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J. J. CASSIDY, III

Systems, Science and Software

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Lewis Research Center

Contract NAS3-21050

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15. Supplementary Notes

16. Abstract

This document is a user's manual for the NASCAP code. NASCAP simulates the charging process for a complex object in either tenuous plasma (geosynchronous orbit) or ground test (electron gun source) environment.

The user's manual begins by describing, in a general way, the workings of NASCAP — user input and program output. It goes on to describe more specifically the program control words, the structure of user input files, and the various user options available.

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PREFACE

This document supercedes NASCAP User's Manual NASA CR-135259.

SUMMARY

This document is a user's manual for the NASCAP code. NASCAP simulates the charging process for a complex object in either tenuous plasma (geosynchronous orbit) or ground test (electron gun source) environment.

The user's manual begins by describing, in a general way, the workings of NASCAP — user input and program output. It goes on to describe more specifically the program control words, the structure of user input files, and the various user options available.

1. OVERVIEW

NASCAP (NASA Charging Analyzer Program) was developed by Systems, Science and Software under contract to NASA-Lewis Research Center. It simulates the charging process for a complex object in either tenuous plasma (geosynchronous orbit) or test tank (electron gun source) environment. It is an extremely powerful and extremely flexible program, which allows user input to determine the scope of the calculation.

The NASCAP user must define a spacecraft or test object geometrically and electrically, and specify the plasma environment. The user may also alter any of a wide range of parameters affecting the calculation. Then NASCAP simulates the charging process in a quasistatic fashion, alternately calculating currents and potentials.

In each discrete timestep, NASCAP calculates the electron flux, ion flux, and secondary, backscatter and photoemitted fluxes for each area of the satellite. These fluxes are assumed to hold for the length of one timestep, subject to the limits imposed by the LIMCEL (LONGTIMESTEP) calculation. The charges on the satellite are updated, and the electrostatic field is calculated for the new charge distribution. This field calculation involves solving Poisson's equation for a computational space of perhaps tens of thousands of points.

To begin the next timestep, satellite fluxes are calculated on the basis of this new field.

The NASCAP code, in its present form, includes the following features:

- Full three-dimensional treatment of spacecraft charging — NASCAP calculations accurately predict phenomena which are beyond the range of 1-D and 2-D models.

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- Flexibility with defaults — the user can closely tailor a NASCAP calculation to his or her particular needs through the use of extensive keyword input. A beginning user can simplify input by accepting program-defined default values.
- Modular program control — the code is structured as a set of separate modules which are called individually, as needed by the user. This sharply reduces wasted computation.
- LONGTIMESTEP option — the calculation proceeds in discrete timesteps. Each step includes a spacecraft charging cycle and a potential calculation cycle. With the LONGTIMESTEP option, NASCAP can take timesteps appropriate to the phenomena of interest, without being restricted to the time scale of rapid charging processes.
- Choice of flux definition — the spacecraft environment can include one of four different flux types — test tank electron beam, isotropic Maxwellian, particle pushing, and double Maxwellian.
- Levels of accuracy — the user can balance cost of computation with need for accuracy by limiting the number of potential solution iterations and shortening or lengthening the timestep.
- Universal surface material — spacecraft surface materials are 100 percent user defined. Any known material or imagined material may be used. (This manual includes suggested material properties for some common substances.)
- Efficient potential solver — the scaled conjugate gradient technique allows an iterative solution to Poisson's equation that converges in minutes, not hours, of computer time.

- Conductor coupling — spacecraft conductors may be defined as floating, held at fixed potential, or biased relative to one another.
- External file usage — external "scratch" files are used efficiently to minimize IO time. External permanent files are automatically updated to allow program restart.
- Automatic satellite rotation — the new ROTATE control word makes necessary adjustments to rotate the satellite relative to the sun.
- Adjustable computational grid.
- Optional uniform and dipolar magnetic fields.
- Potential contour and charge contour plotting.
- Satellite illustration with hidden line elimination.
- Shadowing of surfaces from incident sunlight.
- Adjustable output.

The NASCAP code is a large, highly segmented FORTRAN program. It requires 200000_8 words (∿65 K decimal) of core memory, and several external storage files. For output, it requires a high-speed printer and some kind of graphics device. Presently, there are versions of NASCAP running on a UNIVAC 1110 with Tectronix graphics terminals (at NASA-LeRC), a UNIVAC 1100/81 with Gould plotter (at S^3), and a CDC 6600 with Tektronix terminal (at AFGL/Hanscom AFB).

The run time and output are highly variable, depending on the problem the user runs. A short run may take less than a minute, and a long run several hours.

This manual is an attempt to introduce NASCAP to a new user. We have tried to include, first, all the information necessary to run the code and, second, enough description to give the user some feeling for what is going on. This manual

is not intended either as a programming guide or as a scientific description of the physics of NASCAP.

Chapter 2 (Input) is the most basic user orientation chapter. Chapter 3 provides information on program output. Chapter 4 discusses discretization of the physical problem. Chapters 5 through 8 discuss in detail the various program modules. Chapter 9 shows a sample NASCAP run. Finally, subroutine descriptions are given in Chapter 10.

2. INPUT

Two kinds of input are necessary to run NASCAP. First is the machine-specific job control input, which consists mainly in assigning temporary and permanent files.

Second is the NASCAP input. This includes a list of control words which control the progress of the computation by invoking modules of NASCAP. In addition, three input files are used for a full NASCAP simulation. The keyword file required by the RDOPT module, the object definition file (required by OBJDEF), and the flux definition file (required by TRILIN), all hold user-supplied data. By default these files are found in file numbers 26, 20, and 22, respectively, but the user can change these file numbers, or (by changing to file 5) incorporate these files into the runstream.

2.1 CONTROL WORDS

The seven control words and the function of the logical NASCAP segment they invoke are as follows:

Control Word	Function of Logical Segment
RDOPT	— Call subroutine RDOPT to read options (see Section 4). RDOPT must be called on entry to NASCAP, and may be called subsequently to change options. (Options need not be respecified unless changed.)
OBJDEF	— Perform object definition.
SATPLT	— Generate object display plots.
HIDCEL	— Perform a shadowing calculation for sunlit cases. Must be called before photoemission is calculated unless the CONVEX option has been specified.
ROTATE	— Calculates a new sun direction, and calls HIDCEL if necessary.
CAPACI	— Perform capacitance analysis of satellite. Must be called prior to TRILIN for a new calculation.
TRILIN	— Call TRILIN to perform charging and potential calculations. Reads flux definition file.

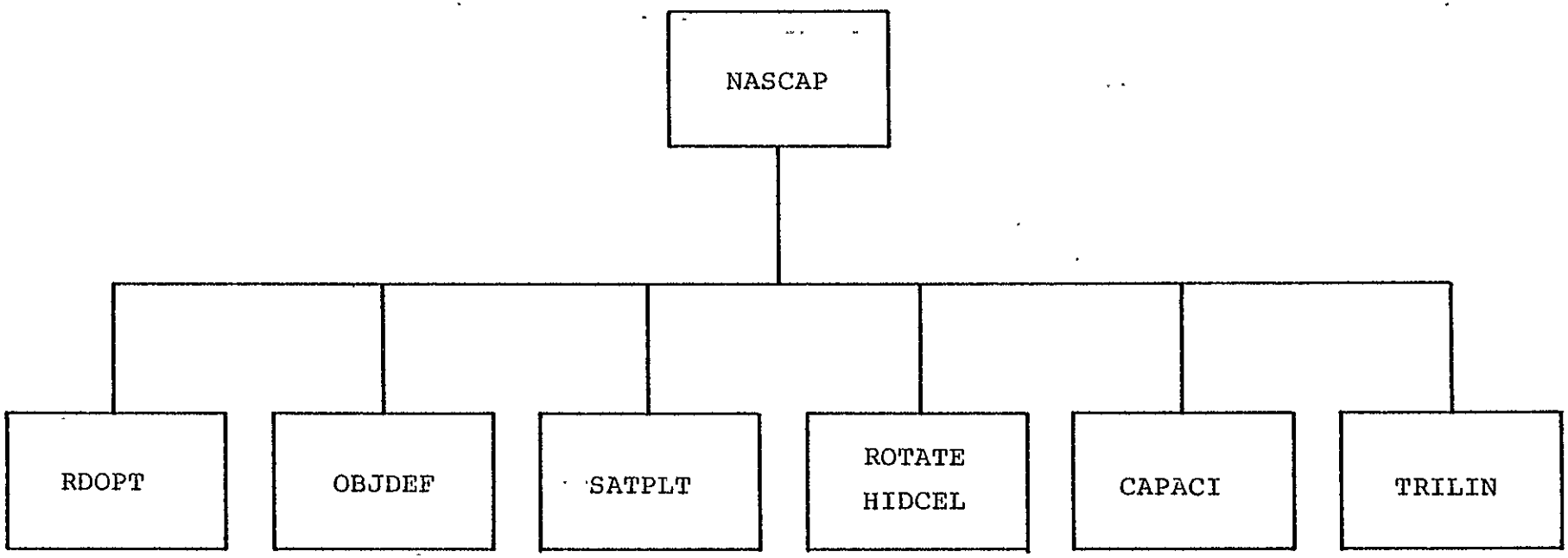

Figure 2.1. Block diagram of the NASCAP code.

The control words RDOPT, OBJDEF, and TRILIN cause the program to look for a keyword option file, an object definition file, and a flux definition file, respectively. SATPLT, ROTATE, CAPACI, and HIDCEL assume that an object has already been defined and user options have been selected. CAPACI, SATPLT, and HIDCEL take no further input. ROTATE optionally reads two cards.

2.2 CONTROL WORD ORDER

RDOPT is the one control word which must be present in each run. In fact, RDOPT has to be the first control word in all NASCAP runs. It is usually followed by OBJDEF, unless the run is a restart of a previously set up problem.

Once the keyword options have been chosen and the object has been defined, the user may call for SATPLT, TRILIN, HIDCEL, or ROTATE, in any order. CAPACI must be called once, immediately before the first TRILIN. All other control words may be repeated any number of times.

2.3 THREE INPUT FILES

The six control words cause subroutines of the same name to be executed. Subroutine RDOPT is invoked when control word RDOPT is encountered. RDOPT causes the reading of a keyword option file in which the user can change default values for the running of NASCAP. If all default values are accepted, the keyword option file consists of one card, reading "END". The keyword options file is file number 26, unless another number is given on the RDOPT card. Additional information on this and the other input files will be found in the section for the corresponding control word.

An object definition file is read by OBJDEF. There is no default object. You must provide an object definition. The object definition file begins with a list of materials and

material properties. Then the user gives a list of building blocks to define an object on the innermost grid. An object is built from a set of six types of building blocks — rectangular parallelepiped, right prism, tetrahedron, angled wedge, octagonal right cylinder, and quasisphere (a solid with 26 faces). Two or more objects may be defined. The object definition file is file 20.

There are four choices possible for flux definition. Each time TRILIN is called, a flux definition is read. Different fluxes can be used for different TRILIN calls. The four flux types are test tank electron beam, isotropic Maxwellian, particle pushing, and double Maxwellian. The flux definition is found on file 22.

The default file numbers for these three files can be changed by putting an integer (I2 format) in columns 9-10 of the RDOPT, OBJDEF, or TRILIN cards. If the file number is changed to 5, the input stream must contain the information. So a card punched "RDOPT 5" followed by a card punched "END" could begin a run in which all default values are accepted.

2.4 RESTART FILES

If you are experimenting with different environments, or you want to fiddle with other parameters such as timestep or conductor bias, you will probably use the RESTART feature. This allows you to run a few cycles of NASCAP, stop and look at the results, then continue. The restart calculation will bring back the same object and the same potential and charge arrays. Keyword options may be changed if desired.

NASCAP automatically writes out the information it needs for restart on six files. By default, these six files have logical unit numbers 10, 15, 16, 17, 19, and 21, but the file numbers for any files can be changed through keyword input.

The main duty of the restart user is to ensure that these six files are saved as permanent files between the initial run and the restart run. This requires a few cards in the runstream. Aside from preserving these six files, the user need only insert a "RESTART" card into the keyword file on the second, or restart, run. If the "RESTART" keyword is omitted, TRILIN will begin with timestep 1 for an uncharged object.

2.5 PROGRAM FLOW

The main uses of the NASCAP code fall naturally into two categories — pure object definition and potential calculations.

2.5.1 Object Definition

A large amount of processing is necessary to take the user input of satellite "building blocks" and turn it into a form that NASCAP can use for calculations. The code must generate a list of surface cells and their attributes, as well as a list of volume elements that are partially filled with a piece of the satellite. In addition, there are lists describing the electrical connectivity of the object and other miscellaneous tables.

In order to be sure that object definition is proceeding properly, the user will generally make a few runs purely for the purpose of defining and displaying the object. To make such a run, the control words RDOPT, OBJDEF, and SATPLT are used, in that order. A keyword option file and object definition file are needed.

Figure 2.2 shows a complicated NASCAP object. The plot was automatically generated by HIDCEL.

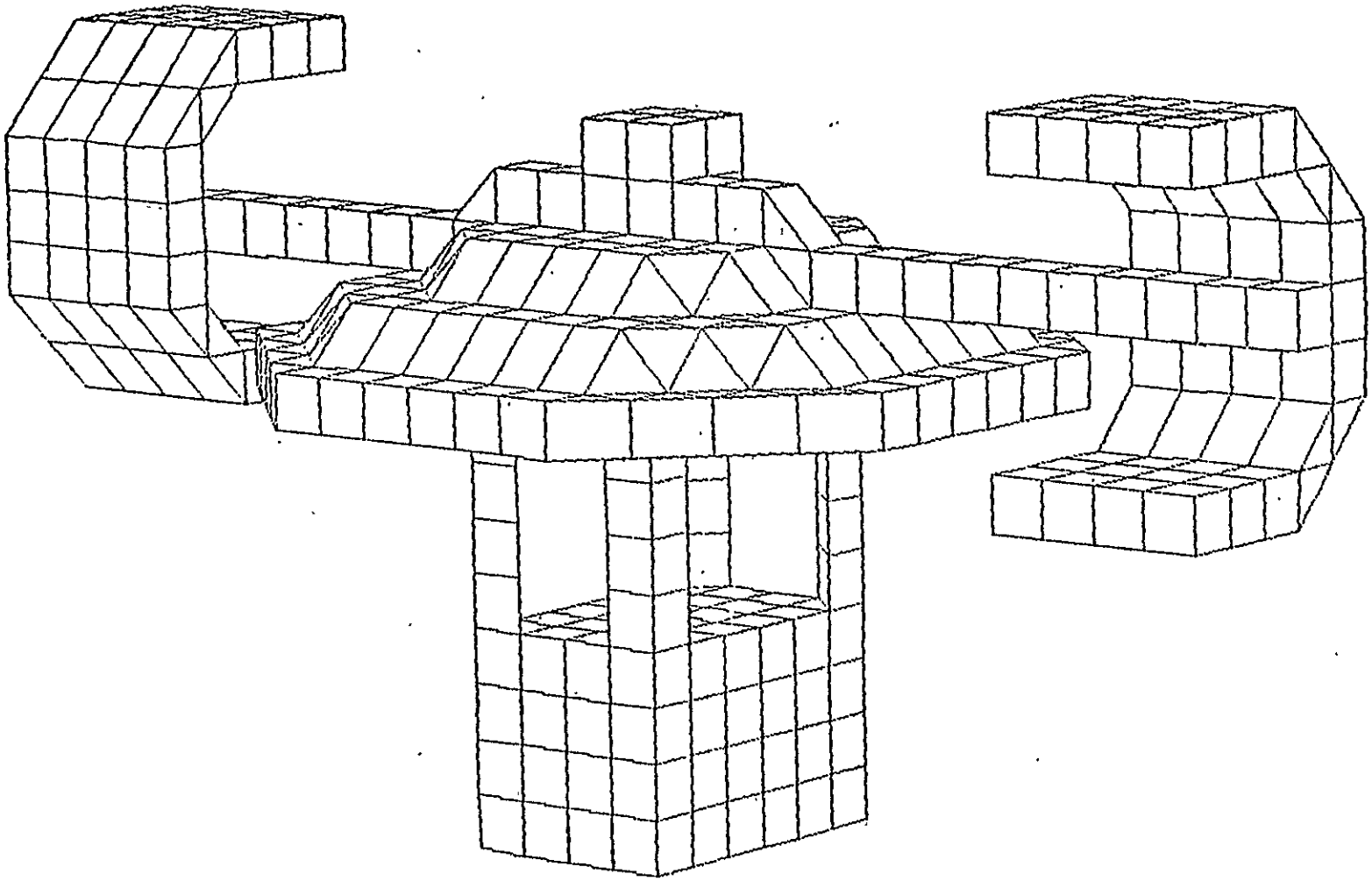

Figure 2.2. Hidden line plot of object defined for NASCAP.

2.5.2 Charging Simulation

A charging simulation (control word TRILIN) requires a set of keyword options, a defined object, and an electrical environment. It also requires one call of CAPACI. It proceeds with a series of alternate charging cycles and potential cycles, one for each timestep as specified by the user in the keyword file.

A charging simulation may be run along with object definition, or may be restarted from previous runs. So if you wanted to test one object in different flux environments, you could do it in two ways. To do everything in one run, you would call for RDOPT, OBJDEF, SATPLT, CAPACI, TRILIN, TRILIN. In this case two different flux definitions would be provided by the user.

If you wanted to look at the results of the first few timesteps of a simulation before continuing, you would use a restart calculation. The initial run would go RDOPT, OBJDEF, SATPLT, CAPACI, TRILIN. Then you would add a RESTART card to the keyword file. The second run would go RDOPT, TRILIN. Do not call CAPACI again on a restart run. For these restart runs you would catalogue files 10, 15, 16, 17, 19, and 21 as permanent files.

In the above charging simulations, photoemission is not a significant factor. To include photoemission, we would have to have set a sun intensity in the keyword file and have called HIDCEL before the first TRILIN.

3. OUTPUT

Each section of NASCAP has its distinctive printed output section to let you know it has been called and is doing something. Some sections also have graphical output. Following is a section by section account of what to expect.

3.1 RDOPT

The RDOPT section gives a check on the user's choice of keyword options. It prints a list of the value of all keyword variables, including the default values of those for which the user has not specified changes.

3.2 OBJDEF

The object definition section of NASCAP has no graphical output of its own. The user must call SATPLT to get a satellite picture. But OBJDEF does provide printed output that is valuable for diagnostic purposes.

OBJDEF prints a summary of material properties, a surface cell list, and a short volume element table. For information on the structure and use of these outputs, see the OBJDEF section of this report.

3.3 SATPLT

SATPLT generates just enough printer output to let you know it has been called. However, it generates a good deal of graphical output. By default, SATPLT generates six <u>material plots</u> — views of the satellite in which each surface cell is shaded according to surface material. The user can specify additional material plot views through the NDIV keyword. Also by default, six 3-D satellite illustration plots are drawn. These are generated by three calls to subroutine HIDCEL. From each of three directions we see the satellite composed of

building blocks, including hidden lines. Then we see the satellite as a set of surface cells, with hidden lines removed. Additional satellite illustration plots can be called for with the NDIR keyword.

3.4 TRILIN

TRILIN generates the bulk of NASCAP output. It runs through a user-specified number of timesteps, each timestep consisting of a charge cycle and a potential cycle. Each charge cycle produces flux data for all surface cells in which the user has expressed interest (through the SURFACE CELL keyword). If no surface cell has been specified, the information is printed for cell number 1.

The potential section gives a running commentary on the value of certain variables concerned with potential convergence. At the end of the potential cycle, a printer plot shows the rate of convergence. After the end of the last time cycle, potential values for all points in computational space are printed out.

All graphical output from TRILIN is optional. The defaul is no graphical output. By using the keywords ICON, IROUSP, ITCUR, and IPART-ITPART, the user can call for potential contour plots, charge contour plots, current contour plots, and particle trajectory plots. The default contour plots show three cuts of constant X, Y, and Z through the middle of computational space. Additional cuts can be requested through the NCON keyword.

3.5 HIDCEL – ROTATE

ROTATE merely generates one call to HIDCEL each time it occurs in the runstream. It passes HIDCEL a sun direction calculated from the current timestep and the user-specified rotation values.

HIDCEL prints only one line — the value of a variable called NA1. This lets you know it has been called. It also generates two frames of graphical output. The first plot shows the user building blocks as they appear from the sun direction, all lines show. The second shows the code-generated surface cells, from the same direction, with hidden lines removed.

Finally, HIDCEL writes out on mass storage the percentage exposure for each surface cell, to be used later by the charge section of TRILIN.

3.6 CAPACI

The main work of CAPACI is to make a preparatory call to subroutine TRILIN. Therefore the CAPACI output is merely the output from TRILIN, except that it is headed by an echo of the CAPACI control word card.

3.7 A NOTE ON RESTARTING

Aside from printed and graphical output, NASCAP also writes data onto mass storage files for later program restart. If the user wants to preserve this data, he must insure that logical unit numbers 10, 15, 16, 17, 19, and 21 refer to permanent files. Otherwise, the data will be written on temporary files, it will be lost, and restart will be impossible.

Figure 3.1 shows another view of the NASCAP object in Figure 2.2.

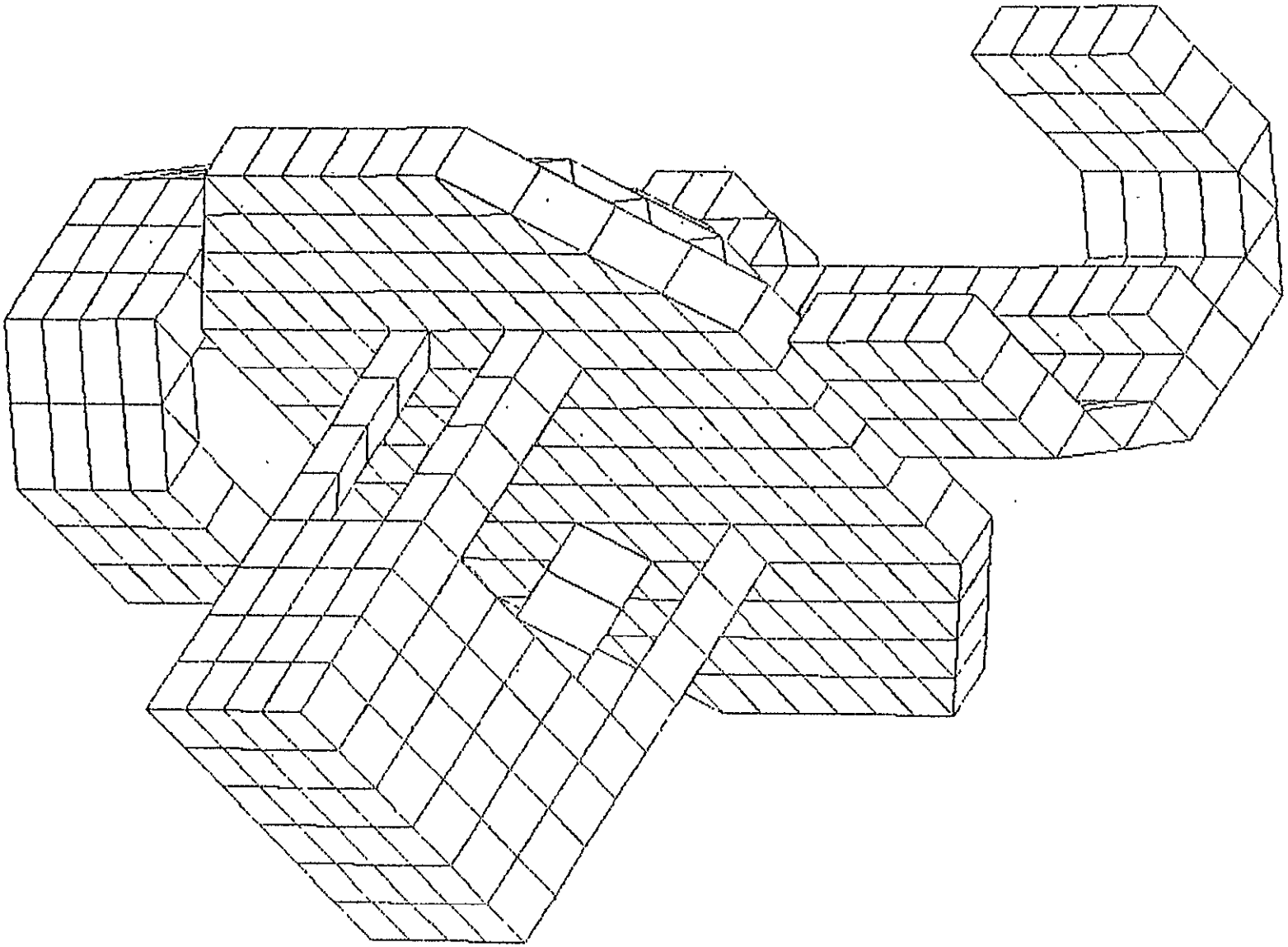

Figure 3.1. Another view of object in Figure 2.2.

4. A CAST OF THOUSANDS

One problem for anyone trying to figure out the physics or coding of NASCAP is trying to decide just what approximations are made. How is the continuous physical problem turned into a discrete computer model? What are the important data structures that are manipulated? This section is meant to be an informal introduction to some of the most important characters in the NASCAP cast of variables and arrays.

The basic fact about NASCAP is that everything takes place on a three-dimensional grid of dimension 17 by 17 by 4n+1 ($4 \leq n \leq 8$). There is a series of these grids, each larger than the one before, and containing the preceding one as a subgrid.

For a maximum grid (17 x 17 x 33), the grid lines will intersect at 9537 points. The grid can equally well be thought of as this collection of points, or as the 8192 cubic spaces (16 x 16 x 32) that lie between the grid lines. Each larger grid has a mesh spacing exactly twice that of the one before. So the cubic volume spaces of any grid are eight times the size of the next smaller grid.

But let us focus on the innermost grid, grid #1. It is here that the bulk of the spacecraft resides, and here that the most complicated calculations take place. Here we find examples of every type of NASCAP abstraction. We will briefly introduce five of them — points, volumes, surfaces, conductors, and fields.

4.1 POINTS

On our grid of 17 x 17 x 33, each grid point is uniquely identified by an ordered triple (i,j,k) where i and j run from 1 to 17 and k ranges from 1 to 33. There is a potential associated with each point on the grid, and we keep track of these

with a potential array called P. So the potential at point $x = 5$, $y = 15$, $z = 9$, is just the array entry P(5,15,9).

The potential at a location somewhere in space in between grid points is easily found. We just linearly (or trilinearly) interpolate from the potentials at the closest grid points. So we have potentials for all of computational space, once we have solved for potentials at the grid points.

To solve Poisson's equation and find these potentials, we need to know the distribution of electrical charge in the system. One way to do this would be to introduce a large number of charges, and constantly keep track of their spacial location. But this would be too slow to be practical. So we have another array called ROUS that stores an electrical charge value for each point on the grid. Then if we know for some reason there is a charged particle at some location in space (not right on top of a grid point) we reverse interpolate that amount of charge and store a fraction of it at each of the nearest grid points.

These two arrays, the potential array P and the charge array ROUS, tell us most of what we need to know about the electrical environment. In particular, the electric field at any location can be calculated from the potential array.

Currently being implemented in the NASCAP code is a scheme to "get in between" the grid points, by introducing at locations of interest a limited number of "subdivision points". This will make it possible to store charges and directly calculate potentials at selected points that do not happen to fall on the grid.

Figure 4.1 illustrates in two dimensions the nesting of computational grids.

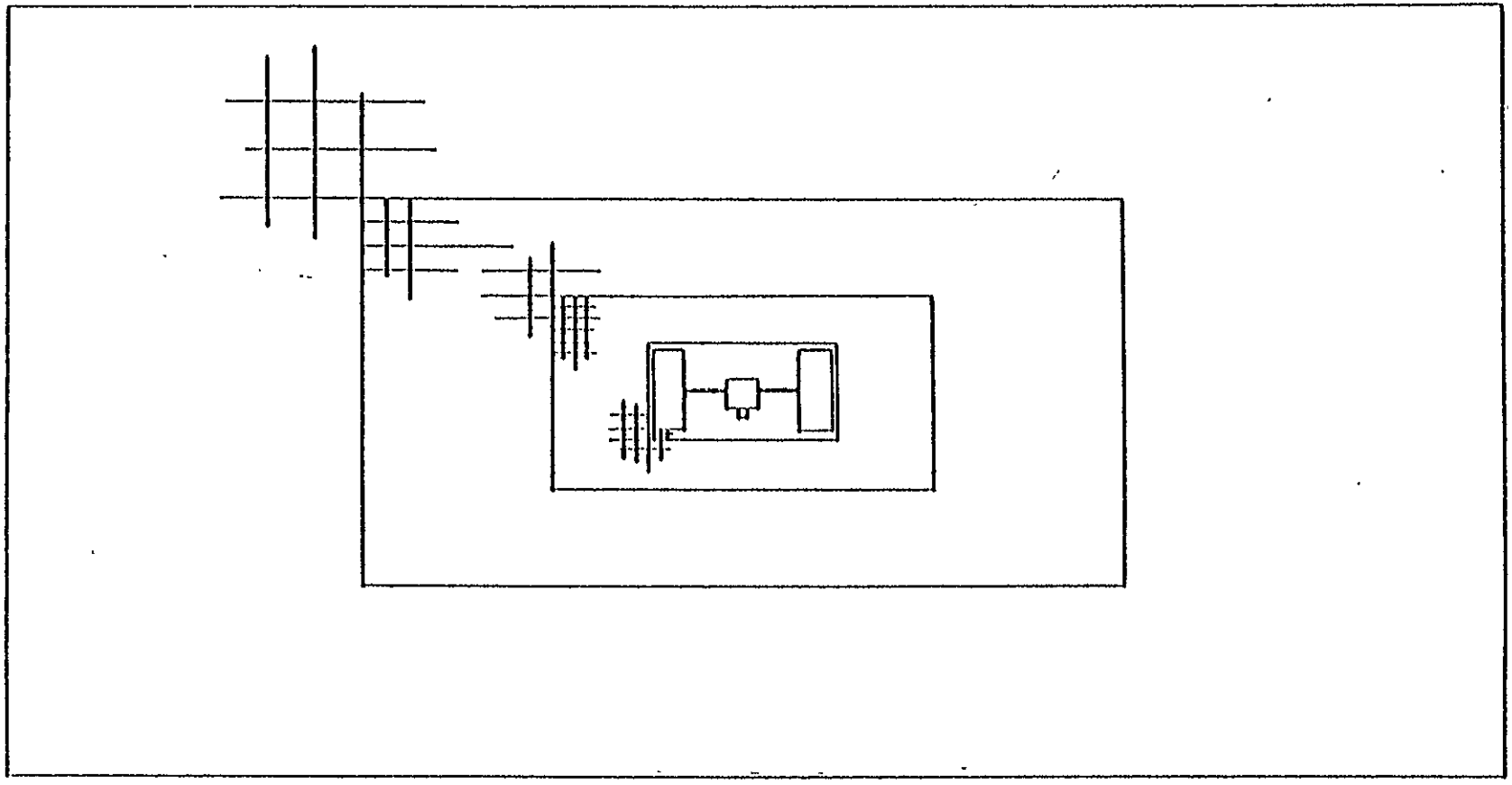

Figure 4.1. Cross-section of grid, showing first four embedded meshes.

4.2 VOLUMES

If there are 17 x 17 x 33 points on our three-dimensional grid, then in between the grid points there are 16 x 16 x 32 three-dimensional unit cube spaces. In NASCAP these little cubes are referred to as cubic volume elements or volume elts. Each volume elt has eight vertices, each of which can be found as an entry in the potential and charge arrays. Likewise, each grid point serves as a vertex for the eight volume elts around it in space.

The process of spacecraft definition is in part a process of specifying which volume elts are occupied by the spacecraft. Some elts will be completely occupied, some will represent empty space, and some will be partly occupied and partly empty. NASCAP keeps a table called the element table which is created at object definition time and specifies exactly what is the location and shape of the object.

One limitation of this method is that no part of the spacecraft can be modeled to be thinner than a volume element. We are currently implementing a way to represent thin plates and rods in the computational space.

4.3 SURFACES

The spacecraft surface — the boundary between filled space and empty space — is a very busy place. NASCAP performs very sophisticated calculations for this area, including the effects of incident particle flux, secondary emissions, electron backscatter, and photocurrent. A significant part of object definition is describing the surface material of every exposed part of the object.

The unit of spacecraft surface is the surface cell. Every surface cell is either the boundary between an occupied volume elt and an empty space volume elt, or it is the boundary

between the filled and empty portion of a partly occupied elt. The surface cell shapes that result from object definition are four: unit square, rectangle, right triangle, and equilateral triangle.

There is a list of all the surface cells, called as you would expect, the surface cell list. This list contains such information as whether the surface is bare conductor or coated with a dielectric. There is a pointer to a list of material properties to indicate the response of each surface cell to a given local environment.

Grid points that lie on the spacecraft surface get special treatment. A separate list is kept of surface nodes and the surface cells they bound. The fact that they are not surrounded by empty space makes the special handling necessary.

4.4 CONDUCTORS

Conductors, like points, have potential and charge arrays. Unlike a point, a conductor can be in several places at once, lying beneath surface cells all over the spacecraft body. There may be up to seven conductors specified, and each surface cell must claim one for its own.

Conductor #1 is considered to be spacecraft ground, and other conductors may be floating, fixed to a certain potential, or biased with respect to #1. In addition, any two conductors may be capacitively coupled, as desired by the user.

4.5 FIELDS

Fields per se have no permanent representation. They are calculated when needed from other information that is permanently stored.

Electric fields are calculated when needed from the potentials of adjacent grid points. The magnetic field at any point is the sum of a user-specified constant field plus the effects of any user-specified magnetic dipoles.

5. RDOPT

The RDOPT input file consists of any number of keyword options, in any order. The last card must be an END card.

Although there are many keyword options, the user need not concern himself with the complete set. Default values are supplied for all keywords. A non-trivial program can be run in which the entire RDOPT file contains only an END card.

Aside from the COMMENT and END cards, the keywords break down into five categories. Space Description options allow the user to tailor certain physical properties of the computational space. Object Description is concerned with potentials on spacecraft conductors. Program Control gives the user various ways to affect the progress of the calculation. This includes such parameters as the length and number of time cycles and the way that potentials are calculated.

The first keywords in the Output Control section (SURFACE CELL, ICNVP, APRT) control the amount of printed output. The rest of the keywords are requests for optional plots on a graphics device.

The final keyword category is File Numbers.

5.1 KEYWORD CARD FORMATS

The standard keyword card format is as follows: a keyword in columns 1-10, data if necessary in columns 21-30, 31-40, 41-50, etc. Standard integer data is read in I10 format, which requires integers to be right-justified in a ten character field. All real number data is read in F10.0 format. This allows a real number anywhere within the ten character field, so long as a decimal point is used.

Non-standard data formats are used on keyword cards TANKSIZE, CIJ, and NDIV. Also, keyword cards NCON, NDIR, and NDIV request additional data cards that do not have keywords, and have data fields starting in column 1.

In Section 5.3, keyword meanings and formats are shown. Remember that keyword card data begins in column 21.

