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REPORT OF INVESTIGATIONS/1989

Basic Parameters of Conveyor Belt Cleaning

By C. A. Rhoades, T. L. Hebble, and S. G. Grannes

BUREAU OF MINES



UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel J. Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

Library of Congress Cataloging in Publication Data:

Rhoades, Charles A.

Basic parameters of conveyor belt cleaning.

(Report of investigations / United States Department of the Interior, Bureau of Mines; 9221)

Bibliography: p. 19.

Supt. of Docs. no.: I 28.23:9221.

1. Conveyor belts—Maintenance and repair. 2. Mine haulage. I. Hebble, T. L. (Terry L.). II. Grannes, Steven G. III. Title. IV. Series: Report of investigations (United States. Bureau of Mines); 9221.

TN23.U43

[TN335]

622 s [622'.66]

87-600104

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

A	ampere	mil/yr	mil per year
°C	degree Celsius	mm	millimeter
ft	foot	μm	micrometer
g/ft^2	gram per square foot	pct	percent
h	hour	psi	pound (force) per square inch
in	inch	wt pct	weight percent

BASIC PARAMETERS OF CONVEYOR BELT CLEANING

By C. A. Rhoades,¹ T. L. Hebble,² and S. G. Grannes³

ABSTRACT

The spillage that accumulates under conveyor belt lines presents a possible fire and explosion hazard to mine personnel, especially to those who must clean up the spillage. The U.S. Bureau of Mines conducted research to reduce this hazard by identifying and investigating the parameters affecting the efficiency of conveyor belt cleaning.

The amount of material carried back under the conveyor and the wear rates of metal cleaning blades decreased with increasing blade-to-belt pressure to a limiting value, after which the carryback and wear rates remained essentially constant. The optimum blade-to-belt pressure was found to be 11 to 14 psi for the research conveyor system. Greater pressures increased the blade-belt friction without improving either cleaning or blade life. The modes of blade wear were three-body abrasion and slurry erosion caused by the sand-lime test mixture. Wear rates were reduced by increasing the metal hardness, optimizing the pressure, and removing conveyor belt imperfections. Corrosion was not observed to affect the wear of various steels in tests of less than 34 h.

The results of this study should allow mine operators to run their conveyors under conditions that will maximize cleaning and minimize equipment wear.

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INTRODUCTION

As part of its health and safety program, the Bureau of Mines has undertaken a basic study of the effectiveness of conveyor belt cleaning to reduce the exposure of mine personnel to the dangerous situation resulting from spillage accumulating on and beneath troughed conveyor belts. The accumulation of fine particles results when the material carried back on the return strand of the belt falls off under the conveyor frame. These particles can create an explosion and respirable dust hazard. Buildup of carryback material on idlers can cause belt mistracking and, more seriously, can result in sticking idlers, creating a fire hazard because of the friction between the belt and frozen idler. Also, mining personnel are exposed to other hazards such as pinch points, as they attempt to clean up this spillage. Recent Mine Safety and Health Administration (MSHA) accident statistics show conveyors as being the most dangerous form of haulage used in mining (table 1).

The hazards of carryback have been recognized by MSHA in 30 CFR 75.326, which requires all belt line ventilation to be a separate air split and directed into the return airway. MSHA reports have also identified the

TABLE 1. - Incidence of U.S. mining accidents by job category

Job	1983	1984
Conveyor person	571	590
Ore haulage truck operator	477	547
Front-end loader operator	449	485
Load-haul-dump operator	398	410
Power shovel operator	370	317

Source: MSHA's Health and Safety Analysis Center.

ineffectiveness of conveyor belt cleaners as a major factor contributing to conveyor safety problems (1).⁴ Poor performance of belt cleaners results in the increased use of hazardous hand labor to clean the material from around the moving belt. Although belt cleaners have been recognized as a key to improving conveyor safety, design deficiencies remain inherent in commercial cleaners, affecting long-term performance. In this study, the Bureau identified and investigated the parameters leading to poor belt cleaner performance, particularly focusing on cleaner blade wear.

BACKGROUND

CONVEYOR SPILLAGE

Spillage from conveyors is of two types. The first occurs at the loading points, where material is spilled as it is being loaded onto the conveyor. The second form of spillage occurs when fine material sticking to the belt falls off as the belt makes its return trip on the underside of the conveyor frame. This material usually consists of fines, whereas the spillage at the loading points can be of any size.

The spillage at the loading points is the result of poor design and can be corrected by proper modifications to the system, such as improved skirtboarding and better chute design.

The Bureau's conveyor safety project was directed toward controlling the second type of spillage problem. The fine material can drop from the belt at various points along the return trip. The three most common points are

1. Where the belt leaves the head pulley; belt vibration at this location can cause the adhering material to fall off.
2. At each of the return idlers; when carryback comes in contact with the return idlers it can adhere to them, causing buildup that will eventually fall off as the material dries out.
3. At the tail pulley; carryback material, which will have dried somewhat, can peel off the belt as it is bent around the pulley.

In an attempt to reduce the spillage problem, the conveyor industry has developed various methods for cleaning operating conveyor belts. These cleaning methods vary greatly in design and effectiveness. Most try to remove the adhering material from the belt by scraping or wiping the belt as it leaves the underside of the head pulley to start its return trip under the conveyor frame.

Many different methods are used to accomplish the cleaning. These include

1. Scraping with rigid blades.
2. Scraping with spring-mounted or movable blades.
3. Brushing with rotating brushes.

The most commonly used of these systems is the spring-mounted, segmented-blade scraping device.

PREVIOUS BUREAU CONVEYOR WORK

In April 1981, a Bureau contract was awarded to Wyle Laboratories to conduct a "Safety Evaluation of Conveyor Belt Cleaning Systems" (2). The work consisted of two phases.

⁴Italic numbers in parentheses refer to items in the list of references at the end of this report.

Phase 1 involved collection and analysis of data on belt cleaner efficiency. In this phase, the contractor visited field sites with over 400 operating conveyor systems. Samples of carryback material were collected and analyzed in an attempt to create, in the laboratory, a material that would replicate the worst carryback in the field. It was found that the material could be simulated with a mixture of 3 parts mason sand, 1 part lime, and 12 pct moisture.

In phase 2, the contractor conducted a series of laboratory tests using a specially designed test conveyor, which was horizontal and 30 ft long, with a 36-in-wide belt. A test fixture was constructed to hold blade-type belt-cleaning systems against the 2-ft-diam head pulley. The test fixture contained a row of six segmented scraper blades, perpendicular to the belt, that were pneumatically held against the belt as it left the underside of the head pulley. The blade-to-belt contact pressure could be adjusted by varying the air pressure in air cylinders that held the blades against the belt.

In a series of tests, contact pressure was varied and carryback that passed by the scraper blade was measured. The results indicated a functional relationship between belt carryback material and blade contact pressures. Figure 1 shows that carryback material linearly decreased to a limiting value as contact pressure between the belt and various scraper blades increased. The research identified the phenomenon of a "critical pressure" beyond which cleaning is not improved (2).

Nearly 100 tests were run using 4 different blade materials and 12 different blade-to-belt contact pressures. This large number of variables prevented the extensive investigation of the reproducibility of any of the data. However, the potential significance of this research led to the development of an in-house closed-loop conveyor test laboratory for further analysis of the conveyor cleaning problem.

Numerous parameters were identified that could affect belt cleaner efficiency,⁵ including

1. Blade contact pressure.
2. Blade wear.

EXPERIMENTAL APPARATUS AND PROCEDURE

A full-size conveyor test facility was constructed, consisting of two 30-ft-long troughed conveyors with 24-in-wide belts. The two conveyors were mounted side by side and inclined in opposite directions to facilitate the recycling of material (fig. 2). Only one of the two conveyors was used for the belt cleaning research; the other conveyor

⁵Cleaning efficiency is defined in this study to mean minimizing carryback.

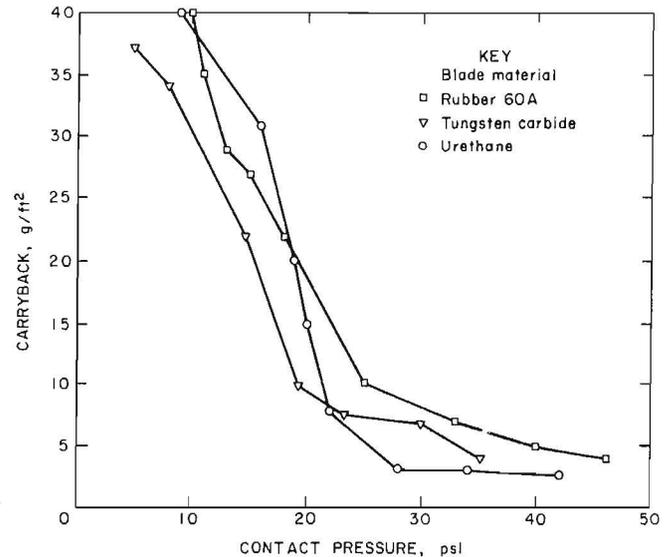


Figure 1.—Carryback material versus blade-to-belt contact pressure curves (Wyle Laboratories contract).

3. Roughness of the belt.
4. Speed of the belt.
5. Vibration of the system.
6. Characteristics of the material being transported.

Since the Bureau's goal was to characterize belt cleaning systems, the study was directed to cover the first two parameters, blade contact pressure and blade wear. The experimental procedures were designed to keep the remaining variables constant.

was used for recycling material. The discharge end of the test conveyor was fitted with a 24-in-diam pulley to closely represent the size commonly used by industry for large-scale haulage systems. The test conveyor was fitted with a bracket to which the experimental belt cleaning system was attached. The recycling conveyor was fitted with a large storage hopper at its discharge end, to provide constant material flow to the test conveyor.

