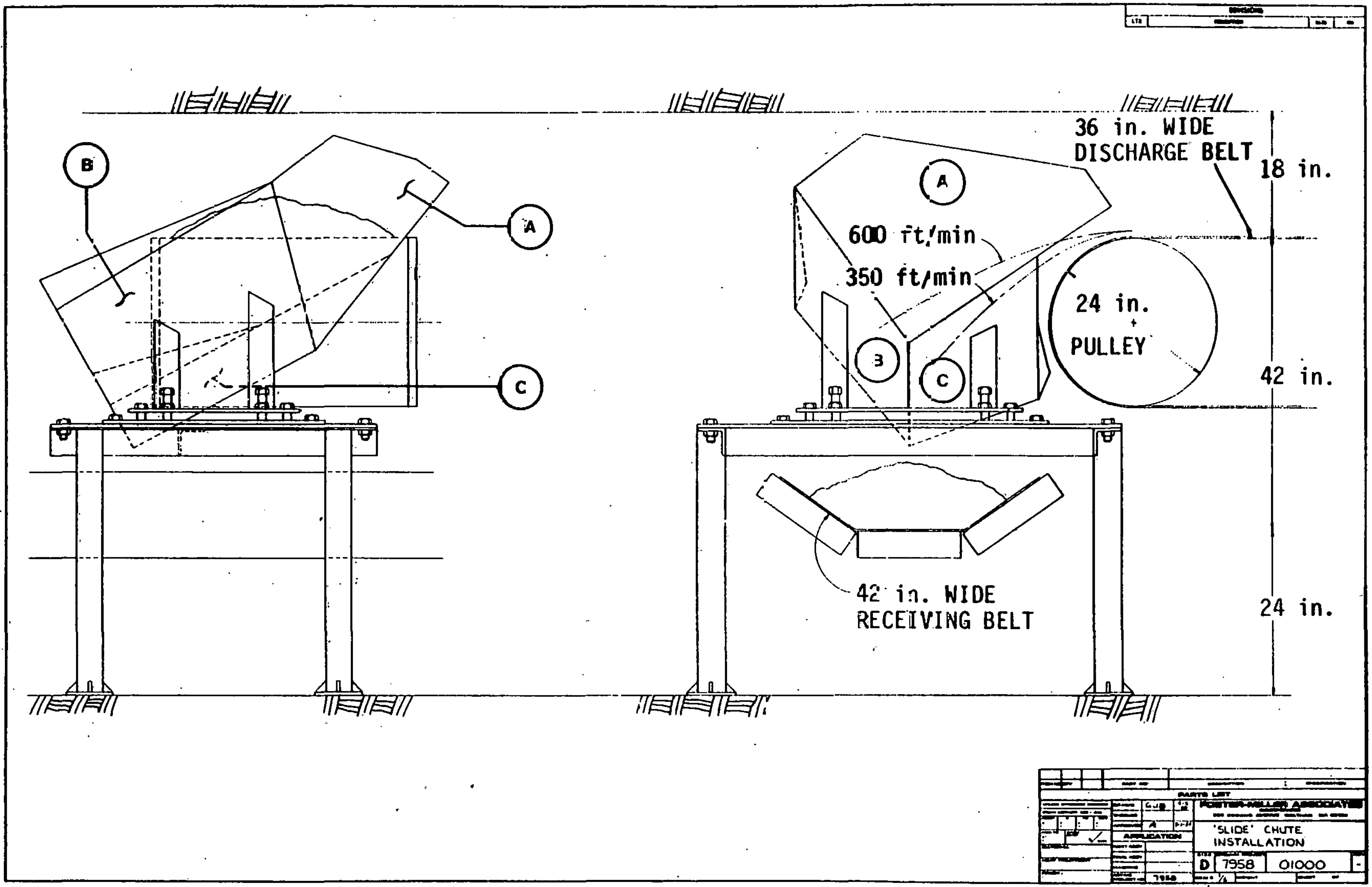

FIGURE 6. - Slide chute description.

The three plates, A, B, and C, come together at a point; therefore, the corner so formed is simulating a *two degree* of curvature surface.

The "curve" formed by plates A and B is perpendicular to the centerline of the material trajectory at the point of impact. These two plates redirect the material in the direction of the receiving belt. Plate A tends to be tangent to the discharge belt and starts to bend the material flow path with a minimum of turbulence. Plate B, on the other hand, tends to be tangent to the receiving belt and therefore deposits material onto that belt with a similar minimal disruption in flow.

In the construction of a full-scale chute, one curved plate could be substituted for the two flat plates A and B. In the one-sixth scale model tests we observed only a minimal improvement in the flow pattern when this change was made. For the sake of design simplicity, we have therefore not included this curved plate in the design. Note that for a chute constructed as shown in Figure 6 with the three flat plates, filler plates can easily be added in the field to smooth out flow patterns in the chute corners should the need arise. In the full-scale installation undertaken at Carbon Fuel Co. of Chesapeake, WV, the performance of the slide chute to date has not required the addition of plates to form a smoother curvature.

Plates B and C form the vee discharge portion of the chute, which allows centering the material flow on the receiving belt. Plate C also serves to catch the dribble from the belt scraper and keep it in the conveyor system.

5.2 Construction of the Slide Chute

The dimensions of a full-scale slide chute are indicated in Figures 7 and 8. This geometry has been defined for a transfer point with the following specifications:

- Discharge belt speed: 350 ft/min
- Receiving belt speed: 520 ft/min
- Discharge belt width: 36 in.
- Receiving belt width: 42 in.
- Vertical distance between tops of the two belts: 30 in.

For a transfer point with different specifications, the geometry would have to be tailored slightly to suit the application.

Because the design is comprised entirely of flat plates, the plate material of choice would be abrasion-resistant plate, such as U.S. Steel's T-1. As this plate wears out, a replacement liner can be overlaid and welded in place. For a more sophisticated chute of curved plate construction, the base chute would probably be mild steel with abrasion-resistant plate attached to it. In this way the sophisticated curvature would be retained during the wear plate replacement.

The method of fabrication is dependent on the mine conditions. The chute can be bolted or welded together, in the shop or underground. Depending on the working space available around the transfer point, the flat plates may require additional segmentation to facilitate installation.

5.3 Installation of the Slide Chute

The mounting arrangement indicated in Figure 6 is floor-mounted; based on the conditions at the transfer point, it may

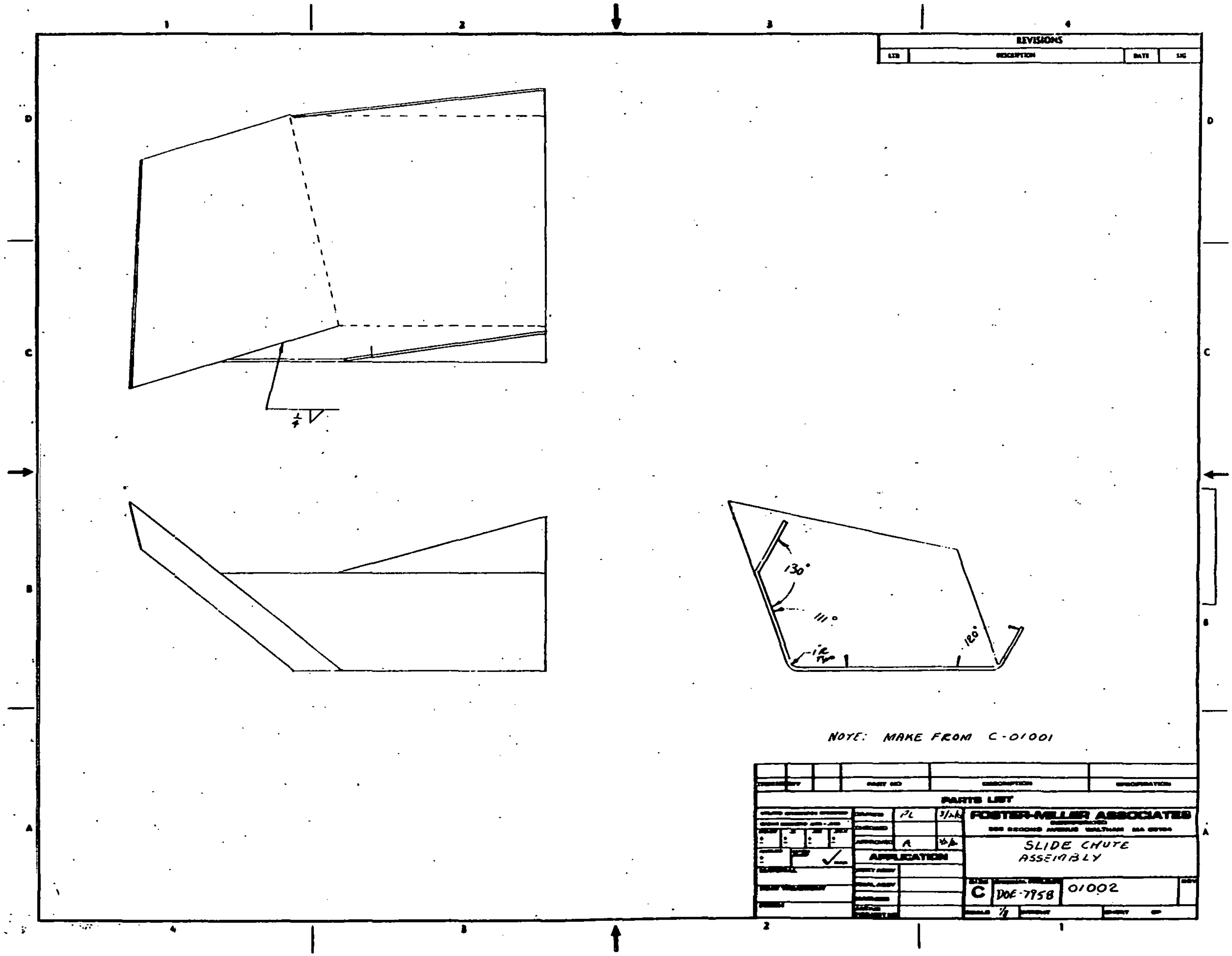

FIGURE 7. - Slide chute construction.

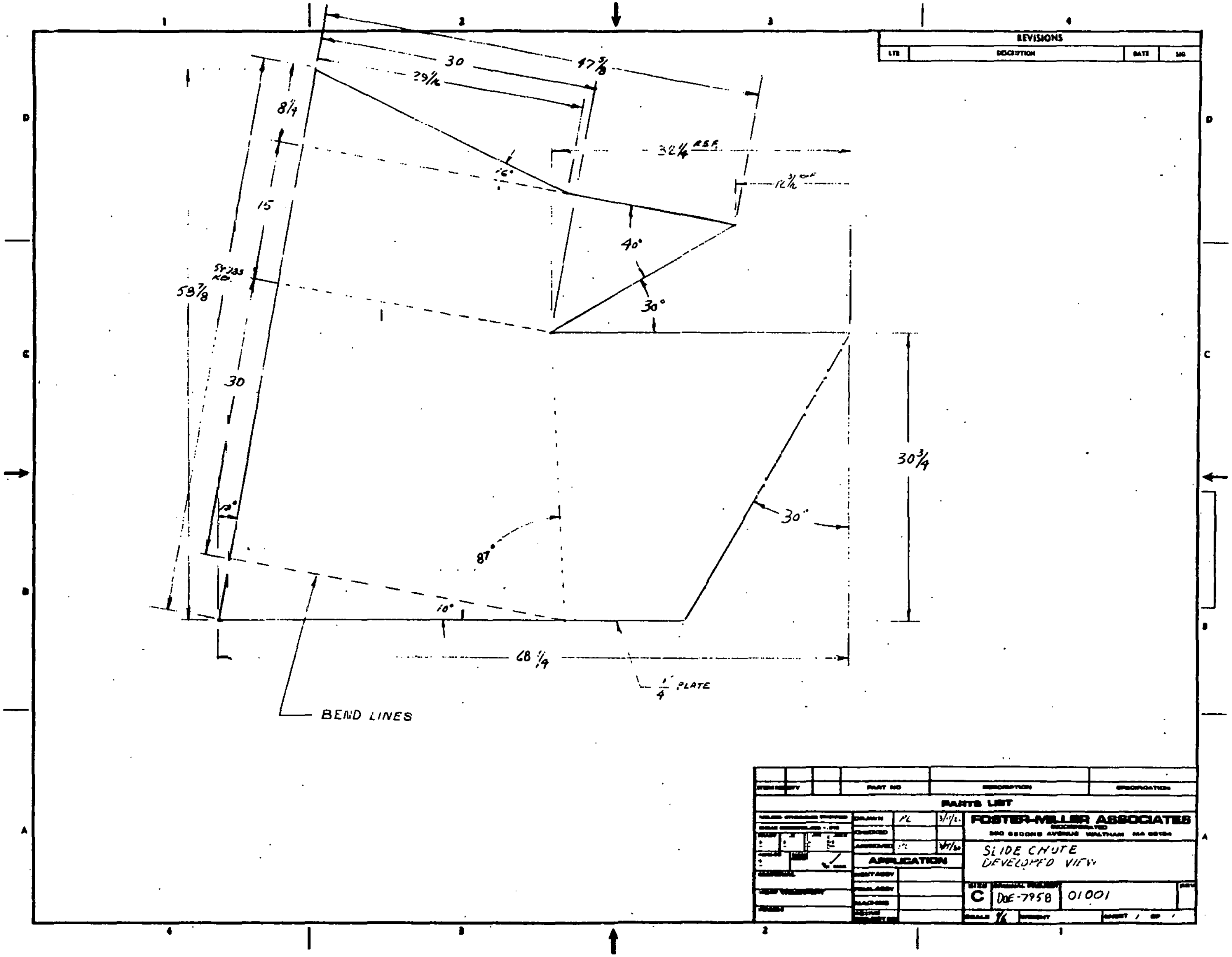

FIGURE 8. - Slide chute developed view.

be more convenient to attach the structure to the roof. The actual method of mounting is best left to the artistry of the maintenance crew, because it varies with each mine.

It is strongly recommended that a mounting scheme be used that can be adjusted while the conveyor is in operation so that the flow characteristics of the chute can be optimized soon after installation. We have seen installations where 1-in. threaded bar has been used for this purpose; once the proper alignment has been determined, the adjusting nuts can be welded in place.

6.0 GUIDELINES FOR DESIGN OF A LOW HEADROOM TRANSFER CHUTE

Based on the data gathered from personal contacts with industry and the model testing, FMA has developed some general guidelines to be followed for a successful low headroom transfer chute. Although the model tests permitted the analysis of model chutes with gross differences in geometry, some of the finer points of the designs could not be optimized in one-sixth scale and must be finalized during full-scale tests. It should also be noted that the model conveyor belt rode in a trough which prevented an analysis of the detraining tendencies of the different designs; we would be able to come to more conclusions regarding detraining of the receiving belt during field tests where the belt is allowed to move laterally on the idlers.

6.1 Area of Application

Before a chute is designed, it should be determined if one is needed. The major considerations here are the belt speeds involved and the amount of material being moved.

We have found that below about 350 ft/min a 90-deg transfer can be made with no chutework at all. If the transfer is designed so that the discharge trajectory lands in the center of the receiving belt, then only skirtboards are required to eliminate spillage. If the tonnage involved is large, it may prove desirable to install an impact plate or deflector plate suspended from the roof for belt speeds between 250 and 350 ft/min.

All of the belts observed underground were loaded so that the material load had a 6- to 8-in. distance to the edge of the belt. Reasons for this amount of overcapacity include bad training of the belts, subsequent damage to the belt edges, the capability to handle large surges and blocky coal, the concern over significant material spillage and cleanup costs, and the requirement to extend belt life as long as possible. If this duty remains constant, there should be no need for a transfer chute. One advantage inherent in a low headroom transfer is that the kinetic energy in the discharge trajectory is low enough that it can be safely absorbed in the belt and supporting idlers; this is not the case when the material drops 60 in. or more. The fully loaded (scaled 2-in. edge distance) model conveyors *did* require chutes. Because the effect of tonnage rate on the need for a chute is related to the detraining tendency, it can only be analyzed adequately in a full-size demonstration.

6.2 Geometry

The conceptual designs developed for model testing were kept as simple as possible. Based on these tests, the conclusion was reached that the benefits of a two degree of curvature chute justify the added complexity. Except for the loop design, which choked at high flow rates, each of the other designs performed better when a second degree of containment was added. The jay, the catenary, the can, and the slide all accumulated material on the high end of the slope until a second curvature was added at that point.

In some cases this material built up until it flowed out the back of the chute; in all cases it acted as a stone box and generally detracted from the chute performance. In the hopper design, a distinct belt detraining flow vector was established until a second degree of curvature plate was added.

When the plate was added to the slide concept (shown in Figure 2) to help the material turn the corner, the dead material zone was eliminated and the flow kept the corner scoured clean. In the model, there was only a minor improvement in performance when this "corner turning" plate was curved instead of flat;

for that reason it was decided that the curved plate was unjustified. Because it is expected that the flow characteristics will become more obvious in the full-scale tests, we hope to be able to accommodate a curved plate at this location should the flat plate construction prove too inefficient.

Most 90-deg transfer points encountered underground are intermediate transfers from a panel belt to the mainline belt. It is common, therefore, to have material previously deposited on the belt from an upstream transfer. One consequence of this feature is that the majority of the installations of skirtboards serve only to prevent spillage and cannot be used to center the load on the belt because of the extreme outward alignment to allow material to pass. In other words, the chute design itself must adequately center the material, necessitating a curvature in that direction to control the flow.

To prevent spillage and detraining of the belt, the material should be deposited on the middle two-thirds of the belt. Bad tail transfers are most apt to detrain the belt because it is not loaded down with previously deposited material; a bad intermediate transfer, on the other hand, will cause more spillage problems because the receiving belt is normally already partially loaded.

To reduce the possibility of plugging the chute due to a surge in flow or a block of material, the design must be as open as possible. In the model tests, the loop and can designs proved to jam very easily due to tight radii or closed construction. The open designs of the slide and stone box passed very large blocks of material.

Chute side slopes should be 60 deg or more to prevent material accumulation. The determination of the proper angle of the bottom of the chute parallel to the centerline of the receiving belt, called the cutoff angle, is more complicated.

To minimize headroom and flow turbulence, the cutoff angle should be as small as possible. Values measured underground ranged from 25 to 35 deg. Because friction and gravity cannot be scaled, a 35-deg slope was required on the smooth galvanized steel surface of the slide chute for adequate performance. The rusted full-scale chutes observed could go as low as 25 deg because the increased vertical drop provided a much higher speed and scouring action. (The use of stainless steel would permit this value to be even lower. One mine has settled on 310 stainless specifically due to its polishing characteristics that ensure low friction). The low headroom installation will decrease the available kinetic energy in the discharge and a 30-deg cutoff angle may prove necessary. This figure could be optimized in full-scale tests.

Because the bottom of the chute is sloped, minimization of the length of the chute also minimizes the vertical height required for the installation. Reducing the chute length less than the width of the feed belt subjects the receiving belt and conveyor structure to some of the impact loads normally transmitted to the chutework. Proper spacing and selection of receiving belt idlers allow this arrangement to succeed and contribute to the total headroom reduction. In some cases, the use of a grizzly to allow the fines to pass through and form a bed to cushion the impact of larger chunks has been beneficial.

Implied in the previous discussion on the discharge to the receiving belt is the fact that the speed and direction of the material flow have proven to be secondary considerations in the success or failure of a transfer point; centering the load is critical.

Of course, if the material speed is matched to the receiving belt speed, spillage and dust generation do not need to be contained by secondary features as skirting and water sprays.

6.3 Construction

If at all possible the two degree of curvature chute geometry should be constructed from flat plate segments, as with the slide. To further facilitate replacement (or construction of the chute in its entirety underground) every attempt should be made to make each piece as light as possible; a good rule-of-thumb is to keep all plates less than 100 lb each.

The chute walls subjected to sliding and impact wear should be constructed of a weldable abrasion-resistant plate such as T1 or Jalloy. If the installation is expected to be installed in one location for a long period, the better performance obtainable with 310 or 316 stainless may be worth the added expense. Stainless is not widely used underground mainly due to the unfamiliarity of the miners with its welding characteristics.

If the chute is at an intermediate transfer and handling longwall production, the probability of previously loaded blocky coal trying to pass under the chute may require that the chute be hinged or slung to allow the block to pass without a pile up of material. On continuous miner sections a feeder breaker is frequently installed between the shuttle car and the panel belt, thereby insuring that no large pieces get into the conveyor system. In this case, a rigid chute mounting with 8- to 12-in. clearance with the receiving belt is adequate.

6.4 Accessories

A transfer point requires several auxiliary devices to allow the chute itself to function properly. Brief mention will be made of each.

The *belt scraper* in a low headroom installation should be mounted as high on the head pulley as possible. A high position permits the *dribble plate* to be short because the scrapings are already over the receiving belt; headroom is minimized.

The *head pulley* itself should be as small as possible to condense the transfer point installation. Pulleys as small as 12 in. diam have been used with PVC belting. The *feed belt* itself should be thin to allow the use of the small diameter head pulley.

Skirtboards should be high and long to eliminate spillage. Designs which are easy to adjust and maintain encourage good performance.

Water sprays, controlled with paddle switches that sense material flow, wet the material to minimize dust, and yet do not fill the unloaded belt with water. The location should be 10 ft upstream of the feed belt head pulley or at the trajectory itself.

A mercury *tilt switch* mounted in the chute senses any backup of material and can shut the belts down before serious damage is done. A *rip detector* built into the belt carcass is worth the investment on long, expensive belt systems. An undetected roof bolt that pierces the carcass can do a lot of damage.

All belts must have *emergency pull switches* along their length. These should be located so that if someone falls onto a moving belt they can reach the cord and stop the belt.

Electrical lock outs on the drive and *cross-over points* minimize potential hazards common to spillage cleanup operations.

Impact idlers are recommended at loading zones, especially at low headroom locations where the belt may be called upon to absorb more kinetic energy from the discharge trajectory, because the chute may be designed very short to minimize vertical height. *Minimization of idlers*, especially steel roll idlers, in the impact zone prevents crushing the belt and allows its own elasticity to absorb the impact forces. The idlers last longer, too.

7.0 ECONOMIC ANALYSIS OF A TRANSFER CHUTE INSTALLATION

There are two general scenarios for which the mine operator would consider the use of a low headroom transfer chute in a new installation. They are:

- Installation of a high-performance low headroom chute in a low headroom location where a deflector plate would otherwise have to be used.

- Installation of a high-performance low headroom chute in a location which otherwise would require formation of a high headroom boom hole and installation of a high-performance high headroom chute.

It is also possible that increased production passing through an existing low headroom deflector plate installation, resulting in unsatisfactory performance, would force an operator to make one of the above decisions.

The figures used in the following calculations were obtained from mine operators, consultants, and conveyor equipment manufacturers. Although the assumptions are open to discussion, the basic conclusions remain valid. All calculations use 1980 costs.

The headroom and boom hole dimensions are based on being able to install a low headroom chute in a vertical distance comprised as follows:

- Floor to top of receiving belt: 14 to 24 in.
- Top of receiving belt to top of feed belt: 30 to 42 in.
- Top of feed belt to roof: 6 to 18 in.
- Overall, floor to roof 50 to 84 in.

These dimensions correspond to a 36-in. feed belt width, a 42-in. receiving belt width, a 24-in. diam head pulley, and a 550-ft/min feed belt speed. Based on individual conditions at different mines, these dimensions will vary somewhat.

Three options will be evaluated to ascertain which is most economically viable for underground use. These are:

1. Cut boom hole for feed belt and install a *curved chute* with its attendant high headroom (as seen in some of the mines visited).

2. Use the 84-in. headroom without cutting a boom hole and install the *slide chute*.

3. Use the 84-in. headroom without cutting a boom hole and install a *deflector plate*.

7.1 Curved Chute with Boom Hole

The estimated material cost of a curved chute with support structure is $600.

The cost of installing a boom hole is five shifts at four men per shift: three men at \$144/shift and one foreman at \$219/shift.* Equipment is estimated at 15 percent of labor.

Labor = (5 shifts) [(3 men) (\$144) + (1 man) (\$219)] = \$3,255

Equipment Cost = (0.15) (\$3,255) = \$488

Installation of the chute is estimated to be 8 hr for two men or \$288; this includes hauling into location and setting in place. Total cost of installation is \$4,031.

Maintenance manpower is estimated to be 1/4-hr/shift = \$4.50/shift.

Assume two shifts per day, 5 days/week, 52 weeks/year.

Maintenance Cost = (\$4.50) (2) (5) (52) = \$2,340/year.

The total first-year cost of a typical curved chute installed is estimated to be \$6,371, with \$2,340/year required for maintenance thereafter.

7.2 Low Headroom Slide Chute without Boom Hole

The estimated cost of the slide chute with support structure is \$660.**

Routine daily maintenance on the slide chute, including spillage cleanup, adjustment, monitoring liner wear, and checking belt training, should require the same amount of time as the

*Labor rates are based on personal communication with an assistant mine superintendent at an underground mine in West Virginia, verified with the UMW pay scale, and a calculated overhead rate of 70 percent.
**Quotation from Long Airdox.

curved chute just analyzed. Due to the smoother transition and lower material drop onto the liner plates, liner plate replacement should be less frequent. Maintenance costs are therefore estimated to be slightly less than the curved chute, $2200/year. Cost of slide chute installed is estimated to be $948 with $2200/year for maintenance thereafter.

7.3 Deflector Plate without Boom Hole

The estimated cost of the deflector plate is $250.

Installation is estimated at 4 hr for two men, or $144.

Maintenance for the deflector plate installation is 1 manhour/shift. Cost of maintenance = (1 hr) (2 shifts) (5 days) (52 weeks) ($18/hr) = $9360/year.

The cost of the deflector plate installed is $394 with $9360 required per year for maintenance thereafter.

