Dewayne Isbell

Chief, Shop Operations

DIO

Maintenance Division

Fort Hood, TX 76544

12 September 1983

Col. John J. Tedesco

Commander

DARCOM

Material Readiness Support Activity

Lexington, KY 40511

Re: Request for Sanctioning of Lubrication Tests

Dear Sir;

In April of this year we received a suggestion concerning the lubrication of the M—113 angle drive cooling fan. This has been one of our worst problems.

In order to ascertain whether or not there was merit in the suggestion, we asked CamTron II, Inc. to run some tests to see if they could help with the problem, and also to help us decide if the problem was one of design or of the lubricant we were using, as per the M.L.O. for this unit.

Attached to this request is a copy of the report of testing which we conducted. We agree with the test report and would like to make additional studies and tests with other possible applications.

For instance, we would like to put this lubricant in a 6V—53T engine and observe the results. It does not appear that there is any lubrication application within our scope of responsibility, wherein we are currently using from a ten weight oil up to a fifty weight oil, which we could not lubricate with this lubricant. However, we do not have any hard data to substantiate this belief.

We have sufficient capability to perform such testing here at our facility and feel that we could conduct creditable tests, in cooperation with CamTron II, Inc. This testing would be conducted within our facilities and without fee to CamTron II, Inc.

Analysis of components by electron microscope photography using the facilities of N.A.S.A will be coordinated through Jonco Industries, Inc. without cost to this department.

In addition to the 6V—53 tests, we would like sanction to conduct evaluation tests on all other components within our scope of responsibility.

In the attached PROPOSAL OF TESTING OF MULTI-PURPOSE FLUID/DRY FILM LUBRICANT, CamTron II, Inc. has proposed this type of lubricant as being a possible "single lubricant" for units of the Rapid Deployment Force which we support. We would like to try to prove this as being either a "correct" or "incorrect" proposal on their part.

We do not have info on any other fluid/dry film synthetic lubricants and do not know of the existence of any others which claim specifications in any manner approaching those claimed by CamTron II for their CT-4039 Lubricant. We also have not seen any Mil-specs to cover this type of lubricant, although this product does seem to meet or exceed those referred to in the attached Proposal of Testing.

We wish only to be authorized to perform these tests without any manner of precommitment.

If you have any additional questions, please contact me at AC 817—287—2791 or Autovon 737—2791. I will be contacting you via telephone in a few days to ask your reaction.

Thanking you in advance for you cooperation and assistance, I remain,

Cordially yours;

Dewayne Isbell

Chief, Shop Operations

D. I.O., Ft. Hood, TX

cc: file

Jerry Cammack

ref : mrsa1.mss

LUBRICANT DESCRIPTION

CamTron II, Inc. blended a lubricant specifically for the testing performed at Ft. Hood, Texas during May and June 1983. The lubricant: was designated CamTron II CT-4039. The lubricant met or exceeded the following: MIL—L—2104C (CC), (CD), (SE) ,(SF), (SD), MIL—L--4615213, Mack EO—J, Detroit Diesel, GM6048M, GM6049M, Ford ESE—M2C153B, SAE SW—40.

CT—4039 was compounded from various synthetic components, plus Matrix Metalloid Fusion Lubricant, developed and manufactured by Jonco Industries, Inc.

SPECIFICATIONS

Viscosity Cst	
@ 100 C	15.3
@ 40 C	75.0
Cold Crank Simulator, CP	
@ -18 C	890.0
@ -25 C	2000.0
Flash Point (COC)	210 C
Pour Point	-55 C
Viscosity Index	243
Sulfated Ash %	0.81

Testing thus far has shown Camtron CT-4039 to be compatible with ocher petroleum and mineral base oils. It has also shown that oil changes do not need to be made with the same frequency as with stock oils, but the extended period between changes varies with the application.

The lubricant also contains an engine flux which does not cause any reduction in the lubricity, nor other specifications of the oil, but does perform cleaning functions which allow for a better bonding of the dry film lubricant.

The dry film lubricant is bonded by a process developed by Jonco Industries. Other factors concerning the bonding materials and bonding processes and the blending of this lubricant are confidential material and the property of Jonco Industries, Inc.

Other Mil-Spec comparisons will be published at a later date, or some will be provided upon request.

CamTron II, Inc.

P.O. BOX 1281

TEMPLE, TEXAS 76503

Ac 817/778-2509

CONFIDENTIAL MATERIAL

This proposal contains material of a sensitive nature and is

NOT FOR GENERAL PUBLICATION

PROPOSAL OF TESTING OF MULTI—PURPOSE LUBRICANT
CAMTRON 4039 SPECIAL APPLICATION SYNTHETIC OIL
7 SEPTEMBER 1983

SCOPE

This proposal details the specifications of proposed testing of a multi—purpose synthetic combination fluid/dry film lubricant to ascertain whether this lubricant has the potential to meet all the needs of lubricants within an Air Mobile, Armoured and Airborne Division which are presently utilizing SAE 10 thru SAE 50 oils.

HISTORY AND CURRENT SITUATION

The United States Army currently uses several different lubricating oils with SAE ratings of SAE 10 thru SAE 50 within armoured, air mobile or airborne division. This has created a potential for misapplication of lubricants which can result in damage to vehicles and rendering such vehicles as "Not Mission Capable".

With the advent of higher technology vehicles such as the Ml Abrahms Tank and the M2 Bradley Fighting Vehicle, the potential for greater damage and NMC ratings has increased, and the amount of damage per incident has also increased.

Logistical support for an armoured division has never been a simple matter due to the requirement of several different classes and weights of oils which are required for the various vehicles, both tracked and wheeled. There have been incidents wherein units have arrived at a location and had a surplus of one type of oil, but none of another essential oil.

Although Military Logisticians have become very adept at estimating the requirements for a division in a given situation, there have also been incidents in which various circumstances have made it impossible for the P.O.L. procurement personnel to comply with the desires of the logistical personnel.

An additional problem comes with the standardization of packaging for military applications. The cans all have the same color paint and it is easy for a container of one lubricant to be stocked with lubricants of a different type. This gives rise to the possibility of accidental intromission of an inappropriate lubricant thru simple mistaken identity. Although this need not happen when proper care is exercised, it is a fact that this has happened in several instances and the result was a NMC rating for a combat vehicle.

Probably the greatest single cause of equipment failure, related to lubricant is not the lubricant which was used, but rather the lubricant which was not used.

The optimum solution would be for the engines not to need lubrication and then there could be no accidents, nor shortages, but this is not possible.