5.2 KEYWORDS LISTED ALPHABETICALLY

Keyword	Default
APRT	1
BFIELD	(0.,0.,0.)
BIAS	-
CIJ	-
COMMENT	-
CONVEX	-
DELFAC	1.0
DELTA	.001
DIPOLE	-
END	-
FIXP	-
IAREA	27
IAUN	11
ICNOW	21
ICNVP	1
ICON	0
ICREST	0
IDIV	25
IFLUX	22
IKEYWD	26
ILTBL	17
IOBJ	18
IOBPLT	19
IOUTER	0
IP	10
IPART	28
IPQCND	16
IPREST	0
IR	12
IROUS	15
IROUSP	0
ISAT	20
ISPARE	14
ITCUR	0
ITPART	0
ITYPE	2
IU	13
LONGTIMESTEP-NOLONG	-
MAXITR	10
MCYC	1
NCON	0
NCYC	1
NDIR	0
NDIV	(0,0,0,0,0,0)
NG	2
NZ	33
RESTART	-
SCALE-NOSCALE-DSCALE	-
SECOND	-
SUNDIR	(1.,1.,1.)
SUNINT	0.
SURFACE CELL	1
TANKSIZE	(1,NZ)
XMESH	0.1

5.3 KEYWORD MEANINGS BY CATEGORY

Keyword	Default	Meaning and Format
		Comment and End
COMMENT	N.A.	Ignore this card.
END	N.A.	Stop reading keyword cards.
		Space Description
NZ	33	Number of z-direction grid points. Must be of the form 4n+1, with $4 \leq n \leq 8$. (I10)
NG	2	Number of nested NX x NY x NZ grids. Potential solving is done in NG grids; particle tracking is done in at most two grids. (I10)
ITYPE	2	Flux definition flag. (I10) ITYPE = 1 implies test tank case. ITYPE = 2 implies isotropic Maxwellian plasma approximation. ITYPE = 3 implies particle-pushing space case (experimental data or Maxwellian ambient plasma). ITYPE = 4 implies double Maxwellian plasma approximation. The flux type from the keyword (RDOPT) file <u>must</u> be the same as the flux type given in the flux definition (TRILIN) file.
SUNDIR	(1.,1.,1.)	Vector indicating direction from center of inner grid to sun for shadowing calculation. SUNDIR will be used to calculate new shadowed areas only if HIDCEL or ROTATE is called. SUNDIR need not be normalized. (3F10.0)
SUNINT	0.	Solar intensity in units of 1 solar constant. If $\neq 0$ either CONVEX option must be specified or HIDCEL must be called prior to first TRILIN. (F10.0)

Keyword	Default	Meaning and Format
	Space Description (Continued)	
XMESH	0.1	Distance between innermost mesh grid points. (F10.0)
TANKSIZE	(1,NZ)	The Z-dimension of the outer grid may be truncated from the left and/or right. (The outer grid must include the next inner grid.) (2I5)
BFIELD	(0.,0.,0.)	Constant magnetic field in Webers/m^2. (3F10.0)
DIPOLE	N.A.	Data P(3), R(3) ... magnetic dipole with moment $\vec{P}$ (A-m^2) at location $\vec{R}$ (grid units). (6F10.0)

Keyword	Default	Meaning and Format
		Object Description
CIJ	(empty space capacitance value between conductors)	Data I, J, C ... Capacitance C (farads) between conductors I and J. This is to be used for conductors which are glued together or are separated by a thin insulating layer; capacitance between disjoint conductors is handled implicitly. (2I5, F10.0)
BIAS	(no conductor bias)	Data I, VBIAS ... Conductor I to be biased at VBIAS (volts) relative to conductor 1, which is considered spacecraft ground. Biasing must be done in order, beginning with conductor 2. (I10, F10.0)
CONVEX	N.A.	Satellite is convex. Allows photoemission calculation (i.e., SUNINT $\neq$ 0) in TRILIN without ever calling HIDCEL. Surface cell illumination determined solely by angle to sun.
FIXP	(all conductors float)	Data I, VFIX ... Potential of conductor I to be fixed at VFIX. Spacecraft ground (conductor 1) may be fixed. (I10, F10.0)

Keyword	Default	Meaning and Format
		Program Control
IOUTER	0	Boundary condition and potential initial guess option. (I10) IOUTER = 0 implies begin with zero potential everywhere. IOUTER = 1 implies begin with 1/r potentials on outer boundary of system; zeroes in all other locations. (Not recommended.) IOUTER = 2 implies begin with 1/r potentials everywhere. IOUTER = -N (negative integer) implies multiply previous potentials and charges by 10^{-N} if ICREST = 0 and IPREST = 1. (Start at cycle 1 with scaled version of previously calculated potentials.
MAXITR	10	Number of potential iterations desired. Zero is allowed; 50 is a suggested maximum. (Note possibility of potential restart.) (I10)
NCYC	1	Number of time cycles to be run.(I10)
MCYC	1	POTENT call flag. (I10) MCYC = 0 implies POTENT will not be called to calculate new potentials; scaled potentials will be used. MCYC > 0 implies POTENT will be called every MCYC time cycles beginning with cycle 1.
DELTA	.001	Length of time step in seconds for one charging cycle (time cycle).(F10.0)
DELFAC	1.0	Factor by which DELTA is multiplied at each cycle. (F10.0)

Keyword	Default	Meaning and Format
		Program Control (Continued)
LONGTIMESTEP—NOLONG	NOLONG	The LONGTIMESTEP option invokes the LIMCEL routine, which causes the satellite to be charged in an implicit fashion. If the satellite is charged explicitly, (NOLONG) then the chosen time-step must be characteristic of the most rapid physical process.
SCALE-NOSCALE-DSCALE	(see meaning)	The potential may be scaled from the previous result according to the total charge prior to the conjugate gradient calculation. The default is SCALE if conductor 1 is floating and NOSCALE if conductor 1 is fixed. DSCALE causes potential to be scaled according to [total charge - (sum of charge on fixed potential conductors)]. (Often appropriate to ground-test simulations.)
SECOND	'ANGLE'	The secondary emission formulation keyword 'SECOND' allows the user to specify a literal (starting in column 21) to be passed to the current emission routines BSCAT, ELSEC, and PROSEC. (The value is placed in the variable SEEMIT of common block/MOROPT/, and takes the default value of 'ANGLE'.) The only other currently implemented value is 'NORMAL', which causes PROSEC and ELSEC (but not BSCAT) to ignore angular dependence of the emission coefficients. Any other value is ignored. A sophisticated user may wish to use this flexibility to implement his own alternative emission formulations. (A6)
ICREST	0	Restart flag. See Table 5.1. (I10)
IPREST	0	Restart flag. See Table 5.1. (I10)
RESTART	N.A.	Calls for restart calculation. Equivalent to ICREST = IPREST = 1. (I10)

TABLE 5.1

RESTART OPTIONS

ICREST	IPREST	IOUTER	Description
0	0	≥ 0	New problem.
1	1	ignored	Full restart at new cycle. (Equivalent to RESTART keyword.)
0	1	≥ 0	Potential restart. Start with potential calculation for final cycle of previous run.
0	1	-n	New start on a problem which has been done previously; e.g., in a different environment. Start with cycle 1, t = 0, with initial charges and potentials 10^{-n} times those at end of preceding run, then scale appropriately.
0 or 1	-n	$\gtrless 0$	Same as IPREST = 1 above, except potentials are obtained from file n rather than file IP.

Keyword	Default	Meaning and Format
		Output Control
SURFACE CELL	1	Print detailed information for specified surface cell. If particle plots are made, they are for the lowest numbered such cell. (I10)
ICNVP	1	Potential convergence printer plot flag indicating whether or not and how often printer plots of convergence data are desired. (I10) ICNVP = 0 implies no plots. ICNVP > 0 implies plot convergence data every ICNVP time cycles starting with cycle 1.
APRT	1	This is the number of grids for which potentials will be printed at the end of each potential cycle. Allowed values range from 0 (no potentials printed) to NG (potential at all points of all grids printed). (I10)
ICON	0	Potential contour plot flag indicating whether or not and how often potential contour plots are desired. (I10) ICON $\leq$ 0 implies no plots. ICON > 0 implies plot potential contours every ICON time cycles, starting with cycle 1.
ITPART	0	Plot flag for tank test particle trajectory plots. (I10) ITPART = 0 implies no plots. ITPART $\neq$ 0 implies plot particle trajectories.

Keyword	Default	Meaning and Format
		Output Control (Continued)
ITCUR	0	Plot flag for tank test current contour plots. (I10) ITCUR = 0 implies no plots. ITCUR ≠ 0 implies plot current contours.
IROUSP	0	Plot flag for ROUS (space charge density) contour plot. (I10) IROUSP = 0 implies no plots. IROUSP ≠ 0 implies plot final ROUS contours.
NCON	0	NCON is the number of additional potential contour plot cuts desired. If NCON is non-zero, we read: READ 3010, ((ICNOPT(I,J),I = 1,2), J = 1, NCON) 3010 FORMAT (15I5) ICNOPT(1,J) = 1, 2, or 3 indicating the Jth cut is through fixed x, y, or z plane. ICNOPT(2,J) is an integer between 1 and NX, NY, or NZ (depending on ICNOPT(1,J), indicating the fixed value of the cut. This value is in units of the next-to-inner grid.

Keyword	Default	Meaning and Format
		Output Control (Continued)
NDIR	0	NDIR is the number of additional viewing directions for which the 3-D satellite illustration plots are desired. If NDIR is non-zero, we read: DO100 I = 1, NDIR READ 1030, (DIROPT(J,I), J = 1,3) 100 CONTINUE 1030 FORMAT (3F10.0) DIROPT(1,I), DIROPT(2,I), and DIROPT(3,I) form the direction-of-view vector from the satellite center to the viewer for the Ith optional view. DIROPT need not be normalized.

Keyword	Default	Meaning and Format
		Output Control (Continued)

NDIV	(0,0,0,0,0,0)	Extra material plots. FORMAT (6I5) in columns 26-55, not columns 21-50. NDIV(I) is the number of extra division plots desired for the Ith view of the material composition silhouette plots (views 1 through 6 correspond to +x, -x, +y, -y, +z, and -z).
		
		For each non-zero entry of NDIV, we read one card:
		
		DO 200 IVIEW = 1,6
		
		NDIVI = NDIV(IVIEW)
		
		If (NDIVI.EQ.0) go to 200
		
		READ 3020, IVIEW2, ((NDVAL(I,J, IVIEW2), I = 1,2), J = 1, NDIVI)
		
		If (IVIEW2.NE.IVIEW) RETURN 0
		
		3020 FORMAT (I5, 5X, 10I5)
		
		200 CONTINUE
		
		For a given view IVIEW, a card is read in with a check variable IVIEW2 (which must equal IVIEW) and NDVAL. NDVAL(1,J,IVIEW2) and NDVAL(2,J,IVIEW2) are the lower and upper limits of the Jth optional division for view IVIEW. The optional plot for this division will plot shaded surface areas for only those cells which lie within these limits (limits for the default plots are 1 to NX, 1 to NY, and 1 to NZ).

File Numbers

File number keywords are IP, IAUN, IR, IU, ISPARE, IROUS, IPQCND, ILTBL, IOBJ, IOBPLT, ISAT, ICNOW, IFLUX, IDIV, IKEYWD, IAREA, and IPART. The default file number and file purpose for each is shown in Table 5.2. File usage is broken down by code section in Table 5.3.

Default file numbers for ISAT, IFLUX, and IKEYWD can also be changed by using the optional LUN (logical unit number) specification on the OBJDEF, TRILIN, and RDOPT control cards, respectively. The LUN, if present, is read in I2 format from columns 9 and 10.

TABLE 5.2

AUXILIARY FILE NUMBERS, NAMES, AND USAGE

User Input	Restart	Scratch	
20 ISAT (OBJDEF)	10 IP (potential)	11 IAUN	Conjugate Gradient
22 IFLUX (TRILIN)	15 IROUS (charge)	12 IR	
26 IKEYWD (RDOPT)	16 IPQCND (various)	13 IU	
	17 ILTBL (element table)	14 ISPARE	
	18 IOBJ (subdivision)	25 IDIV	
	19 IOBPLT (various)	28 IPART (plots)	
	21 ICNOW (surface charge)		
	27 IAREA (booms)		

NOTE: For a NASCAP run that is not a RESTART, when no further restart is anticipated, there is no difference between Restart files and Scratch files.

TABLE 5.3

FILE USAGE BY CODE SECTION

Section	User Input	Restart	Scratch
RDOPT	26	21	-
OBJDEF	20	17,18,19,21,27	14
SATPLT	-	19	-
ROTATE — HIDCEL	(user specified, if any)	16,19,21	-
CAPACI	-	10,15,16,17,18,19, 21,27	11,12,13,14,25,28
		(all restart files)	(all scratch files)
TRILIN	22	10,15,16,17,18,19, 21,27	11,12,13,14,25,28
		(all restart files)	(all scratch files)
DETECT	(user specified, if any)	10,15,16,17,19	11,12,13,14,28

5.4 SAMPLE KEYWORD FILES

Here we have three examples of keyword files to be read by RDOPT. They are shown in example 5.1.

File 'USED' is the one used for the sample run — Chapter 9. The keyword meanings are, in order of appearance: The computational grid will be 17 x 17 x 17. There will be just one such grid (NG). Boundary conditions will be 1/r and initial guess potentials will be 1/r (IOUTER = 2). For each potential solution, 20 iterations will be taken (MAXITR). The sun will be located in the direction (1,1,-1/2) (SUNDIR), and will have intensity of 1 a.u. (SUNINT). The timestep for each cycle (there is only one time cycle for each TRILIN call, as NCYC has the default value of 1) will be 1/10 second (DELTA). The LONGTIMESTEP option will be used. Finally, potential contour plots are requested at the end of each time cycle.

File 'END' has just one card — the 'END' card. This is a complete keyword file as it stands. All keywords assume their default values, and you can proceed with object definition, or even a complete charging simulation.

File 'NOTUSED' shows some other keywords. XMESH sets the grid spacing for the innermost grid to 0.25 meter. (Each outer grid has twice the spacing of the one before.) In this run there would be two nested grids, as NG adopts the default value of 2. BFIELD sets up a constant magnetic field with x, y, and z components given in Webers/m^2. FIXP fixes the potential of conductor #1 (spacecraft ground) at zero. NCYC, DELTA, and DELFAC together determine that there will be 10 time cycles, the first will be 0.1 second, the next will be 0.15 second, and so on, each 1.5 times the one before. SURFACE CELL will cause flux information to be printed for surface cell #15. Potentials for both grids will be printed at the end of each TRILIN invocation (APRT = 2). IROUSP asks for charge contour plots. NCON requests extra potential contour

plots — one each at the planes X = 6 and Y = 6 in outer grid units. In inner grid units this would correspond to X = 3 or Y = 3. X or Y = 9 would mean the same plane (mesh center) in either grid. Finally the user changes the file number for IP (potential array) to 29, instead of the default of file 10.

```
******  END  ******


   1.            END


******  NOTUSED  ******


   1.            XMESH                          .25
   2.            BFIELD                          0.  -.000040   .000049
   3.            FIXP                             1       0.
   4.            NCYC                            10
   5.            DELTA                           .1
   6.            DELFAC                         1.5
   7.            SURFACE CELL                    15
   8.            APRT                             2
   9.            IROUSP                           1
  10.            NCON                             2
  11.                1     6     2     6
  12.            IP                              29
  13.            END


******  USED  ******


   1.            NZ                              17
   2.            NG                               1
   3.            IOUTER                           2
   4.            MAXITR                          20
   5.            SUNDIR                      1.          1.          -.5
   6.            SUNINT                      1.
   7.            DELTA                       .1
   8.            LONGTIMESTEP
   9.            ICON                             1
  10.            END
```

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Example 5.1. Three keyword files. The bottom file is used as the keyword input file for the sample run in Chapter 9.

6. OBJDEF

When describing a complicated three-dimensional object, people are apt to use sketches, hand gestures, and the expression, "It's like ...." An object definition that NASCAP understands must be limited to words and numbers, which can seem at times awkward and unwieldly.

NASCAP needs for its computations several detailed lists indicating which grid points touch on what surface material and which conductors lie below. The user obviously does not want to describe the object one grid point at a time. Therefore, the user needs only know about what we call <u>user building blocks</u>. These can be used to describe simple objects very simply, yet they can also be used for the most complicated objects NASCAP can handle. (The more complicated objects generally require building block overlap — see Overlap section).

The program takes the building block information and generates its own lists of smaller blocks and surface cells. Beyond verifying that this code breakdown does indeed represent the proper object, the user can largely ignore this process.

6.1 USER BUILDING BLOCKS

These six building blocks represent the basic shapes you would imagine necessary. There is a rectangular parallelepiped, a wedge, and a tetrahedron. There are objects to generate the best approximation we can make to a sphere and a cylinder, and there is a special object called FIL111.

Our computational scheme demands two basic restrictions on the objects to be defined. First, no dimensions can be smaller than one grid unit. Second, any surface must be normal to one of the twenty-six symmetry directions of the cubic mesh.

For pictures of the six user building blocks, see Figure 6.1.

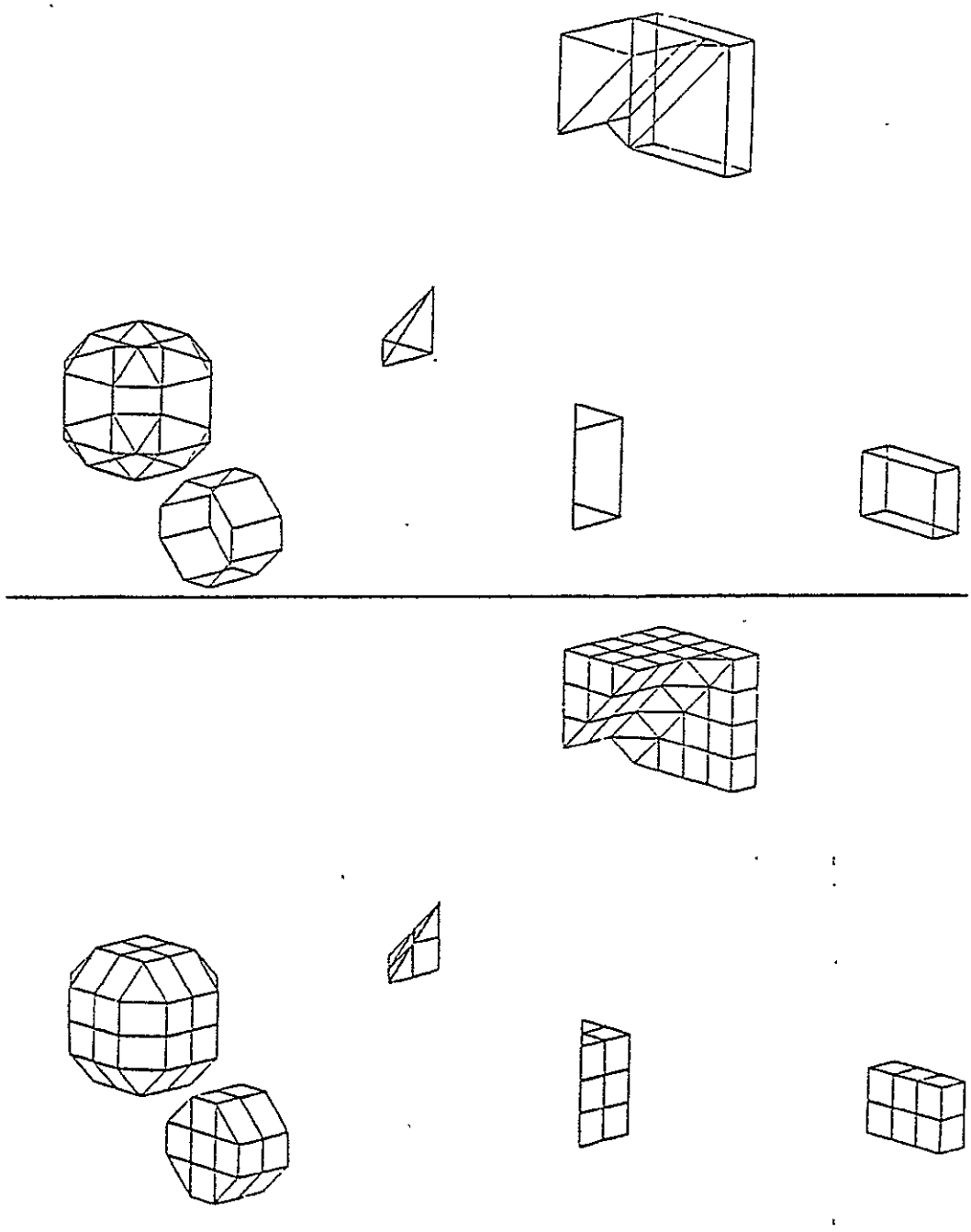

Figure 6.1. The six building block types are shown here. The uppermost object shows a FIL111 smoothing a corner. Below, from left to right are quasisphere, octagon right cylinder, tetrahedron, wedge, and rectangular parallelepiped.

6.2 MATERIALS

In addition to object shape and position, the user has to tell NASCAP what the surface materials are all around the object boundary. Surface materials can be anything at all, as the user defines the materials. Each exposed surface must be associated with some surface material. Otherwise the surface will be "invisible" to NASCAP. (Exception: The octagon and quasisphere surfaces default to the first defined material if none is specified.)

The present version of NASCAP makes use of fourteen material properties; storage is provided for twenty. The twenty values are read on three cards following the material name using FORMAT (F10.0). The input values are converted to code values by subroutine MATPRO and its subsidiary routines.

Property 1: Relative dielectric constant (dimensionless).

Property 2: Thickness of dielectric film or vacuum gap (meters).

Property 3: Electrical conductivity (mho/m). The value -1. indicates a vacuum gap over a conducting surface.

Property 4: Atomic number (dimensionless).

Property 5: Maximum secondary electron yield for electron impact at normal incidence (dimensionless).

Property 6: Primary electron energy to produce maximum yield at normal incidence (keV).

Properties 7-10: Range for incident electrons. <u>Either</u>:

$$\text{Range} = P_7 E^{P_8} + P_9 E^{P_{10}}$$

where the range is in angstroms and for the energy in keV,

<u>or</u>

P_7 = -1. to indicate use of Feldman's[1] empirical range formula

P_9 = density (g/cm^3)

P_{10} = mean atomic weight (dimensionless).

Property 11: Secondary electron yield for normally incident 1 keV protons.

Property 12: Proton energy to produce maximum secondary electron yield (keV).

Property 13: Photoelectron yield for normally incident sunlight (A/m^2).

Property 14: Surface resistivity in ohms/square. If less than 0 ignore this property.

6.2.1 Sample Values

There is a great deal of uncertainty in all property values concerned with particle range, low energy electron emission or conductivity of insulators. With that warning, we present below the input values we have tentatively adopted for clean aluminum, clean magnesium, teflon, kapton and SiO_2.

Aluminum

Property	Value	Comment
1	1.0	Vacuum gap
2	0.001	$\sim 10^{-2}$ mesh units
3	-1.	Conductor
4	13.	
5	0.97	See Reference 2-4
6	0.3 keV	
7	260 A	
8	1.3	See Reference 5
9	240 A	
10	1.73	
11	1.36	
12	40 keV	
13	4.0×10^{-5} A/m^2	See Reference 6
14	0.0	

Magnesium

Property	Value	Comment
1	1.0	Vacuum gap
2	0.001	$\sim 10^{-2}$ mesh units
3	-1.	Conductor
4	12.	
5	0.92	See Reference 2-4
6	0.25 keV	
7	-1.	Feldman's formulation, Reference 1
8	--	
9	1.74	Density, gm/cm^3
10	24.3	Atomic weight
11	1.36	
12	40. keV	
13	2.0×10^{-5} $A.m^2$	
14	0.0	

Teflon

Property	Value	Comment
1	2.0	
2	1.27×10^{-4}	5 mil
3	1.0×10^{-14} mho/m	
4	10.	
5	3.0	Reference 7
6	0.3 keV	
7	-1.	Feldman's formulation, Reference 1
8	--	
9	2.00	Density, gm/cm^3
10	16.7	Atomic weight
11	1.40	
12	70. keV	
13	2.0×10^{-5} A/m^2	
14	3.0×10^{13} ohms	

Kapton

Property	Value	Comment
1	3.5	
2	1.27×10^{-4}	5 mil
3	1.0×10^{-14} mho/m	
4	5.0	
5	2.1	Reference 7
6	0.150 keV	
7	-1.	Feldman's formulation, Reference 1
8	--	
9	1.42	Density, gm
10	9.8	Atomic weight
11	1.40	
12	70. keV	
13	2.0×10^{-5} A/m^2	
14	1.0×10^{16} ohms	

SiO_2

Property	Value	Comment
1	4.0	
2	1.27×10^{-4}	5 mil
3	1.0×10^{-14} mho/m	
4	10.	
5	2.4	Reference 2-4
6	0.4 keV	
7	250 A	
8	0.12	Reference 8
9	360 A	
10	1.63	
11	1.40	
12	70.0 keV	
13	2.0×10^{-5} A/m^2	
14	1.0×10^{19} ohms	Uncoated glass value is 1.0×10^{9} ohms

6.3 FURTHER PROCESSING

Object definition for the user ends when a set of building blocks has been chosen and located in space and surface materials have been specified. But NASCAP still has work to do. The code takes the defined user building blocks and breaks them into a set of smaller blocks — the volume elements. Each volume element is a single unit cube or part of a single unit cube in the computational grid. (See Figure 6.6.)

NASCAP will use the volume elements throughout the rest of the computation. To be sure that NASCAP and the user have the same object in mind, it is important for the user to examine a set of satellite plots. The cycle of object definition — plot examination — revised object definition, should be expected to run for several iterations before an object of any complexity is properly defined.

6.4 OVERLAP

The NASCAP user building blocks are unlike children's toys in one respect — two or more blocks can occupy the same space. When this happens, the most recent definition has priority. It is often necessary to use this feature to define surface material patterns.

In Figure 6.2 for example, most of the large cube has a bare aluminum surface. Two surface cells, however, have a coating of teflon. We could define a set of five disjoint rectangular parallelepipeds, each with the proper surfaces, to make up the cube. But an easier way is to use the overlap feature. We need define only two building blocks.

Example 6.1 is the object definition file used to define this object. Figure 6.3 shows one of the resulting material plots.

Notice that we have only defined one surface of the second building block. All other surfaces (in particular the minus x surface) are invisible. They do not replace existing surface definitions.

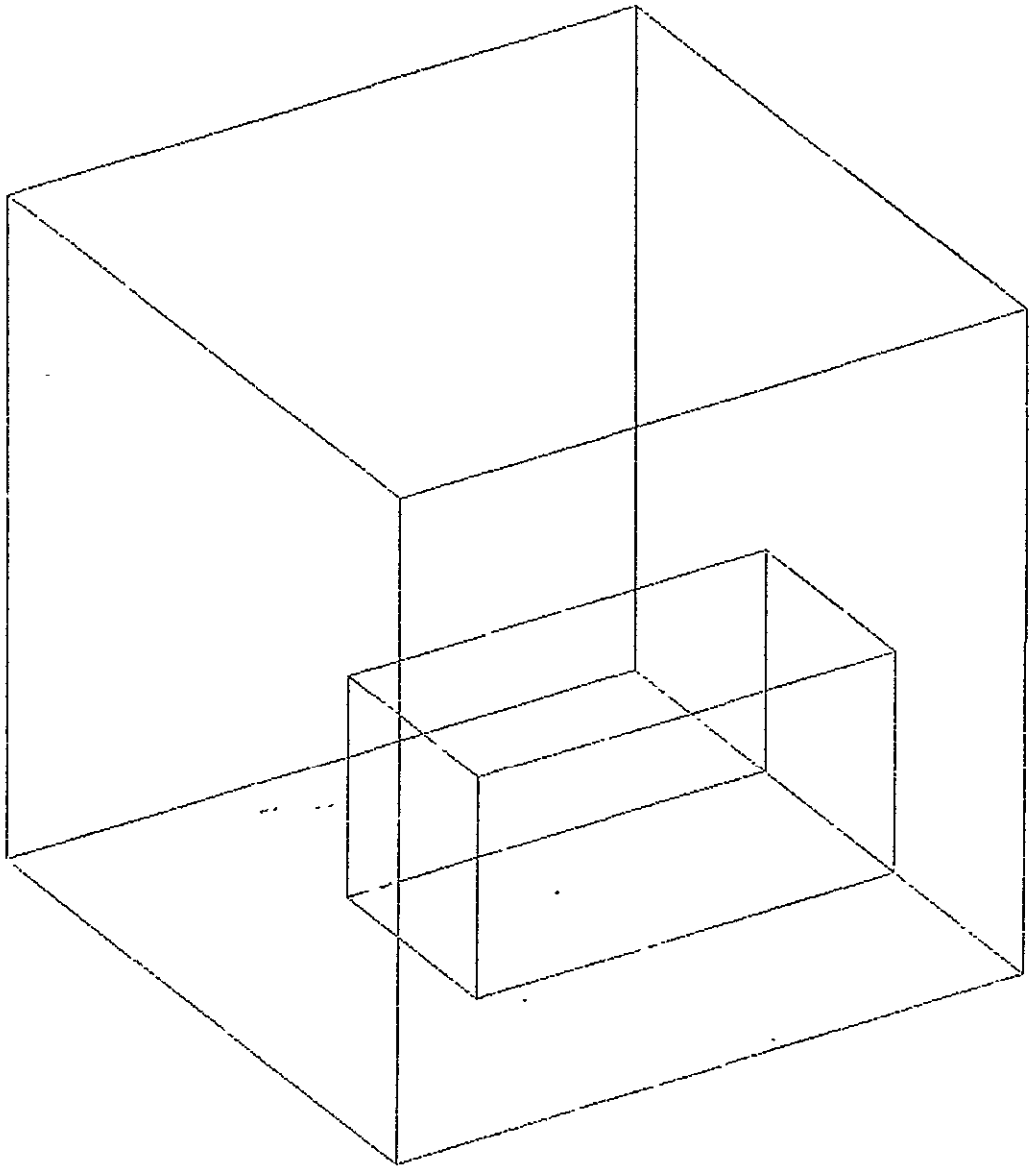

Figure 6.2. Two rectangular parallelepipeds are overlapped.

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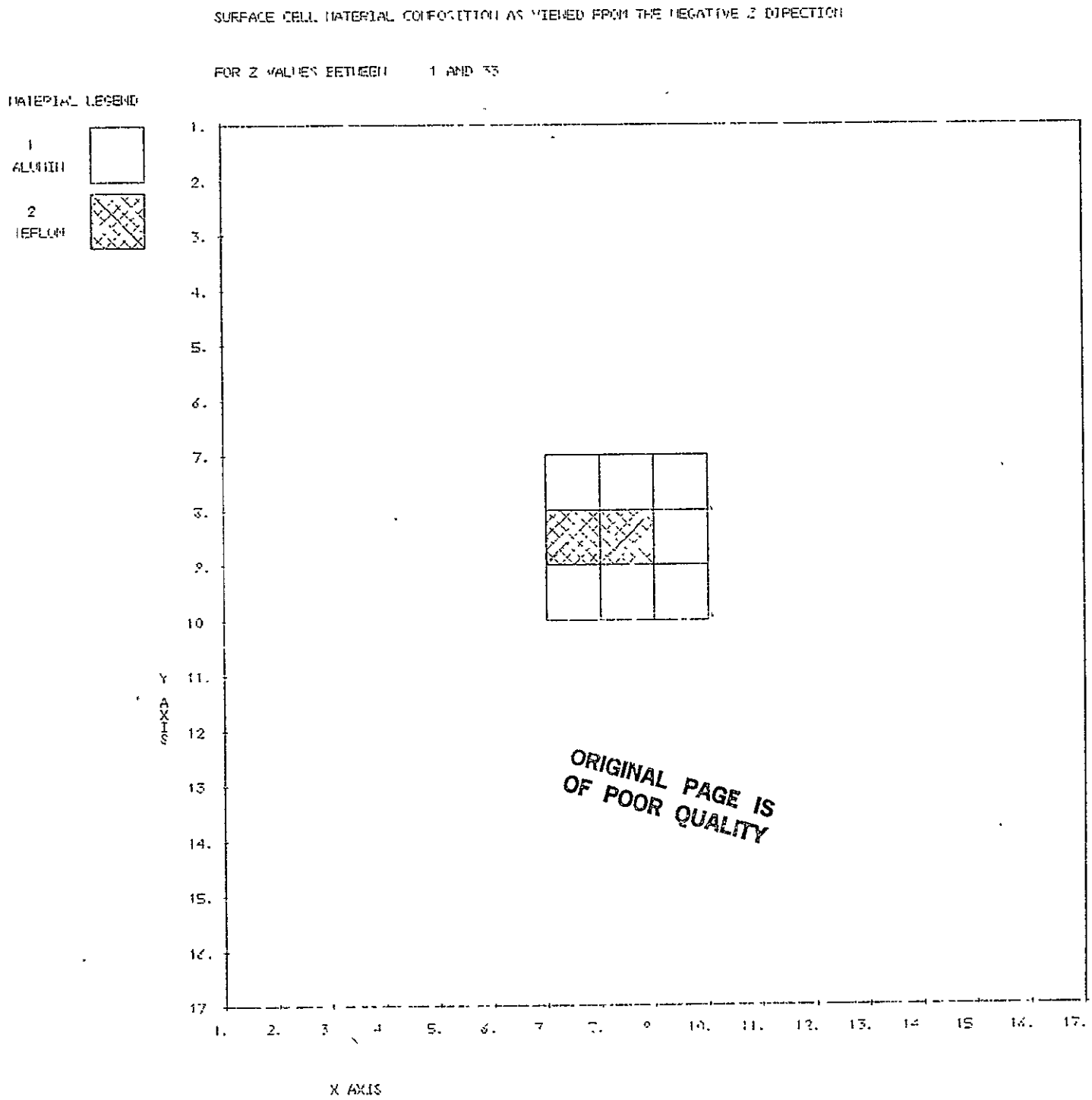

Figure 6.3. As a result of the overlap shown in Figure 6.2, two surface cells are redefined as being teflon coated.

6.5 SATPLT

Satellite illustration plots clearly show the three important structures at object definition time — user building blocks, NASCAP code blocks, and surface materials cell-by-cell. These plots should be generated and examined whenever the user has any uncertainty about an object.

It is simple to get the satellite plots. The control word SATPLT will generate a complete set. The default set includes six material plots (two-dimensional plots from $\pm x$, $\pm y$, and $\pm z$ directions), three building block plots (all lines show), and three corresponding code block plots (hidden lines removed).

6.6 THE OBJDEF FILE

The OBJDEF file has two main sections — a materials section and a building block section.

The materials section is a set of one or more material definitions. Each material requires one card with the material name, and three cards with material property values, 20 values in all. Notice that with these cards you are defining a material to be whatever you want. If you make up a crazy material name and give it physically impossible values, NASCAP will accept your definition with a straight face. Likewise, if you misdefine teflon, your mistake will not be corrected. There are no default materials.

The material name is read in A6 format from the first six columns, and the 20 material properties come in 8F10.0 format. Any unrecognized keyword is taken to be a material name.

The building block section is a set of one or more user building block definitions, plus miscellaneous other optional inputs.

Each building block definition is constructed as shown in Table 6.1 (Building Block Formats). A building block definition starts with one of the words RECTAN, WEDGE, TETRAH, OCTAGO, QSPHER, FIL111. It ends with the word ENDOBJ. In between, various inputs are required according to the building block being defined. Columns 1-10 are read in A6 format (columns 7-10 ignored). All numerical input in this section is I5 format.

The miscellaneous words recognized in the building block section are ENDSAT, COMMENT, OFFSET, CONDUCTOR, COMPRESS, and DELETE.

ENDSAT marks the end of object definition input. The other six words may occur in any order before the first building block, between building blocks, or after the last building block. Only the first six characters of each word are significant.

ENDSAT: End of satellite definition. Must appear as last card in file.

COMMENT: No action initiated. Ignore this card.

OFFSET: Subsequent coordinate definitions for building blocks are taken relative to the absolute coordinates on this card. Format is 3I5 in columns 11-25. Default offset is the center of the mesh. Default offset is not (0,0,0).

CONDUCTOR: The surfaces of subsequent building blocks will overlay the conductor whose index is given in column 15. The maximum conductor index is 7. The default is 1. If different surfaces of a single building block are to overlay different conductors, define the building block twice. Each time include SURFACE cards only for the surfaces over the conductor number in effect at the time.

COMPRESS: Causes elimination of redundant surface cells. This is sometimes necessary to stay under the 1024 limit.

