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for
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ADVANCED TECHNOLOGY AND MANUFACTURING PRACTICES FOR MACHINING AND INSPECTING METAL MATRIX COMPOSITES

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ABSTRACT

Lockheed Martin Energy Systems, Inc. (Energy Systems) and the Lanxide Corporation (Lanxide) negotiated a Cooperative Research and Development Agreement (CRADA) to develop advanced technology and manufacturing practices for machining and inspecting metal matrix composites (MMC).

The objective of this CRADA was to develop machining parameters to allow manufacturing of automotive components from MMCs. These parts exhibit a range of shapes and dimensional tolerances and require a large number of machining operations. The common characteristic of the components is the use of the light weight MMC materials to replace heavier materials. This allows smaller and lighter moving parts and supporting structural components thereby increasing fuel mileage.

The CRADA was divided into three areas: basic investigation of cutting parameters, establishment of a mock production line for components, and optimization of parameters in the mock facility.

This report covers the manufacturing of MMCs and preliminary Phase I testing for silicon carbide having various loading percentages and extensive Phase I testing of cutting parameters on 30% alumina loaded aluminum.

On January 26, 1995, a letter from the vice president, technology at Lanxide was issued terminating the CRADA due to changes in business.

OBJECTIVE

Lockheed Martin Energy Systems, Inc. (Energy Systems) and the Lanxide Corporation negotiated a Cooperative Research and Development Agreement (CRADA) to develop advanced technology and manufacturing practices for machining and inspecting metal matrix composites (MMC). The objective of this CRADA was to examine the existing MMC machining and inspection processes, develop the necessary interface for the implementation of Department of Energy (DOE), Defense Programs (DP) precision manufacturing technology, and Energy Efficient and Renewable Energy (EE) materials properties' expertise, and apply this dual-use technology in a mutually beneficial manner. This project will support DOE technical needs in fabricating components from hard materials as well as enabling U.S. industry to maintain a position of leadership in the MMC and ceramics field. (Reference 7)

ASSESSMENT OF OBJECTIVE ACHIEVEMENT

The objectives of the CRADA, as stated in the 'OBJECTIVES' statement are:

1. To examine the existing MMC machining and inspection processes.
2. To develop the necessary interface for the implementation of Department of Energy (DOE), Defense Programs (DP) precision manufacturing technology, and Energy Efficient and Renewable Energy (EE) materials properties' expertise.
3. To apply this dual-use technology in a mutually beneficial manner.
4. To support DOE technical needs in fabricating components from hard materials.
5. To enable U.S. industry to maintain a position of leadership in the MMC and ceramics field.

These objectives have been met by the activities concerned with this CRADA.

BENEFITS TO DOE SPONSOR

As stated in the Statement of Work, Appendix A of the Agreement, The goal of this CRADA was to examine the existing MMC machining and inspection processes, develop the necessary interface for the implementation of Department of Energy (DOE), Defense Programs (DP) precision manufacturing technology, and Energy Efficient and Renewable Energy (EE) materials properties' expertise, and apply this dual-use technology in a mutually beneficial manner.

This project will support DOE technical needs in fabricating components from hard materials as well as enabling U.S. industry to maintain a position of leadership in the MMC and ceramics field. The project will accomplish this by providing DOE contractor personnel with experience in machining the hard and abrasive MMC materials which are finding favor with today's designers.

The project provided funding for the testing program which evaluated the usefulness of various cutting tools. Tools which were highly proclaimed to be the tools of choice for MMCs were found to be almost useless. Other tools, such as natural and polycrystaline diamonds, which are the time proven standard for cutting hard and abrasive materials proved to be only marginally useful. Still other tools which appeared at first consideration to be ill-suited for use on MMCs proved to be the performance and price leaders.

Published information on parameters for cutting MMCs is often contradictory. This was especially true regarding the use of cutting fluids. This project provided an opportunity to evaluate wet and dry machining.

MMC materials are not cheap to purchase nor are they plentiful. The tools normally used to machine the material are also very expensive. This project provided adequate quantities of material in several loading concentrations, grain morphologies, heat treats, grain sizes, and different loading materials. By carefully controlled statistical experiments, an attempt was made to extract the maximum amount of information from each log or tool.

TECHNICAL DISCUSSION

Introduction

Aluminum based metal matrix composites (MMC) are being evaluated widely for automotive, electronic, and other applications because of their attractive high temperature mechanical properties, high stiffness, light weight and high wear resistance. Automotive applications include such areas as brake rotors and calipers, cylinder liners, drive shafts, connecting rods, rocker arms, and transmission components.

Another important application area for these composites is in packaging, substrates, and support structures for electronic components. For these applications, a high loading of SiC particles is incorporated in an aluminum alloy matrix to obtain the desired combination of properties. These properties are low coefficient of thermal expansion matched to that of the electronic device, high thermal conductivity for heat dissipation, high stiffness to minimize distortion, and low density for minimum weight. MMCs have also been used as armor plating for military vehicles. Its light weight for comparable or superior energy dissipation make it desirable in this role.

Present MMC component applications are limited by manufacturing difficulties associated with the hardness and abrasive properties of the material. Even when it is possible to achieve the desired geometry, full utilization of MMCs is often prohibited by the cost of the manufacturing techniques that must be utilized. Furthermore, the extent of quality limitation imposed by the overall variability of the machining and tooling processes is essentially an unknown factor. Since different applications require different reinforcement materials, loadings, reinforcement size, and morphology as well as different matrix chemistries, the development of the machining parameters must be done for a range of materials.

Despite the fact that MMCs have been available for some time, literature on successful machining parameters does not exist, is not applicable, or is contradictory. A good example of this is the recommendations for wet/dry machining. One report recommends milling without a coolant because it appears to prolong the life of diamond cutting tools with no degradation of surface finish. Another report recommends that cutting be done dry when rough machining and wet when finish machining. A third report states that under no circumstances should any dry machining be done on MMCs. Similar contradictions can be found on the type of diamond tool to be utilized (continuous vapor deposition, CVD versus polycrystalline diamond, PCD), and cutting parameters (recommended cutting speeds of greater than 5000 SFM and less than 1000 SFM can be found in literature). (Reference 9)

Metal Matrix Composite Technology

Lanxide Corporation invented and patented technology that permits the economical fabrication of a broad range of aluminum matrix composites. A variety of ceramic reinforcements, such as particles or fibers of silicon carbide or aluminum oxide, can be combined with aluminum metal using a molten metal infiltration process. This PRIMEX™ pressureless metal infiltration process forms composites featuring 30 to 75 or more volume percent reinforcement, uniform microstructures, and net or near-net shapes (References 1 to 5). A wide variety of reinforcement shapes, such as fibers, platelets, particulates (with sizes down to < 1 μm) can be used.

The basic process is shown in Figure 1. In the first step, the reinforcement is formed into the desired shape using traditional ceramic-forming methods; this "preform" contains 30 to 50 volume percent interconnected porosity. In the next step, the preform is placed in contact with an aluminum alloy in an environment that causes the ceramic reinforcement to be wet by the molten matrix alloy, resulting in the spontaneous infiltration of the preform to form the composite. The infiltration is conducted in a nitrogen atmosphere at ambient pressure and at a temperature above the melting point of aluminum. The resulting components are completely infiltrated with matrix alloy and feature uniform distributions of particles, as shown in Figure 2. Parts having complex geometries can be made to net or near-net shape (requiring finishing of only the critical dimensions).

Recently, Lanxide has adapted this technology to traditional aluminum casting methods. The PRIMEX CAST™ casting process can produce aluminum components reinforced with 1 to 40 volume percent silicon carbide particles (Reference 6). Parts have been made using investment shell, die, squeeze, and sand casting methods in production foundries, Figure 3, demonstrating the feasibility of economical production of cast MMCs using existing manufacturing capacity. A schematic of the process is shown in Figure 4. The key first step uses PRIMEX™ pressureless metal infiltration with an excess of aluminum. The reinforcement is made highly wettable by the molten aluminum - a crucial requirement for achieving the best mechanical properties. The second step involves uniformly dispersing the reinforcement in preparation for casting. Sizes and dimensional accuracy's of MMC castings fall within typical ranges for the various casting processes. The silicon carbide particles are uniformly distributed in the aluminum matrix as shown in the microstructure in Figure 5.

The inherent flexibility of these two processes enables component properties to be tailored to the application by manipulating the reinforcement volume fraction and type, the matrix alloy composition, and the microstructural features.

Despite being able to cast to near net shape, some amount of machining is usually required to finish parts. Successful application and marketing of the MMC material is highly dependent on being able to furnish unambiguous machining data to the potential user. To

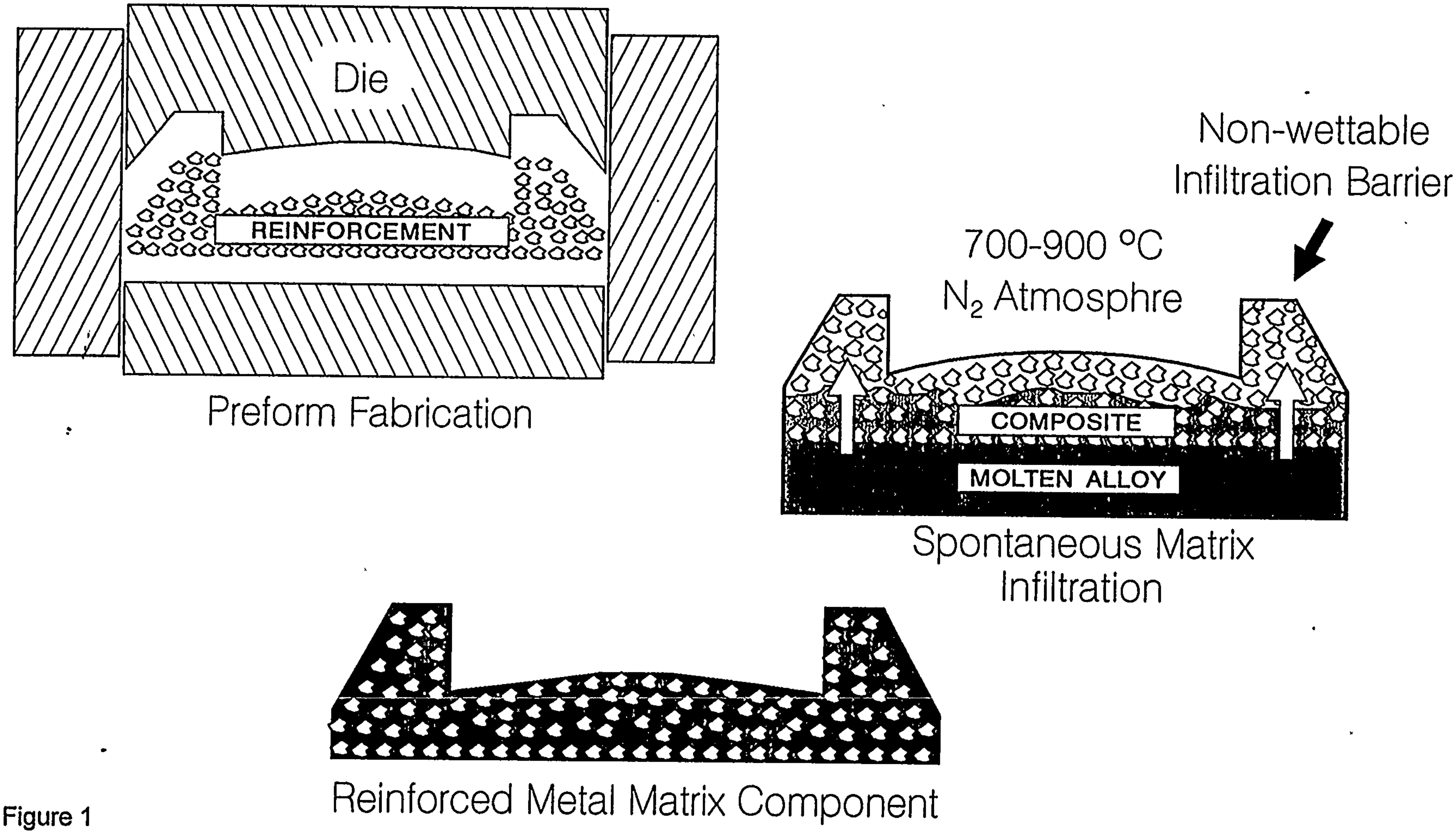
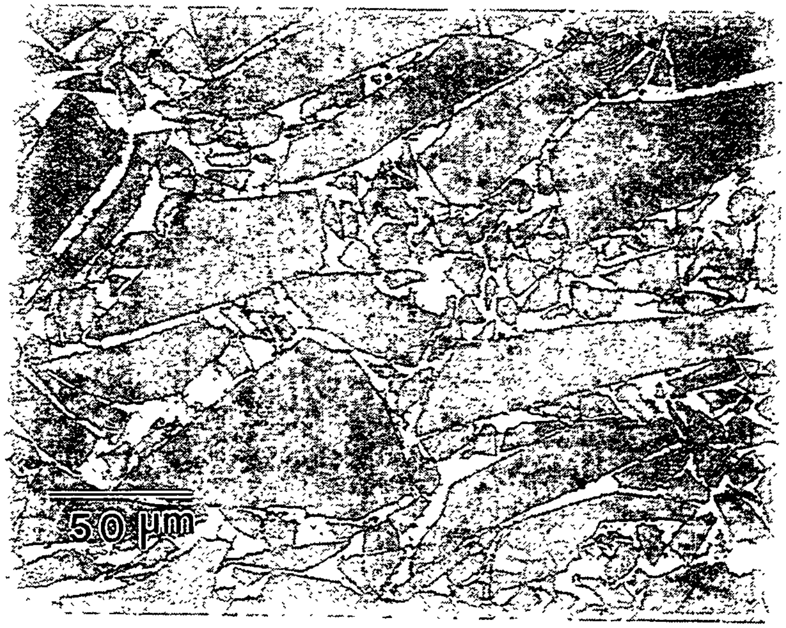
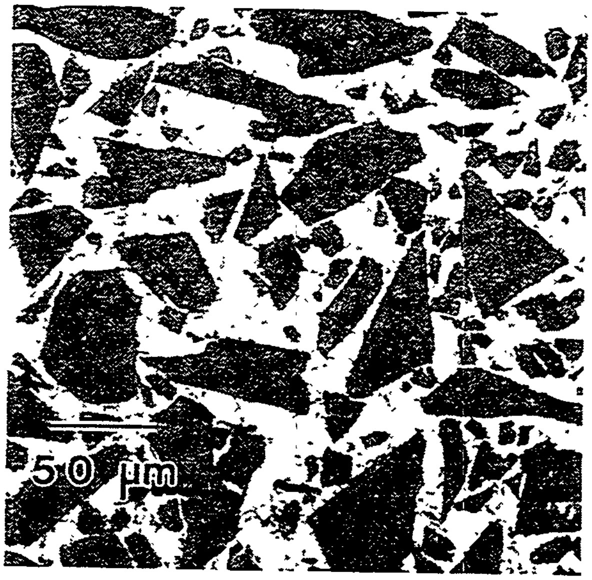


Figure 1
Schematic of PRIMEX^{tm} pressureless metal infiltration process



Al/SiC/70p 400x



Al/SiC/55p

Microstructure of NX-5251

Figure 2
Microstructure of reinforced aluminum made by the PRIMEX™ pressureless metal infiltration process 70 volume percent silicon carbide (top); 55 volume percent silicon carbide (bottom). 400 x

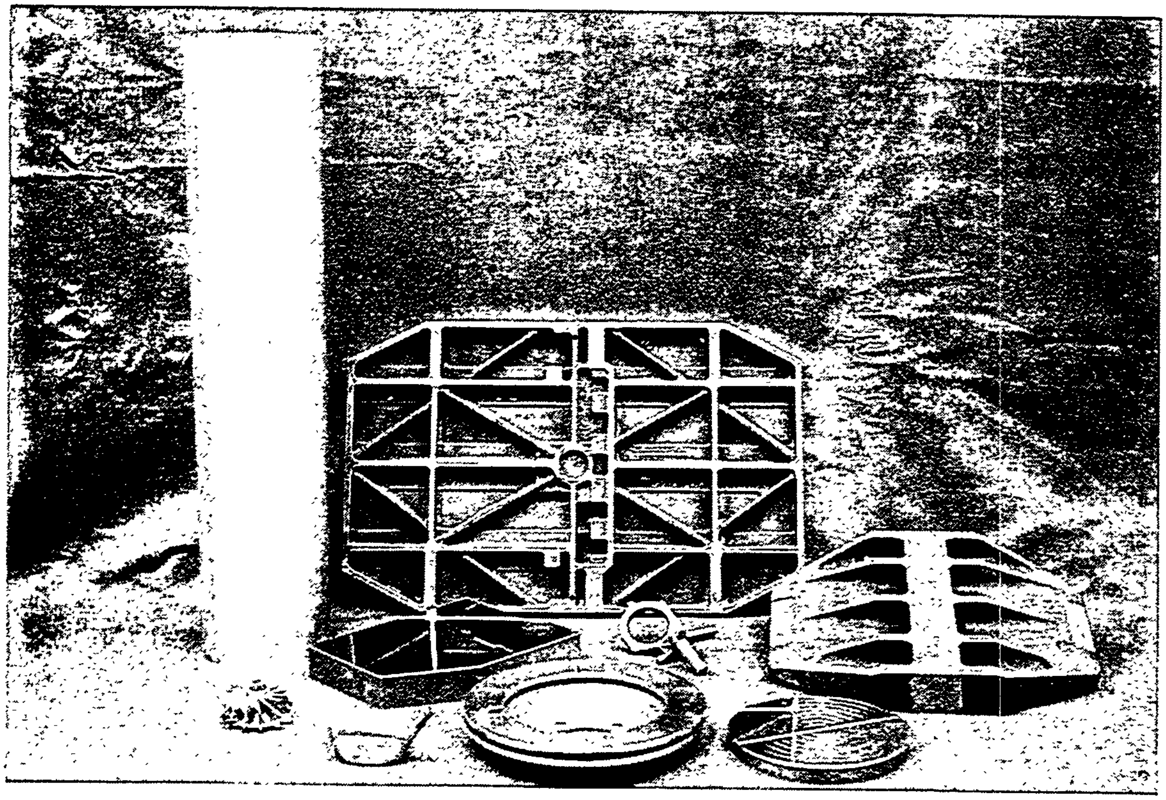


Figure 3
Components made of PRIMEX CAST™ material

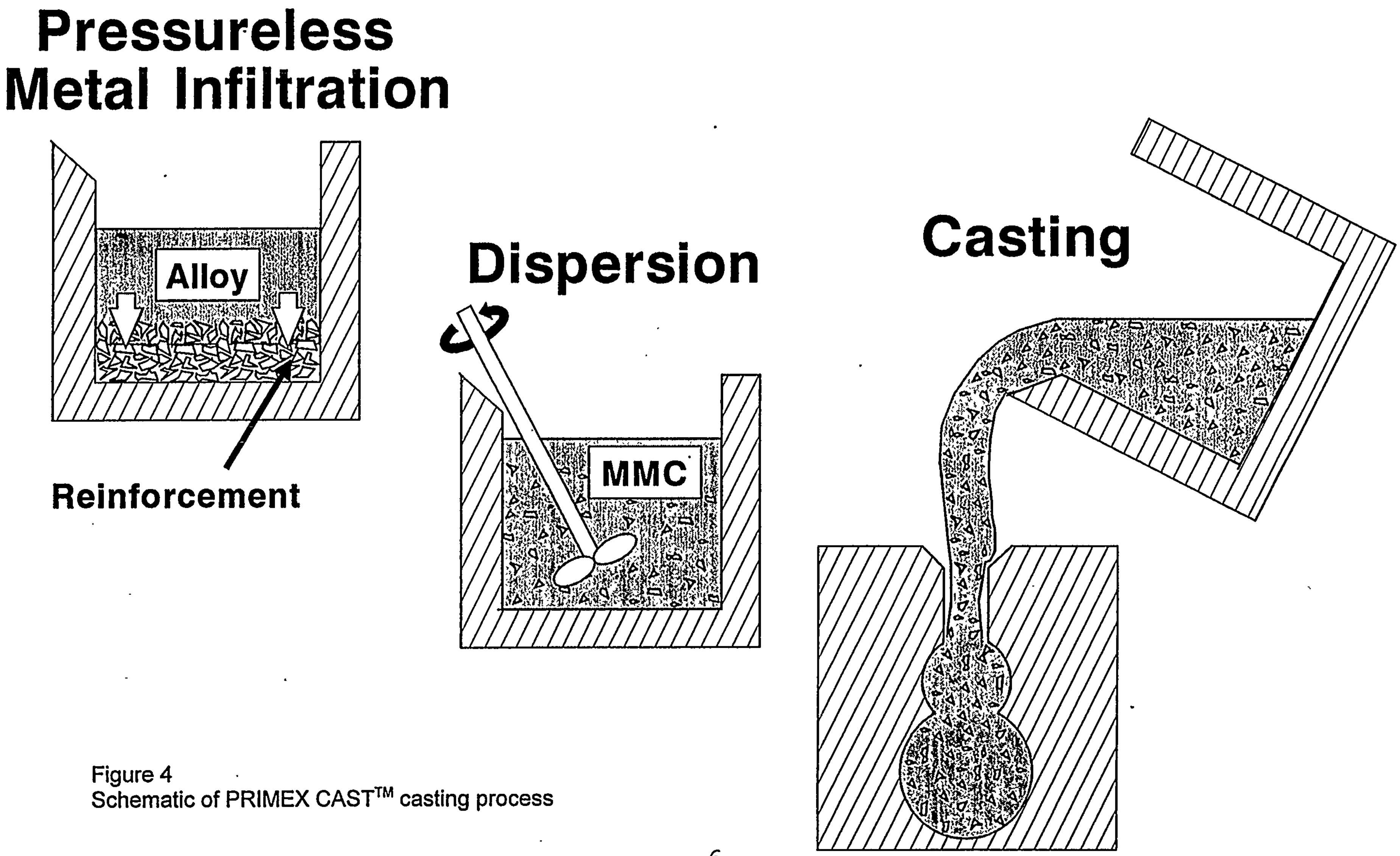


Figure 4
Schematic of PRIMEX CAST™ casting process

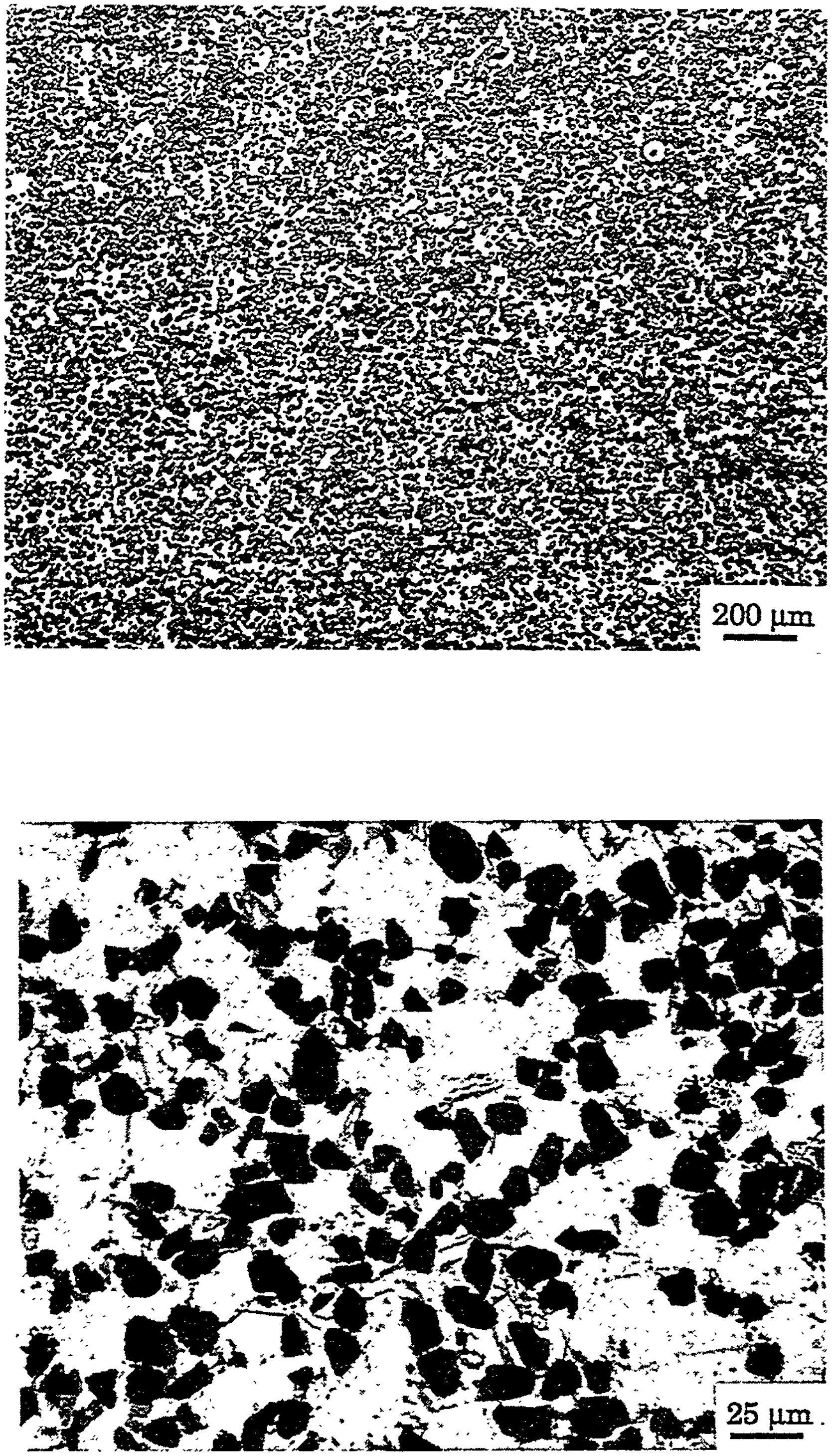


Figure 5
Microstructure of reinforced aluminum made by the PRIMEX CAST™ process

30 volume percent silicon carbide
50 x (top); 400 x (bottom)

achieve this end, Lanxide entered into the CRADA with Energy Systems in which Lanxide supplied test material and Energy Systems supplied cutting tools, machinery, personnel and expertise to develop the necessary cutting parameters. Original plans called for Energy Systems to determine the cutting parameters for a range of materials, use the parameters to mock-up a production line for an automotive component, and optimize the cutting sequence and parameters for the material chosen for the automotive component.

Two material chemistries were investigated during the course of this CRADA. The search for a suitable tool and the development of cutting parameters for those materials is the subject of this report. Machining of alumina loaded aluminum brake rotors was undertaken and most conclusions and recommendations are the result of rotor machining. Detailed statistical plans for the milling, drilling, and tapping of MMC material have been documented but are not included in this report. Results of initial machining of silicon carbide loaded aluminum logs are included in this report. (Reference 8)

Test Material

Initial testing was performed on silicon carbide logs having a variety of make-up characteristics. These Lanxide supplied logs were approximately 4 to 5.5 inches in diameter by 14 inches long with a hollow core of approximately 1.5 inches. Because of this shape, tool testing on these blanks was done by straight turning. The logs were chucked in the lathe and were turned from the tailstock end of the machine toward the headstock end.

Because the MMC material can be varied to suit the application, the effects of several make-up variables on machining difficulty were to be investigated. These included the reinforcement material, volume percent reinforcement, particle size, heat treatment, and particle morphology. Full factorial combinations in the range of interest led to a large number of tests that should be run. By limiting the range to several discrete values and assuming that there is no interaction between the variables, the experiment could be carried out with only seven carefully selected silicon carbide loaded logs. Table 1 is a listing of the required logs.

Log #	Particle loading (Vol. %)	Particle material	Particle size (μm)	Particle morphology	Heat treatment
1	45	SiC	17	Regular	No
2	30	SiC	17	Regular	No
3	45	SiC	66	Regular	No
4	30	SiC	66	Regular	No
5	30	SiC	17	Regular	Yes
6	30	SiC	31	Regular	No
7	30	SiC	17	Round	No

Table 1
SILICON CARBIDE LOGS

This selection allows comparisons to be made between high and low loading, coarse, medium and fine grain size, heat treated versus non-heat treated material, and round versus regular morphology. It was expected that additional logs of specific make-up would be needed to differentiate between some parameters.

At the request of Lanxide, emphasis was placed on developing suitable turning parameters for 30% aluminum oxide (alumina) loaded aluminum for automotive applications. Test material supplied by Lanxide was in the form of rough machined disk brake rotors of the proper alloy as shown in Figure 6. It was assumed that there was no difference between rotors and no attempts were made to correlate wear data to specific rotors. Records of which rotor was used to test a particular tool have, however, been maintained.

Machine

The machine tool used for the turning and facing tests is a LeBlond 3220 NC turret lathe. The machine is controlled by a GE 2000 controller; and is equipped with a 30 horsepower spindle drive motor which can turn the workpiece up to 1300 RPM. A typical feature found on machinery of this mechanical and electronic sophistication is a 'constant SFM' mode that varies the spindle RPM during a facing cut across a part to maintain, within spindle speed limitations, the same cutting speed. The machine has DC electric servo drive motors to drive the slides with positioning monitored by resolver feedback devices. The four sided turret with 12 rotational positions was fixed because a devibrating carbide boring bar was utilized to hold the tool. Machining was performed inside a ventilated containment hood to prevent spreading the abrasive chips over the shop area. Figure 7 is a photograph of the lathe and hood. The control pendant, containment hood and turret can be observed. The back end of the devibrating boring bar is visible on the far side of the turret below the coolant inlet pipe.

Tools

Since the silicon carbide logs were the first MMC material to be cut in this testing program, a variety of tool materials and shapes were tried. Among these were carbide, cubic boron nitride (one of the newer supertool materials), and various ceramics. Many of these tools failed so rapidly that useful data could not be collected. No attempt has been made to include these tools in this report. Raw data on the tools are included in Appendix 4, however. Polycrystalline diamond tools provided the only alternative for machining the silicon carbide material. Silicon nitride tools were not available at the time of testing the silicon carbide loaded material and were not tried.

As in the case of the silicon carbide loaded MMC, a variety of tools were tested against the alumina loaded material. Carbide tools were almost useless in cutting the material, with

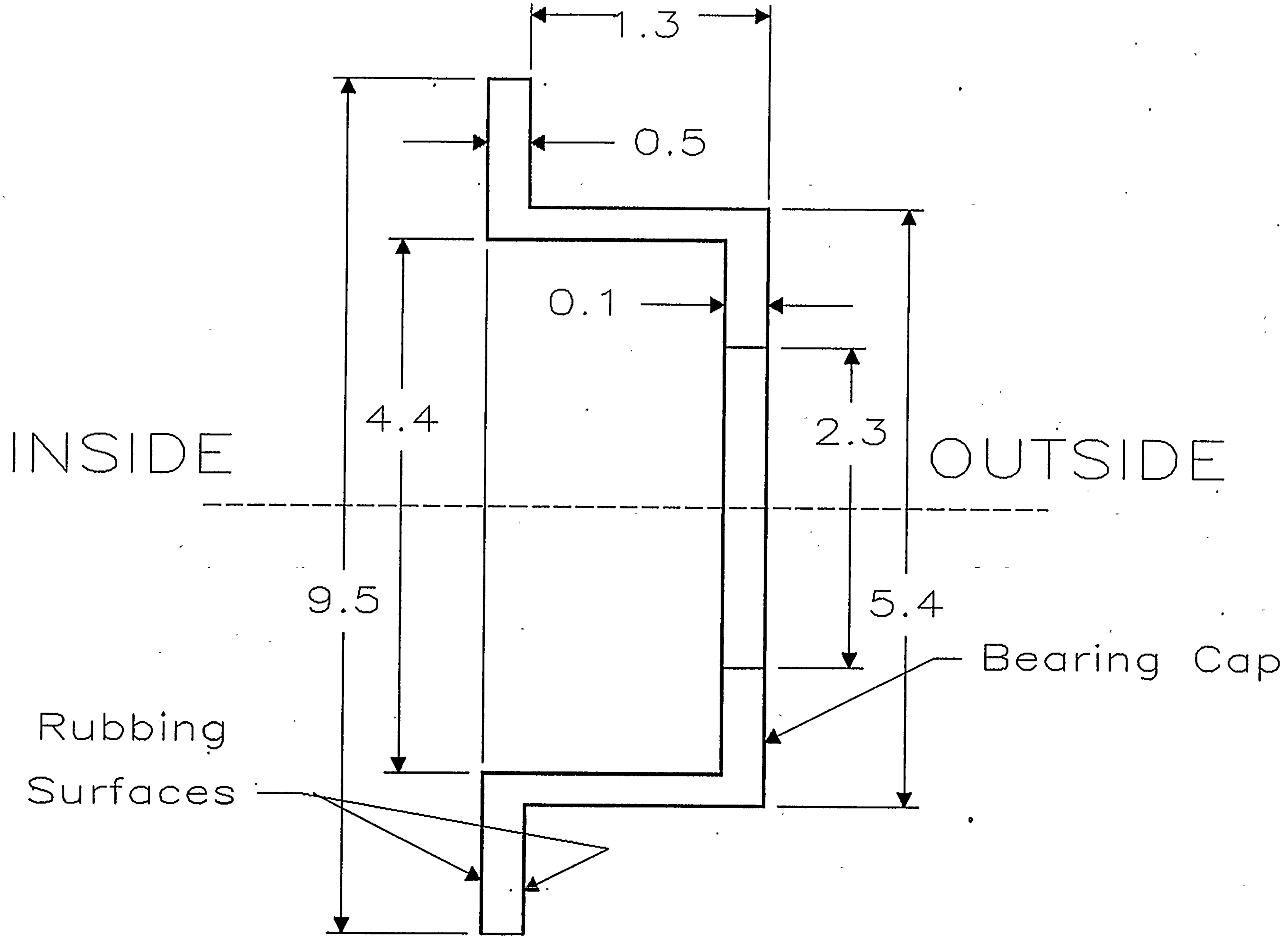
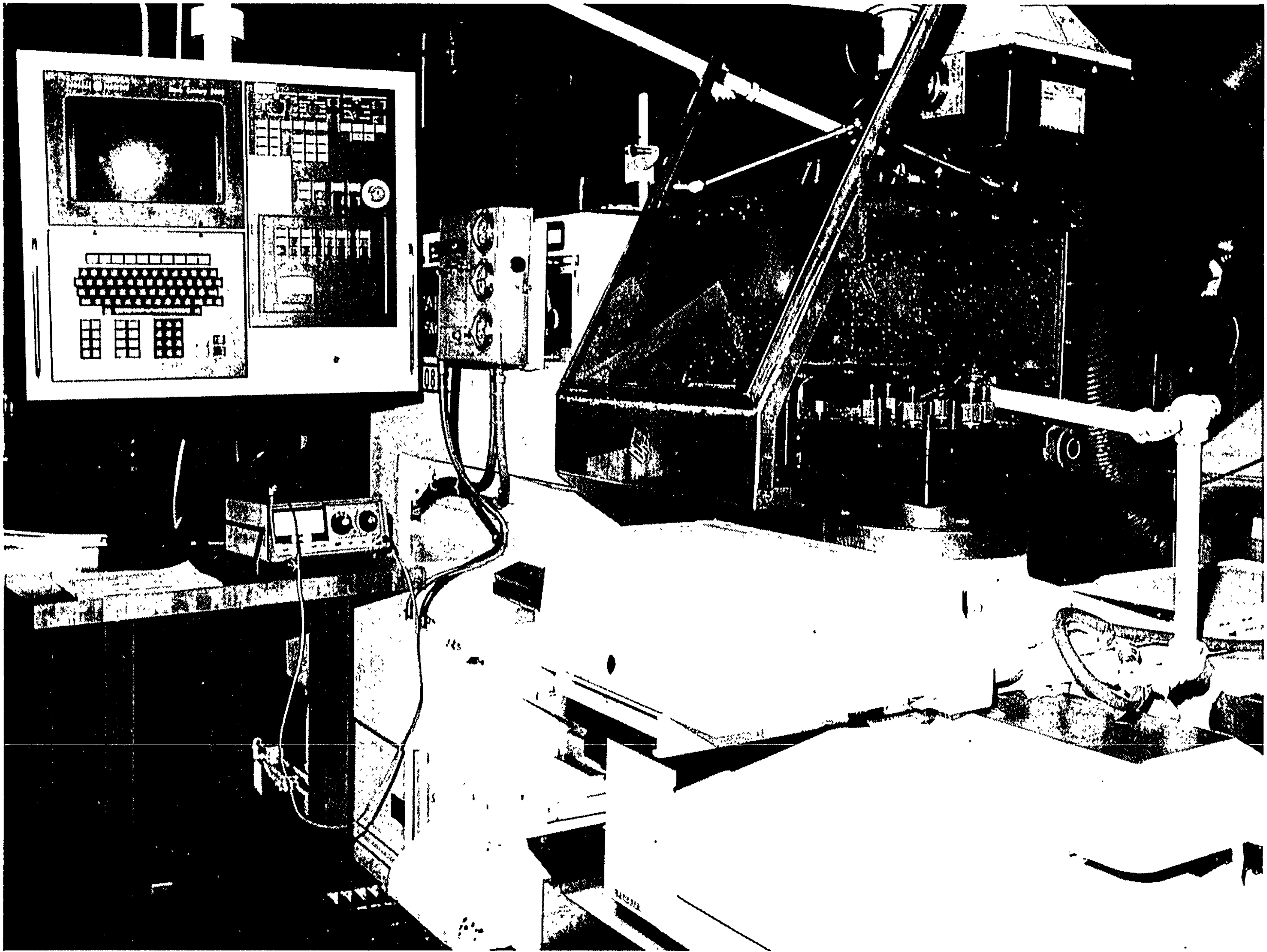


FIGURE 6

As Supplied Rotor-Dimensions in Inches



wear to such an extent that cutting ceased and only rubbing occurred before the tool had completed a full pass across the brake rotor. Titanium carbide coated tools and cubic boron nitride also exhibited rapid wear. As before, polycrystalline diamond (PCD) tipped tools were a feasible alternative. The results of the testing the PCD tools comprise the majority of reported results.

