

NIST HANDBOOK 150-10 CHECKLIST EFFICIENCY OF ELECTRIC MOTORS PROGRAM

Instructions to the Assessor: This checklist addresses specific accreditation requirements prescribed in NIST Handbook 150-10, *Efficiency of Electric Motors*. The Test Method Review Summary, which is used to review the laboratory's ability to perform Efficiency of Electric Motors test methods, is to be used in conjunction with this checklist.

- All items on this checklist shall be addressed.
- Select "X" for each item that represents a nonconformity.
- Select "C" for each item on which you are commenting for other reasons.
- Select "OK" for each item you observed or verified as compliant at the laboratory.
- Record the item number and the nonconformity explanation and/or comment on the appropriate comment sheet.

Note 1: The numbering of the checklist items correlates to the numbering scheme in NIST Handbook 150-10, clauses 3, 4, and 5.

Note 2: In this document the term *polyphase electric motor*, written in italics, refers to polyphase induction motors with rated output of 1 hp to 500 hp for which test standards IEEE 112 method B and CSA C390 method 1 may be used to determine efficiency. The term *small electric motor* refers to single-phase induction motors and polyphase induction motors 1 hp or less. Efficiency of these motor types may be determined using IEEE 114, CSA C747, or IEEE 112 method A (for small polyphase motors). DOE-recently-amended definitions of these two categories may be found in the *Federal Register*, Vol. 77 No. 87 (May 4, 2012). The new DOE definition of Electric Motor is broader and not restricted to polyphase 1 hp to 500 hp.

3 Accreditation process

3.2 Management system review

- ___ 3.2.1 If management system documentation is not organized the same as NIST Handbook 150, a cross-reference document shall verify that all requirements of NIST Handbook 150-10 and clauses 4 and 5, as well as annexes A through B, of NIST Handbook 150 are addressed and their locations identified in the management system documentation.

3.3 On-site assessment

- ___ 3.3.3 All laboratory equipment required to perform accredited testing shall be available for assessment and in good working order.

The laboratory shall be prepared to demonstrate selected test methods as requested by the assessor

___ 3.3.4 The laboratory shall make available all supporting technical information in a format that is conducive to a detailed review.

___ 3.3.8 The laboratory shall make available all calibration, traceability, and verification records for all equipment and instrumentation.

3.4 Proficiency testing

___ 3.4.3 The laboratory shall have satisfactorily participated in all required proficiency testing during its previous accreditation period.

Laboratories applying for initial accreditation shall also participate satisfactorily in proficiency testing (or a suitable alternative, if available), provided the proficiency testing is offered during the application period, before accreditation will be granted.

___ 3.4.4 The proficiency testing shall not be contracted out to another laboratory.

___ 3.4.5 Using the test data from proficiency testing, the laboratory shall monitor its own testing performance.

Procedures for analyzing and monitoring the laboratory's own proficiency testing results shall be documented in its management system documentation.

___ 3.4.6 If the laboratory performs unsatisfactorily in any proficiency test, the laboratory shall take corrective action to investigate and resolve nonconformities in a timely manner, according to the requirements of NIST Handbook 150 for the control of nonconforming work.

___ 3.4.7 The results of proficiency testing shall be made available to NVLAP assessors for use during laboratory on-site assessment visits.

4 Management requirements for accreditation**4.2 Management system**

___ 4.2.1 Staff shall demonstrate, if authorized, the retrieval of needed documents and/or records.

___ 4.2.2 The laboratory shall create a cross-reference document that facilitates verification by both the laboratory and the NVLAP assessor that all program requirements have been addressed by the management system. This cross-reference shall include clauses 4 and 5 and annexes A and B of NIST Handbook 150 and the corresponding NIST Handbook 150-10. The cross-reference requirement is satisfied if the management system documentation is organized and numbered the same as NIST Handbook 150.

4.6 Purchasing services and supplies

___ The laboratory shall evaluate vendors and verify or test incoming equipment, materials, and supplies that affect the quality and accuracy of the test results. Records that these items have been reviewed for technical completeness shall be examined by the assessor.

These records of evaluations shall include (but are not limited to):

- ___ a) calibration service providers/calibration certificates;
- ___ b) general laboratory equipment and supplies, including thermocouples and thermocouple wire;
- ___ c) data processing and acquisition equipment.