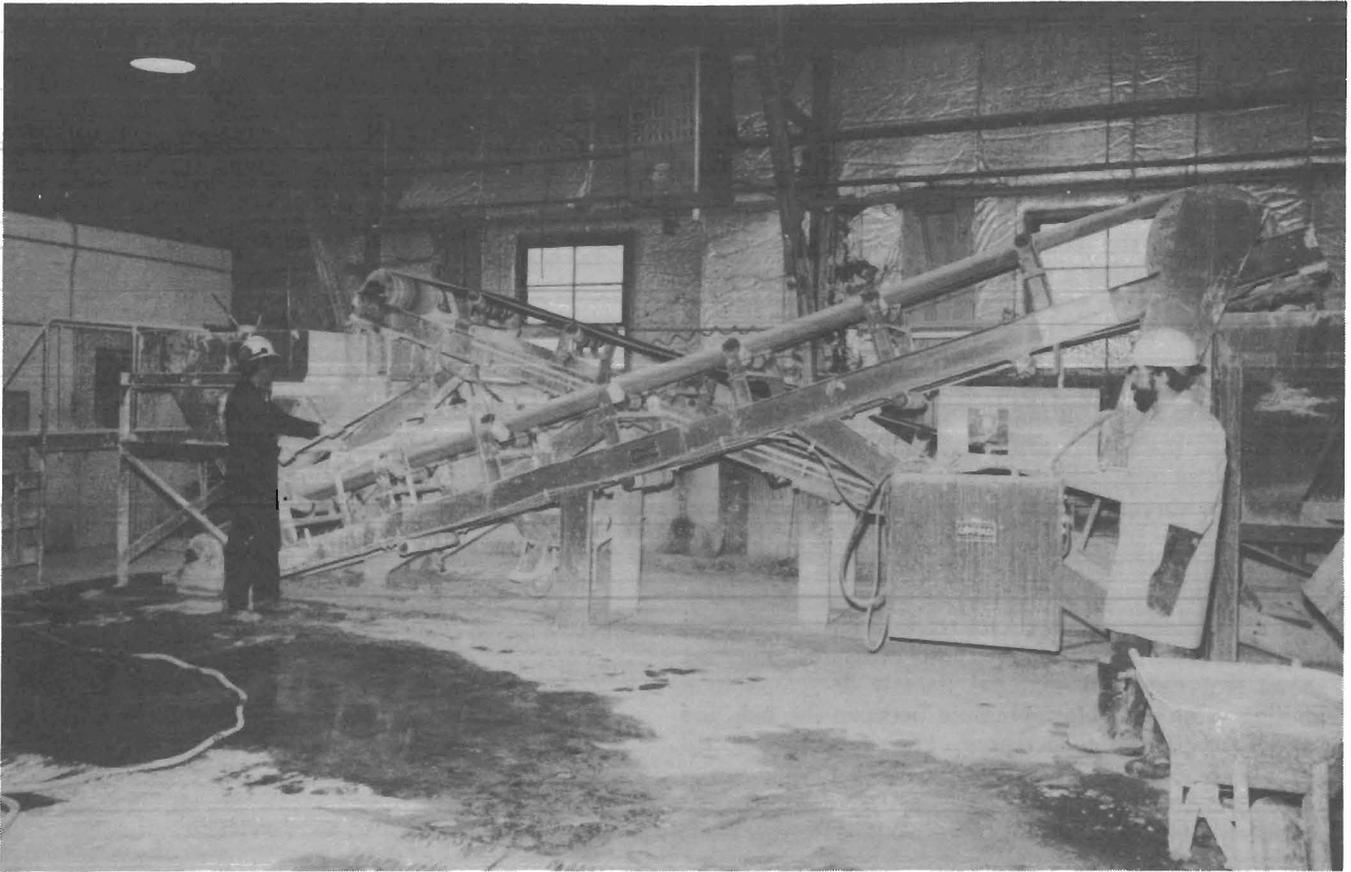


Figure 2.—Bureau test conveyors.

TEST FIXTURE BRACKET

A test fixture bracket was designed to hold four cleaner blades against the conveyor belt. For convenience during data interpretation and reporting, the blades were numbered 1 through 4, from right to left as viewed in figure 3. Each blade was attached to one end of a 1/2-in threaded steel rod. The other end of each rod pivoted about a 1-in rod mounted parallel to the head pulley axis. This arrangement allowed the blades to be swung to and from the surface of the belt in an arc. When they were in contact with the belt surface they formed a 90° angle to the belt. The blades were held against the belt by air cylinders mounted perpendicular to the belt. The force applied to the blades and belt could be controlled by varying the air pressure in the cylinders.

CLEANER BLADES

The conveyor cleaner blades used in the tests were fabricated from 2-in-wide, 1/4-in-thick flat stock of the following steels:

Hot-rolled plain (mild) carbon steel (AISI-SAE Type 1045).

Stainless steel (AISI-SAE Type 316).

Tool steel (AISI-SAE Type A-2).

Low-alloy steel (AISI-SAE Type 4140).

Sets of four 6-in-long blades were made from the 1045 and 316 steels, to cover the entire 24-in width of the belt. Only two blades of the 4140 and A-2 steels were used; the outside-edge blades were plain carbon steel (1045). The tool steel was cut to the desired length, heat treated in a neutral calcium chloride bath, and tempered to the desired hardness before use. The 4140 steel was cut from a larger plate and required milling for an acceptable edge. The 4140 steel was used as received [Rockwell C hardness (HRC) = 26].

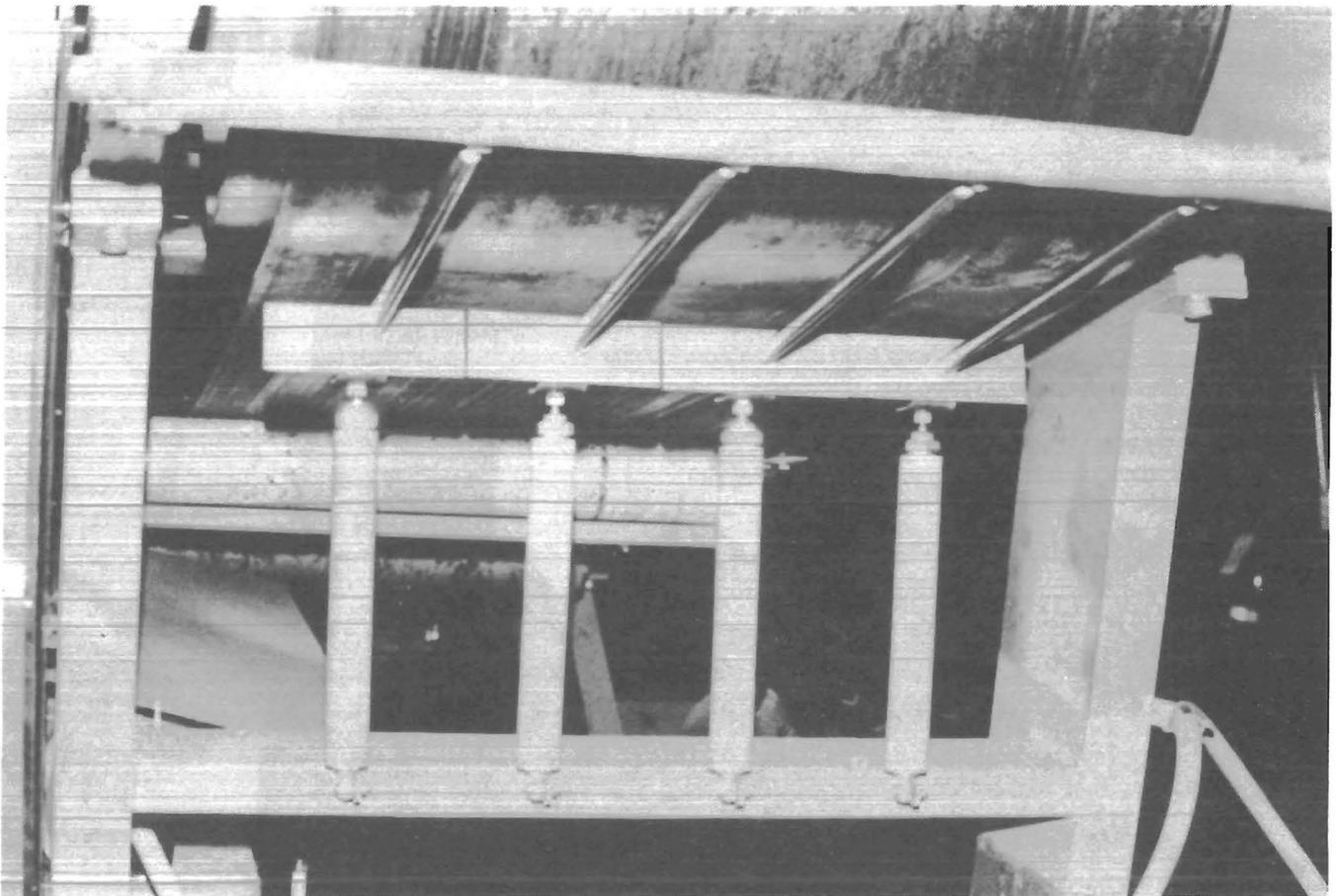


Figure 3.—Test fixture bracket for cleaner blades.

