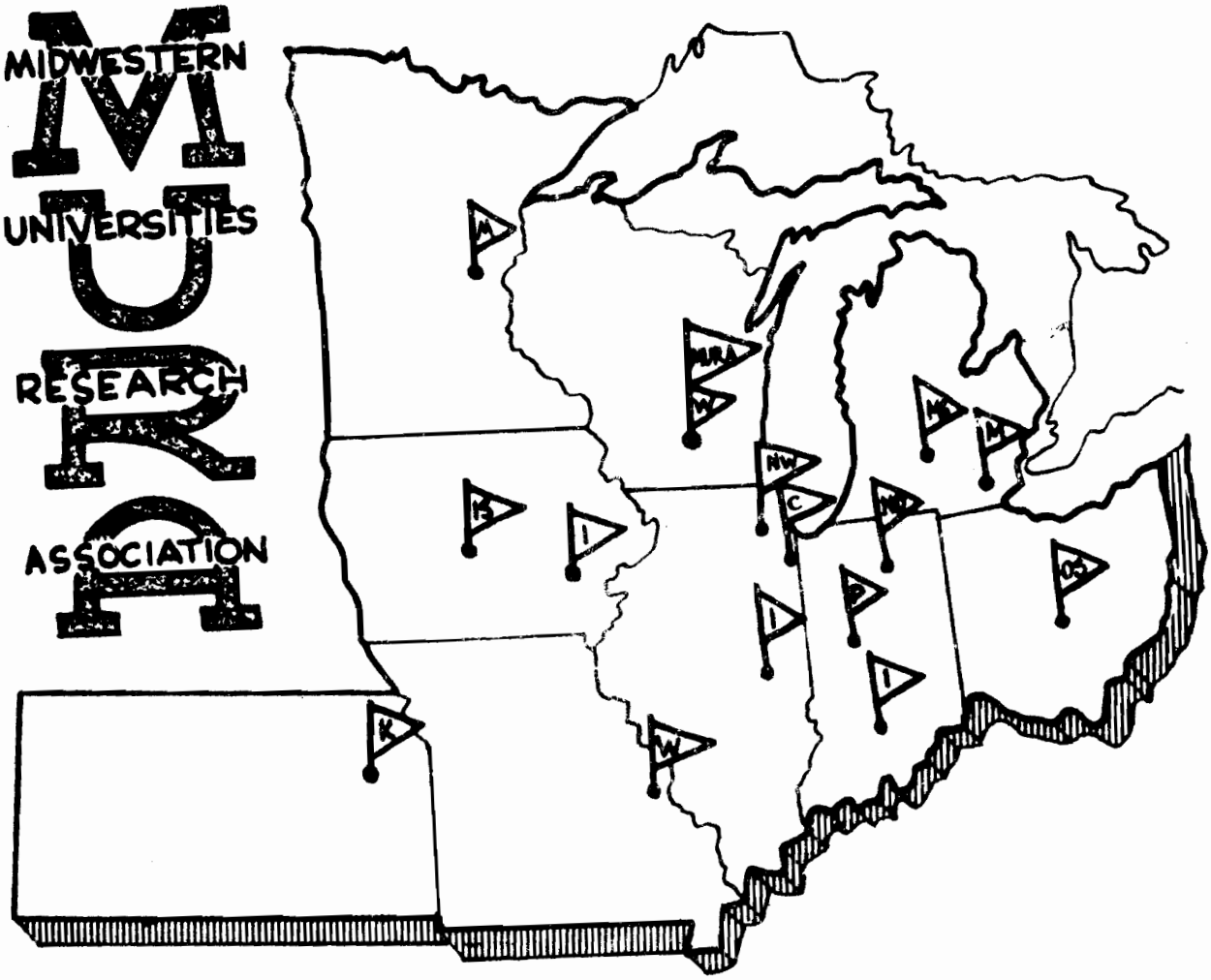
642

Fermilab Library
0 1160 0038902 7

MIDWESTERN UNIVERSITIES RESEARCH ASSOCIATION



NUMBER 642
Internal
(IBM Program)

REPORT MESSYMESH
(Program F-46)
May 28, 1962
Revised Dec. 31, 1962

MESSYMESH
(Program F-46)

TABLE OF CONTENTS

INTRODUCTION ---------- 1

MESSYMESH SYSTEM ---------- 2

EQUATIONS ---------- 3

PROGRAMS ---------- 7

- General Remarks ---------- 7
- Agenda Formats ---------- 7
- Program A- MAIN CALCULATING PROGRAM ---------- 10
  - Data Specifications ---------- 10
  - Remarks ---------- 12
  - Subroutines and Their Functions ---------- 14
  - Allocation of Core Storage; Core Map ---------- 16
- Program B-PLOTTING PROGRAM ---------- 22
  - Data Specifications ---------- 22
  - Remarks ---------- 22
  - Subroutines and Their Functions ---------- 23
  - Allocation of Core Storage; Core Map ---------- 23
  - Typical Plot ---------- 26
- Program C-MESH TAPE PREPARATION PROGRAM ---------- 27
  - Data Specifications ---------- 27
  - Remarks ---------- 27
  - Allocation of Core Storage ---------- 27
- Program D-MESH TAPE INDEX PROGRAM ---------- 28
  - Remarks ---------- 28
  - Allocation of Core Storage ---------- 28
- Program E-MESH TAPE LISTING PROGRAM ---------- 29
  - Data Specifications ---------- 29
  - Remarks ---------- 29
  - Allocation of Core Storage ---------- 29
- Program F-MESH TRANSFER PROGRAM ---------- 30
  - Data Specifications ---------- 30
  - Remarks ---------- 30
  - Allocation of Core Storage ---------- 31

TAPES ---------- 32

SENSE SWITCHES ---------- 33

OPERATING PROCEDURES ---------- 34

MESSYMESH
(Program F46)

TERRY W. EDWARDS

INTRODUCTION

MESSYMESH is a series of programs written for an IBM 704 computer system, consisting of a 32,768 word memory capacity, at least 4 IBM 727 tape units, and an associated IBM 1401 computer, necessary for output purposes. Although the system is primarily written in FORTRAN language, liberal use of SAP machine language instructions has been made, both within Fortran compiled programs and subprograms, and also as separate Sap subprograms assembled so as to be compatable with the Fortran routines.

MESSYMESH programs compute, print out, and plot eigenfunctions, eigenvalues, and several associated quantities for linear accelerator cavities, loaded with square or round corner drift tubes, with or without axial holes.

