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# LARGE ROTORCRAFT TRANSMISSION TECHNOLOGY DEVELOPMENT PROGRAM


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Boeing Vertol Company




prepared for

National Aeronautics and Space Administration

NASA Lewis Research Center

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16. Abstract

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At the 100% design power rating of 10,620 horsepower, the power transferred through a single spiral bevel gear mesh is more than twice that of current helicopter bevel gearing. In the original design of these gears, industry-wide design methods were employed and failures were experienced which identified problem areas unique to gear size. To remedy this technology shortfall, a program was developed to predict gear stresses using finite element analysis for complete and accurate representation of the gear tooth and supporting structure.

To validate the finite element methodology gear strain data from the existing U.S. Army HLH aft transmission was acquired, and existing data from smaller gears were made available.

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## 1.0 SUMMARY

Testing of a U.S. Army XCH-62 HLH aft rotor transmission under NASA Contract NAS3-22143 was successfully completed. This test establishes the feasibility of large, high power rotorcraft transmissions as well as demonstrating the resolution of deficiencies identified during the HLH advanced technology programs and reported by USAAMRDL-TR-77-38.

In all, over 100 hours of testing was conducted including:

- 50 hours at 100% design rated power
- 25 hours each at 80% and 90% design rated power, and
- 6 hours of dynamic strain testing at various power loadings up to 100%

At the 100% design power rating of 10,620 horsepower, the power transferred through a single spiral bevel gear mesh is more than twice that of current helicopter bevel gearing. In the original design of these gears, industry-wide design methods were employed and failures were experienced which identified problem areas unique to gear size. Experimental testing provided the basis for design modifications, but termination of the HLH program precluded verification testing. Verification has now been demonstrated, and the capacity of spiral bevel gearing has been extended in the testing just completed.

The NASA Lewis Research Center project manager for this contract was Mr. N. E. Samanich. The Boeing Vertol project manager was Mr. Gordon Fries. The Boeing Vertol project engineer was Mr. John Mack.

## 2.0 INTRODUCTION

The purpose of this effort is to develop the design technology for high speed, high power, lightweight gears of rotorcraft and V/STOL transmissions. Current analytical methods do not adequately predict stresses, and hence load carrying capacity, of spiral bevel gears. The limitations of these current methods are observed throughout the size range of gears encountered in helicopter and V/STOL operation. However, the problem is particularly acute in the largest sizes since these represent the greatest extrapolation from previous successful experience.

To remedy this technology shortfall, a program was sponsored by the Lewis Research Center of NASA. This program develops the analytical methodology to predict gear stresses using finite element analysis for complete and accurate respresentation of the gear tooth and supporting structure.

To validate the finite element methodology developed under this program, gear strain data from the existing U.S. Army HLH aft transmission have been acquired, and existing data from smaller gears have been made available. Additionally, an endurance test of the HLH aft transmission has been performed as a demonstration of the validity of previously developed gear steel stress allowables.

The HLH aft transmission was designed and built in the 1971-1975 time period as part of the U. S. Army Advanced Technology Component development program. It represents a major element of a complete aircraft drive system (Figure 1) designed to provide a significant increase in vertical lift capability. The design requirement for the rotor transmissions (.6 X 17,700 or 10,620 h.p., equivalent to 7,900 KW) exceeded the maximum power levels for any single flight weight bevel gear mesh known at that time, or indeed, since that time. A limited test program identified problems in the initial bevel gear design. A redesign was prepared and fabricated but was never tested because of program termination. This redesign has now undergone a successful test program as described in this report.

The elements of this test program include:

- o Resonant frequency testing of the spiral bevel gear and pinion.

- o Static strain surveys of the transmission gears performed over a range of torque loadings up to 130% design torque. Bevel gear and pinion contact patterns were acquired at each torque level.

- o A 50 hour endurance test at full-power rated speed and torque.

Two additional test elements were added by the contractor at no direct cost to the program. These were:

- o Dynamic strain surveys of the bevel gear and pinion and first stage sun gear.

- o Preparatory testing consisting of 25 hours at 80% design torque and 25 hours at 90% design torque. Both were accomplished prior to the 50 hour endurance test.

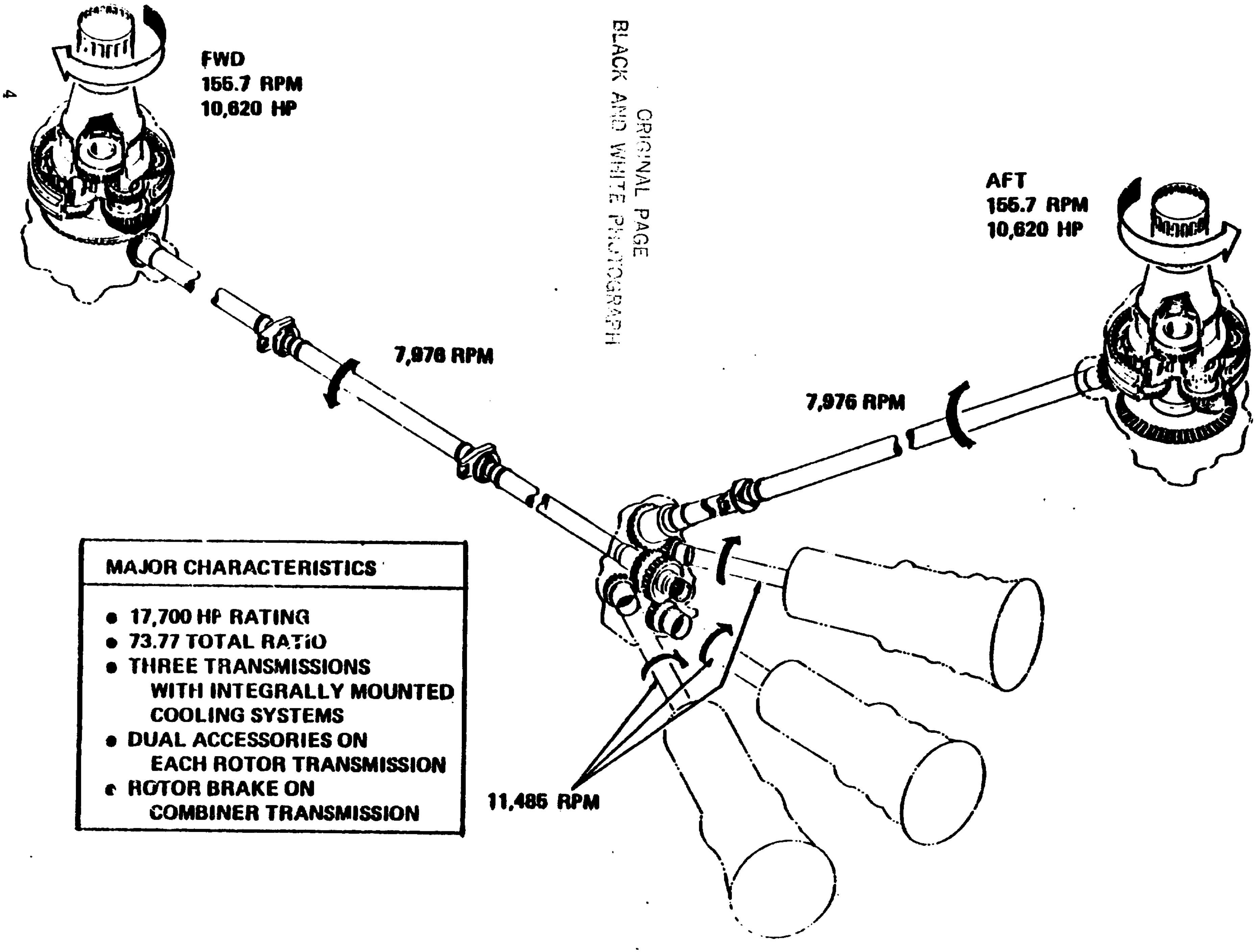





FIGURE 1. XCH-62 HLH DRIVE SYSTEM

## 3.0 TEST SPECIMEN

### DESCRIPTION

The aft transmission, Boeing Vertol P/N 301-10400-2, is shown in Figure 2. The overall gear ratio is 51 to 1, from synchronizing shaft to rotor. The bevel gear accounts for 2.86 to 1 reduction, and the two-stage planetary for 17.88 to 1 reduction.

All main drive gearing is made from carburized BMS 7-223 (VASCO X-2) high hot hardness steel. Bevel gears are supported in tapered roller bearings modified and lubricated for high-velocity application. Planet gears are supported by spherical roller bearings, allowing a greater misalignment across the bearing than would normally be possible with cylindrical bearings.

The rotor shaft is a titanium forging (6 AL-4V), with surface treatments at the bearing journals and at the upper spline designed to protect the titanium from fretting and wear. The upper cover, which supports the rotor shaft and carries torque and hub loads to the airframe, is a 7075 T-73 aluminum forging. The attachment of the cover to the airframe through four bolts, any three of which can carry full load, follows failsafe criteria.

The lower case is a magnesium casting of ZE 41A material selected for improved properties in heavy sections typical of these large housings. Beneath the cast housing a glass reinforced epoxy sump closes the gearbox and provides pickup points for the main and auxiliary lubrication system. Glass fiber was selected for ballistic considerations, as its high-strength low-modulus properties allow it to absorb ballistic impact without large fracture areas.

The oil cooler is integrated with the transmission to eliminate fluid connections and reduce vulnerable area. Two lube pumps are used, with the auxiliary pump drawing from a protected deep sump, to supply critical areas in emergency conditions. An electrified debris detector screen is provided in the sump intake of each lube pump.

Accessory drives are arranged around the periphery of the sump at the transmission base. Two separated drive trains, beginning with a dual face central gear, supply power to duplicated accessory arrangements.

## TEST CONFIGURATION

The test specimen is an HLH aft transmission defined by drawing 301-10400-2 (Figure 3) with certain modifications made to suit the particular nature of this test series, or to incorporate design improvements recognized since the close of the HLH program.

Deviations from 301-10400-2 were as follows:

Upper Cover 301-65025-1 - Original design (301-10456-1) cover was used to match existing test stand interface. Original configuration carries same bearings as modified version. High-strength studs were fitted to the cover to eliminate a breakage problem that occurred in past testing.

Ring Gear 301-10412-3 - Original (301-10412-1) ring gear was used to match upper cover fastening size and location. Modified by instrumentation hole. Original ring gear has thinner section.

Planet Gears 301-10460-3 and 301-10414-3 - Modified by incorporation of a chamfer at the intersection of the spherical bore and the side faces to eliminate a stress riser. Gear tooth tips radiused to improve lubricant film stability.

Spiral Bevel Pinion 301-10428-3 - Modified grind to improve tooth contact pattern and reduce bending stresses. Instrumentation holes added to pinion and sun-bevel 301-10419-3.

Tapered Roller Bearings (Pinion and Gear) 301-10424-4, -10420-4, -10443-4 and -10440-4 - Baked at 260°C for improved thermal stability and reinspected.

Main Housing 301-10402-1 - The -1 housing assembly was used since oil cooled generators were not required.

Accessories were not used in this test (with the exception of the oil cooler fan and main and auxiliary lube pumps). Consequently, hydraulic and alternator drive gears were removed from the transmission.

BEVEL GEAR CONTACT PATTERNS

The input gear and pinion were ground to a contact pattern (Figure 4) derived from earlier testing under the ATC program. No-load contact patterns were taken in conventional manner by applying marking compound to the tooth surfaces and rolling gear and pinion through mesh under a light braking load. This pattern, which represents the sixth development of this gear set since design inception, was deemed satisfactory and was maintained throughout the testing program. As confirmation that the bending stress distribution derived from this grind was satisfactory, a static strain survey was conducted and is described in this report.

HARDWARE REVIEW

Planet and bevel gears and planet carrier were inspected by magnetic particle and by visual examination. The lower housing was given a dye-check examination in the region of the rib intersections with the center island and outer ring.

Planet gears were inspected by measuring over wires to determine uniformity of size and thus assure proper load-sharing. Inspection results are shown in Table 1.

## LOAD HISTORY

Transmission load history is summarized in Tables 2, 3 and 4. With the exception of the main housing, no component has any significant load history as revealed by engineering records. The main housing underwent testing at 60% torque for 147 hours and at 70% torque for 25 hours.

## CONDITION MONITORING DEVICES

Debris and vibration monitoring was used to assess transmission condition during the load testing. Debris monitors were installed in four locations within the transmission. Indicating chip detectors were located at the bottom of the oil sump and in the bevel pinion drain area. The detectors were monitored by a QDM (quantitative debris monitor) supplied by the Technical Development Company. The purpose of this system is to discriminate between debris particle size as well as quantity, to provide a more useful interpretation of condition than is normally provided by a simple electrical chip detector which responds to any magnetic, conductive material.

Full-flow indicating screens were located at the suction side of both main and auxiliary lube oil pumps. These screens monitor the total flows, as compared to a sampling of the flow past one point, and are also responsive to any conductive debris, not necessarily magnetic. Screen opening size is 1.5 mm x 1.5 mm. The screen is formed by an arrangement of positive and negative wires. Conductive material provides an electrical path which completes the debris indicating circuit.

In addition to the above debris monitors, particulate materials could be observed by oil filter checks. A pressure-drop indicator on the filter body signals an impending bypass caused by particle buildup on the filter element. The filter used a 20 micron (nominal) element of the pleated throw-away type.

Vibration was monitored by accelerometers mounted on the exterior of the transmission adjacent to the bevel pinion bearings, the planetary ring gear, and the rotor shaft bearings. Vibration readings were observed at intervals throughout the load tests. Vibration data was treated by the Incipient Failure Detection (IFD) approach, using high frequency as a carrier wave and resolving this by narrow band analysis to investigate specific and precalculated mechanical passage frequencies.

Other transmission monitoring consisted of lube oil pressure at the entrance to the main jet feeding gallery, and also lube oil temperature as monitored in the sump, before cooling.

## TABLE 1. PLANET GEAR MEASUREMENT OVER WIRES (MOW)

The following inspections were performed to verify planet gear size:

First Stage - Drawing Dimension: 12.8542 - 12.8564 inches (326.496 - 326.552 mm)
301-10466-2 Gear
(301-10414-3 Gear Bearing Assembly)

| | |
|---|---|
| P125 - Assembled | 12.85455 |
| P128 - Assembled | 12.85463 |
| P137 - Spare | 12.85228 (.0019 BLL) |
| P148 - Assembled | 12.85317 (.0010 BLL) |
| P143 - Spare | 12.85325 (.0010 BLL) |
| P152 - Assembled | 12.85454 |

Comment: Maximum deviation of this set is .00235 inches (.059 mm). Tolerance spread by drawing is .0022 inches (0.056 mm). Any of the above gears are satisfactory as a set. Spare P137 was substituted for P125 during the 100% load test.

Second Stage - Drawing Dimension: 11.0819 - 11.0840 inches (281.480 - 281.534 mm)
301-10468-2 Gear
(301-10460-3 Gear Bearing Assembly)

| | |
|---|---|
| P115 - Assembled | 11.08174 (.0002 BLL) |
| P128 - Assembled | 11.08184 (.0001 BLL) |
| P134 - Spare* | 11.08135 (.0006 BLL) |
| P141 - Assembled | 11.08179 (.0001 BLL) |
| P142 - Assembled | 11.08287 - |
| P146 - Assembled | 11.08139 (.0005 BLL) |
| P150 - Assembled | 11.08070 (.0012 BLL) |
| P152 - Spare* | 11.08180 (.0001 BLL) |

Comment: Maximum deviation within this set is .00217 inches (.055 mm) Drawing tolerance spread by drawing is .0021 inches (.054 mm). Any of the above gears are satisfactory as a set.

*Spares were found to have magnetic particle indications in the bearing inner races and were not available for use.

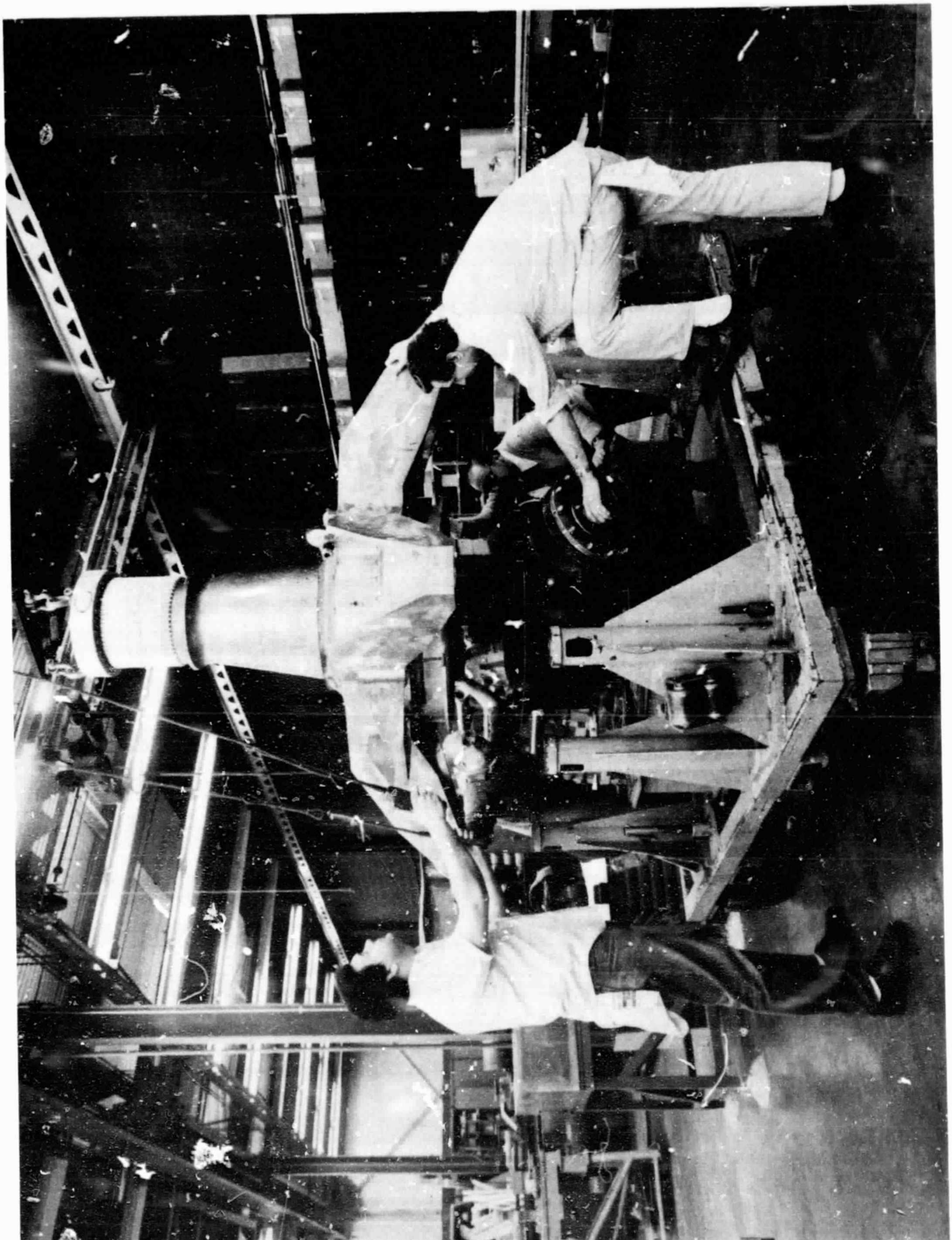
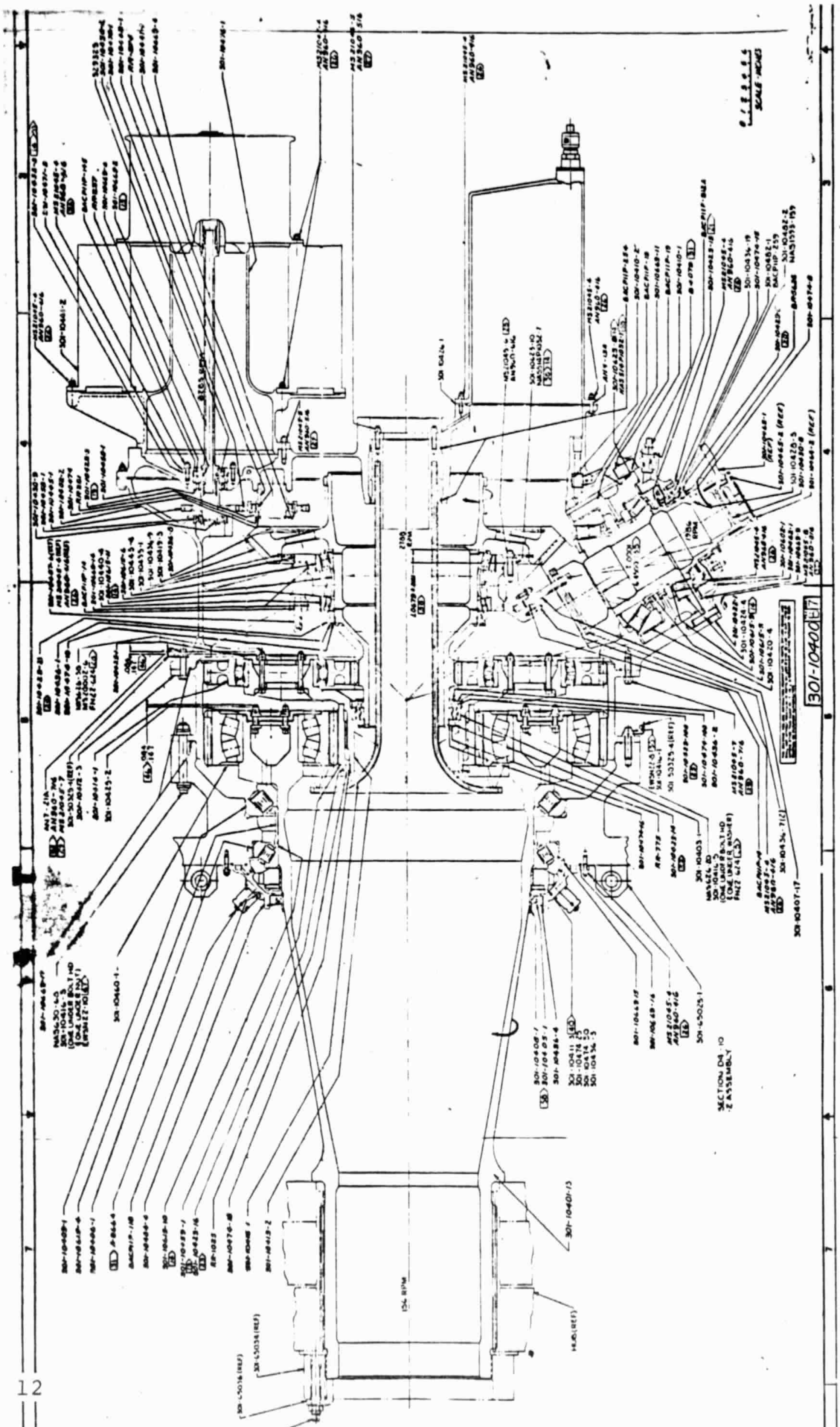


FIGURE 2 HLH AFT TRANSMISSION



## BEVEL GEAR BENCH/DEFLECTION TEST PATTERN RECORD

(PLEASE FILL IN ALL INFORMATION)

| AIRCRAFT | TEMPERATURE | XMSN S/N | DATE | LOAD LEVEL |
|---|---|---|---|---|
| 301-10400-914 | ROOM | A9-100X | 12/11/81 | |

H.L.H.

| PATTERN | SHIM SIZE | PART NUMBER | PART S/N | PART B/L | PART M.D. |
|---|---|---|---|---|---|
| RING GEAR | .043 | 301-10419-3 | P111 | .0275 | 12.363 |
| PINION GEAR | .095 | 301-10428-3 | P116 | .012 | 18.6875 |
| BACKLASH (TOTAL) | .054 TO .056 | | | | |
| | | DEVELOPMENT | | | |

| RING GEAR TAPES | PINION GEAR TAPES |
|---|---|

| ROOT | ROOT |
|---|---|
| CONVEX | CONCAVE |

| ROOT | ROOT |
|---|---|
| CONCAVE | CONVEX |
| ROOT | ROOT |
| CONVEX | CONCAVE |
| ROOT | ROOT |
| CONCAVE | CONVEX |

| CHECKER | MECHANIC(S) | INSPECTOR |
|---|---|---|
| RJD 12/11/81 | 00818 | |
| COMMENTS | | PINION AXIAL PLAY |
| | | GEAR AXIAL PLAY |

(PLACE ADDITIONAL TAPES ON REVERSE SIDE)

FIGURE 4. BEVEL GEAR TOOTH CONTACT PATTERN

TABLE 2

HLH AFT TRANSMISSION - LOAD RUN TEST CONFIGURATION

LOAD HISTORY - LOAD PATH COMPONENTS

| COMPONENT | P/N (301-) | S/N | TUR (301-) | DATE | LOAD HISTORY |
|---|---|---|---|---|---|
| ROTOR SHAFT | 10401-13 | P107 | | | NO LOAD HISTORY |
| RING GEAR | 10412-1 | P104 | 344071-80 | 3/11/75 | STATIC DEFLECTION TEST 4D PINION AND DYNAMIC TESTING |
| | | | 344071-24 | 9/13/74 | STATIC DEFLECTION TEST |
| 2ND STAGE PLANETS | 10460-3 | VB 105S/P115 | 344071-24 | 9/13/74 | STATIC DEFLECTION TEST |
| | | VB 106S/P128 | | | NO LOAD HISTORY |
| | | VB 104S/P142 | | | NO LOAD HISTORY |
| | | VB 9R/P146 | | | NO LOAD HISTORY |

TABLE 3

HLH AFT TRANSMISSION - LOAD RUN TEST CONFIGURATION

LOAD HISTORY - LOAD PATH COMPONENTS

| COMPONENT | P/N (301-) | S/N | TUR (301-) | DATE | LOAD HISTORY |
|---|---|---|---|---|---|
| | | VB 107S/P141 | | | NO LOAD HISTORY |
| | | VB 16R/P150 | 344071-24 | 9/13/74 | STATIC DEFLECTION TEST |
| 2ND STAGE SUN | 10459-1 | P111 | | | NO LOAD HISTORY |
| 1ST STAGE PLANETS | 10414-3 | VB 19R/P128 | | | NO LOAD HISTORY |
| | | VB 18R/P125 | | | NO LOAD HISTORY |
| | | VB 105T/P152 | | | NO LOAD HISTORY |
| | | VB 107/P148 | | | NO LOAD HISTORY |
| | | V 108T/P137 | | | NO LOAD HISTORY |

TABLE 4

HLH AFT TRANSMISSION - LOAD RUN TEST CONFIGURATION

LOAD HISTORY - LOAD PATH COMPONENTS

| COMPONENT | P/N (301-) | S/N | TUR (301-) | DATE | LOAD HISTORY |
|---|---|---|---|---|---|
| CARRIER | 10413-2 | P109 | | | NO LOAD HISTORY |
| SUN/BEVEL | 10419-3 | 111 | | | NO LOAD HISTORY |
| BEVEL PINION | 10428-3 | 116 | | | NO LOAD HISTORY |
| HOUSING ASSEMBLY | 10402-1 | P105 | 730001-45 | 7/1/75 | DSTR TESTING<br>25 HR. BENCH TEST |
| CARRIER BEARING | 10403-1 | 1 | 344071-80 | 3/11/75 | STATIC DEFLECTION TEST 4D PINION AND DYNAMIC TESTING |

3

## 4.0 TEST STAND

The HLH aft transmission test stand originally built under the U.S. Army HLH Program is a closed-loop (4-square) facility (Figure 5) in which the aft transmission forms one corner of the loop, with the other corners formed by industrial type gearboxes and shafting. The transmission is located on a steel mounting plate that is bolted to the test stand structure. The rotor shaft fits to a splined flexible coupling that is connected to the test stand upper gearbox. The input shaft is connected to the test stand lower gearbox through a length of aircraft type aluminum tube shafting with multi-plate flexible metal disc couplings at each end. The input shaft is used as the torquemeter, with torque bridges on the tube connecting to a telemetry signal system. The input shaft is calibrated to provide a total system accuracy (including indicator) of ±2%.

Other features of the test stand facility include:

- o Torquing device capable of static and dynamic loading.
- o 10% overspeed capability at maximum horsepower.
- o Exhaust ducting for integral lubrication system cooling.
- o Variable speed control at all torque levels.

Instrumentation requirements for this facility are defined in Table 5. Instrumentation is calibrated to specification MIL-C-45662A where applicable.

The existing facilities (Figure 6) utilized for this test program are located at the Boeing Vertol Company's complex in the suburbs of Philadelphia, Pennsylvania. The testing is performed in test cell number 2 in the test facility Building 3-31. The test cell has a floor area of approximately 6,000 square feet (550 $m^2$) and is 50 feet (15m) high. The test cell houses the complete test stand assembly. The 6250 horsepower (4600 KW) prime mover and variable speed clutch is housed in a separate room.

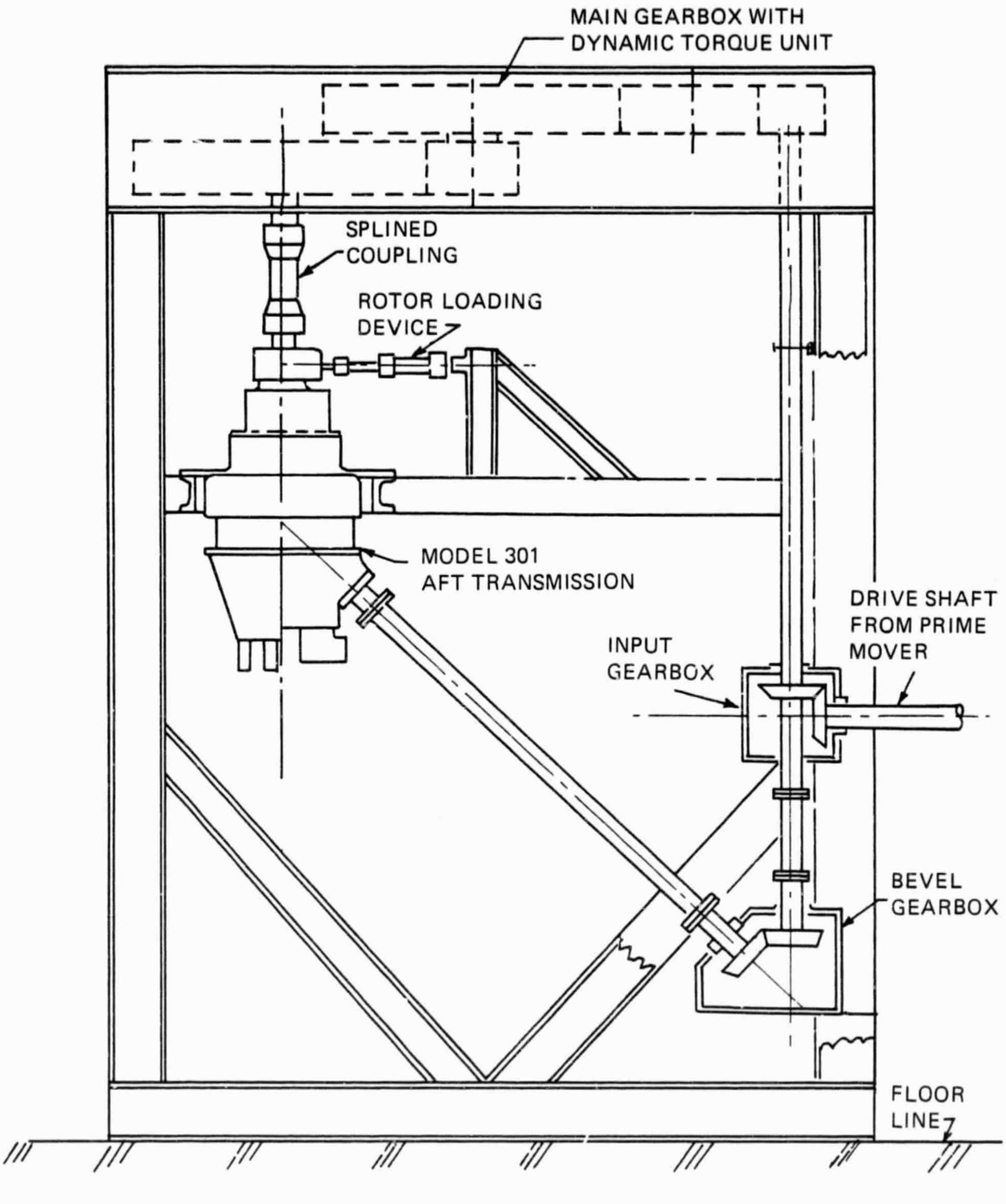



FIGURE 5.

