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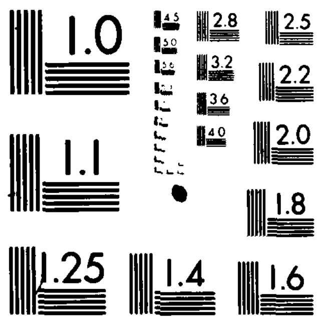

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DEPARTMENT OF DEFENCE

ROYAL AUSTRALIAN AIR FORCE

AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

EDINBURGH, SOUTH AUSTRALIA

TECHNICAL INVESTIGATION NO 778

EVALUATION OF NEW IROQUOIS TORQUEMETER PN 73-30-1

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A requirement to replace Iroquois UH-1H torquemeter PN 332-00121 precipitated an evaluation of a prototype torquemeter PN 73-30-1, manufactured by National Instrument Corporation, Melbourne, Victoria. The purpose of this investigation was to supervise the installation of a prototype torquemeter in an Iroquois UH-1H and to evaluate the accuracy, damping, drift and ergonomic aspects of the new torquemeter.

Tests showed that torquemeter accuracy was unacceptable and the indicating system was prone to significant drift. Tradesmen found adjustment of the 'zero set' difficult to perform due to poor access to the adjustment screw. Instrument markings in the range greater than 30 psi were obscured when viewed from the co-pilot's seat. The night-lighting of the instrument and the reflection characteristics of the glass cover were also unsatisfactory.

The procedure for torquemeter a[illegible]ment for installed engine Data Plate Torque, ~~as outlined~~ [illegible] Draft Modification Order, was found to be in error and a revise[illegible]dure is proposed. Several modifications to the instrument are recommended to be made before fleet-wide installation. A limited number of flight tests should be made to check that the production torquemeter and the new performance calculator are compatible. If significant delays occur before introduction of a suitable production torquemeter, an interim method of displaying maximum permissible torque is proposed.

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AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

EVALUATION OF NEW IROQUOIS TORQUEMETER PN 73-30-1

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DEPARTMENT OF DEFENCE

ROYAL AUSTRALIAN AIR FORCE

AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

TECHNICAL INVESTIGATION NO 778

EVALUATION OF NEW IROQUOIS TORQUEMETER PN 73-30-1

SUMMARY

A requirement to replace Iroquois UH-1H torquemeter PN 332-00121 precipitated an evaluation of a prototype torquemeter PN 73-30-1, manufactured by National Instrument Corporation, Melbourne, Victoria. The purpose of this investigation was to supervise the installation of a prototype torquemeter in an Iroquois UH-1H and to evaluate the accuracy, damping, drift and ergonomic aspects of the new torquemeter.

Tests showed that torquemeter accuracy was unacceptable and the indicating system was prone to significant drift. Tradesmen found adjustment of the 'zero set' difficult to perform due to poor access to the adjustment screw. Instrument markings in the range greater than 30 psi were obscured when viewed from the co-pilot's seat. The night-lighting of the instrument and the reflection characteristics of the glass cover were also unsatisfactory.

The procedure for torquemeter adjustment for installed engine Data Plate Torque, as outlined in the Draft Modification Order, was found to be in error and a revised procedure is proposed. Several modifications to the instrument are recommended to be made before fleet-wide installation. A limited number of flight tests should be made to check that the production torquemeter and the new performance calculator are compatible. If significant delays occur before introduction of a suitable production torquemeter, an interim method of displaying maximum permissible torque is proposed.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ANNEXES

EVALUATION OF NEW IROQUOIS TORQUEMETER PN 73-30-1

1. INTRODUCTION

1.1 Background

1.1.1 In Reference A, Aircraft Research and Development Unit (ARDU) recommended a torquemeter with larger presentation and more stable and accurate indication. The requirement was satisfied by Iroquois Modification No 194 which installed torquemeter PN 332-00121 in UH-1H aircraft. When this torquemeter was purchased, Headquarters Support Command (HQSC) believed that the item would be supportable. The manufacturer, however, later declined to provide either support spares or additional indicators. Consequently, a replacement item was sought.

1.1.2. The requirement to replace torquemeter PN 332-00121 also allowed HQSC to address the long-standing problem of accurate torque indication for various installed engine Data Plate Torque (DPT) values. National Instrument Corporation (NIC), Melbourne, was funded for development of a suitable instrument. Initial tests of a prototype instrument were conducted at No 5 Squadron and results were reported as encouraging; however, before proceeding with fleet-wide modification, Reference B tasked ARDU to evaluate the new instrument.

1.2 Purpose

1.2.1. The purpose of this investigation was to supervise the installation of a prototype torquemeter PN 73-30-1 in an Iroquois UH-1H and to evaluate the accuracy, damping, drift and ergonomic aspects of the new torquemeter.

1.3 Description of Torquemeter PN 73-30-1

1.3.1 The indicator operates in conjunction with the engine-mounted variable reluctance torque pressure transmitter. The output of the transmitter is demodulated for comparison with the 26 VAC (approximately) power supply voltage. The result is displayed on a moving coil taut band suspension meter. An integral electronic circuit is included and is designed to control meter damping, thus preventing an apparent unstable indication without introducing significant lag.

1.3.2 The physical dimensions and electrical connections of the prototype torquemeter are the same as those of the instrument it is designed to replace. The display face and an exploded view of the meter are shown in Annex A, Figures 1 and 2. A 'zero set' function is incorporated so that the instrument can be adjusted for installed DPT. Torquemeter Serial No (S/N) A-3 was evaluated by ARDU.

2. TESTS MADE

2.1 Laboratory Tests

2.1.1 Laboratory tests were conducted at ARDU, RAAF Base Edinburgh SA, during the period 18-22 February 1982 and included:

a. accuracy,

b. instrument response,

c. zero set adjustment, and

d. adjustment for installed engine data plate torque.

2.2 Flight Line Tests

2.2.1 Flight line tests were conducted at No 5 Squadron, RAAF Base Fairbairn ACT, on 1 March 1982 and included:

a. installation and adjustment,

b. readability,

c. positioning, and

d. illumination.

2.3 Flight Tests

2.3.1 Flight tests were conducted at RAAF Base Fairbairn ACT, and comprised one flight of 40 minutes duration on 2 March 1982. Tests included:

a. indicated rotor profile power,

b. control inputs in the hover,

c. engine power checks, and

d. autorotations.

3. RESULTS OF TESTS AND DISCUSSION

3.1 Accuracy

3.1.1 The accuracy of the instrument was evaluated by utilizing the circuit shown in Annex A, Figure 3. After allowing a warm-up period of approximately one hour, several calibration runs were made. The two following test techniques were used:

a. The ratio transformer was set to 0.5895 and the zero set adjusted to make the instrument read zero psi. The transformer was then set at ratios equivalent to zero instrument error in 10.0 psi increments and the indicated readings recorded. The procedure was repeated at zero set values of +3.0 psi and -3.0 psi. The results are summarized in Table 3.1. Table 3.2 shows the results of similar tests conducted by NIC on 28 and 30 July 1981. Exactly the same readings were obtained on each day.

