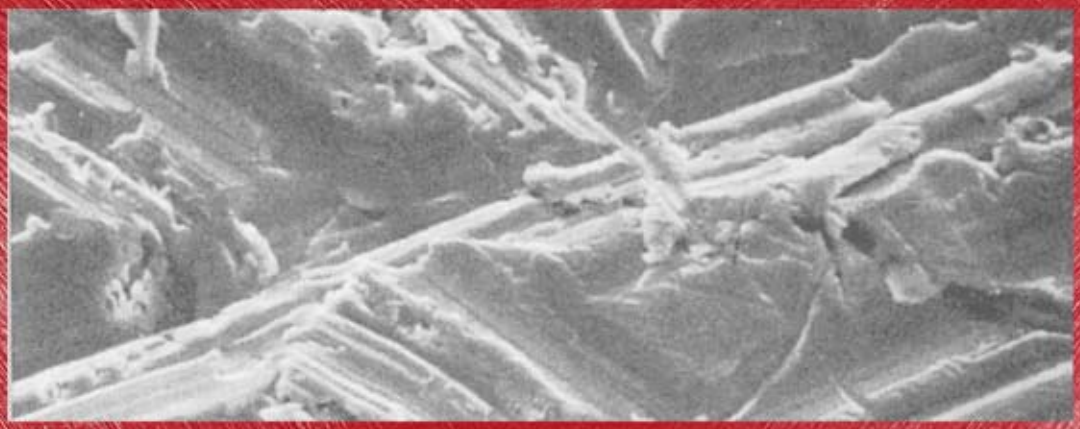


A STUDY OF A CYLINDER WALL MICRO-STRUCTURE

BRM

BRUSH RESEARCH MANUFACTURING CO., INC.

EVOLUTION OF A STUDY IN THE MICRO-FINISHING OF CYLINDER WALLS

When it was first introduced the Flex-Hone was considered a sort of "brush" that was a simple and fool proof way of deglazing engine combustion and brake cylinders. It gained quick acceptance in the trade.

Then came reports from all over of rapid ring seating and great savings in oil consumption. We put out a booklet called "An Observation of Some Common Practices in Cylinder Boring, Honing and Wall Finishing". The front cover emphasizes that "Nothing improves until someone stops and questions an accepted assumption". This "gold book" subsequently was translated into fifteen languages and had over 200,000 copies printed. Most schools use it as a text reference book. In rapid succession we obtained Service Approvals from John Deere, International Harvester, Perkins, Massey Ferguson UK, Caterpillar, Burmeister Wain, Klockner-Humboldt-Deutz, S.E.M.T. Pielstick, OMC, Saviem, Citroen, Peugeot, Mercury Marine, and Countless others.

We had learned by this time using comparison profiles that the Flex-Hone deburred the finish left by either boring or rigid honing and greatly increased the plateaued area. Feeling that this was probably the answer to the "secret" of its performance we produced a second booklet on "The Necessity of a Plateaued Cylinder Wall Finish". In it we showed in detail the results of two performance tests, one on a gasoline powered auto engine, and the second on a Detroit Diesel. This booklet with over 40,000 now distributed has had a great impact in the engineering field and has resulted in our doing (in cooperation), a great many more tests into problem areas. We still did not know the real "why" of its unique performance qualities.

We think, now, that we have come a lot closer to the answer by studying the micro-structure with a Scanning Electron Microscope and by taking before and after photographs of different surfaces. That is what this booklet is all about. And we would like you to study this subject with us and help us in our continued search for the reasons why the results turn out the way they do. We used to say that the only way you could tell, was to performance test. And that is still true. But now perhaps we can have a little better understanding of what it is we are testing.

We are not a large company and we do not operate on grants or financial assistance from the government. Most of our work in this field is done with the cooperation of interested customers and/or our very capable distributors from around the world. You will recognize the many renowned companies that have worked with us or approved our products as they are listed or mentioned in our previous publications. Our reward for our extensive service in this area is the reception that we have received from you and we are dedicated to pursue the technology of cylinder wall finishing so as to provide the most up-to-date information to the industry.

Of equal importance is the finishing of hydraulic and Pneumatic Cylinders. Under heavy pressures, with different types of seals, finish is vital to their performance. Too common is the all-consuming mania of cost reduction, so the continuance of roller-burnishing or pre-finished rigid honed tubing because of speed and cost. Like a lot of products today, make it acceptable for selling. Let the consumer worry about the resultant problems. But the picture today is slowly changing. Competition by quality, or mandated performance levels, will demand changes in improved methods.

If you haven't read our Plateaued Booklet recently then we urge you to do so now. Most top engineers consider it to be the best presentation in its field. Pages 20-21, 22, and 23 deals with our patented concepts in the theory of the sliding surfaces and co-acting metals. We continue its study.

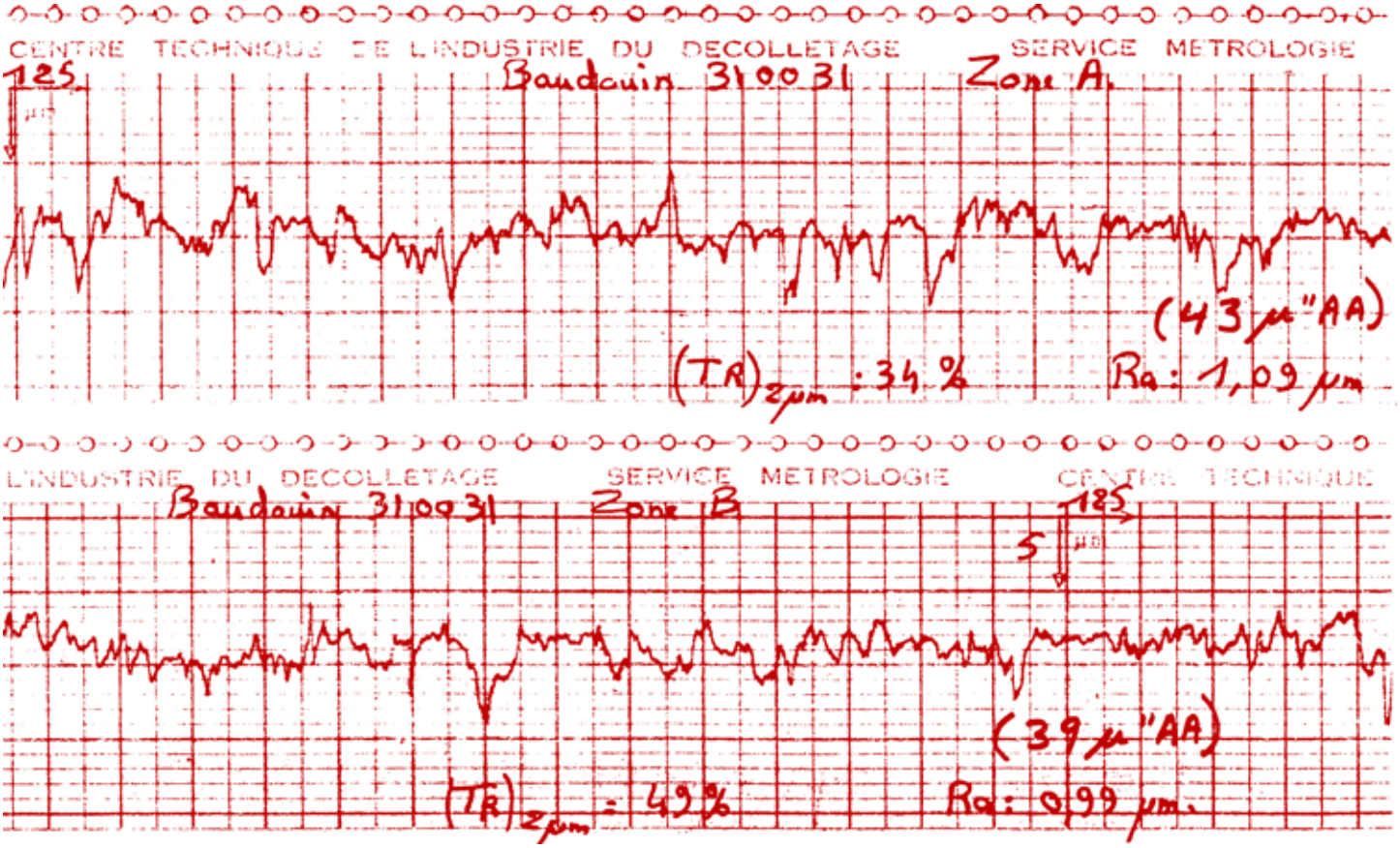
Footnote:
The "Flex-Hone" tool is a patented or has patents pending in all major industrial nations of the world and the name "Flex-Hone" is a Registered trade mark of Brush Research Manufacturing Co., Inc of Los Angeles and is registered or has registrations pending in almost every trading area of the world. Use of the name of Flex-Hone must show that it is a Brush Research Manufacturing Co., Inc. Trademark. Exclusive distributors in almost every country are equipped for your immediate service.

BAUDOUIN'S STRIVE FOR QUALITY

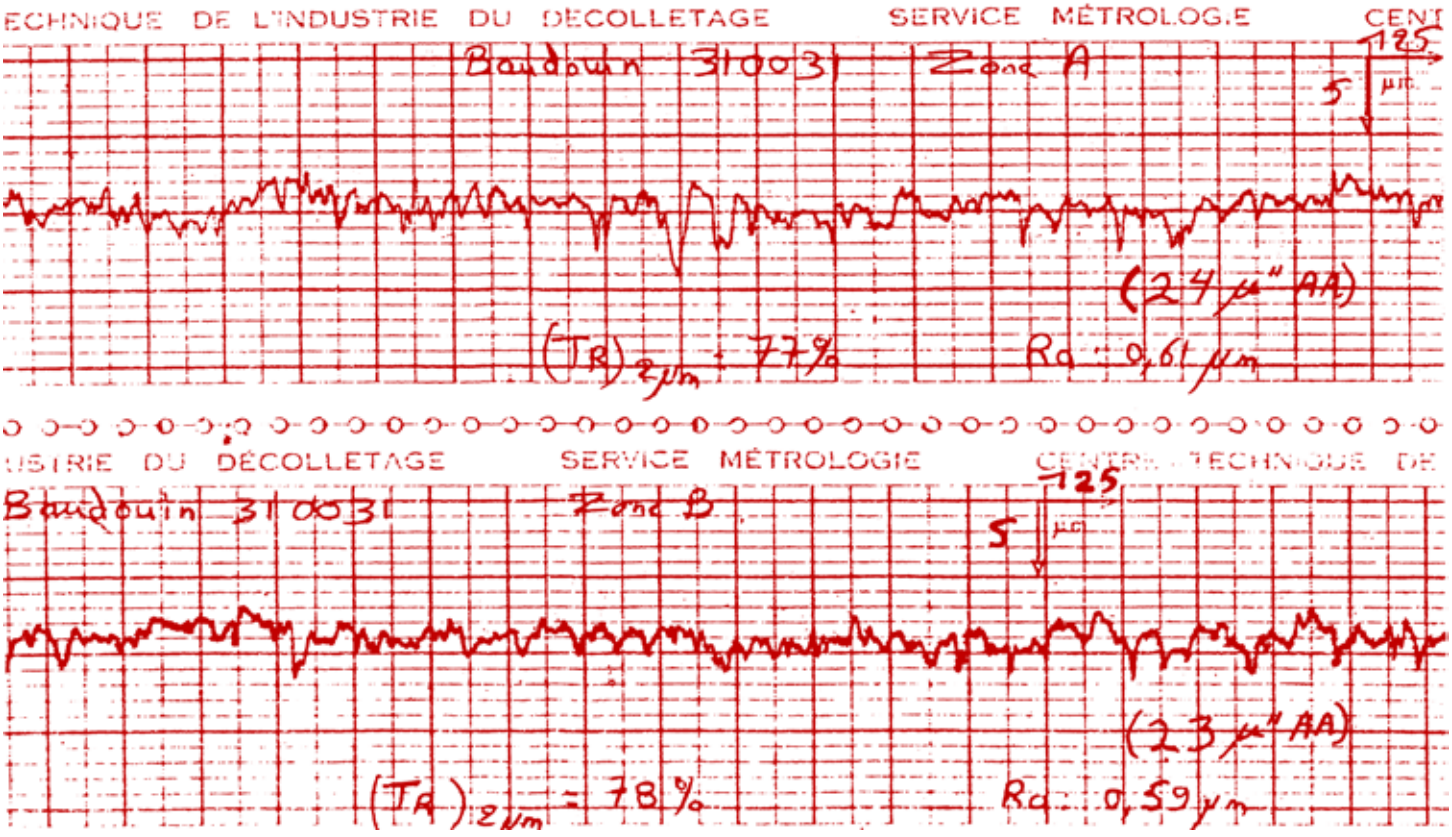
The first presentation is from our distributor for France, SEDIMAT, Baudouin have been purchasing their liners from Associated Engineering of France and they had discovered that by Flex-Honing the liners after receipt from A.E.F. that they eliminated many problems of oil consumption and scuffing. Baudouin had issued a service approval for the Flex-Hone back in 1975.

Baudouin asked A.E.F. to Flex-Hone all liners before final anti-rust coating and delivery to eliminate the problem of doing the Flex-Hone operation after receipt. These normal liners are shown in the following profiles, labeled No. 310031, before and after the Flex-Hone Process.

A.E.F. said they would plateau hone them by their own methods and the finish would be the same as with the Flex-Hone. This type of liner is shown by SEM photographs labeled No. 30202. A.E.F. said that liner No. 30202 had been rigid plateau-honed so it was not necessary to apply the Flex-Hone Process. Mr. Faure offered to have the finishes analyzed for Baudouin and the results are presented on the following pages. Needless to say, Baudouin again requested that all liners be Flex-Honed before delivery. A.E.F. has agreed to Flex-Hone all Baudouin liners at normal price.



Zone A and Zone B represent an area approximately 5 CM in from the top and bottom of the cylinder liner. The above show the profile in the As Received condition. A.E.F. said they had been rigid normal honed. Finish top was Ra:1.09 and bottom Ra:0.99. PLATEAUED AREA 34% AND 49%

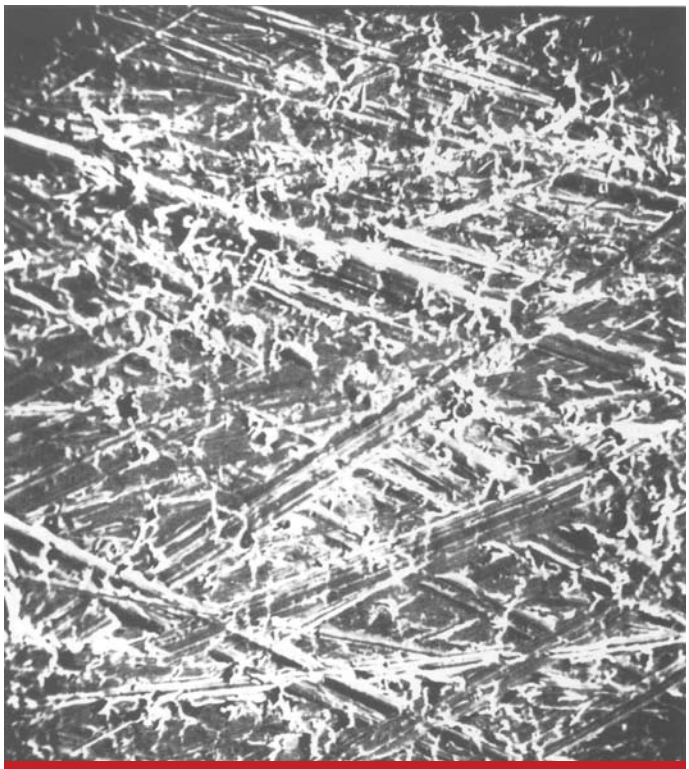


The above two profiles represent the same areas but have been FLEX-HONED with an 80 grain for 60 seconds. Finish has been refined to Ra:0.61 and Ra:0.59 and the PLATEAUED AREA 77% and 78%.

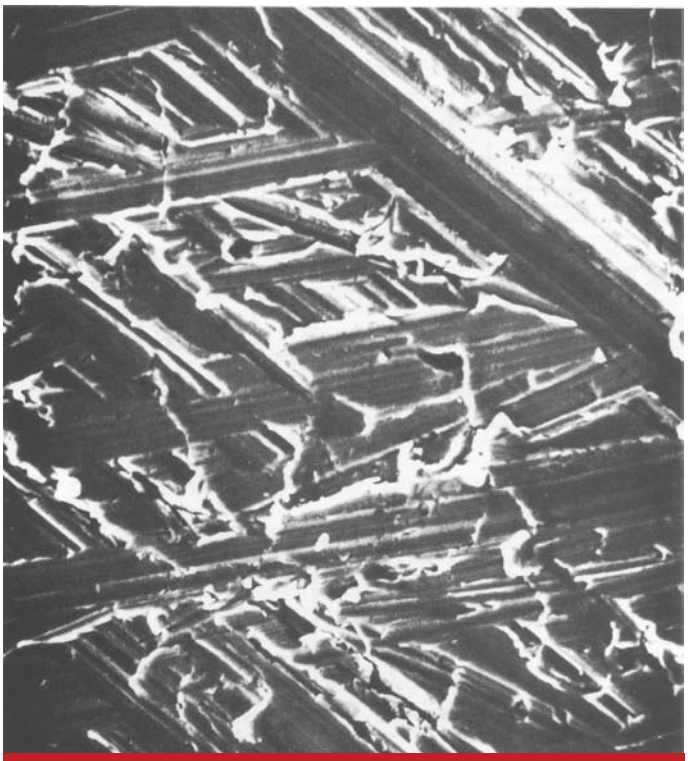
These are SEM photos of Liner 30202, Plateau-Rigid Honed by A.E.F.

Left side are sections of the A.E.F. Plateaued Rigid Honed liner. On the Right Side the same sections Flex-Honed with an 80 grain SC.

No 6 X200 AE PLATEAU



No 4 X200 FLEX-HONE 80

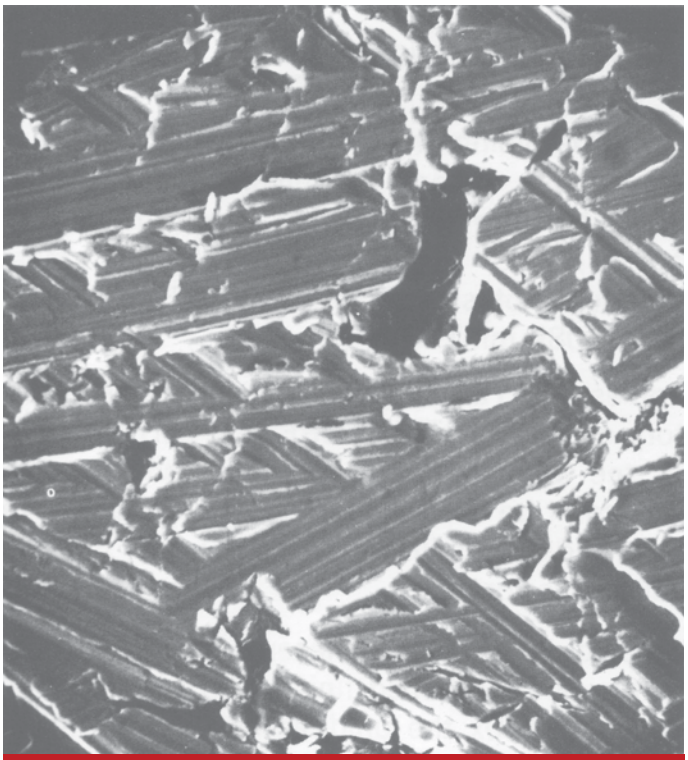


No 6 AE PLATEAU X1000

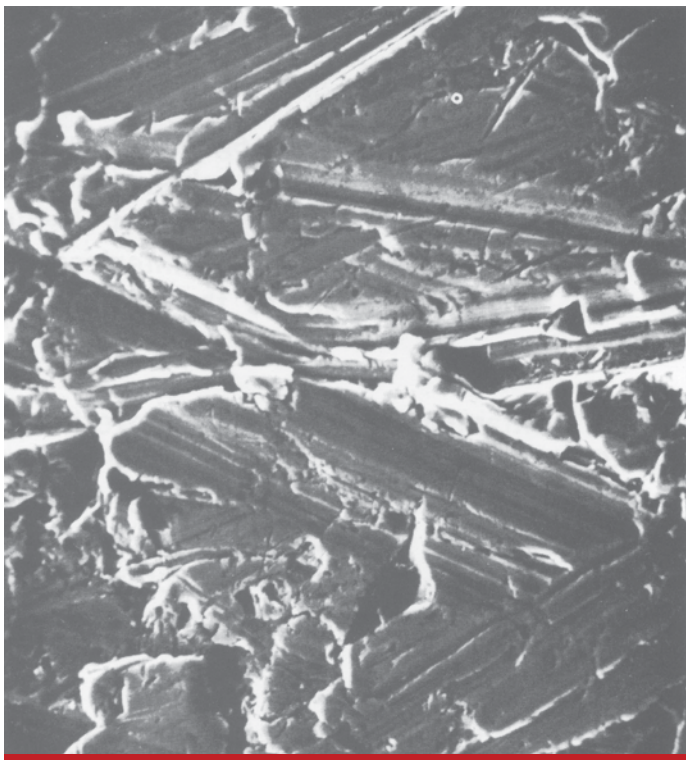
No 4 X1000 FLEX-HONE 80

We feel that an 80 grit is too course for the average application, but manufacturers of large diameter heavy duty engines still want the courser finishes. A few seconds with a finer grit should remove any remaining proud metal.