The most feasible solution would be to have a single lubricant which would perform in the manner of the several types which are now being utilized. This lubricant would also have a dry film which would be bonded to the surfaces of the metal after the lubricant had been added to the unit. This is now possible.

Although the lubricant we are proposing does not have all of the total characteristics of every lubricant from the ten (10) weight required for the M2/3, nor meet the exact specifications of the fifty (50) weight used in some of the tank gearboxes, it does come close enough to the published specifications that it is suspected that it will perform satisfactorily and in most cases in a superior manner to the lubricant currently in use.

LUBRICANT DESCRIPTION AND SPECIFICATIONS

CamTron II, Inc. worked in concert with Jonco Industries, Inc. to produce a lubricant which would solve the lubrication problems of the M-113 angle drive cooling fan. The lubricant which was produced thru that research and development was designated CamTron 4039 and was tested at Fort Hood during May and June 1983.

It utilized extremely wide range synthetic oil which used a Jonco produced product to provide additional uniqueness. The product was Matrix Metalloid Fusion Lubricant. This product utilizes a polymer and bonding process which treats the metal surfaces of an engine or gearbox with an exceptionally long lasting coating of dry film lubricant.

The lubricant has shown all the advantages of a synthetic 5W-40 lubricant. This provides, for example, immediate 1ubricant dispersal within the oil system, as would be a characteristic of five (5) weight oil, yet retains viscosity in excess of fifteen (15) centistokes, a characteristic of a forty weight lubricant. Thus far, all indications are that it is compatible with any and all lubricants which are now being utilized.

Electron microscope photography at N. A. S. A. also showed that a one (1) micron thick matrix of the polymer had been bonded to the metal surfaces of the fan and that this dry film lubricant had only re-bonded to the bare metal and not to itself, thereby preventing any manner of clogging or accumulation which would be detrimental to the operation of the assembly.

This gave exceptional protection to the components. Pictures of the components as inspected and photographed at N. A. S. A. are to be found in the attached Report of Testing of the M—113 Angle Drive Fan Assembly.

Previous testing has shown that there is a marked degree of corrosion protection afforded due to the bonding of the polymer to the metal. This has not been sufficiently tested to provide hard data and percentage statistics, however it is known that the polymer is virtually impervious to water oxidation, sc we car, expect some degree of protection.

Initial data indicates there is the probability that this lubricant could replace the following fluid lubricants in current usage:

MIL-L--2104C, Grades: 10, 30, 40 and 50

(CC), (CD), (SE), (SF), (SD)

MIL—L—21260C, Grades: 10, 30 and 50

MIL—L—46152B, Grades: 1OW, 30, ZW—20, 1OW—30 and 1SW—40

MIL—L—46167

Again, it is noted there are some variances from the published required specifications for some of these lubricants, however, it is believed that the nature of the fluid/dry film lubricant will provide lubrication in excess of that desired at the time of the drafting of the various physical and chemical property requirements of the above listed engine oils. This is attributable to the state of the art at the time of the evolvement of the criteria and the unforeseen advances in the technology which have made a combination fluid/dry film lubricant a reality rather than a theory.

SPECIFICATIONS:

VISCOSITY, cSt			ASTM Method
+100	deg C	15.3	D445
+ 40	deg C	75.0	
— 18	deg C	890.0	
— 25	deg C	2000.0	

VISCOSITY INDEX	243.0	D2270
FLASH POINT	210 deg C	
POUR POINT	—55 deg C	D97
SULPHATED ASH %	0.81	D874
T.B.N.	7.4	

ANYLITICAL INSPECTIONS MASS %

Phosphors	0.13
Boron	0.02
Nitrogen	0.14
Magnesium	0.13
Zinc	0.14
Sulfur	Nil

CamTron 4039 has an extended life—span over any comparable fluid lubricant currently being used. This attribute provides for a smaller requirement of lubricant in a theatre of operations. It also has a direct bearing on the cost—effectiveness.

This is complimented by the reduction in wear experienced when providing lubrication with 4039. The reduction in wear is shown dramatically in the pictures in the attached Report of Testing in, the M-113 Fan Angle Drive.

Users of this and associated products have experienced a considerable decrease in the requirement of "top" oil, i.e. the quantity of oil which must be added during normal operations to maintain the desired level in the reservoir. This is resultant from the characteristics of the dry film lubricant which decreases friction and reduces operating temperatures, thereby wasting less lubricant in "blow—by" situations.

These factors combine to provide a longer T. B. 0. (Time Between Overhaul) in many applications.

The problem of intromission of an undesired lubricant into a unit is also eliminated.

The most unique quality of this lubricant is its ability to continue to provide limited lubrication in the event that the fluid lubricant is lost or depleted. This is not to say that it is possible to run an engine indefinitely after the loss of fluid but it has been proven that continued operation can take place for at least some period of time in excess of what would he expected in normal operation with a conventional lubricant.

METHODOLOGY OF PROPOSED TESTING

Initial testing could be conducted using one engine and gearbox combination, such as a 6V—53T with gearbox attached and the entire assembly placed on a dynamometer.

Performance can be easily recorded and evaluated. Some of the data to be gathered would include: horsepower, torque (corrected and raw readings), fuel consumption, various engine and gearbox operating temperatures, coolant flow, etc.

Baseline information on the unit can be gathered during a fifty (50) hour test period and collated and then the unit can be purged and the test lubricant cars be introduced and test runs totaling one hundred (100) hours of operation under a variety of simulated conditions can be conducted.

Additional data can be gathered from utilization of oil sample analysis when they are conducted on a regular basis. These would be on a linear progression, i.e., samples would be taken on a predetermined frequency interval, so that cumulative evaluation could be used, as opposed to just taking samples at the beginning and end of testing, as these would have little validity, due to the nature of the ingredients and the actions of the lubricant being tested.

Where feasible, micrometer measurements can also be conducted, as well as weight loss comparisons.

As with the M—113 tests, electron microscopic photography and analysis can be conducted by N.A.S.A. to provide visual confirmation of the resulting wear.

RECOMMEDATIONS

In view of the afore listed argument, it is recommended that this type of lubricant be tested in the entire variety of fluid lubricant applications as would be found in Armoured, Air Mobile, and Airborne Divisions of the United States Army, especially those which are used by the afore described types of divisions which are part of the Rapid Deployment Forces of the United States Army.

In view of the fact that CamTron 4039lubricant was developed specifically for this manner of application and there is no other known lubricant with these specifications, it is suggested that CamTron 4039 be tested the afore captioned applications.