TEST PROCEDURES

The procedure for a test run was to load a small amount of the test mixture (sand and lime) onto the belt and spread it into a layer approximately 3/4 in thick. Because of the design of the troughed conveyor, only the middle two-thirds of the belt could be covered with material. Therefore, the outer two blades were installed but not used in the reported test results. The test material mix was similar to the mix developed under the Wyle Laboratories contract, the major difference being a much higher moisture content than noted in the contract report. It was found early in this study that a moisture content of

30 to 40 pct was required to obtain adequate cohesion of the material and adhesion of the material to the belt.

SAMPLING PROCEDURE

To sample the carryback, the test conveyor was shut down and the drive power was locked out. Several 1-ft-long strips of the 6-in-wide area swept by each blade were marked off. The carryback material was then scraped off of the belt (fig. 4). The sample was weighed wet and then dried at 90° C for 24 h and reweighed to determine the dry weight. The data were used to determine the moisture content of the sample.



Figure 4.—Sampling carryback material.

RESULTS

The results were examined relative to three separate phenomena:

1. System cleaning mechanisms.
2. Wear mechanisms.
3. Blade-to-belt system friction.

These three phenomena were found to be interrelated and interdependent. Each exhibited a transition through a critical pressure region when plotted against blade-belt pressure. The functional similarities among cleaning, wear, and friction show a relationship among them.

SYSTEM CLEANING MECHANISMS

Early trial runs confirmed that conveyor cleaning was directly related to blade pressure. Figure 5 shows the carryback-versus-pressure relationship found during

testing. The carryback-pressure relationship consists of two distinct regions. The first region is characterized by decreasing carryback with increasing pressure to a limiting value or critical pressure. This critical pressure range was found to be 11 to 14 psi. The second region occurs above the critical pressure and is characterized as having a constant amount of carryback with increasing pressure. These two carryback regions are characterized by two general mechanisms: blade-belt separation and particle wedging.

In order to understand the mechanisms of cleaning, it is necessary to examine the forces that cause the carryback material to be carried between the belt and the cleaner blade. The interactive dynamic forces moving the carryback material include friction, adhesion, cohesion, inertia, and collision. The interrelationships among these forces are complex. Figure 6 illustrates these phenomena at the cleaning edge of the blade and belt system. It is at this location that the material will either pass under the blade or be separated from the belt.

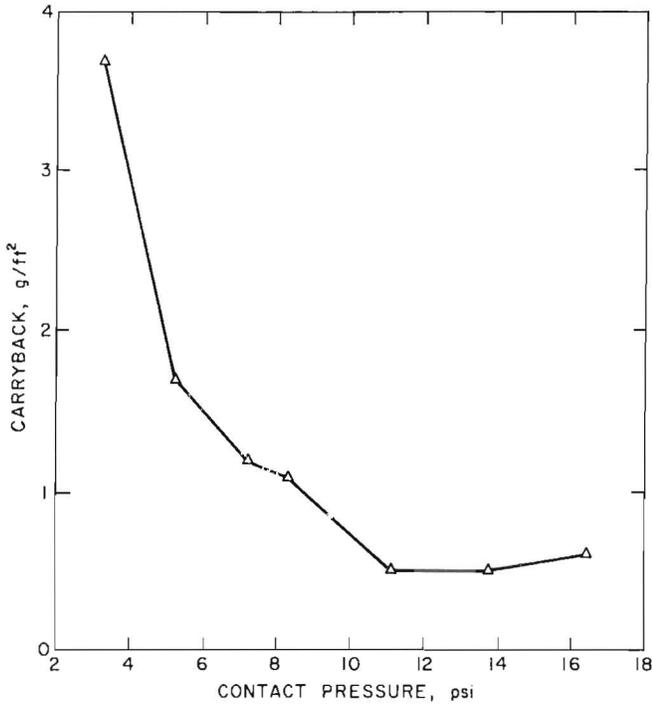


Figure 5.—Carryback material versus increasing contact pressure.

In the first region of the cleaning relationship described by figure 5, material passing under the blade must effectively separate the blade and belt surfaces. This separation is the first general carryback mechanism. The average separation distance is directly related to the carryback amount and is dependent on the pressure exerted by the material between the belt and the blade. This separation pressure is induced by several phenomena, including the momentum change of deflected material, the compression of streamlines because of the curved blade edge, and viscous forces (assuming the test mixture to behave as a viscous fluid). Figure 7 shows a simplified representation of the mechanism by which viscous forces cause material to be carried past the cleaner blade.

As the blade-to-belt distance decreases to a few particle diameters, the viscous fluid approximation is no longer applicable, since a few layers of relatively large material particles cannot behave as a viscous fluid. This is the situation described by the second region of the cleaning relationship of figure 5, in which carryback remains constant with increasing blade-to-belt pressure. The relative size of the particles with respect to the dulled edge of the cleaner blade, in combination with friction and adhesion, determines if the particles will pass between the

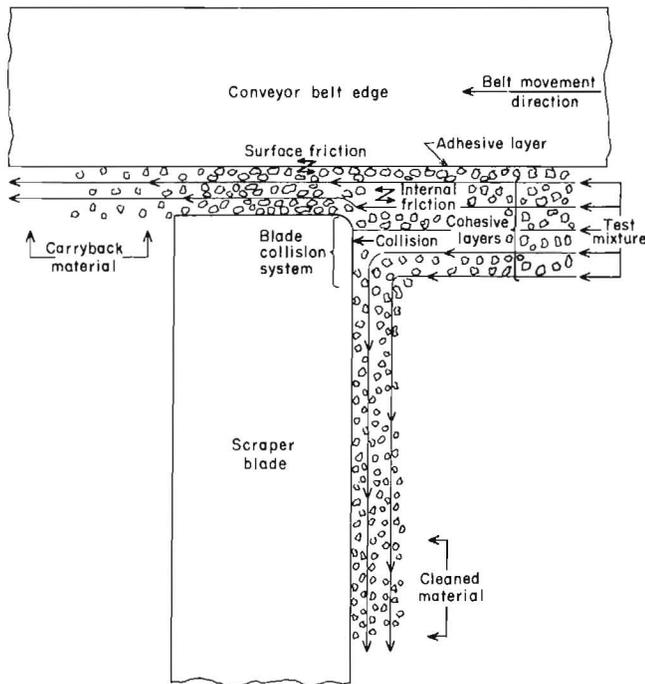


Figure 6.—Interrelationships of forces involved in belt cleaning.

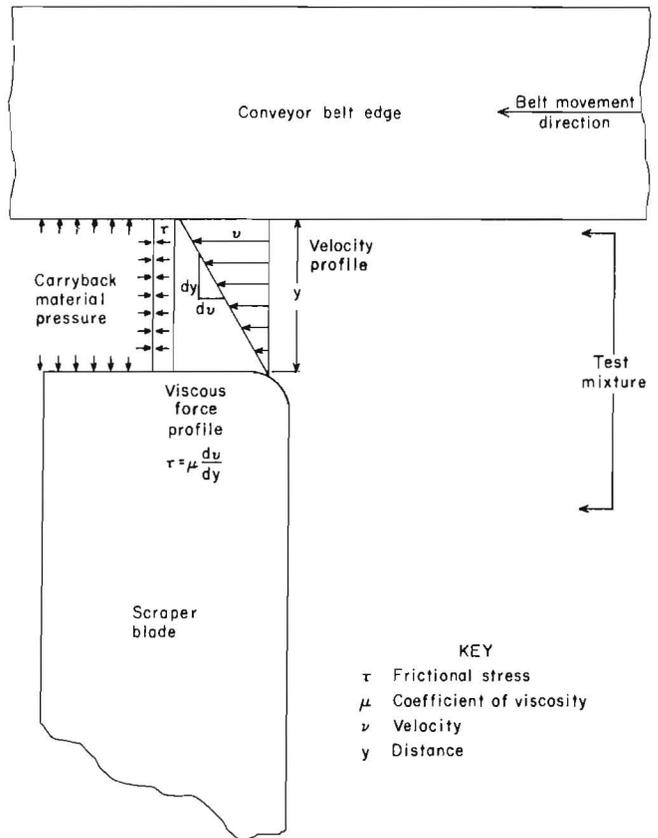


Figure 7.—Forces causing blade and belt separation.

blade and belt. Particles passing between the blade and belt are typically trapped by wedging. This is the second cleaning mechanism and is illustrated in figure 8. Blade pressure is insignificant in this region, and belt smoothness and cleaner blade sharpness are more important for proper cleaning.

A cleaning limit is achieved with this second cleaning mechanism, which is related to the belt roughness, the blade condition, and the blade material (3). This limit is a function of the natural roughness of the blade and belt, which allows material to be trapped or wedged in small pockets in the belt or to pass through microscopic crevices in the blade.

INFLUENCE OF BLADE WEAR ON CLEANING RELATIONSHIP

The carryback-versus-pressure relationship, as depicted in figure 5, is highly subject to the wear of the cleaner blade edge. It was found in every experimental trial for all blade-to-belt pressures that cleaning effectiveness decreased over time because of uneven blade wear. The unevenness of the wear pattern was found to be the key to understanding cleaner effectiveness. Figure 9 shows the influence of wear time on the carryback-pressure relationship. The cleaner blade were found to effectively wear out and lose cleaning effectiveness after a few hours.