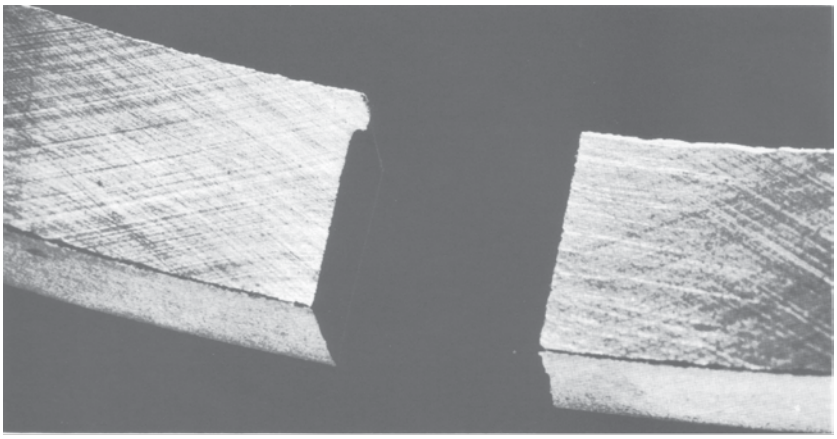
Two more SEM photos of Liner 30202 with the 1000 magnification.



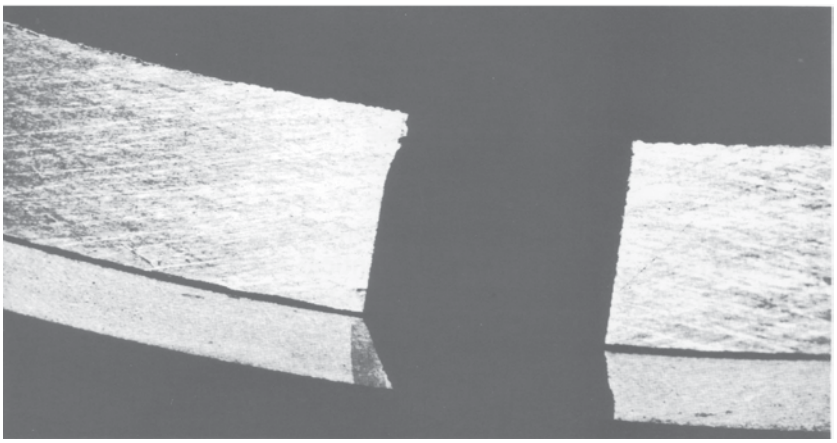
No 6 X1000 AE PLATEAU



No 4 X1000 FLEX-HONE 80



The Baudouin Liner as supplied by A.E.F., Plateau-Rigid Honed Finish. Liner was sectionalized and shows the piece removed for the SEM photo-graphs.



The lower section has been Flex-Honed. The vast difference in the finish and the cross hatch is very evident to the naked eye. Note the over-all consistency is a feature of the Flex-Hone finish.

A COMPARISON STUDY ON TWO V-6 BUICK ENGINES

With minimum fuel economy regulations becoming increasingly difficult to achieve, internal FRICTION plays a very important part. Reduction of piston ring to cylinder wall interface friction will measurably add to the engine's efficiency.

The oil contamination factor of converters is also VERY important. Emission Control Devices may soon have a mandated mileage warranty and they are very adversely affected by excess oil in the emission. Too, if the oil factor is lower, then the manufacturer can start with higher emissions.

With some of these problems in mind, and with the possibility of contributing to the solution of them, we received two V-6 engine blocks from Buick off the assembly line for experimentation and reports. One engine was a new acceptable block which had been double honed, first for size and second for finish. The second engine block had been re-honed and was from the rework facility. The blocks were identified, cylinders marked and the blocks cut into individual cylinders.

To assure a true comparison of before and after Flex-Honing, the individual cylinders were cut into four short sections. One of these was left "As-Is". Only one grit size was used on each section and grits 80, 120, 180, 240, 320 silicon carbide were used in GBD 4" Flex-Hones. A random selection of five cylinders was made for test procedures.

After Flex-Honing, the sections were cut yielding one inch squares in order to fit into the vacuum chamber of a Scanning Electron Microscope (SEM). SEM photos were taken by Scanning Electron Analysis Laboratories of Los Angeles. SEM photos of 100 and 1000 times magnification were taken at an angle of 45 degrees to give a three-dimensional effect. Surfanalyzer profiles were taken by BRM.

When examining the photographs, it will also help to use a hand magnifying glass and to realize that the 100x photos represent an area of .032 x .035" (.81 x .89 mm). The 1000 magnification photos cover an area of .0032 x .0035" (.081 x .089 mm).

Profiles and Fax Films do not show the whole story of MICRO-STRUCTURE, the part you cannot see with the naked eye. The common cold virus can't be seen either, but it creates lots of havoc and costs millions of dollars yearly through reduced performance.

While you are studying these comparisons, note the typical rigid honed finish, and in the photographs of 100x the unidirectional cuts, and in the 1000x photos the debris left on the surface. Notice how the Flex-Hone process has cleaned it up and for the most part, has removed it. Notice the appearance of the cross hatch pattern of the Flex-Hone finish.

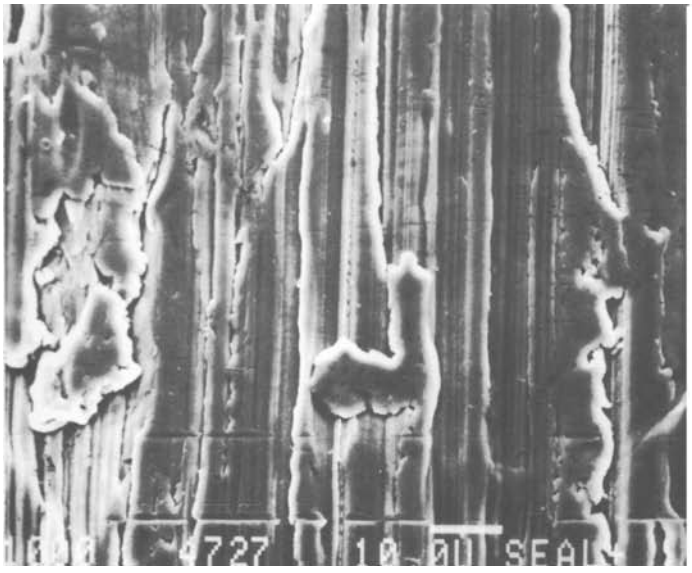
Profiles have been shown using the various grits with the resultant AA finishes as compared to the original. Compare these to the photos to see what the various grit sizes also do to the surface texture. Courser profiles are normally required on a standard rigid honed surface as the smeared-over metal and covered-up graphite needs extra lubrication grooves. In the running-in process with hard and peaky ring surfaces the whole surface gets abraided and except for the deep scratches, the cross hatch finish disappears.

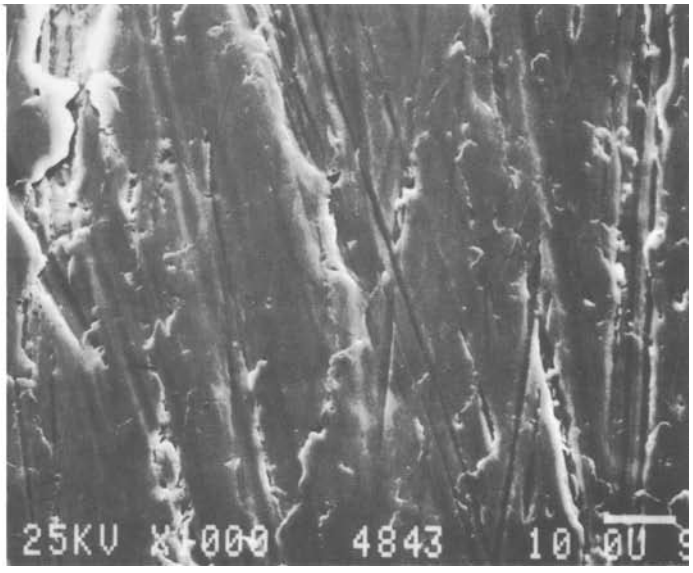
In the Flex-Hone Finish, the ring seating is rapid in comparison, and the abrasive attrition of cleaning up the cylinder wall is greatly reduced or eliminated, so the Flex-Hone finish generally remains. Please turn to our Booklet on the "Necessity of a Plateaued Finish" and look at Comparison photos of the cylinders, (page 14), an OEM, a Rigid Honed, and a Flex-Honed cylinder, run under identical conditions and see the difference. The Flex-Hone finish retains its almost dull-matte look, open and clean.

The following operations were carried out as previously explained and a study is possible of the different finishes achieved by the different grit or grain sizes.

Cylinder	Condition	Grit & Type	Honing Time In Seconds	Finish AA µ"	Finish µm	Profile Characteristics	SEM Photos
A-2	As Received	—	—	20 - 25	.51 - .63	Peaky saw-tooth	A
A-2	Flex-Honed	80 SC	30	30 - 40	.76 - 1.02	Peaky semi- plateau	C
A-2	Flex-Honed	120SC	30	20 - 25	.51 - .63	Semi- plateau	E
A-3	As Received	—	—	20 - 25	.51 - .63	Saw- tooth	G H
A-3	Flex-Honed	80 SC	30	30 - 40	.76 - 1.02	Peaky semi- plateau	I J
A-3	Flex-Honed	120 SC	30	20 - 25	.51 - .63	Semi- plateau	K L
A-3	Flex-Honed	180 SC	30	20 - 25	.51 - .63	Semi- plateau	M N
A-6	As Received	—	—	20 - 25	.51 - .63	Peaky saw-tooth	O P
A-6	Flex-Honed	180 SC	30	20 - 25	.51 - .63	Semi- plateau	Q R
A-6	Flex-Honed	240 SC	30	12 - 18	.30 - .46	Semi- plateau	S T
A-6	Flex-Honed	320 SC	30	7 - 10	.18 - .25	Semi- plateau	U V
B-1	As Received	—	—	40 - 50	1.02 - 1.27	Very Peaky	W
B-1	Flex-Honed	180 SC	30	20 - 25	.51 - .63	Semi- plateau	Y
B-2	As Received	—	—	25 - 35	.63 - .89	Very Peaky	A A
B-2	Flex-Honed	180 SC	30	20 - 25	.51 - .63	Semi- plateau	C C

"A" cylinders were from production rigid honed engine block. "B" cylinders were from rehoned engine block by factory rework section.
As you are analyzing the following SEM photographs and the corresponding profiles, Please Note:
The cut, torn and folded-over metal that is quite evident on the surface. This is what sometimes is referred to as the "Deformed Layer" or the "Stress Layer", or "the Plastically Deformed Surface Layer", all of which is different from the basic structure of the metal. The surface should fully represent the microstructure as it existed in the metal before working. You will note that the Flex-Hone Process has removed the fragmented, damaged, deformed slip bands and in the removal of the common cut, torn and folded metal has opened up the surface structure to a condition that will allow oil retention, reduce friction and abrasive wear on the rings and further damage to the wall surface. This also allows the free graphite (provided that particles have not been torn out by the boring tool or the rigid hone) to appear on the surface to aid in the important role of adding to the lubrication. It is also possible that any hardened martensitic layers may also be removed to assist in ring seating and to cut down excessive ring wear and ring surface configurations. With such surfaces as the Flex-Hone Surface now being possible, then perhaps it may no longer be necessary for piston rings to have the original heavy peaky finish for mutual attrition.

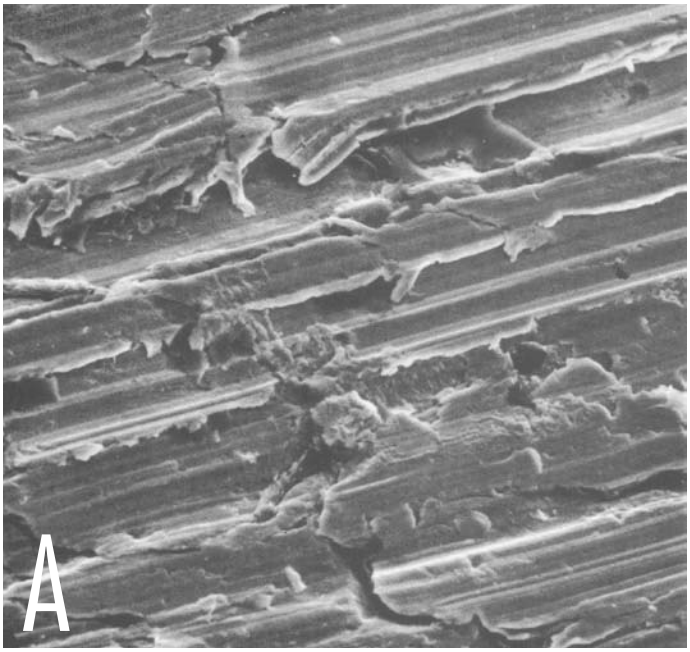


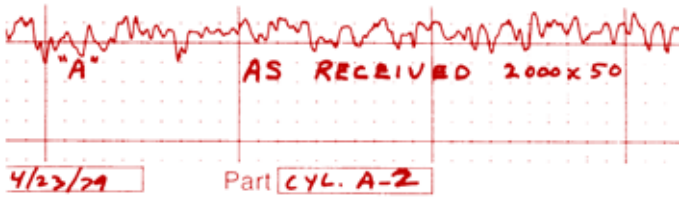


ANOTHER SHOCKER!

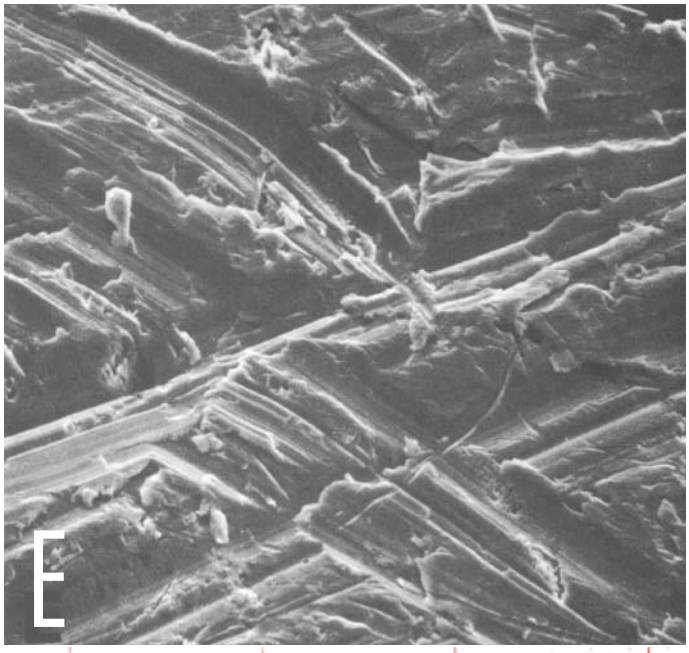
Off the subject of this booklet, we would like to present a small sample of some developmental work in progress on O.D. Finishing of shafts with the Flex-Hone Process. These two SEM photos were taken of a C-1045 ground and polished steel shaft in the before and after Flex-Hoe conditions.

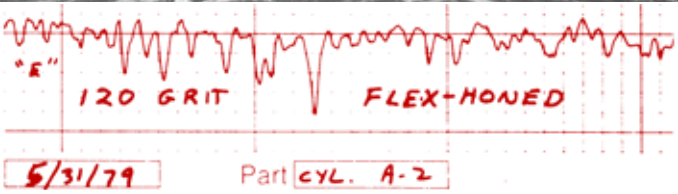
Continuing on the consideration of Co-Acting Metals-the two fields of motion and rest-can you visualize the As Is finish rotating at high speed under pressure on a sliding bearing (including journals, thrust and guide bearings), and the attempt to keep these two metals separated by lubricant, a liquid or a gas? A comprehensive study is to be presented at a later date.



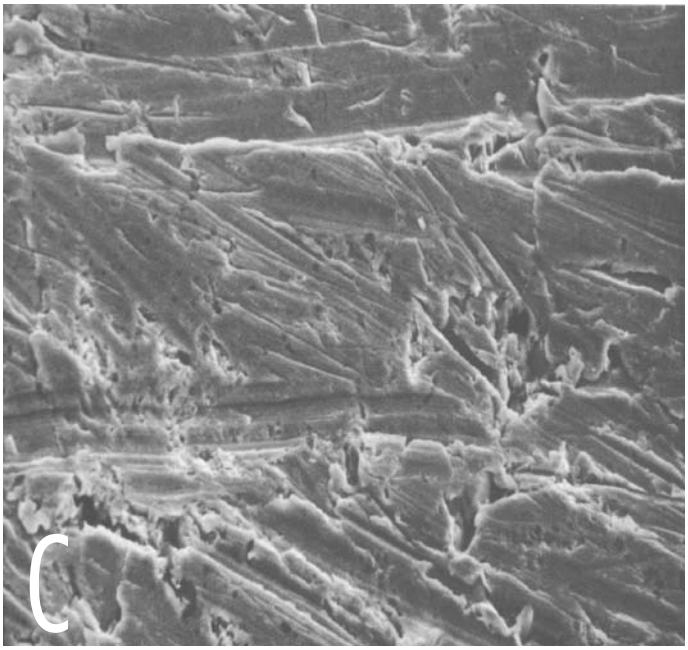


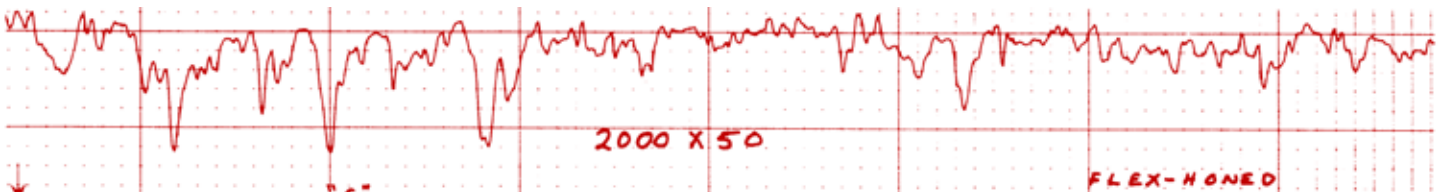
AS RECEIVED, PRODUCTION RIGID HONED, "A" photo taken at 1000x. Unidirectional cut pattern from hone operation. Torn, jagged, folded and smeared metal on surface. Pieces of smeared metal loosely adheared to surface. 20 to 25 µ" finish. Peaky saw tooth appearance to profile. #A-2 cylinder.