7.4 Discussion

Costs have been summarized in Table 1. In comparing the slide with the curved chute requiring the boom hole cutout, the slide is less expensive to install and is less costly to maintain. In comparing the slide with the deflector plate, the slide is costlier to install, but is considerably less costly to maintain.

The additional cost of installing the slide chute would be paid for in less than 1 month.

Although one of our consultants quoted *at least* 1 manhour of maintenance per transfer point per shift, based on the maintenance practices observed underground, we do not feel that this

TABLE 1. - Transfer point costs

	State-of-the-art curved chute with boom hole	Low headroom slide chute	Low headroom deflector plate
Boom hole	$3743	0	0
Chute cost	600	$ 660	$ 250
Chute installation	288	288	144
Fixed cost	4631	948	394
Yearly Maintenance cost	2340	2200	9360
Total cost after 1 year	6971	3148	9754

level of maintenance is actually taking place. By the same token, the deflector plate installations observed in operation often were detraining the receiving belts substantially. Based on the fact that the most common reasons for replacing a belt underground are:

- Belt edge wear
- Repeated destruction of the mechanical belt splice due either to contact with a stationary piece of conveyor structure or to rotting of the carcass at the splice, it is safe to assume that the lack of attention at (deflector plate) transfer points is a direct contributer to the demise of underground conveyor belts.

By using 1 manhour of maintenance per shift in the previous calculations for the deflector plate, we are in effect stating that *in order to sustain conveyor belt life equal to that which would be expected from a good transfer point installation, a deflector plate arrangement would have to be repeatedly adjusted throughout a working shift* to keep the receiving belt centered under varying load conditions. If maintenance manhours were set equal in the previous calculations, then the economic trade-off would appear in the increased frequency with which the receiving belt would have to be replaced; here again, time and materials vary from one mine to another, but the conclusions would be the same.

It should be noted that the coal production lost in the construction of the boom hole has not been included in the analysis.

Besides the economic advantages outlined, there are some obvious safety advantages as well. Formation of the boom hole subjects the miners to the perils of unsupported, yet disturbed, roof conditions. Rock, and frequently roof bolts, may get loaded onto an established belt line, thereby contaminating the product and possibly damaging downstream equipment.

The additional maintenance required at a poor transfer requires that the maintenance man expose himself to the hazards of working around the conveyor belt, probably while it is moving, for longer periods of time.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The testing of the one-sixth scale models and the full-size installation of the slide chute by Carbon Fuel Co. indicates that the problem of turning coal 90 deg from belt to belt in a low headroom configuration is soluble and the slide chute is one solution to this problem. Installation of the slide chute can be accomplished by precutting the chute into pieces that can be easily handled and welded at the site, or, if adequate equipment is available, the chute can be formed out of the mine and brought in in one piece. The economic analysis indicates that the properly-installed chute is economically superior to the other alternatives.

This program has identified one promising chute geometry to transfer material in low headroom. This project has not:

- Optimized fabrication and assembly techniques and costs

- Proved the concept in an operating mine.

If the mining industry agrees that the potential benefits of low headroom transfer are worth the initial risks to optimize the full-scale chute itself, then no further development effort by the DOE is warranted. The initial response by Carbon Fuel Co. seems to indicate that further development can be undertaken successfully by industry. Especially in the areas of field fabrication and assembly where the technique probably varies with each mine, optimization is best executed for the mine in question.

On the other hand, should the industry not adopt low headroom transfer chutes in the future, due to the distinct advantages in productivity, performance, safety, and economics, we believe the concept should be more strongly promoted. At that point, if government funding of a mine demonstration appears justified, then it should be the next step in the DOE development process.

9.0 REFERENCES

1. Army Test and Evaluation Command, "Belt Conveyor, Final Report on Materiel Test Procedure," June 1970

2. Blankenship, Jack B., "New Materials for Slidability Plus Longer Wear," Mining Congress Journal, October 1975

3. Chiarella, C., W. Charlton, and A.W. Roberts, "Optimum Chute Profiles in Gravity Flow of Granular Materials: A Discrete Segment Solution Method," Journal of Engineering for Industry, February 1975

4. Colijn, H., and P.J. Conners, "Belt Conveyor Transfer Points," Seminar on Conveyor Systems for Bulk Materials Handling, University of Pittsburgh, December 8 and 9, 1971

5. Colijn, H., "General Design and Selection of Conveyor Systems," Seminar on Conveyor Systems for Bulk Materials Handling, December 8 and 9, 1971

6. Colley, Clay, "Tips on Designing Chutes and Spouts," Material Handling Engineering, January 1966

7. Conveyor Equipment Manufacturers Association, "Belt Conveyors for Bulk Materials," Cahners Publishing Co., Inc., Boston, MA, 1966

8. Cooper, F.D., and J.R. Garvey, "Flow of Coal," Mechanical Engineering, May 1958

9. Davis, Harold, "Continuity Raises Thin-Seam Output," Coal Age November 1978

10. Foote, P., "Transit Shock Recorders and Coal Breakage," Colliery Guardian, September 1970

11. Gupta, R.N., and B. Singh, "Design and Performance of Spiral Chute Installations in India and Abroad," Journal of Mines, Metals, and Fuels, July 1970

12. Hockel, Hanswalter, "Elektromagnetische Vibrations-forderrinnen im Bergbau unter Tage," Techn. Mitt. AEG-Telefunken, Vol. 6 pp. 161 to 165, 1971

13. Holliday, Terrell L., "Low Headroom Transfer Chute for Underground Belt Conveyors: Analysis of Coal Flow Through Ninety Degree Transfer Point and Preliminary Design," Final Technical Report DOE No. H0166113, May 1978

14. Hoover, Stanley M., Charles K. Dunlap, and Robert W. Dalzell, "Recirculation Resulting From Dust Collector Operation at Belt Transfer Points," NCA/BCR Coal Conference and Expo III, October 19 and 21, 1976

15. Jenike, A.W., "Steady Gravity Flow of Frictional-Cohesive Solids in Converging Channels," Transactions of the ASME, March 1964

16. Johanson, J.R., "Modeling Flow of Bulk Solids," Powder Technology, May 1971

17. Johanson, Jerry R., "Particle Segregation ... and What To Do About It," Chemical Engineering, Vol. 85, May 1978

18. Jones, K.T., and H. Horke, "An Anti-Degradation Belt Conveyor Transfer Point Using a Dirt Box And Straight Chute," Open Report of BISRA, The Inter-Group Laboratories of the British Steel Corporation, March 1968

19. Mehta, B.C., D. Patel, R.W. Heins, R.W. Christensen, "The Effects of Material Properties on Materials Handling Processes," Semi-Annual Technical Progress Report, NTIS, October 1973

20. MSA Research Corporation, "Improved Dust Control at Chutes, Dumps, Transfer Points, and Crushers in Noncoal Mining Operations," Final Report USBM Contract No. H0230027, June 1978

21. Ridgway, K., and R. Rupp, "Mixing of Powder Layers on a Chute: The Effect of Particle Size and Shape," Powder Technology, July 1970

22. Roberts, A.W., "An Investigation of the Gravity Flow of Noncohesive Granular Materials Through Discharge Chutes," Journal of Engineering for Industry, May 1969

23. Roberts, A.W., and G.J. Montagner, "Flow in a Hopper Discharge Chute System," Chemical Engineering Progress, Vol. 71, No. 2, February 1975

24. Roberts, A.W., "The Dynamics of Granular Material Flow Through Curved Chutes," Mechanical and Chemical Engineering Transactions, November 1967

25. Roberts, A.W., "Transfer Chutes," Seminar on Storage, and Flow and Conveying of Bulk Solids, University of Newcastle, August 27 through 29, 1979

26. Schmitz, Konstantin, "Transfer Point 'F' at Tarbela Dam," World Construction, Vol. 27, January 1974

27. Van Buren, W.H., "Factors in Good Chute Design," Modern Materials Handling, September 1953

28. "A Review of the Development of Chutes Underground, With Descriptions of the Products of Some of the Leading Manufacturers," Colliery Guardian, September 1962

APPENDIX A

MINE VISITS

APPENDIX A

Four underground coal mines were visited to observe and obtain data on the chutes used at their transfer points. These mines will be designated A, B, C, and D.

Descriptions of the transfer points follow:

Mine A

At Location No. 1, considerable headroom was available because the panel conveyor had to clear an overcast. The transfer chute consisted of a carbon steel "J" shaped member with an impact sheet of T1 steel welded to the J. A schematic sketch of the chute and conveyor arrangement is shown in Figure 9.

The coal at this transfer point emanates from a continuous miner and is very moist so dusting was not visually detectable. The practice at this mine is to wet the coal so that dusting does not create a problem.

The bottom of the J chute was inclined about 30 deg from the horizontal. The curvature at the bottom of the chute was circumvented since a flat impact plate was welded to the chute. A structural steel angle was welded on the other side of the curvature as shown in the sketch. The coal impacted on the flat plate, slid down the flat surface and was directed onto the conveyor by the structural angle. Almost none of the curvature was utilized.

Sheet metal strips 1/4 in. thick by 12 in. high by 36 in. long extended beyond the J chute. Strips of 1/4 in. thick conveyor belt were attached to these strips to act as skirts to minimize spillage at the transfer point; these proved to be

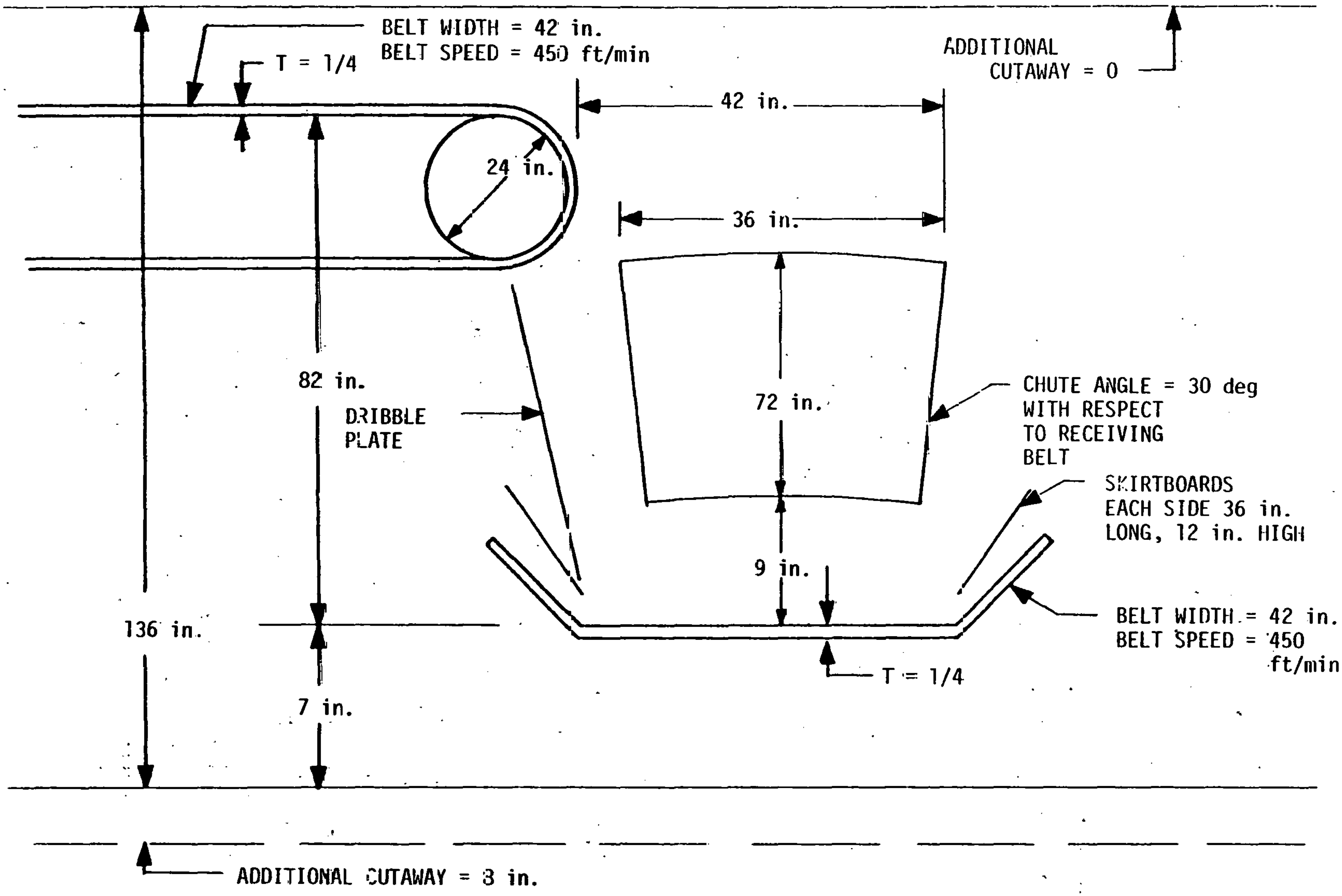

FIGURE 9. - Schematic of transfer point - Mine A - location No. 1.

quite successful. The feed belt and receiving belt both travel at 450 ft/min at this location. The receiving belt had 1 in. wide by 6 in. diam rubber discs on 2 in. centers for impact idlers spaced 2 ft apart. Spray nozzles were available to spray the coal prior to entering the transfer chute but were not used due to the moistness of the coal.

This transfer chute works quite well but uses too much height; namely, 82 in. from top of feed belt to top of receiving belt.

Transfer point No. 2 is an intermediate transfer, loading onto a previously loaded belt. The upstream material is deposited uniformly across the width of the belt by a feeder-breaker fed by the miner section shuttle cars. Because the upstream material is uniform both in size and deposition on the belt, there is no problem with upstream material interfering with the intermediate transfer chute or its supporting structure. The chute is securely welded to an angle frame with no provision for pivoting away from large lumps on the belt.

At Location No. 2, headroom was reduced but was still considerable. The height from the top of the feed belt to the top of the receiving belt is 68 in. which is 26 in. more than our goal. See Figure 10.

The curved chute used at this location is again a J shape. In this instance, a flat impact sheet is welded along the top seam and is allowed to deflect as the coal stream impacts it. This design does not utilize the structural angle to direct the coal onto the conveyor as at No. 1. Also, the side skirts with belting were not used and were sorely missed. Coal was deposited on one side of the belt resulting in considerable spillage.

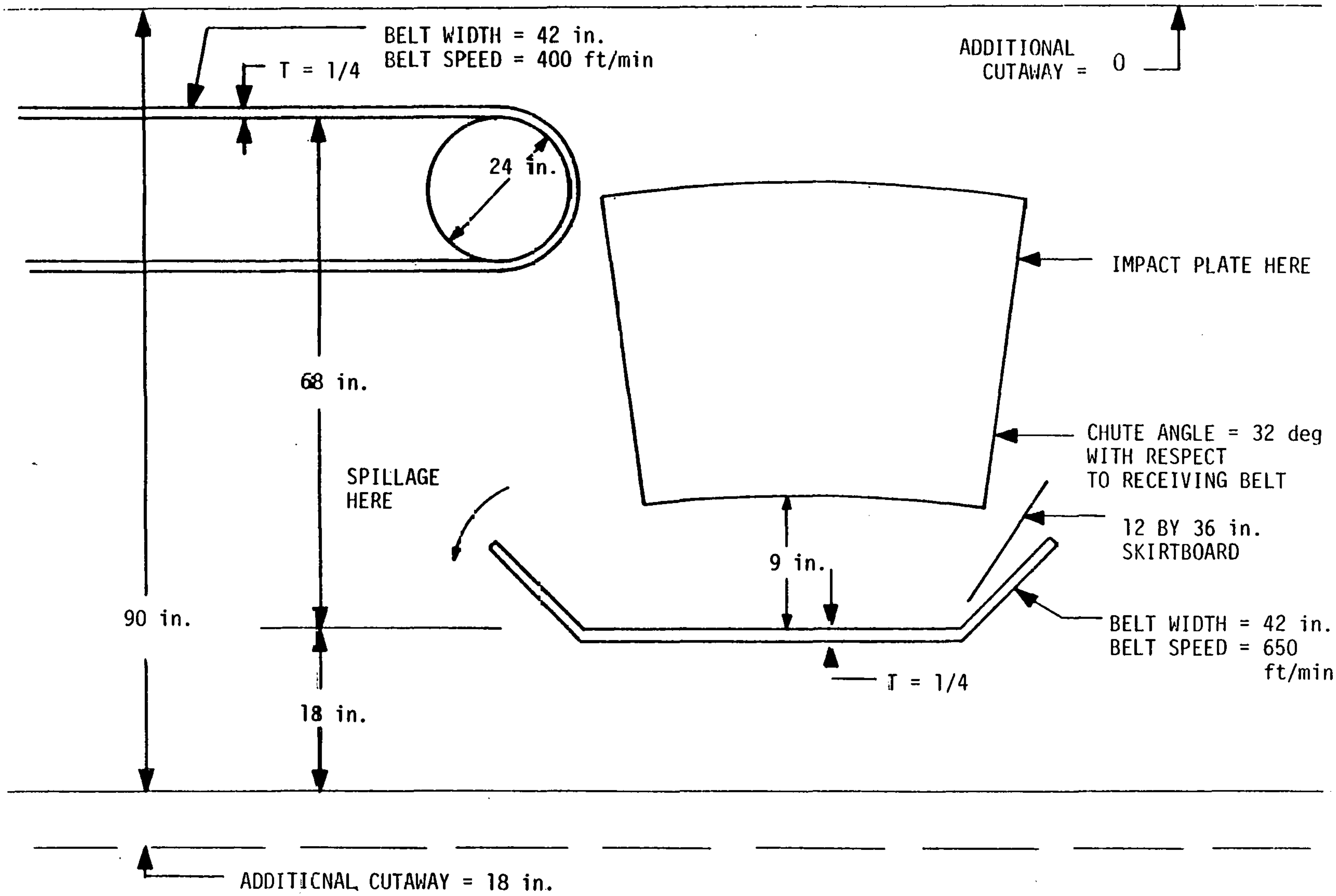

FIGURE 10. - Schematic of transfer point - Mine A - location No. 2.

The chute angle with respect to the horizontal was about 30 deg. The feed belt speed was 505 ft/min and the receiving belt speed was 650 ft/min.

It is interesting that the dynamics of the coal stream allows the coal to continuously flush out of the chute at a small angle of 30 deg with respect to the horizontal.

A further item of interest is the comment that the chief industrial engineer made regarding belt replacement. He indicated that belt wear is not of significance at this mine. Belt replacements are predicated on the number of times the belt has been spliced because of the carcass rotting or because the belt tears. In this mine one belt was changed since 1973 and this was done because the belt had too many splices in it, not because it was worn. Hank Colijn, our consultant, independently confirmed the same thing.

This transfer chute made more use of the curvature of the J-shaped chute but it appears that the location of the chute and the angle of the chute with respect to the feed conveyor were not optimized to direct the coal stream onto the receiving conveyor more centrally.

Improvements in the operation of the chutes at locations 1 and 2 appear to be possible. A better marriage between chute and conveyor could be realized with judicial alignment of the chute intercept the trajectory at a softer angle by rotating the leg of the J toward the feed conveyor and by varying the angle of the chute with respect to the feed conveyor.

At the belt conveyor drive, the measured headroom was 87 in., comparing well with the 84 in. that will be required for a transfer point with a 42-in. belt-to-belt distance. The turnbuckle arrangement on this Continental head frame is typical of the design of other manufacturers and enables easy adjustment of the head pulley elevation; however, the tension is resisted by cables connecting the head frame to roof bolts and adjustment of the head pulley location would require repositioning these tie-offs. On the other hand, the receiving belt passes through belt checks near the transfer making it difficult to raise the belt to lower the belt-to-belt distance for testing purposes.

Mine B

At one in-line transfer point no transfer chute was used. The coal was deposited directly to the belt. Side skirts helped to center the coal on the belt.

At the second in-line transfer point, a 42 in. diam half cylinder at 25 deg to the horizontal intercepted the trajectory and directed the coal onto the center of the receiving belt. A counterweighted belt scraper was used to clean the belt at the head pulley at this transfer point only, all others had spring loaded belt scrapers.

At the first 90 deg transfer point that we looked at, a 36-in. belt travelling at 506 ft/min was feeding coal to a 42-in. wide belt travelling at 590 ft/min. The distance from the top of the feed belt to the top of the receiving belt is 46 in. (4 in. over our goal). This transfer point used straight plates at 15 deg with respect to the vertical to direct the coal to the receiving belt. A schematic sketch is shown in Figure 11.

Standard 35 deg troughing idlers were used in the impact area at 12-1/2 in. spacing; 30-in. long skirts with belts attached were used to help direct the coal onto the receiving belt. Spray nozzles were provided at the transfer point but were not actuated. This arrangement deposited the coal on the receiving belt fairly evenly with no spillage but the operation was quite dusty.

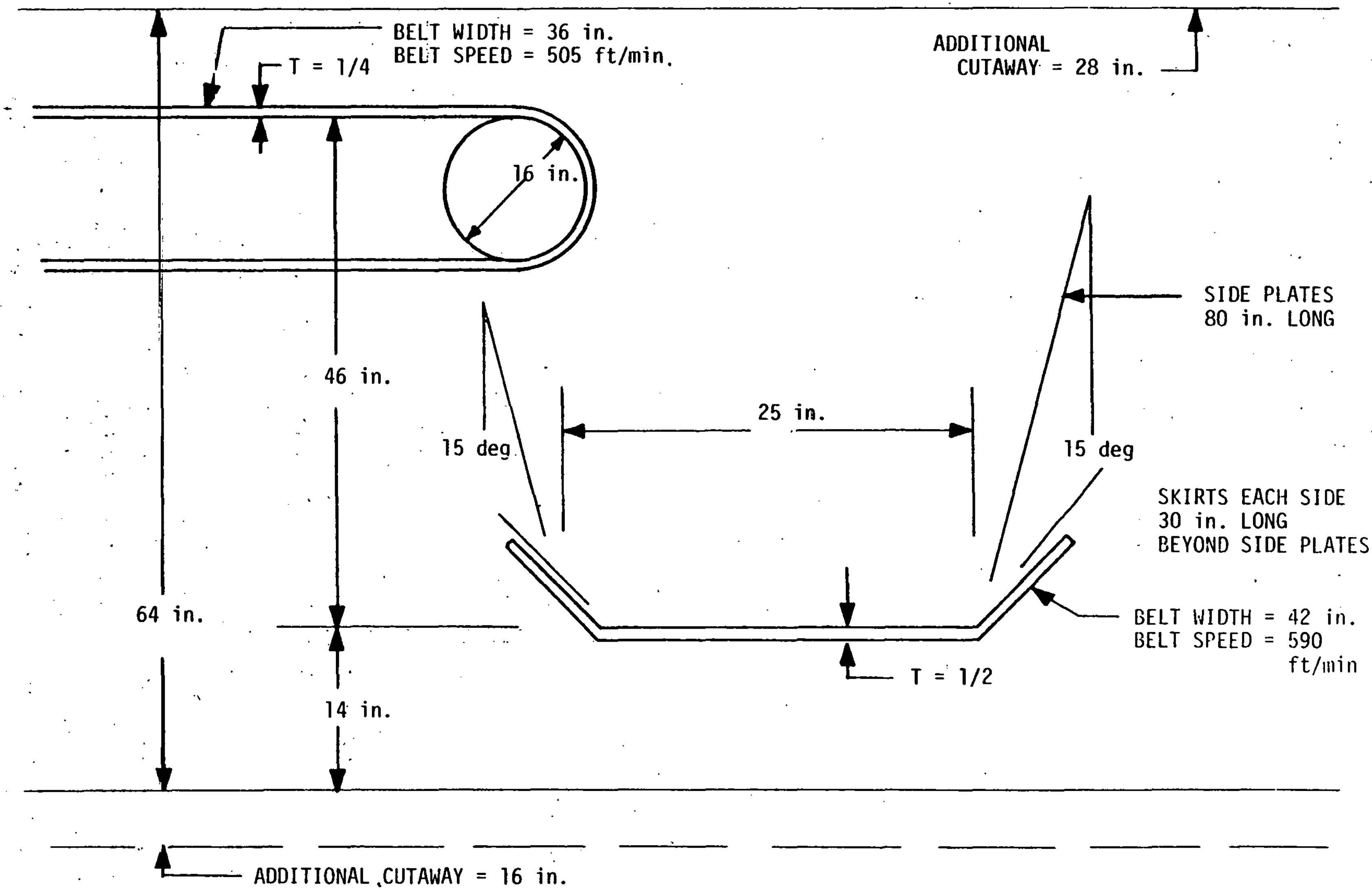

FIGURE 11. - Schematic of transfer point - Mine B - location No. 1.

At the second 90 deg transfer point both feed and receiving belts were 36 in. wide. The feed belt speed was 250 ft/min and the receiving belt speed was 516 ft/min.

The transfer chute consisted of a plate 24 in. high by 36 in. long suspended on two chains. A 3 × 3 in. wood member was positioned 3-1/4 in. behind the plate to limit the plate movement when the stream of coal impinged on the plate. A sketch of the arrangement is shown in Figure 12. This transfer chute, although it diverted the coal adequately, caused difficulty in that the receiving belt detrained badly because the coal was deposited on one side of the conveyor. Pushing on the plate to deposit the coal more centrally on the belt reduced detraining. Relocating the deflector plate chain supports and the backup would improve the operation of this transfer point considerably. This station had water sprays actuated by a paddle so that when the coal flowed the water sprays were turned on; there was very little dust at this transfer. This arrangement indicates that for slow speed feed belts (250 ft/min) a 90-deg turn can be made in 39 in., which is the distance from the top of the feed belt to the top of the receiving belt for this station with the aid of water sprays and assuming wear on the belt is of little or no significance.

