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UNCLASSIFIED

TECHNICAL MEMORANDUM

WEAR TEST RESULTS OF CANDIDATE MATERIALS FOR THE OK-542 TOWED ARRAY HANDLING MACHINE LEVEL WINDER

Date: 29 December 1994

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ABSTRACT

This Technical Memorandum (TM) reports the findings of a series of wear tests conducted for possible replacement materials for the Towed Array Handling Machine Level Winder Pawl.

In the existing system, the Pawl is manufactured from C63000 Nickel-Aluminum-Bronze (Ni-Al-Br) and the drive shaft, from C71500 70-30 Copper-Nickel (Cu-Ni). The problem under investigation is that of severe wear on the sides of the Pawl occurring within short time periods.

A test apparatus was designed and built that simulated operating conditions of the Handling Machine. Speed, loading, environment, and shaft material were designed to match that of the system. Different materials were then selected as candidate Pawl replacements and tested.

Materials that were tested consisted of standard and specialty materials. Coating processes were also investigated. The standard materials consisted of 304 and 316 Stainless Steel, Inconel 625, Nickel-Aluminum-Bronze, and Titanium. The specialty materials: Inconel 625, Monel, Stainless and Stellite, were clad-welded metals on a base of 1040 Carbon Steel. Finally, an economic carbide coating was deposited on a 316 Stainless Steel and Inconel 625 sample.

Within a short time span, from the materials discussed, varied differences in performance were observed and several conclusions were reached. First, the existing material, Nickel-Aluminum-Bronze, was one (1) of the worst performers. As a result of the experiment, this sample showed the greatest amount of damage in the shortest period of time. The Inconel 625 bar stock that was tested performed the best. It sustained the least amount of damage for one (1) of the longest durations of the test.

ADMINISTRATIVE INFORMATION

This Document was prepared for the Mechanical Design and Systems Installation Branch (Charles Gray, Code 423) for OK-542 Towed Array Handling Machine using Job Order K15040.

ACKNOWLEDGMENTS

The author wishes to thank the following individuals for their assistance and support: Mr. Phil Watrous (Code 4211) for scrounging the components for and building the Wear Machine and monitoring testing and to Messrs. Roger Tryon and Eric VonWinkle of McLaughlin Research Corporation, Waterford, Connecticut, for fabricating samples and test monitoring.

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INTRODUCTION

Code 21 has been experiencing a wear problem associated with the OK-542 Towed Array Handling Machine Level Winder Pawl and Shaft. It seems that there is an excessive amount of wear manifesting itself on the Pawl in an unreasonably short period of time. Figure 1 is a schematic representation of these parts and Figures 2 and 3, respectively, are photographs showing the wear on a Pawl and Shaft. The material specifications (specs.) are included in Appendix A for reference.

Initially, the Materials Laboratory (hereinafter referred to as the Materials Lab) was tasked to conduct a series of hardness measurements on three (3) Pawls and three (3) Shafts. Reference (a) reports the results of this investigation.

The effort continued to focus on evaluating the Ni-Al-Br material. The decision had been made to conduct a series of experiments in which many different materials would be evaluated under operating conditions similar to those of the actual Handling Machine. There was, however, a time constraint on the work. It was imperative, therefore, to accelerate the processes involved.

The Materials Lab, working in conjunction with personnel from the Code 4211 Pressure Laboratory (hereinafter referred to as the Pressure Lab), was able to devise an apparatus from in-house components that would simulate the contacting components, place them under a load. lubricate them, and move them at the same speeds as those of a Handling Machine.

For the most part, the materials were selected from available stock within the Naval Undersea Warfare Center Newport Division Detachment New London (NUWCNPTDIVDETNL) Machine Shop facilities. The tested materials included the following weld cladding on a 1040 mild steel base: Inconel 625, Monel, Stainless, and Stellite. Other tested bar-stock materials were 306 and 316 Stainless, Inconel 625, Titanium, C63000 Ni-Al-Br, and Rocklinized Inconel 625 and 316 Stainless Steel. The wheels always remained the same, the 70-30 Cu-Ni.

Concurrent to the experiments, other options were being considered. Unfortunately, these other options, which included thermal spraying, carbide inserts and wear coatings required long lead times and financial backing. They were not conducive to rapid turnaround. They are discussed within this Memorandum, however, in the Conclusions.

EXPERIMENTAL APPARATUS

The apparatus [machine] used for testing was designed and built within Code 4211, utilizing materials and equipment on-hand. Figure 4 is a simplified schematic representation of the operating principle behind the apparatus.

Wheels were fabricated from the same kind of material as the that of the actual Level Winder Shafts, Ni-Al-Br. These Shafts were supported on an axle and rotated at a speed that matched the operating speed of the actual Level Winder System, approximately six (6) revolutions per minute (rpm). The calculations for this speed (which may be found in Appendix B) were based on information provided by Mr. C. Gray (Code 4221). Also included in Appendix B are calculation regarding placement of the 84-pound (lb.) applied load.

The width of the contact area of the wheels was based on the approximate contact area of the Pawl. It appeared that about .20 inch (in.) of the curved tang on the Pawl made contact with the side land of the Shaft groove. The width of the contact area varied, since the tang is a curved surface. The experimental wheels were designed with a contact surface of about .25".

A pan was placed under the wheels and filled with artificial seawater. A circulating pump was set up to provide a continuous water bath which was directed to the contact point between the wheel and test sample.

Figures 5 and 6 are photographs of the actual machine used to conduct the test. A large motor was set up on a table, and an axle assembly was devised and outfitted with a set of bearings and supports. The wheels were bored out to fit the shaft, and aluminum collars were fabricated to it. A mechanical cycle counter was connected to the shaft to provide a continuous readout of elapsed cycles.

Another bracket was constructed with a hinge and a piece of steel channel that would pivot above the wheels. On this channel rested an 84-lb. weight. Use of the channel provided the apparatus with the ability to adjust the actual load experienced by the test samples.

The samples, themselves, were made by obtaining a piece of the respective test material, drilling a 1/4-20 hole in the center of one (1) side and bolting it to the under side of the channel. It is this free surface that was being wear tested and it was, therefore, imperative that the free surface of this test sample have the desired surface finish to be tested. As depicted in the Figures, it was designed to run two (2) samples concurrently.

Four (4) of the materials that were tested were weld-clad metals on a substrate of 1040 mild steel. The claddings were Stellite, Inconel 625, Monel, and a Stainless. These clad samples had been used for some previous corrosion and hardness experiments; their condition, however, was excellent. There were no signs of corrosion, and the surfaces were a ground finish of approximately 63 to 125 microinches (μin). The indentations from the hardness tests were located such that they did not interfere with this wear test.

Other materials that were tested included Inconel 625, Titanium, 304 Stainless, 316 Stainless, and Ni-Al-Br. All of these samples were cut from bar stock and both ends were faced off on a lathe and maintained a surface finish of approximately 63 μin.

As alluded to in earlier discussions, different coating process and wear-resistant materials were being investigated. While many of these could prove beneficial to this project, none could be obtained in a timely or economical manner. However, two (2) samples, Inconel 625 and 3116 Stainless, were given a special coating of Tungsten Carbide, in a process called "Rocklinizing" which is electronically deposited to approximately .002" of thickness. Small areas on each of the sample surfaces were prepared and tested. This process was included because the vendor offered it for experimentation.

EXPERIMENTAL TECHNIQUE

With the aforementioned apparatus, the outside diameter (OD) of each wheel was measured and recorded prior to the start of a test. The samples were inspected and mounted under the channel. The motor and water pump were then started; and the channel, with the sample and weights, were brought in contact with the wheels. Once contact was made and the experiment was underway, the cycle counter was zeroed. At this point, the experiment was underway.

A test life of approximately 60,000 cycles was equated to 9.5 array deployment/retrieval cycles. This was based on an array length of 5,000 feet. In the context of this TM, An array cycle is being considered one (1) deployment or one (1) retrieval. Appendix B includes the calculations that support these values. This array deployment/retrieval life was an arbitrary selection, based on the time constraints imposed on the testing.

During testing, the samples were inspected several times a day for signs of degradation to either the sample or the wheels. If wear was observed, it was noted. If severe wear was observed, the sample was removed from the test. The second sample was not effected by the removal of one (1) sample, the test continued.

Once a sample was removed, the wear on both the sample and associated wheel was microscopically examined and photographed, the number of cycles logged and the OD of the wheel was measured and recorded.

Once a sample is removed from the test, it remains available for further examination--if necessary. The wheel, however, is machined, remeasured and made available for the next test.

This procedure was followed throughout the testing for each sample material and wheel combination.

TEST RESULTS

The results of the Wear Test are summarized in Tables 1 and 2 and Figures 7 through 31. The evaluation information consists of measurement of the wear surfaces, dimension changes, visual observations and surface comparisons.

The Tables provide a quick-look view of the materials, test cycles, dimensional changes, and a condition rating. No sample actually failed this experiment. The samples that have 59,000 or more cycles were stopped for time constraints. Samples that lasted for shorter cycle spans were discontinued because it was the opinion of the author that the damage was severe enough to warrant their elimination from further consideration. These decisions are strictly arbitrary, based on physical evidence and limited knowledge of the Handling System.

The Condition Rating that is presented is based on a visual inspection of the test materials and the wheels. It is a comparison of the actual surfaces (or a photograph of the surface) against a GAR S-22 Microfinish Comparator. The choices were narrowed from 22 finishes, to three (3), with a fourth category, galling, added because of the Monel test. The larger the rating number, the smoother the surface. In the legend that accompanies the tables, the "ST" designation indicates that the finishes were compared to shaped/turned finishes.

The dimensions measured for the wear damage included: the width, measured perpendicular to wheel rotation; the length, measured parallel to the wheel rotation; and , the depth, measured into the thickness of the material. Because the contact surface of the wheel was about .250" wide, most of the numbers are between .21" and .28", depending upon how the load compressed the test samples. Most of the samples did not wear in straight lines; instead, they wore in a trapezoidal shape. The length measurements are measured as a chord, across the top surface of the material. The depth is measured at the deepest part of the damage area.

In Table 2, along with the Cycles and Condition Rating, the Wheel Diameter Change is presented. This number is based on measurements of the outside diameter of the wheel before and after testing. After a test, the wheels were measured, inspected and photographed, then redressed for the next test. Redressing consisted of turning the test section on a lathe to obtain a smooth surface (about a 63 μin). Naturally, as the testing progressed through different material candidates, the diameter of the wheels became smaller.

Figures 7 through 14 depict the weld-clad samples and the wheel surfaces that were in contact with them. On Figures 9 and 10, the galling of the Monel is visible. As noted, this occurred in a relatively short period of time. Although there is no photograph available to support the appearance of the wheel, it, too, showed similar wear characteristics. On both parts, it appeared that metal had been peened over, it was shiny and rough to the touch. Figures 21 and 22 show the Titanium sample and wheel, respectively. The wheel used shows similar rough characteristics, but, the Titanium sample itself, does not.