DELETE: Changes to type 0 (empty elt) the volume elt with origin X, Y, Z (format 3I5 in columns 11-25). All surface cells associated with this volume elt are deleted.

TABLE 6.1
BUILDING BLOCK FORMATS[1,2,3,4]

Columns 1 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45
For the Rectangular Parallelepiped							
RECTAN							
CORNER	x	y	z				
DELTAS	Δx	Δy	Δz				
(Surface Cards)							
ENDOBJ							
For the Wedge							
WEDGE							
CORNER	x	y	z				
FACE	(material name)		(normal to face — type 110)				
LENGTH[5]	Δx	Δy	Δx				
ENDOBJ							

Columns 1 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45
For the Tetrahedron							
TETRAH							
CORNER	x	y	z				
FACE	(material name)		(normal to face — type 111)				
LENGTH[6]	Δx						
(3 Surface Cards)							
ENDOBJ							
For the Octagonal Right Cylinder							
OCTAGO							
AXIS[7,8]	x	y	z	(blank)	x′	y′	z′
WIDTH[9]	w						
SIDE[9]	s						
(3 Special Surface Cards[10]	"+","-" or "C"						
ENDOBJ							

Columns 1 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45
For the Quasisphere							
QSPHER							
CENTER[11]	x	y	z				
DIAMETER[12]	d						
SIDE[12]	s						
MATERIAL	(material name)						
ENDOBJ							
For the FIL111 Surface							
FIL111							
CORNERLINE[13]	x	y	z	(blank)	x´	y´	z´
FACE[14]	(material name)		(normal to face — type 111)				
ENDOBJ							
The Surface Card							
SURFACE	±x,y,z (col.11-12)	(blank)	(material name)				

NOTES:

1 All small letters refer to user-specified integers in I5 format.

2 (material name) means a word of one to ten letters identical to a material that has been defined.

3 (normal to face) is three integer values in I5 format. Only permissible values are -1, 0, +1. For type 110 normals, one of the three values is zero. For type 111, zero is not permitted as a value.

4 (surface cards) represents from zero to six cards specifying surface material. Columns 1-7 read "SURFACE". Columns 11, 12 read '+x', '-x', '+y', '-y', '+z', or '-z', to indicate the outward normal of some face. Columns 21-30 contain a material name of any previously defined material.

5 Wedge — two of the values Δx, Δy, Δz must be equal. All must be greater than 0.

6 For the tetrahedron $\Delta x = \Delta y = \Delta z$.

7 (x,y,z) is the low index end of the axis. (x´,y´,z´) is the high index end. The axis must lie along a grid line.

8 If the width is odd, the axis line will be moved +1/2 grid unit in both normal directions. This aligns the octagon faces with the grid.

9 Width and side lengths must be both even or both odd. See Figure 6.5 for illustration of octagon.

10 Special surface cards recognize only the symbols '+' (for plus end), '-' (for minus end), and 'C' (for circumference) of cylinder.

11 If diameter is odd, quasisphere center will be moved +1/2 grid unit in each direction. This aligns the quasisphere on the grid.

12 Diameter and side lengths must be both even or both odd. These are analogous to width and side on the octagon.

13 Two of the differences (x´-x), (y´-y), and (z´-z) must be equal. The other must be zero.

14 All surfaces of the FIL111 will be of the same material as the face. Usually, most of the other surfaces will be interior to the corner being filled in.

6.7 OCTAGON AND QSPHERE

In defining the building blocks OCTAGON and QSPHERE, the user must be aware of one restriction. The specification of WIDTH (or DIAMETER) and SIDE must be both even or both odd to allow the object to fit into the three-dimensional grid. Figure 6.4 shows the meaning of these specifications.

Note also that if the octagon WIDTH and SIDE are both odd, the CENTER will be incremented by 1/2 grid unit in both directions, perpendicular to the axis. A quasisphere with odd diameter will have its center incremented in all three directions. This is necessary to align the object on the grid.

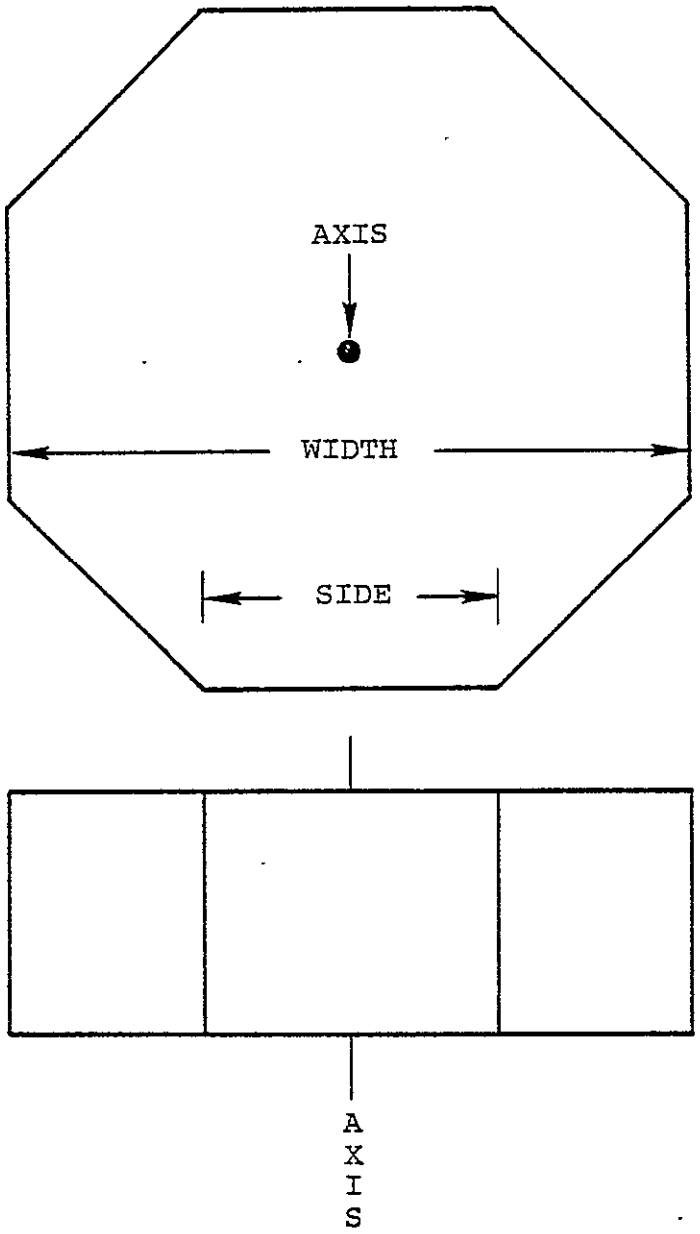

Figure 6.4. Axis, width and side of octagonal right cylinder.

6.8 FIL111

The FIL111 building block is a special purpose item designed expressly to fill in right angle corners that do not lie along grid lines. As such, it has some unavoidable peculiarities which should be noted by the FIL111 user.

If defined all alone, without a corner to fill in, the FIL111 looks like Figure 6.5. We see it is made of truncated cubes and tetrahedra volume elts. Now look at the way the FIL111 is actually used in Figures 6.11-6.22. Notice where the teflon of the FIL111 overlaps the aluminum of the wedge blocks. This is a square face of the truncated cube turning up where you might not expect it.

There are two other peculiarities of this building block that should be mentioned. The most important is that it must be defined <u>after</u> the corner it fills. Otherwise you would end up replacing the truncated cube elts with wedge elts. (See Section 6.10, Restriction #6.)

Secondly, and of little practical importance to the user, the building block representation of the FIL111 is not congruent to the volume elt representation. The building block version ignores the "back half" of each truncated cube elt.

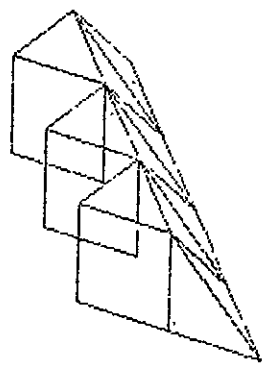

Figure 6.5. A FIL111 building block all by itself.

6.9 ELTS AND CELLS

The six types of user building blocks give rise to four types of code-generated volume elements or volume elts. The four volume elt types give rise to four distinct surface cell types.

The four volume elt types (shown in Figure 6.6) are cube, wedge, tetrahedron, and truncated cube. Inspection of these types will reveal the four types of surface cell needed.

1. Square: With sides of one grid unit, the square surface cell is part of the cube, wedge, and truncated cube.
2. Rectangle: It has dimensions 1 x $\sqrt{2}$ grid units, and is found only on the wedge. The normal to a rectangle surface is type (110), i.e., it forms a 45° angle with exactly two of the coordinate axes.
3. Right triangle: Found on the wedge, tetrahedron, and truncated cube. Like the square, it has a type (100) normal (parallel to a coordinate axis).
4. Equilateral triangle: Found on the tetrahedron and truncated cube — has sides of length $\sqrt{2}$. It has a type (111) normal.

6.9.1 Surface Cell List

OBJDEF prints out the full Surface Cell List, as well as a breakdown of each surface cell word. Figure 6.7 shows the surface cell codes. Figure 6.8 shows a sample Surface Cell List.

The normal as shown in the list is the outward normal. The X, Y, and Z coordinate shown for a surface cell is the origin of the volume element out of which the surface normal points. This is the lowest index vertex of the volume element on or within which the surface resides. It is not necessarily

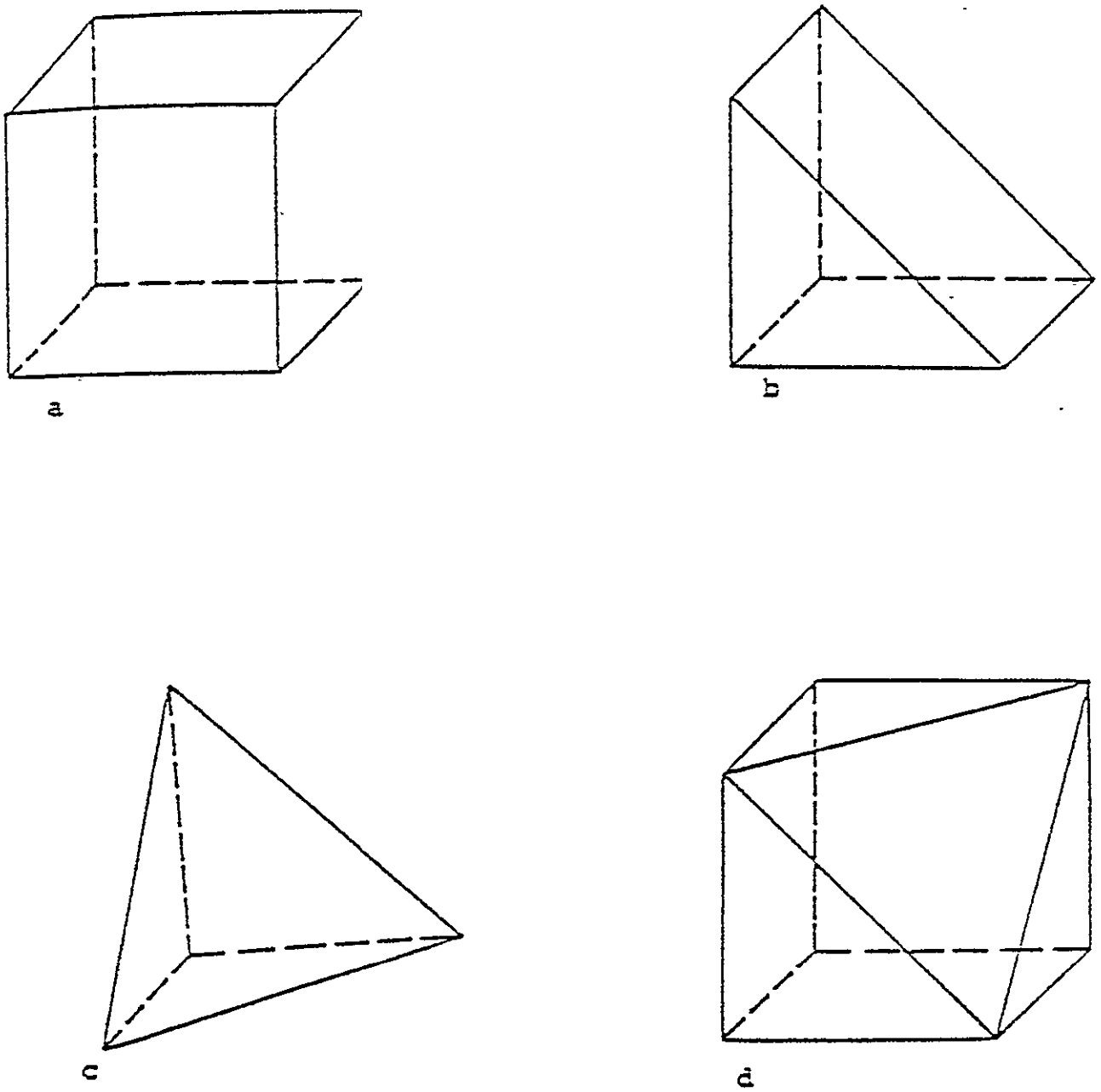

Figure 6.6. Four shapes of volume elts to be considered by NASCAP code: (a) empty cube; (b) wedge-shaped cell with 110 surface; (c) tetrahedron with 111 surface; (d) truncated cube with 111 surface.

```
5 43 210 987654 321098 765432 109876 5 43210
  |__| |___| |______| |______| |______| |_____| | |_____|
   H   G      F       E       D       C    B    A
```

Field	Bits	
A	4-0	Material index
B	5	Set for right-triangular 100 surfaces and for 111 surfaces whose enclosing volume cell is mostly empty
C	11-6	Direction of surface normal (in crystallographic notation)
D	17-12	Z-coordinate
E	23-18	Y-coordinate
F	29-24	X-coordinate
G	32-30	Conductor index
H	34-33	Orientation code for right-triangular 100 surfaces

Figure 6.7. Surface cell list (JSURF) entry format.

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IX	IY	IZ	NORMAL			MATERIAL
1	010707077742	1	7	7	7	-1	-1	-1	TEFLON
2	010707107402	1	7	7	8	-1	-1	0	TEFLON
3	010707117402	1	7	7	9	-1	-1	0	TEFLON
4	010707127542	1	7	7	10	-1	-1	1	TEFLON
5	010710076302	1	7	8	7	-1	0	-1	TEFLON
6	010710106002	1	7	8	8	-1	0	0	TEFLON
7	010710116002	1	7	8	9	-1	0	0	TEFLON
8	010710126102	1	7	8	10	-1	0	1	TEFLON
9	010711076302	1	7	9	7	-1	0	-1	TEFLON
10	010711106002	1	7	9	8	-1	0	0	TEFLON
11	010711116002	1	7	9	9	-1	0	0	TEFLON
12	010711126102	1	7	9	10	-1	0	1	TEFLON
13	010712076742	1	7	10	7	-1	1	-1	TEFLON
14	010712106402	1	7	10	8	-1	1	0	TEFLON
15	010712116402	1	7	10	9	-1	1	0	TEFLON
16	010712126542	1	7	10	10	-1	1	1	TEFLON
17	011007071702	1	8	7	7	0	-1	-1	TEFLON
18	011007101402	1	8	7	8	0	-1	0	TEFLON
19	011007111402	1	8	7	9	0	-1	0	TEFLON
20	011007121502	1	8	7	10	0	-1	1	TEFLON
21	011010070302	1	8	8	7	0	0	-1	TEFLON
22	011010120101	1	8	8	10	0	0	1	ALUMIN
23	011011070302	1	8	9	7	0	0	-1	TEFLON
24	011011120101	1	8	9	10	0	0	1	ALUMIN
25	011012070702	1	8	10	7	0	1	-1	TEFLON
26	011012100402	1	8	10	8	0	1	0	TEFLON
27	011012110402	1	8	10	9	0	1	0	TEFLON
28	011012120502	1	8	10	10	0	1	1	TEFLON
29	011107071702	1	9	7	7	0	-1	-1	TEFLON
30	011107101402	1	9	7	8	0	-1	0	TEFLON
31	011107111402	1	9	7	9	0	-1	0	TEFLON
32	011107121502	1	9	7	10	0	-1	1	TEFLON
33	011110070302	1	9	8	7	0	0	-1	TEFLON
34	011110120101	1	9	8	10	0	0	1	ALUMIN
35	011111070302	1	9	9	7	0	0	-1	TEFLON
36	011111120101	1	9	9	10	0	0	1	ALUMIN
37	011112070702	1	9	10	7	0	1	-1	TEFLON

Figure 6.8. Partial Surface Cell List, as printed by OBJDEF.

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a vertex of the surface cell itself. In fact, if the surface normal points in the +X, +Y, or +Z direction, the coordinates given will represent a point that is definitely not on the surface itself.

6.9.2 Volume Element Table

After it prints out the Surface Cell List, OBJDEF prints a summary of material properties — input values and code values. Then it prints a digest of the Volume Element Table.

The Volume Element Table or eltable is a 17 x 17 x 33 array with an entry for each of the unit cubic volume spaces in the innermost grid. Naturally, most of the spaces represent either empty space or space completely filled by the object. It is only cubic spaces that are part filled and part empty and those that are subdivided that require special handling.

These partly filled volume elts and subdivided elts are the ones printed out in a table by OBJDEF. They are, to put it in a different way, all those elements with an element type greater than zero. Element type 0 is the empty space elt. Element types are pictured in Figures 7.4 to 7.9 (in TRILIN Chapter).

The element table code is described in Figure 6.9. Figure 6.10 shows a sample volume elt table.

CODE FOR ELEMENT TABLE [LTBL(NX,NY,NZ)].

```
54321 0987654321 0 9 8 765 432109876 5 43210
      |__________|   | |    |__________| |_____|
           E         D C         B          A
```

Field	Bits	
A	4-0	Elt-type code
B	14-6	Orientation code
C	18	Set if elt is completely filled (interior)
D	19	Set for an empty special elt
E	30-21	Index used to reference PHOJ array to determine low energy electron currents

ORIENTATION CODE

3 x 3 bits. Each group of 3 contains 1, 2 or 3 in the lower 2 bits, with the high bit set for negative.

Code $(-)^{m_1} i_1$, $(-)^{m_2} i_2$, $(-)^{m_3} i_3$

takes (r_1,r_2,r_3) to $(-)^{m_1} r_{i_1}$, $(-)^{m_2} r_{i_2}$, $(-)^{m_3} r_{i_3}$

e.g., the following codes take a point to (x,y,z):

Octal Code	Dec. Code	Point
123	1,2,3	(x,y,z)
365	3,-2,-1	(-z,-y,x)
532	-1,3,2	(-x,z,y)
176	1,-3,-2	(x,z,-y)
567	-1,-2,-3	(-x,-y,-z)
617	-2,1,-3	(y,-x,-z)

Figure 6.9. Element table codes and orientation codes.

ELEMENT TABLE

I	J	K	ENTRY
7	7	7	000000056704
7	7	8	000000056301
7	7	9	000000056301
7	7	10	000000056304
7	8	7	000000075201
7	8	10	000000035201
7	9	7	000000075201
7	9	10	000000035201
7	10	7	000000052704
7	10	8	000000052301
7	10	9	000000052301
7	10	10	000000052304
8	7	7	000000067101
8	7	10	000000063101
8	10	7	000000027101
8	10	10	000000023101
9	7	7	000000067101
9	7	10	000000063101
9	10	7	000000027101
9	10	10	000000023101
10	7	7	000000016704
10	7	8	000000016301
10	7	9	000000016301
10	7	10	000000016304
10	8	7	000000071201
10	8	10	000000031201
10	9	7	000000071201
10	9	10	000000031201
10	10	7	000000012704
10	10	8	000000012301
10	10	9	000000012301
10	10	10	000000012304

56 VOLUME CELLS NUMBERED BY NUMLTB.

Figure 6.10. Sample Volume Element Table, as printed by OBJDEF.

6.10 RESTRICTIONS ON OBJECT GEOMETRY

There are certain objects that can be defined using the six user building blocks, which NASCAP would not be able to handle. The restrictions are as follows:

1. The maximum number of surface cells is 1024.[a]
2. All objects are defined in the innermost mesh.[b]
3. No point of the object surface can lie on the boundary of the innermost mesh. That is, all surfaces must be at least one unit away from the mesh edges.[c]
4. Every volume element at the border of the innermost mesh must be type 0 (empty space — trilinear potential function). This implies that a subdivided surface cell must be two units from mesh boundary, likewise right triangle surface cells.[c]
5. Only volume cells of standard type are allowed. For instance, an empty cube cell cannot have two right triangle faces.
6. A partially filled volume elt cannot be superseded by partially filled elt, except through the use of the DELETE command.

(a) This limit to be increased to 1250.

(b) Long booms will be allowed to extend to the outer meshes.

(c) Restriction 4 to be eliminated. Restriction 3 will then be that no surface cell can correspond with the inner mesh boundary.

6.11 SAMPLE OBJECT DEFINITION

Several examples of object definition files follow. Most of the satellite illustrations in this manual were produced using these files.

The final object definition file shown here defines an example of each type of user building block. The FIL111 block is shown filling in a corner between a wedge and a rectangular parallelepiped — the intended use for the FIL111.

The final Figures 6.11 to 6.22 illustrate the types. This is the default set of plots from SATPLT. First material plots, then three dimensional projections and hidden line views.

```
ALUMINUM
1.          0.001       -1.         13.         0.97        .3          260.        1.3
240.        1.73        1.36        40.             4.E-05  14.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
TEFLON
2.          0.000127        1.E-14   10.        3.          0.3         -1.         0.
2.2         16.7        1.4         70.             2.E-05  14.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
OFFSET        0     0     0
RECTANGULAR PARALLELEPIPED
CORNER        7     7     7
DELTAS        3     3     3
SURFACE   +X         ALUMINUM
SURFACE   -X         ALUMINUM
SURFACE   +Y         ALUMINUM
SURFACE   -Y         ALUMINUM
SURFACE   +Z         ALUMINUM
SURFACE   -Z         ALUMINUM
ENDOBJ
RECTANGULAR PARALLELEPIPED
CORNER        7     6     7
DELTAS        2     1     1
SURFACE   -Z         TEFLON
ENDOBJ
ENDSAT
```

Example 6.1. Overlap object definition. This file defines the overlapping rectangular parallelepipeds shown in Figure 6.2.

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```
ALUMINUM
1.          0.001       -1.         13.         0.97        .3          260.        1.3
240.        1.73        1.36        40.             4.E-05  -1.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
TEFLON
2.          0.000127        1.E-14    10.       3.          0.3         -1.         0.
2.2         16.7        1.4         70.             2.E-05  -1.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
OFFSET          0     0     0
QSPHERE
CENTER          9     9     9
DIAMETER        4
SIDE            2
MATERIAL    TEFLON
ENDOBJ
RECTANGULAR PARALELLEPIPED
CORNER          8     8     9
DELTAS          2     2     2
SURFACE     +Z          ALUMINUM
ENDOBJ
ENDSAT
```

Example 6.2. Teflon coated QSPHER with one aluminum face. This file was used as the object definition file (NASOBJ) for the sample run in Chapter 9.

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```
ALUMINUM
1.        0.001     -1.       13.       0.97      .3        260.      1.3
240.      1.73      1.36      40.           4.E-05  14.     15.       16.
17.       18.       19.       20.       21.       22.       23.       24.
TEFLON
2.        0.000127      1.E-14   10.    3.        0.3       -1.       0.
2.2       16.7      1.4       70.           2.E-05  14.     15.       16.
17.       18.       19.       20.       21.       22.       23.       24.
KAPTON
3.5       0.000127      1.E-14    5.    2.1       0.15      -1.       0.
 1.42     9.8       1.4       70.           .00002   14.    15.       16.
17.       18.       19.       20.       21.       22.       23.       24.
OFFSET        0     0     0
TETRAH
CORNER       10    10     6
FACE      TEFLON       -1    -1     1
LENGTH        4
SURFACE   +X        KAPTON
SURFACE   +Y        KAPTON
SURFACE   -Z        KAPTON
ENDOBJ
RECTAN
CORNER        8     8     8
DELTAS        4     4     2
SURFACE   +X        ALUMINUM
SURFACE   -X        ALUMINUM
SURFACE   +Y        ALUMINUM
SURFACE   -Y        ALUMINUM
SURFACE   +Z        ALUMINUM
SURFACE   -Z        ALUMINUM
ENDOBJ
ENDSAT
```

Example 6.3. Unidentified compound object. This file generated the object shown in Figure 8.1.

```
ALUMINUM
1.          0.001       -1.         13.         0.97        .3          260.        1.3
240.        1.73        1.36        40.             4.E-05  14.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
TEFLON
2.          0.000127        1.E-14    10.       3.          0.3         -1.         0.
2.2         16.7        1.4         70.             2.E-05  14.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
KAPTON
3.5         0.000127        1.E-14     5.       2.1         0.15        -1.         0.
 1.42       9.8         1.4         70.             .00002  14.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
MAGNESIUM
1.          0.001       -1.         13.         0.97        .3          260.        1.3
240.        1.73        1.36        40.             4.E-05  14.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
SIO2
1.          0.001       -1.         13.         0.97        .3          260.        1.3
240.        1.73        1.36        40.             4.E-05  14.         15.         16.
17.         18.         19.         20.         21.         22.         23.         24.
CONDUCTOR      1
OFFSET         2     2     2
MESH SIZE    .0254
RECTANGULAR PARALLELEPIPED
CORNER         0     0     0
DELTAS         2     3     1
SURFACE    +X          ALUMINUM
SURFACE    +Y          ALUMINUM
SURFACE    +Z          ALUMINUM
SURFACE    -X          KAPTON
SURFACE    -Y          KAPTON
SURFACE    -Z          KAPTON
ENDOBJ
CONDUCTOR      2
OFFSET        12    12    28
QSPHERE
CENTER        -3    -2     0
DIAMETER       4
SIDE           2
MATERIAL   TEFLON
ENDOBJ
CONDUCTOR      3
OFFSET        12     4    24
TETRAHEDRON
CORNER        -1    -1    -1
FACE       TEFLON          1     1     1
LENGTH         2
SURFACE    -X          ALUMINUM
SURFACE    -Y          ALUMINUM
SURFACE    -Z          ALUMINUM
ENDOBJ
CONDUCTOR      4
```

Object 1
RECTAN

Object 5
QSPHER

Object 3
TETRAH

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Example 6.4. Page 1 of 2.

```
OFFSET          3    12    22
OCTAGON
AXIS            0     0    -1          0     0     1
WIDTH           3
SIDE            1
SURFACE    -Z          ALUMINUM
SURFACE    +Z          ALUMINUM
SURFACE    C           SIO2
ENDOBJ
CONDUCTOR       5
OFFSET          4     9    12
WEDGE
CORNER         -1    -1    -1
FACE      TEFLON          C     1     1
LENGTH          3     2     2
SURFACE    -X          ALUMINUM
SURFACE    -Y          MAGNESIUM
SURFACE    -Z          ALUMINUM
SURFACE    +X          KAPTON
ENDOBJ
CONDUCTOR       6
OFFSET         12    12     2
RECTANGULAR PARALLELEPIPED
CORNER         -1    -1     0
DELTAS          4     4     1
SURFACE    +X          ALUMINUM
SURFACE    +Y          ALUMINUM
SURFACE    +Z          ALUMINUM
SURFACE    -X          ALUMINUM
SURFACE    -Y          ALUMINUM
SURFACE    -Z          ALUMINUM
ENDOBJ
WEDGE
CORNER          3     3     1
FACE      ALUMIN          -1    -1     0
LENGTH          3     3     3
SURFACE    +X          ALUMINUM
SURFACE    +Y          ALUMINUM
SURFACE    -Z          ALUMINUM
SURFACE    +Z          ALUMINUM
ENDOBJ
OFFSET          0     0     0
FIL111
CORNER         12    15     3          15    12     3
FACE      TEFLON          -1    -1     1
ENDOBJ
ENDSAT
```

Object 4 OCTAGO

Object 2 WEDGE

Object 3 RECTAN, WEDGE, FIL111

Example 6.4. Page 2 of 2. Six disjoint objects. This object definition file produces each of the various user building blocks. The result is shown in Figures 6.11 to 6.22.

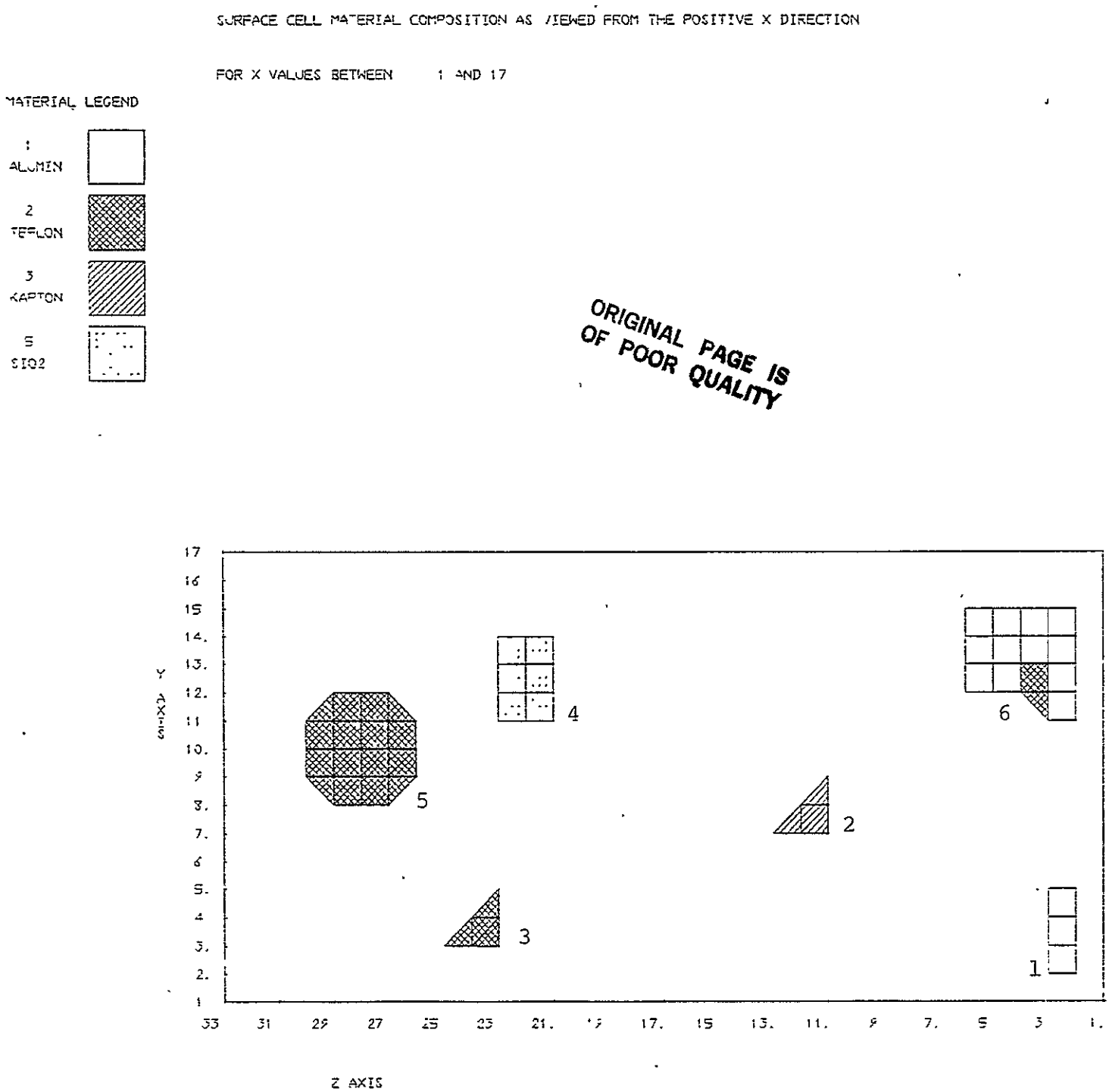

Figure 6.11. Material plots of six user building blocks. (1) rectangular parallelepiped; (2) wedge; (3) tetrahedron; (4) right octagonal cylinder; (5) quasisphere; (6) compound object consisting of aluminum rectangular parallelepiped, aluminum right triangular prism, and teflon <111> wedge.

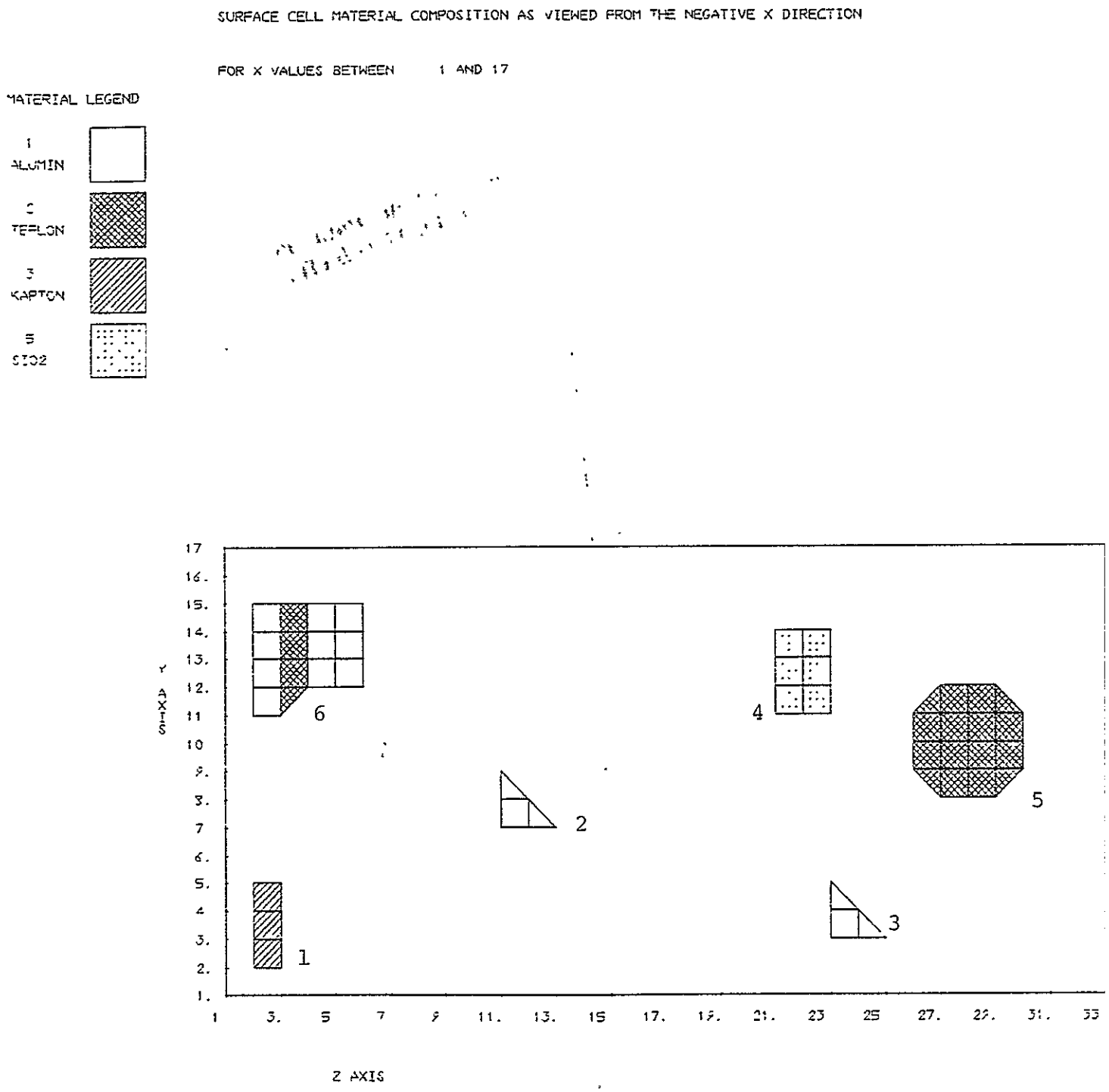

Figure 6.12. Another view of Figure 6.11.

