

AEROSPACE RECOMMENDED PRACTICE

ARP4755™

REV. C

Issued 1994-03
Revised 2016-09
Reaffirmed 2023-05

Superseding ARP4755B

(R) Turboshift/Turboprop Gas Turbine Engine Test Cell Correlation

RATIONALE

To update the references to be aligned with the other correlation papers from this committee and to meet SAE Standards.

ARP4755C has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

1.1 General

This paper describes a recommended practice and procedure for the correlation of test cells that are used for the performance testing of turboprop and turboshaft engines. This Aerospace Recommended Practice (ARP) shall apply to both dynamometer and propeller based testing. Test cell correlation is performed to determine the effect of any given test cell enclosure and equipment on the performance of an engine relative to the baseline performance of that engine. Although no original equipment manufacturer (OEM) documents are actually referenced, the experience and knowledge of several OEMs contributed to the development of this document. Each engine manufacturer has their own practices relating to correlation and they will be used by those OEMS for the purpose of establishing certified test facilities.

1.2 Beneficiaries

This ARP will benefit the original equipment manufacturer (OEM), commercial users, repair stations, military depots as well as intermediate level maintenance activities. Specific cases in which the information contained herein will be beneficial are:

- a. As an aid for providing correlation of test cell data between engine and airframe companies supporting commercial and military requirements.
- b. As an aid for providing military maintenance facilities and commercial repair stations a method by which to correlate test cells.
- c. As an aid in establishing correlation practices for new test cells, for updating, and for maintaining existing test cells.
- d. As an aid to an engine manufacturer's facility in correlation of test cells used for engine development and acceptance in accordance with the applicable engine model specification.

1.3 Limitations

Known methods of turboprop/turboshaft test cell correlation include, but are not limited to, the following:

- a. Back-to-Back
- b. Cross-Cell
- c. Correlation Engine

The "Correlation Engine" procedure is the recommended and most common method for the correlation of an engine test cell. This paper is limited to the discussion of this one method.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP741	Turbofan and Turbojet Gas Turbine Engine Test Cell Correlation
ARP4990	Turbine Flowmeter Fuel Flow Calculations
AIR5026	Test Cell Instrumentation
ARP5435	APU Gas Turbine Engine Test Cell Correlation
ARP5758	Trend Analysis for Maintaining Correlation of Gas Turbine Engine Test Cells
ARP6028	Configuration Control for Maintaining Correlation of Gas Turbine Engine Test Cells
ARP6196	Gas Turbine Engine Test Facility Audit Process

Webb, W., "A Forward Look at Gas Turbine Testing Facilities," SAE Technical Paper 801124, 1980, doi:10.4271/801124.

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

Annual Book of ASTM (American Society for Testing Materials) Standards., Section 5, Petroleum Products, Lubricants and Fossil Fuels. Volumes 05.01, 05.02, and 05.03.

2.1.3 Other Publications

Advisory Group for Aerospace Research and Development (AGARD). Operation and Performance Measurement on Engines in Sea Level Test Facilities. AGARD-LS-132.

Advisory Group for Aerospace Research & Development (AGARD). Measurement Uncertainty Within the Uniform Engine Test Programme. AGARD-AG-307.

Advisory Group for Aerospace Research & Development (AGARD). Comparative Engine Performance Measurements. AGARD-LS-169.

Advisory Group for Aerospace Research & Development (AGARD). Propulsion and Energetics Panel Working Group 15 on the Uniform Engine Test Programme. AGARD-AR-248.

Krengel, J.H. Air-Breathing Engine Test Facilities Register. AGARD-AG-269

Mitchell, J.G. Comparability Tests in the International Turbine Engine Test Facilities. AIAA-88-3020. (American Institute of Aeronautics and Astronautics)

The Aerospace Industries Division of Instrument Society of America. Measurement Uncertainty Handbook. AEDC-TR-73-5.

United States Air Force. Test Cell Correlation Set Technical Manual; Operation, Maintenance and Parts Breakdown. United States Air Force Technical Order (TO) 33DA-6-261.

2.2 Definitions

The following list defines the terms and phrases used in this document:

BACK-TO-BACK: A test performed with the same engine before and after a modification to the facility or associated equipment.

BASELINE FACILITY: A facility designated as the standard for certification of an engine.

CALIBRATION: The comparison of a particular instrument or system with a standard of known accuracy.

CORRELATION: The comparison of engine performance parameters measured on a common engine tested in two test facilities, where one facility is the reference.

CORRELATION ENGINE: An engine of known and repeatable performance used for test cell correlation.

CORRELATION FACTOR: A multiplier or delta used where appropriate to adjust for the difference in performance between the customer facility and the reference facility, also known as a "Facility Modifier" or "Correction Factor".

CROSS-CELL: The comparison of engine performance parameters measured on a common engine, which is not necessarily a correlation engine, in at least two previously correlated test cells for the purpose of checking facility correlation of a third test cell.

CUSTOMER FACILITY: The facility which is to be correlated against the reference facility.