MESSYMESH SYSTEM

The MESSYMESH system consists of the following six programs which are stored successively on the MESSYMESH F-46 PROGRAM TAPE.

A. Mesh Calculating Program.
B. Plotting Program.
C. Mesh Tape Preparation Program.
D. Mesh Tape Index Program.
E. Mesh Tape Listing Program.
F. Mesh Transfer Program.

Program A is the fundamental program. Programs B through F are supplementary and are written in support of program A.

The results of program A are stored on magnetic tapes which, via program A or C, have been prepared with a unique first record. Programs B and D through F process these magnetic tapes in various ways as indicated below in this report.

EQUATIONS

A detailed analysis of the linear accelerator problem, with emphasis on the variational principle associated with the solution has previously been given.[1] Hence only pertinent final formulae employed by MESSYMESH Program A are reproduced here.

Maxwell's electromagnetic field equations yield, for azimuthally independent modes, a scalar wave equation for the azimuthal component of the magnetic field:

$$\frac{\partial^2 F}{\partial r^2} - \frac{1}{r}\frac{\partial F}{\partial r} + \frac{\partial^2 F}{\partial z^2} + k^2 F = 0, \qquad \frac{\partial F}{\partial n} = 0 \text{ on } C,$$

where $F = rH_\varphi$ and where the boundary condition is to be applied on all metallic and nodal surfaces as shown in Fig. 1 and where in addition $F(0, Z) = 0$.

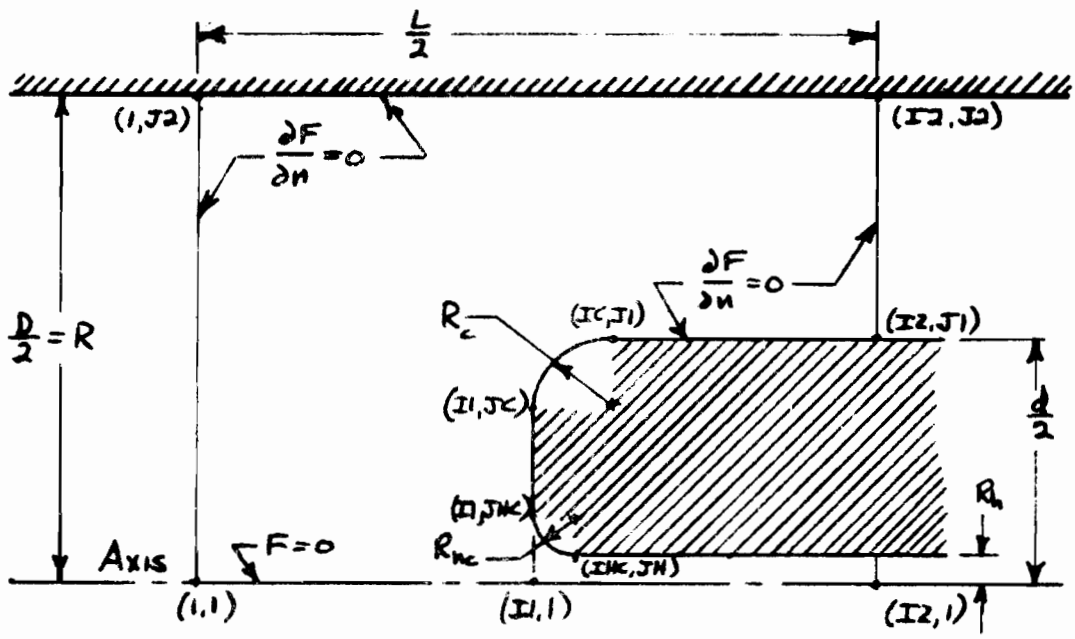


Fig. 1. One fourth of a meridian plane crosssection of a linear accelerator cavity.

The above differential equation is solved for the geometry shown in Fig. 1 by establishing a mesh or grid in the region penetrated by the

[1] Edwards, Terry W., "Proton Linear Accelerator Cavity Calculations," MURA Report 622, 1961.

field, in a way such that a mesh line coincides everywhere with the metallic and nodal boundaries. Obviously, this would be very difficult to accomplish in the most general case; therefore, the geometries for which MESSYMESH will provide answers are limited to cylindrical walled cavities with azimuthally symmetric drift tubes with or without holes and with circularly bounded or square outer corners and hole corners. In order to achieve solutions for these restricted geometries overlapping rectangular and circular polar meshes are established, such that the boundary everywhere does coincide with a mesh line.

Finite difference approximations to the differential equation may be found for the square mesh and polar meshes. The Liebmann four point algorisms for the two mesh types are, respectively:

$$F_{ij}^{n+1} - F_{ij}^{n} = \alpha\left\{F_{ij}^{n}\left(\frac{k^2h^2}{4}-1\right) + \frac{1}{4}\left[F_{i,j+1}^{n}\left(1-\frac{h}{2r}\right) + F_{i,j-1}^{n+1}\left(1+\frac{h}{2r}\right) + F_{i+1,j}^{n} + F_{i-1,j}^{n+1}\right]\right\},$$

$$\begin{aligned} F_{\ell m}^{n+1} - F_{\ell m}^{n} = \alpha\Bigg\{ & F_{\ell m}^{n}\left[\frac{k^2}{\left(\frac{2}{h_\rho^2}+\frac{2}{h_\theta^2}\right)}-1\right] + \frac{1}{\left(\frac{2}{h_\rho^2}+\frac{2}{h_\theta^2}\right)}\Bigg[F_{\ell+1,m}^{n}\left\{\frac{1}{h_\rho^2}+\frac{1}{2h_\rho}\left[\frac{r_c}{\rho(r_c+\rho\sin\theta)}\right]\right\} + \\ & + F_{\ell-1,m}^{n+1}\left\{\frac{1}{h_\rho^2}-\frac{1}{2h_\rho}\left[\frac{r_c}{\rho(r_c+\rho\sin\theta)}\right]\right\} + F_{\ell,m+1}^{n}\left\{\frac{1}{h_\theta^2}-\frac{1}{2h_\theta}\left[\frac{\cos\theta}{(r_c+\rho\sin\theta)}\right]\right\} + \\ & + F_{\ell,m-1}^{n+1}\left\{\frac{1}{h_\theta^2}+\frac{1}{2h_\theta}\left[\frac{\cos\theta}{(r_c+\rho\sin\theta)}\right]\right\}\Bigg]\Bigg\}. \end{aligned}$$

Repetitive calculation of improved field values at the mesh points leads to an iterative convergence, provided α, the over-relaxation factor is properly (and perhaps optimally) chosen.