Typical wear consisted of distinct troughs or channels at blade edges and across the blade. (Specifics of blade wear mechanics are discussed in the following section.) These edge and channel wear areas provided local pathways for carryback to pass between the belt and the blade, which compromised cleaning effectiveness because the belt could not conform to the blade in these relatively deep and narrow blade wear troughs. Once the channels formed, no realistic level of blade-to-belt pressure could prevent the blade from wearing out. Material passing through these troughs would form visible stripes on the belt. With consideration given for blade wear, the carryback-pressure relationship was found to be predominantly influenced by the belt conformance to the blade, irrespective of pressure.

Any material passing through these blade troughs caused further local blade wear. The material flow past the blade in these pathways is described by the viscous model. The depth of blade erosion is subject to the viscous forces and velocity gradient previously discussed. As the depth of blade erosion increases, the viscous carryback erosive forces decrease. As these pathways develop, it becomes possible to have both viscous and wedge carryback phenomena operating simultaneously. The viscous carryback mechanism occurs in blade channel wear areas, and the wedge carryback occurs on the higher flat areas of the blade. This understanding pointed out the importance of blade wear characteristics in conveyor cleaning effectiveness.

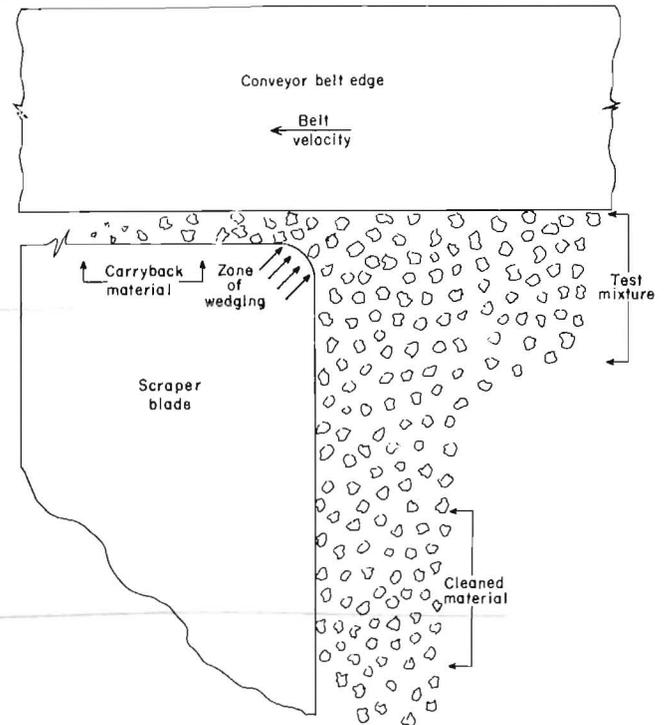


Figure 8.—Wedging mechanism for generating carryback material.

WEAR MECHANISMS

The wear mechanisms were studied by monitoring changes in the conveyor belt and the cleaner blades. The conveyor belt was noticeably worn after 1,000 h of use in the test program. During the course of this investigation, an attempt was made to quantify belt wear. Belt thickness was measured over a period of 200 h with a blade pressure of 40 psi in a special test stand. Belt thickness decreased by 0.015 in because of wear, but after 80 h it increased by an equivalent amount, probably because of swelling of the carcass and/or cover. It was not possible to continue this line of inquiry.

Several types of used, commercial blades were obtained to characterize industrial blade failure. These blades were made of polyurethane, ceramic inserts, tool steel, and mild steel, as shown in figure 10. The four blades in this figure show the same characteristic uneven wear pattern of worn edges and breakthrough troughs as the mild steel blades used on the research conveyor (fig. 11). The two blades located on the outside edges of the conveyor belt (1 and 4 in figure 11) exhibit severe edge wear and many troughs that expanded with time. The severe wear is believed to be caused by excessive belt vibration at the sides, allowing large quantities of carryback mix to flow past blades as

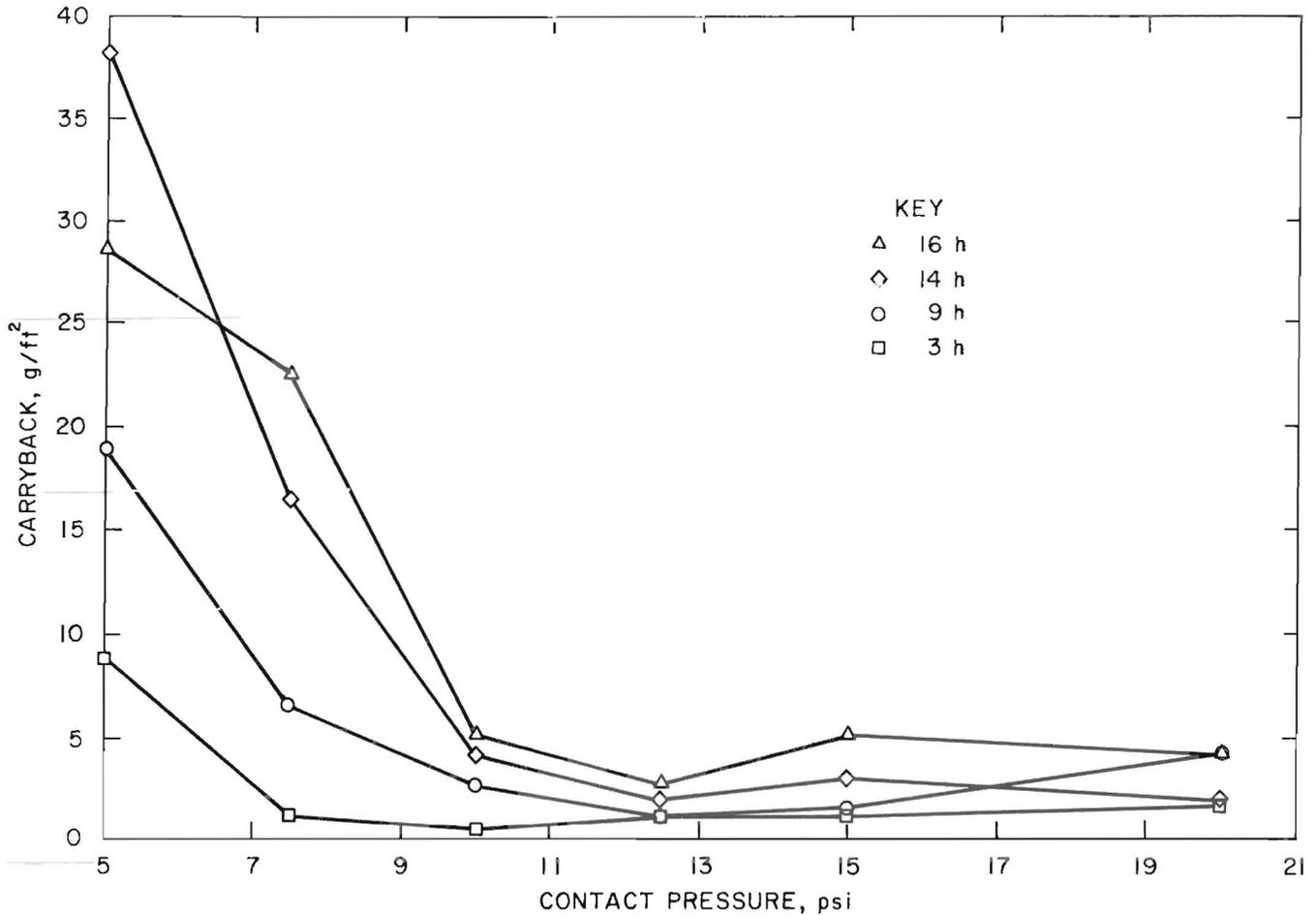


Figure 9.—Influence of wear on relationship of carryback material to contact pressure.

described by the carryback wedging model. The two center blades (2 and 3) show edge wear and only one or two troughs. These two blades were used to study the wear mechanisms and cleaning parameters.

Longitudinal and cross-sectional photomicrographs of a mild steel (1045) cleaner blade are shown in figure 12. Uniform grain structure is shown in figure 12; the grain size decreases near the surface because the samples were hot rolled. There is no evidence of pitting or intergranular attack. No chemical corrosion would be evident because of the high alkalinity of the carryback mix (pH >12) and the short test period of 34 h (4-5).

The details of the gross metal loss or wear from a mild steel (1045) blade are shown in figures 13 and 14. The leading edge after 1 h is shown in figure 14A, while the same material after 8 h is shown in figure 14B. Both figures show deep grooves cut into the cleaner blade's

surface by the wedging phenomenon. The direction of the abrasive particles is shown to be mainly parallel to the conveyor belt's direction, but some particles changed direction. The occurrence of the nonparallel paths indicates that particles rotated or moved relative to each other, while removing metal from the cleaner blades as described by the cleaning mechanisms. This is typical of abrasion and erosion wear. Abrasion is caused by the individual quartz and feldspar particles being wedged or pulled through the blade-belt interface by the belt motion. Erosion is caused by the viscous fluid going through the deep paths cut by the quartz and feldspar particles during abrasion. Tables 2 and 3 list the masonry sand particle size distribution, composition, and hardness. This information shows that coarse quartz and feldspar particles can easily cut the softer mild steel.

Polyurethane



Ceramic insert



Tool steel



Mild steel



Figure 10.—Worn commercial conveyor cleaner blades of various materials. Mild steel blade is 6 in long.