AFT TRANSMISSION TEST STAND SCHEMATIC

TABLE 5. TRANSMISSION MONITORING - INSTRUMENTATION

| PARAMETER | SIGNAL SOURCE | RANGE | ACCURACY | MONITOR | WARNING | SHUT DOWN | RECORD |
|---|---|---|---|---|---|---|---|
| Ambient Air Temp | Thermocouple | 4° - 65°C | ±1° C | Indi. | - | - | M.P. |
| Sump Oil Temp | Thermocouple | 65° - 150°C | ±1° C | Indi. | - | O.M. | M.P. |
| Main Oil Inlet Pressure | Pressure Transducer | 0 - 200 PSIG | ±5 PSI | Indi. | Lo-Press Light | O.M. | M.P. |
| Auxiliary Oil Inlet Pressure | Pressure Transducer | 0 - 200 PSIG | ±5 PSI | Indi. | Lo-Press Light | O.M. | M.P. |
| Main Oil Indicating Screen | Conductive Screen | On/Off | - | - | Chip Light | O.M. | M.P. |
| Auxiliary Oil Indicating Screen | Conductive Screen | On/Off | - | - | Chip Light | O.M. | M.P. |
| Pinion Magnetic Chip Detector | Magnet | Quantitative | - | Counter | Chip Light | O.M. | M.P. |
| Sump Magnetic Chip Detector | Magnet | Quantitative | - | Counter | Chip Light | O.M. | M.P. |
| Input Shaft Torque | Torque Bridge | 0-1.5 x $10^5$ In-Lb | ±2% | Indi. | - | O.M. | M.P. |
| Input Shaft Speed | Magnet Pickup | 0-10,000 RPM | ±50 RPM | Indi. | - | O.M. | M.P. |

M.P. = Manual Periodic

O.M. = Operator Manual
Indi. = Indicator

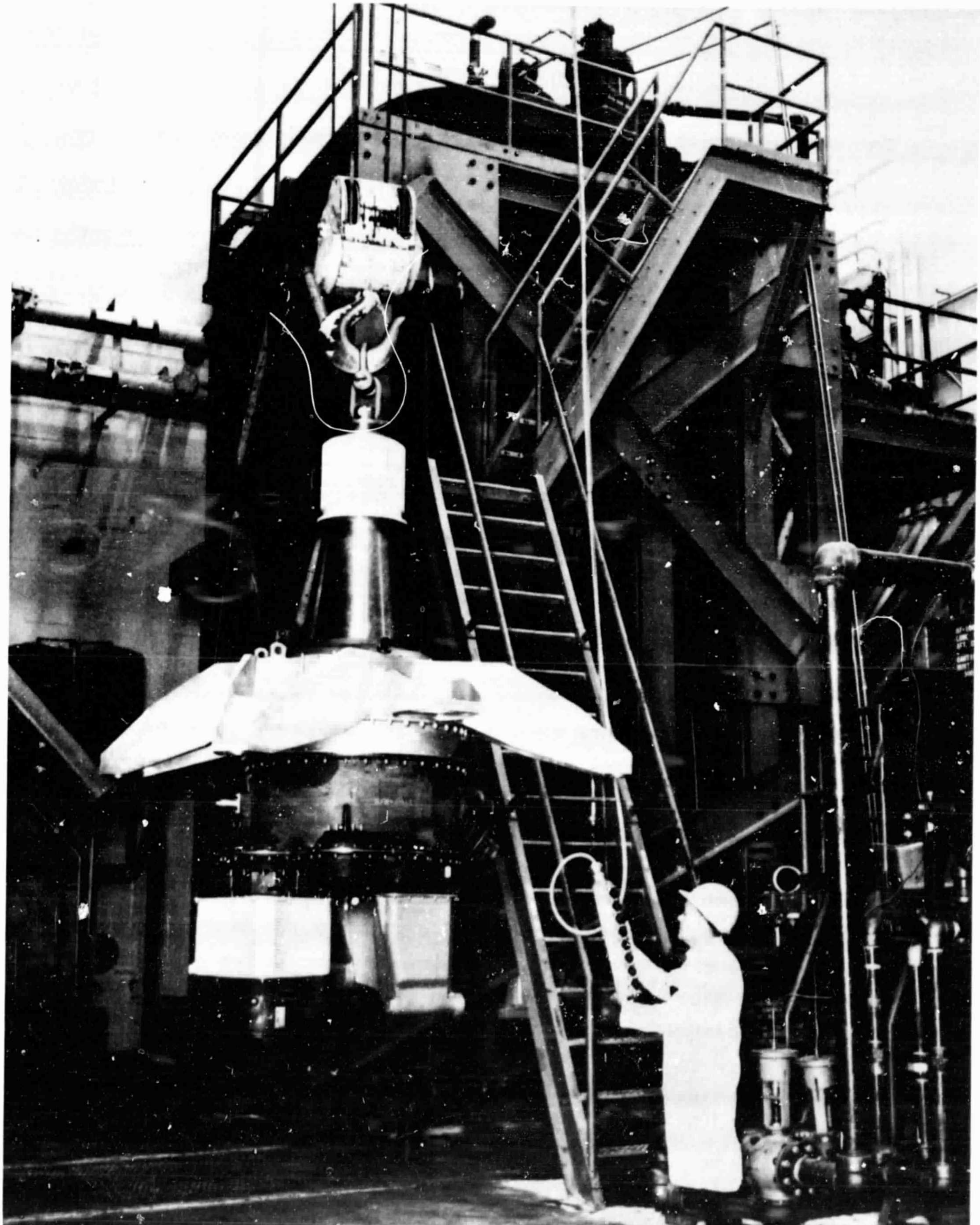


FIGURE 6. AFT TRANSMISSION TEST STAND

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OF POOR QUALITY

## 5.0 STATIC STRAIN SURVEY

The static strain survey was conducted by slowly rotating the transmission under load, with strain gages transmitting data through trailing wires.

There were several tasks to be accomplished in the static survey. First, the contact pattern of the spiral bevel gears was to be evaluated and stresses measured along the pinion and gear face width. From this, a decision would be made to regrind to a different pattern or to run subsequent tests with the pattern as developed at the inception of this program. Secondly, the stresses of the planet gears would be measured. Because of their orbital motion around each planet carrier post, combined with their motion around the transmission centerline, it is impractical to measure stresses dynamically. They can be measured statically, using trailing wires.

INSTRUMENTATION - Strain gages were applied to the bevel pinion, gear, and to two planets from each stage as shown in Figures 7, 8, 9, and 10. Gages were located across the gear faces to determine load distribution, and on successive teeth to evaluate load sharing. Gages were applied in the root of the teeth to determine ring bending and at the fillet to determine gear tooth bending stresses. All gages had an active length of .031 inches. Gages used on the spiral bevel pinion, spiral bevel ring gear and 1st stage sun gear tooth roots were ED-DY-031EC-350. Gages used on the planetary tooth roots were EA-06-031EC-350. The gages used on the planetary land diameter were EA-06-031CE-350. All gages were manufactured by Micromeasurements, Vishay Intertechnology Incorporated.

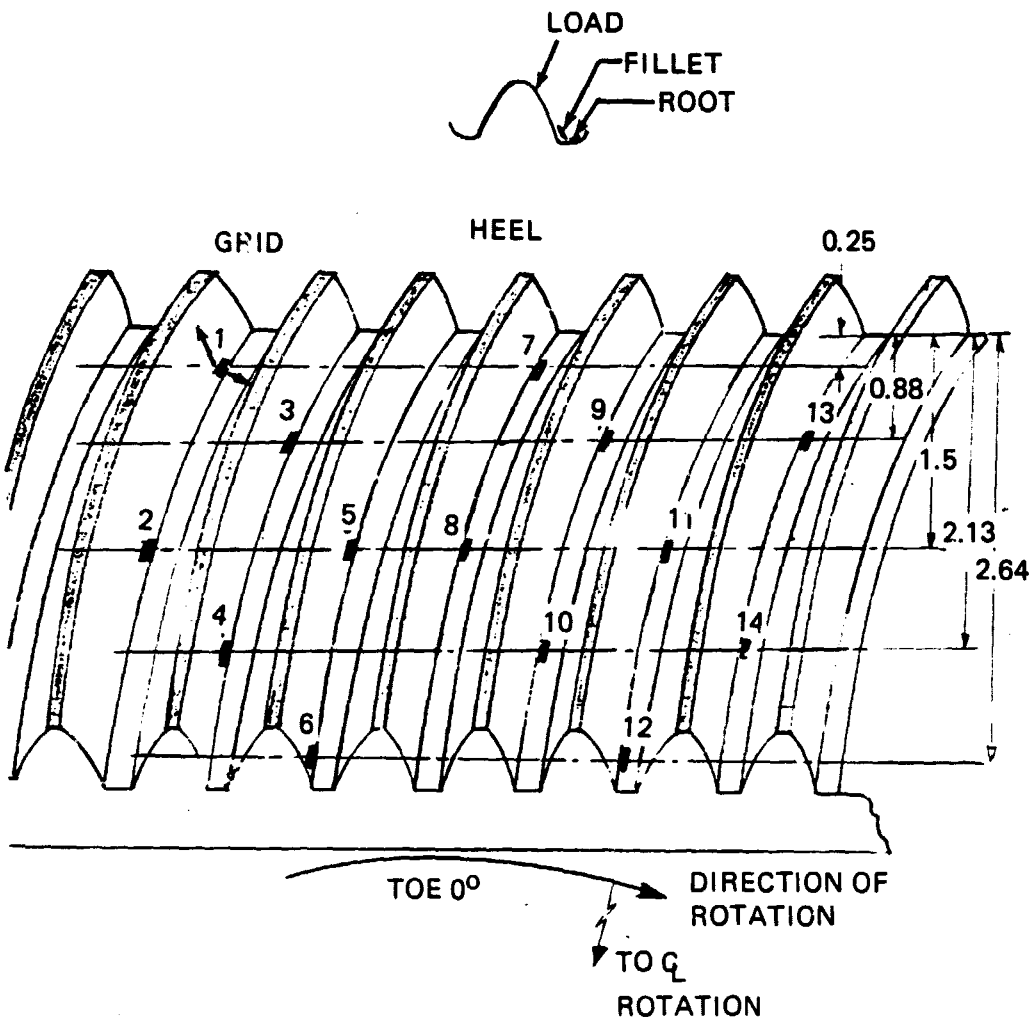
The placement of gages was closely controlled by taking plastic casts of the tooth space and marking the desired gage position on the cast. Each gage was applied and inspected for conformity to the marked cast. A deviation of ±.010 inch (±.25 mm) was allowed. Gage location was initially determined by reference to photoelastic test data.

<u>TEST PROCEDURE</u> - The instrumented gears were assembled into an HLH aft transmission and the transmission was installed in the load stand. The transmission was enclosed in an insulated box with heat lamps to raise the temperature to 230°F, ±10°F. (110°C ± 5.5°C)

The transmission gear train was slowly rotated under torque, while the gaged teeth rolled through mesh. Approximately one revolution of the spiral bevel gear was obtained. Torque was varied from 50% to 130% of the design value (83,810 inch/lbs equivalent to 9463 Nm) in successive tests. In addition to the strain data, a visual determination of tooth contact pattern was obtained at each load level by coating the bevel tooth with marking compound.

Following the bevel gear tests at elevated temperature, the planet gears were tested at room temperature. Bevel gear load contact patterns, and hence, stresses, are dependent upon relative positions of gear and pinion. These, in turn, are influenced by thermal expansion of magnesium housings and bearings. In the planetary, thermal growth is more uniform because of design and material, and hence has less effect on gear stresses. The test procedure, except for temperature, was the same as used for the bevel gears.

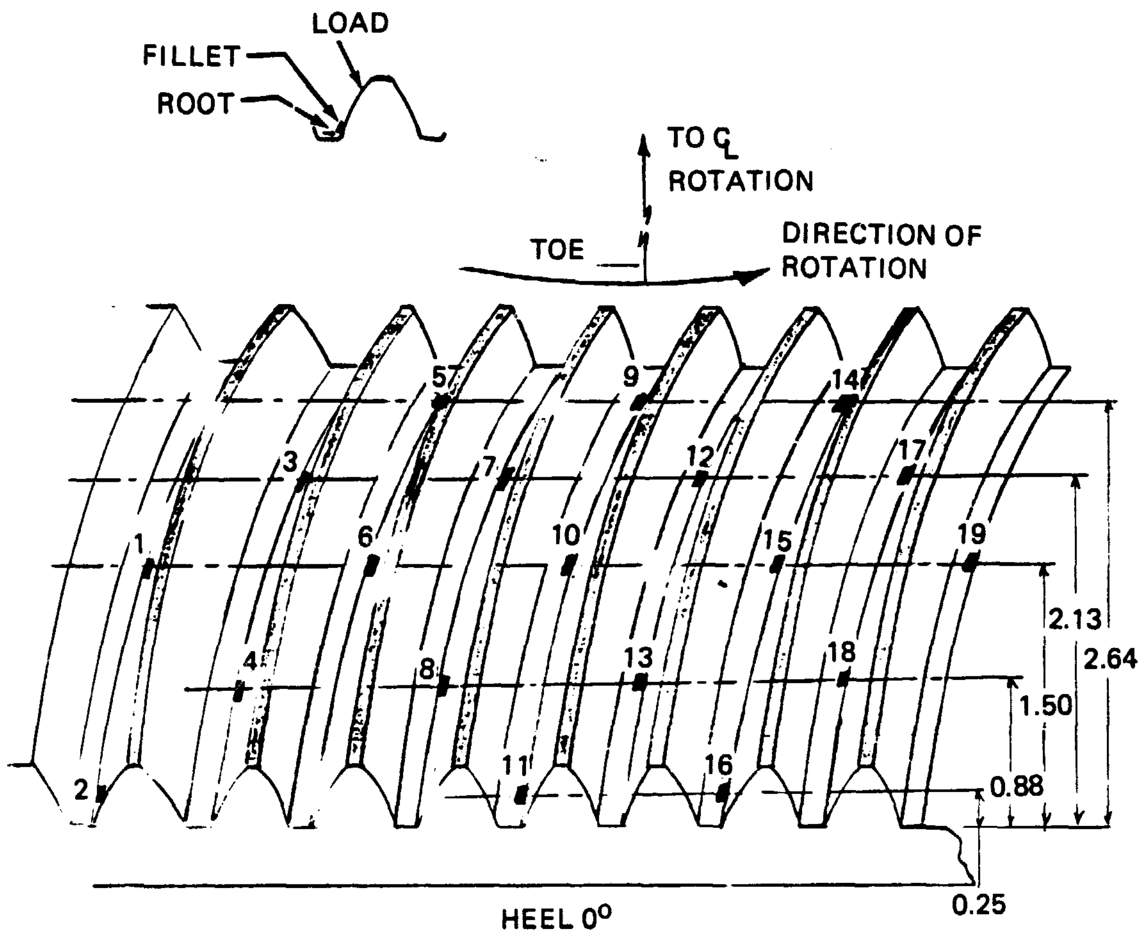
TEST RESULTS - Maximum measured stresses at 100% design torque are shown in Figure 11 and compared there to Boeing Vertol successful experience. The stress waveform of a driving gear rotated thru mesh is illustrated in Figure 12. There is a characteristic compressive stress engendered by the pre-ceeding tooth bending under load, and then a tensile stress as the instrumented tooth picks up load. The data are presented in terms of maximum tensile stress and alternating stress. The mean of the alternating stress is mid-way between compressive and tensile peaks. Figure 11 illustrates mean steady stresses and alternating stresses in the form of a Goodman diagram. Figures 13 and 14 show gear root and fillet stress magnitudes as they are distributed across the face of the bevel pinion at full torque. On the basis of this distribution, and examination of the visual contact pattern, this grind was accepted for load running the gears. Figure 15 and 16 exemplify stress level increase with increasing torque. Gages are identified as toe, intermediate toe, mid, intermediate heel and heel as they progress in 5 stations from toe (small end of pinion) to heel. Figures 17 and 18 show bevel gear stress distributions across the face, corresponding to the pinion data shown previously. The disparity between apparently identical gages on opposite sides of the gear is greater than experienced in other surveys. The reason in this case is believed to be in gage placement, which is extremely critical in the high stress gradient region at the tooth base. Figure 19 shows first and second stage planet gear stresses as a function of torque, for various positions across the gear faces.




6 FILLET GAGES (NUMBERS 1 THROUGH 6)
8 ROOT GAGES (NUMBERS 7 THROUGH 14)
ALL TO HAVE 0.031 IN. GAGE LENGTHS

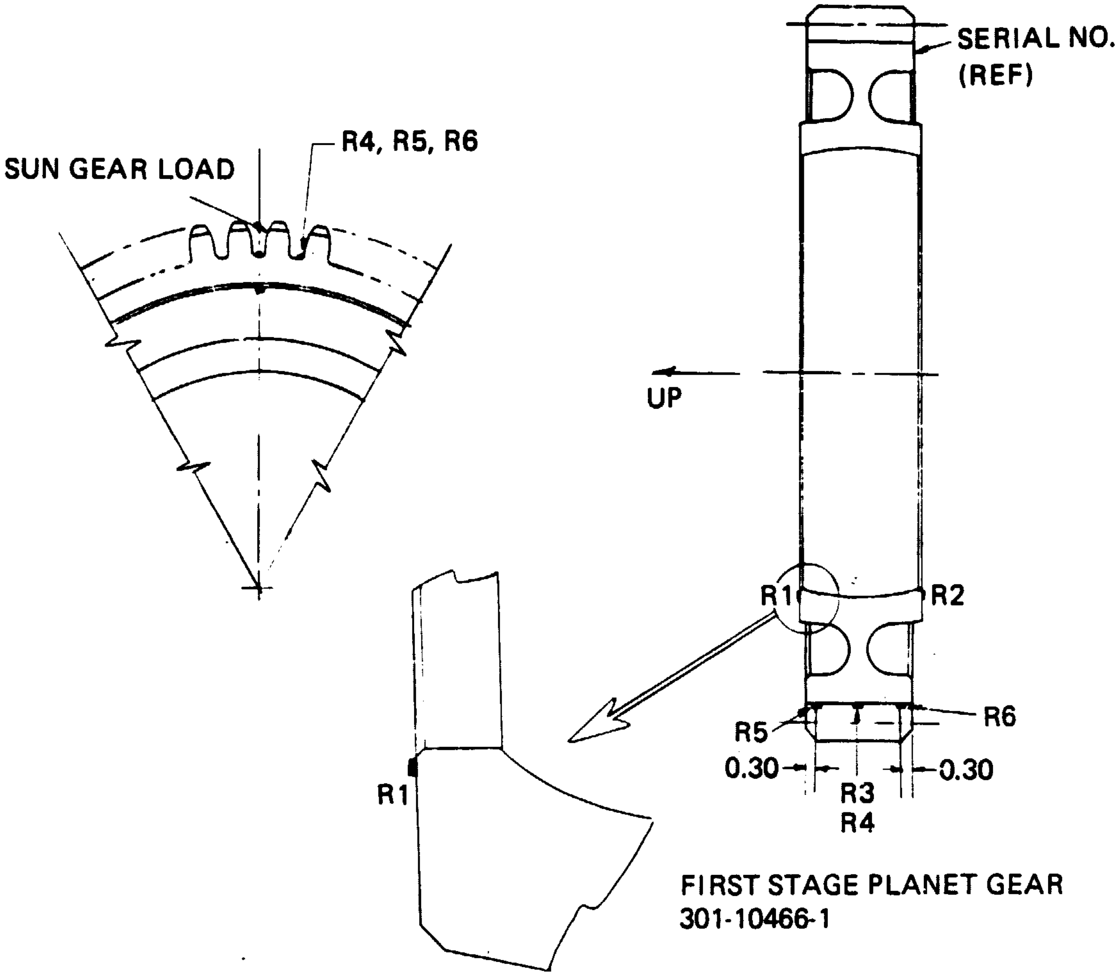
FIGURE 7

INPUT BEVEL PINION STATIC STRAIN SURVEY GAGE LOCATION




8 FILLET GAGES (NUMBERS 1 THROUGH 8)
11 ROOT GAGES (NUMBER 9 THROUGH 19)
ALL TO HAVE 0.31 IN. GAGE LENGTHS

FIGURE 8.
OUTPUT BEVEL GEAR STATIC STRAIN SURVEY GAGE LOCATION

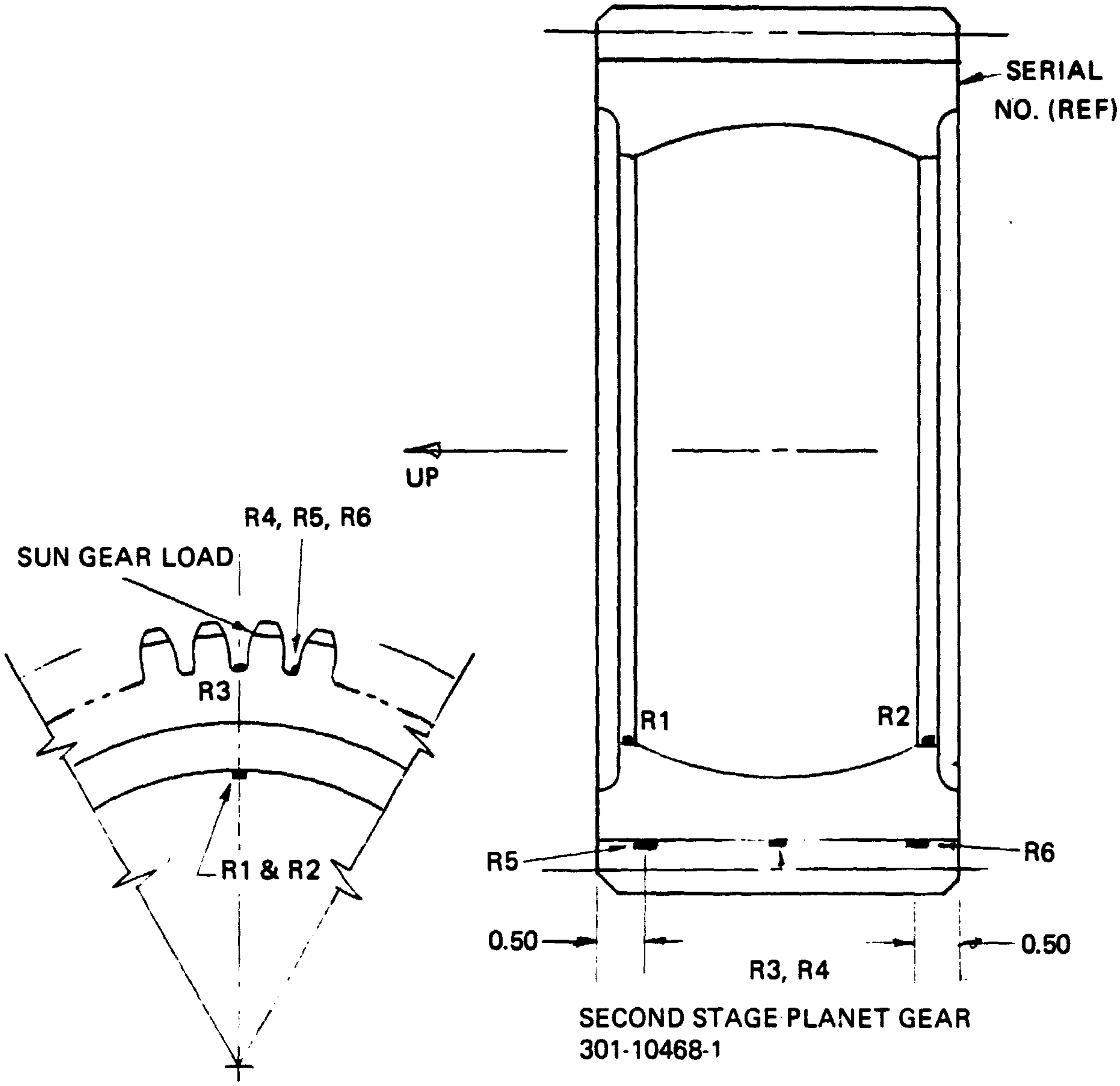



GAGE POSITIONS

| GEAR NO. 1 | GEAR NO. 2 | LOCATION | GRID DIRECTION |
|---|---|---|---|
| R2 | R1, R2 | I.D. LAND | CIRCUMFERENTIAL |
| R3 | R3 | TOOTH ROOT (CENTER OF SPACE) | ↕ |
| R4, R5, R6 | – | TOOTH ROOT (BIASED TO SUN-MESH DRIVE FLANK) | CIRCUMFERENTIAL |

ALL GAGES TO HAVE 0.031 IN. GAGE LENGTH

Figure 9.
FIRST STAGE PLANET GEAR STATIC STRAIN SURVEY GAGE LOCATION




GAGE POSITIONS

| GEAR NO. 1 | GEAR NO. 2 | LOCATION | GRID DIRECTION |
|---|---|---|---|
| R2 | R1, R2 | I.D. LAND | CIRCUMFERENTIAL |
| R3 | R3 | TOOTH ROOT (CENTER OF SPACE) | ↕ |
| R4, R5, R6 | – | TOOTH ROOT (BIASED TO SUN-MESH DRIVE FLANK) | CIRCUMFERENTIAL |

ALL GAGES TO HAVE 0.031 IN. GAGE LENGTH

FIGURE 10.
SECOND STAGE PLANET GEAR STATIC STRAIN SURVEY GAGE LOCATION

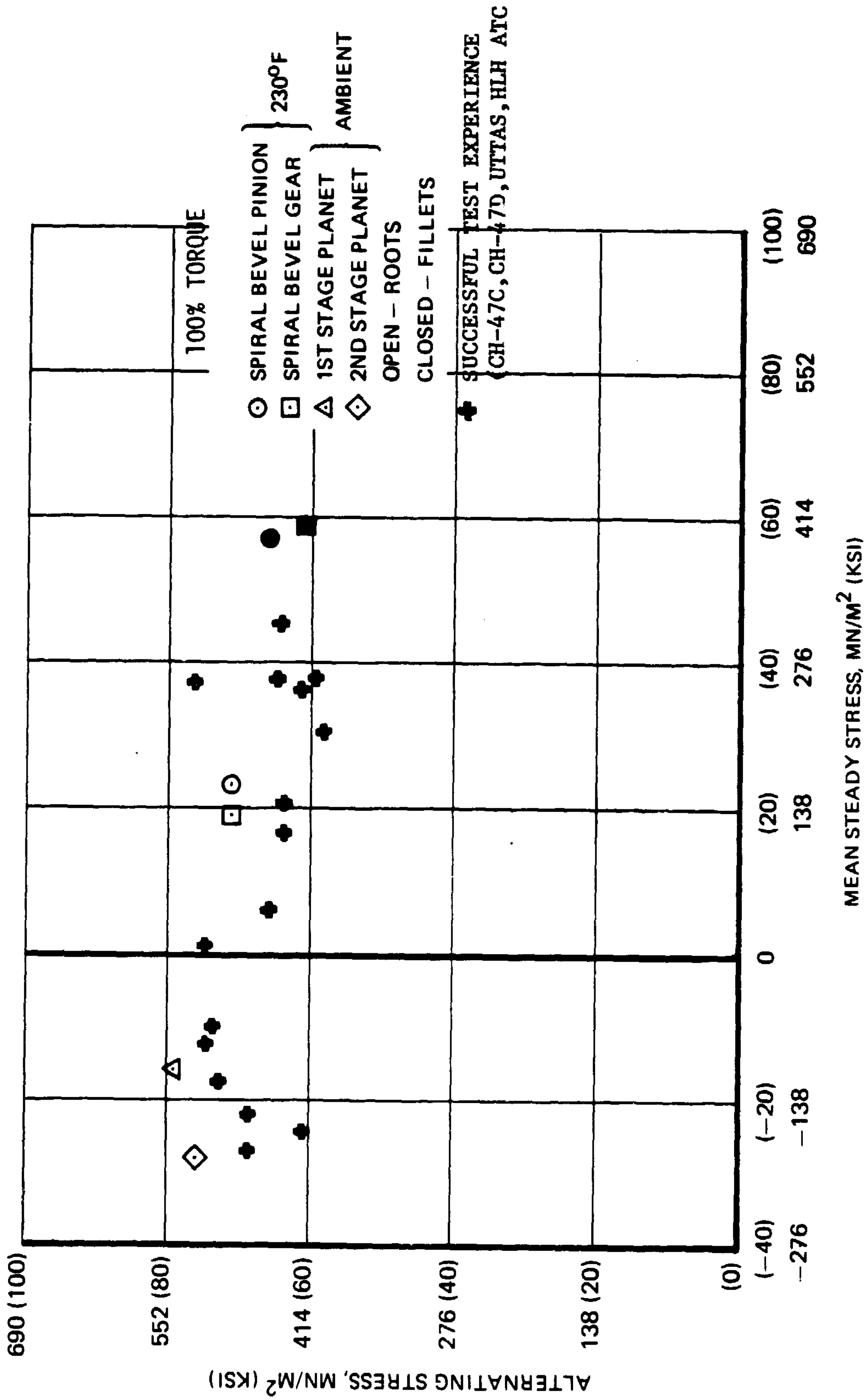



FIGURE 11

SUMMARY OF STATIC STRAIN SURVEY RESULTS



**ORIGINAL PAGE IS OF POOR QUALITY**

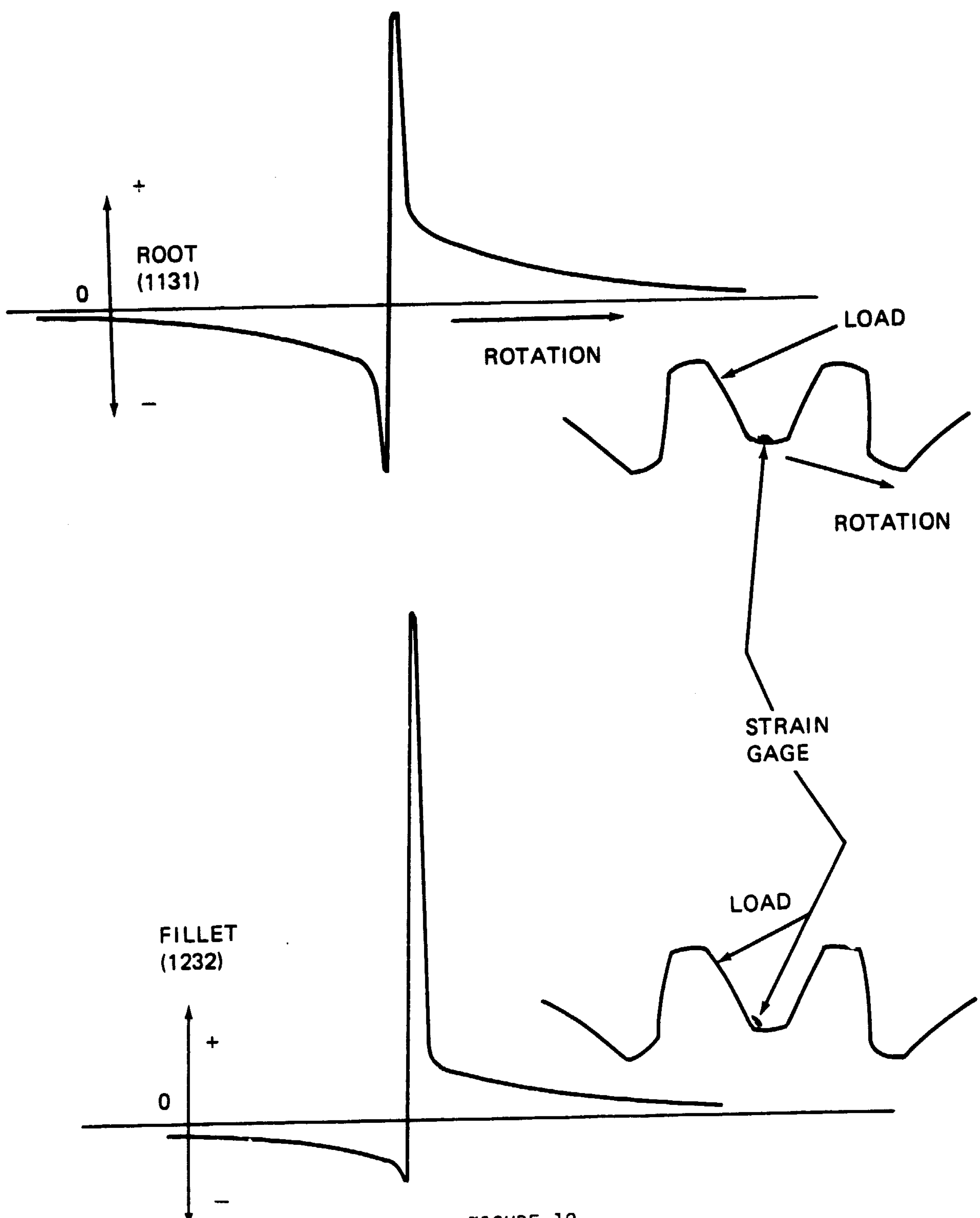



FIGURE 12.

