ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Control of Inspection, Measuring and Test Equipment

7.6 Control of Inspection, Measuring and Test Equipment

7.6-01 Measuring Equipment

7.6-01-01 Control of Inspection, Measuring and Test Equipment

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Control of Inspection, Measuring and Test Equipment

1. PURPOSE OF PROCEDURE

Ensure that the measuring equipment used in standard tests is efficient and its metrological characteristics ensure test results with the intended accuracy.

2. SCOPE

Laboratory in which the ITTC procedures related to experimental hydromechanics are implemented.

3. NORMATIVE REFERENCES

ISO 10 012 : 1992
"Quality assurance requirements for measuring equipment"

ISO/IEC 17025 : 2000
"General requirements for the competence of testing and calibration laboratories."

4. DEFINITIONS

(<u>*absolute) error of measurement*</u>*:* The result of a measurement minus the true value of the measurand.

<u>*accuracy of measurement*</u>**:** The closeness of the agreement between the result of measurement and the (conventional) true value of the measurand.

<u>*adjustment*</u>**:** The operation intended to bring a measuring instrument into a state of performance and freedom from a bias suitable for its use.

<u>*calibration*</u>**:** The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values of a quantity represented by a reference standard.

<u>*correction*</u>**:** The value which, added algebraically to the non corrected result of a measurement, compensates for an assumed systematic error.

<u>*drift*</u>**:** The slow variation with time of a metrological characteristic of a measuring instrument.

<u>*influence quantity*</u>**:** A quantity which is not the subject of the measurement but which affects the value of the measurand or the indication of the measuring instrument.

<u>*limits of permissible error (of a measuring instrument*</u>**):** The extreme values of an error permitted by specifications, regulations, etc. for a given measuring instrument.

<u>*measuring equipment*</u>**:** All of the measuring instruments, measurement standards, reference materials, auxiliary apparatus and instructions that are necessary to carry out a measurement. This term includes measuring equipment used in the course of testing and inspection, as well as that used in calibration.

<u>*measurement:*</u> The set of operations having the object of determining the value of a quantity.

<u>*metrological confirmation*</u>**:** Set of operations required to ensure that an item of measuring equipment is in compliance with requirements for its intended use.

Metrological confirmation normally includes calibration, any necessary adjustment or repair and subsequent recalibration, as well as any required sealing and labelling.

measurand: A quantity subjected to measurement.

measuring instrument: A device intended to make a measurement, alone or in combination with supplementary equipment.

(*measurement) standard***:** A material measure, measuring instrument, reference material or system intended to define, execute, preserve or reproduce an unit or one or more values of a quantity in order to transmit them to other measuring instruments by comparison.

*national (measurement) standard***:** A standard recognised by an official national decision to serve in the country, as the basis for fixing the value of all other standards of the quantity concerned.

*(quality) audit***:** A systematic and independent examination carried out in order to determine whether quality activities and the related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve the intended objectives.

*reference conditions***:** Conditions of use for a measuring instrument prescribed for performance of tests, or to ensure valid mutual comparison of the measurement results.

resolution (of an indicating device): A quantitative expression of ability of an indicating device permitting a significant distinguishing between immediately adjacent values of the quantity indicated.

*specified measuring range***:** The set of values for a measurand for which the error of a measuring instrument is intended to lie within specified limits.

*stability***:** The ability of a measuring instrument to maintain its metrological characteristics constant.

traceability: The property of the result of a measurement whereby it can be related to appropriate measurement standards, generally international or national standards, through an unbroken chain of comparisons.

*uncertainty of measurement***:** A result of the evaluation intended for determining the range within which the true value of a measurand is estimated to be found, generally with a given likelihood.

5. RESOURCES OF MEASUREMENT EQUIPMENT

An important aspect of the efficient operation of Quality System according to measuring equipment is a full identification of devices used for the tests. In relation to definition presented in chart 3 the term "measuring equipment" is taken to encompass "measuring instruments" and "measuring standards". Moreover the term "measuring instruments" is taken to encompass measuring instruments which are used in tests and other items called "auxiliary apparatus" which may be used for indications only.

A system for storage, transport and handling should be established for measuring equipment, except instruments used for indication only, in order to prevent abuse or misuse.

