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[ACHINING WOOD WITH COATED ABRASIVES

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SUMMARY

The studies presented in this report comprise an attempt to obtain further information on the machining of wood with coated abrasives under controlled conditions.

They include a determination of the effect of lower velocities on the performance of coated abrasives, tests to obtain factual information on belt length to increase the efficiency of the testing methods, effect of four different species and two moisture-content levels, comparative tests of competitors' materials, operational differences of open- and close-coated belts, statistical analysis of a group of data, exploratory controlled abrasion tests on Masonite, and, finally, controlled tests to determine the performance characteristics of Sandscreen as a furniture rubbing material.

It is hoped the information presented here will serve as a valuable tool that will enlarge the knowledge of coated abrasives.

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MACHINING WOOD WITH COATED ABRASIVES

EFFECT OF LOWER VELOCITIES

Scope

This inquiry was organized to determine the effect of lower belt velocities on the relative life of coated abrasive materials.

Introduction

Previous velocity studies have indicated that rate of material removal increases with an increase in velocity from 5000 to 7500 sfpm, this increase being roughly proportional to the increase in speed. On doubling the velocity to 10,000 sfpm, the cutting rate is initially high but declines rapidly, the rate being comparatively less after 60 to 90 minutes adjusted running time than at 5000 and 7500 sfpm for the garnet and 7500 sfpm for the Aloxite. This reduction is attributed to excessive loading, which results from the wood substance plasticizing at the elevated surface temperatures created.

As these tests were conducted at belt velocities in excess of those recommended for garnet, it was considered expedient to take into account lower belt velocities. In conjunction with this plan, Aloxite was included although belt speeds lower than 4000-5000 sfpm are not generally recommended for this material.

Procedures

Abrasive belts were close-coated garnet and Aloxite paper-backed glue-bonded material. Belt velocities of 2340 (the lower velocity limit of the testing machine) and 3750 sfpm at 0.8 psi platen pressure on a 4-inch side-grain hard-maple specimen were used. The grit size was 120 (3/0) from run WW2T in the case of the garnet and 5HWH2 for the Aloxite.

Results and Discussion

As anticipated, lower velocities did not alter the performance characteristics of the abrasive materials with the rate of material removal decreasing as the belt velocity decreases (Figs. 1 and 2). This decline is roughly proportional to the decrease in belt velocity.

As previously observed, the drop in cutting capacity of the belts in respect to running time for a given velocity level is primarily due to the abrasion of the grits, as loading at these reduced speeds was not serious. Surface temperatures generated were considerably below the range at which wood substance plasticizes to cause clogging of the grits (Fig. 3). No evidence was found of the grits fracturing at these low speeds.

Of interest is the fact that Aloxite maintained a cutting rate superior to garnet at the lower belt velocities although lower belt speeds are not normally recommended for this material.

In general, it appears more advantageous from the standpoint of belt wear and rate of material removal to employ low speeds and heavy pressures rather than high speeds and light pressures. For a given rate of material removal, lower speeds and heavier pressures are more efficient in that a heavier chip results from an increase in depth of cut. As a consequence, a greater amount of material is removed with fewer cuts. Another factor contributing to the increase in belt life is that contact distance is reduced. This reduction in contact distance lessens to some degree the abrasion of the grits, allowing them to maintain a satisfactory cutting capacity for a longer period. In addition to these reasons, temperatures have a tendency to be slightly lower at reduced speeds and heavier pressures because, for a given pressure increase, additional abrasive grits come in contact with the work piece. This results in a higher cutting rate with slightly lower temperatures.

CHANGE TO TESTING MACHINE

Scope

This series of tests was designed to determine the possibility of increasing the efficiency of the present testing method by reducing the length of the abrasive belt.

Introduction

At the beginning of this project a standard Wysong and Miles No. 171 horizontal-belt sander was adapted to a 20-foot-belt. This length was selected with the intention of approximating production conditions as close as possible.

Testing procedures conducted on a 20-foot belt require from four to five hours to complete, i.e., to bring the belt to a point where the cutting life is reduced to constancy. By reducing this testing time, more information could be obtained per unit of work, thus increasing the efficiency of the test. It was felt that this could best be accomplished by reducing the length of the belt.

A 10-foot length was selected as it is a multiple of the original length of 20 feet. This has the advantage of ease in adjusting contact time. Contact time has been defined as that time during which a given area of an abrasive belt is in contact with the workpiece. Thus, at any given belt velocity, a 10-foot belt has twice the contact time as a 20-foot abrasive belt. An adjustment in this time places the two belts on an equal comparative basis.

Procedure

To accomplish this change, the original standards of the testing machine were replaced by those from an Oliver horizontal-belt sander installed at the Laboratory. This machine is equipped with a 2-hp motor rated at 890 rpm. Operational speeds on 60-cycle line current was found to be 900 rpm, providing a velocity of 4710 sfpm.

These standards were mounted in front of the testing machine to allow for the present table with its oscillating mechanism and pressure-application system to be used (Figs. 21 and 22).

The design of the original testing machine provided for the belt to operate with the grit in contact with the rubber-capped drive and idler pulleys. In making the changes to a shorter belt it was necessary to operate the belt with the backing against the facing of the pulleys.

A composite hard-maple test specimen four inches in length at 0 percent moisture content was used throughout the study (Fig. 23).

Belts were close-coated garnet and Aloxite, with grit sizes 80 (1/0), 120 (3/0), and 180 (5/0), the material for the 10-foot belts being of the same runs as the 20-foot belts. During the course of the study it was discovered that Aloxite exhibits very nearly the same extremes in variation as the garnet. Consequently, the Aloxite was dropped as it appeared repetitious.

A belt velocity of 4710 sfpm was used for this study. This velocity closely approaches the 5000 sfpm employed in the original study on the 20-foot belts. In plotting the data for the 10-foot belts, an adjustment in contact time was made for this difference in velocity. A platen pressure of 0.8 psi was employed on the contact area.

Results and Discussion

A plot of material removal over length of time the belt has been in use gives a hyperbolic curve for the 10-foot belts similar to that obtained for the 20-foot belts. As evident from Figs. 4 to 6, for the 1/0, 3/0, and 5/0 garnet belts, considerable variation exists in their relationship to one another, although they maintain the same general form. It is believed this variation can be attributed to those chance and "assignable causes" responsible for variation in a testing procedure and does not reveal a significant difference between the performance characteristics of the two belt lengths.

Chance variation is the sum of effect of the whole complex chance causes that go into a testing procedure, about which little can be done. The set of chance causes that produces this variation has been likened to the set of forces that operate to cause a penny to turn up heads or tails when it is tossed up in a random manner. Thus, the variation due to chance cannot be traced to any one single cause in the abrasive belts used and in the design of the testing procedures.

This is not true of "assignable causes" as the name implies. They are relatively large variations that may be attributed to special causes and for the most part, in this testing procedure, consist of the following:

(1) Difference in operators
(2) Difference in materials
(3) Difference in machine
(4) Difference in each of these factors over time

Each of these "assignable causes" is discussed in the order listed as to their probable effect on the variation of the test results.

1. Difference in Operators. During the first year of this project, the testing procedures were conducted by one person. Since this time, assistance has been given to the project in the form of part-time student help, employed to assist the full-time research assistant assigned to the project. Their work consists chiefly of preparing the necessary materials and operating the testing machine.

Although the testing procedures have been developed to a point where the operations are repetitious, it is impossible to eliminate all operator bias from the test results. Although every attempt is made to operate the testing machine within narrow operational limits, difference due to the operators are inherent and add to the variation within the data collected.

2. Difference in Material. As explained previously, chance causes of variation are inherent in a testing procedure. Likewise, in a manufactured product, such as an abrasive belt, chance causes for variation are present about which nothing can be done short of revising the manufacturing process itself. Hence, regardless of the care exercised in selecting the abrasive belts in respect to run numbers and conditioning pretreatment, any variation in the belts will be reflected to some degree in the information collected.

In addition, wide variation is recognized in the strength of clear wood, which is usually associated with a difference in the density of the material and with the variable conditions under which it is grown. These variations in strength, plus other factors such as organic and inorganic filtration products, grain direction, moisture content, etc., affect the abrasion resistance of wood.

In an attempt to overcome these factors of wood variability, a composite specimen was developed at the beginning of this project. The material in this specimen is selected through use of tables of random numbers. This was done to secure a test specimen that represented the average of the species. Preliminary examinations indicated that the hard-maple stock used for the test specimens has an average relative density that closely approximates the average of the species. However, in spite of the design of the test specimen and the care exercised in selecting straight-grain clear material, a slight variation will exist in the test specimens and should be recognized in the final test results.

3. Difference in Machine. As noted previously, operating conditions in respect to the orientation of the abrasive to the pulley was different for the test runs on the 10-foot belts as against the original 20-foot belts. It was considered that this condition was perhaps responsible for a large portion of the variation in the curves. As a result, a number of 20-foot belts were re-run under conditions identical to the 10-foot belts. As the variation for these belts was as large as for the 10-foot belts, it is impossible to attribute the difference in the rate of material removal to this factor. However, some variation is to be expected as a result of the machine and must be considered together with that caused by the other factors.

4. Difference in Each of these Factors over Time. In addition to the change in personnel connected with the operation of the testing machine, it may be assumed that some change in the abrasive belts has occurred due to aging that may affect their relative cutting life. Also, changes in the relative humidity and temperature of the Laboratory are to be expected through the course of the study as outside atmospheric conditions vary due to seasonal

changes. Hence, a change in these factors will, in respect to time, introduce an expected variation in the test results.

Conclusions

In view of the results of this study, the testing machine was permanently converted to one that uses a 10-foot belt. It is felt this was possible as variation in the coincidence of the material-removal curves can be explained and does not represent a significant difference in the performance characteristics of the belts due to length. In addition, interfacial sanding temperatures and belt loading were not significantly different from those of the 20-foot belts. Power requirements varied as the material removal varied. The same factors that operate to cause variations in material removal cause variations in the power requirements.

EFFECT OF SPECIES AND MOISTURE CONTENT

During the first phase of this project an exhaustive study was conducted to determine the effects of grit size, pressure, and velocity on such factors as belt life, rate of material removal, temperature, and power requirements. Sanding was conducted parallel to the grain on a hard-maple specimen composed of randomly selected wood samples. This was necessary to provide a statistically representative sample for sanding and to minimize the danger of variation in the wood masking the effects of changes in other conditions.

A logical supposition is that other species may have different effects on coated abrasives, as each species will differ in properties and will offer different resistances to the forces tending to abrade them. In view of this, it was deemed advisable to determine this effect of species on coated abrasives. Four species, cherry, Honduras mahogany, red oak, and Ponderosa pine, were selected to be used.

Mahogany and cherry are two of the most handsome of the hardwoods because of their reddish-brown color and luster when finished. For this and other reasons, they are valued highly in the making of quality furniture where sanding is one of the more important operations. Whereas mahogany and cherry are diffuse-porous and semidiffuse-porous, respectively, oak is a ring-porous wood. (A diffuse-porous wood is one in which the pores exhibit little or no variation in size; a semidiffuse-porous wood is intermediate between diffuse-porous and ring-porous. In a ring-porous wood the pores formed at the beginning of the growing season are much larger than those farther out in the ring). Because of this difference, a dissimilarity in behavior may be expected in the coated abrasive and wood surfaces. Ponderosa pine finds widespread use in the sash and door and mill-work industries because of its softness and uniformity of grain and attractive clear color. It is also used extensively in the manufacture of unfinished furniture.

In addition, the moisture content of wood is of considerable importance in the performance of an abrasive belt. When wood is dried below the fiber saturation point (a point where all water has been evaporated from the cell cavities, but the cell walls are still fully saturated with moisture), the cell walls become denser with bonds formerly attached to water molecules mutually satisfied, and as a result, the wood becomes stiffer and stronger. Thus, a decrease in moisture content in wood causes a corresponding increase in most of the strength properties of wood. Since an increase in strength accompanies a loss in moisture, this relationship will effect the behavior of coated abrasives when used to machine wood. Thus, it was considered necessary to conduct an organized study on the effects of moisture content. Two moisture content levels, 6 and 12 percent (± 1 percent) based on the oven-dry weight of the wood were selected to be used. For comparison purposes, spot-checks were made at 0 percent moisture content. The values of 6 and 12 percent closely approach those used by the furniture, sash and door, and mill-work industries. This study was incorporated with that of species effect to increase the scope of the information to be obtained.

In the original working plan for this series of studies, two belt velocities, 3750 and 7500 sfpm, were selected on the basis of the capabilities of the testing machine at the time this research was planned. Since the testing machine has been changed to one using a 10-foot belt, the lowest velocity level of the machine is 3300 sfpm. With the frequency changer in the system, the lowest velocity level is 4470 sfpm. On the basis of this it was decided to eliminate the velocity of 3750 sfpm and substitute 5000 sfpm. Moreover, previous investigations have shown that the rate of material removal is roughly porportional to velocity, and it is felt that no additional information is to be gained by repeating the entire procedure at 6000 sfpm as previously planned. The results obtained at this speed would be, at the most, of a quantitative difference.

Procedures

Belts were closed-coated garnet on belt paper with an animal-glue bond, 90 flex, 120 (3/0) grit, with a platen pressure of 0.4 and 0.8 psi. Testing was carried out in accordance with the procedures outlined in Progress Report No. 1.

Results and Discussion

The results of the investigation have shown that generally only quantitative differences result when species and moisture content are varied provided that wood characteristics, such as resin accumulations in pine, do not overshadow the effects of other factors, namely, density and moisture content. Nevertheless, significant information was obtained that is of considerable importance, along with an indication of the general relationships to be expected.

Figure 7 is a plot of rate of material removal over running time for three species: Honduras mahogany, black cherry, and northern red oak at 6 percent moisture content, with closed-coated animal-glue-bonded garnet belts at 5000 sfpm and 0.8 psi platen pressure.

The relationship of these curves appears to be associated to a large extent with the density of the species involved, as resistance to indentation is dependent primarily on this factor. That the less dense species, mahogany, is abraded at a higher level is indicative of the increase chip load per grit due to the greater depth of penetration of the grit particles.

Of significant interest is the slope of these curves. After approximately 15-minutes running time the curves are very nearly identical in slope, possibly indicating the cutting capacity of the belts is decreasing at approximately the same rate for the three species shown. Where loading is not a factor, as in this case, a loss in cutting capacity is primarily attributed to grit wear. It is evident from these curves then, that grit wear is proceeding at very nearly the same rate regardless of species or relative density. This might be explained on the basis of the actual density of wood, that is, the material making up the walls of the wood constituents, which is practically the same for all species. Disregarding organic or inorganic infiltration products, one wood will weigh more or less than another at a given moisture content depending on the relative volume of wood substance and voids.

Hence in abrading wood, the actual wear of the abrasive is the result of the abrasion of the grits by the wood substance comprising the cell walls. However, as explained previously, relative density controls to the greatest extent the penetration of the grit particles. Thus, for any given set of conditions, a larger chip will be formed with the less dense species, giving a higher rate of material removal.

It is recognized that other wood factors, e.g., resin accumulations, will influence the relative cutting life of an abrasive. These factors must be taken into consideration when appraising the cutting efficiency of a coated abrasive. This was found to be true to a high degree in abrading Ponderosa pine which contains considerable resin (Fig. 10). Loading occurred almost immediately and the rate of material removal dropped with extreme rapidity. Washing the belts with mineral spirits removed a considerable portion of the resin and restored the cutting ability of the belts but at a lower level of material removal. This is supposedly due to the abrasion of the grits during the period of loading.

Sanding temperatures were found to be somewhat lower for the less dense species than for the denser species investigated. However, for the range of species studies, the slight differences were not considered to be significant.

There appeared to be no discernible differences in the degree of loading between the various species tested except for the Ponderosa pine. Because of the range of temperatures developed during sanding, loading was negligible. Surface temperatures were below the point at which wood plasticizes and chars.

Figures 8 and 9 are a plot of the effect of moisture content on the rate of material removal for two species, Honduras mahogany and cherry, sanded at 0, 6, and 12 percent (± 1 percent) moisture content with close-coated glue-bonded garnet abrasive at 5000 sfpm and 0.4 psi platen pressure.

The levels of these curves are unquestionably controlled by the moisture content of the stock, being the greatest for the higher moisture content. This is indicative of the reduction in strength properties which accompanies an increase in moisture content. The slopes of the curves for the two species shown at the various moisture contents are again very nearly identical. From this it may be assumed that moisture content does not appreciably influence rate of grit wear.

Sanding temperatures were slightly lower for the higher moisture contents, but as before, the temperatures developed between the various moisture-content levels were not considered to be significantly different.

Loading of the belts was negligible, there being no noticeable increase with an increase in moisture content. Loading is normally dependent upon surface temperatures developed. During these tests, sanding temperatures were not in the range where wood plasticizes and loading takes place. As a result, loading was at a minimum. An exception is the loading which occurs with pine which is due to resin and not temperature.

Cupping of the abrasive belts showed a pronounced increase as the moisture content of the stock being sanded was increased. This is apparently due to the absorption of moisture by the adhesive causing an expansion of this film. As the swelling stresses imposed upon the adhesive are greater than those caused by the paper, the belt will tend to cup toward the backing. The greater the degree of moisture absorption by the adhesive, the greater is the resulting belt cup. Aiding this is the shrinkage of the backing that may occur due to moisture being driven from the paper as the result of the frictional heat generated through contact with the platen. Reverse cupping or cupping towards the adhesive will take place if the magnitude of these stresses is for some reason reversed.

COMPARATIVE TESTS OF SWEDISH MATERIAL

Scope

This series of tests was planned to compare on the basis of cutting life, sanding temperatures, and power requirements the following abrasive materials: Aloxite 2HWH, Naxalumo KAS 6800, and Naxolit KJA 6543.