Ref:B:TAECOMP1. MSS/jvc/kp

—6—

REPORT OF TESTING
M—113 COOLING FAN ANGLE DRIVE

May, June 1983
Fort Hood
Texas

CamTron II, Inc.
P.O. BOX 1281
TEMPLE, TEXAS 76503
817/778—2509

INDEX

SCOPE OF THIS REPORT

This report details testing performed at Fort Hood, Texas during May and June 1983 on the Cooling Fan Assembly of the M—113 Armored Personnel Carrier and related series vehicles.

This report contains specific data accumulated during the testing period and presents analysis, evaluation and the conclusions derived from such data and from the post—testing studies of the components and lubricants.

SI TUAT I ON

The cooling fan assembly in these vehicles experiences a higher failure rate than would seem normal for such a mechanical assembly. This has led to a disproportionate recurrence of Not Mission Capable (NNC) ratings resulting from failure.

The failures most frequently occur in the bearings captioned as 1OA—1OB—1OC—1OD in the exploded diagram (appendix II). Deterioration of gears 13A and 13B occurs in concert with the bearing failure. When these failures occur, the results can range from cessation of movement of the impeller to total disintegration of the gear assembly.

TEST OBJECTIVES

The objective of the tests was basically two—fold. First, to determine if the currently used lubricant was sufficient for this application, and secondly, to determine the feasibility of a lubricant which provided a wide S.A.E. range coupled with dry—film lubricant bonding.

Both objectives sought to find a manner in which the life span of the units could be extended.

PREMISE OF TESTING

It was believed that intensive operation of this Lam assembly could provide the equivalent of prolonged operation within a relatively short period of time. This is an acceptable procedure and was patterned after the Federal Aviation Administration test procedures for lubricant certification and type acceptance.

The procedure which was followed used periods of operating the fan assembly as accelerated speed for periods greater than would be encountered in normal operation.

Without sufficient control and baseline data from other operations, it is not known what the comparable field usage time would be, therefore’ no comparisons of that nature are presented herein.

TEST METHODOLOGY

With safety as the prime consideration, and the known tendency of the unit to disintegrate, an armored steel test stand was designed and fabricated. The design was such as to provide maximum protection to those conducting the tests, yet allow mounting of the fan assemblies in a manner as closely as possible reproducing the orientation of the fan when installed in a vehicle. Observation of the units during testing as also considered.

The fans were driven by a seven and one—half (7 horsepower electric motor on each fan assembly, through a pulley and belt arrangement. The motors provided 1760 r.p.m. fixed speed and were wired for three phase, 220 v.a.c. operation. Both motors were connected to tachometers which could be read from the shielded back of the test stand.

A remote temperature sensing device was attached to each fan, but these proved ineffective, necessitating the development of a subjective temperature scale. (See Appendix I)

Two (2) pulley ratio arrangements were utilized. In Phase I, the ratio was 14.5:7.0, producing an input rpm (rpm of 3641; and a ratio of 14.5:5.25, producing 4861 rpmi in Phase LI.

Unit #1 was a salvage M—113A2 cooling fan (Serial Nr. 2895) repaired and assembled by L.V. Cammack and inspected and certified as being in compliance with the specifications and tolerances of TM 9—2520—238—34, C2, by Charles Tyler and Jack Peeples. It was lubricated with Camtron CT—4039.

Unit #2 was a new issue unit (Serial Nr. 0084) from D.I.0., inspected and certified as in compliance with the aforelisted TM by Jack Peeples. This unit was lubricated with MIL—L—21260, Grade 2, SAE 30, drawn from stock.

VARIANCES

During assembly of Unit #1, it was discovered that the gear housing around needle bearing (20) was scarred. This was filed and emory clothed — after the unit had been dipped in solvent and blow—dried. The can used to fill Unit #1 was dipped in solvent and blow—dried before usage, and oil tests showed that some residue remained. Both Input/Output gears of Unit #1 were shimmed to obtain backlash of .0025” and I/O bearings required S inch/pounds pressure for movement.

The “Synopsis of Test Runs explains the reasons for the units not always being tested simultaneously and the duration of each run with the cumulative elapsed time on each unit are contained in Appendix III.

SYNOPSIS OF TEST RUNS

General:

Test units were monitored at all times with at least two persons present. A major consideration was safety and the most prudent methodology was followed at all times.

Representing CamTron II, Inc. were Jerry V Cammack, Philip 1-I. Boatright and Luther V. Cammack; the latter as a consultant for this series of tests, as he is not an employee of CamTron II, Inc., nor of Jonco Industries, Inc.

Various persons from DIO, Ft. Hood, were present during one or more segments of the testing. These included: Dewayne Isbell, Joel (Jerry) Beck, Charles Tyler, Jack Peeples, Bill Carter, and many of the mechanics, helpers and personnel under the supervision of either Mr. Isbell and/or Mr. Beck.

Comments and observations from the personnel from DIO, Ft. Hood, are contained in this synopsis, and are attributed to the appropriate person.

Notes from Jerry Cammack were used in preparing this report. There were approximately fifty (50) pages of such notes and they were taken during the actual testing, but are condensed herein in the interest of brevity and clarity. Additional notes taken by Philip Boatright were also referred to and utilized.

During all phases of the testing, there were problems of an electrical nature which necessitated assistance from Electrician Ray Greene. These are not contained herein, but it is stated that he also was an observer and active participant in the conduct of the testing, due to rewiring of the units being a frequent occurrence during all phases of the tests.

Ambient temperature is not noted herein, as both units were tested side by side and sustained the same environment. It should be noted however that the operating temperatures within the test stands are considerably lower than those encountered in the vehicles.

The devices intended to measure internal temperatures during operation did not function as anticipated; indeed only the gauge on unit #2 showed any temperature elevation. Consequently, a subjective scale was developed to plot temperature of the external surfaces which could be touched with the fingers. This scale is explained in Appendix I.

Identical tachometers were installed on the motor shafts thru 2:1 ratio adapters, producing a reading of 3520 @ 1760 rpm. It was noticed that one tachometer showed a variation of —50 rpm when installed on either unit. Allowance was made for this error, depending on which unit it was installed at the time. All r.p.m. readings are presented with the correction factor applied.

Noise levels and descriptions presented another area which required subjective descriptions. Numerous attempts were made to develop some degree of standardization, but all failed to establish any method of objective description, therefore the descriptions contained herein are admittedly subjective. Sound detection was accomplished with the naked ear; solid conductor; stethoscope and bone conduction.

Evaluations which depend on other sensory functions are not further described in this section.

Prior to beginning timed testing, several short test runs of less than three (3) minutes were conducted Co check for proper installation of the test units and to check the normal functions of such a test procedure.