Figures 23, 24, 25 and 26 show the behavior of the Ni-Al-Br Pawl material in this test. the sample used was fabricated from and actual Pawl. Of all the samples tested, it showed the highest degree of wear.

Figures 27 through 31 characterize the behavior of the Rocklinized samples. Each of the base materials was coated with approximately .002" of the carbide coating which was worn through. This coating was applied to the base metals cold; further information is contained in Appendix C.

CONCLUSIONS

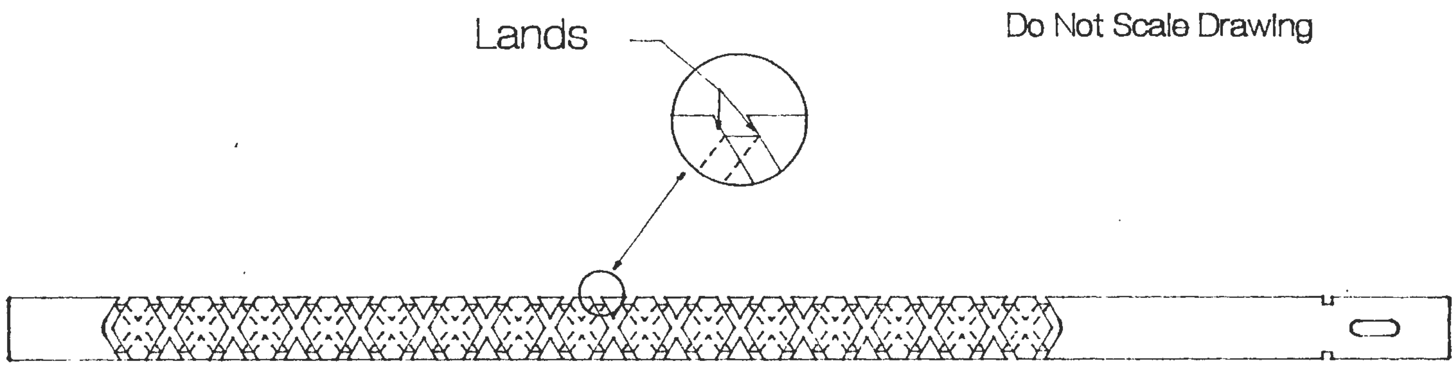
It is the opinion of the author that very careful consideration should be given to the test data that has been presented. While care was taken to duplicate service conditions, this was an experimental set-up, with design, fabrication and testing accomplished in a very short time period. It is important to realize that it was an experiment and there may be some facet of service operation that was inadvertently overlooked which could render even the best material ineffective.

Due to the time constraint imposed, several options were not thoroughly investigated. They should, however, probably be considered for future applications. these include various wear-resistant coatings, thermal spraying, and the use of special inserts.

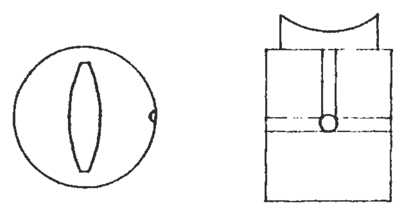
Based on the testing and observations discussed herein, it seems that Inconel 625 bar stock is the best choice, both mechanically and economically. While both the cladding and bar forms indicate consistent and damage-tolerant behavior, weld cladding can be a labor-intensive operation adding cost to the part. Inconel 625, while extremely resistant to corrosion, is very strong mechanically and is readily available in bar form from local suppliers.

Figure 32 represents the existing Pawl material and the Inconel 625 bar test sample. It becomes readily apparent why Inconel is being recommended as the replacement material. The comparison is one (1) of severe wear and material degradation versus virtually no significant damage.

The reader is, again, reminded that these materials were selected because they were readily available and there was a time constraint imposed. Further testing under actual service conditions is highly recommended. It is entirely possible that the Inconel 625, while performing well under these artificial conditions, could behave poorly when it is subjected to a higher number of cycles.



C71500 Cu-Ni Level Winder Shaft



C63000 Aluminum-Nickel-Bronze Pawl

Figure 1. Level Winder Shaft and Pawl

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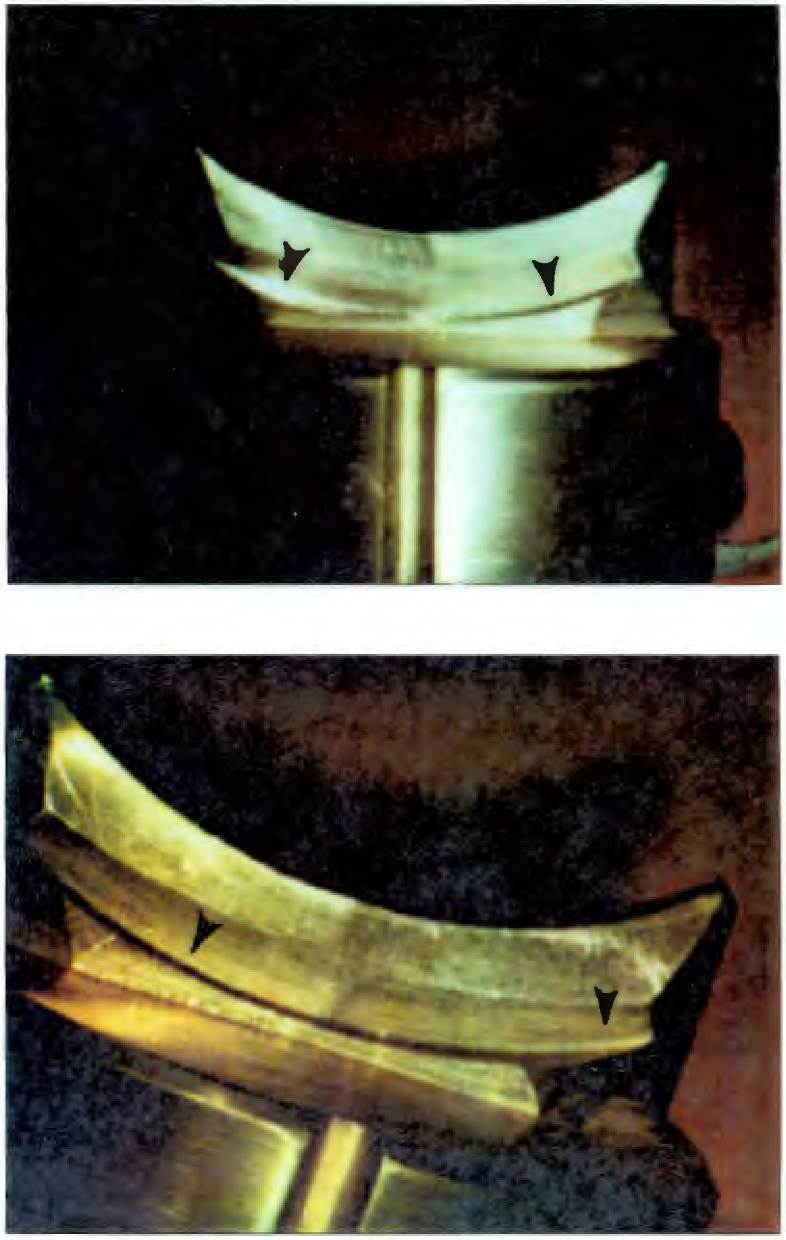