At the third 90 deg transfer point, see Figure 13, a curved chute with the radius of the curved section equal to about 18 in. was used. Again, a flat plate was welded to the chute for impact. The curved chute was installed at 30 deg to the horizontal. The height from the top of the receiving belt ot the top of the feed belt is 65 in. The two belts are 36 in. wide, travelling at 505 ft/min. The water sprays on this transfer point were shut off and the dust was excessive.

A slab of coal had lodged in the chute and the coal was impacting and sliding on the block of coal. There was considerable spillage out of the back of the chute. The mine super-

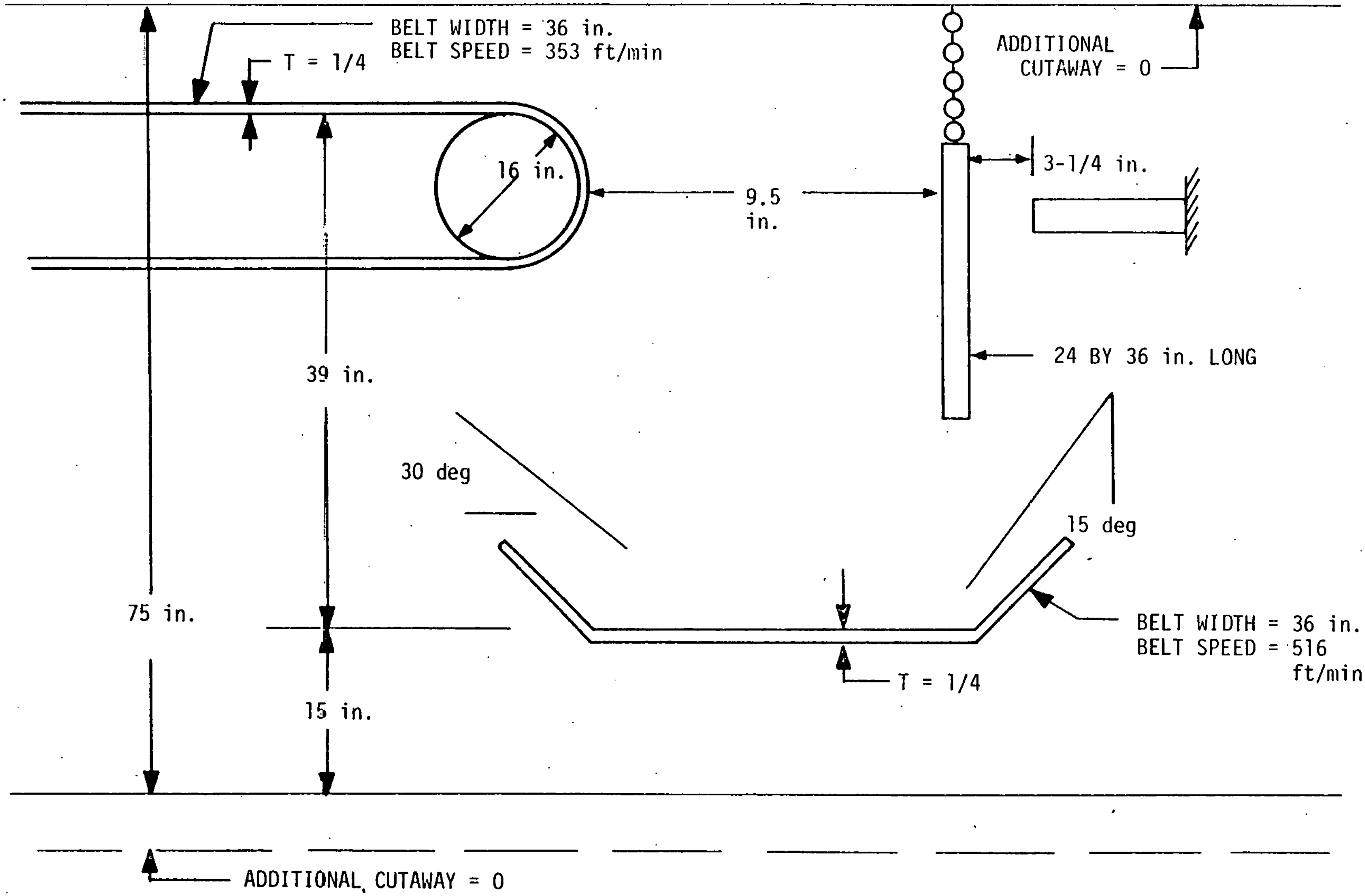

FIGURE 12. - Schematic of transfer point - Mine B - location No. 2.

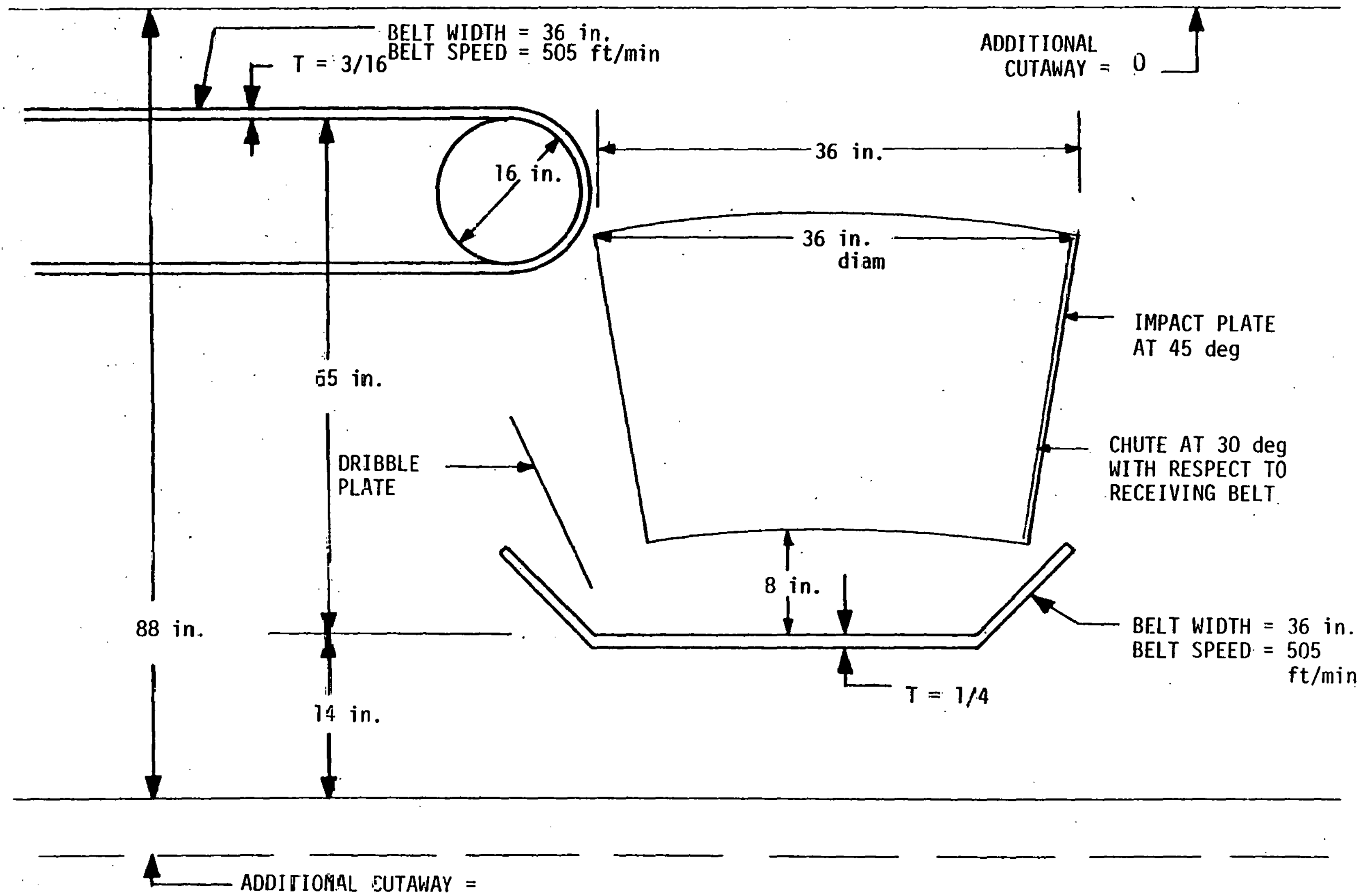

FIGURE 13. - Schematic of transfer point - Mine 3 - location No. 3.

intendent broke away the slab of coal and turned the sprays on for a short period and the chute operated better.

Mine C

This mine is in the process of installing a 54-in. main line conveyor which will travel at 600 ft/min. The 48-in. belts travel at 500 ft/min and the 36-in. belts at 400 ft/min. Again, as in mines previously visited, belt wear is not of particular importance. Tearing of belts and splices ripping out account for belt replacment.

We were escorted to two 90-deg and one 123-deg transfer points in this mine. Both were fed from continuous miners.

At two locations, one 90 deg and the other 123 deg, the conveyors were shut down so it is not possible to relate how well these chutes operate.

At the first transfer point observed, the belt center lines intersected at 123 deg. The chute was a bent piece of 1/2-in. abrasion resistant metal forming an angle with the vertical leg 19-in. high and the horizontal leg 16-in. wide. The angle is 40-in. long and the 16-in. leg is at 40 deg with respect to the receiving belt. The feed and receiving belts are 36-in. wide. The distance from the top of the feed belt to the top of the receiving belt is 43 in. See Figure 14.

Standard 35-deg troughing idlers were used in the impact area spaced 12 in. apart. Skirts were formed from a piece of conveyor belting 36 × 60 in. on one side and 12 × 60 in. on the other side. The 36-in. wide piece also acted as a dribble plate.

The belt wiper was made from a piece of conveyor belting attached to a 2 × 2 in. angle across the pulley. No counterweight or springs were used to maintain pressure against the belt. A sketch of this transfer point is attached.

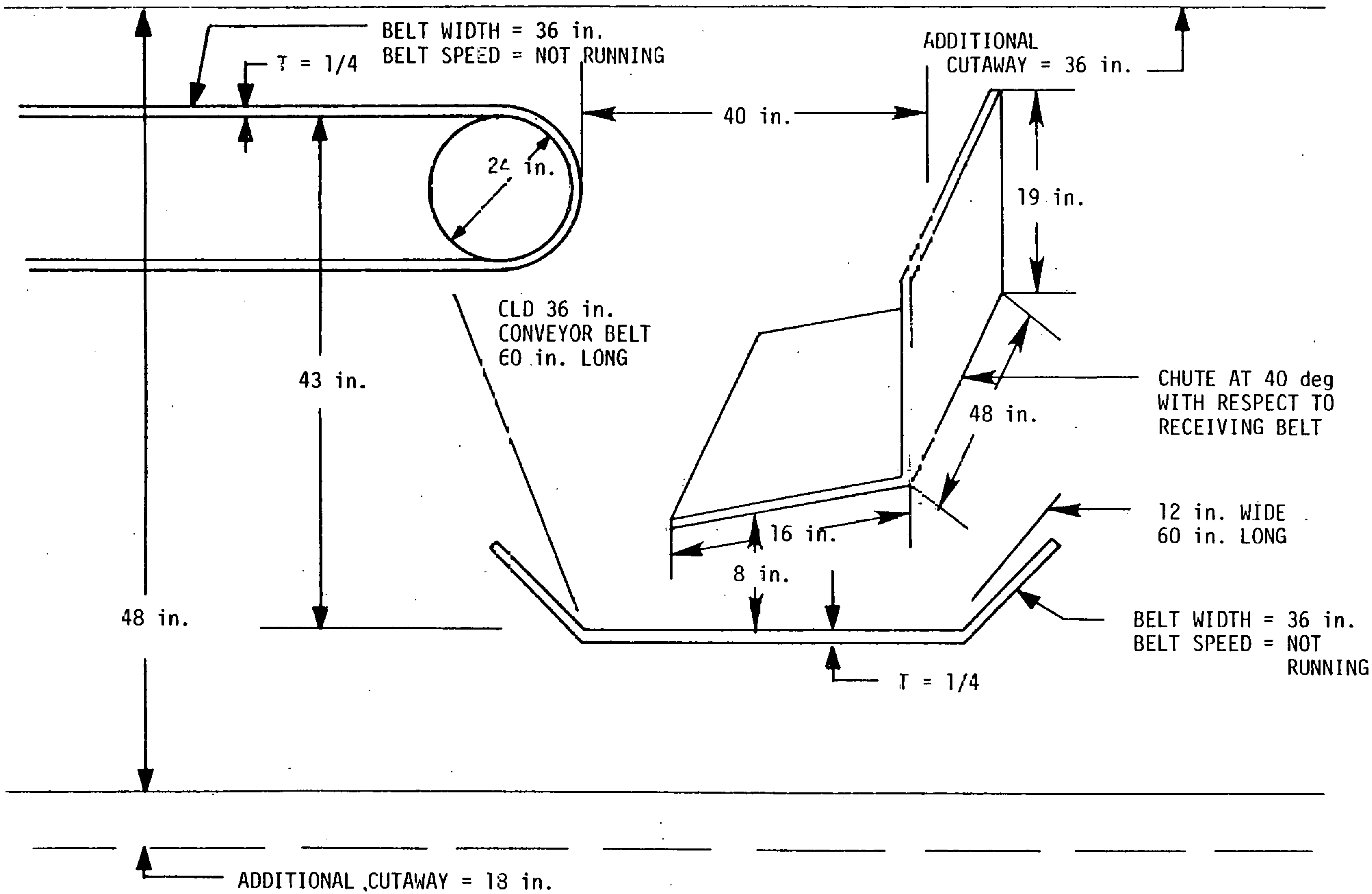

FIGURE 14. - Schematic of transfer point - Mine C - location No. 1.

At the second nonoperating transfer point the belt centerlines were at 90 deg. The chute was a half cylinder 36 in. in diameter, 48 in. long. This chute was at 25 deg with respect to the receiving belt. The distance between the top of the 36 in. feed belt to the top of the 36 in. receiving belt is only 36 in.; unfortunately, this transfer point was not in operation. It is thought that material would build up on a chute at 25 deg, particularly moist coal from a continuous miner. Again, strips of conveyor belt were provided to form skirts to center the coal on the receiving belt. A 1/2 in. wide piece of belt conveyor attached to a metal plate formed the belt wiper. No counterweight or springs were used.

Standard 35 deg troughing idlers were used, in the impact area at 28-1/2 in. spacing. This transfer point is shown in Figure 15.

The third transfer point utilized a deflector plate to transfer coal from a 36-in. belt at 400 ft/min to a 48-in. belt at 500 ft/min. The distance from the top of the feed belt to the top of the receiving belt is 36 in. The deflector plate dimensions are 1/2 × 17 × 60 in. The plate is angled across the receiving belt as shown in Figure 16. Strips of conveyor belting were used to help center the coal. The belt wiper was constructed by attaching a strip of conveyor belt to a 2 × 6 in. wooden plank without counterweight or springs. Standard 35-deg troughing idlers spaced at 12 in. were used in the impact area.

At the time of observation, the feed belt was not heavily loaded (edge distance was 6 in. each side) and the material deposited fairly well on the receiving belt with the help of the skirts.

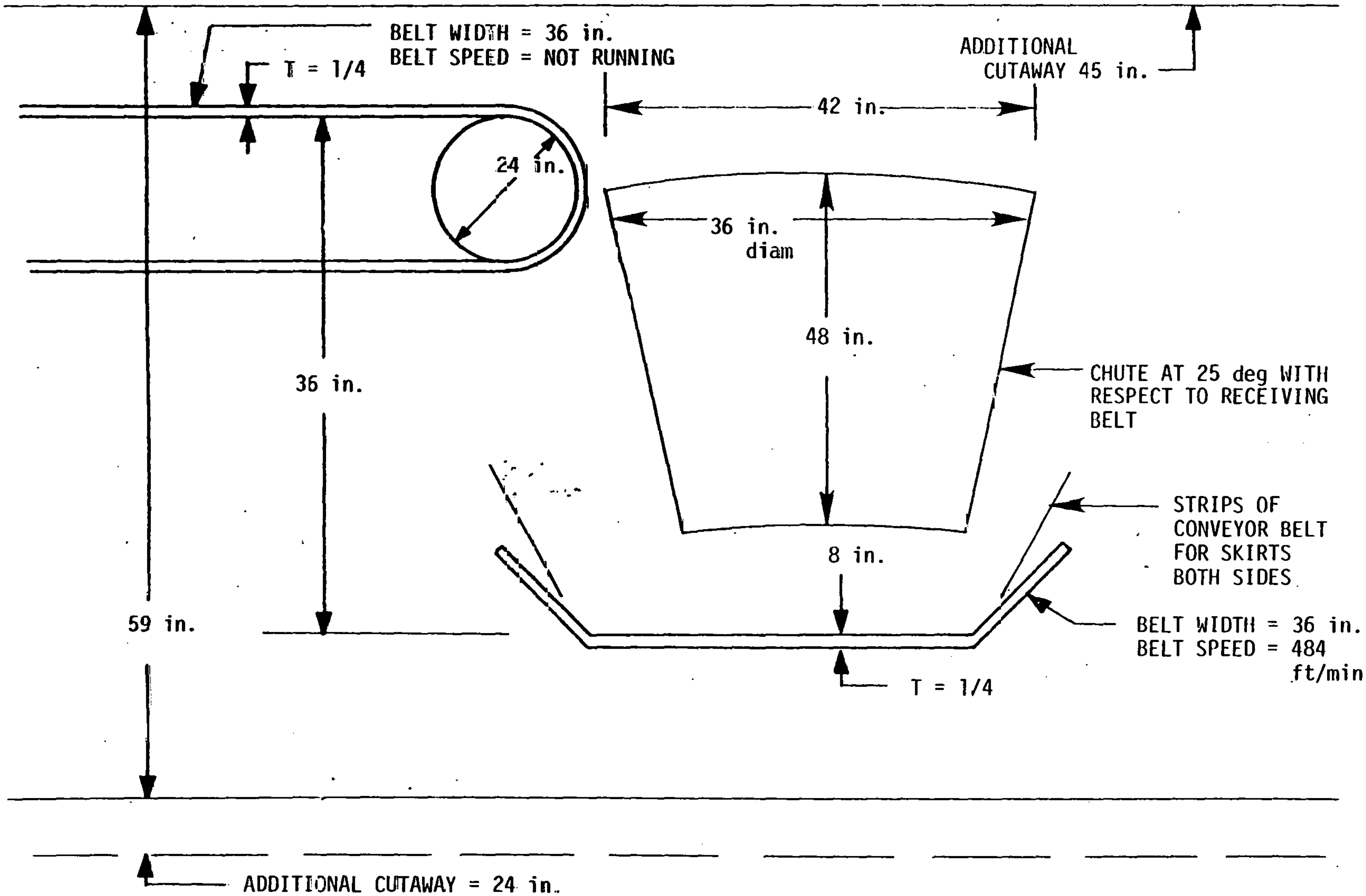

FIGURE 15. - Schematic of transfer point - Mine C - location No. 2.

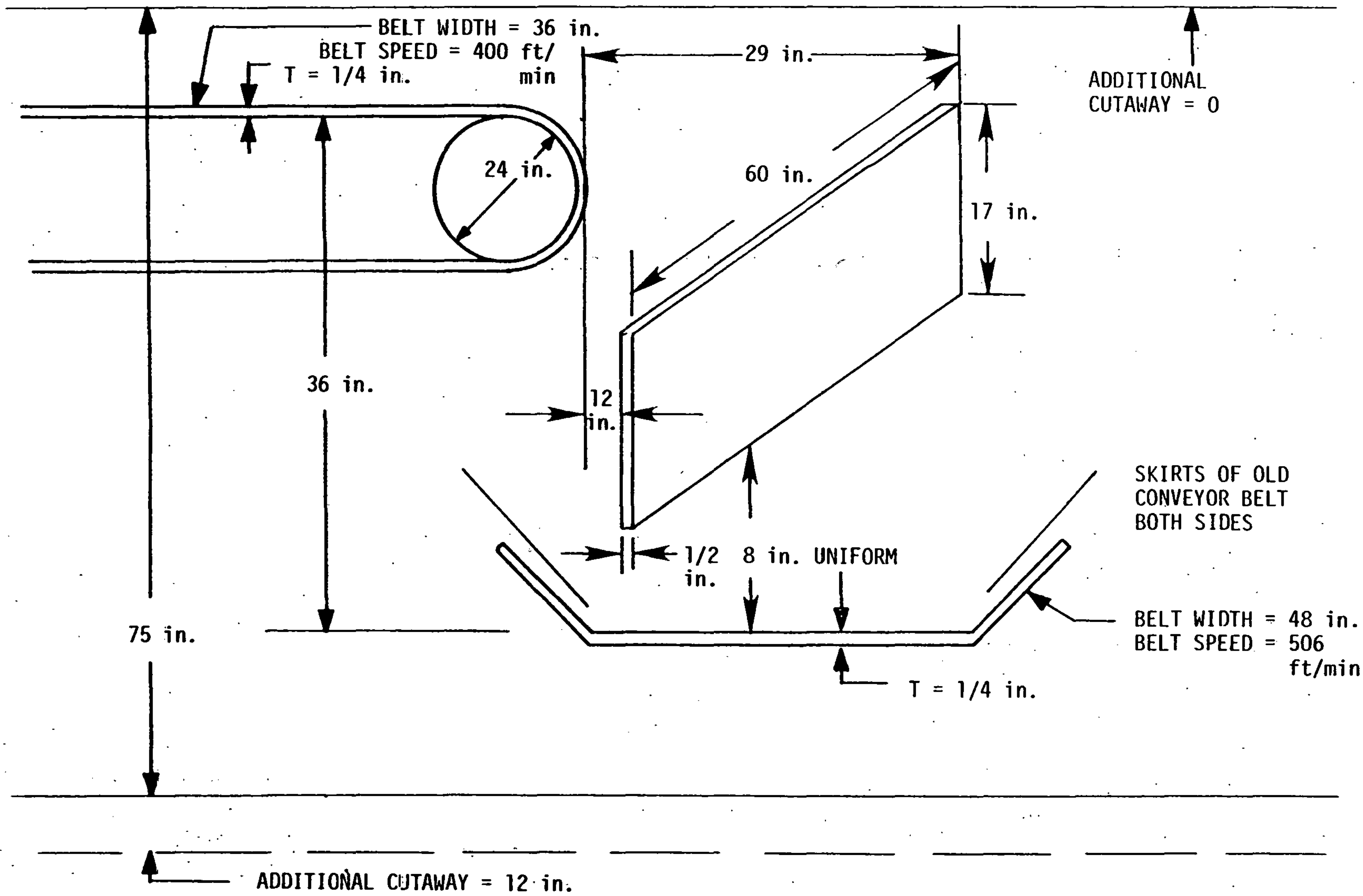

FIGURE 16. - Schematic of transfer point - Mine C - location No. 3.

Mine D

Three transfer points were observed at this mine. Two were at 90 deg and one was at 155 deg. All belts were 36-in. wide travelling at 450 ft/min. Pulleys are 16 in. in diameter and all transfers are at the tail pulley of the receiving belt.

At location No. 1, the distance from belt-to-belt is only 31-1/2 in. This transfer is outside on the side of a hill. The feed belt is angled up 10 deg. No chute is used: the coal is deposited directly on the belt, with skirt boards on each side of the receiving belt. A schematic of the transfer point is shown in Figure 17.

The receiving belt runs displaced on the idlers when the belt is empty. That is, the edge of the belt is up over the edge of the idler toward the feed belt. When coal is deposited on the receiving belt, the belt centers in the idlers and runs true with no spillage.

At location No. 2, the distance from belt-to-belt is 43 in. The included angle between belts is 155 deg. No chute is used: the coal is deposited directly on the receiving belt. Here also, skirt boards are used to prevent spillage and center the coal on the receiving belt. See Figure 18.

At location No. 3, the distance between belts is 49 in. A deflector plate is used to direct the coal onto the belt. Skirt boards on each side of the belt help center the load on the belt and prevent spillage. The feed belt is angled up 10 deg. This transfer is accomplished without detraining the belt. The load centers on the belt very well and no spillage was evident. A schematic of this transfer point is shown in Figure 19.