TEST RUN 1

The first timed run lasted eight (8) minutes and thirty (30) seconds at which time two (2) fuses in each unit blew. During this run it was noted that both units seemed to be functioning in a normal manner. Unit #1 had a pronounced vibration which could be felt in the dust cover and also had a low frequency noise of undetermined origin. Coast down time of the fans was almost identical, although Unit #1 may have been slightly quicker to stop.

TEST RUN 2

This run was also shortened by blown fuses in both units. Again Unit #2 had a longer coast down time, but this may have been the result of the fuses blowing in Unit #1 first. Nothing remarkable was noted in either unit.

TEST RUN 3

Another fuse related problem terminated this run in nine (9) minutes. Nothing remarkable noted.

TEST RUN 4

Unit #1 continued to have slight vibration in dust shield and to produce a low level noise of unknown origin. Unit #2 operated in a normal manner with nothing remarkable noted. Both units were inspected immediately after the power failure which terminated this test. B. Carter remarked that there was a considerable temperature difference in the input shafts. This was confirmed by J. Cammack, P. Boatright and L. Cammack. Top of housing was at ambient temperature; bottom of housing on Unit #1 was also ambient temperature (1), but bottom of unit #2 was warm (1); input shaft of unit #1 was (1), but input shaft of unit #2 was very warm (4) at housing bearing and warm (3) at input bearing; unit #1 input shaft bearing was slightly warm (2). Coast down time of unit #1 was 1—2 seconds faster.

TEST RUN 7 continued

but their origin remained unknown; bottom of housing was Warm (3) and the shaft and shaft bearing were both Very Warm (4); Unit #1 was without remarkable deviation from normal operation and no temperature elevations above Slightly warm (2) were found.

At 09:57:32 fuses in both units failed and a quick inspection revealed the following: Unit #1 displayed linear cessation of impeller movement, shaft bearing was slightly warm (2), housing was slightly warm (2), and there was evidence of slight oil loss in chamber. Unit #2 had very slight 'play in impeller, housing was very warm (4), inner shaft bearing was slightly hot (5), shaft was very warm (4), a grinding noise could be detected with stethoscope and was more pronounced in latter stages of rotation prior to cessation of movement with a distinct growl at moment of stop, coast down time was about seven seconds shorter than unit #1.

At 12:05:00 it was noted that the output air of unit #2 was warmer than that of unit #1.

At 23:00:00 of test) both units were operating in a seemingly normal manner. During preceding eight (8) hours, the whine and grinding noises in unit #2 were sporadic and the frequency and amplitude changed intermittently.

At 28:12:00 Unit #2 had a loud whine that lasted for about one (1) minute and then disappeared. It sounded like some manner of metal to metal contact was taking place, but then the amplitude of the whine dropped to where it was barely discernable with the naked ear. Unit #1 also has a slight whine which seemed to be coming from the needle bearing. Unit #2 now had a vertical and horizontal oscillation which could be seen when marks were watched on the impeller base and the housing.

At 30:30:00 both units were momentarily stopped from inspection. A new noise had been heard in Unit #2 and this unit had a coast down time of approximately ten (10) seconds less than unit #1. Unit #1 remained slightly warm (2) to warm (3) on all surfaces, but unit #2 housing was warm and shaft bearing were both hot (6). Grinding noise in Unit #2 seemed to be coming from the gears and there was a pronounced bearing whine.

At 32:37:43 a new loud grinding noise was heard in unit #2 for about fifteen (15) seconds. Units were not stopped but were given careful visual and aural inspections. A strong vibration could be felt in the housing of unit #2, and this coincided with the grinding noise which could be heard with the naked ear. Stethoscopic examination indicated that this noise was generated internally and seemed to be coming from the gears. The bearing whine was much louder and at times this whine would have a secondary grinding sound. Unit #1 continued to operate in a normal manner.

TEST RUN 7 continued

At 34:04:27 the quick disconnect handles were pulled. A very loud grinding noise developed in unit #2. Unit #2 coasted down time was approximately fifteen (15) to twenty (20) seconds shorter than that of unit #1. Inspection showed no surface of unit #1 had a temperature elevation greater than slightly warm (2), but unit #2 had a very warm (4) upper housing, slightly hot (5) lower housing, hot (6) shaft and a very hot (7) inner bearing. Unit #2 had grinding which could be heard by the naked ear and this increased as the impeller slowed down and was very pronounced at the moment of cessation of movement. There was movement in the impeller shaft. Slight marking of the inner diameter of the fan tower housing was also found. Unit #2 was inspected by Jack Peeples and he * declared it to be unserviceable. TESTING OF UNIT #2 WAS THEREFORE TERMINATED. Unit #1 was operating in a normal manner.

TEST RUN 8

Unit #1 was run for 12:48:20 with no remarkable notations. Unit was momentarily stopped at 03:00:00, 06:00:00, 08:12:30, and 10:21:00 for inspection. Inspection consisted on reaching down thru the impeller and feeling the lower housing, shaft, and shaft bearing. In all these inspections, none of the surfaces were warmer than warm (3). Other than the noise generated by the dust shield, no unusual noises were heard.

A decision was made to try to knock out the bearing by increasing the r.p.m. and the run was terminated.

Careful inspection of both units revealed that unit #1 was still serviceable, and chat unit #2 had not been serviceable since approximately 32:00:00 of run 7. However, it was decided chat both units would be run at higher r.p.m. in order to push at least one of the units to some degree of self destruction.

TEST RUN 9

Unit #1 was run for 14:43:15 at 4861 rpm. During the run, there were no remarkable notations. Periodic momentary suspension of the run to feel the shaft and lower housing found chat the unit was running only slightly warm (2) to warm (3).

TEST RUN 10

Both units were ran side by side, again. Unit #1 performed normally and ran with no greater temperature elevation than warm (3). Unit #2 sounded almost normal in initial period of testing this run. The noise levels were far less than they had been during the latter stages of their previous run. This may be attributed to the unit having cooled down and the lubricant being spread but over the surface of the bearing race sufficiently to provide an ‘oil wedge’ and lubricate the surfaces of the race and bearings. During the first few hours, there was nothing to indicate that scoring of the inner diameter of the fan tow was occurring.

TEST RUN 10 continued

Considerable difficulty was experienced with the electrical system when both units were running with the higher amperage demand now placed on the electrical system as compared to the higher ratio pulley system and at 05:27:45 it was determined that the units should be operated individually until wiring could be modified to accommodate the increased load.

