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COMPUTER PROGRAMS: MECHANICAL AND STRUCTURAL DESIGN CRITERIA

CASE FILE COPY

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Foreword

The National Aeronautics and Space Administration and Atomic Energy Commission have established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace and nuclear communities. By encouraging multiple application of the results of their research and development, NASA and AEC earn for the public an increased return on the investment in aerospace and nuclear research and development programs.

This publication, part of a series to provide such information, is intended for design engineers in the mechanical and structural fields and is divided into two sections. Section one presents some computerized design criteria in the mechanical field and is largely devoted to turbomachinery and the constraints imposed by very high rotational speeds. The second section covers a variety of computerized design criteria that should be of interest to designers of structures and structural components.

Additional information on individual items can be requested by circling the appropriate number on the Reader Service Card included in this compilation; or from: COSMIC, 112 Barrow Hall, University of Georgia, Athens, Georgia 30601.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this compilation.

Jeffrey T. Hamilton, *Director*
Technology Utilization Office
National Aeronautics and Space Administration

Contents

Section 1. Mechanical Design Criteria

VELOCITIES AND STREAMLINES OF BLADE-TO-BLADE STREAM SURFACE OF A TURBOMACHINE

This program is a revision of an existing program for blade-to-blade aerodynamic analysis of turbomachine blades and it is a simpler program while consistent with related programs. The analysis is for two-dimensional, subsonic, compressible (or incompressible), nonviscous flow in a circular or straight infinite cascade of blades, which may be fixed or rotating. The flow may be axial, radial, or mixed, and the stream channel thickness may change in the through-flow direction.

The program input consists of blade and stream channel geometry, total flow conditions, inlet and outlet flow angles, and blade-to-blade stream channel weight flow. The output includes blade surface velocities, velocity magnitude and direction at all interior mesh points in the blade-to-blade passage, and streamline coordinates throughout the passage.

Language: FORTRAN IV (98%), MAP (2%)
Machine Requirements: IBM-7094 II/7044 DCS, Release 13

Source: Lewis Research Center
(LEW-10788)

Circle 1 on Reader Service Card.

DESIGN AND OPTIMIZATION OF HIGH PERFORMANCE, ONCE-THROUGH POTASSIUM BOILERS

A computer program has been developed for the thermal-hydraulic design and optimization of liquid metal heated once-through potassium boilers. The calculating procedures are based upon local pressure loss and heat transfer correlations. These procedures consider five different regions of heat transfer; superheated vapor, film boiling, transition boiling, nucleate boiling, and liquid heating. Each region is solved using appropriate heat transfer and pressure loss predictions, and the computed heat transfer coefficients and temperatures are included as part of the program output.

The computer program as developed permits the use of lithium or sodium as the primary heating fluid and with a variety of tube materials such as 316 stainless steel, Haynes 25 alloy, Columbium-1% zirconium alloy, FS-85 alloy and T-111 alloy.

The computer program will calculate the boiler tube length required for either single-tube or multiple-tube boilers. A tube-in-shell geometry is employed in all cases with the potassium flowing inside the tubes and the primary fluid flowing counter-current in the shell.

Calculations can be performed for boiler tubes containing vortex-generating inserts for enhancement of heat transfer performance as well as for tubes containing no inserts.

Language: FORTRAN IV
Machine Requirements: IBM-7094, GE-625/635

Source: General Electric Co.
under contract to
Lewis Research Center
(LEW-10942)

Circle 2 on Reader Service Card.

DESIGN-POINT PERFORMANCE OF TURBOJET AND TURBOFAN ENGINE CYCLES

This program is designed for the calculation of design-point performance of turbojet and turbofan engine cycles. This program requires as input the airplane Mach number, the altitude-state conditions, turbine-inlet temperature, afterburner temperature, duct-burner temperature, bypass ratio, coolant flow, component efficiencies, and component pressure ratios.

The output yields specific thrust, specific fuel consumption, engine efficiency, and several component temperatures and pressures.

The thermodynamic properties of the gas are expressed as functions of temperature and fuel-to-air ratio.

The program is provided with an example case.

Language: FORTRAN IV
Machine Requirements: IBM-7094
Source: Lewis Research Center
(LEW-10952)

Circle 3 on Reader Service Card.

INDUCER DYNAMICS PARTIAL-FLOW TURBINE DRIVE PROGRAM

This program predicts the transient performance of a low-speed inducer driven by a partial-flow hydraulic turbine. One of the necessary inputs to the dynamic program is a steady-state performance map of the hydraulic turbine. There is a simple method of obtaining a map from the original velocity diagram of the turbine and the program for computing the performance map.