For each item of measuring equipment, the Laboratory Quality Manager shall designate a competent member of staff as authorised officer to ensure that confirmations are carried out in accordance with the system and that the equipment is in satisfactory condition.

In case where any measurement equipment is supplied from an outside source, the laboratory shall ensure that their metrological characteristics and confirmation data comply with requirements of the own confirmation system.

5.1 Records

Measuring equipment instruments shall have their individual cards in which the following data shall be placed:

- - name of equipment
- - manufacturer
- - model
- - series
- - laboratory identification number (optionally)
- - status (verified, calibration, indication)

Moreover the information about the date of last and next calibration or verification shall be placed on this card (see Appendix1). All the data shall be signed by authorised officer.

5.2 Labelling

The laboratory shall ensure that all measuring equipment is securely and durably labelled, coded or otherwise identified to indicate its status (verified, calibrated or indication). Any confirmation labelling shall clearly indicate date of last confirmation and when the date of the next confirmation according with the Supplier's or own system requirements. The labelling shall also permit ready identification of person responsible for meeting this deadline.

Measuring equipment that is deemed not to require confirmation shall be clearly identified as such, so that it may be distinguished from equipment that requires confirmation but which label has become mislaid or detached.

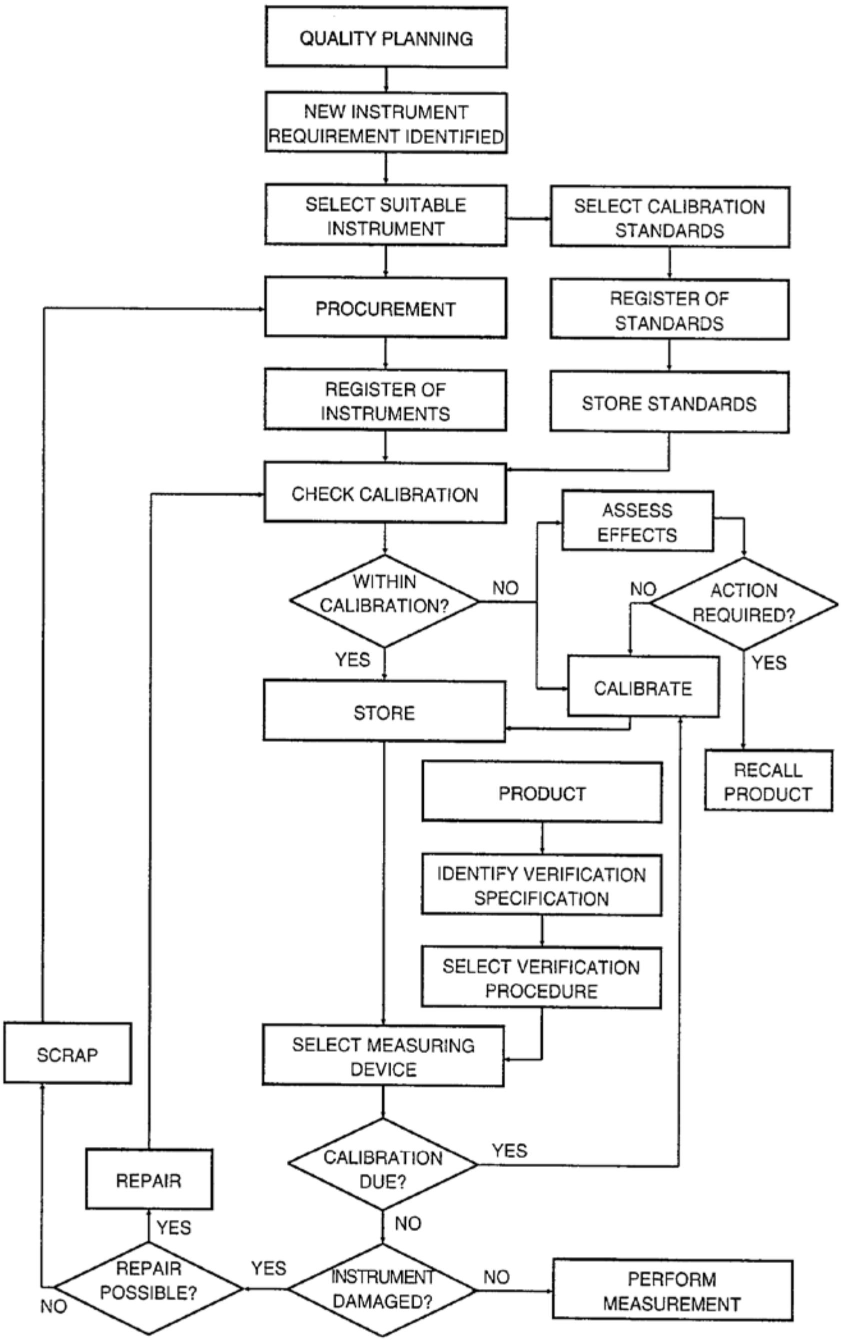

Fig.1 Inspection measuring and test equipment control function

6. CONFIRMATION SYSTEM

The intention of the confirmation system is to ensure that the risk of measuring equipment producing erroneous results remains within acceptable limits.

6.1 Measuring standards

Measuring standards used in laboratory for calibration purposes, shall be confirmed (verified) by Weights and Measures Office at appropriate intervals (defined by the Weights and Measures Office).

All measuring standards used in laboratory for the confirmation purposes shall be supported by certificates, reports or data sheets for the equipment confirming the source, uncertainty and conditions under which the results were obtained. Such document shall be signed by a person confirming the correctness of the results.

6.2 Calibration

The laboratory shall ensure that the calibration tests are carried out using certified measuring standards having a known valid relationship to international or nationally recognised standards.

The laboratory shall ensure that all confirmation of metrological characteristics (stability, range, resolution and ”calibration factor” or „calibration curve” are performed by staff having appropriate qualifications, training, experience and skill, working under proper supervision. Calibration tests shall be carried out according to the Calibration Procedure (Sample see Appendix 4).

The environmental conditions shall be controlled during the test and , if possible, correcting compensations shall be applied to the measured results. The records shall contain both the original and the corrected data.