Inspection of the two units showed that there was considerable difference in the temperatures of the surfaces. The housing of unit #1 remained only slightly warm (2) and the shaft and shaft bearing were both only warm (3). Unit #2 housing was warm (3) on top and very warm (4) on the bottom and the shaft was hoc (6) and the shaft bearing was very hot (7). The coast down time of unit #2 was about fourteen (14) seconds less than unit #1. Although the grinding and whine in unit #2 had been barely noticeable during operation it was very apparent during coast down and very pronounced at the moment of cessation of movement.

TEST RUN 11

This was a 07:09:15 run with only three momentary periods of dormancy for changing fuses. Only unit #2 was operated. There were sporadic instances of loud whine and grinding, especially during coast time. The vibration in the housing paralleled these noises. The constant noises were of low level and seemed to be increasing slightly in both frequency and amplitude. Stethoscopic examination confirmed that several new sets of low level whines were developing.

When each fuse change occurred, the surfaces were felt. The housing would be warm (3) to very warm (4) on top and slightly hoc (5) on the bottom. The shaft was slightly hot (5) to hot (6) and the shaft bearing was very hot: (7).

TEST RUN 12

Both units were again run simultaneously. Heavier wiring was used, but this did not correct the situation of overloading.

Unit #2 continued to function as it had in test run 11, except for a slight increase in the noise level and vibrations. Unit #1 operated in much the same manner that it had during the entire testing. At 04:07:15, the tests were suspended on unit #1, as the fuses were blowing too frequently to run effective testing. Unit #1 was inspected and the following noted: the surfaces of the unit remained in the temperature range of only slightly warm (2) to warm (3); the vibration in the dust shield was still present; the whine from the needle bearing was still present and had not increased in amplitude; the housing outer bearing was now slightly hot (5) (this was the bearing which had been sprayed with Matrix MFC in hopes of getting it thru the testing without replacement); with the exception of the needle bearing whine, the unit remains serviceable.

TEST RUN 12 continued

Unit #2 was also inspected and the following were noted: the upper housing was warm (3) and the lower housing was slightly hot (5); the shaft was hot (6) and the bearing was very hot (7); the coast down time was almost twenty seconds less than unit #1; the grinding and whine continued to increase;

and, there was now slight evidence of additional scoring on the inner diameter of the fan tower [there was not agreement of the observers as to whether this was actually occurring].

TEST RUN 13

For this and the final run, both electric motors were used in parallel in order to lessen the overloading of the electric system. This was successful and, no more fuses were blown.

The run was terminated at 04:31:17. A loud whine and grinding had developed and it was thought that the bearings and/or races were failing. There was also evidence of gear failure as the coast down time seemed very short, however, there was nothing for comparison. It was noted that the noise and the vibrations were caused by the same sources, i.e., the greater vibration was accompanied by increased amplitude of the whine and grinding noise. The temperature elevations were identical to those of test run 12.

TEST RUN 14

This run was terminated at 02:10:50. In addition Co the increased whine and grinding noise, a new scraping noise w heard during the final thirty (30) seconds of the run. The electric motors seemed to require greater power to turn the fan and it was feared that either the electric motors were failing, or that the fan was deteriorating. It was decided chat in the interest of safety that the tests should be terminated. This was discussed and agreed to by D. Isbell.

Inspection of the unit showed that the upper housing was slightly hot (5) and that the lower housing was very hot (7); the shaft was hot (6) in the middle and very hot (7) near the bearings; the inner bearing was found to be extremely hot (8); the grinding noise was very high in frequency during operation and dropped in frequency while increasing in amplitude during coast down; coast down was very short and it seemed that there was considerable metal—co—metal contact occurring; numerous sub-harmonic and low level sounds were heard which indicated that bearings were involved; the inner diameter of the fan cower showed a band about one and one-quarter (1k) inch wide around the entire inner diameter; vertical and horizontal movement of the impeller were apparent to the naked eye (however, this actually decreased after the assembly had cooled down); there was no evidence of any oil loss from the unit.

POST TEST INSPECTION

Following the completion of in—stand testing, both units were disassembled and inspected. Following the inspection at Ft. Hood, the parts were taken to the National Aeronautics and Space Administration Laboratory in Pasadena, Texas for detailed electron microscopic examination and photography. Oil samples were analyzed at both Ft. Hood and by Jonco Industries.

Appendix IV contains the results of the oil analysis conducted at Ft. Hood. This is further discussed in the “Evaluation” section of this report.

Unit #1 was disassembled first. L. Cammack and P. Boatright performed the actual disassembly work, which was verified by

B. Carter, J. Peeples and C. Tyler.

Both units backlash was measured. Unit #1 measured .00275" com pared to .0025" initially. Unit #2 measured .0045", but the starting backlash is not known. Specifications call for a backlash between .002" and .004".

All components of Unit #1 were found to be serviceable with no indication of wear or deterioration, with the exception of the input housing bearing which was not replaced in the rebuilding of the unit. Although it was unserviceable and allowed slight movement in all planes, it was still capable of free movement. Several persons who inspected it commented that the lubricant which was sprayed into the unit had apparently prolonged the life, and indeed may have actually been responsible for some degree of "rebuilding" within the bearings, retainer and/or race. Further testing and evaluation could be conducted to ascertain the benefits of a combination wet and dry—film grease, however this is currently being done by the Supply and Maintenance Assessment Review Team in Ft. Lee, Va. so will not be further addressed herein. A picture of the bearing is shown in Appendix V, Figure 2

In the inspection of Unit #2, the first feature to be noted is the scoring of the inner diameter of the fan tower. This is shown in Appendix V, Figure 1. It was this scoring which led to the cessation of testing on unit #2 at 37:48:52 of Phase I. This scoring underlined the potential for extensive damage in the event of lubrication failure leading to disintegration of the unit.

When the impeller was removed it was noted that there was a marked degree of "play" in all planes. Manual rotation of the impeller resulted in grinding and oscillation. It was suspected that there had been a bearing failure far greater then what was suspected while the unit was in the test stand. This was confirmed when the disassembly was completed. It was then found that bearings 10A and 1OB were difficult to manipulate and produced the typical grinding noise associated with bearing failure. The bearings were not disassembled, as it was desired to maintain the integrity of the testing by having the disassembled in a more sterile environment in a laboratory. Inspection of the gears did not produce any remarkable notations.

<u>POST TEST INSPECTIOM continued</u>

The gears of unit #1 were inspected and it was found that they were 'bottoming—out' and that the shimming had not resulted in a perfect alignment.