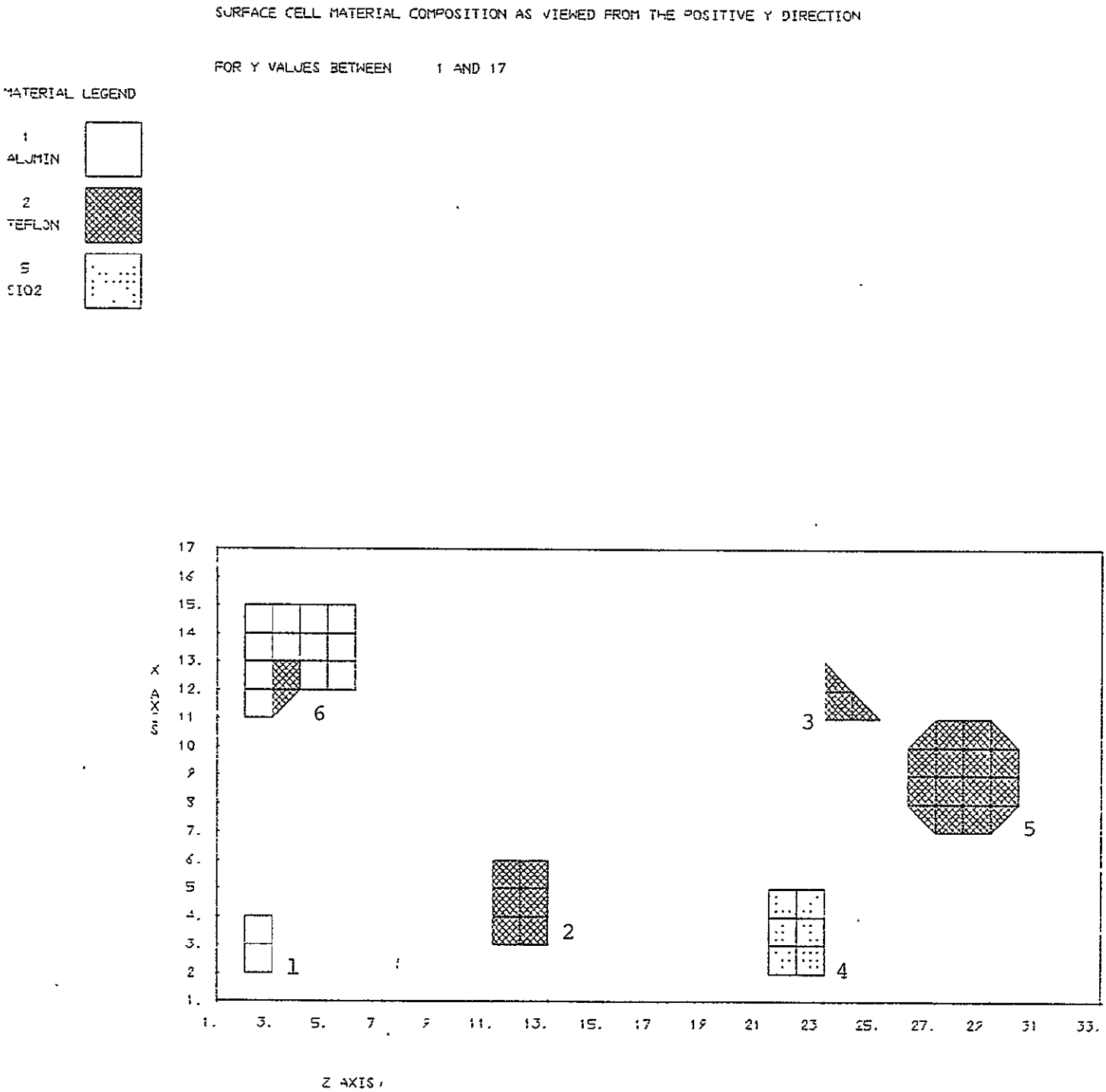

Figure 6.13. Another view of Figure 6.11.

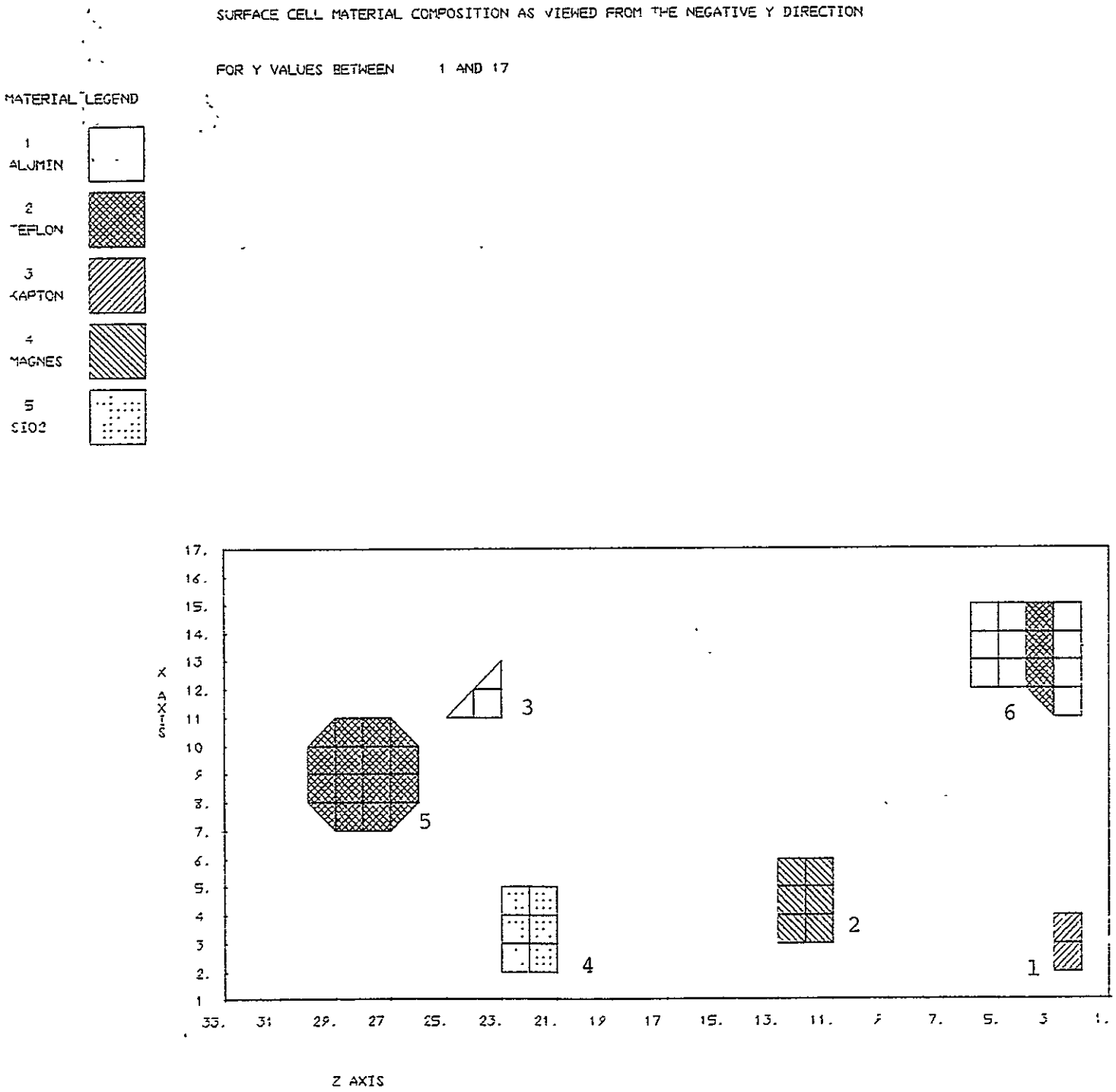

Figure 6.14. Another view of Figure 6.11.

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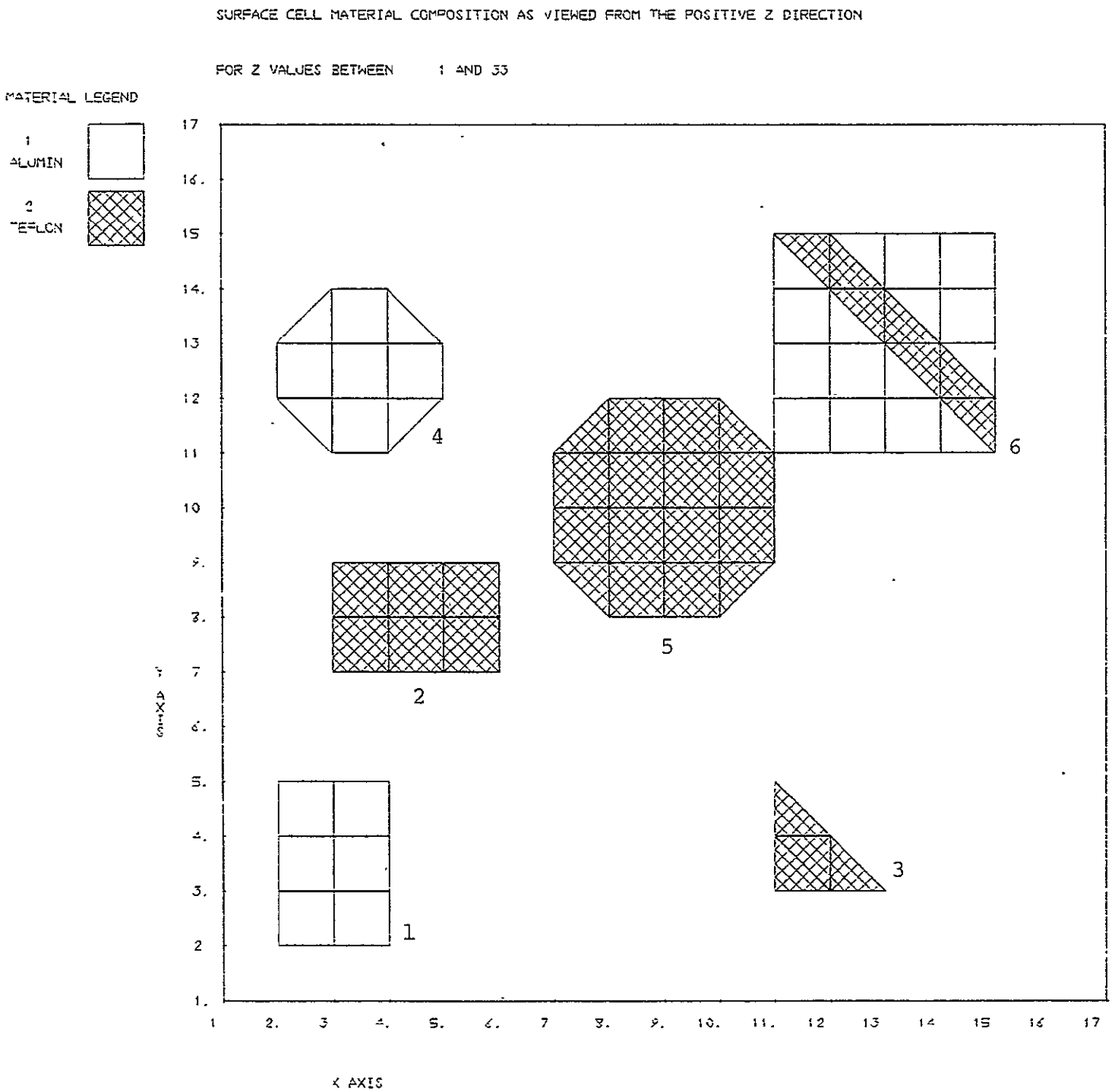

Figure 6.15. Another view of Figure 6.11.

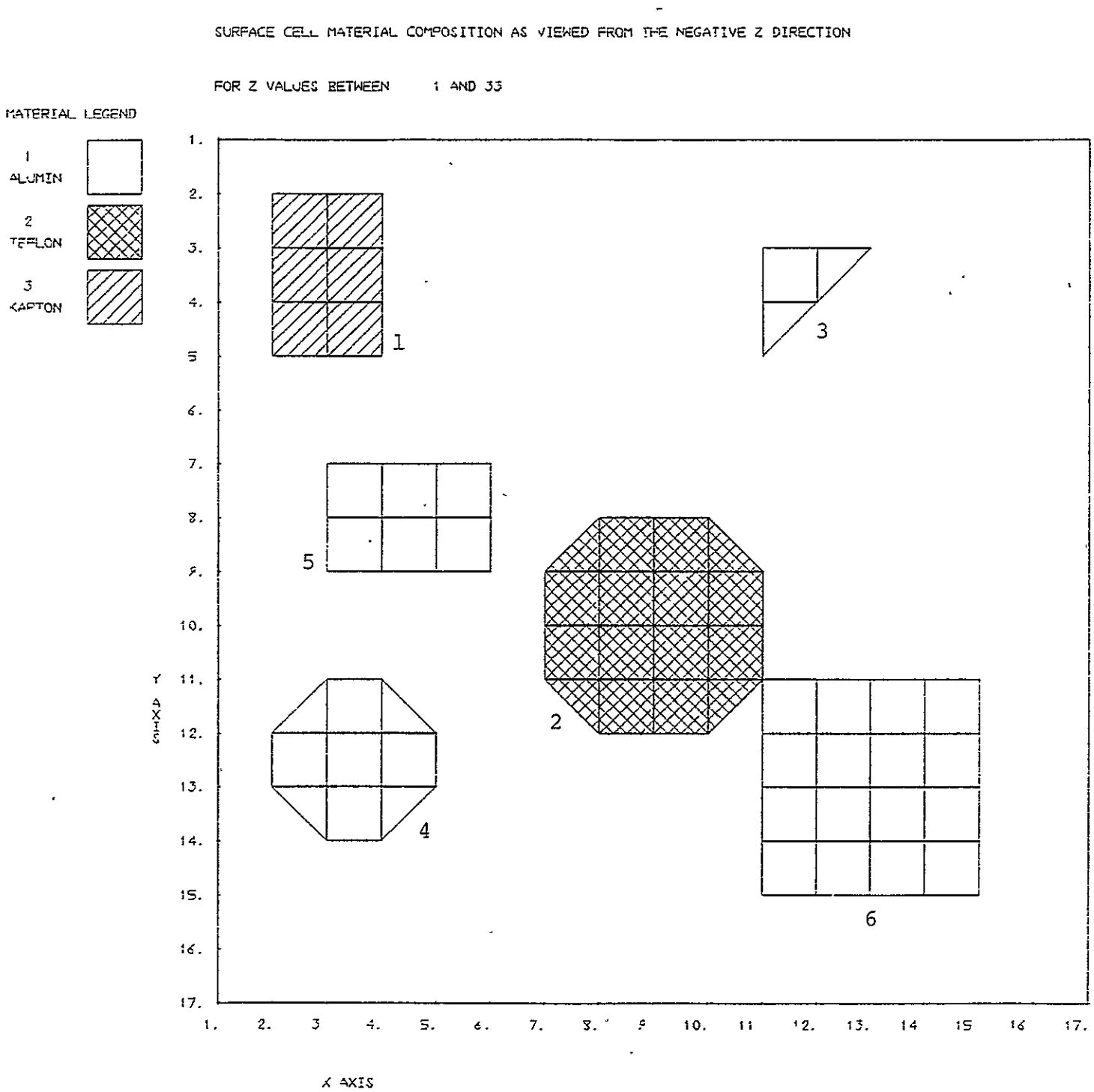

Figure 6.16. Another view of Figure 6.11.

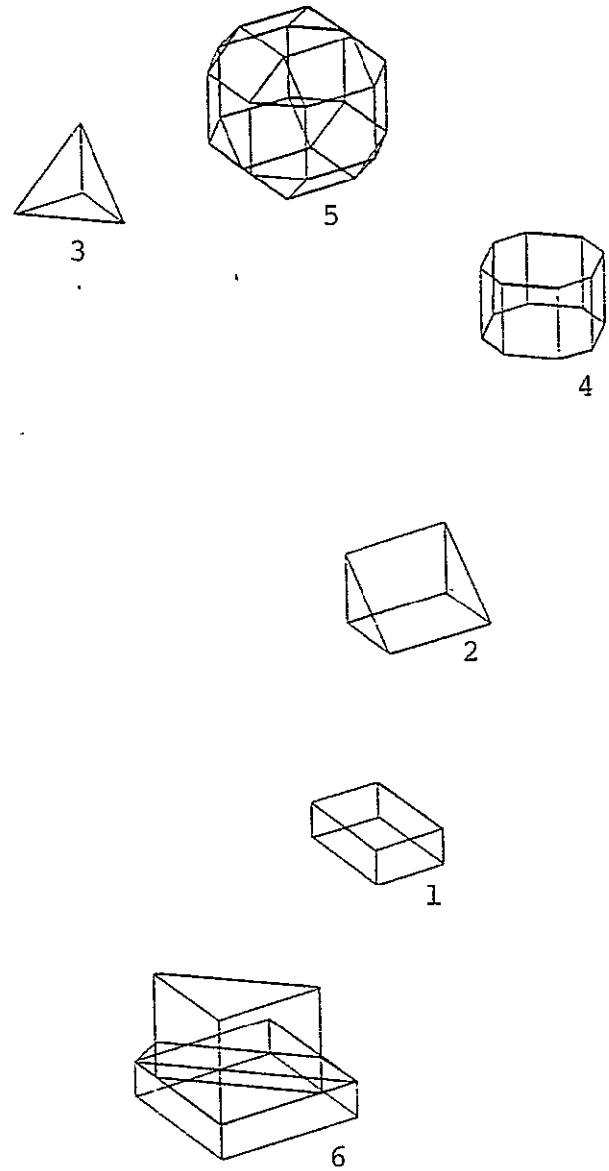

Figure 6.17. A perspective view of the six user building blocks; no hidden line elimination.

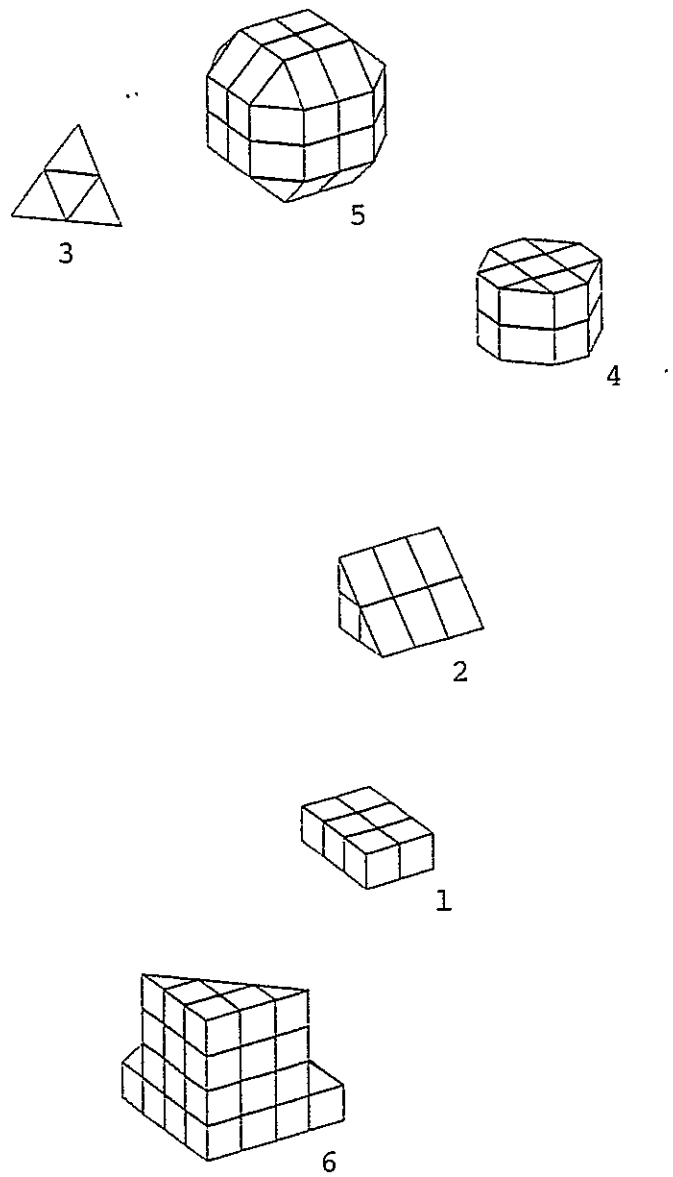

Figure 6.18. The same as Figure 6.17, but with hidden line elimination and showing surface cells.

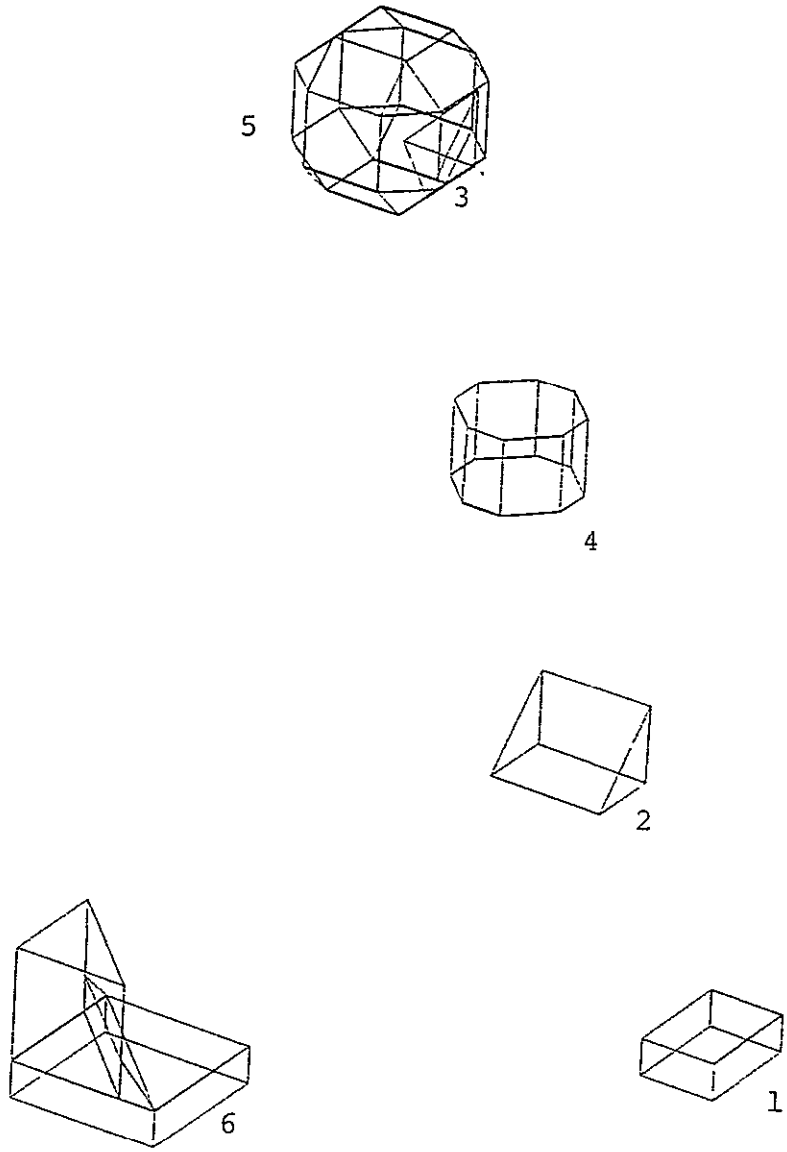

Figure 6.19. Another view of Figure 6.17. The tetrahedron is behind the quasisphere.

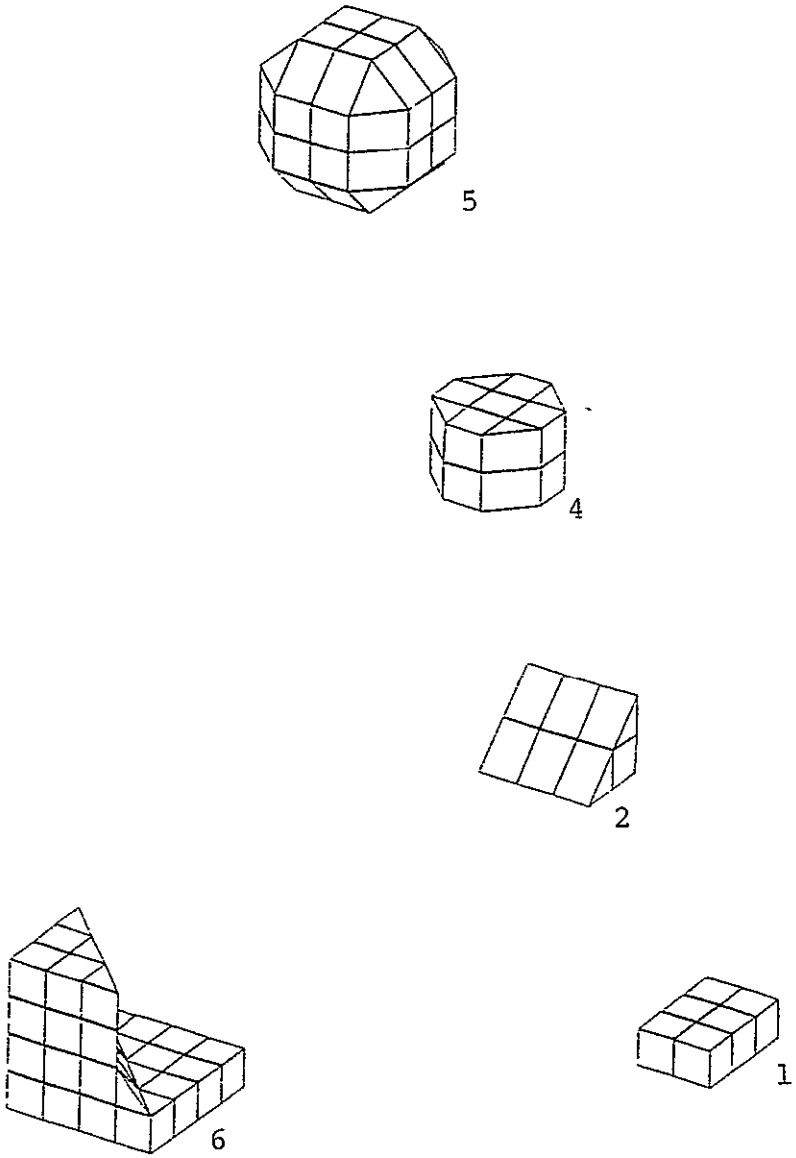

Figure 6.20. Hidden lines removed. The tetrahedron is almost completely obscured.

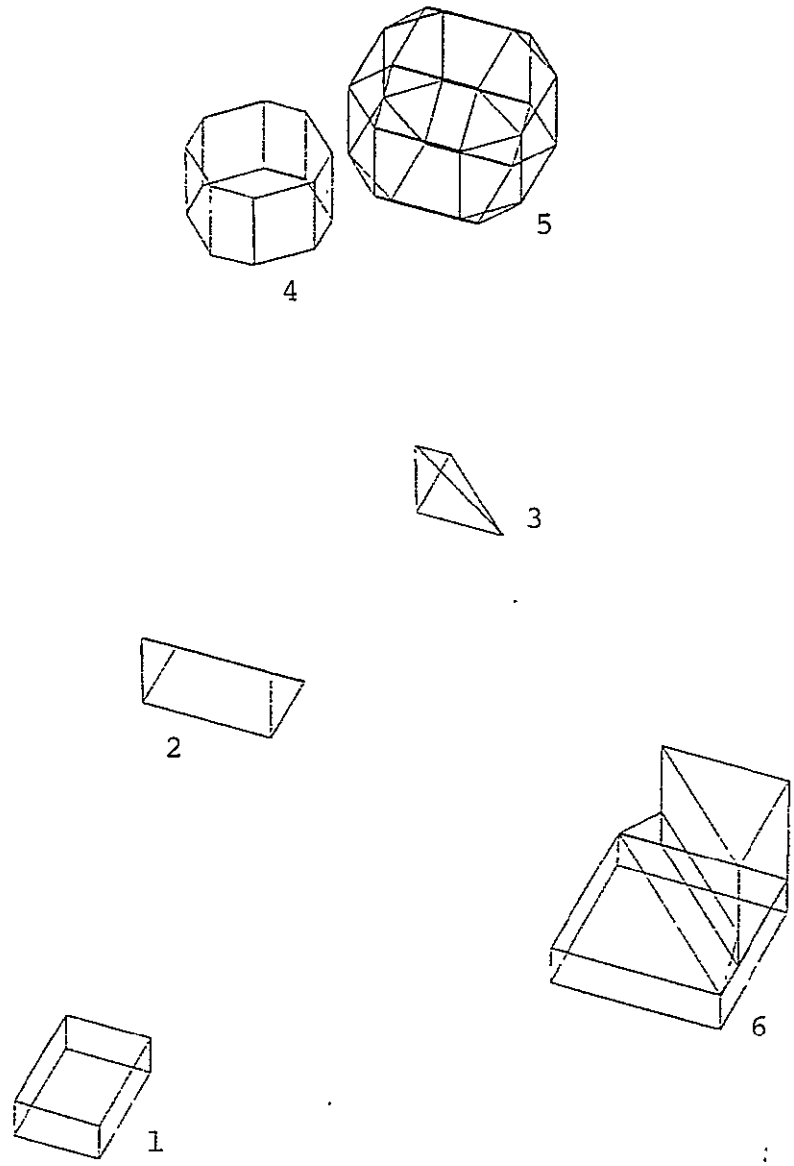

Figure 6.21. Another view of Figure 6.17.

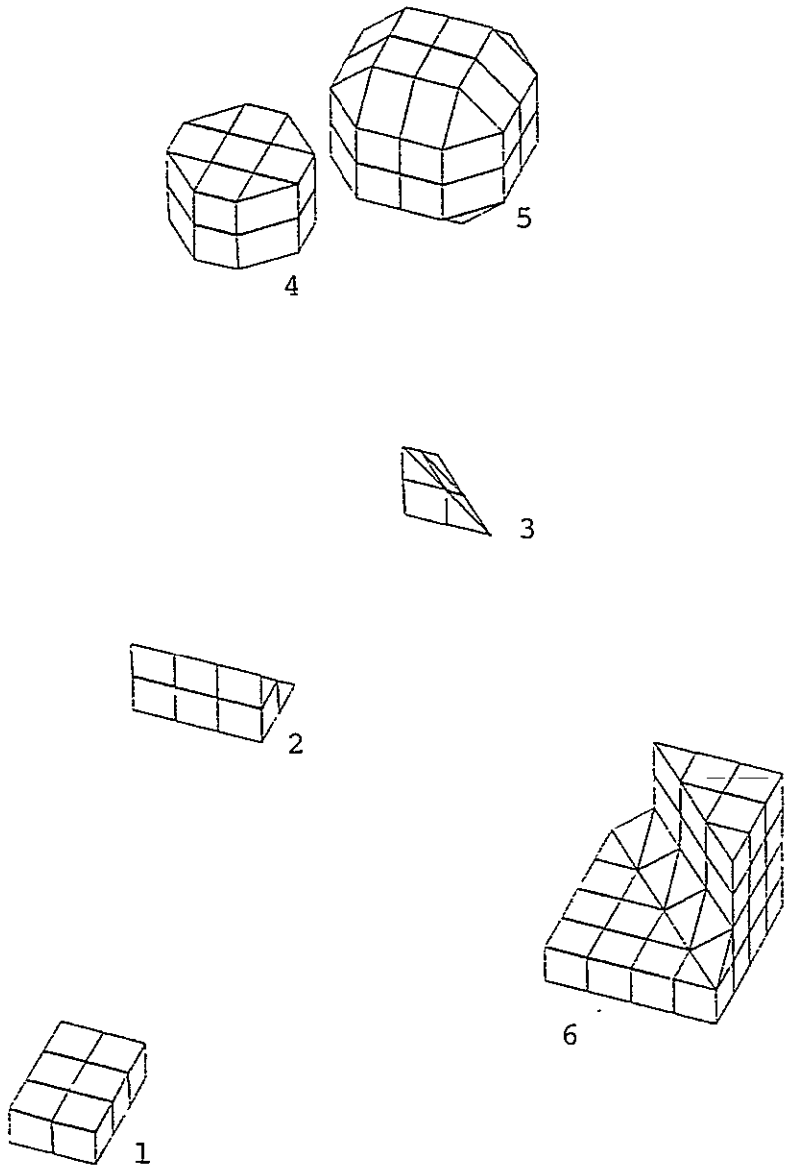

Figure 6.22. One last view. This is the twelfth of twelve default plots generated by SATPLT.

C-2

7. TRILIN — CAPACI

TRILIN performs the actual satellite charging calculation. It is the heart of the NASCAP code. This subroutine is initiated by a control card reading "TRILIN ii" where ii is an optional I2 integer specifying the file number where a flux definition is to be found. File number 5 is the input stream, i.e., flux definition immediately follows the TRILIN card. A blank field means the flux definition is in file IFLUX (by default, file 22).

TRILIN operates by alternating calls to CHARGE and POTENT. POTENT calculates potentials on the entire computational grid, given the charge distribution generated by CHARGE and LIMCEL. CHARGE generates a new current distribution from the user flux definition and the most recent potentials from POTENT. TRILIN also makes use of the new LIMCEL routines when the LONGTIMESTEP option is invoked.

7.1 CHARGE

Subroutine CHARGE, called by TRILIN, obtains the required information from external files to calculate currents to the object. CALFLX calls routines to calculate the incident and emitted fluxes for each surface cell. Surface cell properties are decoded by GETCEL. For the test tank case, the incident flux is computed by SOURCE and ETNGUN; for the reverse trajectory case by PUSH. ELFLUX, PRFLUX, BKSCAT and SOLFLX compute emitted fluxes of electron- and proton-produced secondaries, backscattered electrons and photoelectrons, respectively. IOFLX performs printouts of these properties as requested. SHECAL (called from CHARGE) and PHOCUR perform the photosheath calculation. EFIELD and BFIELD provide the force fields required by the particle-tracking routines PUSH, ETNGUN and PHOCUR.

7.2 POTENT — POISSON'S EQUATION

To solve Poisson's equation on our three-dimensional mesh, we are faced with solving a system of linear equations

$$Ap = q$$

where q is a vector representing the charge at every point on the three-dimensional grid. The vector p is our solution vector — the potentials at every grid point. A is a large square matrix.

Realize that p and q are very large vectors — for a two grid problem with NZ = 33, they would be 2 x (17 x 17 x 33) = 19,074 words long. (They are most easily thought of here as one-dimensional arrays.) Our large A matrix would then be 19,074 x 19,074; that is, more than three hundred million words long, far too large to handle as a whole. Fortunately, A is a sparse matrix which we can form piece by piece as needed.

To solve this system of equations without inverting A, we use an iterative method — the Scaled Conjugate Gradient technique. This method converges very rapidly — ten to forty iterations are sufficient for most NASCAP problems.

7.2.1 Scaled Conjugate Gradient Algorithm

Figure 7.1 outlines the scaled conjugate gradient technique, as it is performed by subroutine POTENT. Capital A and D represent square matrices (D is a diagonal matrix). Lower case letters represent vectors — in particular p^n is the desired solution potential vector. Scalars are represented by Greek letters.

The diagonal matrix D is represented in storage by a vector. The sparse matrix A is never constructed. The operation (A) (u^n) is performed as a series of 16 x 16 x 32 (maximum) times the number of grids, operations.

In the code documentation, the names of the various arrays and scalars are

	Code Name
D	DIV
a	AUN
p	P
r	R
u	U
q	ROUS
ρ	RDOTRS
ρ'	RDOTR
α	ALPHA
β	BETA

There is also an intermediate variable UDOTAU = $u^n \cdot a^n$.

