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AEROSPACE STANDARD

SAE AS681 REV. G

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GAS TURBINE ENGINE STEADY-STATE AND TRANSIENT PERFORMANCE PRESENTATION FOR DIGITAL COMPUTER PROGRAMS

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1. SCOPE:

This Aerospace Standard (AS) provides a method for the presentation of gas turbine engine steady-state and/or transient performance as calculated by means of digital computer programs. It also provides a method for the presentation of gas turbine parametric performance, weight and dimensions by means of digital computer programs.

It is intended to facilitate calculations by the program user without unduly restricting the method of calculation used by the program supplier.

2. REFERENCES:

The following documents form a part of this specification to the extent specified herein.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

ARP755A Gas Turbine Engine Performance Station Identification and Nomenclature
ARP1210A Gas Turbine Engine Interface Test Data Reduction Computer Programs
ARP1420 Gas Turbine Engine Inlet Flow Distortion Guidelines
ARP4191 Gas Turbine Engine Performance Presentation for Digital Computer Programs Using Fortran 77

2.2 International Organization for Standardization (ISO):

Available from American National Standards Institute, 1430 Broadway, New York, NY 10018.

ISO 1000 SI units and recommendations for the use of their multiples and of certain other units
ISO 2533 ISO Standard Atmosphere. This is consistent with the U.S. Standard Atmosphere, 1962, for altitudes up to 50 000 meters.
ISO 2955 Representations for SI and other units to be used in systems with limited character sets

2.3 Other Documents:

U.S. Standard Atmosphere, 1962, United States Committee on Extension of the Standard Atmosphere.

NASA Technical Paper 1906, Thermodynamic and Transport Combustion Properties of Hydrocarbons with Air, Part I - Properties in SI Units, Sanford Gordon, 1982.

NASA Technical Paper 1907, Thermodynamic and Transport Combustion Properties of Hydrocarbons with Air, Part II - Compositions Corresponding to Kelvin Temperature Schedules in Part I, Sanford Gordon, 1982.

2.3 (Continued):

NASA Technical Paper 1908, Thermodynamic and Transport Combustion Properties of Hydrocarbons with Air, Part III - Properties in U.S. Customary Units, Sanford Gordon, 1982.

NASA Technical Paper 1909, Thermodynamic and Transport Combustion Properties of Hydrocarbons with Air, Part IV - Compositions Corresponding to Rankine Temperature Schedules in Part III, Sanford Gordon, 1982..

3. GENERAL REQUIREMENTS:

3.1 General Steady-State Program Requirements:

The steady-state program is intended to represent the steady-state performance of the engine. Steady state means all inputs are constant and the time derivatives are zero.

3.2 General Transient Program Requirements:

The transient program is intended to provide simulation of engine response to input variables with an equivalent sine wave frequency content of up to approximately 30 hertz (Hz). Although programs can be constructed to respond to much higher frequencies, there is insufficient practice at this time to establish procedures in this area. A minimum requirement of the transient program is the ability to adequately simulate the effects of normal throttle and mission profile transients.

3.3 Program Operation:

3.3.1 The program will be supplied in a form readily adaptable to the user's computer. Provision for operating the program on more than one computer type or operating system should be individually coordinated between user and supplier.

3.3.2 The program will have the capability of functioning both as a subroutine (herein called the engine subroutine) and as an independent program (consisting of a MAIN program containing a CALL statement to the engine subroutine).

3.4 User's Manual:

3.4.1 The program supplier will deliver the User's Manual with the program. The User's Manual shall stand alone in that it will be independent of previous Users' Manuals.

3.4.2 The following information will be contained in the User's Manual under the following headings:

1. Introduction:

2. Table of Contents:

3. Engine Description: This section will enable the user to identify the engine and its general characteristics including operating and control limits that are functionally dependent on variable engine parameters. A general description of the engine will be provided. This description will include the type of engine, engine configuration, and all general characteristics that are necessary to understand the performance and operation of the engine represented by the computer program. Examples are: thrust or power class, performance level (e.g., average, minimum), airflow, pressure ratios, airbleed stations, nozzle type, bypass ratio, method of thrust augmentation, and engine control characteristics.

4. Program Description: This section will enable the user to identify the computer equipment, programming practices, and software quality assurance standards upon which the program relies.

5. Nomenclature: This section will include station identification and other information required to understand the User's Manual.

6. Program Setup: This section will include instructions and information to enable the program user's computer staff to set up the program. It will include an overall program structure flowchart and sufficient information to set up and execute the program in independent mode. An example of a flowchart for a user calling program is included as Appendix A.

7. Engine Program Performance Options: This section will describe the interfaces, options, limitations, and other features contained in the program, to enable the user to understand fully the capability of the program. This section will also include an overall flowchart that illustrates the performance calculation flow path between major engine components. Examples of calculation flowcharts are included as Appendix B.

8. Input/Output: This section will describe all program inputs and outputs in sufficient detail to avoid ambiguity and will list the units of all input and output parameters.

9. Program Messages: This section will explain the messages produced during program operation and identify the Numerical Status Indicator codes.

