FSEL PROCEDURE FOR CALIBRATION OF LOAD CELLS

1 PROCEDURE OVERVIEW

The calibration of a compression, tension, or compression-tension load cell is outlined in this procedure. A calibration factor is determined based on the use of a master load cell, or combination of master load cells, meeting the requirements of ASTM E74.

The calibration process applies load using three cycles. The first cycle is a relatively rapid cycle from 0 to 100 percent of the calibration. The second and third cycles are performed more slowly so that data can be taken during loading.

1.1 Student Responsibilities for Calibration

- Read and understand the requirements of this procedure
- Determine the upper and lower limits of calibration needed
- Move load cell to be calibrated to test machine
- Move data acquisition to be used for calibration to test frame
- Set up data acquisition for calibration (See Section 4.4 for details)

1.2 Staff Responsibilities for Calibration

- Read and understand the requirements of this procedure
- Identify master load cell(s) with the appropriate range of load
- Move master load cell(s) to test machine
- Verify the calibration load cell(s) has a valid calibration
- Apply and control loading with the appropriate test machine
- Sign and retain digital copies of calibration records

2 EQUIPMENT AND TOOLS

▪ Load Cell ▪ Data Acquisition System ▪ Master Load Cell(s) with Force Indicator(s)

▪ Uniaxial Testing Machine ▪ Assorted Shimming or Alignment Materials and Fixtures

3 PERSONAL PROTECTIVE EQUIPMENT

▪ Safety Glasses ▪ Safety Shoes ▪ Hardhat

4 DETAILED PROCEDURE

4.1 Select the mode and corresponding set of verification forces for calibration of the load cell.

4.1.1 If the load cell is capable of both compression and tension measurements, select the mode to be calibrated during this instance of the procedure implementation.

The master load cells available at FSEL are compression-only. Calibration of load cells in tension is described in this procedure, but is not possible with current FSEL hardware.

This procedure must be implemented on two separate occasions for calibration of both compression and tension modes. The tension and compression modes of a load cell should be calibrated on an independent basis as deemed necessary.

4.1.2 Determine the upper and lower limits of the range of forces over which the load cell will be verified.

The limits of verification may be controlled by the calibrated range of the master load cell(s). Each master load cell must be used over only the Class A loading range identified within the corresponding calibration certificate. The approximate load ranges for the calibration load cells are:

Load Cell	Approximate Calibration Range
840521 (LO)	1 to 10 kips
840512(HI)	10 to 100 kips
821204	100 to 1,000 kips

4.1.3 Select a set of verification forces that are well distributed over the desired range of forces and inclusive of the upper and lower limits identified above.

Typically, 10 verification forces are used for calibration. For example, typical verification forces for a 500k load cell are: 50k, 100k, 150k, 200k, 250k, 300k, 350k, 400k, 450k, and ≈500k. The set of verification forces may also be determined per the applicable guidance of ASTM E4.

4.1.4 Record the load cell mode (compression or tension), selected set of verification forces, and the serial number, or other unique identifiers, of the load cell.

An electronic Excel form for recording pertinent information and data is available and recommended for use with this procedure. The completed form will serve as the official record of the load cell calibration.

4.2 Verify that the master load cell(s) to be used for load cell calibration comply with test specification.

4.2.1 Select the most appropriate master load cell, or combination of master load cells, for calibration of the load cell over the desired range of forces.

It may be necessary to use two or more master load cells to calibrate the load cell over the full set of verification forces. In such cases, the lowest subset of the forces corresponding to the smallest master load call should be verified first.

If two or more master load cells are used to obtain the correct calibration range, the two loading cycles required by Article 4.9 should be performed for each master load cell used.

These cycles should be completed on with each master load cell before changing to the next master load cell.

4.2.2 Verify that the ASTM E74 calibration of each master load cell was completed by an A2LA, NVLAP-, ACLASS-, L-A-B-, IAS-, or PJLA-accredited laboratory in conformance with the requirements of ISO 17025 (Ref. 6.3).