Simultaneous to the improvement of each of the mesh point field values from an initially guessed set of values to the correct eigenfunction, a calculation of the eigenvalue must take place. A variational principle indicates that a lower limit exists for the calculation:

$$K^2 = -\frac{\langle F, \mathcal{L}F\rangle}{\langle F, F\rangle} = -\frac{\iint_s \frac{F}{r}\left[\frac{\partial^2 F}{\partial r^2} - \frac{1}{r}\frac{\partial F}{\partial r} + \frac{\partial^2 F}{\partial z^2}\right] dr\,dz}{\iint_s \frac{F^2}{r}\,dr\,dz}.$$

The lower limit of this calculation occurs when F is the eigenfunction of the differential equation. In this event K is just the corresponding eigenvalue k. (In the presence of non-rectangular boundaries, the variational principle is apparently only approximately true.)

Calculation of improved eigenvalues can be reduced to finite difference approximations similar to the algorisms given above. For the square and polar meshes the expressions becomes, respectively:

$$\frac{K^2h^2}{4} = \frac{\sum_i \sum_j \frac{F_{ij}^n}{r} \left\{ \frac{1}{4}\left[F_{i,j+1}^n\left(1-\frac{h}{2r_j}\right) + F_{i,j-1}^n\left(1+\frac{h}{2r_j}\right) + F_{i+1,j}^n + F_{i-1,j}^n \right] - F_{ij}^n \right\} \Delta S_{ij}}{\sum_i \sum_j \frac{F_{ij}^2}{r_j} \Delta S_{ij}} ,$$

$$\frac{K^2h^2}{4} = \frac{\sum_\ell \sum_m \left\{ \left[\frac{F_{\ell,m}^n}{\left(\frac{r_\ell}{h} + \frac{\rho \sin\theta}{h}\right)} \right] \cdot \frac{1}{4} \left[\frac{h^2}{h_\rho^2}\left(F_{\ell+1,m}^n + F_{\ell-1,m}^n\right) + \frac{h^2}{h_\theta^2}\left(F_{\ell,m+1}^n + F_{\ell,m-1}^n\right) + \right.\right.}{\left. \left. + \left(\frac{h}{h_\rho}\right) \frac{\left(F_{\ell+1,m}^n - F_{\ell-1,m}^n\right)}{2\left(\frac{\ell}{\ell}\right)\left(\frac{r_\ell}{h} + \frac{\rho \sin\theta}{h}\right)} + \left(\frac{h}{h_\theta}\right) \frac{\cos\theta\left(F_{\ell,m+1}^n - F_{\ell,m-1}^n\right)}{2\left(\frac{r_\ell}{h} + \frac{\rho \sin\theta}{h}\right)} - 2\left(\frac{h^2}{h_\rho^2} + \frac{h^2}{h_\theta^2}\right) F_{\ell,m}^n \right] \right\} \Delta S_{\ell,m}}{\sum_\ell \sum_m \frac{\left(F_{\ell,m}^n\right)^2}{\left(\frac{r_\ell}{h} + \frac{\rho \sin\theta}{h}\right)} \Delta S_{\ell,m}} .$$

Alternate improvement of the field values and calculation of an improved eigenvalue is thus the method of solution. Because of the existance of the variational principle, a convergent process is virtually assured.

Employment of overlapping meshes necessitates interpolation of field values, etc. between meshes. Consistancy with the differential equation and the accuracy of the above algorisms, etc. requires that a field value on one mesh be given in terms of five field values on the other overlapping mesh such that, for example:

$$F_{ij} = \frac{\lambda_1 F_{00} + \lambda_2 F_{01} + \lambda_3 F_{10} + \lambda_4 F_{11} + \lambda_5 F_{AB}}{\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 - K^2} ,$$

where the λ's are determined via a 5th order matrix solution previously specified.[2]

Formulae for the auxiliary quantities calculated by MESSYMESH Program A include the following.

Energy Stored Per Unit Volume: $$\frac{W}{V} = \frac{\mu}{2} \frac{\iint_s \frac{F^2}{r} dS}{\iint_s r\, dS} .$$

Power Lost to Cavity Walls: $$P_W = \pi R_s \oint \frac{F^2}{r} dl .$$

---

[2] Ibid., pp. 29-32.

Q Factor: $$Q = \frac{\omega\mu}{R_s} \frac{\iint_S \frac{E_r^2}{r} dS}{\oint \frac{E_r^2}{r} dl} .$$

Average Axial Accelerating Field: $$\mathcal{E}_0 = \frac{1}{\omega\epsilon L} \int_{-L/2}^{L/2} \left(\frac{1}{r}\frac{\partial F}{\partial r}\right)_{0,z} dz .$$

Shunt Impedance: $$Z_s = \mathcal{E}_0^2 / (P_w/L) .$$

Transit Time Factor: $$T = \frac{1}{\omega\epsilon L \mathcal{E}_0} \int_{-L/2}^{L/2} \left(\frac{1}{r}\frac{\partial F}{\partial r}\right)_{0,z} \cos\frac{2\pi z}{L} dz .$$

Coupling Coefficient: $$S = \frac{1}{\omega\epsilon L^2 \mathcal{E}_0} \int_{-L/2}^{L/2} \left(\frac{1}{r}\frac{\partial F}{\partial r}\right)_{0,z} z \sin\frac{2\pi z}{L} dz .$$

These quantities are calculated from the final converged fields and, together with the eigenvalue, serve as indicators of the merits of the geometry for which they have been calculated.

PROGRAMS

General Remarks

The programs on the MESSYMESH F-46 PROGRAM TAPE are similar in several respects: each is prefaced by a MULUCY* loader; each accepts card input data via MURA library subroutine MURCD2; each uses (logical) tape 7 (and/or possibly tape 8) as a mesh input/output tape; each expects a unique four-word first record on the mesh input/output tape(s); each checks for this first record before reading or writing mesh input/output tape(s); and each contains diagnostic statements to instruct the computer operator when incompatable situations are encountered.

Agenda Formats

Agenda for the various MESSYMESH programs must be specified in formats compatable with card reading subroutine MURCD2.** For this purpose, either standard MURA/FORTRAN or MURA/MESSYMESH agendum sheets are satisfactory. A sample of the latter is included.

Detailed exposition of the required input data for the various MESSYMESH programs are given below.

---

*MULUCY is a slight MURA revision of NULUCY; tape 6 map is written on tape 9, and the ensuing end of file removed.