Procedures

The abrasive belts were closed-coated aluminum oxide on belt paper with an animal-glue bond. Grit size was 80 (1/0) used with a platen pressure of 0.8 psi and a velocity of 5000 sfpm. The testing specimen was hard maple at 0 percent moisture content.

Results

The plotted data on material removal is shown in Fig. 11. The cutting ability of the Naxolit KJA material appears to be superior to that of Carborundum Aloxite 2HWH and Naxalumo KAS. The cutting rate of Aloxite in turn was somewhat greater than that of Naxalumo KAS, the most significant difference being observed during the initial cutting period.

Wood surface temperatures generated were practically identical for the three belts tested with a drop from 350° F at the beginning of the test to approximately 300° F at the end of 80 minutes running time when the tests were terminated.

Power requirements for the material were plotted against running time, as shown in Fig. 12. It is apparent that the curves closely parallel those for material removal, being initially high at the beginning of the test and dropping off due to belt wear.

COMPARATIVE TESTS OF COMPETITORS' MATERIAL

Scope

This series of tests was planned to compare abrasive materials manufactured by 3M, Behr-Manning, and four experimental runs and one regular run of Carborundum's Aloxite.

Procedure

Tests were made on 120 (3/0) grit EC close-coated aluminum oxide on belt paper with an animal-glue bond at 5000 sfpm and 0.8 psi platen pressure on hard-maple stock at 6-7 percent moisture content. Two belts of each of the following runs were tested.

Belts	Run No.
3M	SM04
B-M	382
Aloxite	11W5N
Aloxite	1W5N
Aloxite	2LDTN
Aloxite	1LDTN
Aloxite	5HWH2

Results and Discussion

Rates of material removal (g/min) for the fourteen belts tested are given in Table I. From this test data, the rate of material removal for the two belts in each series was averaged and the information plotted as shown in Fig. 13. The family of curves obtained approximate the same form; the slight variation being attributed to experimental error. The curves representing the data for all belts except 3M are essentially the same, indicating that there is little difference in these belts in respect to material removal. As shown, the curve for 3M indicates a significantly higher rate of cutting.

In determining product differential of coated abrasives in a test such as this, it is possible to control those factors which apply to the abrasive and those which apply to the wood being abraded. Of those factors which apply to the abrasive, it is possible to assume that the factors in Group A below are constant to some degree, while those in Group B must operate out of control.

Group A:
(1) Abrasive grit material
(2) Method of coating
(3) Characteristics and type of backing
(4) Adhesive
(5) Belt age

Group B:
(1) Grit size and shape
(2) Grit spacing and position
(3) Condition of the abrasive

Of the items in Group A the assumption of constancy for 4 and 5 would appear to be the least reliable. It is recognized that the type, filler, quantity of make and size coats, and the humidity and cure conditions will affect, to some degree, the operational characteristics of an abrasive belt. However, as the belts tested were animal-glue bonded, the adhesive factors may be assumed to be constant except for the quantity of make and size coats, which is understood to have been varied to some degree on the experimental belts. In this respect, it is worth noting that varying the amount of adhesive had no effect upon the rate of material removal. This is substantiated by the coincidence of the curves of rate of material removal for the experimental and regular-run belts tested. Nevertheless, a decided advantage, in addition to economies in the manufacturing process, is gained by decreasing the quantity of the make and size coats within certain limits. This will be discussed later.

It is conceivable that belt age will also affect the operational characteristics of an abrasive belt. However, the fact that run 5HWH2 performed as well as the experimental runs in respect to material removal is evidence that in these tests belt age was of no consequence.

Of those factors in Group B, no direct observations could be made on the characteristics of the abrasive grit particles that might affect its abrasion resistance. However, an indirect observation is possible through use of the rate of material removal curves plotted in Fig. 13. The slope of these curves is practically identical after the first 15-minutes running time. A logical assumption is that each belt is losing its cutting capacity at very nearly the same rate, an indication that grit wear is proceeding at approximately the same rate. A further assumption then is that the grit particles of different belts have very much the same characteristics and that other factors in Group B are contributing to the higher level of material removal maintained by the 3M belts. Microscopic examination with a stereoscopic microscope of the 3M product and Carborundum run 1W5N revealed differences in grain shape, spacing, and position which are described below. Run 1W5N was chosen for comparison purposes as it is representative of Aloxite paper in addition to having less grain and less glue.

1. Actual contact grits appear to be more numerous on Aloxite than on 3M Production paper.

2. There appears to be a larger percentage of needle-like contact grits on the 3M Production paper. There appears to be a larger portion of short chunk-like grits doing the actual cutting on the Aloxite.

3. A larger percentage of contact grits appear to be oriented perpendicular to the backing on 3M paper than on Aloxite paper.

It would seem that with a larger percentage of contact grits, the Aloxite paper should be superior to that of the 3M, but at no point in the tests did this occur. It is significant to note (Fig. 13 and Table I) that the cutting rates were approximately equal during the initial cutting period though the Aloxite soon fell off to a lower material-removal level. A possible explanation of this is in the rapid deterioration of the original sharp edges on the chunk-like grits of the Aloxite. At the beginning of the tests, the cutting edges of these grits were capable of maintaining a rate of material removal comparable to those of the 3M belt, but as running time is extended these edges are quickly worn away, causing the grits to dull and result in an increase in the bearing area of the contact grits. A reduction in unit pressure follows, decreasing the penetration of the grits into the wood. This initial attrition undoubtedly occurs with a needle-like particle, but due to the reduced area of these grits because of their shape and perpendicular orientation, a larger effective unit pressure operates to provide a higher level of material removal by embedding the grits further into the wood. Moreover, because of shape and spacing, dulling of the grits due to abrasion by the wood substance is of a less serious nature.

In addition to these observations, it was noted that less wood dust collected on the 3M belts than on the Aloxite paper. This can, in part, be attributed to a partial open-coated effect on these belts achieved through additional spacing of the contact grits. This phenomena is not to be construed as loading, where the wood fibres form around grits to a point where the conglomeration of wood substances protrudes above the cutting points of the grits. This prevents the grits from contacting the wood and reduces the effectiveness of pressure at these points. During the course of these tests, conditions were such that loading was negligible.

Power requirements for sanding showed little variation except for the 3M Production paper, where the necessary power was higher. This reflects the difference in the levels at which material removal was maintained.

Of significant interest was the reduction in belt cupping occurring with the Aloxite experimental belts as compared with the Aloxite regular run. This is thought to be the result of the reduction in the amount of glue in bonding the grits to the belt. It is believed that as the belt reaches equilibrium with the conditions imposed upon it during sanding, the glue film tends to develop stresses which deform the belt. Because these stresses are higher in the adhesive film than in the paper, the belt will cup towards the backing. By reducing the thickness of the adhesive film, the construction of the belt tends more toward a system of dimensional stability. As the resulting stresses developed in the thinner film are such that the paper backing can resist them to a greater degree, the abrasive belt will have less tendency to cup in service.

COMPARATIVE TESTS ON OPEN- AND CLOSE-COATED MATERIALS

Scope

This series of tests was organized to compare open- and close-coated garnet and Aloxite-coated abrasives.

Procedure

Tests were made on 120 (3/0) grit gravity-coated garnet and EC Aloxite on belt paper with an animal-glue bond at 5000 sfpm and 0.8 psi platen pressure on hard-maple stock at 6-7 percent moisture content. Four belts of each of the following runs were tested:

Abrasive Materials and Coating	
Garnet OP	3T8D
Aloxite OP	LDTN
Garnet CC	1W5N
Aloxite CC	OTH4

Results and Discussion

Rate of material removal was averaged for the four belts in each series and the information plotted as shown in Fig. 15. The family of curves approximate the same form, differing only in their relation to each other.

It is worth noting that the open-coated material appears slightly superior to the close-coated belts. This is to be expected when it is considered that unit contact pressure increases as the number of contact grits decreases. This results in a relatively higher cutting rate for a given pressure. Consequently, each grit particle is imbedded into the workpiece to a greater degree resulting in a higher rate of material removal.

The curves for garnet show an initially higher cutting rate than the Aloxite. There appears to be no discernible reason for this condition and it must be assumed to be due to the difference in coating methods, which may affect spacing and position, and to grain characteristics, provided grit size and shape are constant for the two materials.

The drop in cutting capacity appears to be greater for the garnet than for Aloxite for either condition of grain quantity. However, when total material removal is taken into consideration, a slightly higher degree of material removal is indicated for the garnet. The values listed below are an average of total material removal of the four belts in each series.

Abrasive Material	Average Total Material Removal	Diff. (g)	Diff. (%)
Garnet OP	2075		
Aloxite OP	2040	35	1.7
Garnet CC	1925		
Aloxite CC	1870	55	2.9

The small percentage difference appears to indicate that the belts function approximately identically up to the point where the tests were terminated. It is generally recognized that Aloxite maintains its cutting capacity to a higher degree. It is possible that an expected difference would have been indicated had the running time been extended. For the test conditions employed, it is evident that the equality in material removal for the two abrasives is largely due to the initial cutting characteristics of the garnet belts.

Little difference was noted in sanding temperatures. As these temperatures were lower than that at which wood plasticizes and lignin flows, belt loading was negligible.

Power requirements showed little variation. A slight increase was reflected for garnet belts. However, in view of the fact that these differences are less than the accuracy to which the recording wattmeter can be read, they are considered not to be significant.

Of particular interest was the decrease in amount of sanding dust which collected on the open-coated belts in comparison to the close-coated material. It is felt that this decrease may be attributed to the increase clearance offered the chips as they are formed, reducing to some degree the lodging of chips in the areas between grit particles. Consequently, chips formed during the abrading action are dislodged with less effort, resulting in a belt with a cleaner appearance. This phenomena is not to be construed as loading which results from excessive temperatures.

It was observed that cupping of the open-coated belts was especially severe in contrast to the close-coated material. The open-coated material cupped on the average of one inch towards the abrasive face, whereas the close-coated belts were nearly flat at the termination of the tests. It is believed that this phenomena is due to the resulting stresses set up in the adhesive film.

DEVELOPMENT OF A STANDARD COMPARISON OF EXPERIMENTAL MATERIAL

Scope

This series of studies was organized in an attempt to establish test standards for the purpose of judging and comparing experimental material.

Introduction

During the initial stages of this research program, as reported in Progress Report No. 1, the work was exploratory in nature and an effort was made to determine the general relationships that existed between a number of factors and their effect upon abrasive belts. Having determined this relationship, the present phase of the research is concerned with more detailed tests on the factors affecting performance of coated abrasives in machining wood. In view of this, it is necessary that a standard be established as a means whereby material may be accurately judged and compared. This is particularly applicable to the comparison of experimental material.

Procedure

To define this standard, twelve belts each of EC Aloxite and garnet were tested. In view of the possibility of experimental material being developed using either garnet or Aloxite, both materials were included. In order to reduce the magnitude of the tests, one grit size, 120 (3/0), was run at 5000 sfpm at 0.4 and 0.8 psi platen pressures. Two pressure levels were selected to determine the effect of this factor on the variation of the test results. Paper-back close-coated glue-bonded material was used for all runs.

To secure representative data it was felt necessary to randomize the materials as much as possible. Hence, the belts in each set were assigned a number. Corresponding numbers were then drawn at random to determine the order in which the belts were to be used. Wood factors were treated in a similar manner. The numbers comprising the billets from which specimens were cut were first assigned a number. A group of ten was then selected using a table of random numbers. This group makes up one billet from which are cut 8 specimens, 4 x 8-1/2 inches, the thickness of the specimen being approximately 3 inches (Fig. 21). A total of 100 specimens were prepared and each assigned an identifying number. These specimens were then divided into groups of four using a table of random numbers. Four specimens are required to test two belts, one at each pressure level. These groups of four specimens were then assigned a number and corresponding numbers drawn at random to determine the order in which the specimens were to be used. The same procedure was used for the second pressure level.

The hard-maple stock used for these studies was conditioned in a constant humidity room at 6-7 percent equilibrium moisture-content conditions prior to being made into specimens. After machining, the specimens were returned to this room and conditioned approximately two weeks before using. Thus, the wood was at a constant moisture content of 6-7 percent at the time of test. Equilibrium moisture conditions of the area in which the testing machine is located averaged 7-2 percent during the course of this study. Because of the similarity in these conditions, it is believed that atmospheric conditions had little or no affect upon the results of these tests.

Belts were run for a total of seventy minutes. Although somewhat greater than originally planned, running time was extended in order to extract more information from the tests. Specifically, it was desired to determine the variability of the test at designated intervals, particularly during the initial stages of the tests.

Temperatures were determined by means of calibrated pyrometric sticks. Power requirements were obtained by means of a recording wattmeter.

To determine the standard deviations and averages for the belts, total material removal was taken into consideration. This value, computed for each belt, divided by 70 (total running time in minutes) determined the average rate in grams per minute for each belt. By summing these twelve values and dividing by the number of belts in each set an average for each series was obtained. Standard deviations were computed in the usual manner for ungrouped data by using the average rate in grams per minute for each belt in a set.

To compare dispersion between levels it is necessary to use a measure known as the coefficient of variation, as a measure of dispersion must be compared to the size of the average about which it is measured. To relate the measure of dispersion to its average and to convert it to a percentage form, the standard deviation is divided by the average. This measure in percentage form solves the problem of comparing variation at different pressure levels and different time intervals.

Results and Discussion

The values of the average, standard deviation, and coefficient of variation obtained for each set of 12 belts are shown below.

0.8 psi platen pressure

Garnet	Aloxite
n = 12 belts	n = 12 belts
Ave = 26.7 g/min	Ave = 28.0 g/min
SD = 2.25 g/min	SD = 2.37 g/min
CV = 8.4%	CV = 8.5%

0.4 psi platen pressure

Garnet	Aloxite
n = 12 belts	n = 12 belts
Ave = 8.8 g/min	Ave = 10.9 g/min
SD = 1.02 g/min	SD = 1.43 g/min
CV = 11.6%	CV = 13.1%

It is evident that the Aloxite is slightly superior to the garnet in material removal. However, it shows a slightly higher average of variation within a pressure level. This might conceivably be due to its higher cutting capacity. The corresponding coefficients of variation indicate the test functions with a greater variation at the lower index of pressure.

To determine variation with respect to time, the average variation was computed at each time interval for the 12 belts in a series. As the average rate changed with time, the coefficient of variation is required as a measure of dispersion. In general, it appears that variation increases with an increase in running time and a decrease in pressure. However, variation seems to be more constant during the initial stages of the test. This occurs when the abrading capacity of the belt is the highest, indicating that abrasive wear and reduction in contact unit pressure possibly increases the variation in the test results. Also, the rate of material removal is reduced by means of a decrease in chip size which might contribute to this increase.

Figure 16 is a family of curves obtained by plotting material removal (g/min) over running time (minutes) for the data obtained in this study. Each plot on a curve is the average rate of material removal for that time interval for 12 belts.

For each level of pressure, the garnet shows an initially higher cutting rate than the Aloxite. This difference is more pronounced at 0.8 psi platen pressure than at 0.4 psi. This phenomenon has been observed in other tests and is presumed to occur because of differences in coating methods, which might affect spacing and position of the grain and differences in grain characteristics, provided that grit size and shape are the same for the two materials.

Power curves as shown in Fig. 17, coincide in form and pattern set by the material-removal curves. This indicates that a close approximation of the cutting ability of a belt might be obtained from the curve of power requirements.

Surface temperatures generated during all runs were below the point at which wood plasticizes. Loading, therefore, was negligible and not considered a critical factor in these tests.

ABRASION TESTS ON MASONITE

Scope

This series of tests covers details and results on an exploratory study using a substitute material for wood in controlled abrasion tests.

Introduction

One of the characteristics of wood is its inherent variability. Moreover, the strength properties are notably involved in that they differ in the three structural planes of the wood. Variations are also recognized in species, structure, growth conditions, specific gravity, and moisture content, which affect strength properties. Furthermore, they are considerably reduced by natural defects. Thus, it is important in using wood for abrasive tests to give careful consideration to the selection of material being used. Such factor as limitation of defects, direction of grain, specific gravity, and moisture content are all of paramount importance. Accordingly, a material in which some of these difficulties were overcome and yet was cellulosic in nature would be a decided advantage in conducting controlled tests on coated abrasives.

An ideal cellulosic material for conducting tests on wood abrasives should be uniform strength in all directions, density, hardness and be reasonably dimensionally stable. It should be readily available, moderate in cost, and should not unfavorably affect the coated abrasive. It is because hardboards closely approach these ideal requirements that this exploratory research was organized.

In view of the several kinds of hardboards on the market today, this investigation was limited to one material, Masonite. Two types, tempered and untempered, were considered.

The manufacture of Masonite is based upon the use of the Masonite explosion process. Wood is reduced to chips and fed into explosion chambers.

In this chamber the chips are subjected to closely controlled high-pressure steam cycles. When the pressure reaches approximately 1000 psi., the explosion chamber is opened suddenly to the atmosphere. It has been suggested that two different actions take place because of the instantaneous pressure differential. First, under the influence of high steam pressure, moisture, and high temperatures, a hydrolytic reaction takes place which breaks down the bond between the lignin and the cellulose. This action reportedly activates a portion of the lignin. It is then available for rebonding when this mass is subjected to controlled conditions of heat, pressure, and moisture. Secondly, the sudden release of pressure tears the hydrolyzed chips apart to produce a brown, fluffy fiber.

After refining, the fibers are "felted" on a screen and passed to the press. At this point, under controlled heat, time and pressure, the ligno-cellulose bond is reconstituted so that the resulting board is reconstructed without the benefit of a resin binder.

If the screen remains with the felted material in pressing, the board has the familiar screen pattern. A modification of this process consists in drying the mat in an oven before pressing. The resulting hardboard is smooth on both sides. A second modification is achieved by incorporating a drying oil in the pressed panel and then baking. It is reported that this "tempered" material has improved water and alkali resistance and increased strength and abrasion resistance.