BEVEL PINION STRESS WAVEFORMS

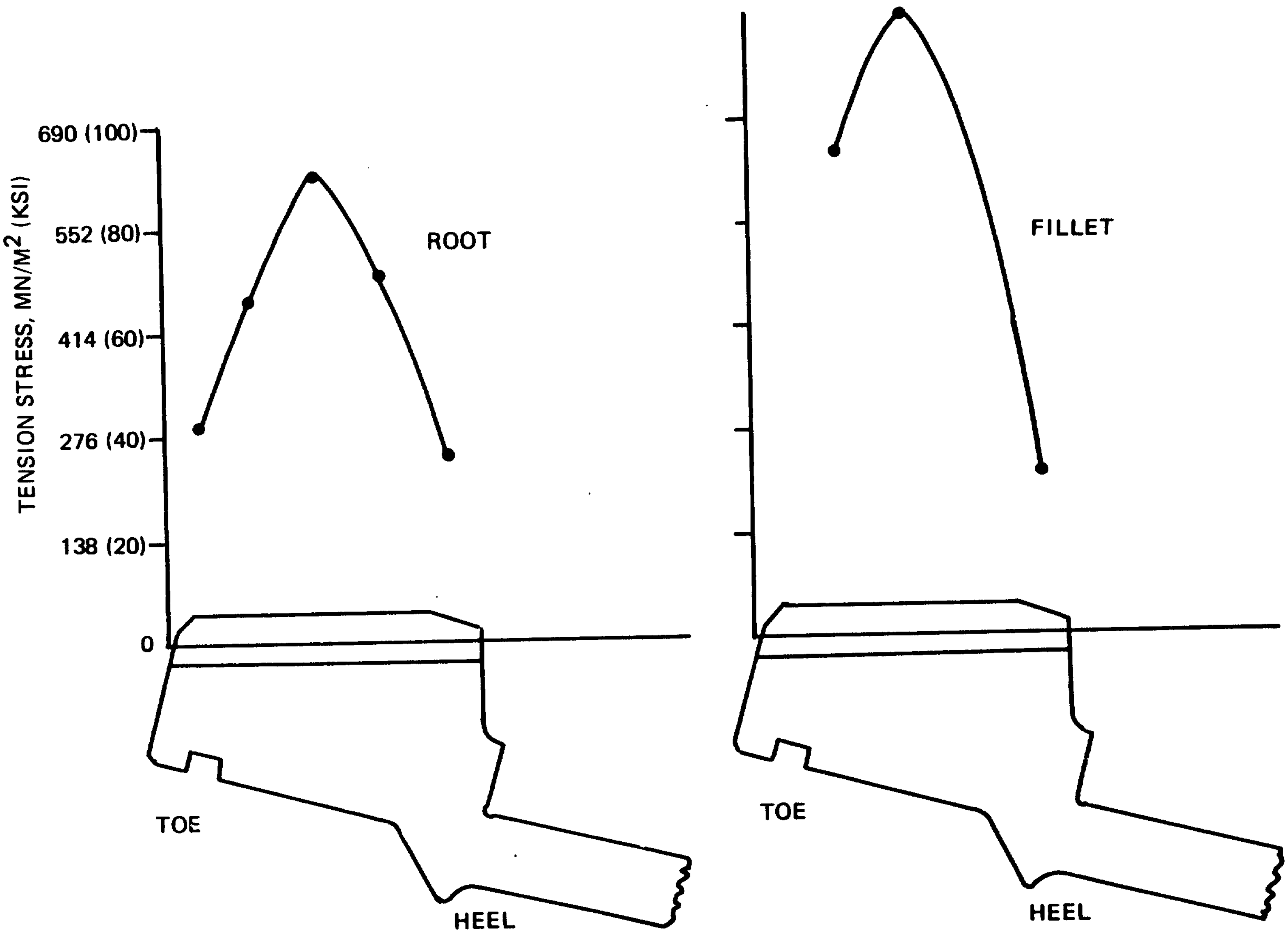



FIGURE 13. BEVEL PINION FACEWISE TENSION STRESS DISTRIBUTION

(100% TORQUE)

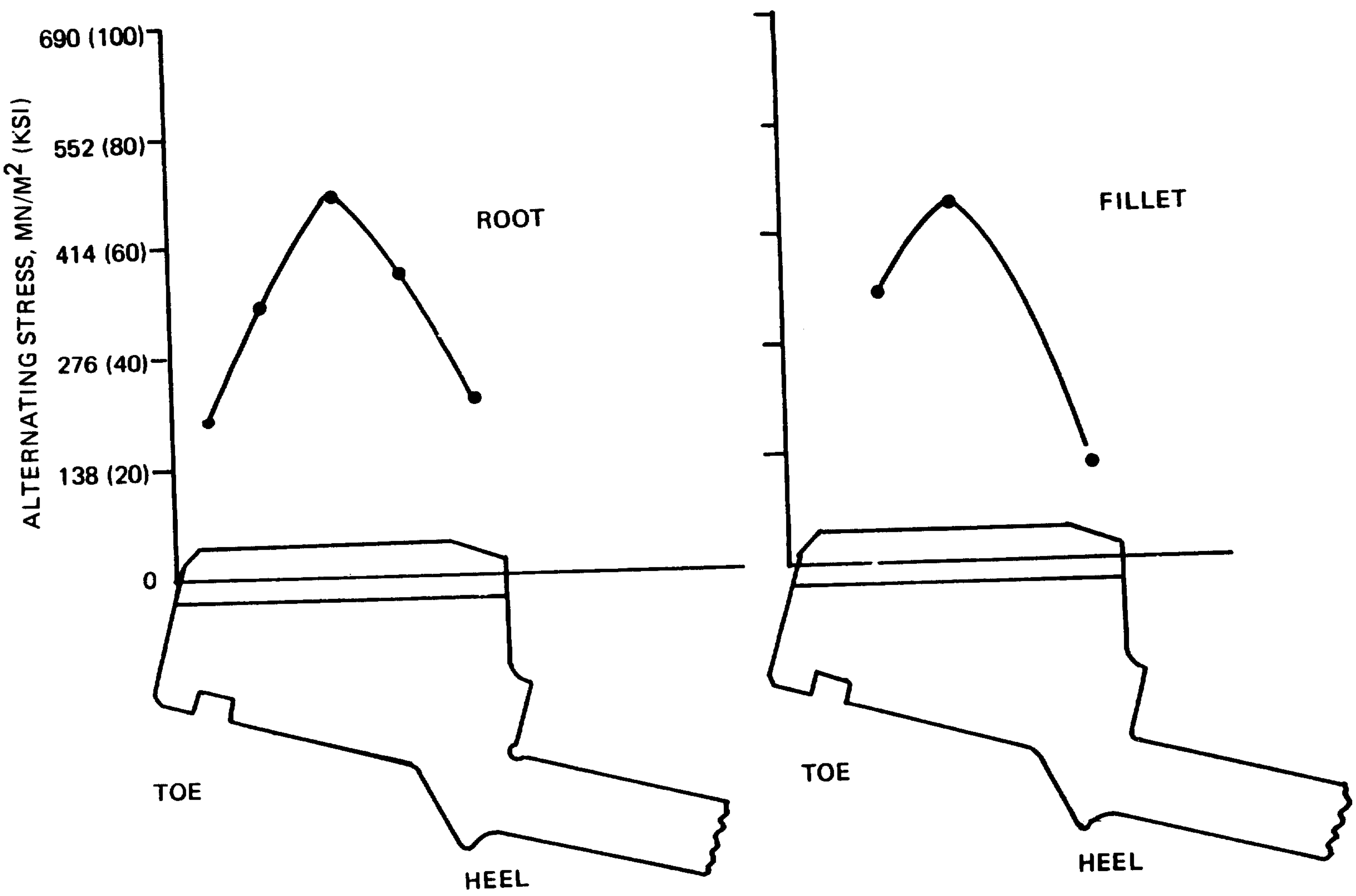



FIGURE 14. BEVEL PINION FACEWISE ALTERNATING STRESS DISTRIBUTION
(100% TORQUE)

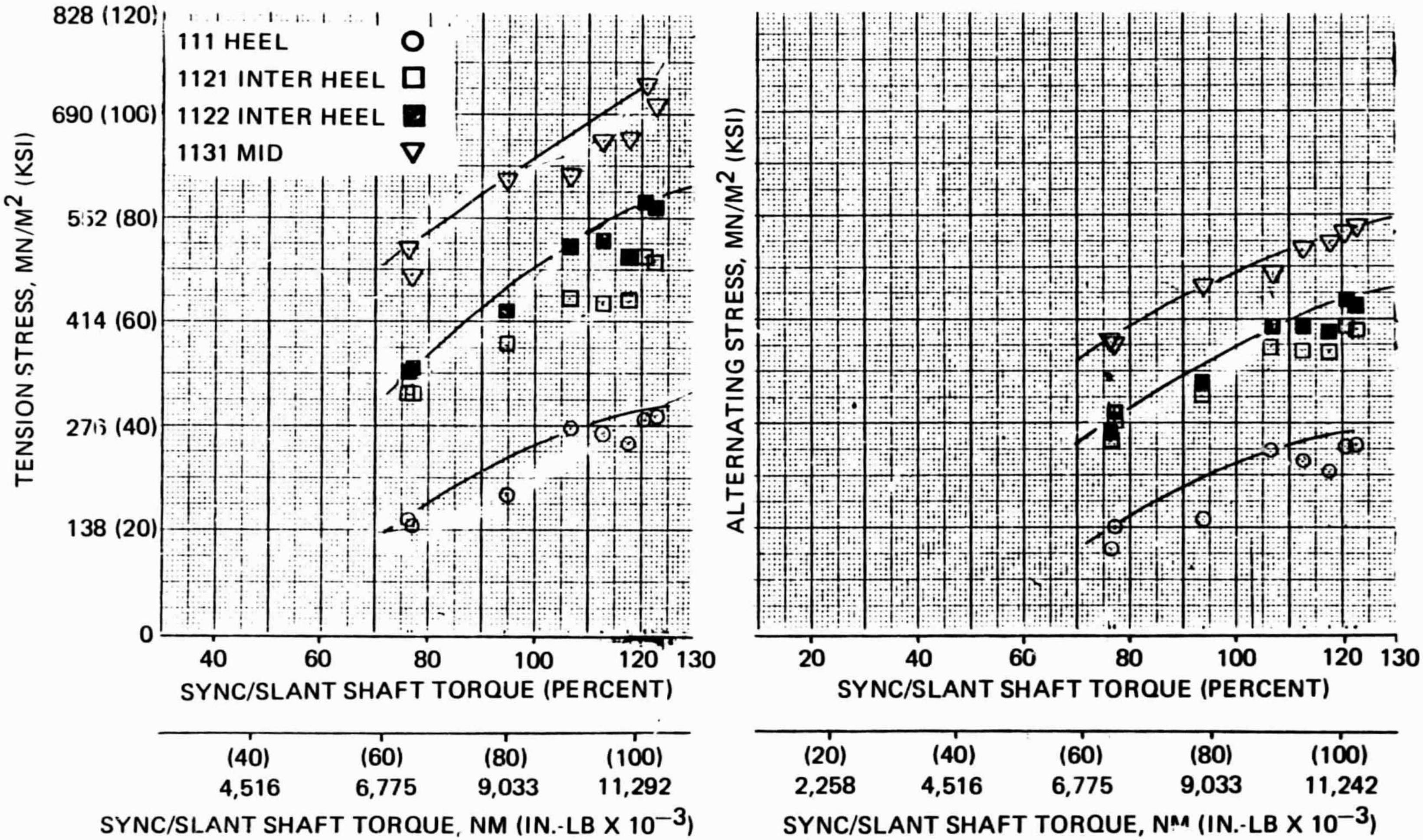



FIGURE 15. BEVEL PINION STRESS VS TORQUE - ROOT GAGES

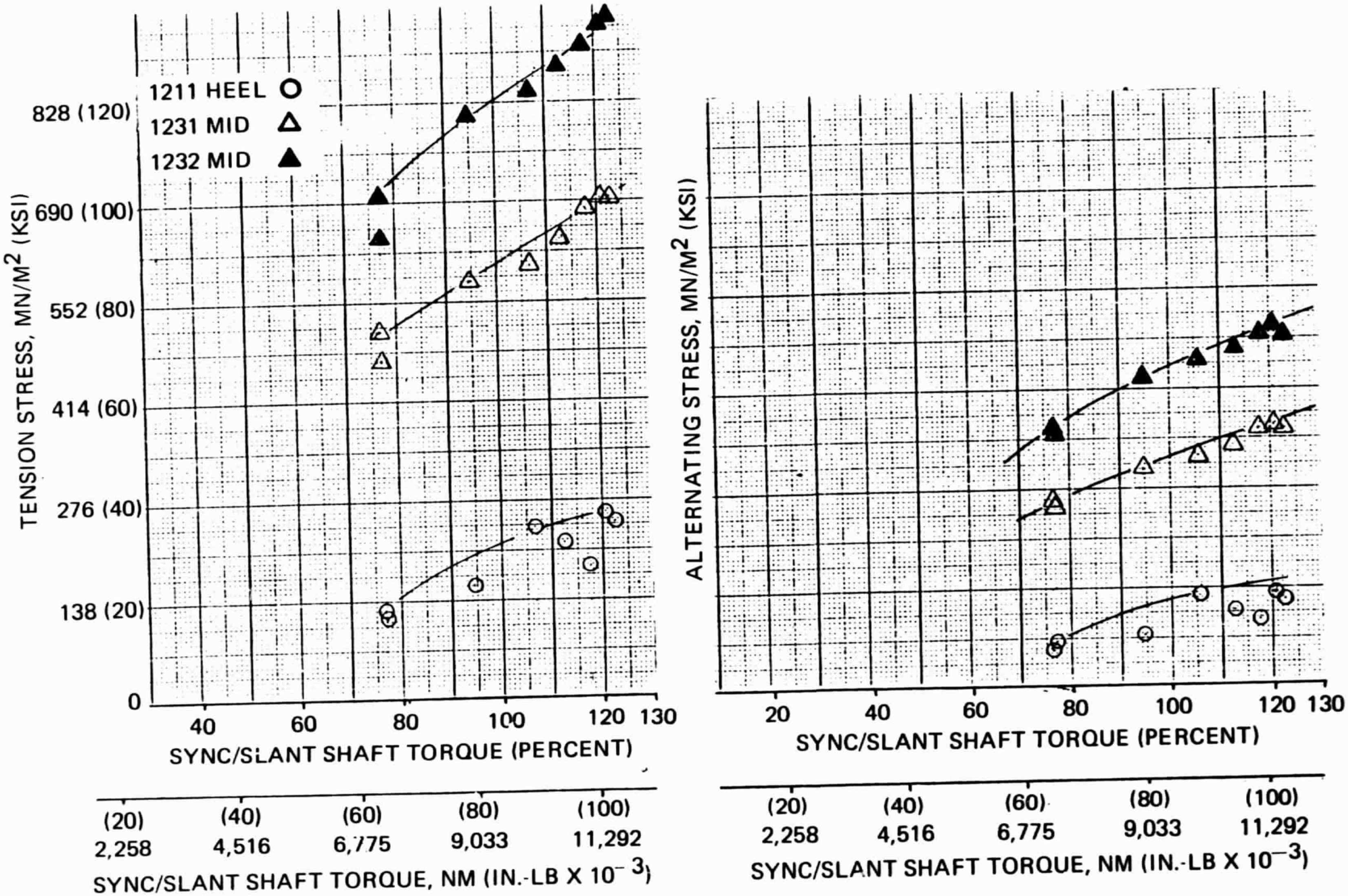
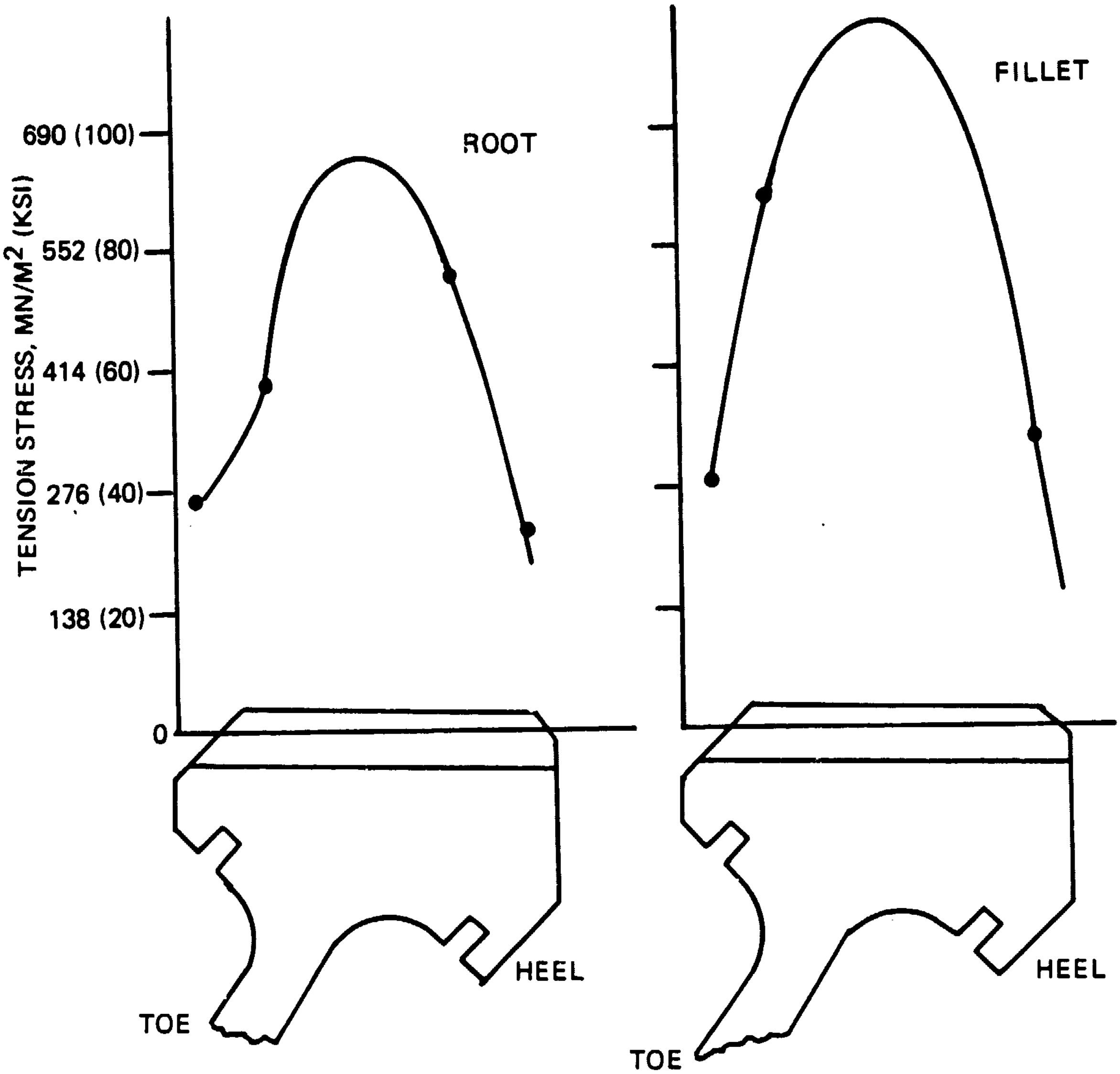


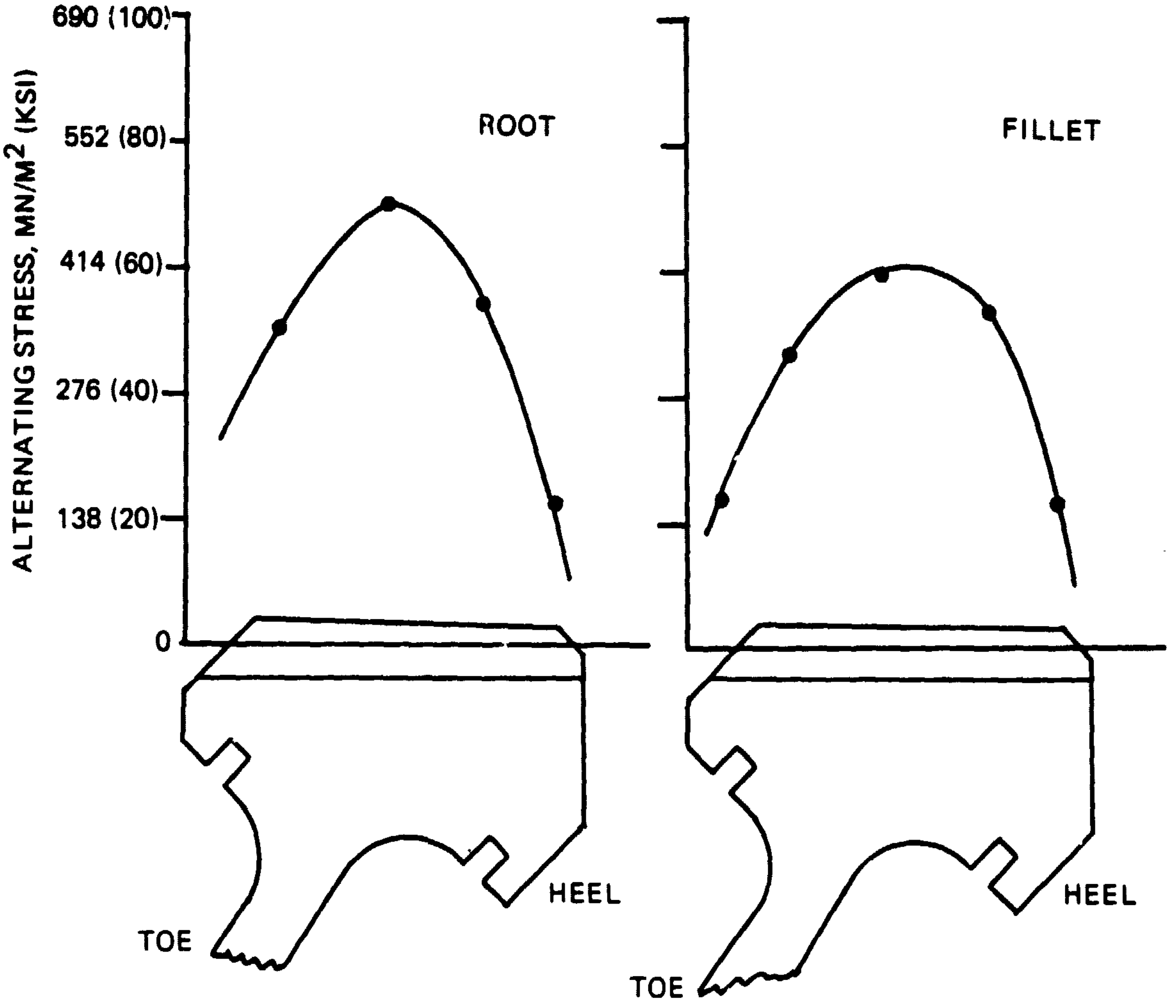

FIGURE 16. BEVEL PINION STRESS VS TORQUE - FILLET GAGES




(100% TORQUE)

FIGURE 17.

BEVEL GEAR FACEWISE TENSION STRESS DISTRIBUTION




(100% TORQUE)

Figure 18.
BEVEL GEAR FACEWISE ALTERNATING STRESS DISTRIBUTION

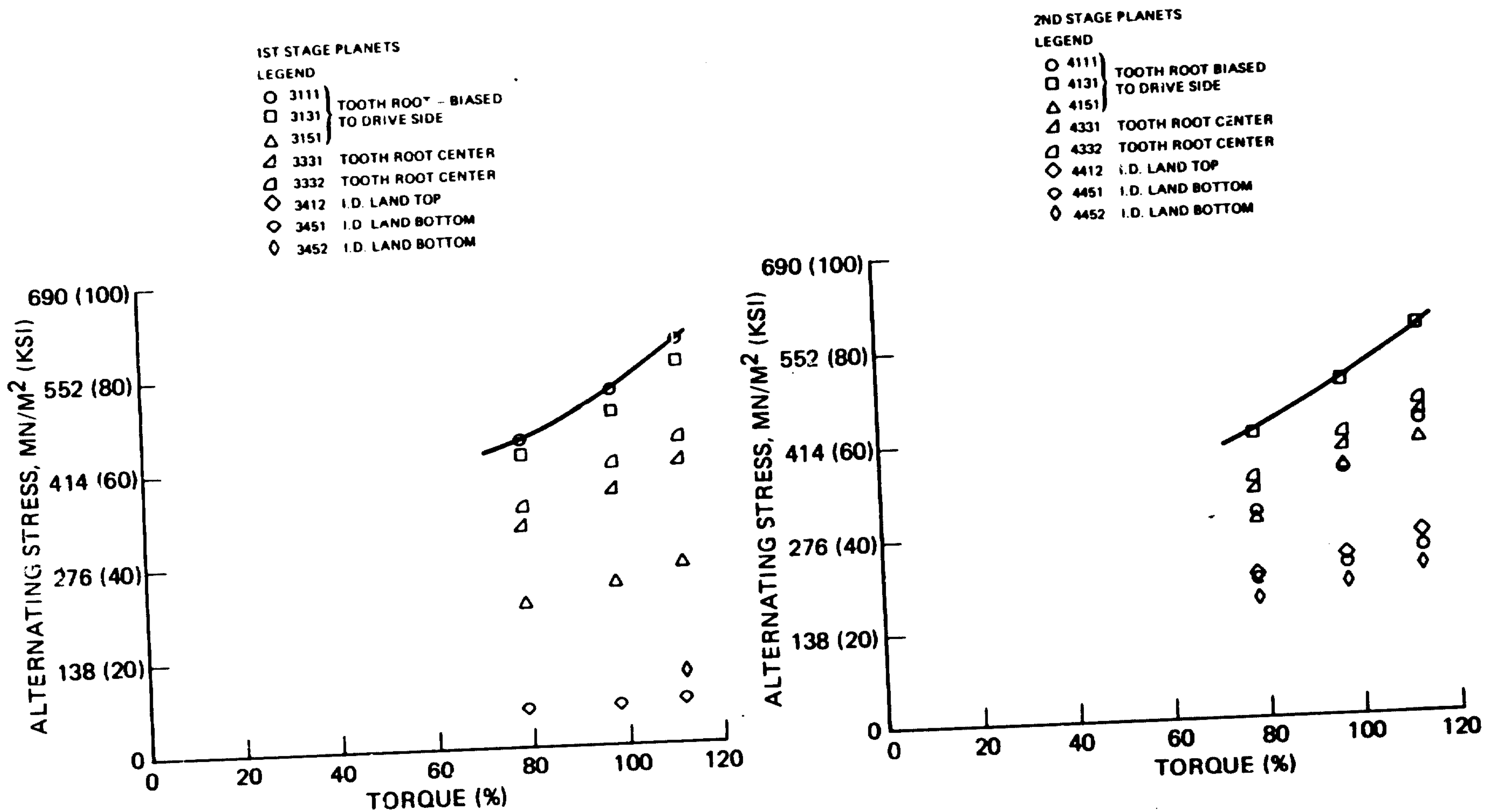



Figure 19.

PLANET GEAR STRESSES VS TORQUE

## 6.0 DYNAMIC STRAIN SURVEY

The purposes of the dynamic strain survey were to confirm that dynamic stresses are within the range of successful operation of Boeing Vertol helicopter transmissions as well as to verify stresses obtained during the static strain survey under actual thermal effects.

The conclusions of the dynamic strain survey were as follows:

- o Measured stress levels are within the range of successful operation of Boeing Vertol helicopter transmissions.
- o Maximum stresses at 100% torque were determined to be:
  - Spiral bevel pinion +21,000 ± 74,000 psi (root) (+144.795 ± 510.230 $Mn/m^2$)
  - Spiral bevel gear +42,000 ± 69,000 psi (fillet) (+289.590 ± 475.755 $Mn/m^2$)
  - First stage sun gear -1,000 ± 53,000 psi (center root) (-6.895 ± 365.435 $Mn/m^2$)
- o No significant resonant induced stresses were observed.
- o Comparison of dynamic to static data for spiral bevel members at 100% torque indicates:
  - Shift of peak stress distribution toward heel.
  - Generally good agreement between alternating stress levels.

- Less consistent agreement between temperature influenced maximum tension stress levels.

## TEST APPROACH AND PREPARATION

Strain gages for the dynamic survey were applied to the bevel pinion, the bevel gear and the first stage sun gear as shown in Figures 20 and 21. The spacing of gages along the tooth face was designed to obtain a facewise stress distribution. Gages were placed in the tooth roots and fillets where they were primarily responsive to ring bending (roots) and tooth bending (fillets).

Strain data were transferred from the rotating shafts to the data collection system through telemetry units mounted on the input shaft and on the sun/bevel gear. In order to accommodate instrumentation lead wires and telemetry, both the pinion and the gear were modified internally. Figure 22 shows the sun-bevel gear dynamic strain survey gages and lead wire assembly. Figure 23 illustrates six gages laid in adjoining tooth spaces of the bevel gear. Gages have also been laid on the sun gear as Figure 24 shows. Also shown is the instrumentation access hole which allows the lead wires to enter the gear inside diameter. The sun and bevel gear leads are joined to the housing module (Figure 25). One of the transmitters is pointed out. The housing module fits within the circular recess at the bottom (left hand) end of the sun-bevel (Figure 22). Figure 26 shows the stationary elements of the telemetry system attached to the existing lubrication standpipe assembly. The standpipe is coaxial with the sun-bevel gear and is non-rotating. The power coil and antenna rings have been added to the standpipe. Figure 27 shows the modification to the bevel pinion designed to provide access for the instrumentation leads across the damping ring groove in the bore of the pinion. Also shown are the instrumentation leads, which originate at tooth strain gages, passing down the pinion bore. At the other end of the pinion, these terminate in a rotating module similar to that shown in Figure 25.

The method of operation for the dynamic strain surveys was to allow the instrumented transmission to run long enough to stabilize oil temperature before taking data. The histogram of torque versus time is shown in Figure 28. Two types of runs were conducted - constant speed with various torque levels, and constant torque with speed excursions to search for resonant frequencies. Part II is the continuation of the dynamic survey following gaging of the bevel pinion made necessary by the progressive loss of gages during Part I.

## DISCUSSION OF DATA

Figures 29 summarizes the dynamic strain data by displaying it on a Goodman diagram, allowing steady and alternating stresses to be plotted together. As already noted, the HLH maximum stresses are in the band of Boeing Vertol successful experience.

Figures 30 through 33 display data taken at various points along the face width, at various torque levels, and for both gear and pinion. The data are subdivided into the matrix:

| | Fillet | Root |
|---|---|---|
| Maximum Tension | X | X |
| Maximum Alternating | X | X |

Figures 34 and 35 illustrate a sampling of stress versus torque taken from the three instrumented gears. The data are subdivided into tension and alternating stresses, and root and fillet stresses. Data points include all positions across the face. Generally the data display a linear relationship of stress and torque as would be expected.

Figures 36 and 37 illustrate face-wise data for the first stage sun gear. Figure 38 illustrates the stress distribution of the sun as it rotates through mesh. It will be noticed that the predominantly compressive stress seen before mesh, changes to a tension stress at the mesh point ($0^{o}$) and then diminishes to essentially zero stress at 15° after the mesh.

TESTING FOR RESONANCE

Before the transmission was assembled for the strain surveys, the bevel pinion and bevel gear had individually been subjected to a resonant frequency test using a variable frequency excitation source. From this test, the resonant frequencies of the pinion (Figure 39) and the gear (Figure 40) are plotted. The pinion has no natural frequencies in the operating regimes of ground idle and 100% rotor rpm. The sun bevel gear has a number of frequencies close to 100% rotor rpm. These data are plotted for both the current test gear (-3) and an earlier (-2) gear which was used during the ATC program "iron-bird" testing, at reduced power, but for 140 hours. Because the -2 gear experienced no resonant frequency problems, it was judged that the similar but heavier wall -3 gear would not. This was confirmed during the dynamic strain survey, when speed excursion developed a maximum high-frequency measured stress level of ±7470 psi (±51.05 $Mn/m^2$) (Figure 41). This is evidence that resonant energy is adequately dissipated through the damping rings fitted inside the bevel portion of the gear. Data taken at the sur-gear end of the bevel showed a maximum of ±6380 psi, (±43.990 $Mn/m^2$) while the pinion showed a maximum of ±3810 psi (±26.269 $Mn/m^2$).