Figure 7.1. Scaled conjugate gradient technique, as performed by subroutine POTENT. (Page 1 of 2.)

```
SUBROUTINE POTENT
        CALL GETDIV              (construct D)

        CALL COPROD              a^o = (A) (p^o)

        CALL URSET0              r^o = q^o - a^o
                                 u^o = (D) (r^o)
                                 ρ = r^o · u^o

        n = 0

A:      CALL COPROD              a^n = (A) (u^n)
                                 α = ρ/(u^n · a^n)

        CALL PUPDAT              p^(n+1) = p^n + αu^n

        CALL RUPDAT              r^(n+1) = r^n - αa^n
                                 ρ´ = r^(n+1) · (D) (r^(n+1))
                                 β = ρ´/ρ

        CALL UUPDAU              u^(n+1) = βu^n + (D) (r^(n+1))

        n = n+1

        ρ = ρ´

        IF finished RETURN

        ELSE GO TO A:
```

Figure 7.1 (Page 2 of 2.)

7.2.2 POTENT Data Management

The two big problems in executing the routines in Figure 7.1 are first, to perform data management in an efficient way, and second, to calculate Au or Ap.

Efficient data management is necessary because available core space is barely sufficient to store the entire p vector for a three grid problem. Therefore we bring only one grid's worth of the p vector into core at a time, while the rest resides on a mass storage file. The same goes for the other five vectors r, u, q, a, div.

In addition, because I-O time for these vectors is a significant factor, we use seven files to store the six vectors. Then when, for instance, a new p vector is being calculated, the new p is written out on the spare file while the old p is read in from the old p file. The old p file then becomes the spare file for the next operation.

7.2.3 Coproduct Calculation

The calculation $a^n = (A)\ (u^n)$ is a complicated matter, handled by subroutine COPROD. As stated before, the A matrix is too large to be stored in any fashion. So a^n is calculated in a series of 8 x 8 matrix operations which, if taken all together, would add up to the complete A matrix.

Each volume element in our computational space is represented by an 8 x 8 array. This array, when multiplied by part of the u^n array (the eight vertex points of the given volume element), will yield a part of the a^n array. The 8 x 8 array used depends on the element type. Figures 7.5 to 7.10 show the arrays for each type.

7.2.4 Interface Region in COPROD

One volume element type not shown in these figures is the interface element. Figure 7.2 shows, in a two-dimensional sense, what happens at the boundary between two grids. The square marked A has nodes at its four vertices. The square B has five nodes, an extra one along one side, and must receive special handling. In three dimensions, a typical empty space element has eight nodes (at the vertices). Most interface elements have thirteen nodes — five extra. The subroutine COPROD calls special routines to handle interface nodes.

Data management is a problem for the interface regions. During most of the COPROD calculation we have in core one grid worth of the u^n array, and one grid worth of the a^n array. For the interface region we need two grids worth of u^n to calculate two grids worth of a^n. Unfortunately, it won't all fit. Two grids of u^n and one of a^n is our limit.

So we do the interface calculation twice — once for the interface nodes of the inner grid, and once for the interface nodes of the outer grid.

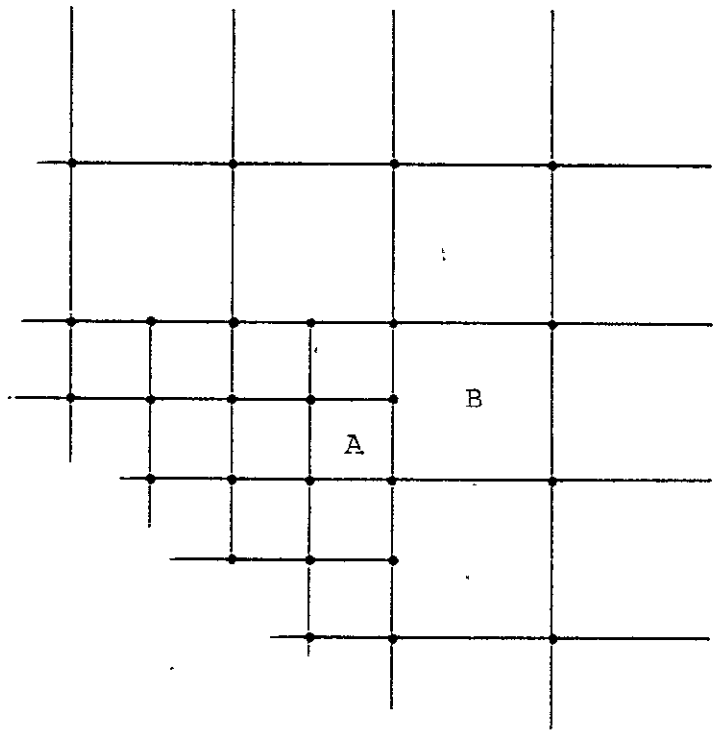

Figure 7.2. Two dimensional representation of grid interface region. "A" is typical empty space element. "B" and all like it are interface elements.

7.3 FLUX DEFINITION FILE

The first card of the IFLUX file must contain the word 'TYPE' in columns 1-4 and 1, 2, 3, or 4 in column 10. The value must agree with the value of keyword ITYPE. If ITYPE is not specified in the keyword file, it assumes a default value of 2. The types are:

1 — Test tank, electron beam case

2 — Isotropic Maxwellian space case

3 — Particle-pushing space case

4 — Double Maxwellian space case

Subsequent cards differ for each case.

Type 1 — Test tank with electron beam source (see Figs. 7.3, 7.4)

Card 2	— IBMCAL (I4) Normally 0; set to 1 for stop after initial beam calibration.
Card 3	— Z-location of beam calibration plane in grid units (F10.1).
Card 4	— Beam size (X and Y) at the calibration plane (meters) (2F10.2).
Card 5	— Beam energy (eV) (F10.1).
Card 6	— Initial electron velocity in code units (E10.2).
Card 7	— Gun location in outer grid units (3F10.1).
Card 8	— Sample plane (in grid units) (F10.1).
Card 9	— Total beam current (amperes) (F10.1).
Cards 10-45	— Current density calibration values (11F4.1).

All beam information is calibrated using the maximum value of the beam size from card 4. The current density array contains the current density profile as a function of (R,θ) for 36 evenly spaced angles and 11 evenly spaced radial values. Each card read contains the 11 radial values at a single angular value.

$$r_i = \frac{(i-1)}{10} \times \text{beam size (card 4)}$$

$$\theta_i = \frac{(i-1)}{36} \times 2\pi$$

The central value is repeated on each card. The values are read in arbitrary units and the code will normalize the total beam current to the input value. Card 8, the sample plane location, should be on or behind the target; it is used for terminating particle trajectories. (See Figures 7.10, 7.11.)

Type 2 — Maxwellian probe approximation

All cards are FORMAT (F10.0, A6). Accepted literals are MKS and CGS for plasma density, EV, JOULES, KEV, and KELVIN for plasma temperature. The first density/energy refers to electrons and the last to protons. The literal END is also accepted, and terminates the flux definition.

Type 3 — Flux determined by reverse trajectory particle tracking

Card 2 contains one of the two literals (A6) MAXWEL or DEFOR. Following 'MAXWEL' input is as in Type 2, (q.v.), except an END card is required. Following 'DEFOR', cards are required giving IUNIT, IHOUR, IDAY (I5/F10.0/I5). The data contained in the ELT NASCAP.DEFOR must have been copied onto file IUNIT.

Subsequent cards contain

NSPEC	(I5)	Number of species
NENG	(I5)	Number of energies
NTHET	(I5)	Number of polar angles
NPHI	(I5)	Number of azimuthal angles
NSTP	(I5)	Maximum number of steps per particle

RMASS(1), CHARGE(1)	(2F10.16)	
.		Mass (kg), charge (C)
.		
.		
RMASS(NSPEC), CHARGE(NSPEC)		
VCODE	(F10.6)	Initial code velocity
STV(3)	(3F10.0)	Vector characterizing flux anisotropy

The present code requires NSPEC = 2, with species 1 being electrons and species 2 protons. The final card, STV, may be omitted, in which case the flux is assumed isotropic.

Type 4 — Double Maxwellian flux definition input

Flux definition input file consists of the TYPE card specifying type 4, followed by up to four cards specifying Maxwellian components, and (optionally) an END. Each component card consists of five 10-column fields, each field containing a (left-justified) literal or a floating-point number (F10.0).

The fields of the component cards and their permissible entries are:

Field	Column	Contents	Permitted Entries
1	1-6	Species	'PROTONS', 'ELECTRONS', 'IONS', 'END'
2	11-20	Density	(F10.0)
3	21-26	Density Unit	'CGS', 'MKS'
4	31-40	Temperature	(F10.0)
5	41-46	Temperature Unit	'EV', 'KEV', 'JOULES', 'KELVIN', 'ERGS'

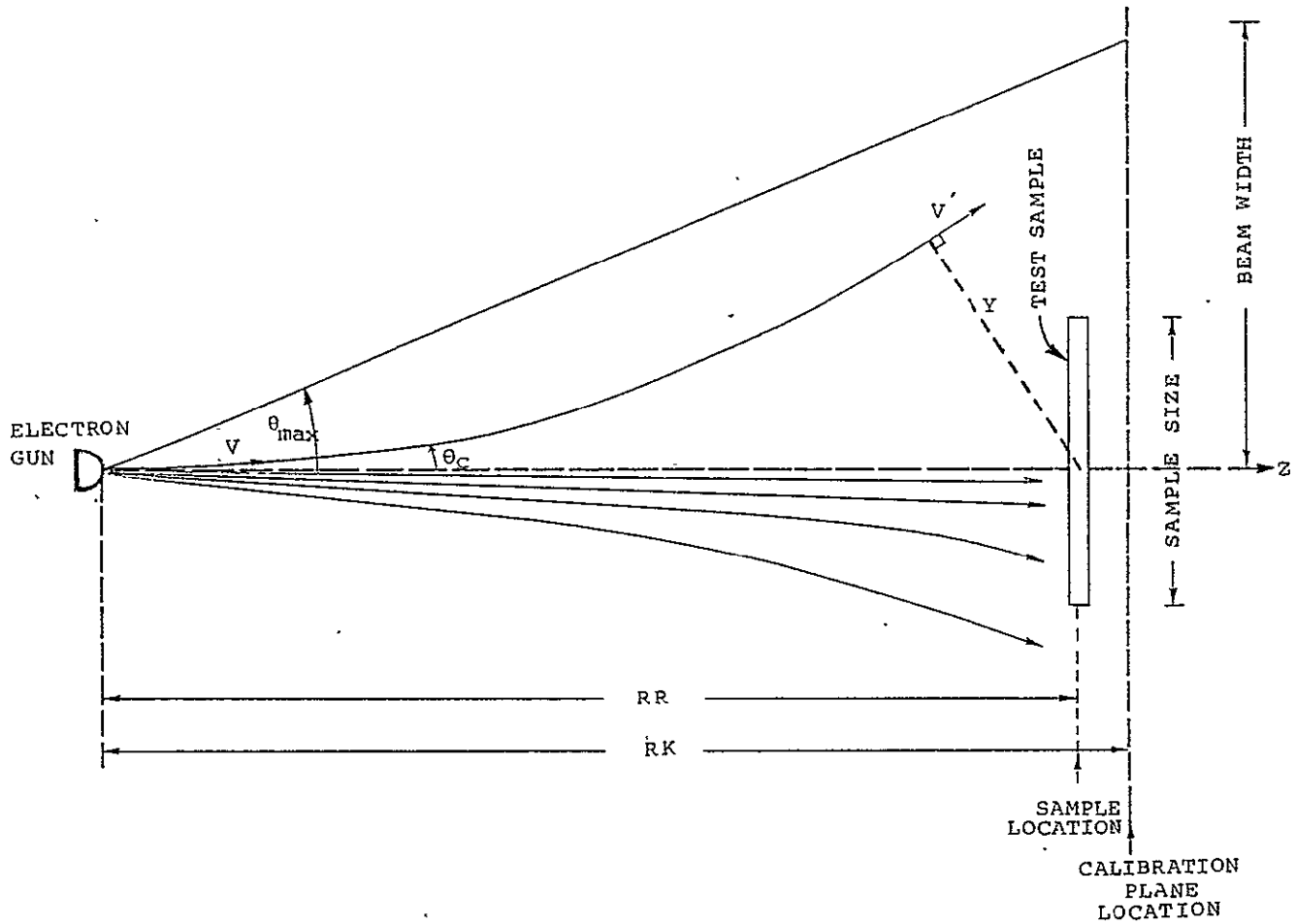

Figure 7.3. Geometry of the test tank configuration.

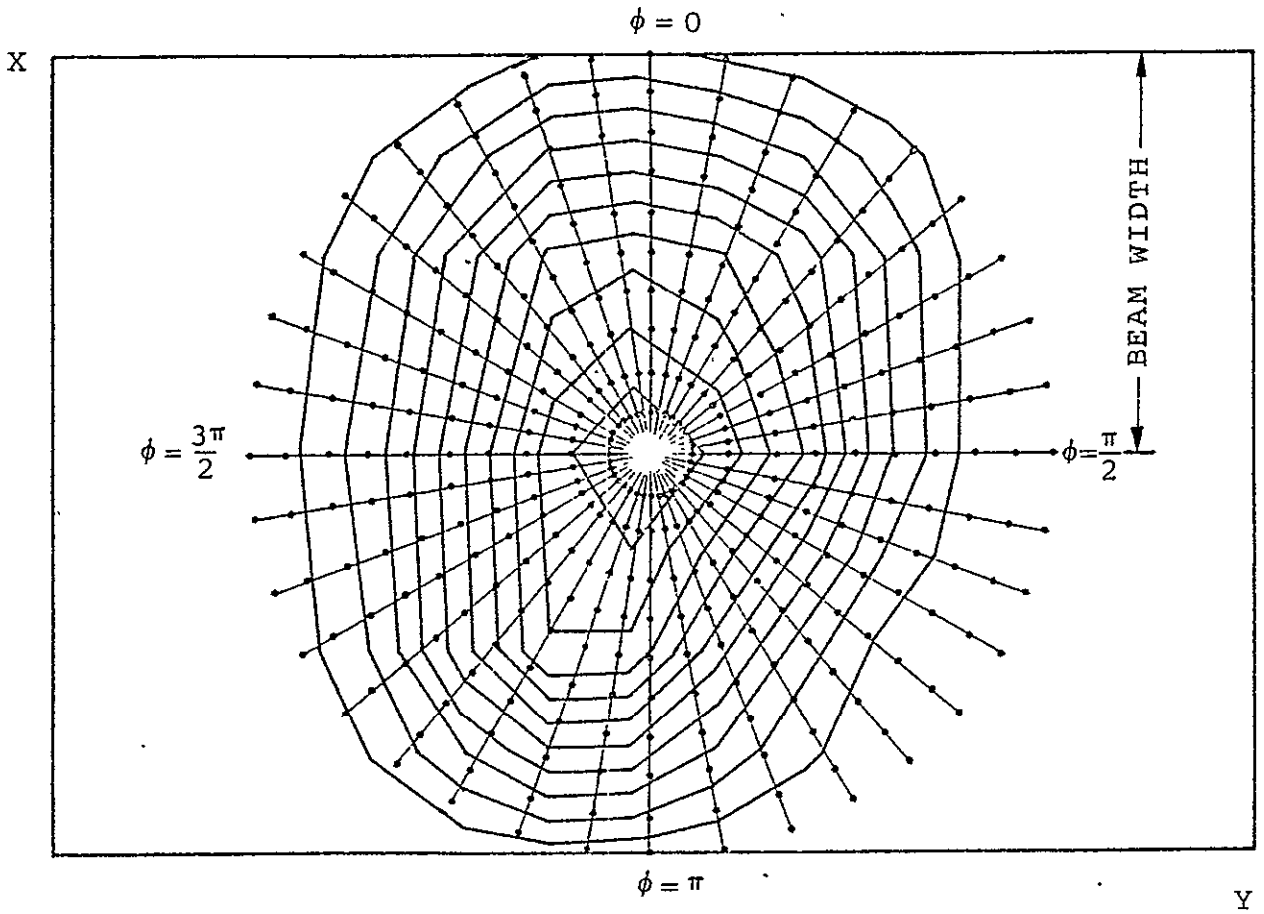

Figure 7.4. Specification of electron gun characteristics for the test tank case. Electron fluxes at the sample plane for an uncharged environment are to be specified at the solid points.

```
1.      TYPE     2
2.       1.00     CGS
3.       1.0      CGS
4.       10.00    KEV
5.      10.0      KEV
```

Example 7.1. (Flux Definition) Defines a neutral 10 keV plasma for use in the Maxwell probe operating mode.

```
1.      TYPE     3
2.      MAXWELL
3.       1.00     CGS
4.       1.0      CGS
5.       10.00    KEV
6.       10.00    KEV
7.                END
8.          2                NSPEC
9.          5                NENG
10.         5                NTHET
11.         5                NPHI
12.       100                NSTP
13.        9.1E-31  -1.6E-19        MASS, CHARGE
14.       16.7E-28   1.6E-19        MASS, CHARGE
15.       0.3                VCODE
```

Example 7.2. (Flux Definition) Defines a neutral 10 keV Maxwellian plasma for use in the reverse trajectory particle pushing mode.

```
 1.        TYPE
 2.        DEFOR
 3.            9
 4.        9.998
 5.           73
 6.            2                NSPEC
 7.            5                NENG
 8.            5                NTHET
 9.            1                NPHI
10.          200                NSTP
11.        9.1E-31   -1.6E-19          MASS, CHARGE
12.       16.7E-28    1.6E-19          MASS, CHARGE
13.        0.3                  VCODE
```

Example 7.3. (Flux Definition) Takes flux from DeForest environmental data for hour 9.998 of day 73. The data is read from LUN 9.

```
 1.        TYPE      3
 2.        MAXWELL
 3.         0.53     CGS
 4.         0.6      CGS
 5.         4.114    KEV
 6.        0.43      KEV
 7.                  END
 8.            2                NSPEC
 9.           05                NENG
10.            5                NTHET
11.            1                NPHI
12.          100                NSTP
13.        9.1E-31   -1.6E-19          MASS, CHARGE
14.       16.7E-28    1.6E-19          MASS, CHARGE
15.        0.3                  VCODE
```

Example 7.4. (Flux Definition) Defines a non-neutral, non-equilibrium Maxwellian plasma for use by the reverse trajectory particle pushing mode.

```
1       TYPE      4
2       ELECTRONS .6        CGS          .3      KEV
3       ELECTRONS .4        CGS         20.      KEV
4       PROTONS   .3        CGS         20.      KEV
5       PROTONS   .7        CGS          .3      KEV
6       END
```

Example 7.5. (Flux Definition) Defines a double Maxwellian flux environment.

```
 1.          TYPE     1
 2.             0
 3.                21.0
 4.                 .30        .30
 5.             2000.0
 6.              .50E00
 7.                 9.0        9.0        9.0
 8.                21.0
 9.             8.40E-7
10.          10.010.0 9.0 8.3 7.6 6.6 4.7 3.2 1.5 0.5 0.0
11.          10.0 9.8 9.0 8.0 7.9 6.5 4.5 2.9 1.4 0.5 0.0
12.          10.0 9.7 9.0 8.0 6.9 5.8 4.4 2.8 1.4 0.5 0.0
13.          10.0 9.6 8.9 7.6 6.6 5.6 4.4 2.6 1.3 0.5 0.0
14.          10.0 9.6 8.8 7.5 6.3 5.3 3.9 2.3 0.9 0.5 0.0
15.          10.0 9.7 8.7 7.4 6.0 4.5 3.0 1.7 0.5 0.0 0.0
16.          10.0 9.8 8.6 7.5 5.7 3.9 2.7 1.0 0.5 0.0 0.0
17.          10.0 9.9 8.7 7.3 5.5 3.4 1.8 0.5 0.5 0.0 0.0
18.          10.010.0 8.9 7.4 5.5 3.3 1.7 0.3 0.5 0.0 0.0
19.          10.0 9.9 8.7 7.2 5.4 3.2 1.5 0.1 0.5 0.0 0.0
20.          10.0 9.8 8.5 6.8 4.9 2.7 1.1 0.5 0.0 0.0 0.0
21.          10.0 9.8 8.4 6.7 4.6 2.6 1.0 0.5 0.0 0.0 0.0
22.          10.0 9.8 8.5 6.7 4.7 2.7 1.1 0.5 0.0 0.0 0.0
23.          10.0 9.9 8.5 6.9 5.0 3.1 1.4 0.1 0.5 0.0 0.0
24.          10.0 9.9 8.6 7.1 5.2 3.5 1.7 0.6 0.5 0.0 0.0
25.          10.010.0 8.7 7.4 5.6 3.9 2.6 1.1 0.1 0.5 0.0
26.          10.010.0 9.0 7.7 6.3 4.8 3.2 1.8 0.4 0.5 0.0
27.          10.010.0 9.2 8.3 7.5 5.8 4.0 2.5 0.7 0.5 0.0
28.          10.010.0 9.6 9.0 8.5 7.5 5.5 3.5 1.5 0.5 0.0
29.          10.010.0 9.9 9.0 8.7 6.6 5.8 4.0 2.1 0.5 0.0
30.          10.010.0 9.6 9.0 8.9 6.9 5.0 3.8 1.9 0.5 0.0
31.          10.010.0 9.4 9.0 8.7 6.6 5.4 3.5 1.6 0.5 0.0
32.          10.010.0 9.4 9.0 7.8 6.6 4.7 3.0 1.4 0.5 0.0
33.          10.010.0 9.4 8.7 7.6 5.5 3.6 2.2 1.0 0.5 0.0
34.          10.010.0 9.3 8.5 6.6 5.2 3.0 1.6 0.5 0.0 0.0
35.          10.010.0 9.3 8.1 6.2 4.4 2.5 1.2 0.2 0.5 0.0
36.          10.010.0 9.4 8.2 6.3 4.3 2.4 1.1 0.1 0.5 0.0
37.          10.010.0 9.5 8.3 6.2 4.2 2.4 1.1 0.1 0.5 0.0
38.          10.010.0 9.4 8.1 6.2 4.3 2.5 1.2 0.2 0.5 0.0
39.          10.010.0 9.3 8.1 6.2 4.4 2.7 1.5 0.5 0.0 0.0
40.          10.010.0 9.2 8.2 6.5 4.8 3.4 2.0 0.8 0.5 0.0
41.          10.010.0 9.1 8.1 6.8 5.5 4.0 2.4 1.1 0.5 0.0
42.          10.010.0 9.1 8.2 7.3 6.3 4.5 2.7 1.5 0.5 0.0
43.          10.010.0 9.2 8.3 7.4 6.6 5.0 3.1 1.4 0.5 0.0
44.          10.010.0 9.1 8.4 7.5 6.5 4.7 3.4 1.5 0.5 0.0
45.          10.010.0 9.0 8.4 7.6 6.5 4.6 3.3 1.5 0.0 0.0
```

Example 7.6. (Flux Definition) Defines flux in the tank test mode with a 2 keV beam.

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7.4 CAPACI

CAPACI is to be called once, and only once, before the first TRILIN call. It forms a capacitor model of the spacecraft body that is used to generate limits to the charging process. No matter how many times TRILIN appears, CAPACI should not be called again, and in a restart run, CAPACI should not be called at all.

7.5 THE LONGTIMESTEP OPTION (SUBROUTINE LIMCEL)

NASCAP, as originally conceived, performed explicit timesteps in order to study the dynamics of a particular charging situation and find an eventual steady state. However, it became apparent late in the first year of NASCAP development that the disparate time scales of the various physical processes involved in satellite charging made such an approach impractical. For example, photocurrents tend to raise the overall potential of a body at $\sim 10^6$ volts per second. However, this current ceases when the body becomes a few volts positive, since the low energy emitted electrons cannot escape from the neighborhood of the satellite. Meanwhile, incident electrons tend to develop kilovolts of differential charging over a period of many seconds or minutes. Explicit timesteps suited to the differential charging processes tend to cause unacceptable oscillations in the mean body potential.

The LIMCEL routines were developed to allow a simulation to proceed on the time scale of interest to the user and in a fashion guaranteed to be stable. The basic strategy used by these routines is:

1. A lumped-circuit-element model of the body is constructed using NASCAP's information about geometry, material properties, and electrical connectivity.

2. The current to each node of the model is divided into low energy emitted electron current and "other" current. If the former is dominant, the node is held fixed at a quasi-equilibrium potential determined from the potential in space nearby.

3. For other nodes, a treatment which is fully implicit for (linear) bulk and surface conductivities and approximately implicit for (nonlinear) incident and emitted currents is used.

4. A user-specified parameter, DVLIM, is employed as follows: (a) No "fixed" node can change in potential by an amount larger than DVLIM, and (b) if any conductor is found to have a potential charge larger than DVLIM, LIMCEL is repeated using a shortened timestep.

5. The resulting change in nodal charges is returned to TRILIN for use by the full potential solver, POTENT.

(Format)

Description

Standard Orientation

Potential Function = $\sum_i N^i \phi_i$

Weight Matrix, W_{ij}: $\int d\Omega |\nabla\phi|^2 = \sum_{ij} W_{ij}\phi_i\phi_j$

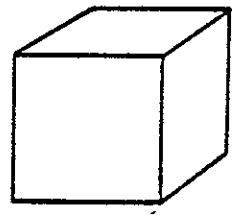
Point Index	Cube Corner
1	0 0 0
2	1 0 0
3	0 1 0
4	1 1 0
5	0 0 1
6	1 0 1
7	0 1 1
8	1 1 1

Figure 7.5. Format and definition of point indices for Figures 7.6-7.10.

Standard Cell 0

Empty trilinear cube

Orientation: Arbitrary



Potential Function:

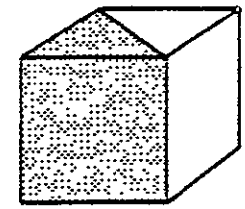
i	N^i
1	$(1-x)(1-y)(1-z)$
2	$(1-z)(1-y)x$
3	$(1-x)y(1-z)$
4	$(1-z)yx$
5	$z(1-y)(1-x)$
6	$x(1-y)(z$
7	$zy(1-x)$
8	xyz

W_{ij}

1/3							
0	1/3						
0	-1/12	1/3					
-1/12	0	0	1/3				
0	-1/12	-1/12	-1/12	1/3			
-1/12	0	-1/12	-1/12	0	1/3		
-1/12	-1/12	0	-1/12	0	-1/12	1/3	
-1/12	-1/12	-1/12	0	-1/12	0	0	1/3

Figure 7.6. The empty cube volume cell.

Standard Cell 1



Half-Empty Wedge

$$1 < x + y < 2$$
$$0 < z < 1$$

Orientation: Right angle along line 7-8

Potential function:

i	N^i
1	0
2	$(1-y)(1-z)$
3	$(1-x)(1-z)$
4	$(x+y-1)(1-z)$
5	0
6	$(1-y)z$
7	$(1-x)z$
8	$(x+y-1)z$

W_{ij}

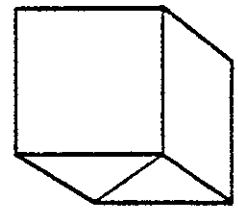
0							
0	1/4						
0	1/24	1/4					
0	-1/8	-1/8	5/12				
0	0	0	0	0			
0	0	-1/24	-1/8	0	1/4		
0	-1/24	0	-1/8	0	1/24	1/4	
0	-1/8	-1/8	-1/12	0	-1/8	-1/8	5/12

Figure 7.7. The half-empty wedge volume cell.

Standard Cell 2

Cube with diagonal line on one face

Orientation: Line from 2 to 3



Potential Function:

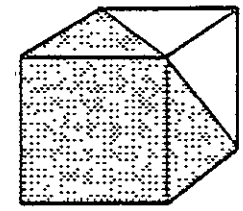
i	N^i
1	$(1-x-y)(1-z)\Theta(1-x-y)$
2	$[x\Theta(1-x-y)+(1-y)\Theta(x+y-1)](1-z)$
3	$[y\Theta(1-x-y)+(1-x)\Theta(x+y-1)](1-z)$
4	$(x+y-1)(1-z)\Theta(x+y-1)$
5	$(1-x)(1-y)z$
6	$x(1-y)z$
7	$(1-x)yz$
8	xyz

W_{ij}:

5/12							
-1/8	1/2						
-1/8	1/12	1/2					
0	-1/8	-1/8	5/12				
7/360	-37/360	-37/360	-23/360	1/3			
-11/180	-1/45	-19/180	-11/180	0	1/3		
-11/180	-19/180	-1/45	-11/180	0	-1/12	1/3	
-23/360	-37/360	-37/360	7/360	-1/12	0	0	1/3

Figure 7.8. The empty special cell.

Standard Cell 3



Tetrahedron

$$2 < x + y + z < 3$$

Orientation: Empty corner at point 8

Potential Function:

i	N^i
1	0
2	0
3	0
4	1-z
5	0
6	1-y
7	1-x
8	x+y+z-2

W_{ij}:

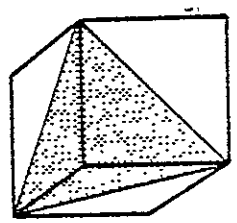
0							
0	0						
0	0	0					
0	0	0	1/6				
0	0	0	0	0			
0	0	0	0	0	1/6		
0	0	0	0	0	0	1/6	
0	0	0	-1/6	0	-1/6	-1/6	1/2

Figure 7.9. The tetrahedron volume cell.

Standard Cell 4

Truncated Cube

Orientation: 000 corner (point 1) missing



Potential Function:

i	N^i
1	0
2	
3	exercise
4	for
5	reader
6	
7	
8	

W_{ij}:

0							
0	5/12						
0	1/72	5/12					
0	-11/120	-37/360	13/36				
0	1/72	1/72	-1/9	5/12			
0	-37/360	-1/9	-7/180	-11/120	13/36		
0	-1/9	-11/120	-7/180	-37/360	-7/180	13/36	
0	-5/36	-5/36	1/45	-5/36	1/45	1/45	7/20

Figure 7.10. The empty truncated cube volume cell.

8. HIDCEL — ROTATE

If photoemission effects are to be included in a NASCAP charging simulation, we need a table of which surface cells are illuminated by the sun, and which are shadowed by other surface cells. HIDCEL produces such a table, including effects of partial shadowing and angle of incident sunlight. The orientation of the spacecraft with respect to the sun is given by the SUNDIR keyword in the RDOPT file. (We use a pre-Copernican system in which the sun rotates around our spacecraft.)

The ROTATE control word generates a new sun direction for a rotating spacecraft. It then calls HIDCEL to generate a new table of surface cell illumination.

8.1 HIDCEL

For purposes such as calculating photoemission effects it is desirable to be able to calculate the shadowing effects of the satellite upon itself for an arbitrary angle of incident sunlight. A subroutine called HIDCEL computes for each surface grid cell the area of that part of the cell which remains exposed when partially or completely shadowed by some other portion of the satellite (or, of course, when not shadowed at all). The program is completely general: For any satellite which NASCAP can treat, any incident angle may be specified as a vector from the center of the satellite out towards the viewer (sun). In addition to calculating the cell-by-cell areas needed for code computations, HIDCEL plots a diagnostic (and informative) hidden line 3-D plot of the satellite as viewed from the incident angle requested.

The code accomplishes both the area calculations and 3-D plots by a long series of polygon maskings. The set of cell faces whose normals produce positive dot products with the vector pointing towards the viewer are selected and projected into 2-D polygons. We call this set of individual cell polygons the A1 polygons. A second but much shorter set of polygons is selected and projected into 2-D by finding those faces of each parallelepiped, wedge, tetrahedron, octagon, etc. forming the satellite (as determined by user input), which meet the dot product criterion. We call this set the A2 polygons.

The cell-by-cell (A1) set of 2-D polygons is then masked one at a time against each of the larger "building-block" (A2) polygons, and at each step we discard any polygon which is partially or completely shielded and replace it, if necessary, with the polygon (or polygons) representing that part of the original cell which remains visible.

An A1 polygon which is completely shadowed, but is masked by several different surfaces, will then be "whittled

down" a bit at a time, each masking leaving an appropriately smaller polygon until the last masking for that cell finally removes it from the system. A polygon whose middle is masked but whose ends remain visible will be split into two or more new polygons; the code maintains records, however, indicating which original cell has generated each new polygon. Consequently, when all maskings have been completed and a finalized set of masked Al polygons exists, we may calculate areas of each polygon and add into the appropriate cell area the area of each polygon contributing to that cell.

The areas stored for further NASCAP calculations are fractional areas with the dot product (2-D projection) effect removed. We do this by calculating the areas of each cell's 2-D projection before any masking takes place and then computing the fraction of this area which remains visible following all maskings. This procedure also precludes any area normalization problems.

As is evident, for a satellite of this complexity, we may be masking on the order of 500 cell faces against on the order of 150 building-block faces for a total of about 75,000 individual maskings. Computing time (including plot generation) on S^3's UNIVAC 1100/81 varies from 5 to 60 seconds per view, depending on satellite complexity. Figure 8.1 shows two plots of the object defined by Example 6.1.

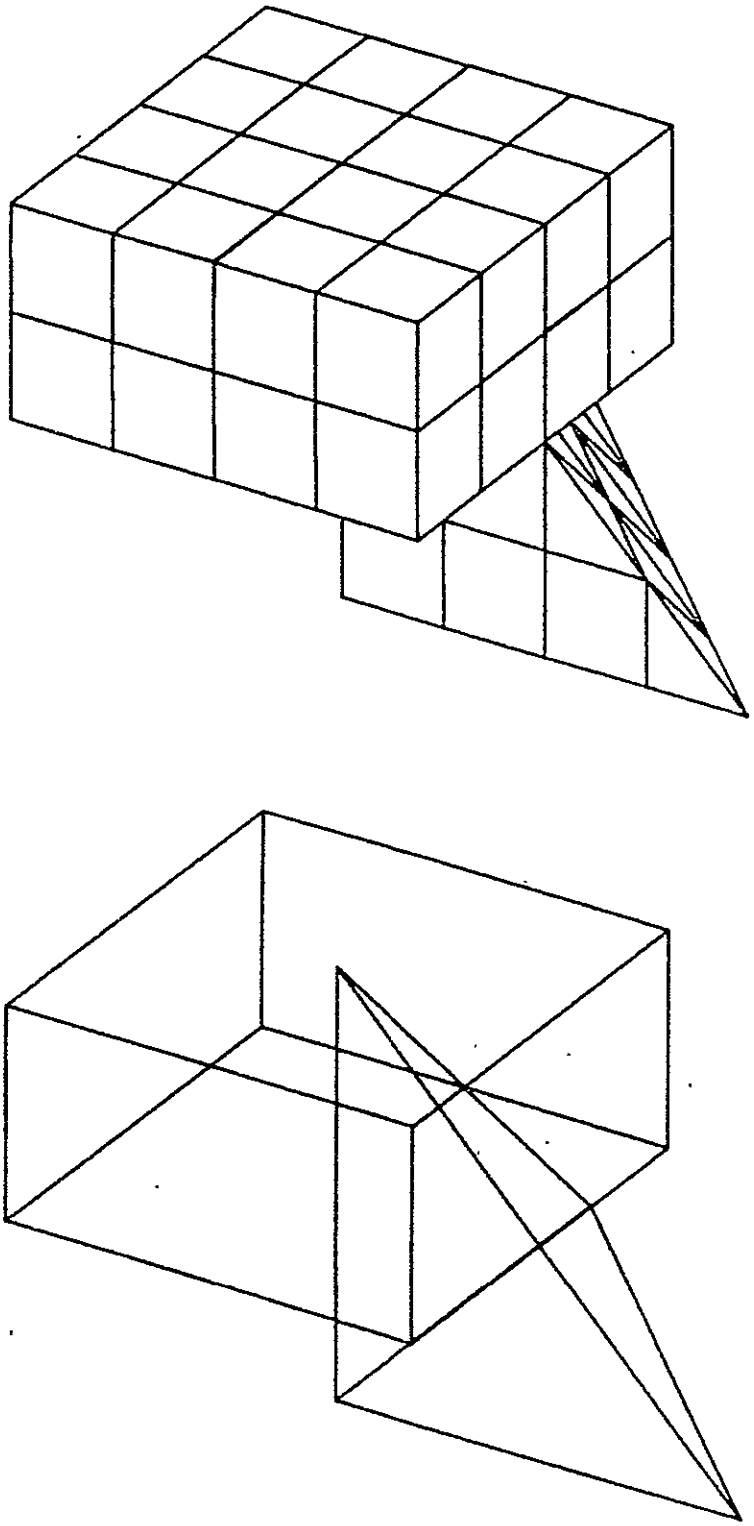


Figure 8.1. Unidentified compound object.