Recent cutting tests indicate that silicon nitride and diamond coated silicon nitride tools may also be a viable choice for both MMC materials. Preliminary data on the silicon nitride tools used for cutting the alumina loaded brake rotors are included in this report.

The preferred tool shape for testing on either material is the 1/2" size, 55° parallelogram (diamond) shaped tool, although other shapes were utilized. Drawings of the alternative configurations for tools are included as Appendix 1. The diamond shaped tool has the American National Standards Institute (ANSI) code designation Dxxx-43x. The first digit (D) designates the 55° diamond shaped tool. Digits 2,3, and 4 contain information about the relief angle, tool tolerances, and hole/chipbreaker features. The digit 4 in the fifth position indicates the tool size (1/2" inscribed circle). Digit 3 in the sixth position is the code for a 3/16" thick tool. The seventh digit describes the nose radius of the tool with a 2 indicating 1/32" nominal radius and a 3 indicating a 3/64" nominal radius. The tools selected for testing are 3/16" thick and have either a 3/64" (0.047") or 1/32" (0.032") tip radius. Charts and diagrams are available in tool manufacturer's catalogs which list and illustrate the various configurations. The applicable ANSI standard is ANSI B212.4-1986 which is available from the American National Standards Institute, 1430 Broadway, New York, New York 10018.

Tools from nine different manufacturers having a total of 15 differing geometries (relief angles, tolerances, hole/chipbreaker features, and radii) were tested on the brake rotors. In addition, the tools were tested at five different cutting speeds. Two feed rates and two depths of cut were examined to provide evidence of extrapolation of the tests to differing conditions. If possible, the tools were tested in different rake angle holders to determine the effect of resultant cutting rake angle.

The cost of the tools tested were very competitive. The price per tool for the small quantity of tools bought for testing (usually less that 12) is shown in Table 2.

TOOL BRAND	PRICE
Accurate	$68.25
Clapp & Haney (GE 1500)	$66.25
DC Tools	$62.40
J & M Tools	$68.50
Kennametal (two styles)	$94.43 $70.44
Norton	$71.00
Sumitoma	$79.40
Tungaloy	$122.08
Valenite	$82.00

Table 2
PRICE OF DIAMOND TOOLS

Each tool has a single cutting edge and it is estimated that two or three regrinds will be possible on each tool. In some cases, the tools in this test were tested to destruction or to a point where regrinding is impossible. This should not be done in production. A limit should be set on the amount of flank wear permissible and tools should not be used beyond that point. Discussions with a tool reconditioner revealed that 0.003" to 0.006" of radial wear is considered normal and that the cost of reconditioning is $15 to $17 if the tools have no chips on the cutting edge.

A specie of tools that is new on the scene, as far as testing on MMCs, is silicon nitride tools. Testing had just begun on these tools using the alumina loaded rotors as the test medium. Only preliminary data is available for presentation. These tools are available in both the diamond coated and bare state. Tools were available from Greenleaf Corporation and fabricated from Lanxide Gemini Material at the Oak Ridge Y-12 Plant.

The silicon nitride tools obtained for testing are not the 55° diamond shape that was used for testing PCD tools. They are triangular shaped tools have a 1/2" inscribed circle, 3/16" thick, having 0.032" radii. All tools selected for testing have an 11° clearance angle on all sides. Their ANSI designation is therefore TPxx-432. In the opinion of the investigator, there should not be a significant performance difference because of shape between the diamond shaped tools and the triangular tools. The diamond shaped tool has a 55° included angle whereas the triangular tool has a 60° included angle. In both cases, the centerline of the tool is aligned 45° to the centerline of rotation of the spindle. The basic difference, therefore, is 2.5° greater lead angle for the triangular tool during the facing of the bearing cap and rubbing surfaces. The small difference in lead angles would probably not be significant under any circumstances, but would be less significant during light cuts. Because the depth of cut (0.010") is less that the radius of the tool (0.032"), it is felt that there is no difference at all in the tool/part interface geometry. Figure 8 is a picture of the triangular insert mounted in the boring bar using an adapter. There is some loss in rigidity due to the testing setup, however this is minimized by taking light cuts. The loss in rigidity would only tend to make the tool perform less satisfactorily.

The true value of the silicon nitride tools lies in the price of the tools. Each tool has three cutting edges and, bought in small quantity lots, costs approximately $17.42. The price of each edge is therefore $5.80. This should be compared to the average price of a (three use) PCD diamond tool ($78.47) plus two resharpening/rehoning services (approximately $20 per service) to give an average cost per PCD edge of $39.49. This simplistic comparison does not account for machine downtime during tool changes, but this should be as good or better for the silicon nitride tool based on test results.

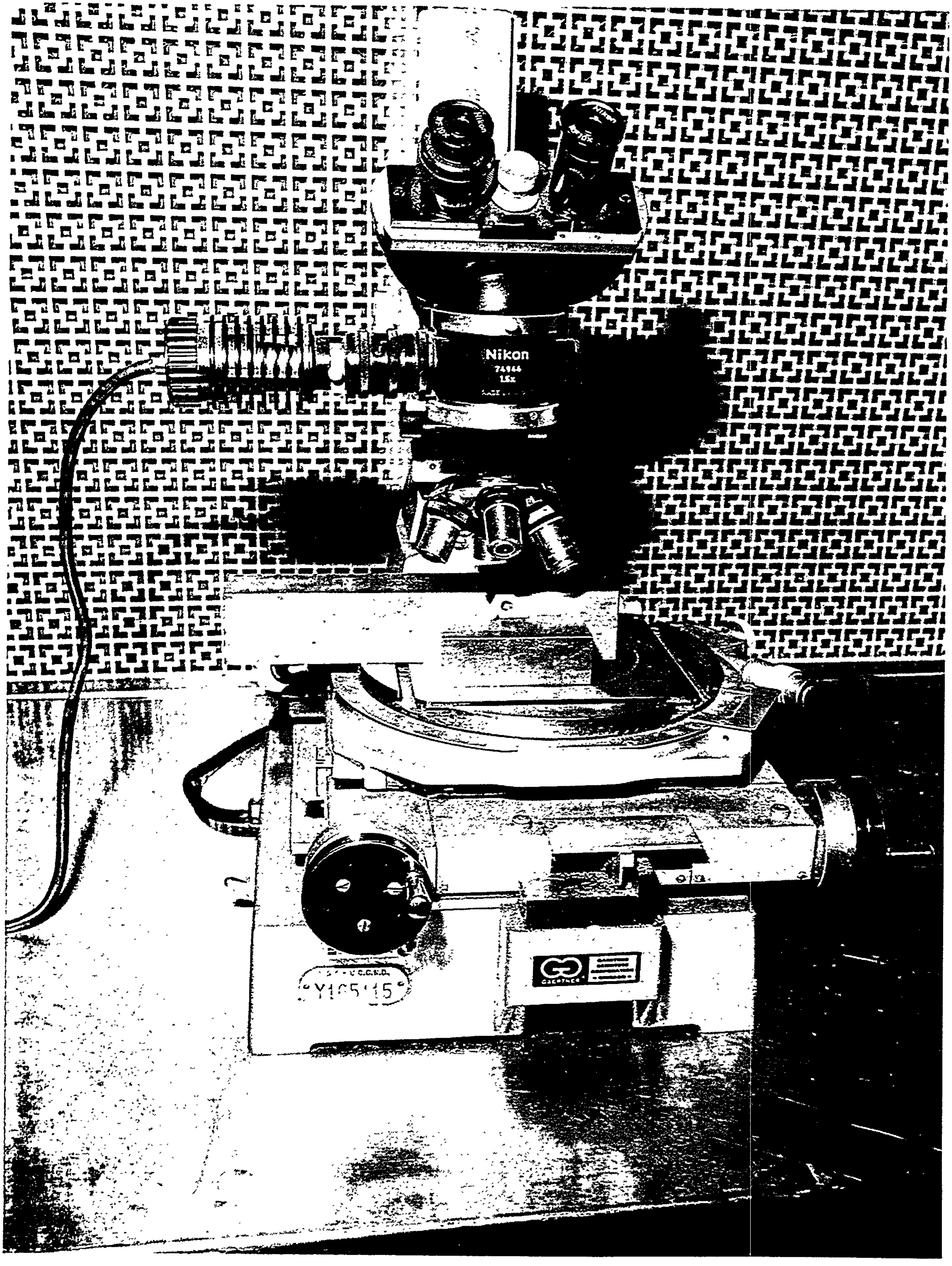
Cutting Fluid

Cutting tests on the silicon carbide loaded logs were performed dry at the request of Lanxide. On the alumina loaded brake rotors, cutting was performed using Trim Sol, a water soluble cutting oil manufactured by Master Chemical Company. This was based on a review of previous work performed on automotive components by others. The concentration of coolant was three to five volume percent.

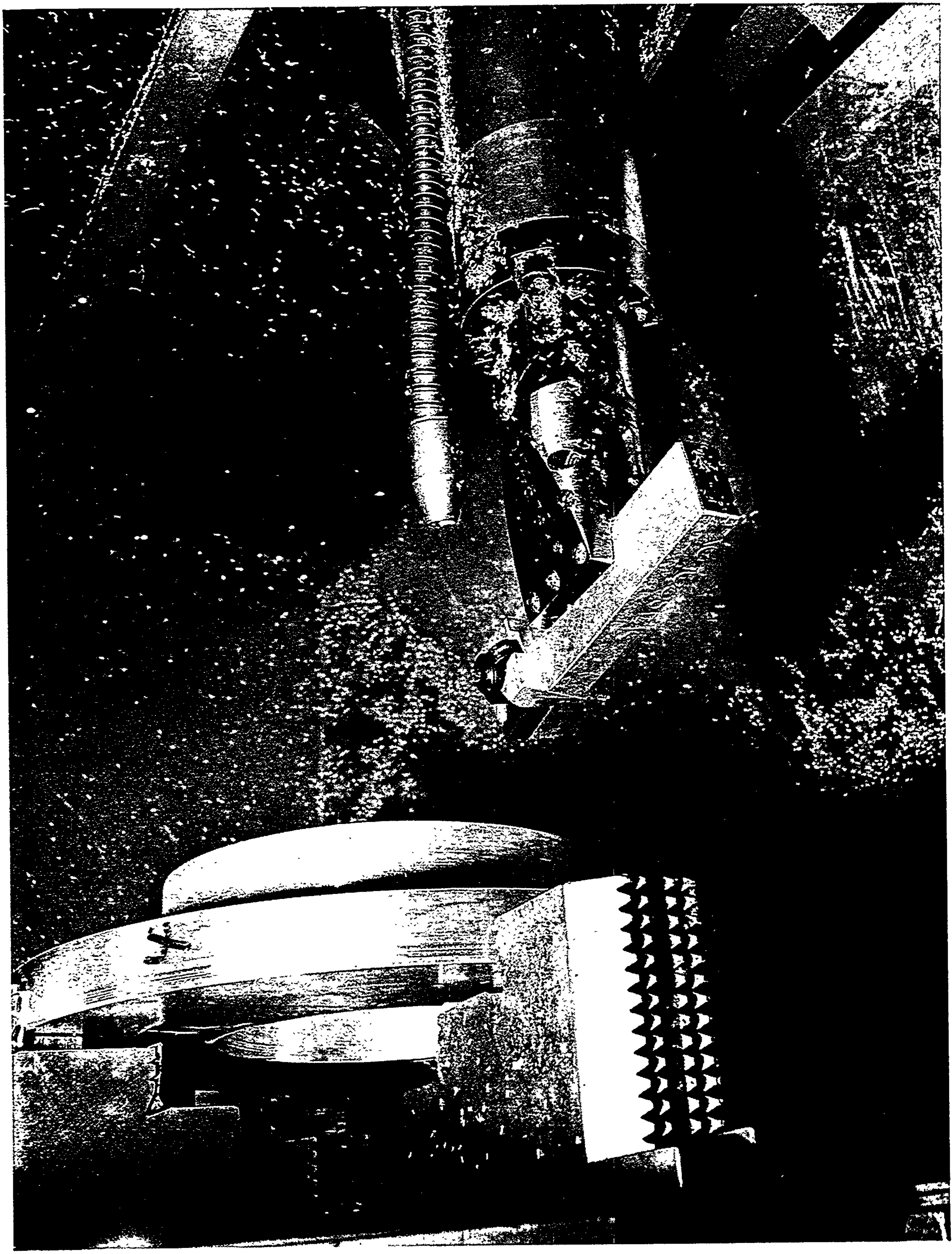
Measuring Instruments

Initial tool wear measurements made at the machine were made using a Titan 30x pocket microscope. More accurate measurements are obtained using a 50x Nikon binocular microscope head mounted on a Gaetner Scientific Instruments microscope base. Figure 9 is a photograph of this measuring system. Measurement is further refined after testing is completed by taking photographs of the final wear surface using a Zeiss toolmaker's microscope with 10x magnification. A separate report will contain photomicrographs of all tools used during the test.

Surface finish measurements were made with a Federal PocketSurf portable surface roughness gage, Model PMD-90101.



Nikon



Testing Procedure

The material being tested is securely chucked in the lathe. After installing the tool in the boring bar head, tool height is adjusted if required. The tool is then "set-up" (registered) on the surface of the part in both the X and Z direction. This assures that the correct amount of stock is taken at each pass even though the tool is removed and re-installed after each pass and the size of the test part is constantly changing. The tool tip is then driven to an imaginary starting point in space (PMID) which is located a specified distance from the spindle face and centerline. All cuts begin and end at PMID point. Figure 10 shows a diamond shaped tool mounted in a tool cartridge on the end of the devibrating boring bar in preparation for a cutting pass on a brake rotor. The coolant delivery system used during rotor cutting and the workpiece (rotor) held in a 4-jaw chuck are also shown in this photograph.

When testing silicon carbide material (therefore, straight turning operations on a log are being performed), the cut is started by driving the tool under machine control to a point in the vicinity of the face of the part and 0.010 below the outer periphery (diameter) of the part. The spindle reaches rotational speed for the desired cutting speed and the tool is fed toward the headstock and into the part at the required feed rate. After the tool has cut 6 inches of part length, it is withdrawn and returned to the PMID point and the spindle rotation is shut down to allow the tool to be inspected. Figure 11 shows the actual cutting sequence. Because this is a straight turning cut, all cutting action takes place on the same area of the tool radius.

For each cutting pass down the log, the volume of material removed is:

$$V = \pi (R^2 - r^2) \text{ x } L$$

Where R is the outer radius of the log before the cut,

r is the outer radius of the log after the cut,

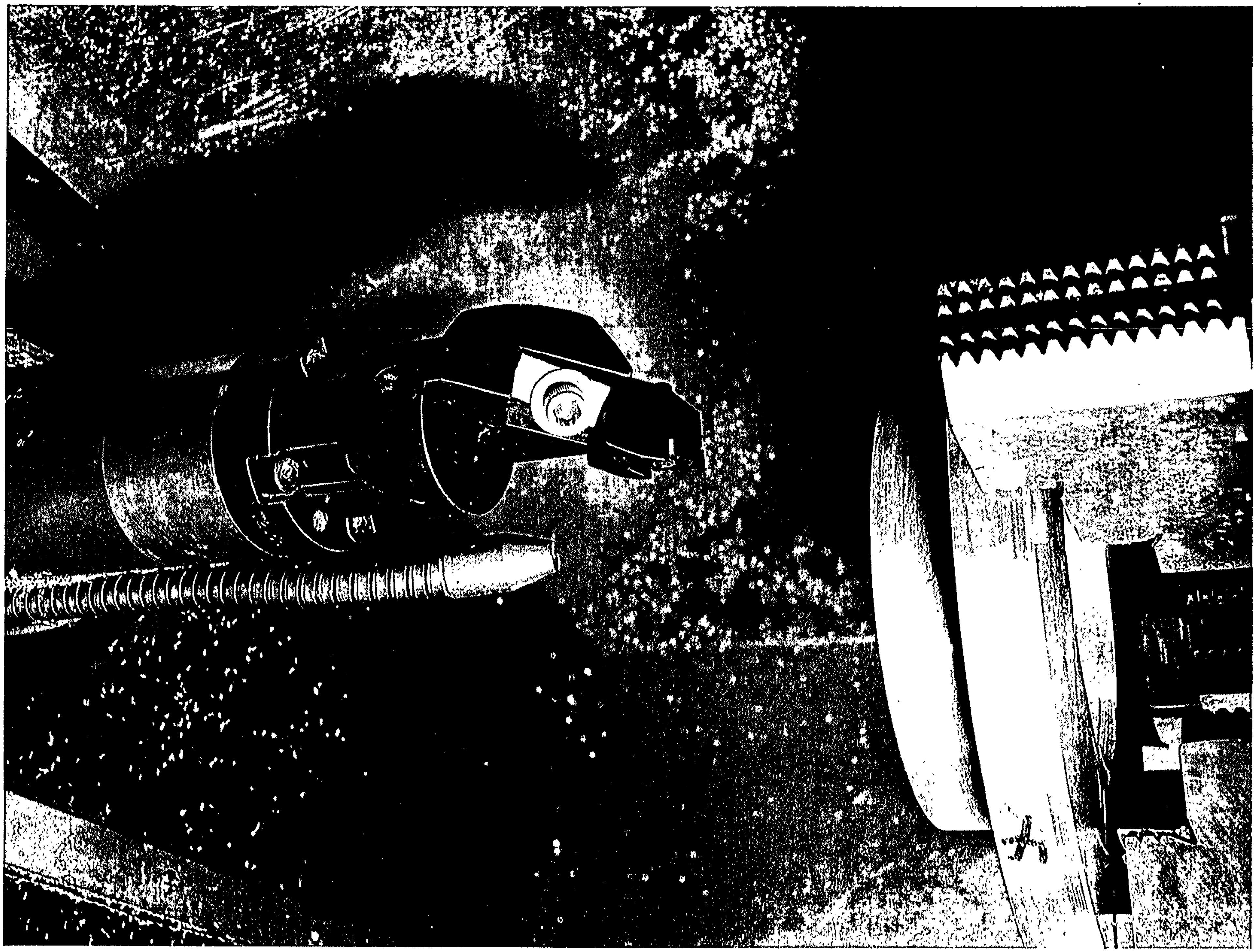
L is the length of cut, set to 6" for all cuts

A typical cut, assuming a 5" log before the cut, 0.010" depth of cut, and 6" length of cut, removes:

$$V = \pi ((5''/2)^2 - (((5''/2) - 0.010'')^2) \text{ x } 6'')$$

$$= 0.940 \text{ cubic inches of material removed.}$$

The outer radius of the log has been reduced by 0.010" after the cut and a new outer radius before cutting, R, has been established for the next cut. This calculation must be made for each cut with the correct parameters.



Details of testing are discussed under the 'Testing Conditions' section.

The testing procedure for the alumina loaded MMC consisted of facing a brake rotor under specific conditions and measuring the subsequent tool wear after each pass. Testing was continued until a cutoff value was reached for tool wear. Other factors (such as cost) neglected, the superior tool will remove a greater amount of metal before reaching the limit. Screening tests were performed to establish the specific testing conditions which are not optimal cutting parameters, but are parameters which allow comparisons between tools without expending inordinate amounts of test material. The test conditions are discussed under the 'Testing Conditions' section.

When testing alumina loaded material (therefore cutting brake rotors), the setup of the tool and positioning at the PMID point is as described above. When the cut is started, however, the tool tip is driven to the centerline of rotation of the spindle and 0.010" below the outer surface of the bearing cap. The spindle reaches rotational speed for the desired cutting speed and the tool is fed outward and into the part at the required feed rate. The cut begins at the edge of the thru-hole on the outboard bearing cap surface and proceeds outward to the cylindrical surface. The cylindrical surface is then cut toward the rubbing surfaces of the rotor. The outboard rubbing surface is then machined from the smallest diameter to the outer edge. After the tool clears the periphery of the rotor, it is driven in rapid traverse back to the PMID starting point and a program stop is initiated for tool inspection and measurement. The actual cutting sequence on the rotor is shown in Figure 12.

The cutting sequence is a continuous operation. In cutting the rotor, the area of the tool which is cutting changes when the portion of the rotor being machined changes from the outboard surface to the diameter and changes back to the original area when cutting progresses from the diameter to the rubbing surfaces. This change in cutting area is shown in Figure 13.

Measurement of the wear on the tool is done only on the area that cuts the outboard surface and rubbing surface. Because of this, only that material removed from those surfaces is used to calculate specific tool wear.

For each pass across the rotor, the area cut by the portion of the tool being studied is:

$$A = \pi (R^2 - r^2)$$

where R is the outer diameter of the brake rotor and

r is the diameter of the thru-hole in the bearing cap

or, for the particular size rotor that was supplied:

$$A = \pi ((9.5 ''/2)^2) - ((2.3''/2)^2) = 66.73 \text{ in.}^2$$

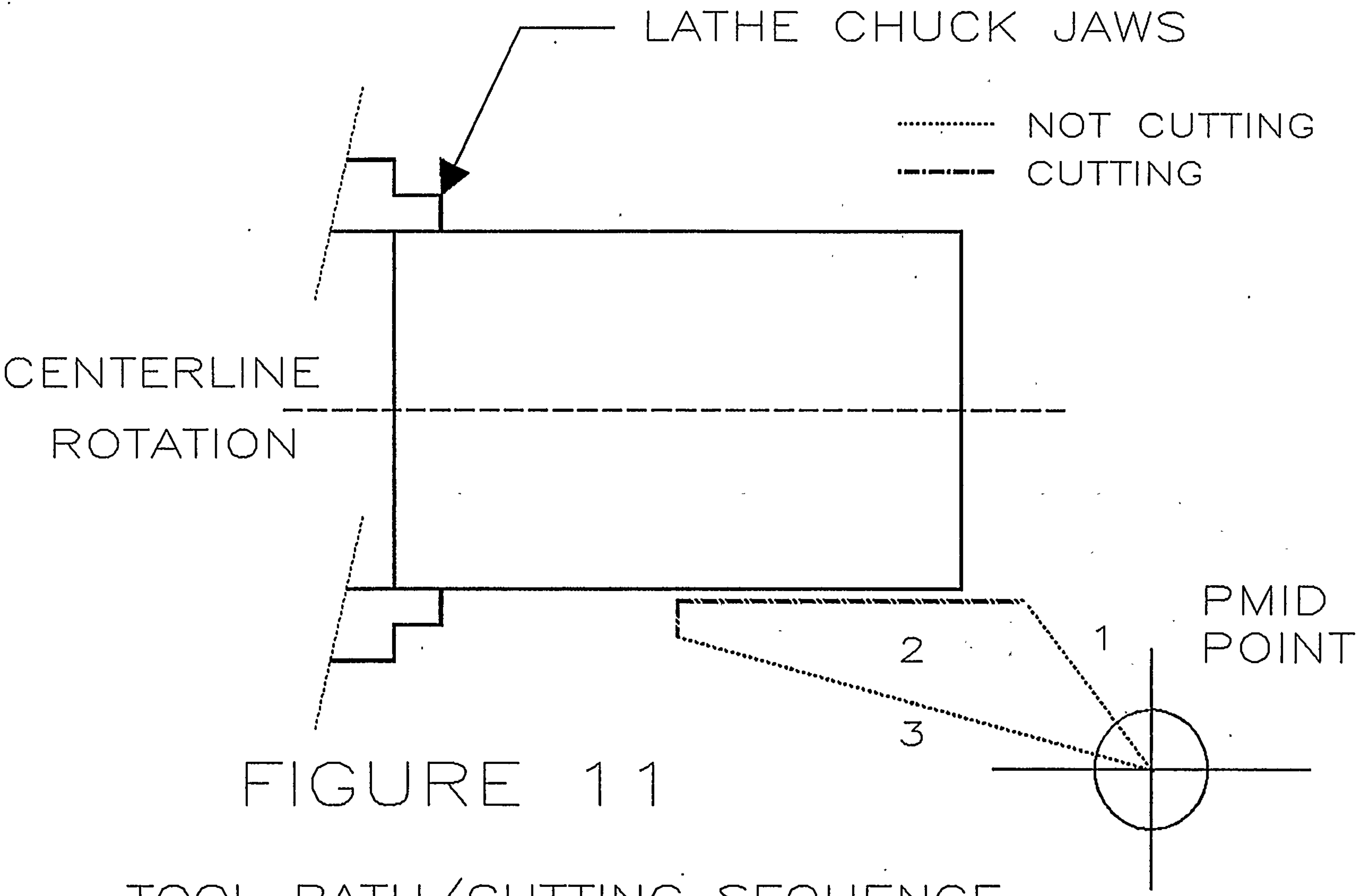


FIGURE 11

TOOL PATH/CUTTING SEQUENCE

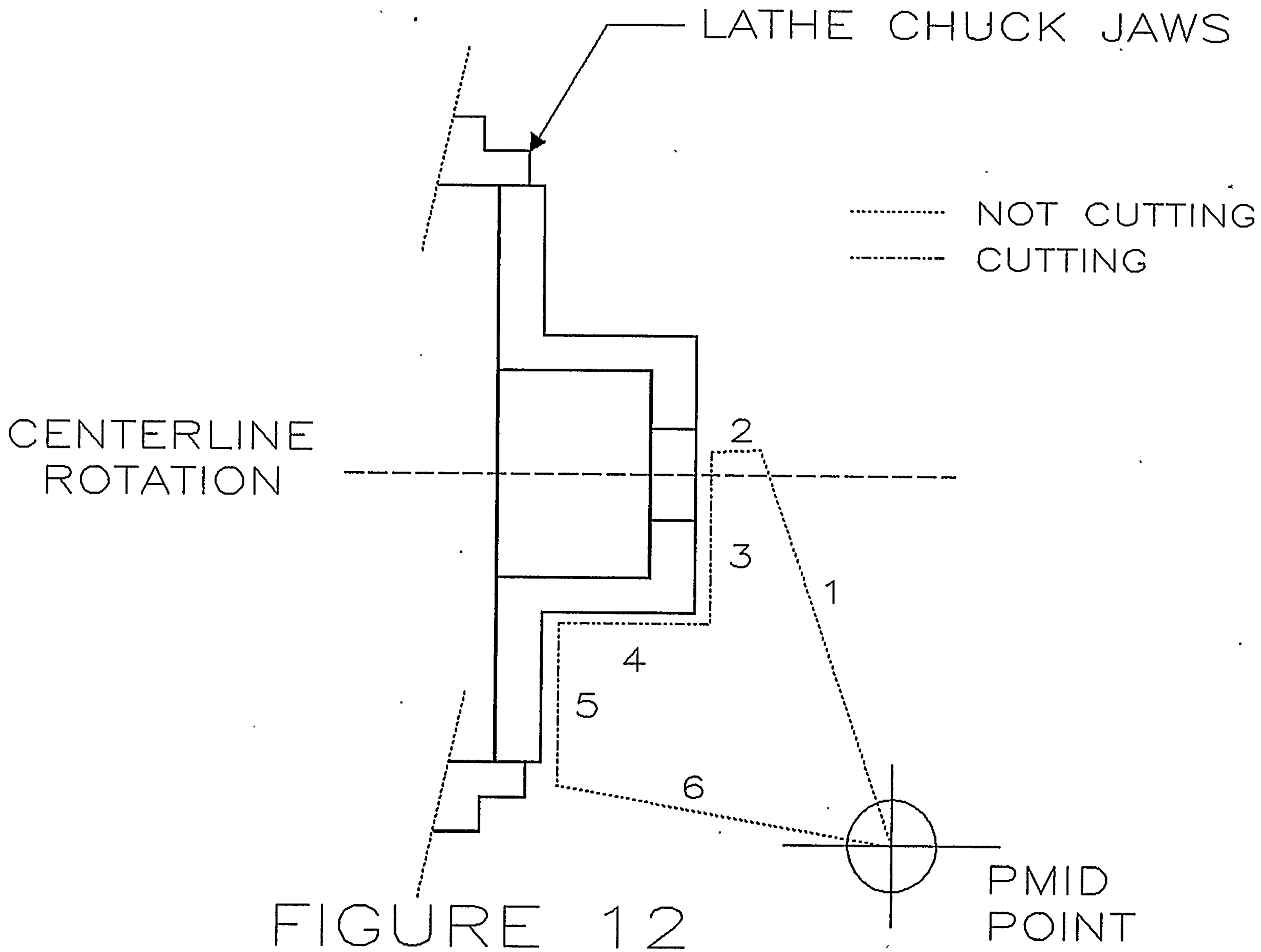


FIGURE 12

TOOL PATH/CUTTING SEQUENCE

55 DEGREE DIAMOND SHAPED TOOL
TOOL CENTERLINE AT 45 DEGREES TO X-Z AXES

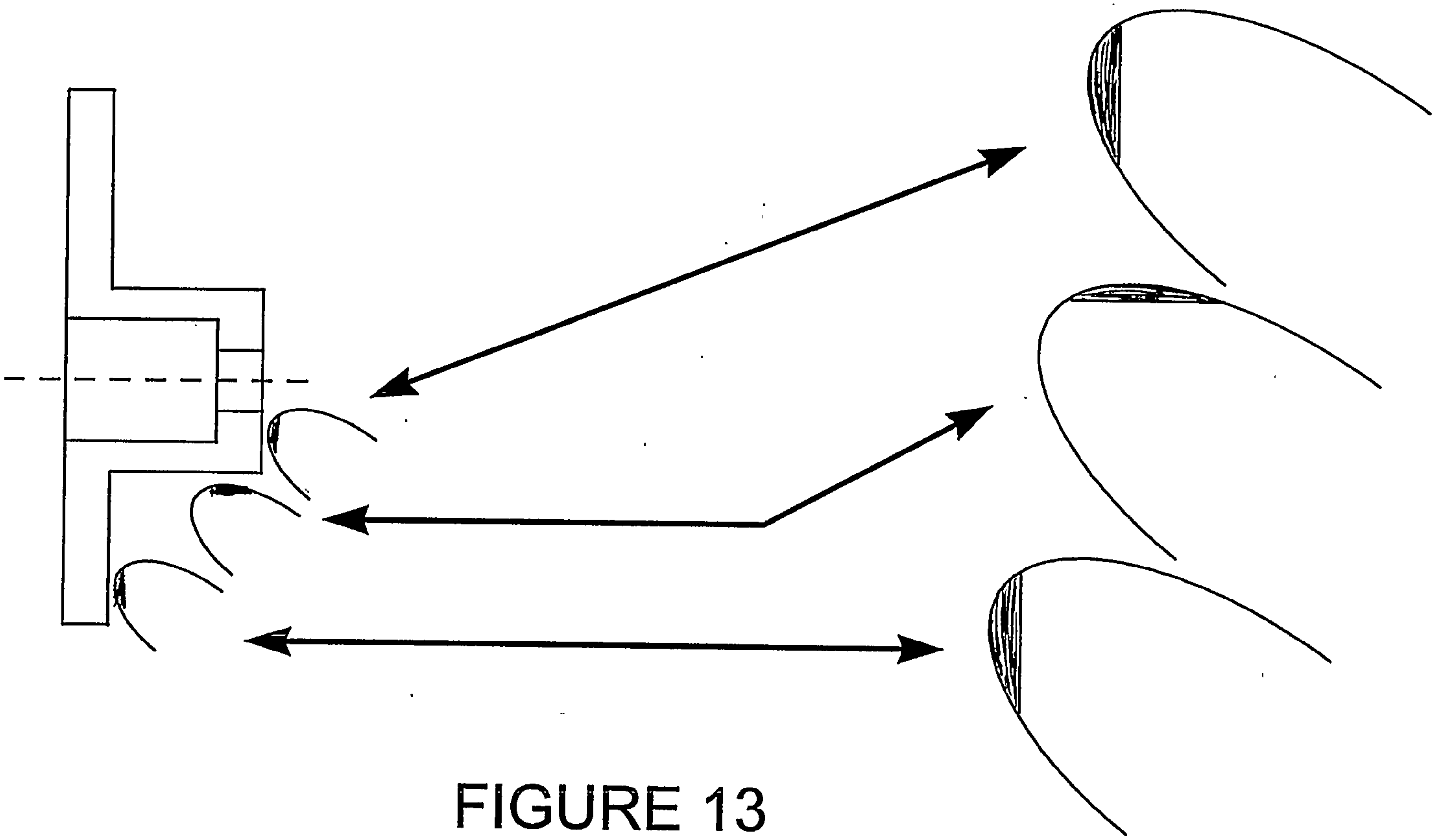


FIGURE 13
CUTTING AREA OF TOOL

Since under normal cutting conditions, the depth of cut has been held at 0.010 inches, the volume of material removed for each cut is:

$$V = A \times \text{Depth of Cut}$$

or, for the test rotors supplied:

$$V = 66.73 \text{ in.}^2 \times 0.010 \text{ in.} = 0.6673 \text{ in.}^3 \text{ per pass across the rotor.}$$

After the tool has been inspected, it is either retired due to wear or replaced in the tool holder for further cutting. Tools retired from service are taken to the Zeiss microscope for photographs of the wear lands.