3.4.2 (Continued):

10. Listings: Source code listings of the calling program and of the input and output statements utilized directly by the calling program will be supplied with the computer program and may be included in the user's manual. The supplier is encouraged to include descriptive comments in the listings to facilitate user understanding.

11. Test Cases: This section will describe the test cases that the supplier provides for program checkout by the user. All test case inputs and printouts will be supplied with the computer program or in the User's Manual.

12. Identification and Revision Procedure:

13. References:

3.5 Program Scope:

3.5.1 Categories of Data:

3.5.1.1 Steady-State Data: Steady-state engine performance computer programs will be the primary source for steady-state engine performance. Steady-state engine performance programs in this standard will be confined to four basic performance categories:

a. PRELIMINARY DESIGN: Preliminary design programs may vary in scope, but will be representative of the defined engine performance until the engine is defined by a specification. Typical application of a preliminary design program is to provide data for preliminary aircraft performance.

b. SPECIFICATION: Specification programs will accurately represent the engine described by the specification and will identify the appropriate model specification. Normally, the computer program will be the primary source of performance data. Typical application of specification programs is to generate data for engine and aircraft guarantees.

c. STATUS: Status programs are neither preliminary design nor specification programs. They are intended to provide the best estimate of performance for an engine or group of engines at the time of program preparation and will normally include greater test experience than a specification program. Typical applications of status programs are:

   (1) To provide a prediction for an engine test; a baseline for comparison with test data reduction output

   (2) To model an engine in order to investigate test operating procedures for ground test and/or flight test

3.5.1.1 (Continued):

(3) To maintain a management information system current with development or production program status

(4) To allow performance comparisons between an engine or group of engines and an average or specification engine

(5) To allow performance extrapolation and interpolation of limited test data

d. PARAMETRIC: Parametric programs are special categories of preliminary design programs. They are intended to provide a preliminary estimate of the performance, weight, and dimensions of a class of engines of similar configuration over a range of design parameters (e.g., compressor pressure ratio, turbine inlet temperature, airflow). The performance, weight, and dimensions are normally derived from a less detailed analysis than a conventional preliminary design, specification, or status program. The intended application of parametric programs is to provide data used in vehicle system studies in order to narrow the range of system design parameters to be utilized in further detailed studies. These detailed studies may result in alterations in performance, weight, and dimension levels. However, trends predicted by varying design parameters in the parametric programs are expected to be maintained.

An additional category of programs is data reduction interface programs, which are covered by ARP1210.

3.5.1.2 Transient Data: Transient engine performance computer programs will be the primary source for time-dependent variations of engine performance. Transient engine performance calculations will be based on one of three steady-state performance categories: preliminary design, specification, or status. Typical application of transient programs are:

a. To provide prediction of engine acceleration and deceleration performance

b. For airframe/engine integration studies

3.5.2 Engine Limits and Program Limitations: Engine limits observed by the computer program will be defined in the User's Manual. When engine limits are functionally dependent on other parameters, it will be so stated in the User's Manual. When the input calls for an operating point outside engine limits, the program will proceed to complete its calculation, if possible, and output the appropriate numerical status indicator. The numerical status indicator will clearly define output validity, limiting parameters and/or the applicable limiting engine controlling variable. The program will always be capable of continuing with the next case provided the user's subroutines and/or computer operating system do not override this capability.

3.5.2 (Continued):

Program limitations are those that define the bounds within which the program will function and will adequately simulate the engine. Program limitations will exceed corresponding engine limits, but preliminary design programs may have additional limitations because component definition is inadequate.

3.5.3 Consistency: Consistency herein means the agreement between transient program output of steady-state conditions and steady-state program output for the engine or group of engines represented. Transient and steady-state program requirement differences can cause program output differences. For status and specification programs at all power settings higher than 30% of maximum nonaugmented power, the transient performance program gross thrust and/or shaft power, total fuel flow, and airflow output should agree with that of the corresponding steady-state performance program output within ±3%. Consistency requirements may be modified if coordinated between user and supplier.

3.5.4 Validity: The boundaries within which the model is valid should be described in the program User's Manual.

3.5.4.1 A status program may not produce valid performance over the entire flight envelope due to limited availability of test data. These limits will be described in the program User's Manual.

3.5.4.2 A parametric program may not produce valid performance over the entire flight envelope and power level due to the limited availability of design and test data. Capabilities for including such effects as anti-ice bleed, distortion effects, windmilling, etc., are not normally included in these programs. These limitations will be described in the program User's Manual. Life and duty cycle assumptions must be made clear in the engine description section of the program User's Manual in order to aid in the interpretation of the performance, weight, and dimensions.

4. PROGRAMMING PRACTICES:

4.1 Computer Capabilities:

4.1.1 Computer size requirement and program execution time depend on the complexity of the engine/control simulation and the type of computer and therefore, must be individually coordinated. Execution time will be dependent on memory cycle time, the complexity of the engine simulation, and the frequency range of the problem being investigated with the program.