All significant uncertainties including those attributable the measuring equipment (as well as to measuring standards) and those introduced by human and environmental factors, shall be taken into account when performing measurements and calibrations.

All relevant data including those available from any statistical process control system shall be taken into account when estimating the uncertainties.

The results of calibration in the form of ”calibration reports” or „calibration certificate” shall include:

- identification of certificate for measuring standards
- description of environmental conditions
- calibration factor or calibration curve
- uncertainty of measurement
- “minimum and maximum capacity” for which the error of measuring instrument is within specified (acceptable) limits.

The calibration results shall be recorded including necessary details so that the traceability of all the measurements can be demonstrated and so that any measurement can be reproduced under conditions close to the original conditions, thereby facilitating the detection of any anomalies.

6.2.1 Calibration Records

The recorded information shall include:

a) description and unique identification of equipment;

b) date on which each confirmation was completed;
c) calibration results obtained after and, where appropriate, before any adjustment and repair;
d) assigned confirmation interval;
e) identification of the confirmation procedure;
f) designated limits of permissible error;
g) source of the calibration used to secure the traceability;
h) relevant environmental condition and the information on necessary corrections;
i) information on the uncertainties involved in calibrating the equipment and on their cumulative effect;
j) details of any maintenance carried out, such as servicing, adjustment, repairs or modifications;
k) any limitations in use;
l) identification of the person(s) performing the confirmation;
m) identification of person(s) responsible for ensuring the correctness of the recorded information;
n) unique identification (such as serial numbers) of any calibration certificates and other relevant documents concerned.

The laboratory shall maintain clear documentation of measuring activities (including the duration and safeguarding of the records). The records shall be kept until it is no longer probable that they may need be referred to.

6.3 Intervals of Confirmation

The measuring equipment (including measuring standards) shall be confirmed at appropriate (usually periodical) intervals, established on the basis of their stability, purpose and wear. The intervals shall be such that confirmation is carried out again prior to any probable change in the equipment accuracy, which is important for the equipment reliability. Depending on the results of preceding calibrations, the confirmation period may be shortened, if necessary, to ensure the continuous accuracy of the measuring equipment.

The intervals of confirmation shall not be prolonged unless the results of calibrations at preceding confirmations provide definite indications that such action will not affect confidence in the accuracy of the measuring equipment.

The laboratory shall have specific objective criteria for decisions concerning the choice of intervals of confirmation.