**MURA report 536, Westlund, G.A.

MURA/MESSYMESH AGENDUM

PROGRAM NO. F46 SUBMITTER _____

Instructions:

1. Circle tapes to be mounted, specify program used, and circle sense switch settings.

2. Enter addresses and values of desired input parameters in table. (The format must be compatable with MURA subroutine MURCD2).

Tapes: Program _____

0. Dump/save (erasable tape).

1. MESSYMESH PROGRAM TAPE.

3.

7. Circle Sense

8. Switches Down

9. Output tape. 1 2 3 4 5 6

Special Operator Instructions: _____

Address	Value	Address	Value	Address	Value

MURA/MESSYMESH AGENDUM (CONT.)

Address	Value	Address	Value	Address	Value

Program A - MAIN CALCULATING PROGRAM

This program is designed to calculate eigenfunctions, eigenvalues, and auxiliary quantities for linear accelerator cavities of the type depicted in Fig. 1.

Data Specifications

Address	Data	Example
1	Identification number to be assigned to mesh being calculated.	28519
2	Mesh number of initial load source: >0: loads from tape 7 or 8. $=0$: loads from Bessel Function. <0: loads previous run from core.	28428
3	Profile identification number: $=1$: square corner drift-tube. $=2$: round (circular) corner drift-tube.	2
4	Scaled size of g/2. Must be ≥ 2.	11
5	Scaled size of L/2. Must be $\geq g/2$.*	37
6	Scaled size of d/2. Must be ≥ 2.**	14
7	Scaled size of D/2. Must be $\geq d/2 + 2$.*	31
8	Scaled size of R_h.	2
9	Scaled size of R_{hc}.	2
10	Scaled size of R_c.	5
12	Initial value of alpha, the over-relaxation parameter. If not specified, program assumes minimum of tape loaded value and 1.7.	1.75
13	Normalization value of stored energy. If not specified, program assumes $W_o = 9.791 \times 10^{-7}/R^2$ joules/cubic meter.	9.5-7

*Addresses 5 and 7 must not exceed 99.

**For an unloaded cavity address 6 must be zero.

Address	Data	Example
14	First convergence criterion (i.e. the change in eigenvalue per iteration.) If not specified, program assumes PC = 10^{-3}.	5.0-4
15	Second convergence criterion (i.e. the average residual per mesh point.) If not specified, program assumes SCC = 10^{-10}.	1.0-11
20	De-bug printing from subroutine START.	20
21	De-bug printing from subroutine EXPAND.	21
22	De-bug printing from subroutine ITERAT.	22
23	De-bug printing from subroutine ALG.	23
24	De-bug printing from subroutine ALGC.	24
29	New value of alpha entered during calculation time.	1.0
30	New second covergence criterion entered during calculation time.	1.0-12

Only data address 1 must be changed each time in a succession of calculations. Addresses 2 through 15 will remain unchanged if not specified differently. Addresses 20 through 24 are set to zero between runs so as to reduce the amount of off-line output. Addresses 29 and 30 are ineffective at the beginning of a run; they are intended to allow mid-run changes via manual control of sense switches 3 and 5.

Input data for successive calculations must be separated by one END DATA card; the last calculation of such a succession is best followed by at least two END DATA cards.

Data addresses 1 through 10 must be integers. Data addresses 4 through 10 specify the geometry of the linear accelerator cavity in non-dimensional terms; thus they are simply a set of integers proportional to the various dimensional quantities as illustrated in Fig. 1.

Remarks

1. Each mesh must be assigned a unique number. The program will not write two meshes with the same number on an input/output mesh tape.

2. Meshes may be loaded from or stored on mesh input/output tapes set to (logical) numbers 7 or 8. Tape 7 is always required. The use of tape 8 is optional; if so used, however, tape 7 will be interrogated first both before loading and storing meshes via tape 8; if tape 7 is the correct one, tape 8 will not be used.

3. Mesh input/output tapes may not be interchanged during the time calculations are underway since the program remembers not only which tape(s) have been employed, but also the identification numbers of all the meshes located prior to the position of the reading head on the tape(s).

4. A maximum number of 150 meshes may be stored on one magnetic tape. However, the time required to locate those meshes rather far down the tape can become considerable. A recommended number of meshes to be stored on one tape is 100 or less.

5. If an identification number is specified for a mesh which cannot be stored on either tape 7 or tape 8, the program will instruct the operator as required to store the mesh on (logical) tape 3. Preparation of this tape 3 in a manner identical with that of Program C is possible; attention to this fact can, of course, circumvent use of program C. Once this tape is prepared in this manner, numerous meshes may be loaded on to this tape in the series of mesh calculations underway.

6. The program analyzes the input data to see if it is geometrically sensible. If it is not, the run is aborted and the next one is attempted.

7. If a run is aborted because of unsensible geometrical input data or via the all sense switch down feature the next run will not be possible if a core load is required. In this event, the succeeding run will be attempted, etc.

8. The meshes stored on mesh input/output tapes must be preceeded by a unique four word record, written by Program C and explained below. This record determines which (identification numbered) meshes may be stored on the particular tape.

9. The format of each mesh stored on a mesh input/output tape is as follows:

   Record 1: 28 words containing geometrical data and output auxiliary quantities.

   Records 2 through I2 + 1: Square mesh final field values. Each record contains J2 + 1 words. The mesh field values are stored column-wise beginning at the lower left corner (see Fig. 1).

   Next 3 records: Curvilinear drift-tube corner mesh final field values <u>if such exists</u>. Existence is indicated in Record 1.

   Next 3 records: Curvilinear hole-corner mesh final field values <u>if such exists</u>. Existence is indicated in Record 1.

10. An End-of-File gap is always searched for, erased and, after writing a mesh on an input/output tape, restored. This End-of-File signifies the end of useful information on an input/output tape.

11. Primary output of data, both a summary of the calculations themselves, and final field values and auxiliary quantities, is off-line via BCD output tape 9. However, via sense-switch control, limited on-line printing is possible.

12. Although efficient input/output tape usage demands that the square mesh field be stored column-wise, ease of visual inspection requires that they be printed out in row-wise form.

13. Use of data addresses 20 through 24 insures voluminous off-line output, especially addresses 23 and 24. Hence extreme discretion should be employed. It is doubtful that an entire mesh calculation, when in this mode of operation, is practical; time and output tape requirements are prohibitive.