4.1.2 The frequency effects normally studied with the engine transient programs range from 0 to 5 Hz. Transient studies dealing with effects in the neighborhood of 30 Hz may require execution times up to 100 times greater than normal and may require additional computer resources.

4.2 Program Language:

Any computer language (e.g., C, ADA, FORTRAN 77) may be used for engine computer programs if the language has been coordinated between the user and the supplier. If not otherwise coordinated, engine computer programs will use as a minimum language FORTRAN 66 [level: full FORTRAN (Number 1)] as originally defined in ANSI X3.9, 1966a. This language may be augmented by features found in the commonly used FORTRAN languages of industry when these features are known to be acceptable to the program users. ARP4191 contains additional information for FORTRAN 77 applications.

4.3 Precision:

Hardware and software differences (e.g., word length, compiler, and operating system) among computers can cause differences in performance output from otherwise identical programs. Differences from the supplied test cases greater than 0.25% should be coordinated between user and supplier. For transient programs differences smaller than ±1.0% at a given output time should be considered normal for engine transients of 10 seconds or less. Larger differences should be coordinated between the user and the supplier.

4.4 Station Identification:

The numbering system described in ARP755 will be used in program input and output to identify the points in the gas flow path that are significant to engine performance definition. Supplements to the system of ARP755 that are necessary will be detailed in the User's Manual.

4.5 Nomenclature:

4.5.1 The list of symbols contained in ARP755 will be used for identification of input and output parameters. These symbols are not required to be used for FORTRAN names within the engine subroutine.

Throughout this document:

a. ϕ denotes the numeric symbol
b. O denotes the alphabetic symbol

NOTE: This is reversed from the convention used prior to revision F.

4.5.2 The following symbols, which refer specifically to computer programs, are added to those of ARP755:

a. CASE — Numerical case identification
b. CLASS — Engine program security classification
c. IDENT — Engine program titles - for printout
d. NIN — Input file number
e. NOUT — Output file number
f. NSI — Numerical status indicator
g. PC — Power code
h. RC — Rating code
i. SDIST — Inlet pressure and temperature distortion selection
j. SERAM — Ram pressure recovery selection
k. SIM — Inlet mode selection
l. SWIND — Windmilling performance selection
m. TITLE — Title supplied by program user
n. Z (leading) — Prefix for a variable name used in input that may also be used in output; all physical parameters in the labeled common FIXIN will have the leading Z.

4.5.3 Compilers limit the number of characters per parameter name. When this limitation is not compatible with 4.5.1 and 4.5.2, each parameter name abbreviation will be determined by the program supplier and defined in the appropriate section of the User's Manual.

4.6 Power Definition:

Power level and other performance parameters for the significant engine ratings (e.g., intermediate, takeoff) will be available from the program by simple input.

The power level selection will be implemented using the following input hierarchy: Power Lever Angle (PLA), Power Code (PC), Rating Code (RC), and any additional performance selection. The User's Manual will describe the selection process.

4.6.1 Power Lever Angle or Power Code: The Power Code is defined as follows:

4.6.1.1 When positive, the power code is intended to represent the power level specification. When power lever angle is known, it should replace the power code. Positive Power Code values are assigned as follows in Table 1 and, in the case where unassigned power codes are used, they must be coordinated between program user and supplier and defined in the User's Manual.

TABLE 1 - Power Code Assignments

	Power Code	Definition
Augmented	100.0 to 60.0	Maximum to Minimum
Nonaugmented	50.0 to 20.0	Maximum to Idle
Reverse	15.0 to 5.0	Idle to Maximum

4.6.1.2 When zero, performance consistent with the input value of Rating Code will be calculated.

4.6.1.3 When negative, Power Code will be used to select alternative methods of power level specification, e.g., iteration to a specified net thrust or selection of an incremental power series. The values and uses of these negative values of PC will be defined in the User's Manual.

4.6.2 Rating Code: The Rating Code permits selection of specified ratings that may require different Power Lever Angles as flight or atmospheric conditions vary.

Rating Codes are defined as follows in Table 2. Unassigned Rating Codes may be used for additional ratings in which case they must be coordinated between program user and supplier and defined in the User's Manual.

TABLE 2 - Rating Code Assignments

	Rating Code	Definition Military	Definition Commercial
	100.0	Maximum	Emergency
Augmented	90.0	Maximum Continuous	Maximum
	60.0	Minimum Augmented	Minimum
	55.0	---	Wet Takeoff
	55.0	Maximum	---
	50.0	Intermediate	Dry Takeoff
	45.0	Maximum Continuous	Maximum Continuous
Nonaugmented	40.0	---	Maximum Climb
	35.0	---	Maximum Cruise
	21.0	Idle (Flight)	Flight Idle
	20.0	Idle (Ground)	Ground Idle
Reverse	15.0	Idle	Idle
	5.0	Maximum Reverse	Maximum

4.6.3 Additional Performance Selection: Additional performance selection may be required, e.g., windmilling performance by use of windmilling selection, SWIND.