The program is based on the following assumptions: (1) the turbine is a full-admission, repeating-stage type; (2) flow is two-dimensional; (3) design is fixed by velocity diagram at only one radius; (4) flow is incompressible; (5) nozzle and rotor discharge angles

are determined by a basic velocity diagram at the design point; and (6) efficiency at the design point is known.

Language: FORTRAN H
Machine Requirements: IBM-360, Release 11
Source: Rockwell International Corp.
under contract to
Lewis Research Center
(LEW-10958)

Circle 4 on Reader Service Card.

PRE-INDUCER PROGRAM

Rocket engine propellant tank pressurization can be simplified or eliminated by the use of a hydraulic, turbine driven, inducer upstream of the main turbo pump. This inducer-turbine combination is commonly called a pre-inducer. The inducer is designed to operate at very low suction pressures and generates sufficient pressure to prevent cavitation of the main pump. Since the pre-inducer absorbs power from the main pump, it is important to design an efficient and practical inducer-turbine combination which requires minimum horsepower from the hot gas turbine of the main pump.

This program is used to determine the optimum

design parameters as a function of inducer head and turbine weight flow. From the results, it is possible to determine an optimum design point for the pre-inducer and main pump combination.

Language: FORTRAN IV
Machine Requirements: IBM-360
Source: Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-18882)

Circle 5 on Reader Service Card.

BLADED-WHEEL ASSEMBLY FOR MINIMUM IMBALANCE

This program determines the best possible arrangement for minimum imbalance, of a given collection of pump or turbine blades, for assembly on disks of predetermined imbalance.

Input consists of an array of actual blade weights, linear regression coefficients A and B for the established relation between weight (W) and moment (M) about the center of the wheel,

$$M = AW+B,$$

and a number of entries specifying disk imbalance, total number of blades, number of blades per wheel, and number of wheels to be bladed. Each blade has a preassigned number which is input along with its weight.

The entire number of blade weights is sorted and listed in order of increasing weight. Each disk is theoretically bladed with the proper number of blades taken from the sorted list and then rearranged for minimum imbalance of disk plus blades. The final position sequence is printed out with associated blade numbers and weights.

Language: FORTRAN H
Machine Requirements: IBM-360, Release 11
Source: R. J. Huft of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-13026)

Circle 6 on Reader Service Card.

PROGRAM CALCULATES VELOCITIES AND STREAMLINES
IN A TANDEM BLADE TURBOMACHINE

Efforts are being made to design compressors and turbines with smaller diameters, fewer stages, and fewer blades per stage. All these factors tend to increase diffusion. Therefore, it is desired to design blades with high diffusion, and at the same time avoid flow separation. Two concepts for accomplishing this are the tandem blade and the slotted blade. However, it is necessary to have a method of calculating the velocity distribution on the surface of such blades; this computer program provides an easy method.

A computer program gives the blade-to-blade solution of the two-dimensional, subsonic, compressible (or incompressible), nonviscous flow problem for a circular or straight infinite cascade of tandem or slotted turbomachine blades. The blades may be fixed or rotating. The flow may be axial, radial, or mixed.

The method of solution is based on the stream function using an iterative solution of nonlinear finite-difference equations. These equations are solved using two major levels of iteration. The inner iteration consists of the solution of simultaneous linear equations by successive overrelaxation, using an estimated optimum overrelaxation factor. The outer iteration then changes the coefficients of the simultaneous equations to correct for compressibility.

The program input consists of the basic blade geometry, the meridional stream channel coordinates fluid stagnation conditions, weight flow and flow split through the slot, and inlet and outlet flow angles. The output includes blade surface velocities, velocity magnitude and direction throughout the passage, and the streamline coordinates.

Language: FORTRAN IV (99%), MAP (1%)
Machine Requirements: IBM-7094/7044 DCS
Source: Lewis Research Center
(LEW-10743)

Circle 7 on Reader Service Card.

GEOMETRY AND DESIGN-POINT PERFORMANCE
OF AXIAL-FLOW TURBINES

It was necessary to develop a non-restrictive method for determining the alternative geometries and associated design point performance of axial-flow turbines capable of satisfying specified design requirements.

Program TD (Turbine Design) is a computer program that solves the flow field within the turbine without making the simplifying assumptions that result in restrictive designs.