6.4 Non-Conforming Measuring Equipment

Any item of measuring equipment

- that has suffered damage,
- that has been overloaded or mishandled,
- that shows any malfunction,
- whose proper functioning is subject to doubt,
- that has exceeded its designated confirmation interval, or
- the integrity of whose seal has been violated,

shall be removed from service by segregation, clear labelling or cancelling.

Such equipment shall not be returned to service until the reasons for its nonconformity have been eliminated and it is confirmed again.

If the results of calibration prior to any adjustment or repair were such as to indicate a risk of significant errors in any of the measurements made with the equipment before the calibration, the laboratory shall take the necessary corrective action.

6.5 Periodic Audit And Review Of The Confirmation System

The laboratory shall carry out, or shall arrange to be carried out, periodical and systematic quality auditing of the confirmation system in order to ensure its continuous effective implementation.

Based on the results of the quality audits and of other relevant factors, such as feedback from Purchasers, the laboratory shall review and modify the system as necessary.

Plans and procedures for the quality audit and review shall be documented. The quality audit and review and any subsequent corrective actions shall be recorded.

Appendix A **: SAMPLE OF MEASURING EQUIPMENT CARD**

QM 4.10.5.1	**Measurement Equipment Card**	**L**aboratory **I**dentification **N**umber	
Equipment		Manufacturer Serial No.	Model Date of Purchase
	Basic range		
Work Instructions Calibration Instructions Verified at			**Status** Calibrated Indication Verified

Date of Check	Certificate. No.	Period	Date of Next Check	Responsible	Department	Approval

Appendix B **: SAMPLE OF CALIBRATION CERTIFICATE.**

QM 4.10.6.2	**CALIBRATION CERTIFICATE for**		**NO.**	
	PROPELLER DYNAMOMETER		**LIN**	
Calibration Instructions			Calibrated by :	
Date of calibration			Checked by :	
Measurement combination				
DYNAMOMETER	Manufacturer		Model	
LIN	Serial No		Date of purchased	
	Work instruction		Last calibration	
Cable				
AMPLIFIER	Manufacturer		Model	
LIN	Serial No		Date of purchase	
	Work instruction		Type of transducer	
	Excitation		Frequency of excit.	
Thrust :	Amp. gain		Zero not load	
Torque :	Amp. gain		Zero not load	
Cable				
A/C TRANSDUCER	Manufacturer		Model	
LIN	Serial No		Date of purchased	
	Work instruction		Certificate No	
MEASUREMENT STANDARDS	Mass		Certificate No	
	Length arm of force		Certificate No	
	Voltmeter		Certificate No	

QM 4.10.6.2

CALIBRATION RESULTS

Environmental condition

Place of test :				
Temperature :	initial		final	
Dampness :	initial		final	

Computation results of calibrations test

Executed program	procedure	certificate NO.

	Thrust	**Torque**
Drift :		
Non Linearity errors :		
Hysteresis :		
Precision errors :		
Total uncertainty :		
Calibration factor :		

Calibration requests :

Specified limits of	Thrust	**Torque**
errors :		
Maximum capacity :		
Minimum capacity :		

Note : tests and computations results are included in report

Prepared by : .... Approved by : .... Date : ....

Appendix C SAMPLE DTMB ISO 9000 PROCEDURE

Title:	Procedure Number: 00-5230-113-01	Revision Number: Rev 3	Effective Date: April 12, 1996
Control of Inspection, Measuring and Test Equipment	Prepared by: **D. Downin**	Approved by: R. J. Stenson	Page : 1 of 2

Section 11.0 - Control of Inspection, Measuring and Test Equipment

Calibration of Torsionmeter/Thrustmeter Equipment

In addition to Division procedures for Inspection, Measuring and Test Equipment, the Full Scale Trials Branch calibrates torsionmeters and thrustmeters capable of determining propeller shaft torque and thrust. The calibration of the torsionmeters is traceable to ISO 9001 Certificate of Registration 12 100 4192 and the National Institute of Standards and Technology (NIST). The calibration of the thrust load cells are traceable to NIST.