Procedures

As mentioned previously, the tests were performed on "tempered" and untempered stock. Trials were duplicated on four belts each of open- and close-coated garnet and EC Aloxite. This selection was made to determine whether differences could be detected within products as well as between products. A velocity of 5000 sfpm and 0.8 psi platen pressure was maintained for all conditions during testing. Temperatures were determined by means of Tempilsticks. Power requirements were obtained with a recording wattmeter.

Results and Discussion

Figure 18 is a plot of material removal (g/min) over running time (minutes) for each belt type. Figure 19 is a plot of power required (watts) over running time for the same belts.

These curves show a rapid decrease in material removal with respect to time, indicating that grit wear proceeds at a rapid rate. They approximate the same form as obtained when abrading wood, but for being somewhat more the loci of a true hyperbola. Running time is considerably reduced, increasing the efficiency of the test method. Moreover, less material is required.

A slight difference is noted in the level of the curves, the one for the untempered material somewhat higher. This is attributed to density, being 1.01 for the untempered Masonite and 1.18 for the tempered.

In general, sanding temperatures were lower for Masonite as compared to those generated on a wood surface under the same conditions. This is due to differences in density between these materials and wood and the void space present in wood. In effect, the coefficient of heat conductivity for Masonite is higher than for wood, allowing the heat to travel to the interior of the specimen at a faster rate than from the abrasive-specimen interface. This factor can easily confound temperature determinations as the specimens do not reach room temperature for a considerable time. This is easily remedied by using a different pair of specimens for each belt, allowing the previous specimens to cool to room temperature.

Observations of belt conditions revealed that loading of the abrasive surface was negligible for either material. This lack of loading is derived from the low temperatures developed during sanding. In neither material did surface temperatures approach the point at which wood plasticizes, which is a major cause of belt loading.

Figure 20 is a comparison of material-removal curves for wood and tempered Masonite. Each material was tested under identical conditions, using experimental belts P-14 and P-15, recently furnished by the sponsor. Of importance is the fact that differences within product were detected as with the open- and close-coated material of Fig. 19.

These curves establish the relationship of material removal of the first material tested from the sponsor's experimental machine. It developed that experimental run P-14 was slightly superior to run P-15 in respect to material removal. Surface temperatures developed were practically identical. Power requirements were slightly higher for the P-14 material, reflecting its higher rate of material removal. Neither material showed evidence of serious loading.

PERFORMANCE TESTS ON SANDSCREEN

Scope

This section covers the results of controlled tests to determine the performance characteristics of Sandscreen when used as an abrasive material for furniture rubbing.

Introduction

In accepted furniture rubbing techniques, a satisfactory finish is obtained by removing any slight physical defects present in the surface film and supplanting the raw appearance of this film with a sheen of desired characteristics. This is accomplished by the use of a sequence of successively finer abrasives and a rubbing lubricant to control the degree of abrasion of the surface film as well as the gloss or sheen of the finish.

One of the important requisites of a rubbed finish is the uniformity of the scratch pattern imparted to the surface by the abrasive used. Rubbing is always done parallel to the grain of the wood. This procedure orients the scratches with the grain and reduces the apparent visual effect of the scratch pattern. An interruption of this uniform pattern detracts from the overall effectiveness of the finish.

The sponsor reports that in field trials Sandscreen used as a rubbing abrasive on furniture produces a nonuniform scratch pattern unless employed with a slurry-type rubbing lubricant, which has a number of disadvantages. Upon recommendation of representatives of the sponsor, this research was organized to evaluate the abrasive as a rubbing material and to attempt to develop a satisfactory rubbing technique for this material.

Procedure

The tests were performed on panel stock, 11-1/2 x 16-1/2 inches, especially constructed for these tests. These panels consist of 3/8-inch Douglas fir plywood core, and face and back of 1/16-inch hard maple and yellow birch, respectively. The hard maple was selected as face stock to eliminate a filling and additional sealing operation in the finishing systems.

The panel finishing systems were of the conventional medium-priced high-quality furniture type. They consisted of the following:

A. Lacquer

(1) Non-grain-raising stain
(2) Wash coat
(3) Sealer
(4) Two top coats of clear gloss lacquer

B. Low-baked synthetic

(1) Non-grain-raising stain
(2) Wash coat

(3) Sealer
(4) Two top coats of clear gloss lacquer

Finishing materials used were manufactured by the Grand Rapids Varnish Company, Grand Rapids, Michigan. The lacquer was air-dried, allowing 24 hours between top coats. The low-baked synthetic was forced dried in a kiln under controlled conditions of temperature and relative humidity recommended by the manufacturer.

Rubbing procedures were typical of those used in furniture production to obtain a medium satin sheen. The system outlined below worked equally well on either finishing system. The times employed were determined during the development of the techniques used and were considered sufficient for the area involved.

1. Machine rub with 320 grit and lubricant for 1 minute.

2. Surface wiped dry with clean waste.

3. Machine rub with 360 grit and lubricant for for 1/2 minute.

4. Surface wiped dry with clean waste and cleaned up with mineral spirits.

5. Polished for 2 minutes using polishing compound on the lacquer and a rottenstone slurry on the low-baked synthetic.

6. Waxed for 1-minute.

In addition to the Sandscreen, 320 and 360 Red-I-Cut L was used under the same conditions imposed on the Sandscreen. The Red-I-Cut L paper functioned as a control for comparative purposes.

In developing the necessary techniques for this study, it was learned that polishing and waxing were necessary to accentuate abnormal scratch patterns. To insure equal polishing and waxing to the surface prepared with either abrasive material, each panel was divided in half lengthwise with a strip of masking tape. Each half of the panel was then rubbed with one of the abrasive materials. The masking tape was then removed and the panel polished for two minutes with a rotary buffer with a lamb's wool pad. This was followed by waxing.

The test panels were held in position during rubbing and polishing on a hold-down jig constructed for this purpose. This jig prevented the panels from moving during the operations in addition to keeping them flat.

An attempt was made to obtain a quantitative measure of the effectiveness of rubbing by using a Kerr definometer. This instrument, designed by W. R. Kerr of Armstrong Cork Company, Beaver Falls, Pennsylvania, was devised to measure the image definition of glossy finishes on such materials as decorative wallboard. The evaluation is made by measuring the sharpness of image definition of the surface in terms of a standard graduated chart used to produce a reflected image under definite conditions. At the onset of the problem it was felt that through the use of a reading of image definition before and after rubbing, some measure of the effectiveness of rubbing could be achieved. Preliminary experimentation indicated that this approach was adequate to a certain degree. However, because the quantitative measurement was inadequate in determining visual characteristics of the finish as an entirety, it was necessary to rely on visual observations of the panels for experimental information.

Four rubbing lubricants were used, manufactured by the following:

1. Grand Rapids Varnish Corporation, Grand Rapids, Michigan.
2. Wolverine Finishes, Inc., Grand Rapids, Michigan.
3. Wilkinson Equipment and Supply Co., Chicago, Illinois.
4. Old North Mfg., Lenoir, N. C.

All panels were machine rubbed with a Sundstrand Model 400 air sander. Rubbing pads were of two types, soft rubber and felt.

Results and Discussion

Abrasive Materials. Several advantages and disadvantages were noted for Sandscreen during this study. They are as outlined below.

Advantages:

1. Increase in ease of operation.
2. Less lubricant required for a given area.
3. Both sides of the material can be utilized.
4. Absence of clogging.
5. Absence of dull streaks due to abrasive loading.
6. Ease of cleaning.
7. Less inclination to tear.

Disadvantages:

1. Produces corrugated surface.
2. More difficult to fasten to rubbing machine due to stiffness.
3. Sheets must be attached to the machine individually and not in groups.

4. Some tendency to lose grits when cloth is creased or contacts sharp edge or corner during rubbing.

That less force was required to move the rubbing machine over the surface of the panel is attributable to the increased retention of the rubbing lubricant and air in the mesh of the cloth. This reduction in required force results in less operator fatigue.

Because more rubbing lubricant is retained in the mesh of the cloth, less lubricant is required for a given area. Accordingly, the rubbing operation is more economical. Furthermore, both sides of this material may be used, resulting in further savings.

Clogging of the grits was reduced to a marked degree over that of the Red-I-Cut L paper for the same test conditions. This reduction in clogging is ascribed to the spaces afforded by the mesh of the cloth and the ensuing increase in rubbing lubricant retained. A decrease in dull streaks can be expected with a decline in the loading of the abrasive material.

Sandscreen is less prone to tear when pads of the rubbing machine contact the edges and corners of the piece being rubbed. When tearing occurs, as often happens with abrasive paper during rubbing, extensive damage can be done to the surface, necessitating an expensive repair operation.

It is apparent that the corrugations (Figs. 24 and 25) on the finish are the result of the pattern effect of the thread crossings coupled with the straight line motion of the rubbing machine. Moreover, rubbing contact pressures are increased because of the smaller total contact area. This increase accentuates the pattern effect of the cloth. Because of these corrugations, Sandscreen does not produce as level a surface as Red-I-Cut L paper.

In an attempt to eliminate the number and magnitude of these corrugations, the thread angle of the cloth in respect to the motion of the rubbing pads was varied through three different angles, 15°, 30°, and 45°. These variations in thread angle did not appreciably reduce the corrugations or the magnitude of them.

Orbital pad movement using a Sterling electric hand sander eliminated the corrugations, but resulted in a less acceptable surface because of the circular scratches. These scratches could not be removed by normal polishing procedures. Further variations in movement of the straight line machine over the surface had limited effect upon reducing the corrugations.

The preceding comments have been based on observations of polished surfaces. It is worthy of note that Sandscreen from all outward appearances, produces a dull rubbed surface which is comparable to one rubbed with

Red-I-Cut L paper. However, in view of the practice of in-service polishing of furniture, the corrugations will eventually be noticeable on the surface.

Rubbing Lubricants. With one exception, there was no observable difference apparent between rubbing lubricants. The material manufactured by the Wilkinson Supply Company had a slightly higher viscosity than the other materials. The higher viscosity of this material apparently causes it to remain on the surface under the stroke action of the sander. It also appears that the higher viscosity causes a thicker film to be formed between the surface and the abrasive grit. This reduces the magnitude of the scratch pattern formed by the abrasive to a certain degree,

As the higher-viscosity material gave relatively the best results, a slurry-type rubbing compound was formulated by mixing water, rottenstone, and a liquid detergent. The viscosity of this mixture was considerably higher than the Wilkinson rubbing lubricant but did not eliminate the abnormal scratch pattern formed by the Sandscreen.

Pads. An observable difference was noted between backing pads, the rubber pad producing the more satisfactory surface. The superiority of the rubber pads is most likely due to the difference in density and resiliency of the two materials.

Variations in density along the length of the pads were noted in the felt. These localized dense areas cause dull streaks on the surface of the panel from loading of the abrasive. This results in a less uniformly rubbed appearance. In addition, felt has a tendency to pick up grit particles and dirt, which affect the surface uniformity.

Finish Systems. As far as could be observed, the results were identical for both finishing systems used. The low-baked synthetic was not of the thermoplastic type. Consequently, this film was more difficult to polish, requiring a rottenstone slurry in place of the commercial rubbing compound used on the lacquer. It is generally recognized that low-baked synthetics produce a duller rubbed surface. This was found to be true in this study.

CONCLUSIONS

During the course of these investigations it was apparent that the material-removal activity of a coated-abrasive belt is controlled by the attrition of the grits and the loading of the belt. As previously reported in Progress Report No. 1, the abrasion resistance of the grits is a characteristic of the abrasive material, while loading is dependent on the structure of the abrasive belt, the conditions of machining, and the wood being machined.

The deterioration of abrasive belts is very rapid and the loss in cutting efficiency is accompanied by glazing of the work surface. Except when loading develops, the loss of cutting ability is apparently due to abrasion of the grit particles.

Loading of abrasive belts seems to be primarily dependent on the surface temperatures developed on the workpiece. As working temperatures reach the range where wood plasticizes and begins to scorch, loading takes place rapidly.

Lower velocities at levels of 2340 and 3750 sfpm did not alter the performance characteristics of abrasive belts, with material removal decreasing as the belt velocity decreases. Surface temperatures generated were considerably below the range at which wood substance plasticizes to cause clogging of the grits. No evidence was found of the grits fracturing at these low speeds.

Performance characteristics were not affected by decreasing the belt length from 20 to 10 feet. On this basis, the testing machine was adapted for a 10-foot belt, increasing the efficiency of the testing method by obtaining more information per unit of work.

Generally, only quantitative differences in performance characteristics result when species and moisture content are varied, provided that wood characteristics do overshadow the effects of other factors, namely, density and moisture content. Relative density apparently controls material removal as resistance to identation is primarily dependent upon this factor. Grit wear appears to be a function of abrasion of the grits by the wood substance comprising the cell walls. Other wood factors, e.g., resin accumulations, adversely influence the relative cutting ability of an abrasive belt.

Comparative tests of competitors' materials indicated some significant differences in performance characteristics. These differences were attributed to differences in grain shape, orientation and spacing.

Open-coated material is slightly superior to close-coated material. This is attributed to an increase in unit contact pressures as the number of contact grits decreased. For either grain weight, garnet shows an initially higher cutting rate than Aloxite. Compared on basis of total material removal for a running time of 70 minutes, Aloxite is slightly superior to garnet.

In general, it appears that variation of material removal increases with an increase in running time and a decrease in pressure. Aloxite shows a slightly higher variation than garnet for a given pressure level.

Exploratory controlled abrasion tests with Masonite indicates that this material is capable of detecting differences within, as well as between coated abrasive materials.

Sandscreen was found not adapted for rubbing furniture top coats. Producing corrugated surfaces or "wild scratches" is the chief disadvantage of this material. The many advantages of Sandscreen should lead to significant developments in furniture rubbing materials.

It appears that the main advantages of Sandscreen are connected with its open structure. These same advantages might be achieved with Red-I-Cut L by perforating this paper. This in effect would provide an open structure similar to that of Sandscreen and eliminate somewhat the disadvantages attached to this material.

During the course of the investigations it was noted that cupping was a serious factor in some instances. It appears that this condition exists because of stresses set up in the belt during sanding. Apparently, these stresses result from the activity of the adhesive and paper adjusting to the equilibrium conditions of the sanding operation. This dimensional instability indicates that a proper balance is required between these factors in order to minimize belt cupping. High moisture contents were observed to cause severe cupping, indicating that this factor is a necessary consideration.

PERFORMANCE CHARACTERISTICS OF SILICON CARBIDE

Scope

This inquiry was organized to observe the behavior of silicon carbide when used to machine wood.

Introduction

Silicon carbide finds widespread use in the metal trades industry but is not generally accepted by the wood-using industry. This non-acceptance is usually associated with factors of cost and the performance characteristics of this material as compared to abrasives commonly used for sanding wood. As the reported deficiency of silicon carbide is usually based on subjective field trials, this study was organized to secure objective data on the operating characteristics of this material when used to abrade wood.

In addition, it was felt that the fracturing characteristics of silicon carbide might be such that the conditions imposed upon the grain while sanding wood would not be sufficiently severe to materially reduce the cutting life of the belt after a short period of time. That is, if the grain exhibited a certain degree of toughness to withstand the forces of shock exerted upon it during sanding, yet retained its ability to fracture along planes of weakness to produce new cutting edges, material removal would supposedly operate at a constant level.

Procedures

Abrasive belts were close- and open-coated silicon carbide paper-backed material. Platen pressures of 0.2, 0.4 and 0.8 psi at a belt velocity of 5000 sfpm were used on a 4-inch hard maple specimen at 6-7 percent moisture content. The grit size was 120 (3/0), run 5NWD in case of the close-coated material and N4DT for the open-coated belts.

Results and Discussion

Figures 26 and 27 are a plot of material removal over length of time the belt has been in use for the open- and close-coated material. These curves are based on the information secured from one belt. Hence, they represent only trends in their relationships. At the onset of the study when it was evident the cutting rate of silicon carbide was materially reduced as compared to Aloxite or garnet, it was decided to test but one belt under each condition.

Satisfied that no further information was to be gained by increasing the sample size, it was felt that reliance could be placed upon a sample of one to determine any trends.

The curves representing the data indicates the ability to remove stock increases as the pressure is increased. There is a slight superiority evident for the open-coated material. This advantage results from the increase penetration of the contact grits by reason of the reduction in the number of grits on the open-coated material.

One of the most interesting observations of this study is the lower cutting capacity of the silicon carbide belts as compared to garnet and Aloxite under comparable conditions. It was expected that during the initial stages of a test the rate of material removal would be at least equal to that of Aloxite or garnet. Contrary to this, it developed that the rate for silicon carbide is approximately one-half that of either the other abrasive minerals mentioned for the same given set of conditions and grit size. Microscopic examination of the belts revealed some fracturing and pulling loose of the grits from the adhesive in addition to grit wear. However, this type of examination did not reveal any reasons for this anomaly.

Of considerable interest is the observation that scatter of the points on the curves at the beginning of the tests increases as the pressure increases. A possible explanation for this is that as the pressure increases there is an increase in the shock load operating on the grit. Those grits unable to withstand these loads will either be broke loose from the bond or fracture along a plane of weakness whichever can withstand the smallest stress. In either case, new cutting points or edges are presented to the workpiece. This results in a change in rate of material removal. There appears to be some doubt whether this phenomena continues throughout the course of the test as observed by the closeness of fit of the curve to the plotted points after a short running time. Moreover, at the lower level of pressure where the shock loads are not as great, scatter is considerably reduced even at the beginning of the test. Hence, it is believed, that for the conditions of these tests, fracturing or tearing loose of the grits may occur during the initial stages of belt life to produce new cutting edges. However, when conditions are reached where the remaining grits are capable of withstanding the shock loads imposed upon them, it appears that grit wear is then responsible for the deterioriation in the cutting life of the belt.