4.13 Control of records

___ 4.13.1 The personnel responsible for motor preparation and, where appropriate, the associated date(s), shall also be identified in the records.

4.13.2 The records shall include (but are not limited to):

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- ___ a) acceptance/rejection of motors submitted for testing;
 - ___ b) comprehensive logs for tracking motors and test activities;
 - ___ c) original data collected by the laboratory;
 - ___ d) calibration and verification data;
 - ___ e) data and results of quality control;
 - ___ f) equipment and maintenance records;
 - ___ g) test reports.
- ___ 4.13.3 Test records sufficient to reconstruct the test shall be kept for a period of at least three years following the issuance of a test report, unless a longer period is required by the customer, regulation, or the laboratory's own procedures.
- 4.14 Internal audits**
- ___ 4.14.1 An applicant laboratory shall conduct at least one complete internal audit prior to the first on-site assessment.
 - ___ 4.14.2 Internal audits are separate and distinct from management reviews (see 4.15) and the NVLAP assessment.
- 4.15 Management reviews**
- ___ An applicant laboratory shall perform at least one complete management review prior to the first on-site assessment.

5 Technical requirements for accreditation**5.2 Personnel****5.2.1 Personnel records**

___ 5.2.1.1 The laboratory shall maintain a list of personnel designated to fulfill NVLAP requirements.

___ 5.2.1.2 The laboratory shall document and maintain records on the required qualifications of each staff member, including a résumé of qualifications; laboratory testing procedures to which the person is assigned and authorized to perform; and the results of periodic testing performance (competency) reviews (see also 5.2.3.4), which may include testing among laboratories and/or repeated testing by the same operator or comparative testing with two or more operators.

___ 5.2.1.3 The laboratory shall notify NVLAP when key personnel are added to or removed from the staff. Notification to NVLAP of personnel changes shall include a current résumé for each new staff member.

___ 5.2.2 Specific experience and competence of technical director

The laboratory's technical director (or an appropriate supervisor) shall be experienced in efficiency of electric motors testing and shall have the technical competence and the supervisory capability to direct the work of professionals and technicians in efficiency of electric motors testing.

5.2.3 Competency reviews

5.2.3.1 Staff responsible for conducting the testing shall have technical competence in the following areas as a minimum:

___ a) general requirements of the electric motor test methods;

___ b) testing laboratory system capabilities (electrical, mechanical, and environmental);

___ c) electric motor specimen preparation and/or mounting techniques;

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- d) connection and operation of the test equipment;
 - e) electric motor pre-test temperature procedures;
 - f) techniques for measuring ambient thermal conditions;
 - g) use of equipment for measuring:
 - 1) temperature,
 - 2) resistance,
 - 3) torque,
 - 4) power,
 - 5) speed (rpm) and slip,
 - 6) voltage,
 - 7) current,
 - 8) frequency of input supply;
 - h) equipment calibration techniques, when applicable, for labs that perform in-house calibrations;
 - i) data collection, calculation, and analysis.

___ 5.2.3.2 The laboratory shall evaluate the competency of each staff member for each testing procedure before authorization is conferred to perform that testing independently.

___ 5.2.3.3 For each staff member, the staff member's immediate supervisor, or a designee appointed by the laboratory director, shall conduct annually an assessment and an observation of performance competency.

These reviews shall be planned to cover all authorized testing procedures over a defined period of time. This period of time is not necessarily one year and may vary depending upon the experience and previous performance of the staff member.

___ 5.2.3.4 These annual performance competency reviews shall be documented, dated, signed by the supervisor and the employee, retained in the personnel file, and be available for review by the assessor.

5.2.4 Training

___ 5.2.4.1 The training program shall be updated and current staff members shall be given additional training when test methods are updated or procedures changed, or when the individuals are assigned new responsibilities.

___ 5.2.4.2 Each staff member may receive training for assigned duties either through on-the-job training, formal classroom study, attendance at conferences, or another appropriate mechanism.

___ 5.2.4.3 The laboratory shall ensure that each new staff member is trained for the testing duties assigned.

___ 5.2.4.4 Training materials that are maintained within the laboratory shall be kept up-to-date, including applicable versions of standard test methods, as well as appropriate reference documents, texts, and scientific and industry periodicals.