All master load cells and corresponding force indicators must be recalibrated according to ASTM E74 at intervals not exceeding one year. AT FSEL, Master load cells are typically sent to an accredited laboratory for calibration over each winter break.

4.2.3 Record the serial numbers, or other unique identifiers, of each master load cell and force indicator.

4.3 Turn on the electronic and hydraulic systems of the testing machine or reaction frame that will be used to apply force to the load cells.

4.4 Allow the load cell; indicator or data acquisition system; master load cell; and master load cell indicator to equalize near the testing machine.

4.4.1 Place the load cell and master load cell near, or preferably in, the testing machine.

4.4.2 Connect the load cell to the data acquisition system and the master load cell to the indicator.

4.4.3 Configure the indicator for use per the requirements of the calibration data sheet.

4.4.4 Configure the data acquisition software to output and record the excitation voltage and output voltage for the load cell at each load step chosen in Article 4.1.3.

The calibration calculation template uses these two quantities (excitation and output voltages) to determine the appropriate calibration factor.

4.4.5 Record the applicable hardware and software configurations of the load cell and indicator and the data acquisition system (i.e. serial numbers of hardware, scaling factor, excitation voltages, etc.).

4.4.6 Configure the force indicator for the master load cell to comply with the parameters listed within the calibration records.

4.4.7 Record the configuration (i.e. range, shunt calibration number, etc.) of the force indicator for the master load cell.

4.4.8 Allow the load cell; the data acquisition system; master load cell; and master load cell indicator to equalize in the calibration environment for a minimum of 10 minutes.

Equalization of the devices within the vicinity of the testing machine is necessary to ensure stable readings.

4.5 Implement and repeat the operations outlined in Articles 4.6 through 4.10 as necessary to calibrate the load cell over the full set of verification forces.

4.6 If not done so previously, position the master load cell and load cell in series within the testing machine and ensure that their centerlines coincide with the centerline of the grips or crossheads of the testing machine.

The centerlines should be checked visually and by taking measurements. Shimming materials, spherical bearing blocks, clevises, and other fixtures may be used to ensure that the load axes of the testing machine and measurement devices coincide.

4.7 Prior to force application, zero the force indicator of the master load cell and the indicator or data acquisition system of the load cell being calibrated.

4.8 Load the load cell and master load cell, to the upper limit beginning from an unloaded state, and make adjustments as necessary to ensure that the master load cell and load cell zeroes are stable when no load is applied.

The "upper limit" may correspond to the minimum of: (a) the upper limit of the ASTM E74 Class A loading range of the master load cell in use, and (b) the upper limit of the selected verification forces.

4.9 Complete a minimum of two calibration runs.

During application of force, the force on the master load cell indicator is followed until it reaches the values preselected in Article 4.1.3. The output voltage of load cell is recorded at each of these forces along with the force values indicated from the master load cell.

4.9.1 Obtain readings near zero load for both the load cell and master load cell.

4.9.2 Increase the force applied to the load cells in a slow and steady manner.

Loading rate should be slow enough that a clear indication of load from the master load cell indicator and the load cell data acquisition system can be recorded simultaneously and accurately.

4.9.3 Record the output voltage of the load cell as measured by the data acquisition system and the applied force as measured by the master load cell when each of the verification forces is attained.

It is acceptable for the recorded forces to deviate slightly from the verification forces, but care should be taken to minimize deviations.

When using the LabVIEW-based data acquisition system, it is recommended to use the "Single Record" option so that readings are recorded only at the desired verification forces.

4.9.4 Continue to apply force and complete readings until reaching the upper limit of the desired range of forces.

4.9.5 Remove the force from the load cells, wait approximately 30 seconds, and record the zero readings for both the master load cell and load cell.

4.9.6 Repeat the verification runs as desired, but not less than two times per load cell per calibration.

4.10. Export or record the output voltages for the load cell being calibrated at each verification force from the data acquisition system.