8.2 ROTATE

Because it is not only inconvenient but often impossible for the user to specify sun orientation at each timestep, the ROTATE command has been added to the main routine NASCAP. ROTATE causes the sun direction to be altered in accordance with the sun direction at time zero and the satellite's spin angular velocity. If the CONVEX option was not specified, HIDCEL will be called automatically to perform a shadowing calculation for the new sun direction generated by ROTATE.

Action taken by ROTATE depends on the value of LUN specified in columns 9-10 of the command card. If LUN = 0, the default values will be used. The default initial direction is (1.,0.,0.) and the default angular velocity is 1 RPM about the z-axis. If LUN = 5, ROTATE reads the next two cards from the "card reader". For any other positive value it reads the first two cards of the specified file. The first input card contains the spin angular velocity (rad/sec) and the second the sun direction at t = 0. Both cards are FORMAT(3F10.0).

9. SAMPLE RUN

On the following pages, we reproduce the printer output and graphical output of a sample NASCAP run.

The sample run shown is an object definition and charging simulation for a sunlit quasisphere. The object is rotating at 0.27 rad/sec. The quasisphere surface is coated with teflon, except for one face (four square surface cells) which is bare aluminum.

In this run we do an object definition (OBJDEF), a satellite illustration (SATPLT), a shadowing calculation (HIDCEL), the longtimestep preparation (CAPACI), a charging and potential calculation for time zero (TRILIN), a rotation (ROTATE), and another charging-potential calculation for time t = 0.1 sec (TRILIN). Since keyword NCYC assumes the default value of 1, each TRILIN call handles only one timestep.

The runstream shown on the next page does everything necessary to run NASCAP. The three input files (here called NASOBJ, FLUXES, and KEYS) are shown as examples in Chapters 6, 7, and 5, respectively.

We first assign all of the restart and scratch files using the default numbers as shown in Table 5.2. File number 28 is used only for particle push plots, so we omit it. We then assign the three input files which have previously been created. The absolute version of NASCAP is copied, a format command is given, and the XQT command begins execution.

Then we have the control word list that actually directs the NASCAP program.

Finally, the PMD command requests a postmortem dump in the event of abnormal program termination.

```
 1        EXAMPLE NUG
 2       DEFN + CHARGE
 3        SATPLT
 4        ROTATE
 5       @ASG,T 10.
 6       @ASG,T 11.
 7       @ASG,T 12.
 8       @ASG,T 13.
 9       @ASG,T 14.
10       @ASG,T 15.
11       @ASG,T 16.
12       @ASG,T 17.
13       @ASG,T 18.
14       @ASG,T 19.
15       @ASG,T 21.
16       @ASG,T 25.
17       @ASG,T 27.
18       @USE  20,NASOBJ.
19       @ASG,AX 20.
20       @USE  22,FLUXES
21       @ASG,AX 22.
22       @USE  26,KEYS
23       @ASG,AX 26.
24       @COPY,A  MANDELL-M*NPROG.NASCAP
25       @HDG .M,56,2,2
26       @XQT
27       RDOPT
28       OBJDEF
29       SATPLT
30       HIDCEL
31       CAPACI
32       TRILIN
33       ROTATE    5
34          .27
35           1.          .2          0.
36       TRILIN
37       END
38       @PMD,RED
```

Assign temporary files

Assign input files

Control words

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```
@ASG,T 10.
READY

@ASG,T 11.
READY

@ASG,T 12.
READY

@ASG,T 13.
READY

@ASG,T 14.
READY

@ASG,T 15.
READY

@ASG,T 16.
READY

@ASG,T 17.
READY

@ASG,T 18.
READY

@ASG,T 19.
READY

@ASG,T 21.
READY

@ASG,T 25.
READY

@ASG,T 27.
READY

@USE  20,NASOBJ.
READY
```

Thirteen temporary files are assigned. If a RESTART were anticipated for this run, permanent files would be assigned for file numbers 10, 15, 16, 17, 19, and 21. The object definition file is assigned.

```
@ASG,AX 20.
READY

@USE  22,FLUXLS
READY

@ASG,AX 22.
READY

@USE  26,KEYS
READY

@ASG,AX 26.
READY

@COPY,A  MANDELL-M*NPROG.NASCAP
FURPUR 27R3-1      F35 SL73R1 07/24/78 10:35:07
 1 ABS

@HDG .M,66,2,2
```

Flux definition and keyword files are assigned. The NASCAP absolute element is copied. A format command asks for 62 lines to be printed per page.

```
@XQT
 ******RDOPT    0
```

Execution is initiated. The first control word is RDOPT. Columns 10-11 on the RDOPT card are blank (=0) so file 26 is read for keyword input.

```
          KEYWORD INPUT
NZ
NG
IOUTER
MAXITR
SUNDIR
SUNINT
DELTA
LONGTIMESTEP
ICON
END
```

The keyword input file is echoed. There will be one grid with dimensions 17 x 17 x 17. Boundary conditions and initial potential guess will be 1/r. The potential solver will run for 20 iterations. Photoemission will be calculated with the sun intensity at 1 a.u. and sun direction initially (1,1,-.5). The sun direction will change when ROTATE is called. The timestep will be 0.1 sec. The LONGTIMESTEP option will be used. Potential contour plots are requested.

SUMMARY OF INPUT OPTIONS

```
NX = 17
NY = 17
NZ = 17
NG =  1
NGPRT =  1

IP = 10
IAUN = 11
IR = 12
IDIV = 25
IU = 13
ISPARE = 14
IROUS = 15
IPOCND = 16
ILTBL = 17

IOBJ = 18
IOBPLT = -19
ISAT = 20

ICNOW = 21
IFLUX = 22
IKEYWD = 26
IAREA = -27
IPART =   0

ICREST =  0
IPREST =  0
IOBCAL =  0
ICON =  1
ICNVP =  1
IOUTER =  2
ITYPE =  2
ITPART =  0
ITCUR =  0
IROUSP =  0

MAXITR = 20

NCYC =   1
MCYC =   1
DELTA =  1.0000-01
DELFAC =  1.0000+00
XMESH =  1.0000-01 METERS
NORMALIZED SUN DIRECTION VECTOR =     .667    .667   -.333
RELATIVE SUN INTENSITY =  1.0000+00

NO. OF ADDITIONAL CONTOUR PLOT CUTS =     0

NO. OF ADDITIONAL 3-D PLOT VIEWS =     0

NO. OF ADDITIONAL MATERIAL PLOT VIEWS =     0    0    0    0    0    0

1 SURFACE CELLS SPECIFIED FOR I/O:
                    1
```

Values of all keyword variables are printed, including default values for those not mentioned in the keyword file.

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```
        THE CODE UNIT OF CHARGE IS     8.85-13 COULOMBS.
        THE CODE UNIT OF CAPACITANCE IS     8.85-13FARADS.

CIJ:
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00
          0.00       0.00       0.00       0.00       0.00       0.00       0.00

CIJSUM:     0.00       0.00       0.00       0.00       0.00       0.00       0.00

        LONGTIMESTEP OPTION ='FIX    '       DVLIM =  1.0+03 VOLTS

        POTENTIAL SCALING OPTION ='SCALE '

        SHEATH OPTION ='NO     '

        SECONDARY EMISSION FORMULATION ='ANGLE '

        SHADOWING FORMULATION ='SHADOW'

        FULL OUTER GRID USED

                  CONSTANT MAGNETIC FIELD =(    .00       .00       .00    ) W/M**2.

    NO MAGNETIC DIPOLES

******OBJDEF    0
```

More keyword variables. Object definition is initiated. File 20 is the object definition file (default).

```
ALUMIN                MATERIAL PROPERTIES
            1.00+00    1.00-03   -1.00+00    1.30+01    9.70-01    3.00-01    2.60+02    1.30+00    2.40+02    1.73+00
            1.36+00    4.00+01    4.00-05   -1.00+00    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

TEFLON                MATERIAL PROPERTIES
            2.00+00    1.27-04    1.00-14    1.00+01    3.00+00    3.00-01   -1.00+00    0.00       2.20+00    1.67+01
            1.40+00    7.00+01    2.00-05   -1.00+00    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

OFFSET       0    0    0

QSPHER

   DEFINING Q-SPHERE
         CENTER =   9   9   9
         DIAMETER =   4      SIDE =   2
         MATERIAL = TEFLON      :

   OCTAGON DEFINED
         AXIS = (   8   9   9) TO (  10   9   9)
         WIDTH =    4           SIDE =    2

   OCTAGON DEFINED
         AXIS = (   9   8   9) TO (   9  10   9)
         WIDTH =    4           SIDE =    2

   OCTAGON DEFINED
         AXIS = (   9   9   8) TO (   9   9  10)
         WIDTH =    4           SIDE =    2

RECTAN    R PARALELLEPIPED
 OBJECT NOW DEFINED.
                               8<X< 10
                               8<Y< 10
                               9<Z< 11


SURFAC    +Z        ALUMIN

ENDOBJ

ENDSAT
CALLING TRNGLS
```

Material property input is echoed. The quasisphere is constructed, in part, from three octagons. A cube is defined to overlap the q-sphere so the +z surface is defined as bare aluminum.

SURFACE CELL LIST

CELL NO.	CODE	CONDUCTOR	IX	IY	IZ	NORMAL			MATERIAL
1	010707077742	1	7	7	7	-1	-1	-1	TEFLON
2	010707107402	1	7	7	8	-1	-1	0	TEFLON
3	010707117402	1	7	7	9	-1	-1	0	TEFLON
4	010707127542	1	7	7	10	-1	-1	1	TEFLON
5	010710076302	1	7	8	7	-1	0	-1	TEFLON
6	010710106002	1	7	8	8	-1	0	0	TEFLON
7	010710116002	1	7	8	9	-1	0	0	TEFLON
8	010710126102	1	7	8	10	-1	0	1	TEFLON
9	010711076302	1	7	9	7	-1	0	-1	TEFLON
10	010711106002	1	7	9	8	-1	0	0	TEFLON
11	010711116002	1	7	9	9	-1	0	0	TEFLON
12	010711126102	1	7	9	10	-1	0	1	TEFLON
13	010712076742	1	7	10	7	-1	1	-1	TEFLON
14	010712106402	1	7	10	8	-1	1	0	TEFLON
15	010712116402	1	7	10	9	-1	1	0	TEFLON
16	010712126542	1	7	10	10	-1	1	1	TEFLON
17	011007071702	1	8	7	7	0	-1	-1	TEFLON
18	011007101402	1	8	7	8	0	-1	0	TEFLON
19	011007111402	1	8	7	9	0	-1	0	TEFLON
20	011007121502	1	8	7	10	0	-1	1	TEFLON
21	011010070302	1	8	8	7	0	0	-1	TEFLON
22	011010120101	1	8	8	10	0	0	1	ALUMIN
23	011011070302	1	8	9	7	0	0	-1	TEFLON
24	011011120101	1	8	9	10	0	0	1	ALUMIN
25	011012070702	1	8	10	7	0	1	-1	TEFLON
26	011012100402	1	8	10	8	0	1	0	TEFLON
27	011012110402	1	8	10	9	0	1	0	TEFLON
28	011012120502	1	8	10	10	0	1	1	TEFLON
29	011107071702	1	9	7	7	0	-1	-1	TEFLON
30	011107101402	1	9	7	8	0	-1	0	TEFLON
31	011107111402	1	9	7	9	0	-1	0	TEFLON
32	011107121502	1	9	7	10	0	-1	1	TEFLON
33	011110070302	1	9	8	7	0	0	-1	TEFLON
34	011110120101	1	9	8	10	0	0	1	ALUMIN
35	011111070302	1	9	9	7	0	0	-1	TEFLON
36	011111120101	1	9	9	10	0	0	1	ALUMIN
37	011112070702	1	9	10	7	0	1	-1	TEFLON
38	011112100402	1	9	10	8	0	1	0	TEFLON
39	011112110402	1	9	10	9	0	1	0	TEFLON
40	011112120502	1	9	10	10	0	1	1	TEFLON
41	011207073742	1	10	7	7	1	-1	-1	TEFLON
42	011207103402	1	10	7	8	1	-1	0	TEFLON
43	011207113402	1	10	7	9	1	-1	0	TEFLON
44	011207123542	1	10	7	10	1	-1	1	TEFLON
45	011210072302	1	10	8	7	1	0	-1	TEFLON
46	011210102002	1	10	8	8	1	0	0	TEFLON
47	011210112002	1	10	8	9	1	0	0	TEFLON
48	011210122102	1	10	8	10	1	0	1	TEFLON
49	011211072302	1	10	9	7	1	0	-1	TEFLON
50	011211102002	1	10	9	8	1	0	0	TEFLON

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```
ALUMIN              MATERIAL PROPERTIES
            1.00+00    1.00-03   -1.00+00    1.30+01    9.70-01    3.00-01    2.60+02    1.30+00    2.40+02    1.73+00
            1.36+00    4.00+01    4.00-05   -1.60+00    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

TEFLON              MATERIAL PROPERTIES
            2.00+00    1.27-04    1.00-14    1.00+01    3.00+00    3.00-01   -1.00+00    0.00       2.20+00    1.67+01
            1.40+00    7.00+01    2.00-05   -1.60+00    1.50+01    1.60+01    1.70+01    1.80+01    1.90+01    2.00+01

OFFSET      0    0    0

QSPHER

   DEFINING Q-SPHERE
         CENTER =   9   9   9
         DIAMETER =   4      SIDE =   2
         MATERIAL = TEFLON

   OCTAGON DEFINED
         AXIS = (   8   9   9) TO (  10   9   9)
         WIDTH =    4           SIDE =    2

   OCTAGON DEFINED
         AXIS = (   9   8   9) TO (   9  10   9)
         WIDTH =    4           SIDE =    2

   OCTAGON DEFINED
         AXIS = (   9   9   8) TO (   9   9  10)
         WIDTH =    4           SIDE =    2

RECTAN    R PARALELLEPIPED
 OBJECT NOW DEFINED.
                               8<X< 10
                               8<Y< 10
                               9<Z< 11

SURFAC    +Z        ALUMIN

ENDOBJ

ENDSAT
CALLING TRNGLS
```

Material property input is echoed. The quasisphere is constructed, in part, from three octagons. A cube is defined to overlap the q-sphere so the +z surface is defined as bare aluminum.

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PREPROCESSING OF MATERIAL PROPERTIES

MATERIAL 1: ALUMIN

	PROPERTY	INPUT VALUE	CODE VALUE
1	DIELECTRIC CONSTANT	1.0E+00 (NONE)	1.0E+00 (NONE)
2	THICKNESS	1.0E-03 METERS	1.0E-02 MESH
3	CONDUCTIVITY	-1.0E+00 MHO/M	-1.0E+00 MHO/M
4	ATOMIC NUMBER	1.3E+01 (NONE)	1.3E+01 (NONE)
5	DELTA MAX >COEFF	9.7E-01 (NONE)	7.2E+00 (NONE)
6	E-MAX >DEPTH**-1	3.0E-01 KEV	1.73-02 ANG-01
7	RANGE	2.6E+02 ANG.	3.38+02 ANG.
8	EXPONENT > RANGE	1.3E+00 (NONE)	4.15+02 ANG.
9	RANGE > EXPONENT	2.4E+02 ANG.	1.3E+00 (NONE)
10	EXPONENT	1.73+00 (NONE)	1.73+00 (NONE)
11	YIELD FOR 1KEV PROTONS	1.36+00 (NONE)	1.36+00 (NONE)
12	MAX DE/DX FOR PROTONS	4.0E+01 KEV	4.0E+01 KEV
13	PHOTOCURRENT	4.0E-05 A/M**2	4.0E-05 A/M**2
14	SURFACE RESISTIVITY	-1.0E+00 OHMS	-8.85-13 V-S/Q
15		1.5E+01	1.5E+01
16		1.6E+01	1.6E+01
17		1.7E+01	1.7E+01
18		1.8E+01	1.8E+01
19		1.9E+01	1.9E+01
20		2.0E+01	2.0E+01

MATERIAL 2: TEFLON

	PROPERTY	INPUT VALUE	CODE VALUE
1	DIELECTRIC CONSTANT	2.0E+00 (NONE)	2.0E+00 (NONE)
2	THICKNESS	1.27-04 METERS	1.27-03 MESH
3	CONDUCTIVITY	1.0E-14 MHO/M	1.0E-14 MHO/M
4	ATOMIC NUMBER	1.0E+01 (NONE)	1.0E+01 (NONE)
5	DELTA MAX >COEFF	3.0E+00 (NONE)	1.96+01 (NONE)
6	E-MAX >DEPTH**-1	3.0E-01 KEV	2.95-02 ANG-01
7	RANGE	-1.0E+00 ANG.	4.58+02 ANG.
8	EXPONENT > RANGE	0.0E (NONE)	0.0E ANG.
9	RANGE > EXPONENT	2.2E+00 ANG.	1.65+00 (NONE)
10	EXPONENT	1.67+01 (NONE)	1.0E+00 (NONE)
11	YIELD FOR 1KEV PROTONS	1.40+00 (NONE)	1.4E+00 (NONE)
12	MAX DE/DX FOR PROTONS	7.0E+01 KEV	7.0E+01 KEV
13	PHOTOCURRENT	2.0E-05 A/M**2	2.0E-05 A/M**2
14	SURFACE RESISTIVITY	-1.0E+00 OHMS	-8.85-13 V-S/Q
15		1.5E+01	1.5E+01
16		1.6E+01	1.6E+01
17		1.7E+01	1.7E+01
18		1.8E+01	1.8E+01
19		1.9E+01	1.9E+01
20		2.0E+01	2.0E+01

CALLING SPECEL

Material property values are listed.

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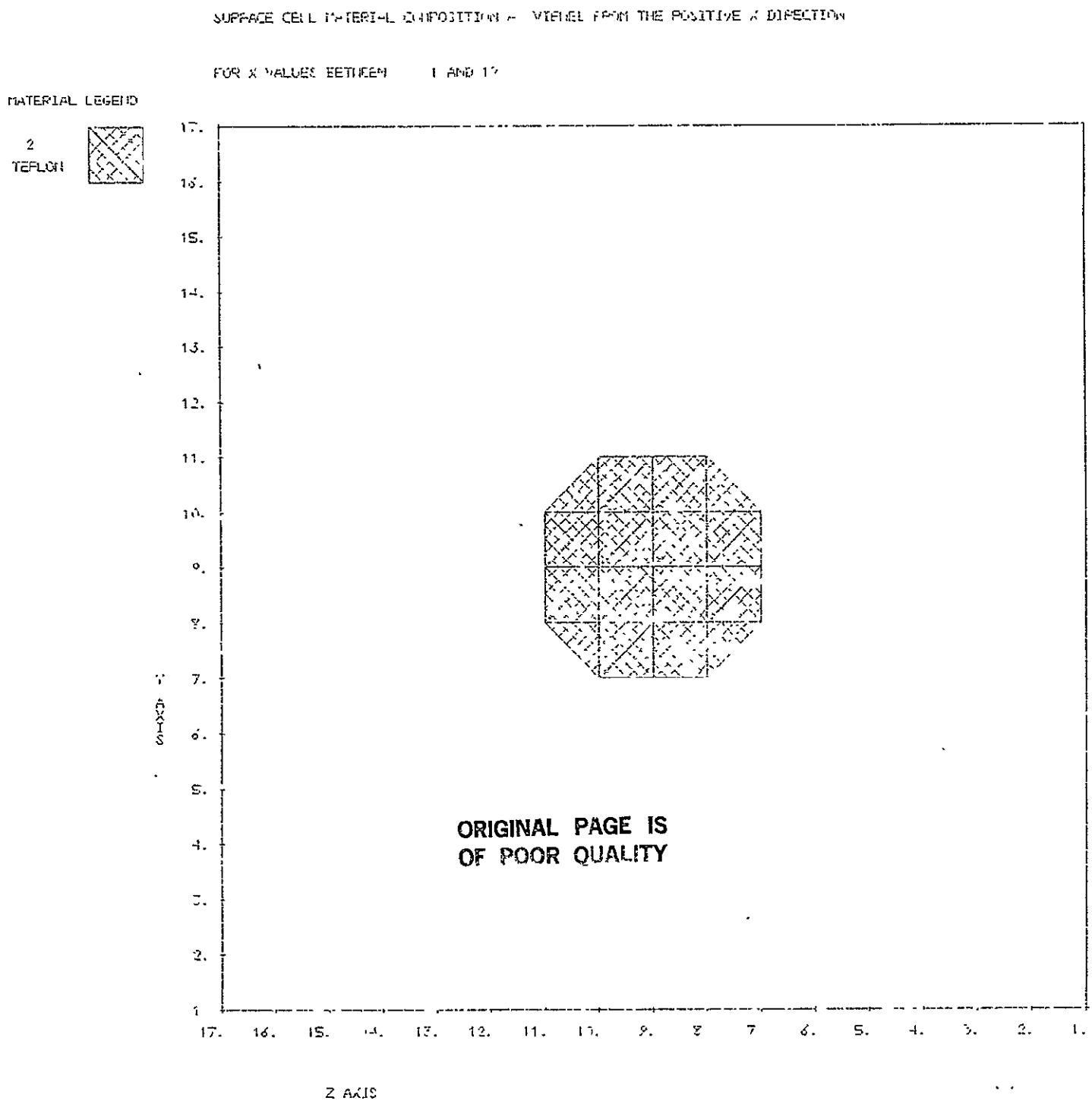
ELEMENT TABLE

I	J	K	ENTRY
7	7	7	000000056704
7	7	8	000000056301
7	7	9	000000056301
7	7	10	000000056304
7	8	7	000000075201
7	8	10	000000035201
7	9	7	000000075201
7	9	10	000000035201
7	10	7	000000052704
7	10	8	000000052301
7	10	9	000000052301
7	10	10	000000052304
8	7	7	000000067101
8	7	10	000000063101
8	10	7	000000027101
8	10	10	000000023101
9	7	7	000000067101
9	7	10	000000063101
9	10	7	000000027101
9	10	10	000000023101
10	7	7	000000016704
10	7	8	000000016301
10	7	9	000000016301
10	7	10	000000016304
10	8	7	000000071201
10	8	10	000000031201
10	9	7	000000071201
10	9	10	000000031201
10	10	7	000000012704
10	10	8	000000012301
10	10	9	000000012301
10	10	10	000000012304

56 VOLUME CELLS NUMBERED BY NUMLTB.

All non-cubic volume elements from the element table are listed. The code is given in Section 6.9.2, Volume Elt Table. This completes object definition. SATPLT and HIDCEL are called. The following twelve plots are generated by SATPLT — material plots and satellite illustration plots. The final illustration plot (thirteenth plot) is generated by HIDCEL.

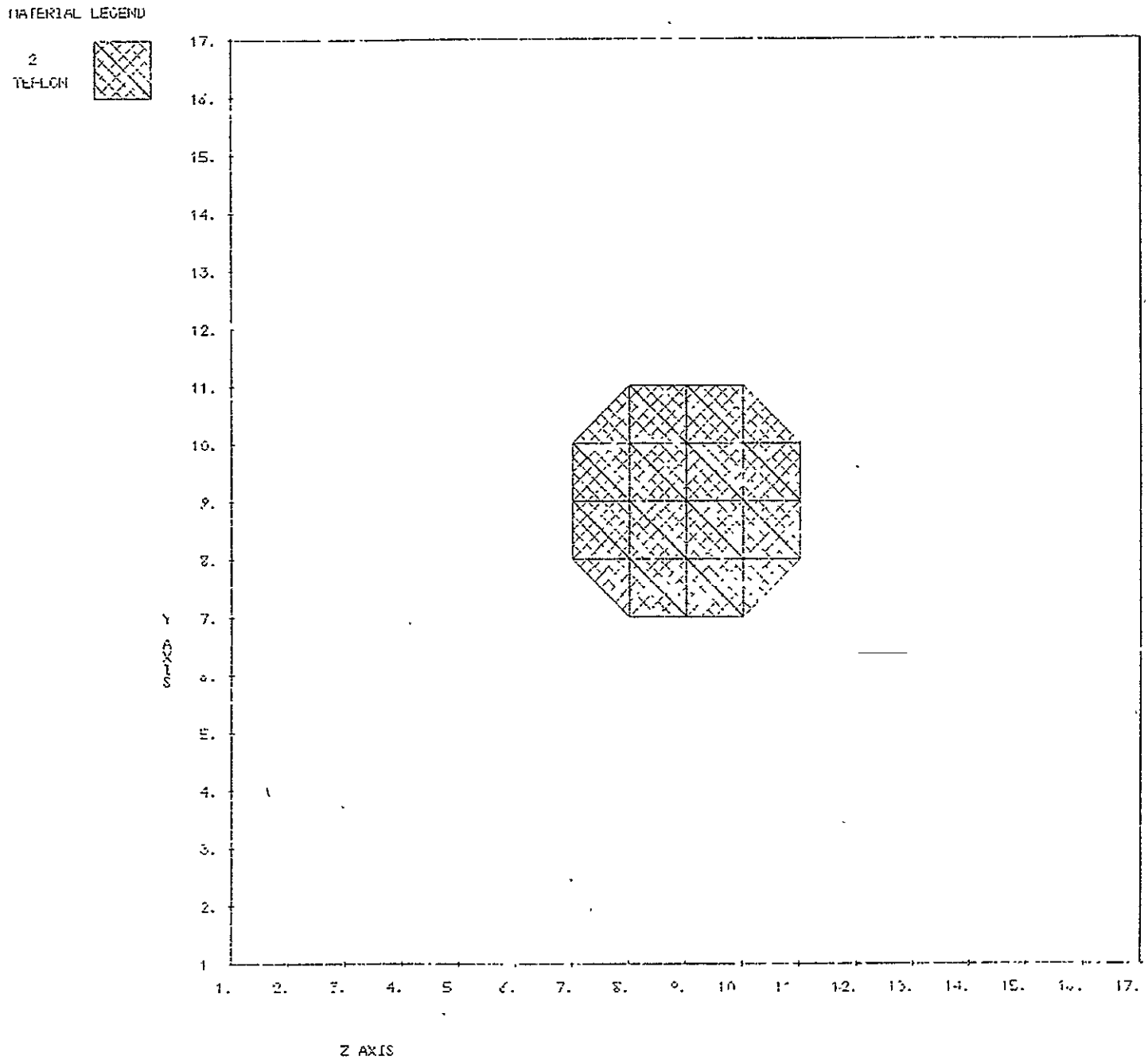
```
******SATPLT    0