That grit wear is taking place is evident by the change in the glaze conditions of the wood surface during sanding. At the beginning of the tests when the belt carries grits with new, sharp cutting edges, glazing is not apparent. However, as running time is extended, glazing becomes apparent, increasing in intensity as time increases. As glazing results from crushing and compressing of the wood constituents at the surface, it must be assumed that the cutting ability of the grits is decreasing, obviously due to grit wear.

Surface temperatures developed during the course of this study did not extend into the range where wood plasticizes and lignin begins to flow. As a consequence, loading of the belts was not a critical factor. As observed before, temperatures decreases as platen pressure decreases. With a decrease in pressure, each grit cuts a smaller chip. As a result, work of deformation is lessened with a corresponding decrease in sanding temperatures.

COMPARATIVE TESTS ON EXPERIMENTAL MATERIAL

Scope

This series of tests represents an investigation to compare on the basis of cutting life, sanding temperatures and power requirements experimental abrasive materials P-14, 15, 20, and 21.

Procedures

The abrasive belts were EC Aloxite on belt paper with an animal glue bond. Grit size was 120 (3/0) used with a platen pressure of 0.8 psi and a velocity of 5000 sfpm. The testing specimens were 4-inch hard maple at 6-7 percent moisture content. The four lots tested carried the following run numbers. Also listed is the sponsor's pretreatment of each commodity.

P-14 - Normal grain weight and normal amount of glue.
P-15 - Ten (10) percent less than normal standard in grain and ten (10) percent less than normal standard in glue.
P-20 - Six (6) pounds of grain per ream.
P-21 - Twelve (12) pounds of grain per ream.

Four belts of each lot were tested. The average rates of material removal of each series of four belts was taken to obtain a grand average. Power requirements were handled in a similar manner. The information obtained was then plotted to give the relationships shown in Figures 28 and 29.

Results and Discussion

It is evident from these relationships that runs P-14 and 15 are more efficient than P-20 and 21, with run P-14 being slightly superior to run P-15. Plotted in conjunction with these materials, is the curve for standard Aloxite, run OTH4. It materialized runs P-14 and 15 are slightly less efficient than run OTH4. However, in view of the fact that the curve representing the latter material is an average of 12 belts, the differences may be of less significance.

Belt cupping was observed to be critical for run P-20, the belts cupping on the average of 1-1/2 inches towards the abrasive face after 70 minutes running time. In contrast, little or no cupping was observed for run P-21. Cupping for run P-14 was slightly greater than P-15, averaging 1-inch and 3/4-inch towards the grit face, respectively. Temperature and relative humidity of the laboratory averaged 90° F and 50 percent on the day run P-14 was tested and 89° F and 53 percent on the day of test for run P-15. The slight differences in these values seems to indicate the differences in belt cupping are associated with grain and glue weight differences. There appears to be no question that the differences in cupping for the two previous materials results from differences in grain and glue weights.

Loading was observed to be negligible in all cases. However, it was noted that the belts carrying less grain have a tendency to collect less wood dust. This is evidently due to the increased clearance afforded the wood chips, allowing them to clear the belt when the grits clear the workpiece. Though it is strongly suspected that within certain limitations wood dust is not detrimental to the efficiency of a belt, it is believed to be a source of operator misunderstanding, and hence, a source of criticism of the commodity. Thus, a cleaner belt would appear to be a more efficient belt.

Power requirements for sanding were found to closely parallel the positional relationship of the curves for material removal. The power curves, however, show considerable spread over that of material removal even though the relationship remains the same. Hence, an erroneous conclusion as to the superiority of runs P-14 and 15 might be drawn from this data.

Average surface temperatures created were practically identical for all lots. Since these temperatures did not reach the level at which wood plasticizes and lignin begins to flow, loading was not a critical factor. Similarly, they were not considered to be of much significance.

It was observed that deposition of grain was not uniform on some of the material received. To overcome this an attempt was made to select the most uniform material in making up the belts to obtain the most representative data. It appears reasonable that variations in uniformity can contribute to variations in test results. Hence, the possibilities of variation in this test data are increased.

TABLE I

Rate of Material Removal (gms/min) for 14 coated abrasive belts. 120 (3/0) EC close-coated aluminum oxide, belt paper, animal glue bond, 5000 SFPM, 0.8 psi platen pressure on hard maple at 6-7 percent M.C.

Time-Running (mins)	3M		B-M		1W5N		11W5N		2LDTN		1LDTN		5HWH2	
1	61.0	63.0	49.0	51.0	58.0	57.0	55.0	60.0	57.0	55.0	48.0	50.0	59.0	59.0
1-10	58.9	53.0	42.9	42.8	45.7	45.6	44.2	46.9	46.8	47.5	39.1	46.7	47.2	49.4
10-20	54.1	50.7	40.4	38.8	42.1	40.2	39.8	44.5	40.7	36.2	33.9	39.1	41.5	42.7
20-28	50.6	48.1	37.0	38.3	37.6	37.7	35.9	39.9	40.1	35.2	32.6	38.7	40.1	41.4
28-35	47.8	45.1	37.2	36.1	37.3	36.0	32.1	37.3	36.6	33.0	26.0	33.5	37.9	38.9
35-45	47.2	44.2	37.4	35.0	34.0	34.3	31.9	38.8	33.9	31.4	25.1	35.2	37.7	35.0
45-55	44.9	40.2	34.3	34.5	33.3	32.1	33.5	34.5	36.0	33.6	24.8	33.3	32.6	35.0
55-65	43.8	40.0	32.3	33.0	31.9	31.3	29.7	35.6	32.1	29.0	25.1	33.9	31.4	33.0
65-75	41.8	36.2	31.7	32.0	30.3	29.1	27.9	28.9	32.6	30.3	23.9	30.4	29.7	32.7
75-80	41.0	38.6	30.0	30.0	30.7	28.0	24.2	33.6	29.4	27.1	23.6	30.6	29.0	31.2
80-85	40.6	37.0	30.0	30.0	28.7	28.1	25.6	32.8	30.8	28.8	23.4	28.4	28.8	31.4
85-90	38.9	37.4	30.0	30.0	28.2	23.2	23.6	27.8	28.4	26.0	22.8	28.6	27.6	31.2
Average	47.6	44.5	36.0	36.0	36.6	35.2	33.6	38.4	37.0	34.7	29.0	35.7	36.8	38.4
Average	46.0		36.0		35.4		36.0		36.0		32.4		37.6	

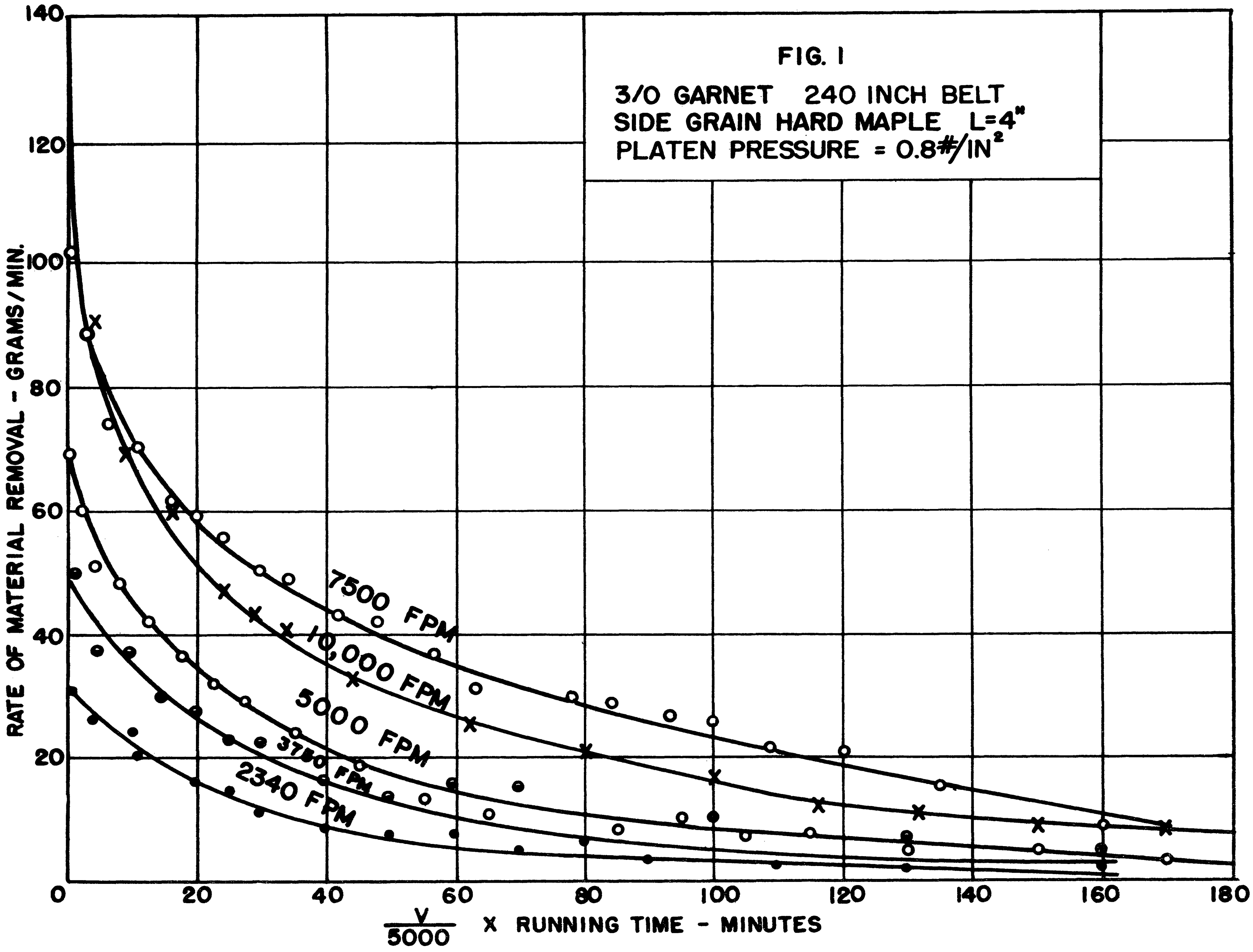
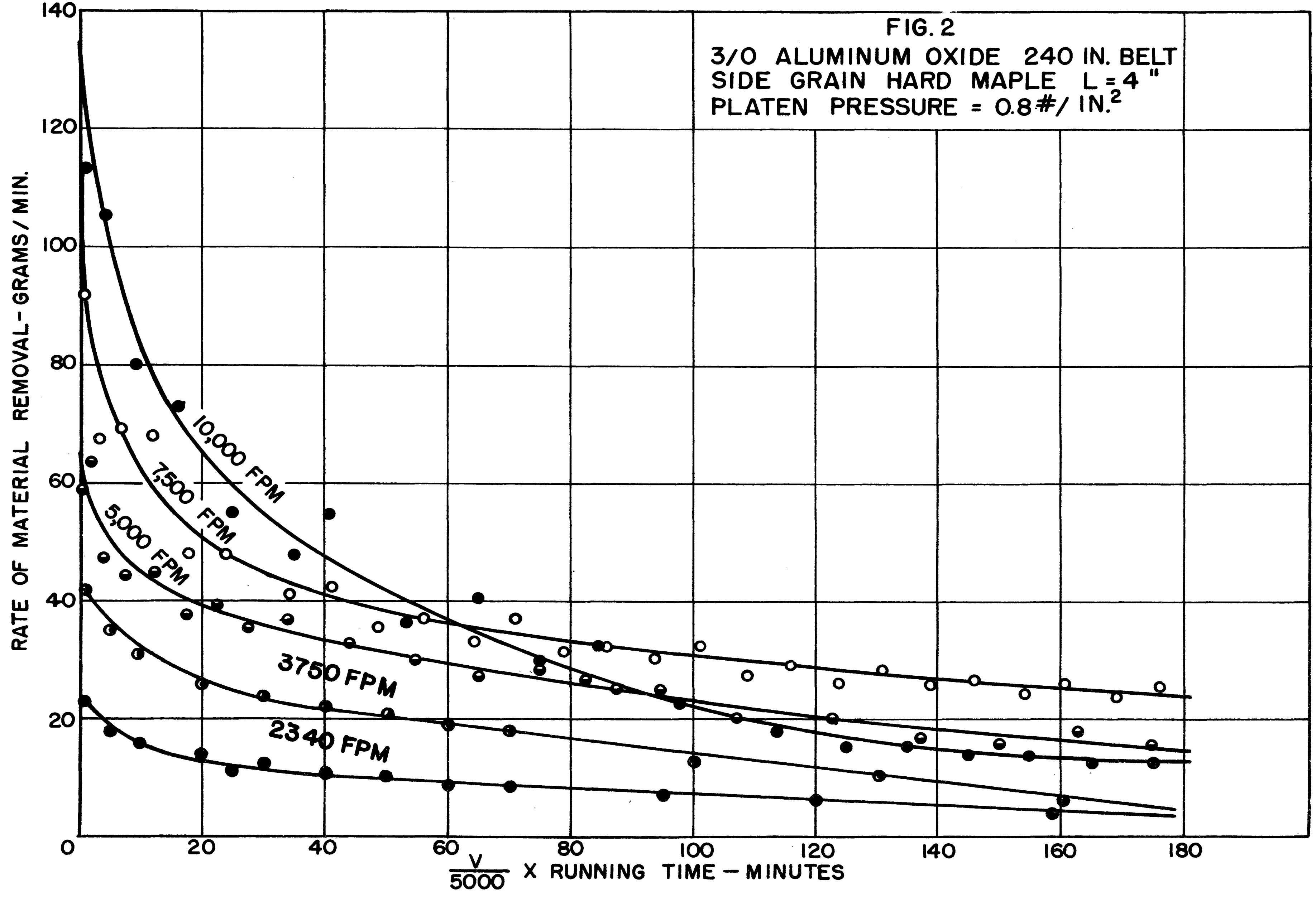