Calibrations will meet or exceed manufacturer's specifications. Bias limits will be calculated at the conclusion of each calibration and will be held to established standards. If the difference between the pre-trial calibration and the post-trial calibration values are greater than the bias error at full-scale voltage, the trial data must be adjusted. The Pass/Fail Instrumentation Check and Calibration Work Instruction 00-5230-114-03 provides further guidelines as well as bias limit values for various data channels.

11.1 Purpose

To provide a procedure for torsionmeter and thrustmeter calibrations which are not covered under Division procedures.

11.2 Responsibilities

The Branch Equipment Manager (BEM) is responsible for ensuring the effective implementation of this process.

11.3 Torsionmeter Calibration Procedure

11.3.1 All Full-Scale Trials Branch Torsionmeter systems will be calibrated in accordance with the Torsionmeter Calibration Work Instruction 00-5230-114-01 prior to use.

11.3.2 Calibration will be done according to the specifications requested by Program Managers using either Calibration Request Form 11A or 11B.

11.3.3 Once a calibration is complete and approved by the requester, a copy of the calibration is put into the Torsionmeter Calibrations book by the person calibrating the torsionmeter. A copy of the calibration is filed in the Ship's Project file by the person requesting the calibration.

11.3.4 Upon return of torsionmeter equipment, a post-calibration is performed on all systems in accordance with the Torsionmeter Calibration Work Instruction 00-5230-114-01.

Calibration Request

Ship #: ____________ Ship Name: ____________
Type of Trial: Builders ___ Acceptance ___ Special ___
Requestor's Name: ____________ Requestor's Signature: ____________
Date Required By: ____________ Date of Request: ____________

DESIGN REQUIREMENTS	VALUE		SOURCE	
Design Torque	(lbft)			
Full-Scale Torque	(lbft)			
Transient Torque	(lbft)			
RPM				
Horsepower				
Modulus of Rigidity	(enter individual values below)			
PRIMARY SYSTEMS	**PORT (3) or Single**	**STBD (1)**	**PORT (4)**	**STBD (2)**
Ring #				
Ring Bore				
Shaft O.D.				
Shaft I.D.				
Modulus of Rigidity				
10 or 16 MHz				
Shaft Rotation (aft -> fwd)				
PANEL METER DISPLAY	**PORT (3) or Single**	**STBD (1)**	**PORT (4)**	**STBD (2)**
Torque (4 digits)				
RPM (3 digits)				
Horsepower (3 digits)				

SPARE SYSTEM

# of Spares Required: ____________ 10 or 16 MHz: ________
ET Box ___ Sensor & Demod ___ Filter ___ RPM/Period ___ HP Calc ___
Panel Meter ___ 160 kHz Supply ___

Please check all parts required.

NOTE:

- Standard procedure is to calibrate to 5.000V Q Filtered at design torque and to to 150% design torque.
- Make any additional notes or special requirements on the reverse of this sheet.

SEPTEMBER 1995

Form 11A (Rev1)

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(when filled in)

Calibration Request

Ship #: ________________ Ship Name: ____________________________

Type of Trial: Builders ___ Acceptance ___ Special ___

Requestor's Name: ________________ Requestor's Signature: ________________

Date Required By: ________________ Date of Request: ________________

DESIGN REQUIREMENTS	**VALUE**	**SOURCE**
Design Torque	(lbft)	
Full-Scale Torque	(lbft)	
Transient Torque	(lbft)	
RPM		
Horsepower		
Modulus of Rigidity	(enter individual values below)	

PRIMARY SYSTEMS	**PORT (3) or Single**	**STBD (1)**	**PORT (4)**	**STBD (2)**
Ring #				
Ring Bore				
Shaft O.D.				
Shaft I.D.				
Modulus of Rigidity				
10 or 16 MHz				
Shaft Rotation (aft -> fwd)				

PANEL METER DISPLAY	**PORT (3) or Single**	**STBD (1)**	**PORT (4)**	**STBD (2)**
Torque (4 digits)				
RPM (3 digits)				
Horsepower (3 digits)				

SPARE SYSTEM

\# of Spares Required: ____________ 10 or 16 MHz: ________

ET Box ____ Sensor & Demod ____ Filter ____ RPM/Period ____ HP Calc ____

Panel Meter ____ 160 kHz Supply ____

Please check all parts required.