4.11 Calculate the sensitivity.

Calculations should be performed based on a least-squares regression. This method is used in the Excel template for determining load cell sensitivity values.

4.11.1 Identify the nominal load cell capacity and input this value into the calibration spreadsheet.

Input cells are highlighted in the Excel file. Values should only be input into these highlighted cells.

Generally, a load cell is calibrated over its entire load range. However, load cells can be calibrated over a smaller range if needed for a particular application. If a smaller range is used, this range should be clearly marked on the load cell and used as the basis for calculating calibration factors.

4.11.2 Based on the data file produced from the data acquisition system, determine the average excitation voltage that was supplied to the load cell during the calibration and enter this value into the calibration spreadsheet.

Excitation voltages will likely change slightly during calibration. If excitation voltage deviates from the average value by more than 1 percent, the calibration should be repeated.

4.11.3 Enter the output voltage of the load cell as recorded by the data acquisition system and the applied force as measured by the master load cell at each of the verification forces into the calibration spreadsheet.

If a National Instruments or Campbell Scientific data acquisition system is used for calibration, the voltage recorded and output by the control software may be normalized by the instantaneous excitation voltage. Thus, each individual output voltage may need to be multiplied by the excitation voltage prior to use in the Excel template. Consult with FSEL staff should there be any question about the normalization of voltages.

If a Keysight/Agilent system was used for calibration, the output voltage need not be multiplied by the excitation voltage if Article 4.4.4 was followed during calibration.

The template uses Excel's least squares regression function to calculate sensitivity as the slope of the best-fit line, in mV/V, that relates the values described in 4.9.3 and 4.11.3. The sensitivity is calculated for the three different data acquisition systems used at FSEL: Keysight/Agilent, Campbell Scientific, and National Instruments.

4.12 Confirm the errors calculated in 4.11 do not exceed 1 percent of the full-scale capacity of the load cell.

If error exceeds 1 percent of the full-scale capacity, the calibration should be repeated. If repeated calibrations are unable to reduce the error to acceptable levels, the load cell may not be functioning properly and should be marked as such after informing pertinent project and FSEL personnel.

If an older sensitivity parameter is available for the load cell (either from factory calibration or a previous calibration at FSEL), compare the result of the new calibration with the existing number. If the difference is greater than 10 percent, inform pertinent project and FSEL personnel before using the new calibration parameters.

4.13 Following successful calibration, affix a label to the load cell to indicate (a) the calibration date, (b) the sensitivity in mV/V, and (c) range of calibration in lb or kip.

Calibration of the load cell should ideally be completed on a pre-use, annual, incidental, and post-use (i.e. completion of program) basis.

4.14 Enter the necessary information into the "Calibration Results" sheet of the calibration template.

Input cells are highlighted in the Excel file. Value should only be input into these highlighted cells. Once this template is completed, send to FSEL staff to be signed and archived.

4.15 Provide electronic copies of all calibration records generated during implementation of this procedure to the pertinent project or FSEL personnel for their signature.

4.16 Save an electronic version of these results in PDF form and store on the FSEL file server.

The calibration records should also be linked to the inventory record of the load cell being calibrated.

5 SUPPORTING DOCUMENTS

5.1. Ferguson Structural Engineering Laboratory. *FSEL Load Cell Calibration Template*. Revision 0.

6 REFERENCED DOCUMENTS

It is the responsibility of project personnel to ensure that the most recent versions of the referenced FSEL documents are utilized during procedure implementation.

6.1. ASTM E74-13: *Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines.* West Conshohocken: ASTM International, 2006.

6.2. ASTM E4-15: *Force Verification of Testing Machines.* West Conshohocken: ASTM International, 2010.

6.3. ISO/IEC 17025-05: *General requirements for the competence of testing and calibration laboratories.* Geneva: International Organization for Standardization and International Electrotechnical Commission, 2005.

RECORD OF REVISIONS

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0	2016-03-10	All	Initial Issue