FIG. 1

3/0 GARNET 240 INCH BELT
SIDE GRAIN HARD MAPLE L=4"
PLATEN PRESSURE = 0.8#/IN²

FIG. 2

3/0 ALUMINUM OXIDE 240 IN. BELT
SIDE GRAIN HARD MAPLE L = 4"
PLATEN PRESSURE = 0.8 #/ $IN.^2$



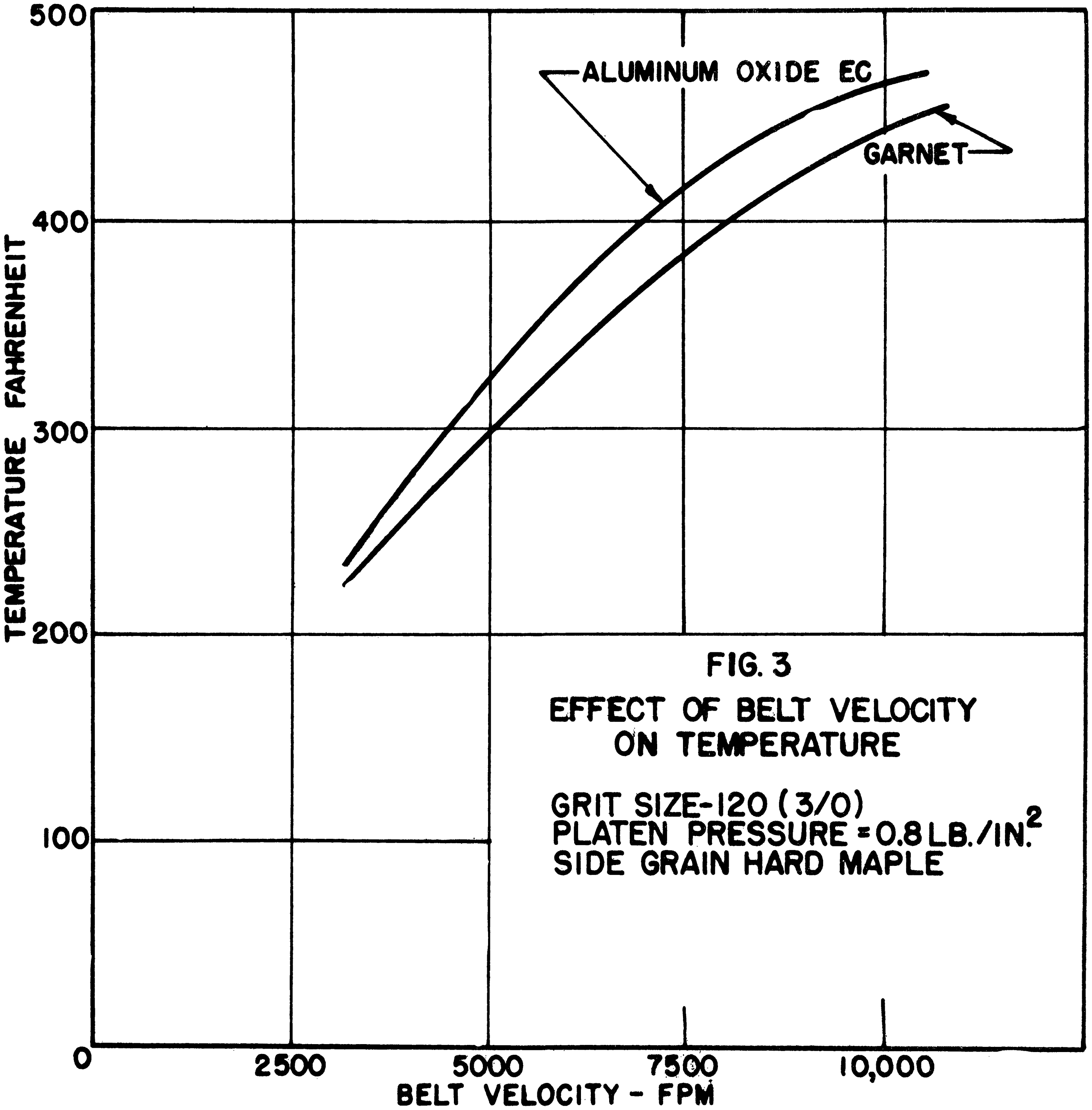


FIG. 3

EFFECT OF BELT VELOCITY ON TEMPERATURE

GRIT SIZE-120 (3/0)
PLATEN PRESSURE = 0.8 LB./IN.^{2}
SIDE GRAIN HARD MAPLE

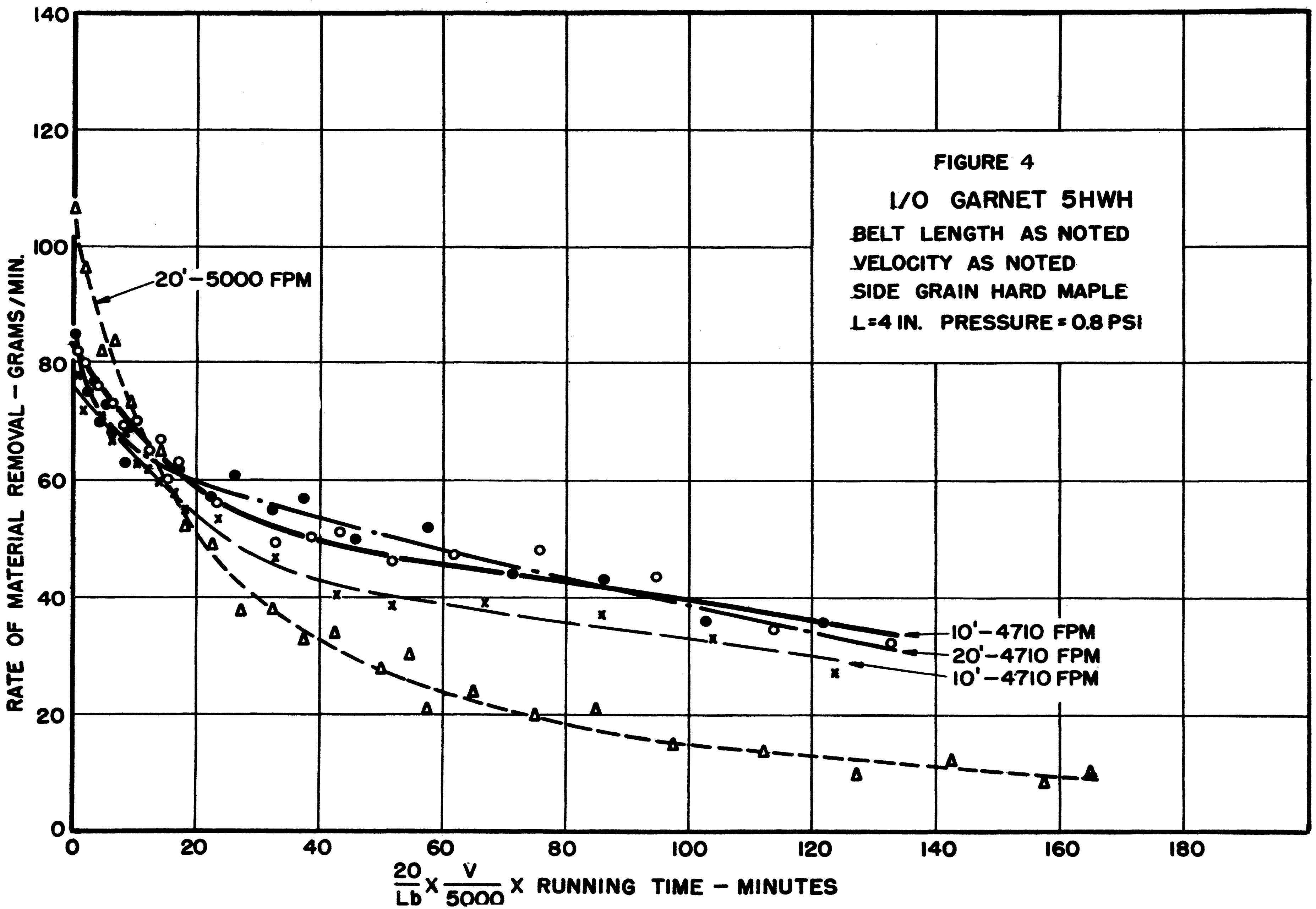


FIGURE 4
1/0 GARNET 5HWH
BELT LENGTH AS NOTED
VELOCITY AS NOTED
SIDE GRAIN HARD MAPLE
L=4 IN. PRESSURE = 0.8 PSI
20'-5000 FPM
10'-4710 FPM
20'-4710 FPM
10'-4710 FPM
RATE OF MATERIAL REMOVAL - GRAMS/MIN.
20/Lb X V/5000 X RUNNING TIME - MINUTES
0
20
40
60
80
100
120
140
160
180

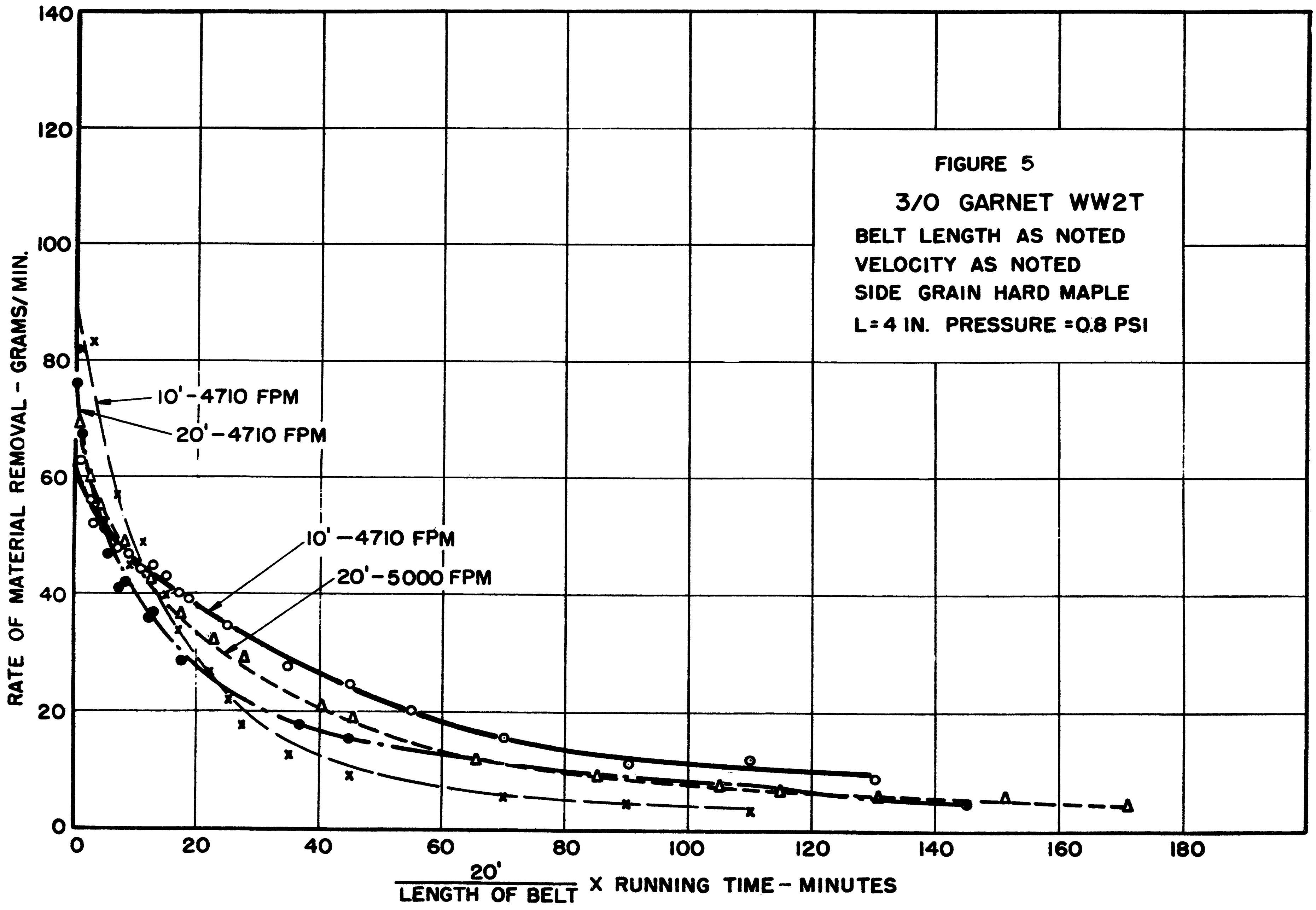


FIGURE 5
3/0 GARNET WW2T
BELT LENGTH AS NOTED
VELOCITY AS NOTED
SIDE GRAIN HARD MAPLE
L=4 IN. PRESSURE =0.8 PSI
10'-4710 FPM
20'-4710 FPM
10'-4710 FPM
20'-5000 FPM
RATE OF MATERIAL REMOVAL - GRAMS/MIN.
0
20
40
60
80
100
120
140
0
20
40
60
80
100
120
140
160
180
20' / LENGTH OF BELT X RUNNING TIME - MINUTES

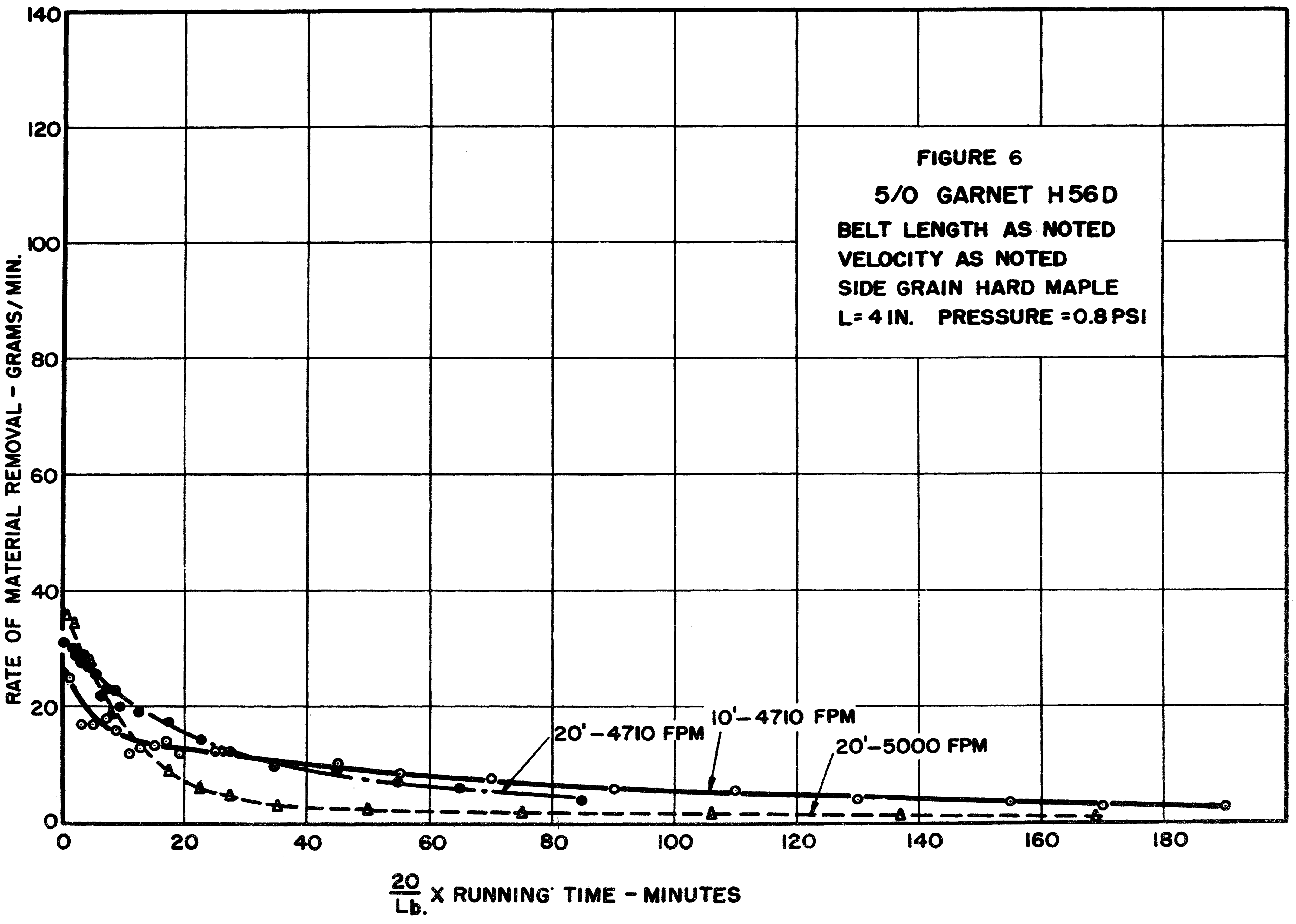


FIGURE 6
5/0 GARNET H56D
BELT LENGTH AS NOTED
VELOCITY AS NOTED
SIDE GRAIN HARD MAPLE
L=4 IN. PRESSURE =0.8 PSI
20'-4710 FPM
10'-4710 FPM
20'-5000 FPM
RATE OF MATERIAL REMOVAL - GRAMS/MIN.
0
20
40
60
80
100
120
140
160
180
$\frac{20}{Lb.}$ X RUNNING TIME - MINUTES

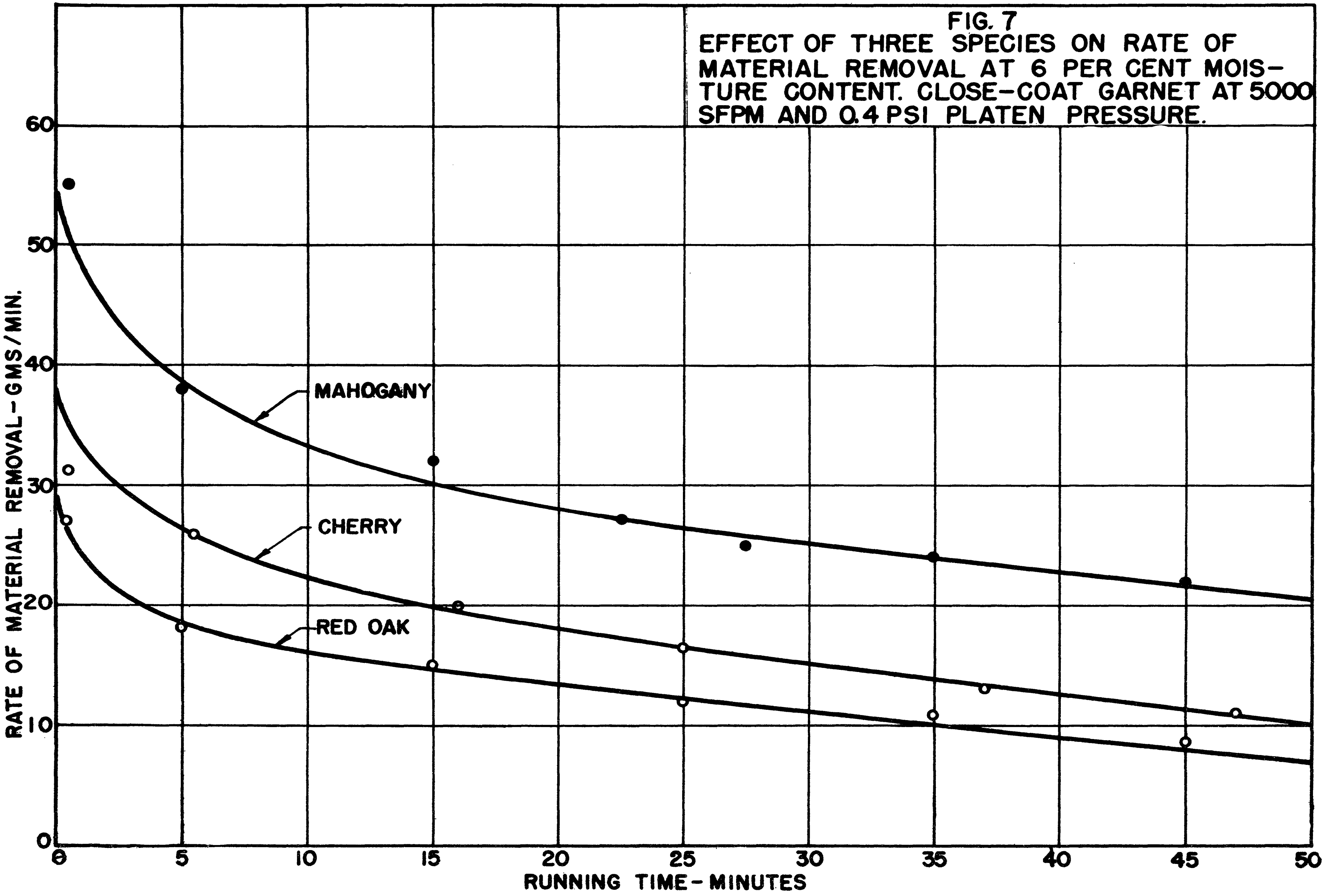


FIG. 7
EFFECT OF THREE SPECIES ON RATE OF MATERIAL REMOVAL AT 6 PER CENT MOISTURE CONTENT. CLOSE-COAT GARNET AT 5000 SFPM AND 0.4 PSI PLATEN PRESSURE.