The program is capable of analyzing both single and multispool units (a maximum of three spools is allowed), and each spool may have up to eight stages. The absolute and relative flow fields are computed at the first stator inlet, at each interblade row plane, and at the final rotor exit. The effects of the radial variation of the following quantities are taken into account: inlet conditions, streamline angle of inclination and curvature, loss coefficient or efficiency, whirl velocity or angle, and power output. Further, the effects of coolant flows, interfilament mixing, and a station-to-station variation of specific heat can be included. As additional features, the program allows for: (1) the internal calculation of losses based on a correlation which has been developed for pressure-loss coefficient, and (2) either subsonic or supersonic solutions for the absolute velocity.

The program will determine the standard turbine design parameters at a preselected number of streamlines. These parameters will be consistent with the requirement of radial equilibrium, the specified or calculated blade element performance, and the input specifications of design requirements. When used for the analysis of a single spool, designs for any number of sets of analysis variables may be computed consecutively.

Language: FORTRAN IV

Machine Requirements: IBM-7094/7044 DCS

Source: Northern Research and Engineering Corp.
under contract to
Lewis Research Center
(LEW-10471)

Circle 8 on Reader Service Card.

OFF-DESIGN PERFORMANCE OF RADIAL-INFLOW TURBINES

A computer program for off-design performance of radial-inflow turbines has been developed and is available.

The program can be used in two ways. For an existing turbine where the performance at the design operating point may be known, this program provides a convenient way to estimate off-design performance without making actual tests. The program is also useful as a design guide. For a proposed turbine design, the design point performance can usually be closely estimated. However, if the off-design operation is of sufficient importance, modifications in the design may be considered. In this case, the effect of a series of small design changes on performance may be studied by repeated use of this program.

Use of the program requires as input information the turbine flow areas, diameters, and blade angles. An estimate of design point performance is also necessary. The output consists of conventional performance parameters at specified flow conditions and speeds.

Language: FORTRAN IV

Machine Requirements: IBM-7094/7044 DCS

Source: Lewis Research Center
(LEW-10764)

Circle 9 on Reader Service Card.

PROGRAMS FOR AXIAL-FLOW COMPRESSOR DESIGN

It was decided to examine a wide range of design parameters to determine their effects and to indicate significant areas for study and research of multistage axial flow compressors.

Four computer programs were developed for the design of axial flow compressors:

1. The first of these programs was based on the assumption of simple radial equilibrium of static pressure and constant efficiency radially. In this program, limits on hub and tip ramp angles, axial velocity ratio across blade rows, rotor hub and stator tip loadings, rotor exit relative flow angle, and stator hub Mach number are specified; the velocity diagram and stage-by-stage performance are calculated.

2. The second program accounts for complete radial equilibrium of flow. Losses are evaluated on the basis of blade element loss prediction methods. Radial distribution of energy is specified as a polynomial variation of whirl velocities at the exit of each blade row; rotor tip loadings are specified as are limiting values of rotor hub relative exit angles, stator hub Mach numbers, stator hub loadings, and the compressor flow path.

3. Program 3 differs from Program 2 in that the radial distribution of total pressure is specified for each rotor blade row rather than the whirl velocity distribution, and there is the option of specifying the flow path or specifying the axial velocity ratios and calculating the resulting flow path.

4. The fourth program developed is an off-design performance calculation. The calculation accounts for variable specific heat and full radial equilibrium and determines energy addition and adiabatic efficiencies on the basis of data for blade element turning and loss.

The program user has available as options either double-circular-arc or NASA 65-series blade performance data, plus the capability of specifying reference incidence angle through tabular input for any individual blade row or through the criterion of suction surface tangency for any double-circular-arc blade row. The off reference increment in deviation angle is furnished in the form of a correlation of selected NASA data.

Language: FORTRAN IV
Machine Requirements: IBM-7094/7044 DCS

Source: General Motors Corp.
under contract to
Lewis Research Center
(LEW-10765)

Circle 10 on Reader Service Card.

AXIAL VELOCITIES IN AN AXIAL-FLOW COMPRESSOR OR TURBINE ANNULUS OF A GAS FLOW PROGRAM

This program calculates the axial velocities in an axial-flow compressor or turbine annulus of a gas flowing under non-isentropic simple radial equilibrium conditions. The equation used is commonly called the NISRE equation.

The NISRE equation is a solution of Euler's equations involving rotation, total temperature variation, total pressure variation, and mass flow of rotating gas flows through an annulus under radial equilibrium conditions. The equation solves for axial velocity in terms of the other variables; in the process, a numerical integration and an iterative solution for the mass flow are necessary.

Language: FORTRAN IV
Machine Requirements: IBM-360, Release 11

Source: J. A. King of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-18744)

Circle 11 on Reader Service Card.