Testing Conditions

In order to evaluate the relative usefulness of the tools for cutting MMCs, a standard set of conditions was selected for each material and all tools used on a specific material were tested under those conditions. Table 3 is a list of the "standard" conditions under which the tools were tested on both materials.

	Silicon Carbide loaded Material	Alumina loaded Material
PARAMETER VALUE	STANDARD TESTING VALUE	STANDARD TESTING VALUE
Cutting speed	900, 1350, 1500 Ft/Min	1000, 1250, 1500, 1800, 3200 Ft/Min
Feed rate	0.020 In/Rev	0.015 and 0.020 In/Rev
Depth of cut	0.010 Inches	0.010 Inches
Holder rake angle	-10°, -7°, -5°, and 0°	-13°, -6°, and 0°
Coolant	None, cutting done dry	Applied, Trim Sol 3-5%

Table 3
STANDARD TESTING CONDITIONS FOR MMC MATERIALS

The values used for feed rate and depth of cut are less than values that would be used in production cutting. These values were selected after consultation with other personnel in the Y-12 Plant who had conducted previous tool wear tests. The rationale behind the choice is that tool wear is more dependent on feed rate than other parameters. Depth of cut results in greater force on the tool and an increase in the length of the wear land on the tool. The object of the test was to determine the best material removal rate for the least tool expended, therefore it was not essential to test the strength of the tool by taking large depths of cut. In a similar manner, testing material utilization can be maximized by using a small feed rate since tool wear tests are comparative.

The value chosen for the cutting speed was determined by initial screening tests. During early alumina loaded material testing, a cutting speed of 1250 surface feet per minute (SFM) exhibited less tool wear for the removal of a predetermined volume of material than 1000 SFM or 1500 SFM, therefore it is at least a local minimum. Statistical tests may indicate that there is no significant difference between the speeds.

Because some tools could not be obtained with relief, a negative rake tool holder was chosen as the standard. To quantify the effect of cutting rake (holder rake algebraically combined with tool rake), some tools having relief were also tested in a neutral rake holder (0°) during the alumina loaded material and silicon carbide tests. A holder having less negative rake (-6°) than the standard holder was obtained for the alumina testing. Using this holder, some tools with no relief still presented a positive rake (or at least a less negative rake) to the workpiece.

All cutting of silicon carbide loaded material was performed dry. During cutting of the alumina loaded material, the tool and workpiece were flooded with coolant from the machine tool sump. The coolant used is Trim Sol from Master Chemical Company. The concentration of the coolant is three to five volume percent in water. No other coolants were tried; however a single trial of dry cutting alumina loaded material was apparently successful and merits further investigation.

Results

Because of the amount of data gathered in this test, results are presented in a spreadsheet form sorted on various parameters. Two materials, silicon carbide loaded aluminum and alumina loaded aluminum, were tested resulting in two spreadsheets. Silicon nitride tools, which were used only on the alumina loaded material, are listed on a separate third spreadsheet. Two different types of turning, straight turning in the case of silicon carbide logs and facing in the case of alumina loaded brake rotors, were used in testing the materials. This leads to slight differences in the appearance of the spreadsheets.

The parameter of interest in selecting the tool to be used for machining is the amount of stock that can be removed for a corresponding amount of tool wear. While flank wear is frequently used as the metric for tool wear, it is the writer's opinion that the correct parameter to use is radial wear. Radial wear can be calculated from flank wear, and this is frequently done because flank wear is much easier to measure and usually there is a magnifying effect of the geometric relationship between the two values. Flank wear, however, is more dependent on the geometry of the tool and holder. In the extreme case, it is possible to have severe radial wear on the tool with little indication of flank wear or vice versa.

Figure 14 is a five page spreadsheet of the cutting tests performed on the SiC logs. The spreadsheet lists the log used in the test, the tool used, cutting conditions, and the measured and calculated data. A complete explanation of all columns is included in Appendix 2. The first eight entries in the spreadsheet are screening data and are included for information purposes only. Because they contain only one or two cutting passes on the part, results from these cuts are not discussed in great detail. Data on the remaining 13 tools support the planned tests and are presented to illustrate the comparisons and contrasts that could be drawn from the testing procedure.

As an example, Figure 15, Braze Tip Tool Comparison shows the radial wear on four braze tip tools as a function of the number of passes made on the 6" length of cut. Two different logs were used in this test as well as two different tool radii. It is apparent that either log 93X3011 or the Carboloy tool cut differently from other braze tip tools and log 91X1060HT. It appears that the larger radius tool does not show a distinct advantage for surviving a greater number of cuts. It should be noted that the tools show a typical time-wear curve; with rapid initial wear followed by a long period of slower wear culminating in a rapid increase in wear as failure of the tip occurs. Another example, Figure 16, Performance of DCTL DPGA 432, illustrates the performance of the same brand and grade of tools on two different logs at two different cutting speeds. In this case, the effect of log 91X1060 versus 91X1060HT is illustrated. For closure, the performance of the DC tool on the 91X1060 log at 1500 SFM should be tried. This is one of the experiments that would have been tried had the CRADA not been prematurely closed. The graph also shows some evidence that polycrystalline diamond tools used at lower cutting speeds have longer cutting lives.

Figure 17 is the spreadsheet for rotor cutting. It lists the nomenclature and conditions under which each tool was tested. It shows specific radial wear (in^3 of material removed/inch of radial wear on the tool) for each tool tested after each cut across the rotor. Appendix 3 is an explanation of all columns listed on the spreadsheet. If a tool was worn to the extent that good machining practice would indicate replacement, it was retired and no data follows the pass after which the decision was made.

Notice that under each cut, one value has been circled. This is the maximum specific radial wear for that number of cuts. In case of ties, all numbers with the same value in the same column have been circled. In each column, a box has been drawn around values which are

FIGURE 14

LOG DATA SUMMARY

													|--MEASURED AND CALCULATED DATA---|			
TEST LOG	REF	MFG	NOM	SIZE	PASS DOWN LOG	ACT DOC	MATL RMVD	CUM MATL RMVD	RPM	SFM	FD RT	THEO DOC	FL WR	in3/in fl wr	RAD WR	in3/in rd wr
91X1060HT	1	DCTL	DNGA	432	1	0.01	1.123	1.123	935	1458.	0.020	0.010	0.0080	140	0.001799	624
91X1060HT	2	ACCU	DNGA	432	1	0.01	1.119	1.119	935	1454.	0.010	0.010	0.0075	149	0.001687	664
91X1060HT	4	JMTL	DNGA	433	1	0.010	1.181	1.181	935	1427.	0.010	0.010	0.0100	118	0.002249	525
91X1060HT	5	SUMI	DNMX	433	1	0.02	2.187	2.187	935	1420.	0.010	0.020	0.0080	273	0.002481	882
91X1060HT	15	KENN	DNGA	433	1	0.019	1.482	1.482	1375	1486.	0.015	0.010	0.0065	228	0.001462	1014
					2	0.017	1.344	2.827	1375	1473.	0.015	0.010	0.0280	101	0.006298	449
91X1060HT	18	KENN		0.15	1	0.019	1.649	1.649	1260	1508.	0.015	0.010	0.0035	471	0.000491	3353
					2	0.014	1.263	2.912	1275	1515.	0.015	0.010	0.0240	121	0.003372	864
91X1060HT	19	KENN		0.021	1	0.017	1.507	1.507	1275	1504.	0.015	0.010	0.0060	251	0.000843	1788
					2	0.015	1.286	2.794	1290	1510.	0.015	0.010	0.0280	100	0.003935	710
91X1060HT	11	DIAS	RND	0.196	1	0.014	1.410	1.410	1110	1500.	0.010	0.010	0.0500	28	0.004374	323
					2	0.009	0.960	2.371	1110	1493.	0.010	0.010	0.0380	62	0.003324	713
91X1060HT	16	VALN	DNGM	432	1	0.02	1.859	1.859	1160	1497.	0.015	0.010	0.0090	207	0.002791	666
					2	0.013	1.251	3.110	1160	1487.	0.015	0.010	0.0105	296	0.003257	955
					3	0.016	1.530	4.640	1195	1522.	0.015	0.010	0.0060	773	0.001861	2494
					4	0.012	1.168	5.809	1200	1520.	0.015	0.010	0.0110	528	0.003412	1703
					5	0.013	1.198	7.008	1200	1515.	0.015	0.010	0.0150	467	0.004652	1506
91X1060HT	3	KENN	DNGA	433	1	0.008	0.930	0.930	935	1449.	0.010	0.010	0.0035	266	0.000787	1181
					2	0.01	1.112	2.042	935	1445.	0.010	0.010	0.0055	371	0.001237	1651
					3	0.007	0.878	2.921	935	1440.	0.010	0.010	0.006	487	0.001349	2164
					4	0.009	1.069	3.990	935	1436.	0.010	0.010	0.0070	570	0.001574	2534
					5	0.008	0.891	4.881	935	1432.	0.010	0.010	0.0100	488	0.002249	2170
91X1060HT	10	CARB	TPG	322	1	0.018	1.827	1.827	1060	1481.	0.010	0.020	0.0075	244	0.001457	1254
					2	0.018	1.864	3.692	1060	1470.	0.010	0.020	0.0075	492	0.001457	2533
					3	0.017	1.744	5.437	1060	1460.	0.010	0.020	0.0100	544	0.001943	2797
					4	0.017	1.692	7.129	1060	1451.	0.010	0.020	0.0160	446	0.003110	2292
					5	0.017	1.729	8.858	1060	1446.	0.010	0.020	0.0175	506	0.003401	2604
91X1060HT	17	DCTL	DPGA	432	1	0.017	1.583	1.583	1200	1502.	0.015	0.010	0.0065	244	0.002693	588
					2	0.031	2.799	4.382	1225	1517.	0.015	0.010	0.0110	398	0.004557	962
					3	0.013	1.225	5.608	1210	1484.	0.015	0.010	0.0110	510	0.004557	1230
					4	0.014	1.299	6.907	1233	1503.	0.015	0.010	0.0110	628	0.004557	1516
					5	0.013	1.140	8.048	1260	1527.	0.015	0.010	0.0110	732	0.004557	1766
					6	0.012	1.100	9.149	1260	1519.	0.015	0.010	0.0140	654	0.005800	1577
91X1060HT	14	DCTL	DPGA	432	1	0.02	1.628	1.628	1325	1498.	0.015	0.010	0.0040	407	0.001657	983
					2	0.016	1.308	2.937	1325	1486.	0.015	0.010	0.0080	367	0.003314	886
					3	0.016	1.293	4.230	1350	1502.	0.015	0.010	0.0080	529	0.003314	1276
					4	0.014	1.144	5.375	1350	1492.	0.015	0.010	0.0080	672	0.003314	1622
					5	0.015	1.227	6.602	1375	1508.	0.015	0.010	0.0090	734	0.003729	1770
					6	0.014	1.101	7.703	1375	1498.	0.015	0.010	0.0130	593	0.005386	1430

													|--MEASURED AND CALCULATED DATA---|			
TEST LOG	REF	MFG	NOM	SIZE	PASS DOWN LOG	ACT DOC	MATL RMVD	CUM MATL RMVD	RPM	SFM	FD RT	THEO DOC	FL WR	in3/in fl wr	RAD WR	in3/in rd wr
91X1060HT	6	NORT	DNGA	433	1	0.006	0.698	0.698	935	1414.	0.010	0.010	0.0025	280	0.000562	1243
					2	0.010	1.103	1.802	935	1410.	0.010	0.010	0.003	601	0.000674	2671
					3	0.008	0.901	2.704	935	1405.	0.010	0.010	0.0035	773	0.000787	3435
					4	0.009	1.069	3.774	935	1401.	0.010	0.010	0.0035	1078	0.000787	4794
					5	0.008	0.869	4.643	935	1396.	0.010	0.010	0.0040	1161	0.000899	5161
					6	0.009	1.054	5.698	935	1392.	0.010	0.010	0.0050	1140	0.001124	5066
					7	0.007	0.757	6.455	935	1388.	0.010	0.010	0.0050	1291	0.001124	5739
					8	0.01	1.065	7.521	935	1383.	0.010	0.010	0.0080	940	0.001799	4179
93X3011	8	CARB		0.021	1	0.009	0.671	0.671	950	900.4	0.010	0.010	0.0030	224	0.000421	1592
					2	0.010	0.729	1.400	950	895.2	0.010	0.010	0.0070	200	0.002900	483
					3	0.009	0.669	2.069	950	890.1	0.010	0.010	0.0085	243	0.003521	588
					4	0.008	0.548	2.617	950	885.6	0.010	0.010	0.0120	218	0.004972	526
					5	0.007	0.478	3.096	950	881.8	0.010	0.010	0.0130	238	0.005386	575
					6	0.009	0.620	3.717	950	877.7	0.010	0.010	0.0130	286	0.005386	690
					7	0.006	0.413	4.131	950	873.8	0.010	0.010	0.0165	250	0.006836	604
					8	0.008	0.577	4.708	950	870.1	0.010	0.010	0.0175	269	0.007251	649
91X1060HT	7	DCTL	DPGA	432	1	0.007	0.841	0.841	935	1379.	0.010	0.010	0.0030	280	0.001243	677
					2	0.007	0.812	1.653	935	1375.	0.010	0.010	0.0030	551	0.001243	1330
					3	0.008	0.933	2.586	935	1371.	0.010	0.010	0.0040	647	0.001657	1560
					4	0.009	1.035	3.621	935	1367.	0.010	0.010	0.0045	805	0.001864	1942
					5	0.006	0.699	4.321	935	1363.	0.010	0.010	0.0045	960	0.001864	2318
					6	0.010	1.063	5.385	935	1359.	0.010	0.010	0.0055	979	0.002278	2363
					7	0.007	0.791	6.176	935	1354.	0.010	0.010	0.0055	1123	0.002278	2710
					8	0.01	1.039	7.216	935	1350.	0.010	0.010	0.0070	1031	0.002900	2488
					9	0.007	0.725	7.942	935	1346.	0.010	0.010	0.0085	934	0.003521	2255
					10	0.009	0.930	8.872	935	1342.	0.010	0.010	0.0085	1044	0.003521	2519
					11	0.010	1.098	9.970	935	1337.	0.010	0.010	0.0145	688	0.006008	1660
91X1060HT	13	DESS		0.021	1	0.020	2.049	2.049	972	1377.	0.015	0.010	0.0055	373	0.000772	2652
					2	0.017	1.782	3.832	972	1368.	0.015	0.010	0.0080	479	0.001124	3409
					3	0.018	1.812	5.644	972	1359.	0.015	0.010	0.0080	706	0.001124	5021
					4	0.016	1.650	7.295	972	1350.	0.015	0.010	0.0080	912	0.001124	6489
					5	0.017	1.780	9.076	972	1346.	0.015	0.010	0.0080	1135	0.001124	8073
					6	0.016	1.612	10.68	972	1333.	0.015	0.010	0.0100	1069	0.001405	7606
					7	0.016	1.602	12.29	972	1324.	0.015	0.010	0.0100	1229	0.001405	8746
					8	0.016	1.633	13.92	972	1316.	0.015	0.010	0.0100	1393	0.001405	9908
					9	0.015	1.493	15.41	972	1308.	0.015	0.010	0.0100	1542	0.001405	10971
					10	0.016	1.573	16.99	972	1300.	0.015	0.010	0.01	1699	0.001405	12091
					11	0.016	1.578	18.57	972	1291.	0.015	0.010	0.01	1857	0.001405	13214
					12	0.016	1.529	20.10	972	1283.	0.015	0.010	0.0120	1675	0.001686	11918
					13	0.015	1.464	21.56	972	1275.	0.015	0.010	0.0150	1438	0.002108	10229
					14	0.015	1.463	23.02	972	1267.	0.015	0.010	0.0175	1316	0.002459	9363

													|--MEASURED AND CALCULATED DATA---|			
TEST LOG	REF	MFG	NOM	SIZE	PASS DOWN LOG	ACT DOC	MATL RMVD	CUM MATL RMVD	RPM	SFM	FD RT	THEO DOC	FL WR	in3/in fl wr	RAD WR	in3/in rd wr
91X1060HT	9	KENN		0.15	1	0.020	2.316	2.316	950	1490.	0.010	0.020	0.0040	579	0.000562	4120
					2	0.030	3.454	5.770	950	1478.	0.010	0.020	0.0040	1443	0.000562	10265
					3	0.016	1.842	7.613	950	1466.	0.010	0.020	0.0045	1692	0.000632	12038
					4	0.017	1.933	9.547	950	1457.	0.010	0.020	0.0055	1736	0.000772	12351
					5	0.017	1.949	11.49	950	1453.	0.010	0.020	0.0060	1916	0.000843	13634
					6	0.017	1.864	13.36	950	1440.	0.010	0.020	0.0060	2227	0.000843	15845
					7	0.015	1.727	15.08	950	1432.	0.010	0.020	0.0060	2515	0.000843	17894
					8	0.017	1.843	16.93	950	1424.	0.010	0.020	0.0060	2822	0.000843	20081
					9	0.016	1.761	18.69	950	1415.	0.010	0.020	0.0060	3116	0.000843	22169
					10	0.015	1.627	20.32	950	1407.	0.010	0.020	0.0065	3126	0.000913	22245
					11	0.016	1.715	22.03	950	1400.	0.010	0.020	0.008	2755	0.001124	19600
					12	0.014	1.477	23.51	950	1392.	0.010	0.020	0.0080	2939	0.001124	20914
					13	0.018	1.897	25.41	950	1384.	0.010	0.020	0.0080	3176	0.001124	22602
					14	0.015	1.599	27.01	950	1376.	0.010	0.020	0.0080	3376	0.001124	24024
					15	0.014	1.547	28.55	950	1368.	0.010	0.020	0.0125	2285	0.001756	16256
					16	0.016	1.701	30.26	950	1360.	0.010	0.020	0.0140	2161	0.001967	15380
					17	0.018	1.853	32.11	950	1352.	0.010	0.020	0.0145	2215	0.002037	15759
					18	0.013	1.384	33.49	950	1344.	0.010	0.020	0.0175	1914	0.002459	13620
91X1060HT	12	KENN		0.021	1	0.019	1.853	1.853	750	1003.	0.015	0.010	0.0040	463	0.000562	3297
					2	0.017	1.665	3.518	750	995.8	0.015	0.010	0.0040	880	0.000562	6259
					3	0.018	1.740	5.259	750	988.8	0.015	0.010	0.0045	1169	0.000632	8316
					4	0.018	1.727	6.986	750	981.6	0.015	0.010	0.0055	1270	0.000772	9039
					5	0.016	1.583	8.569	750	978.0	0.015	0.010	0.0060	1428	0.000843	10163
					6	0.022	2.107	10.67	750	972.3	0.015	0.010	0.0060	1780	0.000843	12663
					7	0.017	1.627	12.30	750	964.4	0.015	0.010	0.0060	2051	0.000843	14593
					8	0.017	1.601	13.90	750	957.5	0.015	0.010	0.0060	2318	0.000843	16492
					9	0.017	1.619	15.52	750	950.6	0.015	0.010	0.0060	2588	0.000843	18413
					10	0.017	1.585	17.11	750	943.7	0.015	0.010	0.006	2852	0.000843	20293
					11	0.017	1.581	18.69	750	936.8	0.015	0.010	0.008	2337	0.001124	16627
					12	0.018	1.614	20.30	750	929.8	0.015	0.010	0.0080	2538	0.001124	18062
					13	0.017	1.535	21.84	750	922.8	0.015	0.010	0.0080	2730	0.001124	19428
					14	0.018	1.597	23.44	750	915.9	0.015	0.010	0.0080	2930	0.001124	20849
					15	0.017	1.498	24.93	750	908.9	0.015	0.010	0.0100	3617	0.001405	25736
					16	0.018	1.573	26.51	750	902.0	0.015	0.010	0.0100	3774	0.001405	26855
					17	0.017	1.503	28.01	750	895.0	0.015	0.010	0.0100	3925	0.001405	27925
					18	0.017	1.499	29.51	750	888.1	0.015	0.010	0.0115	3543	0.001616	25210
					19	0.017	1.473	30.98	750	881.3	0.015	0.010	0.0120	3518	0.001686	25034
					20	0.019	1.657	32.64	750	874.0	0.015	0.010	0.0125	3510	0.001756	24976
					21	0.014	1.200	33.84	750	867.3	0.015	0.010	0.0125	3606	0.001756	25659
					22	0.017	1.412	35.25	950	1095.	0.010	0.020	0.0140	3321	0.001967	23627
					23	0.018	1.503	36.76	950	1081.	0.010	0.020	0.0165	2909	0.002318	20696

					PASS			CUM					|--MEASURED AND CALCULATED DATA---|			
TEST					DOWN	ACT	MATL	MATL				THEO		in3/in		in3/in
LOG	REF	MFG	NOM	SIZE	LOG	DOC	RMVD	RMVD	RPM	SFM	FD RT	DOC	FL WR	fl wr	RAD WR	rd wr
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91X1060	20	KENN	DNMS	432	1	0.019	2.299	2.299	840	1344.	0.015	0.010	0.0030	766	0.000674	3407
					2	0.016	1.859	4.158	845	1344.	0.015	0.010	0.0045	924	0.001012	4108
					3	0.016	1.844	6.003	850	1345.	0.015	0.010	0.0050	1201	0.001124	5337
					4	0.015	1.775	7.778	855	1346.	0.015	0.010	0.0050	1556	0.001124	6916
					5	0.016	1.912	9.691	860	1350.	0.015	0.010	0.0060	1615	0.001349	7181
					6	0.015	1.788	11.47	865	1346.	0.015	0.010	0.0060	1913	0.001349	8506
					7	0.017	1.958	13.43	870	1347.	0.015	0.010	0.0060	2240	0.001349	9957
					8	0.016	1.814	15.25	875	1347.	0.015	0.010	0.0065	2347	0.001462	10431
					9	0.016	1.835	17.08	880	1347.	0.015	0.010	0.0065	2629	0.001462	11687
					10	0.016	1.853	18.94	885	1347.	0.015	0.010	0.007	2706	0.001574	12029
					11	0.017	1.937	20.87	890	1346.	0.015	0.010	0.007	2983	0.001574	13259
					12	0.016	1.812	22.69	895	1346.	0.015	0.010	0.0080	2836	0.001799	12609
					13	0.015	1.686	24.37	900	1345.	0.015	0.010	0.0080	3047	0.001799	13546
					14	0.015	1.677	26.05	905	1346.	0.015	0.010	0.0085	3065	0.001912	13627
					15	0.016	1.802	27.85	910	1345.	0.015	0.010	0.0085	3277	0.001912	14570
					16	0.016	1.762	29.62	915	1345.	0.015	0.010	0.0085	3485	0.001912	15491
					17	0.016	1.687	31.30	920	1344.	0.015	0.010	0.0085	3683	0.001912	16374
					18	0.014	1.567	32.87	925	1344.	0.015	0.010	0.0085	3868	0.001912	17194
					19	0.015	1.649	34.52	930	1344.	0.015	0.010	0.0085	4062	0.001912	18056
					20	0.016	1.675	36.20	935	1343.	0.015	0.010	0.0085	4259	0.001912	18933
					21	0.016	1.708	37.91	940	1342.	0.015	0.010	0.0085	4460	0.001912	19827
					22	0.015	1.565	39.47	945	1345.	0.010	0.010	0.0090	4386	0.002024	19499
					23	0.016	1.682	41.15	950	1341.	0.010	0.010	0.0090	4573	0.002024	20329
					24	0.016	1.681	42.83	960	1346.	0.010	0.010	0.0090	4760	0.002024	21160
					25	0.016	1.673	44.51	965	1345.	0.010	0.010	0.0090	4946	0.002024	21987
					26	0.016	1.680	46.19	970	1343.	0.010	0.010	0.0100	4619	0.002249	20535
					27	0.016	1.623	47.81	975	1342.	0.010	0.010	0.0100	4782	0.002249	21257
					28	0.015	1.491	49.30	980	1341.	0.010	0.010	0.0120	4109	0.002699	18267
					29	0.016	1.656	50.96	990	1346.	0.010	0.010	0.0120	4247	0.002699	18880
					30	0.016	1.629	52.59	995	1344.	0.010	0.010	0.0120	4383	0.002699	19484
					31	0.015	1.472	54.06	1000	1342.	0.010	0.010	0.0130	4159	0.002924	18489

					PASS			CUM					|--MEASURED AND CALCULATED DATA---|			
TEST LOG	REF	MFG	NOM	SIZE	DOWN LOG	ACT DOC	MATL RMVD	MATL RMVD	RPM	SFM	FD RT	THEO DOC	FL WR	in3/in fl wr	RAD WR	in3/in rd wr
-------	----	----	----	----	----	----	----	----	----	----	-------	-------	-------	-------	-------	-------
91X1060	21	DCTL	DPGA	432	1	0.016	1.574	1.574	1010	1348.	0.015	0.010	0.0030	525	0.001243	1267
					2	0.017	1.667	3.241	1015	1345.	0.015	0.010	0.0045	720	0.001864	1739
					3	0.016	1.572	4.814	1020	1343.	0.015	0.010	0.0045	1070	0.001864	2582
					4	0.017	1.613	6.427	1030	1347.	0.015	0.010	0.0045	1428	0.001864	3447
					5	0.017	1.591	8.019	1035	1349.	0.015	0.010	0.0045	1782	0.001864	4301
					6	0.015	1.471	9.490	1040	1342.	0.015	0.010	0.0050	1898	0.002071	4581
					7	0.015	1.432	10.92	1050	1346.	0.015	0.010	0.0050	2185	0.002071	5272
					8	0.016	1.496	12.41	1055	1344.	0.015	0.010	0.0055	2258	0.002278	5450
					9	0.017	1.577	13.99	1060	1341.	0.015	0.010	0.0055	2545	0.002278	6142
					10	0.017	1.557	15.55	1070	1344.	0.015	0.010	0.0055	2828	0.002278	6825
					11	0.016	1.513	17.06	1080	1347.	0.015	0.010	0.0055	3103	0.002278	7489
					12	0.016	1.466	18.53	1085	1343.	0.015	0.010	0.0055	3370	0.002278	8133
					13	0.016	1.449	19.98	1095	1346.	0.015	0.010	0.0060	3331	0.002486	8038
					14	0.016	1.493	21.47	1100	1343.	0.015	0.010	0.0060	3580	0.002486	8639
					15	0.017	1.559	23.03	1110	1345.	0.015	0.010	0.0060	3839	0.002486	9266
					16	0.016	1.435	24.47	1115	1341.	0.015	0.010	0.0060	4079	0.002486	9843
					17	0.017	1.476	25.94	1125	1343.	0.015	0.010	0.0060	4325	0.002486	10437
					18	0.016	1.375	27.32	1135	1345.	0.015	0.010	0.0060	4554	0.002486	10991
					19	0.016	1.412	28.73	1140	1341.	0.015	0.010	0.0060	4789	0.002486	11559
					20	0.015	1.312	30.04	1150	1343.	0.015	0.010	0.0060	5008	0.002486	12087
					21	0.016	1.362	31.41	1155	1340.	0.015	0.010	0.0060	5235	0.002486	12635
					22	0.016	1.343	32.75	1165	1346.	0.010	0.010	0.0060	5459	0.002486	13175
					23	0.015	1.315	34.07	1175	1343.	0.010	0.010	0.0060	5678	0.002486	13704
					24	0.016	1.316	35.38	1185	1344.	0.010	0.010	0.0060	5898	0.002486	14234
					25	0.017	1.443	36.83	1190	1339.	0.010	0.010	0.0065	5666	0.002693	13675
					26	0.017	1.375	38.20	1200	1340.	0.010	0.010	0.0065	5878	0.002693	14186
					27	0.017	1.403	39.60	1215	1345.	0.010	0.010	0.0065	6094	0.002693	14707
					28	0.015	1.247	40.85	1225	1346.	0.010	0.010	0.0065	6286	0.002693	15170
					29	0.016	1.333	42.19	1230	1341.	0.010	0.010	0.0065	6491	0.002693	15665
					30	0.017	1.353	43.54	1240	1341.	0.010	0.010	0.0065	6699	0.002693	16168
					31	0.016	1.294	44.83	1250	1340.	0.010	0.010	0.0065	6898	0.002693	16648
					32	0.017	1.315	46.15	1260	1340.	0.010	0.010	0.0070	6594	0.002900	15913
					33	0.016	1.249	47.40	1270	1339.	0.010	0.010	0.0070	6772	0.002900	16344
					34	0.02	2.306	49.71	840	1345.	0.010	0.010	0.0070	7101	0.002900	17139
					35	0.016	1.840	51.55	845	1345.	0.010	0.010	0.0070	7364	0.002900	17773
					36	0.017	1.959	53.50	850	1346.	0.010	0.010	0.0070	7644	0.002900	18449
					37	0.016	1.917	55.42	855	1346.	0.010	0.010	0.0070	7918	0.002900	19110
					38	0.016	1.828	57.25	860	1346.	0.010	0.010	0.0070	8179	0.002900	19740
					39	0.016	1.805	59.06	865	1347.	0.010	0.010	0.0080	7383	0.003314	17818
					40	0.016	1.868	60.92	870	1347.	0.010	0.010	0.0080	7616	0.003314	18381
					41	0.016	1.809	62.73	875	1347.	0.010	0.010	0.0080	7842	0.003314	18927
					42	0.015	1.720	64.45	880	1348.	0.010	0.010	0.0080	8057	0.003314	19446
					43	0.016	1.848	66.30	885	1348.	0.010	0.010	0.0080	8289	0.003314	20004
					44	0.017	1.877	68.18	890	1347.	0.010	0.010	0.0080	8523	0.003314	20570
					45	0.015	1.714	69.90	900	1355.	0.010	0.010	0.0085	8224	0.003521	19847
					46	0.015	1.705	71.60	900	1347.	0.010	0.010	0.0085	8424	0.003521	20331
					47	0.017	1.827	73.43	905	1347.	0.010	0.010	0.0085	8639	0.003521	20850
					48	0.016	1.708	75.14	910	1347.	0.010	0.010	0.0085	8840	0.003521	21335
					49	0.015	1.686	76.82	915	1346.	0.010	0.010	0.0085	9039	0.003521	21814
					50	0.017	1.799	78.62	925	1353.	0.010	0.010	0.0085	9251	0.003521	22325
					51	0.016	1.750	80.38	930	1352.	0.010	0.010	0.0090	8931	0.003729	21555
					52	0.016	1.665	82.04	935	1351.	0.010	0.010	0.0090	9116	0.003729	22001
					52	0.016	1.657	83.70	940	1351.	0.010	0.010	0.0090	9300	0.003729	22446
					54	0.015	1.548	85.25	945	1350.	0.010	0.010	0.0090	9473	0.003729	22861
					55	0.015	1.627	86.87	950	1350.	0.010	0.010	0.0090	9653	0.003729	23298
					56	0.016	1.642	88.52	955	1349.	0.010	0.010	0.0090	9836	0.003729	23738
					57	0.016	1.658	90.18	960	1348.	0.010	0.010	0.0090	10020	0.003729	24183
					58	0.014	1.484	91.66	965	1347.	0.010	0.010	0.0090	10185	0.003729	24581
					59	0.014	1.476	93.14	970	1346.	0.010	0.010	0.0090	10349	0.003729	24977