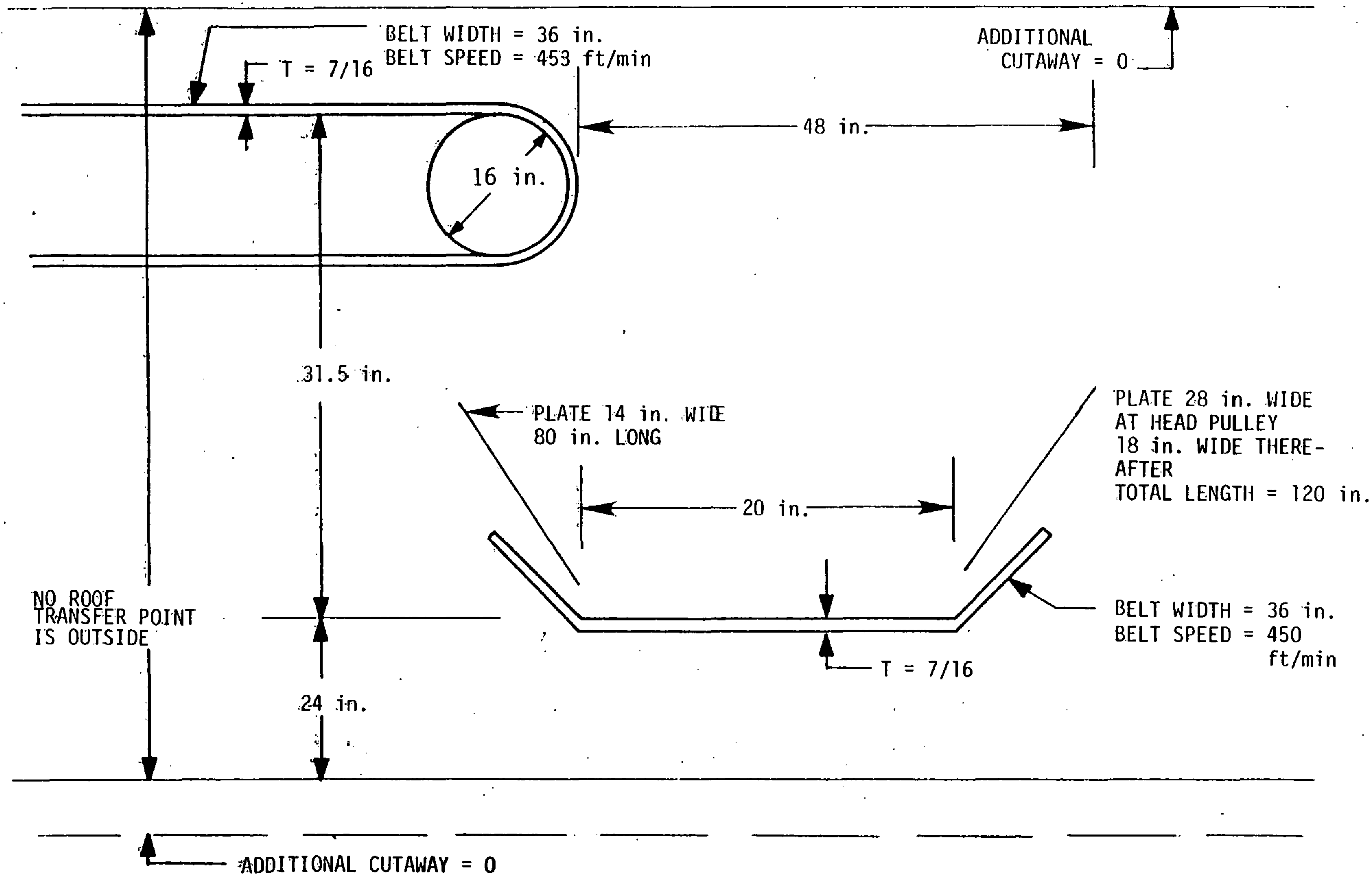

FIGURE 17. - Schematic of transfer point - Mine D - location No. 1.

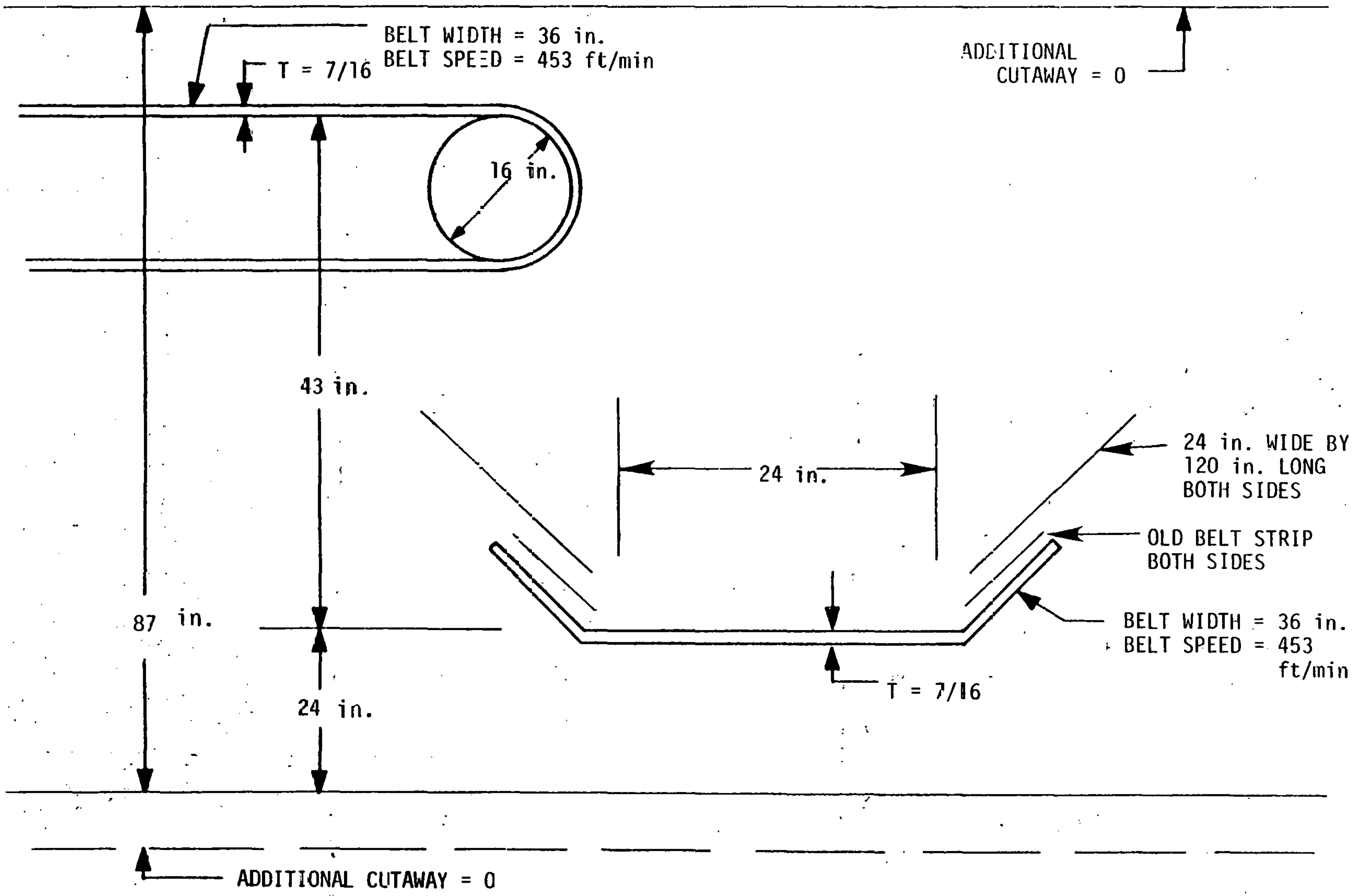

FIGURE 18. - Schematic of transfer point - Mine D - location No. 2.

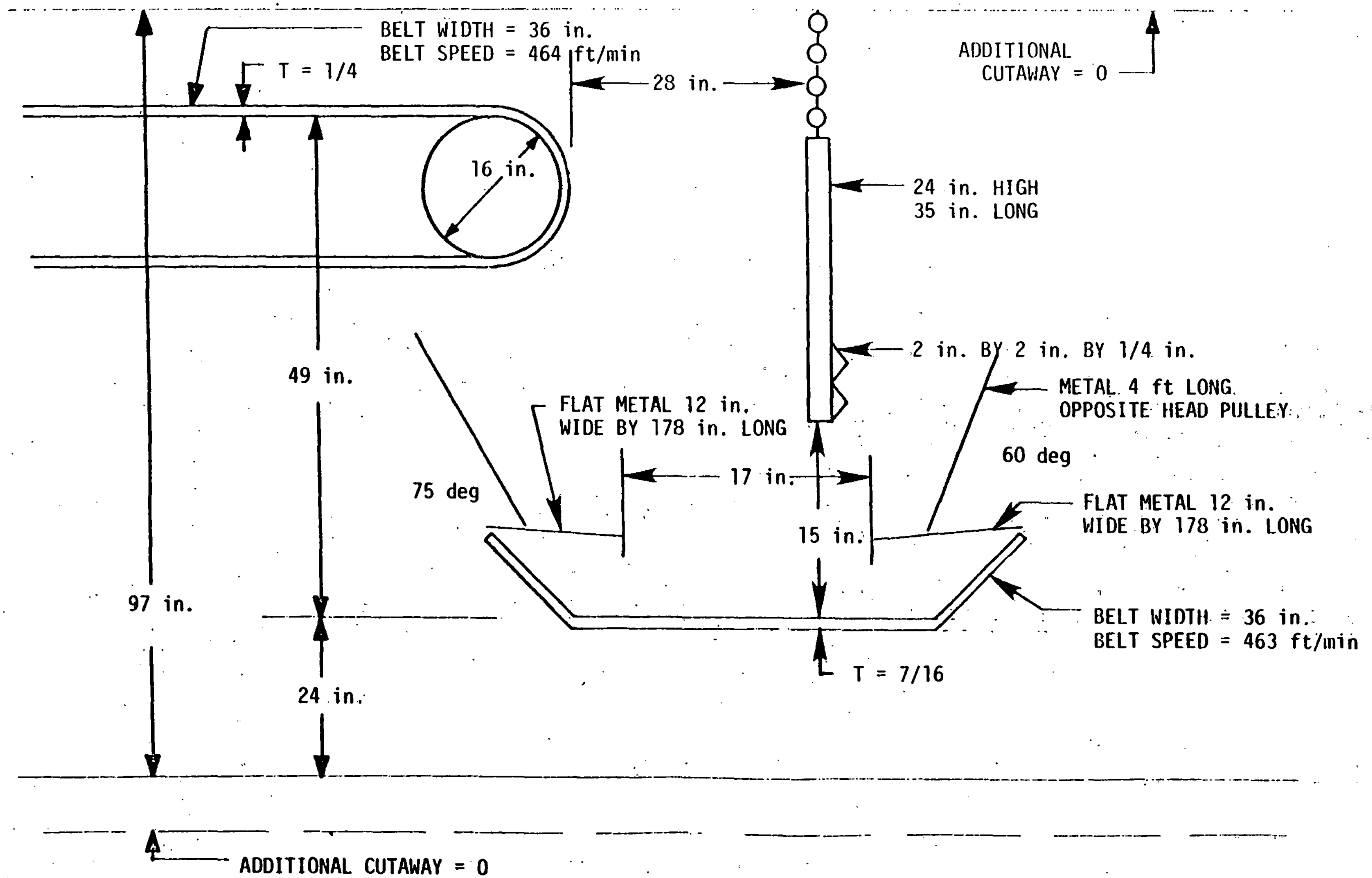

FIGURE 19. - Schematic of transfer point - Mine D - location No. 3.

APPENDIX B

MODEL TESTING

B.1 Chutes

Several chute concepts were generated during the conceptual design portion of Phase I. These concepts have been designated as follows:

- Deflector Plate - This design consists of a heavy plate supported from the roof on chain or wire rope. This plate may be at 90 deg to the feed stream of coal so that coal is directed down onto the receiving belt or at some angle to help deflect the coal in the direction of the receiving belt (see Figure 20).

- Stone Box - The stone box consists of a box arranged over the receiving belt so that the bottom plate cuts diagonally across the receiving belt (see Figure 4, found in Section 1). The coal builds up in the stone box until sufficient height is achieved so that the angle of repose is exceeded and the coal slides onto the receiving belt. The build up in the stone box also helps to deflect the coal in the direction of the receiving belt. This design, commonly found in installations handling very abrasive materials, eliminates chute wear almost entirely.

- Jay - This shape provides a flat extension of the half cylindrical section to interrupt the trajectory and direct the coal into the half cylindrical portion of the chute from which it deposits on the receiving belt (see Figure 21).

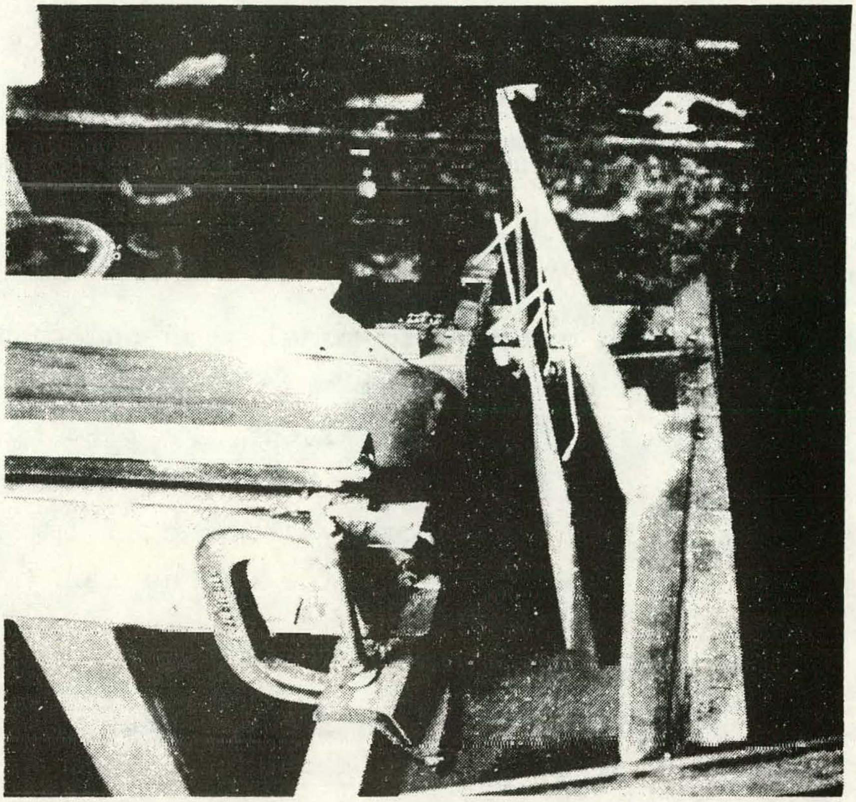

FIGURE 20. - Deflector plate.

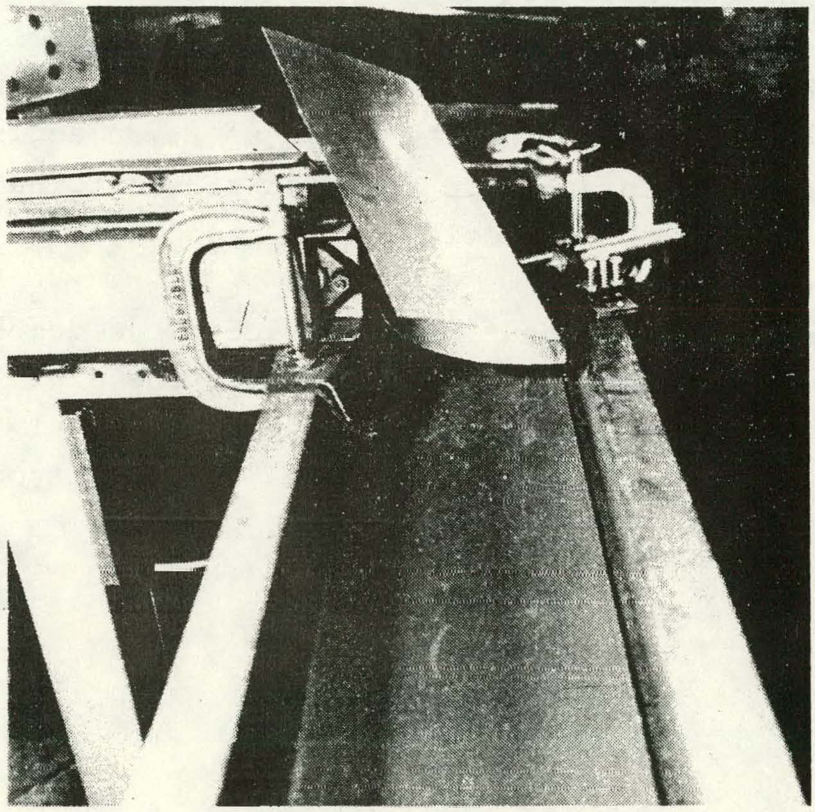

FIGURE 21. - Jay chute.

- Loop - This concept was designed to intercept the coal and turn the coal down and in the direction of the receiving belt using a single degree of curvature. This is similar to the jay shape with sides to contain the coal (see Figure 22).

- Can - This is an attempt to model a 55 gal drum. The can is a "Hi-C" can with one side cut away at an angle to provide access for the coal off the feed belt. It is similar to the jay except there is no vertical flat portion to turn the trajectory. The coal impinges directly against the curved side of the can (see Figure 23).

- Slide - This design is a two degree of curvature chute made with *flat surfaces* to turn the coal (see Figure 2, found in Section 1). The chute is arranged so that it will accommodate heavily or lightly loaded feed belts and deposit the coal centrally on the belt with little or no side vector. This is accomplished by creating a V trough and bringing the sides up at an angle. A plate is added at an angle to the feed stream to help divert the coal in the direction of the receiving belt.

- Hopper - This concept makes use of two sides and a rear, all at steep angles to direct the coal to the center of the receiving belt (see Figure 24). The bottom is open to allow the coal to deposit on the belt.

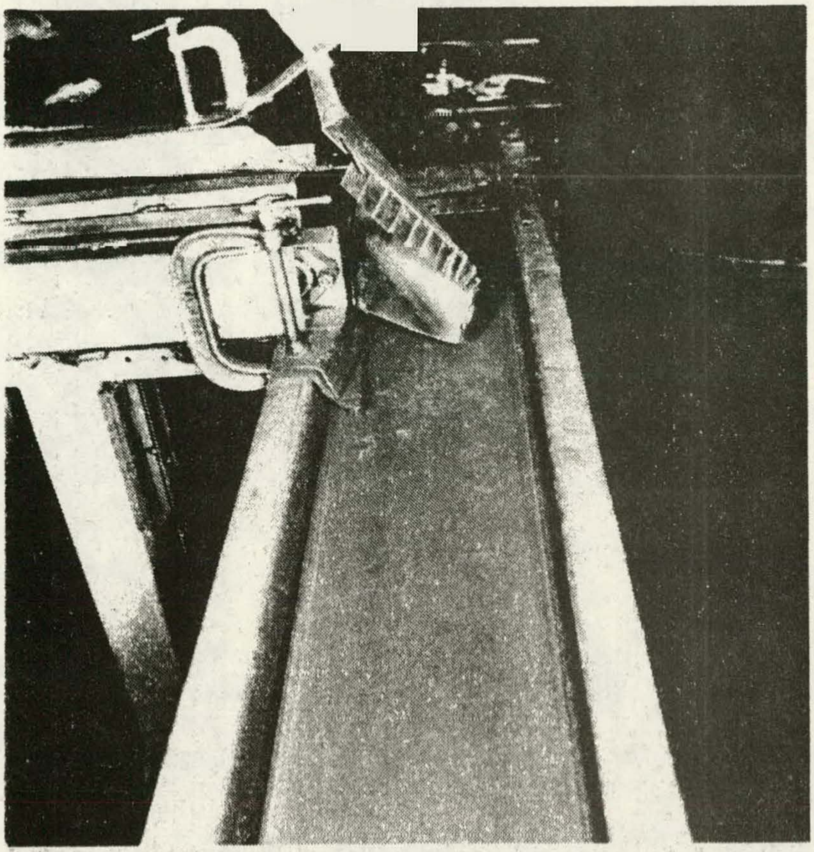

FIGURE 22. - Loop chute.

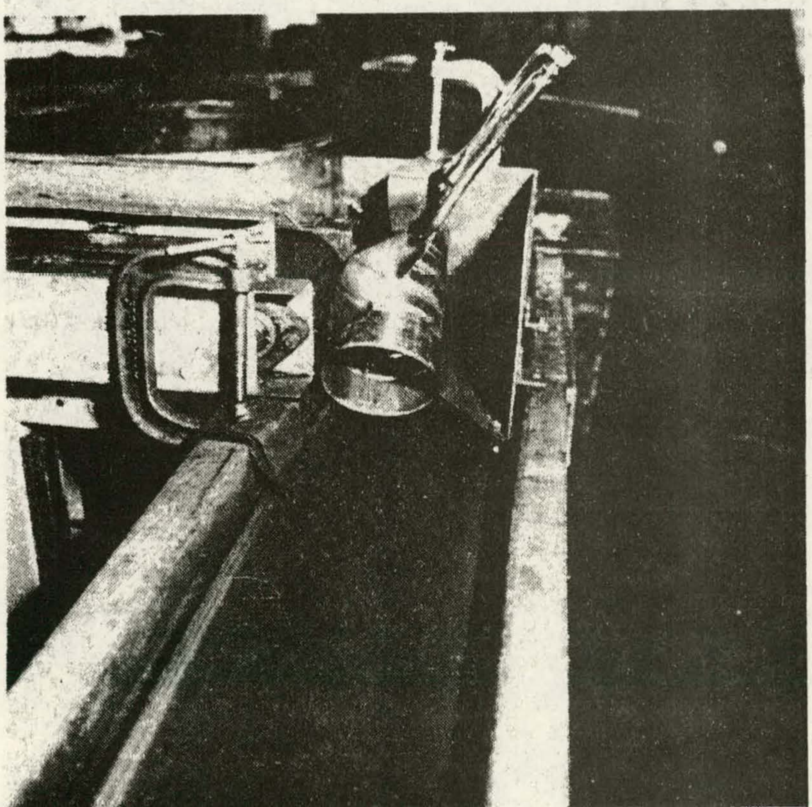

FIGURE 23. - Can chute.

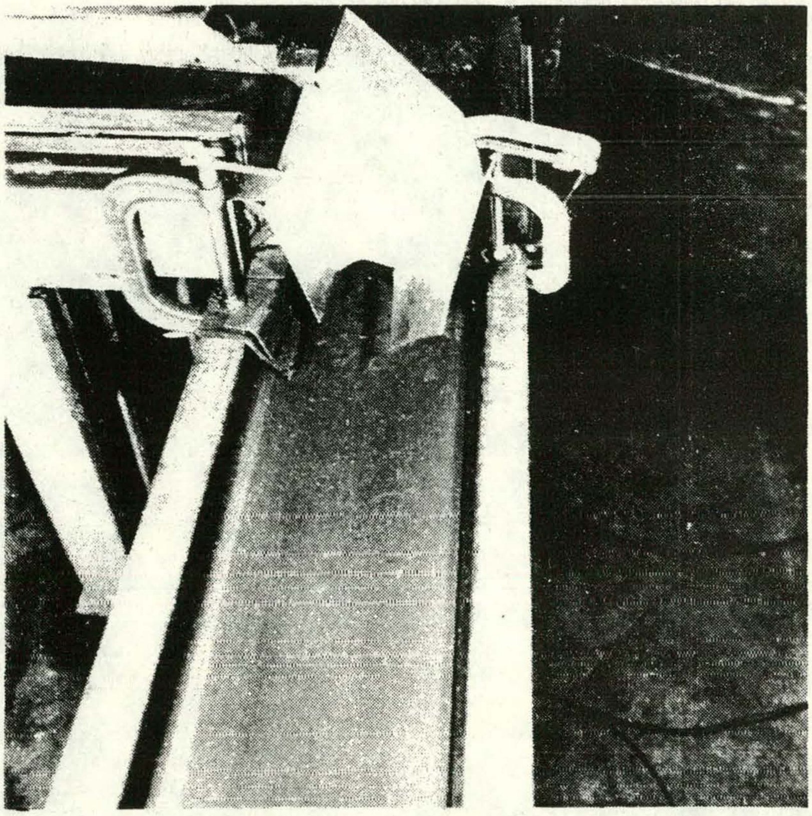

FIGURE 24. - Hopper chute.

- Catenary - Discrete circular wear segments are attached to a flexible backing in order to achieve a two degree of curvature chute with readily available and easily fabricated materials (see Figure 25). It is anticipated that the final chute would make use of 6-in. diam area discs attached to interlocking chains. Discs could be overlapping as in chain mail to prevent fines from building up between discs.

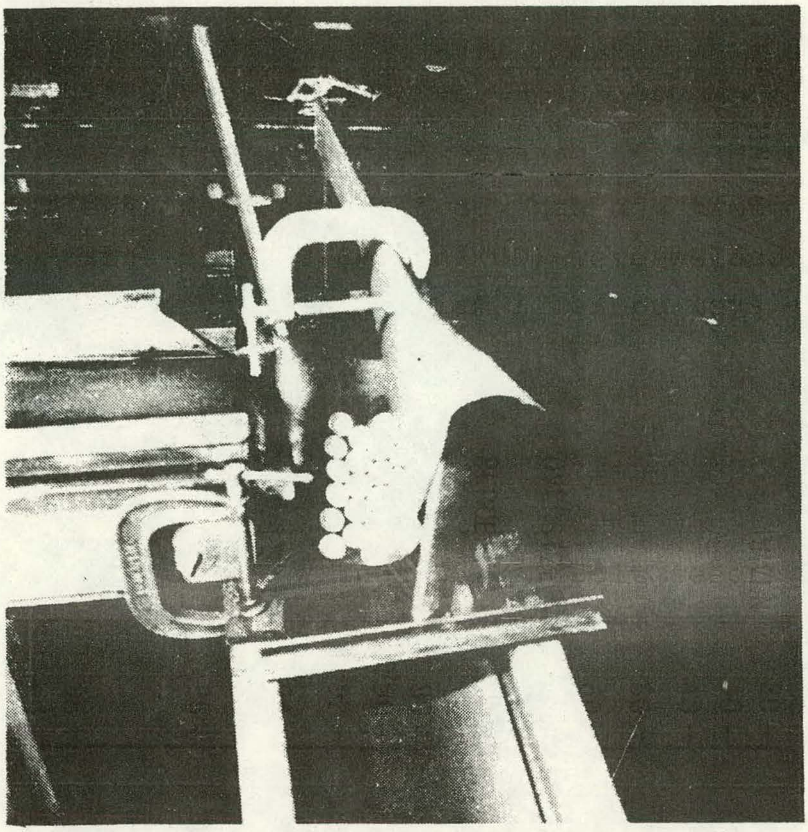

FIGURE 25. - Catenary chute.

B.2 Conveyors

Tests of the one-sixth size scaled-down models of chutes were conducted at the juncture of a 6-in. feed conveyor and an 8-in. receiving conveyor, both available from DOE as used on Contract No. ET-78-X-01-2415. Since the intent was to model the flow of 8 and 12 tons/min with a 36-in. belt feeding a 42- or 48-in. receiving belt, a 1/2-in. stripe was painted along each edge of the 8-in. belt to form a 7-in. width to simulate the 42-in. belt.

The 6-in. conveyor, as received, had a V trough. Three half sections of 3/8-in. pipe (0.675 in. OD) were welded in this V to approximate the effect of 4-in. diam idler pulleys (see Figure 26).