Figure 2. Pawl Wear

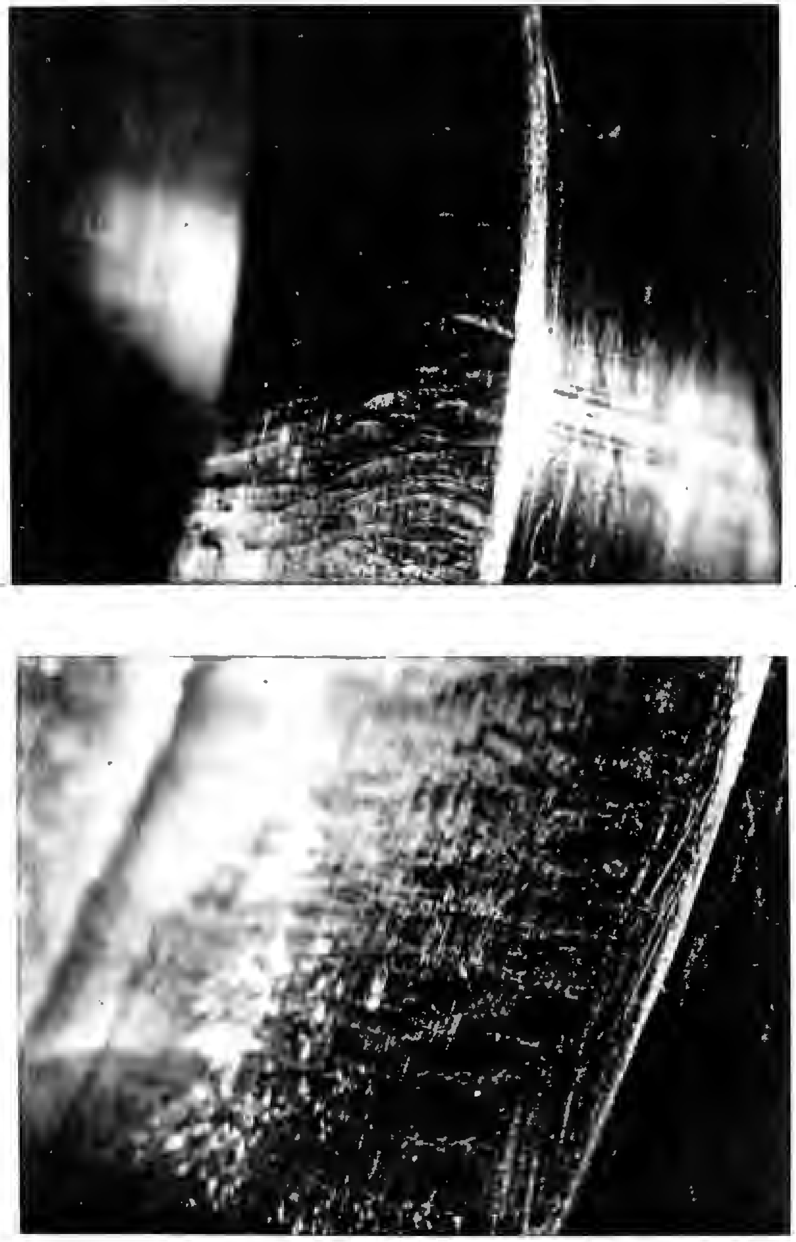


Figure 3. Shaft Wear

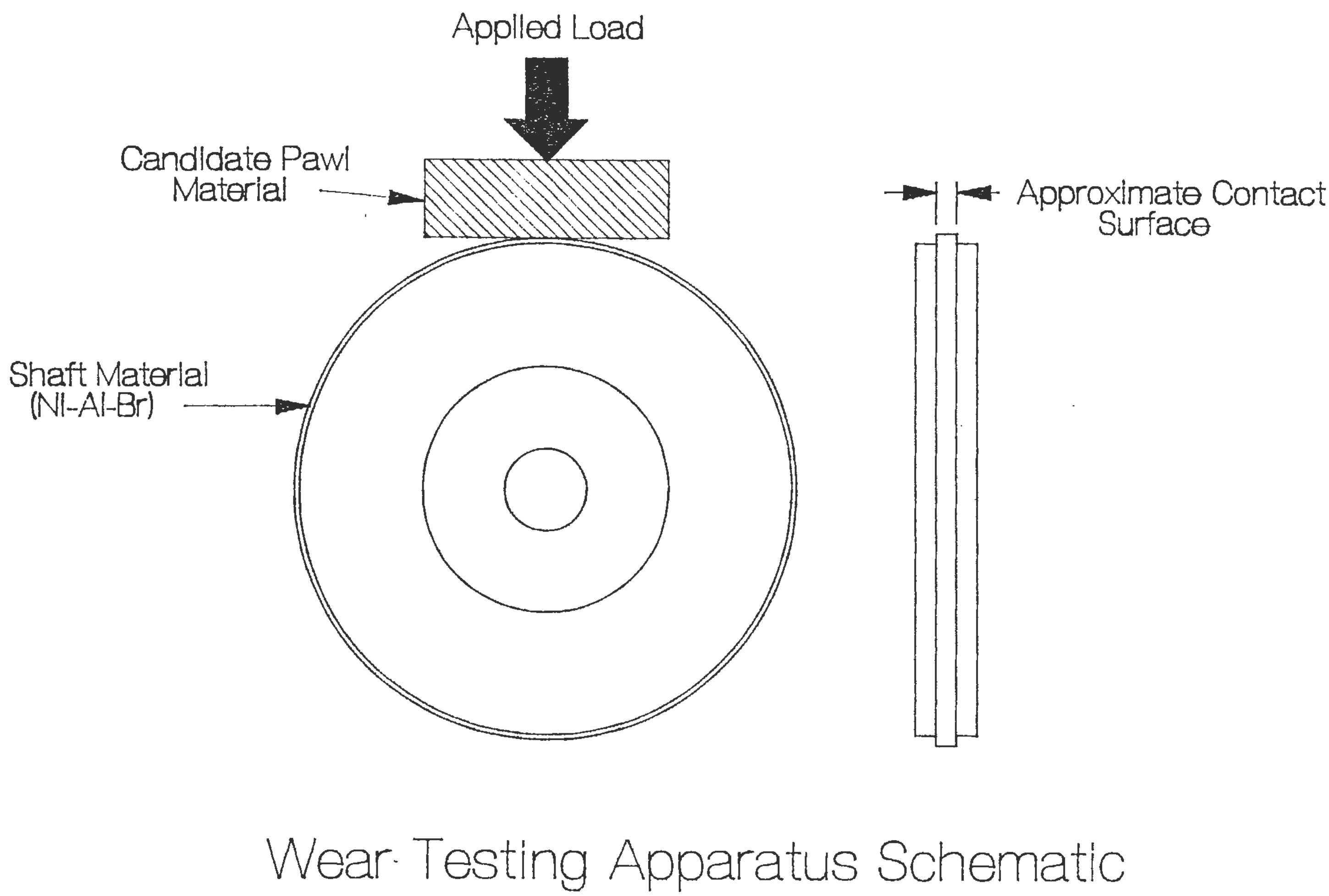


Figure 4. Wear Testing Apparatus Schematic

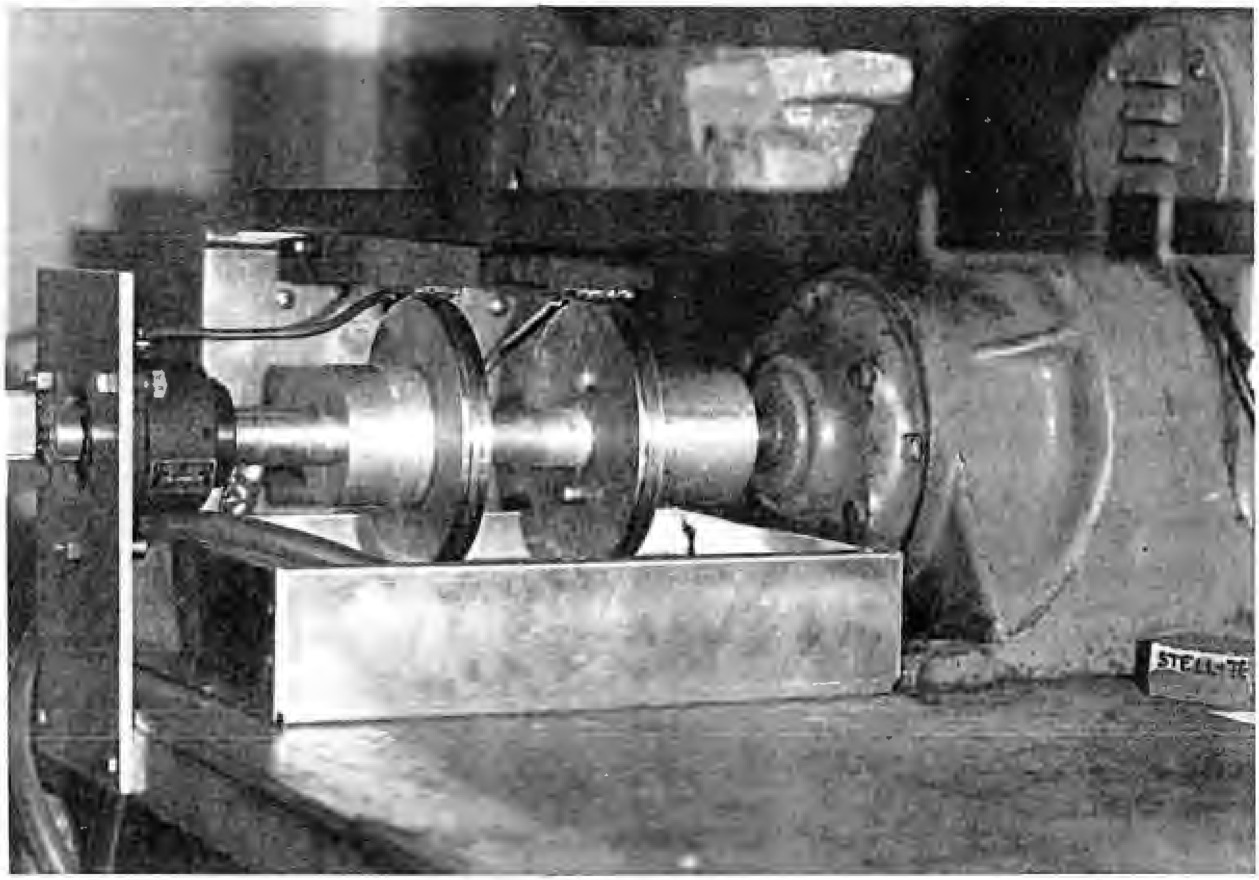


Figure 5. Wear Testing Apparatus Photograph A

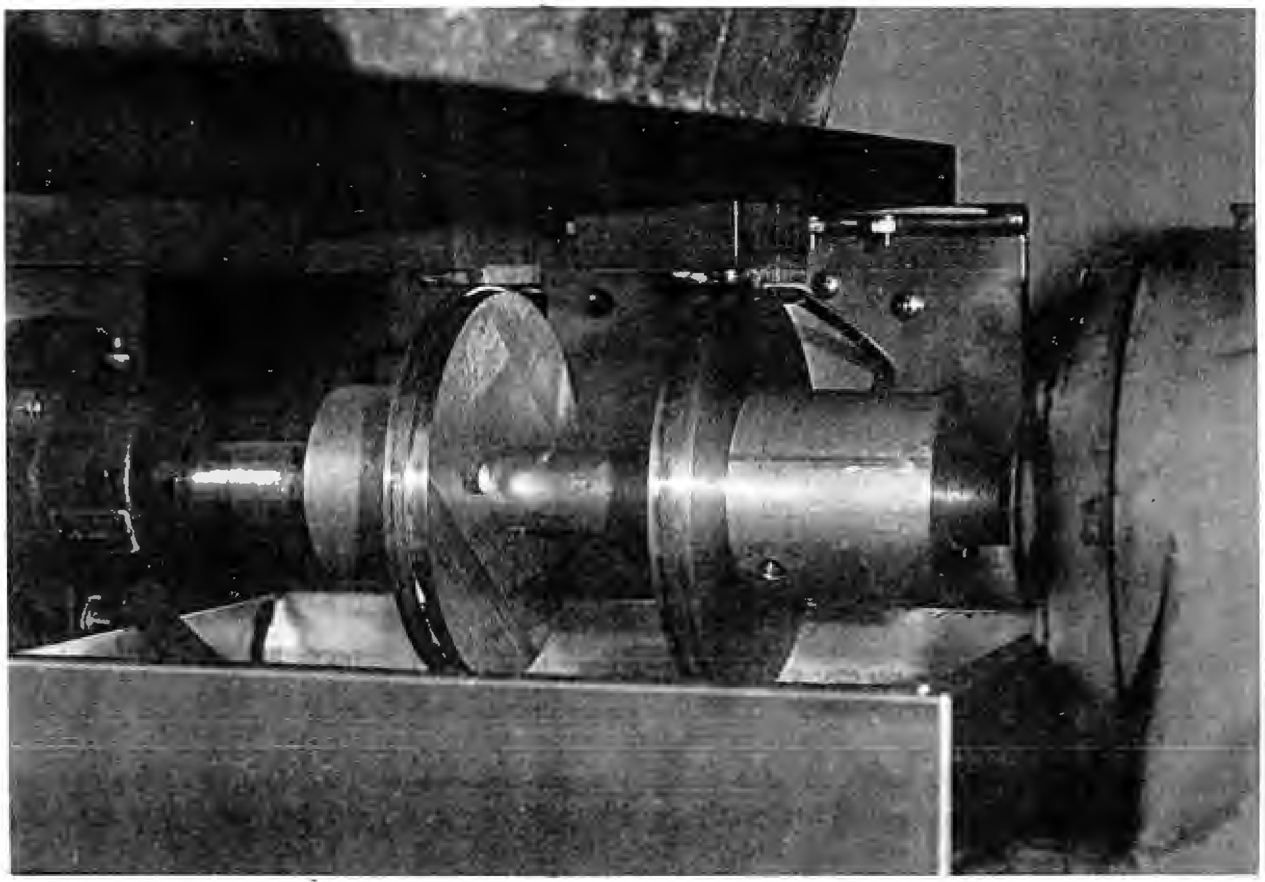


Figure 6. Wear Testing Apparatus Photograph B

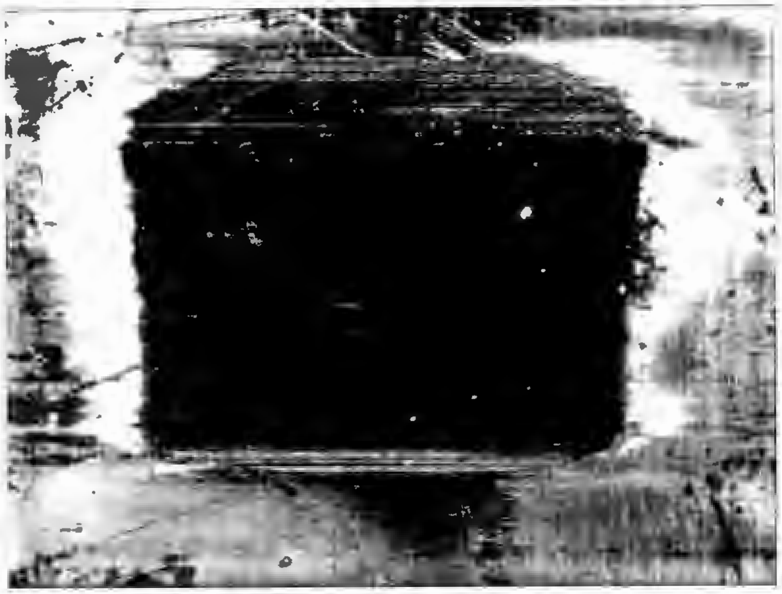


Figure 7. Clad Inconel 625 (10X)