4.7 Standard Thermodynamics:

The following references will be used for engine performance determination:

4.7.1 Standard Atmosphere: Ambient temperature and pressure will be consistent with the geopotential pressure altitude of ISO 2533.

4.7.2 Standard Dry Air: The composition of standard dry air is to be based on that used for ISO 2533, but with the number of molecular species reduced by the reallocation of trace elements. Upon request by the customer, the composition will be provided in an appendix to the User's Manual.

4.7.3 Fuel: Fuel Heating Value assumed by the computer program will be specified in the User's Manual. Fuel Specific Gravity will also be specified if it is used in the performance calculation or its associated control model. Other fuel characteristics used in the program will be provided in an appendix to the User's Manual, upon request by the customer.

4.7.4 Thermochemical Data: Thermochemical data used in the computer program will be provided in an appendix to the User's Manual, upon request by the customer. Thermochemical data for the purpose of gas turbine engine performance calculations will be consistent with data presented in NASA Technical Papers 1906, 1907, 1908, and 1909 within the limitations of physical representation (e.g., reaction rates, heat transfer), engineering accuracy, and computational efficiency requirements. Upon request by the user, the supplier will supply a comparison of the thermodynamic process calculations based on his thermochemical data and that given by NASA Technical Papers 1906, 1907, 1908, and 1909 within the range of applicable engine operating conditions.

4.8 Programming Standards:

4.8.1 The highest level of compiler optimization operationally available to the program supplier is preferred but requires coordination between user and supplier.

4.8.2 The program supplier will provide automatic preventive action for the following illegal arithmetic operations or processes:

a. The square root of a negative number
b. Illegal arguments to exponential
c. Logarithmic and inverse trigonometric subroutines

This preventive action will preclude these illegal arguments from being transferred to the user's system supplied subroutines. The Numerical Status Indicator will clearly define the validity of the output. The program will always be capable of continuing with the next case provided the user's subroutines and/or computer operating system do not override this capability.

4.8.3 The program supplier will assume that the computer memory is NOT cleared when the program is loaded.

4.8.4 The engine program, while operating in the subroutine mode (see 3.3), will be available as one subroutine call rather than separate calls to a collection of subroutines which, when taken in combination, represent the engine.

5. PROGRAM CAPABILITIES:

Program provisions for the effects described in this section will be included when they are applicable. However, it should be recognized that, generally, each addition to the program increases memory requirements, running time, and delays delivery. Coordination of program requirements between user and supplier is recommended. Coordination of these program capabilities between user and supplier is particularly important in transient programs since memory requirements and running time can be limiting factors in the use of the program.

5.1 Time Interval Control (Transient Programs):

5.1.1 A single input, ZTIME, (time from start of transient case, see 6.2.1, item 33) will be used to inform the engine subroutine of the value of time at which it is next to return control to the calling program. In addition, control will be returned when certain values of the Numerical Status Indicators have been created (see 6.5). Engine subroutine output data will be available at each return.

5.1.2 A steady-state solution providing initial conditions for the transient will be generated whenever ZTIME is zero.

5.1.3 TIMEO will be used to define the time interval between generated outputs. ZTIMET will be used to define the termination time of a given transient case.

5.1.4 Within one transient case the engine subroutine shall be capable of generating output at only those values of ZTIME that are equal to or greater than the previous value. If not required by the user, the capability of repeated entries at equal ZTIME values may be omitted.

5.1.5 It may be necessary for the user to obtain accurate engine subroutine output by iteration between user program and engine subroutine. In this case, repeated input to the engine subroutine of the same value of ZTIME will be required, until convergence of the iteration is achieved. The iteration procedure may lead to unacceptable computation times and it may be satisfactory for the user to take engine subroutine output from the previous value of ZTIME or by extrapolation from several previous values. When scheduling requirements are known in advance and precise output is required, coordination between supplier and user will permit a more efficient solution within the engine subroutine iteration.

5.1.6 The engine subroutine may internally select its own computational time step and may generate output by interpolation or extrapolation.

5.1.7 The user will supply as input a frequency above which an accurate response is not required. The engine subroutine will contain logic to ensure that a time step is selected which is adequate for the frequency supplied by the user.

5.1.8 The program may have the capability for the user to change the input frequency from an initial value (FYPH) to a secondary value (FYSH) and back, once during the transient. TIMEF1 is the time at which frequency is changed from FYPH to FYSH and TIMEF2 is the time at which frequency reverts to FYPH.

5.1.9 Failure of the engine subroutine to converge can be caused by severe ramps or step changes of input. If such changes are anticipated, coordination between program user and supplier is essential.

5.2 Variable Input (Transient Programs):

5.2.1 When it is necessary for the program user to vary an input parameter with time (e.g., intake temperature versus time), this capability will be provided by the user.

5.2.2 Provision to schedule an input parameter against internal engine parameters (e.g., distortion parameters versus intake mass flow, power takeoff versus shaft speed) shall be made by the program user where needed. The program user will obtain those internal engine parameters required for his calculations from the engine subroutine output.