FIGURE 15

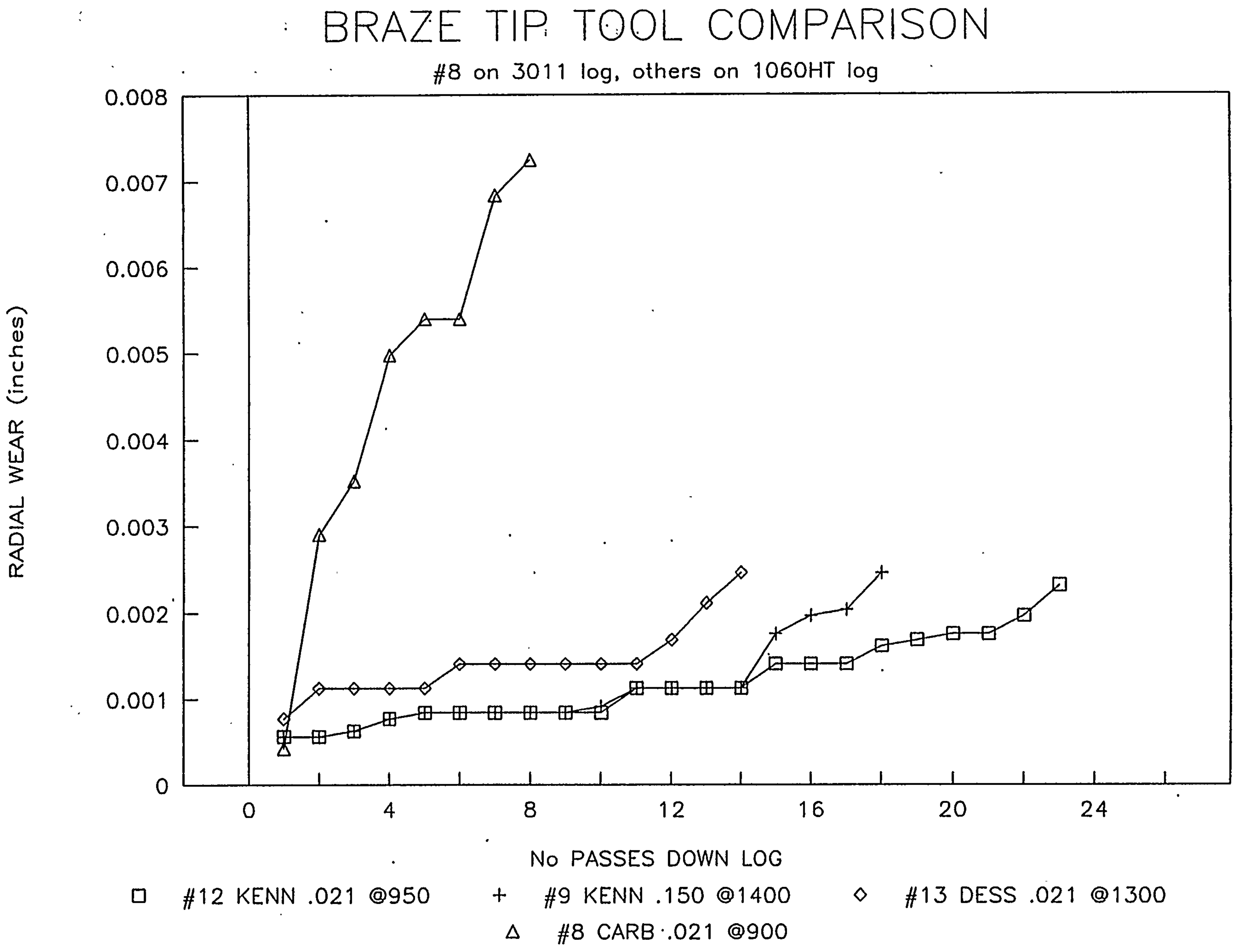
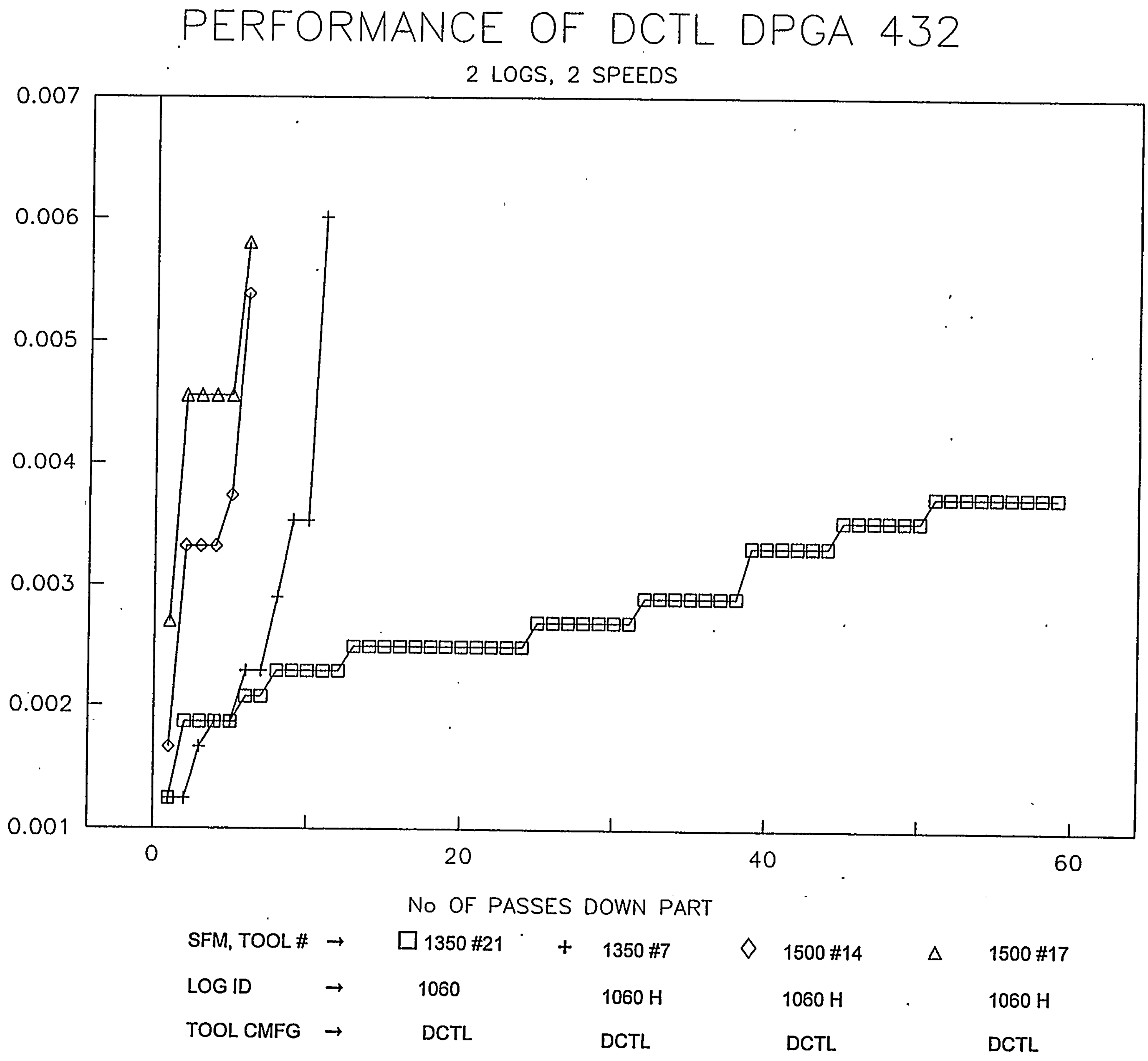

BRAZE TIP TOOL COMPARISON
#8 on 3011 log, others on 1060HT log
RADIAL WEAR (inches)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
4
8
12
16
20
24
No PASSES DOWN LOG
□ #12 KENN .021 @950
+ #9 KENN .150 @1400
◇ #13 DESS .021 @1300
△ #8 CARB .021 @900

FIGURE 16


PERFORMANCE OF DCTL DPGA 432
2 LOGS, 2 SPEEDS
RADIAL WEAR (inches)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
20
40
60
No OF PASSES DOWN PART
SFM, TOOL # →
□ 1350 #21
+ 1350 #7
◇ 1500 #14
△ 1500 #17
LOG ID →
1060
1060 H
1060 H
1060 H
TOOL CMFG →
DCTL
DCTL
DCTL
DCTL

within 20% of the maximum value. This has been done because there is variability in the tools and their performance and specific radial wear values in this range may not be statistically different. Note that in the column for the first cut there are two extremely high values which have been neglected. These numbers were obtained by taking cuts that were 0.030" deep (therefore removing three times as much stock per pass) to test the durability of the tool and to provide some indication of the ability to extrapolate data to more aggressive cuts.

The highlighted values indicate a PCD tool which has shown superior performance in testing on alumina loaded rotors. This ranking is based on removal of larger amounts of stock for less tool wear. This tool is the Sumitoma DNMX 433. The tool has a positive cutting rake angle of 10° and clearance angles of 5° primary and 10° secondary clearance. It is the opinion of the investigator that the superiority of this tool is due to the (almost) unique geometry and that if the geometry were duplicated by other manufacturers similar results could be obtained. The Valenite tool which was modified in house to provide clearance (REF #28) offers much promise.

Two silicon nitride tools are shown on Figure 17. These are identified as REFs #73 and #74. It is convenient to include these tools in this spreadsheet for comparison purposes. They are also included in Figure 18, the silicon nitride tool spreadsheet. In the case of the uncoated Greenleaf SiN tool (REF #74), no data is presented for passes 5 to 9. It is felt by the tester that data taken for these passes was read to the bottom of a chip in the cutting edge of the tool. This error was noted and readings to the bottom of the wear land was resumed on the tenth pass and subsequent passes.

Additionally, six other silicon nitride tools were tested against the rotors and data is shown on Figure 18. Since the spreadsheet has the same layout as the rotor data base, Appendix 3 can be used as an explanation of the column headings. The performance of the silicon nitride tools is not equivalent to the PCD diamond tools in the early passes, but becomes comparable after multiple passes across the rotor. It should be noted that the tool listed as REF #80 was used dry and actually shows better performance than a tool used with coolant applied (REF #79). This should be expected since most vendors advocate the use of ceramic tools without coolant. It should be noted that tools REFs #79 and #80 were used on the inboard surface of the rotor and were subjected to a greater amount of material removed per pass than tools used on the outboard surface of the rotor.

Very preliminary tests of tools fabricated from Lanxide Gemini material show that they are comparable to Greenleaf tools. The effect of low temperature plasma sprayed diamond coating seems negligible. In the test of tool REF #78, the diamond coating flaked away after the first pass across the rotor, but the tool continued to perform well.

TOOLBASY--do NO calculations on this database saved as values
ROTOR DATA BASE flat width calculations deleted SORTED BY SPEED, SIZE, NOM, HOLDR

|<-------- PASSES ACROSS ROTOR -------->>>

REF	TOOL	MFG	NOM	SIZE	HOLDR CLEAR	TOOL CLEAR	TOOL RAKE	SFM	FD RT	DOC	1 in3/in rd wr	2 in3/in rd wr	3 in3/in rd wr	4 in3/in rd wr	5 in3/in rd wr	6 in3/in rd wr	7 in3/in rd wr	8 in3/in rd wr	9 in3/in rd wr	10 in3/in rd wr	11 in3/in rd wr	12 in3/in rd wr	13 in3/in rd wr	14 in3/ir rd wr
2	ACCU DNGA 432	ACCU	DNGA	432	13	0		1000	0.015	0.010	659	742	989	1079										
1	DCTL DNGA 432	DCTL	DNGA	432	13	0		1000	0.015	0.010	659	791	937	989										
5	NORT DPGA 432	NORT	DPGA	432	13	11		1000	0.015	0.010	644	920	805	1074	1150	1208	1326	1288						
4	NORT DPGA 432	NORT	DPGA	432	13	11		1000	0.015	0.010	805	805	878	920	848	966	930							
3	VALN DNGM 432	VALN	DNGM	432	13	0		1000	0.015	0.010	848	848	1047	1079										
6	GE15 DCMT 433	GE15	DCMT	433	13	7		1000	0.015	0.010	646	775	830	968	1139	1223								
7	GE15 DCMT 433	GE15	DCMT	433	13	7		1000	0.015	0.010	553	646	830	911	968									
9	NORT DNGA 433 CVD	NORT	DNGA	433	13	0		1000	0.015	0.010	593	698	809											
8	JMTL DNGA 433	JMTL	DNGA	433	13	0		1000	0.015	0.010	539	659	809											
68	SUMI DNMX 433	SUMI	DNMX	433	0	5	10	1000	0.02	0.01	1271	1907	1907	2179	2542	2692	2810	3051	2860	2724				
10	SUMI DNMX 433	SUMI	DNMX	433	13	5		1000	0.015	0.010	615	782	993	1012	1195	1173								
14	ACCU DNGA 432	ACCU	DNGA	432	13	0		1250	0.015	0.010	593	593												
20	DCTL DPGA 432	DCTL	DPGA	432	13	11		1250	0.015	0.010	537	537	690	805	671	805	902	859						
13	DCTL DNGA 432	DCTL	DNGA	432	13	0		1250	0.015	0.010	494	456												
74	GRNL TPGN 432 UNCOAT	GRNL	TPGN	432	0	11	0	1250	0.015	0.01	572	858	1084	1017						2452	2221	2423	2479	26
73	GRNL TPGN 432 UNCOAT	GRNL	TPGN	432	0	11	0	1250	0.015	0.01	312	528	736	915	1010	1113	1202	1340						
72	KENN DNMS 432	KENN	DNMS	432	6.5	0	15	1250	0.015	0.01	589	982	982	1072	1179	1263	1086							
70	KENN DNMS 432 KD100	KENN	DNMS	432	6.5	0	15	1250	0.015	0.01	380	561	632											
32	KENN DNMS 432	KENN	DNMS	432	13	0		1250	0.015	VAR														
18	KENN DNMS 432	KENN	DNMS	432	13	0		1250	0.015	0.010	742	593												
33	KENN DNMS 432	KENN	DNMS	432	13	0		1250	0.015	0.01	539	625	614	659	674									
69	NORT DPGA 432 DT100L	NORT	DPGA	432	0	11	0	1250	0.015	0.01	458	763	896	1017	1144	1212	1299	1194						
63	NORT DPGA 432 DT100L	NORT	DPGA	432	6.5	11	0	1250	0.015	0.01	363	484	594	670	726	817	847							
30	NORT DPGA 432	NORT	DPGA	432	13	11		1250	0.015	0.010	537	496	604	716	805		705							
19	NORT DPGA 432	NORT	DPGA	432	13	11		1250	0.015	0.010	805	805	805	758	895	878								
16	TUNG DNGG 432 TIC2	TUNG	DNGG	432	13			1250	0.015	0.010	185													
15	TUNG DNGG 432 TIC1	TUNG	DNGG	432	13			1250	0.015	0.010	247													
11	TUNG DOJA 432 160	TUNG	DOJA	432	13	0		1250	0.015	0.010	494	848	989	1079										
12	TUNG DOJA 432 140	TUNG	DOJS	432	13	0		1250	0.015	0.010	742	848	989											
62	TUNG DNJA 432 140	TUNG	DNJA	432	6.5	0	0	1250	0.015	0.01	589	786												
61	TUNG DNJA 432 160	TUNG	DNJA	432	6.5	0	0	1250	0.015	0.01	737	842												
29	VALN X_CL 432	VALN	X_CL	432	0	8	11	1250	0.015	0.01	1357	2110	2191	1310										
37	VALN DNGM 432 2	VALN	DNGM	432	6.5	5	11	1250	0.015	0.01	222	351												
71	VALN DNGM 432	VALN	DNGM	432	6.5	0	11	1250	0.015	0.01	786	1241	1263	1150	893									
36	VALN DNGM 432 1	VALN	DNGM	432	6.5	0	11	1250	0.015	0.01	421	620												
17	VALN DNGM 432	VALN	DNGM	432	13	0		1250	0.015	0.010	593	913	742											
38	DCTL DPGA 433	DCTL	DPGA	433	6.5	11	0	1250	0.015	0.01	1089	726	817	871	990	1089	1173	1245	1225	1210	1141			
28	GE15 DCMT 433 b	GE15	DCMT	433	0	7		1250	0.015	0.01	906	1208	1482	1672	1812	1976	2114	2174						
27	GE15 DCMT 433 a	GE15	DCMT	433	0	7		1250	0.015	0.01	679	836	1019	1208	1359									
39	GE15 DCMT 433	GE15	DCMT	433	6.5	7	0	1250	0.015	0.01	567	811	851	946	1091	1135	1168	1081						
21	JMTL DNGA 433	JMTL	DNGA	433	13	0		1250	0.015	0.010	593	848	1047	1187										
24	JMTL DNMA 433 CBN	JMTL	DNMA	433	13			1250	0.015	0.010	247													
23	KENN DNGA 433	KENN	DNGA	433	13	0		1250	0.015	0.010	742	848	890											
60	NORT DNGA 433 DT100L	NORT	DNGA	433	6.5	0	0	1250	0.015	0.01	536	842												
22	NORT DNGA 433	NORT	DNGA	433	13	0		1250	0.015	0.010	593	593												
31	SUMI DNMX 433	SUMI	DNMX	433	0	5	10	1250	0.015	VAR														
26	SUMI DNMX 433	SUMI	DNMX	433	0	5	10	1250	0.015	0.01	1090	1795	1990	1968	2007	2129	2427	2441	2452					
35	SUMI DNMX 433	SUMI	DNMX	433	0	5	10	1250	0.015	0.03	3269													
64	SUMI DNMX 433	SUMI	DNMX	433	6.5	5	10	1250	0.015	0.01	667	834	1000	1111	1042	1111	1167	953						
34	SUMI DNMX 433	SUMI	DNMX	433	13	5	10	1250	0.015	0.03	2151													
25	SUMI DNMX 433	SUMI	DNMX	433	13	5	10	1250	0.015	0.010	538	860	922	956										
42	ACCU DNGA 432	ACCU	DNGA	432	13	0		1500	0.020	0.010	539	742	890											
46	KENN DNMS 432KD100	KENN	DNMS	432	13	0		1500	0.020	0.010	593	698	848											
47	KENN DNMS 432KD100	KENN	DNMS	432	13	0		1500	0.020	0.010	593	848	890											
65	NORT DNGA 432 DT100L	NORT	DNGA	432	6.5	0	0	1500	0.02	0.01	536	737	707											
48	NORT DPGA 432 CVD	NORT	DPGA	432	13	11		1500	0.020	0.010	537	805	805	859	848									
43	TUNG DNGA 432 140	TUNG	DNGA	432	13	0		1500	0.020	0.010	539	742	890											
44	TUNG DNGA 432 140	TUNG	DNGA	432	13	0		1500	0.020	0.010	494	593												
41	TUNG DNJA 432 160	TUNG	DONJA	432	13	0		1500	0.020	0.010	539	742	774											
40	TUNG DNJA 432 160	TUNG	DONJA	432	13	0		1500	0.020	0.010	593	659												
45	VALN DNGM 432	VALN	DNGM	432	13	0		1500	0.020	0.010	494	742	989	1079										
49	GE15 DCMT 433 #2	GE15	DCMT	433	13	7		1500	0.020	0.010	484	646	830	861	968									
50	GE15 DCMT 433 #1	GE15	DCMT	433	13	7		1500	0.020	0.010	553	775	830	968	1019	1056								
55	JMTL DNGA 433	JMTL	DNGA	433	13	0		1500	0.020	0.010	593	913	937	1032										
52	KENN DNGA 433KD100	KENN	DNGA	433	13	0		1500	0.020	0.010	593	659												
51	KENN DNGA 433KD100	KENN	DNGA	433	13	0		1500	0.020	0.010	494	625	809											
53	NORT DNGA 433 CVD	NORT	DNGA	433	13	0		1500	0.020	0.010	593	848	890											
67	SUMI DNMX 433 DA150	SUMI	DNMX	433	0	5	10	1500	0.02	0.01	1525	1695	1907	2347	2384	2409	2542	2774	2860	2724	2797			
66	SUMI DNMX 433 H00	SUMI	DNMX	433	6.5	9	10	1500	0.02	0.01	411	548	673	759	881	870	959	940						
54	SUMI DNMX 433	SUMI	DNMX	433	13	5		1500	0.020	0.010	538	717	922	860	1076	1173	1205							
58	GE15 DCMT 433 #1	GE15	DCMT	433	13	7		1800	0.015	0.010	484	596	726	815	880	968								
57	NORT DPGA 432 DTR	NORT	DPGA	432	13	11		1800	0.025	0.010														
56	TUNG DNGA 432 140	TUNG	DNGA	432	13	0		1800	0.030	0.010														
59	GE15 DCMT 433	GE15	DCMT	433	13	7		3293	0.015	0.010	387	596	726	861	968	930								
										MAX =>	3269	2110	2191	2347	2542	2692	2810	3051	2860	2724	2797	2423	2479	

FIGURE 17

```
SIC_BASV--DON'T do all calculations on this database  derived from SIC_BASE
ROTOR DATA BASE, SIC TOOLS
SORTED BY SPEED, SIZE, NOM
                                                                                        << <<== PASSES ACROSS ROTOR ==>> >>
                                                                                        AREA CUT/PASS =>=>           66.73
                                            HOLDR TOOL   TOOL                       1       2       3       4       5       6       7       8       9      10      11      12      13      14      15      16      17      17      19      20      21      22      23      24      25
REF          TOOL           MFG    NOM  SIZE CLEAR CLEAR RAKE  SFM  FD RT   DOC   in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in
                                                                                    rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr
   73 GRNL TPGN 432 UNCOATGRNL  TPGN  432    0    11     0  1250  0.015  0.01     312     528     736     915    1010    1113    1202    1340
   74 GRNL TPGN 432 UNCOATGRNL  TPGN  432    0    11     0  1250  0.015  0.01     572     858    1084    1017  <<<<<<< error reading flank wear ••••••>>    2452    2221    2423    2479    2670
   75 GRNL TPGN 432 COAT   GRNL TPGN  432    0    11     0  1500   0.02   0.01     429     597     858    1099    1271
   76 LANX TPGX 432 COAT   LANX TPGX  432    8    11     0  1500  0.020  0.010    144     287     416     555     575
   77 GRNL TPGN 432 COAT   GRNL TPGN  432    0    11     0  1500  0.020  0.010    458
   78 LANX TPGX 432 COAT   LANX TPGX  432    0    11     0  1500  0.020  0.010    381     624     687     915    1144    1287    1502    1616    1716    1907    2041    2168    2125    2289    2341    2388    2432    2472    2607    2591    2670    2746    2820    2841    2905

                                                                                        << <<== PASSES ACROSS ROTOR ==>> >>
                                                                                        AREA CUT/PASS =>=>          111.36
                                            HOLDR TOOL   TOOL                       1       2       3       4       5       6       7       8       9      10      11      12      13      14      15      16      17      17      19      20      21      22      23      24      25
REF          TOOL           MFG    NOM  SIZE CLEAR CLEAR RAKE  SFM  FD RT   DOC   in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in  in3/in
                                                                                    rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr   rd wr
   79 LANX TPGX 432 UNCOATLANX  TPGX  432    0    11     0  1500  0.015  0.010    477     716     955    1175    1364    1495    1744    1871    2105    2338    2521    2594    2708    2864    3069    3274    3417    3437    3569    3581    3702    3878    3933    4044    415·
   80 GRNL TPGN 432 UNCOATGRNL  TPGN  432    0    11     0  1500  0.015  0.01     637    1146    1495    1833    2203    2546    2864
      (cutting performed dry)
```

FIGURE 18

INVENTIONS MADE OR REPORTED

No inventions related to this project were made or reported during the time work was being performed on this CRADA.

ASSEMENT OF COMMERCIALIZATIONS POSSIBILITIES

The potential of commercialization of information obtained from this CRADA is very high, if it is packaged with materials that are made by Lanxide. The commercialization of the machining data by itself, does not have a high potential.

Lanxide and Lockheed Martin entered into the CRADA for the purpose of obtaining data on the machining of hard alloys. Without this data, Lanxide's product is harder to sell to prospective users of the material. It is Lanxide's desire to sell the material to users along with the necessary machining parameters so that the end user does not have to invest his time and dollars to develop the required machining parameters. Since machining parameters are highly dependent on the particular material, the commercialization of cutting parameters for untested material or another company's material does not have a high potential.

PLANS FOR FUTURE COLLABORATION

There are no further plans for future collaboration between Lanxide Corporation and Lockheed Martin concerning this project.

CONCLUSIONS/RECOMMENDATIONS

Based on the work performed, the following conclusions and recommendations are made:

1. Continued testing of silicon nitride tools could be fruitful. Tools from other vendors should be evaluated, as there are several varieties of silicon nitride available. Silicon nitride tools should be tried on silicon carbide loaded material.

2. Tests should be conducted using silicon nitride tools without coolant on both materials. It is a common recommendation from tool vendors that the tools be used dry to avoid thermal shock. A single trial run without coolant on the alumina loaded material shows promising results

3. Silicon nitride tools offer almost a 7:1 cost advantage over polycrystalline diamond tools for cutting alumina loaded MMCs, if replacement time costs are neglected. It is possible that silicon nitride tool will offer an advantage is this area also.

4. The effect of diamond coating on silicon nitride tools appears to be very small. In most tests, the diamond coating was worn/flaked away during the first pass across the rotor. The bare substrate continued to cut

5. If polycrystalline diamond tools are selected as the tool of choice, then a tool having clearance and a net positive cutting rake should be used. The Sumitoma DNMX 432 tool is typical of this design.

6. Polycrystalline diamond tools should be run in the 1000 SFM to 1500 SFM cutting speed range. Moderate feeds and depths of cut should be employed. Metal removal rates of 2.2 in^3 per minute of alumina loaded MMC material were obtained during the tests using light feed rates and depths of cut.

7. Cutting conditions should be optimized for either or both the polycrystalline diamond and the silicon nitride tools on both materials. This was partially included as Phase III of the cooperative research and development agreement (CRADA).

8. Replication of results on the optimum cutting condition should be performed on both materials at Lanxide. Differences in machine tool type, slide stiffness, setup rigidity, etc. may cause serious discrepancies between the two sites.

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ACRONYMS

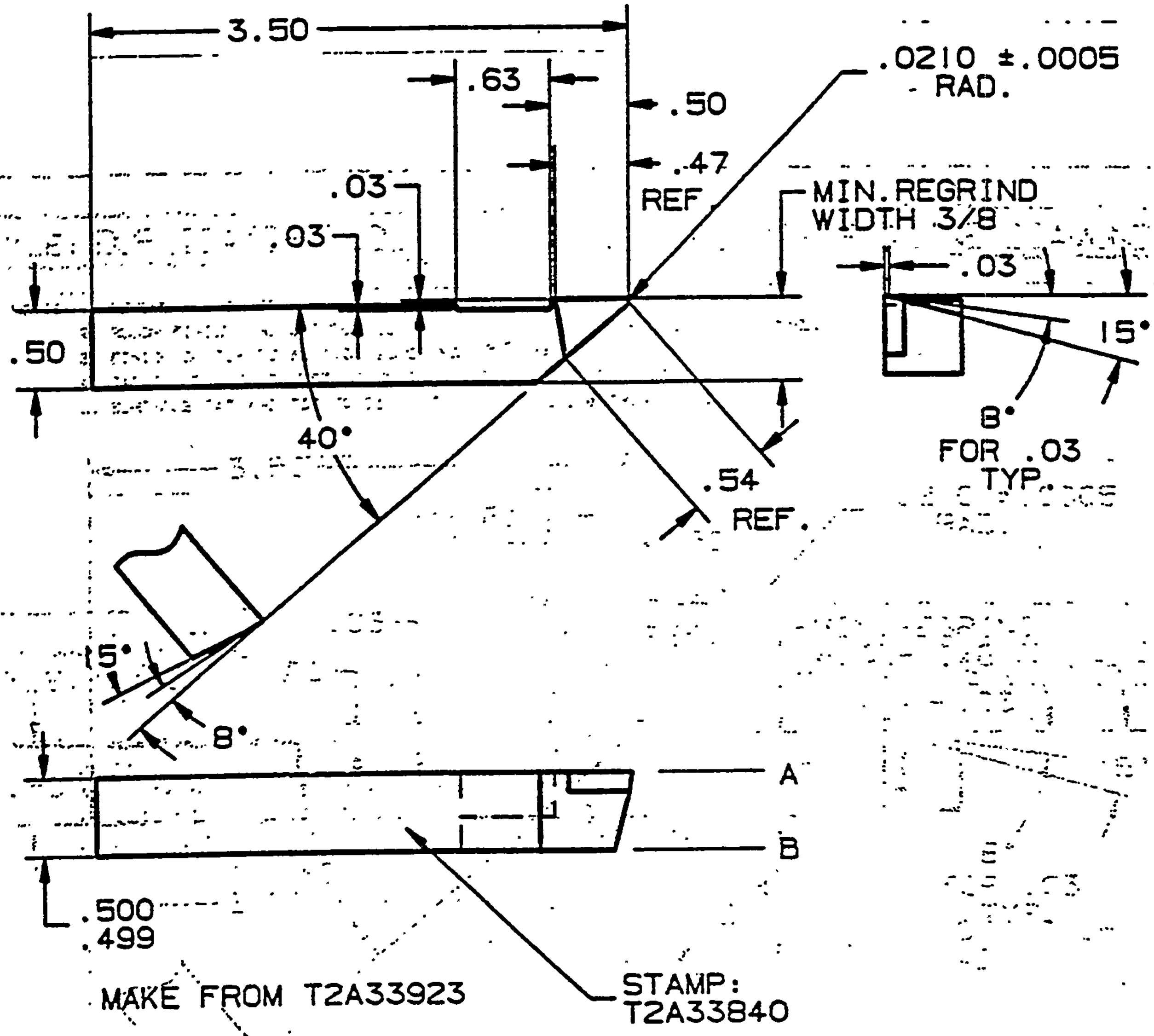
ANSI	American National Standards Institute
CRADA	Cooperative Research and Development Agreement
CVD	Continuous Vapor Deposition
DOE	Department of Energy
DP	Defense Programs
EE	Energy Efficient
MMC	Metal Matrix Composites
PCD	Polycrystalline Diamond
PMID	Tool Position for Starting the Part Program
RPM	Revolutions per Minute
SFM	Surface Feet per Minute

APPENDIX 1

The following drawings are tools which are referenced in the report which do not conform to the ANSI specification for tool nomenclature.

STYLE: DUPLICATOR TOOL | TIP: POLYCRYSTALINE DIAMOND

NOTES: 1. REMOVE ALL BURRS.
2. ROUGH FINISH AND CHIPPED SURFACES TO BE REMOVED FROM CUTTING EDGES.
3. FINISH ON TIP TO BE (10 MICRO-INCH)$^{10}\sqrt{}$ MAX.
4. RADII AND ANGLES MUST BE UNIFORM AND TANGENT TO EDGES.
5. SURFACES "A" AND "B" TO BE FLAT AND PARALLEL WITHIN .001.



REGRIND PRINT

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D	C	2		R. TOLER. WAS ±.00015	E.R.	CVJ	6-'88
C	C	2		REDR & UPDATED	BH		6/88
REV				REVISION	BY	APPR	DATE

DRAWN: HELTON | APPROVALS: JCS 8/82
CHECKED: RCG | MM BROWN 8/82

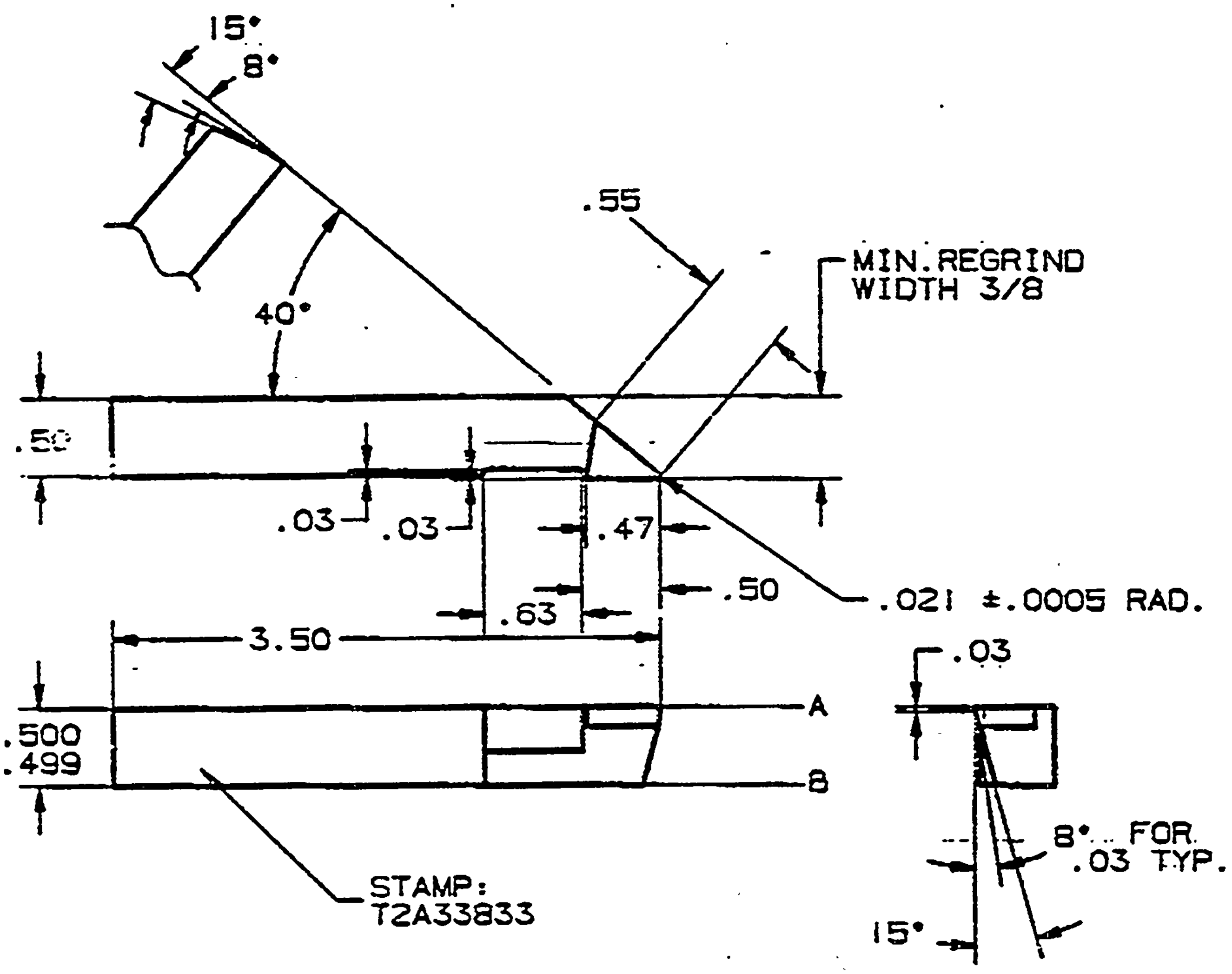
TOLERANCES UNLESS SPECIFIED
FRAC. ± 1/64 DEC. ± .005 ANGLE ± 0.5°

CUT TOOL- SMALL TOOLS
.50 SQ.R.H. DMND TOOL
2 4 G A Y-12 | 51841-025
BLDG. 9204-2 | SHOP NO. 04b | T2A33840 | D
2

MARTIN MARIETTA ENERGY SYSTEMS, INC. Y-12 PLANT OAK RIDGE, TN

TITLE: DUPLICATION TOOL TIP: POLYCRYSTALINE DIAMOND

NOTES: 1. REMOVE ALL BURRS.
2. ROUGH FINISH AND CHIPPED SURFACES TO BE REMOVED FROM CUTTING EDGES.
3. FINISH ON TIP TO BE (10 MICRO-INCH) $^{10}\surd$ MAX.
4. RADII AND ANGLES MUST BE UNIFORM AND TANGENT TO EDGES.
5. SURFACES "A" AND "B" TO BE FLAT AND PARALLEL WITHIN .001.



