GUIDANCE NOTES ON

IN-SERVICE HULL STABILITY VERIFICATION

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Foreword

7-2-5/5 of the ABS *Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)* requires ABS verification of an effective weight control program throughout the operational life of all column-stabilized units. Similar requirements apply to any other column-stabilized units, such as a tender unit, or an accommodation unit. These Guidance Notes provide technical recommendations and guidance for monitoring lightship weight and vertical center of gravity while a column-stabilized unit is in service.

Having a satisfactory in-service hull stability verification program may avoid the excess time and cost spent for preparation and completion of an inclining test.

The in-service hull stability verification program determines the location of vertical center of gravity of a column-stabilized unit at the operating location. This is achieved by performing frequent inclining tests at regular intervals at sea. Allowances can be made for the mooring and other external forces. By applying the in-service hull stability verification program, trends are developed from multiple tests, and these trends can be used to help identify any unaccounted weight onboard. This results in the improvement of the accuracy of the weight log.

These Guidance Notes become effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of these Guidance Notes is the most current.

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SECTION 1 Introduction

1 General

The in-service hull stability verification program allows the location of vertical center of gravity of a Column-Stabilized Unit (CSU), hereafter referred as "unit", to be determined throughout its operation life at any point in time. This is achieved by performing frequent inclining tests at regular intervals at sea. Allowances can be made for the mooring and other external forces. By applying the in-service hull stability verification program, trends developed from multiple in-service hull stability verification tests can be used to help identify unaccounted weight onboard and update the weight log accordingly. This results in a reduction in weight log discrepancies, and helps meet regulatory requirements. In comparison, a conventional inclining test requires the unit to be transported to a sheltered location in order to determine the vertical center of gravity (VCG), which is only known when the inclining test is complete.

7-2-5/5 of the ABS *MODU Rules* and 3.1.5 of the IMO *Code for the Construction and Equipment of Mobile Offshore Drilling, 2009 (MODU Code)* requires a lightweight survey or an inclining test to be conducted during a CSU's first Special Survey of Hull. If the survey or test during first Special Survey demonstrated that the owner was maintaining an effective weight-control program, and onboard records/log of all weight changes throughout the CSU was well maintained in support of daily operations, lightship displacement may be verified by an in-service hull stability verification program described in these Guidance Notes.

3 Objective

These Guidance Notes provide recommendations and technical guidance on verifying the lightship weight and vertical center of gravity while the unit is in service. They supplement the following Rules for satisfying the classification requirements relevant to weight control:

- ABS *Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)*
- ABS *Guide for Building and Classing Mobile Offshore Units (MOU Guide)*
- IMO *Code for the Construction and Equipment of Mobile Offshore Drilling, 2009 (MODU Code)*

5 Scope and Application

These Guidance Notes are primarily applicable to in-service hull stability verification of Column-Stabilized Units (CSU) at the operating location under favorable environmental conditions. Production installations may require special consideration.

Prior to acceptance for statutory purposes, flag State approval is required.

7 Definitions

ABS Recognized External Specialist. Service suppliers, not employed by ABS, who at the request of an equipment manufacturer, shipyard, unit's owner or other clients provide services for a ship or a MODU such as inspection, measurements, test or maintenance of safety systems and equipment, the results of which are used by surveyors in making decisions affecting classification or statutory certification and services. For more information, please refer to: http://ww2.eagle.org/en/rules-and-resources/recognized-specialists.html, or contact Corporate ABS Programs at externalspecialist@eagle.org.

Deadweight. The weight of the unit excluding light weight. Thus, Displacement = Lightweight + Deadweight.

Displacement. Total weight of the unit. For a freely floating body, this is equal to the weight of the displaced water.

Displacement Verification. The lightship displacement is verified in operation by comparing the calculated and observed draft. This provision was introduced in IMO *MODU Code* 2009 to facilitate renewal survey of structures with adequate weight control programs.

Draft. The molded draft is the vertical distance from the molded base line to the assigned load waterline.

Inclining Test. A series of measurements taken by moving a weight in transverse and longitudinal direction and measuring corresponding heel and trim angles. From this information, the unit's vertical center of gravity is determined. The inclining procedure is submitted to ABS for review prior to the test and the inclining test is carried out in the presence of an attending ABS Surveyor. The inclining test is referred to as "conventional inclining test" in this document for clarity.