5.3 Inlet Representation:

5.3.1 Inlet Mode: The engine program will calculate performance when provided with any one of the following combinations (selected by inlet mode selection, SIM, Note: SIM = 1 and SIM = 2 are assigned as discussed below in items 1 and 2 respectively):

1. Altitude, free stream Mach number, deviation of ambient temperature from standard and one of the options of 5.3.2.

2. Ambient pressure and temperature, inlet/engine interface total pressure and total temperature, and a temperature increment for inlet heat transfer to be added to the inlet total temperature.

3. SIM = Other than 1 or 2 coordinated between user and supplier.

4. Inlet heat transfer may be added to any SIM.

5.3.2 Ram Pressure Recovery: Several ram pressure recovery options will be provided (selected by ram pressure recovery selection, SERAM). Two categories of options are provided. The first category is to be used for engine inlet average recovery and the second provides the capability to differentiate primary and secondary stream recoveries. Values of SERAM are defined as follows in Table 3.

TABLE 3 - SERAM Assignments

SERAM	Definition
Average Recovery Options	
1	A specified ram pressure recovery standard.
2	The input ratio of engine inlet total pressure to free stream total pressure.
3	The ratio of engine inlet total pressure to free stream total pressure (ERAM) as a function of referred engine airflow (W1AR) and/or free stream Mach number (XM).
Differentiated Primary and Secondary Stream Options	
4	The input ratio of primary stream engine inlet total pressure to free stream total pressure; and the input ratio of secondary stream engine inlet total pressure to free stream total pressure.
5	The input ratio of primary stream engine inlet total pressure to free stream total pressure; and the ratio of secondary stream engine inlet total pressure to free stream total pressure as a function of referred engine airflow (W1AR) and/or free stream Mach number (XM).
6	The ratio of primary stream engine inlet total pressure to free stream total pressure as a function of referred engine airflow (W1AR) and/or free stream Mach number (XM); and the ratio of secondary stream engine inlet total pressure to free stream total pressure as a function of referred engine airflow (W1AR) and/or free stream Mach number (XM).

5.3.2 (Continued):

SERAM options 4, 5, and 6 are intended for use with high bypass ratio fan engines, and may be omitted for other applications.

SERAM options 3, 5, and 6, which provide for a functional relationship between ram recovery and engine airflow and/or freestream Mach number, require a user supplied subroutine with the following call sequence:

CALL ERAMX (XM, WR*, SECALC, ERAM)

*W1R or W1AR as appropriate.

The user supplied subroutine will interpret the value of SECALC to return the values of ERAM as presented in Table 4.

TABLE 4 - SECALC Assignment

SECALC	ERAM
1.0	Average
2.0	Primary Stream
3.0	Secondary Stream

5.3.3 Distortion: The effects of inlet pressure and temperature distortion (radial, circumferential, and temporal) on the engine will be included in the program when data or estimates are available (selected by distortion selection, SDIST). The input used in pressure distortion calculations will consist of the following four parameters for each instrumented ring (see ARP1420): circumferential distortion intensity (ZDPCQP), circumferential distortion extent (ZDANG), circumferential distortion multiple (ZXMPR), and radial distortion intensity (ZDPRQP).

5.4 Customer Services:

5.4.1 Air Bleed: The engine program will calculate performance when air bleed is extracted for customer services. The user will be able to input the amount of air extracted from each bleed station as a flow rate and/or, where applicable, as a ratio to the component inlet gas flow rate. The rate and ratio of the bleed air are additives in the calculation of bleed flow when both are specified. The corresponding output temperatures and pressures will include all engine induced heat transfer and pressure losses up to the bleed port interface, except in preliminary design programs prior to bleed system definition.

5.4.2 Power Extraction: The engine program will calculate engine performance when power is extracted for customer services.

5.5 Engine Supplied Nozzle Effects:

5.5.1 Nozzle parameters used in the calculation of engine performance will be provided as output. These nozzle parameters will include:

a. Nozzle area(s)
b. All gas flows
c. All engine discharge gas temperatures and pressures
d. Ideal gross thrust
e. Required user supplied nozzle cooling airflow

5.5.2 When a separate subroutine or supplementary data are needed to define external geometry of an engine supplied nozzle for user performance calculations, the appropriate data will be provided in the program output.

5.6 Parasitic Flows:

Parasitic flows include those planned flows, other than the customer bleed flow, which are discharged from the engine at points other than the exhaust nozzle. The engine program will calculate the effect on engine performance of such planned flows, and pressure, temperature, and flow rate will be included in the program output.

5.7 Engine Anti-Icing:

The engine program will have capability of calculating engine performance when operation involves the use of engine anti-icing.

5.8 Liquid Injection:

When operation involves the use of liquid injection for augmentation, e.g., water/alcohol, the engine program will have the capability of calculating engine performance for such operation. The flow rate used in the performance calculation will be included in the program output.

5.9 Fuel Lower Heating Value:

The engine program will have the capability for the user to vary the fuel lower heating value to the following extent:

a. Reflective of those fuels with which the engine is capable of operating.
b. Reflective of the variation in fuel lower heating value for a specific fuel depending on the requirements set forth by various governing federal agencies.