FINAL NA1 =     26

FINAL NA1 =     26

FINAL NA1 =     26

******HIDCEL    0
```



Six plots show surface materials.

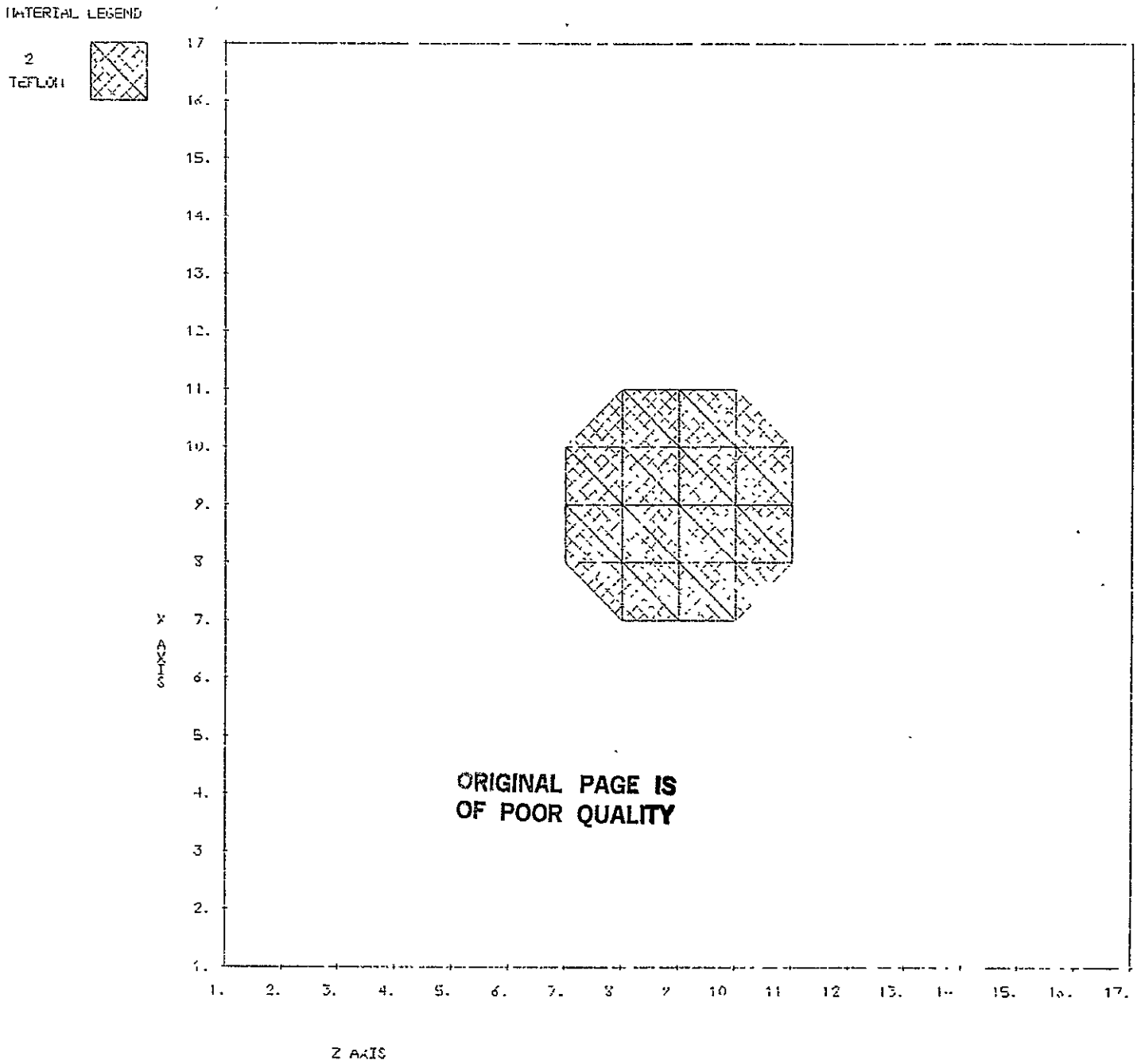
SURFACE CELL MATERIAL COMPOSITION AS VIEWED FROM THE NEGATIVE Y DIRECTION

FOR X VALUES BETWEEN 1 AND 17



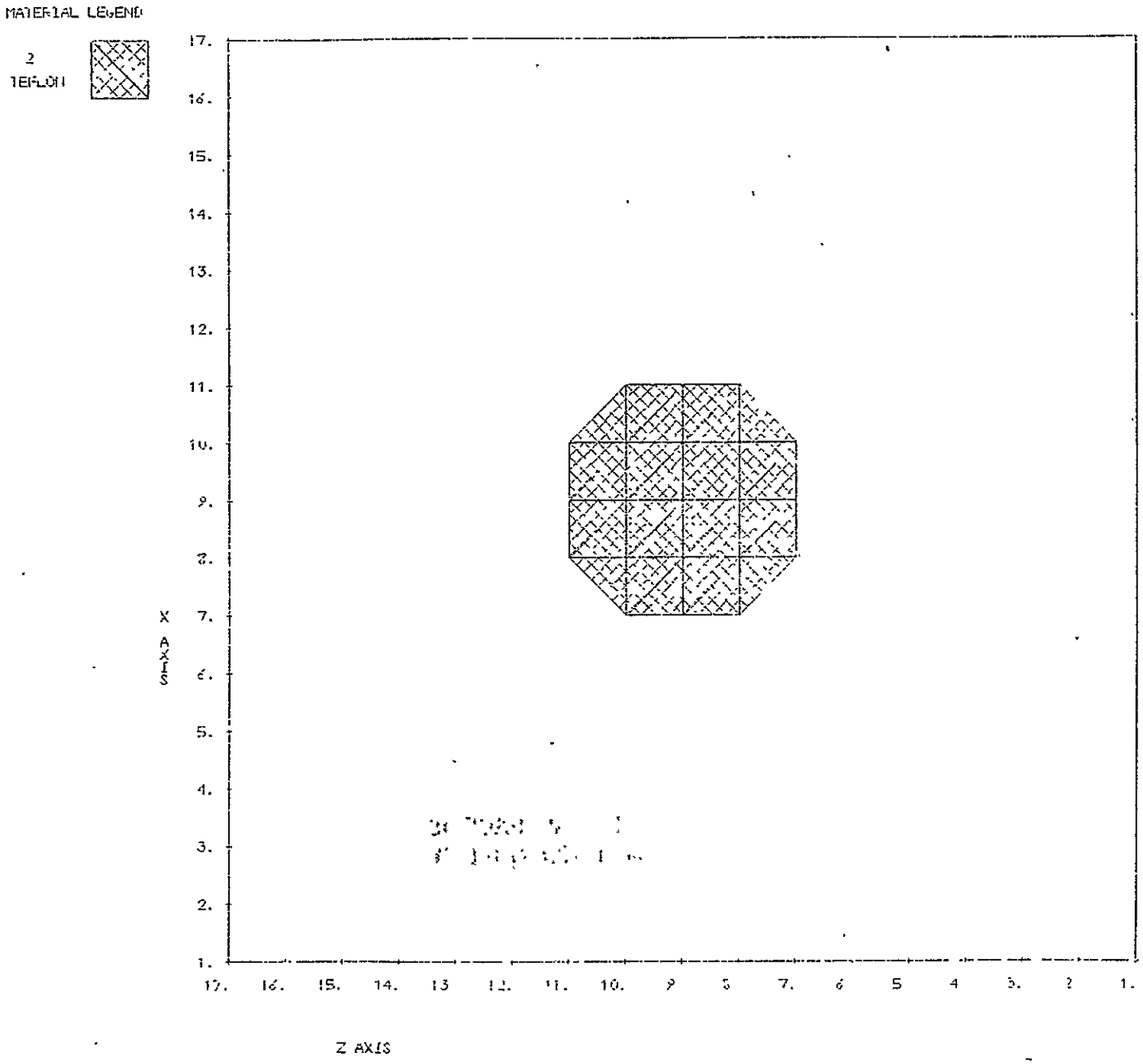
SURFACE CELL MATERIAL COMPOSITION A. VIEWED FROM THE POSITIVE Y DIRECTION

FOR Y VALUES BETWEEN 1 AND 17



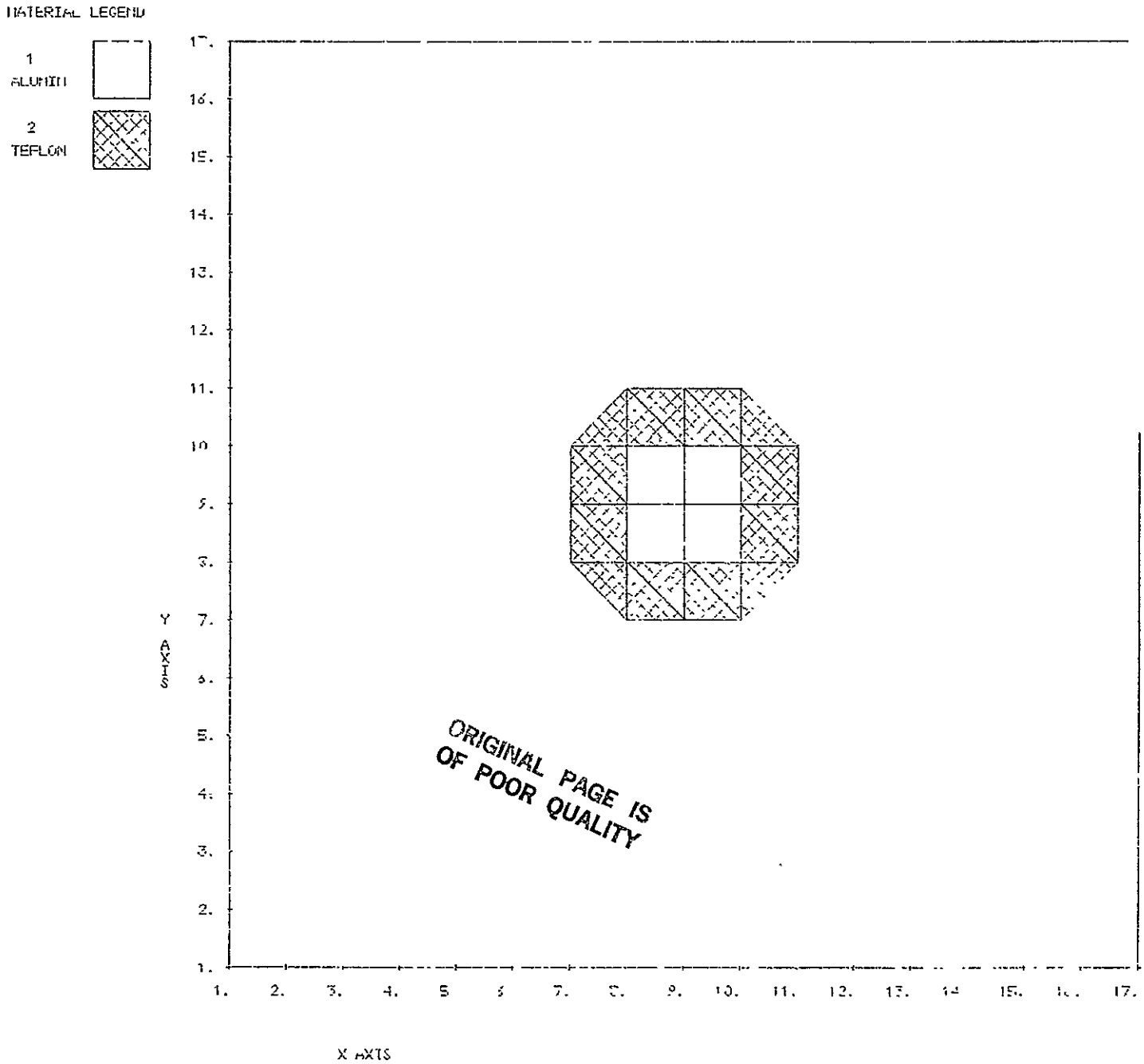
SURFACE CELL MATERIAL COMPOSITION AS VIEWED FROM THE NEGATIVE Y DIRECTION

FOR Y VALUES BETWEEN 1 AND 17



SURFACE CELL MATERIAL COMPOSITION AS VIEWED FROM THE POSITIVE Z DIRECTION

FOR Z VALUES BETWEEN 1 AND 17



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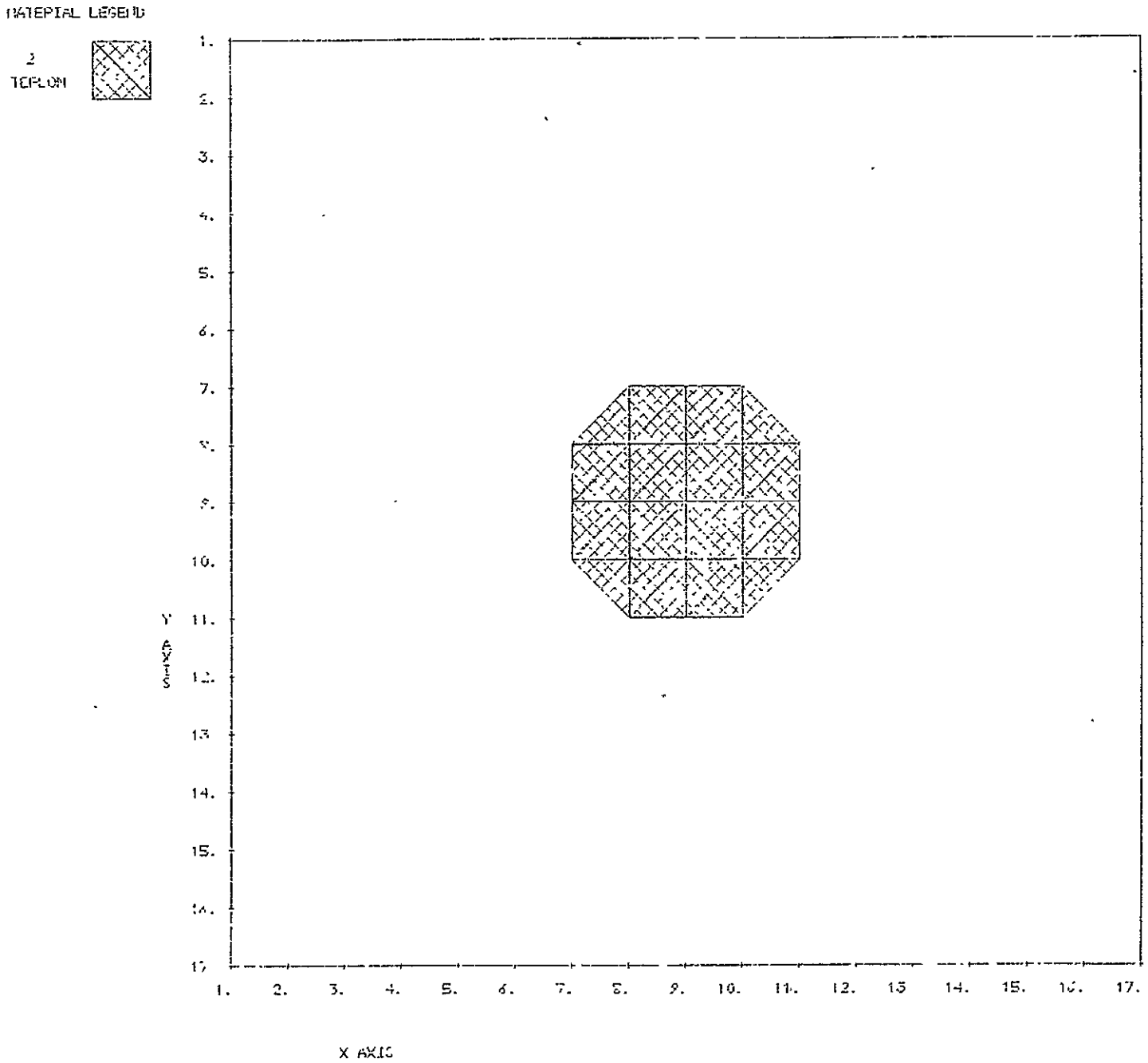
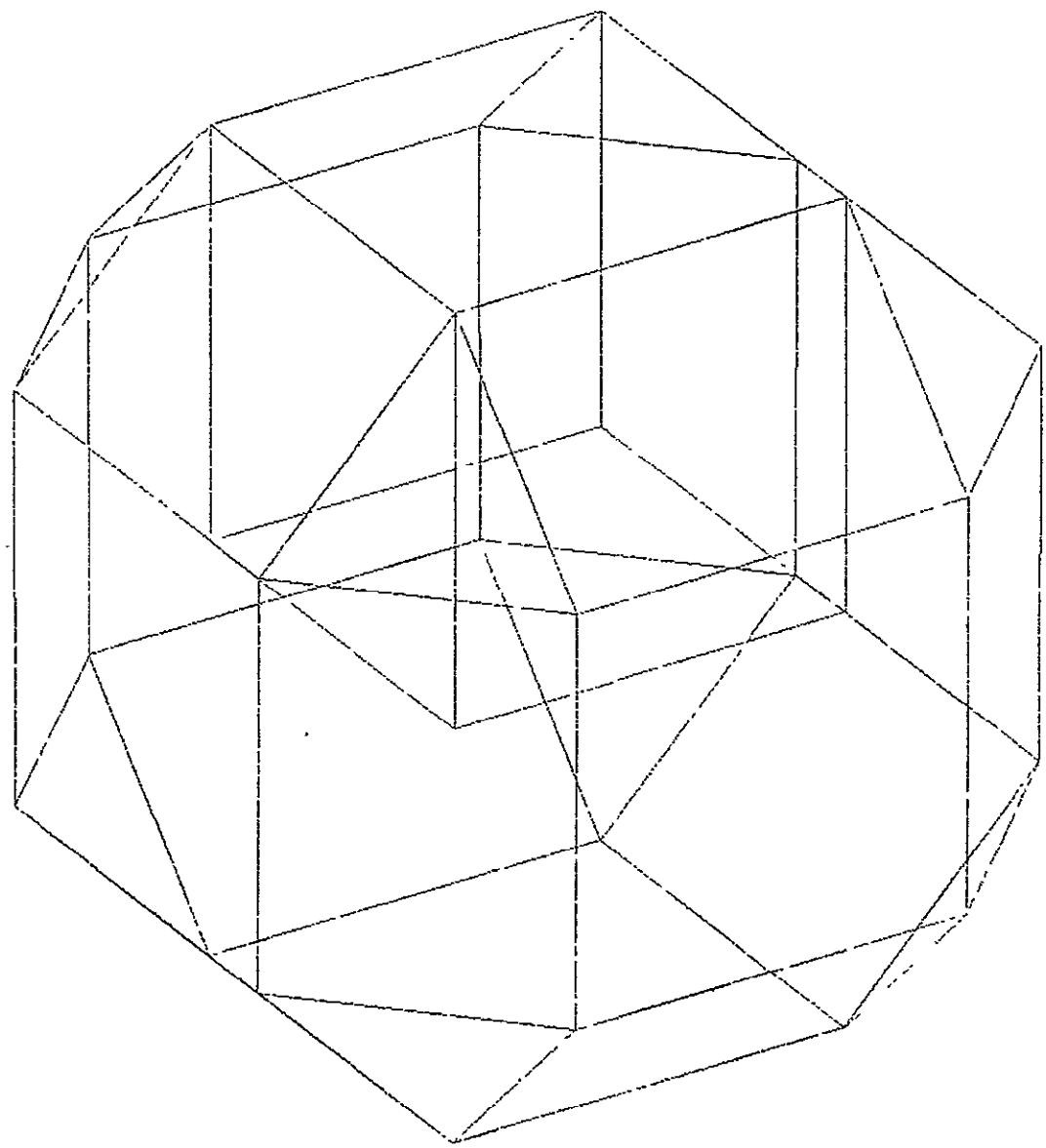
SURFACE CELL MATERIAL COMPOSITION AS VIEWED FROM THE NEGATIVE Z DIRECTION

FOR Z VALUES BETWEEN 1 AND 17





Three building block plots alternate with three hidden line plots.

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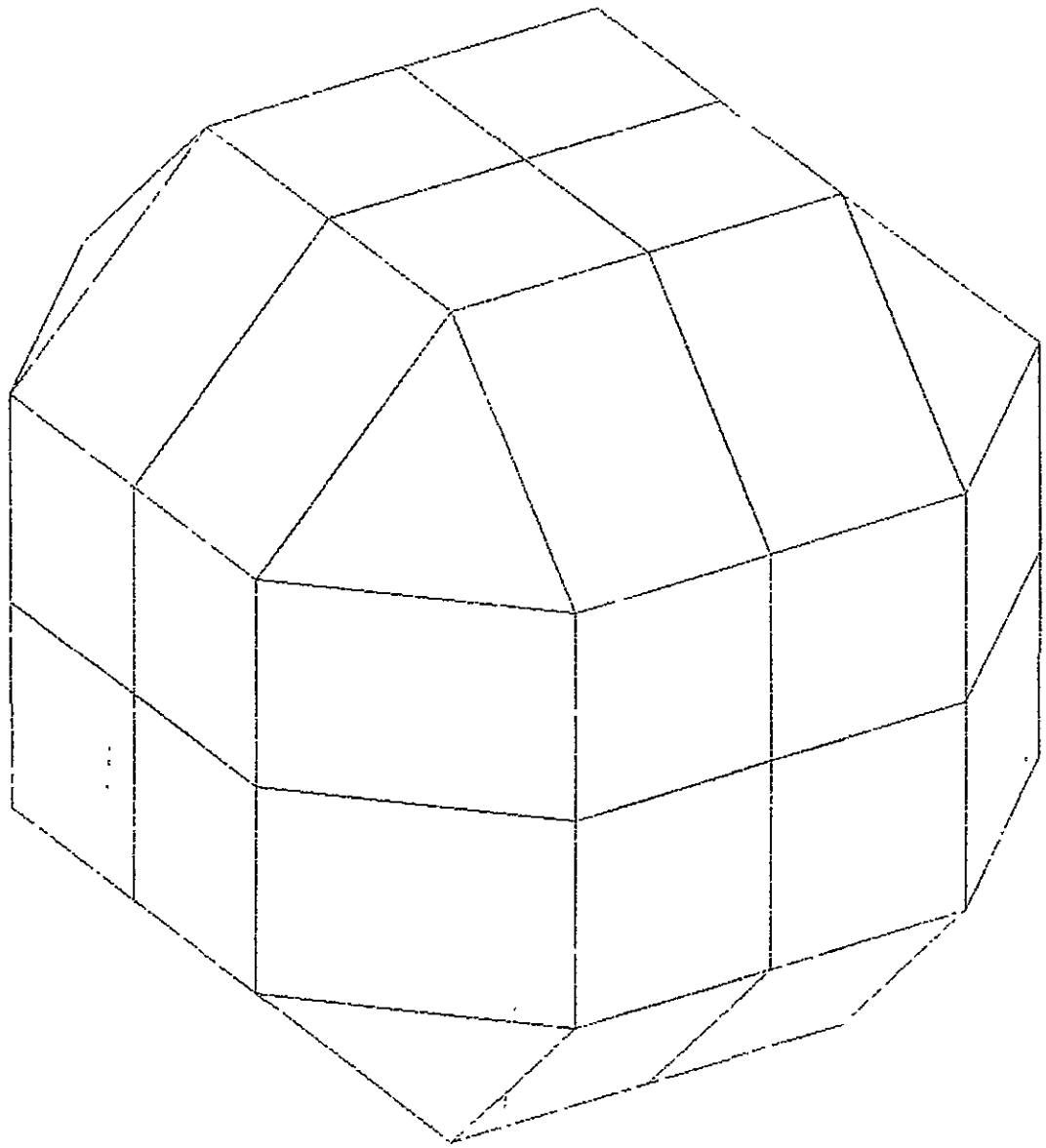

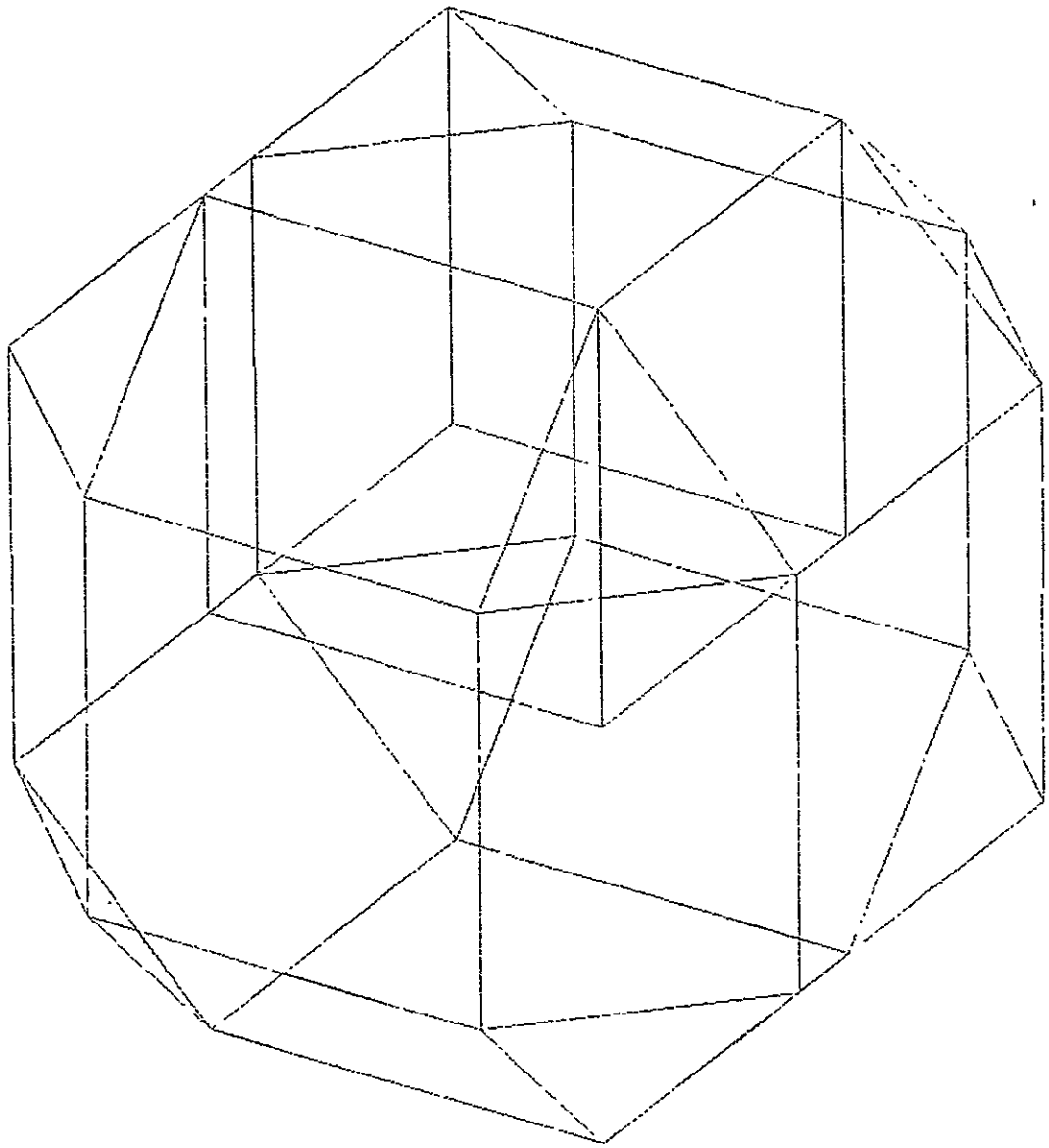

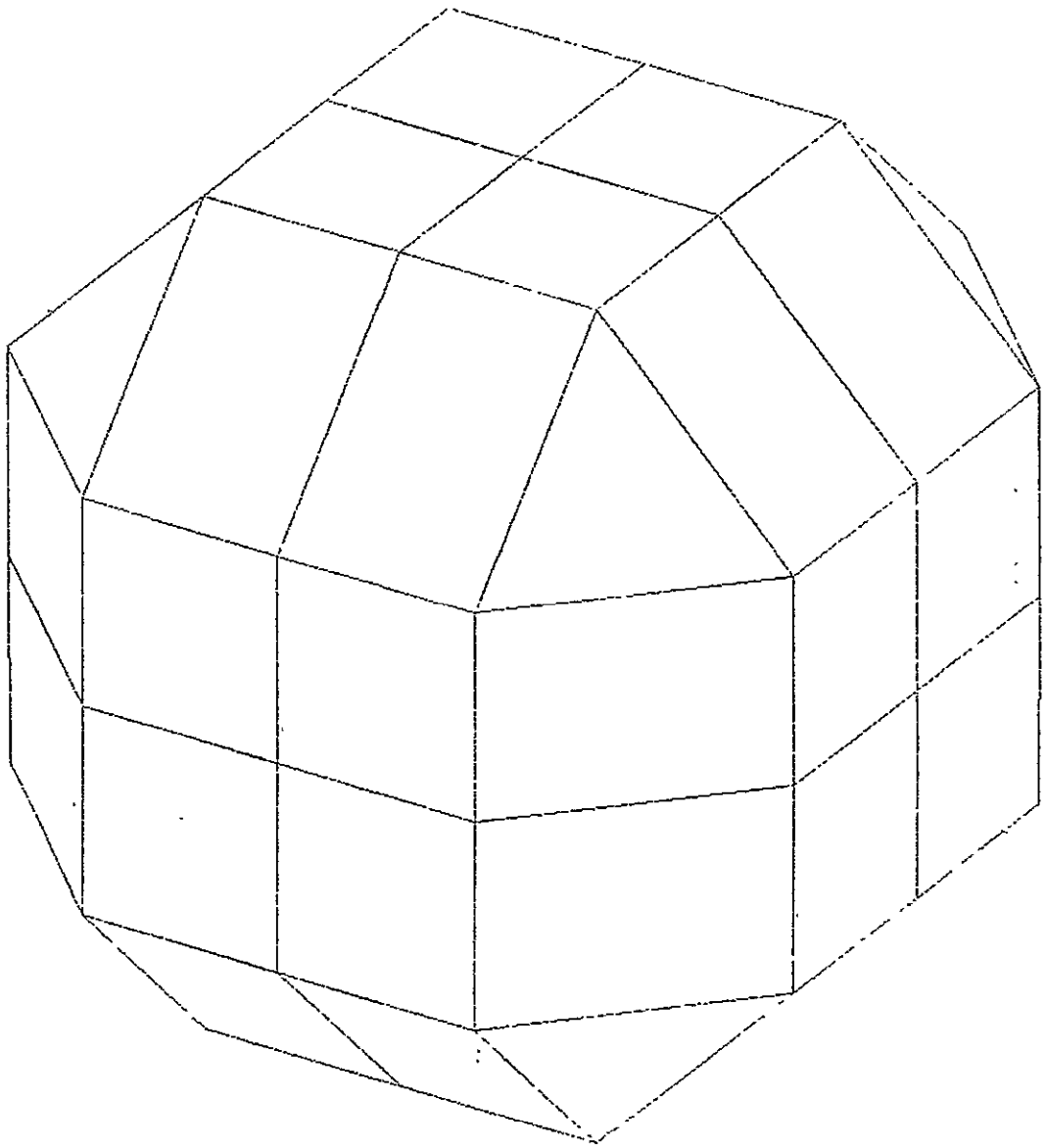

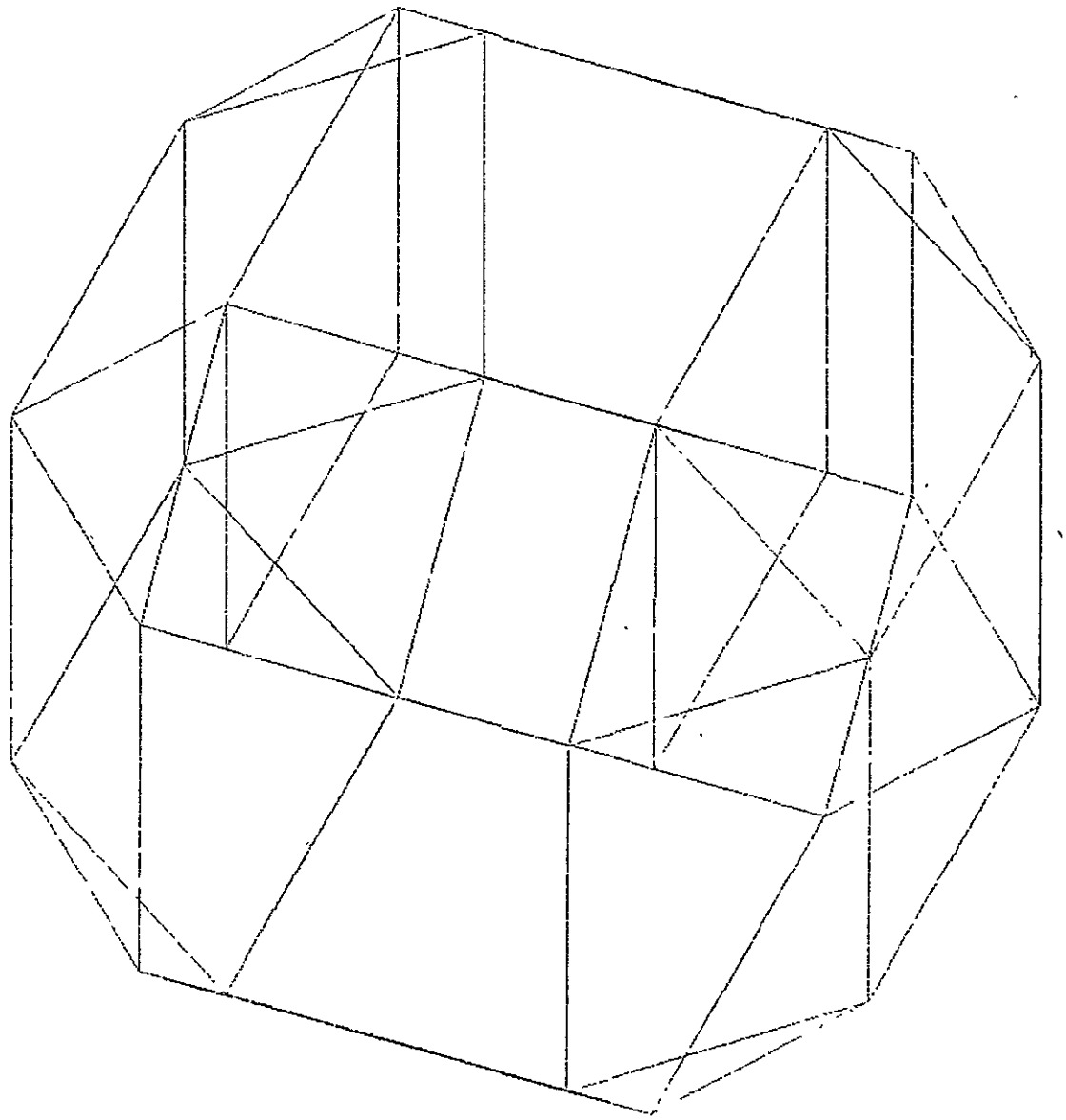

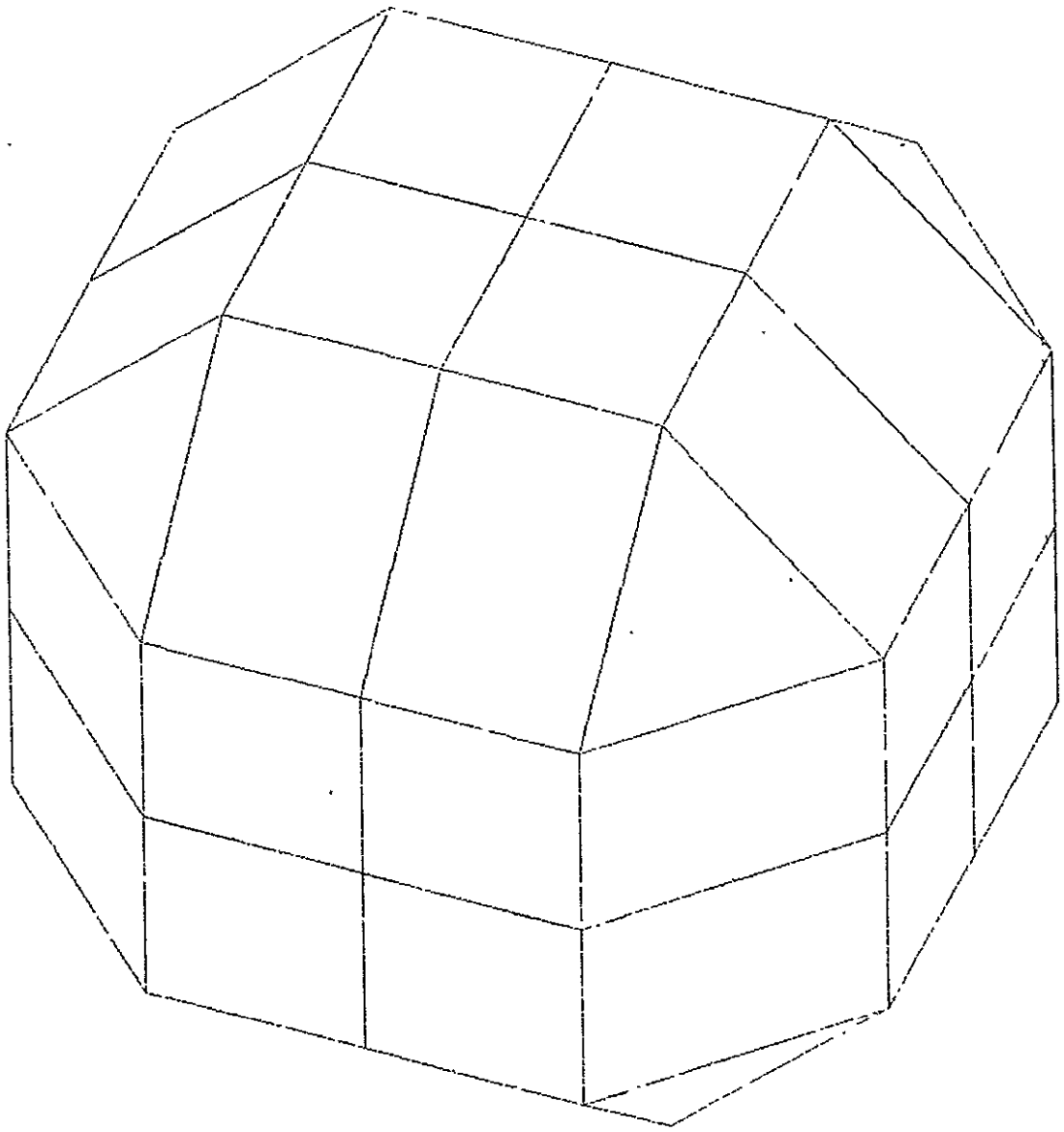

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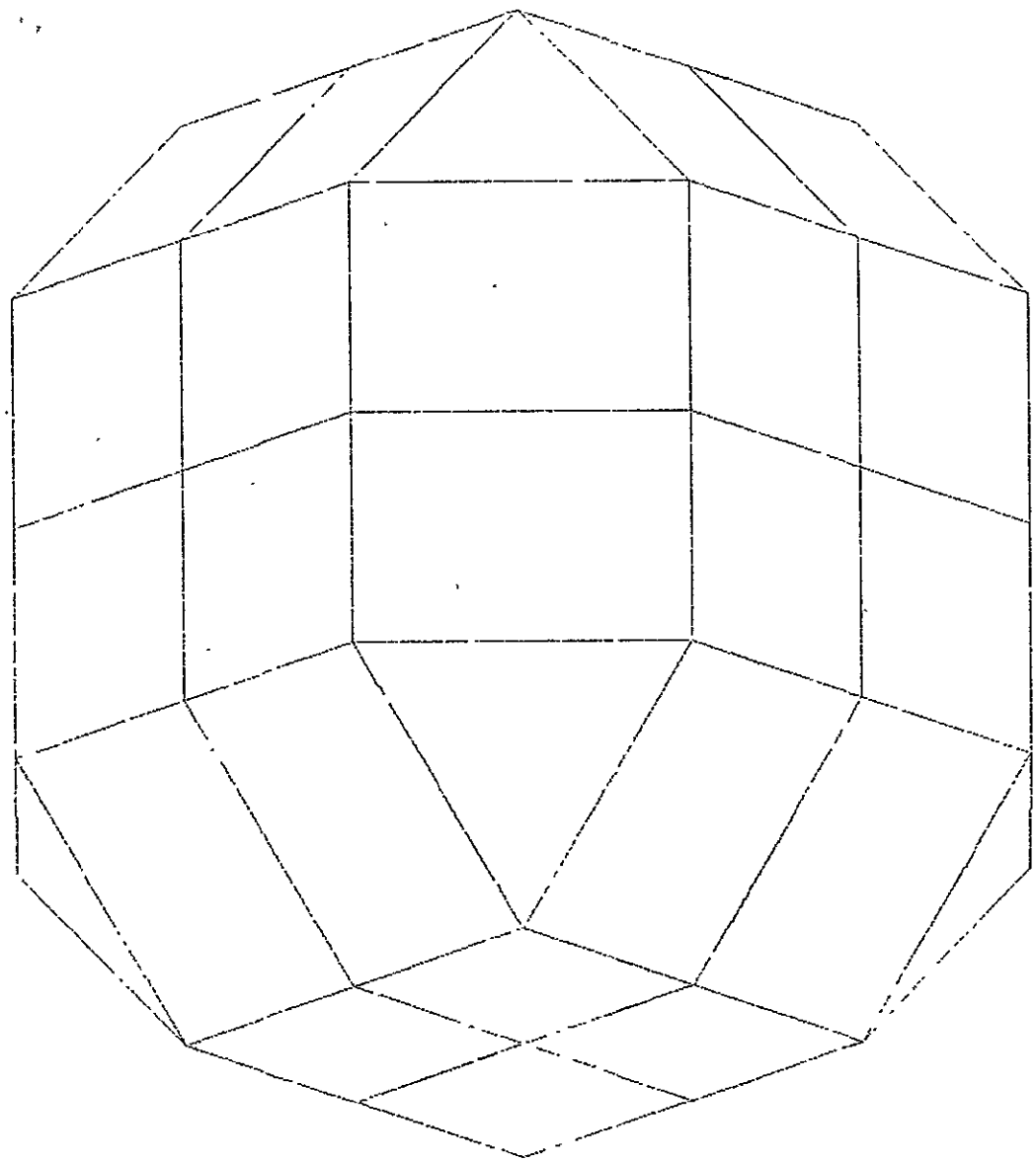

HIDCEL generates a view of the satellite from the sun direction.