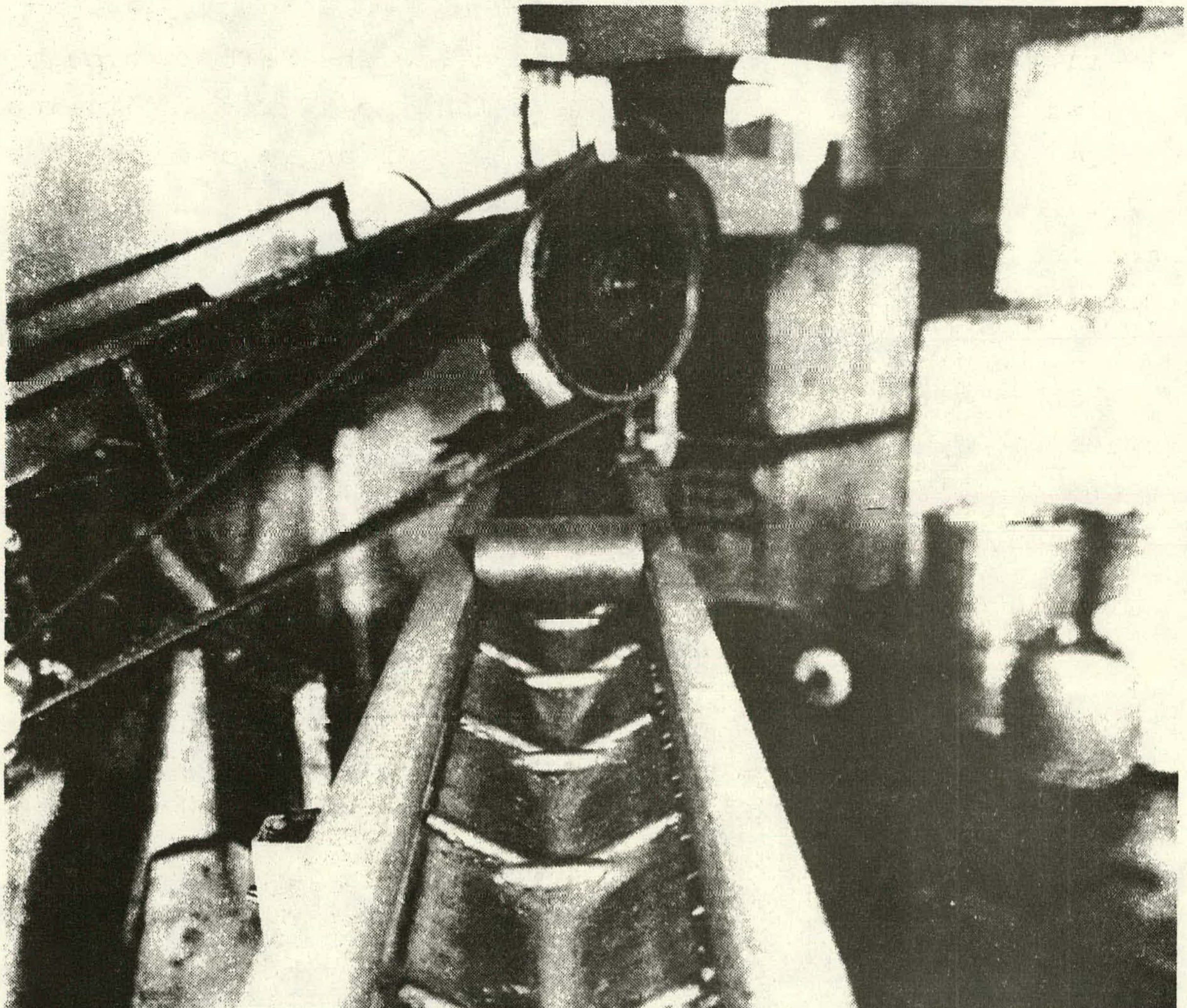

FIGURE 26. - Six-in. conveyor showing simulated idlers.

The 1/4-in. belt received with the conveyor was replaced with a 1/16-in. thick 2-ply nitrile belt to allow the belt to trough in the simulated idlers. The thinner belt also flexed sufficiently to allow the coal to settle into its proper angle of surcharge. A 12-in. wide conveyor 13-ft long was used to close the loop between the 8- and 6-in. conveyors (see Figure 1, found in Section 1).

Both the 6- and 8-in. conveyors are driven by a 1/13-hp motor reduced so the output shaft rotates at 288 rpm. The head pulleys are driven through chain sprockets. Variations in belt speeds are accomplished by changing sprockets.

The speeds used in the models were taken from general design practice for conveyor belts. From the CEMA handbook, 318 tons/hr is the capacity of a 36-in. belt operating at 100 ft/min with a material whose density is 100 lb/ft^3 and has a surcharge angle of 25 deg assuming a standard edge distance of {0.555 × belt width) + 0.9 in.}.

Standard engineering practice calls for the design capacity to be 115 percent of rated capacity which equals 9.2 tons/min for a rated capacity of 8 and 13.8 tons/min for a rated capacity of 12 tons/min. The required speed for the 6-in. belt can be derived from the formula

$$\text{tons/min equivalent} = \text{tons/min desired} \times A \times B$$

where

$$A = \frac{100}{\text{Actual weight/ft}^3 \text{ of Material}}$$

$$B \doteq \frac{100}{\text{Tons/min Conveyor Belt Speed Selected} = S}$$

For 8 tons/min rated capacity:

Tons/min equivalent = 5.3

Tons/min desired = 9.2

$$5.3 = (9.2)\left(\frac{100}{50}\right)\left(\frac{100}{5}\right)$$

$$S = \frac{(9.2)(100)(100)}{(50)(5.3)} = 347 \text{ ft/min}$$

For 12 tons/min rated capacity:

Tons/min equivalent = 5.3

Tons/min desired = 13.8

$$5.3 = (13.8)\left(\frac{100}{50}\right)\left(\frac{100}{5}\right)$$

$$S = \frac{(13.8)(100)(100)}{(50)(5.3)} = 521 \text{ ft/min}$$

Since the scale for the model belt conveyor is one-sixth, the model belt speed will be $1/\sqrt{6}$ of the actual belt speed. The belt speeds for the model will be:

For 8 tons/min simulation, belt speed $= \frac{347}{\sqrt{6}} = 142$ ft/min

For 12 tons/min simulation, belt speed $= \frac{521}{\sqrt{6}} = 212$ ft/min.

Using a 14-tooth drive sprocket and a 26-tooth driven sprocket, the belt speed developed from the 288 rpm output of the gear reducer is 144 ft/min.

Using a 14-tooth drive sprocket and a 17-tooth driven sprocket, the belt speed developed from the 288 rpm output of the gear reducer is 220 ft/min.

The 8-in. belt was operated at 314 ft/min to create sufficient trajectory at the discharge of the 8-in. belt to deposit coal on the 12-in. sloped belt closing the loop. This is equivalent to a speed of 767 ft/min for the full-scale belt. This is a little on the high side for the receiving belt, but tends to be on the conservative side when determining the efficiency of passage through the chute.

Continuous operation through closing the loop was chosen over batch type of operation since it was felt that a better understanding of the operation of the chute would result from observing the chute for longer periods of time. Also, varying the flow rate at a particular belt speed would be relatively easy.

Bituminous coal was used throughout the testing to evaluate the operation of the chutes at varied moisture contents; water was added as necessary throughout testing to control dust generation. The use of bituminous coal in the closed loop operation produced some size degradation, resulting in coal particles with few corners. Fines were carried out of the system and had to be continuously reinserted into the loop.

B.3 Test Equipment

Tests were conducted to determine moisture content and size consist of the coal. Comparative data on sound levels for each of the chutes was obtained. Strobe photographs were taken of a reflective ball passing through the chutes to ascertain the flow efficiency of the chutes. Test data for each of these are included below.

B.3.1 Moisture Level

Samples of coal were taken on each of 7 days for moisture level determination. The samples were dried in an oven at 215°F for 6 hr. The results are shown in Table 2.

The data shown represent the range of moisture that the coal contained for the test period. Continuous passage through three transfer points and along three belts necessitated the addition of water often during the day.

B.3.2 Size Consist

Samples were taken daily for 7 days. The sieve analysis sheets and plots are included in Appendix D. The data show very little fines content. This results from fines being trapped in the coarse surface of the canvas belt on the 8 in. conveyor and deposited in the cavity housing the return belt. Attempts to add a belt scraper to this belt caused excessive friction and either stalled the motor or resulted in erratic speed of the conveyor belt. As a consequence, the fines were cleaned out of the cavity and added to the coarse particles during evaluation of the chutes.

The average of the test results is shown plotted on the graph for the average size distribution for continuous and conventional mining in Figure 27. The curve shows some deviation, but generally follows the trend for both the continuous and conventional mining.

B.3.3 Sound Measurement

Sound levels were taken on a B&K 2209-4165 sound level meter. The data were taken with the probe 24 in. from the surface of the chutes for simulated 8 and 12 tons/min flow rates.

TABLE 2. - Moisture content

Date	Gross wet weight (g)	Gross dry weight (g)	Difference (g)	Net wet weight* (g)	Moisture (percent)
3/12/80	209.4	204.9	4.5	113.5	3.96
3/13/80	303.4	296.5	6.9	207.5	3.33
3/14/80	304.0	281.0	23.0	208.0	11.05
3/17/80	289.0	279.0	10.0	193.1	5.18
3/18/80	308.0	300.0	8.0	212.1	3.96
3/19/80	251.8	244.0	7.8	155.9	5.00
3/21/80	275.0	264.0	11.0	179.1	6.14

*Canister weight = 95.9g

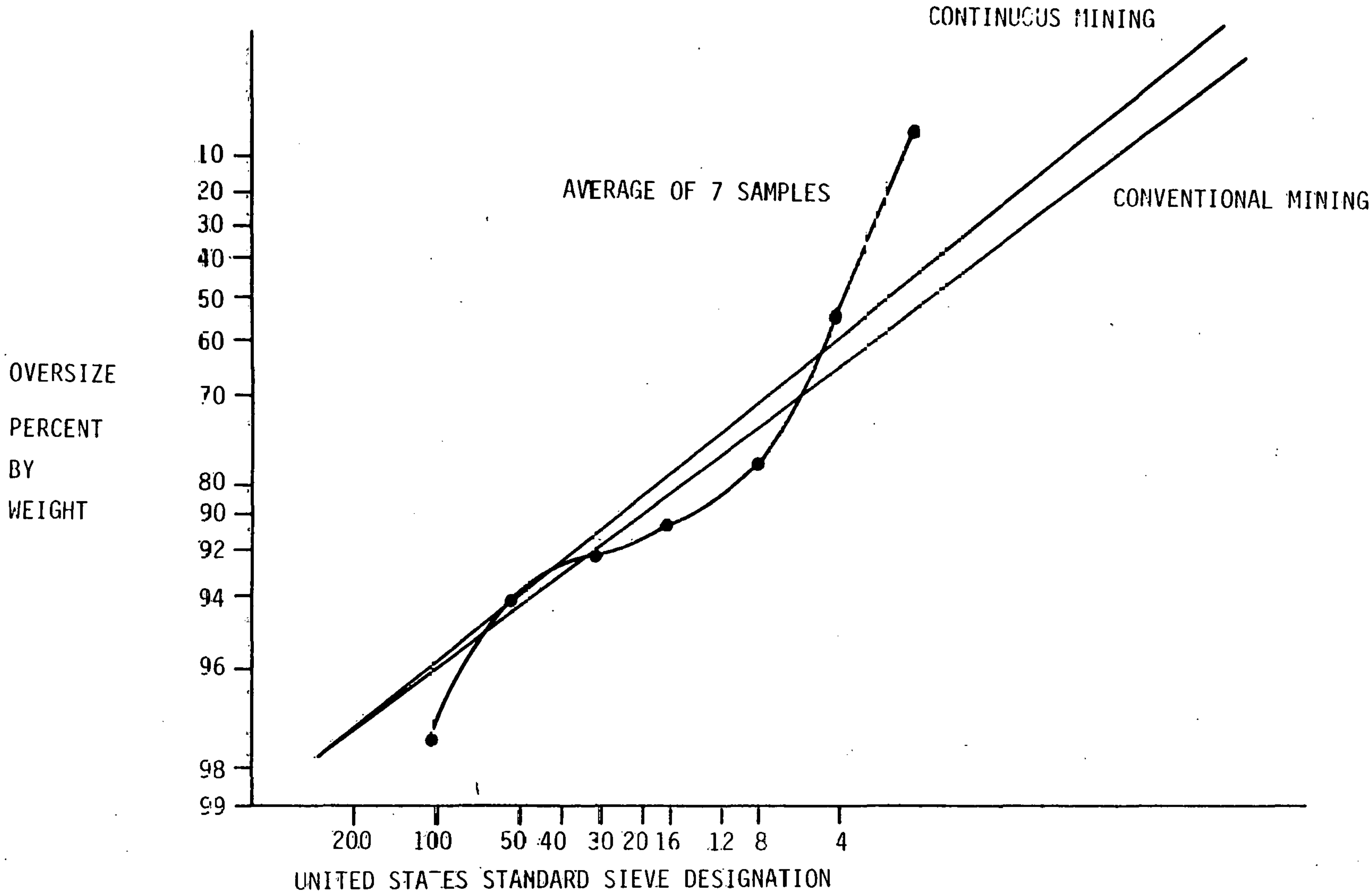

FIGURE 27. - Average size distribution of bituminous coal.

The intent here was not to scale up noise levels to the full-scale operation, but to develop an objective ranking of the chute flow efficiency; it was felt that flow turbulence would generate a detectable noise level increase, thereby signaling a bad chute design. The results are shown in Table 3.

The test results show only a small increase in sound levels for the chutes over the background with the conveyor on. The data show that the laboratory conveyor is responsible for most of the noise measured. This is not usually the case underground. It is difficult to form any significant conclusions from the measured data apart from the fact that lining the chutes with rubber will reduce sound levels.

B.3.4 Efficiency in Passing Through Chute

Photographs were taken using a Graphlex 4 × 5 camera with a Polaroid attachment. An aluminum sheet rolled into a ball was deposited on the coal on the feed belt and the camera shutter opened until the ball passed through the chute while the Strobotac, pulsing at either 150 or 200 pulses/min, provided time spaced bursts of light to capture the image of the ball on the film at discrete locations on the conveyors and in the chute. A typical photograph is shown in Figure 28. See Appendix E for calculations and a full set of strobe photographs for 8 and 12 tons/min simulation.

Table 4 shows the figure of efficiency for the ball passing through the chute. The calculations determine the distance the ball travels on each conveyor belt and the time required on each belt to travel this distance.

TABLE 3. - Noise levels 24 in. from back of chute

Chute	6 in. conveyor speed	Sound level
Jay	144 ft/min	77-79
Loop	144	76-78
Deflector plate	144	77-79
Stone box	144	76-77
Can	144	77-79
Slide	144	77-79
Catenary	144	75-76
Hopper	144	77-79
Jay	220	77-78
Loop	220	77-78
Deflector	220	77-78
Stone box	220	77-78
Can	220	77-78
Slide	220	77-78
Catenary	220	76-77
Hopper	220	77-78
Jay with rubber lining	220	76-77
Deflector plate with rubber lining	220	76-77
Background (conveyor off) = 69 dB		
Background (conveyor on) = 76.77 dB		

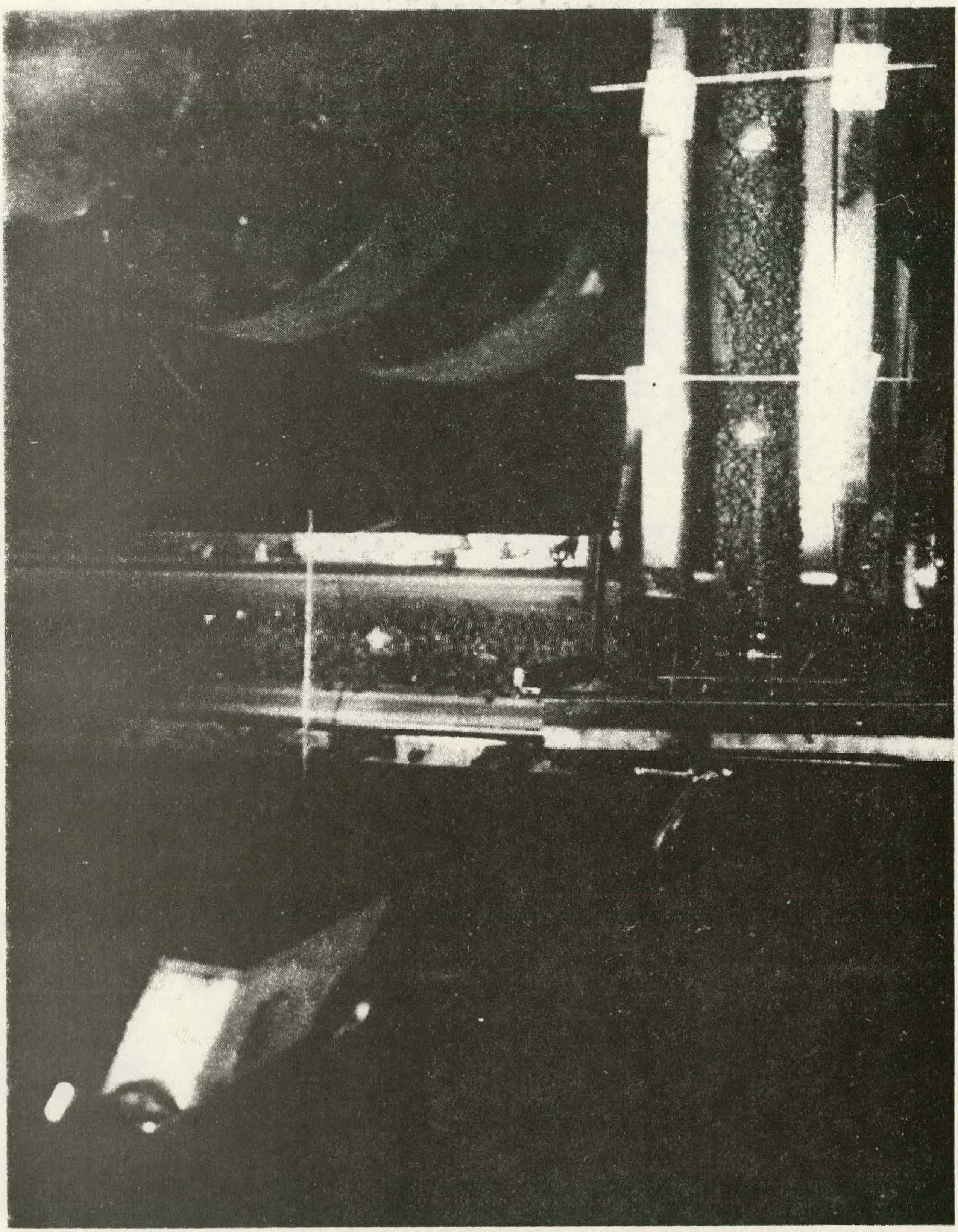

FIGURE 28. - Stone box chute. Strobotac pulsing at 200 pulses/min.

TABLE 4. - Efficiency in travelling through chute

Chute	Efficiency at simulated 8 tons/min	Efficiency at simulated 12 tons/min
Jay	43.4 %	38.4 %
Loop	37.7	31.8
Deflector plate	39.9	49.6
Stone box	33.6	36.8
Can	47.9	35.5
Slide	45.1	43.4
Catenary	42.0	47.7
Hopper	38.5	38.3

It is interesting that for five of the chutes, the efficiency is less at a simulated 12 ton/min that at 8 ton/min. These five chutes quickly choked when a great volume of material passed through them.

B.4 Performance

The eight chutes tested were observed for their ability to deposit the coal evenly and centrally on the conveyor. The direction of the vector the coal assumed in depositing on the receiving belt was also noted. The chute was rated also on its tendency to cause spillage. The chutes generally deposited fairly centrally and evenly. None of the chutes showed marked superiority over all other chutes. The differences between chutes are not glaring, but are rather subtle. One problem working with a one-sixth scale model is that all irregularities in flow and difference in performance between chutes are scaled down by a factor of six. Differences in chutes tend to be hidden. Likewise, a full-scale test will undoubtedly reveal features overlooked in the model. Photographs showing coal flowing through the chutes are included in Appendix F. A brief description of each of the chutes with respect to the characteristics stated above is given in the following subsections.

B.4.1 Jay

The half cylinder works very well in directing the coal onto the receiving belt at low and high speeds of feed belt. The angle between the horizontal and the bottom of the jay is 35 deg. This chute centers the coal well and deposits the coal evenly on the belt. This chute does deposit the coal on the belt with a vector tending to move the belt toward the feed belt. It is also sensitive to alignment between the receiving belt and the chute. It is limited in the size of large lumps that it will pass. The model passed a 3 × 4 × 5 in. piece of coal, equivalent to 18 × 24 × 30 in. full scale.

When the chute is heavily loaded, the coal builds up at the rear of the chute and spills over the rear of the chute.

B.4.2 Loop

As originally conceived and presented in the proposal, the loop was formed from a cylindrical surface which "caught" the discharge of the feed belt on the top of the trajectory and "looped" it over onto the receiving belt. Design layouts revealed that in order to have the trajectory impact nearly tangential to the chute surface, a flat section was required in the impact zone. Additionally, the loop radius became so small for the given transfer that choking in the loop occurred at moderate flow rates.

The loop was installed with the bottom of the loop at a 35 deg angle with respect to the horizontal receiving belt; the flat portion of the loop was at 45 deg when measured in line with the feed belt. This chute directed coal to the receiving belt quite well. This design required very little help from the side skirts to locate the coal in the center of the belt. Attempts to have the trajectory hit the flat portion of the chute resulted in the coal backing up in the chute with the feed at 144 ft/min. The angle of the chute with respect to the receiving belt determines how well centered the coal will be on the receiving belt. Again, when the feed belt is heavily loaded, the coal accumulates at the back of the chute and spills over the back onto the receiving belt. The need for skirt boards is greater for the larger flow rate, that is, 12 tons/min simulation.

B.4.3 Deflector Plate

Coal is deflected down and to both sides of the receiving belt. Skirts help to line up the coal on the receiving belt, and without skirts spillage would be a problem. The problem is lessened at the slower rate, that is, 8 tons/min simulation. In turning the deflector plate 35 deg with respect to the feed belt, the coal hits the receiving belt with a vector away from the feed belt. Behavior at heavy loading is about the same as for normal loading. This design, with the plate hung from the roof, would allow large chunks of coal to pass through the chute. When loading is light, the coal barely hits the deflector plate and is practically equivalent to depositing directly onto the receiving belt.

B.4.4 Stone Box

The stone box depends on the build up of material in its interior to form the surface on which the coal slides around the right angle transfer. To prevent wear on the belt and head pulley, it is preferable that the accumulated material not bury the head pulley. For that reason the stone box concept is better suited for higher belt speeds which allow the stone box structure to be positioned away from the pulley. The model rock box tested was configured, then, to suit the 12 tons/min higher belt speed arrangement and was not very effective at the slower speed of feed belt; the coal just barely contacted the diagonal of the box. Skirts help to keep material in the center of the belt at the high feed belt speed. The flow action is not merely that of hitting the coal in the box and dropping down on the belt, but the coal is deflected in the direction of the receiving belt. At the slower speed, the coal is deposited on the receiving belt with a vector that detrains the belt away from the feed belt. A vector tending to detrain the belt away from the feed belt remains at the higher feed rate but the amount is lessened.

B.4.5 Can

The can is an attempt to model a 55 gal drum. The can moves the coal onto the receiving belt very well at the lower flow rate simulation; coal centers well and has very little vector to detrain the belt, and spillage is minimal. The location of the chute is sensitive to the angle of the chute with respect to the feed and receiving conveyors: the can must be in close to the feed conveyor and must be at an angle with respect to the direction of the receiving belt to assure deposit on the center of the belt with little or no vector. Skirt boards help to center the coal on the receiving belt and reduce spillage. When the loading is increased to the 12 tons/min simulation, the can tends to fill up as coal backs up and spills out the rear. The coal is deposited with a slight vector, detraining the belt away from the feed belt. This design proved to be the most restrictive of all the designs with regard to the maximum size of chunks that will pass through it.

B.4.6 Slide

This chute deposits very well on the receiving belt for high and low flow rates (wet or dry). The slide is at 35 deg with respect to the horizontal. The introduction of a flat plate at an angle to the feed stream helps to direct the coal in the direction of the receiving belt so that coal does not build up at the rear of the slide at heavier loading; the slide without this feature allowed coal to build up at the top rear of the chute. The coal deposition on the receiving belt does not have a vector tending to detrain the belt. Moisture tends to slow the coal going through the chute, but not sufficiently to create a problem. The slide permits large chunks to pass through the transfer point. During tests a 5 × 5 × 5 in. cube passed through the chute. Spillage is no problem at all. The flat plate design is relatively easy to fabricate and assemble in a mine. The slide can be maintained fairly simply by bolting or welding in wear plate on the two surfaces most heavily affected by the moving coal. The alignment of the chute with respect to the feed belt and receiving belt must be maintained for proper operation of the chute.

B.4.7 Catenary

When small quantities are fed, the material deposits on the inside of the receiving belt toward the feed belt. When a large flow rate is delivered, the coal builds up in the back of the chute. Deposition on the belt is uniform and centered. The chute handles fairly large lumps and passed 3 × 4-1/2 × 5 in. lumps of coal. The angle needed for the centerline of the chute to prevent coal from backing up over the rear of the chute is 45 deg; at this angle coal remained at the rear of the chute but did not overflow over the back of the chute. Skirts are required to center the coal on the belt and prevent spillage for the full range of flow rates.