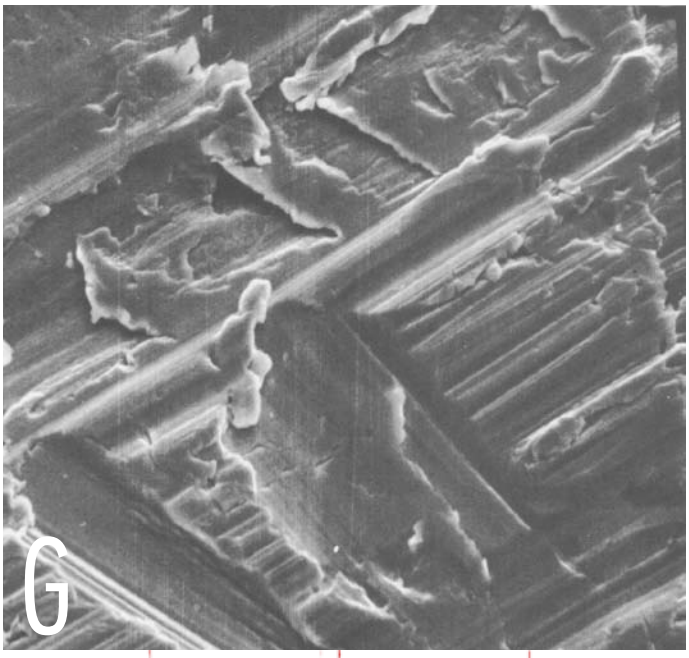


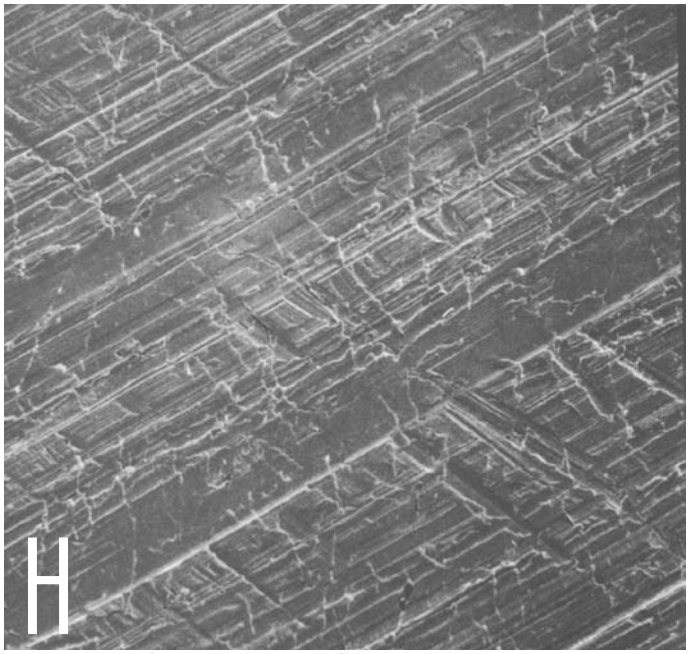
AFTER FLEX-HONE, 120 grit silicon carbide, "E" photo at 1000x. Uniform cross-hatch finish. Most of torn, folded and smeared metal removed. Profiles show good semi-plateaued finish. Surface has clean open appearance. 20 to 25 µ" finish. Section of #A-2 cylinder.

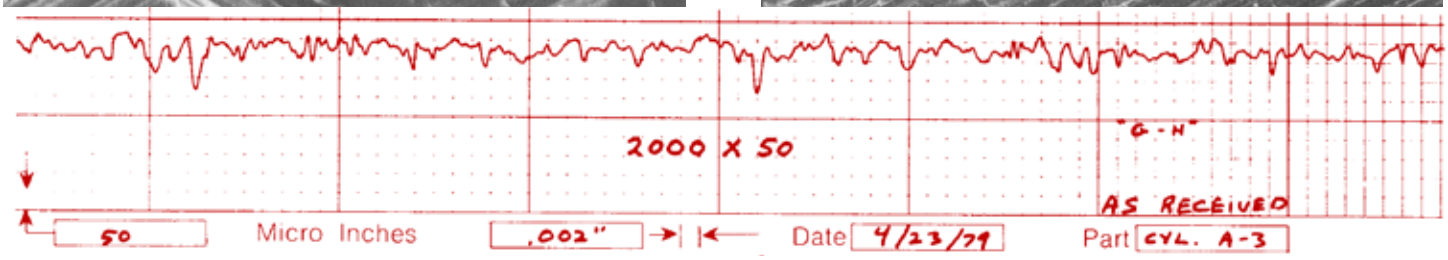




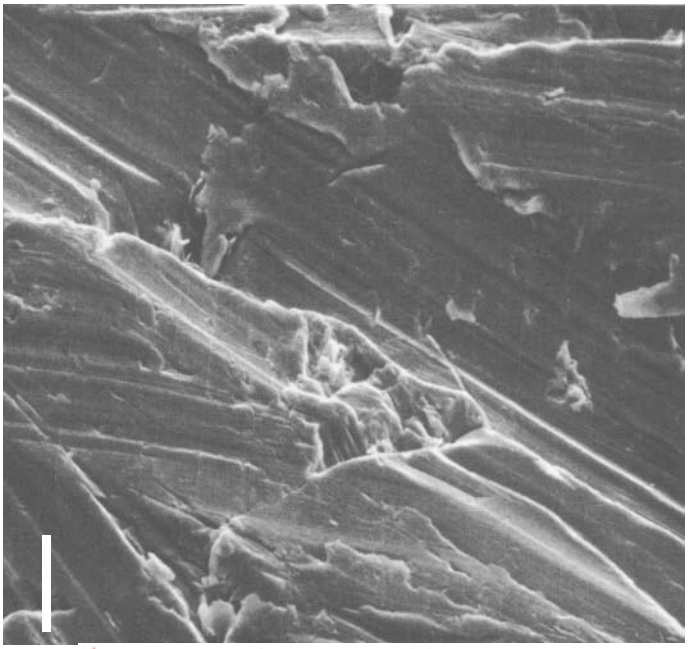
AFTER FLEX-HONE, 80 grit silicon carbide, "C" photo at 1000x. Uniform cross-hatch pattern. Most of torn and folded metal removed. Profile shows some what peaky semi-plateau finish. Profile also reveals that some of original boring operation grooves were opened up by the Flex-Hone operation (deeper grooves on left hand side of profile. 30 to 40 µ" (.76 to 1.02 µm) finish. Section of #A-2 cylinder.

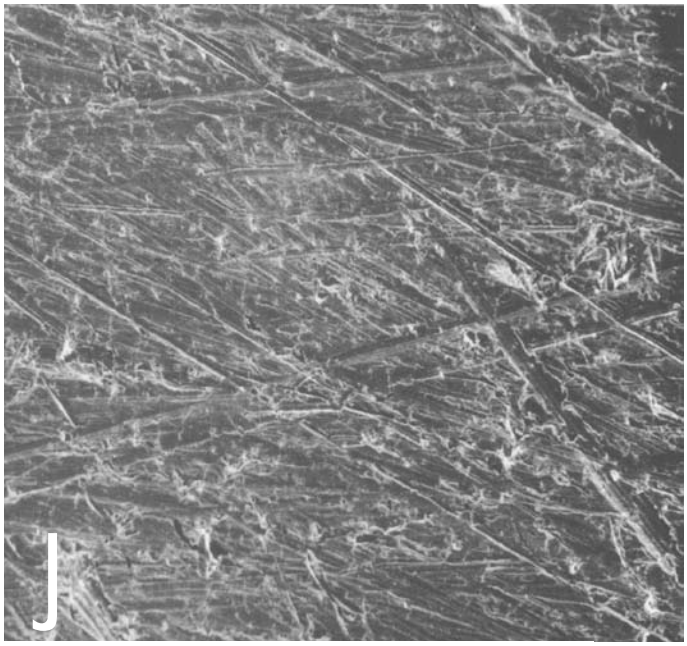


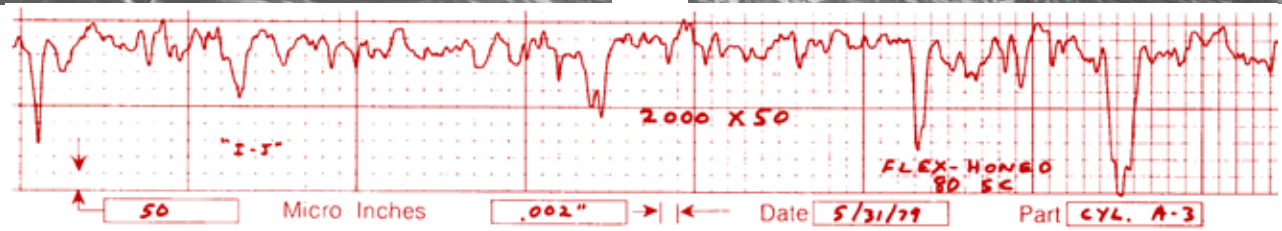




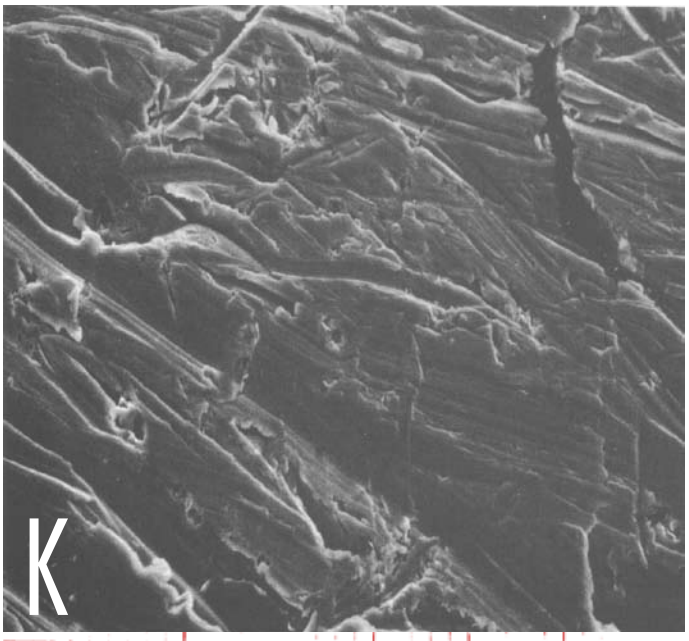
AS RECEIVED, PRODUCTION RIGID HONED, "G" photo at 1000x, "H" at 100x. Cross-hatch not uniform with "skips" in pattern. Torn, jagged, folded and smeared metal. Some of smeared metal loosely attached to surface. 20 to 25 µ" (.51 to .63 µm) finish. #A-3 cylinder

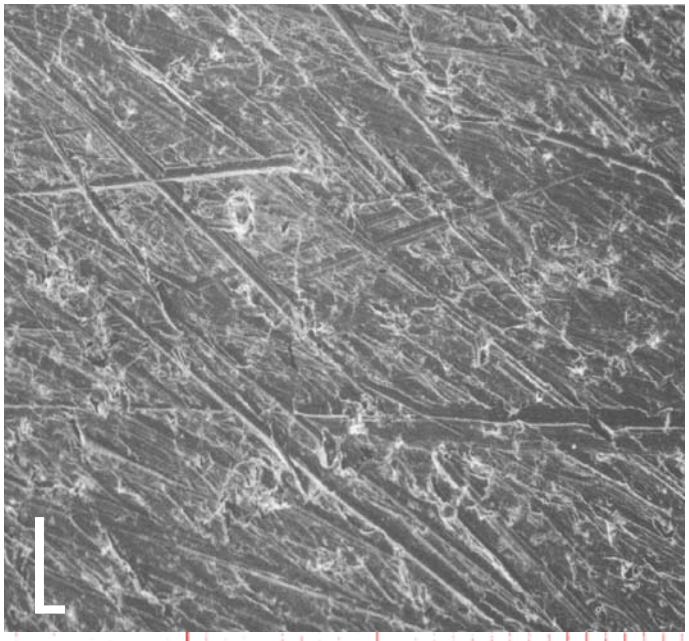


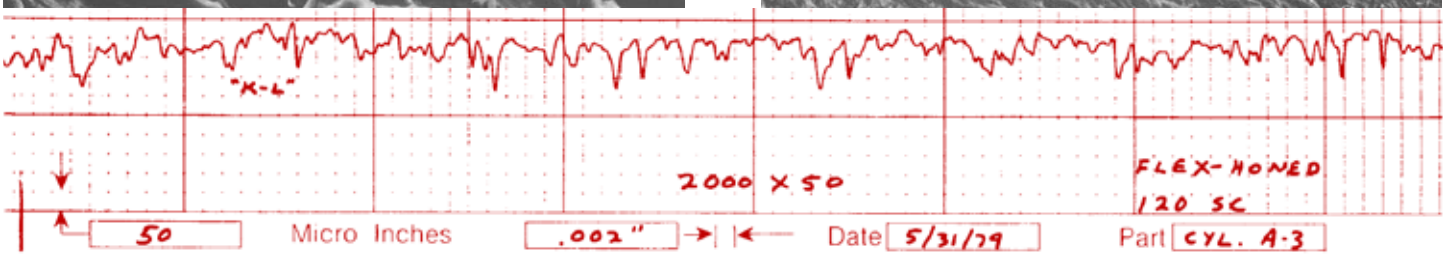




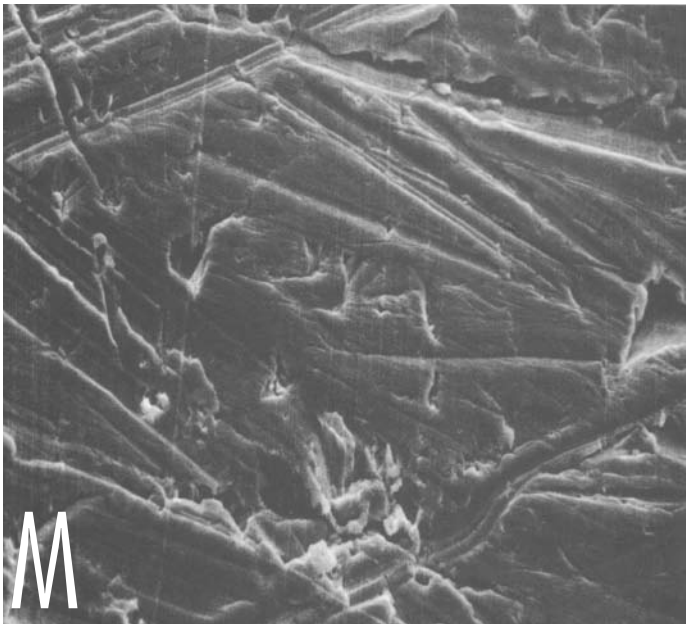
AFTER FLEX-HONE, 80 grit silicon carbide, "I" photo at 1000x, "J" at 100x. Uniform cross-hatch pattern. Surface has a very clean, open appearance with the torn, folded and smeared metal removed. Profiles somewhat peaky due to coarser grit size. 30 to 40 µ" (.76 to 1.02 µm) finish. Section of #A-3 cylinder.

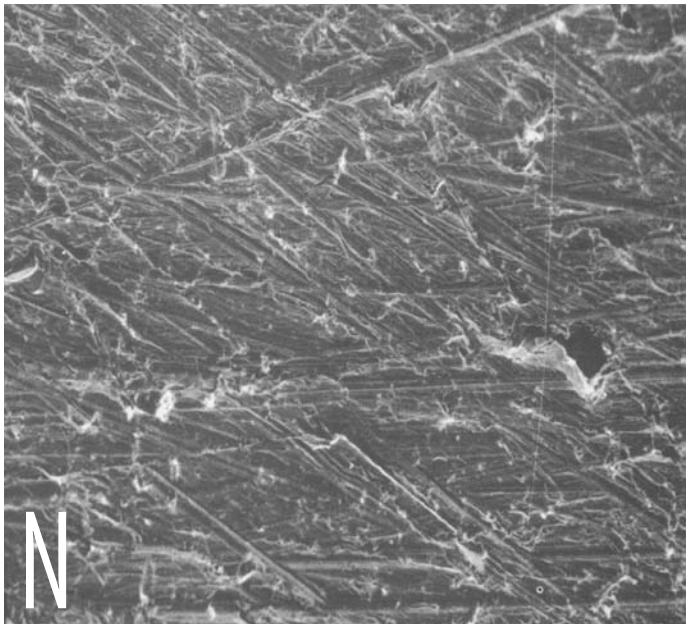


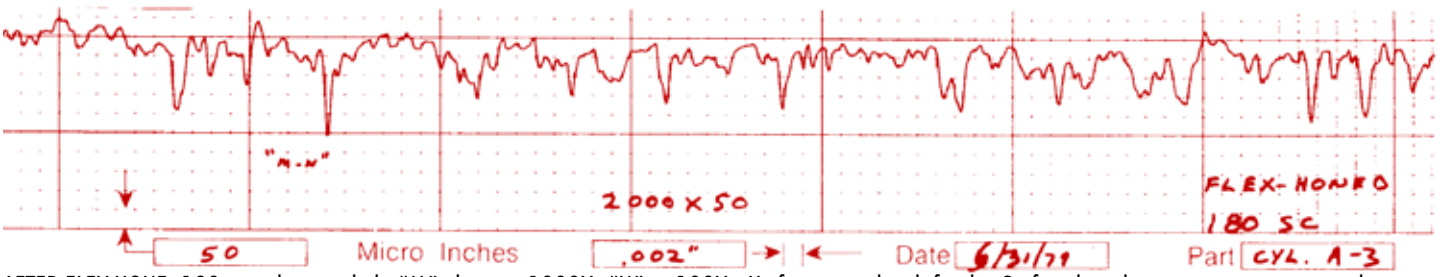




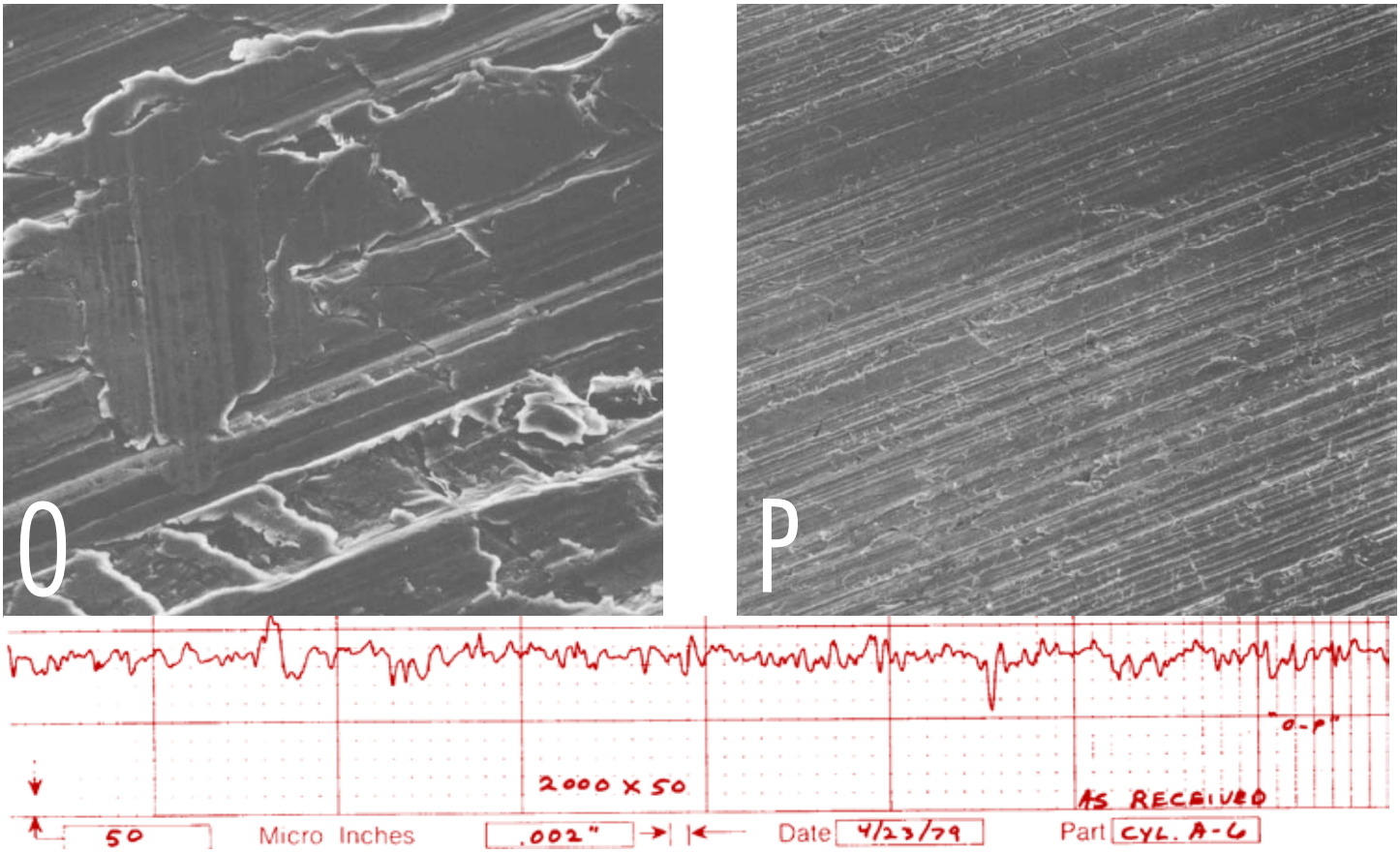
AFTER FLEX-HONE, 120 grit silicon carbide "K" photo at 1000X, "L" at 100X. Uniform cross-hatch pattern. Surface has clean open appearance with most of torn, folded, and smeared metal removed. Excellent semi - plateaued profile. 20 to 25 µ" (.51 to .63 µm) finish. #A-3 cylinder.