In-service. The unit located at its operating site, and thus subject to environmental loads.

Lightweight. Lightweight is the displacement of the complete unit with all of its machinery, equipment and outfit, including permanent ballast, required spare parts and liquids in machinery and piping to their working levels but without liquids in storage or reserve supply tanks, items of consumable or variable loads, stores or crews and their effects.

Lightweight Survey. A survey carried out at the time of the stability test to audit all items which must be added, deducted, or relocated on the unit so that the unit can be adjusted to the lightship condition. The weight and location of each item are accurately determined. Using this information, the unit draft levels and hydrostatic properties, the lightship displacement and longitudinal and transverse center of gravity may be obtained.

Relative Density (Specific Gravity). The ratio of the mass of a material at a given temperature to the mass of gas-free distilled water of the same volume at the same or a different temperature. The reference temperature of the material and water should be explicitly stated.

9 Abbreviations

ASTM:	American Society for Testing and Materials, currently referred as ASTM International
CSU:	Column-Stabilized Unit
GM:	Distance from center of gravity to the metacenter
IMO:	International Maritime Organization
MODU:	Mobile Offshore Drilling Unit
VCG:	Vertical Center of Gravity

SECTION 2 In-Service Hull Stability Verification Procedure

1 General

The in-service hull stability verification uses a number of sensors to obtain the inclination angle, mooring and riser tensions, relative density and temperature of the seawater, unit draft and tank contents. The equipment used should be checked for operability conditions and accuracy. The unit should be prepared prior to performing the onsite test. The test schedule and the unit particular information should be communicated to the involved parties. Best practices for data acquisition and test result reporting specific to the system used for the in-service hull stability verification should be followed. The external specialist providing this service should be evaluated based on organizational and technical capabilities to carry out the required services. Further detail could be found in the ABS Recognized External Specialist program.

3 Typical System Components

3.1 Inclinometer

An inclinometer can be used to measure the change in the unit heel or trim instead of a pendulum or water tube which is used in conventional inclining tests. Calibrated inclinometers with at least 0.05 degree accuracy and recording capability of 0.01 degrees should be used as a system component for in-service hull stability (ASTM F1321 – 14/6.8.1). Devices other than inclinometers should be agreed prior to usage.

Inclinometers should not be used without correction for inertial effects when there is substantial transverse or longitudinal asymmetry in the hull for the angles of heel to be used.

3.3 Hydrometer

Hydrometers are used to obtain the relative density (specific gravity) of the sea water which is then used to convert displaced volume into mass of the floating structure. As the sea water density varies with temperature, it is recommended to use a thermohydrometer, which is a hydrometer integrated with a thermometer. See ASTM standard E100-17 for hydrometer specifications.

3.5 Draft Gauge

Draft gauges are used to measure the draft at each column of the column-stabilized unit. This measurement is then used to obtain the displaced volume. In calm environment, draft measurements could be taken by visual observation of draft marks on the columns or plastic tubes installed internally for draft measurement. However, in the case of in-service hull stability measurement, environmental effects could prohibit accurate visual inspection of draft markers or water tubes. Pressure gage based draft measurement devices are preferred in such cases. The measuring device used should be calibrated and certified for use in the in-service environmental condition. Some form of averaging over time should be applied – either as part of the gauging or by sampling of results.

3.7 Tank Sounding Device

Tank sounding devices should be used to verify the liquid levels. The measuring device used should be calibrated and certified for use in the in-service environmental condition. Some form of averaging over time should be applied – either as part of the gauging or by sampling of results.

3.9 Mooring Tension Sensor

The mooring line tension sensors are used to obtain the tension time-history throughout the in-service hull stability verification. These values are critical to consider as they affect the total vertical load on the unit and thus the unit displacement. The measuring sensor should be calibrated and certified for use in the environmental condition under which the in-service inclination test is performed. Further information regarding calibration of force measurement devices are provided in ASTM E74-13a.