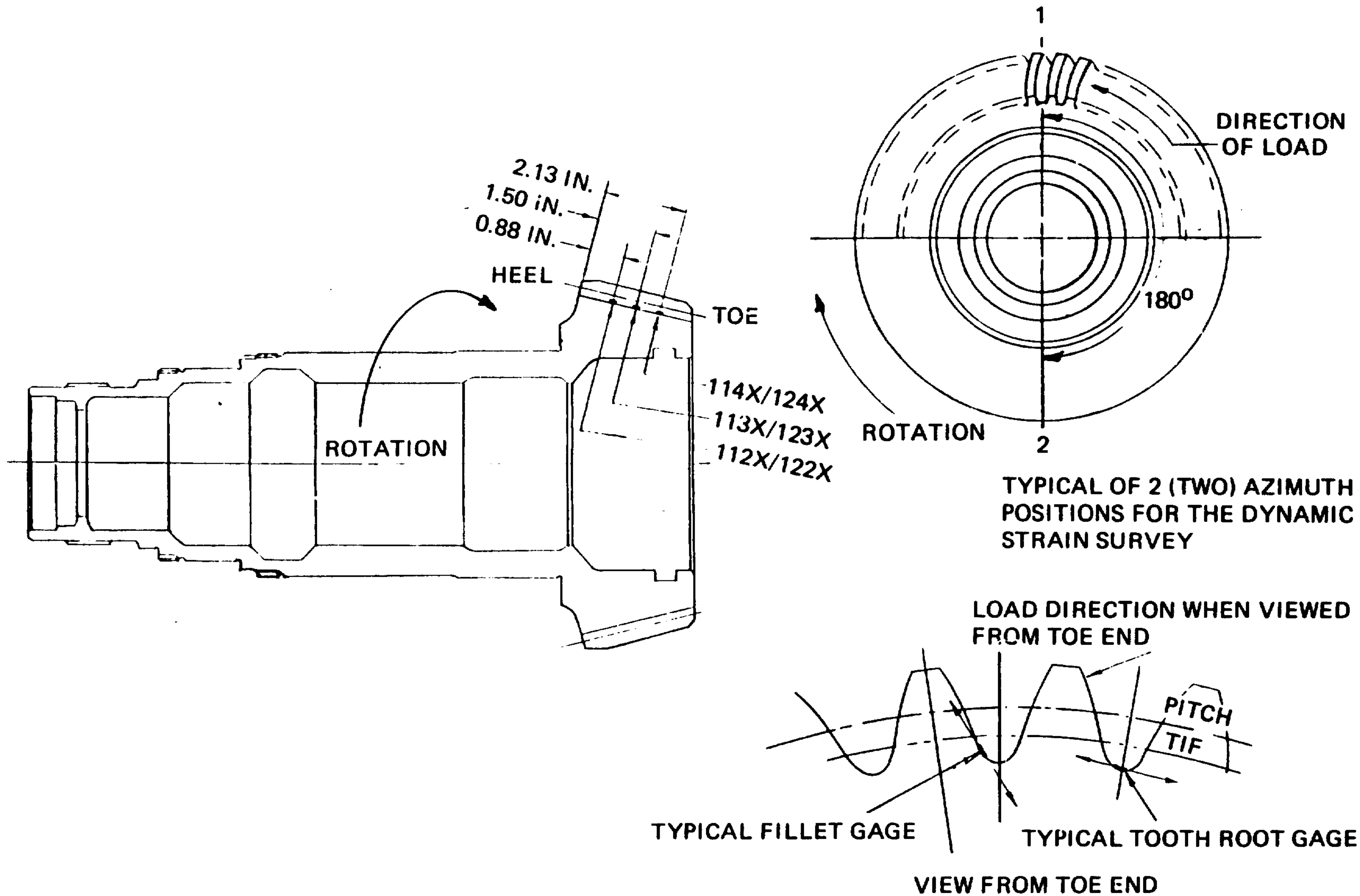
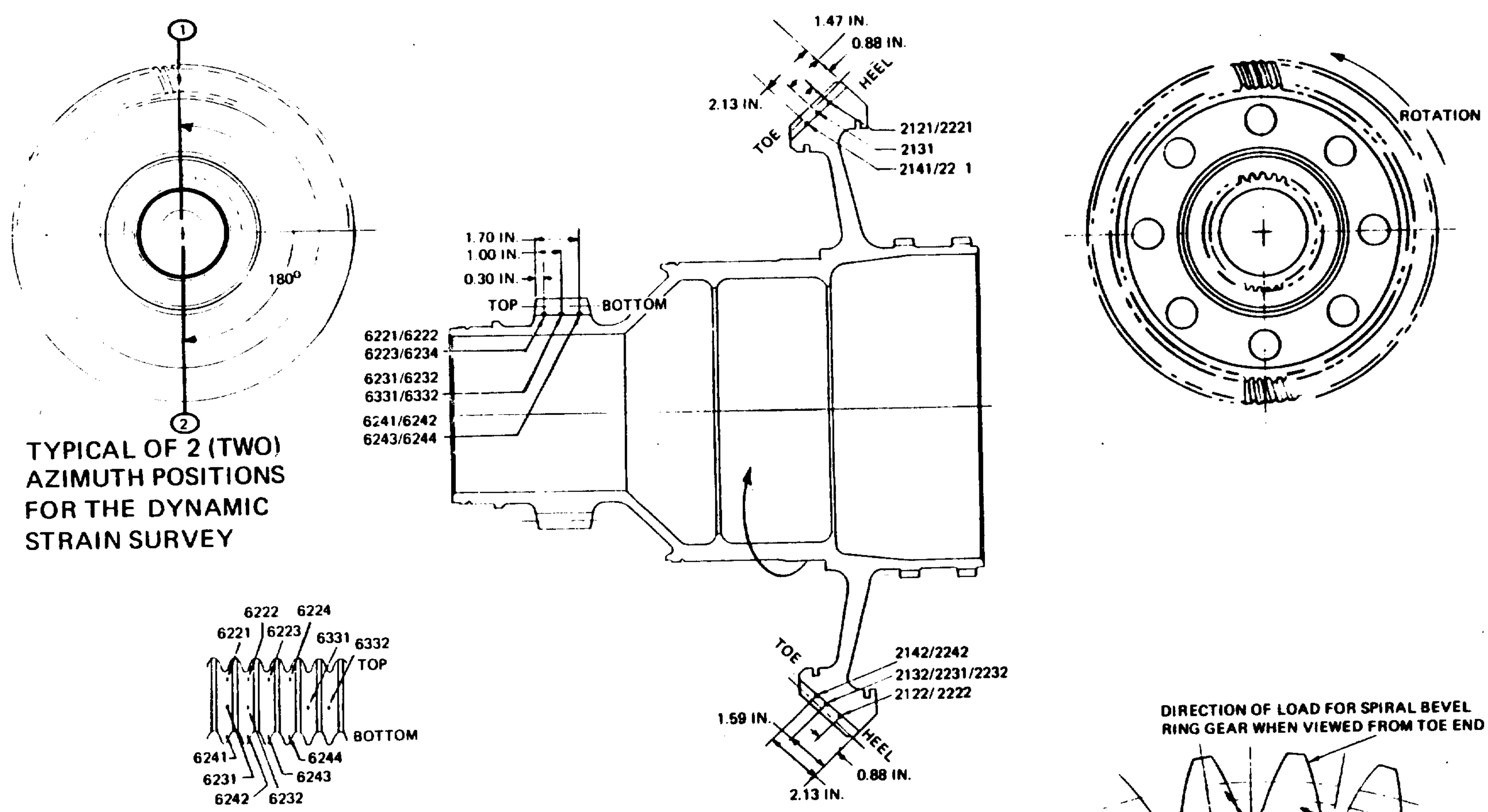



FIGURE 20. BEVEL PINION DYNAMIC STRAIN SURVEY GAGE LOCATIONS




PLACEMENT OF GAGES ON SUN GEAR

622X, 623X, 624X } BIASED TO DRIVE SIDE

633X CENTERED IN TOOTH ROOT

FIGURE 21. BEVEL GEAR DYNAMIC STRAIN SURVEY GAGE LOCATIONS

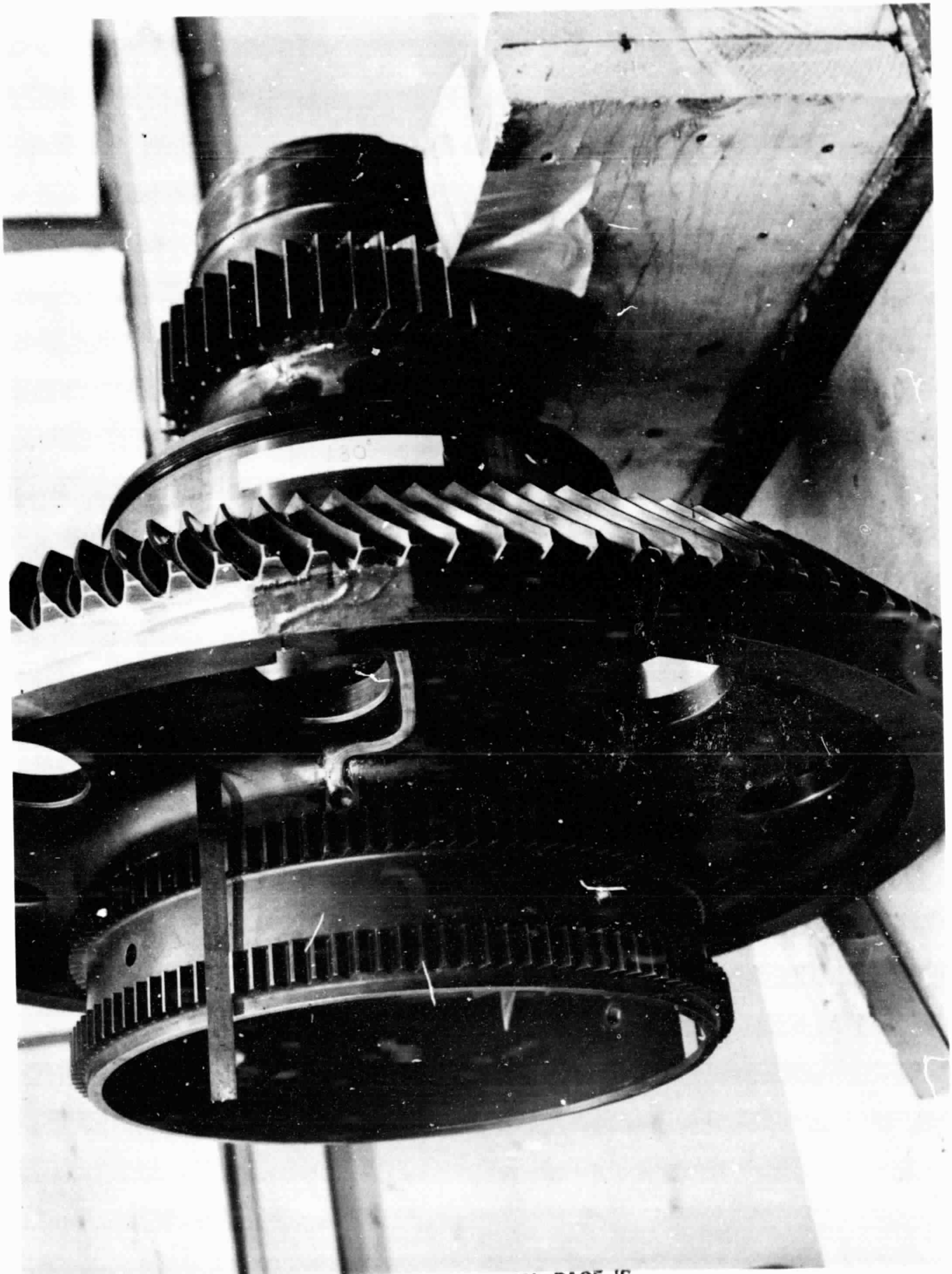



FIGURE 22 BEVEL GEAR INSTRUMENTATION

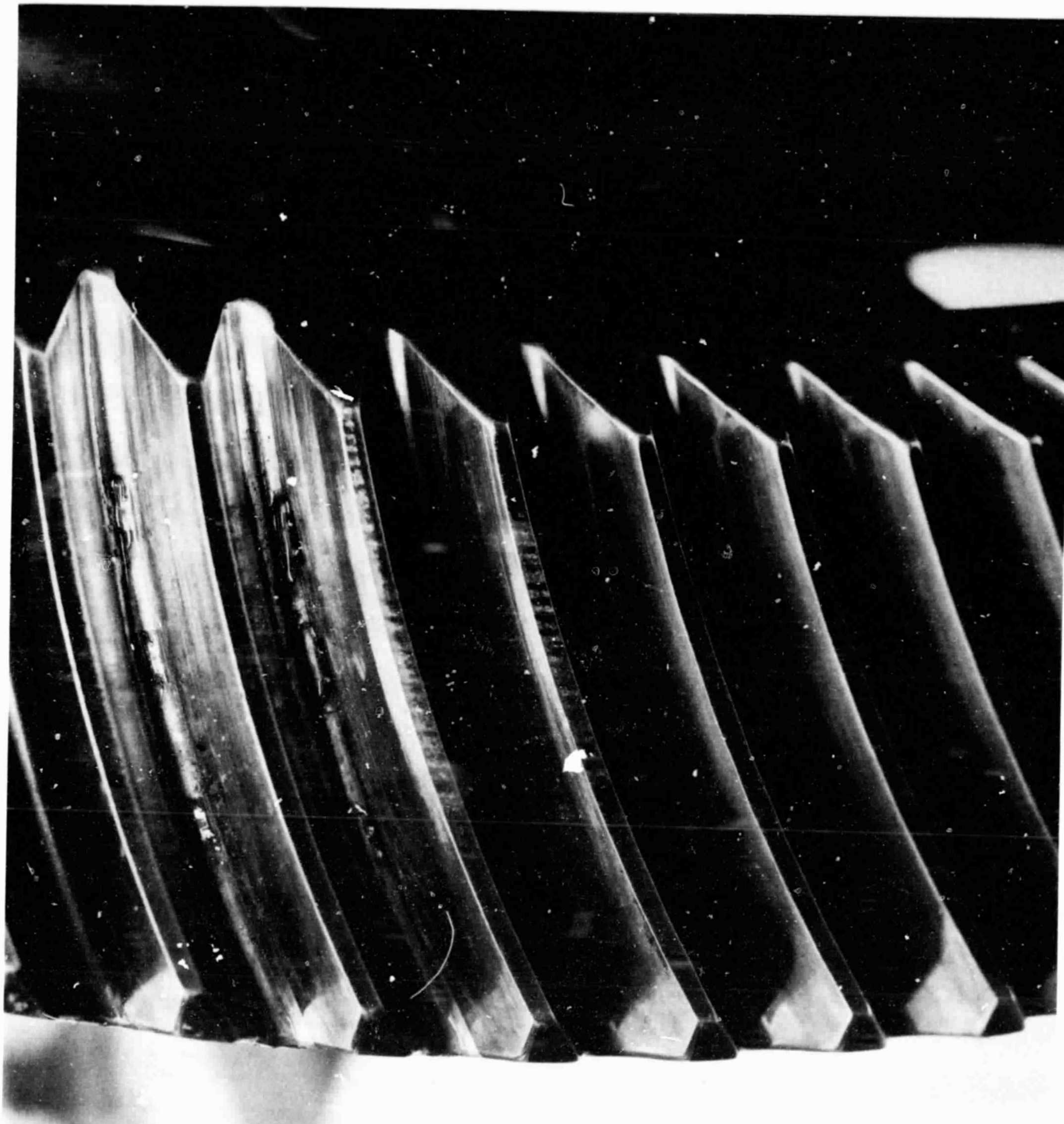


FIGURE 23 BEVEL GEAR GAGES IN BEVEL TOOTH ROOTS

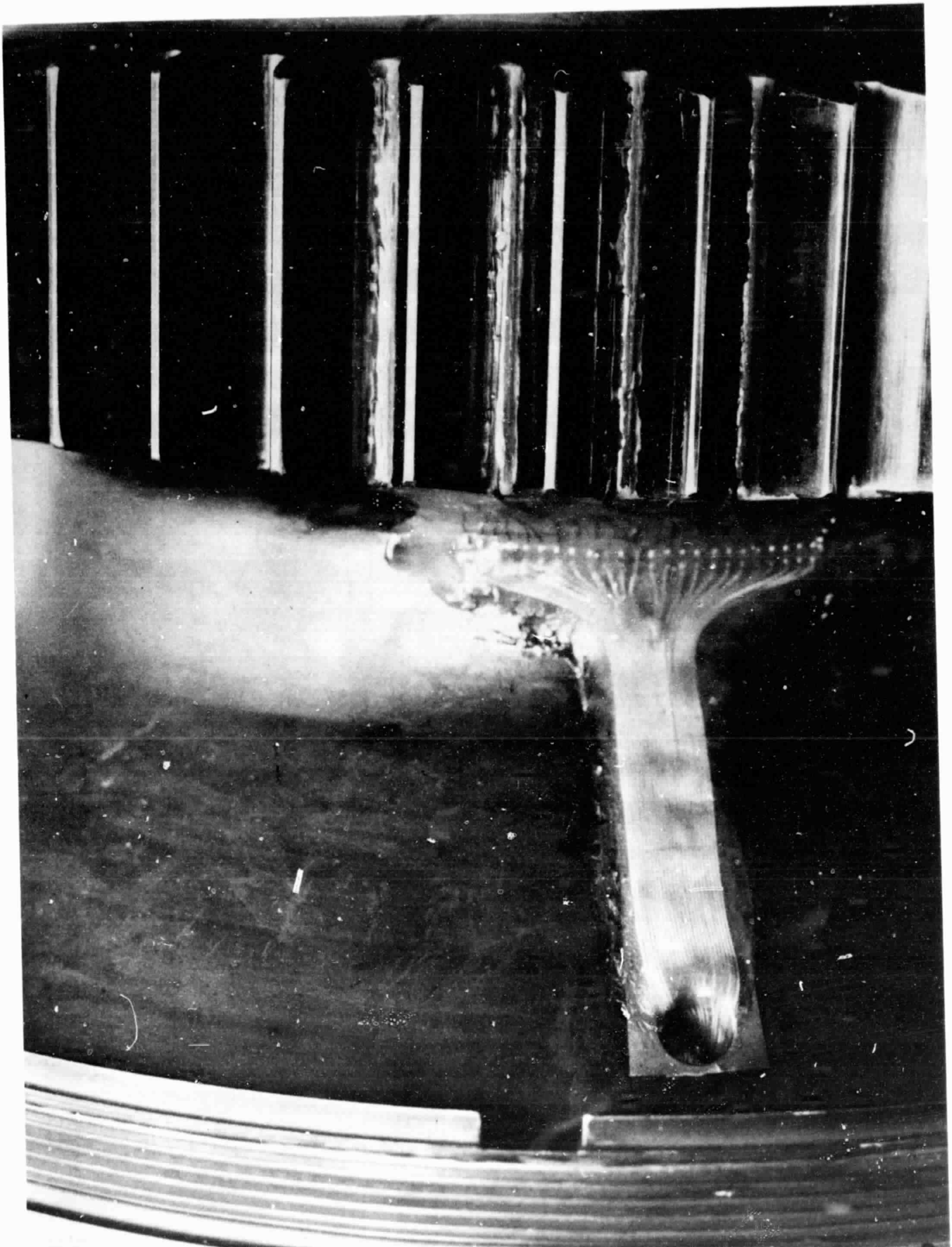


FIGURE 24 BEVEL GEAR GAGES IN SUN GEAR TOOTH ROOTS

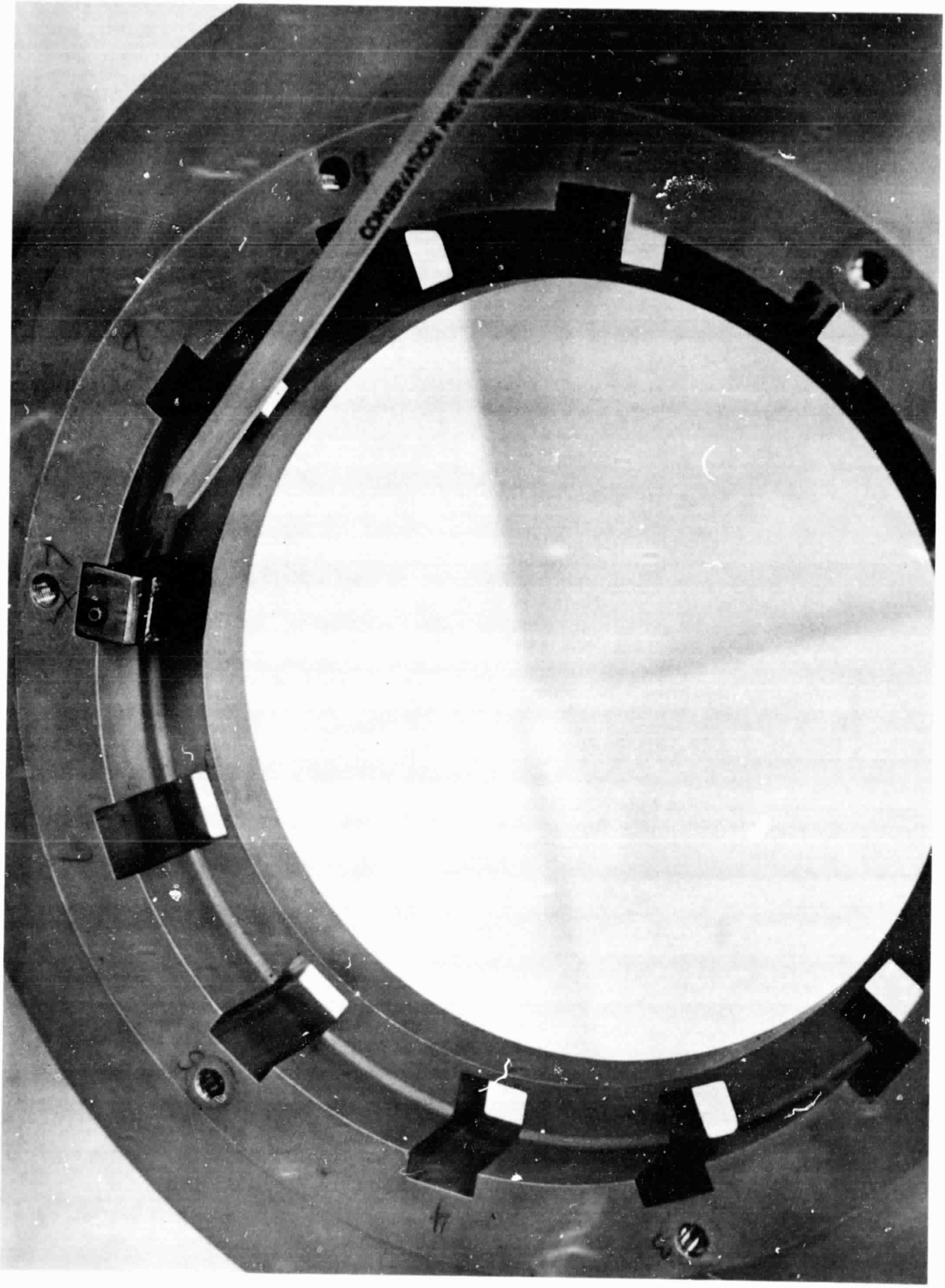


FIGURE 25 ROTATING TELEMETRY MODULE

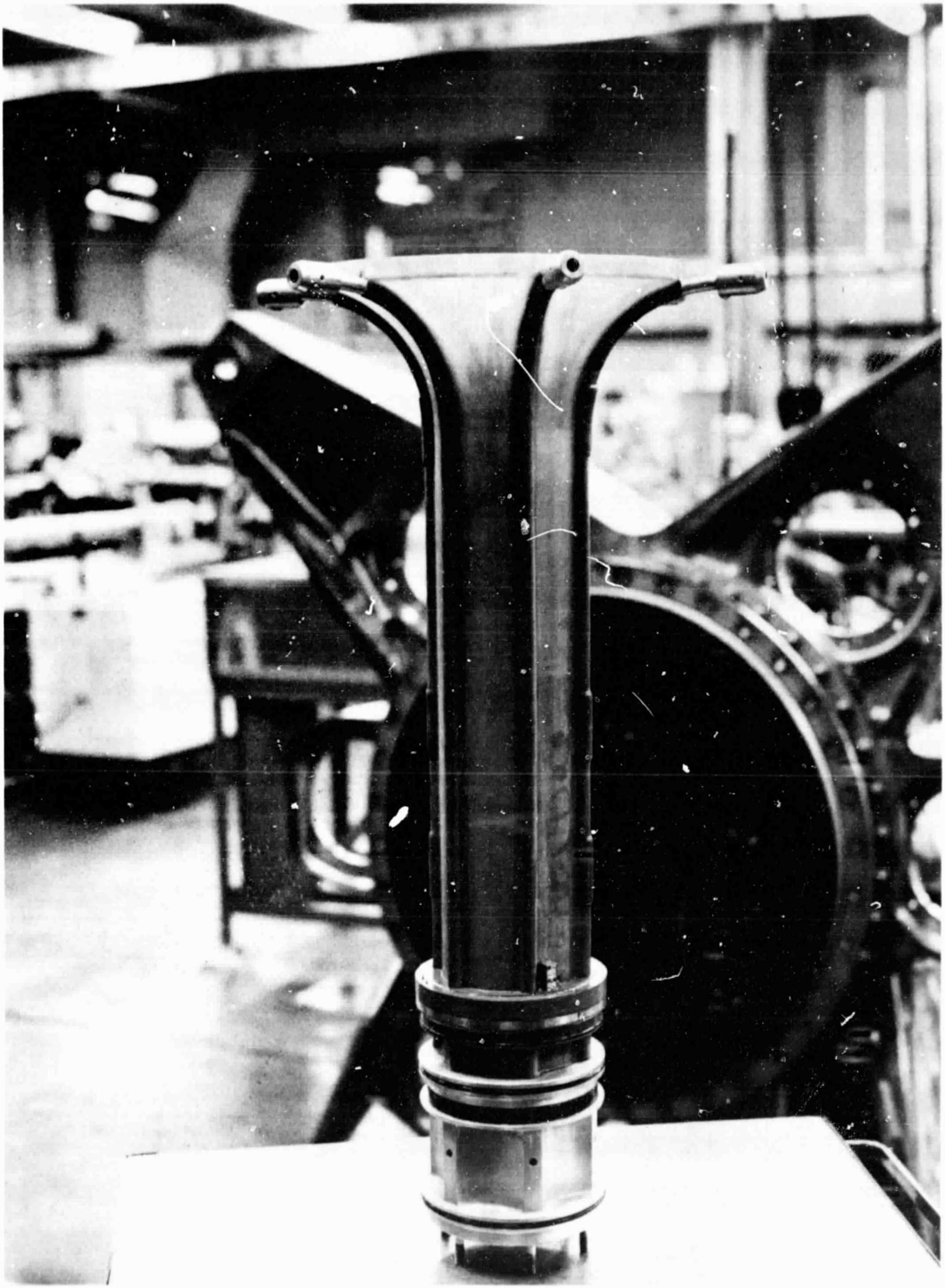




FIGURE 26 STATIONARY TELEMETRY MODULE

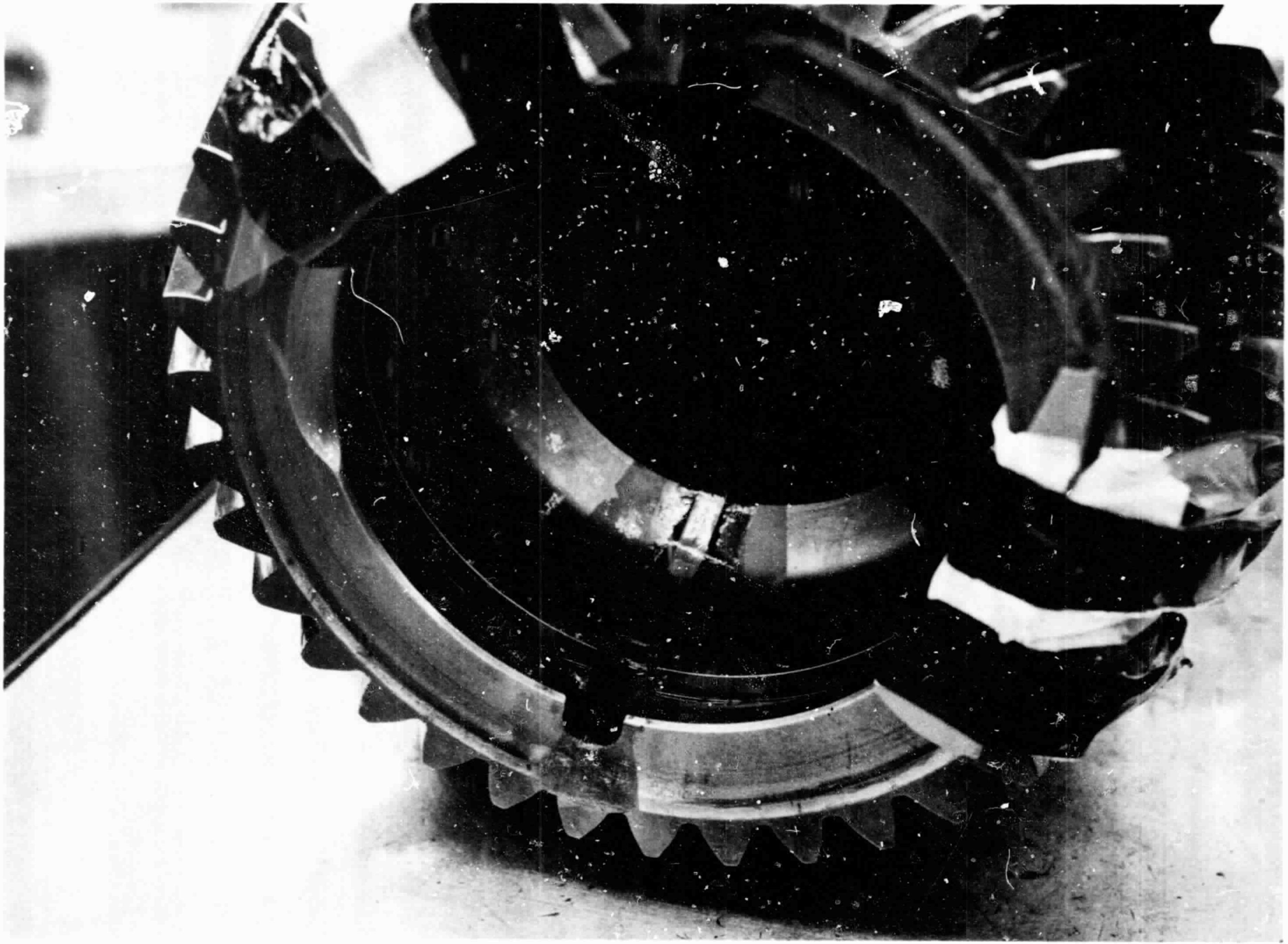


FIGURE 27 BEVEL PINION DURING GAGE INSTRUMENTATION

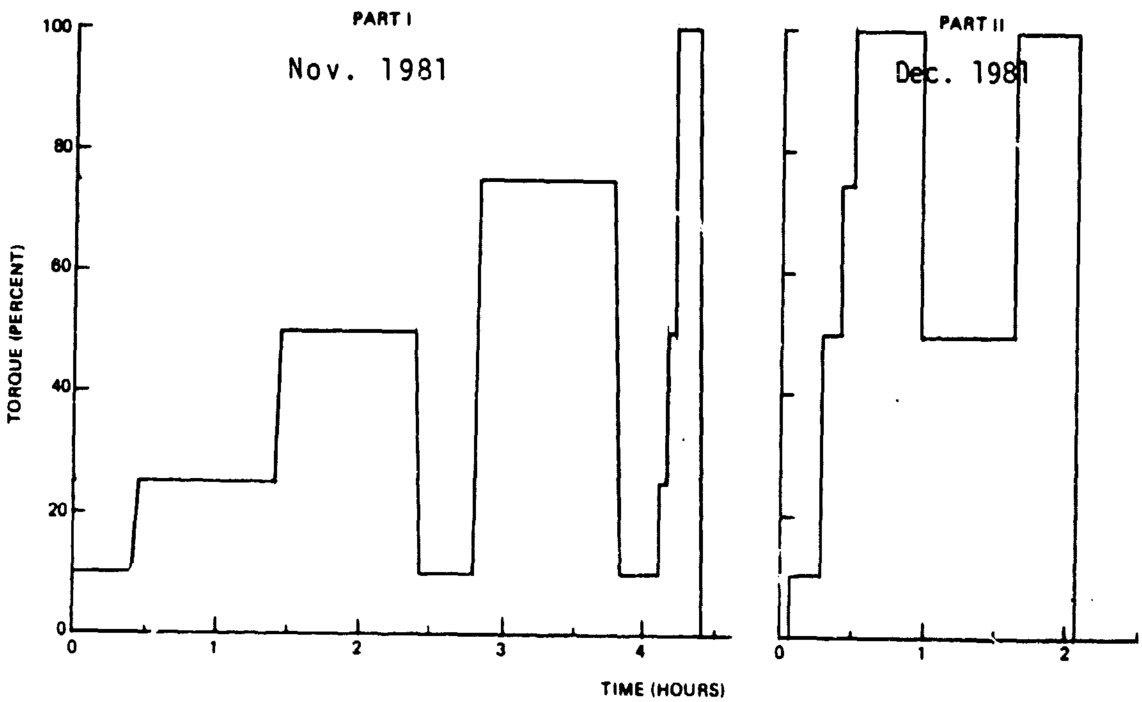



FIGURE 28.