Figure 8. C71500 Copper-Nickel Wheel/ Clad Inconel 625 (10X)

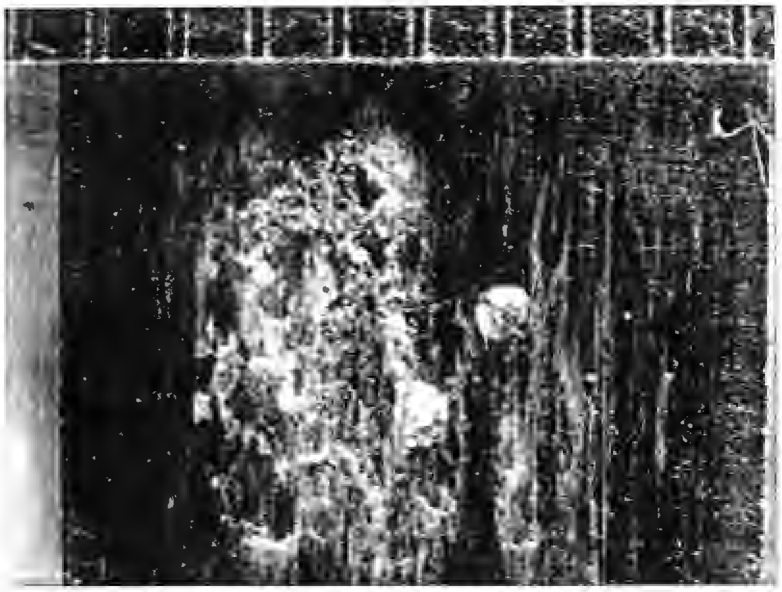


Figure 9. Clad Monel (10X)

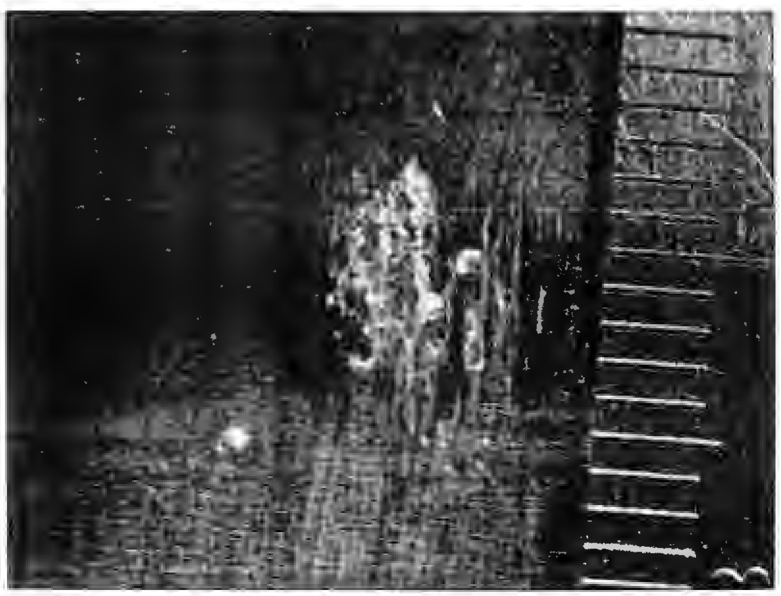


Figure 10. Clad Monel (5X)

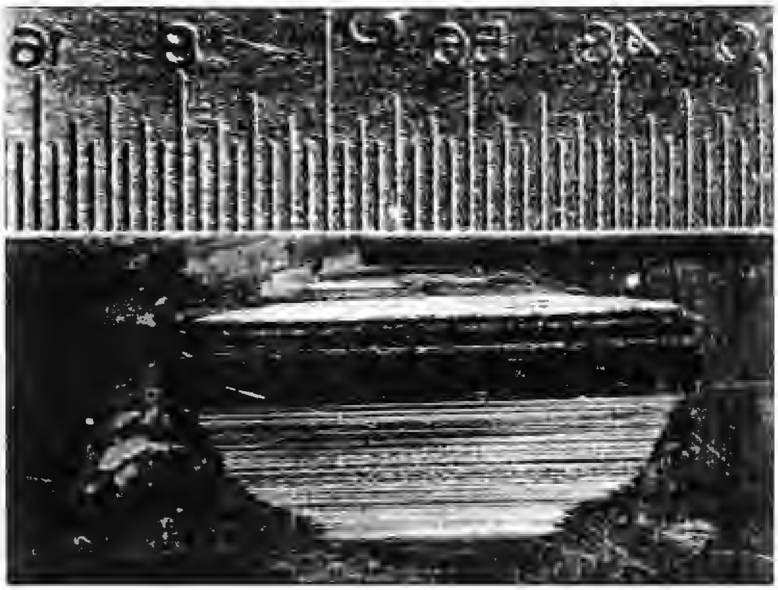


Figure 11. Clad Stainless (5.5X)

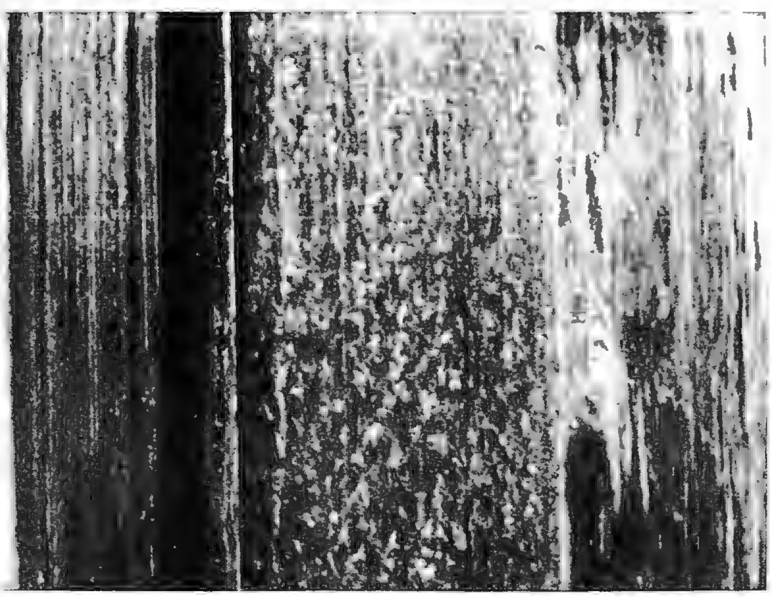


Figure 12. C71500 Copper-Nickel Wheel/ Clad Stainless (11.25X)

Figure 13. Clad Stellite (0.8X)

Figure 14. C71500 Copper-Nickel Wheel/ Clad Stellite (10X)

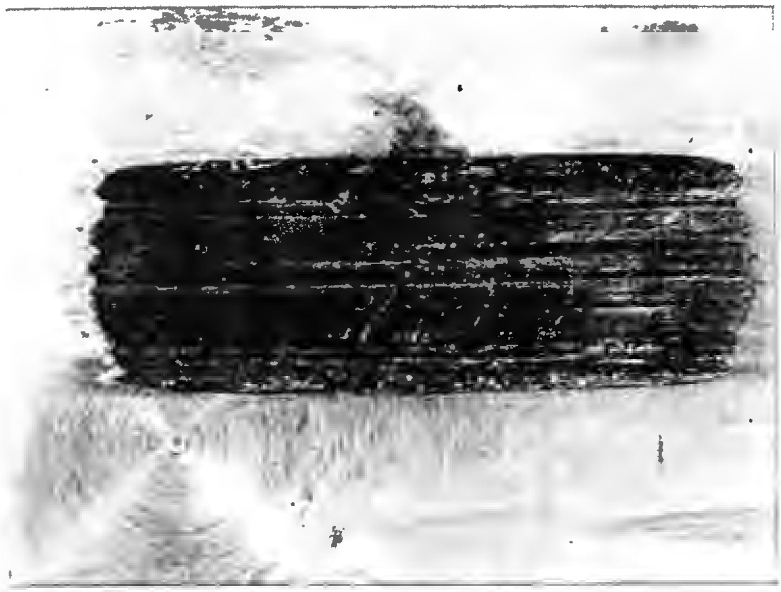


Figure 15. 304 Stainless (6X)

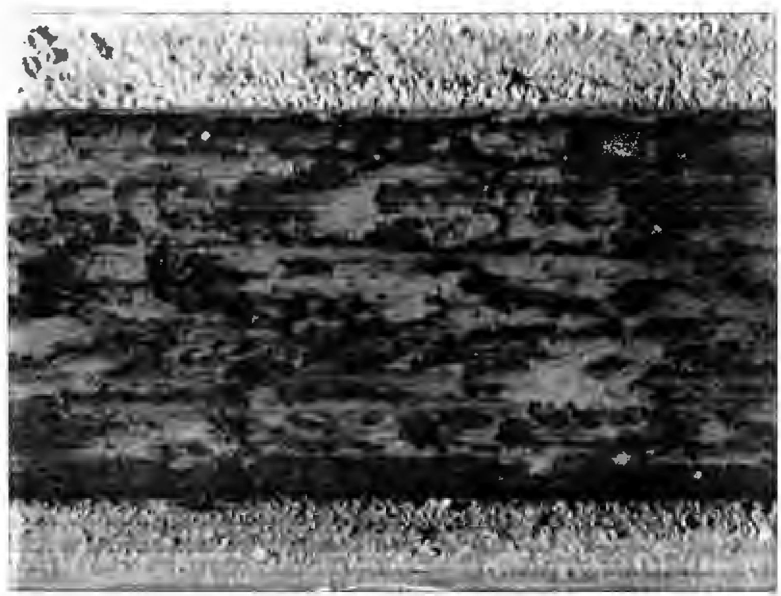


Figure 16. C71500 Copper-Nickel Wheel/ 304 Stainless (10X)