DYNAMOMETER: An apparatus other than a propeller for absorbing the power produced by the engine being tested. This device may or may not have the ability to measure the amount of power produced. This definition includes, but is not limited to: waterbrake, air, electric, hydraulic, or steam dynamometers.

ENGINE DRESS KIT: Typically consists of an engine mounted nacelle (when applicable), aerodynamic hardware (when applicable), accessories and test instrumentation required to permit operation of the engine in the test cell. This kit may or may not include quick engine change items.

FREE FIELD TEST: An engine test performed on an outdoor test stand, to determine the baseline performance of the engine.

INDOOR TEST CELL: A facility for the testing of gas turbine engines in a restricted environment.

OUTDOOR TEST STAND: An open air facility without any enclosure for testing engines.

OUTPUT SHAFT: The engine shaft connected to a loading device, e.g., a dynamometer or a propeller. In general, for a turboprop engine, it is the propeller shaft. For turboshaft engines, it is the shaft connecting the engine to the airframe load, e.g., the main gearbox for helicopter rotors.

QUICK ENGINE CHANGE (QEC) KIT: May include a nacelle or cowl set with engine driven and required aircraft accessories or hardware installed on the engine for faster engine removal and installation on the aircraft.

REFERENCE FACILITY: A test facility of known performance, traceable to the designated baseline facility, against which the customer's facility is compared.

TEST FACILITY (TEST CELL): An area in which a gas turbine engine is operated to determine its performance and other information as required by a given test.

3. FACTORS AFFECTING CORRELATION

The following factors may affect the correlation of an engine test cell:

- a. Configuration of the test cell particularly the primary and secondary inlets, augments tube and exhaust stack configurations
- b. Engine position in the test cell
- c. Ambient conditions and surrounding buildings and their configurations, and topographic characteristics
- d. Instrumentation; calibration, location, measurement accuracy, and quantity
- e. Load absorption system configuration and characteristics (test propeller, or dynamometer and dynamometer to engine shafting)
- f. Propulsion system test configuration
- g. Testing procedures
- h. Data acquisition system
- i. Fuel properties
- j. Waste heat or airflow generated by the dynamometer
- k. The facility fans etc., which may be used to assist airflow thru the test cell
- l. Engine power measurement system
- m. External engine bypass air flow
- n. Engine dress kit

4. PERFORMANCE MEASUREMENTS

4.1 General

The primary function of the engine test facility is to obtain a proper performance evaluation of an engine. The test facility and test configuration must provide a stable test environment conducive to smooth surge-free operation of the engine. The propeller or dynamometer must provide adequate power absorption to control the engine in a stable operating condition.

All test facilities create an environment which may influence the data obtained during testing. In addition, the engine test configuration including the engine dress kit may influence the data taken during testing.

Variations in test facilities and engine test configurations may cause differences in measured engine performance. The test cell correlation provides the means to quantify these differences, to understand them, to reduce them whenever possible, and to establish the appropriate cell correlation factors.

4.2 Performance Parameters

A variety of engine performance parameters should be examined in the process of test cell correlation. This list may include, but is not limited to:

- a. Engine fuel flow
- b. Engine output shaft torque
- c. Engine output shaft speed
- d. Other engine rotor speeds
- e. Engine airflows
- f. Engine pressures and temperatures
- g. Engine inlet conditions
- h. Test cell temperatures and pressures
- i. Test cell inlet airflow
- j. Vibrations

4.3 Instrumentation Calibration

The engine test facility is an article of test equipment and as such requires appropriate design and calibration of measurement systems.

The importance of proper calibration of the test cell and its instruments cannot be overemphasized. This procedure firmly establishes the accuracy of the individual instrument and system measurements. Rather than accept the reading of an instrument, it is essential to make a calibration check to verify the validity of the measurements.

In most cases an end-to-end calibration of a measurement system is better than removing an instrument from the test cell and calibrating it in an instrument shop. However, periodic calibration of individual instruments, either performed in place or in the instrumentation shop, is necessary. For example, a pressure measurement may be affected by a leak or liquids in a pressure line; electrical measurements may be disturbed by noise, or by wiring flaws; liquid flowmeters are affected by turbulence in the liquid. Many such conditions can be detected during calibration, and should be corrected before the final calibration curves are established.

4.3.1 Hierarchy/Secondary Standards

In the United States of America, the National Institute of Standards and Technology (NIST) has the primary responsibility for maintaining the standard units of length, mass, time, temperature, and electrical quantities. Other nations have comparable standards bodies. Instruments used as transfer standards should have calibrations traceable to a national standard.

Common practice requires a secondary or transfer standard be at least four times more accurate than the instrument being calibrated. With the development of electronic equipment, it is increasingly difficult to achieve this hierarchy of secondary standards. In any case the transfer standard should be substantially more accurate than the work instrument.

4.3.2 Traceability

Traceability establishes the calibration hierarchy for a particular measurement. It identifies all possible error contributions between the test facility measurement system and the national standard. Traceability does not reduce the uncertainty of a measurement; it simply documents the process of its determination. Documentation of the instrument and test cell calibrations and hierarchy should be established and maintained.