DYNAMIC STRAIN SURVEY TORQUE - TIME HISTORY

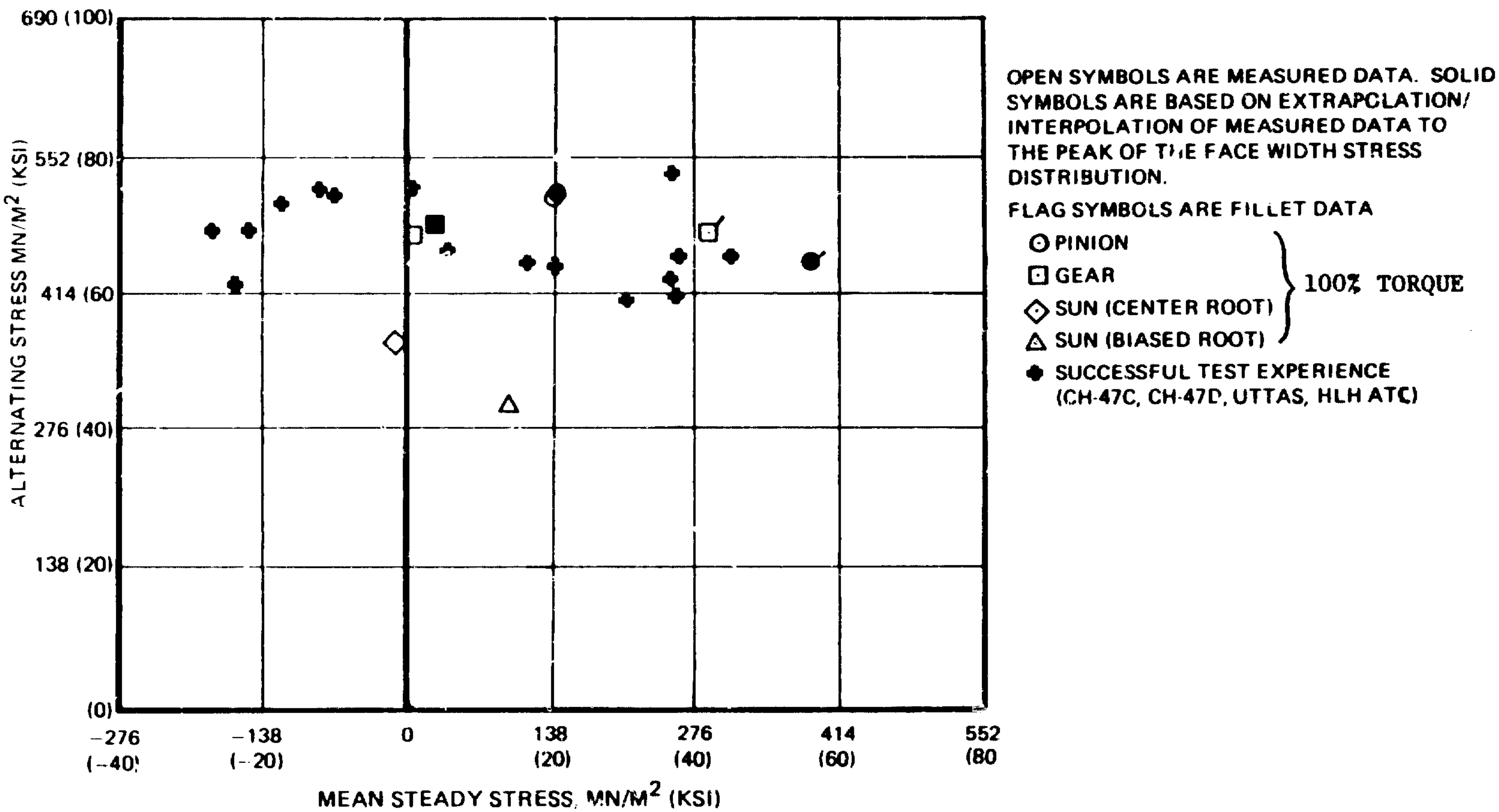



Figure 29. SUMMARY OF DYNAMIC STRAIN SURVEY RESULTS

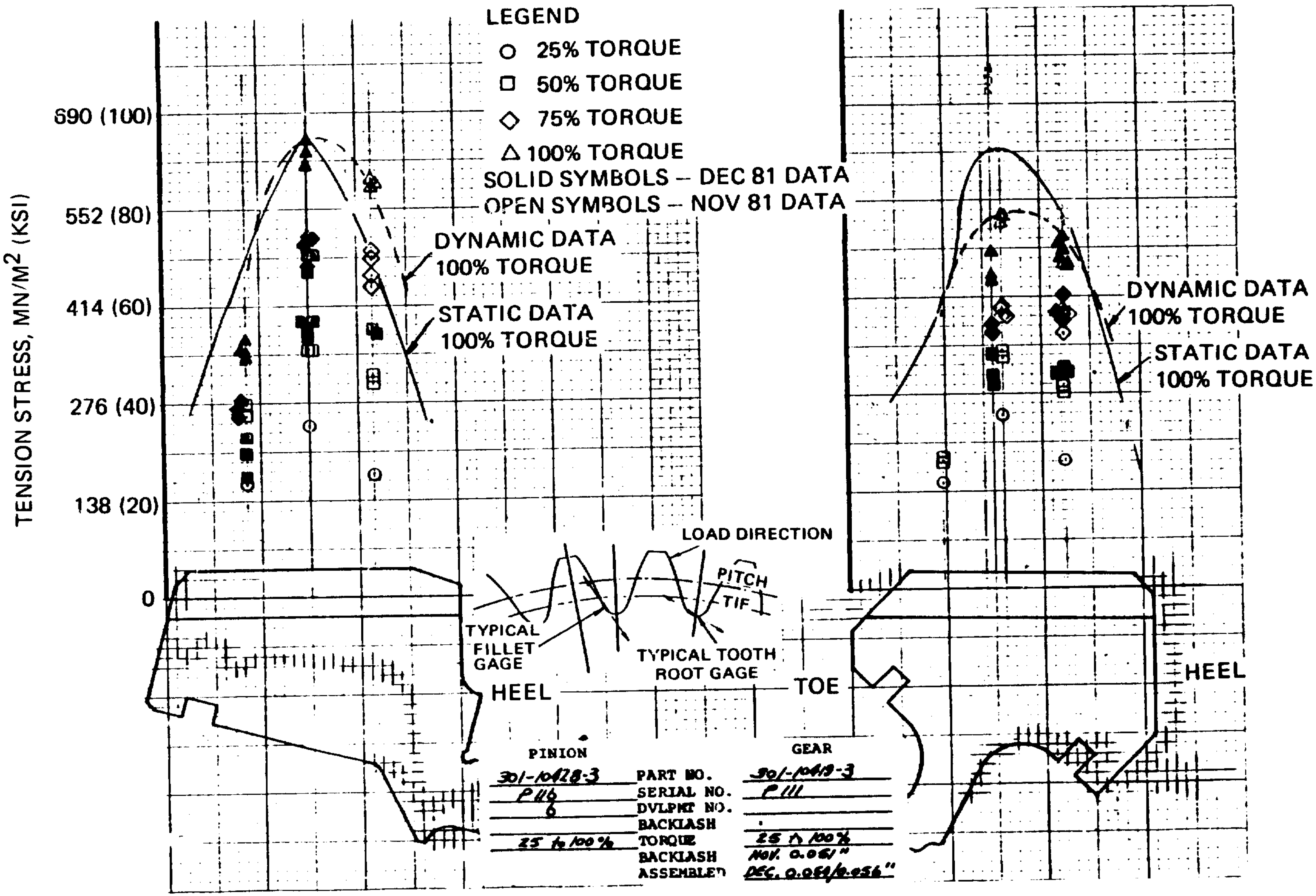



Figure 30.
BEVEL PINION AND GEAR FACEWISE DISTRIBUTION - ROOT TENSION STRESS

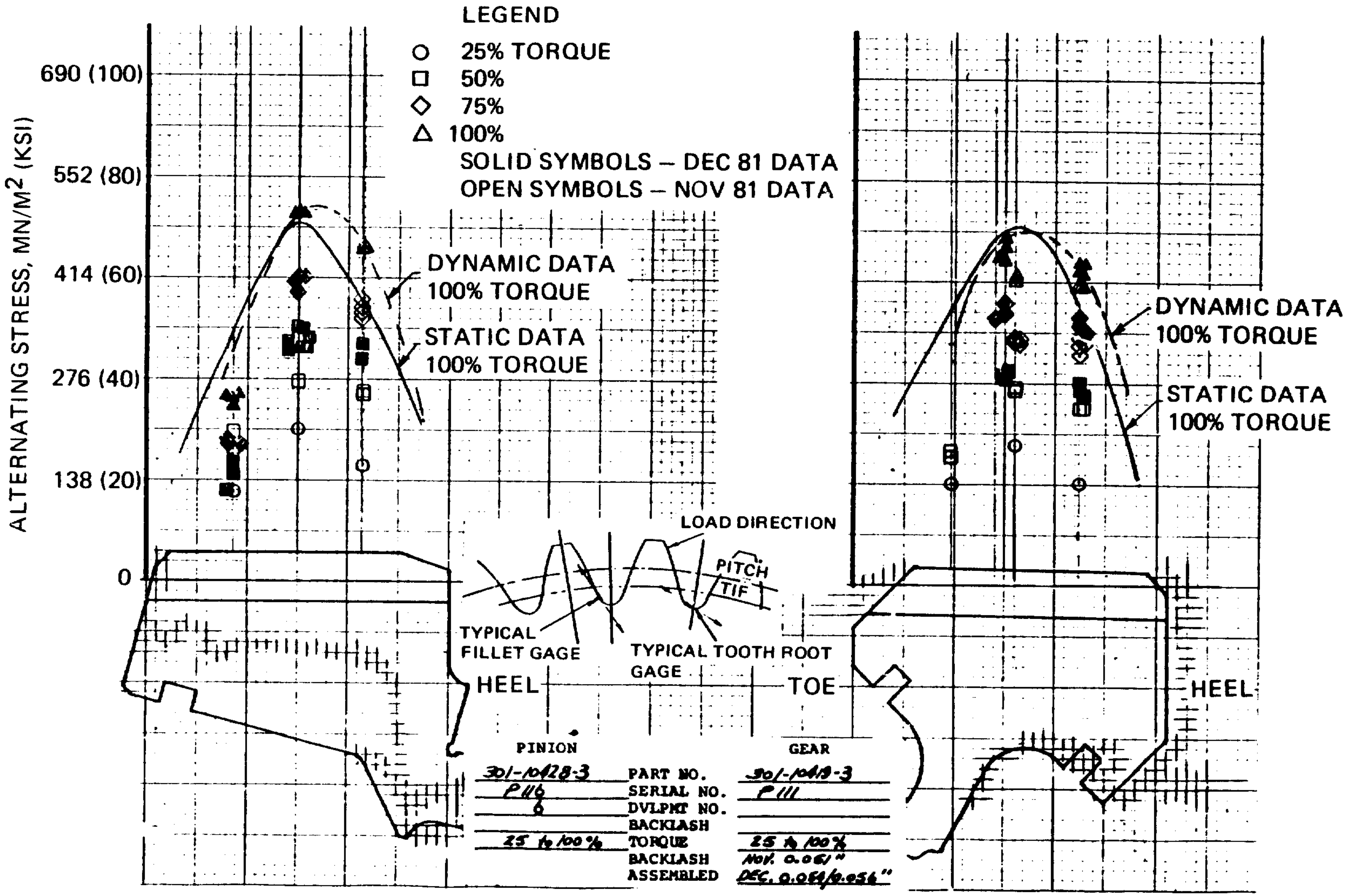



FIGURE 31.

BEVEL PINION AND GEAR FACEWISE DISTRIBUTION - ROOT ALTERNATING STRESS

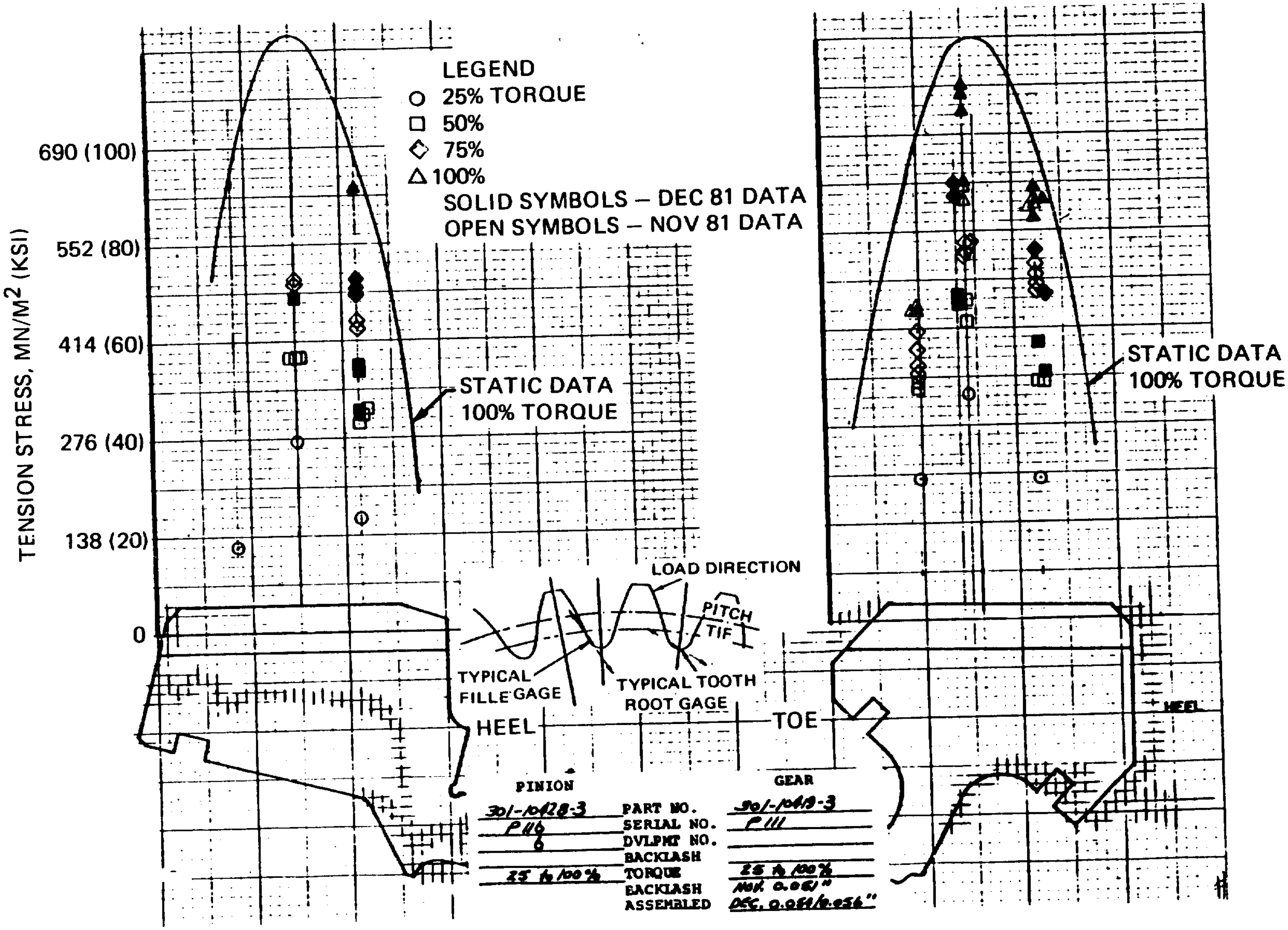



Figure 32.
BEVEL PINION AND GEAR FACEWISE DISTRIBUTION - FILLET TENSION STRESS

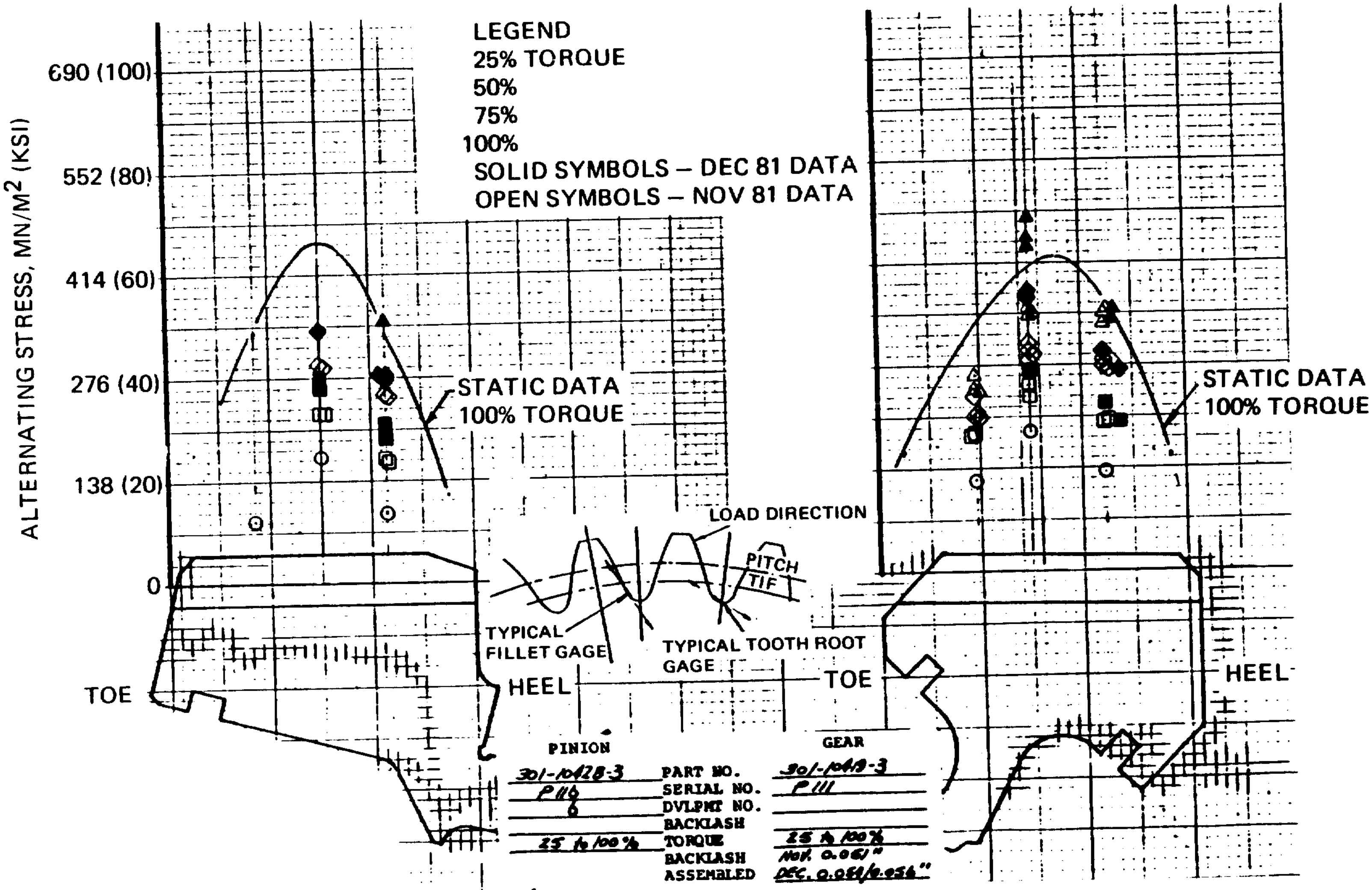



FIGURE 33.

BEVEL PINION AND GEAR FACEWISE DISTRIBUTION - FILLET ALTERNATING STRESS

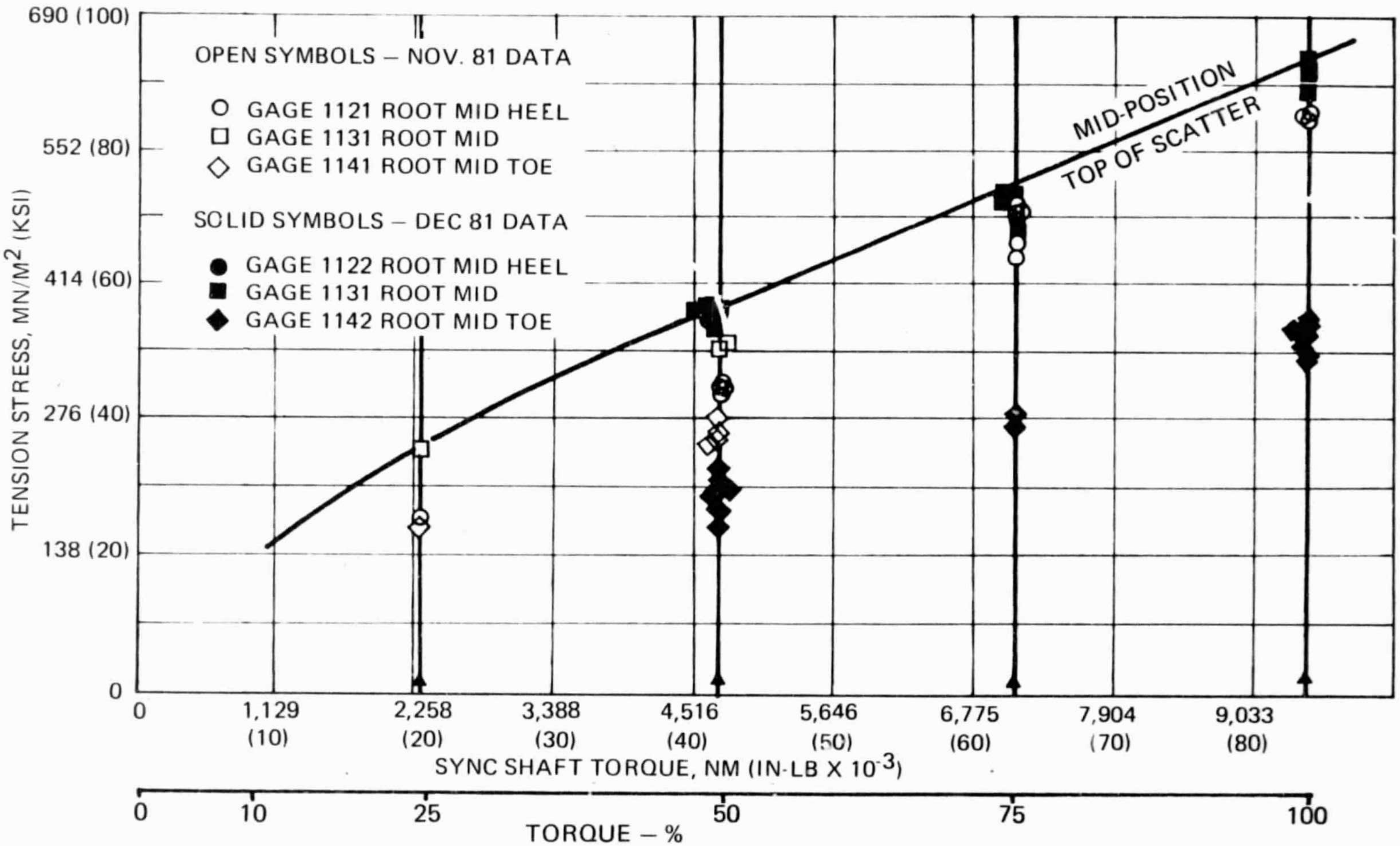



Figure 34.

BEVEL PINION STRESS VS TORQUE - ROOT TENSION

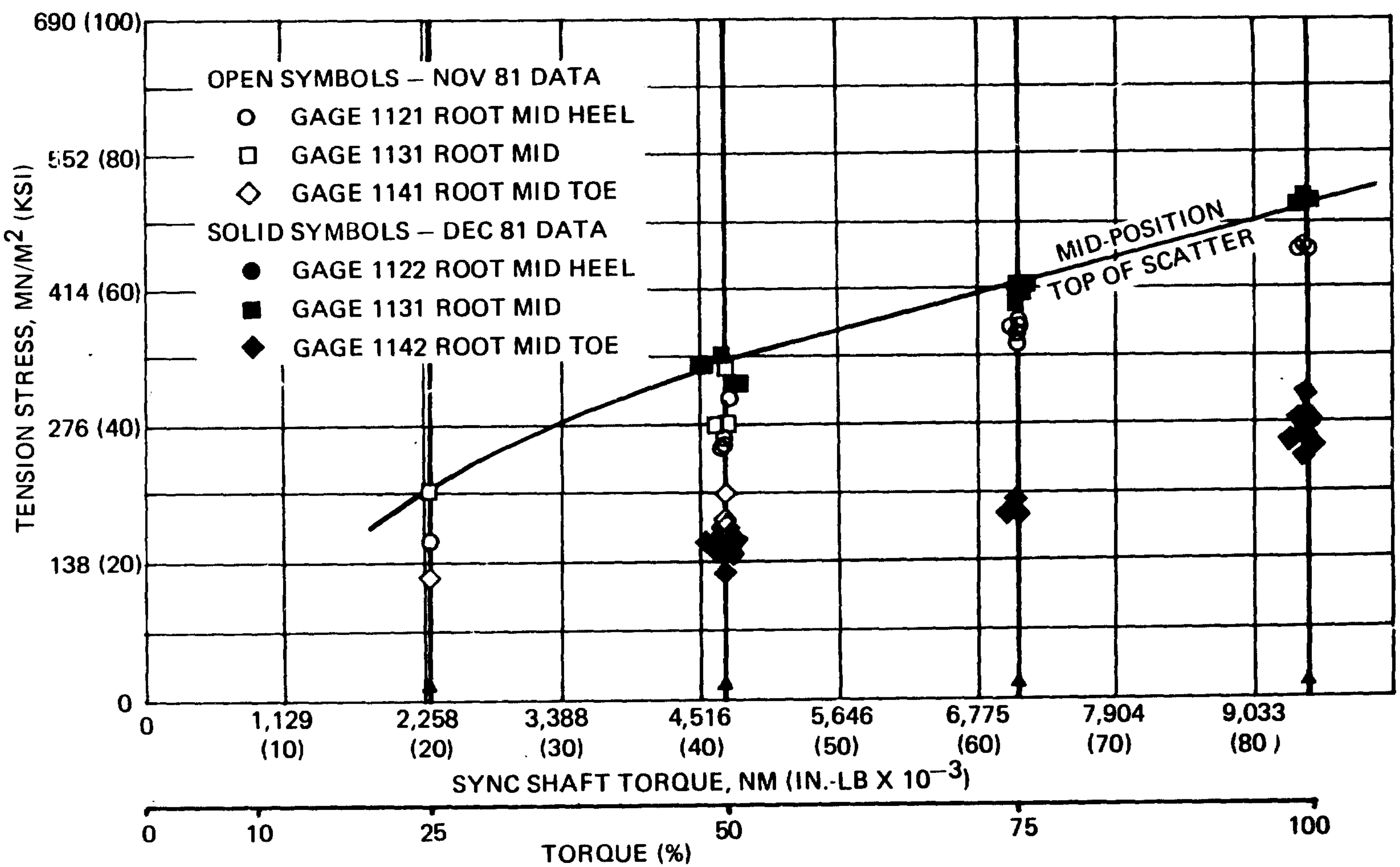



Figure 35.
BEVEL PINION STRESS VS TORQUE - ROOT ALTERNATING

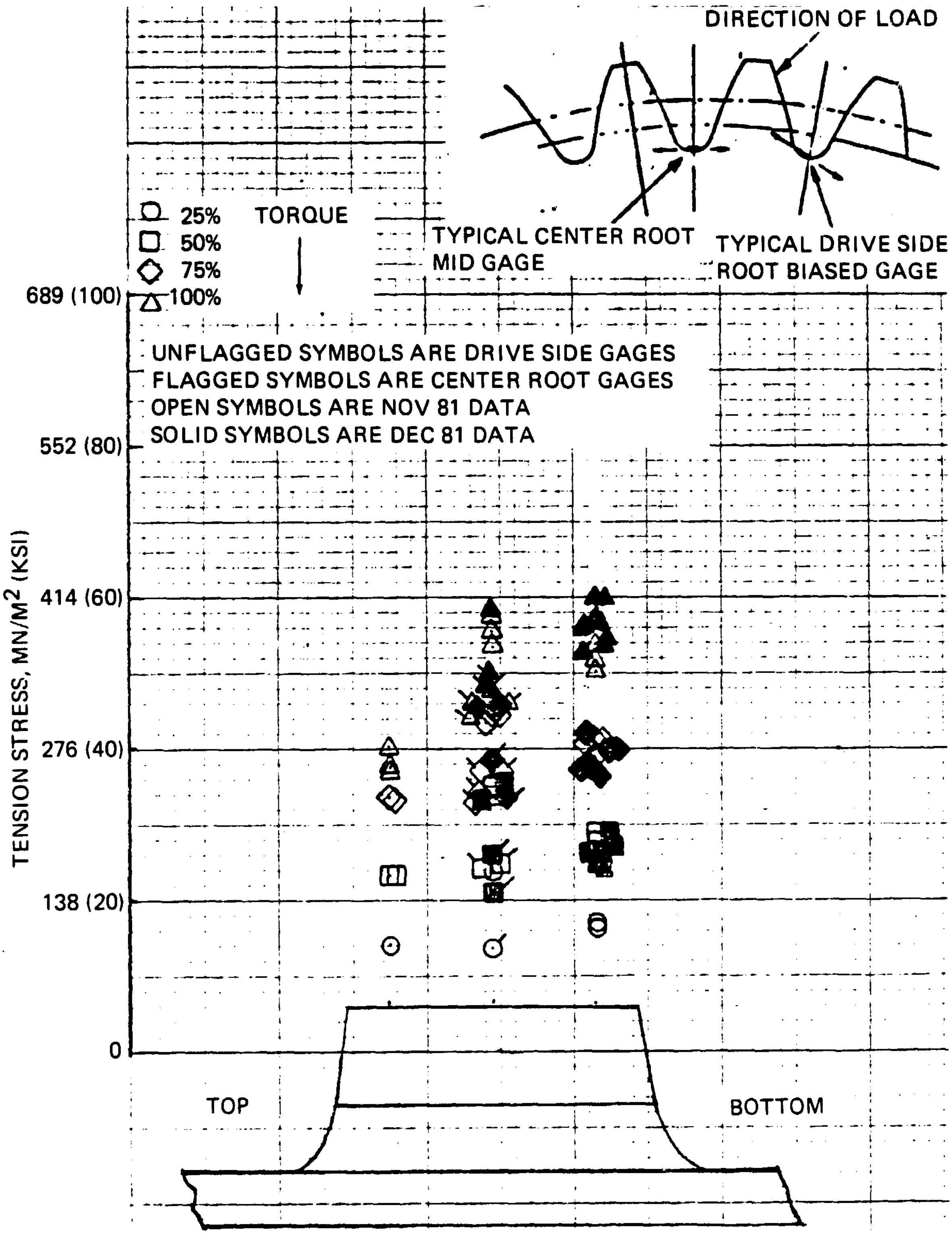



Figure 36.