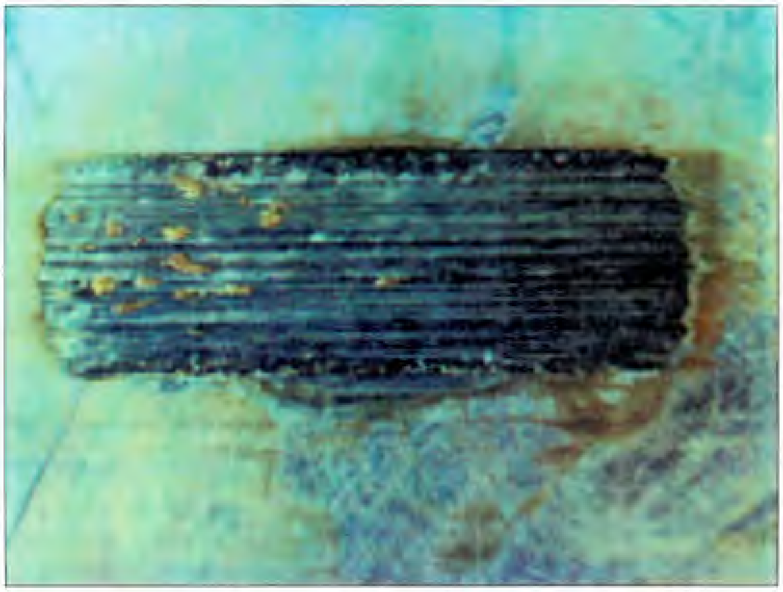


Figure 17. 316 Stainless (6X)

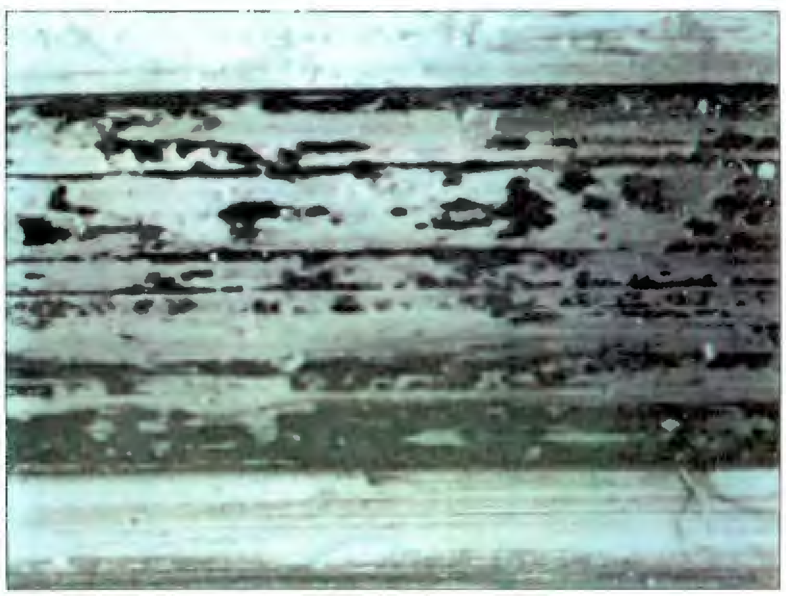


Figure 18. C71500 Copper-Nickel Wheel/ 316 Stainless (10X)

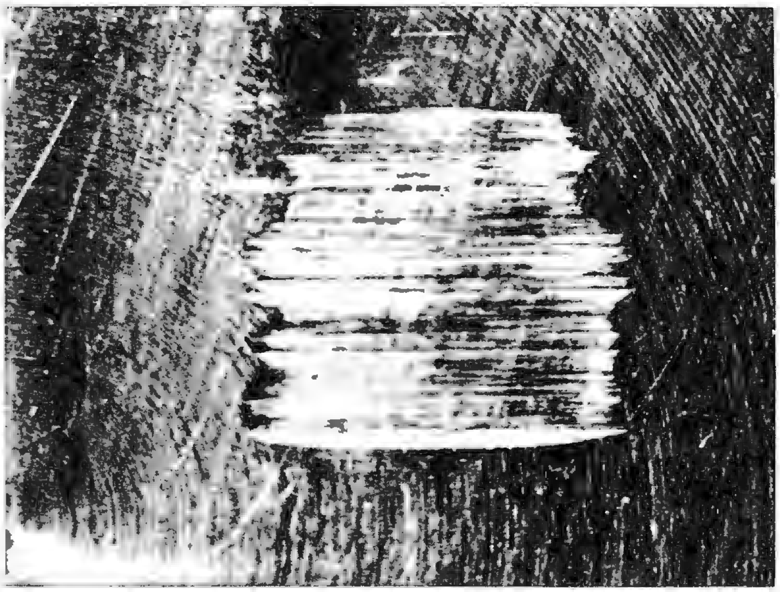


Figure 19. Inconel 625 Bar (10X)

Figure 20. C71500 Copper-Nickel Wheel/ Inconel 625 Bar (10X)

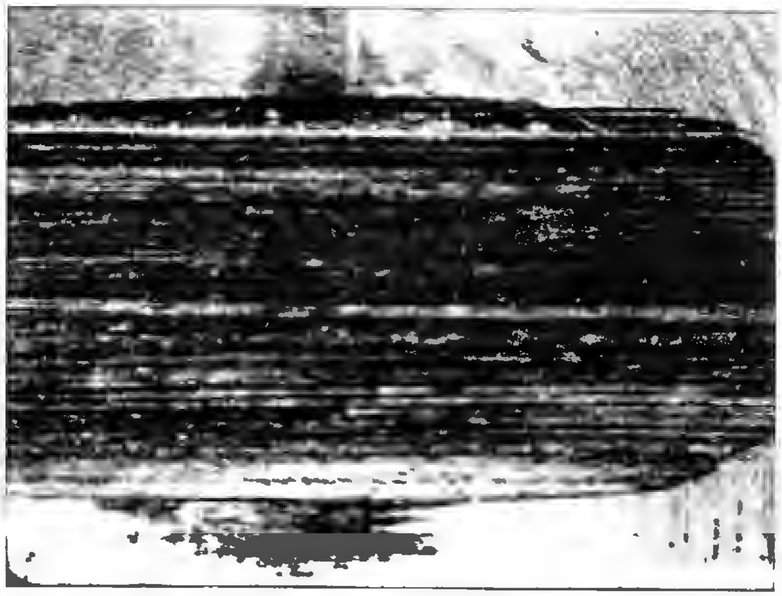


Figure 21. Titanium Bar (10X)

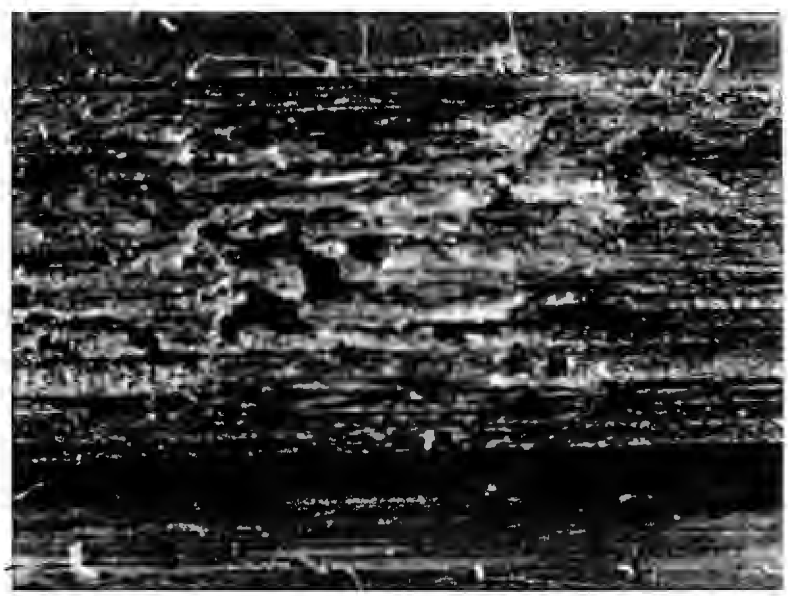


Figure 22. C71500 Copper-Nickel Wheel/ Titanium Bar (10X)

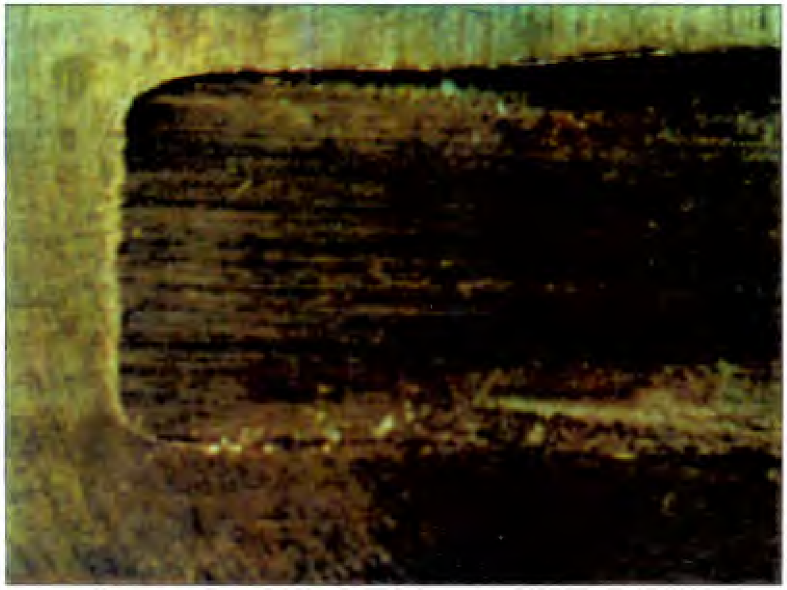


Figure 23. C63000 Nickel-Aluminum-Bronze (Pawl Material, 10X)