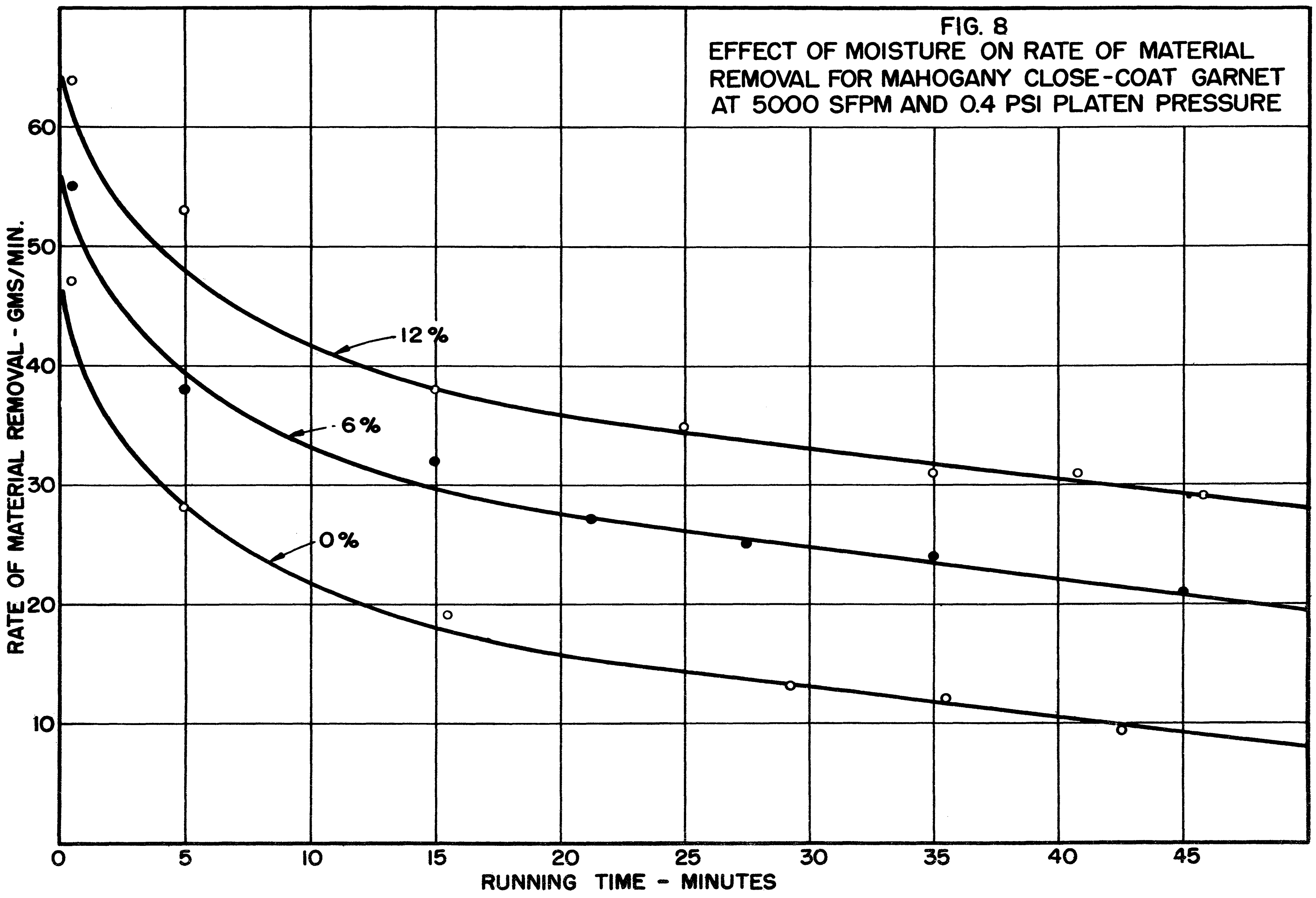


FIG. 8
EFFECT OF MOISTURE ON RATE OF MATERIAL
REMOVAL FOR MAHOGANY CLOSE-COAT GARNET
AT 5000 SFPM AND 0.4 PSI PLATEN PRESSURE
12 %
6 %
0 %
RATE OF MATERIAL REMOVAL - GMS/MIN.
RUNNING TIME - MINUTES
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
45

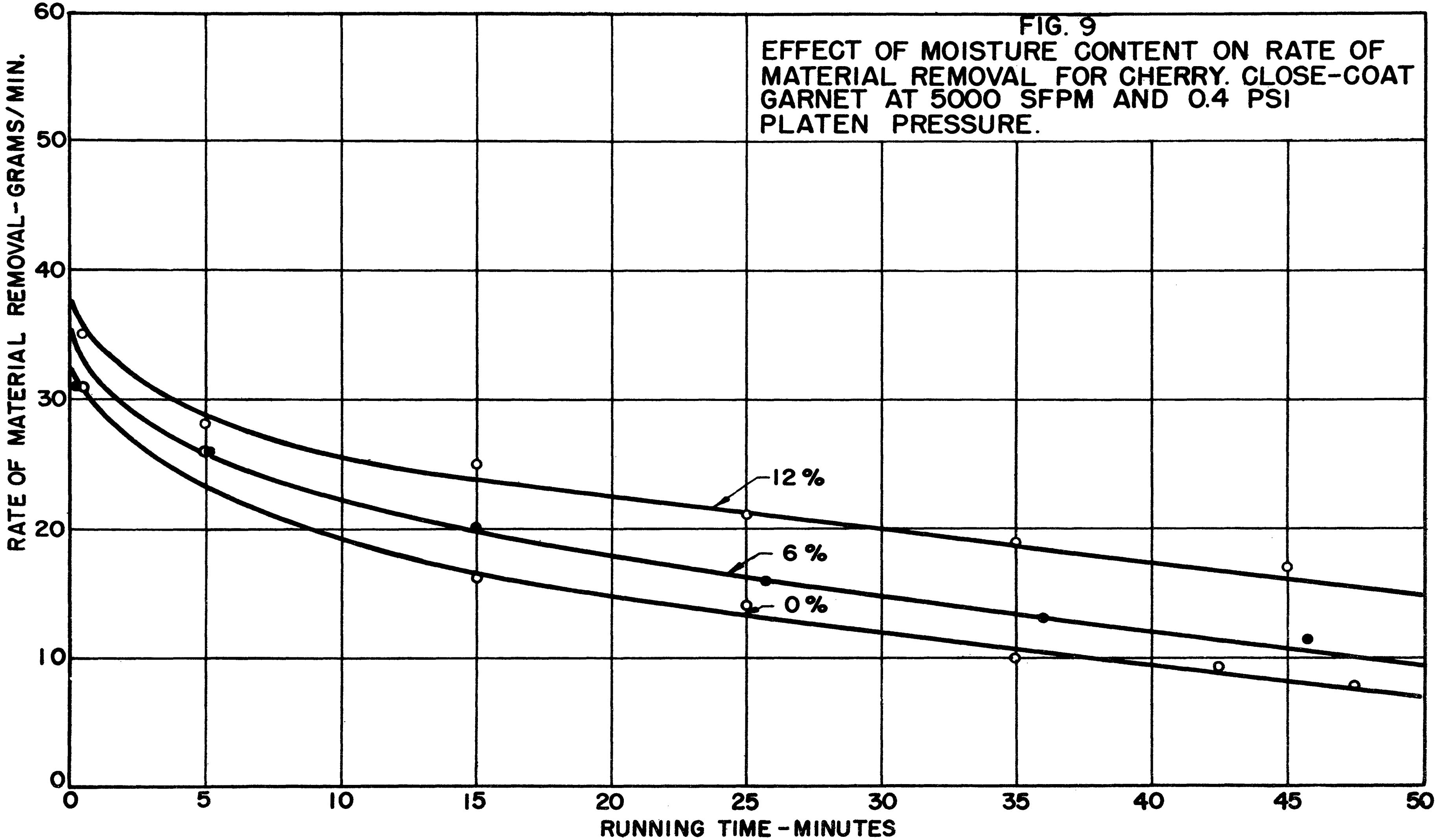


FIG. 9
EFFECT OF MOISTURE CONTENT ON RATE OF MATERIAL REMOVAL FOR CHERRY. CLOSE-COAT GARNET AT 5000 SFPM AND 0.4 PSI PLATEN PRESSURE.

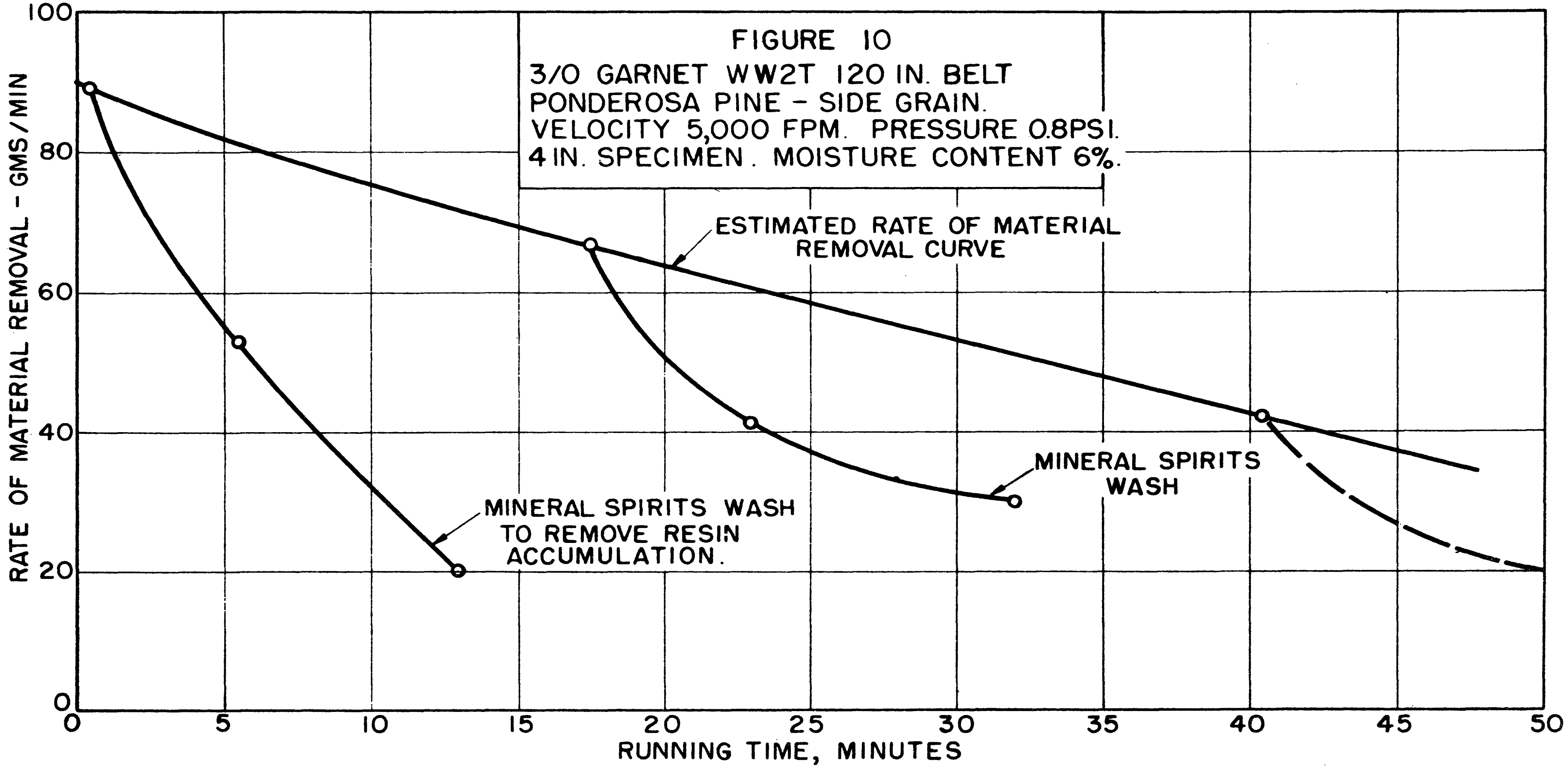


FIGURE 10
3/0 GARNET WW2T 120 IN. BELT
PONDEROSA PINE - SIDE GRAIN.
VELOCITY 5,000 FPM. PRESSURE 0.8PSI.
4 IN. SPECIMEN. MOISTURE CONTENT 6%.

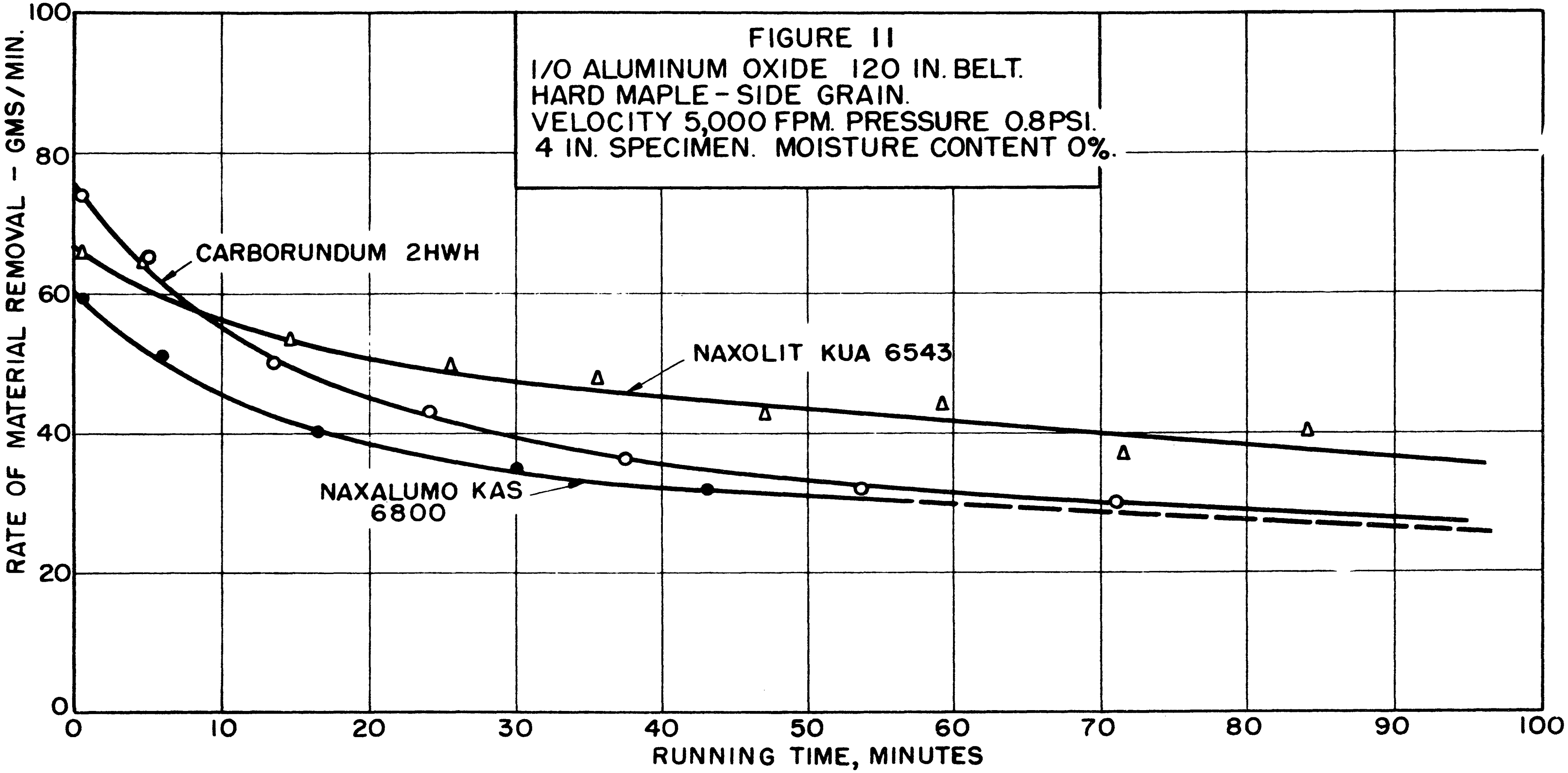


FIGURE 11
1/0 ALUMINUM OXIDE 120 IN. BELT.
HARD MAPLE - SIDE GRAIN.
VELOCITY 5,000 FPM. PRESSURE 0.8 PSI.
4 IN. SPECIMEN. MOISTURE CONTENT 0%.
CARBORUNDUM 2HWH
NAXOLIT KUA 6543
NAXALUMO KAS 6800
RATE OF MATERIAL REMOVAL - GMS/MIN.
RUNNING TIME, MINUTES
0
20
40
60
80
100
10
30
50
70
90