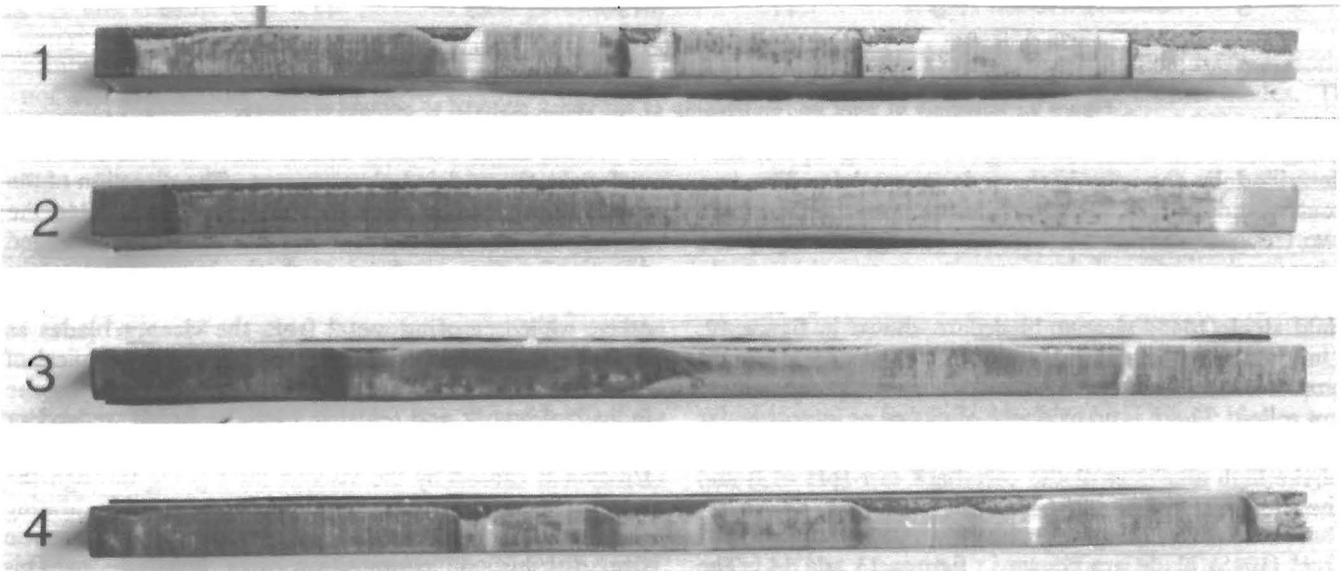


Figure 11.—Worn research conveyor cleaner blades (1045 mild steel) after 18 h. Blades are 6 in long.

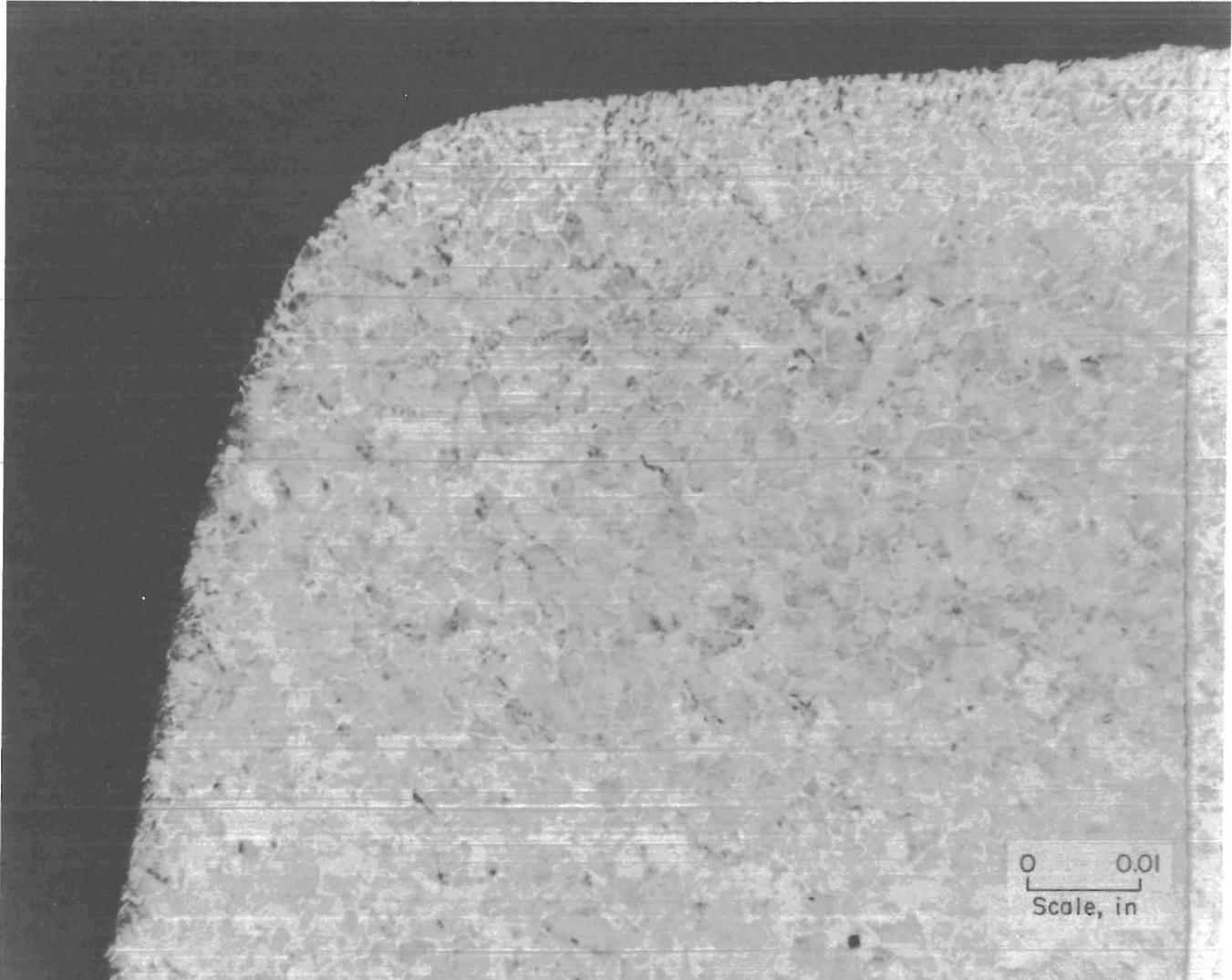


Figure 12.—Mild steel (1045) cleaner blade’s leading edge; photomicrograph.

TABLE 2. - Masonry sand particle size distribution

Particle size, μm	Cumulative fraction, wt pct
833 (+20 mesh)	34.7
600 (+28 mesh)	58.9
425 (+35 mesh)	78.5
212 (+70 mesh)	96.2

TABLE 3. - Masonry sand composition and associated mineral hardness

Mineral	Composition fraction, wt pct	HRC ¹
Quartz	70	62
Feldspar	25	47-55
Calcite	5	≤ 1

¹Mild steel (1045) HRC = 11.

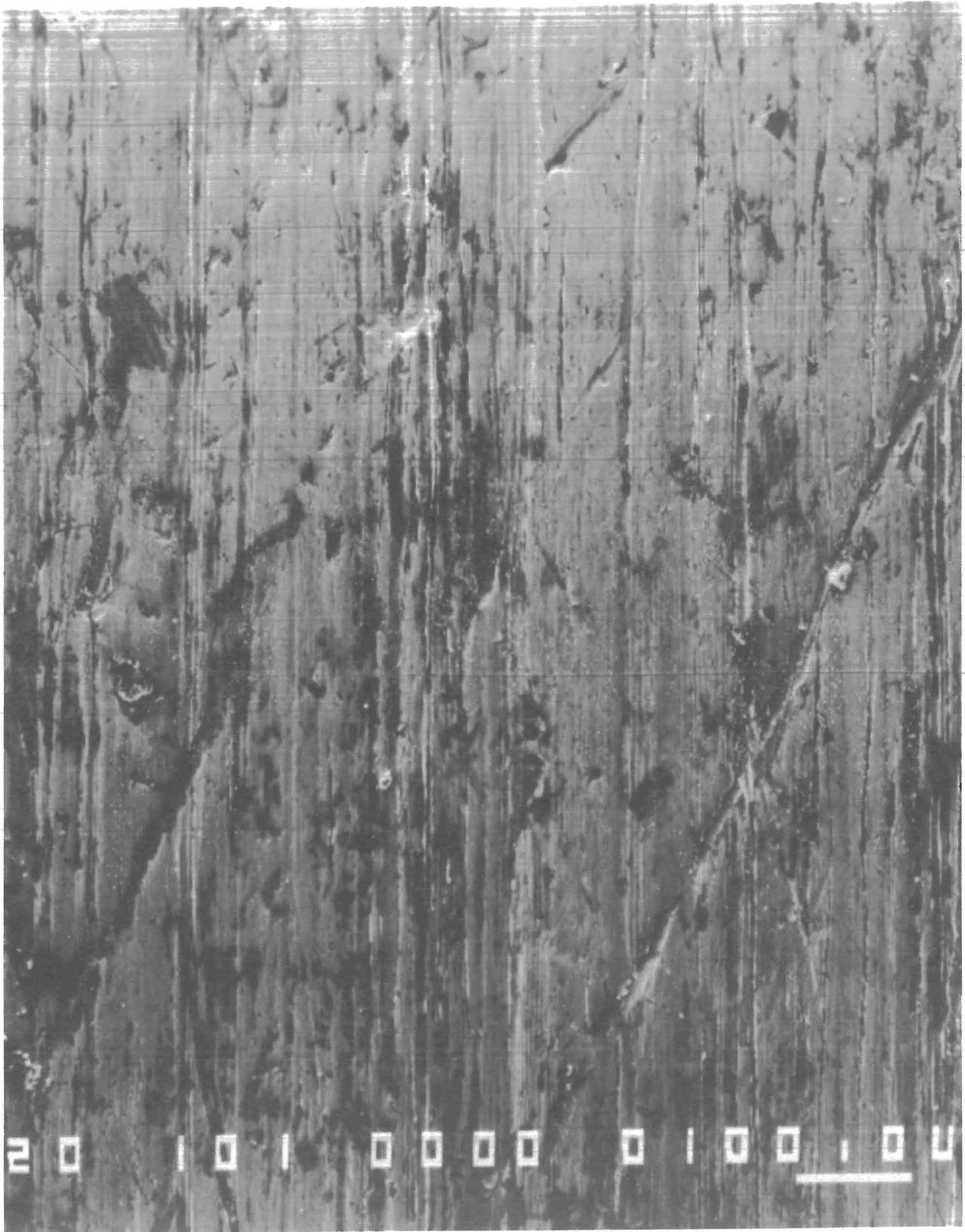


Figure 13.—Mild steel (1045) cleaner blade's wearing surface; photomicrograph.