5.10 Windmilling:

The engine program will provide performance under windmilling conditions. The User's Manual will include the Mach number versus altitude region in which program output is valid.

5.10.1 Preliminary design programs need only output net thrust (i.e., drag) and engine inlet airflow without bleed or power extraction.

5.10.2 Specification programs will have additional capability, as applicable.

5.11 Reverse Thrust:

If the program supplier provides or has primary responsibility for the performance of an engine thrust reverser or spoiler, then the engine program will calculate this performance over the power range mutually agreed between the program supplier and user. The flight envelope, engine limits, or any other specific limitations on the use of this capability will be defined in the User's Manual.

5.12 Variable Geometry:

If the engine represented by the program incorporates variable geometry features that can be rescheduled at the user's option to optimize total system performance, a physical and functional description of this variable geometry will be included in the User's Manual. Also, the engine program output will include definition of the position of the variable geometry for which the performance is calculated. If the user has the option to reschedule the variable geometry without consulting the program supplier, then a description of the method of input and the permissible variation will be included in the User's Manual. This would not normally include variable geometry trim procedures used on production engines.

5.13 Engine Stability:

The engine program will provide indication of the appropriate component stability, (e.g., compressor surge, burner blow-out) by use of an appropriate Numerical Status Indicator.

5.14 User Supplied Programs:

The engine program, when used as a subroutine, may be required to interface with user supplied programs that represent such features as engine inlet, ejector inlet for an engine supplied nozzle, exhaust nozzle, ports for customer services, or secondary nozzles for boundary layer control. The methods of operation of the user supplied program and the engine subroutine must be closely coordinated to allow for interaction between them, and to ensure any necessary input and output is provided. The program user will, therefore, provide to the program supplier documentation describing his intended usage of the interface items.

6. INPUT/OUTPUT:

6.1 Program Interface Definition:

6.1.1 The communication between the calling program (written by either the program supplier or user) and the engine subroutine will be handled completely by six labeled commons. The CALL statement to the engine subroutine will contain no arguments. The six labeled commons will be FIXIN (Fixed Input), VARIN (Variable Input), EXPIN (Expanded Input), FIXOUT (Fixed Output), VAROUT (Variable Output) and EXPOUT (Expanded Output). The engine subroutine will never store computed values in FIXIN, VARIN, or EXPIN.

6.1.2 The fixed input parameters placed in labeled common FIXIN will be limited to the order and quantity defined in 6.2. The fixed output (FIXOUT) will be limited to the order and quantity of parameters defined in 6.3. If any parameter in the FIXIN or FIXOUT list is not used for a particular application, then that location in common will be unused so that the parameters which follow it may be found in the locations indicated in the tables. The remaining required input and output will be dependent on engine configuration and contained in labeled commons VARIN and VAROUT, respectively. Labeled commons EXPIN and EXPOUT will be reserved for additional parameters available through coordination between the program supplier and user.

6.1.3 The nomenclature utilized in the fixed input and output common blocks (FIXIN and FIXOUT) of 6.2 and 6.3 is for clarification only. Logically equivalent nomenclature consistent with ARP755 is permitted, e.g., W1 may be substituted for W1A in FIXOUT when multiple streams have not been distinguished.

6.1.4 Some output parameters have corresponding inputs in FIXIN, where their names are prefixed by the letter Z. The output locations in FIXOUT should contain the values of each parameter as used in the computation, irrespective of whether they have been specified in the input or overridden by the program.

6.2 Input:

6.2.1 FIXIN: The fixed sequence list of the parameters in the fixed input labeled common (FIXIN), and the identity of these parameters (with typical nomenclature consistent with ARP755) are as follows: (all parameters are REAL floating point numbers, except as indicated)

1.	NIN	Input file number (INTEGER)
2.	NOUT	Output file number (INTEGER)
3.	IND	Engine program indicator (INTEGER)
4.	TITLE (18)	User title - dimension 18 (HOLLERITH)
5.	CASE	Numerical case identification
6.	ZALT	Geopotential pressure altitude
7.	ZDTAMB	Ambient temperature minus standard atmospheric temperature
8.	ZDT1A	Temperature to be added to T1A
9.	ZERM1A	Ram pressure recovery at station 1A
10.	ZPWXH	Customer high pressure rotor power extraction
11.	ZPAMB	Ambient pressure
12.	ZPC	Power code

6.2.1 (Continued):