MAKE FROM T2A33924

REGRIND PRINT

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TOLERANCES UNLESS SPECIFIED
FRAC. ± 1/64 DEC. ± .005 ANGLE ± 0.5°

CUT TOOL- SMALL TOOLS

.50 SQ. L.H. DMND TOOL

D C 2 REDR & UPDATED RH KK 6/93
REVISION BY APPR DATE
DRAWN: HELTON APPROVALS: JCS 8/92
CHECKED: ROBBINS MM BROWN 8/92

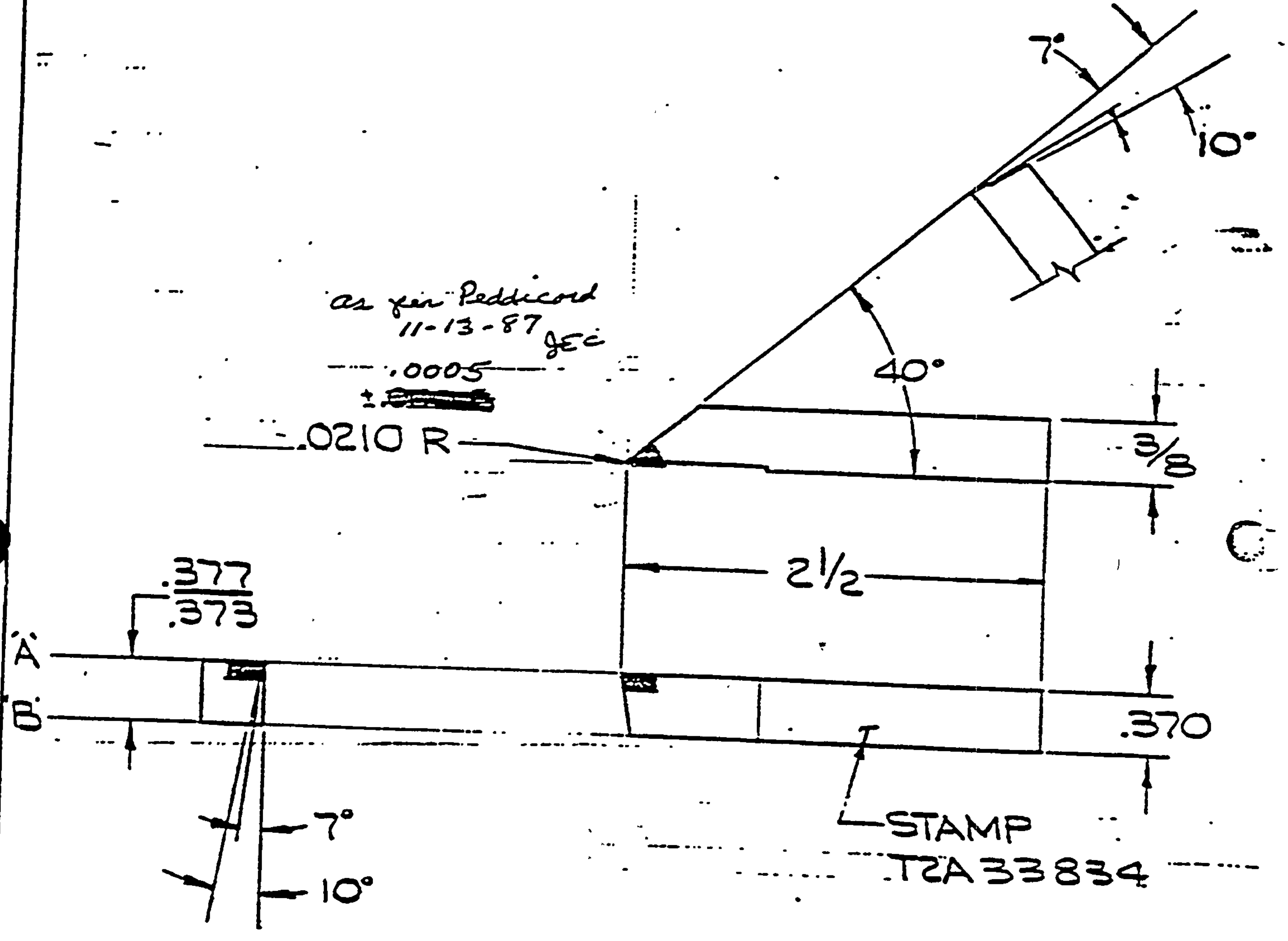
Y-12 51841-025
9204-2 .046 T2A33833 D

MARTIN MARIETTA ENERGY SYSTEMS, INC. Y-12 PLANT OAK RIDGE, TN.

STYLE:

TIP: POLY CRYSTALINE DIAMOND

NOTES:
1. REMOVE ALL BURRS.
2. ROUGH FINISH AND CHIPPED SURFACES TO BE REMOVED FROM CUTTING EDGES.
3. FINISH ON TIP TO BE (10 MICRO-INCH) $\sqrt[10]{}$ MAX.
4. RADII AND ANGLES MUST BE UNIFORM AND TANGENT TO EDGES.
5. SURFACES "A" AND "B" TO BE FLAT AND PARALLEL WITHIN .001.



MAKE FROM T2A33925

REGRIND PRINT

TOLERANCES UNLESS SPECIFIED

FRAC. ± 1/64 DEC. ± — ANGLES ± 1°

CUT. TOOL — SMALL TOOLS

.37 SQ. R.H. DIAMOND TOOL

A	DWG. # CHANGED	BH	JEC	
	REVISION	BY	APP.	DATE

DRAWN: HELTON 8-82

APPROVALS: JEC 8-19-82

CHECKED: RH

MM Brown 9-19-82

2 36	4 40	G 41	A 45	Y-12	UCC-ND CAT. NO.

BLDG: 9204-2

04 b SHOP NO.

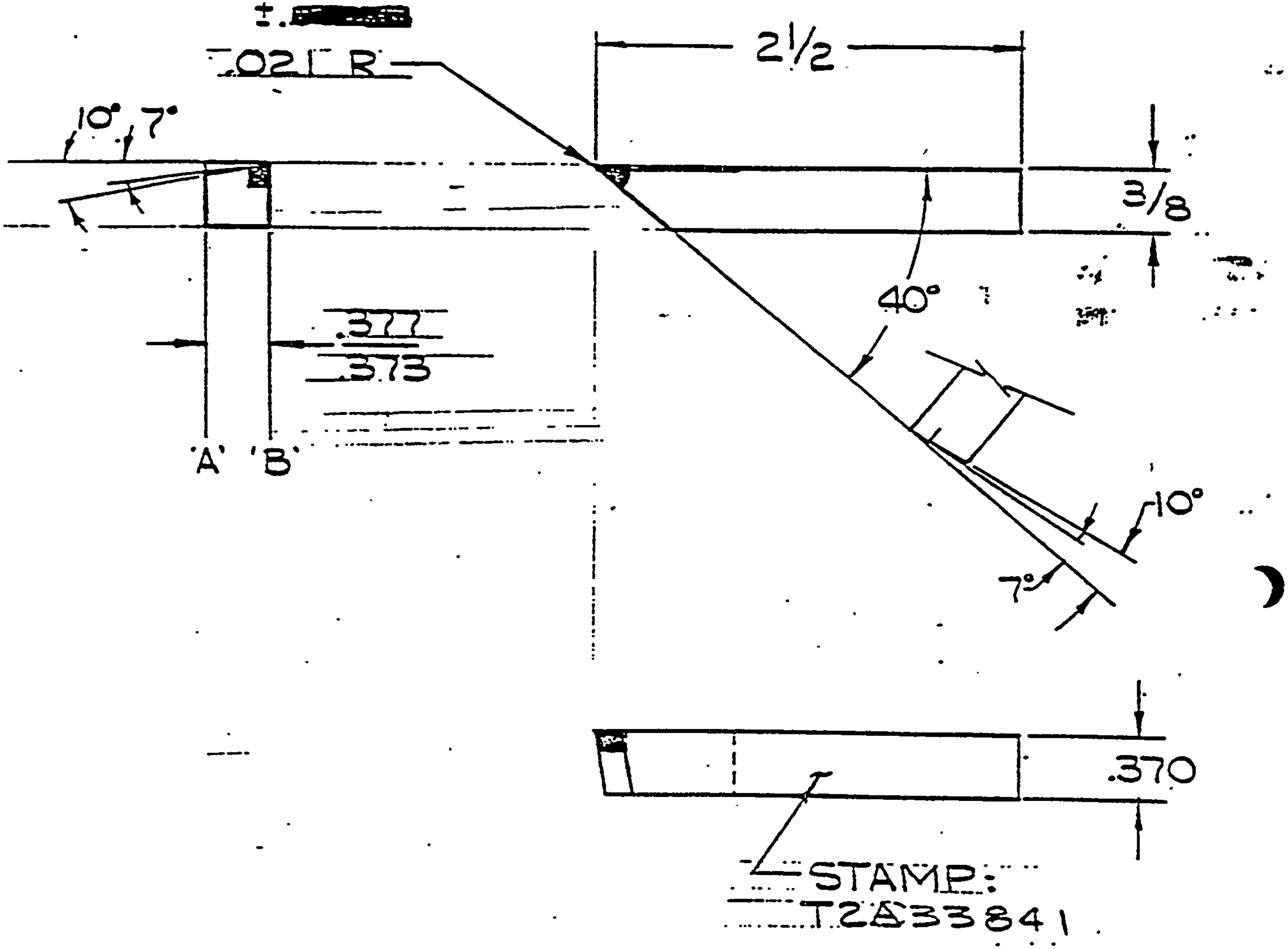
T2.

UNION CARBIDE CORP

STYLE: | TIP: POLYCRYSTALINE DIAMOND

NOTES:
1. REMOVE ALL BURRS.
2. ROUGH FINISH AND CHIPPED SURFACES TO BE REMOVED FROM CUTTING EDGES.
3. FINISH ON TIP TO BE (10 MICRO-INCH) 10 MAX.
4. RADII AND ANGLES MUST BE UNIFORM AND TANGENT TO EDGES.
5. SURFACES "A" AND "B" TO BE FLAT AND PARALLEL WITHIN .001.

as per Peddicord
12-13-87 gec



MAKE FROM T2A33926

REGRIND PRINT

TOLERANCES UNLESS SPECIFIED
FRAC. ± 1/64 DEC. ± ~ ANGLES ± 1°

CUT. TOOL – SMALL TOOLS

.37 SQ-L.H. DIAMOND TOOL

A	Dwg # CHANGED	BH		
	REVISION	BY	APP	DATE

DRAWN: HELTON | APPROVALS: 8-1982
CHECKED: | M M Brown 8-1982

2 36	4 40	G 41	A 45	Y-12	UCC-ND CAT. NO. 50

BLDG: 9204-2 | 046 SHOP NO. | T2A33841 | A

UNION CARBIDE CORP NUCLEAR DIVISION | Y-12 PLANT OAK Appendix 1.6

APPENDIX 2

The following is an explanation of the columns in Figure 14, the spreadsheet for silicon carbide reinforced material. For further information about the spreadsheet, see the appropriate text.

Column 1, labeled TEST LOG is the identification of the test log on which the tool was used. This is Lanxide's code for the test logs.

Column 2, labeled REF is an identifier that is unique for each testing run. Reference to a REF number should point to a unique log/tool/speed/feed/depth combination. Each REF number should appear once and only once in the spreadsheet.

Column 3 is a coded list of the manufacturer of the tool. The column is headed MFG.

Column 4 is the ANSI designator for the geometry of the tool. The column is labeled NOM. If no entry appears in this column, the tool does not conform to the ANSI specification. An Energy Systems drawing for the tool can usually be found in Appendix 1. In some cases, the tool does not conform to the ANSI specification and no drawing of the tool does not exist. These tools are usually ground to the specification of the individual running the test.

Column 5 describes the size of the tool. Designators of the form XXX conform to the ANSI specification. The first digit indicates the size of the insert, the second digit indicates the thickness, and the third digit is a code for the radius of the tool. Designators of the form 0.XX or 0.XXX are the radius of the tool.

Column 6, PASS DOWN LOG indicates the number of a 6 inch cuts taken on the log. The cutting conditions and the measured data taken after the cut are listed in the following columns.

Column 7, ACT DOC, lists the actual depth of cut obtained by measuring the diameter of the log before and after the cutting sequence. Differences from the intended depth of cut (either 0.010" or 0.020") are due to set up inaccuracy and other non-controllable factors.

Column 8, MATL RMVD is the amount of material that was removed by a specific straight turning pass down the log. It is a function of the diameter of the log before the cut, the actual depth of cut, and the 6 inch length of cut. An example of the calculation which produces this column is included in the text.

Column 9, CUM MATL RMVD is the cumulative amount of stock that has been removed by the cutting test. This number is obtained by summing the material removed for all cuts on the tool being tested up to the cutting pass of interest. This number is used for calculating specific flank wear and specific radial wear.

Column 10 lists the lathe spindle revolutions per minute, RPM.

Column 11 lists the cutting speed in surface feet per minute based on the size of the log and the spindle RPM. The column is labeled SFM.

Column 12, FD RT, lists the feed rate used during the test in inches per revolution.

Column 13, THEO DOC lists the theoretical depth of cut.

Column 14, FL WR, is a tabulation of the flank wear at the end of each pass down the part. The units of the column is inches. This is the basic measurement made. Other parameters are calculated from this observation.

Column 15, in^3/in fl wr, is the specific flank wear, or the amount of material that can be removed per unit of flank wear.

Column 16, RAD WR, is the radial wear corresponding to the measured flank wear. Calculation of this column is dependent on knowledge about the tool orientation (holder rake, cutting surface rake, tool relief, etc.).

Column 17, in^3/in rd wr, is the specific radial wear, or the amount of material that can be removed per unit of radial wear.

APPENDIX 3

The following is an explanation of the columns in Figure 17 and Figure 18. For further information about the spreadsheets, see the appropriate text.

Column 1 contains an identifier that is unique for each testing run and is labeled REF. Pointers to a REF number should point to a unique tool/speed/feed/depth/rake/clear combination. Each REF number should appear once and only once in the chart.

Column 2 labeled TOOL is four fields wide and contains an identifier for the tool being used in the run. This is the nomenclature that can be used to specify the major geometry of the tool.

Columns 3, 4 & 5 are a breakdown of Column 2 that allows sorting on the various fields in the identifier.

Column 6 lists the rake angle of the tool holder that was used in the particular testing run.

Column 7 is a listing of the clearance angle of the tool being tested. Columns 6 & 7 play major roles in determining the radial wear from the measured flank wear.

Column 8 is a listing of the rake angle on the cutting surface of the tool. Radial wear has not been corrected for this factor.

Column 9 lists the cutting speed at which the test run was conducted. The spreadsheet has been sorted on this parameter.

Column 10 lists the feed rate that was used for the test run.

Column 11 is a listing of the depth of cut at which the test run was made. Notice that the entry 'VARY' appears in two runs of Figure 17, but no data is listed for those runs. In the conduct of those two runs, machine malfunctions occurred and the depth of cut was variable. Due to the unreliability of those runs, no data are listed.

The following 14 columns (25 columns for Figure 18) are the specific radial wear values after the number of runs listed at the top of the column. Specific radial wear is calculated by dividing the amount of material removed by the radial wear exhibited by the tool. Since it is desired to have large amounts of stock removed for very little tool wear, a large number is desirable in this column. A list of the maximum values found in each column is found in the bottom line of the spreadsheet. By finding the matching number (by searching upwards in the same column), the best tool for a particular number of passes can be found. Do not use the maximum number found in the column for the first pass. Two runs were made at three times the normal depth of cut to test the durability of the tool; therefore, these two runs (REFs #34 & #35) should have high specific radial wear values. The fact that the numbers are proportional indicates that even though the higher depth of cut is possible, higher tool wear rates will also be present.

APPENDIX 4

Attached are the raw data sheets which were generated at the testing site by the technicians, machinists, and engineers responsible for running the tests.

Much of the data presented appears cryptic to an outsider who is not familiar with tool testing. Redundancies are present in the data and sometimes appear to conflict. Discussions with the testing personnel should be instituted before using the data for further calculations or conclusions.

Appendix 4.2

LOG
TURNING

Appendix 4.3

Appendix 4.4

May ~~20~~ 10, 93

Machining Conditions

Part Number: 042892 Machine: LeBlond Tool Type: Kennametal T2A 33833 Polycrystl Coolant: N/A

Material: 500 Grit Log Model/Type: GE 2000 Controller Tape Tool Geometry: .021 Radius Concentration: N/A

Part Dimension: 6.6" Dia. X 8"

Hardness: ______

	Workpiece Diameter(in)	Spindle RPMs	SFPM(in)	Feedrate (ipr)	Depth of Cut	Length ofCut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	F 6.6610	297	518	.020	.010	6"	1st Pass			Dull
6.6653	M 6.6660							.008	.031 .8mm	
	B 6.6690									
	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	F 6.6525	297	518	.020	.010	6"	2nd Pass			Dull
6.6551	M 6.6560							.0045	.031 .8mm	
	B 6.6570									
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
.314 Dia.	F 6.6430	297	518	.020	.010	6"	1st Pass		.067 1.7mm	Dull
Diasil	M 6.6525							.011		
6.6498	B 6.6540									
	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	F 6.6420	297	518	.020	.010	6"	2nd Pass		.067 1.7mm	Dull
6.6488	M 6.6520							.0105		
	B 6.6525									

2nd Dia + KVOLCALC 1

Remarks

Start & Turn Test

(5/10/93)

1

Appendix 4.5

Machining Conditions

Part Number: 93X3014 Machine: LeBlond Tool Type: Diasil Coolant: N/A

Material: 220Grit SiC Model/Type: TapeLathe GE2000 CONTROLLER Tool Geometry: Flat Top Button .314 Dia 7° Neg. Concentration: N/A

Part Dimension: 4" X 12"

Date May 28, 93

Hardness:

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr).	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	F ~~4~~3.9915	425	445	.020	.010	6"	1st Pass	—0—		DULL
3.9915	M 3.9915	91%	100%						.035 .9mm	
	B 3.9916									
					CBN					
	F 3.9865	425	222	.020	.005	1st Pass	(10° Pos	Rake .030	Rad.)	SMALL CURLY CHIPS
	M 3.9875	91%	50%					.0025		Bright Finish
3.9880	B 3.9890								.012 .3mm	
	F 3.9710	425	100%	.020	.010	2nd Pass				Larger Curly Chips
3.9720	M 3.9715	91%	440					.0015	.012 .3mm	
	B 3.9725									
				.393	DIASIL	Flat Top	Button.	10°NEG. Rake		
	F 3.9555	425	440	.020	.010	6"				
①	M 3.9560	91%	100%			1st Pass		.0010	.004 .1[illegible]mm	DULL
	B 3.9565									

3.9560

Remarks: TAPE # 438-11
Pass 540

.010 TAPER 6" Before Starting orginal part taper

Page 3

Machining Conditions

Part Number: 93X3014 Machine: LeBlond Tool Type: DiaSil Coolant: N/A

GE 2000 CONTROLLER

Material: SiC 220Grit Model/Type: TapeLathe Tool Geometry: Flat Top Button 10° NEG. Dia. Concentration: N/A

Part Dimension: 4"X12"

Hardness:

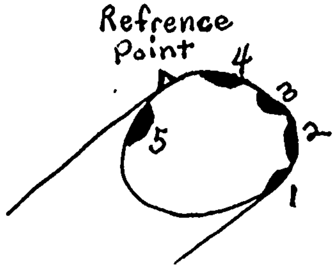
Date May 28, 93

(DIASIC .393) 8/23/93

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	F 3.9405	120%	100%	.020	.010	6"				DULL
3.9413	M 3.9415	550	565					1st Pass	.004 .1mm	
②	B 3.9420							.0015		
	F 3.9230	120%	100%	.020	.010	6"		2nd Pass		
3.9238	m 3.9240	550	565					.0015	.004 .1mm	DULL
	B 3.9245									
3.9100	F 3.9095	500	511	.020	.010	6"		1st Pass	.004 .1mm	DULL
	M 3.9100	112%	100%					.001		
③	B 3.9105									
	F 3.8930	500	511	.020	.010	6"		2nd Pass		DULL
3.8935	m 3.8935	112%	100%					.001	.004	
	B 3.8940								.1mm	

1+Bg bdy —— Lvacalc 2 —— 10ccalc 3+LV

Remarks:



Appendix 4.7

Page ②

Machining Conditions

Part Number: 93X3014 Machine: LeBlond GE 2000 Controller Tool Type: DiaSil Coolant: N/A

Material: 220 GRIT SiC Model/Type: Tape Lathe Tool Geometry: Flat Top Button 10° NEG. Dia. Concentration: N/A

Part Dimension: 4" Dia. X 12"

Hardness:

Date May 28, 93

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.8805	370	[illegible]	.020	.010	6"	1st Pass			DULL
M 3.8810	80%	375					.0005	.004 / .1mm	
B 3.8810									
//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////
F 3.8630	370	[illegible]	.020	.010	6"	2nd Pass			DULL
M 3.8635		375					.0005	.004 / .1mm	
B 3.8635									
//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////
F 3.8505	1380	[illegible]	.020	.010	6"	1st Pass			DULL
M 3.8535		1392					.0045	.035 / .9mm	
B 3.8545									
//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////	//////////
F 3.8385	1000	[illegible]	.020	.010	6"	2nd Pass			DULL
M 3.8410		1006					.0045	.035 / .9mm	
B 3.8430									

3.8808

④

3.8633

3.8528

⑤

TAPE # 435-11

3.8408

VC 4 + by hand

VC5+BV

Remarks:

4

11

Machining Conditions

June 3, 93

Part Number: 93X3011 Machine: LeBlond (GE 2000 CONTROLLER) Tool Type: Dia Sil (.393 Dia. Flat Top) Coolant: N/A

Material: 500 GRIT SiC Model/Type: Tape Tool Geometry: Button (Ø Rake Ø Clearance) Concentration: N/A

Part Dimension: 4" Dia. X 12"

Hardness: ____________

Condition: F

Alloy: Al-10Si

ID#HM-3 022693-2

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 4.0005	325	340	.020	.010	6"				Bright
m 4.0015	100%		100%			1st Pass	.001	.020 .5mm	w/ some chatter
B 4.0015									
F 3.9835	325	340	.020	.010	6"				Bright
m 3.9835	100%		100%			2nd Pass	.001	.020 .5mm	w/ some CHATTER
B 3.9845									
F 3.9705	350	365	.020	.010	6"	1st Pass		.016 .4mm	Dull
m 3.9705	100%		100%				.0005		w/ Some CHATTER
B 3.9710									
F 3.9520	350	365	.020	.010	6"	2nd Pass		.016 .4mm	Dull
m 3.9520	100%		100%				.0015		w/ CHATTER
B 3.9535									

4.001

① 3.98~~43~~38 Pass 140 Prog. RPMs 297

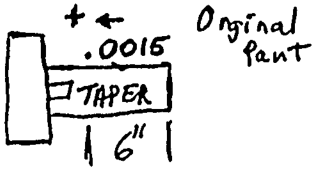
3.9708

② Pass 240 Prog. RPMs 329 3.9528

1 VCC + B# from [illegible]

1 VCT

Remarks:
TAPE 438-11



F 4.0125
m 4.0130
B 4.0135

Part Has Large section of Alum last 3" to 4"

Appendix 4.9

②
June 3, 93

Machining Conditions

Part Number: 93X3011 Machine: LeBlond GE 2000 CONTROLLER Tool Type: DiaSil .393 Dia. Coolant: N/A

Material: 500 GRIT Sic Model/Type: Tape Tool Geometry: Flat Top Button ø Rake ø Clear. Concentration: N/A

Part Dimension: 4" Dia x 12"

Hardness:

Tape 438-11

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.9375	380	390	.020	.010	6"	1st Pass			Dull
M 3.9375	100%		100%				.0005	.012 .3mm	w/CHATTER
B 3.9380									
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
F 3.9195	380	390	.020	.010	6"	2nd Pass		.012 .3mm	Dull
M 3.9205	100%						.001		w/CHATTER
B 3.9205									
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
F 3.9105	415	423	.020	.010	6"	1st Pass		.012 .3mm	VERY DULL
M 3.9105	100%		100%				.0005		LOOK LIKE FINE THREADS
B 3.9110									
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
F 3.8935	415	423	.020	.010	6"	2nd Pass		.012 .3mm	CURLY CHIPS Last 3"
M 3.8935	100%		100%				.0005		
B 3.8940									SMALL AIR HOLES STARTING TO APPEAR

3.9378 Pass 340

③

Prog. RPMs 365 3.9204

3.9106 Pass 440

④

Prog. RPMs 403 3.8936

VC8

VC9

Remarks:

6

6

June 3, 93

Machining Conditions

Part Number: 93X3011 Machine: LeBlond GE 2000 CONTROLLER Tool Type: Diasil .393 Dia. Flat Top Coolant: N/A
Material: 500GRIT SiC Model/Type: Tape Tool Geometry: Button Ø Rake Ø Clearance Concentration: N/A
Part Dimension: 4" Dia X 12"
Hardness:

Tape 438-11 3.878ø Pass 540 ⑤

Program RPMs 433 3.8598

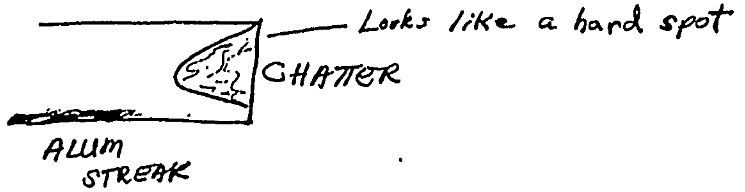
3.8495

Pass 540 3.8363

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.8775	460	467	.020	.010	6"	1st Pass			Little Brighter
M 3.8785	100%						.001	.012 .3 mm	w/Chatter
B 3.8785									
F 3.8595	460	465	.020	.010	6"	2nd Pass			SMALL AIR HOLES
M 3.8600	100%						.0005	.012 .3 mm	
B 3.8600									
	.030	Radius	CBN POS. RAKE						
F 3.8455	460	465	.020	.010	6"	1st Pass			LONG CURLY Chips
M 3.8495	100%						.008		THREAD LIKE SURFACE
B 3.8535				TOOL	BROKE	IN PART	RADIUS		w/CHATTER
			CBN POS	RAKE	.033	Radius			
F 3.8315	410	412	CBN		.033 Radius	7° Clearance		+10° Rake	SAME AS ABOVE
M 3.8365	90%					1st Pass	.0095	.012 .3 mm	
B 3.8410									some Flaking about 1" from end

C-10

Remarks:



Appendix 4.11

④

June 3, 93

Machining Conditions

Part Number: 93X3011 Machine: LeBlond Tool Type: Diasil Coolant: N/A

GE 2000 CONTROLLER .393 Dia. Flat Top

Material: 500 GRIT SiC Model/Type: Tape Tool Geometry: Button Concentration: N/A

Ø Rake Ø Clearance

Part Dimension: 4" Dia X 12"

Hardness:

.033 Rad. CBN POS RAKE

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.8245	410	411	.020	.010	6"	2nd Pass			BRIGHT
M 3.8300	90%						.009	.012 .3mm	w/CHATTER
B 3.8335									
				DIASIL TOOL 6½" Dia 500GRIT LOG					
F 6.6120 6.6370 (?)	380	660	.020	.010	1st Pass		(	)	Dull
M 6.6185 6.6485 (?)							.027	.067 1.7mm	& Rough
B 6.6390									
F 6.6365		660	.020	.010	6"	2nd Pass	.010		Dull
M 6.6430	380		Tool Pushing off about Middle Part					.067 1.7mm	& Rough
B 6.6330									
F 6.6375	380	660	.020	.010	6"	3rd Pass			Dull
M 6.6435							~~.060~~	.067 1.7mm	& Rough
B 6.6400							.006 (?) Hog 8/20/93		

(04289

3.8293

6.6231

6.6373 ⑥

Pass 340

6.6460

Remarks:

	PART TAPER	TOOL WEAR
F 6.6365		.067
M 6.6490	.016	1.7mm
B 6.6525		
RPM 380	SFPM 660	

6.6460

4th Pass Tool Still Pushing off in Middle of Part

8

8

June 3, 93

Machining Conditions

Part Number: 042892 Machine: LeBlond GE 2000 CONTROLLER Tool Type: Kennametal TPG 322 KC910 Coolant: N/A

Material: 500 GRIT SiC Model/Type: TAPE Tool Geometry: ______ Concentration: N/A

Part Dimension: 6" Dia X 8"

Hardness: ______

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
6.6460	F 6.6365	380	660	.020	.010	6"	1st Pass		.047	BRIGHT
	M 6.6500	100%						.015	1.2mm	w/CHATTER
	B 6.6515									
					K060	CERAMIC				
6.6463	F 6.6365	380	660	.020	.010	6"	1st Pass		.177	BRIGHT
	M 6.6505	100%						.0155	4.5mm	
	B 6.6520									
				TPG322	K6	CARBIDE				
6.6475	F 6.6385	380%	660	.020	.010	6"	1st Pass		.055	BRIGHT
	M 6.6515	100%						.014	1.4mm	
	B 6.6525									
				Compact	Diamond	060 Rad.				
6.6440	F 6.6365	380%	660	.020	.010	6"	1st Pass		.031	DULL
	M 6.6435							.0155	.8mm	
	B 6.6520									

Remarks:

June 3, 93

Machining Conditions

Part Number: 042892 Machine: LeBlond GE 2000 CONTROLLER Tool Type: Compact Diamond Coolant: N/A

Material: 500 GRIT SiC Model/Type: TAPE Tool Geometry: .060 Rad Flat Top 10° Clearance Concentration: N/A

Part Dimension: 6" Dia X 8"

Hardness:

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 6.6400	380		.020	.010	6"	2nd Pass			DULL
M 6.6470	100%	660					.0115	.8 mm	
B 6.6515								.031	
//////	//////	////	Compact Dia .125 Radius			Norton	6° Clearance -3° Rake		/////
F 6.6355	380	660	.020	.010	6"	1st Pass			DULL
M OUT PART 6.640	100%		Broke 2" into Cut				.004	BROKE	
B Didn't cut									

6.6461

6.6426

Remarks:

v

Machining Conditions

Part Number: 042892 Machine: LeBlond Tape Tool Type: Kennametal TPG-322 K11 Coolant: N/A

Material: SiC 500GRIT Model/Type: ______ Tool Geometry: Triangle Concentration: N/A

Part Dimension: 6.6 Dia. X 8

Hardness: ______

Tape # BO 435-11 Pass 140 RPM 891 IPR .020

Workpiece Diameter(in)	Spindle RPMs	SFPM(in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F K-11	860	1500	.020	.010	5.800			.062	16mm
K-7H	860	1500	.020	.010	5.800			.078 2.0mm	Rough
K-6	860	1500						.059 1.5mm	
K-68	860 1.8mm	1500	Flat Top	500RPM	(SFRM) 822	5 3/8 cut		[illegible]mm	50.RPMS .070 1.8mm
VESSON 2A5	560	872	[illegible]		5 3/8			.051 1.3mm	
2A7	560	872			"			.059 1.5mm	
YR52	500	872	/		"			.059 1.5mm	
Diasil .393Dia	500	872	START	DIA.	F/6.6365	m/6.6380	B/6.635		
F 6.6195	1st Pass	F 6.6215	Pos Rake					1.4 .055 mm	
B 6.6345	←	M 6.6345			Push off	2nd Pass	Halfway		
B 6.6305	2nd Pass →	B 6.6410	/////////						
F 6.6130	← 1st Pass	F 6.6125	Neg Rake					1.8mm .070	
M 6.6365	2nd Pass →	M 6.6330			Push off	1st Pass	Halfway	Dull	
B 6.6410		B 6.6385				2nd Pass		Finish	

Remarks:

June 16, 93

Machining Conditions

.393 Dia.

Part Number: 93X3014 Machine: LeBlond GE2000 CONTROLLER Tool Type: Diasil Coolant: N/A

Material: 220 GRIT SiC Model/Type: TAPE Tool Geometry: 5° Neg Rake Concentration: N/A

Part Dimension: __________

Hardness: __________

TAPE 438-11

Pass 149

cut #1

[illegible]

Pass 540

cut #2

Tool #2

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.8245	335	350	.020	.010	6"	F 3.7910			Dull Dull
M 3.8250	113%				#1 .008 WEAR	M 3.7915			
B 3.8265					TAPER .002	B 3.7915	.0005		
F 3.8070				VC-11		F 3.7730		.2mm ÷2	
M 3.8065						M 3.7730	12	#2 .008	
B 3.8070					TAPER .0005	B 3.7730	0		
F	475	500	.020	.010	6"				
F 3.7595	110%					F 3.7275			Dull Dull
M 3.7595					#1 .008	M 3.7275			
B 3.7595				VC13	TAPER 0	B 3.7275	0		
F 3.7415						F 3.7085	14		
M 3.7410						M 3.7085		.1mm ÷2	
B 3.7410					TAPER .0005	B 3.7085	0	#2 .004	

297 RPM

433 RPM

Remarks:

669

779.

Appendix 4.16

June 16, 93

Machining Conditions

Part Number: 93X3014 Machine: LeBlond (GE 2000 controller) Tool Type: .393 Dia Diasil Coolant: N/A

Material: 220 GRIT SiC Model/Type: Tape Tool Geometry: 5° Neg Rake Concentration: N/A

Part Dimension:

Hardness:

TAPE 437-11

Pass 240

cut #3

659 RPM

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.6955	715	750	.020	.010	6"	F 3.6640			DULL
M 3.6950	109%				#1 .012	M 3.6645	.0005		
B 3.6955					TAPER .0005	B 3.6645			
F 3.6770						F 3.6460	16		
M 3.6780						M 3.6470	.001	.3 mm^2	
B 3.6785					TAPER .0015	B 3.6460			
								#2 .012	

Remarks:

Appendix 4.17

June 16, 93

Machining Conditions

Part Number: 93X3011 Machine: Le Blond GE 2000 Controller Tool Type: .393 Dia. Diasil Coolant: N/A

Material: 500 GRIT SiC Model/Type: Tape Tool Geometry: 5° Neg Rake Concentration: N/A

Part Dimension:

Hardness:

TAPE 438-11

Pass 140

cut #4

Pass 540

cut #5

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.8110	475	350	.020	.010	6"	F 3.7805		#2 .008	DULL [illegible]
M 3.8130	113%				#1 .004	M 3.7815	.002	[illegible] #2	
B 3.8140					TAPER .003	B 3.7825			
F 3.7935		Tool #1	[illegible]	[illegible]		F 3.7635			
M 3.7950				about 4"	where	M 3.7655	.0025		
B 3.7955				[illegible] Alan spot	TAPER .002	B 3.7660			
	475	500	.020	.010	6"				
F 3.7485	110%		Tool #1 curly	chips start		F 3.7130		#2 .008	DULL
M 3.7500				about 3"	#1 .008	M 3.7145	.0015	[illegible] #2	CHATTER
B 3.7505					TAPER .002	B 3.7140			
F 3.7320						F 3.6945			
M 3.7335						M 3.6955	.001		
B 3.7330					TAPER .0015	B 3.6950			

Remarks:

6/16/93

Machining Conditions

Part Number: 93X3011 Machine: LeBlond GE2000 Controller Tool Type: .393 Dia. Diasil Coolant: N/A

Material: 500 GRIT SiC Model/Type: Tape Tool Geometry: 5° Neg Rake Concentration: N/A

Part Dimension: ____________

Hardness: ____________

actual cut time =23 sec/6" per } auto mode 6/22/93

TAPE 437-11

Pass 240

cut #6

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
F 3.6819	715	750	.020	.010	6"	3,650.5		Tool #1	
M 3.6815	109%	√32 .63				3,651.5		.1 mm .004	
B 3.6815						3,651.5			
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
F 3.6645		√32 .63				3,634			
M 3.6645						3.634		Tool #2 .[illegible] mm	
B 3.6655						3,635		.004	

Remarks:

July 8, 93

Machining Conditions

Part Number: 91X3014 Machine: LeBlond OE 2000 Controller Tool Type: .393 Dia. Diasil Coolant: N/A

Material: 220 GRIT SiC Model/Type: Tape Tool Geometry: 5° Neg Rake Concentration: N/A

Part Dimension: 5.997 X 14

Hardness:

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
2nd cut Tool#1	F 5.9500	335	350	.020	.010	6"				Short Curly
	M 5.9510							.002	.3mm .012	Chips
	B 5.9520									Dull Finish
Pass 240	F 5.9185									Short Curly
Tool#2	M 5.9195							.001	.3mm .012	Chips
	B 5.9195									Dull Finish
		475	500	.020	.010	6"				
3rd cut Tool#1	F 5.8905									" "
	M 5.8920							.002	.4mm .016	"
	B 5.8925									" "
Pass 540 Tool#2	F 5.8585									" "
	M 5.8595							.002	.4mm .016	"
	B 5.8605									" "

Remarks: TAPE # BO 438-11

Machining Conditions

July 8, 93

Part Number: 91X3014 **Machine:** LeBlond GE 2000 CONTROLLER **Tool Type:** .393 Dia. Diasil **Coolant:** N/A

Material: 220 GRIT SiC **Model/Type:** TAPE **Tool Geometry:** 5° Neg Rake **Concentration:** N/A

Part Dimension: 6.023 X14

Hardness:

First cut to Left of Break on tool#1

1st cut Tool#1

Tool#2

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
E 6.0035	715	750	.020	.010	6"				CAST IRON
M 6.0085							.0105	1.0mm .039	LIKE CHIPS
B 6.0140									
F 5.9845									CAST IRON
M 5.9900								1.0mm .039	LIKE CHIPS
B 5.9975							.013		DULL FINISH

Remarks: TAPE# BO 437-11 Pass 240

July 8, 93

Machining Conditions

Part Number: 91X3011 Machine: LeBlond GE 2000 Controller Tool Type: .393 Dia. Diasil Coolant: N/A

Material: 500 GRIT SiC Model/Type: Tape Tool Geometry: 5° Neg Rake Concentration: N/A

Part Dimension: 5 7/8 X 14

Hardness: ________________

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Tool#1	F 5.8130	335	350	.020	.010	6"				Long Curly Chips
	M 5.8135							.0005	.2mm .008	
	B 5.8135									Bright Finish
Pass 240	F 5.7810									Long Curly Chips
Tool#2	M 5.7825							.0015	.2mm .008	
	B 5.7825									
		475	500	.020	.010	6"				
Tool#1	F 5.7190									Long Curly Chips
	M 5.7190							.0000	.3mm .012	
	B 5.7190									
Pass 540	F 5.7505									Long Curly Chips
Tool#2	M 5.7510							.0005	.3mm .012	
	B 5.7505									

Remarks: TAPE: B0438-11

Machining Conditions

July 8,93

Part Number: 91X3011 Machine: LeBlond GE 2000 Controller Tool Type: .393 Dia. Diasil Coolant: N/A

Material: 500GRITSiC Model/Type: Tape Tool Geometry: 5° Neg Rake Concentration: N/A

Part Dimension: 5.719 X 14

Hardness:

Tool#1 cut#3 HAS EDM CUT IN MIDDLE Tool#2 Cut#3 HAS EDM CUT IN MIDDLE TOO.