These materials shall be readily available to the laboratory staff.

5.3 Accommodation and environmental conditions

Specific environmental requirements for laboratories follow:

- a) For testing of *polyphase electric motors* (1 hp to 500 hp using IEEE 112 method B or CSA C390 method 1) or three-phase *small electric motors* (under 1 hp using IEEE 112 method A), the laboratory shall be able to control the ambient air temperature within the temperature range of 10 °C to 40 °C.

- b) For testing of single-phase *small electric motors* (using standards IEEE 114 or CSA C747), the laboratory shall be able to control the ambient air temperature within the temperature range of 20 °C to 30 °C.

- c) The motor shall be protected from movement of the air resulting from sources other than the motor. Drafts and air currents shall be minimized in order to achieve required stable temperature rise during testing.

- d) There shall be sufficient open space around the motor during testing so as not to restrict the normal air flow around or through the motor during testing.

- e) The ambient temperature shall be relatively stable during the test.

- f) The method for securing the motor to restrict movement during testing shall not interfere with the cooling of the motor.

5.4 Test and calibration methods and method validation**5.4.1 Standard test methods**

- 5.4.1.1 a) The management system documentation shall contain detailed written instructions for conducting the test methods for which it seeks or holds accreditation.

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- ___ 5.4.1.1 b) These detailed instructions, including those for equipment operation, calibration checks, and quality control checks, shall address laboratory-specific information not contained in the standard method.
- ___ 5.4.1.2 For compliance with the DOE requirements in the NVLAP EEM LAP, laboratories shall use the test procedures described under “Energy Conservation Program: Test Procedures for Electric Motors and Small Electric Motors, Final Rule,” *Federal Register* 77: 87 (4 May 2012), pp. 26608-26640 (to be codified at 10 CFR Part 431).
- ___ 5.4.1.3 a) The laboratory shall have readily available the regulation(s) and the applicable version of the standard(s) for the test methods for which accreditation is requested.
- ___ 5.4.1.3 b) For testing of *polyphase electric motors* (1 hp to 500 hp) in compliance with U.S. DOE requirements in the NVLAP EEM LAP, the laboratories shall determine efficiency and losses in accordance with NEMA MG1-2011 paragraph 12.58.1 and the test procedures described in IEEE Standard 112-2004 Method B or CSA International (or Canadian Standards Association) Standard C390-10 Test Method (1).
- ___ 5.4.1.3 c) For testing of single-phase *small electric motors* in compliance with U.S. DOE requirements in the NVLAP EEM LAP, the laboratories shall use the test procedures described in IEEE Standard 114-2010, or CSA International (or Canadian Standards Association) Standard C747-09.
- Polyphase *small electric motors* (power output less than 1 horsepower) shall be tested using IEEE Standard 112-2004 Method A or CSA International (or Canadian Standards Association) Standard C747-09.
- ___ 5.4.1.4 When a test method references another test method, guide, practice, or specification, the laboratory shall have readily available the referenced documents, where relevant.
- ___ 5.4.1.5 If a customer, for whatever reason (e.g., regulatory requirement), requires accreditation to versions of a test method that are not the latest published version, then the laboratory shall document that requirement and shall have readily available the required version of the test method.

5.4.1.6 **Requirements related to testing equipment**

5.4.1.6.1 **Heat run**

- a) For *polyphase electric motors* (1 hp to 500 hp) the initial winding resistance measurement shall be taken after the motor is exposed to the ambient temperature for a sufficient time for the windings to reach a stable reference temperature.

For *small electric motors* the initial winding resistance may be measured as above if temperature is to be determined using rise of resistance.

For *small electric motors* the ambient temperature in the test lab shall be not less than 20 °C or greater than 30 °C unless temperature correction of motor losses is calculated as described in IEEE 114-2010.

- b) If a heat run is to be performed, it shall be performed first in the test sequence.

- c) The heat run shall be performed at rated voltage, rated frequency, and rated load (1.0 service factor).

If the motor being tested is a *small electric motor* rated for dual voltage service or service over a range of voltages, it shall be tested at the voltage specified by the motor manufacturer.

- d) If the motor is overloaded at the start of the test to shorten the total test time, the overload shall be kept under 150 % of rated load.