TABLE 3.1 - ACCURACY USING ZERO INSTRUMENT ERROR TRANSFORMER RATIOS

Zero Error Indication (Zero Set = 0.0 psi) (psi)	Zero Error Transformer Ratio	Zero Set = 0.0 psi			Zero Set = +3.0 psi			Zero Set = -3.0 psi		
		Indication (psi)	Error (psi)	% Error(1)	Indication (psi)	Error (psi)	% Error(1)	Indication (psi)	Error (psi)	% Error(1)
0	0.5895	0	0	0	+3.0	0	0	-3.0	0	0
10	0.5585	10.8	+0.8	8.0	13.1	+0.1	1.0	7.9	+0.9	9.0
20	0.5272	21.1	+1.1	5.5	23.1	+0.1	0.5	18.2	+1.2	6.0
30	0.4965	30.7	+0.7	2.3	33.0	0	0	28.0	+1.0	3.3
40	0.4670	41.0	+1.0	2.5	43.5	+0.5	1.2	37.7	+0.7	1.7
50	0.4383	51.8	+1.8	3.6	53.7	+0.7	1.4	47.4	+0.4	0.8
60	0.4110	62.0	+2.0	3.3	64.0	+1.0	1.7	57.4	+0.4	0.7

Notes: 1. Percent error based on $\dfrac{\text{Error x 100}}{\text{Zero Error Indication}}$

TABLE 3.2 - NIC CALIBRATION RUNS

Zero Error Indication (Zero Set = 0.0 psi) (psi)	Zero Error Transformer Ratio	Indication (Zero Set = 0 psi) (psi)	Indication (Zero Set = +3.0 psi) (psi)	Indication (Zero Set = -3.0 psi) (psi)
0	0.5895	0	+3	-3
10	0.5585	10.1	13	7.6
20	0.5272	20.5	23	17.6
30	0.4965	30.0	32.5	27.2
40	0.4670	40	43	36.8
50	0.4383	50	53	46.8
60	0.4110	61.5	>64	56.8

b. The ratio transformer was set to 0.5895 and the zero set adjusted to make the instrument read zero psi. The ratio transformer was then used to make the instrument read in 10.0 psi increments, increasing and decreasing. The required transformer ratios were recorded at each increment. The results are summarized in Table 3.3.

TABLE 3.3 - ACCURACY USING VARIABLE TRANSFORMER RATIOS

Instrument Reading (psi)	Nominal Zero Error Transformer Ratio	Allowable Transformer Ratio Range (Min/Max)	Actual Transformer Ratio Required	Error	% Error(1)
0	0.5895	0.5841/0.5949	0.5895	0	0
10.0	0.5585	0.5523/0.5647	0.5602	0.0017	0.3
20.0	0.5272	0.5210/0.5334	0.5302	0.0030	0.6
30.0	0.4965	0.4919/0.5011	0.4991	0.0026	0.5
40.0	0.4670	0.4655/0.4685	0.4706(2)	0.0036	0.8
50.0	0.4383	0.4369/0.4397	0.4405(2)	0.0022	0.5
60.0	0.4110	0.4056/0.4164	0.4159	0.0049	1.2
60.0	0.4110	0.4056/0.4164	0.4159	0.0049	1.2
50.0	0.4383	0.4369/0.4397	0.4407(2)	0.0024	0.5
40.0	0.4670	0.4655/0.4685	0.4705(2)	0.0035	0.7
30.0	0.4965	0.4919/0.5011	0.4994	0.0029	0.6
20.0	0.5272	0.5210/0.5334	0.5308	0.0036	0.6
10.0	0.5582	0.5523/0.5647	0.5610	0.0028	0.5
0.0	0.5895	0.5841/0.5949	0.5897	0.0002	0

Notes: 1. Percent error based on $\frac{\text{Error x 100}}{\text{Zero Error Transformer Ratio}}$

2. These ratios are greater than the normally allowed maxima.

3.1.2 The tests detailed at Sub-paragraph 3.1.1.a were repeated at No 5 Squadron using their standard test equipment (which included an RT-7 ratio transformer). The results were the same as those obtained by ARDU as listed in Table 3.1. This confirmed that:

a. the correct test technique had been employed at ARDU, and

b. instrument error over some sections of the range was greater than the accepted tolerance of ± 1 psi and the instrument would normally have been the subject of a defect report.

3.1.3 During the ARDU laboratory tests, the pointer stuck several times at 58 psi indicated with increasing differential voltage and at 42 psi with decreasing differential voltage. Even slight tapping would not free the movement and the instrument would have been the subject of a defect report for this deficiency under normal circumstances.

3.1.4 Engine torque is a primary reference for determining aircraft performance in the UH-1H. Instrument errors greater than ±1 psi could lead to significant errors when determining Minimum Acceptable Torque (MAT), hover performance and cruise data. A 'sticky' indicator could cause confusion in critical phases of flight, such as take-off or emergencies, where maximum available power is required. Under the conditions tested, the accuracy of the torquemeter was unacceptable and should be corrected before fleet-wide installation of the instrument.

3.2 Instrument Response

3.2.1 The sensitivity and damping of the instrument were evaluated by making step voltage inputs between equivalent observed torque values of 10.2 psi and 50.2 psi. The times for the needle to pass 40 psi and reach 50.2 psi were recorded for approximately ten runs and then averaged. A rough time history of indication was then reconstructed as shown in Annex A, Figure 4. During these tests, the needle did not overshoot the 50.2 psi reading, showing that indication system damping was critical or higher. Initial needle movement rate was calculated as approximately 130 psi/sec, 40 psi was passed at 0.43 sec and 50.2 psi was reached in approximately 1.3 sec. The Lycoming T53-L-13B engine normally accelerates from idle to maximum engine speed in approximately 2.5 sec.

3.2.2 Indicator lag was evaluated by making ramp voltage inputs between equivalent observed torque values of zero psi and 60 psi in seven seconds (approximately). The indicated value lagged the signal input by approximately 2 psi to 3 psi for both increasing and decreasing voltage differentials.

3.2.3 The response of the instrument to approximately sinusoidal oscillatory inputs was also evaluated. The results are summarized in Table 3.4.

TABLE 3.4 - INSTRUMENT RESPONSE TO OSCILLATORY INPUT

Input Frequency (Hz)	Input (Equivalent torque, psi)	Output (Observed torque, psi)
½	50±10	50±10
3	50±10	50±4

3.2.4 The tests showed that instrument response was generally good with high sensitivity, critical (or higher) damping and minimal lag. These instrument response characteristics are compatible with the engine response characteristics and are satisfactory.

3.3 Zero Set Adjustment

3.3.1 Access to the zero set adjustment screw was achieved by removing a covering/sealing screw on the rear of the instrument housing. A jeweller's screwdriver was then inserted through the hole and engaged in the head of the zero set adjustment screw. Once engaged, the indicator could be finely adjusted to the desired reading by turning the screwdriver in the appropriate direction.

3.3.2 During these adjustments, the tradesman experienced difficulty in properly engaging the screwdriver in the adjustment screw head and, several times, the screwdriver dislodged as adjustment was attempted. The following were considered to be causes of the difficulties encountered:

a. the access hole was too small,

b. the adjustment screw was located deep inside the instrument, and

c. the adjustment screw could not be seen after the screwdriver was inserted.

Tradesmen who are required to adjust the meter will find the task very frustrating and difficult, especially in field conditions, due to poor access to the zero set adjustment screw. This feature was unsatisfactory and should be improved.

3.4 Adjustment For Installed Engine Data Plate Torque

3.4.1 Introduction. Reference C, Paragraph 1.e. contains a chart (reproduced as Table 3.5) for adjusting the torquemeter zero set for installed engine DPT. A DPT of 60.5 psi is cited as the nominal 'on specification' value. For DPT other than 60.5 psi, the torquemeter zero set was to be adjusted on a one-for-one basis with the aim of providing an accurate indication at 50 psi. Research at ARDU has revealed that there are faults with this adjustment methodology.