FIRST STAGE SUN GEAR FACEWISE DISTRIBUTION - ROOT & FILLET TENSION STRESS

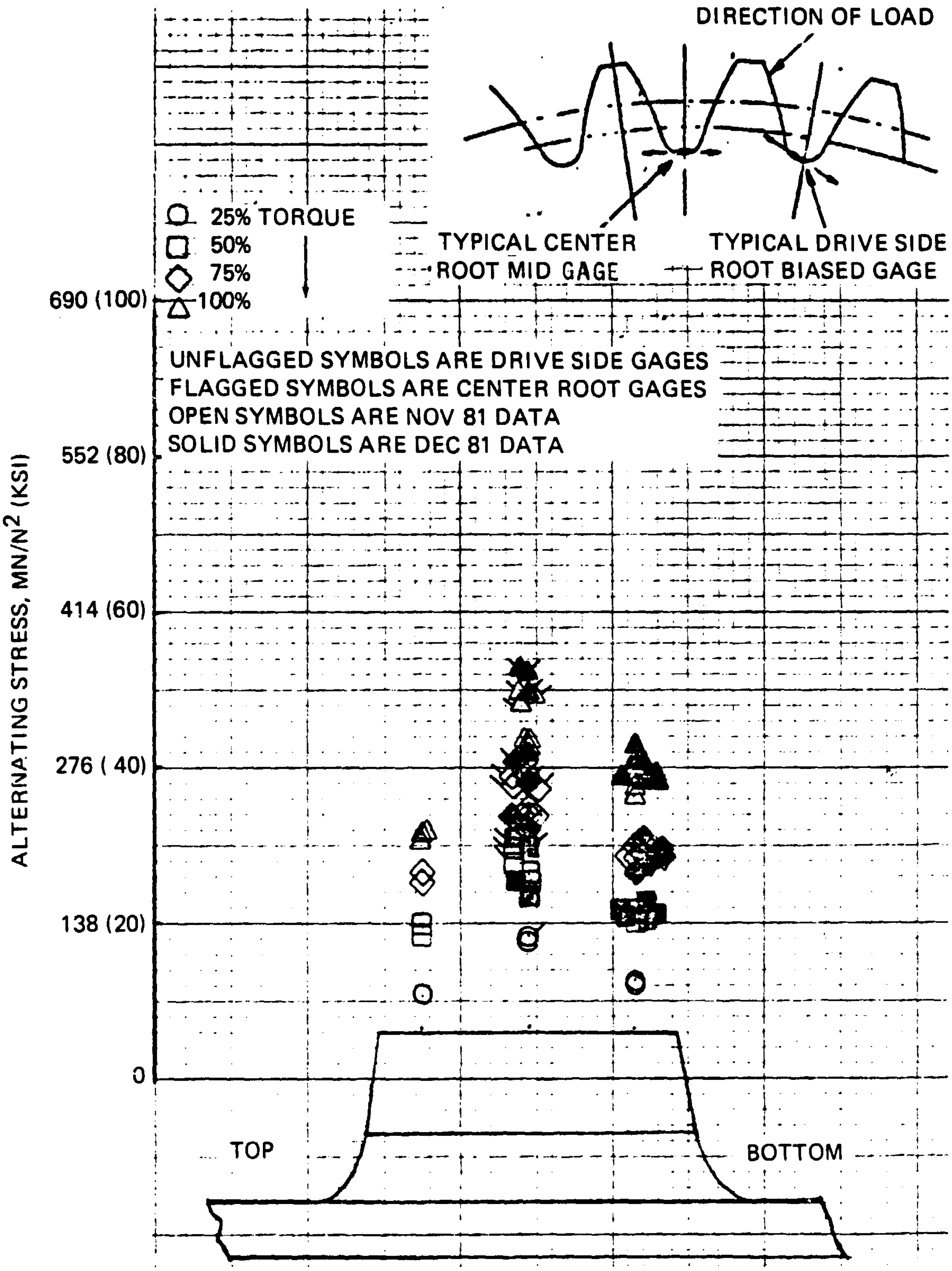



Figure 37.
FIRST STAGE SUN GEAR FACEWISE DISTRIBUTION - ROOT & FILLET ALTERNATING STRESS

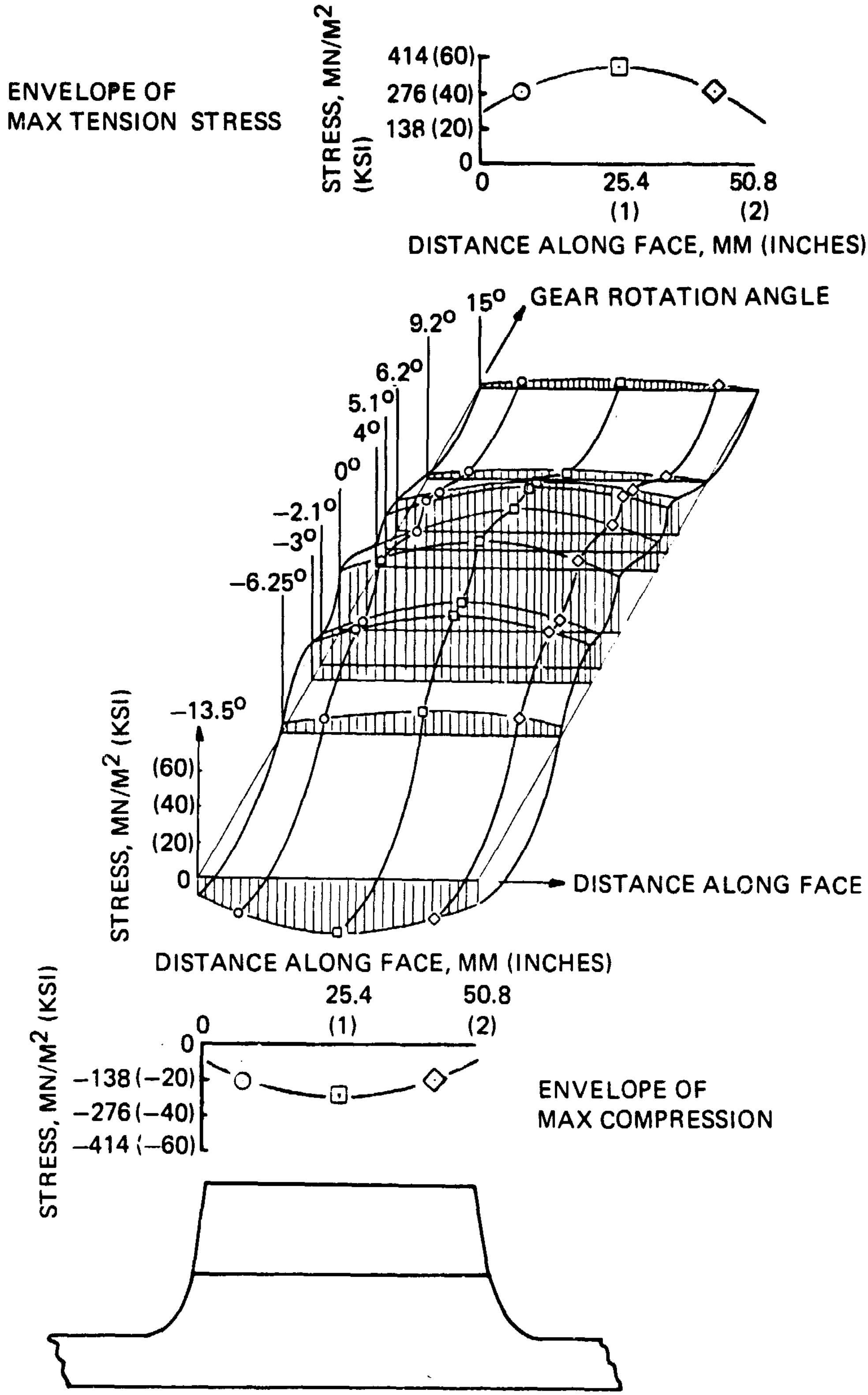



FIGURE 38. FIRST STAGE SUN GEAR STRESS VS ROTATION TIME HISTORY

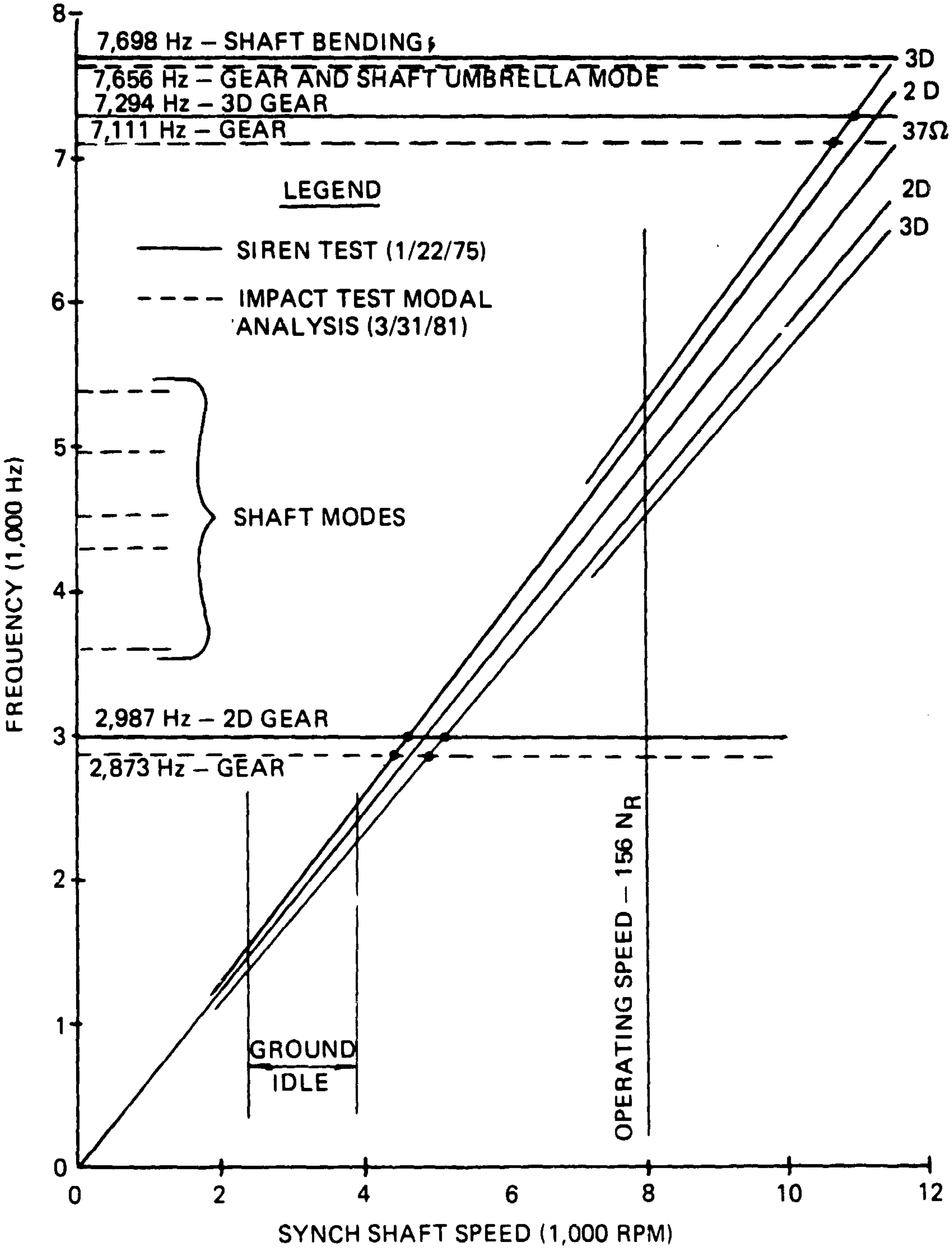



Figure 39.

BEVEL PINION CALCULATED MODAL FREQUENCIES

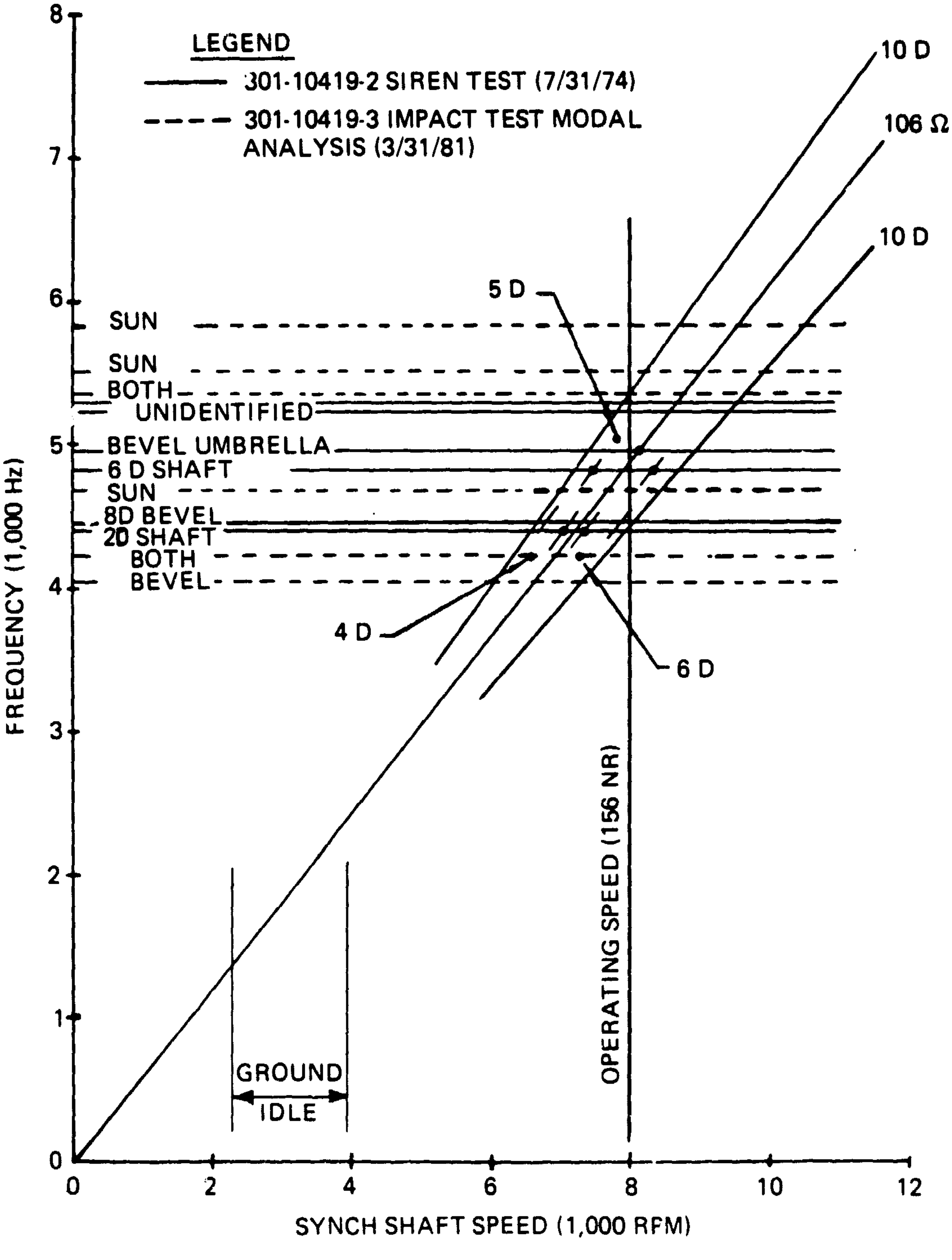



Figure 40.

BEVEL GEAR CALCULATED MODAL FREQUENCIES

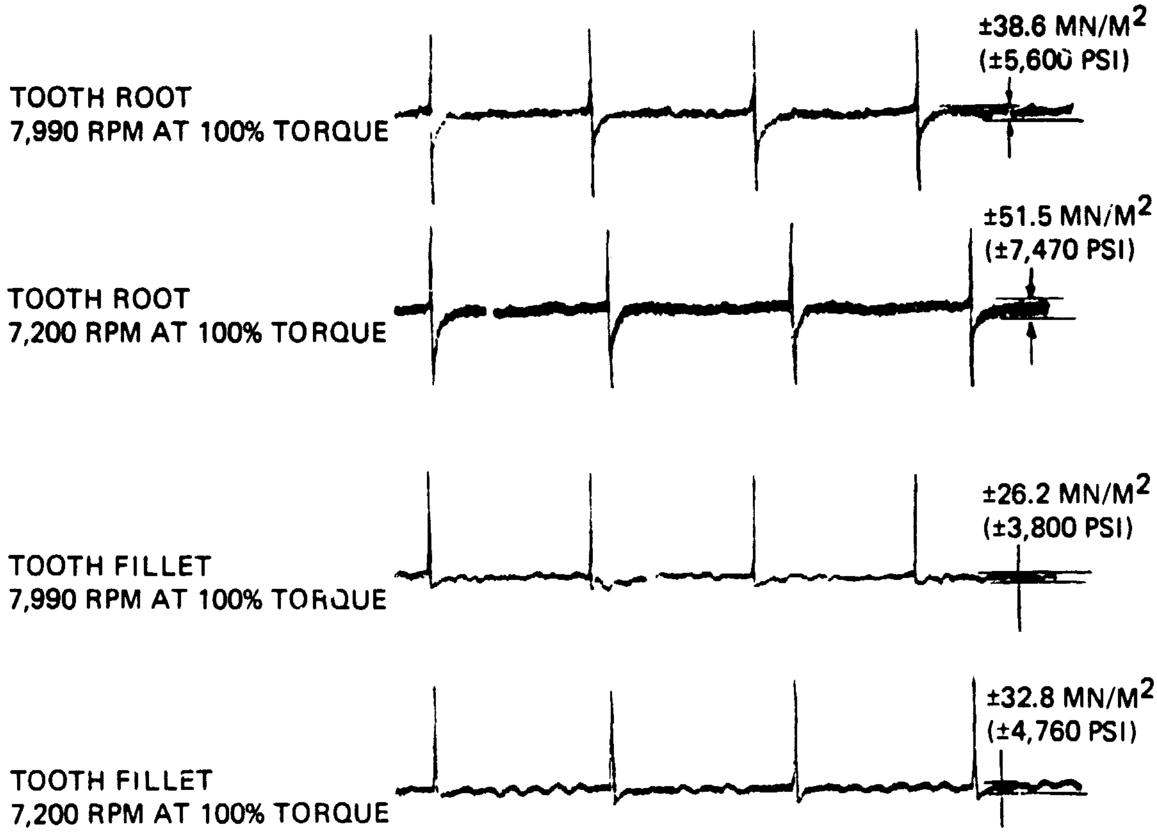



FIGURE 41.

BEVEL GEAR MEASURED VIBRATORY STRESSES AT TOOTH ROOT AND FILLET

## 7.0 LOAD TEST

Load running of the transmission began with 50 hours of load buildup testing at 80% and 90% design torque and concluded with 50 hours of testing at 100% design torque (83,810 inch-pounds, equivalent to 9463 Nm torque at the input shaft). All load testing was conducted at 100% design input speed (7,986 rpm). The combination of 100% torque and rpm equates to 10,620 hp (7900 KW).

The load test program was conducted using a synthetic lubricating oil conforming generally to MIL-L-23699 but with superior load carrying ratings. This oil is Aeroshell 555, a product of Royal Lubricants, Hanover, N.J. The transmission-mounted air-oil cooler and mechanically driven blower was used throughout the test. Test oil temperature was the result of cooling capability and test cell air temperature. Oil at the cooler inlet varied from 80°C to 90°C, or about 60°C over ambient air temperature. This indicates an adequate margin for hot day (52°C) operation without exceeding red-line oil temperature of 140°C.

A record of test conditions and raw data is given in the appended Load Run Log.

The chronology of the 100 hours of testing is shown in Table 6. The incidents noted are further described as follows:

At 10:00 hours - Failure of the pressure switch occurred. This switch is mounted on the transmission housing and is subject to acceleration on the order of 50 G's. The switch body failed through a weld. Corrective action will include redesign and qualification. For this test series the component was replaced with a like part and running was resumed.

At 16:55 hours - The indicating screen warning light flick- ered on. When the screen was removed for inspection, pieces of strain gage instrumentation material were found adhering to it forming a conductive path between positive and negative wires. The screen was cleaned and replaced.

At 52:00 hours - Debris was found in the drain of a test stand gearbox, unrelated to the aft transmission. Disassembly of the test stand gearbox disclosed a bearing failure which was repaired, causing a test delay. At the same time, a piece of debris approximately 2.5 mm square was discovered in the aft transmission sump. It was determined that this material came from a single castellation of an accessory gear bearing locknut. Since the locking system on this locknut is redundant, no replacement was deemed necessary.

At 73:35 hours - Testing was stopped briefly at 73:35 hours due to a main screen indication light. Inspection of the screen revealed nothing, but one small chip was found on the sump magnetic detector. Analysis showed the chip to be M50 steel. The decision was made to continue running.

Before start-up on 3/10/82, several more small flakes were found on the magnetic chip detector. Testing continued to 81 hours. Prior to shut down the main screen light came on at the console. On 3/11/82, inspection of the magnetic detector in the sump revealed one small flake. Inspection of the main screen revealed pieces of instrumentation wiring. Many spall type flakes were found in the main screen sump cavity and upon removal of the sump, additional spall flakes were found in the bottom of the sump.

The transmission was removed from the stand for disassembly. Disassembly inspection revealed the 301-10414-3 first stage planet P125 (bearing assembly S/N VB18R) to be spalled on the upper row of the inner race. This planet assembly was re- placed by P137 (S/N VB108T).

Inspection also revealed that 301-10414-3 first stage planet assembly S/N VB105T had three teeth of the 301-10466-2 gear S/N P152 chipped on the ends due to case/core separation. The teeth were blended smooth for continued testing.

All other first stage planet teeth were magnetic particle inspected and no defects were found.

Visual inspection of the second stage planets and spiral bevel gears found them to be in excellent condition.

At 90:00 hours - An aluminum tube fitting connecting the main lube oil pressure transducer to the transmission housing failed in fatigue. A replacement steel tube fitting was substituted. Shortly after this the transducer failed to transmit a signal and was replaced with a like part.

At 100 hours, the test was completed with no further incident and the test transmission was removed from the test stand.

## POST-TEST INSPECTIONS

All main drive gearing (bevel pinion, bevel gear, sun gear, planets) and first stage carrier were disassembled for magnetic particle inspection. No indications were found. The main housing was zyglo inspected in the intersections between center bearing webs and outer housing, and found free of indications.

Gear tooth surfaces were inspected and the following observations were made:

Spiral bevel pinion - (Figure 42)

General condition of pinion was quite good, with no load related distress observed. A single mark which resembled a small frosted area approximately 1.5 mm x 1.5 mm in size was observed on the upper flank of every tooth at the heel end. This was caused by contact with a very small area of grind non-cleanup on two mating gear teeth. Since the ratio is hunting, each mark on the pinion was identical.

Grinding contact lines were plainly evident on the tooth surface (Figure 43) within the contact pattern but they remained unchanged during the entire run indicating the existence of a good lubricating condition.

Spiral bevel gear - (Figure 44)

Overall condition of teeth was excellent (Figure 45). Pattern was fully developed, free of hard lines, and no evidence of any distress was observed. Two teeth showed a small area of grinding non-cleanup which resulted in the pinion marking described above.

First Stage Sun Gear - (Figure 46)

Some light frosting was present in the dedendum area of the teeth only at the lower end of the face. The distress did not progress and appeared to have healed slightly. This condition indicates that additional profile modification would be desirable. Some slight debris damage was noted. Contact pattern was fully developed and free of any hard lines.

First Stage Planets - (Figures 47, 48, 49 and 50)

Some very light frosting at the very tips of the teeth on the sun side was barely visable. Increased profile modification on the sun will eliminate this. Some debris damage was noted but it was slight on the sun side and somewhat more evident on the ring side. Figure 50 illustrates the blending of the tooth ends of planet gear P152 referred to previously.

Second Stage Sun Gear

The condition of this gear was excellent. Contact patterns on both flanks were fully developed and free of hard lines. Tooth surface still showed original grind marks indicating lubrication state to be good. Some very minor debris damage was noted.

Second Stage Planets - (Figures 51, 52 and 53)

The condition of these gears was the same as the sun. The debris damage on the ring side was somewhat more extensive than on the sun side, but no fatigue propagation was noted.

Internal Ring Gear

The overall condition of this part was quite good except that substantial debris damage (from the planet bearing failure) was noted. Contact patterns were good and no hard lines were noted.

Bearing surfaces were inspected and the following observations were made:

Bevel Pinion Tapered Roller Bearings

Both bearings were in excellent condition. There was no evidence of roller skidding or any surface distress on critical operating surfaces. The inboard bearing (P/N 301-10420) did show heavy fretting on the bore and side faces while the outboard bearing (P/N 301-10424) showed only light fretting on the bore. No other discrepancies were noted. Figure 54 shows the roller paths, inner and outer of 301-10420 bearing.

Bevel Gear Tapered Roller Bearings

Both bearings on the bevel gear were also in excellent condition. The upper bearing (P/N 301-10443) showed evidence of heavy fretting on the bore while the lower bearing (P/N 301-10440) showed only light fretting on the bore. No other discrepancies were noted.

Planetary Bearings

Both the first and second stage bearing assemblies showed debris damage on all components. It appears that the second stage had more damage due to debris from the failed first stage planet bearing. The second stage also showed evidence of glazing on the inner ring raceway. The second stage planet bearing cage had debris embedded into it and several pockets showed heavy polishing of the silver plate. The first stage planet cages were in excellent condition. Figure 55 shows the spalled inner race of first-stage assembly VB18R replaced after 81 test hours.

The rotor shaft bearings were not disassembled. No indications of any problems were observed in this area.

Accessory gears and bearings were examined visually. There were no discrepancies in this area except for the locknut castellation noted in the test record.

DISCUSSION OF LOAD TEST RESULTS

The aft transmission completed 100 hours of load running in generally excellent condition. The minor discrepancies noted in the post-test examination can be corrected by known procedures. For example, the case-core separation at the tooth tips has been corrected in recent designs (CH-47D) by chamfering the ends of the teeth and by increasing the end breaks. The frosting in the root of the first stage sun gear indicates a need for slightly more involute profile modification. The minor surface distress observed on the bevel pinion at the heel was caused by contact with non-cleanup areas on several teeth at the mating bevel gear. Further running of this gear set would be proceeded by a blending out of the non-cleanup areas.

Post test analysis of the spalled planetary bearing inner race was conducted by the bearing manufacturer. The conclusions of this analysis can be summarized as follows:

- Cage pockets exhibit an even wear pattern, indicating that the rollers were properly oriented during operation.

- There was little, if any, sliding of the roller on the roller path.

- Cage lands are in good condition.

- Metallurgical analysis of the inner ring showed it was in conformance with specification limits. Ring hardness was RC 60.5. No grinding damage was found.

- Dimensional checks of the roller path location and radii along with roller characteristics showed all dimensions within drawing limits on the spalled raceway.

- There appeared to be no lubrication problem, based on surface appearance.

The cause of the spall was thus not identified, since the fatigue origin was lost in the damaged area. The spall is considered to be a random occurrence, and no design changes are considered necessary.

## TABLE 6 - CHRONOLOGY OF HLH AFT TRANSMISSION LOAD RUN TESTING

| % LOAD | DATE | HOURS THIS DATE | HOURS CUM. | INCIDENTS/OBSERVATIONS |
|---|---|---|---|---|
| 80% | 01/13/82 | 10:00 | 10:00 | Low oil pressure warning light switch failed & replaced. |
| 80% | 01/14/82 | 6:55 | 16:55 | Strain gage debris found on indicating screen. |
| 80% | 01/15/82 | 5:05 | 22:00 | None |
| 80% | 01/18/82 | 3:00 | 25:00 | None |
| 90% | 01/18/82 | 4:00 | 29:00 | None |
| 90% | 01/19/82 | 7:00 | 36:00 | None |
| 90% | 01/20/82 | 8:00 | 44:00 | None |
| 90% | 01/21/82 | 6:00 | 50:00 | None |
| 100% | 01/21/82 | 2:00 | 52:00 | Test stand gearbox failed. Found segment of bearing locknut in sump. |
| 100% | 03/05/82 | 8:00 | 60:00 | None |
| 100% | 03/08/82 | 8:00 | 68:00 | None |
| 100% | 03/09/82 | 7:00 | 75:00 | Main indicating screen light |
| 100% | 03/10/82 | 6:00 | 81:00 | Bearing spall debris found on screen |
| 100% | 03/18/82 | 1:30 | 82:30 | None |
| 100% | 03/19/82 | 7:30 | 90:00 | Main pressure transducer connection failed and main pressure transducer failed. |
| 100% | 03/22/82 | 7:00 | 97:00 | None |
| 100% | 03/23/82 | 3:00 | 100:00 | None |