NOTE:

- Standard procedure is to calibrate to 5.000V Q Filtered at design torque and to to 150% design torque.
- Make any additional notes or special requirements on the reverse of this sheet.

CONFIDENTIAL

(when filled in)

Form 11B (Rev1) SEPTEMBER 1995

Appendix D **SAMPLE DTMB ISO 9000 WORK INSTRUCTION**

Title: Control of Inspection, Measuring and Test Equipment	Work Instruction Number: 00-5230-114-02	Revision Number: Rev 1	Effective Date: April 12, 1996
Thrustmeter Calibration	Prepared by: J. Webb	Approved by: R. J. Stenson	Page : 1 of 4

Thrustmeter Calibration Work Instruction

Purpose

The purpose of this work instruction is to provide a guideline for calibrating a thrustmeter system for use on Full Scale trials. Each thrustmeter system consists of a number of load cells which are calibrated independently.

Scope

This work instruction applies to the preparation, calibration, and installation of thrustmeters for use in Full Scale trials. It establishes test requirements, procedures and limits.

Responsibility

The Trial Engineer is responsible for the implementation of the procedures outlined in this work instruction.

Procedure

Introduction.

1. Compression Load cells are purchased and maintained in inventory and are installed in the ahead and astern thrust bearings of each shaft when conducting ship trials. Load cells are calibrated prior to installation in accordance with the procedures outlined in this work instruction.

2. Depending on the bearing design the load cells mount in holes in either the shoes or in the leveling plates.

3. Load cells are placed behind every shoe on the ahead and astern side of the thrust bearing. A typical two shaft installation would require 8 ahead and 8 astern shoes per bearing, i.e., 32 load cells must be supplied, calibrated and installed.

Prior to calibration

1. Assemble load cells.

   a. Check branch inventory for suitable sizes and quantities of load cells for the job. This should be done sufficiently in advance so that the load cells can be purchased if they are not available in stock. Typical delivery times for load cell orders are 6 to 12 months.

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b. Most load cells are wired in a Wheatstone bridge circuit with a separate resistor board assembly. The correct resistor board (trimmed to match a given load cell) must be matched to the appropriate load cell by serial number.

c. The trial engineer should **develop** and assemble a system which provides:

- excitation **for each load cell** (typically 5 to 15 VDC),
- Bridge completion (i.e., wiring between resistor board and load cell),
- oil-tight connectors to get **cables** into the thrust housing,
- a provision to shunt cal the bridge,
- amplifiers (with a typical gain of 200).

2. Assemble equipment for the Calibration.

a. An appropriately sized compression load machine is used for the calibration. The machine's range must meet or exceed the full scale rating of the load cells being calibrated. The machine should be in good **operating order**, i.e., when the machine is set to a particular steady load, the applied load will not drift. **The machine should also have a current calibration which is traceable to NIST.** A copy of the calibration papers must be obtained and filed in **the ship's project file, the Trial Engineer's Log/Notebook, and the Thrustmeter Calibration Book.**

b. **A high impedance voltmeter (at least 1 meg ohm input) that is accurate to 1 micro-volt is used to record data at the bridge level.** Typical full scale outputs of our load cells are 10 to 30 mv full scale. An Analog to Digital converter may be used if it does not load the system **and meets the accuracy requirements of 1 µvolt.** A voltmeter is connected to the bridge and used for visual observations.

c. **A computer maybe used in conjunction with Analog-Digital converters or digitizing voltmeters to record calibration data**

d. In the laboratory, the load cell system is assembled with excitation **sources**, bridge completion and system cabling duplicating the upcoming trial configuration. Though not preferable, the load cell can be calibrated without an amplifier. The excitation and resistor board must be connected. If more than one load cell shares one excitation source, then all load cells on that source need to be connected to avoid system problems.

e. Load cells must be calibrated in a leveling plate or shoe, as applicable. Machinists metal blocks are used to support the leveling plate in the load machine.

Title: Control of Inspection, Measuring and Test Equipment **Thrustmeter Calibration**	Work Instruction Number: 00-5230-114-02	Revision Number: Rev 1	Effective Date: April 12, 1996
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Calibration

1. Software

a. Though data can be collected **manually**, a computer **and Analog-Digital converters or digitizing voltmeters** will be used to the maximum extent possible. Use of the computer will facilitate **collecting**, plotting, curve fitting and uncertainty analysis of the data.