TABLE 3.5 - TORQUEMETER ADJUSTMENT FOR ENGINE DPT (FROM HQSC DMO)

DPT	Align Torquemeter Pointer to
62.5	-2.0
62.0	-1.5
61.5	-1.0
61.0	-0.5
60.5	0
60.0	+0.5
59.5	+1.0
59.0	+1.5
58.5	+2.0
58.0	+2.5

3.4.2 Nominal 'On Specification' DPT. Engine DPT is determined for each engine as it is run on the test bed by the contractor (Hawker de Havilland Pty Ltd). During these runs, engine power is absorbed by a water brake system and power measurement is based on the torque indication from a calibrated meter attached to the water brake. Although the engine is run at various power settings (and speeds), DPT for each engine is assigned on the reading produced by the individual engine's torque measuring system when the water brake torque indication is 1,125 lb ft (13,500 lb in). With reference to Annex A, Figure 5, a water brake torque of 13,500 lb in should give an engine torquemeter differential pressure of approximately 61.1 psi for the nominal 'on specification' engine. This is inconsistent with the DMO value of 60.5 psi. The error in the DMO may have arisen by using the maximum continuous torque limit (13,320 lb in) as the value on which the DPT figure is based, instead of the 1125 lb ft (13,500 lb in) value used by the contractor.

3.4.3 Proposed Adjustment Procedure. In the Lycoming T53-L-13B engine, output shaft torque is measured indirectly by sensing differential oil pressure. The variance of differential oil pressure between engines for the same actual torque output is reflected by the various DPT figures. The differential oil pressure is sensed by a transducer mounted on the engine and transmitted to the cockpit-mounted torquemeter. This indirect method of torque measurement causes significant errors. To minimize these errors, a revised torquemeter adjustment procedure is proposed by ARDU and is outlined at Annex B. The procedure is based on some assumptions and logic as follows.

a. Differential Oil Pressure Versus Actual Torque. Differential oil pressure versus actual engine torque is assumed to be linear over the range and to converge on the origin for different DPT engines. This is illustrated in Figure 3.1.

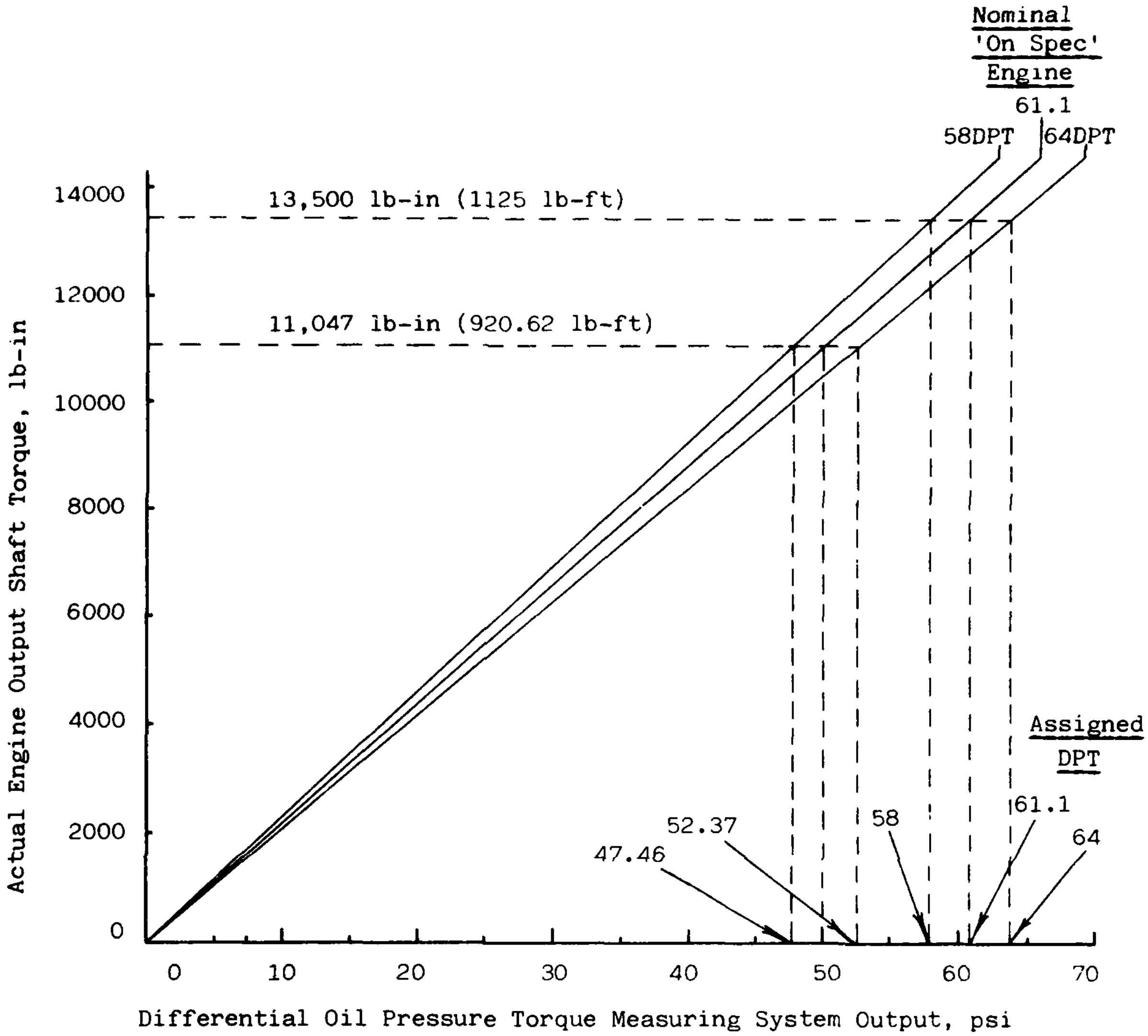


FIGURE 3.1 - DIFFERENTIAL OIL PRESSURE VS ACTUAL TORQUE

b. Adjustment At 11,047 lb in Actual Torque. Given the linear relationship illustrated in Figure 3.1, at 11,047 lb in actual torque (the transmission limit equivalent to 50.0 psi torque for the nominal 'on specification' 61.1 DPT engine) the 64 DPT engine produces a differential oil pressure of approximately 52.37 psi (ie 2.37 psi in excess) and the 58 DPT engine produces approximately 47.46 psi (ie 2.54 psi low). A reasonably correct indication should be obtained by adjusting the cockpit indicator up 2.54 psi for a 58 DPT engine, down 2.37 psi for a 64 DPT engine and zero for the 'on specification' 61.1 DPT engine. Annex B, Figure 1 is based on this logic.

c. <u>Differential Oil Pressure Measuring System Errors</u>. Paragraphs 3.4.3 a. and 3.4.3 b. account for adjustments required for installed engine DPT but do not include adjustment for errors in the engine-mounted differential oil pressure transducer (torquemeter transmitter) and instrument errors. By pumping the system to 50 psi with the NP-1 portable hydraulic rig and then making the torquemeter zero set adjustment, transmitter and indicator errors should be minimized in the range of interest (around 50 psi). If the NP-1 rig is not available and the adjustment is made at zero differential oil pressure, transmitter and indicator errors will not be taken into account.

3.5 <u>Installation and Adjustment</u>

3.5.1 Torquemeter PN 73-30-1 Serial No A-3 was installed in Iroquois UH-1H A2-505, engine Serial No LE22817B, Data Plate Torque 61.0 psi. The Reference C calibration method was employed except as follows:

a. An NP-1 portable hydraulic rig was used to pump the engine system to 50 psi on the NP-1 gauge.

b. The zero set function on the torquemeter was adjusted so that the instrument read 49.5 psi.