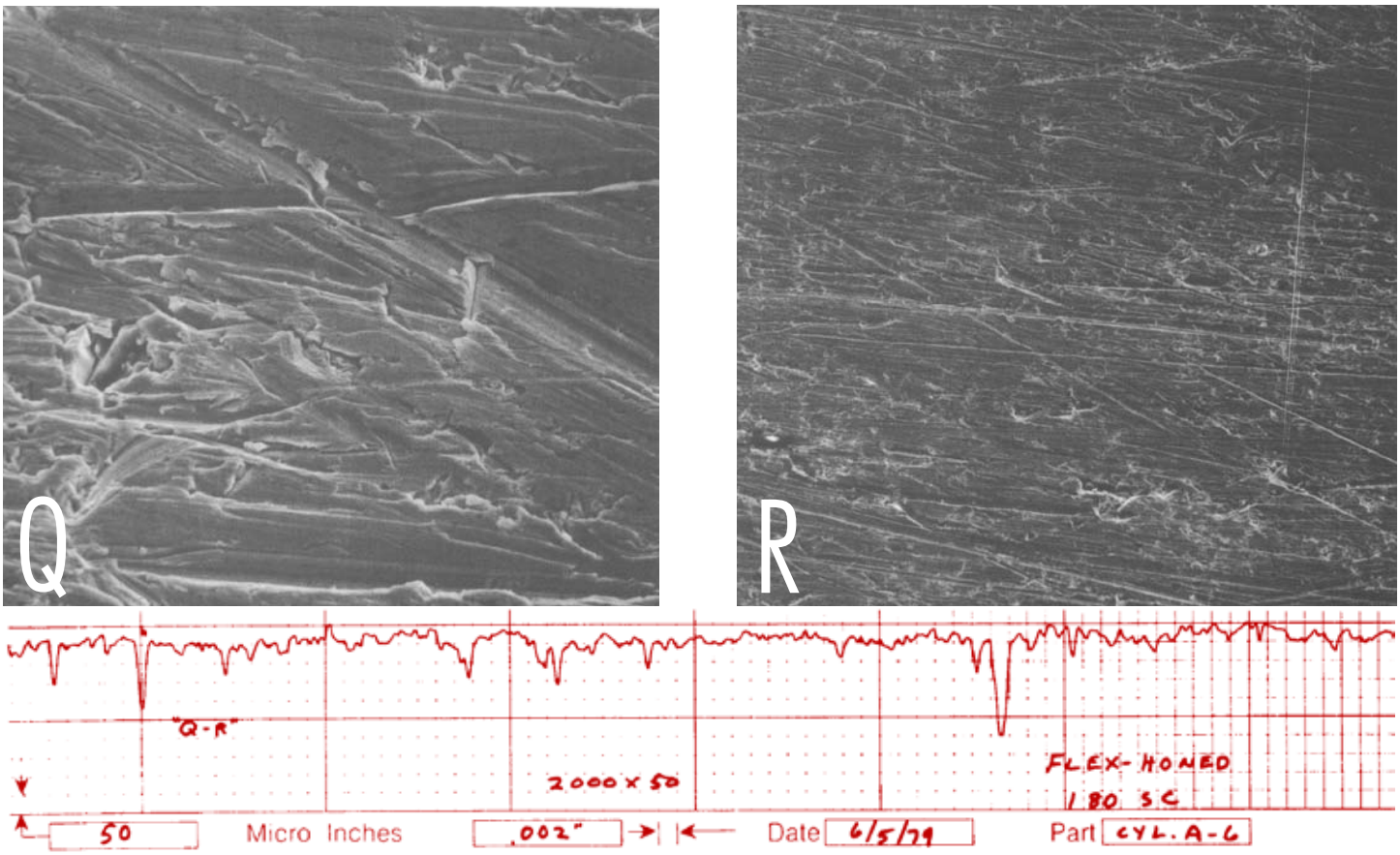




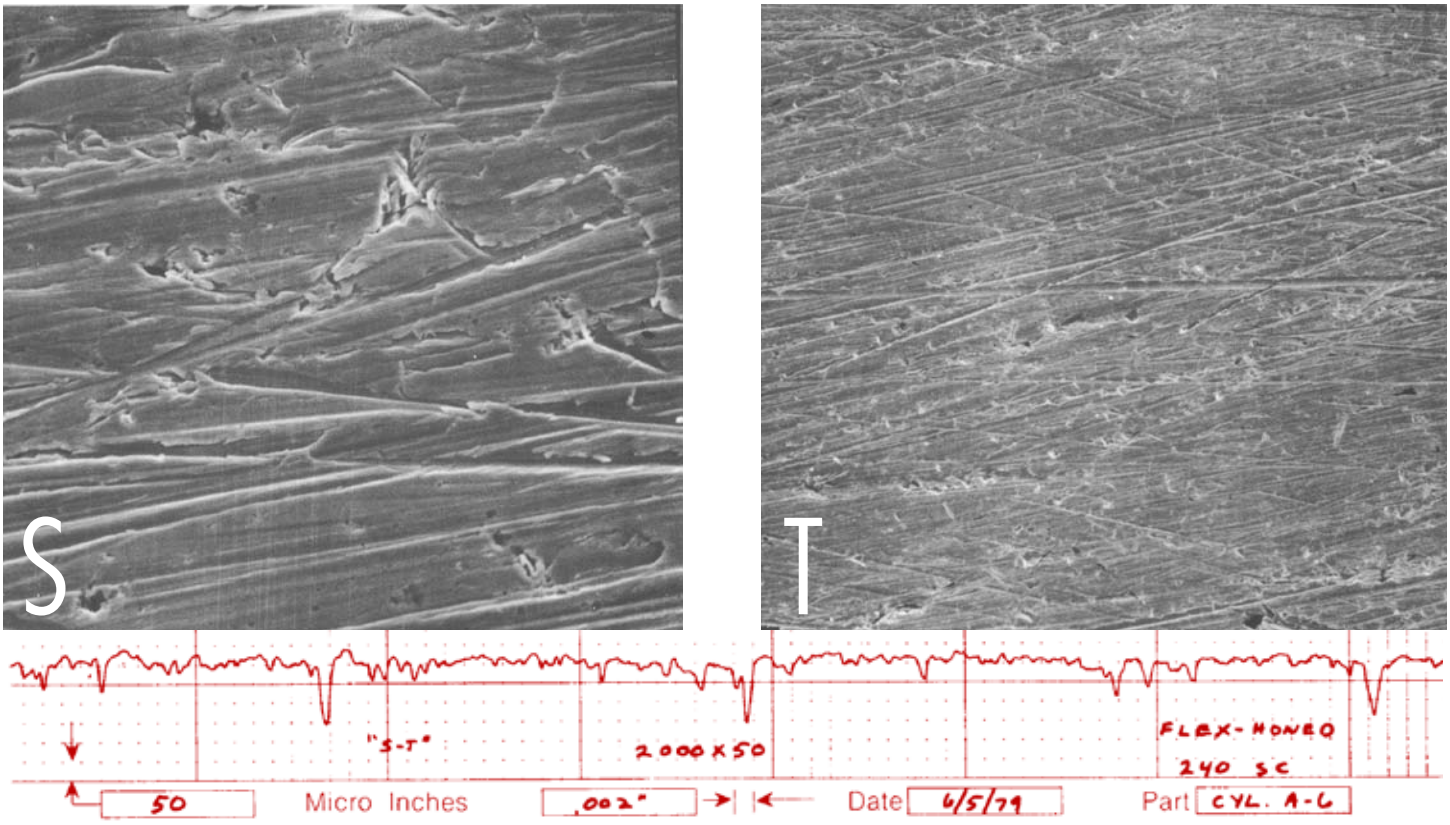
AFTER FLEX-HONE, 180 grit silicon carbide "M" photo at 1000X, "N" at 100X. Uniform cross-hatch finish. Surface has clean open appearance with most of torn, folded, and smeared metal removed. Excellent semi - plateaued profile. 20 to 25 µ" (.51 to .63 µm) finish. #A-3 cylinder.



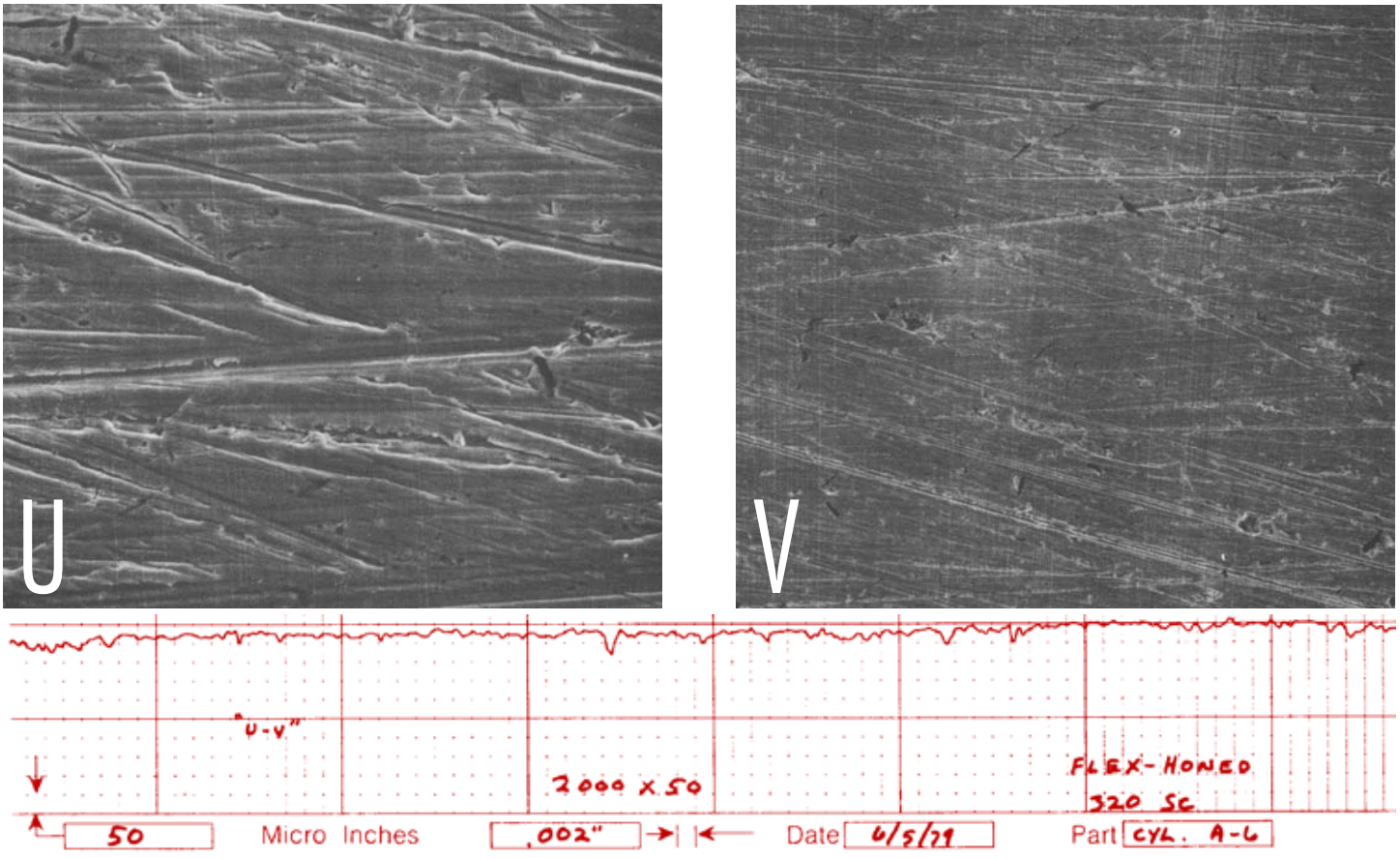
AS RECEIVED, PRODUCTION RIGID HONED, "O"photo at 1000X, "P" at 100X. Undirectional cut pattern from rigid hone operation. Peaky profile with typical saw tooth appearance. 20 to 25 µ" finish. #A-6 cylinder.



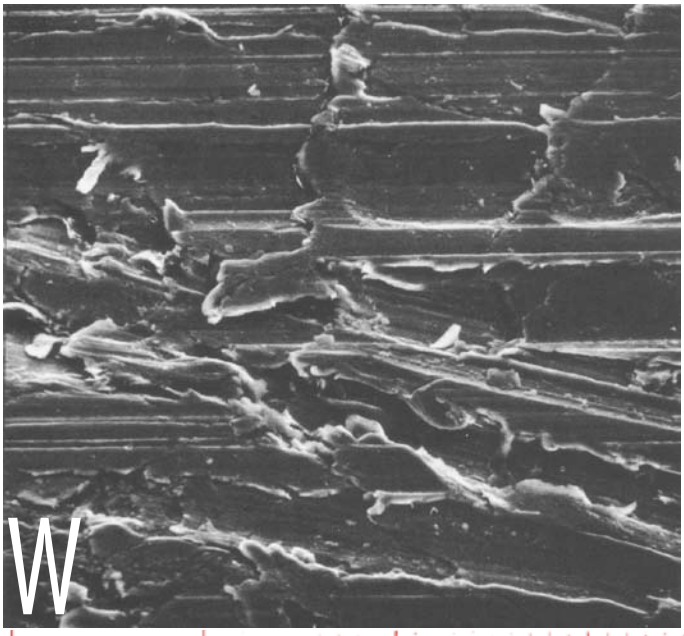
AFTER FLEX-HONE, 180 grit silicon carbide "Q" photo at 1000X, "R" at 100X. Uniform cross-hatch pattern. Surface has clean open appearance with most of torn, folded, and smeared metal removed. Excellent semi - plateaued profile. 20 to 25 µ" (.51 to .63 µm) finish. #A-6 cylinder.



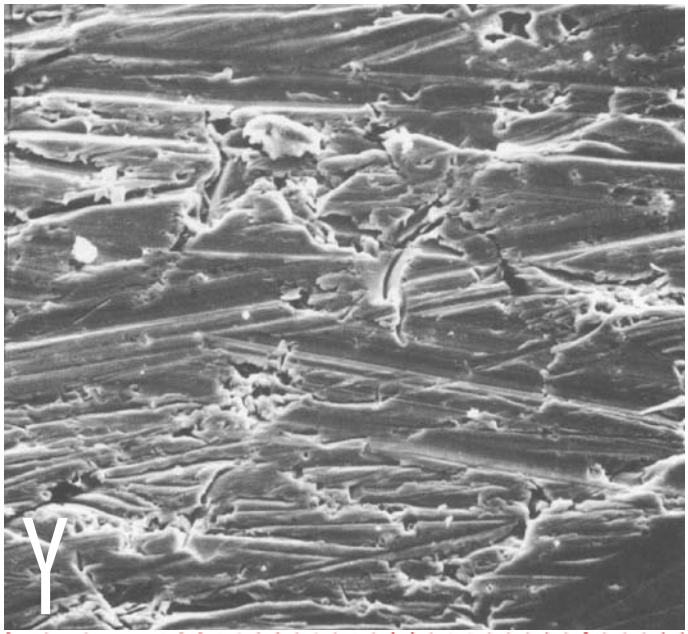
AFTER FLEX-HONE, 240 grit silicon carbide "S" photo at 1000X, "T" at 100X. More refined finish with uniform cross-hatch pattern. Surface has clean open appearance with most of torn, folded, and smeared metal removed. Excellent semi - plateaued profile. 12 to 18 µ" (.30 to .46 µm) finish. Section of cylinder #A-6.



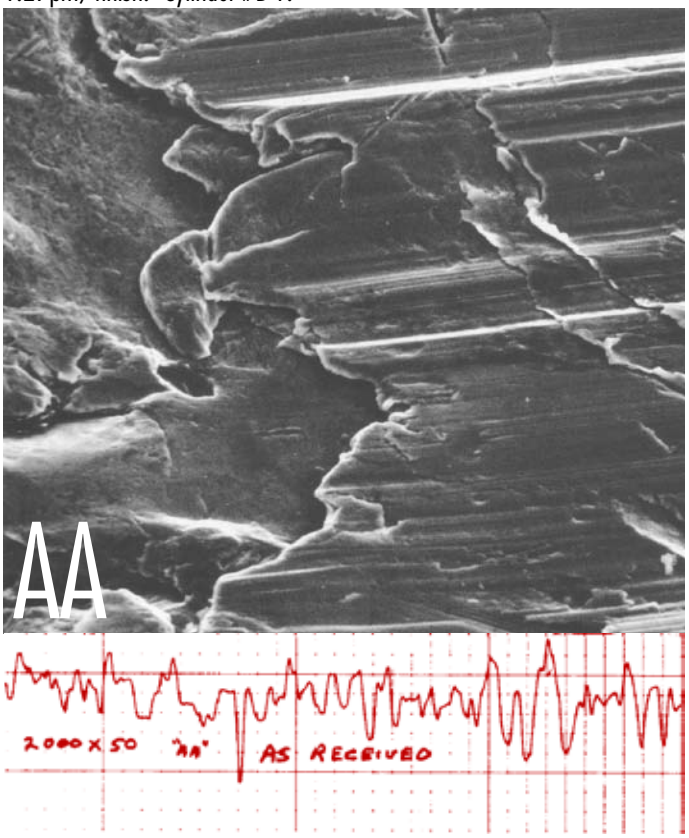
AFTER FLEX-HONE, 320 grit silicon carbide "U" photo at 1000X, "V" at 100X. More refined finish with uniform cross-hatch pattern. Surface has clean open appearance with most of torn, folded, and smeared metal removed. Excellent semi - plateaued profile. 7 to 10 µ" (.18 to .25 µm) finish. Section of cylinder #A-6.



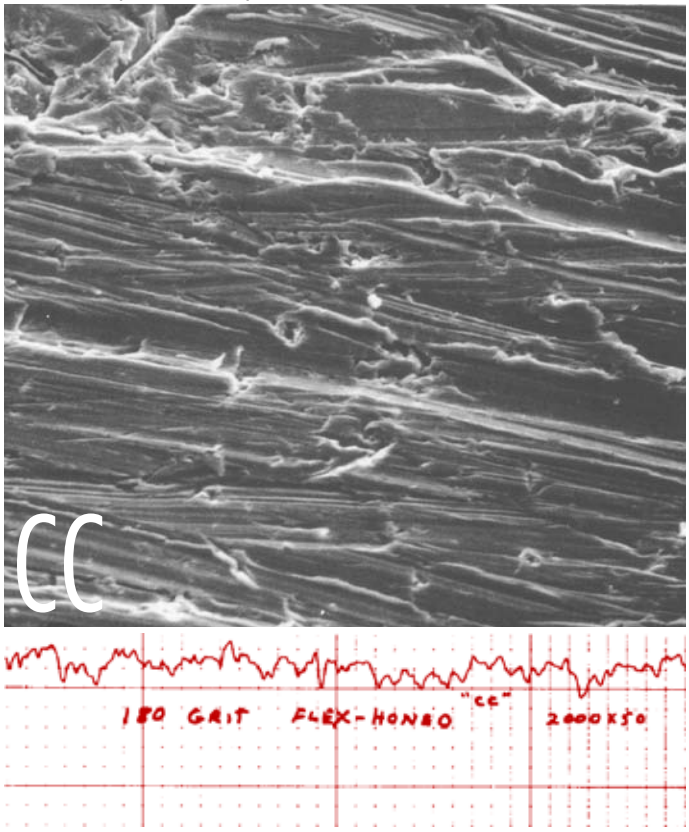
AS RECEIVED RIGID HONED BY FACTORY REWORK SECTION. "W" photo at 1000X. Cross-hatch has majority of cut in one direction. Smeared, torn, jagged and folded metal on surface. Smeared metal loosely attached to surface. Very peaky profile finish. 40 to 50 µ" (1.02-1.27µm) finish. Cylinder #B-1.



AFTER FLEX-HONE, 180 grit silicon carbide "Y" photo at 1000X. Uniform cross-hatch pattern. Surface has clean open appearance with most of torn, folded, and smeared metal removed. Excellent semi - plateaued profile. Small dust particles visible on surface in "Y" photo. 20 to 25 µ" (.51 to .63 µm) finish. Cylinder #B-1.