2. Data collection

a. Load cells must be connected and allowed to warm up at least one hour before taking data. Load cells should be cycled in **the compression load machine** by **raising** the load to full scale and back to zero 3 times prior to data collection. **This exercises** the cell and **decreases** the occurrences of hysteresis.

b. Data is taken over the full range of the load cell or over the range of interest. **Data is taken at zero (unloaded) and at intervals of approximately 20% of the expected full load range of the load cell. Upon reaching the maximum load, data is collected at the same points as the load is incremently decreased down to and including zero.** Upon completion of a full cycle from zero to peak load and back, a second cycle should be done. The second cycle, repeating every other point of the first cycle, is done to check absolute drift. (see **Thrustmeter Calibration Form 11E**).

c. Prior to the first data cycle and after the second data cycle the cal switch will be thrown and the cal step data recorded. Cal steps are to be taken only at zero applied load. A zero reading should be recorded **prior to** each **calibration** reading.

d. Data to be recorded include applied load (lbs), load cell serial number, load cell excitation voltage (v), load cell output voltage (mv), amplified load cell output (v), and resistor board serial number. (See **Thrustmeter Calibration Form 11E**)

e. A running plot of voltage versus load should be created as the data is collected. **Check the data plot for linearity, repeatability of second points and repeatability of the zero points.** If problems are noted, the calibration should be stopped until the problems are corrected. Loose connections, bad solder joints, improper wiring, bad amplifiers, etc. are possible causes of problems.

f. Load cell resistances are checked. Breaks in load cell cables, if not inside the load cell, are repaired. The load cell, if bad, is often used as a blank to fill the hole in the leveling plate unless additional load cells (rare) are available. Thus every attempt to find and repair problems must be accomplished.

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<u>After calibration</u>

1. **Data tables are to be filed as calibrations in the ship's project file, the Trial Engineer's Log/Notebook, and the Thrustmeter Calibration Book.**

2. Curve fits (least squares etc.) to the data will be used to arrive at an overall best gain to be used for each load cell with the trials instrumentation

3. A Calibrated Load Cell Summary table is made listing Gains, Zeros, and Cal steps for each load cell calibrated. **Copies will be filed in the ship's project file and in the Trial Engineer's Notebook.**

4. **Bias limits will be calculated for each load cell calibrated.**

5. Personnel conducting the trial should assign each load cell a location within the thrust bearing based on the quality of the calibration. If all calibrations are **satisfactory**, the order does not matter. If several cells show non-linearity or other anomalies, they should be placed on the astern side of the thrust bearing if the astern cells are the same type/size as the ahead units.

6. Upon completion of trials, the thrustmeter load cells and leveling plates are removed from the ship's thrust bearing. The bearing is restored to its original condition by reinstalling standard unmodified leveling plates/shoes. This generally occurs at the first yard availability period after trials.

7. Upon return of the load cells to NSWC a post-**calibration** of the load cells is accomplished. The post-**calibration** is **to** be examined by the Trial Engineer. If significant changes are noted, the trials data and or reports are modified accordingly.

References

1. Trial Engineer Log/Notebook
2. **Thrustmeter Calibration Book**

Thrustmeter Calibration Form

Ship or Project: ____________________ Date of Calibration: ______________

Calibrated by: ____________________ Initials of Calibrator: ______________

Checked by: ____________________ Initials of Checker: ______________

Load cell Serial No: ______________ Amp S/N: ____________________

Amp Gain: ____________________ DVM S/N: ____________________

Leveling plate Serial No.: ___________ Resistor board Serial No.: ___________

Load %F.S.	Load (lbs)	Bridge out (mV)	Amp out (v)	Excitation (v)
0	______	________	________	________
	Cal step	________	________	________
20	______	________	________	________
40	______	________	________	________
60	______	________	________	________
80	______	________	________	________
100	______	________	________	________
80	______	________	________	________
60	______	________	________	________
40	______	________	________	________
20	______	________	________	________
0	______	________	________	________
40	______	________	________	________
80	______	________	________	________
100	______	________	________	________
80	______	________	________	________
40	______	________	________	________
0	______	________	________	________
	Cal step	________	________	________

Form 11E (Rev 1) OCTOBER 1995