- e) The motor shall be operated at rated load, voltage, and frequency for a sufficient period of time for the temperatures to stabilize with not more than a 1 °C change in temperature rise between two successive readings taken at thirty-minute intervals.

___ f) For *polyphase electric motors* (1 hp to 500 hp)

At the conclusion of the test, the resistance between two lines shall be measured

- Within 30 seconds of shutdown for motors rated 50 hp or less,
- Within 90 seconds of shutdown for motors rated 51 hp to 200 hp, or
- Within 120 seconds of shutdown for motors rated above 200 hp.

If the time limits above are exceeded, then resistance shall be measured as a function of time after shutdown, and the results plotted and extrapolated back to the appropriate time delay to determine the resistance at shutdown.

For *small electric motors* the final winding resistance may be measured as above if temperature is to be determined using rise of resistance.

5.4.1.6.2 **Load performance test**

___ a) The load test shall be performed following a heat run. If performed at another time, the motor temperature shall be adjusted by operating the motor at rated load or some overload condition.

___ b) The temperature of the stator winding shall be within 10 °C of the hottest thermosensor temperature reading during the heat run at rated operating conditions on a machine under test or on a duplicate machine for the rated full load operating temperature prior to beginning the test.

___ c) The temperature shall be stable at the start of a test. The test should be performed as quickly as possible to minimize temperature changes in the motor during the test.

___ d) The motor shall be loaded in decreasing order from the highest to the lowest load.

___ e) The load readings shall be taken at two points suitably chosen above 100 % but not exceeding 150 % of rated load, and at four points including 100 % of rated load and approximately equally spaced between 100 % and 25 % of rated load.

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- ___ f) The load shall be steady during the time the data at each load are recorded.

 - ___ g) The dynamometer correction test shall be performed properly in accordance with the applicable procedure in the test standard used.

 - ___ h) The dynamometer correction test shall be performed after the load test is completed.

5.4.1.6.3 **No-load test**

- ___ a) The motor shall be operated at no-load until the input power at rated voltage and frequency does not vary by more than 3 % between two successive readings over a half hour time interval before starting the test.

This test is not required for the determination of efficiency of a *small electric motor*.

- ___ b) The test shall begin at the highest voltage level and the voltage reduced in steps from that level to the lowest test value.

This test is not required for the determination of efficiency of a *small electric motor*.

- ___ c) The readings shall be taken at voltages from approximately 125 % of rated voltage down to the point where further voltage reduction increases the current or the motor becomes unstable.

This test is not required for the determination of efficiency of a *small electric motor*.

5.4.2 **Estimation of measurement uncertainty**

- ___ a) At a minimum, the management system documentation shall list the important variables that substantially affect the uncertainty of the test results.

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- ___ b) The uncertainty shall be determined and reported when required by the test method, the regulator, or the customer.

5.5 Equipment

___ 5.5.1 *Documentation requirements*

Documentation shall provide detailed descriptions of testing facilities and scope of relevant services offered; specifically the range of output power and speed ratings of motors that the laboratory can test under the scope of its accreditation. For each dynamometer test bed, a list or table shall specify the upper and lower rating limits of motors that can be tested with acceptable measurement accuracy.

5.5.2 *Grounding of motor and test equipment*

- ___ Provisions shall be available to properly ground the motor and test equipment as may be necessary during testing.

5.5.3 *Power supply*

- ___ a) The power supply shall be at rated voltage for the motor being tested.
- If the motor being tested is a *small electric motor* rated for dual voltage service or service over a range of voltages, it shall be tested at the voltage specified by the motor manufacturer.
- ___ b) Polyphase motors shall be tested using a power source with balanced voltages.
- ___ c) The line voltages shall be balanced within 0.5 %.
- ___ d) The voltages should be sinusoidal and shall not have a total harmonic distortion (THD) exceeding 5 %.
- ___ e) The average frequency shall be within ± 0.1 % of the specified test value.

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- f) The frequency variation during the tests shall not exceed 0.33 % of the average frequency.
- g) Any deviation of frequency from the rated frequency shall be taken into consideration when calculating slip.