13. ZPLA Power lever angle
14. ZP1A Engine inlet total pressure at station 1A
15. ZRC Rating code
16. SERAM Ram pressure recovery selection
    Average Options
    SERAM = 1, Selects specified ram pressure recovery
    SERAM = 2, Selects input value of ram pressure recovery
    SERAM = 3, Selects ram pressure recovery from user supplied subroutine (ERAMX)
    Differentiated Options
    SERAM = 4, Selects input values of primary and secondary ram pressure recovery
    SERAM = 5, Selects input value of primary stream ram pressure recovery and calls user supplied subroutine (ERAMX) for secondary stream ram pressure recovery
    SERAM = 6, Selects primary and secondary stream ram pressure recoveries from user supplied subroutine (ERAMX)
17. SIM Inlet Mode Selection
    SIM = 1, Selects altitude and Mach number
    SIM = 2, Selects pressure and temperatures
    SIM = Other than 1 or 2 coordinated between user and supplier
18. ZTAMB Ambient temperature
19. ZT1A Engine inlet total temperature at station 1A
20. ZWB3 High pressure compressor discharge bleed flow rate
21. ZWB3Q High pressure compressor bleed flow ratio (discharge over component inlet)
22. ZXM Free stream Mach number
23. ZERAM1 Primary stream ram pressure recovery
24. ZERM11 Secondary stream ram pressure recovery
25. -- Reserved for historical consistency
26. -- Reserved for historical consistency
27. -- Reserved for historical consistency
28. -- Reserved for historical consistency
29. SDIST Inlet pressure and temperature distortion selection
30. FYPH Primary maximum response frequency
31. FYSH Secondary maximum response frequency
32. ZPWSD Specified shaft power
33. ZTIME Time from start of transient case
34. TIMEF1 Time at which frequency is changed to FYSH
35. TIMEF2 Time at which frequency reverts to FYPH
36. TIMEO Output time interval
37. ZTIMET Termination time of transient case
38. ZXJPTL Polar moment of inertia of power turbine load
39. ZXNSD Specified shaft rotational speed
40. ZTRQSD Specified shaft torque
41. SWIND Windmilling selection

6.2.2 VARIN: The variable input labeled common VARIN will contain input dependent on engine configuration.

6.2.3 EXPIN: The expanded input labeled common EXPIN will contain additional input available through coordination between program supplier and user.

6.3 Output:

6.3.1 FIXOUT: The fixed sequence list of the parameters in the fixed output labeled common (FIXOUT), and the identity of these parameters (with typical nomenclature consistent with ARP755) are as follows: (all parameters are REAL floating point numbers, except as indicated).

1.	CLASS (6)	Engine program security classification - Dimension 6 (HOLLERITH)
2.	IDENT (36)	Engine program titles - Dimension 36 (HOLLERITH)
3.	NSI (10)	Numerical Status Indicator - Dimension 10 (INTEGER). See 5.5.
4.	AE8	Primary exhaust nozzle throat effective area
5.	AE18	Bypass exhaust nozzle throat effective area
6.	ANGBT	Boat-tail angle
7.	FRAM	Ram drag
8.	FG	Gross thrust
9.	FGI	Ideal gross thrust
10.	FG19	Bypass stream gross thrust
11.	FGI19	Bypass stream ideal gross thrust
12.	FHV	Fuel lower heating value
13.	FN	Net thrust
14.	PB3	High pressure compressor discharge bleed flow total pressure
15.	P7	Primary exhaust flow total pressure
16.	P17	Bypass exhaust flow total pressure
17.	SFC	Specific fuel consumption
18.	--	Reserved for historical consistency
19.	TB3	High pressure compressor discharge bleed flow total temperature
20.	TC	Control temperature (cockpit display)
21.	T7	Primary exhaust flow total temperature
22.	T17	Bypass exhaust flow total temperature
23.	WFE	Engine fuel flow rate
24.	WFT	Total fuel flow rate
25.	W1A	Engine inlet flow rate at station 1A
26.	W7	Primary exhaust flow rate
27.	W17	Bypass exhaust flow rate
28.	W2_	High pressure compressor inlet flow rate (The full number representing the relevant station designation, e.g., W21, W215, W2A, will be defined by the program supplier.)
29.	XNH	High pressure rotor rotational speed
30.	XNI	Intermediate pressure rotor rotational speed
31.	XNL	Low pressure rotor rotational speed
32.	XNSD	Delivered shaft rotational speed
33.	ALT	Geopotential pressure altitude

6.3.1 (Continued):

34. ERAM1A Ram pressure recovery at station 1A
35. PAMB Ambient pressure
36. PLA Power lever angle
37. P1A Engine inlet total pressure at station 1A
38. TAMB Ambient temperature
39. T1A Engine inlet total temperature at station 1A
40. XM Free stream Mach number
41. SML Low Pressure Compressor Surge Margin
42. SMI Intermediate Pressure Compressor Surge Margin
43. SMH High Pressure Compressor Surge Margin
44. -- Reserved for historical consistency
45. -- Reserved for historical consistency
46. PWSD Delivered shaft power
47. TIME Output Time, from start of transient case
48. TRQSD Delivered shaft torque
49. ERAM1 Primary stream ram pressure recovery
50. ERAM11 Secondary stream ram pressure recovery
51. -- Reserved for historical consistency
52. -- Reserved for historical consistency
53. -- Reserved for historical consistency
54. -- Reserved for historical consistency
55. DTAMB Ambient temperature minus standard atmosphere temperature
56. DT1A Temperature added to T1A
57. PC Power code
58. RC Rating code
59. WB3 High pressure compressor discharge total bleed flow rate (Resultant from combined inputs 6.2.1 (20) and (21))
60. WB3Q High pressure compressor total bleed flow ratio (discharge over component inlet) (Resultant from combined inputs 6.2.1 (20) and (21))
61. PWXH Customer high pressure rotor power extraction

6.3.2 VAROUT: The variable output labeled common VAROUT will contain output dependent on engine configuration but not included in FIXOUT.