FIGURE 42 BEVEL PINION AFTER TEST

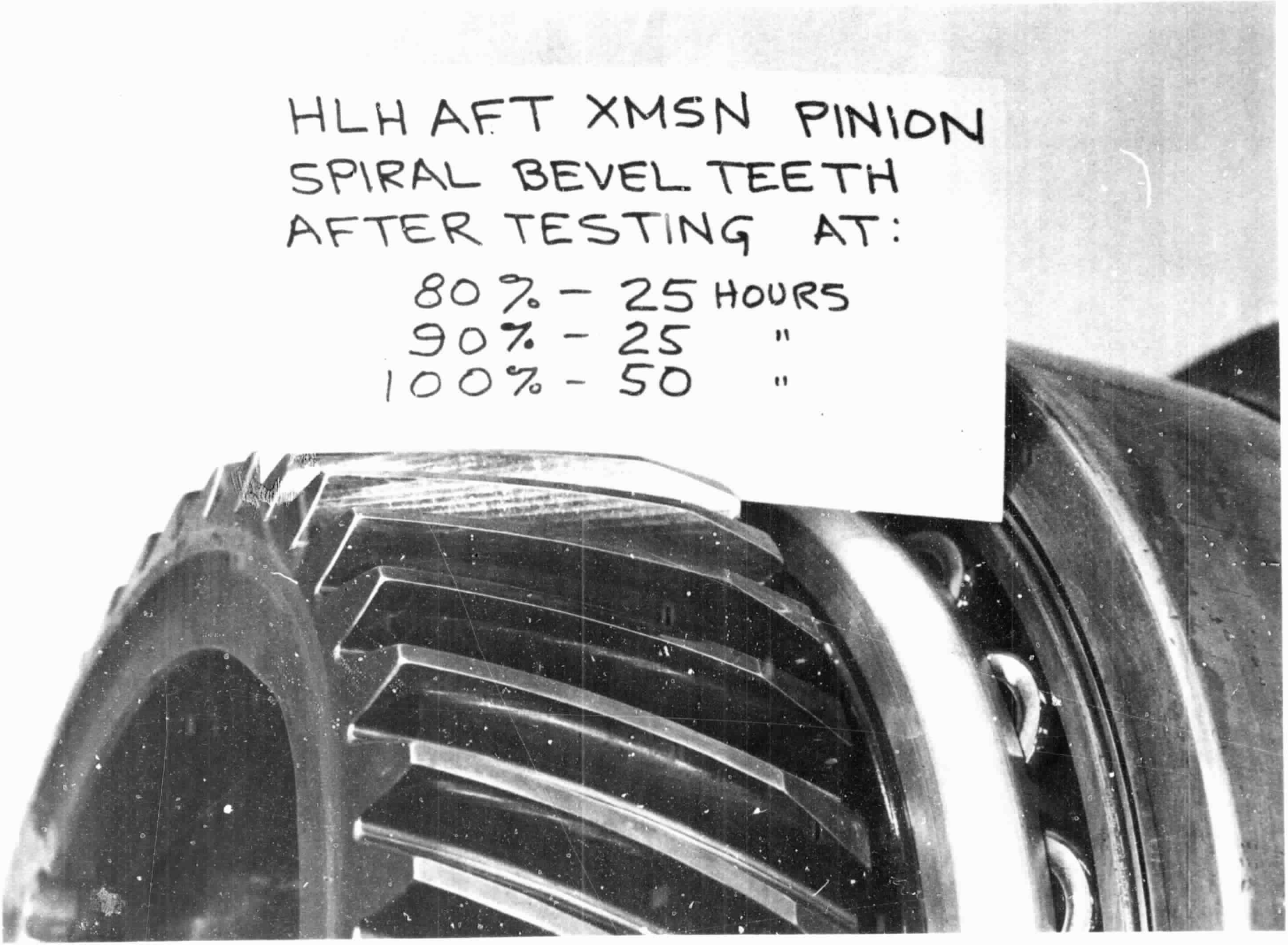



FIGURE 43 BEVEL PINION TOOTH SURFACES


FIGURE 44 BEVEL GEAR AFTER TEST

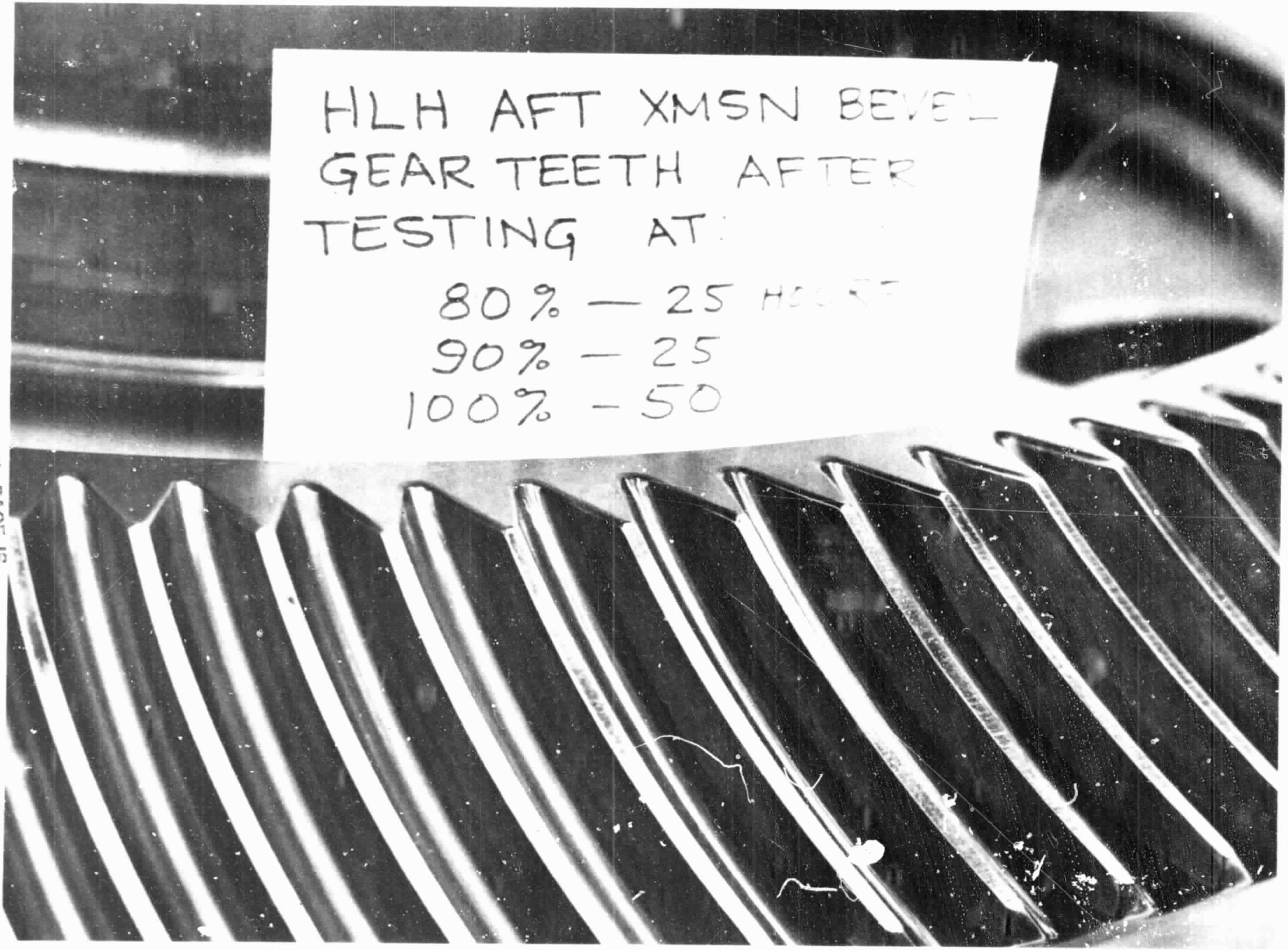



FIGURE 45 BEVEL GEAR TOOTH SURFACES


FIGURE 46 FIRST STAGE SUN GEAR TOOTH SURFACES

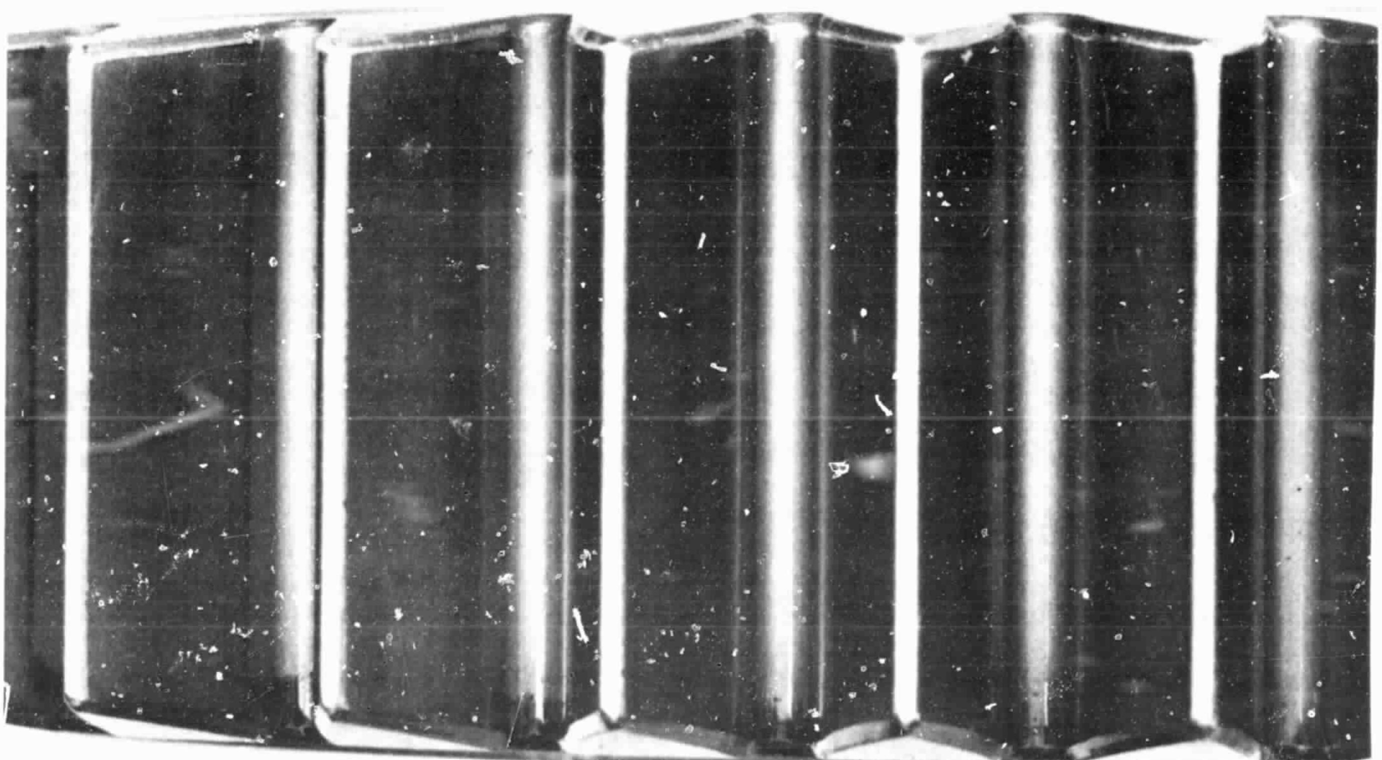


FIGURE 47 FIRST STAGE PLANET TOOTH SURFACES - SUN GEAR CONTACT

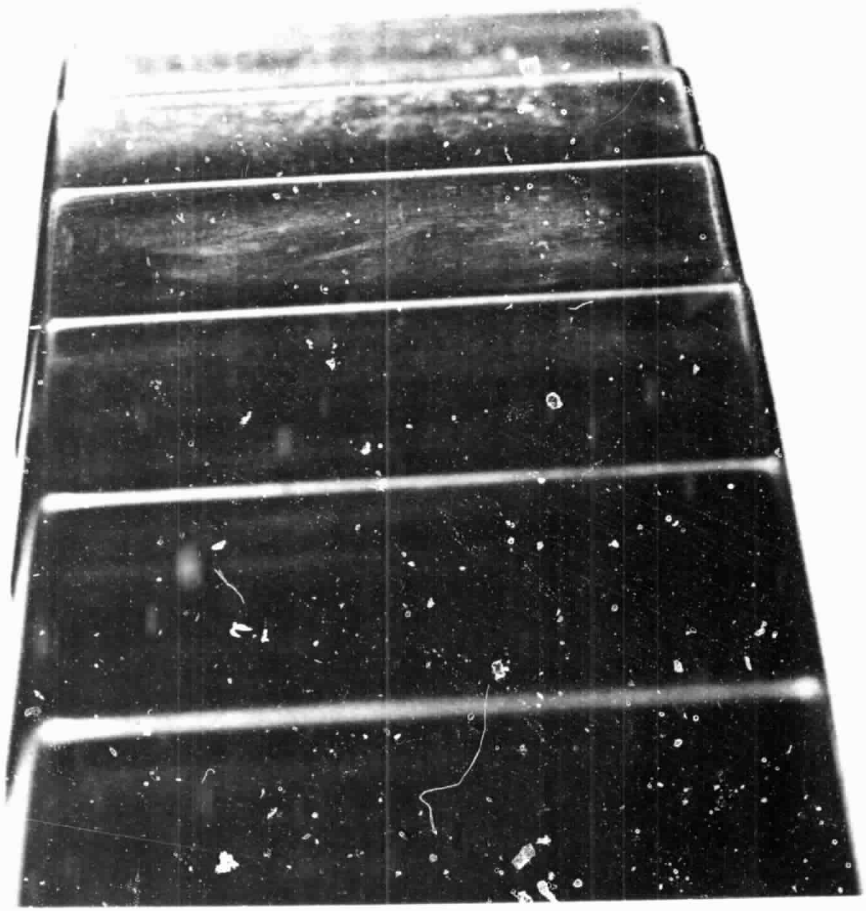


FIGURE 48 FIRST STAGE PLANET GEAR TOOTH SURFACES - RING GEAR CONTACT

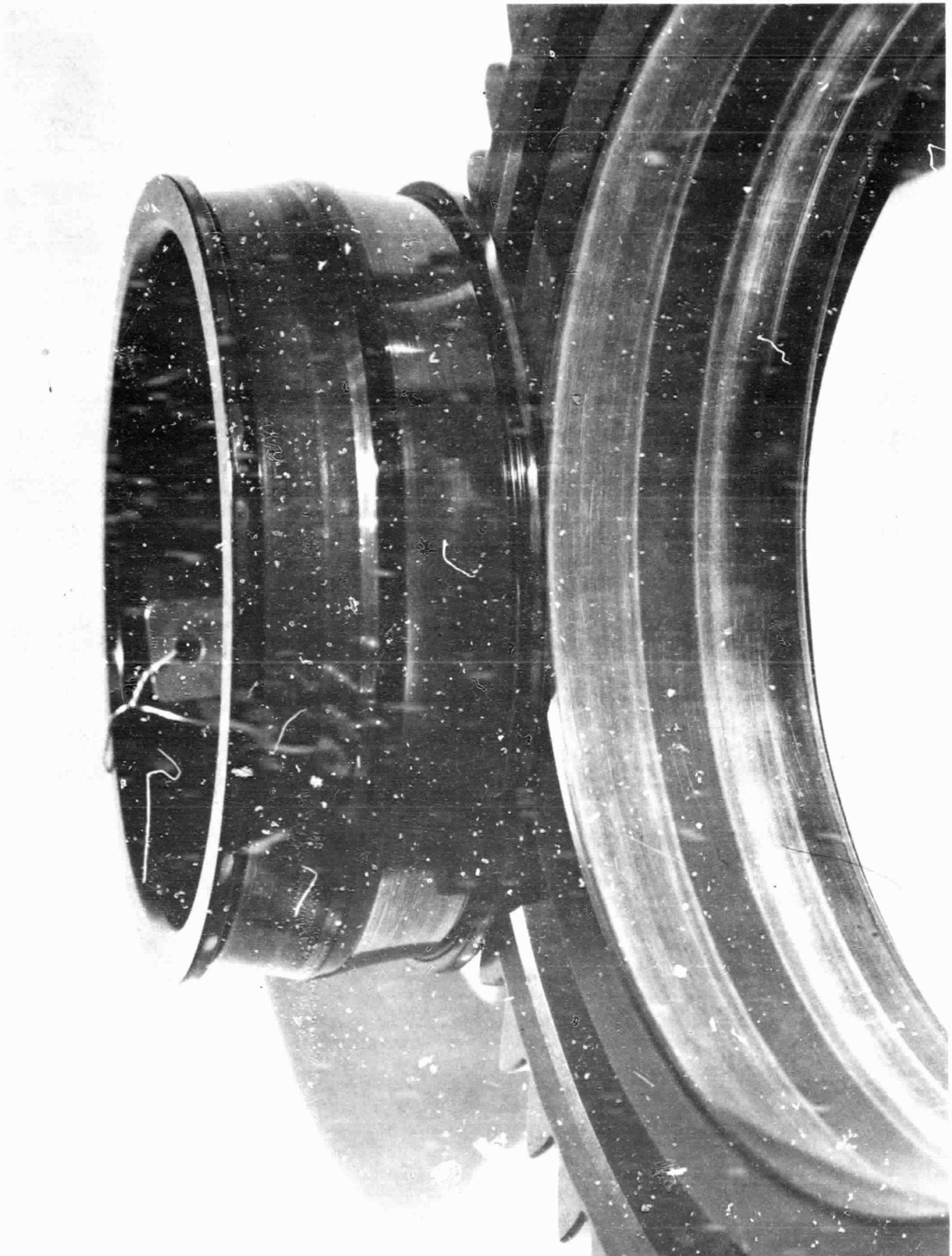


FIGURE 49 FIRST STAGE PLANET SPHERICAL BORE AND INNER RACE

FIGURE 50 FIRST STAGE PLANET TOOTH END ROUND-OFF

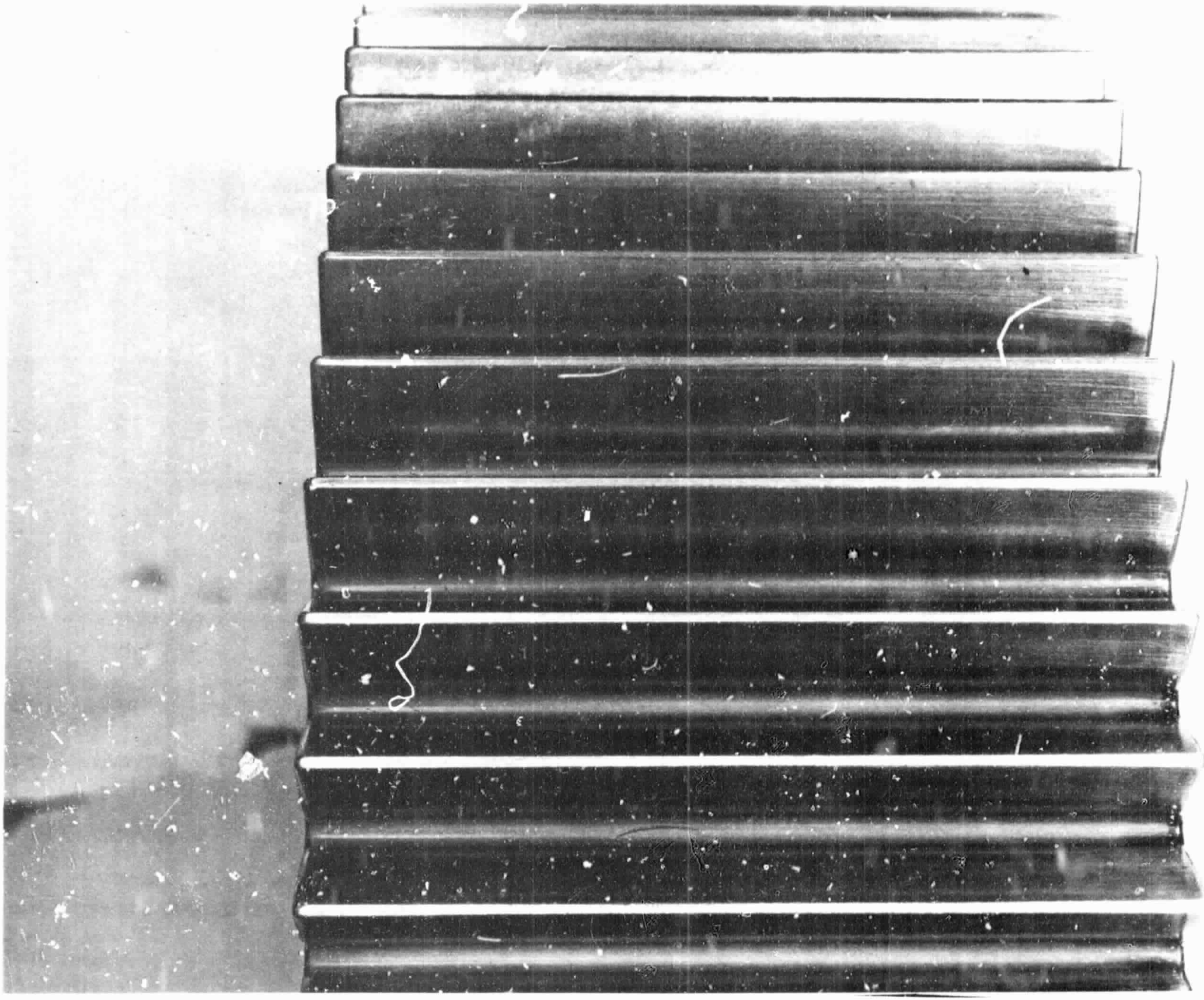


FIGURE 51   SECOND STAGE PLANET TOOTH SURFACES - SUN GEAR CONTACT

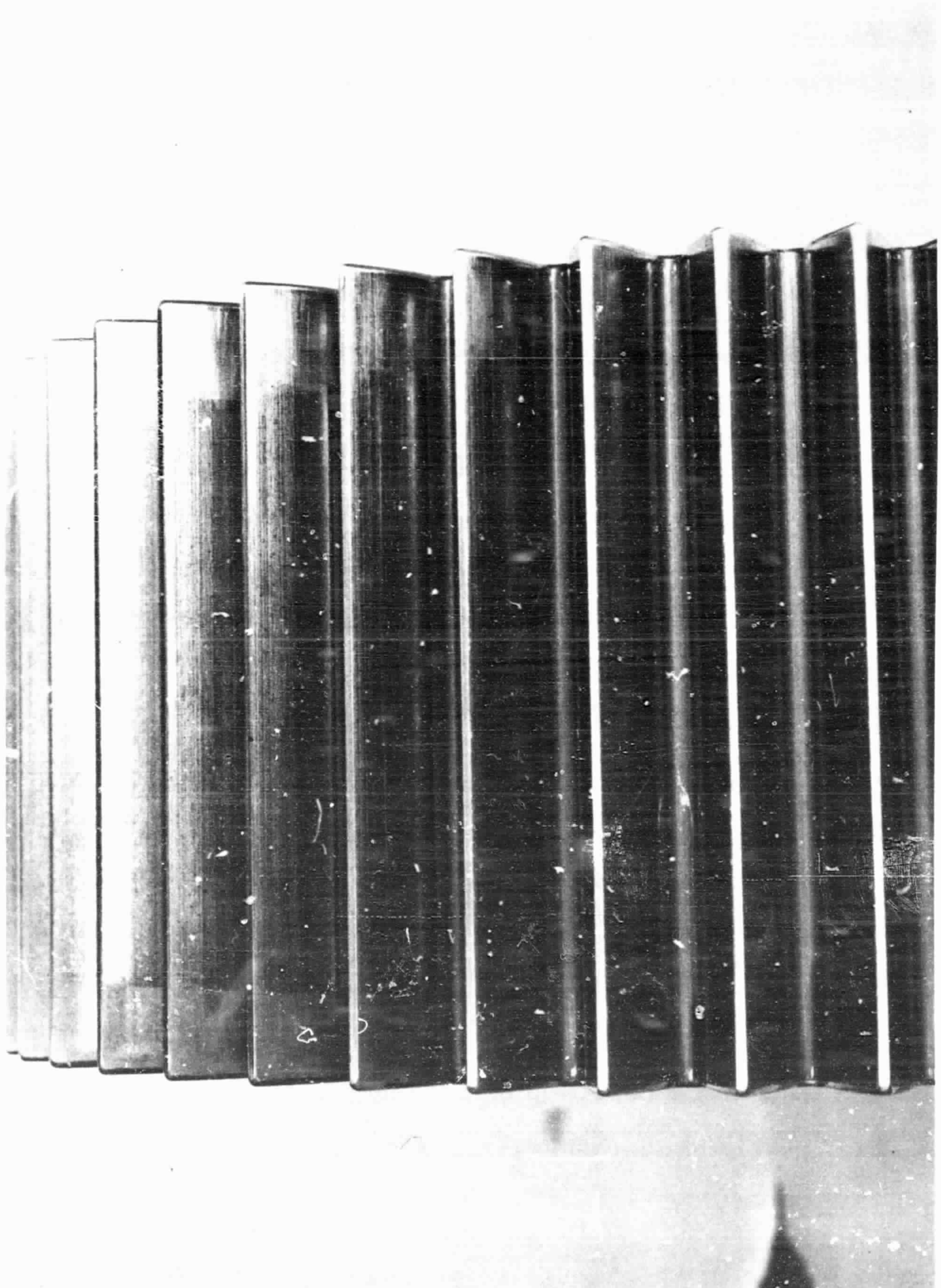


FIGURE 52 SECOND STAGE PLANET TOOTH SURFACES - RING GEAR CONTACT



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BLACK AND WHITE PHOTOGRAPH

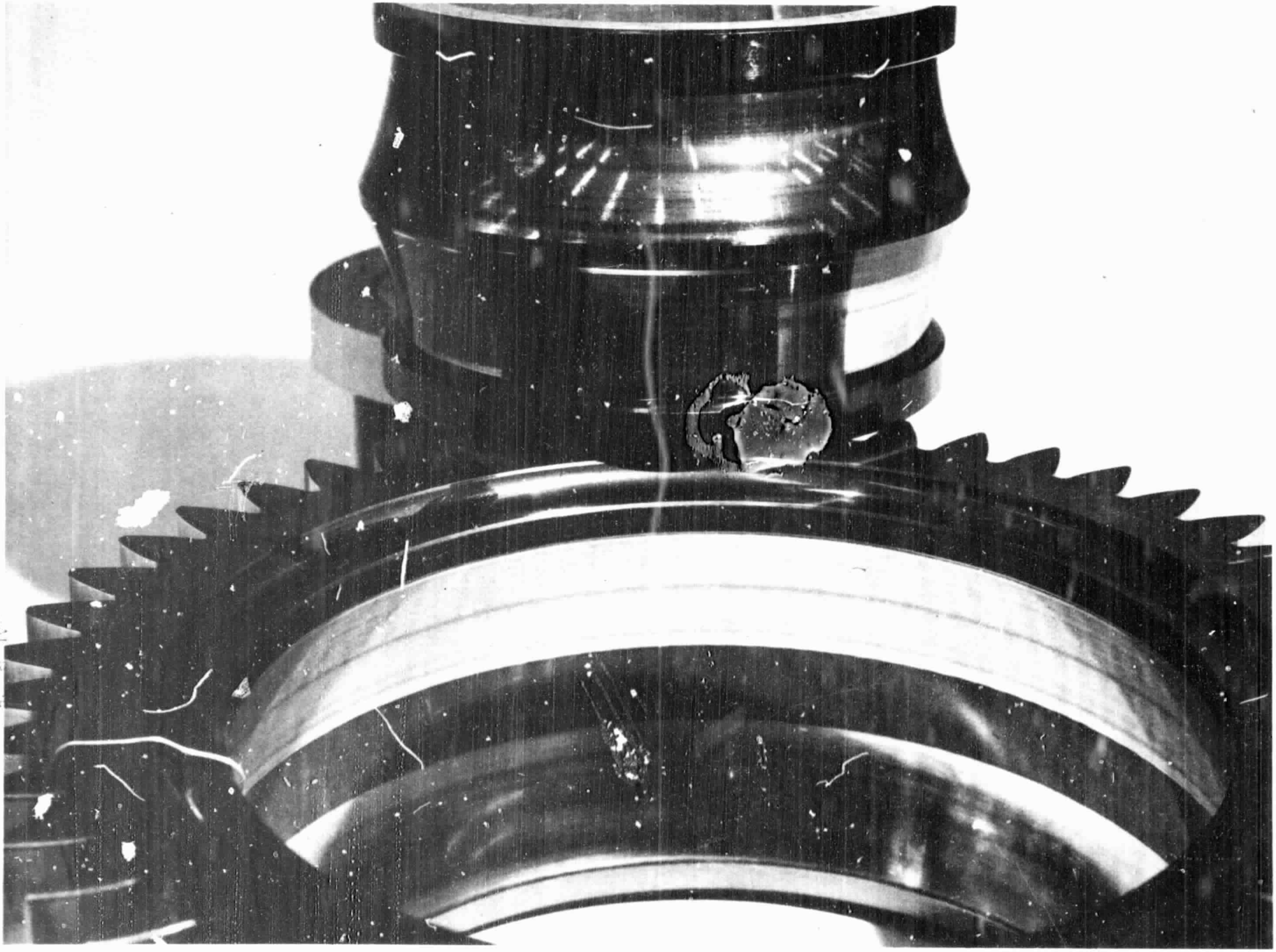

FIGURE 53   SECOND STAGE PLANET SPHERICAL BORE AND INNER RACE

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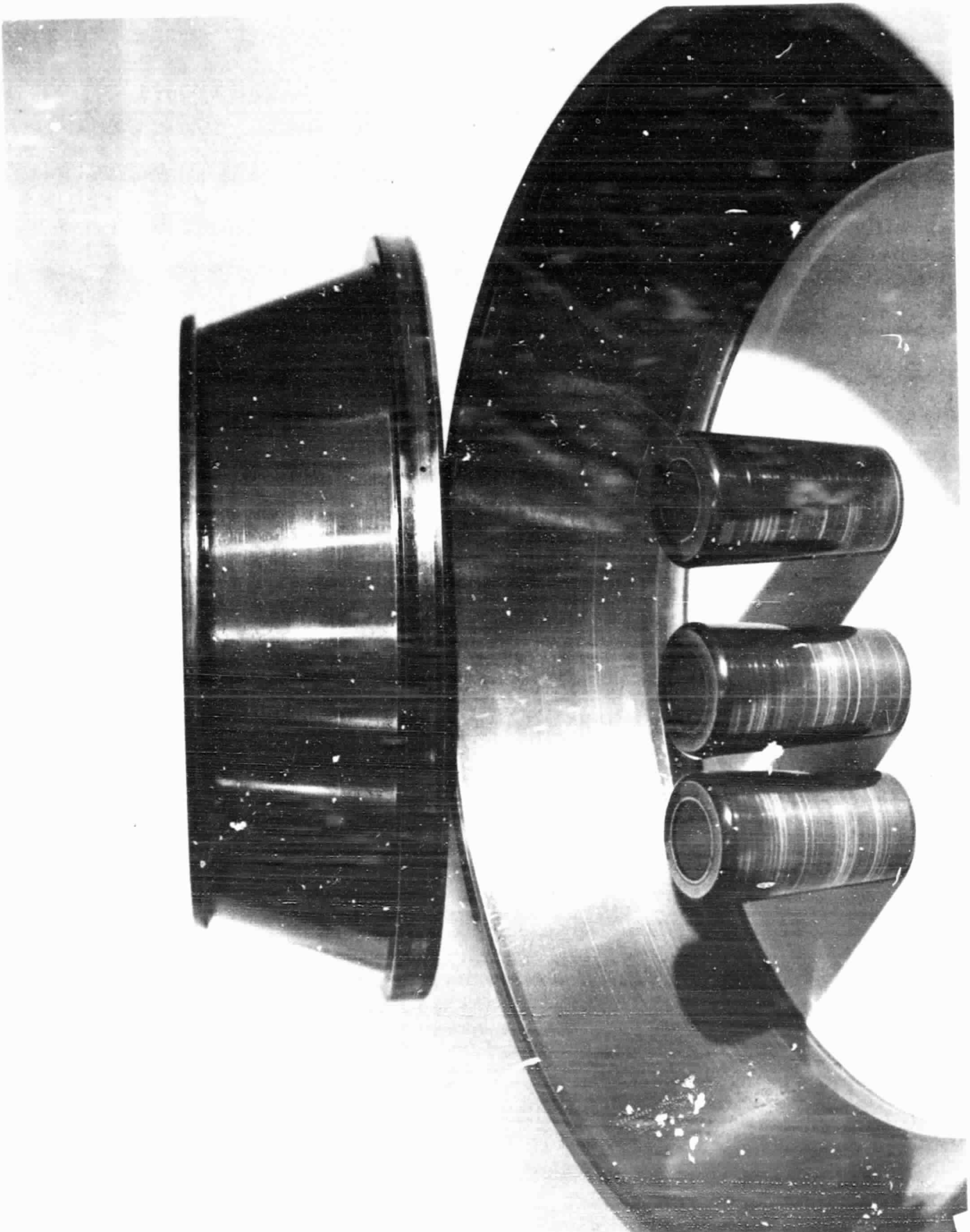

FIGURE 54 PINION INBOARD BEARING - CUP, CONE AND ROLLERS

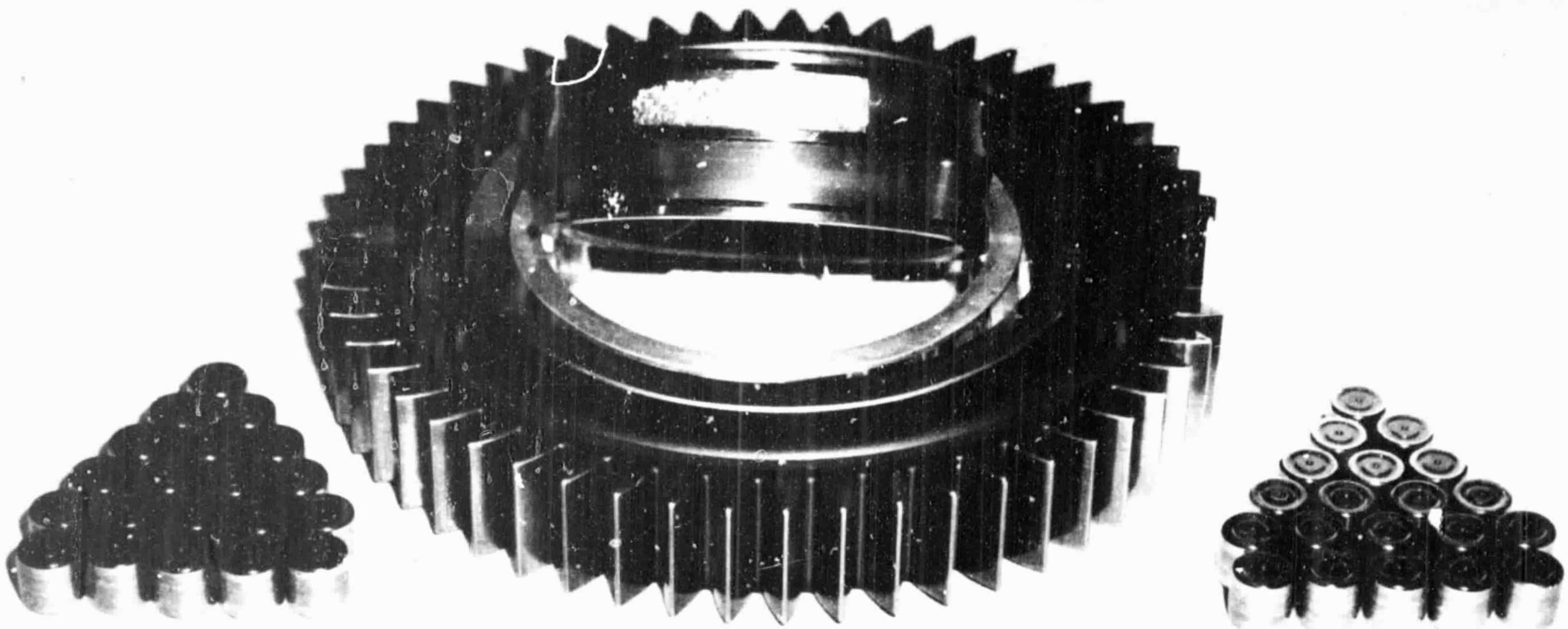

FIGURE 55 FIRST STAGE PLANET BEARING - SPALLED BEARING INNER RACE

APPENDIX

LOAD RUN LOG

DYNAMATIC OUTPUT
RPM 685 AT 7986 SYNC.

# HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 | DESCRIPTION OF TEST 50 HR. ENDURANCE @ 80/100%

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 1-8-82 | F. J. Monemaker | AEROSHELL 555 | NO. 2 | 3-31 807. = 67048 "# |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | [redacted]2 - [redacted] "# 7986 RPM REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 0945 | 10 MIN (WARMUP) | 75 | 9000 | 134 | 7986 | 106 | 104 | 60°C | ADDED 2½ GAL TO DYNAMATIC |
| 0955 | | 76 | 9000 | 131 | 7990 | 104 | 100 | 70 | 1.2 MEGAWATTS ON MOTOR. |
| 1055 | 0 | 77 | 67000 | 700 | 7985 | 100 | 98 | 80 | |
| 1125 | 00:30 | 81 | 67000 | 695 | 7986 | 100 | 95 | 80 | |
| 1155 | 01:00 | 84 | 67000 | 690 | 7987 | 100 | 95 | 82 | |
| 1225 | 01:30 | 85 | 67000 | 688 | 7986 | 100 | 95 | 82 | |
| 1255 | 02:00 | 86 | 67000 | 688 | 7984 | 99 | 95 | 82 | |
| 1325 | 02:30 | 86 | 67000 | 687 | 7984 | 100 | 98 | 82 | |
| 1337 | 02:42 | — | — | — | | — | | — | OVERSPEED TRIP AUTO SHUTDOWN DYNA. FAILURE ~10,000 RPM |
| 1-8 F2 | RESTART | AFTER | REPAIR OF | DYNAMATIC | | TACH | GENERATOR | | |
| 0805 | | 69 | 10000 | 205 | 7988 | 108 | 104 | 40° | |
| 0815 | 10 MIN (WARM-UP) | 71 | 10000 | 203 | 7989 | 104 | 100 | 67 | |
| | | | | | | | | | ADDED 1GAL TO DYNAMATIC |
| 0815 | 02:42 | 71 | 67000 | 705 | 7989 | 104 | 100 | 67 | RESUME TEST |
| 0833 | 03:00 | 74 | 67000 | 700 | 7983 | 102 | 98 | 80 | 1.22 MEGAWATTS ON MOTOR |
| 0903 | 03:30 | 77 | 67000 | 695 | 7986 | 100 | 98 | 80 | 1.2 MEGAWATTS ON MOTOR |
| 0933 | 04:00 | 78 | 67000 | 690 | 7982 | 100 | 97 | 80 | |
| 1003 | 04:30 | 80 | 67000 | 690 | 7988 | 100 | 97 | 81 | |
| 1033 | 05:00 | 81 | 67000 | 685 | 7986 | 100 | 97 | 81 | |
| 1103 | 05:30 | 82 | 67000 | 685 | 7994 | 100 | 97 | 81 | |

# HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 | DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 1-13-82 | H J Honemaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | 80% = 67048 "# 7986 RPM REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 11:33 | 6:00 | 82 | 67000 | 685 | 7992 | 100 | 97 | 81 | |
| 12:03 | 6:30 | 83 | 67000 | 683 | 7985 | 100 | 97 | 81 | |
| 12:33 | 7:00 | 84 | 67000 | 684 | 7984 | 100 | 97 | 81 | |
| 13:03 | 7:30 | 84 | 67000 | 680 | 7981 | 100 | 97 | 81 | |
| 13:33 | 8:00 | 85 | 67000 | 682 | 7985 | 100 | 77 | 81 | |
| 14:03 | 8:30 | 85 | 67000 | 682 | 7983 | 100 | 97 | 81 | |
| 14:33 | 9:00 | 86 | 67000 | 680 | 7980 | 100 | 97 | 81 | |
| 15:03 | 9:30 | 86 | 67000 | 682 | 7981 | 100 | 97 | 82 | |
| 15:33 | 10:00 | 86 | 67000 | 690 | 7984 | 100 | 97 | 82 | 1.47 MEGAWATTS ON MOTOR |
| 1-14-82 | SHUT DOWN END OF SHIFT (MAIN OIL PRESS SWITCH FAILED, REPLACED WITH MOUNTING ON STAND) | | | | | | | | |
| 0800 | 10 MIN (WARM-UP) | 71 | 8000 | 190 | 7986 | 106 | 105 | 33 | |
| 0810 | | 75 | 9000 | 188 | 7982 | 104 | 102 | 70 | |
| 08:10 | 10:00 | 75 | 67000 | 700 | 7988 | 102 | 100 | 75 | RESUME TEST |
| 0840 | 10:30 | 78 | 67000 | 690 | 7984 | 100 | 99 | 80 | |
| 09:10 | 11:00 | 81 | 67000 | 690 | 7987 | 100 | 99 | 80 | |
| 09:40 | 11:30 | 81 | 67000 | 690 | 7990 | 100 | 99 | 80 | |
| 10:10 | 12:00 | 82 | 67,000 | 685 | 7988 | 100 | 98 | 81 | |
| 10:40 | 12:30 | 83 | 67,000 | 685 | 7985 | 100 | 98 | 81 | |
| 11:10 | 13:00 | 84 | 67,000 | 685 | 7989 | 100 | 98 | 81 | 1.06 MEGAWATTS |
| 11:40 | 13:30 | 84 | 67,000 | 685 | 7984 | 100 | 98 | 81 | |
| 12:10 | 14:00 | 84 | 67,000 | 680 | 7988 | 100 | 98 | 81 | |
| 12:40 | 14:30 | 85 | 67,000 | 680 | 7988 | 100 | 98 | 81 | |

HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 1-14-82 | H.G. Moosmaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | 80% = 67048 "# 7986 RPM REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 13:10 | 15:00 | 85 | 67,000 | 680 | 7988 | 100 | 98 | 81 | |
| 13:40 | 15:30 | 85 | 67,000 | 680 | 7989 | 100 | 98 | 81 | |
| 14:10 | 16:00 | 86 | 67,000 | 682 | 7981 | 100 | 98 | 81 | |
| 14:40 | 16:30 | 86 | 67,000 | 682 | 7994 | 100 | 95 | 81 | |
| 15:05 | 16:55 | 86 | 67,000 | 683 | 7995 | 100 | 78 | 81 | MAIN SCREEN CHIP LITE |
| 1-15-82 | END OF SHAFT | | | | | | | | |
| 08:35 | 10 MIN | 74 | 15,000 | 196 | 7990 | 104 | 102 | 62 | |
| 08:45 | WARM-UP | 76 | 15,000 | 196 | 7993 | 102 | 100 | 71 | |
| | | AUX SCREEN LITE | SHUT DOWN | | | | | | |
| 09:05 | 10 MIN | 76 | 15,000 | 184 | 7998 | 104 | 102 | 70 | |
| 09:15 | WARMUP | 77 | 15,000 | 181 | 7986 | 102 | 100 | 71 | |
| 09:15 | 16:55 | 77 | 67,000 | 650 | 7989 | 102 | 100 | 78 | RESUME TEST |
| 09:30 | 17:10 SHUT | DOWN | AUX SCREEN LITE | | | | | | |
| 11:20 | 17:10 | 76 | 67,000 | 640 | 7998 | 104 | 102 | 75 | RESUME TEST |
| 11:40 | 17:30 | 80 | 67,000 | 639 | 7987 | 100 | 99 | 80 | |
| 12:10 | 18:00 | 82 | 67,000 | 639 | 7986 | 100 | 98 | 80 | 1.2 MEGAWATTS |
| 12:40 | 18:30 | 83 | 67,000 | 639 | 7983 | 100 | 98 | 80 | |
| 13:10 | 19:00 | 84 | 67,000 | 637 | 7992 | 100 | 98 | 80 | |
| 13:40 | 19:30 | 84 | 67,000 | 632 | 7993 | 100 | 98 | 80 | |
| 14:10 | 20:00 | 85 | 67,000 | 633 | 7995 | 100 | 98 | 80 | |
| 14:40 | 20:30 | 85 | 67,000 | 635 | 7985 | 100 | 98 | 81 | |
| 15:10 | 21:00 | 86 | 67,000 | 638 | 7999 | 100 | 98 | 81 | |

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# HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 | DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 1-15-82 | H J Honemaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 80% = 67,048 "# 7986 RPM |
| 15:40 | 21:30 | 87 | 67,000 | 638 | 7984 | 100 | 98 | 81 | |
| 16:10 | 22:00 | 87 | 67,000 | 635 | 7982 | 100 | 98 | 81 | SHUT DOWN END OF SHIFT |
| 1-18-82 | | | | | | | | | |
| 08:10 | 30 MIN | 63 | 13,000 | 175 | 8030 | 106 | 104 | 50 | |
| 08:20 | WARMUP | 65 | 13,000 | 171 | 7983 | 104 | 102 | 70 | |
| 08:30 | ~~[illegible]~~ | 67 | 28,000 | 330 | 7984 | 104 | 100 | 70 | |
| 08:35 | | 68 | 41,000 | 456 | 7986 | 102 | 100 | 71 | |
| 08:40 | | 69 | 45,000 | 458 | 7986 | 102 | 100 | 73 | |
| 08:40 | 22:00 | 69 | 67,000 | 665 | 7988 | 102 | 100 | 75 | RESUME TEST |
| 09:10 | 22:30 | 73 | 67,000 | 655 | 7983 | 101 | 99 | 78 | |
| 09:40 | 23:00 | 74 | 67,000 | 655 | 7982 | 101 | 99 | 78 | 1.08 MEGAWATTS |
| 10:10 | 23:30 | 76 | 67,000 | 640 | 7982 | 100 | 98 | 79 | |
| 10:40 | 24:00 | 76 | 67,000 | 640 | 7984 | 100 | 98 | 79 | |
| 11:10 | 24:30 | 78 | 67,000 | 640 | 7990 | 100 | 98 | 80 | |
| 11:40 | 25:00 | 79 | 67,000 | 644 | 7980 | 100 | 98 | 80 | |
| | INCREASE TORQUE TO 90% = 75429 "# @ 7986 RPM | | | | | | | | |
| 11:40 | 25:00 | 79 | 75,500 | 715 | 7982 | 100 | 98 | 80 | 1.08 MEGAWATTS |
| 12:10 | 25:30 | 80 | 75,500 | 718 | 7980 | 100 | 98 | 81 | |
| 12:40 | 26:00 | 81 | 75,500 | 718 | 7988 | 100 | 98 | 82 | |
| 13:10 | 26:30 | 81 | 75,500 | 719 | 7990 | 100 | 98 | 82 | |
| 13:40 | 27:00 | 82 | 75,500 | 720 | 7987 | 100 | 98 | 82 | |
| 14:10 | 27:30 | 82 | 75,500 | 715 | 7989 | 100 | 98 | 82 | |

HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 | DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 1-18-82 | [signature] | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | 90% TQ = 75,429 "# 7986 RPM REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 14:40 | 28:00 | 82 | 75,500 | 715 | 7971 | 100 | 98 | 82 | PANALARM - LOW PRESS AFT XMSN 14:45 (FALSE INDICATION) |
| 15:10 | 28:30 | 82 | 75,500 | 715 | 7994 | 100 | 98 | 82 | |
| 15:40 | 29:00 | 82 | 75,500 | 715 | 7998 | 100 | 98 | 82 | |
| | SHUT DOWN END OF SHIFT | | | | | | | | |
| 07:50 | 10 MIN | 70 | 10,000 | 156 | 7994 | 106 | 104 | 50 | |
| 08:00 | WARMUP | 73 | 21,000 | 263 | 7991 | 104 | 101 | 71 | |
| 08:00 | 29:00 | 73 | 75,500 | 740 | 7980 | 102 | 100 | 76 | RESUME TEST |
| 08:15 | 29:15 | 75 | 75,500 | 730 | 7988 | 100 | 98 | 80 | |
| | SHUT DOWN MAIN LUBE SCREEN LIGHT (NARMCO) | | | | | | | | |
| 09:05 | 10 MIN | 73 | 17,000 | 212 | 7990 | 104 | 102 | 70 | |
| 09:15 | WARM UP | [illegible] | 41,000 | 418 | 7997 | 103 | 101 | 75 | |
| 09:15 | 29:15 | 74 | 75,500 | 727 | 7990 | 102 | 100 | 79 | RESUME TEST |
| 09:30 | 29:30 | 77 | 75,600 | 725 | 7983 | 100 | 98 | 81 | |
| 10:00 | 30:00 | 78 | 75,500 | 720 | 7991 | 100 | 98 | 81 | |
| 10:30 | 30:30 | 79 | 75,500 | 715 | 7978 | 100 | 98 | 81 | 1.18 MEGAWATTS |
| 11:00 | 31:00 | 80 | 75,500 | 716 | 7992 | 100 | 98 | 82 | |
| 11:30 | 31:30 | 81 | 75,500 | 716 | 7987 | 100 | 98 | 82 | |
| 12:00 | 32:00 | 81 | 75,500 | 712 | 7988 | 100 | 98 | 82 | |
| 12:30 | 32:30 | 82 | 75,500 | 712 | 7988 | 100 | 98 | 82 | |
| 13:00 | 33:00 | 82 | 75,500 | 712 | 7989 | 100 | 98 | 83 | |
| 13:30 | 33:30 | 82 | 75,500 | 712 | 7996 | 100 | 98 | 83 | |
| 14:00 | 34:00 | 83 | 75,500 | 712 | 7992 | 100 | 98 | 83 | |

HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 1-18-82 | | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 90% TQ= 75,429 "# 7986 RPM |
| 14:30 | 34:30 | 83 | 75,500 | 715 | 7987 | 100 | 98 | 84 | |
| 15:00 | 35:00 | 84 | 75,500 | 715 | 7987 | 100 | 98 | 85 | |
| 15:30 | 35:30 | 84 | 75,500 | 715 | 7993 | 100 | 98 | 85 | |
| 16:00 | 36:00 | 84 | 75,500 | 714 | 7992 | 100 | 98 | 85 | |
| 1-20-82 | SHUT | DOWN | END OF | SHIFT | | | | | |
| 07:50 | 10 MIN | 73 | 9,000 | 180 | 7986 | 105 | 103 | 51 | |
| 08:00 | WARMUP | 75 | 35,000 | 412 | 7991 | 103 | 101 | 74 | |
| 08:00 | 36:00 | 75 | 75,500 | 770 | 7981 | 102 | 100 | 78 | RESUME TEST |
| 08:30 | 36:30 | 78 | 75,500 | 765 | 7989 | 100 | 98 | 82 | |
| 09:00 | 37:00 | 79 | 75,500 | 757 | 8000 | 100 | 98 | 82 | |
| 09:30 | 37:30 | 81 | 75,500 | 748 | 7990 | 100 | 98 | 82 | |
| 10:00 | 38:00 | 81 | 75,500 | 751 | 7986 | 100 | 98 | 83 | |
| 10:30 | 38:30 | 82 | 75,500 | 750 | 7986 | 100 | 98 | 84 | |
| 11:00 | 39:00 | 83 | 75,500 | 750 | 7988 | 100 | 98 | 84 | |
| 11:30 | 39:30 | 84 | 75,500 | 745 | 7994 | 100 | 98 | 84 | |
| 12:00 | 40:00 | 84 | 75,500 | 745 | 7985 | 100 | 98 | 85 | |
| 12:30 | 40:30 | 84 | 75,500 | 745 | 7994 | 100 | 98 | 85 | |
| 13:00 | 41:00 | 85 | 75,500 | 742 | 7993 | 100 | 98 | 85 | |
| 13:30 | 41:30 | 86 | 75,500 | 745 | 8000 | 100 | 98 | 85 | |
| 14:00 | 42:00 | 87 | 75,500 | 743 | 7991 | 100 | 98 | 85 | |
| 14:30 | 42:30 | 87 | 75,500 | 743 | 7990 | 100 | 98 | 86 | |
| 15:00 | 43:00 | 87 | 75,500 | 742 | 7998 | 100 | 98 | 86 | |

# HLH AFT XMSN TEST DATA SHEET

| XMSN P/N 301-104200-2 | S/N A9-100 | DESCRIPTION OF TEST ENDURANCE TEST | | |
|---|---|---|---|---|
| DATE: 1-20-82 | TEST ENGINEER: R.J. Moreemaker | OIL USED: AEROSHELL 555 | TEST CELL: NO. 2 | BUILDING: 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS (90% TQ = 75,429 IN-LB, 7986 RPM) |
|---|---|---|---|---|---|---|---|---|---|
| 15:30 | 43:30 | 87 | 75,500 | 742 | 7989 | 100 | 98 | 87 | |
| 11:00 | 44:00 | 87 | 75,500 | 742 | 7989 | 100 | 98 | 87 | |
| SHUT DOWN - END OF SHIFT | | | | | | | | | |
| 1-21-82 | | | | | | | | | |
| 07:45 | 15 MIN | 75 | 15,000 | 228 | 7993 | 105 | 103 | 56 | |
| 08:00 | WARMUP | 77 | 57,000 | 600 | 7980 | 102 | 100 | 78 | |
| 08:00 | 44:00 | 77 | 75,500 | 758 | 7994 | 101 | 99 | 79 | RESUME TEST |
| 08:30 | 44:30 | 80 | 75,500 | 758 | 7994 | 100 | 98 | 82 | |
| 09:00 | 45:00 | 81 | 75,500 | 755 | 7979 | 100 | 98 | 82 | |
| 09:30 | 45:30 | 81 | 75,500 | 750 | 7985 | 100 | 98 | 85 | |
| 10:00 | 46:00 | 82 | 75,500 | 746 | 7992 | 100 | 98 | 85 | |
| 10:30 | 46:30 | 83 | 75,500 | 746 | 7994 | 100 | 98 | 85 | |
| 11:00 | 47:00 | 84 | 75,500 | 743 | 7986 | 100 | 98 | 85 | |
| 11:30 | 47:30 | 84 | 75,500 | 743 | 7979 | 100 | 98 | 85 | |
| 12:00 | 48:00 | 83 | 75,500 | 743 | 7984 | 100 | 98 | 85 | |
| 12:30 | 48:30 | 84 | 75,500 | 745 | 7978 | 100 | 98 | 85 | |
| 13:00 | 49:00 | 85 | 75,500 | 745 | 7986 | 100 | 98 | 86 | |
| 13:30 | [illegible] | 85 | 75,500 | 746 | 7987 | 100 | 98 | 86 | |
| 14:00 | 50:00 | 85 | 75,500 | 747 | 7975 | 100 | 98 | 85 | |
| INCREASE TORQUE TO 100% | | | | | | | | | |

C-2



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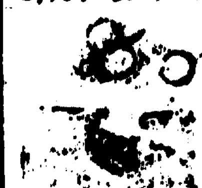
## HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 1-21-82 | H.G. Nonnemaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | 100% TQ = 83,810 in# 7986 RPM REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | CHANGE TORQUE TO 100% | | | | | | | | |
| 14:00 | 50:00 | 85 | 83,800 | 825 | 7989 | 100 | 98 | 86 | 1.18 MEGAWATTS |
| 14:30 | 50:30 | 86 | 83,800 | 820 | 7983 | 99 | 97 | 90 | |
| 15:00 | 51:00 | 86 | 83,800 | 815 | 7987 | 99 | 97 | 90 | |
| 15:30 | 51:30 | 86 | 83,800 | 815 | 7986 | 99 | 97 | 90 | |
| 16:00 | 52:00 | 85 | 83,800 | 815 | 7979 | 99 | 97 | 90 | |
| | SHUT DOWN - END OF SHIFT | | | | | | | | |
| | FAILED BRGS IN PHN GR. INPUT BOX, REMOVED FOR | | | | | | | | SLIVER REMOVED FROM OIL DRAINED IN OIL DRUM PLUS ONE TANG FROM 3 PC LOCKNUT REMOVED FROM SUMP (J. HACK HAS TANG) |
| | REPAIR | | | | | | | | |
| RESUME TESTING 3-4-82 | | | | | PINION 2317 | SUMP 2019 | | | |
| 15:00 | WARM-UP | 72 | 18000 | 248 | 7990 | 104 | 102 | 50 | |
| 15:10 | 30 MIN | 74 | 41000 | 466 | 7981 | 104 | 102 | 72 | |
| 15:20 | — | 75 | 62000 | 643 | 7996 | 102 | 100 | 74 | RESUME 100% RUN |
| 15:30 | 52:00 | 76 | 83,800 | 832 | 7983 | 100 | 98 | 80 | SHUT DOWN END OF SHIFT |
| 16:00 | 52:30 | 80 | 83,800 | 831 | 8000 | 100 | 98 | 89 | |
| | | | | | PINION 15332 | SUMP 5993 | → | → | PINION C.D. SUMP C.D. INSPECTION 0730 |



# HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 3-5-82 | H. J. Monemaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS (100% TQ = 83,810; 7986 RPM) |
|---|---|---|---|---|---|---|---|---|---|
| 0810 | 10 MIN | 75 | 16,000 | 230 | 7989 | 102 | 100 | 50 | |
| 0820 | WARMUP | 78 | 66,000 | 685 | 7982 | 101 | 100 | 76 | |
| 0820 | 52:30 | 78 | 83,800 | 839 | 7982 | 100 | 100 | 80 | RESUME TEST |
| 0850 | 53:00 | 82 | 83,800 | 834 | 7989 | 99 | 98 | 89 | |
| 0920 | 53:30 | 84 | 83,800 | 825 | 7981 | 99 | 98 | 89 | |
| 0950 | 54:00 | 86 | 83,800 | 825 | 7991 | 99 | 98 | 90 | |
| 1020 | 54:30 | 87 | 83,800 | 825 | 7993 | 99 | 98 | 90 | |
| 1050 | 55:00 | 88 | 83,800 | 820 | 7998 | 99 | 98 | 90 | |
| 1120 | 55:30 | 89 | 83,800 | 820 | 8000 | 99 | 98 | 90 | |
| 1150 | 56:00 | 89 | 83,800 | 819 | 7983 | 99 | 98 | 90 | |
| 1220 | 56:30 | 89 | 83,800 | 817 | 7998 | 99 | 98 | 90 | |
| 1250 | 57:00 | 89 | 83,800 | 818 | 7989 | 99 | 98 | 91 | |
| 1320 | 57:30 | 90 | 83,800 | 818 | 7980 | 98 | 97 | 90 | [illegible] 6200 |
| 1350 | 58:00 | 70 | 83,800 | 821 | 7975 | 98 | 97 | 90 | [illegible] - 6200 |
| 1420 | 58:30 | 90 | 83,800 | 820 | 8000 | 98 | 97 | 91 | |
| 1450 | 59:00 | 90 | 83,800 | 820 | 7988 | 98 | 97 | 91 | |
| 1520 | 59:30 | 90 | 83,800 | 820 | 7991 | 98 | 97 | 91 | 1525 LOW COOLING $H_2O$ ALARM ON DYNA. NO SHUTDOWN STARTING COUPLING |
| 1550 | 60:00 | 91 | 83,800 | 820 | 7990 | 98 | 97 | 92 | 1537 SAME THING (SAME TIME AS BOOSTSHAFT SHUTDOWN) |
| | | SHUT DOWN END OF SHIFT | | | | | | | |



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# HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100

DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 3-8-82 | H J Honemaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS (100% TQ = 83,810; 7986 RPM) |
|---|---|---|---|---|---|---|---|---|---|
| 0750 | 10 MIN | 72 | 16,000 | 231 | 7992 | 100 | 99 | 50 | PINION [illegible] SUMP 6200 — MAG PLUGS WERE CLEAN |
| 0800 | WARMUP | 75 | 68,000 | 698 | 7995 | 102 | 100 | 78 | |
| RESUME 100% TQ RUN | | | | | | | | | ~0815 PINION STUCK @ 3349 SUMP " " 6200 |
| 0800 | 60:00 | 75 | 83,800 | 840 | 7991 | 100 | 98 | 80 | |
| 0830 | 60:30 | 80 | 83,800 | 830 | 7996 | 99 | 98 | 85 | |
| 0900 | 61:00 | 82 | 83,800 | 830 | 7773 | 98 | 97 | 86 | |
| 0930 | 61:30 | 83 | 83,800 | 820 | 7981 | 98 | 97 | 86 | P-4087 S-6200 |
| 1000 | 62:00 | 84 | 83,800 | 815 | 7993 | 98 | 97 | 87 | |
| 1030 | 62:30 | 85 | 83,800 | 815 | 7974 | 98 | 97 | 87 | P-8590 S-6200 |
| 1100 | 63:00 | 87 | 83,800 | 816 | 7985 | 98 | 97 | 88 | P-8590 S-6200 } STUCK |
| 1130 | 63:30 | 88 | 83,800 | 812 | 7991 | 98 | 97 | 88 | |
| 1200 | 64:00 | 88 | 83,800 | 812 | 7986 | 98 | 97 | 89 | |
| 1230 | 64:30 | 89 | 83,800 | 812 | 7984 | 98 | 97 | 89 | P-5590 S-6200 |
| 1300 | 65:00 | 89 | 83,800 | 812 | 7988 | 98 | 97 | 89 | |
| 1330 | 65:30 | 88 | 83,800 | 811 | 7977 | 98 | 97 | 89 | |
| 1400 | 66:00 | 88 | 83,800 | 812 | 7968 | 97 | 96 | 90 | |
| 1430 | 66:30 | 87 | 83,800 | 812 | 7988 | 98 | 97 | 90 | |
| 1500 | 67:00 | 87 | 83,800 | 815 | 7975 | 98 | 97 | 90 | |
| 1530 | 67:30 | 88 | 83,800 | 817 | 7974 | 98 | 97 | 90 | |
| 1600 | 68:00 | 87 | 83,800 | 817 | 7982 | 98 | 97 | 90 | |
| SHUT DOWN - END OF SHIFT | | | | | | | | | |

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# HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100

DESCRIPTION OF TEST: ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 3-9-82 | F. J. Honemaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS (100% TQ = 83,810 # 7986 RPM) |
|---|---|---|---|---|---|---|---|---|---|
| 0820 | 10 MIN | 71 | 17,000 | 250 | 8000 | 100 | 98 | 51 | |
| 0830 | WARM-UP | 74 | 66,000 | 675 | 7988 | 102 | 100 | 75 | PINION 0006 SUMP 6236 |
| RESUME TEST - 100% TORQUE | | | | | | | | | |
| 0830 | 68:00 | 74 | 83,800 | 835 | 7987 | 100 | 98 | 80 | |
| 0900 | 68:30 | 77 | 83,800 | 831 | 7997 | 98 | 97 | 85 | |
| 0930 | 69:00 | 77 | 83,800 | 825 | 7991 | 98 | 97 | 85 | |
| 1000 | 69:30 | 78 | 83,800 | 820 | 7988 | 98 | 97 | 85 | |
| 1030 | 70:00 | 78 | 83,800 | 820 | 7988 | 98 | 97 | 85 | |
| 1100 | 70:30 | 79 | 83,800 | 820 | 7981 | 98 | 97 | 86 | |
| 1130 | 71:00 | 81 | 83,800 | 820 | 7991 | 98 | 97 | 86 | |
| 1200 | 71:30 | 82 | 83,800 | 819 | 7988 | 98 | 97 | 87 | |
| 1230 | 72:00 | 82 | 83,800 | 819 | 7987 | 98 | 97 | 88 | |
| 1300 | 72:30 | 87 | 83,800 | 820 | 7983 | 98 | 97 | 90 | |
| 1330 | 73:00 | 85 | 83,800 | 819 | 7989 | 98 | 97 | 90 | CHIP = M-50 |
| 1400 | 73:30 | 84 | 83,800 | 819 | 7994 | 98 | 97 | 90 | PINION-0007 SUMP-6237 |
| 1405 | 73:35 | SHUTDOWN - XMSN SUMP CHIP LIGHT - SCREEN | | | | | | | |
| CLEARED CHIPS - RESTART | | | | | | | | | |
| 1450 | 73:35 | 82 | 83,800 | 824 | 7987 | 98 | 97 | 81 | MAIN SCREEN LITE ON AT 1455 LITE FLICKERING SCREEN CLEARED AT 1520 |
| 1515 | 74:00 | 85 | 83,800 | 824 | 7975 | 98 | 97 | 89 | |
| 1545 | 74:30 | 86 | 83,800 | 820 | 7980 | 97 | 96 | 90 | |
| 1615 | 75:00 | 87 | 83,800 | 820 | 7991 | 97 | 96 | 90 | SHUT DOWN END OF SHIFT |
| 1630 | 75:15 | 88 | 83,800 | 820 | 7981 | 97 | 96 | 90 | |

# HLH AFT XMSN TEST DATA SHEET

| XMSN P/N 301-104200-2 | S/N A9-100 | DESCRIPTION OF TEST ENDURANCE TEST |
|---|---|---|

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING | |
|---|---|---|---|---|---|
| 3-10-82 | R J Honeamaker | AEROSHELL 555 | NO. 2 | 3-31 | REMOVED NEW TEDECO CHIPDET |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS (100% TQ = 83,810 IN# 7986 RPM) |
|---|---|---|---|---|---|---|---|---|---|
| 0910 | 10 MIN. | 73 | 16,000 | 250 | 8000 | 98 | 97 | 53 | PINION CHIP (TEDECO) → |
| 0920 | WARM-UP | 74 | 70,000 | 730 | 7989 | 100 | 98 | 78 | SUMP CHIP (TEDECO) → |
| RESUME TEST - 100% TORQUE | | | | | | | | | PRIOR TO STARTUP |
| 0920 | 75:15 | 75 | 83,800 | 841 | 7995 | 99 | 98 | 80 | |
| 0950 | 75:45 | 78 | 83,800 | 844 | 7987 | 99 | 98 | 83 | |
| 1020 | 76:15 | 80 | 83,800 | 840 | 7985 | 98 | 97 | 86 | |
| 1050 | 76:45 | 81 | 83,800 | 838 | 7971 | 97 | 96 | 88 | |
| 1120 | 77:15 | 82 | 83,800 | 838 | 7971 | 97 | 96 | 89 | |
| 1150 | 77:45 | 83 | 83,800 | 835 | 7975 | 96 | 95 | 89 | |
| 1220 | 78:15 | 84 | 83,800 | 833 | 7962 | 96 | 95 | 89 | |
| 1250 | 78:45 | 84 | 83,800 | 834 | 7975 | 95 | 94 | 89 | |
| 1320 | 79:15 | 84 | 83,800 | 835 | 7787 | 95 | 94 | 89 | |
| 1350 | 79:45 | 84 | 83,800 | 837 | 7987 | 96 | 95 | 89 | |
| 1420 | 80:15 | 85 | 83,800 | 837 | 7978 | 96 | 95 | 89 | |
| 1450 | 80:45 | 85 | 83,800 | 836 | 7988 | 95 | 95 | 90 | |
| 1505 | 81:00 | 85 | 83,800 | 836 | 7988 | 95 | 95 | 90 | |
| SHUT DOWN END OF SHIFT TO CHECK MAG PLUGS, FILTER ETC. | | | | | | | | | SUMP CHIP → |
| | | | | | | | | | FILTER BUTTON POPPED |
| MAIN SCREEN | | | MAIN SCREEN CAVITY | | | | | | PULL XMSN 3/11/82 FOR INSPECTION |



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HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 3-18-82 | R J Monemaker | AEROSHELL 555 | NO. 2 | 3-31 REINSTALLED NEW TEDECO CHIP DET. |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SYNC SHAFT SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | REMARKS 100% TQ = 83,810 IN-LB 7986 RPM |
|---|---|---|---|---|---|---|---|---|---|
| 1430 | 10 MIN | 74 | 17,000 | 248 | 8011 | 108 | 107 | 50 | |
| 1440 | WARM-UP | 77 | 62,000 | 641 | 7988 | 102 | 100 | 80 | |
| | RESUME | TEST – 100% TORQUE | | | | | | | |
| 1440 | 81:00 | 78 | 83,800 | 835 | 7984 | 101 | 100 | 81 | P-0030 S-0023 |
| 1510 | 81:30 | 82 | 83,800 | 821 | 7980 | 101 | 100 | 90 | |
| 1540 | 82:00 | 85 | 83,800 | 820 | 7996 | 101 | 100 | 91 | |
| 1610 | 82:30 | 86 | 83,800 | 819 | 7989 | 100 | 99 | 91 | |
| [illegible] | SHUT | DOWN – END OF SHIFT | | | | | | | |
| 0730 | 10 MIN | 77 | 15,000 | 232 | 8002 | 102 | 106 | 50 | |
| 0740 | WARMUP | 80 | 63,000 | 651 | 8001 | 106 | 102 | 80 | |
| | RESUME | TEST – 100% TORQUE | | | | | | | P-0030 S-0025 |
| 0740 | 82:30 | 80 | 83,800 | 851 | 8001 | 106 | 102 | 80 | |
| 0810 | 83:00 | 83 | 83,800 | 825 | 7966 | 104 | 100 | 90 | |
| 0840 | 83:30 | SHUT DOWN LOW XMSN OIL PRESS. (MAIN OIL PRESS XDUCER FITTING BROKE) | | | | | | | |
| 0910 | 83:30 | 84 | 83,800 | 820 | 7966 | 102 | 100 | 85 | RESUME RUNNING |
| 0940 | 84:00 | 86 | 83,800 | 813 | 7996 | 102 | 100 | 90 | |
| 1010 | 84:30 | 87 | 83,800 | 813 | 7973 | 102 | 100 | 90 | |
| 1040 | 85:00 | 87 | 83,800 | 810 | 7981 | 102 | 99 | 91 | |
| 1110 | 85:30 | 89 | 83,800 | 810 | 7981 | 102 | 99 | 91 | |
| 1140 | 86:00 | 89 | 83,800 | 810 | 7982 | 102 | 99 | 91 | |
| 1140 | SHUT | DOWN LOST MAIN OIL PRESS (PRESS XDUCER FAILED) | | | | | | | |



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# HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 | DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 3-19-82 | [signature] | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER-INLET OIL TEMP °C | REMARKS (100% TQ = 83,800; 7986 RPM) |
|---|---|---|---|---|---|---|---|---|---|
| 1210 | 86:00 | 87 | 83,800 | 810 | 7984 | 120 | 100 | 82 | REPL XDUCER RESUME TEST |
| 1240 | 86:30 | 89 | 83,800 | 810 | 7968 | 118 | 99 | 91 | |
| 1310 | 87:00 | 90 | 83,800 | 813 | 7978 | 118 | 99 | 91 | |
| 1340 | 87:30 | 90 | 83,800 | 811 | 7994 | 118 | 99 | 92 | |
| 1410 | 88:00 | 92 | 83,800 | 811 | 7987 | 118 | 99 | 92 | |
| 1440 | 88:30 | 90 | 83,800 | 812 | 7983 | 118 | 99 | 92 | |
| 1510 | 89:00 | 90 | 83,800 | 812 | 7986 | 118 | 99 | 92 | |
| 1540 | 89:30 | 90 | 83,800 | 813 | 7987 | 118 | 99 | 92 | |
| 1610 | 90:00 | 90 | 83,800 | 812 | 7981 | 118 | 99 | 92 | |
| | SHUT DOWN - END OF SHIFT | | | | | | | | |
| 3-22-82 | RESUME | 100% TQ | | | | | | | ACUREX ANTENNA REPLACED |
| 0845 | 10 MIN | 76 | 16,000 | 232 | 7987 | 124 | 104 | 52 | |
| 0855 | WARM-UP | 77 | 62,000 | 644 | 7994 | 120 | 102 | 79 | |
| 0855 | 90:00 | 77 | 83,800 | 837 | 7989 | 120 | 100 | 80 | |
| 0925 | 90:30 | 81 | 83,800 | 825 | 7994 | 116 | 98 | 89 | |
| 0955 | 91:00 | 84 | 83,800 | 812 | 7994 | 116 | 98 | 90 | |
| 1025 | 91:30 | 85 | 83,800 | 812 | 7966 | 116 | 98 | 90 | |
| 1055 | 92:00 | 86 | 83,800 | 812 | 7965 | 116 | 98 | 90 | |
| 1125 | 92:30 | 87 | 83,800 | 812 | 7978 | 116 | 98 | 90 | |
| 1155 | 93:00 | 87 | 83,800 | 812 | 7977 | 116 | 98 | 90 | |
| 1225 | 93:30 | 88 | 83,800 | 812 | 7971 | 116 | 98 | 90 | |
| 1255 | 94:00 | 87 | 83,800 | 812 | 7982 | 116 | 98 | 90 | |

HLH AFT XMSN TEST DATA SHEET

XMSN P/N 301-104200-2 S/N A9-100 | DESCRIPTION OF TEST ENDURANCE TEST

| DATE | TEST ENGINEER | OIL USED | TEST CELL | BUILDING |
|---|---|---|---|---|
| 3-22-82 | H J Monemaker | AEROSHELL 555 | NO. 2 | 3-31 |

| TIME OF DAY | TOTAL TEST TIME HRS:MIN | AMBIENT AIR TEMP °F | SYNC SHAFT TORQUE IN-LB | SYNC SHAFT TORQUE PSI | SPEED RPM | OIL PRESSURE MAIN PSI | OIL PRESSURE AUX PSI | COOLER INLET OIL TEMP °C | 100% TQ = 83,810 7986 RPM REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 1325 | 94:30 | 87 | 83,800 | 811 | 7983 | 116 | 98 | 90 | |
| 1355 | 95:00 | 88 | 83,800 | 811 | 7986 | 116 | 98 | 90 | |
| 1425 | 95:30 | 89 | 83,800 | 811 | 7985 | 116 | 98 | 91 | LOWER G.B. FINE FILTER BYPASS LIGHT ON |
| 1455 | 96:00 | 90 | 83,800 | 811 | 7996 | 116 | 98 | 91 | |
| 1425 | 96:30 | 89 | 83,800 | 811 | 7981 | 116 | 98 | 91 | |
| 1455 | 97:00 | 89 | 83,800 | 812 | 7986 | 116 | 98 | 91 | |
| SHUT DOWN - END OF SHIFT | | | | | | | | | |
| 3-23-83 RESUME TEST - 100% TQ. | | | | | | | | | |
| 0725 | 10 MIN | 75 | 21,000 | 275 | 7965 | 122 | 102 | 51 | |
| 0735 | WARM-UP | 77 | 62,000 | 638 | 7984 | 122 | 102 | 78 | |
| 0735 | 97:00 | 77 | 83,800 | 825 | 7995 | 120 | 100 | 80 | |
| 0805 | 97:30 | 82 | 83,800 | 820 | 7987 | 118 | 98 | 88 | |
| 0835 | 98:00 | 84 | 83,800 | 819 | 7984 | 116 | 98 | 90 | |
| 0905 | 98:30 | 85 | 83,800 | 811 | 7986 | 116 | 98 | 90 | |
| 0935 | 99:00 | 85 | 83,800 | 811 | 7975 | 116 | 98 | 90 | |
| 1005 | 99:30 | 86 | 83,800 | 811 | 7985 | 116 | 98 | 91 | |
| 1035 | 100:00 | 87 | 83,800 | 811 | 7998 | 116 | 98 | 91 | |
| END OF TEST | | | | | | | | | |