14. As indicated by data addresses 14 and 15, the calculation operates in a two convergence criterion manner. Before the first convergence criterion (approximate convergence of the eigenvalue) is satisfied, both the field and eigenvalue are improved during each iteration. After the first criterion is satisfied, the eigenvalue is improved only every fifth iteration. Upon satisfaction of the second convergence criterion (decrease of field-point RMS residuals to specified value) termination of the run takes place, the auxiliary quantities are calculated, these and the final fields are stored on an input/output tape and are printed off-line, and control is transferred so as to begin the next of a series of runs.

15. Sense lights are indicators of where the program is in its calculations:

    SL1: Persistently on indicates first convergence criterion has been satisfied.

    SL2: Persistently on indicates that the field values are being improved.

    SL3: Persistently on indicates that the eigenvalue is being improved.

    SL4: Persistently on indicates normal run termination is about to begin.

16. The rate of convergence is determined by the quantity alpha (see data addresses 12 and 29), the over-relaxation parameter. Periodic calculation of the optimum/maximum value takes place as the iterative process proceeds. This parameter is quite critical; if it is too large, divergence may occur (the program corrects for this); if it is too small, convergence will be rather slow. Judicious care should be used in manipulating this parameter by the operator; it is not recommended.

Subroutines and Their Functions

The hand coded program and subroutines can be divided into several catogories on the basis of their purpose. Below is a brief indication of their purpose(s).

MAIN CONTROL PROGRAM: Excercises control over loading, initiating, printing, iterating, interpolating, aborting and saving, normalizing, and outputing processes.

Loading Subroutines

INPUT: Reads data cards via MURCD2, searches input tape(s) for required loading mesh.

EXPAND: Modifies mesh dimensions from those of mesh loaded from tape to those of run to be calculated. Interpolates field values accordingly.

Initiating Subroutines

START: Converts input data to useable form, controls establishment of interpolation coefficients, etc.

SETSPC: Calculates backward interpolation coefficients.

SETCOF: Calculates forward interpolation coefficients.

PACK: Packs interpolation coefficients calculated by SETSPC and SETCOF.

Printing Subroutines

ERRPRT: Prints out input data error diagnoses.

PRTHED: Prints out page heading at beginning of each run.

PRTFLD: Prints out fields when requested via SSW 2 and at end of program.

COLHED: Prints out column heading for PRTLIN.

PRTLIN: Prints out a one line summary of each iteration.

Iterating Subroutines

ITERAT: Controls indexing, etc. of iteration processes, for traversal of both square and curvilinear meshes.

ALG: Square mesh algorisms.

SPECFL: Calculates special points contribution to eigenvalue calculation.

ALGC: Curvilinear mesh algorisms.

RFCNST: Calculates R-1/4R for ALG.

FASET: Saves two just previous rows of old field values for calculation of eigenvalue.

ALFCAL: Calculates the optimum value of alpha the over-relaxation factor.

Interpolating Subroutines

INTERP: Interpolates field values from square mesh to outer row and ends of curvilinear meshes.

BACKIN: Interpolates field values and contributions to numerator and denominator of eigenvalue calculations, from curvilinear meshes to square mesh points with incomplete stars.

UNPACK: Unpacks backward interpolation coefficients previously stored by SETSPC and SETCOF.

Aborting & Saving Subroutines

SAVER: Saves memory etc. on an erasable tape 0, via subroutine SAVEX, if SSW 1 is down.

ABORT: Aborts run and proceedes to next one if all SSW's down.

PROTEC: Protects all other sense switch tests against all SSW's down condition.

Normalizing Subroutine

VCALC: Calculates normalizing volume so that the field energy per unit volume can be initially and finally adjusted to the value prescribed by data address 13.

Output Subroutines

QCALC: Calculates and prints the auxiliary quantities at the end of a run or when demanded via sense switch 2.

EZCALC: Performs various axial electric field integrations requested by QCALC.

TAPEWR: Stores geometry, auxiliary field quantities, and fields on input/output tape.

Allocation of Core Storage: Core Map

MULUCY loader: Octal locations 00000-00027.
Program Storage: Octal locations 00030-42473.
Common storage: Octal locations 46021-77462.
Library subroutine storage: Octal locations 77463-77777.

Thus the program requires 17,700 memory locations, while the common storage requires 13,090 memory locations. The remaining 1749 memory locations (octal locations 00000-00027 and 77463-77777 are not available) may be used in revisions and/or extensions of the program.

A core map, produced by MULUCY, showing the division of unique storage among the various subprograms follows.

NAME	VECTOR	ENTRY	START	END	COMMON
000000		00054	00030	02305	46020
	TAPEWR				
	QCALC				
	MURCD2				
	(STH)				
	ALFCAL				
	SAVER				
	(FIL)				
	(SPH)				
	(IOH)O				
	(LEV)				
	PRTLIN				
	COLHED				
	SQRT				
	VCALC				
	ABORT				
	PRTFLD				
	PROTEC				
	LOG				
	ITERAT				
	START				
START		02324	02306	04666	46020
	INTERP				
	SETCOF				
	EXPAND				
	ERRPRT				
	(FIL)				
	(STH)				
	(IOH)O				
	(LEV)				
	SETSPC				
	SQRT				
	INPUT				
INPUT		04701	04667	07407	46020
	(RTN)				
	(FIL)				
	(SPH)				
	(IOH)O				
	(LEV)				
	PRTHED				
	MURCD2				
SAVER		07422	07410	10171	46020
	SAVE				
	DUMP				
	(SPH)				
	(FIL)				
	(STH)				
	(IOH)O				
	(LEV)				

PROTEC	10175	10172	10237	46020
ABORT	10250	10240	10436	46020
(SPH)				
(FIL)				
(STH)				
(IOH)O				
(LEV)				
PRTHED	10447	10437	11423	46020
(STH)				
(FIL)				
(SPH)				
(IOH)O				
(LEV)				
ERRPRT	11434	11424	12267	46020
(STH)				
(FIL)				
(SPH)				
(IOH)O				
(LEV)				
PRTFLD	12277	12270	12776	46020
(FIL)				
(STH)				
(IOH)O				
(LEV)				
COLHED	13007	12777	13127	46020
(SPH)				
(FIL)				
(STH)				
(IOH)O				
(LEV)				
PRTLIN	13141	13130	13333	46020
(SPH)				
(FIL)				
(STH)				
(IOH)O				
(LEV)				
SQRT				
SETCOF	13350	13334	15054	46020
(STH)				
(FIL)				
(SPH)				
(IOH)O				
(LEV)				
XSIMEQ				
PACK				
SIN4				
COS4				