ANALYSIS OF FLOW ACROSS A GAS TURBINE SEAL

This program investigates noncontact face-sealing dams of the type used in gas turbines. Some powerplants, such as advanced jet engines, exceed the operating limits for which face-contact seals were designed. As a result, noncontact seals have become necessary.

A computer program has been developed to carry out an analysis of the flow (leakage) across a sealing dam for the case of steady, laminar, subsonic, isothermal, compressible flow. The analysis considers both parallel sealing-dam surfaces and surfaces with small tilt angles.

The program is based on a sealing-dam model, which consists of two parallel, concentric, circular rings separated by a very narrow gap and rotating at a constant speed. The model is limited by the following physical constraints: the fluid is homogeneous, compressible, viscous, and Newtonian; the flow is steady and laminar; the bulk modulus is ignored; the fluid behaves as a perfect gas; the entrance region effects are negligible; and the fluid film is isothermal.

The governing equations for compressible-fluid flow with constant viscosity are incorporated into the analysis. The physical constraints applied to the model are used to simplify these equations before the boundary conditions of the specific problem are inserted.

The program input variables include the dimensions of the seal, pressure boundary conditions, and the physical properties of the gas. The output includes: mass flowrate; pressure and velocity distributions, Mach number, force, axial film stiffness, center of pressure, rotational and pressure-flow Reynolds numbers, Knudsen number, torque, power loss and approximate temperature rise resulting from viscous shearing in a specified film thickness. The output data are stated in both English and International units.

Language: FORTRAN IV
Machine Requirements: IBM-7094/7044 DCS
Source: Lewis Research Center
(LEW-10975)

Circle 12 on Reader Service Card.

TRANSONIC VELOCITIES IN TURBOMACHINES

This program obtains a transonic flow solution on a blade-to-blade surface between blades of a turbomachine. The flow must be essentially subsonic, but there may be locally supersonic flow. The solution is two-dimensional, isentropic, and shock free. The blades may be fixed or rotating. The flow may be axial, radial, or mixed, and there may be a change in stream channel thickness in the through-flow direction. A loss in relative stagnation pressure may be accounted for.

The program input consists of blade and stream-channel geometry, stagnation flow conditions, inlet and outlet flow angles, and blade-to-blade stream-channel weight flow. The output includes blade surface velocities, velocity magnitude and direction at all interior mesh points in the blade-to-blade passage, and streamline coordinates throughout the passage.

The transonic solution is obtained by a combination of a finite-difference, stream-function solution and a velocity-gradient solution. The finite difference solution at a reduced weight flow provides information needed to obtain a velocity-gradient solution.

Language: FORTRAN IV (98%) MAP (2%)
Machine Requirements: IBM-7094
Source: Lewis Research Center
(LEW-10977)

Circle 13 on Reader Service Card.

PROGRAM FOR THE DESIGN OF AXIAL-FLOW TURBINES

A nonrestrictive method has been developed for determining the alternative geometries and associated design point performance of axial-flow turbines capable of satisfying specified design requirements.

Program TD 2 (Turbine Design) is a computer program that solves the flow field within the turbine without making the simplifying assumptions that result in restrictive designs.

The program is capable of analyzing both single and multispool units. A maximum of three spools; each with up to eight stages, is allowed. The absolute and relative flow fields are computed at the first stator inlet, at each interblade row plane, and at the final rotor exit. Radial variation effects of the following quantities are taken into account: inlet conditions, streamline angle of inclination and curvature, loss coefficient or efficiency, and meridional velocity or angle. Further, the effects of coolant flows, interfilament mixing, and station-to-station variation of specific heat can be included. The program internally calculates losses, based on a pre-developed correlation for pressure-loss coefficient; and either subsonic or supersonic solutions can be used to determine the absolute velocity.

Standard turbine design parameters can be determined at a preselected number of streamlines. These parameters will be consistent with radial equilibrium requirements, specified or calculated blade element performance, and input specifications defining design requirements. When used for the analysis of a single spool, the program can consecutively produce designs for any number of sets of analysis variables.

This program is an updated version of the computer program described in NASA Tech Brief 69-10111, "Geometry and Design Point Performance of Axial Flow Turbines."

Language: FORTRAN IV
Machine Requirements: IBM-7094/7044 DCS

Source: Northern Research and Engineering Corp.
under contract to
Lewis Research Center
(LEW-11029)

Circle 14 on Reader Service Card.