3.5.2 After approximately 30 minutes, a calibration run was made. Another run was made approximately five minutes after the first. The results are shown in Table 3.6.

<u>TABLE 3.6 - INSTALLED INSTRUMENT CALIBRATION</u>

NP-1 Gauge Indication (psi)	Torquemeter S/N A-3 Indication (psi)	
	Run 1	Run 2
0	< -3	< -3
10.0	7.8	8.0
20.0	18.4	18.6
30.0	28.5	28.2
35.0	33.3	-
40.0	38.4	38.8
45.0	44.1	-
50.0	49.0	48.8
55.0	55.0	-
60.0	> 60 (approx 61)	> 60 (approx 61)

3.5.3 The cause of the drift in indications between initial adjustment, Run 1 and Run 2 was not determined but the transmitter was suspected as the source since virtually no drift was observed during bench testing of the indicator in isolation. In any case, the calibration runs showed that the system, as installed, was prone to drift. Given the design of the system, it is probably inevitable that errors of this kind will occur, necessitating regular adjustments to ensure accuracy is kept within acceptable limits (±1 psi). System drift was unsatisfactory but would be acceptable if the system is calibrated on a regular basis.

3.6 Electromagnetic Interference

3.6.1 With power supplied by the aircraft battery (25 VDC) and SPARE inverter (116 VAC), the torque sensing system was 'pumped' to 50 psi using the NP-1 portable hydraulic rig and the following systems operated to determine any electromagnetic interference effects:

a. magnetic compass synchronization;

b. attitude indicator pitch and roll trims;

c. radar altimeters;

d. search and landing lights;

e. fuel quantity test;

f. UHF, VHF-AM, VHF-FM and HF radios; and

g. IFF and ADF.

3.6.2 The only observed effect occurred during keying of the VHF-AM radio. At 116.0 MHz the indicated torque dropped by approximately 0.5 psi as the radio was keyed to transmit. The effect reduced with increasing frequency until, at 149.0 MHz, there was no noticeable effect. Under the conditions tested, the torque indicating system was essentially uneffected by electromagnetic interference effects.

3.7 Ergonomic Aspects

3.7.1 Parallax. Instrument parallax was determined by the project pilot sitting in both pilot crew stations. Seat heights were adjusted so that the pilot's eyes were approximately in the sloping plane of the instrument panel glare shield. The NP-1 portable hydraulic rig was used to 'pump' the torque indicating system to various pressures. The results are given in Table 3.7. The errors were less than ±1 psi, as viewed from either seat, and were considered satisfactory.

TABLE 3.7 - PARALLAX ERRORS

NP-1 Gauge	Torque Pressure Indication (psi)		
	Normal to Instrument Face	Pilot Seat	Copilot Seat
0	< -3	-3.0	< -3
10.0	8.0	8.6	7.1
20.0	18.6	19.0	18.0
30.0	28.2	28.4	27.4
40.0	38.8	38.0	38.0
50.0	48.8	48.1	49.2
60.0	> 60 (approx 61)	60.0	> 60(approx 61)

3.7.2 Scale Obscuration. The needle and all instrument face markings were fully in view from the pilot's seat. From the co-pilot's seat, the outer sections of the scale markings were obscured by the instrument bezel in the range 30 psi to 55 psi. Markings greater than 55 psi were completely obscured by the top left instrument post light. Confined area operations often demand that the pilot's attention is directed outside the helicopter to maintain clearances from obstructions during approaches and departures. The co-pilot is required to monitor engine performance (primarily torque) and clearances on the left side of the aircraft. Obscuration of torquemeter markings in the range greater than 30 psi could cause misreadings. Alternatively, the co-pilot may compensate for this deficiency by leaning to the right so that all markings are visible. This would detract from his secondary task of monitoring clearances on the left side of the aircraft. Obscuration of instrument markings in the range greater than 30 psi, as viewed from the co-pilot's seat, was unsatisfactory. This may be overcome by pilot compensation or alternatively by adopting the modifications recommended in Paragraph 3.7.3.

3.7.3 Pointer and Gradation Marks. The following modifications to the pointer and gradation marks are recommended to help alleviate deficiencies outlined in Paragraphs 3.7.1 and 3.7.2:

a. Incremental 5 psi Marks. The gradation marks at increments of 5 psi should be extended inwards instead of outwards. This would help compensate for the obscuration of the markings when viewed from the co-pilot's seat.

b. Pointer Taper and Length. The pointer should be more finely tapered (eg similar to the EGT indicator pointer) and extended slightly so that the tip reaches approximately the middle of the gradation marks. This would help to reduce parallax errors.

A sketch of the indicator face, incorporating the proposed modifications, is shown in Figure 3.2.

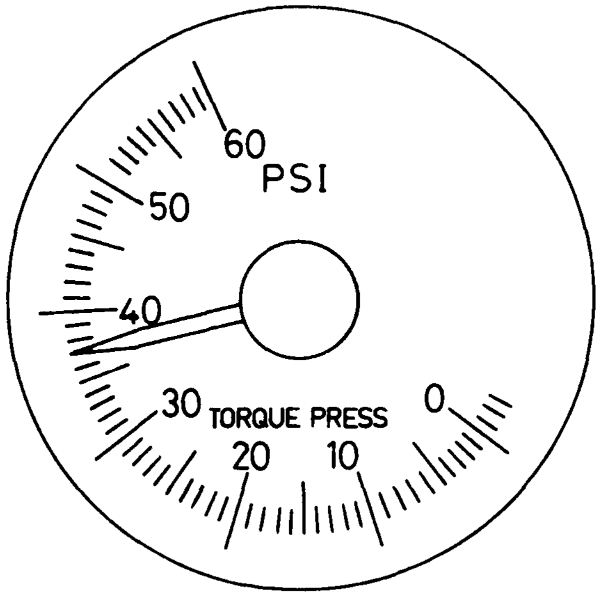


FIGURE 3.2 - MODIFIED GRADATION MARKS AND POINTER

3.7.4 Reflections. The face of the instrument was covered by plain glass. Reflections on the glass made the instrument difficult to read under some conditions. Also, reflections of red and orange coloured objects (eg helmet tape, Life Vests Mk 8) occasionally were misinterpreted by the pilot as activations of warning or caution lights when the instrument was in his peripheral vision. Although many other of the instruments on the panel have plain glass covers which also produce many reflections, there is no reason to perpetuate the deficiency. The reflection characteristics of the torquemeter glass cover were undesirable. The cover should be replaced with an appropriate form of non-reflective glass.

3.7.5 Lighting. The instrument was lit by two red filtered post lights mounted above the instrument at the approximate relative positions of eleven and one o'clock. Instrument lighting was assessed at night with the lighting intensity adjusted to approximately mid-range (representative of the selection made by most pilots for night operations). Figure 3.3 illustrates the light dispersion pattern which resulted. The post light at the one o'clock position virtually provided no illumination of the scale area and served no useful purpose. The red-painted gradation mark at 50 psi blended with the other gradation marks and was difficult to discern from other markings. Inadequate lighting of the scale from zero psi to approximately 35 psi will cause difficulty in reading engine torque during cruise flight and descent when conducting night operations. The night-lighting of the instrument was unsatisfactory and should be corrected to improve lighting in the zero to 35 psi area. Failure to correct this deficiency may force use of higher than necessary overall lighting levels to accommodate the inability to see this area of the instrument.