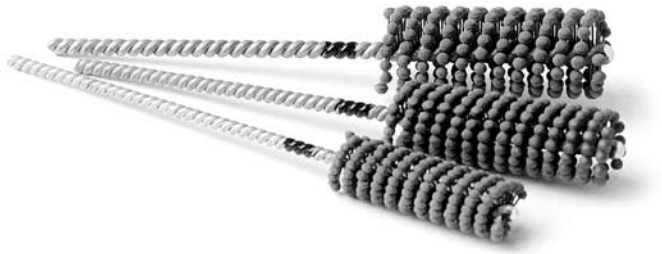


AS RECEIVED RIGID HONED BY FACTORY REWORK SECTION. "AA" photo at 1000X. Uniform cross-hatch pattern. Smeared, torn, and folded metal, smeared metal loosely attached. Very peaky profile.. 25 to 35 µ" (.63 to .89 µm) finish. Cylinder #B-2.



AFTER FLEX-HONE, 180 grit silicon carbide "CC" photo at 1000X. Uniform cross-hatch pattern. Surface has clean open appearance with most of torn, folded, and smeared metal removed. Excellent semi - plateaued profile. 20 to 25 µ" (.51 to .63 µm) finish. Cylinder #B-2.

REPORT OF A TEST PROGRAMME CARRIED OUT BY NICRO (LEAMINGTON) LTD., STROUD, GLOS., ENGLAND



ON THE SURFACE FINISH OF CYLINDER LINERS MANUFACTURED BY TWO OF THE MOST IMPORTANT ENGINE MANUFACTURERS IN THE UK.

We were asked by these two manufacturers to investigate the use of the FLEX-HONE Tool on their cylinder liners as a final finishing process.
This report is in two parts. Part One deals with cylinder liners made by one of the finest producers of engines and cars in the World. Part Two deals with cylinder liners made by the biggest producers of heavy commercial vehicles in the UK.

All cylinder liners were checked for surface finish and surface profile upon receipt. We decided at this juncture to cut sections Out Of two liners of Part One and one liner of Part Two in order to have them photographed by a Scanning Electron Microscope. Our purpose in so doing was to see what level of smeared, torn and folded metal appeared on the surface of these liners in the ''as received" condition. These sections were then refitted into the liners and all liners were then Flex-Honed. After Flex-Honing, the liners were then rechecked for surface finish and pro- file. The sections were then removed from the liners and photographed again by the Scanning Electron Microscope.

All surface measuring was done by our own Ferrants Surfcom IOB instrument and associated recorder. The SEM photographs were done by an independent metallurgical laboratory using a Cambridge Stereoscan 600.

All profile charts shown in this report have a vertical magnification of 2000 and a horizontal magnification of 50. Surface finishes are expressed in µm (micro metres) RA. The profile charts show profiles as TP (total profile).

TEST PART ONE

We received nine liners from the manufacturer, all of which were reported to be in the finish honed condition i.e., they were in the condition in which they would be installed into engines. The manufacturer's specification for final finish is 0.63 . 1.13 µm RA (25-45 µ ins CLA). As can be seen from the following table, none of these liners was anywhere near this in the condition in which we received them, Further more, all had profile characteristics which were very "peaky." We photographed two sections from each of liners (1) & (6) and these photographs are shown below. They show quite clearly that the surface of these cylinders contained a great deal of smeared, torn and folded metal. The finish of all liners showed a very clearly defined "cross hatch" through out.

Every liner was then Flex-Honed with the grade indicated in the following table. The results in terms of surface finish are also shown in this table. The type of Flex-Hone used was GB 4- 5/8". The sections were removed from liners (1) & (6) and re-photographed by the SEM.

The results shown by these photographs are very revealing indeed. It can easily be seen that the surface of these cylinders shows very little evidence of smeared, torn and folded metal. Flex- Honing has cleaned and opened up the surface. The surface has been stress relieved and the profile changed from ''peaky" to an excellent plateau or a "semi-plateau."

PLEASE LOOK VERY CAREFULLY AT THE FOLLOWING TABLE, SEM PHOTOGRAPHS AND PROFILES.

TABLE SHOWING RESULTS OF TEST PART ONE

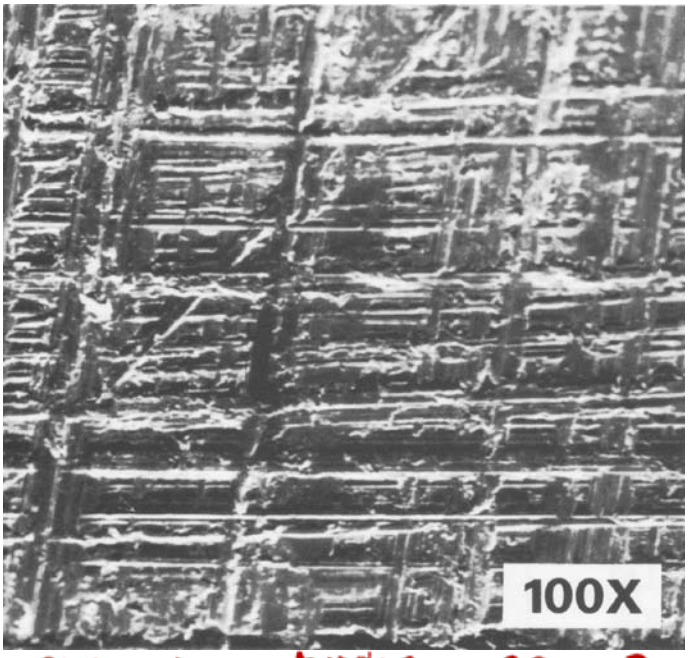
The ''before and after" surface finishes are shown hereunder:

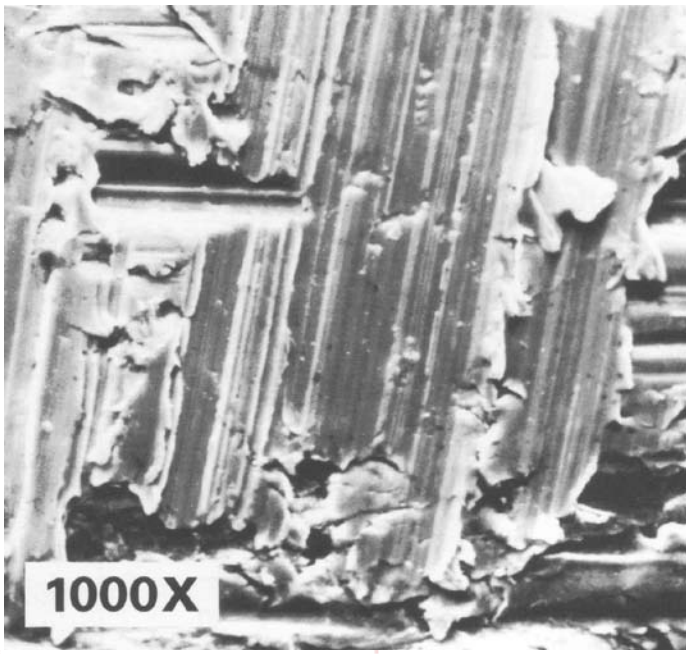
Cylinder	Condition	Grit & Type	Honing Time in Seconds	Finish µm RA	Finish AA µ" or CLA	Profile Characteristics
(1) (1)	As Received Flex- Honed	— 180 SC	— 45	1.25 - 1.50 0.75 - 0.95	49 - 59 30 - 37	Peaky Saw Tooth Plateau
(2) (2)	As Received Flex- Honed	— 180 SC	— 30	1.10 - 1.50 0.60 - 0.80	43 - 59 24 - 31	Peaky Saw Tooth Semi - Plateau
(3) (3)	As Received Flex- Honed	— 180 SC	— 30	1.30 - 1.75 0.70 - 0.95	51 - 69 28 - 37	Peaky Saw Tooth Semi - Plateau
(4) (4)	As Received Flex- Honed	— 180 SC	— 45	1.25 - 2.00 0.70 - 1.00	49 - 79 28 - 39	Peaky Saw Tooth Semi - Plateau
(5) (5)	As Received Flex- Honed	— 180 SC	— 45	1.10 - 1.60 0.70 - 0.95	43 - 63 28 - 37	Peaky Saw Tooth Semi - Plateau
(6) (6)	As Received Flex- Honed	— 180 SC	— 45	1.00 - 1.50 0.80 - 1.00	39 - 59 31 - 39	Peaky Saw Tooth Semi - Plateau
(7) (7)	As Received Flex- Honed	— 180 SC	— 45	1.10 - 1.40 0.70 - 0.80	43 - 55 28 - 31	Peaky Saw Tooth Plateau
(8) (8)	As Received Flex- Honed	— 180 SC	— 45	1.20 - 2.25 0.70 - 1.00	47 - 89 28 - 39	Peaky Saw Tooth Plateau
(9) (9)	As Received Flex- Honed	— 180 SC	— 45	1.10 - 1.60 0.70 - 0.80	43 - 63 28 - 31	Peaky Saw Tooth Plateau

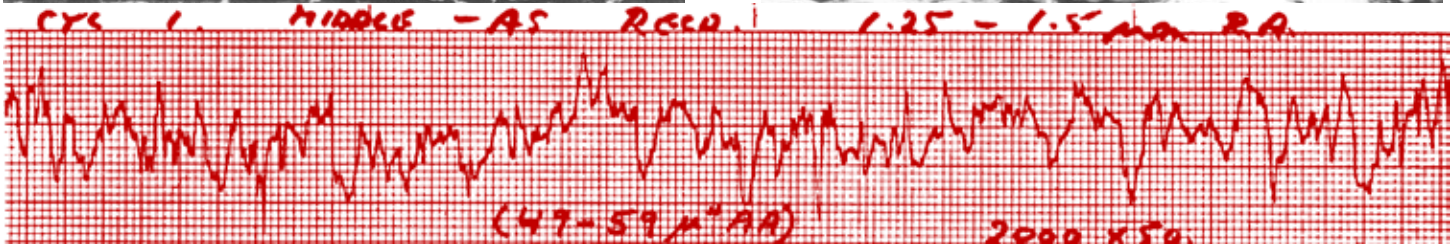
Cylinders One and Six were photographed with a Scanning Electron Microscope and these follow:

CONCLUSION:

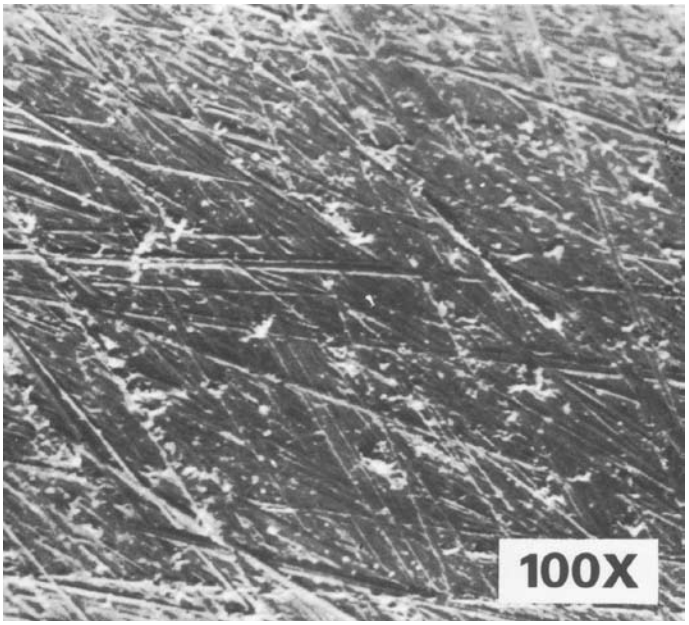
There can be no doubt whatsoever that the Flex-Hone has changed the whole nature of the cylinder walls from the as received condition. The Flex-Honed surfaces are very largely free from smeared, torn, and folded metal. They are of a plateaued or semi - plateaued nature and absolutely within the manufacturers specification. The surface will be sympathetic to piston rings. The as received finishes would have been decidedly unsympathetic to piston rings.

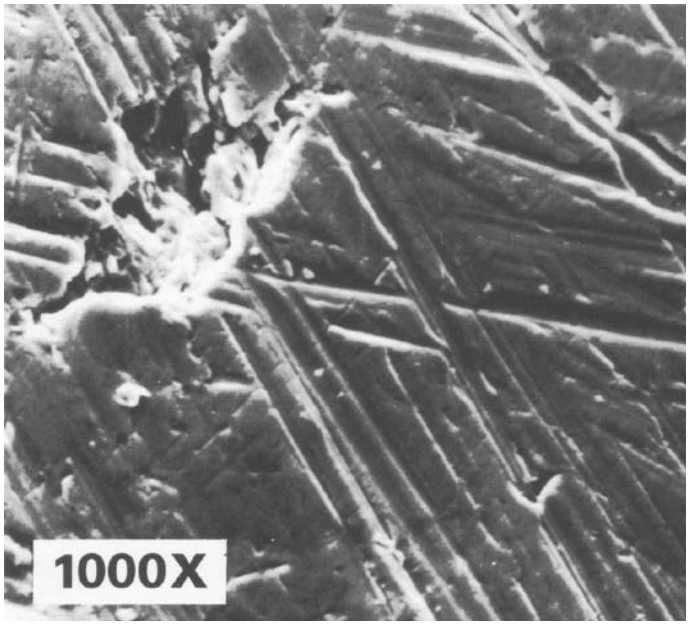


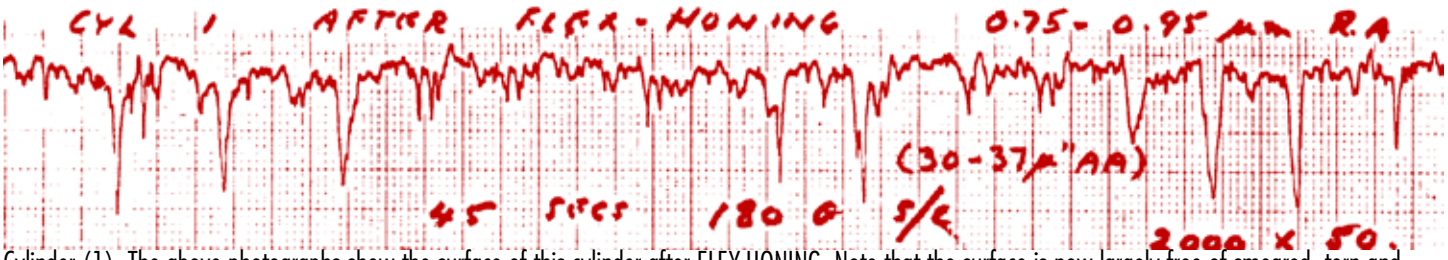




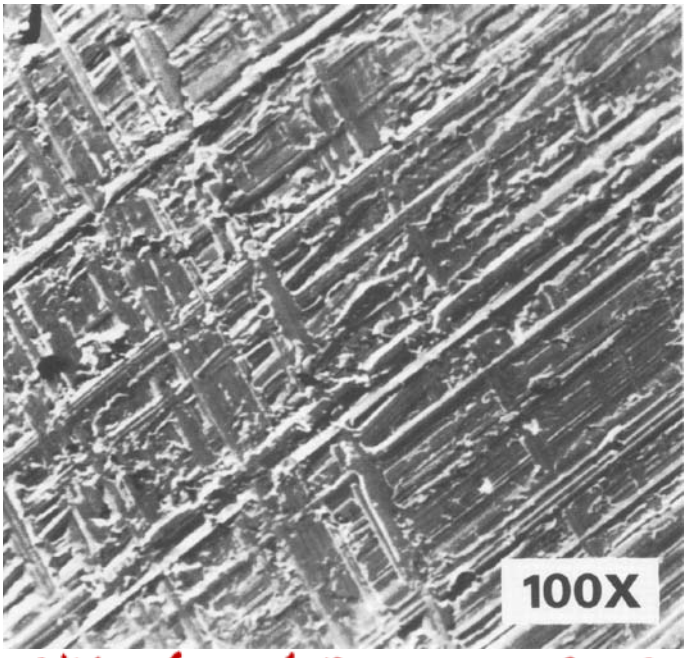
Cylinder (1). The above SEM photographs show the surface in the finished honed, As Received condition. Note the degree of smeared, torn and folded metal. The intersection of the cross hatch clearly shows a highly stressed condition. The profile of this cylinder shows a ''peaky saw tooth" finish.

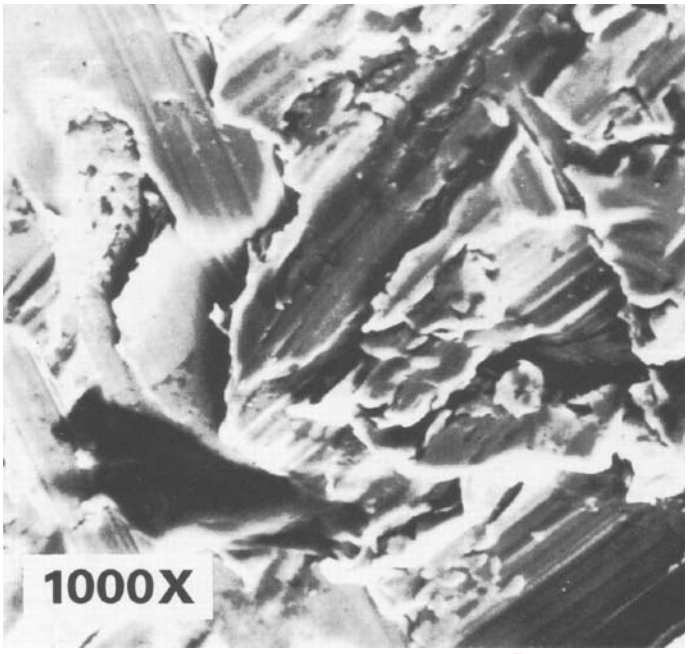


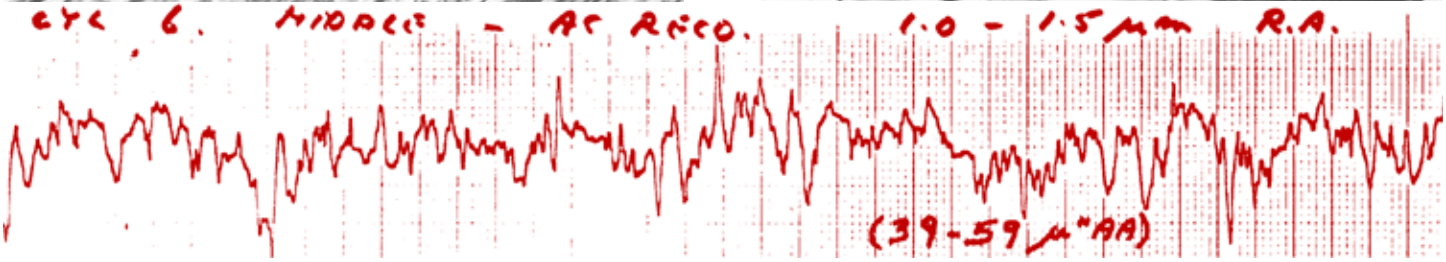




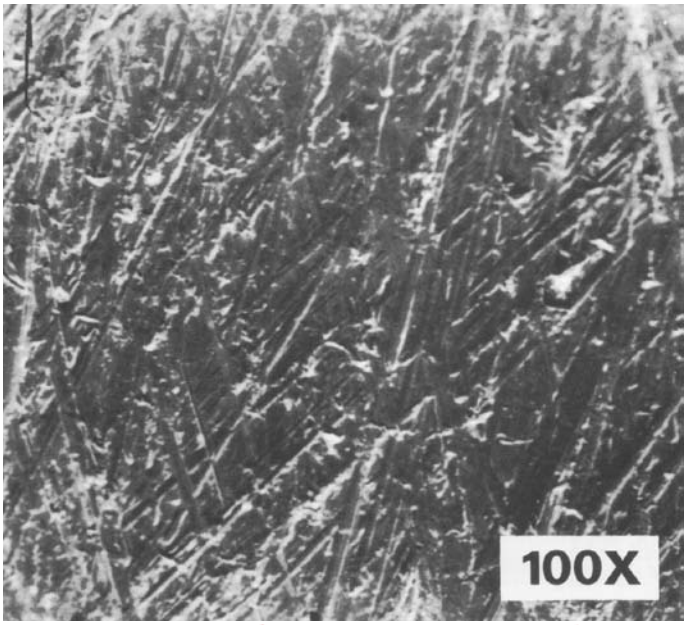
Cylinder (1). The above photographs show the surface of this cylinder after FLEX-HONING. Note that the surface is now largely free of smeared, torn and folded metal. Especially note that the intersections of the cross hatching have been stress relieved. The surface has also been ''opened up" in that the graphite grains on or close to the surface have been revealed rather than smeared over. The profile of the surface shows quite clearly that FLEX-HONING has provided an excellent ''plateau".

