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## APPENDIX 4 1. SAMPLE DTMB ISO 9000 WORK INSTRUCTION

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


Controlled Document

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22 <sup>nd</sup> ITTC QS Group	22 <sup>nd</sup> ITTC 1999
Date	Date

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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.

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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 incrementally 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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After calibration

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**



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### 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	_____	_____	_____