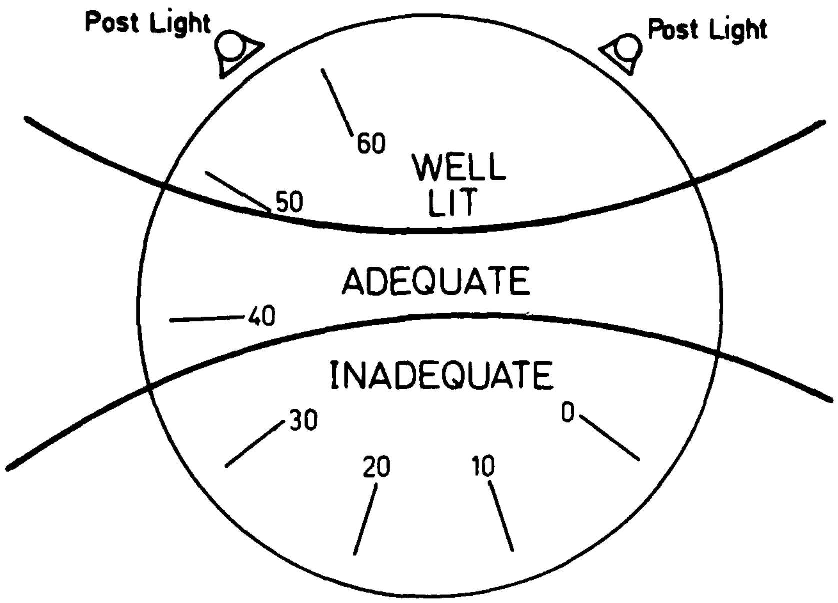


FIGURE 3.3 - LIGHTING LEVELS

3.8 Flight Tests

3.8.1 Rotor Profile Power. Rotor profile power is used as an indication of correct pitch change link adjustment following maintenance actions. With the helicopter on the ground, collective pitch lever lowered to the minimum mechanical stop, 6,600 rpm power turbine speed (N2) and tail rotor pedals level, engine torque should fall in the band 8 psi to 10 psi if the main rotor pitch change links are correctly adjusted. If the torque value is outside this band, rotor rpm in autorotation can be expected to be outside limits. Rotor profile power was measured at 9 psi torque (at 87.5% compressor speed (N1), 6,600 rpm N2, pedals level) for the installation in A2-505. However, if installed engine DPT is significantly different to the nominal 'on specification' value of 61.1 psi and the torquemeter is adjusted in accordance with the procedure outlined in Annex B, a false indication of rotor profile power will result. This should be taken into account during maintenance test flights following any action which may have affected pitch change link settings.

3.8.2 Control Inputs in the Hover. The helicopter was established in an Out of Ground Effect (OGE) hover and a series of collective, cyclic and pedal inputs made. Torquemeter response appeared to be in harmony with N1 and EGT indications during collective pulls and pushes, and pedal inputs. The installed system appeared to be better damped than torquemeter PN 332-00121 and gave a good indication of engine response. Since the engine was not fully instrumented, accuracy of the installed system could not be checked during the test flight; however, negligible effect on the results obtained during laboratory and flight line tests would be expected.

3.8.3 Topping Checks. The results of the two engine topping checks that were conducted are shown in Table 3.8. These show the engine was delivering 2.4 psi torque (average) above minimum acceptable torque (43.3 psi as determined from Reference A, Annex H, Figure 4). Without appropriate engine instrumentation, it was impossible to determine if the indication of excess power was correct. Modifications to increase torquemeter system accuracy, as recommended elsewhere in this report, should ensure that topping check results are correct and appropriate 'GO/NO GO' decisions can be made with confidence.

TABLE 3.8 - RESULTS OF ENGINE TOPPING CHECKS

Parameter	Check 1	Check 2
Pressure Altitude (ft)	7000	7000
OAT (^{o}C)	9.5	9.5
Airspeed (KIAS)	75	75
N2 rpm	6400	6400
EGT (^{o}C)	585	581
N1 speed (percent)	100.1	100.2
Minimum Acceptable Torque (psi)	43.3	43.3
Observed Torque (psi)	45.9	45.5

3.8.4 Autorotations. Two autorotations were performed. Entry to autorotation was made from level flight, 95 KIAS, 30 psi torque and 6400 N2 rpm, by rapidly closing the throttle to flight idle and lowering the collective lever. Torque indication decayed in harmony with N1 speed. Once established in 'stable' autorotation at 70 KIAS, 324 rotor rpm and approximately 5800 to 6000 N2 rpm, torque indication stabilized at less than -3.0 psi (at approximately -4 psi). As the throttle was advanced to reintroduce power, a 2% increase in N1 speed was required from the 'needles joined' (N2 and rotor rpm needles coincident) value to give zero psi torque indication. An engine torque reading of zero psi can be used by Iroquois pilots to confirm autorotation has been established and that engine power contribution has ceased. During emergencies such as engine failure, the torque indicator is also consulted to confirm the nature of the failure. Readings other than zero psi may be momentarily confusing to the pilot and are undesirable. As with rotor profile power, this indication will be dependent on adjustment for installed engine DPT.

3.9 Relation to Aircraft Performance

3.9.1 Headquarters Support Command is presently acquiring performance calculators for the Iroquois UH-1H helicopter fleet. Since aircraft performance for the calculator is based largely on indicated torque for appropriate hover, approach and departure power margins, and cruise and endurance power settings, accurate torque indications (especially in the range 30 to 50 psi) will be required. To ensure that the performance calculator is compatible with the production torquemeter, ARDU should be tasked to conduct a limited number of test flights to 'spot check' the performance data.

3.10 Interim Method to Display Maximum Permissible Torque

3.10.1 If significant delays occur before introduction of a suitable production torquemeter, an interim method to display maximum permissible torque may be required. The method of this adjustment could take the form of that used by the RNZAF (see extract at Annex C). If the logic of Paragraphs 3.4.1 to 3.4.3 is used, the corresponding decal values of maximum indicated torque should be based on the 'reverse' of Annex C, Figure 1. This is shown in Figure 3.4 below.

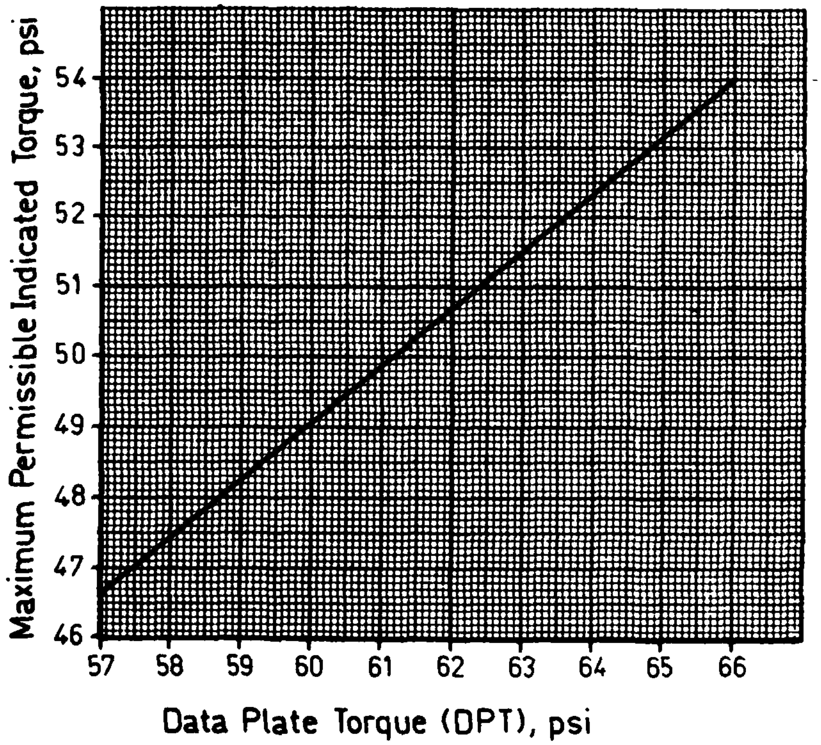


FIGURE 3.4 - MAXIMUM PERMISSIBLE TORQUE VS DPT

4. SUMMARY OF CONCLUSIONS

4.1 Torquemeter accuracy was unacceptable (Paragraphs 3.1.1 to 3.1.4).

4.2 Drift of the torque measuring system was unsatisfactory but would be acceptable if regular system calibrations are conducted. The engine-mounted torquemeter transmitter, rather than the new torquemeter, was suspected as the source of system drift (Paragraphs 3.5.1 to 3.5.3).