3.11 Onboard Software

The data acquisition system includes software that needs to be available onboard the unit. This software is expected to be the command center that controls all peripheral equipment and sensors. It is essential that there is no lag of data acquisition between different sensors, as the synchronized time history data is the key for obtaining the final verification result. A report containing the complete result of the inclining test along with other peripheral sensor readings such as draft gauge, mooring load cell, hydrometer, and tank fluid levels should be prepared for record keeping and review. The in-service hull stability verification test system should have error detection/obstruction of the measurement process and be capable of detecting failure or breakdown of individual components. The system should stop the measurement and release a relevant warning or ask for new data once an error is detected.

3.13 On Shore Analysis

The data obtained from the in-service inclining test should be reported in both printed and electronic format including the items listed in Subsection 2/9. Numerical algorithms are applied for processing of the time history data to obtain the final VCG location. The final approval of the results should be retained on board for verification.

5 Environmental Conditions

A conventional inclining test requires a sheltered location so that pendulums can be used to accurately measure the inclination angle. The in-service hull stability verification procedure is conducted with the use of inclinometers to allow for measurement of the inclination angle of the unit at the location of operation, where significant loadings due to environmental factors such as wind, wave and current is expected. In-service hull stability verification should be performed under acceptable environmental conditions. Adverse weather causes loading on the unit that cannot be measured effectively.

Unit motion due to vortex shedding interaction between hulls could undermine the reliability of the inclinometer data. If such motions are detected, the in-service hull stability verification procedure should not be performed.

7 Preparation and Procedure for In Service Hull Stability Verification

7.1 Unit Condition

The unit should be prepared prior to performing in-service hull stability verification. The amount of variable dead load on the unit should be kept at a minimum for the operations required. Any item that can move during the in-service hull stability verification should be secured in place. The information related to the unit geometry, hydrostatics, tank capacities, and mooring arrangement which are not measured, but derived directly from the approved unit drawings and stability books should be up-to date.

7.3 Tank Conditions and Free Surface Effects

The presence of liquid in the tanks during in-service hull stability verification procedure introduces further complications in determining the metacentric height (GM). As the unit is inclined, the liquid shifts to the lower end causing additional heeling of the unit which is not due to shifting of the test weight. Thus, to correct the GM calculation, exact weight and distance of the shifting liquid needs to be obtained. The free-surface should be minimized by emptying the tanks or by filling the tanks completely, so that no shift of weight occurs. It should be noted that filling the tanks completely is less desirable method as air pockets are difficult to remove between structural members of the tank. Therefore, in general, empty tanks are preferred.

However, for in-service hull stability measurements it is usually hard to confirm if tanks are completely empty and it is good practice to make an allowance for residual fluids below the suction pipe and the associated free surface. The residual level of fluids into tanks should be discussed and agreed upon. For tanks that are full, an allowance should be made for fluids in the air pipe to the mean draft if gravity filled or to the top of the air pipe if pumped. Full tanks should be confirmed as full by regular 'topping-up' in a seaway to minimize the presence of air pockets.

In the case where a tank must be left slack, it is preferred to have the level in the tank where the sides of the slack tank are parallel vertical planes and the waterplane of the tank has a regular shape (i.e., rectangular, trapezoidal, etc.) when viewed from above so that the free surface moments of the liquid can be accurately determined. To avoid pocketing, slack tanks should be 20% to 80% full if they are deep tanks and 40% to 60% full if they are double bottom tanks.

When ballast water is used as inclining weight, the actual transverse and vertical movements of the liquid should be calculated taking into account the change of heel of the unit. This will require accurate knowledge of the position of the tank gages. Free-surface corrections should not apply to inclining tanks.

7.5 Mooring Arrangements

The location of the mooring fairleads should be verified onboard with the provided drawings. The type of mooring arrangement (i.e., catenary mooring or taut mooring) should be noted. The mooring tension measuring sensors should be in working condition. If the mooring tension sensors are found to be inaccurate or damaged, alternative methods for mooring tension estimation should be considered on a case-by-case basis.

If the mooring lines are disconnected and stored in the chain locker during the in-service hull stability verification procedure, the weight and position of the center of gravity of the chain should be recorded.

Propeller wash from any support vessel working in close proximity should be avoided.