5.5.4 **Other equipment requirements**

- a) Test instrumentation shall be properly selected and installed to minimize errors introduced by:
- loading of the signal source,
 - lead calibration,
 - range, condition, and calibration of the instrument,
 - inductive or electrostatic coupling of signal leads to power systems,
 - common impedance coupling or ground loops,
 - inadequate common mode rejection, and
 - conducted interference from the power line.
- b) The loading device, such as a dynamometer, shall be appropriate for the size of the motor. The coupling, friction and windage loss of the dynamometer measured at rated speed should not be greater than 15 % of the rated output of the motor being tested.
- c) The motor shall be aligned correctly with the loading device (dynamometer).
- d) When determining the cold winding resistance, a double bridge shall be used, or other means of equivalent accuracy, and checked by a second instrument, if possible.
- Note:** This requirement does not apply to efficiency testing of *small electric motors* unless temperature is being determined by the rise of resistance.

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- ___ e) If thermocouples are used to monitor temperature, they shall be installed correctly.

 - ___ f) Multiple thermocouples shall be cross-checked at ambient temperature for accuracy and agreement.

5.5.5 ***Accuracy of the test equipment***

The accuracy of the test equipment shall be within the following limits:

- ___ a) Instrumentation for measuring voltage, current, and power shall have an accuracy of ± 0.2 % of full scale.

- ___ b) Instrument transformers shall have an accuracy of ± 0.3 %.

- ___ c) When the above instrumentation is calibrated as a system, the accuracy shall be ± 0.2 % of full scale.

- ___ d) Instrumentation used to measure speed shall have an accuracy within ± 1 rpm of the reading.

- ___ e) Instrumentation used to measure the output torque of the motor shall have an accuracy of ± 0.2 % of full scale.

Dynamometers used for testing of *small electric motors* shall be sensitive to a change in torque of 0.1 % of the rated torque of the motor under test.

- ___ f) The range of each instrument chosen shall be as low as practical for the motor being tested such that readings are in the upper region of the scale.

5.6 Measurement traceability

- ___ 5.6.1 To account for the effects on traceability of the calibration of measurement and test equipment, the laboratory shall determine equipment calibration, verification, and maintenance intervals based on the equipment's frequency of use and the environment in which it is used, and also in accordance with standard test methods, manufacturer's recommendations, or as specified in the following table, whichever results in a shorter time between calibrations.

Extension of the time interval between calibrations is acceptable if the laboratory can provide justification for increasing the interval.

	<i>Apparatus/Instrumentation</i>	<i>Calibration or Verification Frequency</i>
___ a)	ammeters, voltmeters and wattmeters	Annually
___ b)	current transformers (CTs)	Every 5 years
___ c)	potential transformers (PTs)	Every 5 years
___ d)	shunts	Every 2 years
___ e)	data acquisition systems	Annually
___ f)	electronic transducers	Annually
___ g)	frequency meters	Annually
___ h)	resistance measurement equipment	Annually
___ i)	speed sensors	Annually
___ j)	temperature measuring equipment	Annually
___ k)	torque measuring equipment	Annually or more frequently.* See note below for requirements for the calibration interval for torque measurement equipment.
___ l)	calibration weights and torque arm	1 to 3 years *

* With regard to torque measurement, the frequency of recalibration of torque transducers, masses (weights) and arm length needs to be determined by the laboratory.

Torque transducers may need to be recalibrated more often if laboratory calibration records show that the instrument is subject to drifting out of tolerance with time. It is the responsibility of the lab to ensure that torque transducers always meet NVLAP accuracy requirements even if this means more frequent calibrations.

Depending on how often the masses and torque arm are used, their care and storage, and records that the laboratory develops and maintains to see if any change has occurred, the laboratory may determine that the masses and arm length need to be recalibrated relatively infrequently; that is with sufficient documentation for masses and arm length, the laboratory may determine to extend the calibration frequency interval of one year to an interval not exceeding three years.