B.4.8 Hopper

The hopper deflected the coal in the direction of the receiving belt very well. The open bottom allowed coal to flow out the bottom to each side at low flow rates; at high flow rates the flow was more stabilized and the chute acted like a hopper. The coal was centered on the belt uniformly and evenly, but the coal came off the edge away from the feed belt and created a vector to detrain the belt toward the feed belt. The addition of a short piece of metal under the opening at the bottom of the chute helped to choke the flow slightly, reduced the sideways flow out of the bottom, and reduced the vector of the coal deposited on the receiving belt. This chute allows a fairly large chunk of coal to pass: the model passed a 3 × 4-1/2 × 5 in. lump of coal.

APPENDIX C

CHUTE ASSESSMENT

C.1 Methodology

The eight models were evaluated and ranked using a methodology technique based on their performance, compatibility for operation underground, and economic factors. These general categories were weighted so that performance counted for 40 percent of the mark with mine operation and economics weighted at 30 percent each.

The characteristics that were used to establish the performance score were further divided between loading accuracy, 40 percent, sensitivity of loading to changes in material characteristics, 40 percent, and secondary considerations, 20 percent. Information from all sources (personal observation, consultants, mine operators, and calculations) indicates that *centering of the load on the receiving belt is the single most important function of the transfer chute.* A belt with an off-center load is subjected to gravitational forces acting to shift the center of gravity (CG) of the load (and, therefore, the underlying, supporting belt) so that the load CG is centered between the angled idler side rolls. The direction and speed of the loaded material, although important, play a less significant role in chute performance because dust, belt carcass wear, and material spillage can be controlled by auxiliary devices. Excessive dust generated by turbulence due to acceleration of material as it lands on the receiving belt is controlled by adequately wetting the coal. Belt carcass wear attributable to material acceleration is generally disregarded as a factor in belt performance. Spillage which is caused by the speed or direction of the loaded material not being equal to the receiving belt is best controlled through the use of adequate skirtboards.

Because the amount of material being conveyed at any particular moment and its moisture content are constantly changing in the mine environment, the sensitivity of the performance of each chute to these characteristics was weighted as 40 percent of the performance score. A chute that behaves properly only at one tonnage rate should not be considered highly for the mine application.

Secondary factors provide the remaining 20 percent of the performance ranking; although a factor, these considerations can generally be overcome. It is preferable that the chute be relatively insensitive to the accuracy with which it is aligned due to the hostile mine environment. A cohesive material stream exiting from the chute aids alignment of the chute, but can be accomplished with appropriate baffle or side plates added to the chute. The chute design that can accommodate changes in conveyor belt velocity without major design modifications is much more apt to be accepted into mines with extensive belt conveyor systems.

Included in the 30 percent category of mine operation were headroom reduction (35 percent), chute efficiency (30 percent), tendency to choke or plug (20 percent), and the overall complexity of the installation (15 percent). These factors are intended to judge how well a particular chute design fits into the mine environment, and there is some overlap with the performance category. In particular, the amount of dust and spillage generated by a chute design is important not only in the manner that it contaminates the mine, but also as an indication of how well the chute itself is performing its function. Likewise, a chute that plugs up once a day obviously disrupts the mining operations, but it is also therefore a bad performer.

Headroom, the reason for the contract, is of course critical. Whether or not they can actually achieve the goal of a 42-in. belt-to-belt distance, the chutes have been scored on how close they can come to this goal. Checks made on the models indicate the following minimums:

Chute	Minimum full-scale belt-to-belt distance (in.)
Deflector plate	33
Stone box	33
Can	36
Slide	39
Jay	36
Loop	36
Catenary	42
Hopper	39

Additional testing of the slide chute indicated that a belt-to-belt distance of 30 in. can be achieved without detracting from performance.

Chute efficiency is broken up into dust, spillage, chute wear, and noise. Dust and spillage are weighted the most heavily because they must be contended with on a daily basis. Noise is weighted low because the mine transfer points are normally unmanned.

The tendency of a chute to plug due to large lumps or surges in flow contributes 20 percent to the mine operation score. Because most mine belts observed were running considerably below capacity and it is possible to load the feed belt up only to a certain amount before overflowing, surge capacity can be designed into a chute and was therefore weighted lower than the capability of a chute to pass unexpected large blocks of coal.

An abnormally complex arrangement is undesirable because it is difficult to maintain, more prone to damage, and generally less likely to be implemented in the mine. This category overlaps some of the headings included in the economics section.

The 30 percent overall economic score is subdivided into maintenance (60 percent), and purchase (40 percent); maintenance is considered of more importance because it is a continual consideration whereas purchase is a one-time factor. The maintainability score takes into account the following items:

- Ease of adjustment
- Frequency of adjustment
- Ease of repair
- Frequency of repair
- Frequency of spillage clean-up.

It should be noted that one column in Table 5 indicates the individual contribution of each line item after all weighting factors have been multiplied. The high individual contribution allocated for maintainability is a reflection of the concern given to this factor by mine personnel who must contend with it from day to day.

Discussions with mine personnel indicate that the transfer chute might be constructed underground at the transfer point, as would any repairs. Ease of fabrication or producibility has therefore been weighted equal to the initial cost, which includes the cost of the manhours to fabricate the design.

TABLE 5. - Methodology for transfer chutes

Percent	Scoring category	Percent breakdown	Itemized breakdown	Score	Description	Percent	Deflector plate	Stone box	Can	Slide	Jay	Loop	Catenary	Hopper
40	PERFORMANCE	0.40	IMPACT VECTOR	4	Center	8.0	2	1	2.5	4	3	4	3	3
				2	Direction	4.0	1.5	1.5	2	4	2	4	3	2
				2	Speed	4.0	3	1	1	2	3	2	3	3
		0.40	SENSITIVITY	3	Load	9.6	2	3	3	3	3	1	2	2
				2	Moisture	6.4	4	4	2	3	2	2	1	2
		0.20	MISCELLANEOUS	2	Alignment sensitivity	2.7	2	3	2	2	1	1	2	2
				2	Steam cohesion	2.7	1	1	2	4	3	4	4	3
				2	Velocity sensitivity	2.7	2	3	2.5	3	3	3	2	2.5
30	MINE OPERATION	0.35	HEADROOM	5	Amount of reduction	10.5	4	3	3	2	3	3	1	2
		0.30	CHUTE EFFICIENCY	4	Dust	2.8	1	1	2	3	3	4	2	3
				4	Spillage	2.8	1	1	2	4	3	3	2	2.5
				3	Wear	2.1	1	4	2	1	2	3	3	2
				2	Noise	1.4	2	4	3	3	3	3	1	3
		0.20	JAM	4	Maximum cube	4.0	3	4	1	4	2	2	2	3
				2	Maximum flow	2.0	4	4	2	3	3	3	2	3
		0.15	INSTALLATION	2	Complexity	4.5	4	4	3	3	3	2	4	2
30	ECONOMICS	0.6	MAINTENANCE	4	Maintainability	18.0	4	4	2	3	2	3	1	2
		0.4	PURCHASE	3	Producibility	6.0	4	4	3	3	2	1	2	3
				3	Initial cost	6.0	4	3	3	2	2	2	2	2

C.2 Scoring

The methodology along with the itemized scoring of the chutes is listed in Table 5. Scores for each listing were derived from the following schedule:

Superior	4.0
Good	3.0
Acceptable	2.0
Poor	1.0

Scores and ranking of each chute is summarized in Table 6. A perfect chute would receive a score of 100.

C.3 Analysis

The overall ranking of the chutes resulted in the deflector plate, stone box, and slide being ranked 1, 2, 3 in that order, with their scores within 4 percentage points. With the exception of the poor score of the catenary chute, all other designs scored approximately 10 points lower.

In the performance category, the slide proved to be the outstanding candidate, scoring 15 points higher than the jay. The deflector plate and stone box scored very well in both the mine operation and economic areas, ranking 1 and 2, although scores in mine operation were all closely packed. The simple designs scored very well in economics.

TABLE 6. - Summary of scores and ranking for transfer chutes

Item		Plate	Box	Can	Slide	Jay	Loop	Catenary	Hopper
Score		77	74	58	73	62	64	48	59
Rank		1	2	7	3	5	4	8	6
Perform	S	59	58	56	80	65	63	58	60
	R	5	6	8	1	2	3	6	4
Mine Operation	S	75	77	60	68	70	71	50	62
	R	2	1	7	5	4	3	8	6
Economic	S	100	95	60	70	50	60	35	55
	R	1	2	4	3	7	4	8	6

S = Score R = Rank

C.4 Recommendation

Based on the close scores of the top three chute designs, they have all been ranked equivalent as prospects for a low headroom transfer chute; however, *from the standpoint of performance, the slide is the clear cut preference.* Because the deflector is already in common usage in underground coal mines, the slide and stone box would be the designs worthy of further consideration. Due to the promise of far superior performance while obtaining the goal of low headroom, the slide design is the one recommended for additional testing in Phase III of this program.

The full-scale slide design will incorporate versatile design features to permit evaluation of certain performance characteristics that we were unable to detect on the models due to the small scale. The length of the sloped bottom plates will be adjustable to evaluate how short the chute can be made without causing poor performance. A curved plate will be designed to be substituted as the backing of the slide chute to determine if performance is improved enough to justify the additional complexity and cost.

APPENDIX D

SCREEN ANALYSIS

Samples of the coal were taken daily for 7 days. The results are shown on pages 99 through 105 and are plotted in Figures 29 through 35.

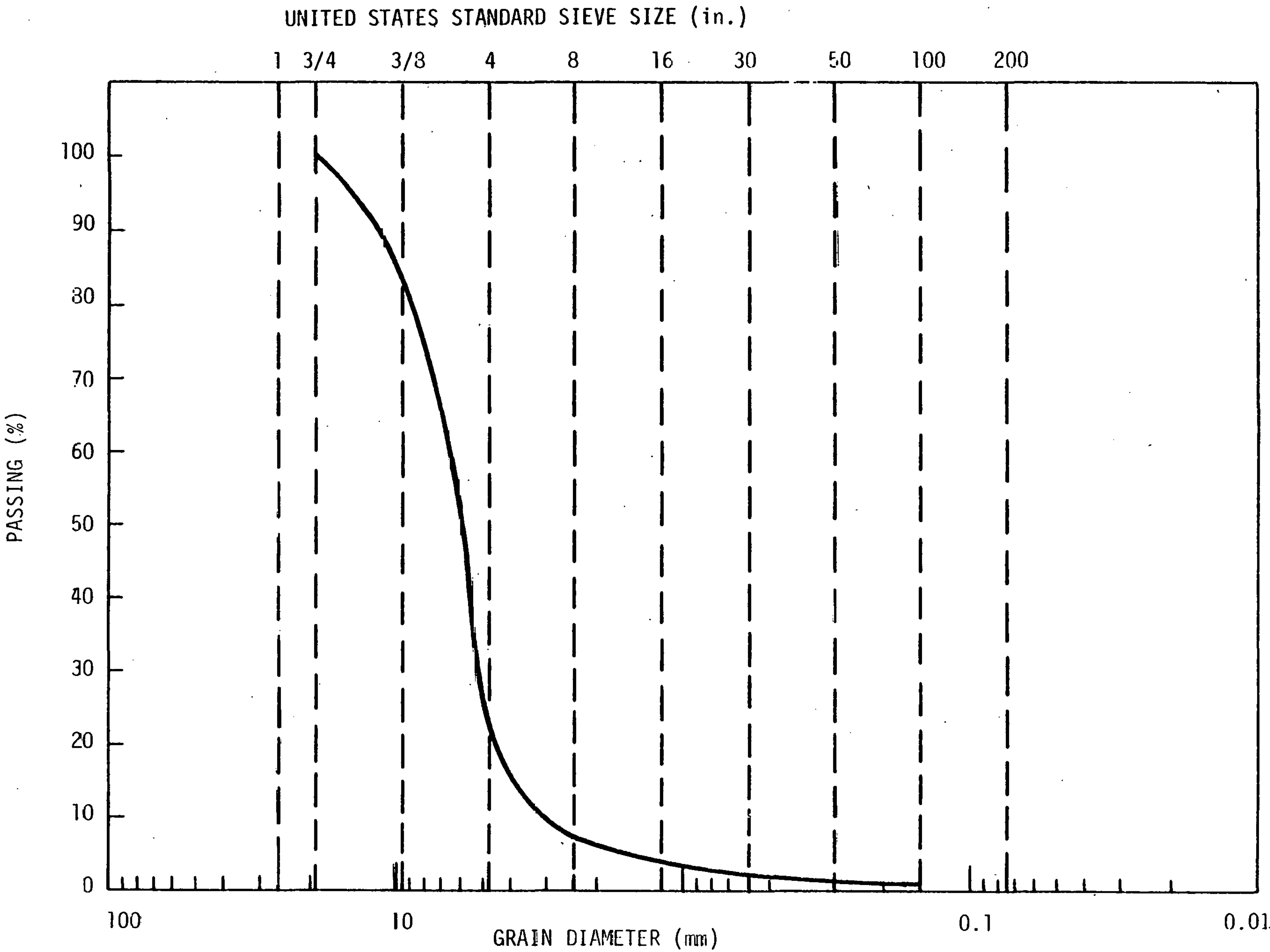

FIGURE 29. - Grain size distribution (sample taken 3/12/80).

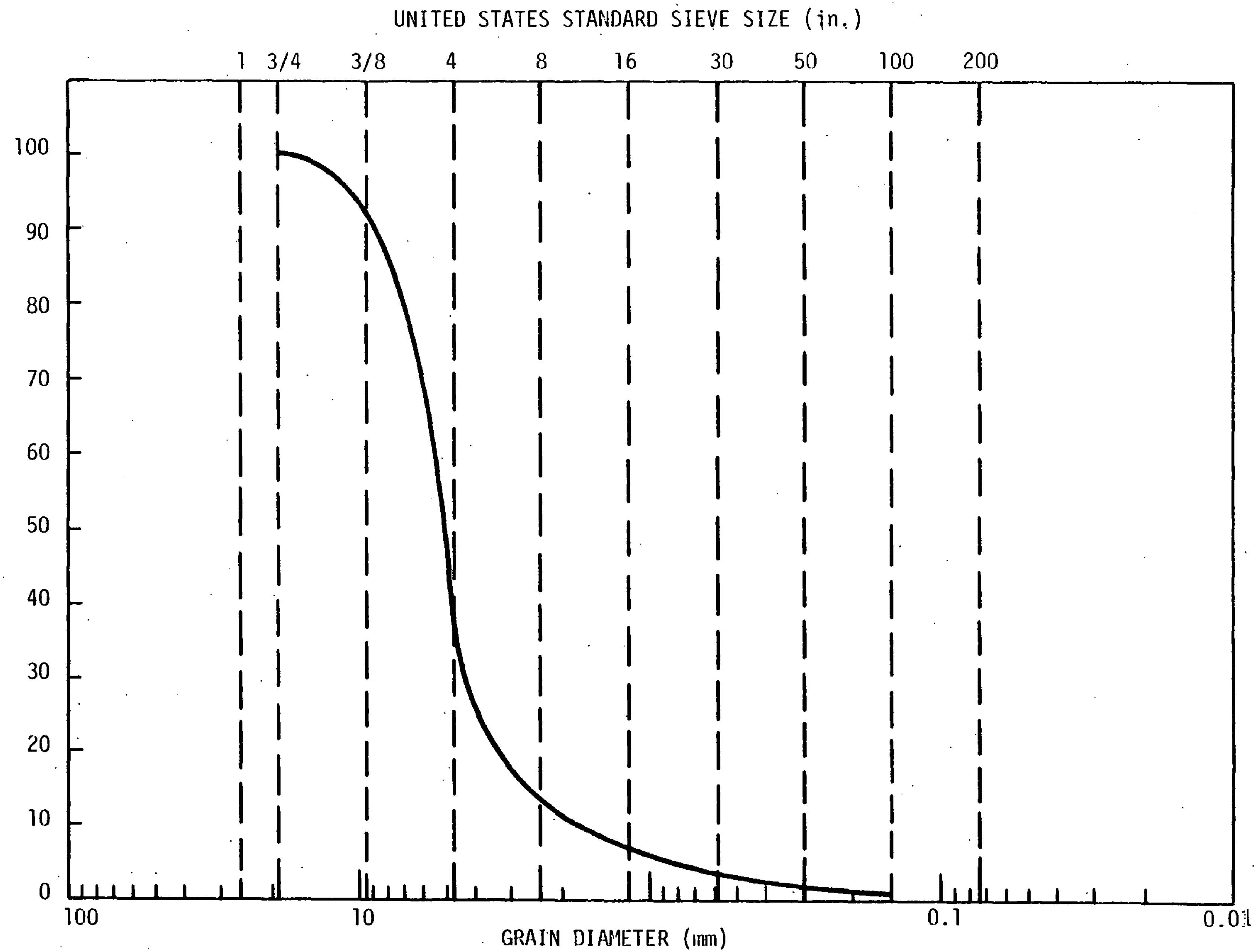

FIGURE 30. - Grain size distribution (sample taken 3/13/80).

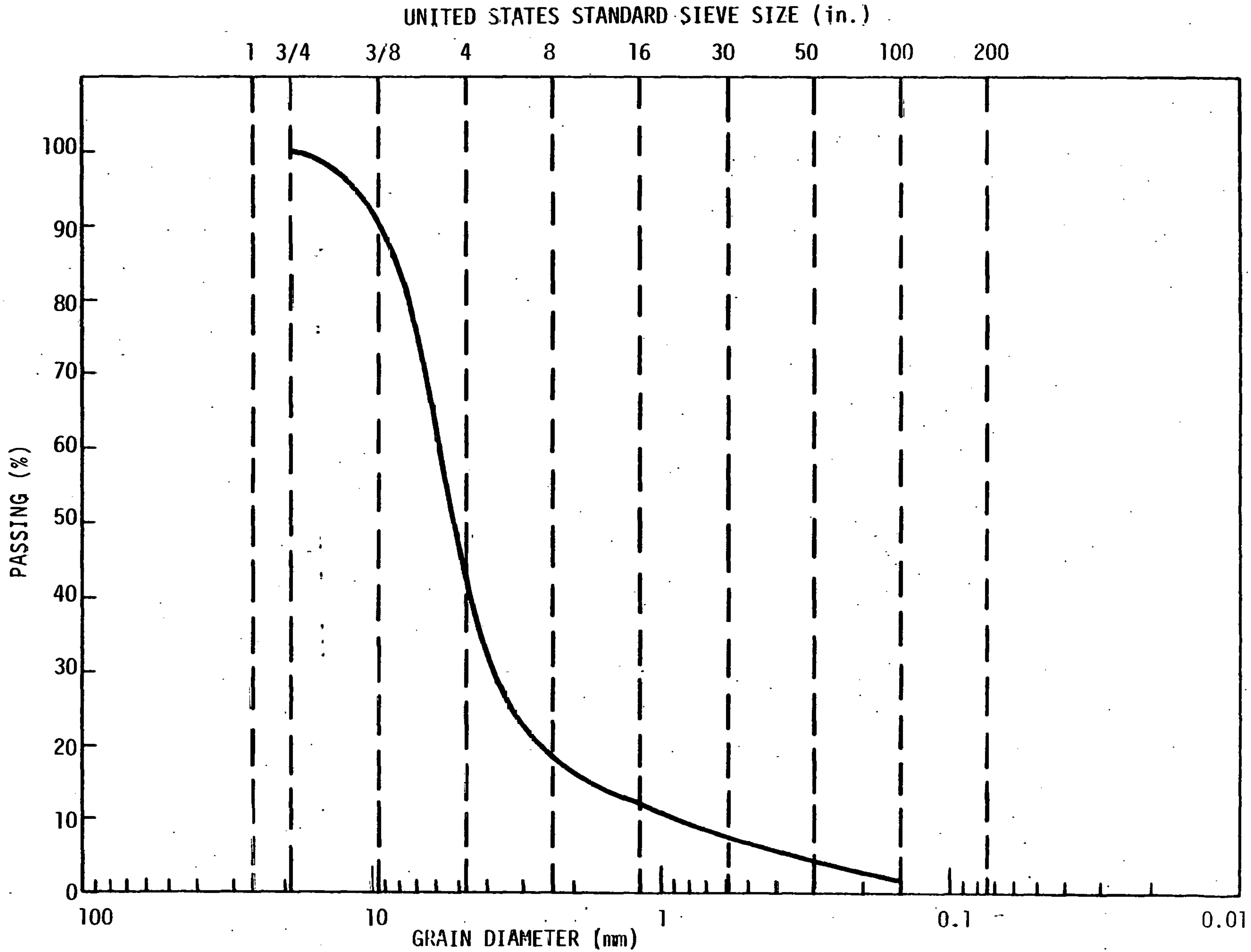

FIGURE 31. - Grain size distribution (sample taken 3/14/80)

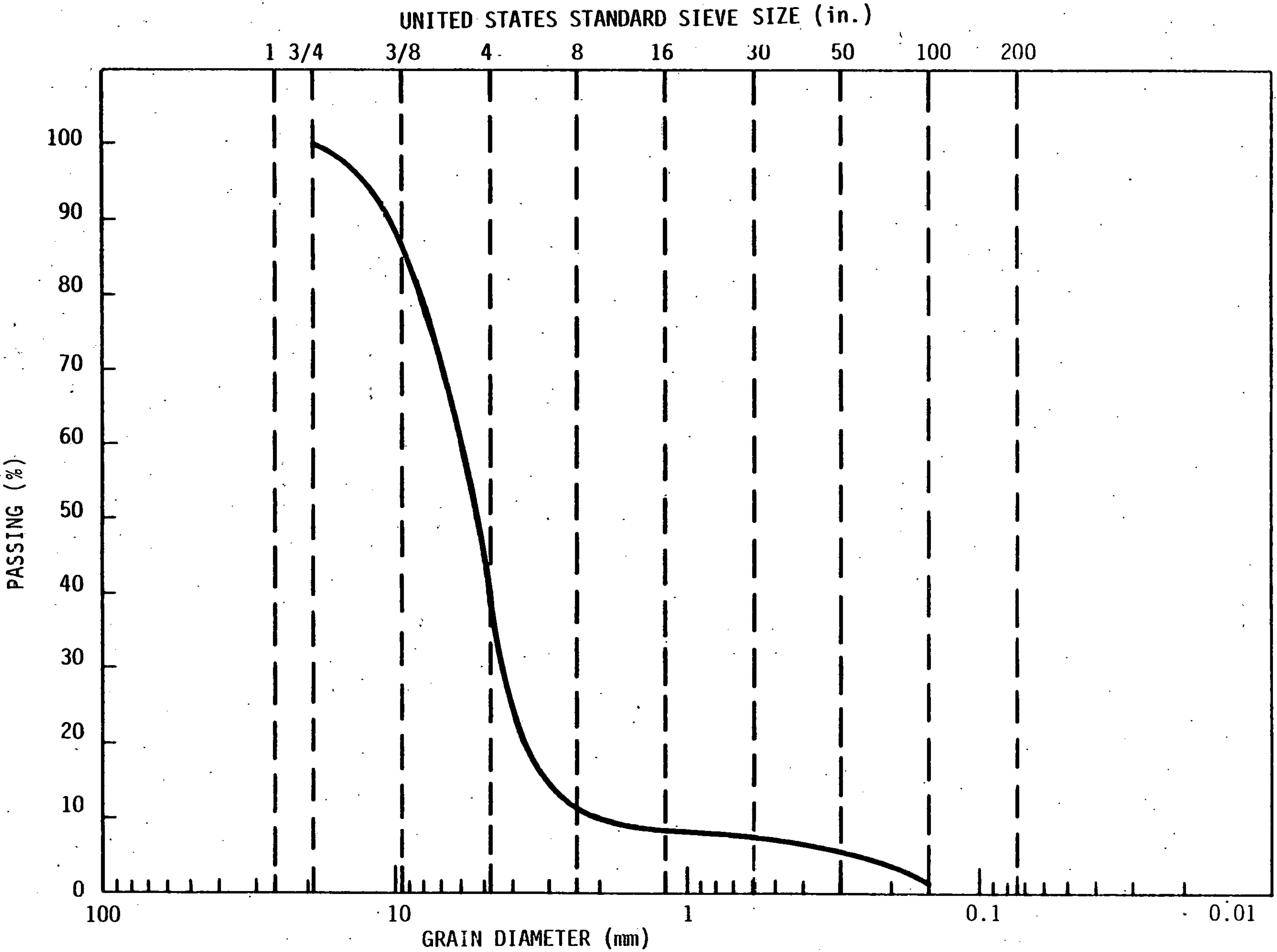

FIGURE 32. - Grain size distribution (sample taken 3/17/80).