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Tool#1	F 5.6875	715	750	.020	.010	6"				CAST IRON
	M 5.6890							.003	.4mm .016	LIKE CHIPS
	B 5.6905									
	F 5.6560									CAST IRON
Tool#2	M 5.6570							.003		LIKE CHIPS
	B 5.6590								.4mm .016	DULL FINISH

Remarks: Tape# B0437-11 Pass 240

Machining Conditions

Part Number: 91X1060HT Machine: LeBlond Tool Type: ______ Coolant: None

Material: S/C/Al Model/Type: GE 2000 CONTROLLER Tool Geometry: 55° Diamond ½ I.C. PCD INSERTS Concentration: N/A

Part Dimension: 6X14

Hardness: ______

Sept. 14 & 15

Page 1 of 2

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
SINGLE PASS	CLEANUP PART*	935	1469	.020	.010	6	SUMITOMO	TOOL	.008	214
ref 1 DC TOOL DNGA 432	① 5.9530 *									TOO HIGH FOR SCALE
700 GRADE	5.9530	935	1458	PROGRAM .020	.010				.009	CHIP SHORT CURLY
	5.9535	SINGLE PASS		20 sec. cutting TIME						SPRAY LIKE CAST IR
ACCURATE	② 5.9335 *									
DNGA 432	5.9330	935	1453	.020/50%	.010				.0075	108
ref 2 CP 100 .021	5.9325	SINGLE Pass		.010 IPR 40 sec. cutting time						
Kennametal	③ A 5.9165 *									
DNGA 433	5.9165	935	1449	.020/50%	.010		40 sec		.0035	63
KD100	5.9160			.010 IPR						
ref 3	B 5.8965								.0055	67
	5.8960	935	1444	50%	.010		80 sec			
	5.8965			.010 IPR						~~67~~
	C 5.8805*								.006	67
	5.8805	935	1440	50%	.010		120 sec			

.010 IPR

Remarks: 5.8805

* Touch Up Pass

Appendix 4.24

1

Machining Conditions

Part Number: 91X1060HT Machine: Le Blond Tool Type: ______ Coolant: None

Material: Sic/Al Model/Type: GE 2000 Controller Tool Geometry: 55° Diamond ½ I.C. PCD INSERT Concentration: N/A

Part Dimension: 5.880 X 14

Hardness: ______

Sept 14 & 15

Page 2 of 2

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Kennametal	D 5.8615			.010 IPR						
DNGA 433	5.8610	935	1435	.020/50%	.010		160 sec		.007	75
KD100	5.8610			40 sec. cutting time						
	E 5.8450 *									
.071	5.8450	935	1431	50%	.010		200 sec		.010	77
	5.8450			.010 IPR						
J+M TOOL	5.8230 *									
DNGA 433	5.8235	935	1426	50%	.010				.010	74
N/A	5.8240			.010 IPR						
J+M FLIP TIP	5.8135 *				TOOL WORN OUT 1st 1 inch or Less					TOO HIGH TO READ
CBN DNMA 433	5.8235	935	1426	50%	.010	Quick - wear too excessive			.100	
	5.8240			.010 IPR		for data to be meaningful				
SUMITOMO	5.7860									
DNMX 433	5.7865	935	1417	50%	.020				.008	74
N/S .063	5.7870			.010 IPR						

Remarks:

* Touch Up Pass

TOTAL STOCK REMOVED .213

[illegible] 27, 93

Machining Conditions

Part Number: 91X1060HT Machine: LeBlond Tool Type: Norton DT 100L DNGA 433 ~~55 Diamond~~ Coolant: None

Material: SIC/AL Model/Type: GE.2000 CONTROLLER Tool Geometry: 55° Diamond Concentration: N/A

Part Dimension: 5.787 X 14

Hardness:

Page 1 of 4

NORTON DT 100L DNGA 433

CHANGE TAPES

Workpiece Diameter(in)	Spindle RPMs	SFPM(in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.7735 *			.010	.010	6"	40			Bright Surface
5.7735	935	1414						.0025	74
5.7740									SHORT CURLY CHIPS
5.7535									
5.7530	935	1409	.010	.010	6"	80		.003	72
5.7535									
5.7370 *			.020						
5.7365	935	1405	50% =.010	.010	6"	120		.0035	75
5.7365									
5.7170			.020						
5.7170	935	1400	50% =.010	.010	6"	160		.0035	69
5.7165									
5.7010 *			.020						
5.7005	935	1396	50% =.010	.010	6"	200		.004	65
5.7005									

[illegible] .004
.003

Remarks: * TOUCH UP PASS

5 Passes Norton Tool

Apr 24, 93

Machining Conditions

Part Number: 91X1060HT Machine: LeBlond Tool Type: NORTON DT100L DNGA 433 Coolant: None

Material: SIC/AL Model/Type: GE.2000 CONTROLLER Tool Geometry: 55° Diamond Concentration: N/A

Part Dimension: 5.700 X 14

Hardness:

Page 2 of 4

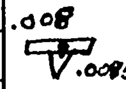
NORTON DT100L DNGA 433

.126

DC. TOOLS DPGA 432

M1

Workpiece Diameter(in)	Spindle RPMs	SFPM(in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.6815			.020	.010	6"	240			Bright Surface
5.6805	935	1392	50% = .010					.005	68
5.6810									
5.6670 *			.020						
5.6670	935	1388	50% = .010	.010	6"	280		.005	68
5.6665									
5.6475			.020					.008	
5.6465	935	1383	50% = .010	.010	6"	320		~~.0165~~	83
5.6470									
5.6305 *			.020	DPGA	432	DC TOOL CO.			DULL SURFACE CAST IRON LIKE CHIPS
5.6310	935	1379	50% = .010	.010	6"	40		.003	116
5.6315									
5.6155			.020						
5.6160	935	1375	50% = .010	.010	6"	80		.003	109
5.6155									



Remarks: * TOUCH UP PASS

8 PASSES TOTAL NORTON TOOL

2 PASSES DC. TOOL

Sept 29, 93

Machining Conditions

Part Number: 91X1060HT Machine: LeBlond Tool Type: DC. TOOL Co. OPGA 432 Coolant: None

Material: SIC/AL Model/Type: GE 2000 CONTROLLER Tool Geometry: 55°Diamond Concentration: N/A

Part Dimension: 5.616 X14

Hardness:

DC. TOOL
OPGA 432

Page 3 of 4

Workpiece Diameter(in)	Spindle RPMs	SFPM(in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.5980 *			.020	.010		120			SURFACE A LITTLE BRIGHTER
5.5980	935	1371	50% = .010					.004	
5.5980									110
5.5780			.020						
5.5785	935	1366	50% = .010	.010		160		.0045	112
5.5785									
5.5650 *			.020						
5.5650	935	1363	50% = .010	.010		200		.0045	119
5.5650									
5.5445			.020						
5.5450	935	1358	50% = .010	.010		240		.0055	117
5.5445									
5.5295 *			.020						
5.5295	935	1354	50% = .010	.010		280		.0055	119
5.5295									

Remarks: * TOUCH UP PASS

Sept. 29, 93

Machining Conditions

Part Number: 91X1060HT Machine: LeBlond Tool Type: DC TOOL CO DPGA 432 Coolant: None

Material: SIC/AL Model/Type: G.E. 2000 Controller Tool Geometry: 55° Diamond Concentration: N/A

Part Dimension: 5.529 X14

Hardness: ______

DC TOOL ~~DPGA~~ 432 DPGA

Page 4 of 4

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.5095			.020	.010	6"	320		.007	134
5.5095	935	1350	50% = .010						
5.5095									
5.4955 *			.020	.010	6"				
5.4955	935	1346	50% = .010			360		.0085	128
5.4955									
5.4780 *			.020						
5.4770	935	1342	50% = .010	.010	6"	400		.0085	134
5.4775									
5.4565			.020						
5.4560	935	1337	50% = .010	.010	6"	440		.0145	132
5.4560									

.191

Remarks: * TOUCH UP PASS

11 ~~9~~ Passes Total
les

Nov. 1, 93

Machining Conditions

Part Number: 93X3011 Machine: LeBlond Tool Type: Carboloy Coolant: N/A

Material: SiC Model/Type: GE 2000 Controller Tool Geometry: .021 Rad Concentration: N/A

T2A 33840
DB3345

Part Dimension: 3.632 X 14

SURFACE AT START 88 Ra

Hardness: 94.8 RK

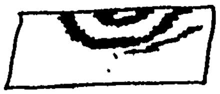
ref 8

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
3.6125									
3.6125	950	900	.010	.010	6"	40	.0005	.003	89
3.6120									CHATTER LIKE FRONT END
3.5915									
3.5905	950	894	.010	.010	6"	80	.001	.007	90 Front
3.5905									42 Back
3.5715									
3.5710	950	889	.010	.010	6"	120	.001	.0085	93 F 55 B
3.5705									
3.5555								.012	95 F 68 B
3.5545	950	885	.010	.010	6"	160	.0015		
3.5540									
3.5405									
3.5405	950	881	.010	.010	6"	200		.013	Rough F
3.5400									65 B

cut too deep can't get reading

Remarks: TAPE # 80435-11

Part has aluminum strikes



Nov 1, 93

Machining Conditions

Part Number: 93X3011 Machine: LeBlond GE 2000 Tool Type: Carboloy Coolant: N/A

Material: SiC Model/Type: Controller Tool Geometry: .02 Rad. Concentration: N/A

T2A 33840
DB 3345

Part Dimension: 3.540 X 14

Hardness: 94.8RK

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
3.5225									
3.5215	950	876	.010	.010	6"	240	.0015	.013	55 Back
3.5210									
3.5100									
3.5090	950	874	.010	.010	6"	280	.0015	.0165	42 Back
3.5085									
3.4925									
3.4915	950	869	.010	.010	6"	300	.0015	.0175	79 Back
3.4910									

Remarks:

Nov. 1, 93

Machining Conditions

Part Number: 91X1060HT Machine: LeBlond Tool Type: Kennametal Coolant: N/A

Material: SIC Model/Type: GE2000 Controller Tool Geometry: .150 Rad. T2A33840 Concentration: N/A

Part Dimension: 6 X 14

Hardness: 87.4 RK

#9

Workpiece Diameter(in)	Spindle RPMs	SFPM(in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.9980			ON CENTER						
5.9975	950	1493	.010	.010	6"	40	.0005		39
5.9975									
5.9775									
5.9775	950	1488	.010	.010	6"	80	.0015	.004	35
5.9760									
5.9355									
5.9345	950	1477	.010	.010	6"	120	.001		44
5.9350									
5.9155									
5.9155	950	1472	.010	.010	6"	160	.0005	.004	41
5.9150									
5.9020									
5.9015	950	1469	.010	.010	6"	200	.001		42
5.9010									

Remarks:

Nov. 1, 93

Machining Conditions

Part Number: 91X1060HT Machine: LeBlond Tool Type: Kennametal Coolant: N/A

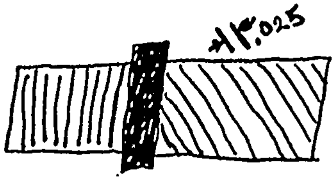
Material: SiC Model/Type: GE2000 CONTROLLER Tool Geometry: .150 Rad T2A 33840 Concentration: N/A

Part Dimension: 5.901X14

Hardness: 87.4 RK

Workpiece Diameter(in)	Spindle RPMs	SFPM(in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.8830									
5.8820	950	1464	.010	.010	6"	240	.0015	.0045	59
5.8815									
5.8675									
5.8665	950	1460	.010	.010	6"	280	.002		75
5.8655									
5.8480									
5.8470	950	1455	.010	.010	6"	320	.0015	.0055	66
5.8465									
5.8315									
5.8305	950	1451	.010	.010	6"	360	.001		46
5.8305									
5.8125									
5.8115	950	1446	.010	.010	6"	400	.0015	.006	56
5.8110									

Remarks:



Machining Conditions

Page 5 of 10

Part Number: 91X1060HT Material: SiC Part Dimension: 5.811X14 Date: Nov 1,93

Machine: LeBlond Model/Type: GE2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: .150 Radius T2A33840

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.7980									
5.7975	950	1443	.010	.010	6"	440	.001		60
5.7970									
5.7785									
5.7775	950	1438	.010	.010	6"	480	.002	.006	61
5.7765									
5.7655									
5.7645	950	1435	.010	.010	6"	520	.002		65
5.7635									
5.7460									
5.7455	950	1430	.010	.010	6"	560	.0015	.006	65
5.7445									
5.7305									
5.7305	950	1426	.010	.010	6"	600	0		60
5.7305									

Remarks:

Machining Conditions

Page 6 of 10

Part Number: 91X1060HT Material: SiC Part Dimension: 5730X14 Date: Nov. 2, 93

Machine: LeBlond Model/Type: GE 2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: .150 Radius T2A 33840

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.7125									
5.7115	950	1421	.010	.010	6"	660	.002	.006	44
5.7105									
5.6980									
5.6975	950	1418	.010	.010	6"	700	.002		52
5.6960									
5.6795									
5.6785	950	1413	.010	.010	6"	740	.0015	.006	66 F 33 B
5.6780									
5.6680									
5.6670	950	1410	.010	.010	6"	780	.002		57
5.6660									
5.6490									
5.6480	950	1406	.010	.010	6"	820	.0015	.0065	44 F 33 B
5.6475									

Diagonal line back

Changed Back to Radial

Last 4"

Finish change Diagonal Lines

Diagonal First 4" Radial Last 2" CUT #16

SOUND/CHANGE T8

Remarks:

Appendix 4.35

Machining Conditions

Page 7 of 10

Part Number: 91X1060HT Material: SiC Part Dimension: 5.647X14 Date: Nov 2, 93

Machine: LeBlond Model/Type: GE2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: .050 Radius T2A33840

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.6345						860			
5.6335	950	1402	.010	.010	6"		.001		41
5.6335									
5.6165									
5.6160	950	1398	.010	.010	6"	900	.0015	.008	36 F 32 B
5.6150									
5.6020									
5.6020	950	1394	.010	.010	6"	940	.0015		51
5.6005									
5.5885									
5.5875	950	1390	.010	.010	6"	980	.001	.008	55 F 31 B
5.5875									
5.5705									
5.5695	950	1386	.010	.010	6"	1020	.001		53
5.5695									

Remarks: Diagonal Lines appear about everyother cut
Have seen a few small sand hole 3-5 .020 - .030 diameter .010 - .020 Deep

Appendix 4.36

Machining Conditions

Page 8 of 10

Part Number: 91X1060HT Material: SiC Part Dimension: 5.569X14 Date: Nov2,93

Machine: LeBlond Model/Type: GE 2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: .150 Radius T2A 33840

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.5525									
5.5515	950	1381	.010	.010	6"	1060	.0015	.008	56 F/35 B
5.5510									
5.5400									
5.5390		1378	.010	.010	6"	1100	.0015		42
5.5385	950								
5.5215									
5.5210	950	1374	.010	.010	6"	1140	.001	.008	45 F/37 B
5.5205									
5.5095									
5.5085	950	1371	.010	.010	6"	1180	.002		59
5.5075									
5.4910									
5.4915	950	1367	.010	.010	6"	1220	.0005	.0125	39 F/34 B
5.4910									

Remarks:

Machining Conditions

Page 9 of 10

Part Number: 91X1060HT Material: SiC Part Dimension: 5.491 X 14 Date: Nov 2, 93

Machine: Le Blond Model/Type: GE 2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal/Tool Geometry: .150 Radius T2A 33840

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.4775									
5.4770	950	1363	.010	.010	6"	1260	.001		49
5.4765									
5.4585									
5.4585	950	1358	.010	.010	6"	1300	.001	.014	36F/38B
5.4575									
5.4415									
5.4415	950	1354	.010	.010	6"	1340	.0015		45F/36B
5.4400									
5.4225									
5.4210	950	1349	.010	.010	6"	1380	.0015	.0145	41F/37B
5.4225									
5.4135									
5.4135	950	1347	.010	.010	6"	1420	.0005		48F/37B
54130									

Lot of Build Up under side of tool

Remarks:

Machining Conditions

Page 10 of 10

Part Number: 91X1060HT Material: SiC Part Dimension: 5.413X14 Date: Nov 2 93

Machine: LeBlond Model/Type: GE 2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: .150 Radius T2A33840

.604

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.3955									
5.3950	950	1343	.010	.010	6"	1460	.0015	.0175	40/370 *
5.3940									

Lot of Build Up UNDER Tool

Remarks:

Machining Conditions

Page 1 of 13

Part Number: 91X1060HT Material: SiC Part Dimension: 5.395 X 14 Date: Nov 4, 93

Machine: LeBlond Model/Type: GE 2000 Controllor Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: .150 Radius T2A 33840

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.3780			75%						Radial
5.3770	1060	1498	.015	.010	6"	24	.002		.68
5.3760									
5.3585									
5.3575	1060	1488	.015	.010	6"	48	.001	.015	71
5.3575									
.020									
CHANGE TOOL TPG		322 PAX 3							
5.3405	1060	1483	.010	.010	6"				Radial
5.3405						40 sec.	.0005		151
5.3410									
5.3215									
5.3215	1060	1477	.010	.010	6"	80	0	.0075	158
5.3215									
.020									

No Diangal Lines

DULL

.010

Remarks: TAPE BO 435-11 Pass 240 988 Program RPM INCREASED 7% 1057 1st two runs
TAPE DO 435-11 Pass 240 7% increase RPM Feed Rate .010

4

Machining Conditions

Page 2 of 13

Part Number: 91X1060HT Material: SiC Part Dimension: 5.321X14 Date: Nov. 4, 93

Machine: LeBlond Model/Type: GE 2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Carboly Tool Geometry: TPG 322 PAX3

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.3035									
5.3040	1060	1473	.010	.010	6"	120	.0005		167
5.3040									
5.2845									
5.2840	1060	1467	.010	.010	6"	160	.0005	.0075	144
5.2840									
5.2690									
5.2685	1060	1463	.010	.010	6"	200	.0005		131
5.2690									
5.2490									
5.2490	1060	1457	.010	.010	6"	240	0	.010	120
5.2490									
5.2335									
5.2335	1060	1453	.010	.010	6"	280	0		111
5.2335									
.108									

Build Up
under Side
of Tool

Sound
change
Little
CHATTER
NEAR
BACK

Remarks:

Machining Conditions

Page 3 of 13

Part Number: 91X1060HT Material: SiC Part Dimension: 5.233X14 Date: Nov 4,93

Machine: LeBlond Model/Type: GE 2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Carboly Tool Geometry: TPG 332 PAX3

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.2150									
5.2145	1060	1447	.010	.010	6"	320	.0005	.016	111
5.2145									
5.1985									
5.1975	1060	1443	.010	.010	6"	360	.001		124
5.1980									
5.1790									
5.1795	1060	1438	.010	.010	6"	400	.0005	.0175	140
5.1795									
DIASIL	.196 Radius	5° Pos. Clearance		¢					
5.1620									
5.1640	1100	1500	.010	.010	6"	40acc.	+.0035		84
5.1655									
5.1460									
5.1510	1110	1498	.010	.010	6"	80	+.008	.050	
5.1540									24 on FRONT END

.162

.025

Remarks:

Lots of Build Up

VIRBRATION FEEL ON Boring Bar

CHATTER ALL OVER

Diangal Line Back again

CHATTER

Build Up Under Side Tool

Machining Conditions

Page 4 of 13

Part Number: 91X1060HT Material: SiC GE2000 Part Dimension: 5.154X14 Date: Nov 4, 93

Machine: LeBlond Model/Type: CONTROLLOR Coolant: N/A Concentration: N/A

Tool Type: DIASIL Tool Geometry: .196 Radius Neg. allway around .030 Below ℄

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.1380	1110		.010	.010	6"	40			24 FRONT 1½" CHATTER
5.1400		1494					+.007		
5.1450									
5.1270									
5.1300	1110	1491	.010	.010	6"	80	+.0075	.038	43 CHATTER
5.1345									
.021 Radius	Kennametal		T2A33832		.040 Below				
5.1115			75%						SHORT CURLY CHIPS
5.1105	750	1004	.015	.010	6"	35 [illegible]	.001		thread like
5.1110									FINISH
5.0925									
5.0920	750	1000	.015	.010	6"	70	.001	.004	Im [illegible]
5.0915									

Remarks:

Appendix 4.43

Machining Conditions

Page 5 of 13

Part Number: 91X1060HT Material: SiC Part Dimension: 5.092X14 Date: Nov 4, 93

Machine: LeBlond Model/Type: GE2000 Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A 33833 .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.0780									Thread like
5.0775	750	998	.015	.010	6"	110	.0005		FINISH
5.0775									
5.0575									
5.0570	750	994	.015	.010	6"	145	.0005	.004	" " "
5.0570									
5.0405									
5.0405	750	990	.015	.010	6"	180	0		" " "
5.0405									
5.0210									
5.0205	750	987	.015	.010	6"	215	.001	.0045	" " "
5.0200									
5.0045									
5.0040	750	983	.015	.010	6"	250	.001		" " "
5.0035									

Remarks:

Machining Conditions

Page 6 of 13

Part Number: 91X1060 HT Material: SiC Part Dimension: 5.003 X 14 Date: Nov 4, 93

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A 33833 .021 Radius

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	4.9835									Thread like
	4.9840	750	979	.015	.010	6"	285	+.0005	.0055	FINISH
	4.9840									
	4.9705									" "
	4.9695	750	976	.015	.010	6"	320	.0015		"
	4.9690									
	4.9505									" "
	4.9500	750	973	.015	.010	6"	355	.001	.006	"
	4.9495									
Nov. 11, 93	4.9580	OPPOSITE	END OF	LOG 91X	1060 HT					
	4.9565	750	974	.015	.010	6"	390	.002		" "
	4.9560									"
	4.9325									
	4.9345	750	969	.015	.010	6"	425	.001	.006	" "
	4.9345									"

Remarks:

Appendix 4.45

Machining Conditions

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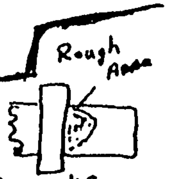
Part Number: 91X1060HT Material: SiC Part Dimension: 4.931 X 14 Date: Nov. 11, 93

Machine: LeBlond Model/Type: CE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A 33833 .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.9160									Thread Like Finish
4.9160	750	966	.015	.010	6"	460	.0005		
4.9155									
4.8970									Rough Spot
4.8965	750	962	.015	.010	6"	495	.0005	.006	
4.8965									Rough Spot TAPERING out
4.8830									
4.8820	750	959	.015	.010	6"	530	.001		
4.8820									
4.8625									Rough Spot GONE
4.8615	750	955	.015	.010	6"	565	.001	.006	SOUND GONE
4.8615									
4.8470									
4.8460	750	952	.015	.010	6"	600	.001		
4.8460									



Looks Like Fibers

Sounds Like Chatter But Not

Remarks:

Machining Conditions

Page 8 of 13

Part Number: 91X1060HT Material: SiC GE 2000 Part Dimension: 4.847 X 14 Date: Nov. 11, 93

Machine: LeBlond Model/Type: Controller Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A 33833 .021 Radius

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.8270									THREAD LIKE FINISH
4.8265	750	948	.015	.010	6"	635	.0015	.006	
4.8255									
4.8120									
4.8115	750	946	.015	.010	6"	670	.001		
4.8110									
4.7925									THREAD LIKE FINISH
4.7910	750	941	.015	.010	6"	705	.002	.006	
4.7905									
4.7765									
4.7760	750	938	.015	.010	6"	740	.001		
4.7755									
4.7570									
4.7560	750	935	.015	.010	6"	775	.0015	.008	THREAD LIKE FINISH
4.7555									

Remarks:

Machining Conditions

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Part Number: 91X1060HT Material: SiC Part Dimension: 4.756X14 Date: Nov 11, 93

Machine: LeBlond Model/Type: GE2000 CONTROLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A33833 .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.7405							.001		
4.7405	750	931	.015	.010	6"	810	~~.0005~~		
4.7395									
4.7205									
4.7200	750	927	.015	.010	6"	845	.001	.008	THREAD LIKE FINISH
4.7195									
4.7065									
4.7055	750	924	.015	.010	6"	880	.0015		
4.7050									
4.6860									
4.6855	750	920	.015	.010	6"	915	.0015	.008	THREAD LIKE FINISH
4.6845									
4.6695									
4.6695	750	917	.015	.010	6"	950	.001		
4.6685									

Remarks:

Machining Conditions

Page 10 of 13

Part Number: 91X1060HT Material: SiC Part Dimension: 4.669X14 Date: Nov 11, 93

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A33833 .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.6495									THREAD LIKE FINISH
4.6490	750	914	.015	.010	6"	985	.001	.008	
4.6485									
4.6350									
4.6340	750	911	.015	.010	6"	1020	.0015		
4.6335									
4.6155									
4.6145	750	907	.015	.010	6"	1055	.0015	.010	THREAD LIKE FINISH
4.6140									
4.5990									
4.5985	750	904	.015	.010	6"	1090	.001		
4.5980									
4.5795									
4.5780	750	900	.015	.010	6"	1125	.002	.010	THREAD LIKE FINISH
4.5775									

Remarks:

Machining Conditions

Page 11 of 13

Part Number: 91X1060HT Material: SiC Part Dimension: 4.578X14 Date: Nov. 15, 93

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: W/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A 33833 .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.5645									THREAD LIKE FINISH
4.5630	750	896	.015	.010	6"	1160	.002		
4.5625									
4.5440									
4.5435	750	893	.015	.010	6"	1195	.0015	.010	THREAD LIKE FINISH
4.5425									
4.5295									
4.5285	750	890	.015	.010	6"	1230	.0015		
4.5280									
4.5090									
4.5080	750	886	.015	.010	6"	1265	.0015	.0115	" " "
4.5075									
4.4945									
4.4930	750	883	.015	.010	6"	1300	.002		" " "
4.4925									

Remarks:

Machining Conditions

Page 12 of 13

Part Number: 91X1060HT Material: SiC Part Dimension: 4.494X14 Date: Nov. 15, 93

Machine: LeBlond Model/Type: CE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A 33833 .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.4740									THREAD LIKE FINISH
4.4735	750	879	.015	.010	6"	1335	.0015	.012	
4.4725									
4.4595									
4.4585	750	876	.015	.010	6"	1370	.001		" " "
4.4585									
4.4345									
4.4335	750	871	.015	.010	6"	1405	.001	.0125	" " "
4.4335									SMALL SAND HOLES 40x5
4.4245									
4.4245	750	869	.015	.010	6"	1440	.0005		THREAD LIKE FINISH
4.4240									
4.4055									
4.4050	750	865	.015	.010	6"	1475	.001	.0125	" " "
4.4045									

Remarks:

Appendix 4.51

Machining Conditions

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Part Number: 91X1060HT Material: SiC Part Dimension: 4.404X14 Date: Nov. 15, 93

Machine: LeBlond Model/Type: GE 2000 CONTROLLER 2 Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: TRA 33833 .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.3915									THREAD LIKE FINISH
4.3905	750	863	.015	.010	6"	1510	.001		
4.3905									
4.3715									
4.3705	750	860	.015	.010	6"	1545	.001	.014	" " "
4.3705									
4.3545									
4.3540	750	856	.015	.010	6"	1580	.001		" " "
4.3535									
4.3345									
4.3340	750	852	.015	.010	6"	1615	.0005	.0165	" " "
4.3340									

NOISE & CHATTER

.777

Remarks:

Machining Conditions

Page 1 of 6

Part Number: 91X1060HT Material: SiC Part Dimension: 5.455X14 Date: Nov. 10,93

Machine: LeBlond Model/Type: GC 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Dessau Tool Tool Geometry: T2A-33840B.021 Radius

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.4180	972	~~1400~~	.015	.010	6"	~~40~~			SMALL CHATTER
5.4190		1381				25	.002		89
5.4170									
5.3990									
5.3975	972	1376	.015	.010	6"	50	.002	.0055	79
5.3970									
5.3830									
5.3820	972	1372	.015	.010	6"	75	.0015		80
5.3815									
5.3635									
5.3625	972	1367	.015	.010	6"	100	.0015	.008	78
5.3620									
5.3460									
5.3460	972	1363	.015	.010	6"	125	.0015		40
5.3445									

Remarks: TAPE B0435-11
Run 140

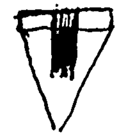
Machining Conditions Page 2 of 6

Part Number: 91X1060 HT Material: SiC GE 2000 Part Dimension: 5.346 X 14 Date: Nov 10, 93

Machine: LeBlond Model/Type: Controlled Coolant: N/A Concentration: N/A

Tool Type: Pessau Tool Tool Geometry: T&A-33 840-B .020 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.3295	972	1358	.015	.010	6"	150	.0015		39
5.3275								.008	1st BUE
5.3260									UNDER SIDE TOOL
5.3135									
5.3130	972	1355	.015	.010	6"	175	.001		46
5.3125									
5.2935									
5.2940	972	1350	.015	.010	6"	200	.0005	.008	47
5.2935									SAME BUE
5.2775									
5.2775	972	1346	.015	.010	6"	225	.001		51
5.2765									
5.2585									
5.2580	972	1340	.015	.010	6"	.250	.0015	.008	48
5.2570									BUE



BUE LOOKS STRAIGHT DOWN TOOL

Remarks:

Machining Conditions

Page 3 of 6

Part Number: 91X1060HT Material: SiC Part Dimension: 5.258 X 14 Date: Nov. 10, 93

Machine: Leblond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Dessau Tool Tool Geometry: T2A33840-B .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.2450									
5.2445	972	1337	.015	.010	6"	275	.001		67
5.2440									
5.2255									
5.2255	972	1332	.015	.010	6"	300	.001	.010	66
5.2245									
5.2120									
5.2120	972	1329	.015	.010	6"	325	.0005		47
5.2115									
5.1935									
5.1925	972	1324	.015	.010	6"	350	.002	.010	46
5.1915									
5.1790									
5.1780	972	1320	.015	.010	6"	375	.0015		49
5.1775									

BUE UNDER SIDE

BUE

BUE

Remarks:

Appendix 4.55

Machining Conditions

Page 4 of 6

Part Number: 91X1060HT Material: SiC Part Dimension: 5.179 X14 Date: Nov 10, 93

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Dessau Tool Tool Geometry: T2A 33840-B .021 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish	
5.1595										
5.1590	972	1316	.015	.010	6"	400	.001	.010	50	BUE
5.1585										
5.1475										
5.1470	972	1312	.015	.010	6"	425	.001		45	
5.1465										
5.1285										
5.1280	972	1308	.015	.010	6"	450	.0005	.010	47	BUE
5.1280										
5.1160	972	1305	.015	.010	6"	475	.002		45	
5.1145										
5.1140										
5.0955										
5.0955	972	1299	.015	.010	6"	500	.001	.010	45	BUE
5.0955										

Remarks:

Machining Conditions

Page 5 of 6

Part Number: 91X1060HT Material: SiC Part Dimension: 5.095X14 Date: Nov. 10,93

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Dessau Tool Tool Geometry: T2A 33840-B .021 Radius

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.0825									
5.0815	972	1296	.015	.010	6"	525	.001		45
5.0815									
5.0635									
5.0625	972	1291	.015	.010	6"	550	.002	.010	47
5.0615									
5.0505									
5.0495						575	.0015		No Reading
5.0 490	972	1287	.015	.010	6"				Too Large STEP
5.0305									
5.0305	972	1283	.015	.010	6"	600	.0005	.012	No Reading
5.0300									
5.0190									
5.0175	972	1279	015	.010	6"	625	.0015		
5.0175									

BUE TURNING DOWN Left side of Tool

FINISH LOOKS ABOUT SAME

BUE

Remarks:

" 0
Supervier
East Shop
Next Week

Machining Conditions

Page 6 of 6

Part Number: 91X1060HT Material: S/C Part Dimension: 5.017X14 Date: Nov.10,93

Machine: LeBlond Model/Type: QC 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Dessau Tool Tool Geometry: T2A 33840B .021 Radius