SETSPC	15073	15055	16435	46020
(STH)				
(FIL)				
(SPH)				
(IOH)O				
(LEV)				
XSIMEQ				
COS4				
SIN4				
PACK				
ATAN				
SQRT				
PACK	16436	16436	16467	77462
EXPAND	16500	16470	21271	46020
SQRT				
(FIL)				
(STH)				
(IOH)O				
(LEV)				
INTERP	21276	21272	22044	46020
UNPACK				
BACKIN	22051	22045	22473	46020
UNPACK				
UNPACK	22474	22474	22524	77462
ITERAT	22543	22525	24714	46020
BACKIN				
ALGC				
INTERP				
SPECFL				
FASET				
ALG				
RFCNST				
(FIL)				
(STH)				
(IOH)O				
(LEV)				
ALG	2472[illegible]	24715	25462	46020
(FIL)				
(STH)				
(IOH)O				
(LEV)				
SPECFL	25476	25463	26534	46020
(FIL)				
(STH)				
(IOH)O				
(LEV)				

RFCNST				
COS4				
SIN4				
UNPACK				
ALGC	26546	26535	27304	46020
(FIL)				
(STH)				
(IOH)O				
(LEV)				
COS4				
SIN4				
RFCNST	27310	27305	27363	46020
FASET	27367	27364	27437	46020
VCALC	27444	27440	30160	46020
UNPACK				
ALFCAL	30165	30161	30250	46020
SQRT				
QCALC	30265	30251	32764	46020
(STH)				
(FIL)				
(SPH)				
(IOH)O				
(LEV)				
EZCALC				
SIN4				
COS4				
SQRT				
EZCALC	32772	32765	33262	46020
SIN4				
COS4				
TAPEWR	33274	33263	36352	46020
(STH)				
(RTN)				
(FIL)				
(SPH)				
(IOH)O				
(LEV)				
MURCD2	36353	36353	36671	77723
DUMP	36672	36672	37140	77462
SAVE	36703			
ATAN	37141	37141	37264	77775
LOG	37265	37265	37333	77775

SIN4	37335	37334	37441	00000
COS4	37334			
SQRT	37442	37442	37466	77776
XDETRM	40112	37467	40340	77771
XSIMFQ	40113			
(FIL)	42013	40341	42152	77541
(BDC)	40346			
(DBC)	40344			
(IOH)O	40343			
(IOH)I	40342			
(RTN)				
(RTN)	42214	42153	42272	00000
(LEV)	42153			
(SPH)	42273	42273	42457	77653
(STH)	42460	42460	42473	00000

Program B - PLOTTING PROGRAM

This program is designed to calculate and plot, on a CALCOMP model #560 30 inch plotter, the meridian plane intercepts of the (linear accelerator cavity) constant valued eigenfunction surfaces.

Data Specifications.

Address	Data	Example
1	Identification number of first mesh to be plotted.	28381
2	Identification number of last mesh to be plotted. If not specified, program will plot only one mesh.	28386
3	Number of constant valued surfaces to be plotted. If not specified, program will plot 12 such surfaces.	15
4	Type of eigenfunction plotted: ≤ 1 or not specified: F field. ≥ 2: H field.	2

Data addresses 1, 3, and 4 may be altered by the agenda, if more than one series of plots is contemplated. Data address 2 is automatically cleared between series of plots so that it is only necessarily specified. if a series of plots consists of more than one plot.

Input data for successive series of plots must be separated by one END DATA card; the data for the last series of plots is best followed by three END DATA cards.

Remarks

1. Meshes may be loaded from mesh input/output tapes mounted as (logical) tapes 7 and/or 8. Tape 7 is always required. The use of tape 8 is optional; if so used, however, tape 7 will be interrogated first in order to find the appropriate mesh to be loaded.

2. Mesh input/output tapes may not be interchanged during the time calculations are underway since the program remembers which tapes have been employed, and the identification numbers of all meshes located prior to the position of the reading head on the tape(s).

3. Sense Light 1 persistently on indicates that the H_ϕ eigenfunction is being processed.

4. Primary output of data, sorted field values, and plotter data is via BCD output tape 9. Manual control of Sense Switch 3, however, allows the sorted field values to be printed online.

Subroutines and Their Functions

The hand coded program and subroutines are listed below with a brief indication of their purpose(s).

PLOT CONTROL PROGRAM: Reads data cards via subroutine MURDC2, searches for and loads the required loading mesh, and initiates plotting.

BNPLOT: Plots the geometrical boundary and a brief heading for the mesh being plotted.

SEARCH: Searches for and interpolates to find the coordinates of the intersection of the constant eigenfunction surface with the meridian plane mesh lines.

EQSORT: Finds the first point (on boundary) of each line of intersection.

TRACE: Traces out, i.e. finds all succeeding points on each line of intersection.

EQPLOT: Writes on BCD output tape 9 the output data (sorted & ordered) field values and plotter records.

PLOTS, SYMBOL, LPLOT, etc.: Constructs plotter records as required.

Allocation of Core Storage; Core Map

MULUCY loader: Octal locations 00000-00027.
Program storage: Octal locations 00030-17232.
Common storage: Octal locations 46021-77462.
Library subroutine storage: Octal locations 77463-77777.

Thus the program requires 7811 memory locations, while the common storage requires 13,090 memory locations. The common storage of this Program B is arranged identically to that of Program A.