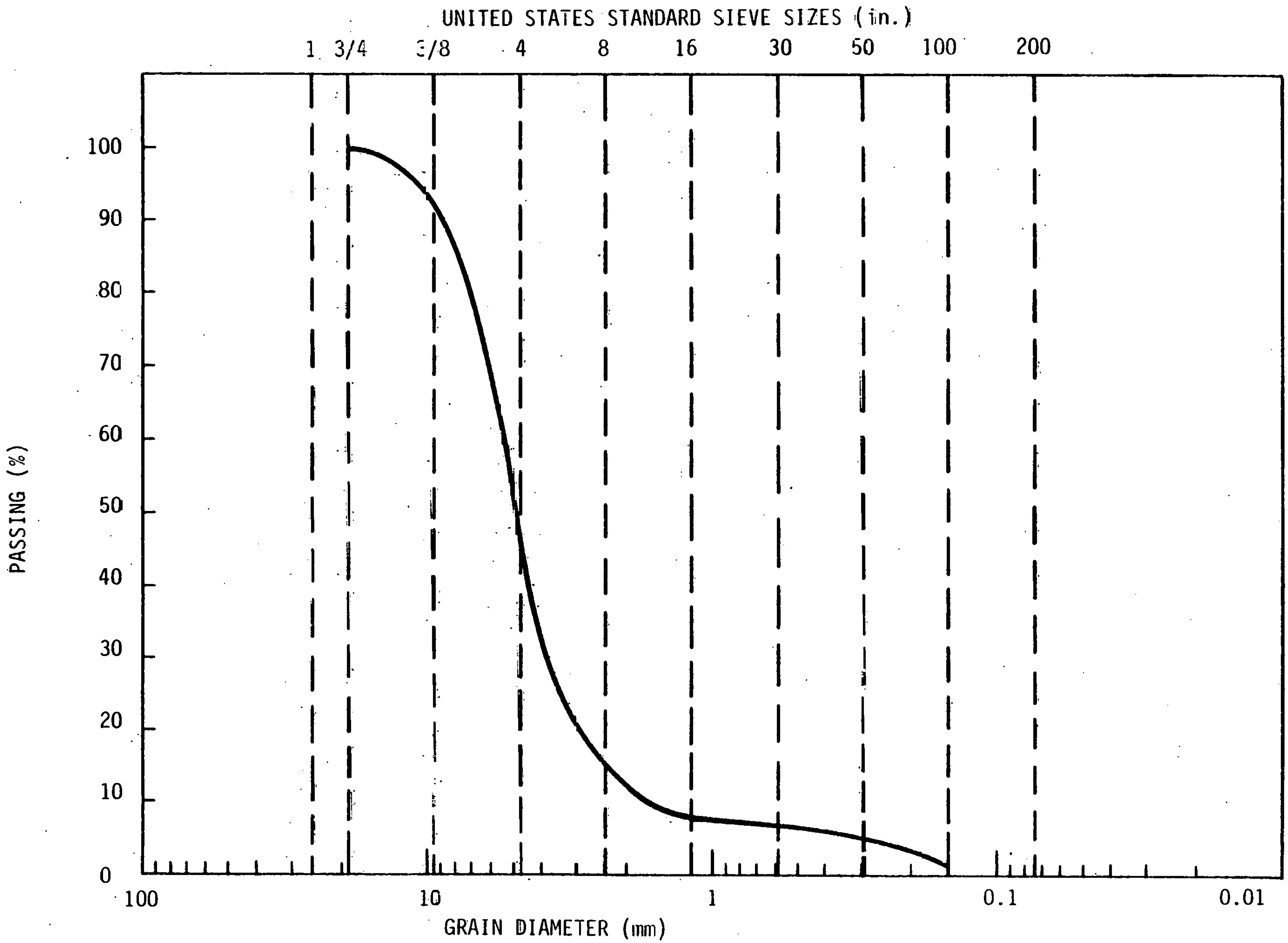

FIGURE 33. - Grain size distribution (sample taken 3/18/80).

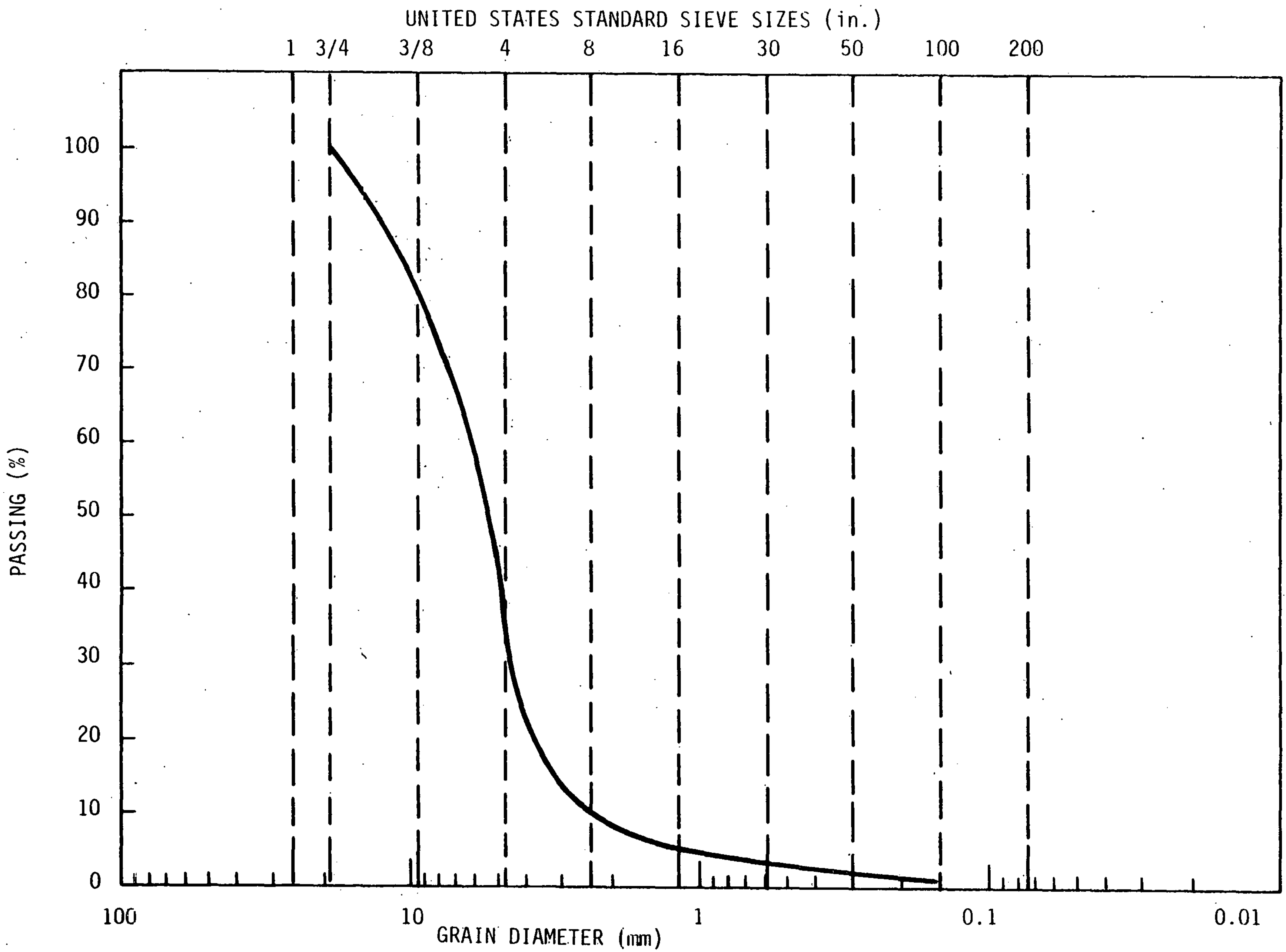

FIGURE 34. - Grain size distribution (sample taken 3/19/80).

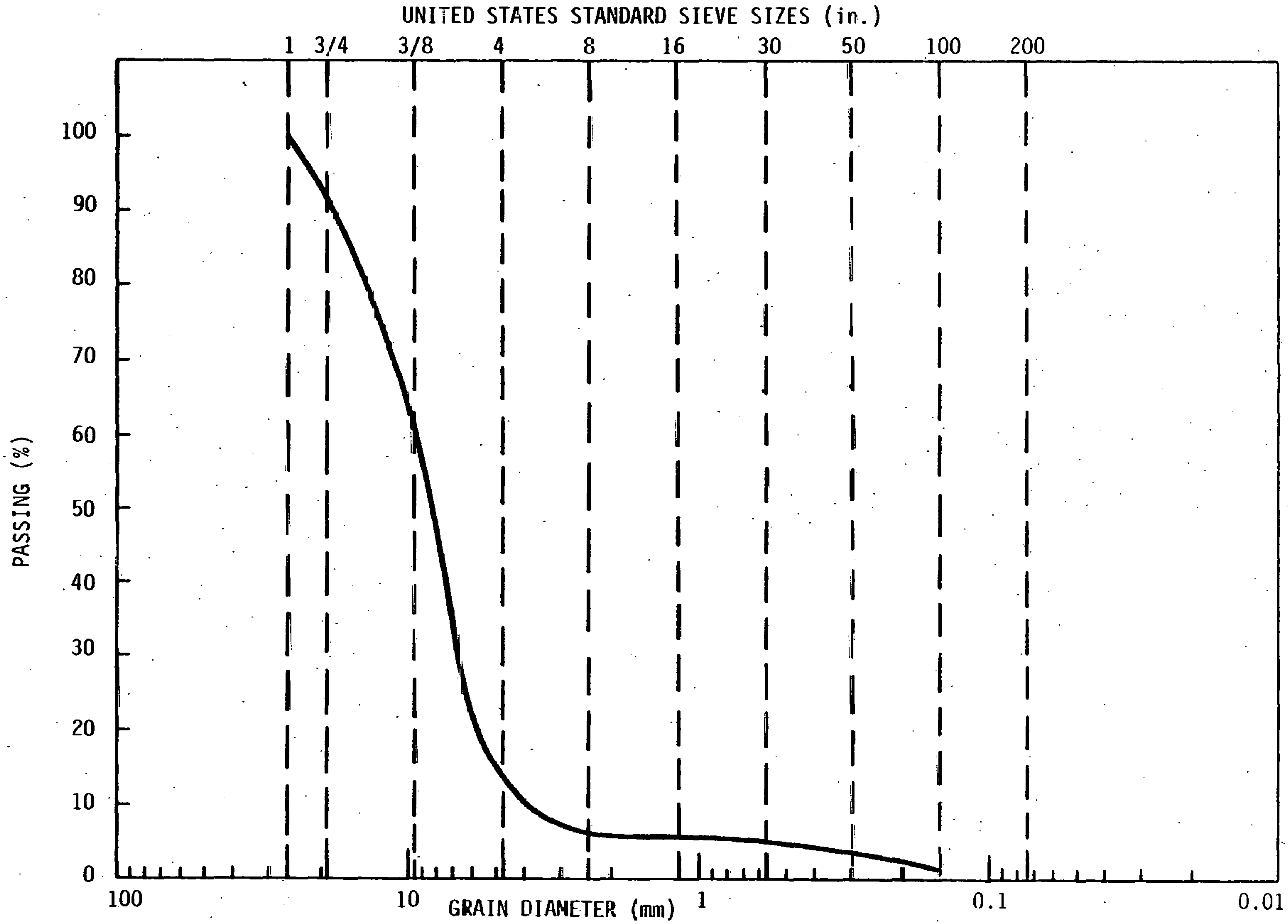

FIGURE 35. - Grain size distribution (sample taken 3/21/80).

MATERIAL SIEVE ANALYSIS

Date: 3/12/80
Time:
Temp:
Avg Time of Sieving: 10 minutes

Type of Mat'l Assumed
Sample Location
Sample #
1023 gr

Foster-Miller Associates, Inc.
Engineers
350 Second Avenue
Waltham, MA 02154
617-890-3200

	1			2			3			4			Combined		
	Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Total		
Sieve Size	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Total Weight Retained	Retained %	Passing %
1"	570			570			570			570					
3/4"	573			573			573			573					
1/2"	547			547			547			547					
3/8"	538	705	167	538			538			538				16.33	83.67
#4	527	1154.5	627.5	527			527			527				61.37	22.30
#8	480	638	158	480			480			480				15.45	6.85
#16	429	457	28	429			429			429				2.74	4.11
#30	522	539	17	522			522			522				1.66	2.45
#50	380	385	5	380			380			380				0.49	1.96
#100	516	527	11	516			516			516				1.08	0.88
#200	332			332			332			332					
Pan	462	471	9	462			462			462				0.88	0
Total	X	X	1022.5	X	X		X	X		X	X			100	
													FM		

Sample Material Meets Specs for__________________

Test Conducted by: P. Larson

Note: All weights in grams unless otherwise noted.

MATERIAL SIEVE ANALYSIS

Date: 3/13/80
Time:
Temp:
Avg Time of Sieving: 10 min
866 gr

Type of Mat'l Assumed
Sample Location
Sample #

Foster-Miller Associates, Inc.
Engineers
350 Second Avenue
Waltham, MA 02154
617-890-3200

	1			2			3			4			Combined		
	Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Total		
Sieve Size	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Total Weight Retained	Retained %	Passing %
1"	570			570			570			570					
3/4"	573			573			573			573					
1/2"	547			547			547			547					
3/8"	538	599	61	538			538			538				7.0	93
#4	527	986.5	459.5	527			527			527				53.1	39.9
#8	480	710.5	230.5	480			480			480				26.6	13.3
#16	429	486	57	429			429			429				6.6	6.7
#30	522	547	25	522			522			522				2.9	3.8
#50	380	394	14	380			380			380				1.6	2.2
#100	516	530	14	516			516			516				1.6	0.6
#200	332			332			332			332					
Pan	462	467	5	462			462			462				0.6	0
Total			865.0											100	
													FM		

Sample Material Meets Specs for ________

Test Conducted by: P. Larson

Note: All weights in grams unless otherwise noted.

MATERIAL SIEVE ANALYSIS

Date: 3/14/80
Time:
Temp:
Avg Time of Sieving: 10 min
967 gr

Type of Mat'l Assumed
Sample Location
Sample #

Foster-Miller Associates, Inc.
Engineers
350 Second Avenue
Waltham, MA 02154
617-890-3200

	1			2			3			4			Combined		
	Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Total		
Sieve Size	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Total Weight Retained	Retained %	Passing %
1"	570			570			570			570					
3/4"	573			573			573			573					
1/2"	547			547			547			547					
3/8"	538	627.5	89.5	538			538			538				9.260	90.74
#4	527	985	458	527			527			527				47.387	43.353
#8	480	725	245	480			480			480				25.349	18.004
#16	429	484	55	429			429			429				5.691	12.313
#30	522	565	43	522			522			522				4.449	7.864
#50	380	414.5	34.5	380			380			380				3.570	4.294
#100	516	544	28	516			516			516				2.897	1.397
#200	332			332			332			332					
Pan	462	475.5	13.5	462			462			462				1.397	0
Total	X	X	966.5	X	X		X	X		X	X			100	
													FM		

Sample Material Meets Specs for________________

Test Conducted by: P. Larson

Note: All weights in grams unless otherwise noted.

MATERIAL SIEVE ANALYSIS

Date: 3/17/80
Time:
Temp:
Avg Time of Sieving: 10 min

Type of Mat'l Assumed
Sample Location
Sample #
805 gr

Foster-Miller Associates, Inc.
Engineers
350 Second Avenue
Waltham, MA 02154
617-890-3200

	1			2			3			4			Combined		
	Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Total		
Sieve Size	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Total Weight Retained	Retained %	Passing %
1"	570			570			570			570					
3/4"	573			573			573			573					
1/2"	547			547			547			547					
3/8"	538	645.5	107.5	538			538			538				13.36	86.64
#4	527	906	379	527			527			527				47.11	39.53
#8	480	710	230	480			480			480				28.59	10.94
#16	429	449.5	20.5	429			429			429				2.55	8.39
#30	522	526.5	4.5	522			522			522				0.56	7.83
#50	380	397	17	380			380			380				2.11	5.72
#100	516	55	34	516			516			516				4.23	1.49
#200	332			332			332			332					
Pan	462	474	12	462			462			462				1.49	0
Total			804.5											100	
													FM		

Sample Material Meets Specs
for ____________________

Test Conducted by: P. Larson

Note: All weights in grams unless otherwise noted.

MATERIAL SIEVE ANALYSIS

Date: 3/18/80
Time:
Temp:
Avg Time of Sieving:

Type of Mat'l Assumed
Sample Location
Sample #
829 gr

Foster-Miller Associates, Inc.
Engineers
350 Second Avenue
Waltham, MA 02154
617-890-3200

	1			2			3			4			Combined		
	Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Total		
Sieve Size	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Total Weight Retained	Retained %	Passing %
1"	570			570			570			570					
3/4"	573			573			573			573					
1/2"	547			547			547			547					
3/8"	538	591	53	538			538			538				6.393	93.607
#4	527	913.5	386.5	527			527			527				46.622	46.985
#8	480	741	261	480			480			480				31.484	15.501
#16	429	492	63	429			429			429				7.600	7.901
#30	522	529.5	7.5	522			522			522				0.905	6.995
#50	380	395.5	15.5	380			380			380				1.870	5.126
#100	516	544	28	516			516			516				3.378	1.748
#200	332			332			332			332					
Pan	462	476.5	14.5	462			462			462				1.749	0
Total	X	X	829.0	X	X		X	X		X	X			100.001	
													FM		

Sample Material Meets Specs for __________

Test Conducted by: P. Larson

Note: All weights in grams unless otherwise noted.

MATERIAL SIEVE ANALYSIS

Date: 3/19/80
Time:
Temp:
Avg Time of Sieving:

Type of Mat'l Assumed
Sample Location
Sample #

895 gr

Foster-Miller Associates, Inc.
Engineers
350 Second Avenue
Waltham, MA 02154
617-890-3200

	1			2			3			4			Combined		
	Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Total		
Sieve Size	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Total Weight Retained	Retained %	Passing %
1"	570			570			570			570					
3/4'	573			573			573			573					
1/2'	547			547			547			547					
3/8"	538	718	180	538			538			538				20.112	79.888
#4	527	887	360	527			527			527				40.223	39.665
#8	480	752	272	480			480			480				30.391	9.274
#16	429	465	36	429			429			429				4.022	5.252
#30	522	534	12	522			522			522				1.341	3.911
#50	380	394.5	14.5	380			380			380				1.620	2.291
#100	516	530	14	516			516			516				1.564	0.727
#200	332			332			332			332					
Pan	462	468.5	6.5	462			462			462				0.726	0
Total	X	X	895	X	X		X	X		X	X			99.999	
													FM		

Sample Material Meets Specs
for ________________

Test Conducted by: P. Larson

Note: All weights in grams unless otherwise noted.

MATERIAL SIEVE ANALYSIS

Date: 3/21/80
Time:
Temp:
Avg Time of Sieving: 10 min
978 gr

Type of Mat'l Assumed
Sample Location
Sample #

Foster-Miller Associates, Inc.
Engineers
350 Second Avenue
Waltham, MA 02154
617-890-3200

	1			2			3			4			Combined		
	Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Full Wt Empty Wt Sample Wt			Total		
Sieve Size	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Emp Wt	Full Wt	Wt	Total Weight Retained	Retained %	Passing %
1"	570			570			570			570					
3/4"	573			573			573			573					
1/2"	547			547			547			547					
3/8"	538	918	380	538			538			538				38.95	61.05
#4	527	985	458	527			527			527				46.950	14.10
#8	480	558	78	480			480			480				8.00	6.10
#16	429	436	7	429			429			429				0.72	5.38
#30	522	530	8	522			522			522				0.82	4.56
#50	380	395	15	380			380			380				1.54	3.02
#100	516	533	17	516			516			516				1.74	1.28
#200	332			332			332			332					
Pan	462	474.5	12.5	462			462			462				1.28	0
Total	X	X	975.5	X	X		X	X		X	X			100.00	
													FM		

Sample Material Meets Specs for__________

Test Conducted by: P. Larson

Note: All weights in grams unless otherwise noted.

APPENDIX E

CALCULATIONS FOR EFFICIENCY OF PASSING THROUGH CHUTE

Figures 36 and 42 are strobe-photographs of an aluminum ball on the coal passing from the 6-in. feed conveyor to the 8-in. receiving conveyor.

Two rods are placed on the 6-in. feed conveyor 1 and 2 ft from the centerline of the 8 in. receiving conveyor.

One rod is placed on the 8-in. receiving conveyor 2 ft from the centerline of the 6-in. feed conveyor.

Measurements are made to determine the distance the ball travels on both conveyors. The assumption is made that the ball is brought up to speed in the time that it would take for the ball to free fall the 7 in. from feed conveyor to receiving conveyor. This establishes the distance required for the ball to travel along the receiving conveyor to get up to speed. The actual time elapsed in bringing the ball up to speed is calculated and the efficiency is determined by dividing the theoretical time by the actual time to bring the ball up to speed.

Theoretical time can be determined from the formula:

$$S = 1/2\ g t_1^2$$

where

S = distance traveled in feet

g = acceleration due to gravity = 32.2 ft/sec^2

t_1 = time in seconds

$$t_1 = \sqrt{2S/g}$$

$$t_1 = \sqrt{\frac{(2)\ (7/12)}{32.2}} = 0.1904 \text{ sec}$$

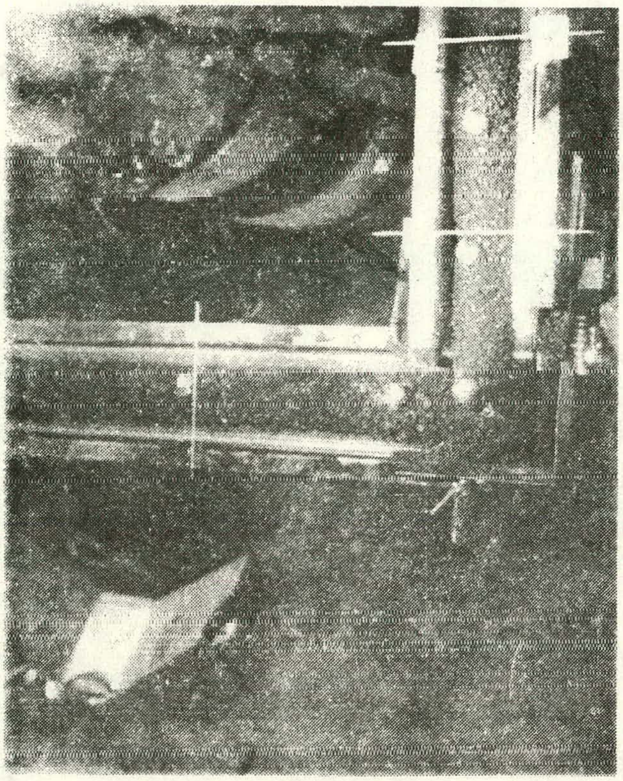

FIGURE 36. - Stone box chute - Strobotac at 200 ppm.

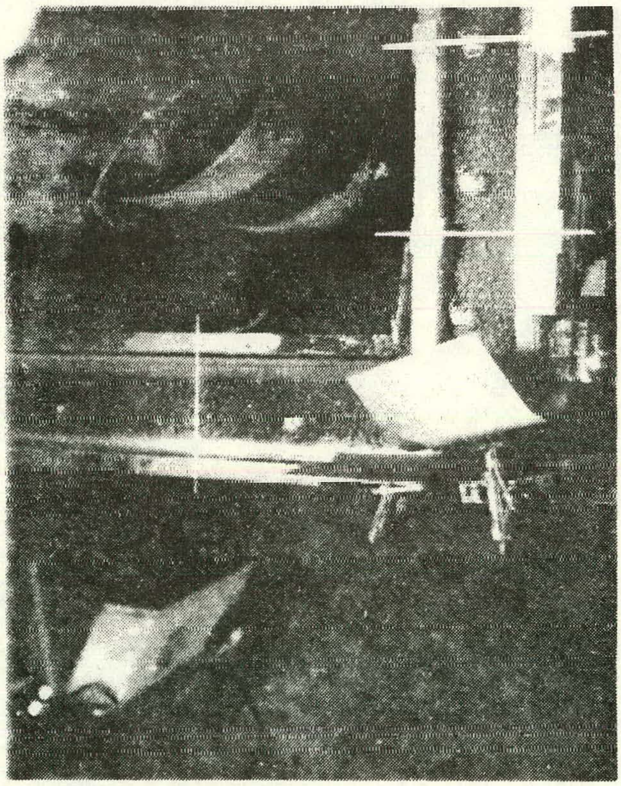

FIGURE 37. - Jay chute - Strobotac at 200 ppm.

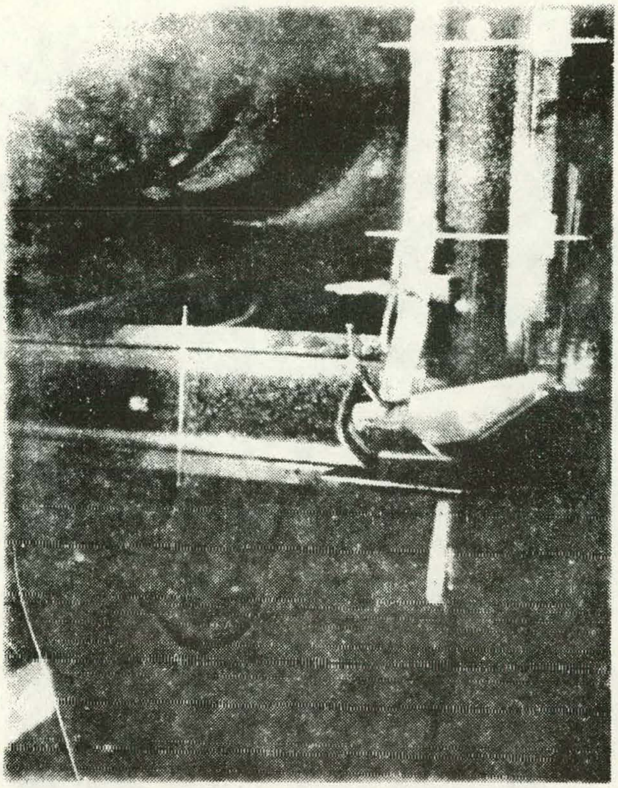

FIGURE 38. - Loop chute - Strobotac at 200 ppm.

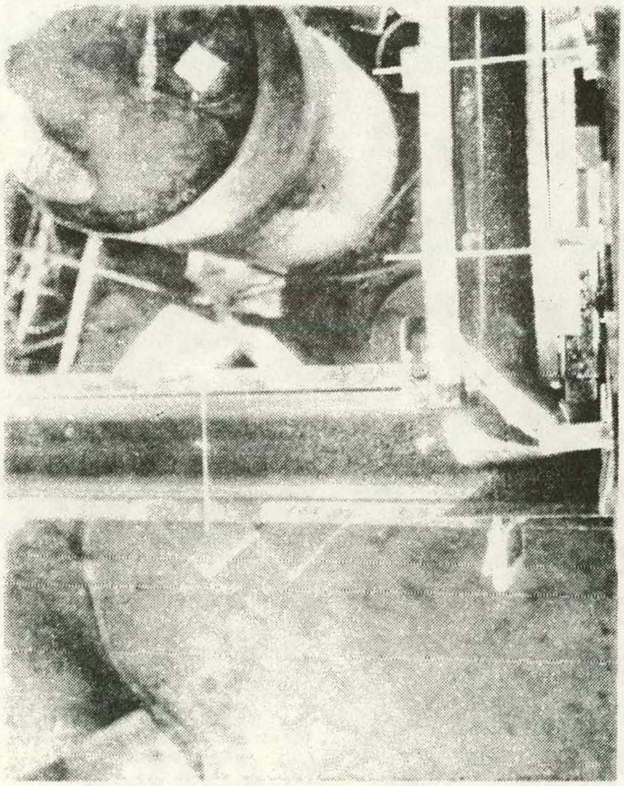

FIGURE 39. - Can chute - Strobotac at 200 ppm.