Bearings 1OC and 1OD of unit #2 were free of any great deal of noise and turn fairly free with only a minor amount of friction.

Oil from unit #1 was clean and manifested no signs of deterioration or burning. Oil taken from unit #2 appeared the have sustained some minor degree of burning.

All internal components were taken Co N.A.S.A. Labs for detailed inspection and electron—microscopic photography. This inspection showed advanced deterioration of the bearing 1OB from unit #2 and advanced surface spalling, ridging and pitting, all of which are indicative of inadequate lubrication. The pictures of the components reflect none of these occurring in Unit #1, and in fact the milling marks are still markedly visible on the gear surface. These pictures and a description are contained in Appendix VI.

EVALUATION

The manner and extent of deterioration of the internal components of this fan assembly seem to indicate that inadequate lubrication is a contributing, if not indeed the major factor in their high rate of failure. This is most vividly demonstrated in the NASA picture of the inner race and the gear surface of unit #2. This type of deterioration is almost always associated with inadequate lubrication.

Several of the mechanics who rebuild these units voiced opinions revolving around the theory that centrifical force in the upper r.p.m. operating ranges causes either a type of cavitation or self purging which retards or negates the formation of the oil wedge, or druckberg, and allows metal—to—metal contact to occur. Some also voiced the opinion that the higher temperatures which occur during prolonged high r.p.m. operation exceed the lubricity of an S.A.E. 30 oil.

Either of these explanations has considerable credulence. It was noted throughout the testing that noises and vibrations occurred intermittently and sporadically. They seemed to be indicative of metal—to—metal contact, yet they would go away. Using the "self—purging" scenario, this could be explained as occurring when the oil had been purged from the retainer and race. Splashing lubricant could then be reintroduced and provide a lubricant which would form an oil wedge and again lubricate. This scenario also provides an explanation for the seemingly virgin surfaces of unit #1. The CamTron 4039 added the factor of a dry film lubricant being present at all times. Although this would have the general characteristics of Polytetrafluorethylene in film form, it would be distributed by the fluid

EVALUATION continued

To all operating surfaces and using the bonding processes inherent in this lubricant, would provide a one (1) micron film throughout the unit. This film would act as the prime lubricant during periods when the bearing was purged of fluid lubricant. This film was introduced in the form of a Matrix Product) manufactured by Jonco Industries, Inc. Further description of the CamTron II lubricant is contained in Appendix VII.

The theory that the operating temperatures exceed the lubricity is valid even if coupled with the theory that there is insufficient circulation of lubricant within the unit. This theory holds that the viscosity drops to such a level that the pressure hill or oil wedge is insufficient to maintain a state in which there is no metal-to-metal contact.

Comparing the gear surfaces shown in the N.A.S.A. photographs, Appendix VI, figures 5 & 6 definitely favors the conclusion that Unit #1 had a bonded dry lubricant on the surfaces. Had there been no film on the surface of the gears, there would have been far greater wear of some nature. Unit #2 is indicative of severe lubrication failure, but the gear is in such position that lubricant is present at most, if not all times. This seems to indicate that wear in the components can be reduced drastically and dramatically with the use of a lubricant such as CamTron II.

Although the oil analysis shown in Appendix IV shows considerably higher iron and other content in the treated unit, there are several explanations for this. The matter of the pre-application contamination of the can and the housing of the unit are increased greatly due to the flux or cleanser found in the Matrix product. Also, the needle bearing race was both filed and emory-clothed after the cleaning. The bite of the gears may have also been a minor contributing factor, but the N.A.S.A. photographs show that wear was negligible, so it is doubted that any increase came from this source. The lack of a pre-test sample from the stock oil precludes any meaningful evaluation.

The fact that Unit #1 ran consistently cooler can be attributed to the reduced friction resulting from the lubricant. The question of whether this is attributable to the lubricity of the oil or the bonded film can only be speculation, therefore it is not addressed herein. It is now known that this combination does provide superior performance in this application and maintains a far lower operating temperature within the gears and bearings. In view of the past history of ocher wide range lubricating oils being tried, and failing, it is apparent that the film reinforcement of the Matrix Product was necessary for the overall performance of the CamTron II.

RECOMMENDATION

It is recommended that the Angle Drive Fan Assemblies of the M—113 and related series vehicles be treated with CamTron 4039 and that they be run only with this lubricant installed.

It is also recommended that further testing of other components be accomplished to ascertain if this lubricant will provide comparable improvement in their operation.

DISCLAIMER

This testing was accomplished in joint venture by CamTron II, Inc. and D.I.O., Ft. Hood and the contents of this report do not reflect the opinions or endorsement of the US Army, N.A.S.A., or any other governmental entity.

This report of testing was prepared for the use of appropriate personnel involved in vehicle maintenance at Ft. Hood, Texas, at their request by CamTron II, Inc., Temple, Texas.