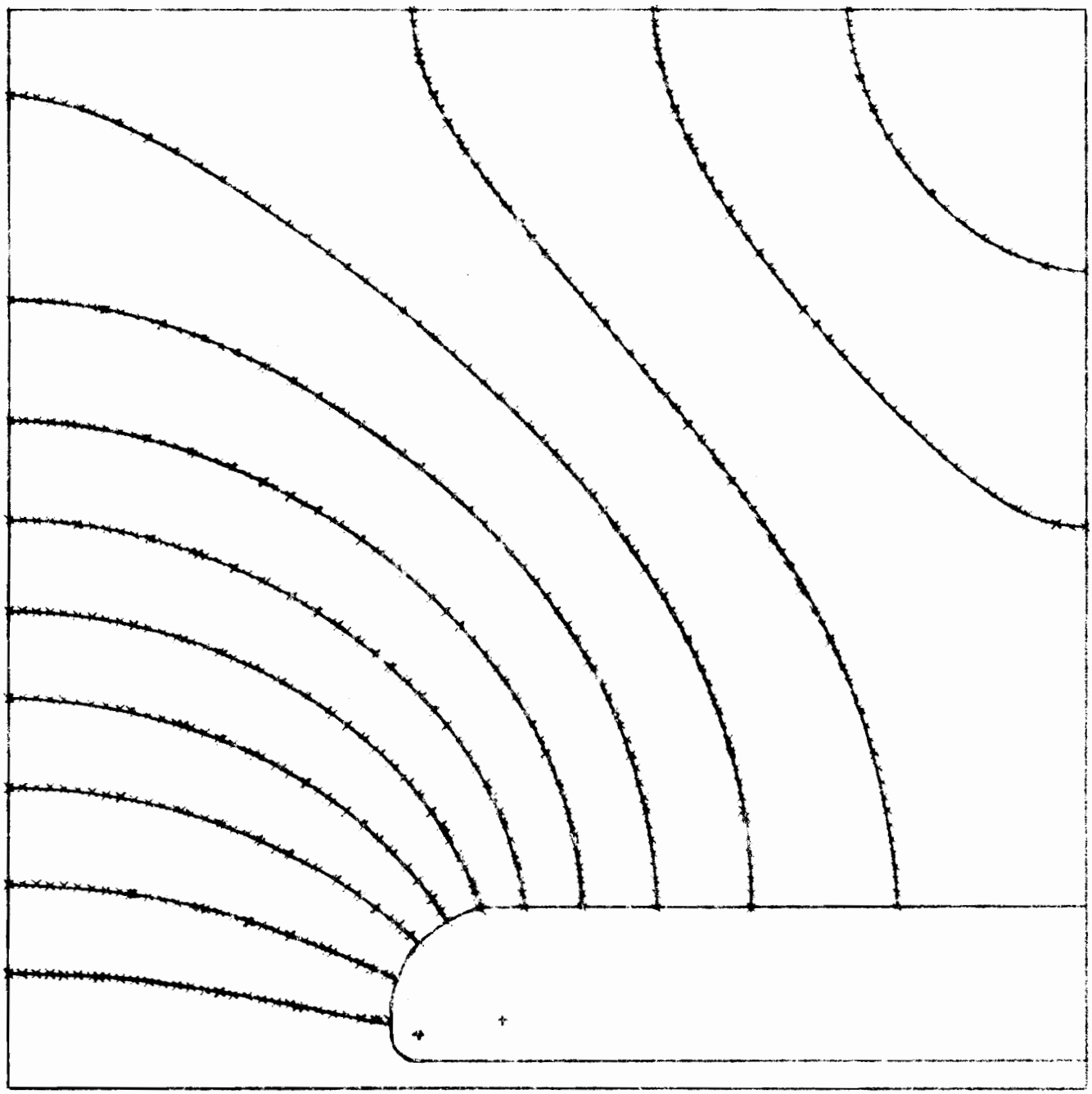
A core map, produced by MULUCY, showing the division of unique storage amoung the various subprograms follows.

NAME	VECTOR	ENTRY	START	END	COMMON
000000		00047	00030	04753	46020
	SAVE				
	SEARCH				
	BNPLOT				
	(STH)				
	COS4				
	SIN4				
	(RTN)				
	(FIL)				
	(SPH)				
	(IOH)O				
	(LEV)				
	PLOT1				
	PLOTS				
	ZRPEN				
	MURCD2				
BNPLOT		04771	04754	06177	46020
	(FIL)				
	(STH)				
	(IOH)O				
	(LEV)				
	VPLOT				
	SYMBOL				
	SIN4				
	COS4				
	PLOT1				
	PLOTS				
SEARCH		06213	06200	10306	46020
	SIN4				
	COS4				
	EQSORT				
	(STH)				
	(FIL)				
	(SPH)				
	(IOH)O				
	(LEV)				
EQSORT		10314	10307	11374	46020
	EQPLOT				
	TRACE				
TRACE		11400	11375	11636	46020
EQPLOT		11651	11637	12250	46020
	SYMBOL				
	PLOT1				
	(STH)				
	(FIL)				
	(SPH)				
	(IOH)O				
	(LEV)				

ZRPEN	12766	12251	13045	00000
PSTOP	12762			
CHGSZ	12315			
SIND	12326			
PLOTS	12252			
PLOT1	12251			
LPLOT	13050	13046	13072	00000
PLOT1				
VPLOT	13376	13073	14203	00000
HPLOT	13305			
EXSYM	13251			
SYMBOL	13076			
(IOH)O				
SIND				
LPLOT				
MURCD2	14204	14204	14522	77723
DUMP	14523	14523	14771	77462
SAVE	14534			
SIN4	14773	14772	15077	00000
COS4	14772			
(FIL)	16552	15100	16711	77541
(BDC)	15105			
(DBC)	15103			
(IOH)O	15102			
(IOH)I	15101			
(RTN)				
(RTN)	16753	16712	17031	00000
(LEV)	16712			
(SPH)	17032	17032	17216	77653
(STH)	17217	17217	17232	00000

TYPICAL PLOT

F-46 MESH NO. 28419 F FIELD.



Program C - MESH TAPE PREPARATION PROGRAM

This program is designed to put a unique four word record followed by an end-of-file on F-46 mesh tapes. The format of this record is:

WORD 1: Blank. Not Used.
WORD 2: Identification Word: BCD for Messy: 442562627033.
WORD 3: Lowest Allowed Mesh Number.
WORD 4: Highest Allowed Mesh Number.

Data Specifications

Address	Data	Example
1	(Logical) tape number to be prepared.	8
2	Identification number of lowest numbered mesh allowed to be stored on this tape.	28800
3	Identification number of highest numbered mesh allowed to be stored on this tape.	28899

Each data address is self perpetuating; if a number of tapes are to be prepared; each data address must be accordingly altered.

Input data for successive tapes to be prepared must be separated by one END DATA card; the data for the last tape to be prepared is best followed by three END DATA cards.

Remarks

1. After each tape is prepared, a pause (HPR 77777) occurs. To go on to the next tape to be prepared, the START button must be pushed.

2. After the unique first record is put on the tape, an end-of-file is also written. When a mesh is written on this tape by Program A or F, the end-of-file is erased and re-written following the mesh.

3. This program will not prepare (anew) a tape that is already a MESSYMESH mesh tape. An on-line diagnostic will be printed accordingly to instruct the operator.

Allocation of Core Storage

MULUCY loader: Octal locations 00000-00027.
Program Storage: Octal locations 00030-03241.
Common Storage: None.
Library Subroutine Storage: Octal locations 77463-77777.

Thus the program length is 1674 words.