7.7 List and Trim

To simplify calculations, it is recommended to perform the in-service hull stability verification with the mean unit position as close as possible to even list and design trim. The maximum initial heel should not exceed 0.5 degrees. The unit should have sufficient draft so that any abrupt change in water plane is avoided. It is also important to have the pontoons sufficiently below the water surface so that the effect of dynamic pressure variation is negligible. If, for any reason, the weights are to be transferred only transversely, a constant trim should be maintained. If, for any reason, the weights are to be transferred only longitudinally, a constant heel should be maintained. Movements that combine transverse and longitudinal weight movements are, however, preferred.

7.9 Test Weights

The method used to create the heeling moment should be sufficient to provide a minimum of 1° and maximum of 4° of heel (or trim, if weights are shifted longitudinally).

If the heeling moment is created by shifting large shipboard equipment, such as a cantilever package, blow-out preventer, etc., then the equipment weighing procedure and its results should be reviewed to certify the weights. In addition, all additions or removals of weights from the equipment should be documented; the overall weight and center of gravity of the equipment should be appropriately updated prior to using them in the inclining calculations.

Precaution should be taken to confirm that the deck strength is sufficient to support the weight movements. Where the weight exceeds the allowable deck load, a structural analysis should be performed to determine if the deck can support the weight.

A crane with sufficient capacity and ability to move the weight to the maximum required distance, or suitable alternative means should be available to shift the weight in a safe manner. If the crane used to move the weight is not part of the inclining weight (as in a cantilever package for example), the crane should be restored to a neutral position before starting the measurement.

Where the shifting of ballast water is used to create the heeling moment, the following precautions are to be followed:

i) The water should be shifted between tanks having vertical or near-vertical sides and well-defined geometry. The sides should be free of large stringers that can create air pockets or the tank structure should be checked for sufficient air holes.

ii) For transverse weight shifts, the tanks used should not significantly change the trim of the unit during the test. For longitudinal weight shifts, the tank used should not significantly change the heel of the unit. Weight shifts that combine transverse and longitudinal rotation may be used upon reviewing the technique used to analyze the corresponding output.

iii) Accurate tank sounding/ullage tables should be provided. The water level should shift within a range of levels where the "permeability" due to internal structure and piping is constant and easy to estimate.

iv) Specific gravity measurements of the shifted water should be taken and recorded before and after the test.

v) The water level in each tank should be measured before and after each weight shift by direct reading of a fixed sounding device.

vi) The vertical, longitudinal and transverse centers of gravity of the contents of each tank should be recorded for each movement. If the VCG of the unit changes with each shift of water, the analysis of the results should account for these changes.

vii) Accuracy in the volume of water shifted and volume found in each tank after each movement should be verified. The water level change in each tank should be recorded for each weight shift. The amount of water removed from the donating tank and the amount of water received by the other tank should be recorded. Differences in these amounts should not be greater than 1.5%.

viii) Continuous valve control should be maintained during the test to verify that water is not diverted and that all the water transfer only occurs between the designated inclining tanks.

ix) Sufficient time should be allowed between completion of a liquid shift and the inclinometer reading to verify that tank contents are not sloshing and that water is not siphoning between tanks through the piping.

x) The anticipated time to conduct the inclining should be estimated. If the period is too long, the procedure may be unacceptable because of the possibility of wind shift.

7.11 Communication

The in-service hull stability verification procedure and task responsibilities should be reviewed and clearly explained to all involved individuals. All other personnel who are not directly involved in the operation should be in known areas of the unit for the duration of the experiment.

All movements of weights on board should be minimized for the duration of the in-service test and any significant continuing weight movements (e.g., oil fuel usage or sanitary water use/discharge should be included in estimates of precision).

A control station with proper measurement display unit should be set up, and the person in charge of recording the results should have complete control over all personnel involved in the test.

7.13 Dynamic Positioning Systems

If the unit is dynamically moored, unit motion records should be obtained in typical operating and typical sea conditions of the impact of the DP system on unit roll and pitch to determine the impact on the averaging of heel and trim. Recording intervals may be required to be adjusted or a limitation on the weather conditions for in-service hull stability verification may be imposed.