4.3 The poor access to the 'zero set' adjustment screw, causing difficulty in making adjustments, was unsatisfactory (Paragraphs 3.3.1 and 3.3.2).

4.4 The night-lighting of the instrument was unsatisfactory (Paragraph 3.7.5). This deficiency could be overcome by pilot compensation; however, the night-lighting should be improved.

4.5 Obscuration of instrument markings in the range greater than 30 psi, as viewed from the co-pilot seat, was unsatisfactory (Paragraph 3.7.3), but can be remedied by adopting the modifications recommended in Paragraph 5.5.

4.6 The reflection characteristics of the torquemeter glass cover were undesirable (Paragraph 3.7.4).

4.7 Torquemeter indications other than zero psi are undesirable during autorotation (Paragraph 3.8.4).

4.8 The minimal errors which occurred due to parallax were considered satisfactory (Paragraph 3.7.1).

4.9 Torquemeter response characteristics were satisfactory (Paragraphs 3.2.1 to 3.2.4 and 3.8.2).

4.10 The torque indicating system was essentially unaffected by electromagnetic effects (Paragraphs 3.6.1 and 3.6.2).

4.11 The procedure for torquemeter adjustment for installed engine Data Plate Torque, as proposed in the Draft Modification Order (Reference B) was in error (Paragraphs 3.4.1 to 3.4.3).

5. RECOMMENDATIONS

5.1 The accuracy of the instrument should be improved to be within ± 1 psi of the desired reading over the full range (Paragraph 3.1.4).

5.2 Torque measuring system calibrations should be performed regularly to counter system drift (Paragraph 3.5.3).

5.3 The instrument should be modified so that 'zero set' adjustment is easier (Paragraph 3.3.2).

5.4 The night-lighting of the instrument should be improved so that the whole of the scale is adequately lit (Paragraph 3.7.5).

5.5 The pointer and gradations should be modified to enhance readability (Paragraph 3.7.3).

5.6 The instrument face glass cover should be replaced with an appropriate form of non-reflecting glass (Paragraph 3.7.4).

5.7 The false indication of rotor profile power, when the torquemeter is adjusted for DPT other than 61.1 psi, should be taken into account during maintenance test flights following any action which may have affected main rotor pitch change link settings (Paragraph 3.8.1).

5.8 The calibration procedure outlined in Annex B should be used in lieu of that in Reference C (Paragraph 3.4.3).

5.9 To ensure that the performance calculator is compatible with the production torquemeter, ARDU should be tasked to conduct a limited number of test flights to 'spot check' the performance data (Paragraph 3.9.1).

5.10 If significant delays occur before introduction of a suitable production torquemeter, an interim method of displaying maximum permissible torque should be adopted (Paragraph 3.10.1).

6. REFERENCES

A. Department of Defence, RAAF, Aircraft Research and Development Unit, 'UH-1H Iroquois Performance Evaluation', ARDU Report No TS 1631 Phase 1, November 1976.

B. HQSC 3000/7/1-778(3), 8 January 1982.

C. HQSC 2601/2/66-7210008241 (undated), Draft Modification Order, Replacement of Iroquois Torquemeter PN 332-00121 with a New Item PN 73-30-1.