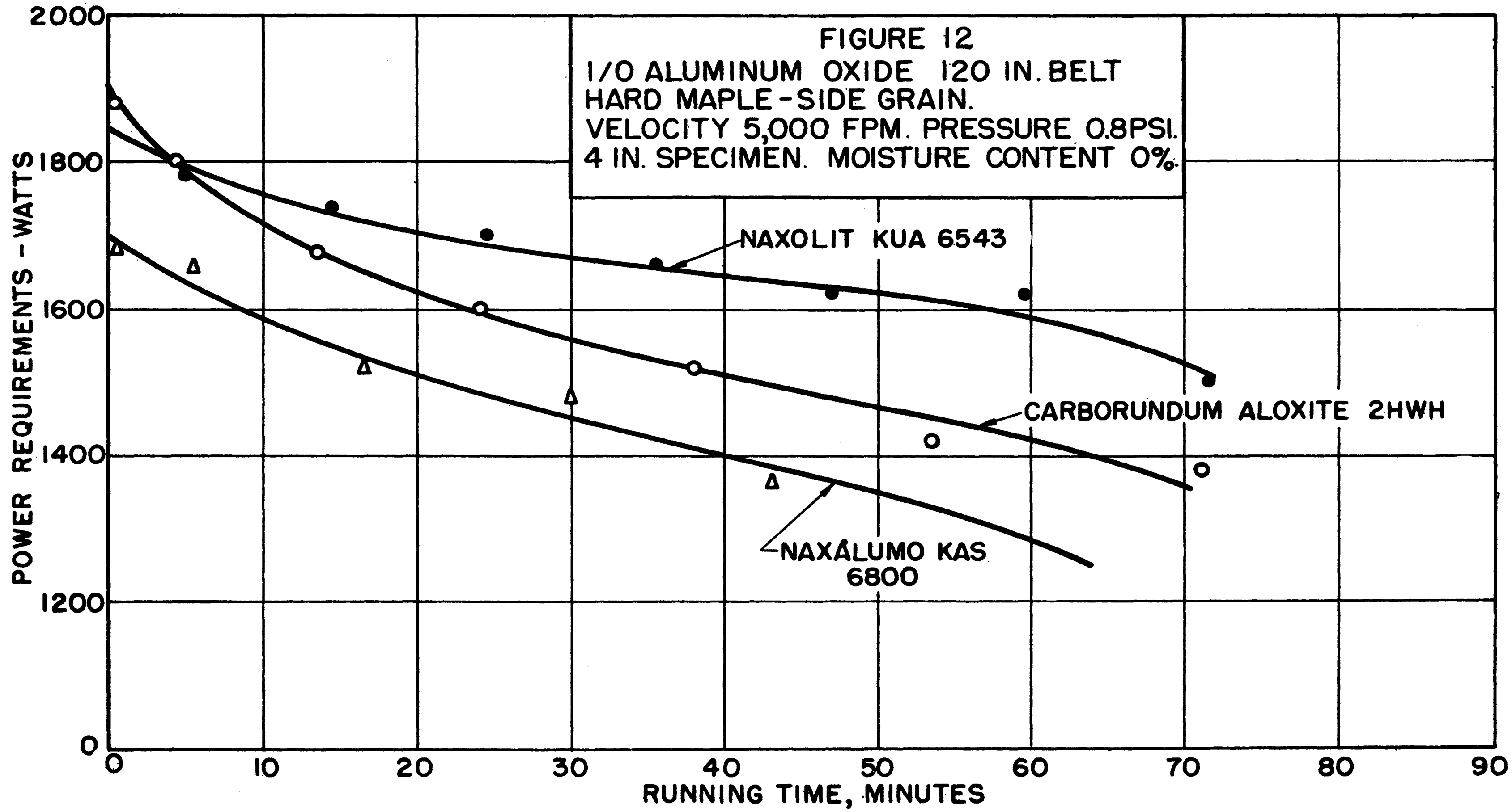


FIGURE 12
1/0 ALUMINUM OXIDE 120 IN. BELT
HARD MAPLE-SIDE GRAIN.
VELOCITY 5,000 FPM. PRESSURE 0.8PSI.
4 IN. SPECIMEN. MOISTURE CONTENT 0%.
NAXOLIT KUA 6543
CARBORUNDUM ALOXITE 2HWH
NAXÅLUMO KAS 6800
POWER REQUIREMENTS - WATTS
RUNNING TIME, MINUTES
2000
1800
1600
1400
1200
0
0
10
20
30
40
50
60
70
80
90

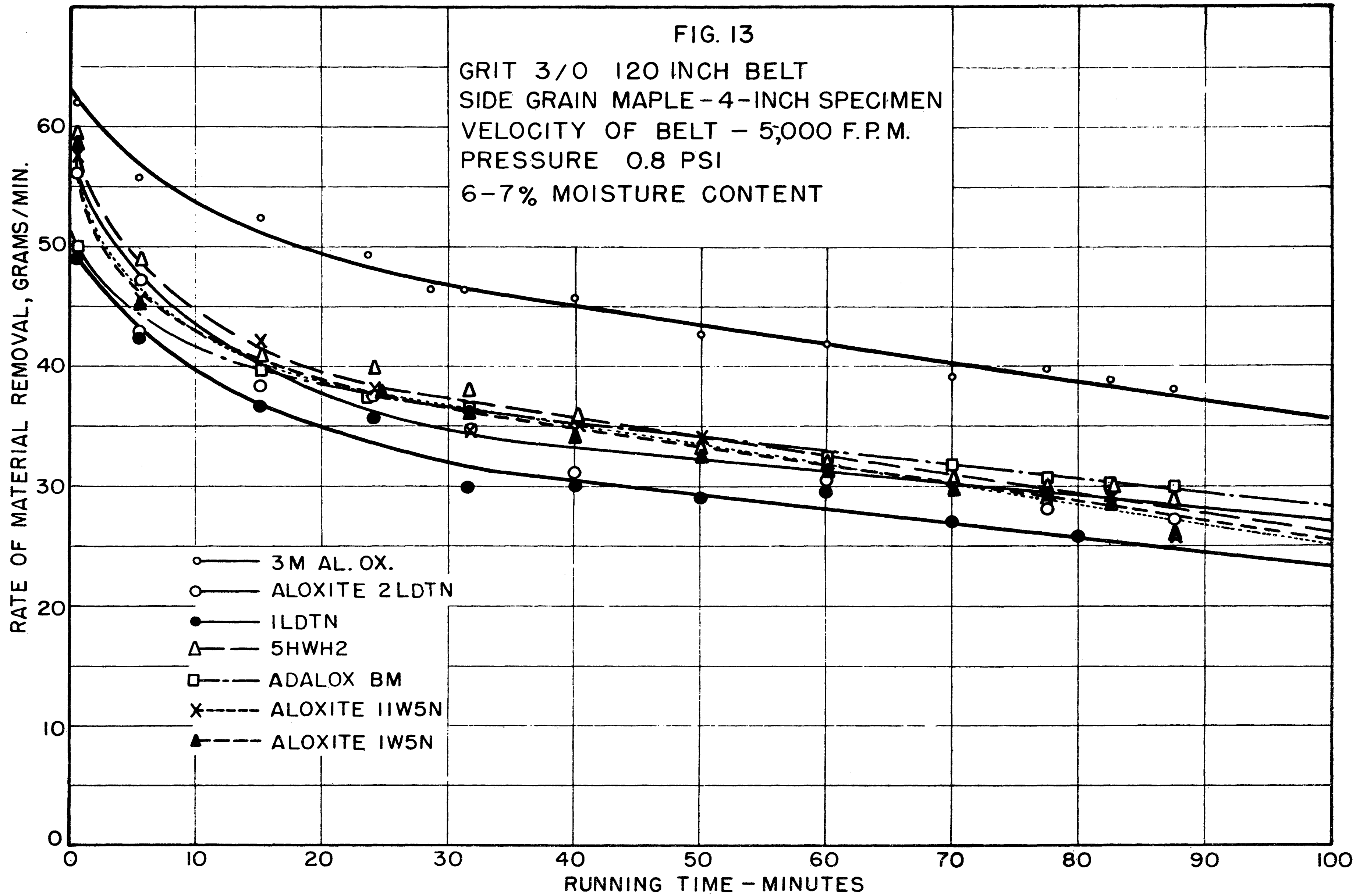


FIG. 13
GRIT 3/0 120 INCH BELT
SIDE GRAIN MAPLE-4-INCH SPECIMEN
VELOCITY OF BELT - 5,000 F.P.M.
PRESSURE 0.8 PSI
6-7% MOISTURE CONTENT
3M AL. OX.
ALOXITE 2LDTN
1LDTN
5HWH2
ADALOX BM
ALOXITE 11W5N
ALOXITE 1W5N
RATE OF MATERIAL REMOVAL, GRAMS/MIN.
RUNNING TIME - MINUTES
0
10
20
30
40
50
60
70
80
90
100

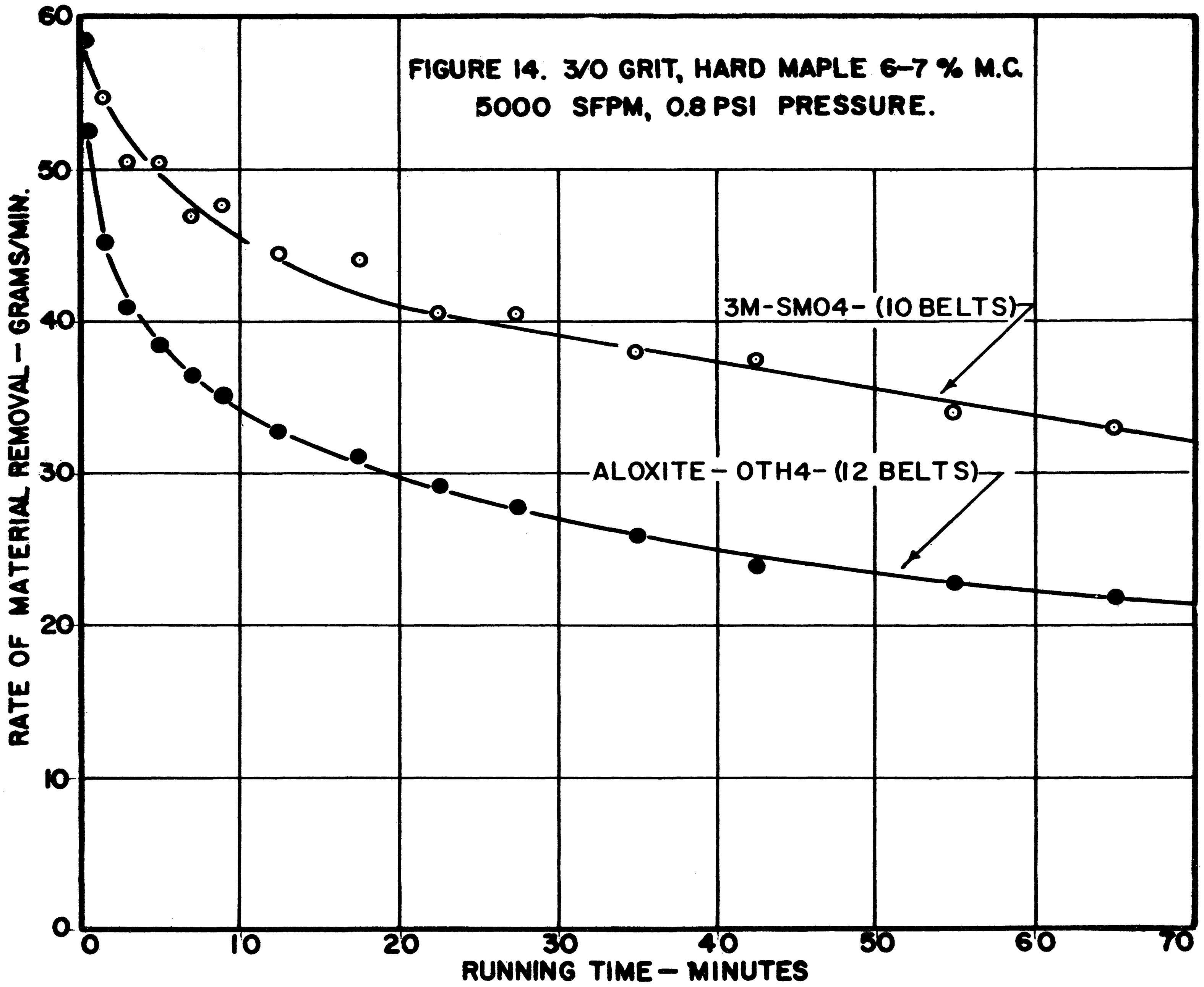


FIGURE 14. 3/0 GRIT, HARD MAPLE 6-7 % M.C.
5000 SFPM, 0.8 PSI PRESSURE.

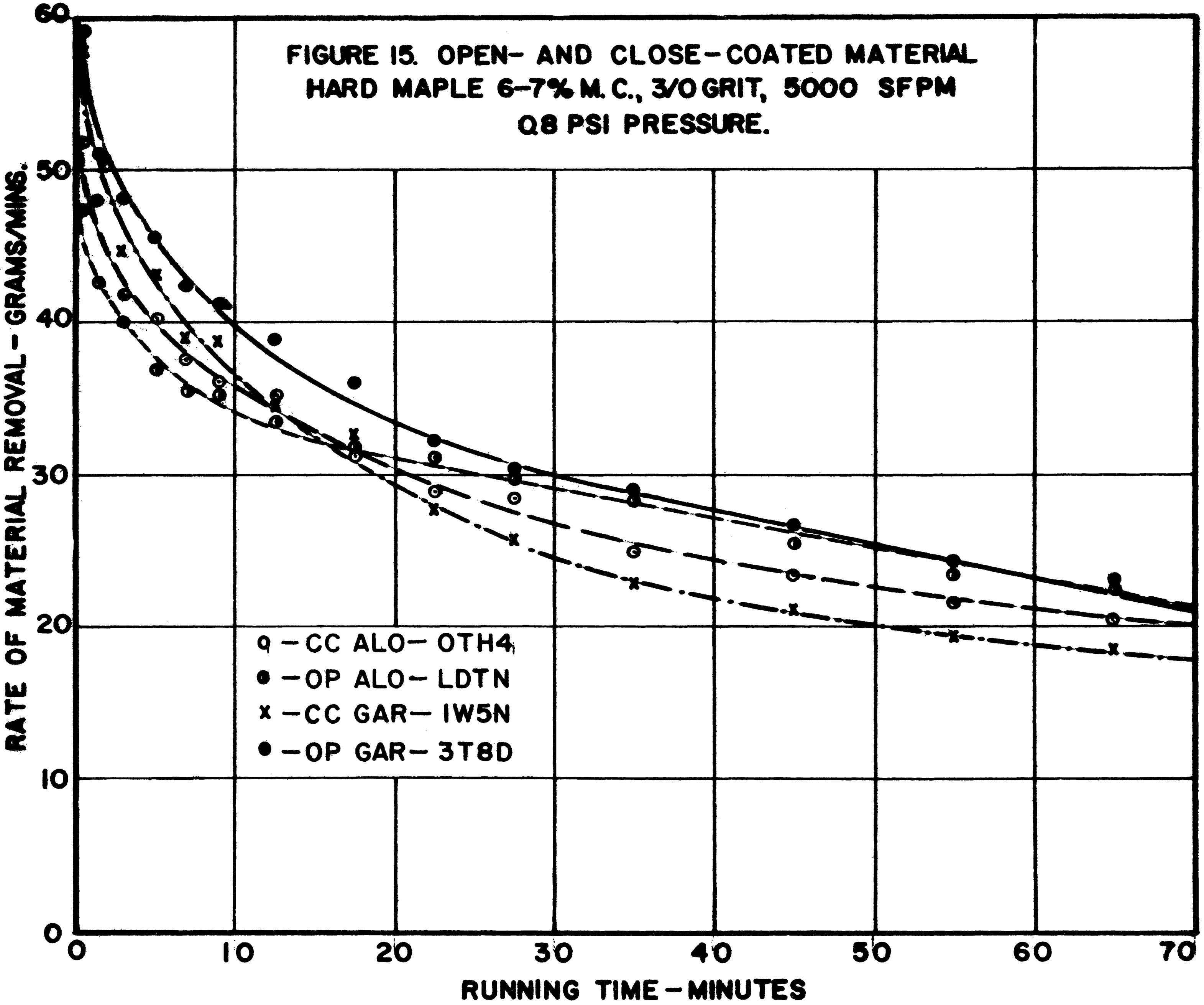


FIGURE 15. OPEN- AND CLOSE-COATED MATERIAL HARD MAPLE 6-7% M.C., 3/0 GRIT, 5000 SFPM 0.8 PSI PRESSURE.

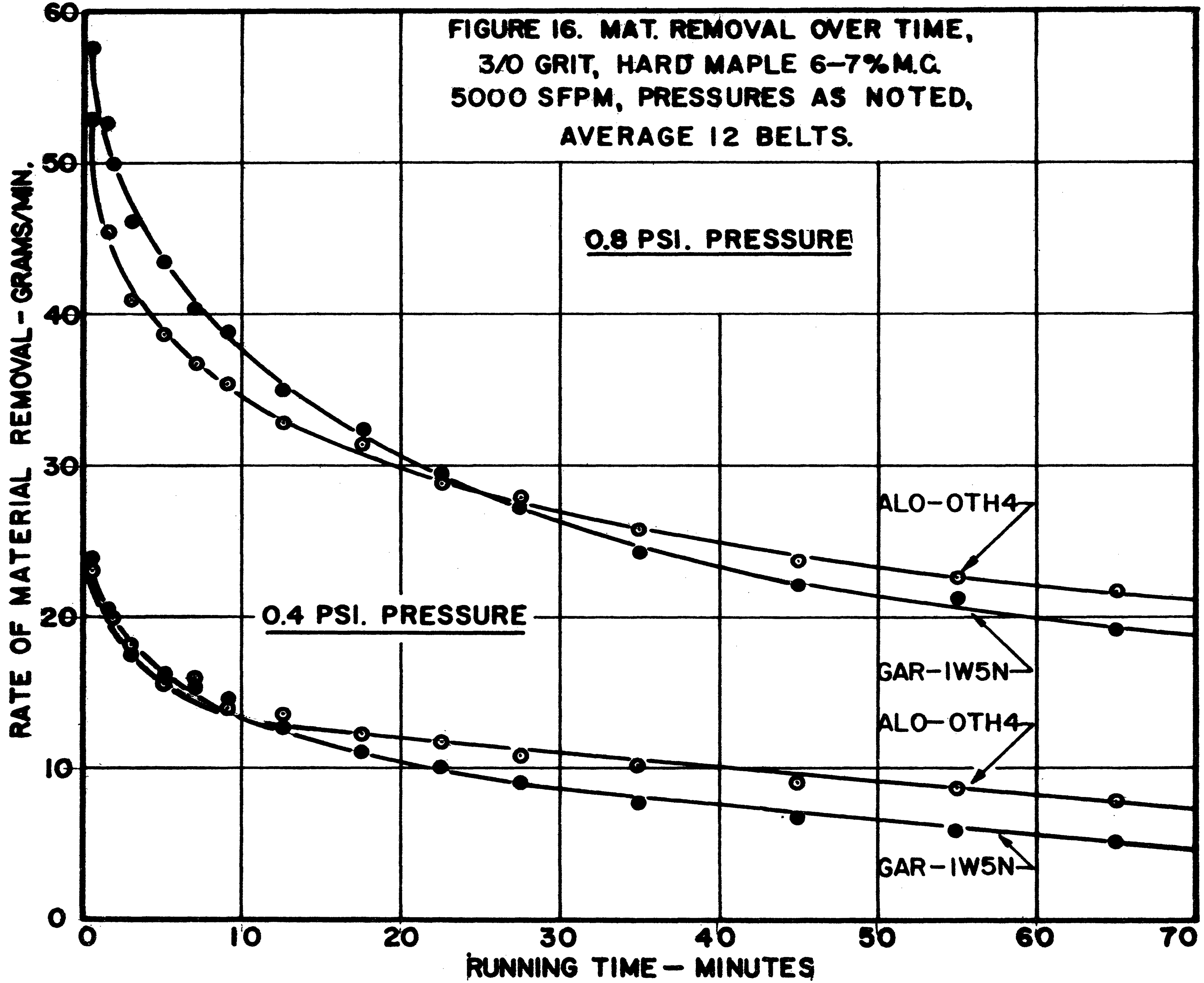


FIGURE 16. MAT. REMOVAL OVER TIME, 3/0 GRIT, HARD MAPLE 6–7% M.C. 5000 SFPM, PRESSURES AS NOTED, AVERAGE 12 BELTS.