- ___ 5.6.2 Proper performance of the testing equipment shall be periodically verified as needed.
- ___ 5.6.3 The reference standards used and the environmental conditions at the time of calibration shall be documented for all calibrations.
- 5.6.4 The following requirements apply for calibrations and calibration certificates:
- ___ a) Certificates are required for calibrations performed by outside services. A calibration certificate shall indicate uncertainty and/or a statement of compliance with an identified metrological specification, and traceability of reference standards.
- ___ b) Certificates are not required when a laboratory performs its own calibration and records are kept. If the testing laboratory performs its own calibration, the identity of the personnel involved, the standard metrological procedures used, the reference standards used, the environmental conditions, and the measurement uncertainty shall be documented. These records shall contain sufficient information to permit repetition of the calibration.
- ___ c) For calibrations performed by the testing laboratory, it shall have properly trained personnel who understand the importance of the various factors that affect the uncertainty of the calibration and its effect on the uncertainty of the final test result (see NIST Handbook 150, 5.4.6).

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- 5.6.5 In addition to the information specified in NIST Handbook 150, 5.5.5, calibration or verification records shall include the following:
- ___ a) a list of all equipment variables requiring calibration, traceability, or verification;
 - ___ b) range of calibration/traceability/verification;
 - ___ c) resolution (precision or the number of digits read) of the instrument and its allowable error (i.e., tolerance);
 - ___ d) periodic verification dates and schedule;
 - ___ e) identity of the laboratory individual/group or external service responsible for calibration;
 - ___ f) identity and source of reference standard(s) and traceability.
- 5.10 Reporting the results**
- 5.10.1 General**
- ___ 5.10.1.1 Where appropriate, test reports shall clearly state that the test results apply to the product or system as tested and, if required, conform to regulator requirements.

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- ___ 5.10.1.2 The correlation factor for smoothing stray-load loss shall be equal to or greater than the minimum value prescribed by the applicable standard with no more than one of the six points omitted from the analysis.

For efficiency testing using IEEE 112-2004 Method B, the minimum value is 0.90.

For efficiency testing using CSA C390-10 Method 1, the minimum value is 0.95.

Note: This requirement does not apply to efficiency testing of *small electric motors*.

- ___ 5.10.1.3 When necessary to repeat the test to obtain a correlation factor equal to or greater than the minimum values listed above, the source of error shall be investigated and corrected prior to rerunning the test.

Note: This requirement does not apply to efficiency testing of *small electric motors*.

5.10.2 Data analysis and report generation

- ___ 5.10.2.1 In some cases, raw data collected by computer are collated, reduced, analyzed, or otherwise treated for direct incorporation in the test report. Such treatment involving transmission of the data, writing, and generation of the test report is generally performed at the laboratory or at an area close to the facility and under the control of laboratory personnel. In such cases, the laboratory personnel responsible for the report writing and generation shall be available during the laboratory's on-site assessment to be interviewed by the assessor for evaluation of the laboratory's compliance with the NVLAP criteria for test reports. The assessor shall perform an independent calculation of the efficiency based on laboratory test results and compare the independently-calculated efficiency with that calculated by the laboratory.

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- ___ 5.10.2.2 At times, the final report may be written and generated at an off-site facility that is located some distance from the testing laboratory such that the assessor cannot interview the off-site personnel. In such a case, the laboratory shall have in place for assessor review appropriate written descriptions in its management system documentation of procedures and documentation for assuring the accuracy and validity of the data transmission, the incorporation and accurate analysis of the data in the test report, and the compliance of the test report with NVLAP criteria. Depending on the on-site laboratory evaluations of these written descriptions, a visit to the off-site facility may be required. When warranted, an assessor will visit the off-site facility at additional cost to the laboratory before accreditation is granted or renewed.
- ___ 5.10.2.3 When a test report is written at an off-site facility such that the assessor cannot interview the off-site personnel, the report shall include the names and addresses of both those responsible for conducting the laboratory tests and for writing and generating the test report. Copies of typical reports written at an off-site facility shall be available at the laboratory at the time of the on-site assessment and these typical reports shall be reviewed by the assessor for compliance with NVLAP requirements. The assessor shall perform an independent calculation of efficiency and compare it to that calculated at the off-site facility as required in 5.10.2.1.
- ___ 5.10.2.4 If a laboratory uses several organizational departments for the discrete functions of testing, data collection, data processing, and test report preparation and generation, it is necessary that lines of responsibility with distinct supervisory positions be defined and that no conflicts exist. The assessor shall review the procedures and documentation of the lines of responsibility with distinct supervisory positions during the on-site assessment, and also shall verify that all NVLAP requirements regarding the writing and storage of reports are followed.