APPENDIX I

TEMPERATURE SCALE EXPLANATION

0 Less than ambient temperature

1 Ambient temperature

2 Slightly warm — a slight temperature elevation can be noted, but is minor.

3 Warm — the temperature elevation is very apparent, but does not cause discomfort if held.

4 Very warm— causes discomfort if held but does not cause pain.

5 Slightly Hot — causes discomfort and pain if held, but does not cause skin discoloration.

6 Hot — causes pain if held and prolonged contact will result in minor skin discoloration.

7 Very Hot — causes pain and skin discoloration if touched.

8 Extremely Hot — causes pain and blistering if touched.

APPENDIX II

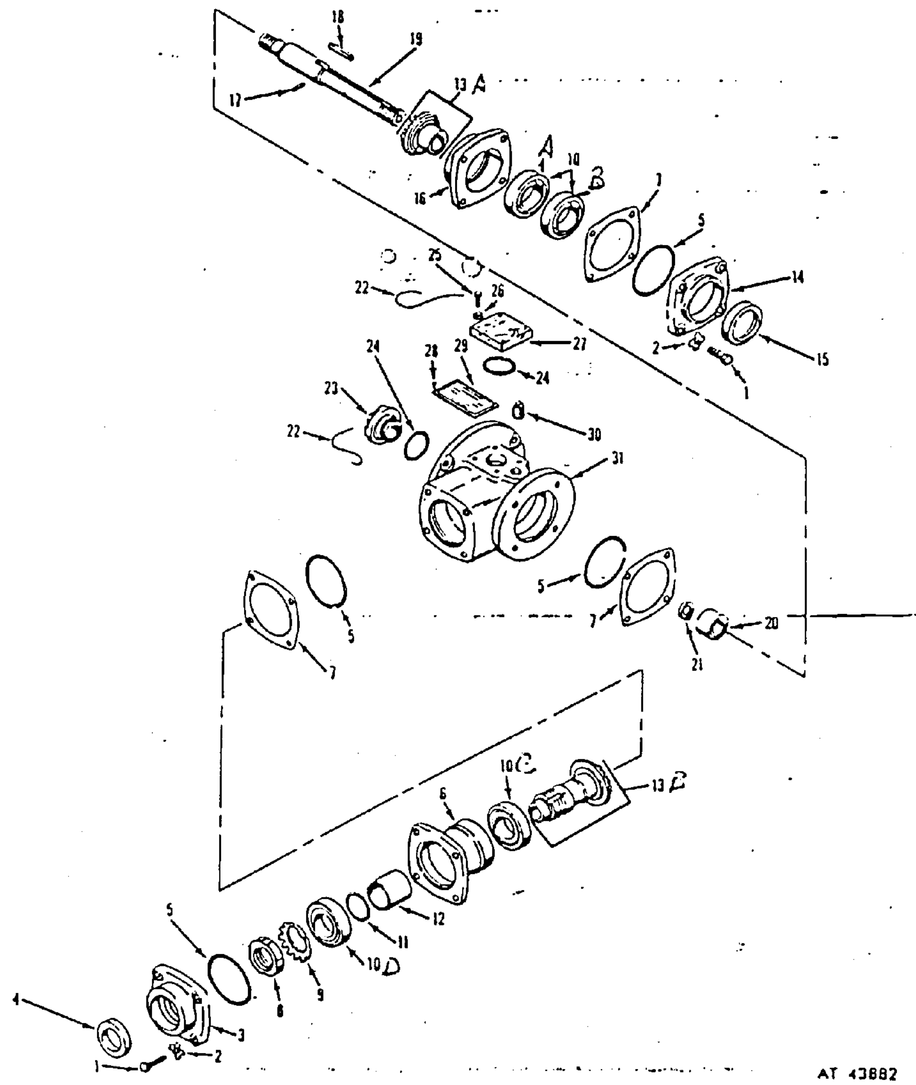


Figure 1. Cooling fan angle drive assembly.

DURATION OF TEST RUNS

Run Nr.	Duration		Cumulative	
	Unit #1	Unit#2	Unit#1	Unit#2
1	00:08:30	00:08:30	00:08:30	00:08:30
2	:13:21	:13:21	:21:51	:21:51
3	:09:00	:09:00	:30:51	:30:51
4	:43:23	:43:28	01:14:19	01:14:19
5	01:20:06	01:20:06	02:34:25	02:34:25
6	01:10:00	01:10:00	03:44:25	03:44:25
7	34:04:27	34:04:27	37:48:52	37:48:52
8	12:48:20	00	50:37:12	37:48:52
*9	14:43:15	00	65:20:27	37:48:52
*10	05:27:45	05:27:45	70:48:12	43:16:37
*11	00	07:09:15	70:48:12	50:25:52
*12	04:07:15	04:07:15	74:55:27	54:33:07
*13	00	04:31:17	74:55:27	59:04:24
*14	00	02:10:50	74:55:27	61:15:14

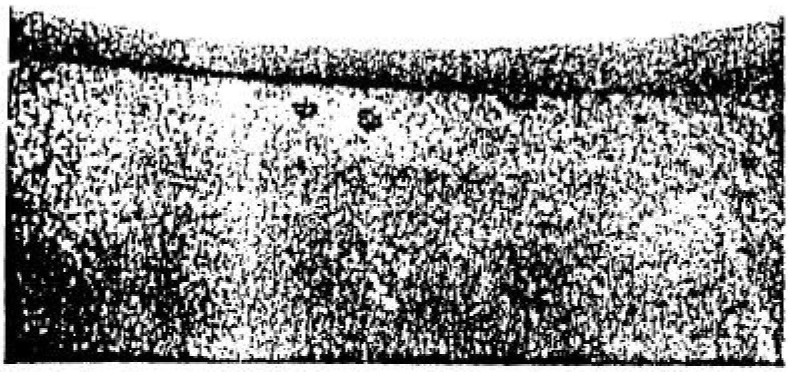
Run #1 thru run #8 were made with input RPM of 3641.

Run #9 thru run #14 were made with input RPM of 4861. (Denoted w/*)

Unit #1 ran 50:37:12 at 3641 rpm and 24:18:15 at 4861 rpm. Unit #2 ran 37:48:52 at 3641 rpm and 23:36:22 at 486.1 rpm.

Testing of Unit #2 was initially suspended at 37:48:52 after being declared unserviceable by Jack Peeples due to impeller blade marking inner diameter of fan Cower. Testing was resumed in order to run both units until one showed signs of total failure of bearings or gears. (Additional safety measures were implemented and followed by all personnel at test site.) Additional data concerning this is contained in "Synopsis of Test Runs" section.

APPENDIX V

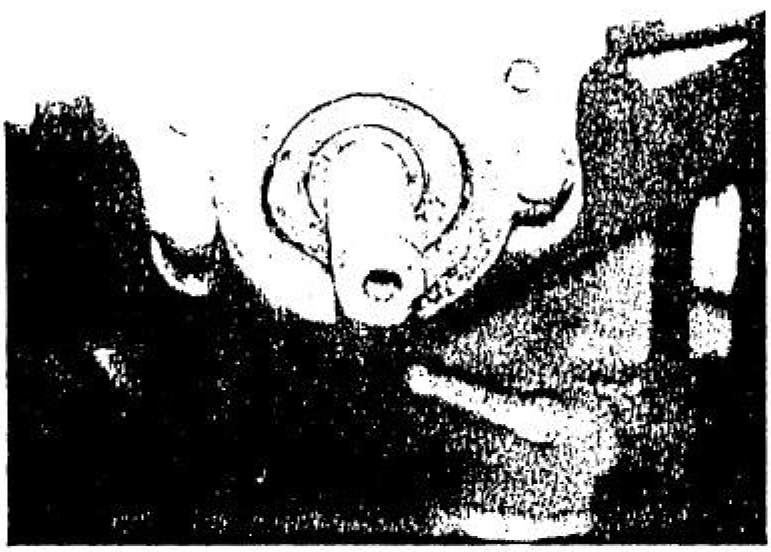


This is the inner diameter of the un-treated fan tower.

The scoring of the housing resulting from the failure of the bearing shown in Appendix VI Fig 2 & 4.

This resulted in the unit being declared 'unserviceable' when only a small band had appeared. Most of this scoring was sustained in the

Phase II portion of the testing.