Section 2. Structural Design Criteria

STRUCTURAL STRESS EVALUATION PROGRAM

This program, which performs structural stress evaluations, incorporates several axial and bending fiber stress formulas and evaluation techniques, as outlined in the American Institute of Steel Construction Manual, with techniques for calculating shear and torsion stresses. The program input consists of member physical properties and loads from which fiber stress for both axial and bending load conditions are computed. The respective shear and torsion stresses are also evaluated by classical means. Overstressed members of 100 percent or more can then be mathematically replaced and the entire routine rerun until an optimum design condition is

achieved. The program evaluates up to 500 members, loaded differently, as many ways as required.

Language: FORTRAN IV (80%), OBJECT (20%)
Machine Requirements: IBM-7094
Source: T. E. Bullock of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-13282)

Circle 15 on Reader Service Card.

Y-RING STRESS ANALYSIS PROGRAM

The Y-Ring Stress Analysis program determines the loads, deflections, slopes, stresses, and moments of the upper and lower fuel and LOX Y-Rings of the Saturn V S-IC vehicle propellant tanks. The program can·be used, however, for design and analysis of large structural rings in general.

The Y-Ring is a three-way joint at the intersection of the tank skins with the bulkhead and one of the following three components: thrust structure, inner-tank, or forward skirt of the Saturn booster. A cross section of the Y-Ring is cut at 10 points, generally at points of structural change, with various points being allowed to deflect independently under applied loads. Shears and moments are applied to the cuts in the structure to restore continuity. By changing the configuration of the Y-Ring and observing the effects of the moments and stresses on each shell, and by making certain assumptions, an optimum design can be accomplished.

The equations used in the solution represent relations between deflections and rotations of adjacent components (beams) of the Y-Ring. By equalizing the deflections and rotations at each end-point of the Y-Ring, a set of simultaneous equations is generated. The solution of the matrix described by these equations is found by P. D. Crout's Elimination Method for the solution of linear simultaneous equations.

Language: FORTRAN IV (Versions 1 and 2), FORTRAN V (Versions 3 and 4)
Machine Requirements: IBM-7094 (Version 1); IBM-360, Release 11 (Version 2); UNIVAC-1108, EXEC-II (Version 3); and UNIVAC-1108, EXEC-VIII (Version 4)

Source: R. A. Dejoie and J. N. Fowler of
The Boeing Company
under contract to
Marshall Space Flight Center
(MFS-15119)

Circle 16 on Reader Service Card.

ANALYSIS AND DESIGN PROCEDURES FOR A FLAT, CENTRAL FINNED-TUBE RADIATOR

An analysis of a flat, direct-condensing, central finned-tube radiator rejecting heat from both sides was performed that enabled the design of space radiators to meet minimum weight and geometric requirements. Two electronic digital computer programs were developed. The first program is based on a fixed conductance parameter and yields a minimum weight design. The second employs a variable conductance parameter and variable ratio of fin length to tube outside radius. This program can be used for radiator designs that have geometric limitations. Both programs consider a Rankine thermodynamic cycle, vapor and liquid headers, pressure drop in the radiator tubes and headers, meteoroid protection for the tubes and headers, radial temperature drop in the tube wall, and fin and tube radiant interchange in the development of the descriptive equations.

Major outputs of the two programs include: tube length, number of tubes, radiator aspect ratio, radiator weight, fin length and thickness, specific-heat-rejection rate, and header geometry. These outputs are based on the choice of input variables such as tube inside diameter, temperature and power levels, fin and armor materials, prescribed pressure drops in tubes and headers, mission time and probability of no punctures by meteoroids, and radiator-header-panel configuration.

Language: FORTRAN IV
Machine Requirements: IBM-7094
Source: Lewis Research Center
(LEW-10893)

Circle 17 on Reader Service Card.

SHELL DESIGN PROGRAM

This program is designed to determine the useful strength of a thin-walled shell once it has been wrinkled. Although it was originally designed for use with the Atlas Booster as a model, the program can be used as a tool for designers of missile shells, pipes for carrying liquids, or cylindrical storage tanks.

Thin walled shells used in spacecraft boosters or as pipe lines are suspected as being failures when wrinkles show up in the structure. The deformation or wrinkling rising from strain and stress is thought to be evidence that the vessel or cylinder will no longer be able to withstand the normal loads and pressures for which it was designed.

A computer program takes the guesswork out of determining the useful strength of a thin-walled shell once it has been wrinkled. It can be used as an analytical tool by designers to determine how much wrinkling or deformation a shell can withstand when subjected to axial compression and bending loads. Using the Atlas Booster as a model, the computer program showed that the shell would collapse at loads nearly twice as great (1.93 times) as the load causing the wrinkles.