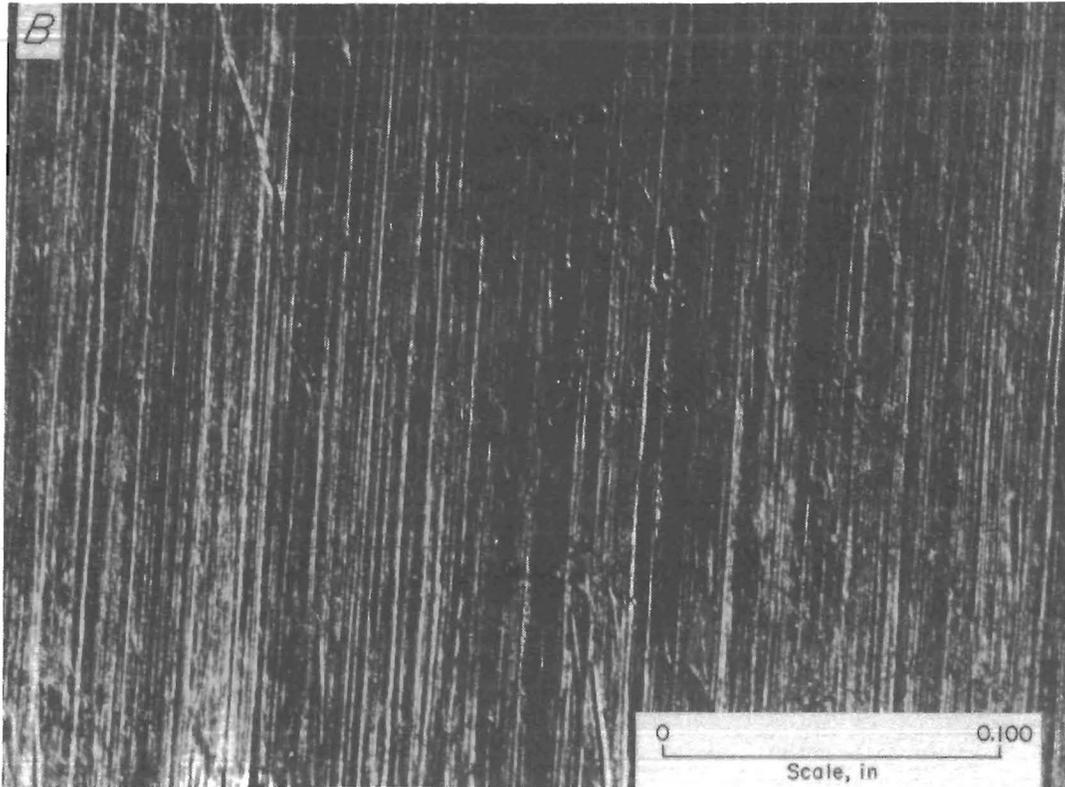
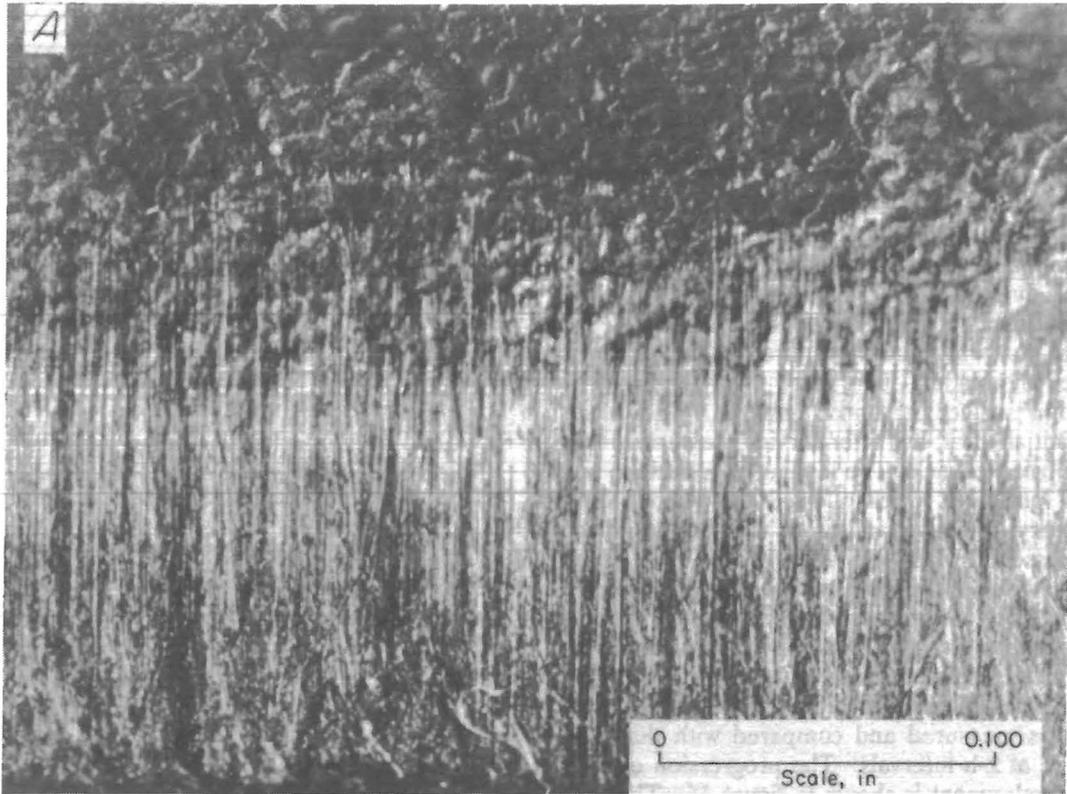


Figure 14.—Mild steel (1045) cleaner blade's surface after 1 h (A) and 8 h (B) exposure to coarse sand-lime slurry.

Recent research has divided abrasive wear into two groups: two-body and three-body systems. Two-body abrasive wear occurs when a rough surface or mass of fixed particles slides across the wear surface. In three-body abrasive wear, the particles are loose and may move relative to one another and possibly rotate while sliding across the wearing surface (6-8). Therefore, the wear mechanism of the cleaner blades can be labeled three-body abrasive-erosive wear.

Visual examination of mild steel blades 2 and 3 (fig. 11) at 1-h intervals during the 18- to 34-h tests showed that the initial wear occurred at the blades' adjoining edges. In several hours, material would go through the adjacent space between the blades. This space slowly enlarged as the worn edge surface advanced inward. The blade surface was initially flat, but after service the surface was angular from front to back. The leading edge surface was rounded and polished, which allowed the viscous fluid (sand-lime slurry) to collect and erode the surface. Once the erosion lessened blade contact with the belt, slurry particles gouged into the blade's surface and were dragged across the blade-belt interface. After several such actions, small troughs were started. Once a trough started, it widened from the inside out as edge wear worked toward the center by abrasion and erosion. The blade surface topography was measured and compared with that of a standard blade at 2-h intervals. The progression of edge and trough development is shown in figure 15. The area where competing trough and edge wear met accounted for the small sharp ridge.

Visual examination of blades 2 and 3 (fig. 11) indicated that both blades wore by similar forces, but at different rates. Specific areas of the blades wore at different rates, but the same patterns were noted on all blades. This similar pattern allows the use of a general wear rate of mils per year to compare the different metal blades. This unit represents the run time, the density of the various metals, the initial amount of surface area in contact with the conveyor belt, and the blade's weight loss.