9 Reporting In-service Hull Stability Verification Results

The in-service hull stability verification is typically performed in two phases, first the data acquisition from both onshore and onboard sources and second processing of the data and obtaining the final result. The following information should be collected related to the data acquisition phase:

i) *Unit Particulars.* Ownership and port of registry, principal particulars, displacement

ii) *Loading Condition.* Lightship weight, deadweight, tank contents and other variable weights

iii) *External Forces.* Riser tension, mooring tension and any other external connection that produces significant loading on the unit that could affect the inclining test. Mooring arrangement and type of mooring, taut or catenary to be identified.

iv) *Environmental Conditions.* Swell, sea, wind, current, water depth, water temperature at the time of test

v) *Weights Used for Inclining.* Position of weights during the inclining test

vi) *Tank Soundings.* Tank sounding data before and after each weight movement

vii) *Ballast Tank Used for Inclining.* If ballast tanks are used for inclining, soundings should be recorded along with position of the tanks

viii) *Draft Readings.* Draft at all draft reading locations should be recorded before and after each in-service inclination to verify displacement. This may be made by continuous recording with averaging over suitable time intervals or short term recordings to obtain an average. Where no suitable systems are in place for such recording, a visual sampling method that averages the reading over a suitable time interval may be used.

ix) *Inclinometer Readings.* Inclination time history for each weight movement

This report should be signed by the captain or the Offshore Installation Manager (OIM). The attending Surveyor should confirm the correctness of the data and that the approved procedure has been followed.

The results from any single in-service hull verification test should be included in a statistical description on a time base of the unit's lightweight and vertical center of gravity. It is recommended that such tests are performed at regular intervals through the unit's life.

The data processing report should include all necessary information required for a thorough review. Integration of in-service hull stability information into stability software programs and loading hardware systems may be reviewed by ABS and accepted on a case by case basis for application subject to effective onboard demonstration of the system. The elements of the in-service hull stability verification may also be included in the ABS Survey Planning Documentation.

SECTION 3 Installation, Operation and Maintenance

1 Location of Measurement Devices

The in-service hull stability verification measurement control center should be located near the unit's operations monitoring station so that the user has access to any relevant operational information during the stability verification procedure.

If required, the unit containing the inclinometers may be restrained using fixtures that do not restrain the unit from following the unit's heel and trim.

The location and positioning of the measurement devices should be confirmed prior to usage. They should not be attached to structures or items which may be moved or subject to vibration.

3 Installation Report and Operations Manual

Once the in-service hull stability verification system is installed and verified, an installation report should be prepared. The report should contain following details:

i) Unit specific user manual containing description of the test procedures and use of the instruments

ii) Techniques to check the instruments for consistent operation at regular intervals

iii) Description of the installation on board the unit

iv) Details of any interfaces to other on board systems or measuring devices

v) A list of all components included or which may be interfaced (inclinometers, computer hardware, sensors etc.)

vi) Flow diagram describing the processing of the input data during a test as well as analysis of measured data incorporated in the software

vii) In the analysis of the results, any limitations for carrying out a test such as environmental limitations or external forces acting on the unit

viii) Sample of documentation provided after each test

ix) List of stored characteristic data and the source of the information (e.g., hydrostatic particulars, tank sounding tables, etc.)

x) Documentation giving description and calibration certificates for any onboard sensors such as mooring tensions, draft gauges and tank sounding gauges. Calibration intervals, accuracy and precision of such instrumentation should be available in the certificates.

5 Verification of Operability

A written confirmation to the unit owner should be issued after commissioning and satisfactory review of the functionality of the in-service hull stability verification system. This will also note that training has been given and that suitable manuals have been provided. Training certificates should be issued to onboard personnel who complete the training and can demonstrate familiarity and competence with the use of the onboard installation. Approved system manuals and personnel trained and certified to perform onboard testing should be utilized. The manual and training qualifications should be reviewed by the surveyor during annual confirmation surveys.

7 Verification of Equipment Performance In-Service

7.1 Access to Instruments

No access should be allowed to the internals of the instrument cases and this should be made clear to the end user in the documentation provided to them. In case of faults, the instrument should be returned for repair and subsequent approval. Measures to identify tampering with equipment such as tamper evident seals or similar techniques should be applied.

7.3 Calibration

The system should be calibrated prior to performing the inclining test using manufacturer provided methods.

7.5 Performance

Performance verification of the operation in-service is based on correct operation and repeatability of signal. If any component of the system is found to be not working or giving non-repeatable signal, the test should be cancelled and the system should be repaired and verified.