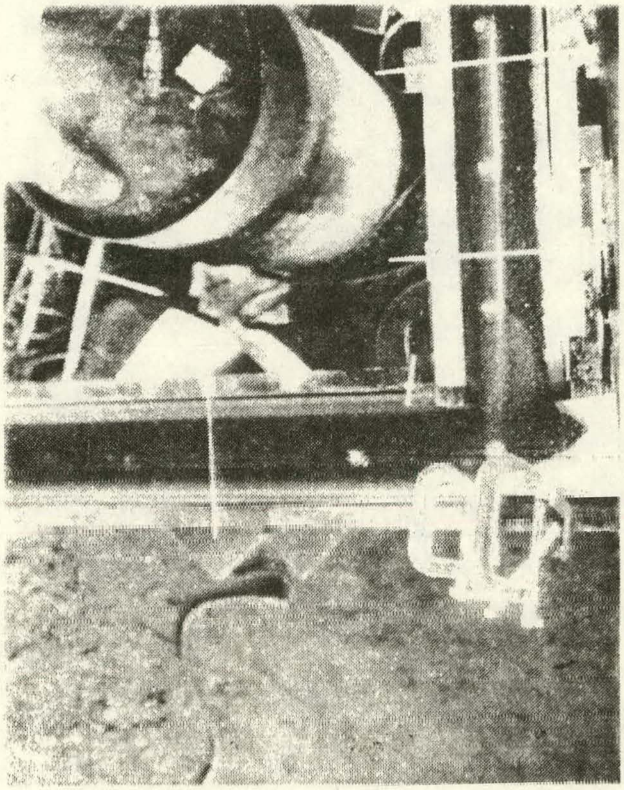

FIGURE 40. - Slide chute - Strobotac at 200 ppm.

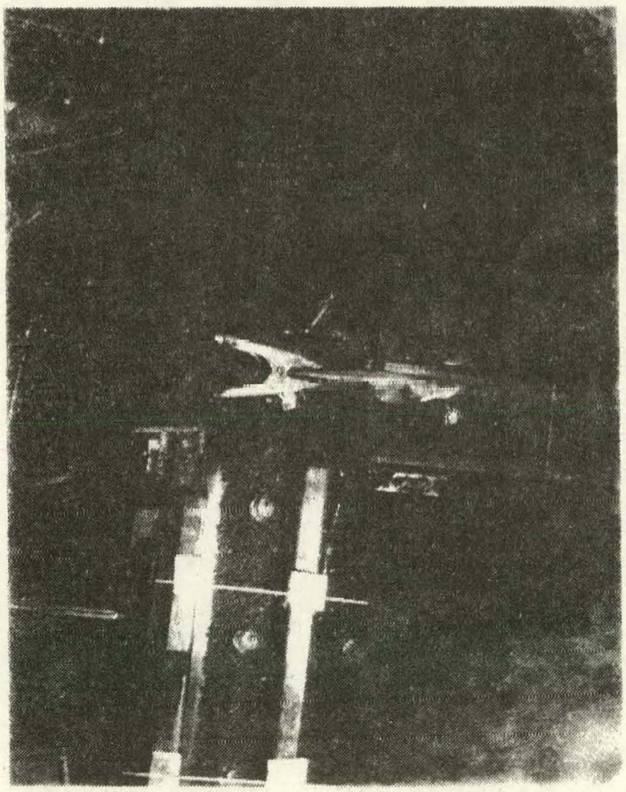

FIGURE 41. - Catenary chute - Strobotac at 200 ppm.

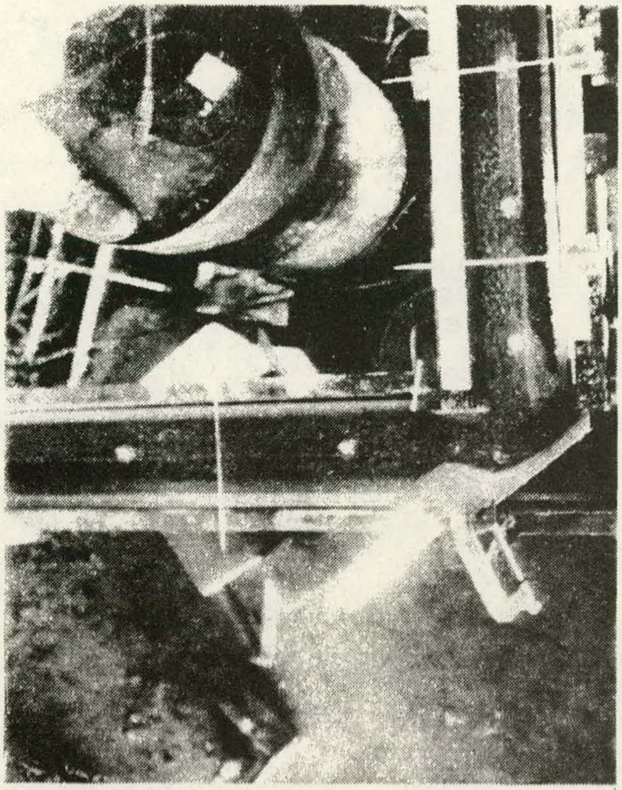

FIGURE 42. - Hopper chute - Strobotac at 200 ppm.

The stone box chute is shown in Figure 36.

For simulated 8 tons/min coal flow, the distances as measured from the centerlines to the rods and the balls on Figure 36 are:

- On feed conveyor 2.22 in. = 2 ft
- Ball is at 1.65 in. = 1.564 ft
- On receiving conveyor 2.11 in. = 2 ft
- Ball is at 1.72 in. = 1.630 ft.

The ball travels 4 in. or 0.333 ft to reach the center of the 8 in. conveyor and travels along the 8 in. belt 0.996 ft to get up to speed. This distance D = belt speed (S) × time t.

The belt speed S = 13.4/60 = 5.23 ft/sec. The time is the same as the theoretical time to drop 7 in. or 0.1904 sec

$$D = (5.23)\ (0.1904) = 0.996 \text{ ft}$$

The actual time required to get the ball up to speed is calculated by subtracting from the total time, the time required for the ball to travel to the edge of the 6-in. belt and the time required to travel from a point 0.996 ft from the centerline of the 6-in. belt to the image of the ball. The total time is the number of images minus one divided by the pulse rate. Using the photograph in Figure 36, the distance from the centerline of the 8-in. belt to the furthest ball is 1.564 ft. Subtracting 4 in. or 0.333 ft equals 1.231 ft from the ball image to the edge of the 6-in. belt. The distance from the centerline of the 6-in. belt to the furthest ball image is 1.630 ft; subtracting 0.996 ft equals 0.634 ft from the edge of the 6-in. belt to the ball.

The time (T_2) required to travel the 1.231 ft on the 6-in. belt plus the time required to travel the 0.634 ft on the 8-in. belt is:

$$T_2 = \frac{S_1}{V_1} + \frac{S_2}{V_2}$$

where

S_1 = distance traveled on the 6-in. belt (ft)

S_2 = distance traveled on the 8-in. belt (ft)

V_1 = 6-in. belt speed (ft/min)

V_2 = 8-in. belt speed (ft/min)

$$T_2 = \frac{1.231}{144} + \frac{0.634}{314} = 0.01057$$

$$\text{Total time} = \frac{\text{number of images} - 1}{\text{pulse rate impulses/min}}$$

$$= \frac{5-1}{200} = 0.02 \text{ min}$$

The actual time (T_a) required to get up to the speed of the 8-in. belt is:

$$T_a = \text{Total time} - T_2$$

$$T_a = 0.02 - 0.01057 = 0.00943 \text{ min}$$

$$\text{Efficiency} = \frac{T_1}{(T_a)(60)} \times 100$$

$$= \frac{0.1094}{(0.0943)(60)} = 33.6 \text{ percent}$$

APPENDIX F

MODEL CHUTE COAL FLOW

Photographs of chutes with coal flowing are shown in Figures 43 through 50 on the following pages.

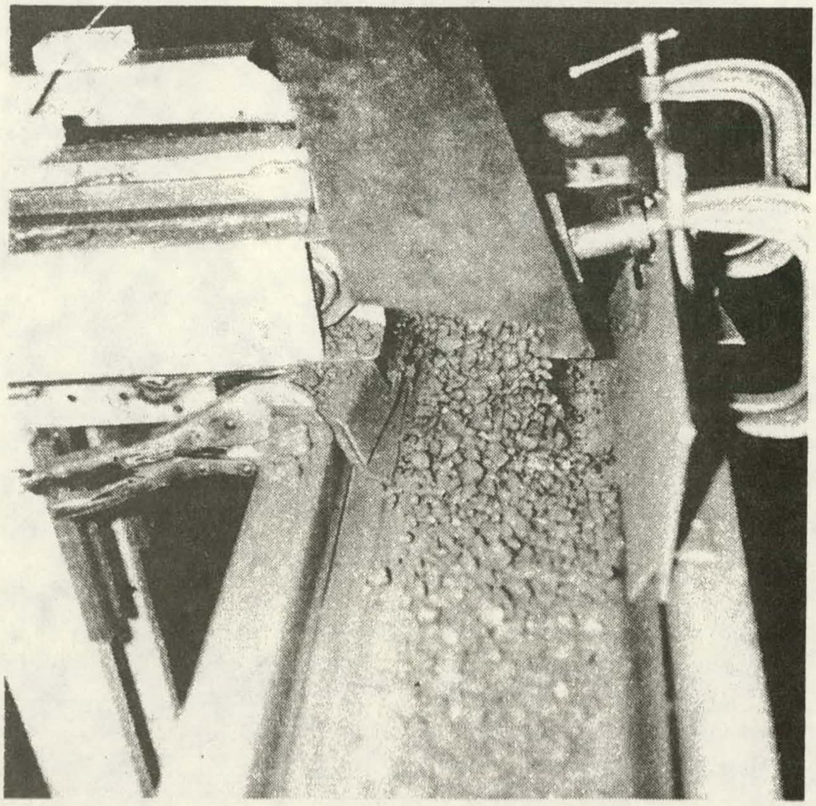

FIGURE 43. - Jay chute.

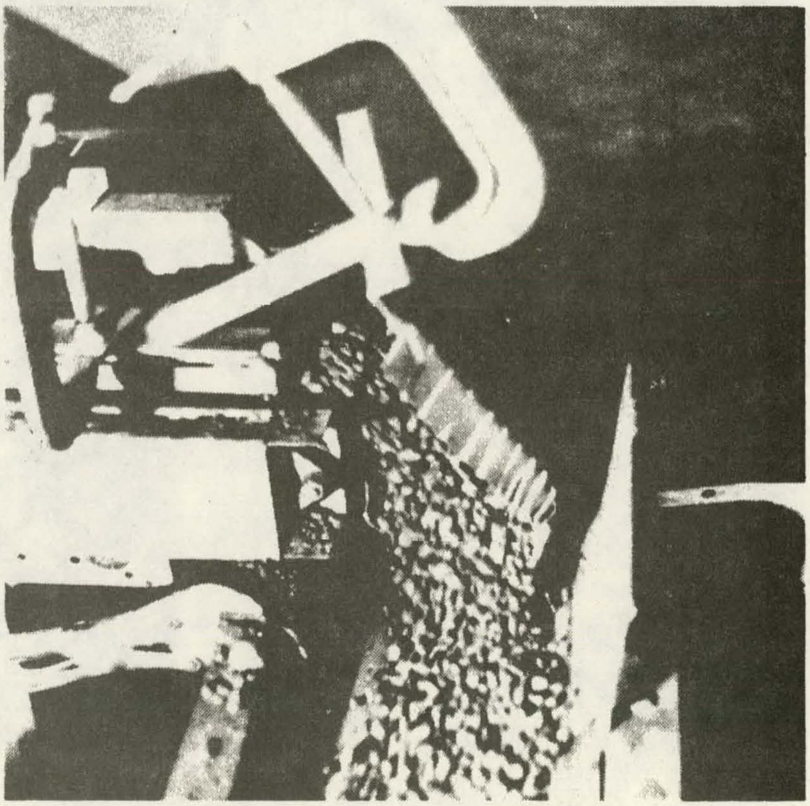

FIGURE 44. - Loop chute.

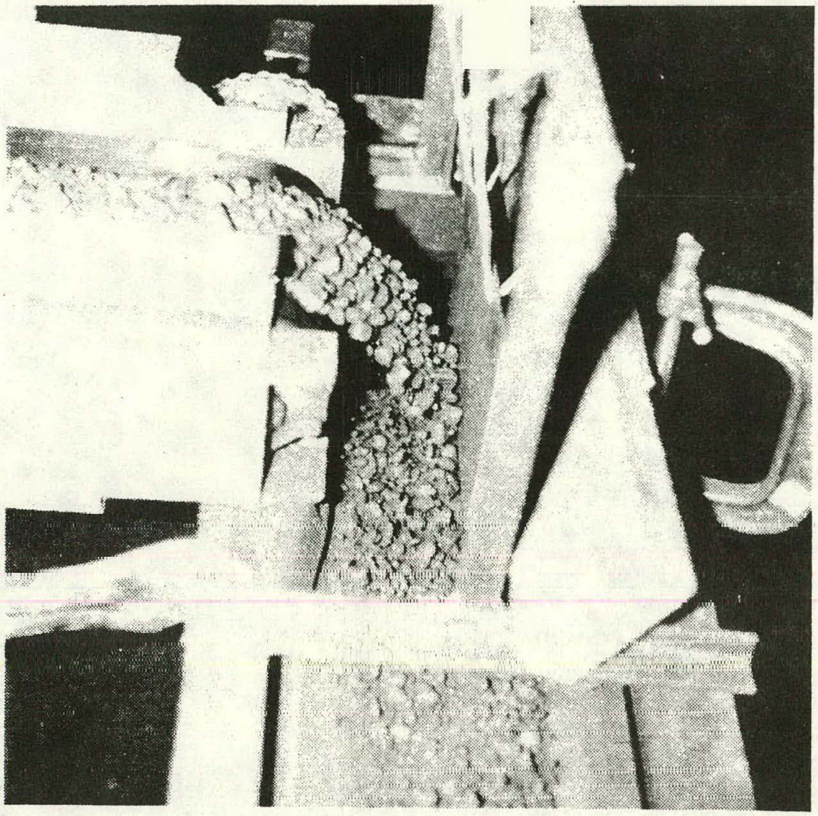

FIGURE 45. - Deflector plate.

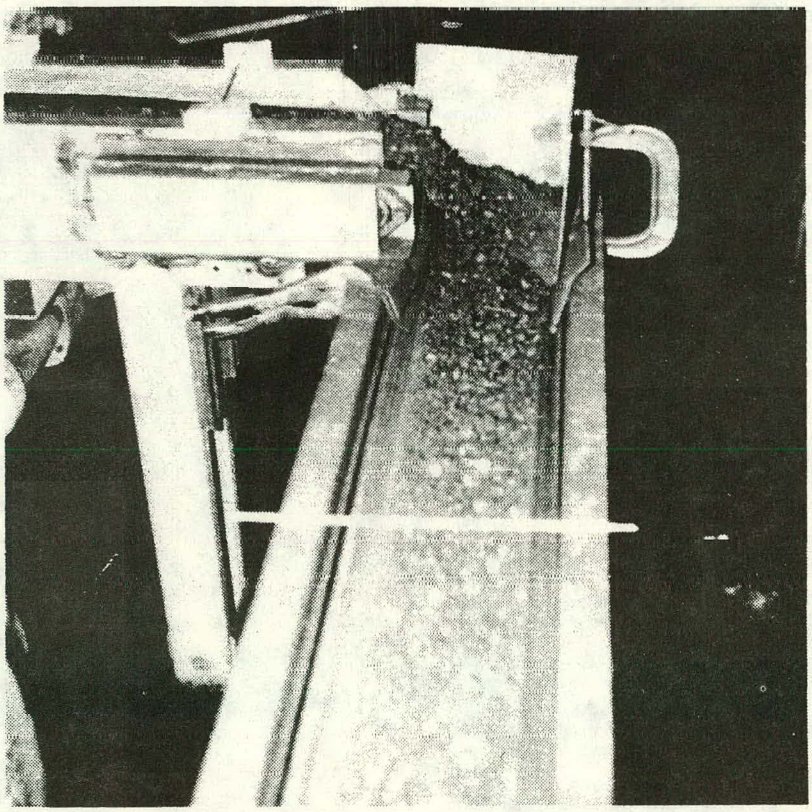

FIGURE 46. - Stone box.

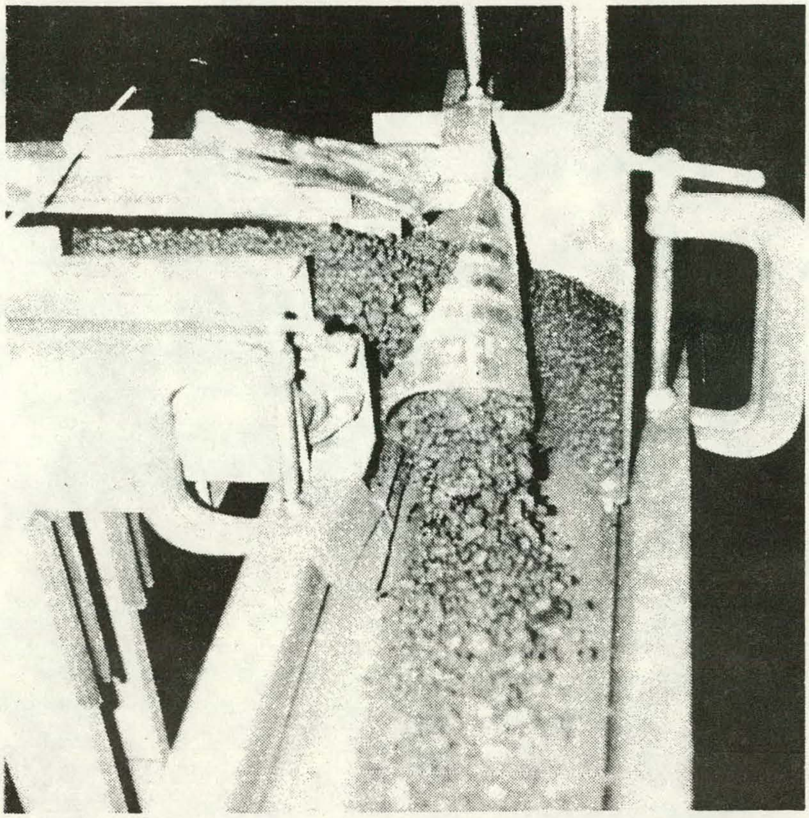

FIGURE 47. - Can chute.

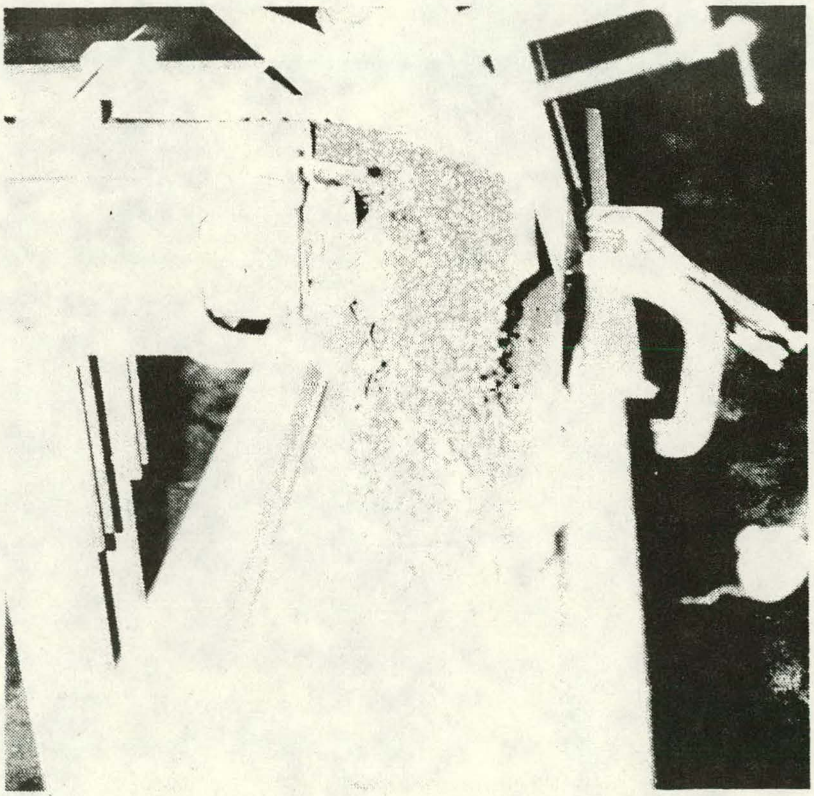

FIGURE 48. - Slide chute.

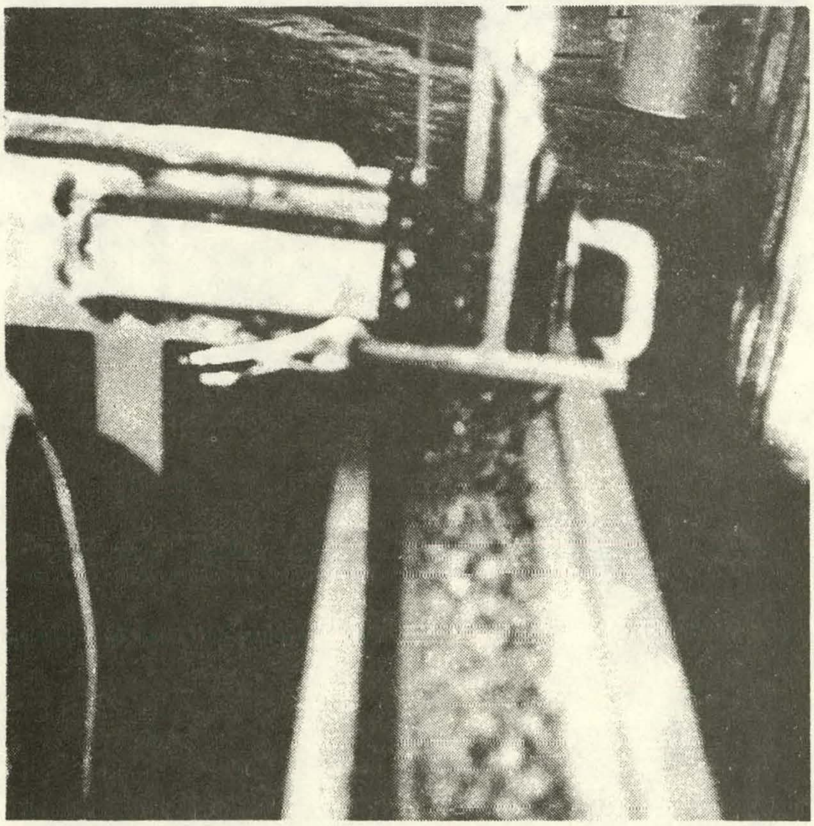

FIGURE 49. - Catenary chute.

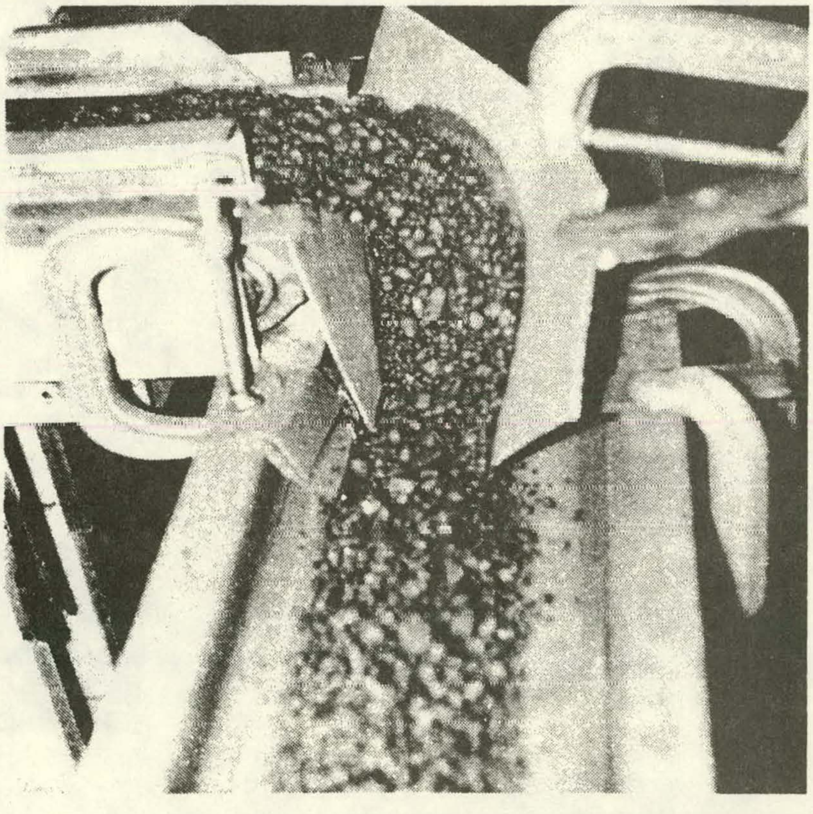

FIGURE 50. - Hopper chute.

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