6.3.3 EXPOUT: The expanded output labeled common EXPOUT will contain additional output available through coordination between program supplier and user.

6.3.4 Printout: In addition to the output parameters in labeled commons FIXOUT, VAROUT, and EXPOUT, the printout will include all input parameters (FIXIN, VARIN, and EXPIN). All printout will be under the control of the calling program.

6.4 Units:

Input and output parameter values will be based on the pound, foot system of measurement commonly used in the United States. The metric International System of Units (SI) is an acceptable alternative. Appendix C defines the units that should be used for either system.

6.5 Numerical Status Indicators:

6.5.1 Numerical Status Indicators will be used, where applicable, to notify the program user of any limitation or qualification of the output data. The Numerical Status Indicator codes defined in 6.5.2 will be used. The program supplier also may elect to print the actual words of the message in the output.

6.5.2 A four-digit number will be used as the message indicator. The first digit will indicate the quality of the output, as defined in Table 5. The second digit will indicate the nature of the problem affecting the output, as defined in Table 6. The third and fourth digits will indicate specific messages that will be defined in the User's Manual. An array of ten Numerical Status Indicators (the first nine and the last one encountered) will be available for output during steady-state operation.

During transient operation, at least one Numerical Status Indicator will be provided in the output. Additional Numerical Status Indicators may be obtained as mutually agreed upon between supplier and user. If an invalid output Numerical Status Indicator occurs, the transient should be terminated and the value of time (TIME) at which failure occurred should be returned.

TABLE 5 - First Digit Numerical Status Indicator Assignments

NSI	First Digit, Quality Indicators
0000	All output valid, no errors, no limits exceeded
0XXX	Input reset to limit, output valid as specified
1XXX	Limit exceeded, output provided for interpolation only
2XXX to 8XXX	Open for supplier's use with definitions supplied in the User's Manual
9XXX	Output not valid

TABLE 6 - Second Digit Numerical Status Indicator Assignments

NSI	Second Digit, Category Indicators
X1XX	Computing problems (e.g., fails to converge, job in loop, failure unknown)
X2XX	Input problems (e.g., missing input, wrong order)
X3XX	Rating or power messages (e.g., thrust requested above or below engine capability, control limits)
X4XX	Installation problems (e.g., bleed flow pressure or percentage exceeded, power extraction exceeded, secondary flow limit exceeded, distortion limit exceeded)
X5XX	Envelope problems (e.g., engine structural limit exceeded, Mach limit exceeded, temperature limit exceeded)
X6XX	Stability problems (e.g., surge, burner blow-out)
X7XX to X9XX	See User's Manual

7. PROGRAM IDENTIFICATION:

Every engine program will have a unique identification and date. Provision will be made to print out this identification on each set of output. Every program will be transmitted in a fashion that is mutually acceptable to both user and supplier (e.g., magnetic tape, diskette, electronic transmission). The following information must be provided for every program transmitted:

a. Program identification and date
b. Originator
c. Engine identification

In addition, the following information must be provided for each file transmitted:

a. Type of information (source or object; data in internal form (unformatted) or in external form (formatted)).

b. If object code, type of machine used, operating system, and compiler (including version).

c. Any other information necessary to retrieve the program from the media.

8. PROGRAM CHECKOUT:

Program checkout will be accomplished with the independent program as supplied. Input for test cases will accompany the engine program or will be included with the User's Manual along with resultant output for sufficient cases to demonstrate the engine program input options described in the User's Manual.

8. (Continued):

Source code will be provided for the calling program.

9. PROGRAM REVISIONS:

9.1 The nature of, and reason for, changes or revisions to computer programs will be documented by the program supplier when the revision is submitted to the user. The User's Manual or program operating instructions will be kept current with the revision.

9.2 When revisions are made they will be identified by an appropriate change to the basic program identification number with a corresponding revision date. Documentation that refers to the program will include revision designations when practicable. Revision designations will be included on the printout.

9.3 Programs revised by the user without written consent of the supplier will be the responsibility of the user.

10. OPTIONAL FEATURES:

Engine steady-state performance programs may contain optional features and capabilities to the extent agreed upon between the program supplier and user. The intent of such optional features will be to facilitate the calculation of total propulsion system performance. Examples of these features are iteration to a requested net thrust, a bleed interface procedure, iteration to a requested shaft power output, a ram recovery interface procedure, iteration to an externally monitored parameter, humidity effects, and inlet water ingestion effects. Engine transient performance programs may also contain optional features. Examples of these features are operation under certain engine failure modes, increased stability margin operation, starting or shutdown. The special nature of starting or shutdown conditions usually dictates the creation of a specific type of transient program.

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