SECTION 4 Monitoring and Record Keeping

1 New Construction

All new built CSUs or existing CSUs that have completed a major modification, are to be subjected to an inclining test as required by 3-3-1/3 of the *MODU Rules*. If an ABS approved in-service hull stability verification system is installed on such CSUs, it should be calibrated using the conventional inclining test results. It is preferred that the provider of the in-service system attends the initial inclining test.

3 Existing Units in Operation *(1 July 2018)*

The in-service hull stability verification system installed on an existing unit that is in operation should be calibrated using a recent lightweight survey and compared to conventional inclining test record. If the in-service inclining test results in lightweight discrepancy of more than 1%, the difference should be quantified to reestablish the baseline. In the event a lightship survey or inclining test is carried out at the time of installation of the in-service hull stability system, it is recommended that the ABS external specialist be in attendance to assure complete data transfer.

3.1 Weight Management

In all cases, any changes to the lightweight of the unit due to change in machinery, structure, outfitting and equipment should be recorded in a lightship data alteration log and be taken into account in daily operations (See 7-2-5/5 of the *MODU Rules*).

It is the responsibility of the Offshore Installation Manager (OIM) to keep an accurate lightweight alteration log.

3.3 Lightweight Survey

For the first renewal survey, the lightweight should be verified through a lightweight survey and the results of the in-service hull stability verification system. In the succeeding renewal surveys, the lightship should be verified based on the record of lightship alteration log as per 7-2-5/5.3.6 of the *MODU Rules*. The lightship displacement may be verified in operation by comparing the calculated and observed draft as an alternative to lightweight survey. If the expected displacement and the displacement based on the draft reading exceed 1% of the operating displacement, a light weight survey should be completed.

Any formal lightweight survey should be conducted according to an ABS approved procedure.

3.5 In-Service Lightship Displacement Verification

The in-service displacement verification is recommended to be conducted on a regular basis and confirmed at the time of annual survey to continuously develop confidence on the lightship particulars. The location of VCG obtained through regular in-service verifications should be monitored, and ABS should be notified if significant deviation from the baseline value is observed. Apart from this, it is recommended to use suitable opportunities such as dry docking time to perform light weight surveys in sheltered environment.

3.7 Discrepancy in Lightship Alteration Log and In-service Lightship Displacement

If the expected displacement and the displacement based on draft surveys and/or the estimates from the in-service hull stability verification system exceed 1% of the operating displacement, a formal lightweight survey should be completed (See 7-2-5/5.3.6 of the *MODU Rules*).

3.9 Recommendation for Conservative Positions

When discrepancy between lightship weights is observed between the lightweight survey and lightship alteration log, and it is decided to put the additional weight in a conservative vertical center of gravity position, the following guidance is recommended:

i) If the lightship weight obtained from lightweight survey is less than the light weight log, meaning the unit is lighter than expected, the weight discrepancy should be placed at the baseline.

ii) If the lightship weight obtained from lightweight survey is greater than the light weight log, meaning the unit is heavier than expected, the weight discrepancy should be placed at the drill floor level or at a similar height for non-drilling units.

5 Modifications

The in-service hull stability verification should be performed after any major modification of the unit and it is recommended that a series of measurements, closely spaced in time are performed. These multiple tests should be treated as one statistical estimate within any continuing series of results. If an in-service hull stability measuring system is installed, it should be re-calibrated after any major modification with a conventional inclining test. If the modification is minor, then only the in-service hull stability verification may be conducted and the change in VCG along with corresponding weights and locations be recorded.

APPENDIX 1 References

1. ABS *Rules for Building and Classing Mobile Offshore Drilling Units*
2. ABS *Guide for Building and Classing Mobile Offshore Units*
3. IMO Code for the Construction and Equipment of Mobile Offshore Drilling, 2009
4. ASTM Standard Guide for Conducting a Stability Test (Lightweight Survey and Inclining Experiment) to Determine the Light Ship Displacement and Center of Gravity of a Vessel (ASTM F1321-14), 2014
5. ASTM Standard Specification for ASTM Hydrometers (ASTM E100-17), 2017
6. ASTM Standard practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines (ASTM E74-13a), 2013