Experimental runs showed that blade wear values were directly related to blade-to-belt pressure. Figure 16A shows the wear-versus-pressure relationship found during testing. The amount of wear decreases with increasing pressure to a limiting value, after which the wear rate remains essentially constant. The relationship of wear to blade pressure consists of two distinct regions. The first region is characterized by decreasing wear rates with increasing pressure to a limiting value or critical pressure, which was found to be 11 to 14 psi. The second region occurs above the critical pressure and is characterized as having a constant wear rate with further increases in pressure. The relationships of carryback pressure (fig. 5) and wear rate to pressure (fig. 16A) are identical but

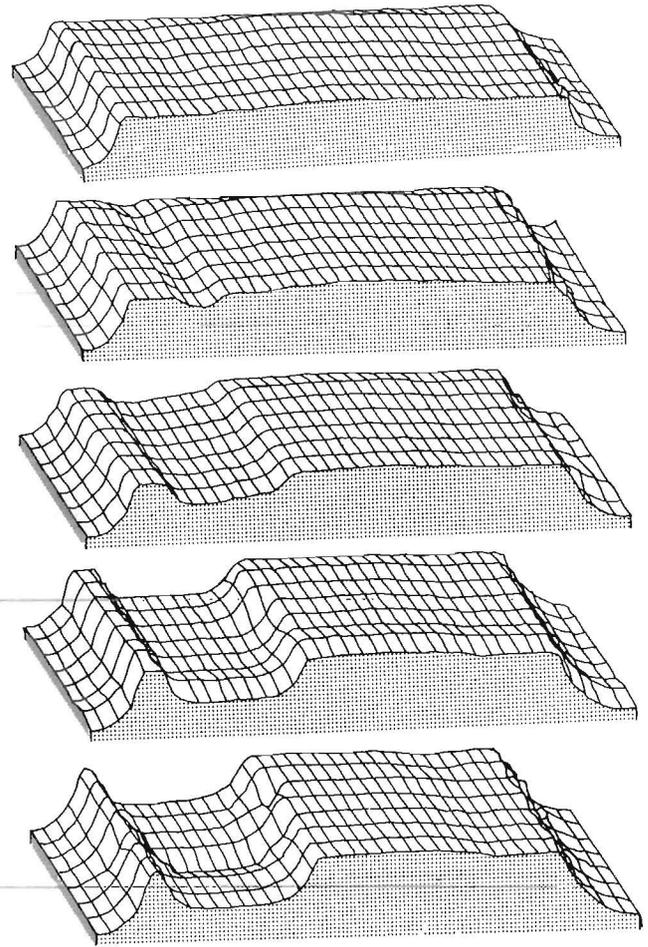


Figure 15.—Graphic progression of edge and trough development cross section at 2-h intervals from bottom to top.

could be unique to the research conveyor. Field evaluation would be required to confirm these data.

During the same experimental runs, blade 3 was observed to behave in a different manner. Figure 16B, shows both a decreasing and an increasing wear rate as pressure increases. Blade 3 wear rates decreased as the pressure entered the optimum range of 11 to 14 psi, but as the pressure increased the constant wear rate tended to increase. The minimum wear rates of 10 to 12 mil/yr are two times the wear rates of 5 to 6 mil/yr shown for blade 2.

The physical comparison of the blades' wear patterns after several different runs showed another difference between blades numbered 2 and 3. Blades in the number 2 position had severe edge wear as did blades in

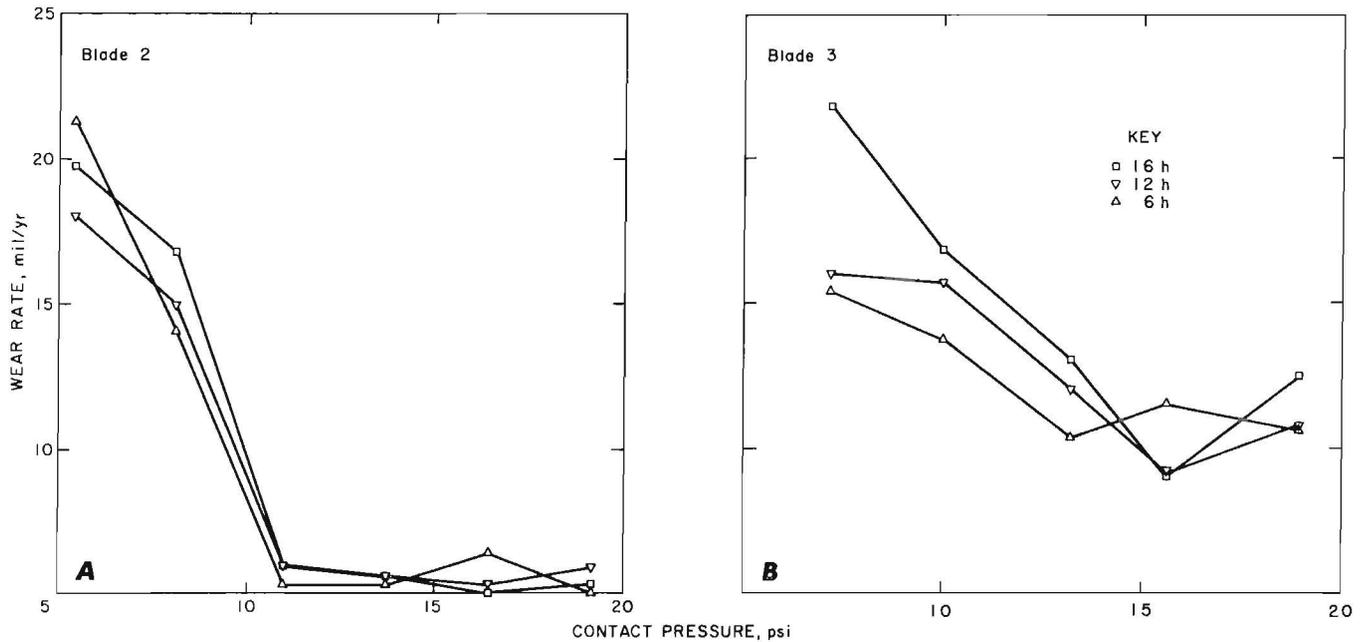


Figure 16.—Effect of applied pressure on wear rates of cleaner blades 2 and 3 (1045 mild steel) at various run times.

the number 3 position, but the characteristics of the blades' center wear were different. No. 2 blades had one trough or none developed randomly over the central part of the blade, while No. 3 blades had two distinct troughs developed in the central part of the blade between the edge wear. The centers of the two troughs were consistently at 46 and 98 mm from the blade edge and one trough was smaller than the other. The reason for the wear pattern on No. 3 blades was found to be the manufacturer's logo on the conveyor belt. Figure 17 shows the logo filled with carryback material after passing blade 3. The logo passed this blade 36 times per minute during a normal 18-h run. The logo's letter center lines and the letters' physical size directly correspond to the different-sized troughs on blade 3's cleaning surface (fig. 11). The logo allowed accelerated localized wear to occur by increasing the effect of the wedging and viscous carryback phenomena or abrasion-erosion. Once the cleaner blade's surface is damaged, no realistic level of blade-to-belt pressure will allow the blade to conform to the belt's surface for proper cleaning.

The effects of blade composition and metal hardness on wear are shown in figure 18. Samples of 2-in flat stock tool steel (type A-2) and a low-alloy steel (4140) were used. All metal test blades' hardness was measured. Then the test blades were installed in the test fixture to duplicate the mild steel blade runs and blade weights at an applied pressure of 12 psi. Figure 18 shows that increasing metal hardness from HRC 11 to 50 decreased the wear rate from 5 to <2 mil/yr. The metal composition affects the wear rate, but not as significantly as the hardness. This is evident by the high wear rates of steel blades with HRC ≤ 18 . The tool and 4140 steel blades (HRC ≥ 26) show that increasing hardness decreases wear rate. Visual observation of the various blades indicated that the wear mechanism and patterns were identical to those of the previously described mild steel blades, as well as the commercial blades. The increased metal hardness decreased the wear rates and increased the blades' service life, but the viscous and wedging phenomena or abrasion-erosion mechanism still damaged the cleaner blades' surface. Again, no form of corrosion was observed.



Figure 17.—Manufacturer’s conveyor belt logo filled with carryback material. Logo has just passed cleaner blade fixture and idler.

BLADE-TO-BELT SYSTEM FRICTION

As noted previously, the amount of carryback decreases with increasing blade pressure to a limiting value of cleaning. The cleaner blade wear rates exhibit an identical trend. Table 4 shows the typical cleaner blade contact pressure and conveyor head pulley drive motor current demand. Measurements of the conveyor’s blade-to-belt friction (motor current draw) follow a pattern consistent with carryback and blade wear relationships (table 4). Conveyor friction is constant until applied blade pressure exceeds the apparent optimum cleaning pressure range, at which point system friction increases drastically. This transition is further evidence for the existence of an optimum cleaning pressure range, which was 11 to 14 psi on the test conveyor. Increased friction beyond this

pressure range will cause heating of the blade and belt and will cause increased belt wear (9). Field tests are necessary to determine if monitoring motor current would be applicable to larger commercial systems.