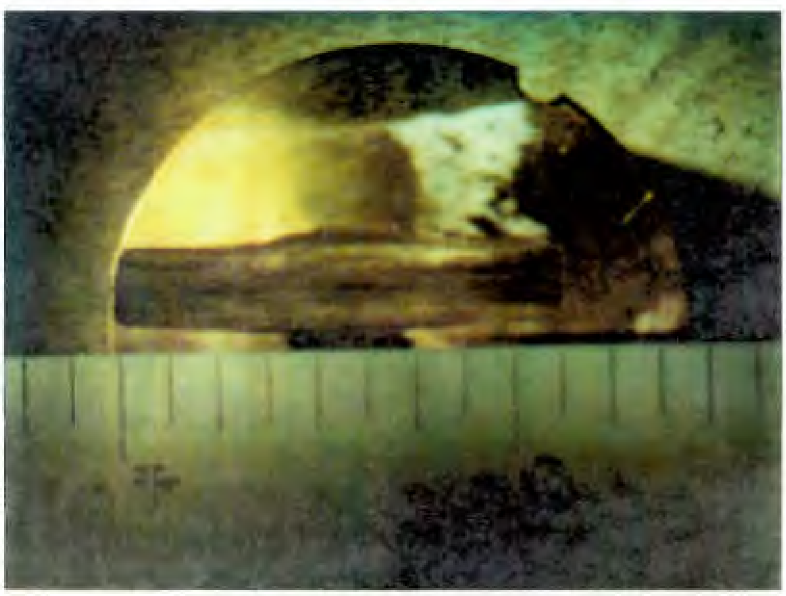


Figure 24. C63000 Nickel-Aluminum-Bronze (Pawl Material, 2.5X)

Figure 25. C71500 Copper-Nickel Wheel/ C63000 Nickel-Aluminum-Bronze (2.5X)

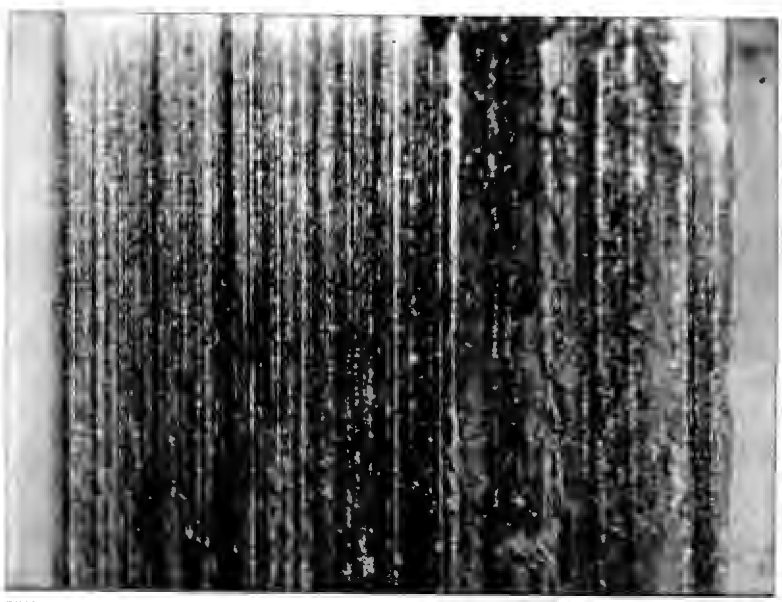


Figure 26. C71500 Copper-Nickel Wheel/ C63000 Nickel-Aluminum-Bronze (15X)

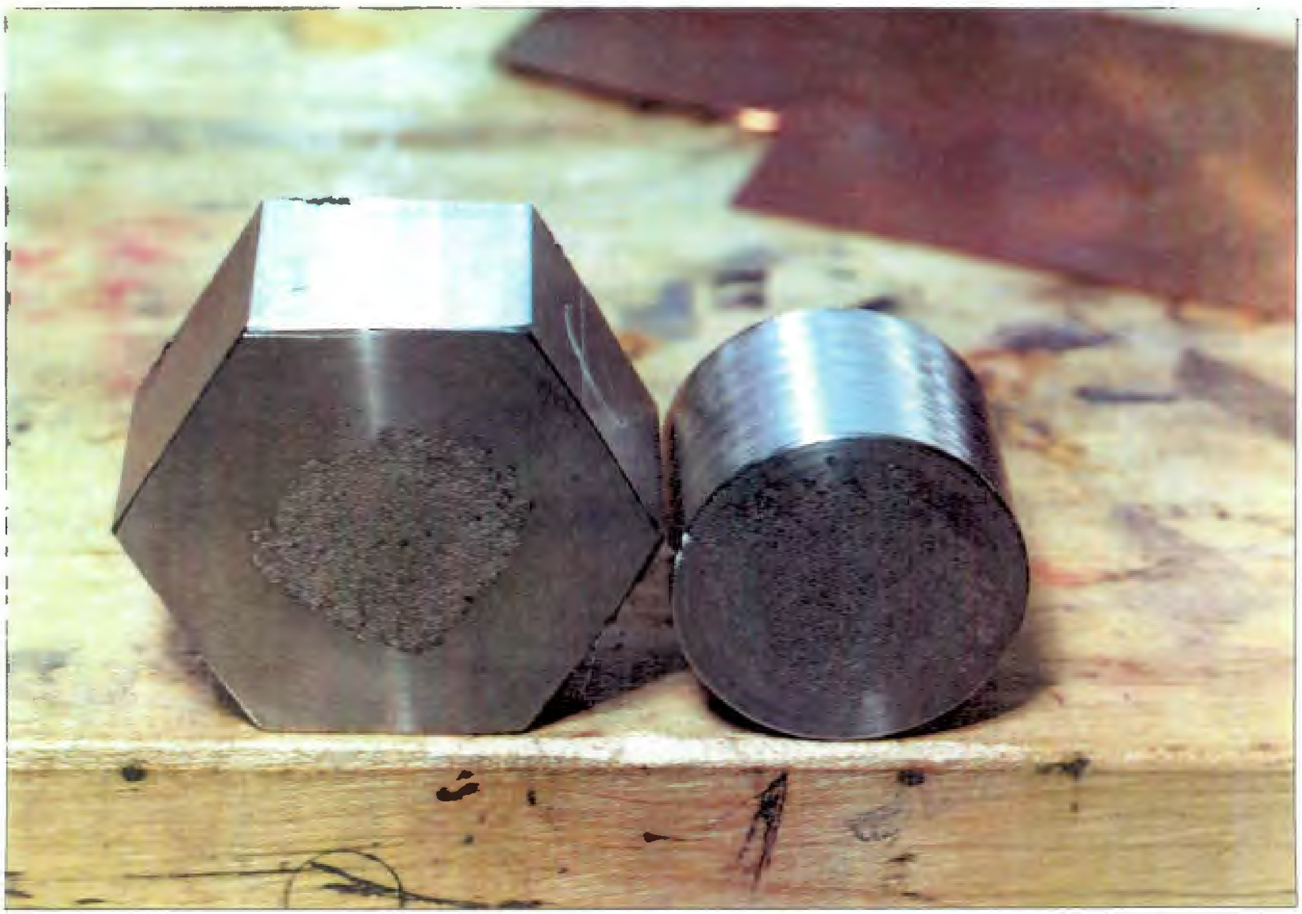


Figure 27. Rocklinized Samples

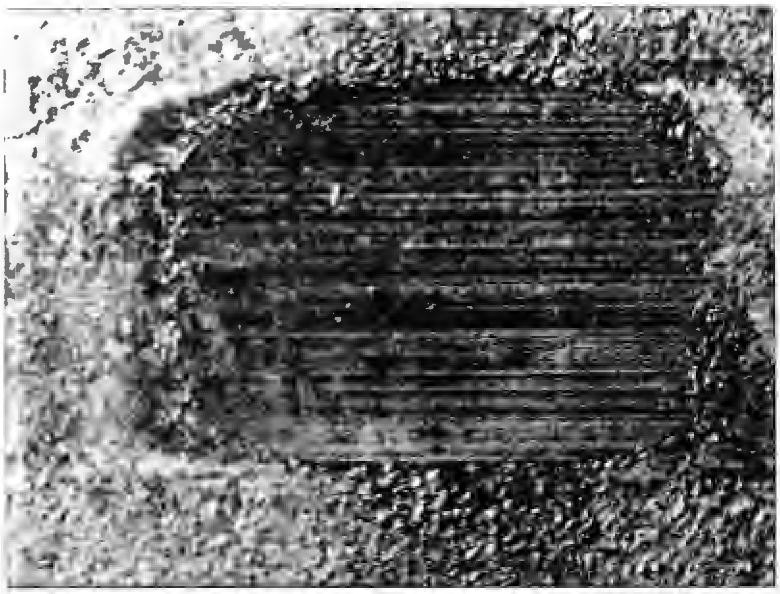


Figure 28. Rocklinized Stainless (10X)

Figure 29. C71500 Copper-Nickel Wheel/ Rocklinized 316 Stainless (10X)

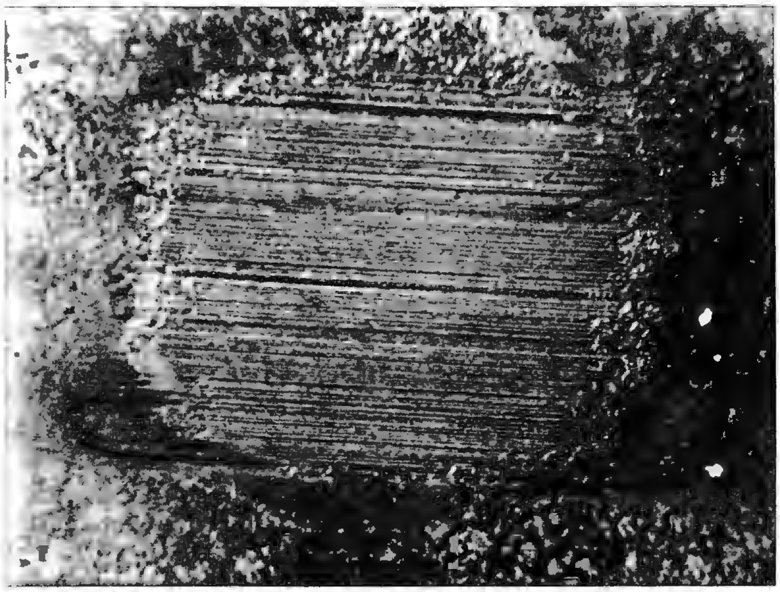


Figure 30. Rocklinized Inconel 625 (10X)

Figure 31. C71500 Copper-Nickel Wheel/ Rocklinized Inconel 625 (10X)