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish	
	5.0000							.0015		Looks about same	
	4.9995	972	1275	.015	.010	6"	650	.~~002~~	.015	45-50	BUE
	4.9985										
	4.9875										
	4.9870	972	1272	.015	.010	6"	675	.0015			
	4.9860										
	4.9680										
.450	4.9685	972	1267	.015	.010	6"	700	.0005	.0175		
	4.9680										

Remarks:

Machining Conditions

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4.3050
.0400
4.3450

Part Number: 91X1060HT Material: SiC Part Dimension: 4.335 x 12 Date: Dec. 16, 93

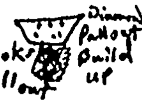
Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C. Tool Tool Geometry: DPGA 432

Tool on ₵ of Part

N/14

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut →	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.3030					2 Passed				Good Finish Fine Thread
4.3020	1325	1494	.015	.010	6" each	40	.002	.004	Cast iron
4.3040									like Chips
4.2703							0		
4.2705	1325	1482	.015	.010		80	.0005	.008	
4.2710									
4.2380									Build Up on
4.2380	1350	1498	.015	.010		120	.001	.008	Bottom of
4.2390									Tool | Diamond looks like it pullout
4.2094									
4.2098	1350	1488	.015	.010		160	.0004	.008	
4.2095									
4.1780									
4.1785	1375	1505	.015	.010		200	.0005	.009	
4.1790									



Remarks:

Machining Conditions

Page 2 of 5

Part Number: 91X1060 HT Material: SiC Part Dimension: 4.179 X 12 Date: Dec 16, 93

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Dc. Tool Tool Geometry: DPGA 432

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	4.1502					2 Passes				Fine Thread
	4.1505	1375	1495	.015	.010	6" each	240	.0004	.013	
	4.1506									
Kennametal DNGA 433	4.1120			Kennametal		KD100	DNGA	433		
	4.1125	~~1400~~					40	.0005	.0065	
	4.1125	1375	1481							
	4.0773									
	4.0778	1375	1468				80	.0005	.028	
TURN LOG OVER	4.0773									
Valenite DNGM 432	4.9138			Valenite	DNGm 432		VC 727	Pos. Rake		
	4.9140	1160	1493				40		.009	
	4.9145							.0007		
VC727 POS. RAKE	4.887									
	4.887	1160	1485				80	Ø	.0105	
	4.887									

Remarks:

Appendix 4.60

Machining Conditions

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Part Number: 91X1060HT Material: S:C Part Dimension: 4.8X12 Date: Dec16,93

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: DC TOOL Tool Geometry: DNGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.8533					2 Passes			.006	Build Up
4.8538	1195	1519	.015	.010	6" each	40	.0005		Bottom SIDE
4.8538									
4.8280								.011	Build Up
4.8280	1200	1517	.015	.010		80	.0003		Rough Finish
4.8277									
4.8000									
4.8020	1200	1509	.015	.010		120	.0027	.015	Rough Looking
4.8027									Torn
4.7660			DC. TOOL DPGA 432						
4.7663	1200	1498	.015			40	.0007	.0065	Smooth
4.7670									
4.7030									
4.7040	1225	1509	.015			80	.001	.011	OK
4.7040									

Dec 17,93
DC TOOL
DPGA
432

mf 17

Remarks:

Machining Conditions

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Part Number: 91X1060HT Material: SiC Part Dimension: 4.704X12 Date: Dec17,93

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: DC. TOOL Tool Geometry: DPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.6768					2 Passed				Fine Thread
4.6760	1210	1482	.015	010	6" each	120	.0018	.011	Like
4.6750									
4.6460									
4.6462	1233	1500	.015	.010		160	.0008	.011	" "
4.6468									
4.6190									
4.6204	1260	1525	.015	.010		200	.0022	.011	" "
4.6212									
4.5940									Fine Thread
4.5950	1260	1516	.015	.010		240	.0015	.014	
4.5955									

Remarks:

Machining Conditions

Page 5 of 5

Part Number: 91X1060HT Material: SiC Part Dimension: 4.595X12 Date: Dec 17, 93

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: T2A33840 .150 Radius

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.5562					2 Passes				GREAT FINISH
4.5565	1260	1504	.015	.010	6" each	40	.0008	.0035	SMOOTH AND
4.5570									SHINEY
4.5276									
4.5270	1275	1512	.015	.010		80	.0011	.024	Rough Pull FINISH
4.5265									
4.4912								.006	can feel cut
4.4916	1275	1500	.015	.010		40	.0006		
4.4918									
4.4612									
4.4609	1290	1504	.015	.010		80	.0003	.028	Look Like TAIRING
4.4610									Material off

ref 18

Kennametal
T2A33833
.021 Radius

ref 19

Build Up ON Bottom EDGE

Lot of Build Up

Remarks:

Machining Conditions

Page 1 of 6

Part Number: 91X1060 Material: SiC Part Dimension: 6.125 Date: Jan 11, 94

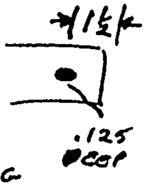
Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: DNMS 432

(1350 SFM)

ref VD
31 entries

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
6.0975	840	1347	.015	.010	6"	50	.0007	.003	APP. 2" long chip curly
6.0968					2 Passes				DULL LOOKING
6.0970									SMOOTH Feel
6.0649		1350	.015	.010	"	100	.0007	.0045	BRIGHT FINISH
6.0642	845								
6.0648									
6.0322	850	1350	.015	.010	"	150	.0003	.005	
6.0321									
6.0325									
6.0008	855	1350	.015	.010	"	200	.0002	.005	
6.0010									
6.0010									
5.9669	860	1350	.015	.010	"	250	.0003	.006	
5.9669									
5.9672									
total .158									



Remarks:

Machining Conditions

Page 2 of 6

Part Number: 91X1060 Material: SiC Part Dimension: 5.967 Date: Jan 11, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant : N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: DNMS 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time (SEC)	Part Taper	Tool Flank Wear	Surface Finish
5.9350	865	1350	.015	.010	6"	300	.0002	.006	SMOOTH FINISH
5.9351					2 Pass				CURLY CHIPS
5.9352									
5.9000	870	1350	.015	.010	"	350	.0001	.006	
5.8999									
5.9000									
5.8668	875	1350	.015	.010	"	400	.0011	.0065	
5.8670									
5.8679									
5.8340	880	1350	.015	.010	"	450	.0002	.0065	
5.8340									
5.8338									
5.7998	885	1350	.015	.010	"	500	.0011	.007	CAST IRON
5.7997									LIKE CHIPS
5.8008									SMOOTH FINISH
total .168									

Remarks:

Machining Conditions

Page 3 of 6

Part Number: 91X1060 Material: SiC Part Dimension: 5.799 Date: Jan 11, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: DNMS 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.7642	890	1350	.015	.010	6"	550	.0008	.007	SMOOTH
5.7644					2 Passes				FINISH
5.7650									
5.7311	895	1350	.015	.010	"	600	.0003	.008	CURLY CHIPS BACK
5.7309									SMOOTH FINISH
5.7312									
5.7000	900	1350	.015	.010	"	650	.0003	.008	
5.6995									
5.6997									
5.6680	905	1350	.015	.010	"	700	.0009	.0085	SMOOTH FINISH
5.6683									
5.6689									
5.6348	910	1350	.015	.010	"	750	.0008	.0085	
5.6348									
5.6340									
total .165									

Remarks:

Machining Conditions

Page 4 of 6

Part Number: 91X1060 Material: SiC Part Dimension: 5.634 Date: Jan. 11, 94

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: DNMS432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5. 6010	915	1350	.015	.010	6"	800	.0004	.0085	SMOOTH FINISH
5. 6013					2 Passes				CURLY CHIPS
5. 6014									
5.5690	920	1350	.015	.010	"	850	.0005	.0085	
5.5690									
5.5695									
5.5391	925	1350	.015	.010	"	900	.0003	.0085	
5.5394									
5.5391									
5.5076	930	1350	.015	.010	"	950	.0005	.0085	
5.5072									
5.5077									
5.4752	935	1350	.015	.010	"	1000	.0002	.0085	
5. 4750									SMOOTH FINISH
5. 4751									
total .159									

Remarks:

Machining Conditions Page 5 of 6

Part Number: 91X1060 Material: SiC Part Dimension: 5.475 Date: Jan 11, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: DNMS 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.4418	940	1348	.015	.010	6"	1050	.0004	.0085	SMOOTH FINISH
5.4418					2 Passes				
5.4420									200 uIN
5.4110	945	1347	.015	.010	"	1100	.0005	.009	
5.4115									
5.4112									
Jan 12, 94 5.3779	950	1346	.015	.010	6"	1150	.0006	.009	200 uIN
5.3780					2 Passes				
5.3785									
5.3447	960	1345	.015	.010	"	1200	.0003	.009	
5.3448									
5.3450									
5.3117			.015	.010	"	1250	.0006	.009	
5.3117	965	1350							
5.3111									
total .164									

Remarks:

Machining Conditions

Page 6 of 6

Part Number: 91X1060 Material: SiC Part Dimension: 5.3111 Date: Jan 12, 94

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant : N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: DNMS 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.2779			.015	.010	6"	1300		.010	160 to 180 FINISH
5.2778	970	1350			2 Passes				
5.2777									
5.2451	975	1350	.015	.010	"	1350		.010	
5.2450									
5.2450									
5.2145	980	1346	.015	.010	"	1400		.012	
5.2149									
5.2149									
5.1808	990	1352	.015	.010	"	1450		.012	
5.1810									
5.1810									
5.1477			.015	.010	"	1500		.012	
5.1473	995	1350							
5.1473									160-180 FINISH
total .194									

FROM NEXT Page 5.117

Remarks:

Machining Conditions

Page 1 of 13

Part Number: 91X1060 Material: SiC Part Dimension: 5.147 Date: Jan. 12, 94

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: Kennametal Tool Geometry: DNMS 432

ref 21
44 passes

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.1169	1000	1348	.015	.010	6"	1550	.0001	.013	
5.1170					2 Passes				
5.1170									
DC TOOL	DPGA	432							
5.0845	1010	1354	.015	.010	6"	50	.0005	.003	140-170 u.in.
5.0842					2 Passes				SHORT STRINGLY
5.0840									CHIPS
5.0490	1015	1352	.015	.010	11	100	.0005	.0045	DULL FINISH
5.0494									
5.0495									
5.0164	1020	1349	.015	.010	11	150	.0004	.0045	
5.0160									
5.0160									
4.9820	1030	1353	.015	.010	11	200	.0002	.0045	
4.9818									
4.9818									

total .136

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 4.981 Date: Jan. 12, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: DC TOOL Tool Geometry: BPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.9480	1035	1350	.015	.010	6"	250	.0005	.0045	FINISH SAMPS
4.9480					2 Passes				
4.9475									
4.9162	1040	1348	.015	.010	11	300	.0007	.005	
4.9158									
4.9165									
4.8853	1050	1352	.015	.010	11	350	.0003	.005	CAST IRON LIKE CHIPS
4.8851									140-170 u IN
4.8850									
4.8527	1055	1350	.015	.010	11	400	.0003	.0055	
4.8524									
4.8524									
4.8180	1060	1347	.015	.010	11	450	.0004	.0055	120-140 u IN,
4.8180									
4.8176									
total .164									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 4.817 Date: Jan 12,94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C. Tool Tool Geometry: DPGA 432

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	4.7835	1070	1350	.015	.010	6"	500	.0001	.0055	FINISH SAME
10	4.7834					2 Passes				
	4.7834									
	4.7495	1080	1353	.015	.010	"	550	.0005	.0055	
11	4.7497									
	4.7500									
	4.7165	1085	1350	.015	.010	"	600	.0005	.0055	
12	4.7170									
	4.7170									
	4.6842	1095	1353	.015	.010	"	650	.0001	.006	
13	4.6842									
	4.6841									
	4.6500	1100	1350	.015	.010	"	700	.0002	.006	
14	4.6502									CURLY CHIP
	4.6502									140-170 u IN
	total .167									

CHANGE TAPE SEE R RE PM ange

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 4.650 Date: Jan 12, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C Tool Tool Geometry: DPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.6148	1110	1352	.015	.010	6"	750	.0006	.006	140 -170 μ IN
4.6142					2 Passes				
4.6142									
4.5812	1115	1347	.015	.010	"	800	.0001	.006	
4.5813									
4.5813									
4.5468	1125	1350	.015	.010	"	850	.0004	.006	
4.5468									
4.5472									
4.5145	1135	1351	.015	.010	"	900	.0005	.006	140 -170 μ IN.
4.5146									
4.5150									
4.4812	1140	1348	.015	.010	"	950	.0003	.006	80 - 110 μ IN
4.4814									
4.4815									
total .169									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 4.481 Date: Jan 13, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: DC TOOL Tool Geometry: DPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
4.4500	1150	1350	.015	.010	6"	1000	.0005	.006	120-160 μ IN.
4.4500					2 Passes				SHORT CURLY CHIPS
4.4505									
4.4172	1155	1346	.015	.010	"	1050	.0008	.006	
4.4174									
4.4180									
4.3852	1165	1348	.015	.010	"	1100	.0002	.006	
4.3852									
4.3850									
4.3530	1175	1350	.015	.010	"	1150	.0004	.006	
4.3531									
4.3534									
4.3210	1185	1351	.015	.010	"	1200	.0002	.006	
4.3210									
4.3208									
total .161									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 4.320 Date: Jan, 13, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C. Tool Tool Geometry: DPGA 432

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	4.2850	1190	1346	.015	.010	6"	1250	.0006	.0065	140-160 u IN,
75	4.2854					2 Passes				SMOOTH FINISH
	4.2856									
	4.2510	1200	1347	.015	.010	"	1300	.0003	.0065	
.16	4.2511									
	4.2513									
	4.2160	1215	1353	.015	.010	"	1350	.0002	.0065	
.21	4.2158									
	4.2160									
	4.1842	1225	1352	.015	.010	"	1400	.0006	.0065	
.11	4.1842									
	4.1848									
	4.1505	1230	1348	.015	.010	"	1450	.0004	.0065	146-160 u IN,
.11	4.1502									SMOOTH FINISH
	4.1506									
	total .170									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 4.150 Date: Jan. 13, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: DC TOOL Tool Geometry: DPGA 432

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	4.1156	1240	1348	.015	.010	6"	1500	.0002	.0065	140-160 uIN
30	4.1158					2 Passes				SHORT CURLY
	4.1156									CHIPS
	4.0820	1250	1347	.015	.010	"	1550	.0004	.0065	
31	4.0820									
	4.0824									
	4.0481	1260	1347	.015	.010	"	1600	.0006	.007	
32	4.0477									
	4.0475									
	4.0146	1270	1346	.015	.010	"	1650	.0004	.007	160-185 uIN
33	4.0150									
	4.0150									
	Total .135									

Remarks: TURN LOG AROUND

Appendix 4.76

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 6,130 Date: Jan 13,94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C. Tool Tool Geometry: DPGA 432

TURN LOG AROUND (1350 SFM)

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
6.1012	840	1350	.015	.010	6"	1700	.0004	.007	160-180 uIN
6.1010					2 Passes				SMOOTH FINISH
6.1014									
6.0693	845	1350	.015	.010	"	1750	.0003	.007	
6.0690									
6.0690									
6.0350	850	1351	.015	.010	"	1800	.0004	.007	
6.0346									
6.0346									
6.0010	855	1351	.015	.010	"	1850	.0003	.007	
6.0010									
6.0007									
5.9683	860	1352	.015	.010	"	1900	.0004	.007	
5.9684									
5.9687									140-160 uIN
total .162									SMOOTH FINISH

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 5.968 Date: Jan 13, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C. Tool Tool Geometry: DPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.9362	865	1352	.015	.010	6"	2000	.0004	.008	
5.9361					2 Passes				
5.9365									.0005 BUE
5.9026	870	1353	.015	.010	"	2050	.0004	.008	
5.9027									
5.9030									
5.8703	875	1353	.015	.010	"	2100	.0004	.008	
5.8702									
5.8699									
5.8390	880	1353	.015	.010	"	2150	.0002	.008	
5.8390									
5.8388									
5.8055	885	1353	.015	.010	"	2200	.0005	.008	.002 BUE
5.8052									
5.8050									
total .163									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 5.805 Date: Jan 13, 94

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C. Tool Tool Geometry: DPGA 432

Workpiece Diameter (in)	Spindle RPMs.	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.7710	890	1353	.015	.010	6"	2250	.0004	.008	
5.7708					2 Passes	37.5 minutes			
5.7706									
total .035									

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Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 5.968 Date: Jun 13, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: D.C. Tool Tool Geometry: DPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.9362	865	1352	.015	.010	6"	2000	.0004	.008	
5.9361					2 Passes				
5.9365									.0005 BUE
5.9026	870	1353	.015	.010	"	2050	.0004	.008	
5.9027									
5.9030									
5.8703	875	1353	.015	.010	"	2100	.0004	.008	
5.8702									
5.8699									
5.8390	880	1353	.015	.010	"	2150	.0002	.008	
5.8390									
5.8388									
5.8055	885	1353	.015	.010	"	2200	.0005	.008	.002 BUE
5.8052									
5.8050									
total .163									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 5.770 Date: Jan. 27, 94

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: DC TOOL Tool Geometry: DPGA 432

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
	5.7390	900	1353	.015	.010	6"	2300	.0005	.0085	130 - 150
4.5	5.7390					2 Pass				
	5.7395									
	5.7072	900	1345	.015	.010		2350	.0006	.0085	BUE on
4..	5.7076									Top of Tool
	5.7078									
	5.6732	905	1345	.015	.010		2400	.0005	.0085	NO - BUE
41	5.6734									
	5.6737									
	5.6412	910	1345	.015	.010		2450	.0003	.0085	
1.1	5.6414									
	5.6415									
	5.6098	915	1345	.015	.010		2500	.0006	.0085	
[illegible]	5.6096									
	5.6092									
	total .161									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 5.609 Date: Jan. 27, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: N/A Concentration: N/A

Tool Type: DC TOOL Tool Geometry: DPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.5755	925	1351	.015	.010	6"	3000	.0003	.0085	140
5.5754					2 Passes				
5.5752									
5.5422	930	1350	.015	.010		3050	.0004	.009	
5.5418									
5.5418									
5.5102	935	1349	.015	.010		3100	.0004	.009	
5.5098									
5.5098									
5.4780	940	1348	.015	.010		3150	.0001	.009	
5.4778									
5.4779									
5.4480	945	1348	.015	.010		3200	.0003	.009	
5.4477									
5.4477									130-140
total .162									

Remarks:

Machining Conditions

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Part Number: 91X1060 Material: SiC Part Dimension: 5.447 Date: Jan 27, 94
Machine: LeBlond Model/Type: GE 2000 Controller Coolant: N/A Concentration: N/A
Tool Type: DC Tool Tool Geometry: OPGA 432

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
5.4160	950	1348	.015	.010	6"	3250	0	.009	~~BUE~~ BUE
5.4160					2 Passes				
5.4160									
5. ~~386~~ 3836	955	1346	.015	.010		3300	.0003	.009	
5. 3836									
5. 3839									
5. 3508	960	1345	.015	.010		3350	.0003	.009	
5. 3509									
5. 3510									
5.3212	965	1345	.015	.010		3400	.0003	.009	
5.3215									
5.3214									
5.2915	970	1344	.015	.010		3450	.0005	.009	
5.2920									
5.2920									140-150
total .155									

Remarks:
1.940 total stock removed

ROTOR TURNING

Appendix 4.83

ROTOR TURNING

Appendix 4.83

Appendix 4.84

Machining Conditions

Page 1 of 1

Part Number: 110993MCG Material: Al_2O_3 Part Dimension: Rotor Date: Feb 1, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: _________

Tool Type: _________ Tool Geometry: _________

(SFM 1250)

REF #	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish	
						MIRCOINCHES					
18	Kennametal DNMS-432	503-1250	1250	.015	.010	.004 140-180	.010 180-220	~~.004~~			
13	DC TOOL DNGA-432		1250	.015	.010	.006 140-180	.013 140-180				
14	Accurate Tools DNGA-432		1250	.015	.010	.005 120-140	.010 140				
✓24	J&M Tool DNMA-433	Flip Top	(CBN)	SFM 1250 .015	.010	.012 190-220					
✓12	Tungoloy DNGA ~~DDJA~~-432	DX140	1250	.015	.010	.004 200-240	.007 160-200	.009 140-160			
22	Norton DNGA-432 3		1250	.015	.010	.005 140-160	.010 140-160				
✓23	Kennametal DNGA-433		1250	.015	.010	.004 140-160	.007 120-130	.010 80-100			
21	J&M TOOLS DNGA 433		1250	.015	.010	.005 140-160	.007 100-120	.0085 100-120	.010 100-120		
✓25	Sumitomo DNMX-433		1250	.015	.010	.004 100-120	.005 100-120	.007 100-120	.009 80-100		
✓17	Valenite DNGM-432		1250	.015	.010	.005 100-120	.0065 100-120	.012 80-100	BUE TOP & SIDE LAST CUT		
	CHANGE	ROTORS	110693 MCH#1		CLEAN FACE W/ TUNGOLOY			DNGG150 408-1 .018 Feedrate			
✓19	Norton DPGA-432	503-1250	1250	.015	.010	.002 150-180	.004 130-150	.006 80-100	.0085 50-70	.009 50-70	.008 50-70
✓11	Tungoloy DNGA ~~DDJA~~-432	DX160	1250	.015	.010	.006 110-130	.007 100-120	.009 100-120	.011 90-110		BUE TOP+S. 1st CUT
✓15	Tungoloy DNGG 150408-1 (TIC)		CROSS SHAPE CHIPBREAKER			.012 120-150					
✓16	Tungoloy DNGG 150408-R-P (TIC)		RADIUS SHAPE CHIPBREAKER			.016 150-170					
✓20	DC TOOL DPGA-432		1250	.015	.010	.003 BUE TOP 80-100	.006 BUE TOP 100-120	.007 BUE TOP 130-150	.008 BUE 120-130	.012 BUE 150-160	

Remarks:			
	6th cut .012 BUE 130-150	.0125 BUE 130-150	.015 NO BUE 130-150

CONTINUED

Appendix 4.85

Machining Conditions

Page 1 of 3

Part Number: 11693MCH#1 Material: Al_2O_3 Part Dimension: Rotor Date: Feb 17,94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ______

Tool Type: ______ Tool Geometry: ______

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in) CSS	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
√57	Norton DiamaTorr DPGA 432 DT100L		1800			.675-.6735-.673-.674				Very Rough
		~~1329~~	~~3119~~ 1800	Program .025	.010			Tool Failure		
√56	Tungaloy DX140 DNGA 432		1800	.030	.010	.6685-.6675-.6670-.6675				Very Rough
√54	Sumitomo DNMX 433		1500	.020	.010	.004 .6605-.6590-.6590-.6590			.004	About 140
	Pos. Rake	avg. 1600 sfm	long curly chips			.6515-.6502-.6500-.6501			.006	About 130
						.6430-.6418-.6414-.6419			.007	About 120
						.6351-.6340-.6338-.6340			.010	80
						.6284-.6273-.6269-.6272			.010	60
			?			.6210-.6198-.6195-.6200			.011	60
						.6135-.6122-.6120-.6121			.0125	50
√45	Valenite DNGM-432-2F	Finish looks like it torn				.6068-.6050-.6048-.6051			.006	240
						.5986-.5975-.5970-.5971			.008	240
						.5920-.5909-.5904-.5909			.009	200
						.5860-.5850-.5844-.5847			.011	200

Remarks:

Appendix 4.86

2

Machining Conditions

Page 2 of 3

Part Number: 11693MCH#1 Material: Al_2O_3 Part Dimension: Rotor Date: Feb 18, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ________

Tool Type: __________ Tool Geometry: __________

MICRO INCHES mu in.

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
√47	Kennametal KD100 DNMS-432 w/CHIP BREAKER		1500	.020	.010	.5788 -.5774	-.5770-	5772	.005	240
		635-1323				.5704-.5690	-.5688-	.5690	.007	240
						.5620-.5610	-.5605-	.5607	.010	200
√53	Norton (CVD) DNGA - 433		1500	.020	.010	.5545-.5530	-.5526-	.5530	.005	240
						.5460-.5446	-.5440-	.5445	.007	150
						.5380-.5370	-.5365-	.5370	.010	150
√ 52	Kennametal KD100 DNGA-433		1500	.020	.010	.5296-.5292	-.5290-	.5293	.005	160
52						.5215-.5205	-.5200-	.5202	.009	160
	CHANGE	ROTOR	110593 MCG		/ / /	/ / /	/ / /	/ / /	/ / /	/ / /
	Clean Up Face with		Kennametal DNGA-433			.016 WEAR AFTER FACING				/ /
√40	Tungaloy DDNGA 432 DX160 DNGA-432		1500	.020	.010	.7502-.7503	-.7505-	.7504	.005	200
						.7427-.7429	-.7430-	.7429	.009	250
√55	J&M TOOL DNGA-432		1500	.020	.010	.7349-.7349	-.7350-	.7349	.005	180
	433					.7263-.7265	-.7264-	.7263	.0065	180
						.7184-.7185	-.7186-	.7185	.0095	150
						.7110-.7111	-.7112-	.7111	.0115	150

Remarks:

Machining Conditions

Page 1 of 3

Part Number: 11693MCH#1 Material: Al_2O_3 Part Dimension: Rotor Date: Feb 17,94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ________

Tool Type: ________ Tool Geometry: ________

	Workpiece Diameter(in)	Spindle RPMs	SFPM (in) CSS	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
√57	Nonton DiamaTorn DPGA 432 DT100L		1800			.675-.6735-.673-.674				Very Rough
		~~1329~~	~~3119~~ 1800	Program .025	.010			Tool Failure		
√56	Tungoloy DX140 DNGA 432		1800	.030	.010	.6685-.6675-.6670-.6675				Very Rough
√54	Sumitomo DNMX 433		1500	.020	.010	.004 .6605-.6590-.6590-.6590			.004	About 140
	Pos. Rake	orig. 1600 sfm	long curly chips			.6515-.6502-.6500-.6501			.006	About 130
						.6430-.6418-.6414-.6419			.007	About 120
						.6351-.6340-.6338-.6340			.010	80
						.6284-.6273-.6269-.6272			.010	60
						.6210-.6198-.6195-.6200			.011	60
						.6135-.6122-.6120-.6121			.0125	50
√45	Valenite DNGM-432-2F	Finish looks like it torn				.6068-.6050-.6048-.6051			.006	240
						.5986-.5975-.5970-.5971			.008	240
						.5920-.5909-.5904-.5909			.009	200
						.5860-.5850-.5844-.5847			.011	200

Remarks:

2

Machining Conditions

Page 1 of 3

Part Number: 110593 MCG Material: Al_2O_3 Part Dimension: Rotor Date: Mar.1,94

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: TRIMSOL Concentration: ______

Tool Type: ______ Tool Geometry: ______

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
✓46	Kennametal K0100 DNMS-432		1500	.015	.6206	.6208	.6209	.6209	.005	180
				Doc .010	.6129	.6130	.6130	.6130	.0085	150
					.6060	.6061	.6062	.6062	.0105	100
✓51	Kennametal K0100 DNGA 433		1500	.015	.5979	.5980	.5981	.5980	.006	100
				DOC .010	.5898	.5899	.5900	.5898	.0095	50
					.5824	.5825	.5825	.5827	.011	50
a ✓44	Tungaloy DX140 DDJA-432		1500	.015	.5750	.5751	.5754	.5751	.006	150
				DOC .010	.5672	.5676	.5678	.5675	.010	150
✓41	Tungaloy DX160 DDNJA-432		1500	.015	.5528	.5530	.5530	.5529	.0055	150
				Doc .010	.5441	.5447	.5448	.5448	.008	150
					.5370	.5375	.5375	.5374	.0115	100
	CHANGE	ROTOR		111593 MCH #2		".876"				
50	CLAPP & KANEY GE 1500 #1		1500	.015	.8640	.8641	.8640	.8640	.0035	160
				DOC.010	.8555	.8559	.8559	.8559	.005	140
					.8465	.8468	.8467	.8466	.007	140
					.8390	.8395	.8391	.8391	.008	120

Remarks:

CONTINUED ON NEXT PAGE ↓

Machining Conditions

Page 3 of 3

Part Number: 110593MCG Material: Al_2O_3 Part Dimension: Rotor Date: Feb 21, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ______

Tool Type: ______ Tool Geometry: ______

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	MIRCOINCHES Surface Finish
√42 Accurate Diamond DNGA 432 CP100	535 - 1323	1500	.020	.010	.7036 - .7039	- .7039	- .7037	.0055	250
					.6959 - .6960	- .6961	- .6960	.008	200
					.6890 - .6892	- .6893	- .6892	.010	180
√43 Tungaloy DNGA 432 DK140		1500	.020	.010	.6815 - .6818	- .6818	- .6818	.0055	250
					.6730 - .6734	- .6734	- .6731	.008	250
					.6663 - .6665	- .6665	- .6666	.010	220
√48 NORTON (CVD) DPGA ~~433~~		1500	.020	.010	6591 - .6593	- .6596	- .6595	.003	180
432					6512 - .6512	- .6515 -	.6514	.004	180
					6440 - .6441	- 6441 -	.6440	.006	200
					6370 - .6371	- .6372 -	6370	.0075	180
					.6288 - .6290	- .6290	- .6290	.0095	180

Remarks:

4

Machining Conditions

Page 3 of 3

Part Number: 111593 MCH #2 Material: Al_2O_3 Part Dimension: Rotor Date: Mar 3,94

Machine: LeBlond Model/Type: GE2000 CONTROLLER Coolant: TRIMSOL Concentration:________

Tool Type:________ Tool Geometry:________

SFm 1000

√6

Workpiece Diameter (in)	Spindle RPMs	SFPM ~~(in)~~	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
CLAPP & Haney GE1500		1000	.015	.7130	.7131	.7131	.7132	.003	110
			.010 DOC	.7040	.7043	.7042	.7041	.005	100
				.6960	.6960	.6959	.6960	.007	60
				.6877	.6879	.6878	.6880	.008	50
				.6800	.6802	.6800	.6800	.0085	40
				.6711	6717	.6716	.6715	.0095	50

Remarks:

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Machining Conditions

Page 2 of 3

Part Number: 111593 MCH #2 Material: Al_2O_3 Part Dimension: Rotor Date: Mar. 2, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration:

Tool Type: Tool Geometry:

CONTINUED FROM PREV PAGE

	Workpiece Diameter (in)	Spindle RPMs	SFPM ~~(in)~~	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
√50	CLAPP & Haney GE 1500 #1		1500	.015	.8319	.8320	.8318	.8320	.0095	120
				.010 DOC	.8247	.8252	.8249	.8250	.011	120
√49	CLAPP & Haney GE1500 #2		1500	.015	.8160	.8163	.8163	.8165	.004	140
				.010 DOC	.8080	.8080	.8079	.8080	.006	140
					.7998	.8000	.7999	.8000	.007	120
					.7928	.7933	.7928	.7930	.009	70
					.7851	.7856	.7853	.7854	.010	80
	CHANGE TAPE									
√5	NORTON DPG-A 432		1000	.015	.7770	.7771	.7770	.7770	.0025	150
				.010 DOC	.7677	.7680	.7678	.7678	.0035	120
					.7598	.7600	.7599	.7600	.006	110
					.7520	.7525	.7521	.7521	.006	100
					.7449	.7452	.7450	.7450	.007	100
					.7370	.7372	.7371	.7370	.008	100
					.7292	.7298	.7293	.7295	.0085	90
					.7213	.7220	.7215	.7218	.010	90

Remarks:

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Machining Conditions

Page 2 of 3

Part Number: 110993MCH #2 Material: Al_2O_3 Part Dimension: Rotor Date: Mar. 8, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ________

Tool Type: __________ Tool Geometry: __________

CLAPP & Handy #1 Mar. 3rd USED TO FACE OFF BACKSIDE OF ROTOR .0115 Flank Wear

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
1	DC TOOL DNGA 432		1000	.015	.8570	.8574	.8572	.8568	.0045	120
				.010 DOC	.8488	.8490	.8490	.8485	.0075	100
					.8404	.8408	.8408	.8400	.0095	100
					.8328	.8330	.8331	.8326	.012	80
✓8	J&M Tool DNGA 433		1000	.015	.8232	.8237	.8237	.8230	.0055	120
				.010 DOC	.8145	.8144	.8148	.8143	.009	60
					.8070	.8075	.8072	.8070	.011	50
✓9	NORTON DNGA 433 (CVD)		1000	.015	.7980	.7983	.7983	.7978	.005	100
				.010 DOC	.7890	.7895	.7892	.7889	.0085	80
					.7808	.7810	.7810	.7803	.011	70
7	CLAPP & Haney GE1500		1000	.015	.7715	.7719	.7719	.7712	.0035	70
				.010 DOC	.7638	.7640	.7640	.7638	.006	100
					.7550	.7555	.7553	.7549	.007	120
					.7465	.7468	.7468	.7462	.0085	120
					.7408	.7411	.7410	.7403	.010	60

Remarks:

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Machining Conditions Page 1 of 3

Part Number: 111593MCH2 Material: Al2 O3 Part Dimension: Rotor Date: Mar. 7,94

Machine: LeBlond Model/Type: CG 2000 CONTROLLEX Coolant: TRIMSOL Concentration: ________

Tool Type: ________ Tool Geometry: ________

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut.	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
√2 Accurate CP100 DNGA 432		1000	.015	.6635	.6630	40 sec. .6631	.6630	.0045	100
			.010 DOC	.6540	.6542	.6541	.6540	.008	80
				.6459	.6461	.6460	.6460	.009	50
				.6375	.6380	.6379	.6378	.011	60
√10 Sumitomo DA150 DNMX 433		1000	.015	.6293	.6294	.6291	.6291	.0035	80
			.010 DOC	.6200	.6202	.6201	.6200	.0055	60
				.6113	.6116	.6117	.6115	.0065	70
				.6034	.6040	.6046	.6040	.0085	80
				.5963	.5964	.5960	.5961	.009	70
				.5877	.5881	.5879	.5879	.011	70
√3 Valonite DNGM 432 2F		1000	.015	.5790	.5791	.5789	5790	.0035	120
			.010 DOC	.5694	.5697	.5698	.5698	.007	100
				.5618	.5615	.5613	.5611	.0085	80
				.5534	.5540	.5537	.5538	.011	80
		CHANGE	ROTORS	TO	110993	MCH #2			

Remarks:

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Machining Conditions

Page 1 of ____

Part Number: ________ Material: Al_2O_3 GE 2000 Part Dimension: ...... Date: Mar. 29, 94

Machine: LeBlond Model/Type: CONTROLLER Coolant: TRIMSOL Concentration: ......