To determine the solution to complicated shell problems, a mathematical model of the actual shell must first be obtained. It is necessary to subdivide the shell into segments such that each segment does not contain discontinuities in geometry, material properties, or loading. Each segment is numbered according to its physical order in the shell. Points which separate segments are called discontinuity points, and the first and last point of the shell are called boundary points. The program input data consists of information pertaining to all of these segments and points.

The solution of such a complex problem is made possible by using the Sanders nonlinear shell theory as a basis for the computer program. Sanders derived field equations for small strains and moderately small rotations. Each of the variables in the equations is expanded in a Fourier series and reduced to eight nonlinear first-order differential equations. These equations are then solved by a modified Newton method which consists of retaining only the nonlinear terms on the left side of the equations that do not couple harmonics; all other nonlinear terms are placed on the right side of the equations. An iteration method is then used on trial solution vectors until the solution converges. Experience in using this method has indicated that the convergence properties are quite good.

Language: FORTRAN IV
Machine Requirements: IBM-7094 II/7044 DCS, Release 13

Source: TRW, Inc.
under contract to
Lewis Research Center
(LEW-10734)

Circle 18 on Reader Service Card.

STRESS ANALYSIS OF RECTANGULAR PLATES

This program was written for stress analysis of rectangular plates. It computes stresses, displacements, and stress resultants in their solid rectangular plates, which are subjected to arbitrary nominal loads, thermal gradients, and edge loads. The program also provides for arbitrarily varying elastic foundation and edge supports as well as thickness. A finite difference method of solution is utilized and is limited to those loads, stresses, and displacement components intrinsic to plate bending theory and will not accommodate in-plane tractions or displacements.

Language: FORTRAN H
Machine Requirements: IBM-360
Source: Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-18688)

Circle 19 on Reader Service Card.

STRUCTURAL DESIGN AND STRESS ANALYSIS PROGRAM FOR ADVANCED COMPOSITE FILAMENT-WOUND AXISYMMETRIC PRESSURE VESSELS (COMTANK)

A computer program, COMTANK, has been developed to design and analyze advanced composite filament-wound axisymmetric pressure vessels.

The program has been specifically developed to handle planar-wound pressure vessels fabricated of either boron/epoxy or graphite/epoxy advanced composite material. The vessel may or may not contain a cylindrical midsection; i.e., the tank configuration may be that of a cylinder with dome closures or an oblate spheroid. In the former case, provision has been made to accept unequal boss openings in the forward and aft domes.

In general, input to the program must be provided in three basic categories:

(1) tank description, consisting of geometry and material property data;

(2) design loading condition; and

(3) analysis loading conditions.

The tank description consists of a definition of overall tank geometry and component geometry relating to the liner, bosses, and skirt attachments. The design loading condition consists of internal pressure only. The analysis loading conditions consist of internal pressure, boss line loadings, and temperature gradients through the tank wall.

Items (2) and (3) above indicate that it is possible to analyze a pressure vessel design for loading conditions other than those for which it was designed.

Given the proper input, COMTANK will perform computations to provide output that describes a detailed pressure vessel design and stress analysis. The vessel design consists of midsurface coordinates defining the entire tank and skirt-support element geometry, element wall thickness throughout the structure, ply construction, enclosed volumes, weight breakdowns and material property details relating to filament tape wrap angles and coefficients of thermal expansion. The stress analysis consists of the entire displacement field of the structure, element nodal forces, stress resultants and couples, and point stress analysis; giving a detailed breakdown of the longitudinal, transverse, and shear stress in each layer of the composite at the point of consideration.

The program makes a call for subroutine TICK which calculates the CPU time of a particular run. The user will have to supply his own TICK subroutine or remove the small amount of logic that utilizes the CPU time.

Language: FORTRAN V
Machine Requirements: UNIVAC-1108, EXEC-8
Source: A. C. Knoell of
Caltech/JPL
under contract to
NASA Pasadena Office
(NPO-11943)

Circle 20 on Reader Service Card.

HEAT TRANSFER PROGRAM

This program computes the stagnation and the wall heat transfer of a vehicle. Five subroutines, excluding system routines, are required for a successful run and peripheral equipment requirements consist of a card reader, a printer, and one tape unit.

The program uses Van Driest, Sibulkin, and Kemp-Riddell equations to compute the temperature-time histories of thick wall bodies. The general method assumes that the body can be broken into a number of individual blocks, and the temperature history of each block can be determined. The process assumes one-dimensional heat transfer. The program can compute the heat transfer of a maximum of twenty blocks. The maximum number of ratios that can be input is fifty.