This is the housing input bearing which was not replaced in Unit #1.

An experiment was conducted on the t4atrix MFC Crease to see if it would allow the unserviceable bearing to continue in operation during the test period.

MFG Aerosol was sprayed into the bearing in sufficient amount purge the small amount of grease that was therein.

At the termination of the test, this bearing was actually 'free' and

produced less noise than at the beginning of the test period.

APPENDIX VI

Ball Bearing from Treated Unit (Figure 1)

The surface shows signs of almost total coating with Matrix and virtually no wear or deterioration. There is no indication of skid smearing, brineeling, or spalling.

Due to the characteristics of s spherical ball, and the hardness of the metal, the ball will reflect the least wear of any component of the ball bearing.

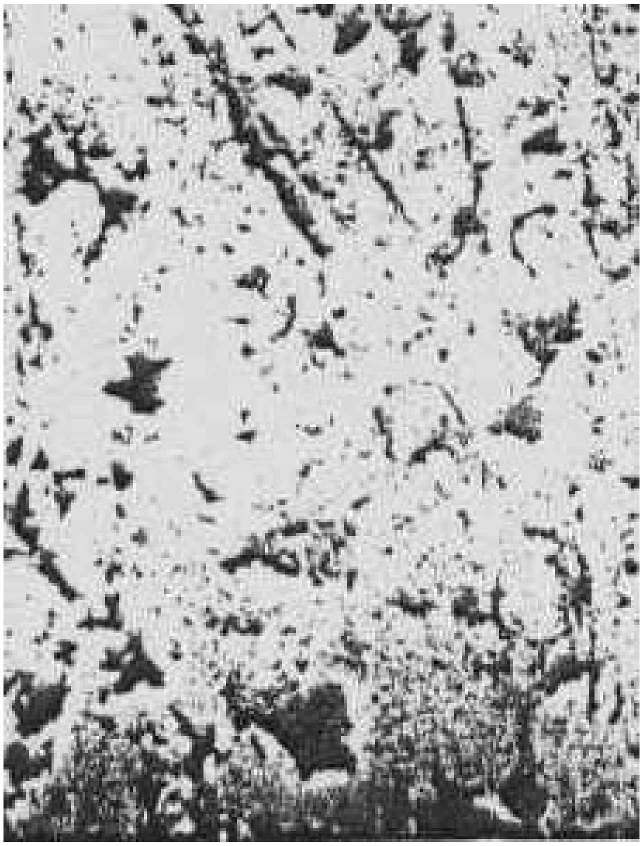
This ball surface is only slightly different from a new ball.

Ball bearing from Untreated Unit (Fig 2)

This ball surface shows considerable wear. There is evidence of primary brineeling, skidding or spalling.

In spite of the fact that the ball wears the least (in comparison with the race) this ball does show that it has been wearing.

Wear of this nature is generally the result of inadequate lubrication. It is discussed in more detail in the Evaluation Section of this report.

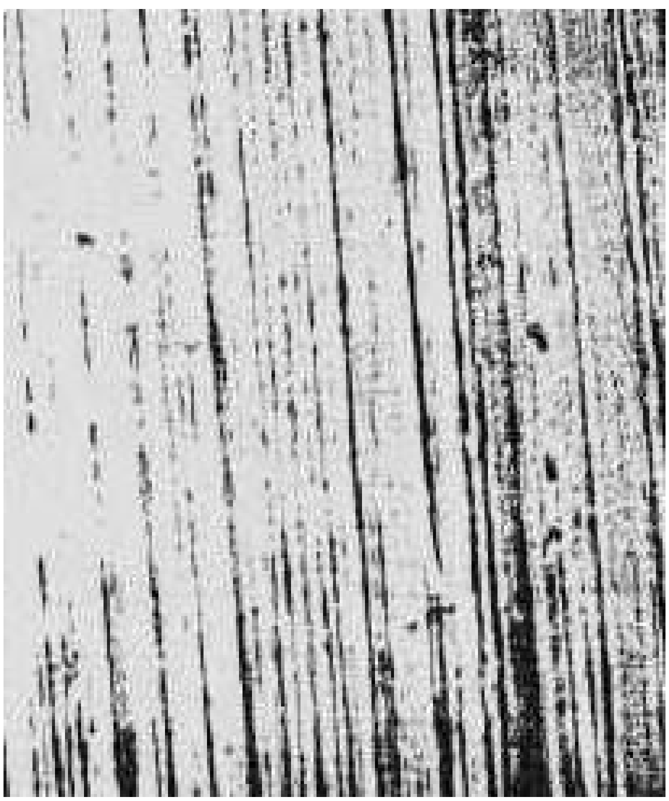


Inner Race from Treated Bearing (Fig 3)

The surface of coated with Matrix and although the coverage is not complete, the picture shows conclusive evidence of the protection afforded the surface and chat the bonding has withstood a considerable amount of extreme friction.

For all practical purposes, this surface can be considered ‘brand new’. It becomes more dramatic when compared with the untreated surface below, and it is remembered that both surfaces were sustaining identical amounts of use.

This race is apparently capable of sustained operation and would still be serviceable.



Inner 1 from Untreated Unit (Fig 4)

This photo shows the results of the ball in Fig. 2 skidding across the surface.

This is the classic example of galling of a race by a ball due to inadequate lubrication. Close examination shows that the metal is being ‘peeled’ as well as scored. Pitting is also occurring.

It was this wear which allowed the impeller to develop the horizontal movement which resulted in the scoring of the inner diameter of the fan tower.

Gear In Treated Unit (Fig5)

This gear is virtually without wear. Were it not for the coating of film it could be brand new.

The marks left by milling prove conclusively that the bonding agent does not re- bond to itself. The one (1) micron thick coating has not filled the holes left by the milling process, but the coverage is almost total. This dry-film Lubricant was responsible for the extraordinary temperature drop in the treated unit.

The fluid lubricant has fulfilled its job in this unit and the dry film of Matrix has reduced friction without producing a 'build-up' as would be encountered with graphite or molybdenum disulfide, yet has provided the beneficial qualities which are associated with their use.

Gear In Untreated Unit (Fig 6)

The gear surface has sustained consider able wear and deterioration. Galling has occurred and brineeling also.

The flaking of the metal can be seen and in the lower left hand corner, an actual flake can be seen.

The temperature has been exceedingly high, as evidenced by the bubbling effect.

Wear of this nature is almost always a result of inadequate lubrication. It can result in a syndrome wherein the surface is worn, then that wear defeats the formation of the oil wedge which creates higher heating which defeats the oil wedge, etc, etc.