FIGURES

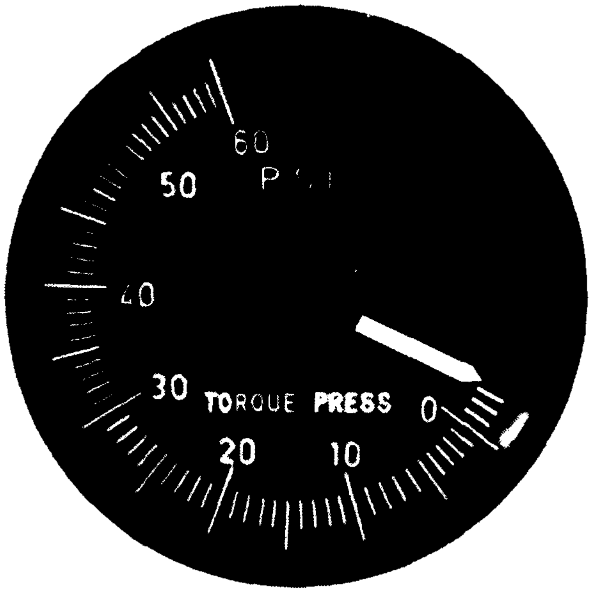


FIGURE 1 - FACE OF TORQUEMETER PN 73-30-1

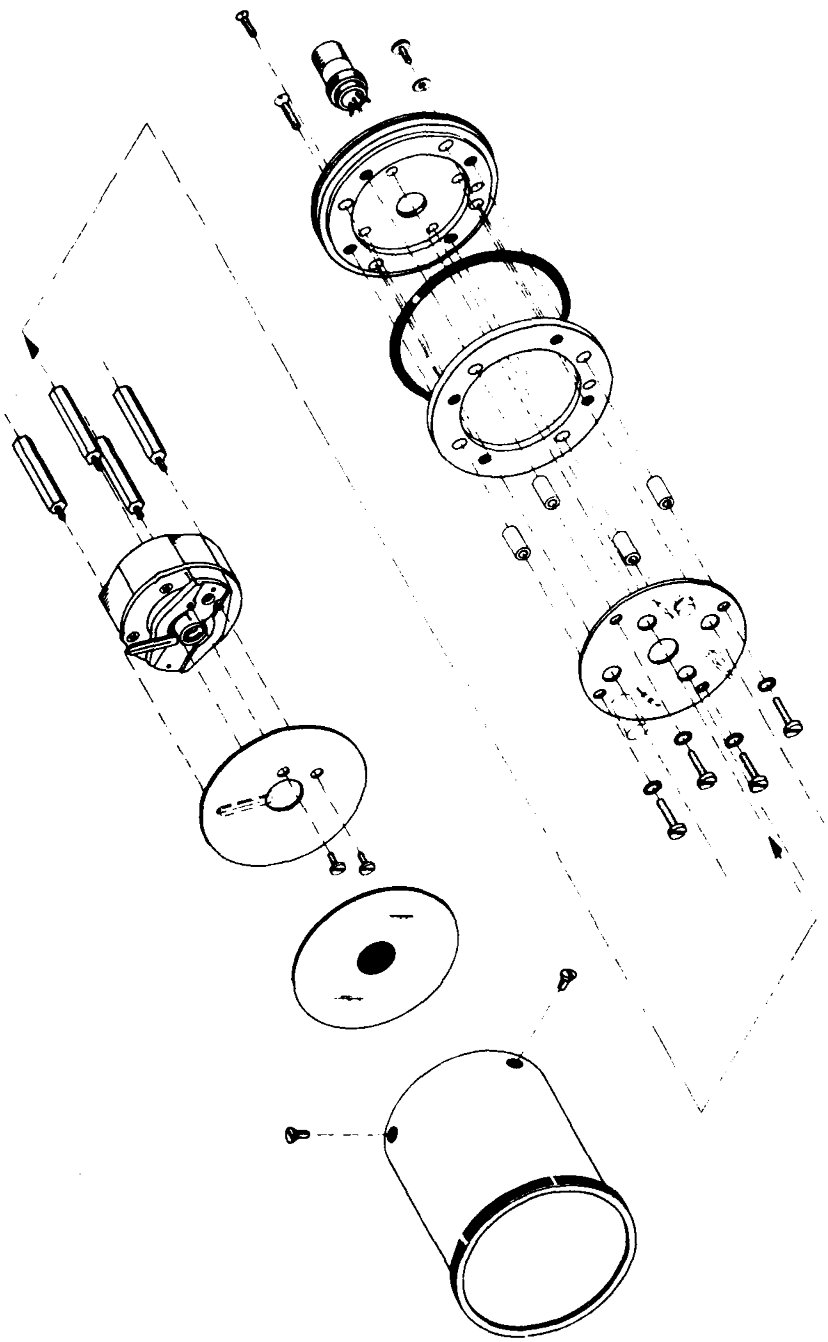


FIGURE 2 - EXPLODED VIEW OF TORQUEMETER PN 73-30-1

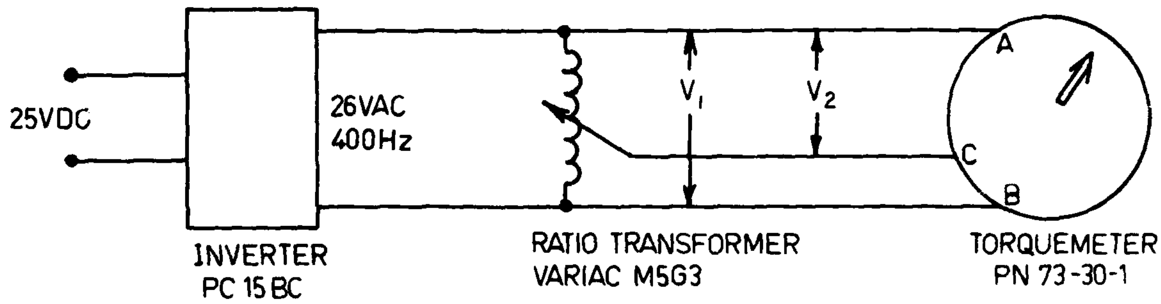


FIGURE 3 - CIRCUIT DIAGRAM - ARDU LABORATORY TESTS

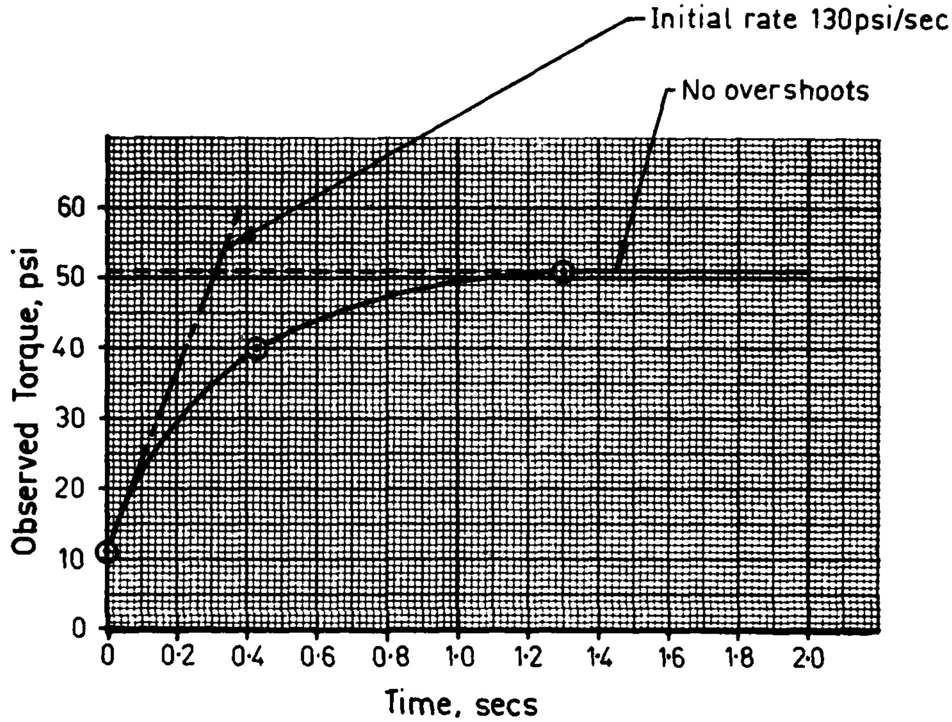


FIGURE 4 - INSTRUMENT RESPONSE TO STEP INPUT

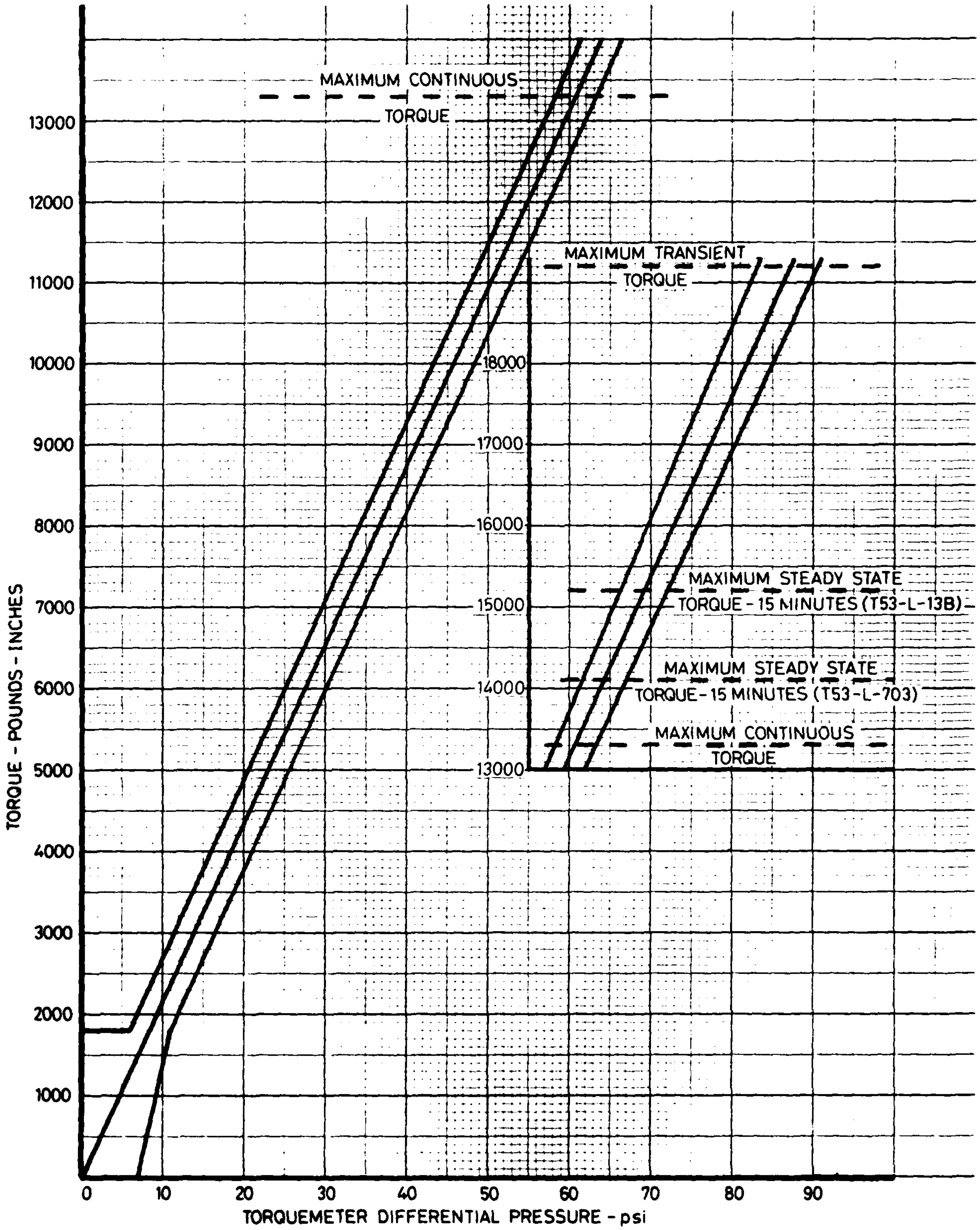


FIGURE 5 - TORQUEMETER ACCURACY LIMITS (T53-L-13B)

PROPOSED TORQUEMETER ADJUSTMENT PROCEDURE

1. The following torquemeter adjustment procedure is proposed by ARDU to minimize indication errors for an installed engine and torque measuring system:

a. Determine the Data Plate Torque (DPT) value of the installed engine.

b. Enter the torquemeter adjustment graph, Figure 1, with DPT and determine the corresponding Desired Torquemeter Indication.

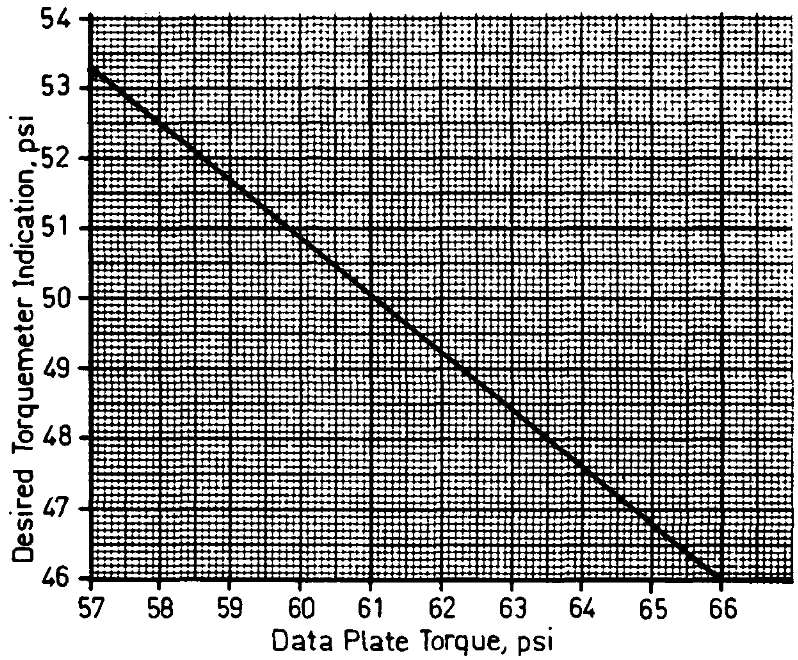


FIGURE 1 - TORQUEMETER ADJUSTMENT GRAPH

c. Using the NP-1 portable hydraulic rig, pump the engine torque measuring system to 50 psi indicated on the calibrated NP-1 meter.

d. Use the 'zero set' adjustment on torquemeter PN 73-30-1 to make the instrument read the desired torquemeter indication determined in step b.

e. Reduce the engine torque measuring system pressure to zero and place a reference decal on the face of torquemeter PN 73-30-1 at the indicated reading. This will be used as a guide to system serviceability (calibration) when an NP-1 rig is not available (eg during Before- and After-flight Inspections).