Language: FORTRAN IV
Machine Requirements: GE-625
Source: Wallops Station
(WLP-10036)

Circle 21 on Reader Service Card.

GENERAL INSTABILITY OF ECCENTRICALLY-STIFFENED
CYLINDRICAL SHELLS

This program is used to determine the general instability load of an orthogonally stiffened cylindrical shell under axial compression and lateral pressure. The governing equations are derived using small deflection theory; and, consequently, the validity of the method must be restricted to moderately or heavily stiffened cylinders. All the stiffness occurring in stiffened shells of this type have been incorporated, and the rings and stringers are considered eccentric with respect to the skin middle surface. Local buckling of the skin between adjacent stringers before general instability is allowed, and the resulting reductions in stiffness properties of the skin are determined as a function of the two principal strains.

Analytical and experimental results are compared for twenty-nine stiffened cylinders loaded in compression and for six stiffened cylinders loaded in bending.

Language: FORTRAN IV
Machine Requirements: IBM-7094
                    Source: J. N. Dickson and R. H. Brolliar of
                                         Brown Engineering Co.
                                          under contract to
                                    Marshall Space Flight Center
                                             (MFS-20649)

Circle 22 on Reader Service Card.

AUTOMATED INPUT DATA PREPARATION FOR THE
NASTRAN STRUCTURAL ANALYSIS PROGRAM

This program package consists of five computer programs which are available to aid the structural engineer in preparing input data for the NASTRAN structural analysis program. The first three programs — AXIS, SHELBY, and COONS — are coded in Fortran IV for operation on the IBM-7094 or the IBM-360 computer; while the last two programs — BANDAID and MOVE — are coded in PL-1 for operation on the IBM-360 computer. Each program may be briefly described as follows:

AXIS generates data for shells described by the rotation of a plane curve about an axis.

SHELBY generates data for shells described by the translation of a plane curve along an arbitrary axis in space. The scale factor may vary along the length of the axis.

COONS generates data for free-form shell structures based on the description of four bounding curves.

BANDAID automatically resequences the grid points of a structural problem to achieve a reduced bandwidth in the stiffness matrix, given the NASTRAN data deck for the problem.

MOVE generates data for structures having a number of identical segments, given the NASTRAN bulk data for one of the segments.

Language: FORTRAN IV (61%), PL-1 (39%)
Machine Requirements: IBM-360, IBM-7094
                    Source: Goddard Space Flight Center
                                             (GSC-11039)

Circle 23 on Reader Service Card.

GENERAL INSTABILITY OF RING-STIFFENED CORRUGATED CYLINDERS

This is a program used to determine the general instability load of a ring-stiffened corrugated cylinder under axial compression. The method used is developed using linear small deflection theory. The stiffness properties of the rings are uniformly distributed along the cylinder and the eccentricity of the rings with respect to corrugation centerline is taken into account.

Analytical and experimental results are compared In this comparison, good agreement is obtained for cylinders loaded in pure compression. For the cylinders subjected to bending or a combination of bending and compression, the analytical calculations are conservative.

Language: FORTRAN II
Machine Requirements: IBM-7094
Source: J. N. Dickson and R. H. Brolliar of
Brown Engineering Co.
under contract to
Marshall Space Flight Center
(MFS-20650)

Circle 24 on Reader Service Card.

STRUCTURAL SYNTHESIS OF A STIFFENED CYLINDER

This program designs minimum weight ring-and-stringer-stiffened cylinders which are subjected to axial and lateral pressure loadings. The basic approach is to regard weight as a merit function in the design variable space and then to determine the minimum weight by mathematical programming techniques. The program adjusts seven design variables: the thickness of the skin, and the thickness, depth, and spacing of solid, rectangular, integral rings and stringers; adjustments continue until the design of minimum weight is obtained.

Cylinders are designed to prevent general and local buckling, and to prevent the skin and stiffener from yielding under prescribed loading conditions. The linear membrane prebuckling state is the stress state examined for buckling and yielding. The program considers stiffener eccentricity, provides for minimum gage limitations, and designs for multiple load conditions. The buckling and yielding failure conditions constitute constraints in the design variable space for the optimization problem. A penalty function method is used to convert the constrained optimization problem to a sequence of unconstrained problems which are solved by a gradient method.