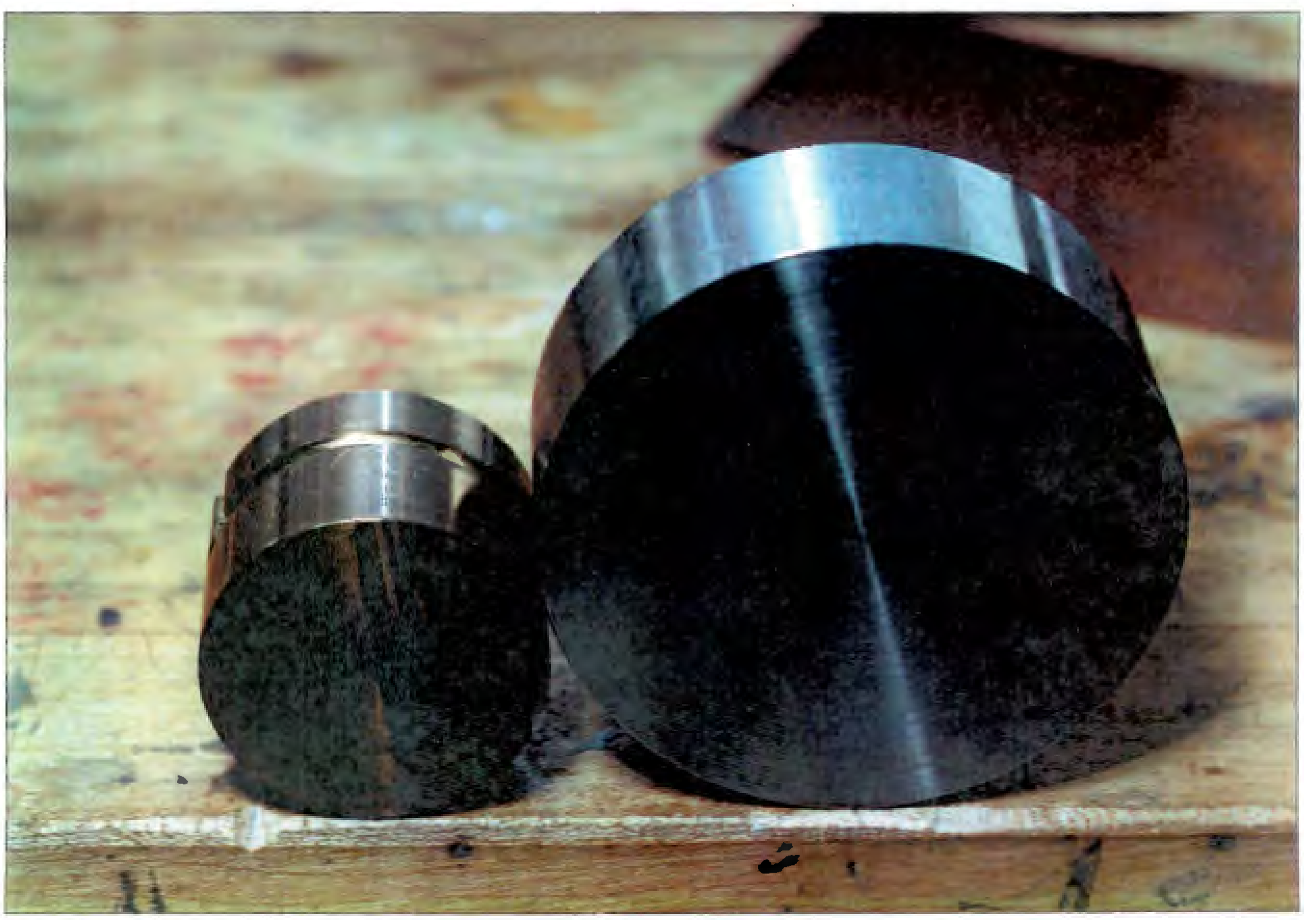


Figure 32. C6300 Pawl Material and Inconel 625 Bar Test Comparison

Table 1. Level Winder Pawl Material Wear Test Summary					
Material	**Cycles (Approximate)**	**Condition Rating***	**Width (in.)**	**Length (in.)**	**Depth (in.)**
Clad Inconel 625	59,400	4	.253	.275	.002
Clad Monel	128	1	.258	.309	Galled
Clad Stainless	65,500	2	.275	.464	.007
Clad Stellite	49,400	4	.251	.232	.0017
304 Stainless	60,000	2	.231	.615	.014
316 Stainless	60,000	3	.224	.611	.010
Inconel 625	60,000	4	.212	.210	.001
Titanium	55,000	3	.222	.552	.011
Nickel-Aluminum-Bronze (C63000)	5670	4	.211	1.149	.055
Rocklinized 316 Stainless	51,200	3	.219	.298	.004
Rocklinized Inconel 625	51,200	4	.219	.268	.002

* Condition Ratings:
1. Galled Surfaces
2. 250ST μin
3. 125ST μin
4. 63ST μin

Table 2. Level Winder Wheel Wear Test Summary

Material	Cycles (Approximate)	Condition Rating*	Wheel Diameter Change (in.)
Clad Inconel 625	59,400	4	.002
Clad Monel	128	1	0
Clad Stainless	65,500	3	0
Clad Stellite	59,400	3	0
304 Stainless	60,000	2	.001
316 Stainless	60,000	2	0
Inconel 625	60,000	3	0
Titanium	55,000	2	.0005
Nickel-Aluminum-Bronze (C63000)	5670	3	.001
Rocklinized 316 Stainless	51,200	3	0
Rocklinized Inconel 625	51,200	3	0

* Condition Ratings:

1. Galled Surfaces
2. 250ST μin
3. 125ST μin
4. 63ST μin

REFERENCES

(a) NUWC Memorandum Ser 44211L/56, "Hardness Testing of Towed Array Pawl and Shaft", dated 17 May 94, W. Maciejewski to C. Gray

Appendix A

Material Specifications

Manganese Bronzes

ALLOY/ UNS NUMBER	NOMINAL CHEMICAL COMPOSITION: Copper	Aluminum	Iron	Nickel	Other (Max.)	MECHANICAL PROPERTIES: Tensile Strength (KSI) Min.	Typ.	Yield Strength (KSI) Min.	Typ.	Elongation (%) Min.	Typ.	Hardness BHN 3000 Kg. Min.	Typ.	Density Lb/Cu. In.
AMPCO 663HT	60.5				2.6Mn 1.0Pb 1.0Si/ 1.0 Bal. Zn	69	74	35	43	12	16	126	149	0.299
AMPCO 666 C67400	58.5				2.5Mn 0.3Pb 0.7Si 38.0Zn		90		58		12		183	0.292
AMPCO 668 C67300	61.0				2.5Mn 2.5Pb 1.0Si 33.0Zn	68	75	48	55	12	15	126	153	0.300

Copper Nickel Iron Alloys

ALLOY/ UNS NUMBER	Copper	Aluminum	Iron	Nickel	Other (Max.)	Tensile Min.	Tensile Typ.	Yield Min.	Yield Typ.	Elongation Min.	Elongation Typ.	Hardness Min.	Hardness Typ.	Density Lb/Cu. In.
AMPCO 521 C96400	68.0		0.5	30.0	1.0Mn 0.5Si/ 0.5	60	68	32	37	20	28		140	0.323
✓ AMPCO 522 C71500	68.5		0.5	30.0	0.5Mn/ 0.5	50	55	20	23	30	40		85 (500 Kg) SoF,	0.323
AMPCO 525 C96200	87.0		1.5	10.0	1.0Mn 0.1Si/ 0.5	45	50	25	30	20	28		100	0.323
AMPCO 526 C70600	88.0		1.5	10.0	0.5	45	50	18	25	30	38		71 (500 Kg)	0.323
AMPCO 570 C99300	71.8	11.5	0.7	14.0	1.5Co/ 0.5	80	85	50	53	1	3		202	0.269

Copper Tin Alloys

ALLOY/ UNS NUMBER	Copper	Aluminum	Iron	Nickel	Other (Max.)	Tensile Min.	Tensile Typ.	Yield Min.	Yield Typ.	Elongation Min.	Elongation Typ.	Hardness Min.	Hardness Typ.	Density Lb/Cu. In.
AMPCO 51 C92500	87			1.0	11.0Sn 1.0Pb	40	45	24	28	10	18		80 (500 Kg)	0.315
AMPCO 711 C90700	88.3				11.0Sn 0.2P/ 0.5	50	55	26	30	12	16	93	102 (500 Kg)	0.314
AMPCO 712 C91700	86.8			1.5	11.5Sn 0.2P	50	60	28	32	12	16	100	106 (500 Kg)	0.316
AMPCO 715 C90800	87.8				12.0Sn 0.2P		60		32		16	95	106 (500 Kg)	0.315

High Copper Alloys

ALLOY/ UNS NUMBER	Copper	Aluminum	Iron	Nickel	Other (Max.)	Tensile Min.	Tensile Typ.	Yield Min.	Yield Typ.	Elongation Min.	Elongation Typ.	Hardness HRB Min.	Hardness HRB Typ.	Density Lb/Cu. In.
AMPCO 92	88.2	11.5			0.3	65	70	30	33	2	3	90	93	0.265
AMPCO 94	BAL			1.3	0.7Cr 0.6Si/ 0.5	55	65	35	45	10	15	70	78	0.320
AMPCO 97 C18200	98.5				1.0Cr/ 0.5	65	72	60	65	13	18	75	82	0.320
AMPCO 97 C81500	98.5				1.0Cr/ 0.5	47	51	35	40	13	17	65	68	0.320
AMPCO 98 C18200	98.5				1.0Cr 0.5		65		61		19	65	70	0.320
AMPCO 910	99.75				0.15Zr/ 0.10		62		60		15	65	70	0.321
AMPCO 940† C18000 (wrought) C81540 (cast)	96.5			2.5	0.6Si 0.4Cr	95	100	70	75	9	13	90	94	0.315
AMPCO 945 (patent pending)	96.5			2.5	0.6Si 0.4Cr		132		72		8	30 HRC	32 HRC	0.310
AMPCO 972 C18150	98.85				1.10Cr .12Zr	65	78		70		13	75	84	0.320

† AMPCO 940 alloy is protected by patents in the following countries: United States, Australia, Austria, Belgium, Canada, Finland, France, West Germany, Great Britain, Italy, Japan, Korea, Spain, Sweden and Switzerland.

* Mechanical properties are based on test bar values of 1" rounds where applicable.