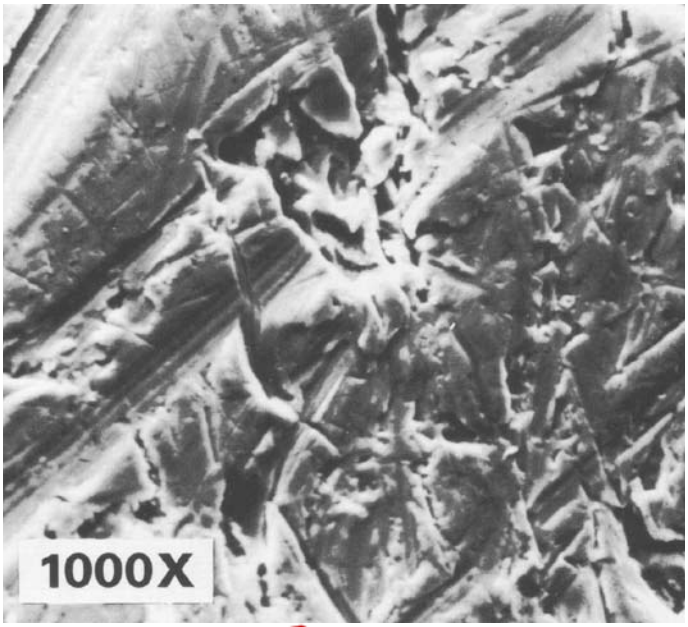


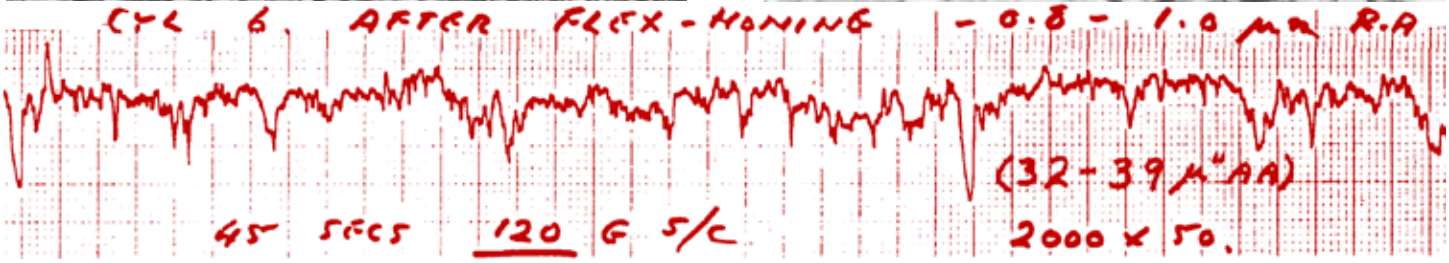




Cylinder (6). The above SEM photographs show the surface in the rough honed, As Received condition. Note the high degree of smeared, torn and folded metal. Note also the high stress areas at the cross hatch intersections. The profile of the surface is "peaky raw tooth."

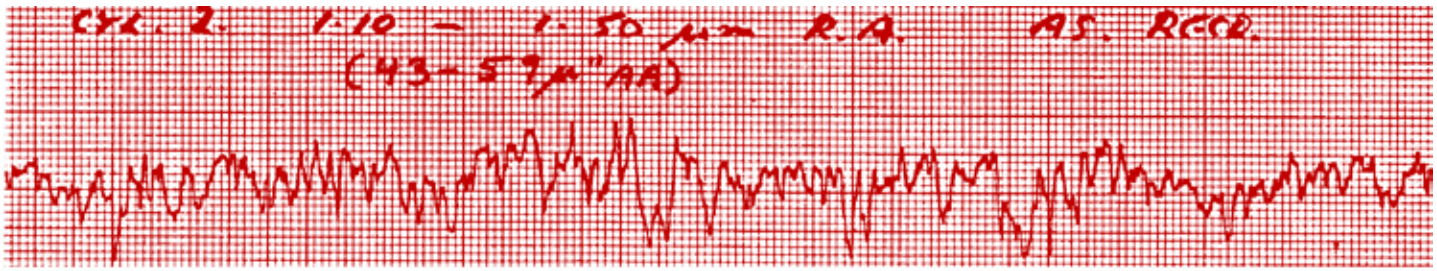


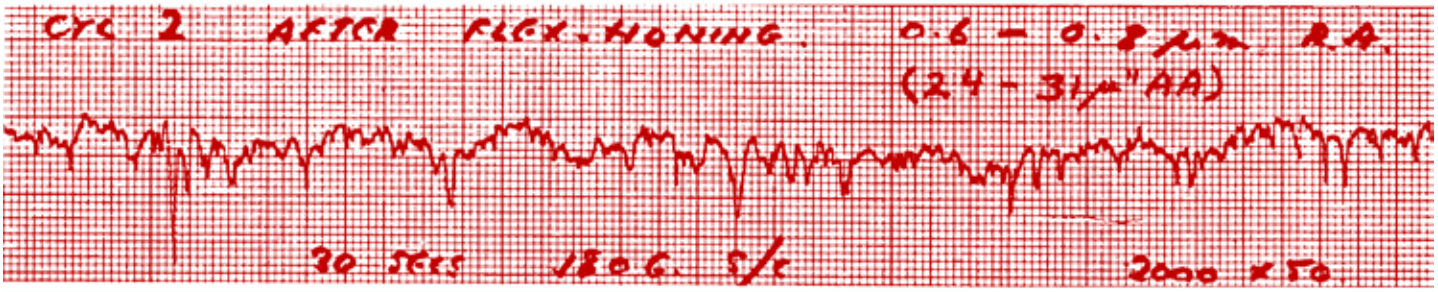


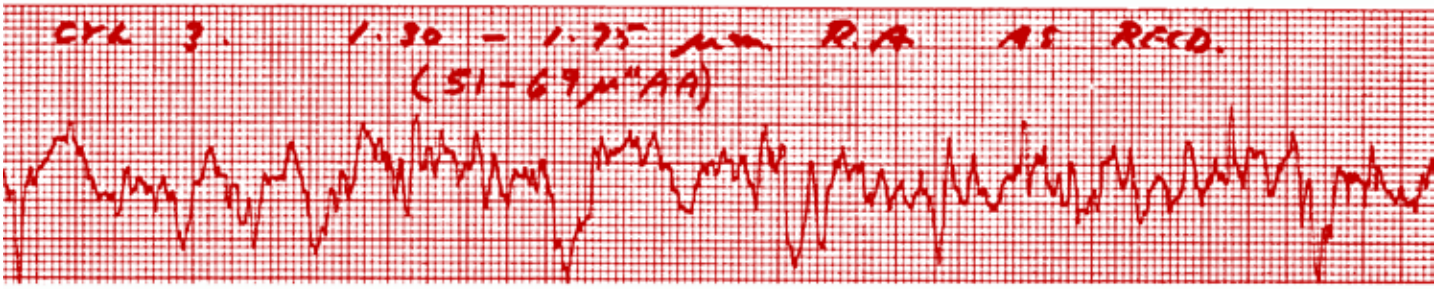


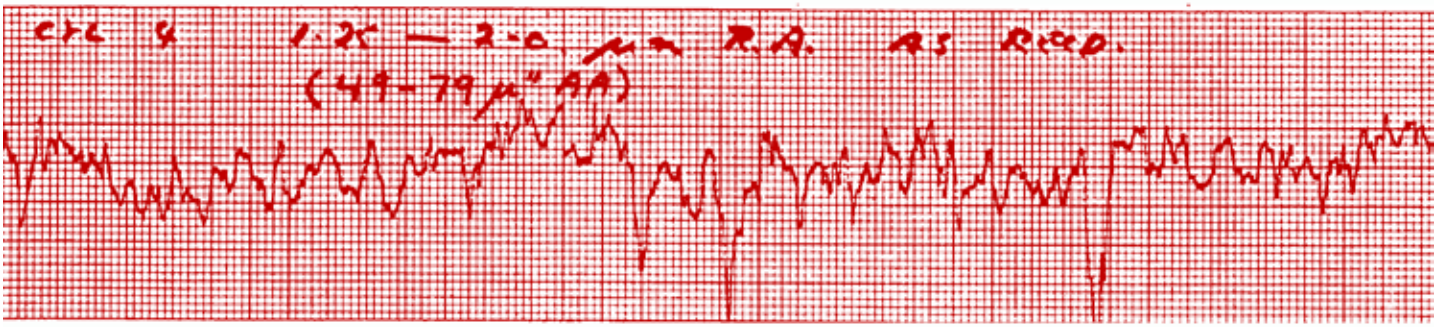
Cylinder (6). The above SEM photographs show the surface after FLEX-HONING. Note that the surface is now largely free of smeared, torn, and folded metal. Slightly less so than Cylinder (1) after FLEX-HONING. Cylinder (6) was FLEX-HONED with l 20 grit silicone carbide as opposed to 180 grit on Cylinder (1). Again note that the surface has been ''opened up" to expose the graphite grains. The profile after FLEX-HONING shows a good ''semi-plateau."

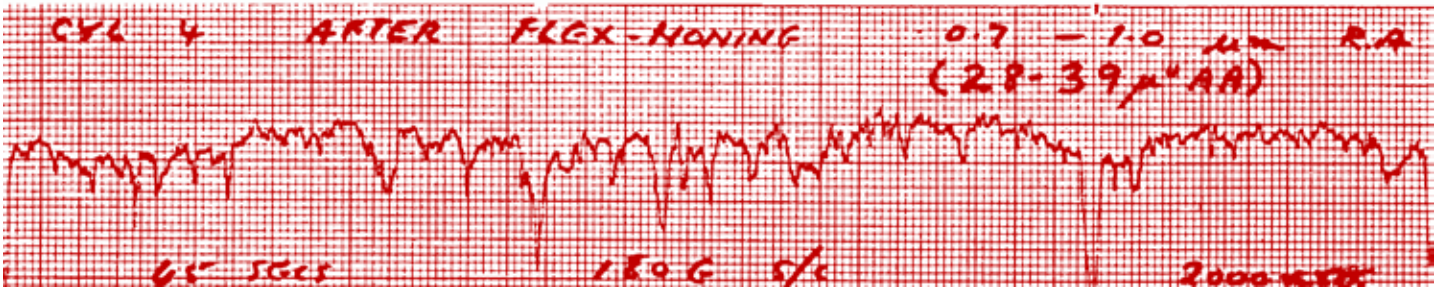
BEFORE AND AFTER PROFILES OF CYLINDER LINERS 2, 3, 4, 5, 7, & 8 OF TEST PART ONE:

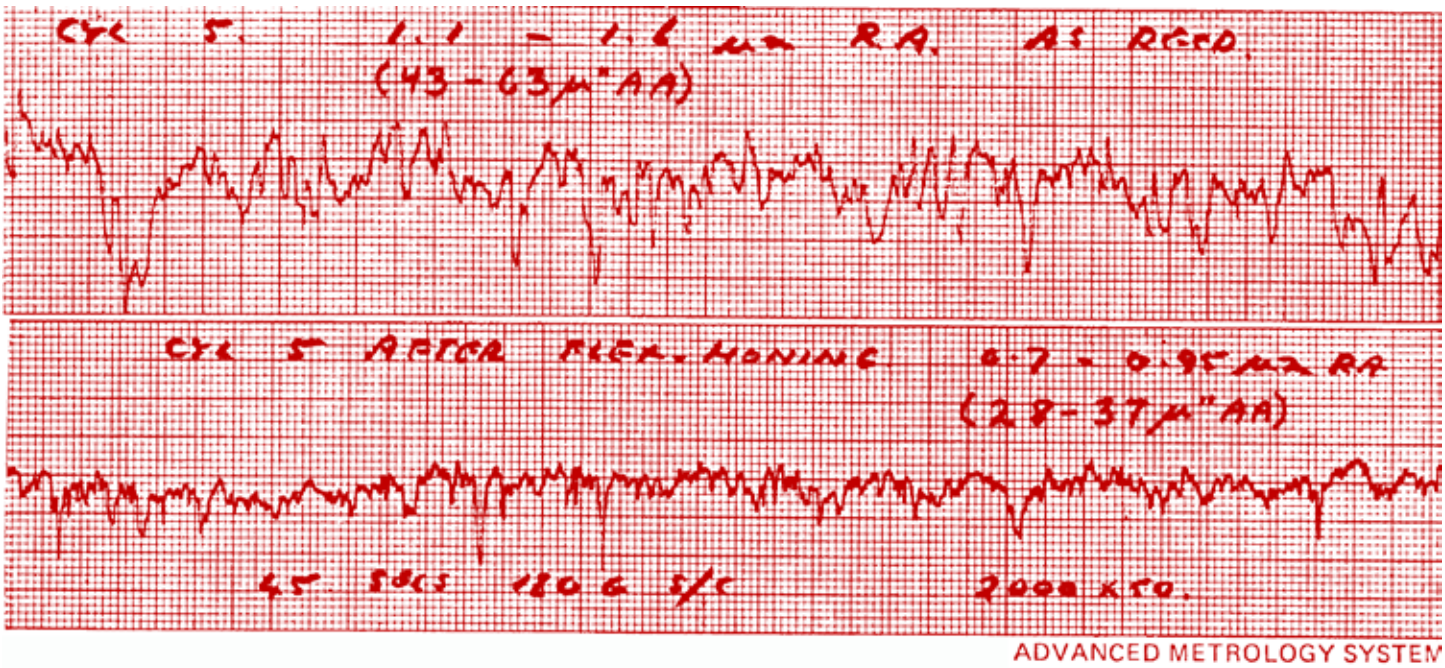




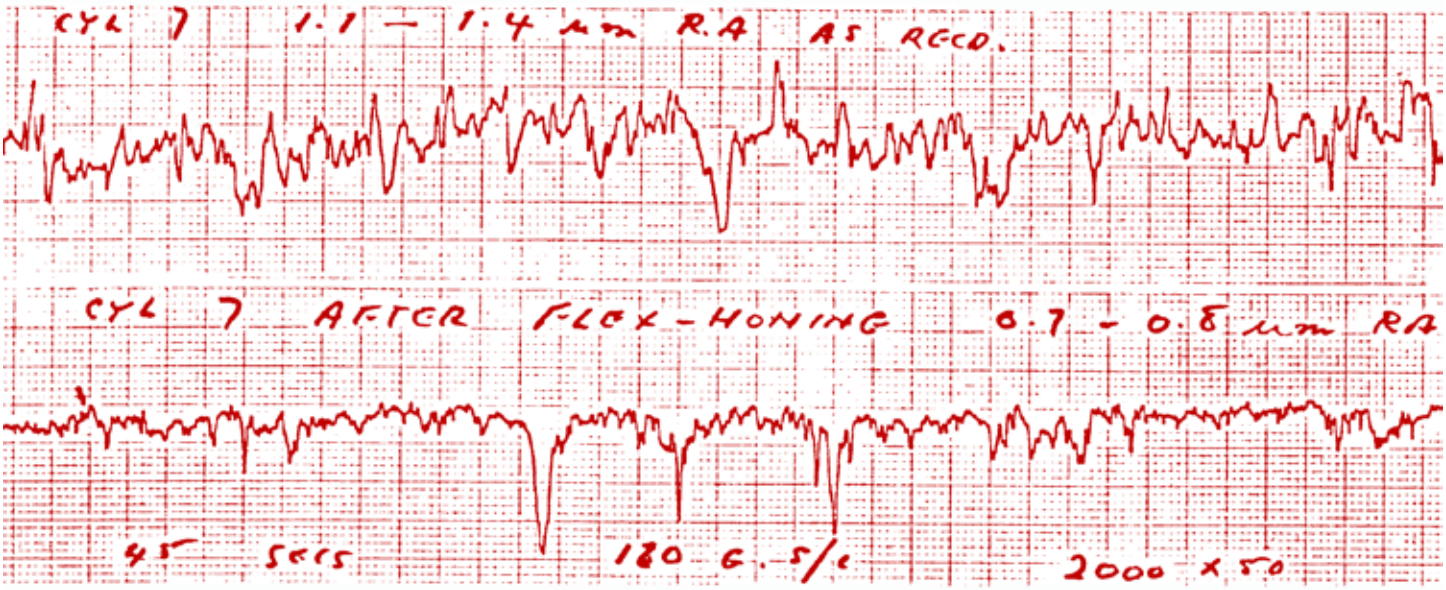


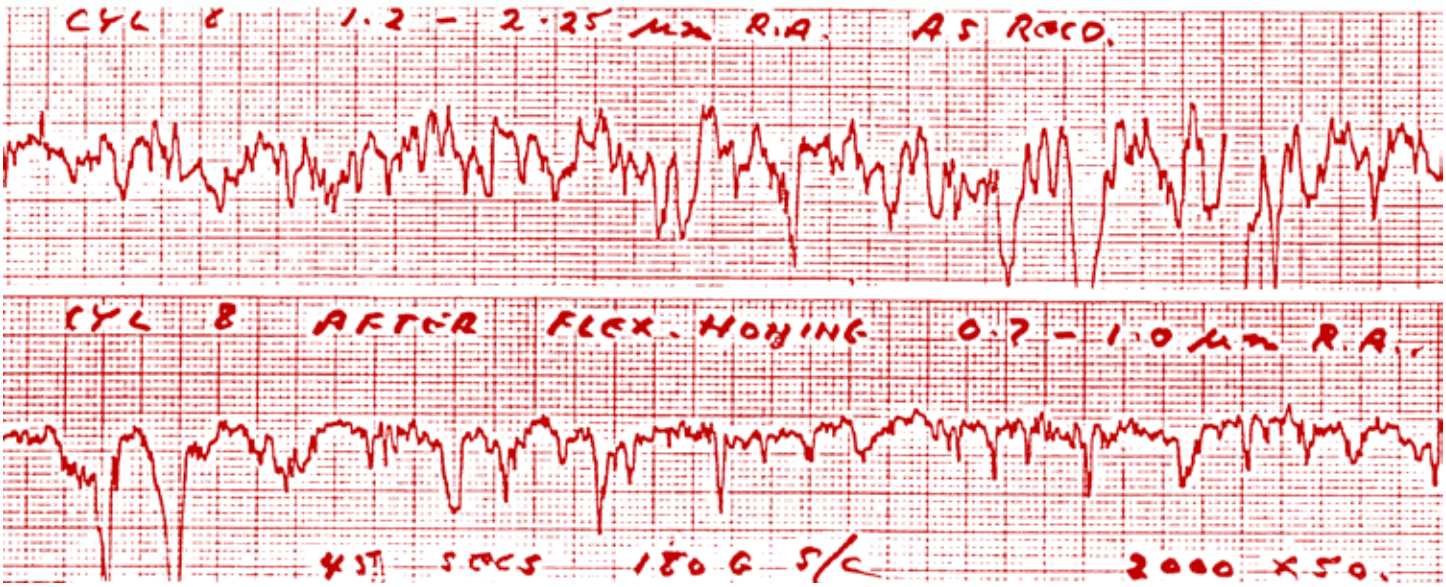






ADVANCED METROLOGY SYSTEM





Please note the result of the Flex-Honing on the profiles of the above cylinders. In every case, Flex-Honing has resulted in a "plateau" or "semi-plateau" profile. Note also how consistent the surface finishes are after Flex-Honing.

TEST PART TWO:

We received just two liners from this manufacturer of large diesel engines. Both were in the ''Rough" honed condition. That is to say they had been honed for size but not for final finish. The manufacturer's final finish specification is 0.63 - 1.00 Am RA (25-40 pH ins. CLA). We cut a section out of cylinder one for the purpose of an SEM photograph. Both cylinders were checked for surface finish and profile. As can be seen from the following table, the results were very rough indeed and very "peaky."

We Flex-Honed both cylinders in a two stage operation. We used a GBD 4-1/2" 120 grit silicon carbide Flex-Hone for one minute and followed with GBD 4-1/2" 180 grit silicon carbide Flex- Hone for a further minute. In so doing, we achieved an excellent surface finish within the manufacturer's specifications with a very good plateaued profile indeed.

A close look at the following table and SEM photographs will show the results in detail. A look at the SEM photographs will reveal that there was an excess of torn, folded and smeared metal on the surfaces of the cylinders in the as received condition. Compare the SEM photo- graphs of the cylinders after Flex-Honing with those in the as received state and you will see that the surface have been "opened up," stress relieved and are largely free of debris.