Tool Type: ________ Tool Geometry: ________

1250 SFM Neutral Tool Holder

R1 -> √26

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Sumitomo DNMX 433	CSS	1250	.015	.5912	.5916	.5915	.5908	.0070	100
11° Back Rake			.010 DOC	.5872	.5880	.5880	.5872	.0085	100
5° Side Clearance				.5808	.5809	.5810	.5800	.0115	80
				.5750	.5752	.5753	.5742	.0155	80
				.5703	.5705	.5709	.5700	.0190	80
				.5655	5658	.5659	.5650	.0215	70
				.5600	.5603	.5603	.5592	.0220	70
				.5540	.5544	.5545	.5538	.0250	70
				.5502	.5503	.5507	.5500	.0280	100
Valenite DNGM-432 2F	Change	Rotor	To	110293	MCH #2	▨	▨	▨	▨
machine Down Electrical Problem	CSS	1250	.015	.8260	.8258	.8260	.8260	.002	80
NEW TOOL			.010 DOC	.8190	.8170	.8170	.8180	.002	120
				.8180					
				Machine	Lost	Z AXIS			

CURLY CHIP

Remarks: 110293 MCH#2 .846 THICK USED Kennametal DNMS-432 TO FACE OFF BACKSIDE DID NOT CUT PUSHED OFF
Kennametal DID NOT CUT PUSH OFF
GE1500 CUT WITH IN .0002 THICKNESS

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Machining Conditions

Page 3 of 3

Part Number: 110993mcH#2 Material: Al_2O_3 Part Dimension: Rotor Date: Mar 9, 94

Machine: LeBlond Model/Type: CG 2000 CONTROLLER Coolant: TRIMSOL Concentration:

Tool Type: Tool Geometry:

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish	
√4	NORTON DPGA 432		1000	.015	.7310	.7315	.7315	.7309	.002	150	
				.010 DOC	.7229	.7230	.7231	.7223	.004	120	
					.7140	.7143	.7141	.7136	.0055	120	
					.7050	.7054	.7054	.7048	.007	100	
					.6963	.6967	.6970	.6961	.0095	70	
					.6900	.6903	.6902	.6897	.010	70	
					.6825	.6827	.6826	.6819	.0115	100	
√58	CLAPP & Haney GE 1500 #1		1800	.015	.6722	.6729	.6729	.6721	.004	90	
				.010 DOC	.6637	.6639	.6639	.6633	.0065	50	
					.6570	.6571	.6569	.6569	.008	80	
					.6524	.6529	.6528	.6520	.0095	50	
					.6473	.6481	.6480	.6474	.011	70	
√59	CLAPP & HANEY GE 1500 #2		3293	.015	.6410	.6415	.6413	.6408	.012	110	WRONG END OF TOOL
				.010 DOC	.6318	.6323	.6323	.6313	.005	110	.002 BUE
					.6210	.6214	.6212	.6202	.0065	80	NO BUE
					.6131	.6139	.6139	.6129	.008	150	
					.6090	.6094	.6091	.6080	.009	110	
					.6049	.6054	.6054	.6047	.010	120	
					.5981	.5983	.5983	.5981	.0125	110	

Remarks:

Machining Conditions

Page 2 of ____

Part Number: 110293 MCH#2 Material: Al_2O_3 Part Dimension: ______ Date: April 2994

Machine: leBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ______

Tool Type: ______ Tool Geometry: ______

1250 SFM NEUTRAL HOLDER

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Valenite w/extra		1250	.015	.6908	.6899	.6890	.6900	.0035	200
DNGA clearance 432 2F			.010DOC	.6841	.6836	.6820	.6834	.0045	180
				.6780	.6769	.6760	.6770	.0065	150
				.6720	.6706	.6700	.6710	.0145	150
NORTON DPGA 432	▨	▨	▨	.6500	.6490	.6484	.6498	.0030	120
				.6301	.6290	.6283	.6295	.0065	110
				.6262	.6252	.6240	.6255	.0080	100
			w/ELECTRIAL PROBLEM	.6109	.6103	.6090	.6100	.0090	100
	Machine Down			.6638	.6023	.6019	.6030	.0100	100
April 27,94				.5762	.5750	.5745	.5758	.0160	100

EXTRA CUTS FOR ELECTRIC PROBLEM

V30

Remarks:

Machining Conditions

Page 1 of ____

Part Number: 110293 MCH #2 Material: Al_2O_3 Part Dimension: .... Date: April 19, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TIRMSOL Concentration:

Tool Type: ________ Tool Geometry: ________

1250 Neutral Holder

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
√27 GE 1500 #1				.8001	.7998	.7990	.8000	.008	100
Part has		1250	.015	.7920	.7915	.7910	.7916	.013	100
Large Pit			.010 DOC	.7838	.7829	.7820	.7828	.016	100
in surface				.7738	.7720	.7710	.7720	.018	80
maybe reason for .008 wear 1st pass				.7640	.7639	.7630	.7635	.020	80
√28 GE 1500 #2				.7520	.7510	.7506	.7515	.006	80
				.7406	.7390	.7383	.7397	.009	80
				.7329	.7313	.7309	.7319	.011	80
				.7270	.7253	.7250	.7260	.013	80
				.7197	.7190	.7182	.7190	.015	80
				.7145	.7120	.7120	.7120	.0165	80
				.7080	.7070	.7066	.7078	.018	80
				.7000	.6988	.6983	.6992	.020	90
VALENITE									
DNGM 432-2F					TOOL BROKE				

Remarks:

12

90

Machining Conditions

Page 1 of ____

Part Number: 11093MCH #1 Material: Al_2O_3 Part Dimension: ________ Date: May 3, 94

Machine: ________ Model/Type: ________ Coolant: TRIMSOL Concentration: ________

Tool Type: ________ Tool Geometry: ________

1250 SFM

33

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish	
~~Kennametal~~		NEUTRAL		.7910	.7911	.7915	.7915		250	TOOL RUBBING ON SIDE
DNMS ~~432~~		HOLDER		.7862	.7864	.7867	.7869			
Kennametal				.7710	.7710	.7710	.7712	.0055	80	
DNMS 432		Negative		.7649	.7649	.7650	.7650	.0095	80	
		Holder		.7550	.7551	.7552	.7553	.0145	60	
		-13 Holder		.7478	.7480	.7480	.7481	.0180	70	
				.7377	.7379	.7374	.7375	.0220	70	
~~Kennametal~~		Netural		.7330	.7332	.7331	.7333	.005	200	
DN~~MS~~ 432		Holder		.7253	.7251	.7240	.7244	.009	170	5.7000
				.7160	.7156	.7140	.7140	.016	200	5.6902
Rub like a grinding wheel				.7047	.7038	.7030	.7022	.020	250	5.6830
~~Valenite~~				.6992	.6978	.6974	.6973	X	250	5.6440

Remarks:

15

Machining Conditions

Page 1 of ____

Part Number: 11093MCH #1 Material: Al2O3 Part Dimension: ________ Date: May 2, 94

Machine: LeBlond Model/Type: GE2000 Controller Coolant: TRIMSOL Concentration:

Tool Type: ________ Tool Geometry: ________

Netural Tool Holder 1250 SFM

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Face off with		1250	.015	.8974	.8974	.8974	.8976		
Norton ORGA 432			.010 DOC	.8881	.8882	.8883	.8886		
31 Sumitomo			START	.8660	.8662	.8661	.8663		
DNMX 433				.8610	.8612	.8615	.8616		
				.8580	.8582	.8580	.8581		
				.8508	.8508	.8509	.8510		
				.8414	.8413	.8415	.8415		
				.8340	.8339	.8339	.8340	.0160	
32 Kennametal				.8310	.8310	.8312	.8312		
DNMS 432				.8220	.8220	.8221	.8221	.0055	140
				.8160	.8166	.8166	.8169	.008	110
				.8045	.8045	.8047	.8047	.0095	60
				.7952	.7954	.7955	.7956	.020	50

~~O.C. 5.905~~

O.C. 5.904

Remarks:

Machining Conditions

Page 1 of ____

Part Number: 111093 MCH #1 Material: Al_2O_3 Part Dimension: ______ Date: May 4, 94

Machine: LeBlond Model/Type: GE 1000 CONTROLLER Coolant: TRIM SOL Concentration: ______

Tool Type: ______ Tool Geometry: ______

1250 SFM

	Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
34	Sumitomo	Neg. Holder	1250	0,15	.6559	.6560	.6560	.6560	.003	70
	DNMX 433	13°		.030 DOC						Short Curly Chips
35	Sumitomo									
	DNMX 433	Natural	1250	.015	.6340	.6340	.6335	.6335	.007	90
		Holder		.030 DOC						Long Stringy Chips
9, 94 36	Valenite #1				.6230	.6233	.6232	.6232	.014	70
	6½° Neg. Rake		Second Pass After #2 Tool		.5945	.5949	.5944	.5945	.019	130
10-11 Rake 37	Valenite #2	-6½° 1250 .010 .015			.6135	.6138	.6139	.6139	.015	50
	-6½° Holder				.6020	.6023	.6021	.6021	.019	60
10, 94	D.C. Tool			(START .8250)	.8132	.8130	.8139	.8139	.002	150
Roton	-6½° Holder			(O.D. 6.0458)	.8010	.8011	.8018	.8019	.006	120
293 MOF 38				(6.0380)	.7900	.7849	.7900	.7904	.008	90
				6.0290	.7788	.7789	.7794	.7795	.010	60
				6.0200	.7679	.7679	.7688	.7688	.011	60
				6.0085	.7570	.7568	.7574	.7575	.012	50

Remarks: 5.9988

CONT ↓ NEXT PAGE

Appendix 4.100

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94

Machining Conditions

Page 2 of ____

Part Number: 110293 MCF Material: Al_2O_3 Part Dimension: ________ Date: May 10, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ________

Tool Type: ________ Tool Geometry: ________

1250 SFM

CONT PREV PAGE

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Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
AC. Tool	1250 SFM			.7450	.7448	.7455	.7456	.013	60
-6½° Holder	.010 DOC			.7350	.7348	.7352	.7354	.014	60
	.015 FR			.7240	.7238	.7246	.7247	.016	70
				.7130	.7130	.7140	.7138	.018	100
				.7018	.7017	.7029	.7029	.021	100
GE. 1500	SFM=1250	(OD)	5.9490	.6917	.6918	.6921	.6922	.005	100
-6½° Holder	DOC=.010		5.9290	.6810	.6808	.6811	.6815	.007	70
	FR=.015			.6701	.6701	.6709	.6700	.010	50
				.6599	.6596	.6605	.6603	.012	60
				.6480	.6475	.6488	.6485	.013	60
				.6374	.6370	.6382	.6384	.015	80
				.6270	.6268	.6279	.6278	.017	80
				.6151	.6149	.6162	.6160	.021	100

√39

compare to 4/19 runs in 0° holder GE#1 & #2

Remarks:

Appendix 4.101

17

95

Machining Conditions

Page____of____

Part Number: 110293 MCF Material: Al2O3 Part Dimension:________ Date: May 11, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration:______

Tool Type:________ Tool Geometry:________

1250 SFM .010 DOC .015 IPR

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
√60 NORTON	1 −6	½° Holder	OD. 5.8402	.6060	.6059	.6063	.6073	.011	110
DNGA 433 DT100L				.5950	.5949	.5960	.5960	.014	100
//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
√61 Tungaloy			OD. 5.8125	.5869	.5865	.5874	.5874	.008	130
DX160/DDNJA432	−6	½° Holder	5.7940	.5778	.5773	.5780	.5781	.014	120
DNGA150408-DIA									
//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
Tungaloy			OD. 5.7740	.5693	.5690	.5700	.5700	.010	100
√62 DX140/DDNJA432	−6	½ Holder		.5585	.5583	.5590	.5592	.015	90
DNGA150408-DIA									

Remarks:

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Machining Conditions

Page 1 of ____

Part Number: 110993MCH#1 Material: Al_2O_3 Part Dimension: ________ Date: May 13, 94

Machine: LeBlond Model/Type: GE 2000 CONTROLLER Coolant: TRIMSOL Concentration: ________

Tool Type: ________ Tool Geometry: ________

1250 SFM .010 DOC .015 IPR.

√63

-4.5 [illegible] [illegible] 70° -ORANGE [illegible]

√64

-6.5 [illegible]

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Norton			OD. 6.045	.8495	.8500	.8500	.8501	.006	170 2 Passed
✓ DPGA 432			.864 Thick	.8400	.8400	.8400	.8399	.009	140
DT100L	-6½		6.0185	.8285	.8288	.8284	.8286	.011	110
				.8180	.8181	.8180	.8181	.013	100
				.8068	.8070	.8068	.8070	.015	90
				.7960	.7966	.7960	.7964	.016	80
				.7851	.7854	.7850	.7851	.018	100
			OD. 5.963						
✓ Sumitomo				.7753	.7756	.7754	.7756	.005	70
DNMX 433	-6½			.7625	.7630	.7625	.7629	.008	60
DA 150				.7530	.7532	.7530	.7530	.010	60
				.7405	.7405	.7404	.7412	.012	60
				.7330	.7331	.7329	.7329	.016	60
				.7209	.7210	.7209	.7210	.018	90
				.7110	.7113	.7110	.7112	.020	100
				.7000	.7000	.6995	.6999	.028	110

MAY 16 ↓

MAY 16 ↓

Remarks:

Appendix 4.103

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Machining Conditions

Page____of____

Part Number: 110993MCH*1 Material: Al_2O_3 Part Dimension:________ Date: May 16, 1994

Machine: LeBlond Model/Type: GE 2000 Controller Coolant: Trimsol Concentration:________

Tool Type:________ Tool Geometry:________

1500 SFM .010 DOC ~~.015~~ .020 IPR

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	Depth of Cut	Length of Cut	Total Elapsed Time	Part Taper	Tool Flank Wear	Surface Finish
Norton			O.D 5.874	.6921	.6914	.6914	.6914	.011	220
DNGA 433		5.851	THK .7000	.6794	.6795	.6794	.6795	.016	200
DT100L				.6700	.6700	.6696	.6699	.025	190
/ / /	/ /	/ /	O.D. 5.838	/ /	/ /	/ /	/ /	/ /	/ / /
Sumitomo			5.819	.6603	.6608	.6605	.6604	.006	150
DNMX 433			5.810	.6490	.6493	.6490	.6492	.009	130
DA150			5.801	.6370	.6372	.6372	.6372	.011	120
			5.790	.6255	.6255	.6253	.6253	.013	100
			5.7810	.6150	.6152	.6149	.6151	.014	90
			5.7672	.6035	.6039	.6033	.6035	.017	100
			5.7620	.5912	.5919	.5912	.5920	.018	70
			5.7540	.5802	.5801	.5800	.5803	.020	100

-6.5° Holder

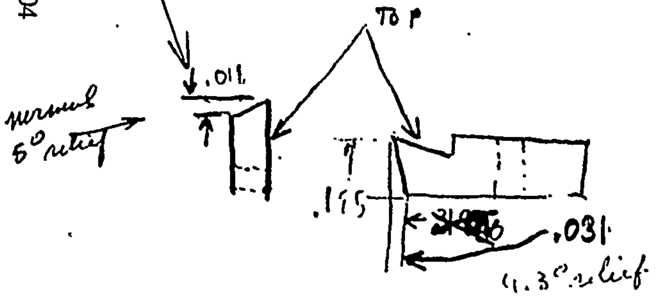
65 ✓

-6.6° Holder

66 extra clearance

centre 50-1: Pr

Remarks:



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Machining Conditions

Page 1 of 1

Part Number: 11093MCG #1 Material: Al_2O_3 Part Dimension:________ Date: June 19, 99

Machine: LeBlond Model/Type: GE 2000 Controller Coolant: Trimsol Concentration:______

Tool Type:________ Tool Geometry: 0° Tool Holder

1500 SFM .010 Doc .020 IPR

√67

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	
		Starting	O.D. 5.996	5.979						
Sumitomo	June 19		Thk. .7865	.7774	.7768	.7778	.7783	.005	160	1st Pass
DNMX 433		5.970	.7853 .7856	.7670	.7665	.7670	.7678	.009	150	
DA 150		5.960	.7865	.7568	.7560	.7567	.7577	.012	160 ?	
		5.950		.7468	.7451	.7455	.7464	.013	130	4
		5.941		.7350	.7344	.7348	.7355	.016	100	5
		5.927		.7232	.7228	.7232	.7237	.019	100	
		5.9212		.7123	.7119	.7120	.7128	.021	80	
		5.9125		.6995	.6993	.6996	.7005	.022	70	8
		5.902		.6875	.6875	.6879	.6883	.024	110	
		5.888		.6780	.6775	.6760	.6785	.028	150	10
		5.878		.6665	.6660	.6663	.6668	.030	210	11

Remarks:

Machining Conditions

Page 1 of ____

Part Number: 111093MCG#1 Material: Al_2O_3 Part Dimension: ____ Date: June 27, 1994

Machine: LeBlond Model/Type: GE 2000 Cortal Coolant: TrimSol Concentration: ____

Tool Type: ____ Tool Geometry: 0° Tool Holder

1000 SFM .010 DOC .020 IPR

68

Workpiece Diameter (in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Total Tool Flank Wear	Surface Finish	Pass
	START	5.864		.6656	.6650	.6655	.6660			
Sumitomo		5.847		.6563	.6558	.6562	.6568	.006	150	1st
DNMX 433		5.827		.6469	.6465	.6468	.6480	.008	150	2
DA150		5.805		.6381	.6375	.6380	.6375	.012	140	3
		5.7945		.6288	.6280	.6282	.6290	.014	130	4
		5.775		.6185	.6182	.6185	.6193	.015	100	5
		5.747		.6093	.6090	.6093	.6100	.017	60	6
		5.734		.5995	.5990	.5990	.6005	.019	60	7
		5.714		.5920	.5918	.5920	.5925	.020	60	8
		5.6995		.5825	.5823	.5825	.5830	.024	50	9
		5.691		.5738	.5735	.5739	.5745	.028	80	10

Remarks:

22

100

Machining Conditions

Page i of ____

Part Number: 111093MCG#1 Material: Al_2O_3 Part Dimension: ______ Date: Aug. 22, 1999

Machine: Leblond Model/Type: GE 2000 Control Coolant: Trimsol Concentration: ______

Tool Type: ______ Tool Geometry: 0° Holder

1250 SFM .015 IPR .010 DOC

69

Workpiece Diameter (in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	
	START	5.685		.573	.572	.5725	.5735			
Norton		5.6665		.565	.564	.5645	.565	.0075	250 - 200	1st
DPGA 432		5.667		.5545	.554	.554	.555	.009	150 · 200	2nd
DT100L		5.663		.5475	.547	.5475	.548	.0115	125 1[illegible]	3
		5.6555		.537	.537	.537	.538	.0135	150 125	4
		5.6505		.526	.5255	.5255	.5265	.015	150 125	5
		5.6225		.514	.5135	.5135	.515	.017	125 150	6
		5.607		.503	.503	.5035	.504	.0185	100 - 125	7
		5.590		.495	.494	.494	.495	.023	125 · 150	8
								.003" into Substrate		9
										10

Remarks:

23

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Machining Conditions

Page____of____

Part Number: 110493MCH Material: Al_2O_3 [illegible] Part Dimension:________ Date: 5-30-91

Machine: Leblond Model/Type: [illegible] Coolant: [illegible] Concentration:________

Tool Type:________ Tool Geometry: -6½°

1250 SFM .015 IPR .010 DOC

70

Workpiece Diameter (in)	Spindle RPMs	~~SFPM~~ (in) O.D.	Feedrate (ipr)	Depth ~~of Cut~~ 1	~~Length of Cut~~ 2	~~Total~~ Elapsed Time 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
	Start	5.9975		.717	.722	.720	.715			
Kennametal		5.927		.709	.713	.711	.707	.0155	125 150	1
DNMS 432		5.908		.7015	.705	.703	[illegible]	.021	110-125	2
KD100		5.[illegible]8		.690	.6955	.693	.689	.028	110-125	
Tool # 1										

Remarks:

[illegible]
10:30 AM -- 11:00 AM

Machining Conditions

Page 2 **of** 2

Part Number: 110493MCH Material: Al_2O_3 Rotor Part Dimension: ________ Date: Aug 31, 1994

Machine: Leblonde Model/Type: GE 2000 Control Coolant: Trimsol Concentration: ________

Tool Type: ________ Tool Geometry: -6½°

1250 SFM .015 IPR .010 DOC

71

Workpiece Diameter(in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
	Start	5.777		.621	.616	.620	.629		[illegible]	
Valenite		5.728		.612	.608	.610	.614	.0075		1
DNGM		5.707		.603	.599	.602	.606	.0095		2
432 2F		5.686		.590	.592	.590	.594	.014		3
		5.650		.577	.575	.577	.561	.0215		4
		5.630		.567	.564	.566	.570	.033		5

Remarks:

9:00 - 11:22 AM

Machining Conditions

Page 1 **of** 2

Part Number: 110493MCH Material: Al_2O_3 Rotor Part Dimension: ________ Date: Aug. 31, 1994

Machine: Leblonde Model/Type: GF 2000 Central Coolant: Trimsol Concentration: ________

Tool Type: ________ Tool Geometry: -6½°

1250 SFM .015 IPR .010 DOC

72

Workpiece Diameter(in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
	Start	5.8[illegible]		.692	.696	.693	.689			
Kennametal		5.862		.682	.686	.683	.679	.010	120	1
DNMS		5.840		.668	.672	.670	.665	.012	80-120	2
432		5.822		.663	.668	.665	.660	.018	[illegible]	3
KD100		5.806		.653	.658	.655	.650	.022		4
(Tool #2)		5.785		.641	.645	.642	.639	.025		5
		5.768		.631	.635	.631	.628	.028		6
		5.747		.620	.624	.621	.616	.038		7
								.008 [illegible]		

Remarks:

SiN
TOOLS

Appendix 4.111

Appendix 4.112

(GSN)

Machining Conditions

Page____of____

Part Number: 110493MCH Material: Al_2O_3 Part Dimension: __________ Date: 9-6-94

Machine: Leblonde Model/Type: GE 2000 Control Coolant: Trimsol Concentration: ________

Tool Type: Greenleaf Uncoated Tool Geometry: 0° 1250 SFM .015 IPR .010 DOC

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Workpiece Diameter(in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass:
	START	5.616		.560	.556	.559	.562			
~~AEROCHEM~~		5.610		.553	.549	.552	.5558	.011		1
~~L-444=203~~		5.593		.5415	.538	.541	.5498	.013		2
~~748-855~~		5.571		.5301	.5267	.5294	.5332	.014		3
(Greenleaf) Uncoated		5.552		.5193	.5151	.5181	.522	.015		4
		5.5312		.507	.504	.507	.5105	.017		5
		5.511		.4962	.493	.4959	.499	.018		6
		5.4912		.4847	.4817	.4842	.488	.019		7
		5.476		.471	.4675	.470	.474	.0205		8
		5.4466		.4597	.4564	.4597	.4632	.0215		9

Remarks:

(GSN) At This Point

Machining Conditions

Page____of____

Part Number: 111593MCH#1 Material: Al_2O_3 Part Dimension:________ Date: 9-7-94

Machine: Leblonde Model/Type: GE 2000 control Coolant: Trimsol Concentration:________

Tool Type: Greenleaf SN Tool Geometry: Triangle 0° holder

Started on a new Rotor.

74

1500 SFM .020 IPR .010 DOC

Workpiece Diameter(in)	Spindle RPMs	SFPM (in) 00	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
	Start	6.0458		.8478	.848	.846	.8476			
Greenleaf		6.022		.838	.8386	.8382	.8382	.006		1
GSN		6.0015		.8285	.829	.8288	.8285	.008		2
Uncoated		5.9823		.819	.8199	.8194	.8190	.0095		3
		5.959		.8049	.8056	.805	.8045	.0135		4
		5.9135		.7997	.8003	.800	.7996	.019	FLAKE	5
		5.9228		.7887	.7894	.7891	.789	.0195		6
		5.9048		.7764	.7772	.7767	.7764	.020		7
			9-8-94							
		5.8665		.768	.769	.7685	.7683	.023	FLAKE	8
		5.8683		.757	.7574	.7575	.7571	.019	Tool Flaked off	9
		5.849		.745	.7455	.746	.7455	.019	.014	10
		5.8256		.7334	.7341	.7313	.734		.017	11
		5.8083		.7221	.7226	.7227	.7224		.017	12
		5.7892		.7101	.7106	.711	.7106		.018	13
		5.7694		.700	.7002	.7005	.700		.018	14

Remarks:

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Machining Conditions

Page____of____

Part Number: 111593McHM Material: Al_2O_3 Part Dimension:__________ Date: 9-9-94

Machine: Leblonde Model/Type: GP 2000 control Coolant: Trimsol Concentration:__________

Tool Type: Greenleaf Aerochem Tool Geometry: 0° Holder Triangle (748-855)

1500 SFM .020 IPR .010 DOC

Workpiece Diameter (in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total~~ Elapsed ~~Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
Start		5.7708		.7001	.7002	.7004	.7004			
		5.7470		.6933	.6939	.6936	.6934	.008		1 2*
Aerochem		5.6864		.6923	.6928	.6928	.6925	.0115		~~2~~ 3
RL		5.6677		.6835	.6838	.684	.6838	.012		~~3~~ 4
748		5.6477		.672	.6729	.6728	.6726	.0125		5
		5.6196		.652	.6524	.6526	.6523	.0135		6

Remarks: * Machine malfunction: Left a step on 5.7" dia. during 1st pass. A second pass was taken which removed the step, but did not remove material from the face. This pass was run over again to make sure the machine would not respond to these offsets, the 5.7" dia was lightly touched, the faces were not. Additional offsets were entered and run. The result was apx. 60/1000" removed from the dia and .001" from the face. .010" more offset was placed in each axis and the program run with satisfactory results.

in SeTup → R 746 L ← TesT of This Tip

Machining Conditions

Page 1 **of** 3

Part Number: 111593MCH#1 Material: Al_2O_3 GIS 2000 Part Dimension:______ Date: 9-12-94

Machine: Leblond Model/Type: Control Coolant: Trinsel Concentration:______

Tool Type: Lankide Aerochem Tool Geometry: 8° Holder Positive Rake Triangle (746-857)

1500 SFM .020 IPR .010 DOC

Workpiece Diameter(in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
START	{Mishap	in	Touch up	chiped	The	Coating	off	The Tip "F"	}	
	One	of The	other Tips	was	Splintered	off	"R"			
AeroChem	→	5.6193		.652	.6522	.6525	.6523			
Coated		5.601		.6435	.644	.644	.6438	.014	.010	1
Lankide		5.5809		.634.1	.6344	.6347	.6345	.014	.012	2
L-444-202-		5.551		.6304	.631	.631	.6307	.0146	.012	3
746-857	NO added offset	5.551		.6286	.6286	.6287	.6285	.0145	120	4
Test of Tip "L"		5.539		.6138	.6134	.6138	.6139	.0175	125	5

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LNX
UNCOAT
+RAKE

Remarks:

T ← Test of This Tip

Machining Conditions

Page 3 of 3

Part Number: 111593MCH#1 Material: Al_2O_3 OF 5000 Part Dimension: ______ Date: 9-12-94

Machine: Leblondo Model/Type: Contrel Coolant: Trinsol Concentration: ______

Tool Type: Carbide Tool Geometry: 0° holder FLAT TOP (742-859)

1500 SFM .020 IPR .010 DOC

Workpiece Diameter (in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	PASS
START		5.5264		.606	.6062	.6064	.6062			
		5.5095		.5963	.5984	.599	.5987	.009	80	1
AeroChem			Diamond	Coating	chipped	off.				
Coated			Testing	suspended	for	the Day				
Carbide	9/13/94	5.4907		.5898	.5899	.5904	.5898	.011	90	2
L-444-201-		5.4688		.580	.580	.5805	.5805	.015	70	3
742-859		5.4491		.5692	.5698	.570	.5696	.015	90	4
Tip "T"		5.4312		.5587	.5587	.5593	.5587	.015	100	5
		5.410		.5472	.5472	.5475	.5474	.016	150	6
		5.3907		.5358	.5362	.5364	.5363	.016	100	7
		5.3712		.527	.527	.5274	.5274	.017	120	8
		5.351		.5157	.5159	.5166	.5167	.018	130	9
		5.332		.505	.5055	.5063	.5062	.018	170	10
		5.312		.497	.4969	.4976	.4972	.0185	150	11
		5.292		.4876	.4873	.488	.488	.019	.120	12

Remarks:

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Continued test of This Tip

Machining Conditions

Page 3A of 3

Part Number: 111593MCH#1 Material: Al_2O_3 Part Dimension: ________ Date: 9-15-94

Machine: Leblond Model/Type: GE2000 Control Coolant: Trimsol Concentration: ________

Tool Type: Lanxide Tool Geometry: 0° holder Flat Top (742-859)

1500 SFM .015 IPR .010 DOC

Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	PASS
			STARTED	CUTTING	ON	BACK	FACE	TWO Each Set	Passes for of Readings	
AeroChem	9-15-94			.4731	.4716	.473	.4718	.021	50	13
Coated				.450	.4482	.450	.4492	.021	60	14
Lanxide				.4278	.4256	.4274	.4262	.022	80	15
L-444-201-				.4088	.4073	.4088	.4076	.023	120	16
742-859				.3885	.3864	.3882	.387	.024	140	17
Tip "T"	Spots		That Look Like	.3682	.3659	.3673	.3663	.025	60	18
	water spots are showing on			.3488	.3468	.3481	.347	.025	50	19
	The face			.3216	.3296	.3309	.3299	.0265	50	20
				.3145	.3122	.3125	.3127	.027	60	21
				.2898	.2888	.2891	.2878	.0275	40	22

Remarks:

2 cuts/reading

78

110


of this tip

Machining Conditions

Page 3B of 3

Part Number: 111593MCH#1 Material: Al_2O_3 GE 2000 Part Dimension: ________ Date: 9/16/94

Machine: Leblond Model/Type: Control Coolant: Trimsol Concentration: ________

Cutting back Face

Tool Type: Lanxide Tool Geometry: 0° Holder Flat Top (742-859)

Two cuts Across back Face for each set of readings

1500 SFM .015 IPR .010 DOC

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Workpiece Diameter (in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total.~~ Elapsed ~~Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
				.2718	.2708	.2713	.2704	.028	50	23
				.2533	.2508	.2525	.2513	.029	65	24
AccuChem				.2323	.2312	.232	.2304	.0295	50	25
Coated										
Lanxide										
L-444-201-										
742-859										
Tip "T"										

Remarks:

UNCOAT
LAN

Machining Conditions

Page 1 of ____

Part Number: 11593MCH41 Material: Al_2O_3 Part Dimension: ____ Date: 9-19-94

Machine: Leblond Model/Type: GE 2000 Control Coolant: Trimsol Concentration: ____

Tool Type: Uncoated Lanxide Tool Geometry: O'holder Flat top Tool

Cutting The Back Rubbing surface of The Rotor. 2 Passes for each set of readings.

1500 SFM .015 IPR .010 DOC

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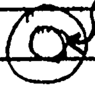
Workpiece Diameter (in)	Spindle RPMs	~~SFPM (in)~~ OD	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
	START			.2318	.2295	.2313	.2298		200	
				.2095	.2089	.2086	.207	.012	150	1
Uncoated		Little or no Metal Built up on Edge		.1904	.1884	.1904	.1879	.016	150	2
Lanxide Tool				.1700	.1691	.1699	.1685	.018	230	3
L-444-201				.1521	.1512	.1520	.1506	.0195	110	4
742-859				.1360	.1350	.1341	.1344	.021	150	5
Tip "R"				.1158	.1134	.1142	.1132	.023	90	6
				.0918	.0924	.0930	.0913	.023	90	7
Changed to Rotor	110293MCF	START		.5592	.5584	.5596	.5593		170	
Hard spots			.5547	.5450	.5390	.5412	.5441	.0245	80	8
				.5195	.5139	.5171	.5193	.0245	140	9
		9/20/94		.5015	.496	.4990	.5018	.0245	110	10
hard spots	have cut away			.4816	.4761	.4790	.4820	.025	140	11
				.4632	.4576	.4604	.4631	.0265	160	12
				.4422	.4372	.4402	.4425	.0275	180	13
		2 PASSES	(-.010?)	.4125	.4073	.4100	.4123	.028	170	14

Remarks:

42

T

Machining Conditions Page 2 of ____

Part Number: 110293MCF Material: Al_2O_3 Part Dimension: ____ Date: 9/20/94

Machine: Leblond Model/Type: GE2000 Central Coolant: Trimsol Concentration: ____

Tool Type: Uncoated LANKIDE Tool Geometry: 0° holder Flat Top

Cutting back side of rotor, 2 passes for each set of readings.

1500 SFM .015 IPR .010 DOC

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	Pass
	110593MCF	2 passes		.4012	.3955	.3990	.4013	.028	240	15
				.3795	.3740	.3790	.3795	.028	250	16
Uncoated				.3614	.3558	.3590	.3615	.0285	350	17
Lanxide Tool				.3401	.3351	.3379	.3401	.030	220	18
L-444-201				.3225	.3165	.3198	.3225	.0305	150	19
742-859				.3005	.2948	.2980	.3003	.032	220	20
Tip "R"				.2798	.2740	.2780	.2800	.0325	140	21
				.2602	.2548	.2578	.2602	.0325	130	22
				.2390	.2330	.2370	.2388	.0335	120	23
				.2185	.2130	.2174	.2185	.034	140	24
				.1978	.1928	.1963	.1976	.0345	140	25

Remarks:

(GSN)

Machining Conditions

Page 1 of ____

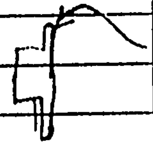
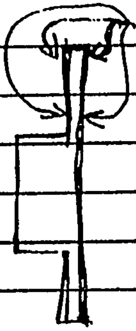
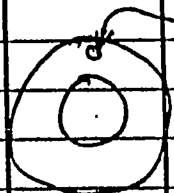
Part Number: 110293MCF Material: Al_2O_3 Part Dimension: ______ Date: 9-22-94

Machine: Leblond Model/Type: ______ Coolant: None Concentration: ______

Cutting back face, 2 passes per set of readings.

Tool Type: Greenleaf Tool Geometry: 0° holder flat top

1500 SFM .015 IPR .010 DOC

Workpiece Diameter(in)	Spindle RPMs	SFPM (in)	Feedrate (ipr)	~~Depth of Cut~~ 1	~~Length of Cut~~ 2	~~Total Elapsed Time~~ 3	~~Part Taper~~ 4	Tool Flank Wear	Surface Finish	PASS
		Material is cutting nicely		.1818	.1765	.1803	.1812	.009	120	1
Greenleaf GSN		white powder noted on Insert when removed		.1608	.1555	.1590	.1603	.010	130	2
uncoated				.1415	.1369	.1398	.1412	.0115	140	3 lunch
No Coolant				.1225	.1192	.1201	.1240	.0125	150	4
				.1060	.1032	.1009	.1042	.013	140	5
	Outer edge is rounding over			.0825	.0800	.0810	.0817	.0135	160	6
				.0623	.0609	.0620	.0636	.014	130	7
	Variation in Thickness, Thickness Increases with distance from hub					hole appeared in rotor with pass 7				

Remarks:

(changed rotor & will continue w/ dry cutting)

MG 9/24/94

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