Language: CDC FORTRAN
Machine Requirements: Control Data 6000 Series
Source: W. J. Stroud
Langley Research Center and
W. M. Morrow II and L. A. Schmit, Jr., of
Case Western Reserve University
under contract to
Langley Research Center
(LAR-10473)

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BUCKLING OF SHELLS OF REVOLUTION (BOSOR)
WITH VARIOUS WALL CONSTRUCTIONS

It was necessary to perform stability analysis for a wide class of shells without unduly restrictive approximations.

A computer program has been developed, which uses numerical integration and finite difference techniques to solve, with reasonable accuracy, almost any buckling problem for shells exhibiting "orthotropic behavior". For this type of shell in the prebuckling state, axisymmetrical loads produce axisymmetrical displacements.

For the geometry of the meridian, the general branch of the program calls for input in the form of cartesian coordinates for a number of points along the meridian. Special branches are provided for cylindrical, conical, spherical, and toroidal shells.

The general branch for the shell wall stiffness data calls for input in the form of coefficients of the constitutive equations. Special branches calling for simpler input data are provided for: shells with ring and stringer stiffening; shells with skew stiffeners; fiber

reinforced shells; layered shells; corrugated ring stiffened shells; and shells with one corrugated and one smooth skin. The stiffness coefficients must be constant along the meridian.

The most general form of the boundary conditions for the prebuckling analysis is a set of four nonhomogeneous equations containing twenty coefficients. For the stability analysis, the homogeneous boundary conditions consist of eight equations and sixty-four coefficients which are called for as input by the general branch. The boundary conditions can be calculated internally (with only control integers required as input) by several provided branches which include force or displacement boundary conditions, support by elastic edge rings or support by an elastic medium. The shell can be opened or closed at the apex.

In the first part of the analysis, the Newton-Raphson procedure is used to solve the set of nonlinear algebraic equations. These equations result from a finite-difference analog of the nonlinear, nonhomogeneous, second-order ordinary differential equations governing the prebuckling state of the shell. The solution of the equations yields the prebuckling meridional rotation and meridional and circumferential stress resultants.

The second part of the analysis solves the stability equations (Donnell type formulation) which are linear, homogeneous, fourth-order, partial differential equations. Since the dependent variables are harmonic, dependence on the circumferential coordinate can be eliminated and the resulting ordinary differential equations solved by the method of finite differences. The stability analysis is formulated as an eigenvalue problem with the lowest eigenvalue of the stability equations corresponding to the critical load.

Language: FORTRAN IV
Machine Requirements: UNIVAC-1108

Source: D. Bushnell, B. O. Almroth, and L. H. Sobel of Lockheed Missiles and Space Company under contract to Langley Research Center (LAR-10441)

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TORSION ANALYSIS OF OPEN SECTIONS

An open section is a section in which the centerline of the wall does not form a closed curve. Channels, angles, I-beams, and wide-flange sections are among many common structural shapes characterized by combinations of thin-walled rectangular elements; a variety of thin-walled curved sections is used in aircraft and missile structures. The basic characteristic of these sections is that the thickness of the component element is small in comparison with the other dimensions.

This program performs the torsional analysis of thin-walled open sections for both unrestrained and restrained torsion sections. Torsional shear stress, angle of twist, and warping deformations are determined for unrestrained torsion. Torsional shear stress, warping shear stress, warping normal stress, angle of twist, and the first, second, and third derivatives of angle of twist are determined for restrained torsion.

Language: FORTRAN IV
Machine Requirements: IBM-7094

Source: Brown Engineering Co. under contract to Marshall Space Flight Center (MFS-20648)

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GAS LINE ORIFICE SIZE DETERMINATION

This program directly solves the problem of determining the size of an orifice required to achieve a desired pressure drop in a gas line with a uniform flow.

An orifice pressure drop solution using data from "Fluid Meters", a report of the ASME Research Committee on fluid meters, is adapted to the digital computer and used in this analysis. The solution requires an iterative procedure that was programmed with a straight-line zero error curve fit. The calculated orifice is checked to determine if critical or choke flow is achieved. For this calculation, the working fluid is assumed to be a perfect gas.

Input consists of flow rate, an initial estimate of ratio of the diameter of the orifice to the ID of the pipe, the pressure in the pipe, temperature, specific gas constant and a table of d_0/d_1 versus loss coefficient. Output consists of orifice size (diameter and area), loss coefficient, flow, and choked flow.

Language: FORTRAN IV
Machine Requirements: IBM-1130
Source: Aerojet-General Corp.
under contract to
Space Nuclear Systems Office
(NUC-10310)

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Notes:

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

— NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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