Note: For Figures 17 to 25 inclusive, refer to file copy.

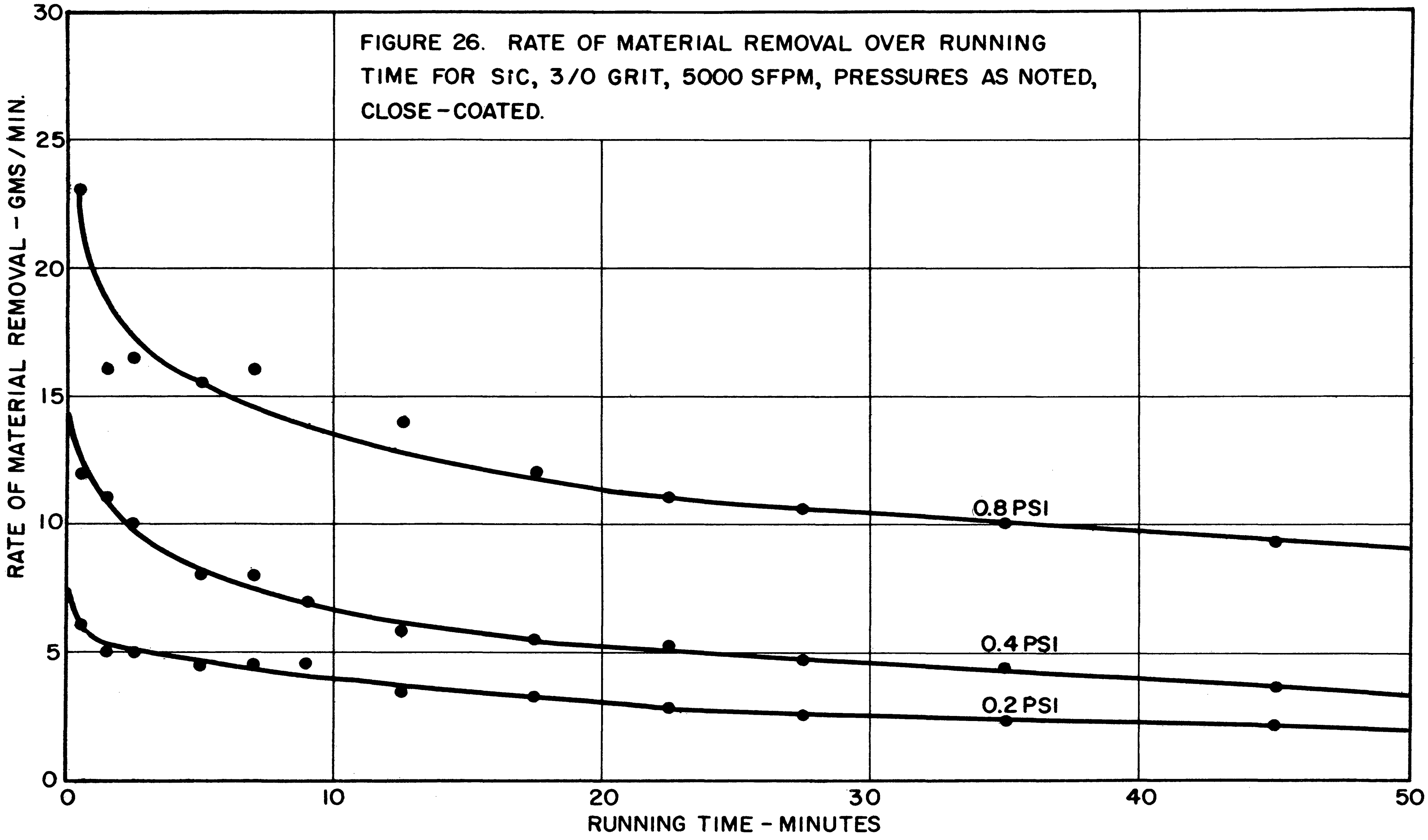


FIGURE 26. RATE OF MATERIAL REMOVAL OVER RUNNING TIME FOR SiC, 3/0 GRIT, 5000 SFPM, PRESSURES AS NOTED, CLOSE-COATED.

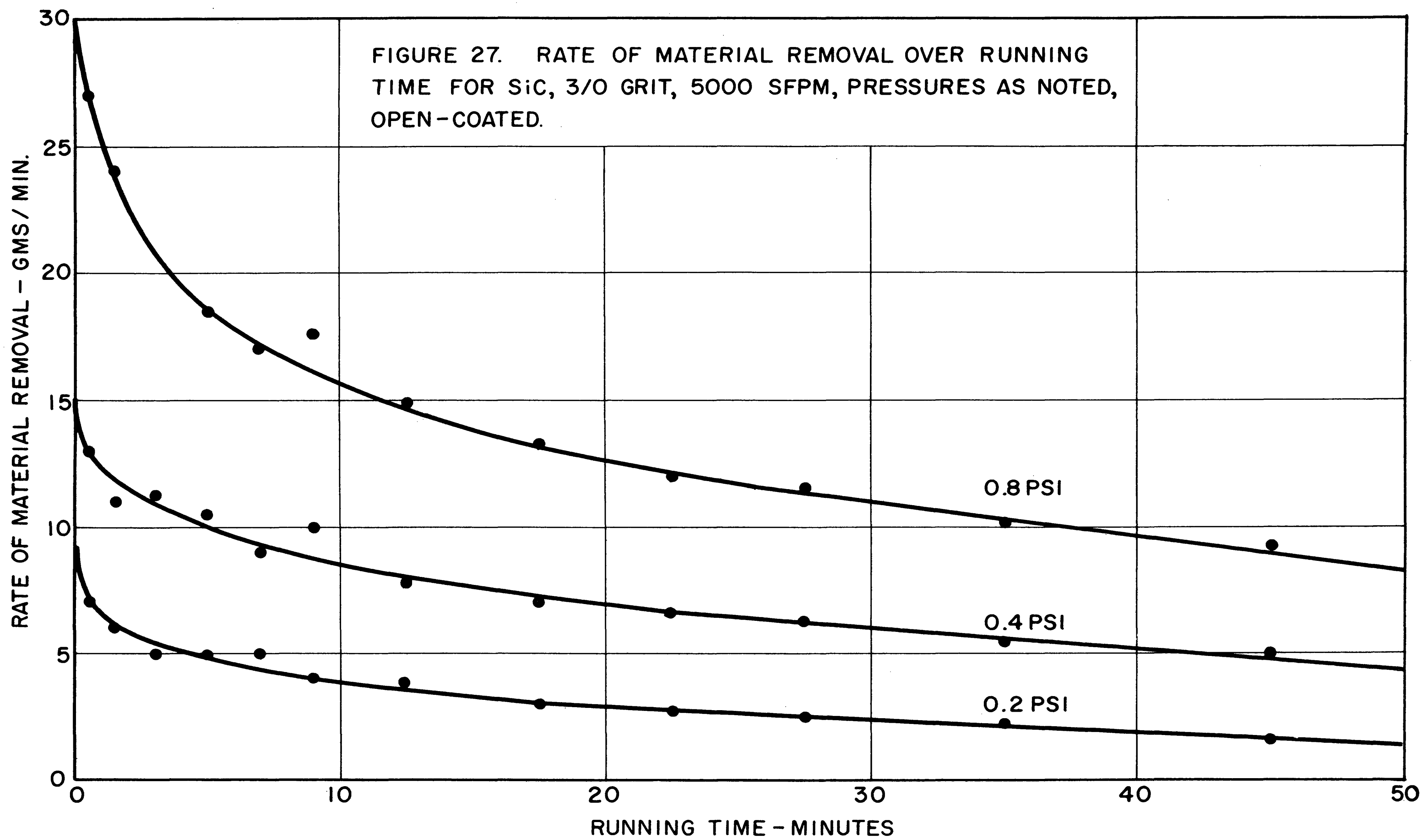


FIGURE 27. RATE OF MATERIAL REMOVAL OVER RUNNING TIME FOR SiC, 3/0 GRIT, 5000 SFPM, PRESSURES AS NOTED, OPEN-COATED.
0.8 PSI
0.4 PSI
0.2 PSI
RATE OF MATERIAL REMOVAL - GMS/MIN.
RUNNING TIME - MINUTES
0
5
10
15
20
25
30
0
10
20
30
40
50

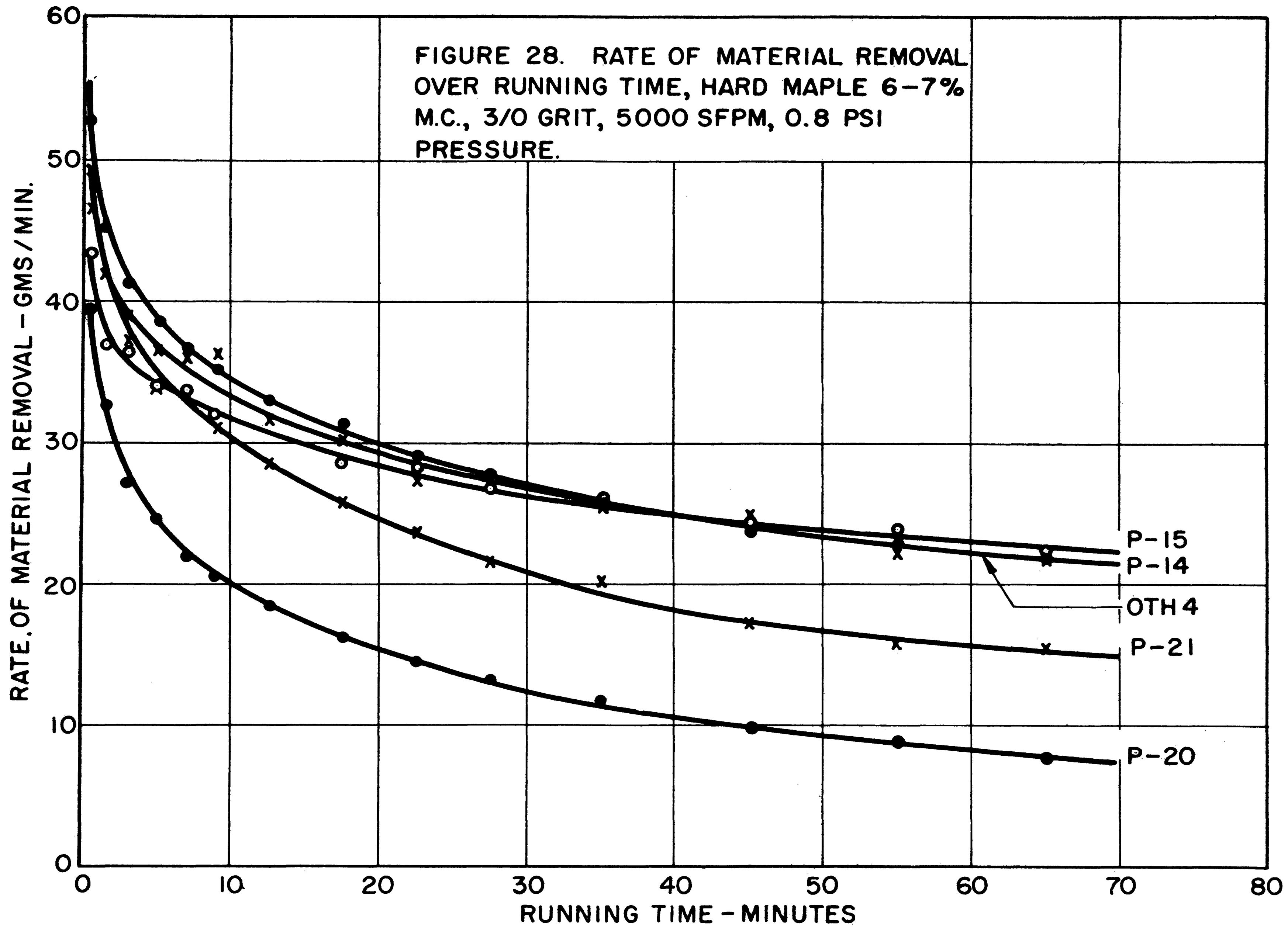


FIGURE 28. RATE OF MATERIAL REMOVAL OVER RUNNING TIME, HARD MAPLE 6-7% M.C., 3/0 GRIT, 5000 SFPM, 0.8 PSI PRESSURE.

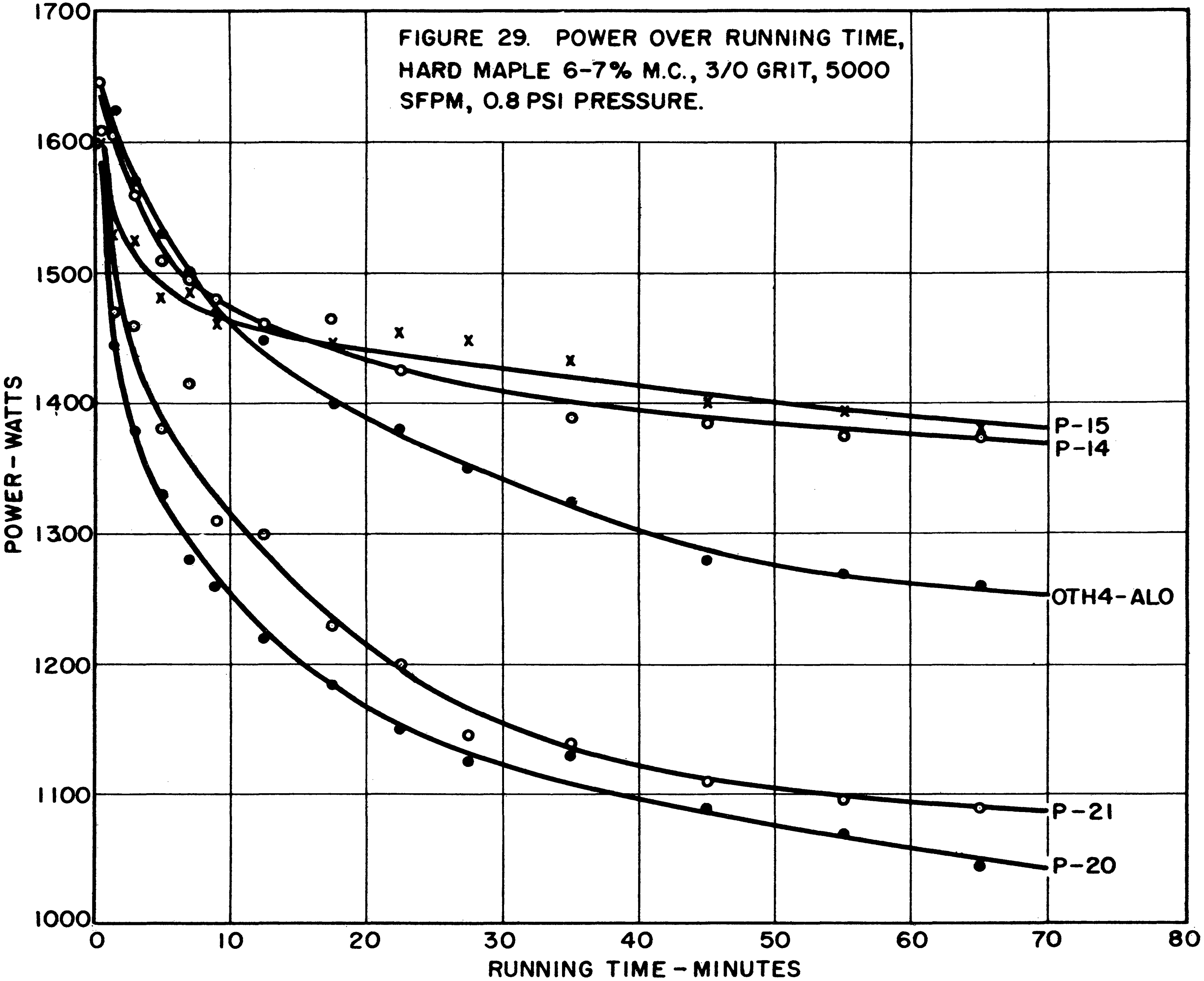


FIGURE 29. POWER OVER RUNNING TIME, HARD MAPLE 6-7% M.C., 3/0 GRIT, 5000 SFPM, 0.8 PSI PRESSURE.