TABLE 4. - Conveyor drive motor current draw at various pressures

<u>Applied pressure, psi</u>	<u>Current draw, A</u>
5.5	15.0
6.8	15.2
8.2	15.2
9.6	14.8
12.2	15.6
15.0	15.8
17.6	16.8
20.3	18.7
22.0	19.8

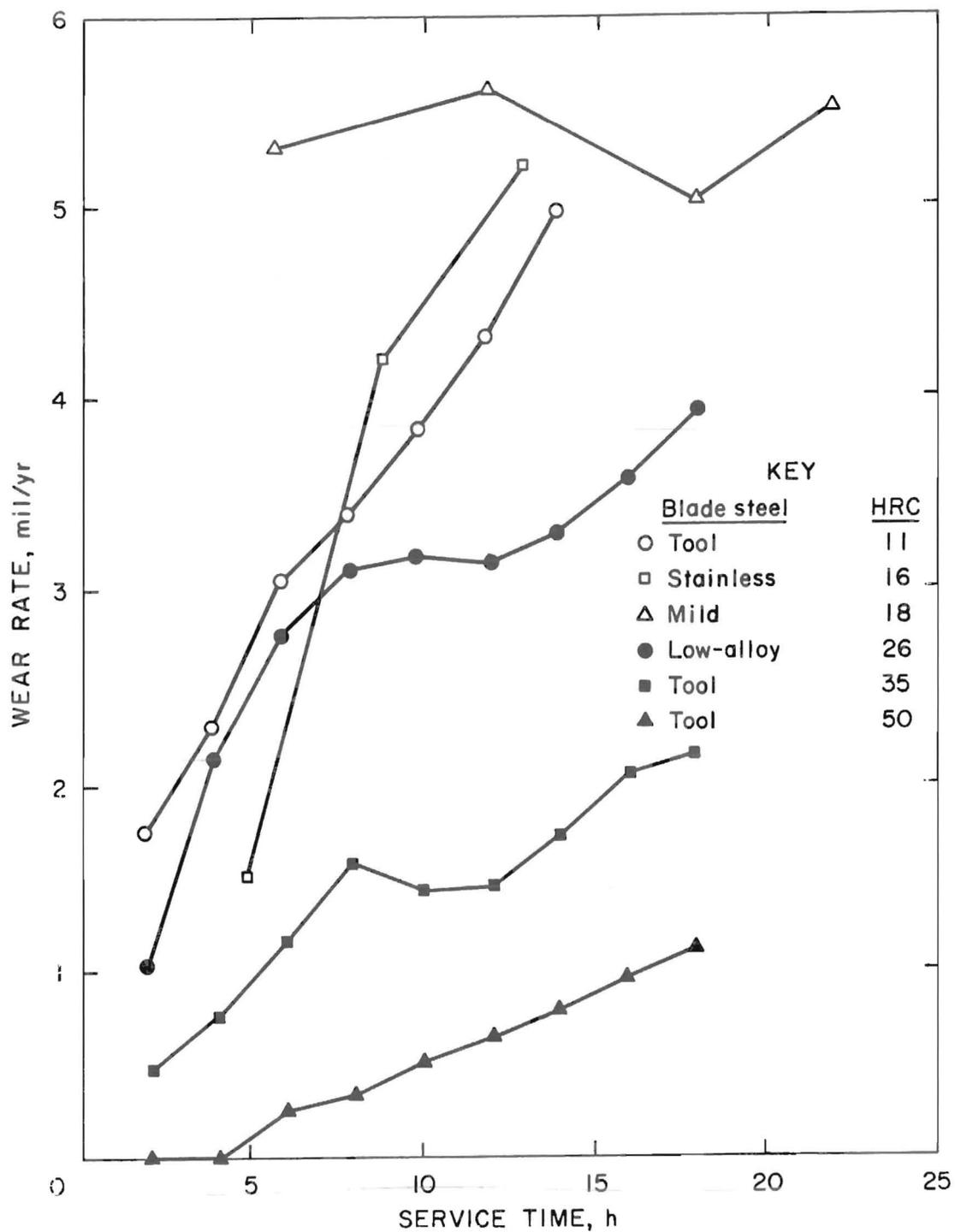


Figure 18.—Effect of service time on cleaner blade (1045 mild steel) wear rates at various steel hardnesses.

CONCLUSIONS

The carryback- and wear-versus-pressure curves indicate the existence of an optimum operating pressure for the type of conveyor belt cleaning system used in this study. Above this optimum pressure, no significant decrease in carryback was observed, but the conveyor belt-blade friction increased. Pressure dependencies of the parameters are shown in figure 19.

Nonuniform wear patterns were observed on the cleaning edge of all blades. The channels or grooves worn into the blade edge allowed passage of carryback that could not be eliminated by increasing the blade-to-belt contact pressure.

Company logos or other patterns that are recessed into the belt cover allow material to get between the blade and belt and greatly accelerate uneven blade wear. The

uneven wear pattern of the blade edge will be characteristic of the pattern in the belt and can reduce blade service life by 55 to 60 pct.

There was no evidence of corrosion on any of the blades used for up to 34 h by scanning electron microscope examination. No evidence of excessive belt wear was noted in the region of critical pressures.

The results of this study should provide mine operators with information that will allow them to operate conveyor belts with greater cleaning efficiency and lower rates of blade wear. This should minimize the amount of carryback material that accumulates under a conveyor, thus reducing the hazards of fire and explosions caused by this material.

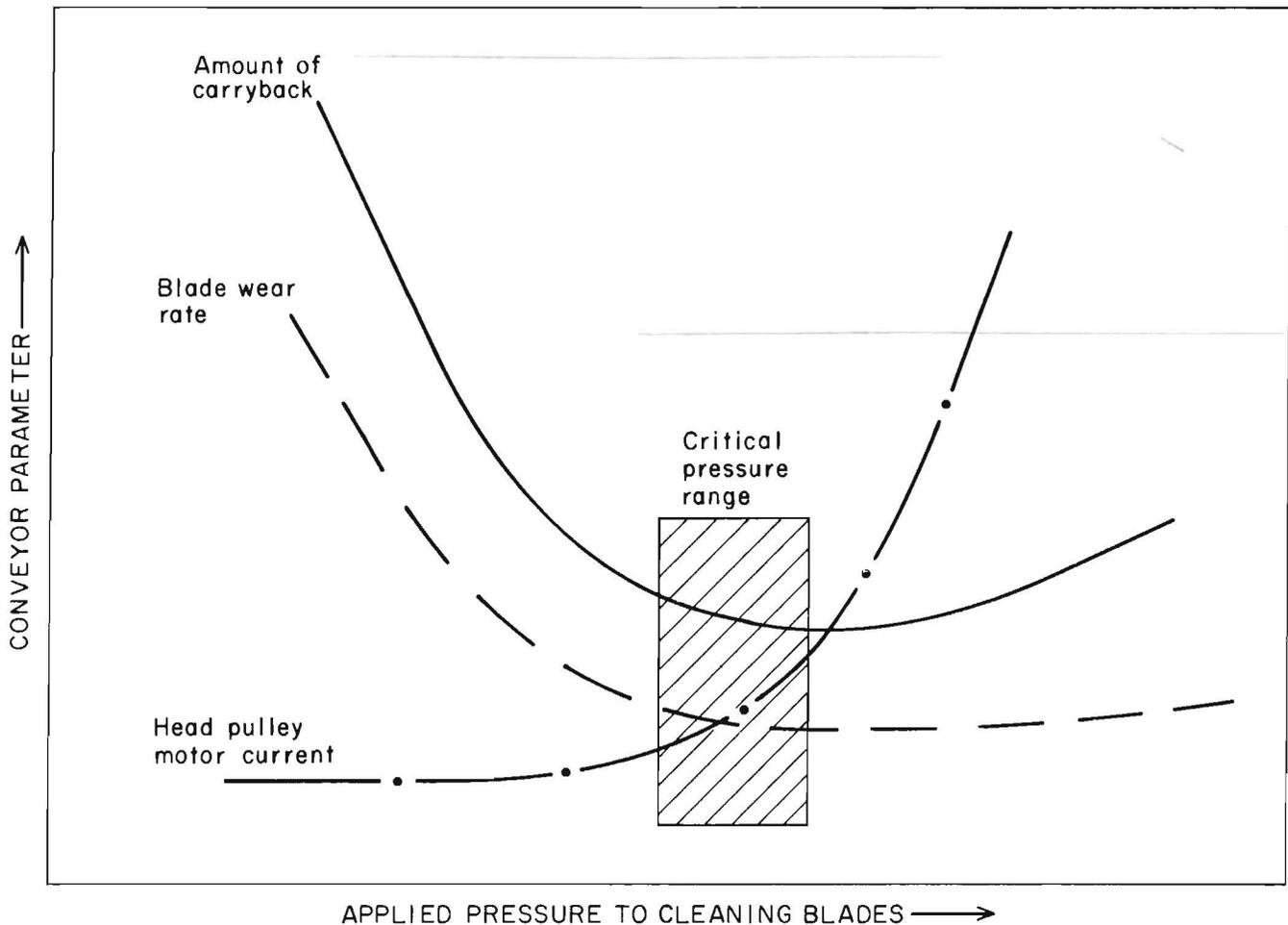


Figure 19.—Pressure dependencies of parameters.

REFERENCES

1. Mason, W. A. Analysis of Underground (Non-Face) Conveyor Accidents. Coal 1978-80. MSHA Tech. Rep., undated, 12 pp.
2. Kleysteuber, W. Safety Evaluation of Conveyor Belt Cleaning Systems (contract J0215015 Wyle Lab.). BuMines OFR 174-83, 1983, 119 pp.; NTIS: PB 83-262600.
3. Roberts, A. W. Conveyor Belt Cleaning - A Bulk Solid/Belt Surface Interaction Problem. Pres. at 11th Annu. Powder and Bulk Solids Conf., Chicago, IL, May 12-15, 1986; available from C. A. Rhoades, Twin Cities Res. Cent., BuMines, Minneapolis, MN.
4. Avery, H. S., et al. Wear Failure. Ch. in Metals Handbook. ASM, v. 10, 8th ed., 1975, pp. 134-141.
5. Fontana, M. G., and N. D. Greene. Corrosion Engineering. McGraw-Hill, 1978, pp. 70-107.
6. Misra, A., and I. Finnie. A Classification of Three-Body Abrasive Wear and Design of a New Tester. Wear, v. 60, 1980, pp. 111-121.
7. _____. A Review of the Abrasive Wear of Metals. Trans. ASME, Ser. H, v. 104, No. 2, 1982, pp. 94-101.
8. Moore, M. A. A Review of Two-Body Abrasive Wear. Wear, v. 27, 1974, pp. 1-17.
9. Verbeek, H. J. Tribological Systems and Wear Factors. Wear, v. 56, 1979, pp. 81-92.