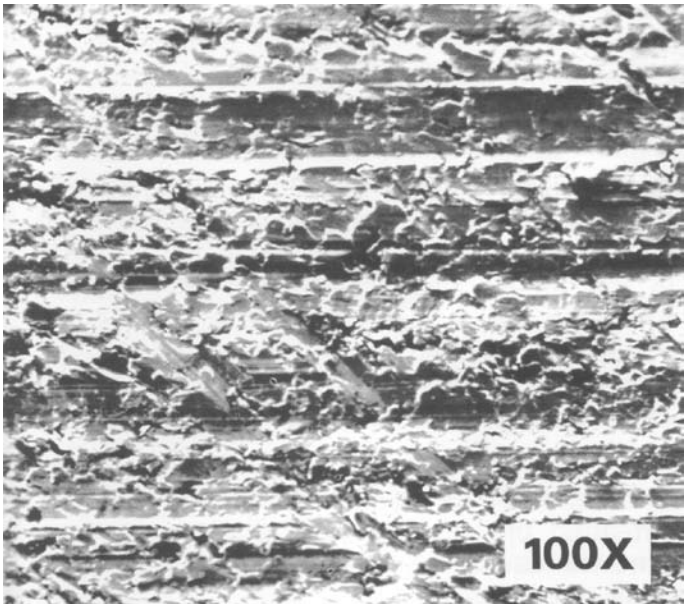
The Cylinder Liners in Part Two were supplied to us as Hardened & Tempered and rough honed to size.

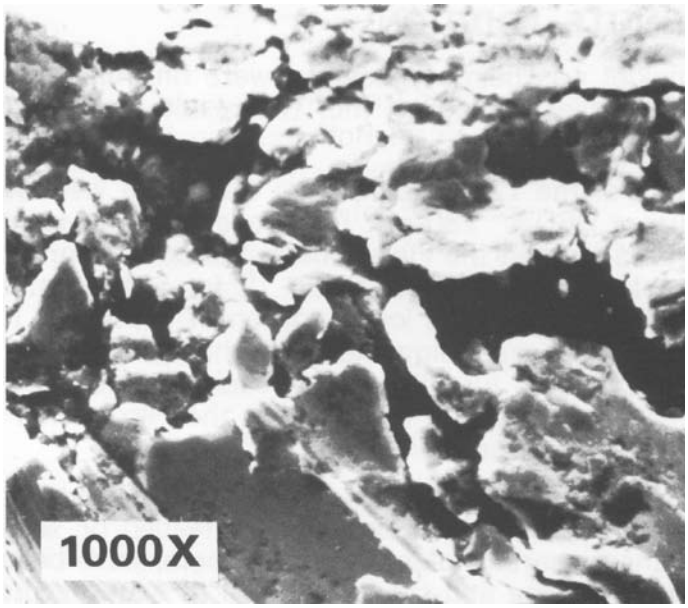
The "before and after" surface finishes are shown hereunder:

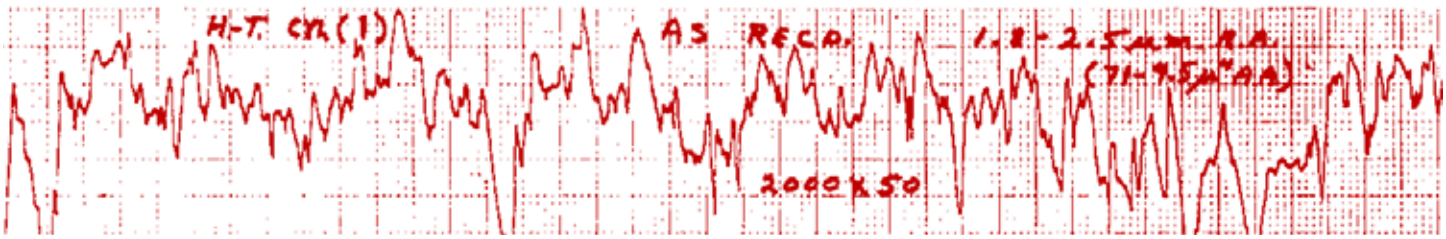
Cylinder	Condition	Grit & Type	Honing Time in Seconds	Finish µm RA	Finish AA µ" or CLA	Profile Characteristics
(1)	As Received	—	—	1.80 - 2.50	71 - 98	Peaky Saw Tooth
(1)	Flex- Honed	120	60			
		180	60	0.80 - 1.10	31 - 43	Plateau
(2)	As Received	—	—	1.80 - 2.20	71 - 87	Peaky Saw Tooth
(2)	Flex- Honed	120	60			
		180	60	0.80- 1.00	31 - 39	Plateau

CONCLUSION:

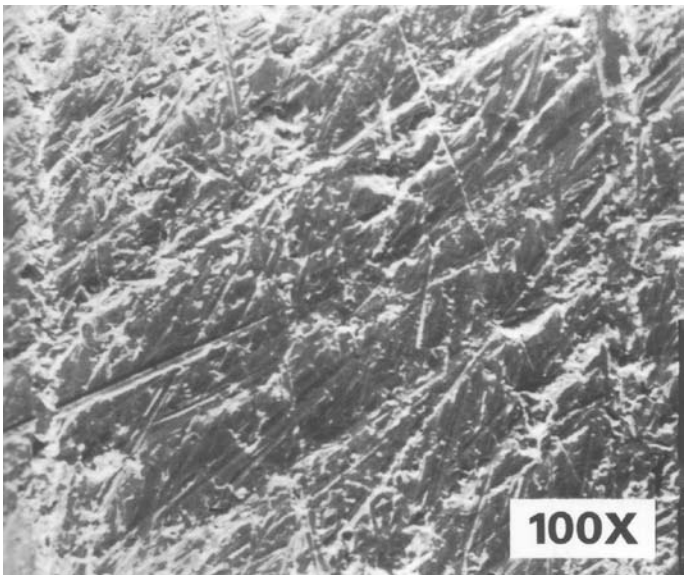
There can be no doubt whatsoever that the results of Flex-Honing these liners are excellent. The finish is according to the manufacturer's specification, has an excellent plateau profile and the photographs indicate that the surface has been opened up, stress relieved, and cleared very largely of any torn, folded and smeared metal. The Flex-Hone has produced a clearly defined cross hatch and the finish is very consistent right through the bores. In fact, Flex-Honing has provided a finish which would be very sympathetic to piston rings during the initial running-in period.

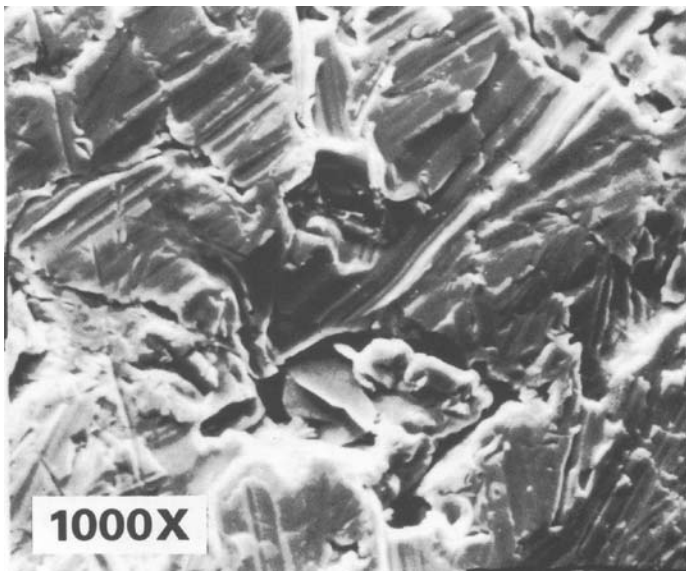


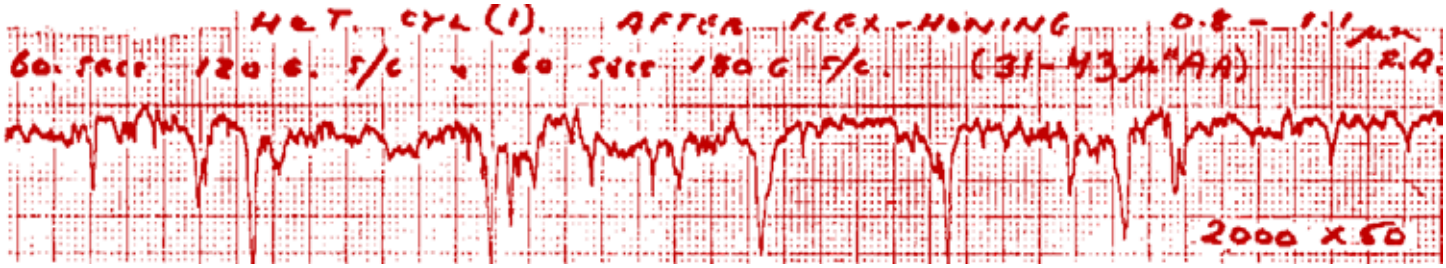




Cylinder (1). The above SEM photographs show the surface in the As Received condition, i.e. Rough Honed to size by standard production rigid hones. Note that the surface is of smeared, torn and folded metal and that the graphite grains are substantially smeared over. The profile of the surface, as is to be expected at this stage of production, is very "peaky saw tooth."







Cylinder (1). The above SEM photographs show the surface after FLEX-HONING. Note that most of the smeared, torn and folded metal has been removed and that the surface has been ''opened up" to reveal the graphite grains on or close to the surface. The profile shows quite clearly how the FLEX-HONE has refined the rough honed surface to an excellent Plateaued finish.

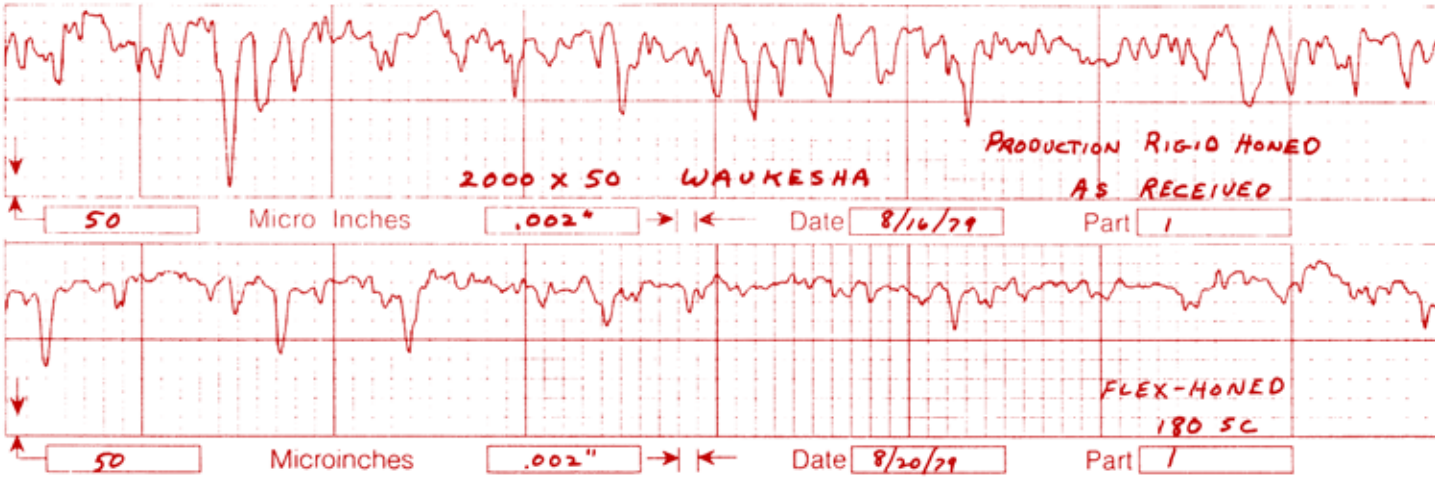
LAST MINUTE ADDITION:

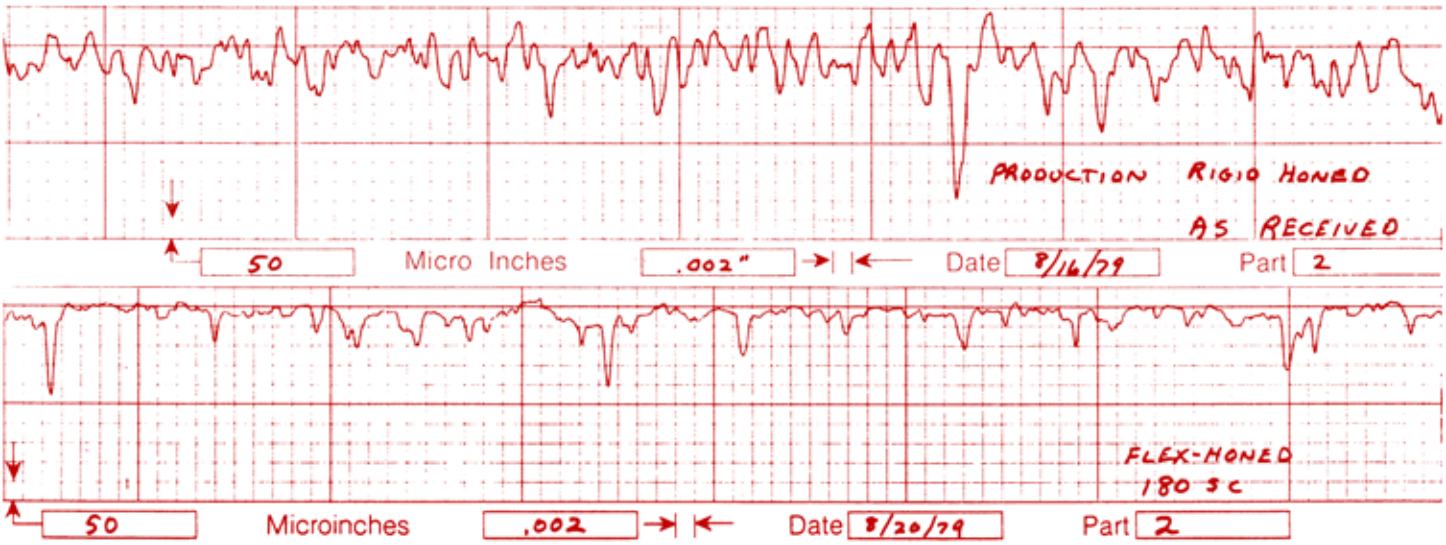
As this booklet was being typeset we were finishing up an evaluation study for Waukesha Engine Division of Dresser Industries, Inc. The results are so typical and graphic that we decided to include them.

Upon receipt of the 12 cylinders from Waukesha we made Surfanalyzer profiles of all bores. We decided to use a GBD - 4" 180 grit Flex-Hone with Flex-Hone Oil as a lubricant. We used a 500 RPM hand drill and stroked the Flex-Hone in the bore to produce a 25 to 30° cross-hatch angle. We cut off the top 1" of cylinders # 11 and 12 for SEM photos in the As Received condition. We Flex- Honed, for 30 seconds, the lower portion of #11 and 12 and then cut a 1" square piece out for SEM photos. After examining the SEM photographs and profiles we decided to Flex-Hone the remaining 10 cylinders for 45 seconds each. Profiles were then taken of all bores for final comparison. We feel you will agree with us that the Flex-Hone Process has improved both final condition of the surface and the surface profile.

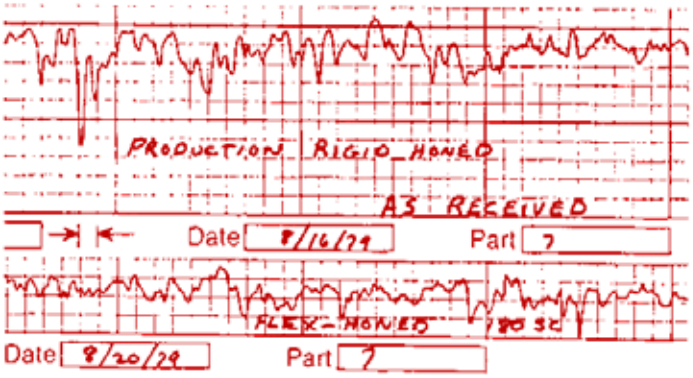
The As Received condition was typically a peaky saw truth profile. After being Flex-Honed the surface finish was refined to a consistent plateaued or semi-plateaued profile. The SEM photographs show that the smeared, folded and torn metal have been removed leaving an open "clean" surface for rapid ring seating and the elimination of scuffing problems.

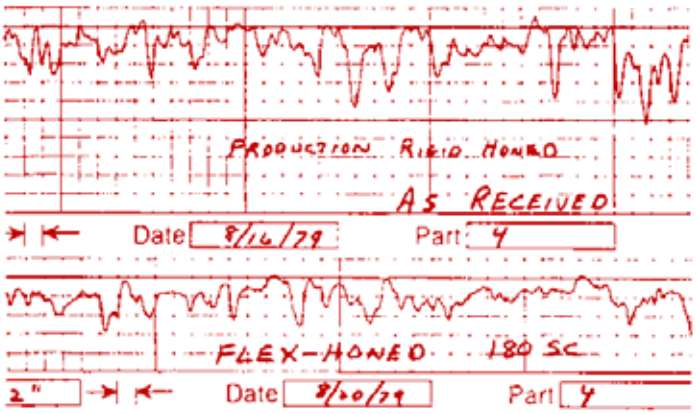
Our decision to Flex-Hone the above cylinders for 15 additional seconds was based on the SEM photos of the first two cylinders. The two cylinders Flex-Honed for 30 seconds still had traces of smeared metal on the surface, which we feel was removed with the additional 15 seconds.

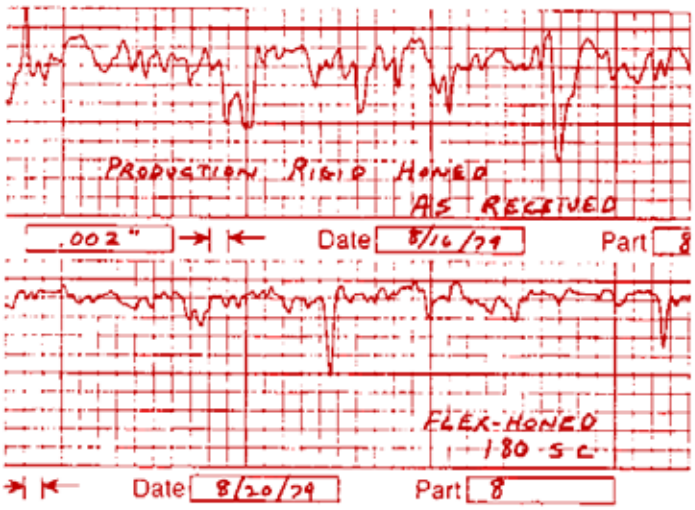


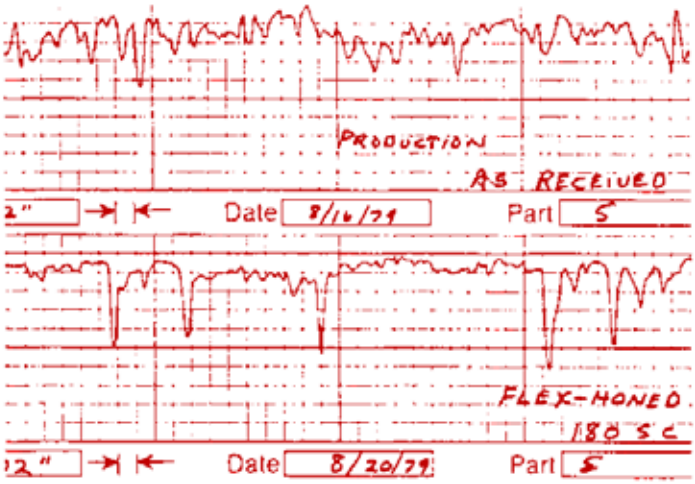


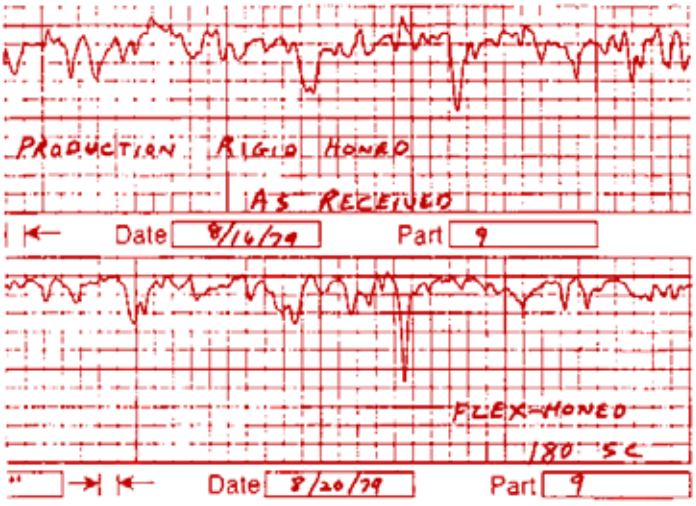

PRODUCTION RIGID HONED
AS RECEIVED
Date 8/16/79
Part 3
FLEX-HONED
180 SC
Date 8/20/79
Part 3