2. If an engine change is undertaken in the field and an NP-1 portable hydraulic rig is not available, the adjustment should be made at an engine torque measuring system pressure of zero. The indicator should be made to read the desired indication determined from Figure 1, MINUS 50 psi. The system should be properly calibrated as soon as an NP-1 hydraulic rig is available.

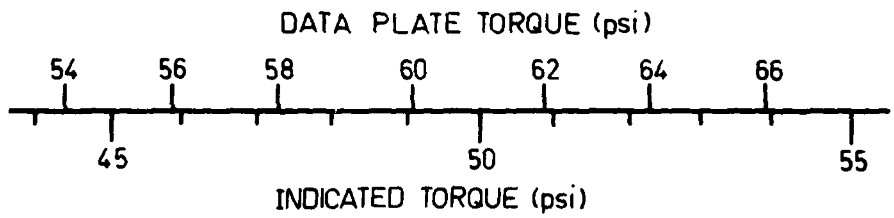
EXTRACT FROM RNZAF TORQUEMETER CALIBRATION PROCEDURE

1. The procedure listed below is to be accomplished if either the engine, torque pressure transmitter or torque pressure indicator is changed:

a. Determine the engine torque calibration factor from the engine data plate.

b. Using the scale below determine the equivalent indicated torque. (Note: This scale is extrapolated from TM55-1520-210-10 Fig 14-21).

TORQUE CALIBRATION FACTOR



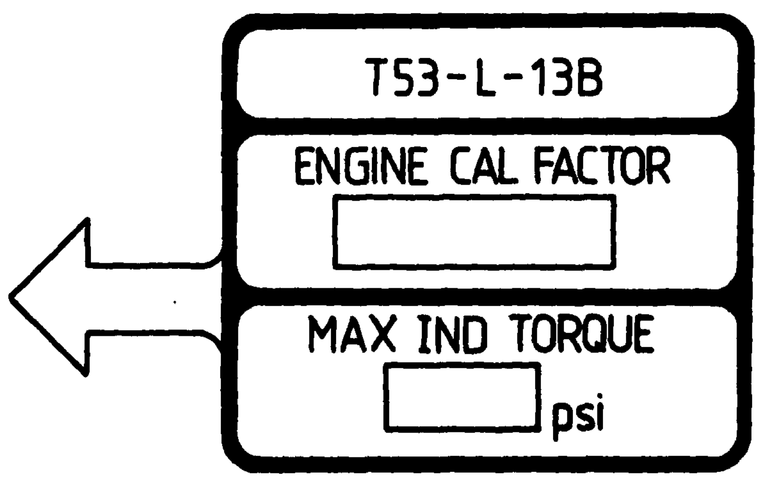
c. Connect a dead weight tester to the torque pressure transmitter and apply the indicated torque pressure derived from the scale. (Tolerance = ±1 psi).

d. Note the torque pressure indicator reading and enter this figure in the 'MAX IND TORQUE' space on the decal shown below.

e. Enter the torque calibration factor from data plate in the 'ENGINE CAL FACTOR' space on the decal shown below.

f. Replace the existing decal with the new decal.

g. Adjust the green/red line around the torque indicator perimeter so that the transition from green to red is in line with the new maximum indicated torque when viewed from the pilot's seat.



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