Program D - MESH TAPE INDEX PROGRAM

This program is designed to yield (on-line) a summary of the contents of a MESSYMESH mesh tape, mounted as (logical) tape 7. No card input data is required.

Remarks

1. After each tape is indexed, a pause (HPR 77777) occurs. If another tape is to be indexed it should be set to (logical) tape 7 and the start button must be pushed.

2. This program detects errors in the format of the meshes on logical tape 7. An indication of these errors is printed out.

Allocation of Core Storage

MULUCY loader: Octal locations 00000-00027.
Program Storage: Octal locations 00030-03225.
Common Storage: None.
Library Subroutine Storage: Octal locations 77463-77777.

Thus the program length is 1662 words.

Program E - MESH TAPE LISTING PROGRAM

This program is designed to print (offline) the eigenfunction, etc. contained in a consecutively numbered sequence of meshes from an F-46 mesh tape.

Data Specification

Address	Data	Example
1	Identification number of the first mesh of a consecutively numbered sequence of meshes to be printed.	28107
2	Identification number of the last mesh of a consecutively numbered sequence of meshes to be printed.	28112

Each data address is self perpetuating in a series of runs, unless changed by the adgenda.

Input data for successive series of meshes must be separated by one END-DATA card; the data for the last series of meshes is best followed by three END DATA cards.

Remarks

1. The meshes printed must be stored in successive numerical order on a mesh input/output tape. Violation of this rule will result in a program stop.

Allocation of Core Storage

MULUCY loader: Octal locations 00000-00027.
Program Storage: Octal locations 00030-05634.
Common Storage: Octal locations 46021-77462.
Library Subroutine Storage: Octal locations 77463-77777.

Thus the program requires 2949 memory locations, while the common storage requires 13,090 memory locations. The common storage of this Program E is arranged identically to that of Program A.

Program F - MESH TRANSFER PROGRAM

This program is designed to transfer meshes from one mesh input/output tape to another, a consecutively numbered sequence of meshes with an accompanying change of mesh number if desired.

Data Specifications

Address	Data	Example
1	(Logical) tape number on which meshes are to be found.	6
2	(Logical) tape number to which meshes are to be transferred.	7
3	Identification number of first of consecutively numbered meshes to be transferred.	28603
4	Identification number of last of consecutively numbered meshes to be transferred. If specified as zero, only one mesh will be transferred.	28607
5	New identification number of first transferred mesh.	28181
6	New identification number of last transferred mesh. If specified as zero, only one mesh will be transferred.	28185

Each data address is self-perpetuating in a series of transfers, unless changed by the agenda.

Input data for successive series of transfers must be separated by one END DATA card; the data for the last series of transfers is best followed by three END DATA cards.

Remarks

1. The meshes transferred must be initially stored in successive numerical order on a mesh input/output tape. If it is desired to transfer meshes not in numerical order, a number of series of transfers is necessary, such that within each series, numerical order exists.

2. The meshes will be assigned sequential numerical identification numbers and will be stored in the same manner on the output mesh tape.

3. The output mesh tape must have been previously prepared with the specific four-word first record written by Program C.

Allocation of Core Storage

MULUCY loader: Octal locations 00000-00027.
Program Storage: Octal locations 00030-31643.
Common Storage: None.
Library Subroutine Storage: Octal locations 77463-77777.

Thus the program (together with unique storage) is 13,197 words in length.

TAPES

NO. 1: MESSYMESH F-46 PROGRAM TAPE. This tape contains the six Messymesh programs in the following order:

A. Mesh Calculating Program.
B. Plotting Program.
C. Mesh Tape Preparation Program.
D. Mesh Tape Index Program.
E. Mesh Tape Listing Program.
F. Mesh Transfer Program.

After any one program is loaded into the 704 from tape, no further reference is made to this tape.

NO. 0: Dump/Save tape. This tape is referenced only by Programs A and B. Depressing SSW1 permits interruption and saving of entire memory onto tape 0. Program A will also automatically and periodically dump the entire memory onto tape 0. Programs C, D, E and F cannot be saved or dumped.

NO. 3: Alternate mesh output tape. This tape is referenced only by program A and is not always needed. If this tape is required, it may be so indicated on the agenda sheet or by the program itself. If this tape is requested by the program itself, instructions for the operator will be printed on the on-line printer. The correct mesh input/output tape or an erasable tape should be mounted.

NO. 7: Primary mesh input/output tape. This tape is required by all six programs. This and all other mesh input/output tapes must contain the specific four word first record, written by either program A or program C.

NO. 8: Secondary mesh input/output tape. Optional requirement for program A and program B only. This tape is used on the event that meshes calculated, loaded, or plotted have identification numbers different from those allowed on tape no. 7. This tape is selected only if program A or program B cannot employ tape no. 7, i.e. tape no. 7 is always interrogated prior to tape no. 8. This tape must also contain a specific four word first record.

NO. 9: BCD output tape. Required of programs A, B, and E only. The off-line printing on this tape may be gotten via the 1401 satellite computer, using programs X25, X50, etc.

SENSE SWITCHES

The normal position of each sense switch is UP.

Below are listed the functions of the various sense switches when in the down position.

SSW 1: Interrupts and saves calculations of programs A or B only on an erasable (logical) tape no. 0.

SSW 2: Periodically prints online and/or offline (as per SSW 3 below) values of Q, ZT^2, etc. from program A only.

SSW 3: Controls online printing of calculation summaries for programs A or B only. This feature should be used with discretion, as it may appreciably increase the computing time.

SSW 4: Suppresses optimazation of alpha, the over-relaxation factor for program A only.

SSW 5: Allows new values of alpha and the second convergence criterion to be entered into program A only via the card reader. Instructions to the operator will be printed on-line. This feature operates only if SSW 3 is down.

SSW 6: Prints (offline only) extra and/or intermediate fields during calculations of programs A or B only. This feature should be used with discretion, since the offline output will become quite voluminous.

ALL SSW's DOWN: Permits abortions of run under calculation (program A only) and continuation to the next run. When program A operates in this mode, for all other purposes, sense switches 1, 2, 4, 5, and 6 are effectively in the up position.

OPERATING PROCEDURES

Any one of the six MESSYMESH programs may be loaded into the 704 from the MESSYMESH F-46 PROGRAM TAPE via manual manipulation of the control switches and buttons on the 704 console. Programs A and B may be interrupted, saved on an erasable tape, and later resumed if such becomes necessary in the course of calculation.

A detailed description of loading and interruption procedures, of sense switch control features, and other operating instructions is given in MURA TECHNICAL NOTE #304.