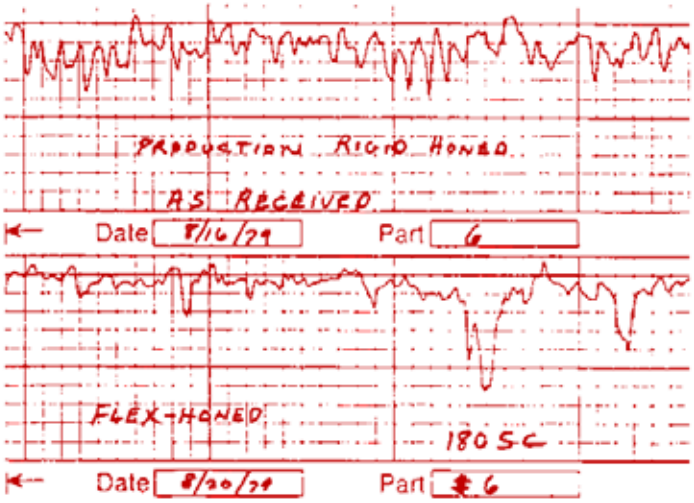

PRODUCTION RIGID HONED
AS RECEIVED
Date 8/16/79
Part 7
FLEX-HONED
180 SC
Date 8/20/79
Part 7

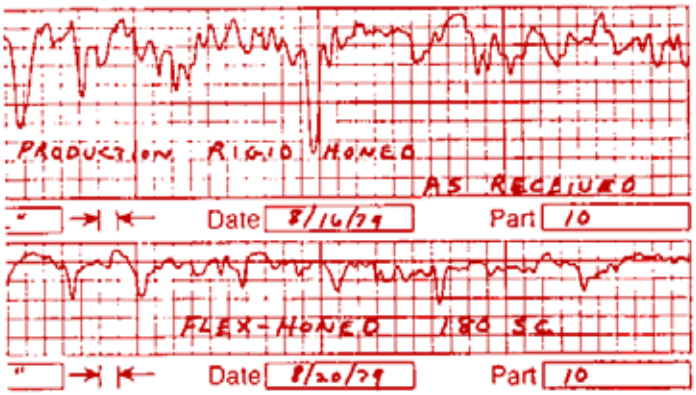

PRODUCTION RIGID HONED
AS RECEIVED
Date 8/16/79
Part 4
FLEX-HONED
180 SC
Date 8/20/79
Part 4

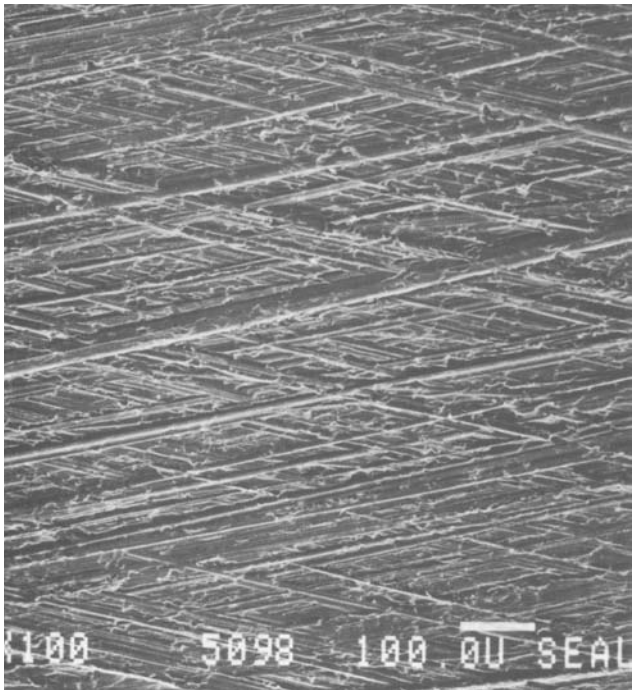

PRODUCTION RIGID HONED
AS RECEIVED
.002"
Date 8/16/79
Part 8
FLEX-HONED
180 SC
Date 8/20/79
Part 8

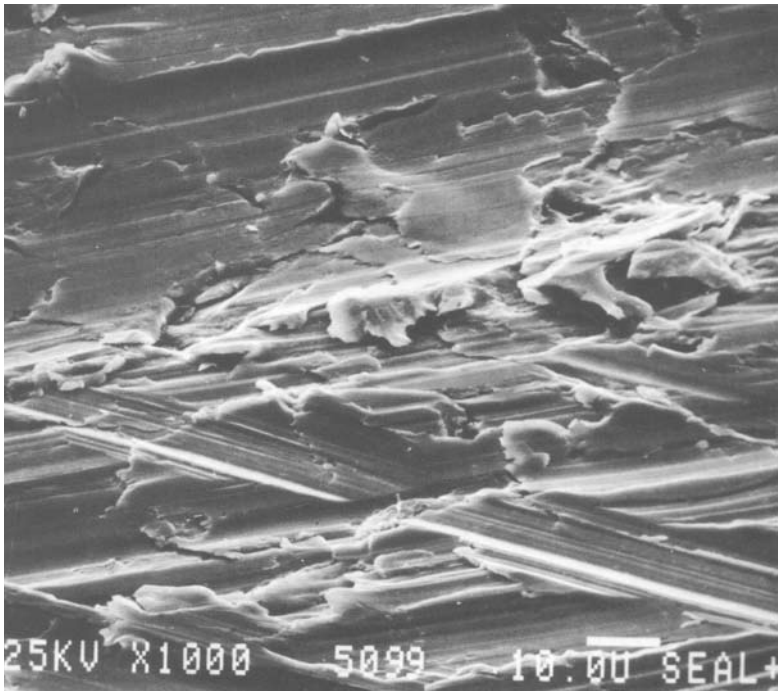

PRODUCTION
AS RECEIVED
Date 8/16/79
Part 5
FLEX-HONED
180 SC
Date 8/20/79
Part 5

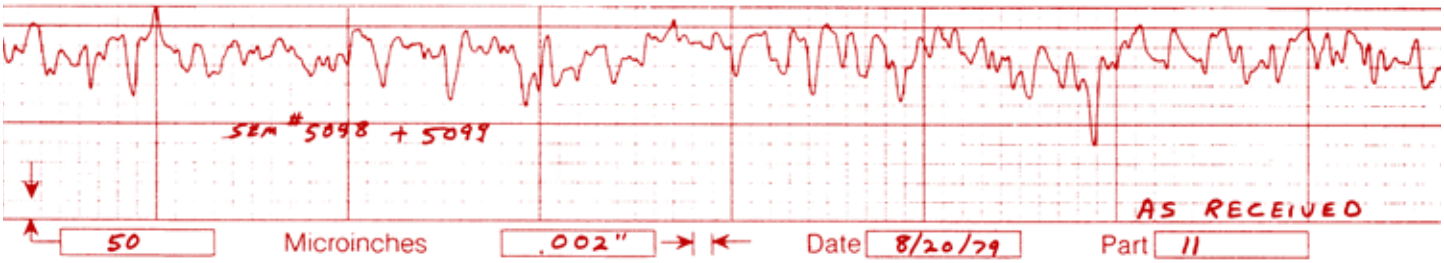

PRODUCTION RIGID HONED
AS RECEIVED
Date 8/16/79
Part 9
FLEX-HONED
180 SC
Date 8/20/79
Part 9

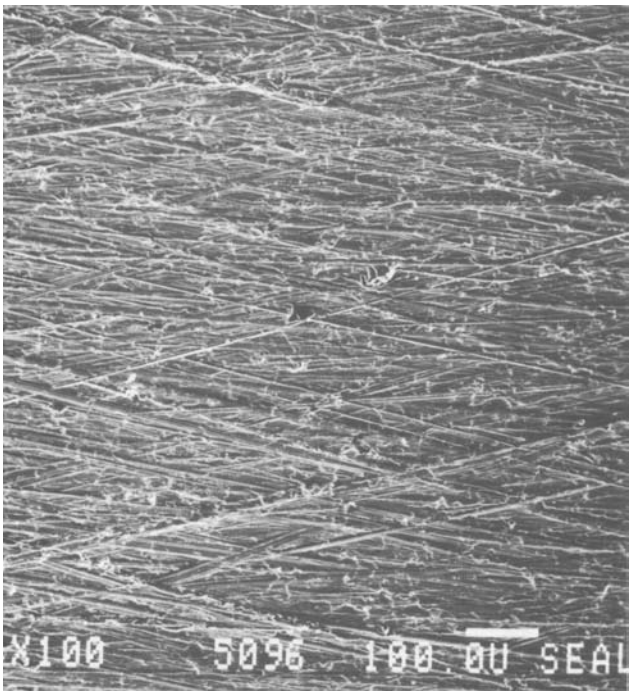

PRODUCTION RIGID HONED
AS RECEIVED
Date 8/16/79
Part 6
FLEX-HONED
180 SC
Date 8/20/79
Part 6

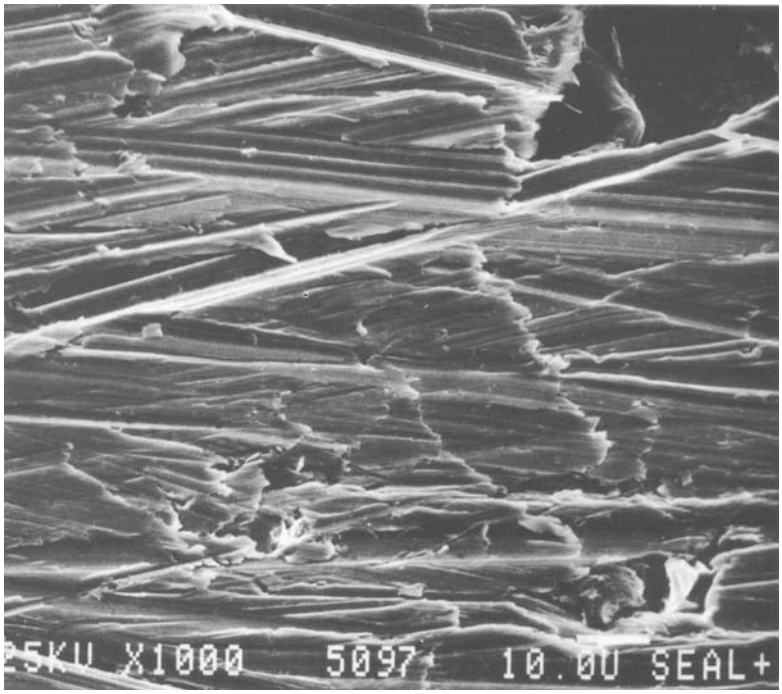

PRODUCTION RIGID HONED
AS RECEIVED
Date 8/16/79
Part 10
FLEX-HONED
180 SC
Date 8/20/79
Part 10

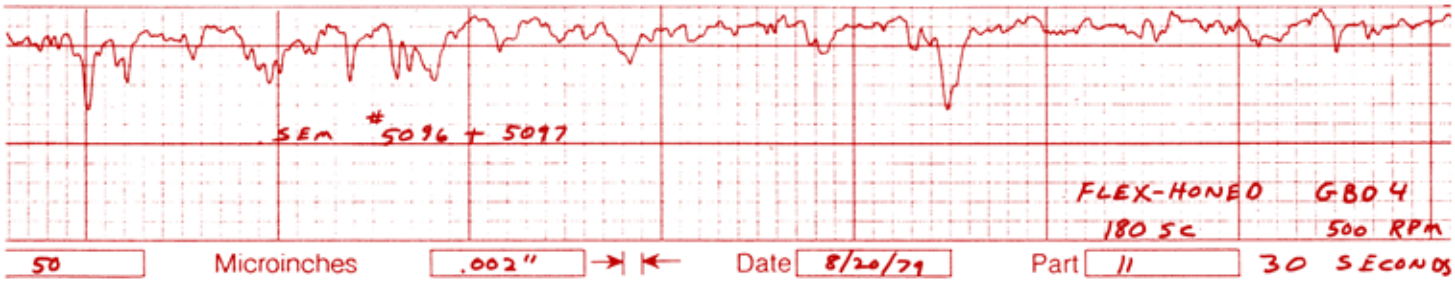

X100 5098 100.0U SEAL

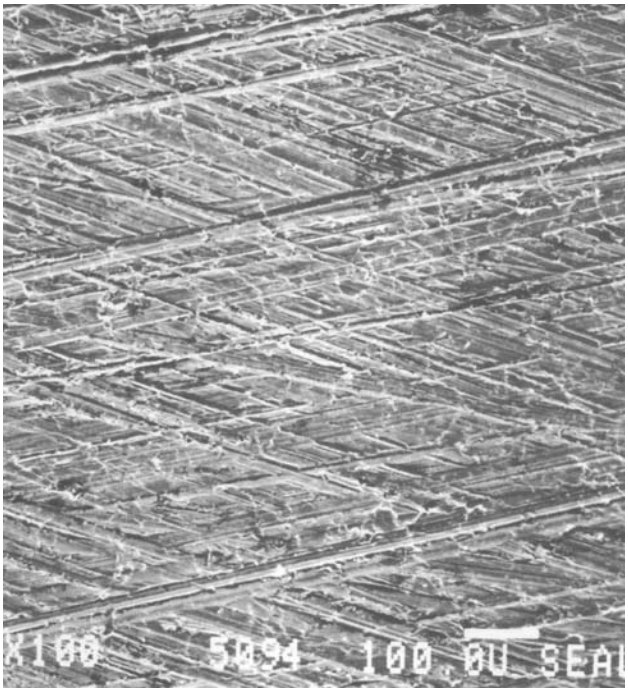

25KV X1000 5099 10.0U SEAL+

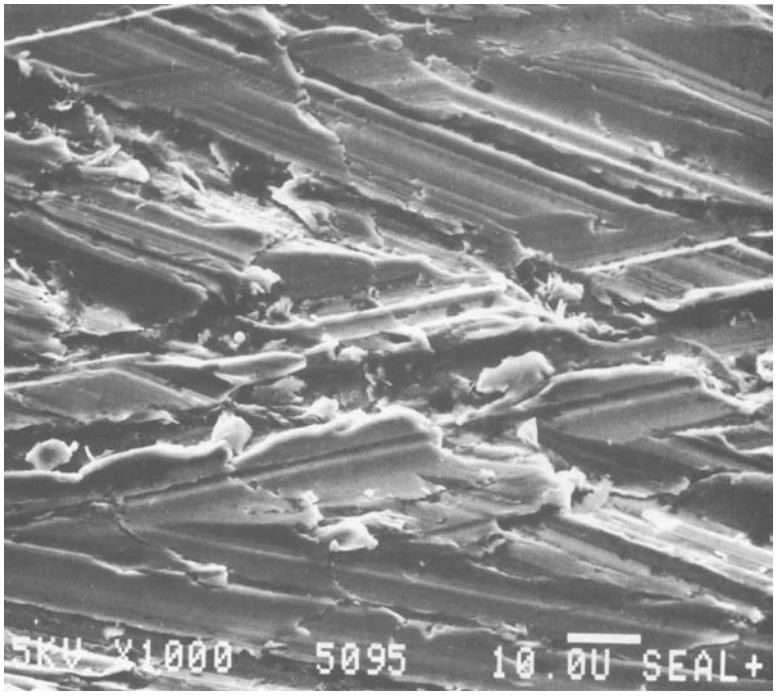

SEM #5098 + 5099
AS RECEIVED
50
Microinches
.002"
Date 8/20/79
Part 11

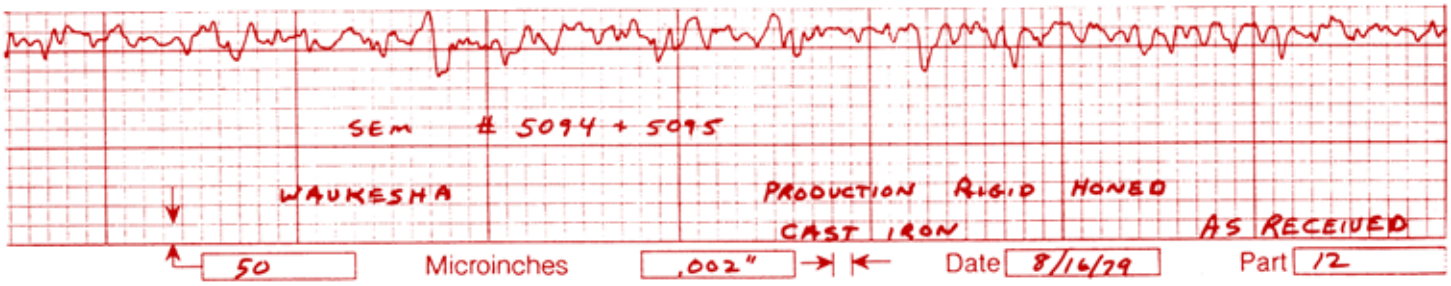

X100 5096 100.0U SEAL

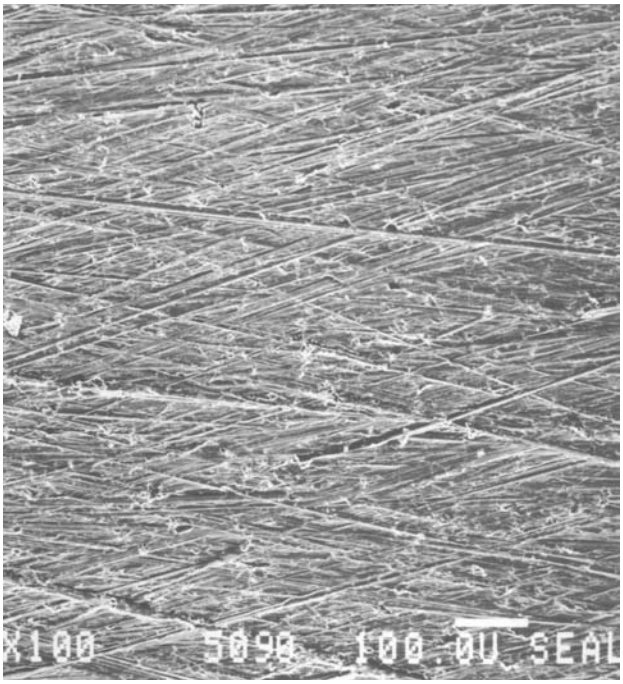

25KV X1000 5097 10.0U SEAL+


SEM #5096 + 5097
FLEX-HONED G804
180 SC
500 RPM
50
Microinches
.002"
Date 8/20/79
Part 11
30 SECONDS

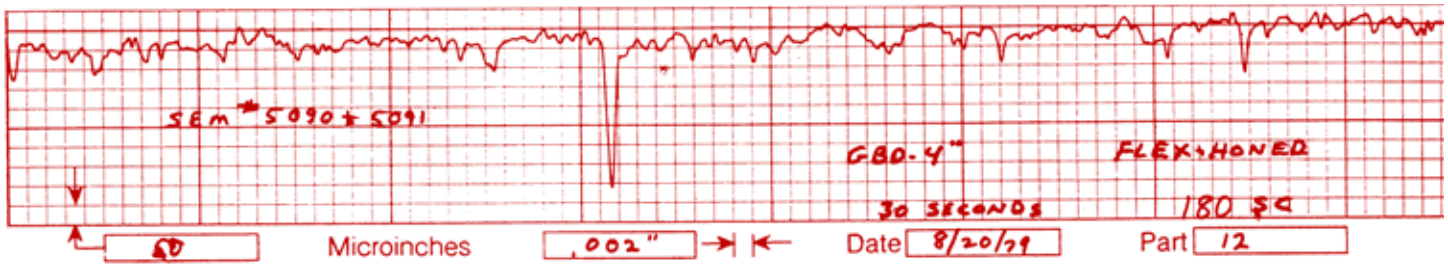

X100 5094 100.0U SEAL


5KV X1000 5095 10.0U SEAL+


SEM # 5094 + 5095
WAUKESHA
PRODUCTION RIGID HONED
CAST IRON
AS RECEIVED
50
Microinches
.002"
Date 8/16/79
Part 12


X100 5090 100.0U SEAL


25KV X1000 5091


SEM # 5090 + 5091
GBD-4"
FLEX-HONED
30 SECONDS
180 SC
50
Microinches
.002"
Date 8/20/79
Part 12

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