F... 2

Aluminum Bronzes

ALLOY/ UNS NUMBER	NOMINAL CHEMICAL COMPOSITION: Copper	Aluminum	Iron	Nickel	Other (Max.)	MECHANICAL PROPERTIES*: Tensile Strength (KSI) Min.	Tensile Strength (KSI) Typ.	Yield Strength (KSI) Min.	Yield Strength (KSI) Typ.	Elongation (%) Min.	Elongation (%) Typ.	Hardness BHN 3000 Kg. Min.	Hardness BHN 3000 Kg. Typ.	Density Lb/Cu. In.
AMPCO C-3 C95400	85	10.5	4.0	2.5 (Max.)	0.5Mn/ 0.5	75	82	30	34	12	14	143	174	0.269
AMPCO C-3HT C95400HT	85	10.5	4.0	2.5 (Max.)	0.5Mn/ 0.5	90	95	45	47	6	10	180	192	0.269
AMPCO D-4 C95500	79.5	10	5	5	0.5	90	95	40	43	10	12	170	187	0.270
AMPCO D-4HT C9550HT	79.5	10	5	5	0.5	110	115	60	65	10	14	216	228	0.270
AMPCO M-4+ C95520	77.6	11	4.8	5.1	1.0Mn/ 0.5	125	130	95 (At 0.2% offset)	105	2	4	255	269	0.269
AMPCO M-4+ C63020	77.6	11	4.8	5.1	1.0 Mn/ 0.5	135	145	100 (At 0.2% offset)	115	6	8	262	286	0.269
AMPCO 45 C63000	80.0	10.0	3.5	5.0	1.0Mn/ 0.5	110	118	68	75	10	15	202	228	0.272
AMPCO 483 C95800	81	9	4.0	4.5	1.0Mn/ 0.5	85	92	35	39	18	24	159	174	0.276
AMPCO 483 C63200	81	9	4.0	4.5	1.0Mn/ 0.5	95	105	50	53	18	22		212	0.276
AMPCO 495 C95700	75	8.0	2.5	2.0	12.5Mn/ 0.5	92	96	42	48	22	28	160	180	0.273
AMPCO 642 C64200	90.5	7			2.0 Si/ 0.5	88	90	44 (At 0.2% offset)	53	15	30	130 (1000 Kg)	166	0.278

750 Rock B 92

Manganese Bronzes

ALLOY/ UNS NUMBER	Copper	Aluminum	Iron	Nickel	Other (Max.)	Tensile Strength (KSI) Min.	Tensile Strength (KSI) Typ.	Yield Strength (KSI) Min.	Yield Strength (KSI) Typ.	Elongation (%) Min.	Elongation (%) Typ.	Hardness BHN 3000 Kg. Min.	Hardness BHN 3000 Kg. Typ.	Density Lb/Cu. In.
AMPCO 62 C86500	58.0	1.0	1.0		0.3 Mn 39.5 Zn	65	72	25	28	25	35	112	131	0.296
AMPCO 64 C86200	64.0	4.0	3.0		3.5 Mn 25.5 Zn	90	95	45	48	20	25	170	192	0.289
AMPCO 66 C86300	62.0	6.0	3.0		3.5Mn 25.5Zn	110	115	60	65	12	15	192	223	0.284

ENCL 2

+ U.S. Patent No 3,378,413

*Mechanical properties are based on test bar values or 1" rounds where applicable

Appendix B

Calculations

/

W. Maciejewski

19 July. 94.

[Per Charles Gray 11 July 94]

Transfer Rate: 200 Ft/min

Stowage Drum : 7.92 FPM = full > 12.35 avg.
16.78 FPM = empty

$\frac{12.35}{200} \times 150 = 9.26$ SHAFT SPEED

150 is the transfer rate Gray decided to use.

Per Vic Spezialli [SEA] min shaft speed 8 > 12.5 avg
max " " 17

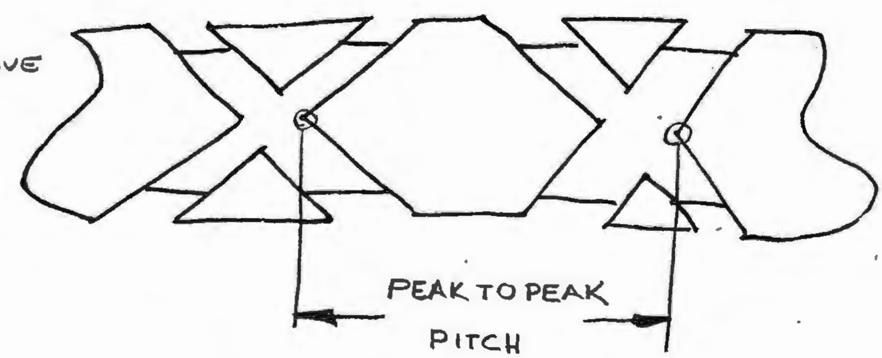
coincides with Charles info.

Based on our measurements of actual shaft segments;

At top of Groove 6.5"

At Bottom of Groove 5.5"

Avg = 6"



6.5×15 = 97.5" [8.12'] (15 on SHAFT)
6×15 = 90" [7.5']
5.5×15 = 82.5" [6.9]

W. MACIEJEWSKI
19 July 94

$8.12/9.26 = .877$ MIN
$7.5/9.26 = .809$ MIN
$6.9/9.26 = .745$ MIN

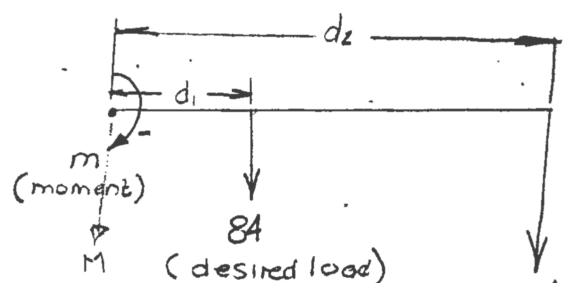
$\frac{FT}{FT/MIN}$ = MIN TO COMPLETE 1 REVOLUTION

Check: to deploy a 5,000 FT array using average speed

Since shaft transfer rate is 9.3 FT/MIN;
it takes $\frac{5000 \text{ FT}}{9.3 \text{ FT/MIN}} = 537.6$ MIN = 8.96 HR. TO DEPLOY AN ARRAY.

CONTACT AREA ON PAWL
$.4 \times .2 = .8 \text{ IN}^2$ SURFACE
based on drawing & actual part measurements.

84 lb load   free body diagram



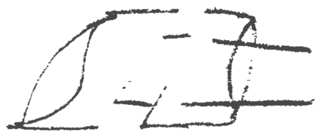
W (applied load at some distance.

For equilibrium:

$\Sigma F\uparrow = 0$
$84 + W - M = 0$

$\Sigma M_m = 0$
$84 d_1 + W d_2 = 0$

SHAFT WEAR TESTING | 16 AUG 94



1.527 dia.

$C = \pi d = 4.8\,in = .4\,ft.$

if shaft speed is 9.26 FPM

1 rev = 4.8" = .4 ft

$$\frac{9.26\,\frac{FT}{MIN}}{.4\,\frac{ft}{rev}} = 23.15\,\frac{rev}{min}$$

I have a 6" dia — $C = 18.85" = 1.6\,ft$

$\therefore$ 1 rev = 1.6 ft

$$\frac{9.26}{1.6} = 5.79 \simeq 6\,\frac{rev}{min}$$ ⟸ OUR SPEED!

$$\frac{\frac{FT}{MIN}}{\frac{\cancel{ft}}{rev}} = \frac{rev}{MIN}$$

	Level Winder	16 AUG 94

1 dep'y for Charles is 5000 ft.

my wheels are $1.6 \frac{FT}{rev}$.

$$\therefore \frac{5000\ \cancel{FT}}{1.6\ \frac{\cancel{FT}}{rev}} = \underline{\underline{3125}}\ rev.$$

FOR a 5,000 FT WHEEL.

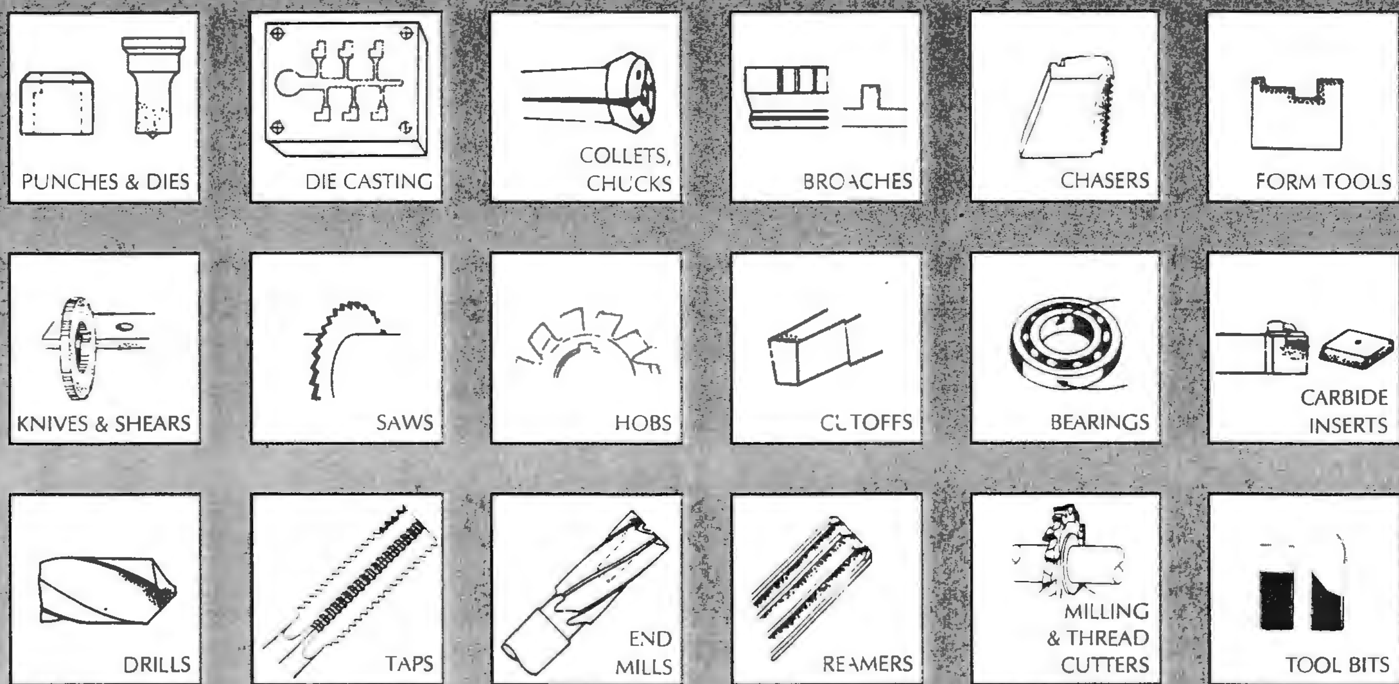
$$\frac{60000}{3125} = 9.6$$

Appendix C

Rocklinizing Data Sheet

LONGER WEAR FOR METALS !

WHERE TO APPLY
HOW TO APPLY



The ROCKLINIZER electronically applies electrode material by a spark deposition process. Material is impregnated both underneath and on top of the workpiece surface. Because no appreciable heat is generated, the temper of the workpiece is retained. ROCKLINIZING is applied to new or reground and resharpened surfaces.

TYPICAL APPLICATIONS

Punching, Stamping, Forging and Extruding: Stop slug pull back, reduce galling, extend time between sharpenings

Die Casting: Restore parting lines, prevent heat checking, soldering, seizing of cores, protect gates and runners

Gripping and Screw Machining: (i.e. bending clamps, collets, pusher pads, feed fingers, chuck jaws) Provide a suitable textured finish and restore tolerances

Perishable Tools and Dies: Reduce wear on high speed steel and carbide tooling

Maintenance: Restore tolerances on bearings, shafts, and other wear areas

Solid Carbides and Inserts: Surface seal and prevent chipping

Plastics and Composites: Improve fabrication operations including molding, machining, trimming, and protecting abrasive wear areas

Glass Processing: Molds, cut off tooling, glass handling equipment

Wood Industry: Saws, cutters, planer blades, and chipper knives

Paper Products: Die cutting knives and shear blades