```
 NA1 =    26     NA2 =    17     IP =     0


FINAL NA1 =    26

******CAPACI   0

  POTENTIALS TO BE SET BY SETALL TO    1.00+00/(4*PI*R)

*** CYCLE LOOP FROM CYCLE   1 TO CYCLE   1


          NC DETERMINED BY GETNC TO BE  1
IN POTENT, NC =      1
MBIAS =   1     VBIAS =  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
CIJSUM =  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
ROUSCN =  1.0000+00   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
  ITER =    10C= 1.0000+00  AUNC= 2.0202+01  PC= 3.4677-02  RC=-1.9202+01  UC =-1.9949-04
PCOND =    3.4677-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  7.3813-03  RDOTRS = 4.6613-01

  ITER =    20C= 1.0000+00  AUNC=-3.8495+01  PC= 3.4481-02  RC= 1.8649+01  UC = 1.9059-04
PCOND =    3.4481-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  7.4262-06  RDOTRS = 7.3813-03

  ITER =    30C= 1.0000+00  AUNC= 3.6665+01  PC= 3.4578-02  RC=-2.7926-02  UC =-9.8379-08
PCOND =    3.4578-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  1.2405-06  RDOTRS = 7.4262-06

  ITER =    40C= 1.0000+00  AUNC=-4.2840-02  PC= 3.4578-02  RC= 1.9216-02  UC = 1.8319-07
PCOND =    3.4578-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  3.9306-07  RDOTRS = 1.2405-06

  ITER =    50C= 1.0000+00  AUNC= 6.2866-03  PC= 3.4578-02  RC= 9.4209-03  UC = 1.5592-07
PCOND =    3.4578-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  2.1003-07  RDOTRS = 3.9306-07

  ITER =    60C= 1.0000+00  AUNC= 8.8588-05  PC= 3.4578-02  RC= 9.2434-03  UC = 1.7934-07
PCOND =    3.4578-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  1.1110-07  RDOTRS = 2.1003-07

  ITER =    70C= 1.0000+00  AUNC= 3.7563-04  PC= 3.4579-02  RC= 8.5199-03  UC = 1.8338-07
PCOND =    3.4579-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  6.4350-08  RDOTRS = 1.1110-07

  ITER =    80C= 1.0000+00  AUNC= 2.4836-04  PC= 3.4579-02  RC= 8.0205-03  UC = 1.8954-07
PCOND =    3.4579-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  3.7093-08  RDOTRS = 6.4350-08

  ITER =    90C= 1.0000+00  AUNC= 1.5556-04  PC= 3.4579-02  RC= 7.6313-03  UC = 1.6854-07
PCOND =    3.4579-02
QCOND =    1.0000+00
```

The CAPACI control word causes a call to POTENT which runs through twenty potential iterations. At each iteration, several variables are printed.

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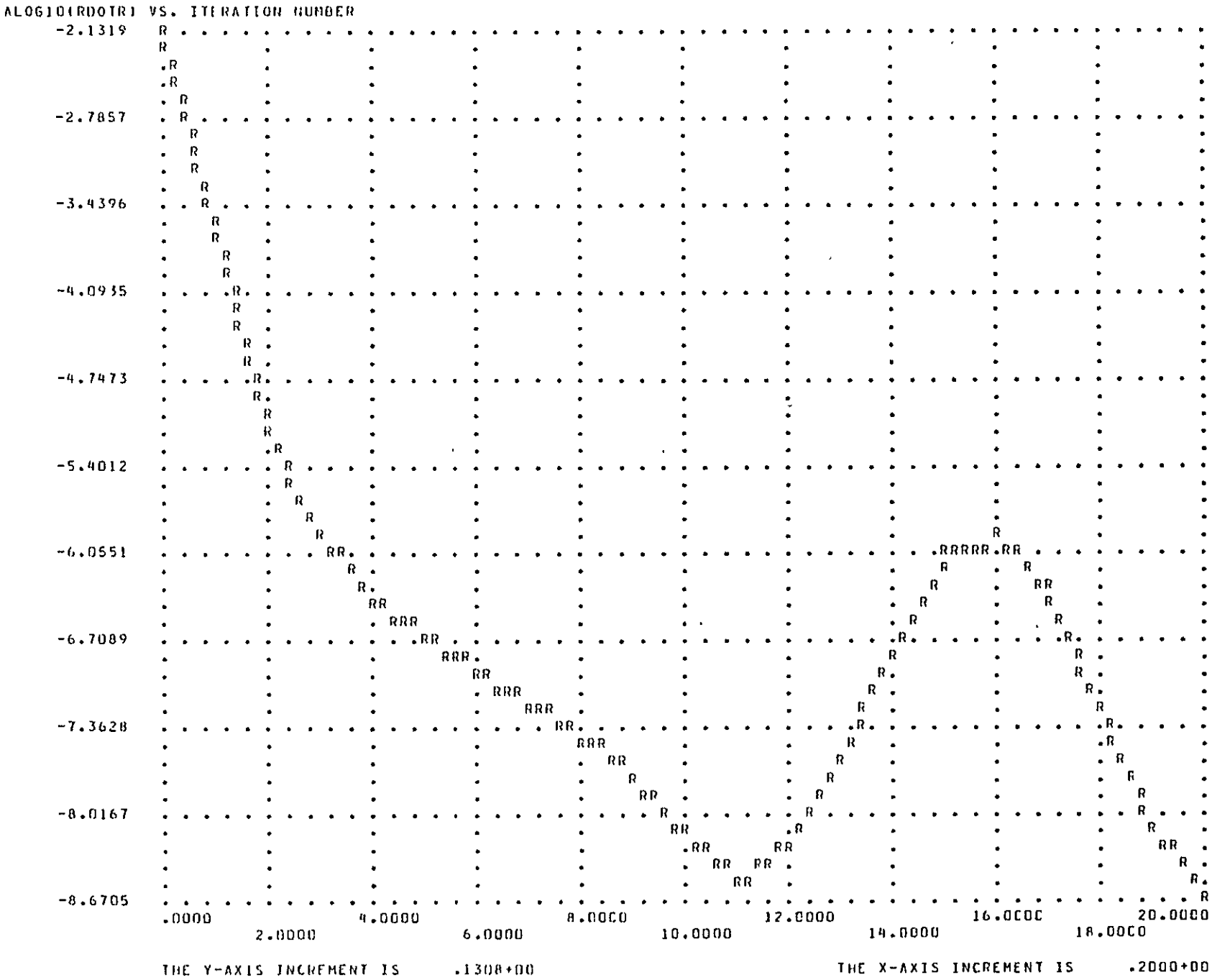
```
AFTER RUPDAT RDOTR =  1.8373-08  RDOTRS = 3.7093-08

  ITER =   100C= 1.0000+00  AUNC= 4.1506-05  PC= 3.4580-02  RC= 7.5558-03  UC = 1.7188-07
PCOND =    3.4580-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  6.3277-09  RDOTRS = 1.8373-08

  ITER =   110C= 1.0000+00  AUNC=-4.6866-07  PC= 3.4580-02  RC= 7.5567-03  UC = 1.3770-07
PCOND =    3.4580-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  2.9994-09  RDOTRS = 6.3277-09

  ITER =   120C= 1.0000+00  AUNC= 1.6949-04  PC= 3.4580-02  RC= 7.2607-03  UC = 1.4070-07
PCOND =    3.4580-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  5.1596-09  RDOTRS = 2.9994-09

  ITER =   130C= 1.0000+00  AUNC=-2.4099-04  PC= 3.4581-02  RC= 8.0261-03  UC = 3.2542-07
PCOND =    3.4581-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  2.2098-08  RDOTRS = 5.1596-09

  ITER =   140C= 1.0000+00  AUNC= 7.5080-04  PC= 3.4583-02  RC= 3.4991-03  UC = 1.4301-06
PCOND =    3.4583-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  1.6206-07  RDOTRS = 2.2098-08

  ITER =   150C= 1.0000+00  AUNC=-4.9677-03  PC= 3.4595-02  RC= 4.6381-02  UC = 1.0970-05
PCOND =    3.4595-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  8.1670-07  RDOTRS = 1.6206-07

  ITER =   160C= 1.0000+00  AUNC= 4.1223-02  PC= 3.4647-02  RC=-1.4736-01  UC = 5.3751-05
PCOND =    3.4647-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  1.0731-06  RDOTRS = 8.1670-07

  ITER =   170C= 1.0000+00  AUNC=-9.9686-02  PC= 3.4778-02  RC= 9.7002-02  UC = 7.1633-05
PCOND =    3.4778-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  4.6534-07  RDOTRS = 1.0731-06

  ITER =   180C= 1.0000+00  AUNC= 5.6429-02  PC= 3.4925-02  RC=-1.8455-02  UC = 3.0872-05
PCOND =    3.4925-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  6.4496-08  RDOTRS = 4.6534-07

  ITER =   190C= 1.0000+00  AUNC=-1.4113-02  PC= 3.4969-02  RC= 1.9181-03  UC = 4.2987-06
PCOND =    3.4969-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  7.8372-09  RDOTRS = 6.4496-08

  ITER =   200C= 1.0000+00  AUNC= 1.6994-03  PC= 3.4975-02  RC=-2.1037-04  UC = 5.2017-07
PCOND =    3.4975-02
QCOND =    1.0000+00
AFTER RUPDAT RDOTR =  2.1354-09  RDOTRS = 7.8372-09

PCOND =    3.4976-02
QCOND =    1.0000+00
```



Three printer plots show convergence of the potential routine.

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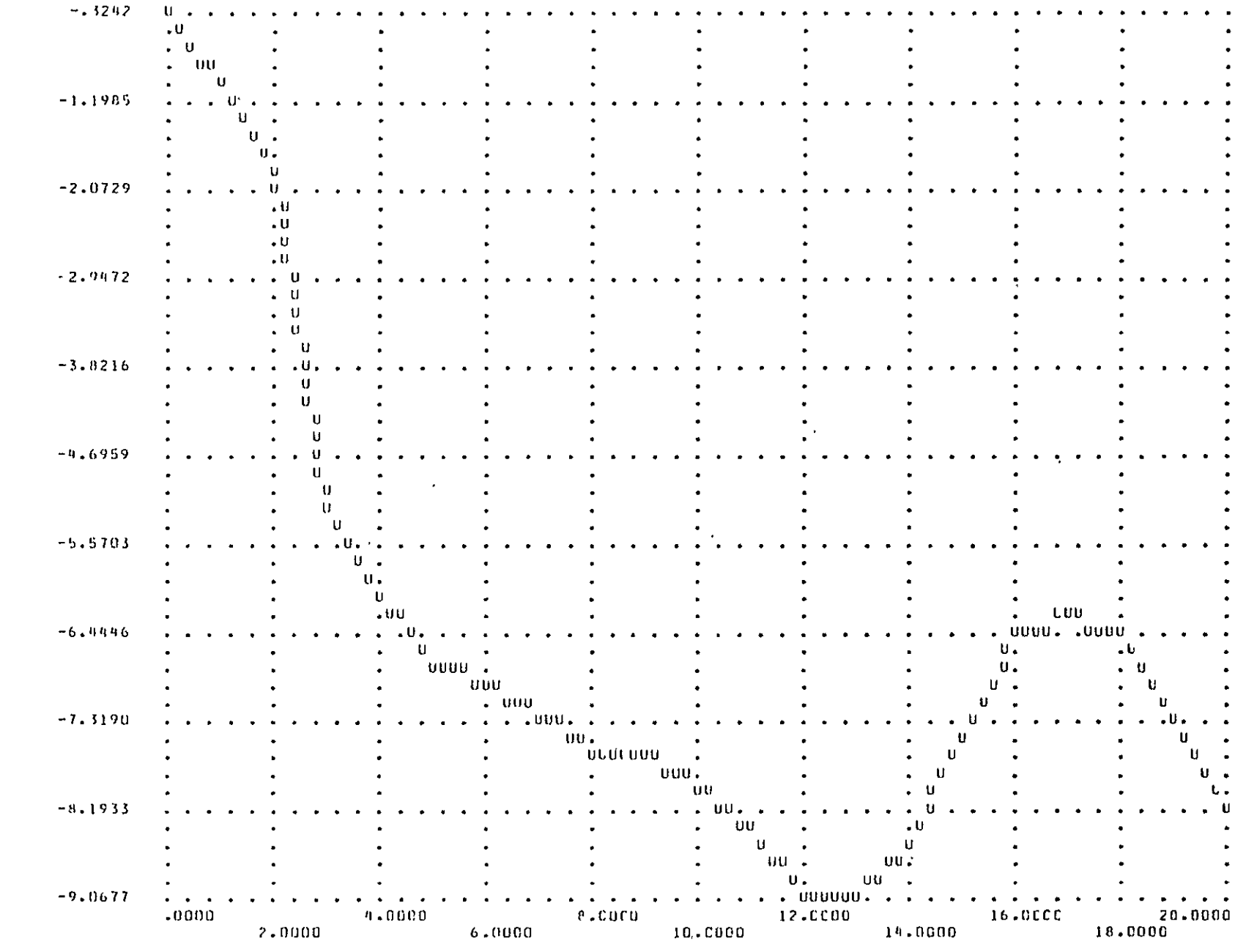
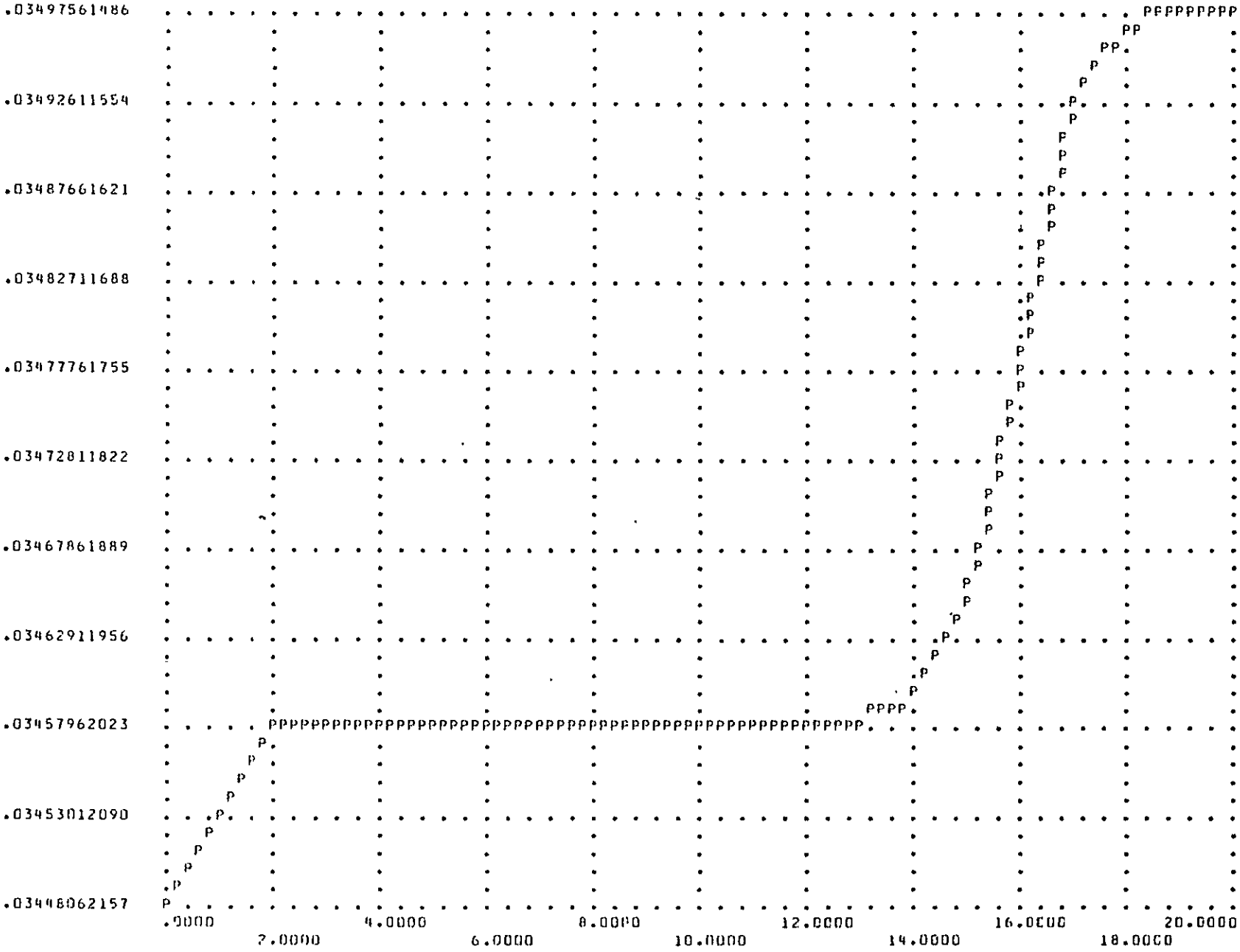
ALOG10(UDOTAU) VS. ITERATION NUMBER



P(COND. 1) VS. ITERATION NUMBER



THE Y-AXIS INCREMENT IS .9900-05 THE X-AXIS INCREMENT IS .2000+00

VBAR= 3.4966-02 -- CS SCALED BY 9.9992-01

0 MULTICONDUCTOR POINTS FOUND

1.25-02	1.96+03	6.39-01
1.21-02	1.90+03	4.79-01

3	1.25-02	1.96+03	6.39-01
4	1.21-02	1.90+03	4.78-01
5	1.00-02	1.57+03	3.01-01
6	1.21-02	1.90+03	4.78-01
7	1.25-02	1.96+03	6.39-01
8	1.21-02	1.90+03	4.78-01
9	1.25-02	1.96+03	6.39-01
10	1.25-02	1.96+03	6.39-01
11	1.21-02	1.90+03	4.78-01
12	1.25-02	1.96+03	6.39-01
13	1.25-02	1.96+03	6.39-01
14	1.25-02	1.59+03	6.39-01
15	1.21-02	1.90+03	4.78-01
16	1.21-02	1.16+03	4.78-01
17	1.25-02	1.96+03	6.39-01
18	1.25-02	1.59+03	6.39-01
19	1.25-02	1.96+03	6.39-01
20	1.21-02	1.90+03	4.78-01
21	1.25-02	1.96+03	6.39-01
22	1.21-02	1.90+03	4.78-01
23	1.00-02	1.57+03	3.01-01
24	1.21-02	1.90+03	4.78-01
25	1.21-02	1.90+03	4.78-01
26	1.21-02	1.16+03	4.78-01
27	1.00-02	1.57+03	3.01-01
28	1.21-02	1.90+03	4.78-01
29	1.21-02	1.16+03	4.78-01
30	1.21-02	1.90+03	4.78-01
31	1.00-02	1.57+03	3.01-01
32	1.21-02	1.90+03	4.78-01
33	1.25-02	1.96+03	6.39-01
34	1.21-02	1.90+03	4.78-01
35	1.25-02	1.96+03	6.39-01
36	1.25-02	1.96+03	6.39-01
37	1.25-02	1.59+03	6.39-01
38	1.21-02	1.90+03	4.78-01
39	1.21-02	1.16+03	4.78-01
40	1.25-02	1.96+03	6.39-01
41	1.25-02	1.59+03	6.39-01
42	1.25-02	1.96+03	6.39-01
43	1.21-02	1.90+03	4.78-01
44	1.25-02	1.96+03	6.39-01
45	1.25-02	1.96+03	6.39-01
46	1.21-02	1.90+03	4.78-01
47	1.25-02	1.96+03	6.39-01
48	1.21-02	1.90+03	4.78-01
49	1.00-02	1.57+03	3.01-01
50	1.21-02	1.90+03	4.78-01
51	1.25-02	1.96+03	6.39-01
52	1.21-02	1.90+03	4.78-01
53	1.25-02	1.96+03	6.39-01

******TRILIN 0

FLUX DEFINITION

TYPE 2

ELECTRON TEMPERATURE = 2.00+04 ELECTRON VOLTS

The CELGET subroutine (called by CAPACI) generates a list of capacitance values for points on the object surface (surface nodes) to end CAPACI. The TRILIN card is read, and a flux definition is taken from file 22.

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```
ELECTRON DENSITY =          1.00+06 METER**(-3)
ION TEMPERATURE =           2.00+04 ELECTRON VOLTS
ION DENSITY =               1.00+06 METER**(-3)
POTENTIALS TO BE SET BY SETALL TO     1.00+00/(4*PI*R)
*** CYCLE LOOP FROM CYCLE   1 TO CYCLE   1

NC DETERMINED BY GETNC TO BE  1
```

```
TIMESTEP NO.    1          TIME =    0.000    SECONDS.

QSUM =  1.0000+00
PCOND =  3.4677-02
QCOND =  0.0000

-----------------------------------------------------------------------------

 SURFACE CELL NO.    1                                    CODE =       010707077742
                                                          LOCATION =    7  7  7
                                                          NORMAL =     -1 -1 -1
                                                          MATERIAL =  TEFLON
                          POTENTIAL =   3.249-02 VOLTS
                          FIELD =   1.724+01 VOLTS/METER
  FLUXES IN A/M**2
       INCIDENT ELECTRONS                          3.78-06
            RESULTING BACKSCATTER                  1.02-06
            RESULTING SECONDARIES                  1.23-06
       INCIDENT PROTONS                            8.83-08
            RESULTING SECONDARIES                  9.15-07
       PHOTOCURRENT                                0.00
                                                 -----------
     NET FLUX                                     -5.34-07

        NET CHARGING CURRENT =   3.27+06 (CODE UNITS/SEC.).

  BADCEL ---    0 OUT OF   53 NODES SET.

  BADCND ---  0 OUT OF  1 CONDUCTORS SET.

  DO
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02  4.9+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02  1.1+03 -6.1+02  3.0+03
        -4.4+02  8.0+03  1.3+03  9.9+03  6.8+03  4.9+03 -7.4+02 -6.2+02 -7.4+02  3.0+03 -4.4+02  6.9+03  1.4+04  3.3+03  1.8+04
         1.4+04  1.0+04  4.9+02 -7.4+02 -7.6+02  8.0+03  1.3+03  1.4+04  3.3+03  1.9+04  6.9+03  2.2+04  2.2+04  1.6+04  9.9+03
         6.8+03  4.9+03  1.8+04  1.4+04  1.0+04  2.2+04  2.2+04  1.6+04

 ENTERING ICCG1 -- VCTRI =   0.000

 LIST CONTAINS   160 ENTRIES.

   CAPPOT --- RDOTR/RDOTR1 =    1.41-14/   3.68+10

 LEAVING ICCG1 -- VCTRI =   1.134+04

  DO
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02  4.9+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02  1.1+03 -6.1+02  3.0+03
        -4.4+02  8.0+03  1.3+03  9.9+03  6.8+03  4.9+03 -7.4+02 -6.2+02 -7.4+02  3.0+03 -4.4+02  6.9+03  1.4+04  3.3+03  1.8+04
         1.4+04  1.0+04  4.9+02 -7.4+02 -7.6+02  8.0+03  1.3+03  1.4+04  3.3+03  1.9+04  6.9+03  2.2+04  2.2+04  1.6+04  9.9+03
         6.8+03  4.9+03  1.8+04  1.4+04  1.0+04  2.2+04  2.2+04  1.6+04

  BADCEL ---   34 OUT OF   53 NODES SET.

  BADCND ---  0 OUT OF  1 CONDUCTORS SET.

 ENTERING ICCG1 -- VCTRI =   0.000

 LIST CONTAINS   160 ENTRIES.

   CAPPOT --- RDOTR/RDOTR1 =    1.08-23/   1.22+05

 LEAVING ICCG1 -- VCTRI =  -3.020-01
```

Detailed flux information for surface cell #1 (default) is printed. Diagnostic printout from the LIMCEL section of TRILIN is given.

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```
 DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02  4.9+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02  1.1+03 -6.1+02  3.0+03
        -4.4+02  8.0+03  1.3+03  9.9+03  6.8+03  4.9+03 -7.4+02 -6.2+02 -7.4+02  3.0+03 -4.4+02  6.9+03  1.4+04  3.3+03  1.8+04
         1.4+04  1.0+04  4.9+02 -7.4+02 -7.6+02  8.0+03  1.3+03  1.4+04  3.3+03  1.9+04  6.9+03  2.2+04  2.2+04  1.6+04  9.9+03
         6.8+03  4.9+03  1.8+04  1.4+04  1.0+04  2.2+04  2.2+04  1.6+04

 DL
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

ENTERING ICCG1 -- VCTRI =  -3.020-01

LIST CONTAINS   160 ENTRIES.

  CAPPOT --- RDOTR/RDOTR1 =    6.68-24/   1.22+05

LEAVING ICCG1 -- VCTRI =  -3.020-01

 DQC( 1) = -5.5250+03

 DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02  6.0+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02  6.0+02 -6.1+02  5.7+02
        -4.4+02  6.0+02  4.8+02  6.0+02  5.7+02  6.0+02 -7.4+02 -6.2+02 -7.4+02  5.7+02 -4.4+02  4.7+02  5.7+02  3.5+02  5.7+02
         4.7+02  5.7+02  6.0+02 -7.4+02 -7.6+02  6.0+02  4.8+02  5.7+02  3.5+02  6.0+02  4.8+02  6.0+02  5.7+02  6.0+02  6.0+02
         5.7+02  6.0+02  5.7+02  4.7+02  5.7+02  6.0+02  5.7+02  6.0+02

 VFIX ---   34 OUT OF   53 NODES FIXED.

ENTERING ICCG1 -- VCTRI =  -3.020-01

LIST CONTAINS   160 ENTRIES.

  CAPPOT --- RDOTR/RDOTR1 =    1.57-21/   2.01+06

LEAVING ICCG1 -- VCTRI =   1.812+00

 DQC( 1) = -5.5250+03

 DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02 -3.7+03 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02 -3.1+03 -6.1+02 -1.7+03
        -4.4+02  3.1+02 -2.2+03  8.9+02 -4.9+01 -8.9+02 -7.4+02 -6.2+02 -7.4+02 -1.7+03 -4.4+02  3.7+02  2.0+03 -3.0+02  2.7+03
         2.1+03  1.1+03 -3.7+03 -7.4+02 -7.6+02  3.1+02 -2.2+03  2.0+03 -3.0+02  2.8+03  4.1+02  3.4+03  3.3+03  2.3+03  8.9+02
        -4.9+01 -8.9+02  2.7+03  2.1+03  1.1+03  3.4+03  3.3+03  2.3+03
```

PREDICTED NODE POTENTIALS

NODE	V-PRED	DQ	V-OLD	PTLIST
1	1.42	-763.94	.03	000710100001
2	1.42	-744.22	.04	000710110001
3	1.42	-763.94	.03	000710120001
4	1.42	-744.22	.04	000711100001
5	1.42	-621.18	.04	000711110001
6	1.42	-744.22	.04	000711120001
7	-.06	-3660.80	.03	000712100001
8	1.42	-744.22	.04	000712110001
9	1.42	-763.94	.03	000712120001
10	1.42	-763.94	.03	001007100001
11	1.42	-744.22	.04	001007110001
12	1.42	-763.94	.03	001007120001
13	.22	-3113.45	.03	001010070001
14	1.43	-610.85	.03	001010131001
15	.90	-1729.54	.04	001011070001
16	1.44	-436.16	.04	001011131001
17	1.97	310.82	.03	001012070001
18	.40	-2243.93	.03	001012131001
19	2.26	885.54	.03	001013100001
20	1.79	-49.19	.04	001013110001
21	1.36	-889.51	.03	001013120001
22	1.42	-744.22	.04	001107100001
23	1.42	-621.18	.04	001107110001
24	1.42	-744.22	.04	001107120001
25	.90	-1729.54	.04	001110070001
26	1.44	-436.16	.04	001110131001
27	2.05	372.18	.04	001111070001
28	2.85	1975.44	.04	001112070001
29	1.55	-301.57	.04	001112131001
30	3.22	2681.17	.04	001113100001
31	3.15	2098.88	.04	001113110001
32	2.39	1101.83	.04	001113120001
33	-.06	-3660.80	.03	001207100001
34	1.42	-744.22	.04	001207110001
35	1.42	-763.94	.03	001207120001
36	1.97	310.82	.03	001210070001
37	.40	-2243.93	.03	001210131001
38	2.85	1975.44	.04	001211070001
39	1.55	-301.57	.04	001211131001
40	3.23	2798.11	.03	001212070001
41	2.07	409.37	.03	001212131001
42	3.54	3393.50	.03	001213100001
43	3.53	3270.11	.04	001213110001
44	3.00	2343.62	.03	001213120001
45	2.26	885.54	.03	001310100001
46	1.79	-49.19	.04	001310110001
47	1.36	-889.51	.03	001310120001
48	3.22	2681.17	.04	001311100001
49	3.15	2098.88	.04	001311110001
50	2.39	1101.83	.04	001311120001
51	3.54	3393.50	.03	001312100001
52	3.53	3270.11	.04	001312110001
53	3.00	2343.62	.03	001312120001

SUM(DQ)= 5.57602612+03

SUM(CS*DV)= 5.05303435+01

LIMCEL predicts new potentials for surface nodes.

```
DQC = -5.52496552+03
V-C =  1.81165567+00
```

When the new charge distribution has been calculated, POTENT is called to calculate potentials.

```
          TIMESTEP NO.    1          TIME =    1.000-01 SECONDS.

QSUM =  5.1061+01
PCOND =  1.7706+00
QCOND = -5.5250+03
IN POTENT, NC =      1
MBIAS =   1      VBIAS =  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
CIJSUM =  0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
ROUSCN = -5.5250+03   0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
  ITER =     10C=-5.5250+03  AUNC= 1.0315+03  PC= 1.7706+00  RC=-6.5565+03  UC =-6.8115-02
PCOND =    1.7706+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  8.7987+02  RDOTRS = 8.4532+04

  ITER =     20C=-5.5250+03  AUNC=-1.3115+04  PC= 1.7032+00  RC= 6.4165+03  UC = 6.5952-02
PCOND =    1.7032+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  6.1910+00  RDOTRS = 8.7987+02

  ITER =     30C=-5.5250+03  AUNC= 1.2692+04  PC= 1.7369+00  RC=-6.7643+01  UC =-2.3869-04
PCOND =    1.7369+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  1.5985+00  RDOTRS = 6.1910+00

  ITER =     40C=-5.5250+03  AUNC=-4.9194+01  PC= 1.7366+00  RC= 1.0543+01  UC = 4.7901-05
PCOND =    1.7366+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  6.3113-01  RDOTRS = 1.5985+00

  ITER =     50C=-5.5250+03  AUNC= 6.1439+00  PC= 1.7366+00  RC=-7.0406-01  UC = 1.1598-05
PCOND =    1.7366+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  3.0663-01  RDOTRS = 6.3113-01

  ITER =     60C=-5.5250+03  AUNC=-1.0086+00  PC= 1.7367+00  RC= 1.2673+00  UC = 1.8801-05
PCOND =    1.7367+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  1.6636-01  RDOTRS = 3.0663-01

  ITER =     70C=-5.5250+03  AUNC= 2.3545-01  PC= 1.7367+00  RC= 7.8511-01  UC = 1.8356-05
PCOND =    1.7367+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  6.2527-02  RDOTRS = 1.6636-01

  ITER =     80C=-5.5250+03  AUNC=-2.0190-02  PC= 1.7367+00  RC= 8.2412-01  UC = 1.5461-05
PCOND =    1.7367+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  2.2004-02  RDOTRS = 6.2527-02

  ITER =     90C=-5.5250+03  AUNC= 4.4093-03  PC= 1.7368+00  RC= 8.1711-01  UC = 1.3930-05
PCOND =    1.7368+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  5.9209-03  RDOTRS = 2.2004-02

  ITER =    100C=-5.5250+03  AUNC= 2.4078-02  PC= 1.7368+00  RC= 7.7602-01  UC = 1.1810-05
PCOND =    1.7368+00
QCOND =   -5.5250+03
AFTER RUPDAT RDOTR =  1.6295-03  RDOTRS = 5.9209-03

  ITER =    110C=-5.5250+03  AUNC=-3.3024-02  PC= 1.7368+00  RC= 8.2973-01  UC = 1.1876-05
PCOND =    1.7368+00
```

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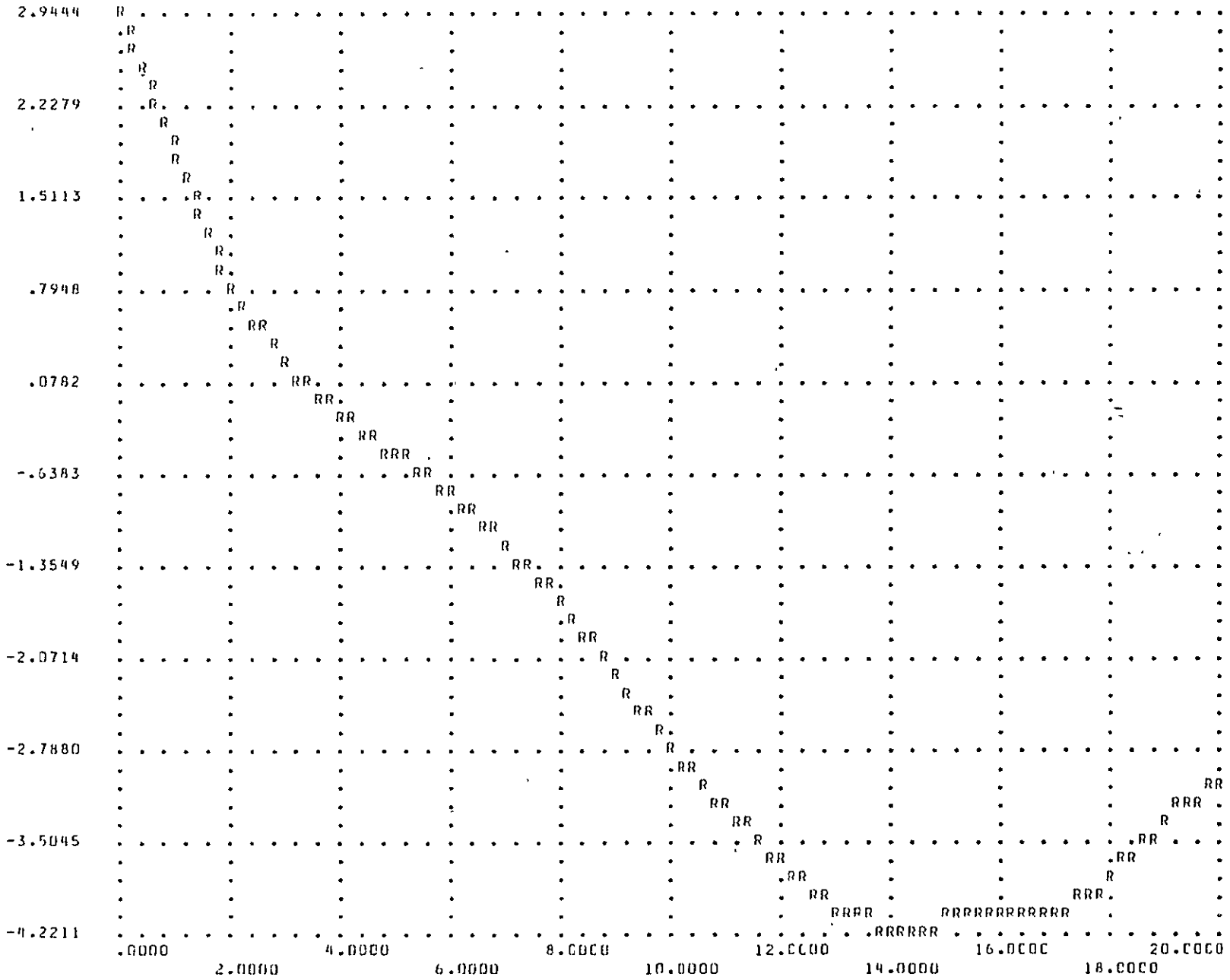
```
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  5.7578-04  RDOTRS = 1.6295-03

  ITER =    120C=-5.5250+03  AUNC= 6.7072-02  PC= 1.7368+00  RC= 7.2522-01  UC = 1.1729-05
PCOND =     1.7368+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  2.1538-04  RDOTRS = 5.7578-04

  ITER =    130C=-5.5250+03  AUNC=-9.9502-02  PC= 1.7368+00  RC= 9.0446-01  UC = 1.3784-05
PCOND =     1.7368+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  9.5149-05  RDOTRS = 2.1538-04

  ITER =    140C=-5.5250+03  AUNC= 2.0821-01  PC= 1.7369+00  RC= 5.1943-01  UC = 1.1486-05
PCOND =     1.7369+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  6.0105-05  RDOTRS = 9.5149-05

  ITER =    150C=-5.5250+03  AUNC=-4.2171-01  PC= 1.7369+00  RC= 1.3651+00  UC = 2.1437-05
PCOND =     1.7369+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  7.2642-05  RDOTRS = 6.0105-05

  ITER =    160C=-5.5250+03  AUNC= 9.2006-01  PC= 1.7369+00  RC=-4.9968-01  UC = 2.0717-05
PCOND =     1.7369+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  8.1827-05  RDOTRS = 7.2642-05

  ITER =    170C=-5.5250+03  AUNC=-1.4208+00  PC= 1.7370+00  RC= 1.9222+00  UC = 4.3307-05
PCOND =     1.7370+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  8.3769-05  RDOTRS = 8.1827-05

  ITER =    180C=-5.5250+03  AUNC= 7.2273-01  PC= 1.7371+00  RC= 2.8515-01  UC = 4.7297-05
PCOND =     1.7371+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  1.5480-04  RDOTRS = 8.3769-05

  ITER =    190C=-5.5250+03  AUNC=-1.9154-01  PC= 1.7372+00  RC= 9.4925-01  UC = 9.7263-05
PCOND =     1.7372+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  4.5025-04  RDOTRS = 1.5480-04

  ITER =    200C=-5.5250+03  AUNC= 7.0349-02  PC= 1.7377+00  RC= 5.9390-01  UC = 2.8907-04
PCOND =     1.7377+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  9.3807-04  RDOTRS = 4.5025-04

PCOND =     1.7390+00
QCOND =    -5.5250+03
```

ALOG10(RDOTR) VS. ITERATION NUMBER



THE Y-AXIS INCREMENT IS .1433+00

THE X-AXIS INCREMENT IS .2000+00

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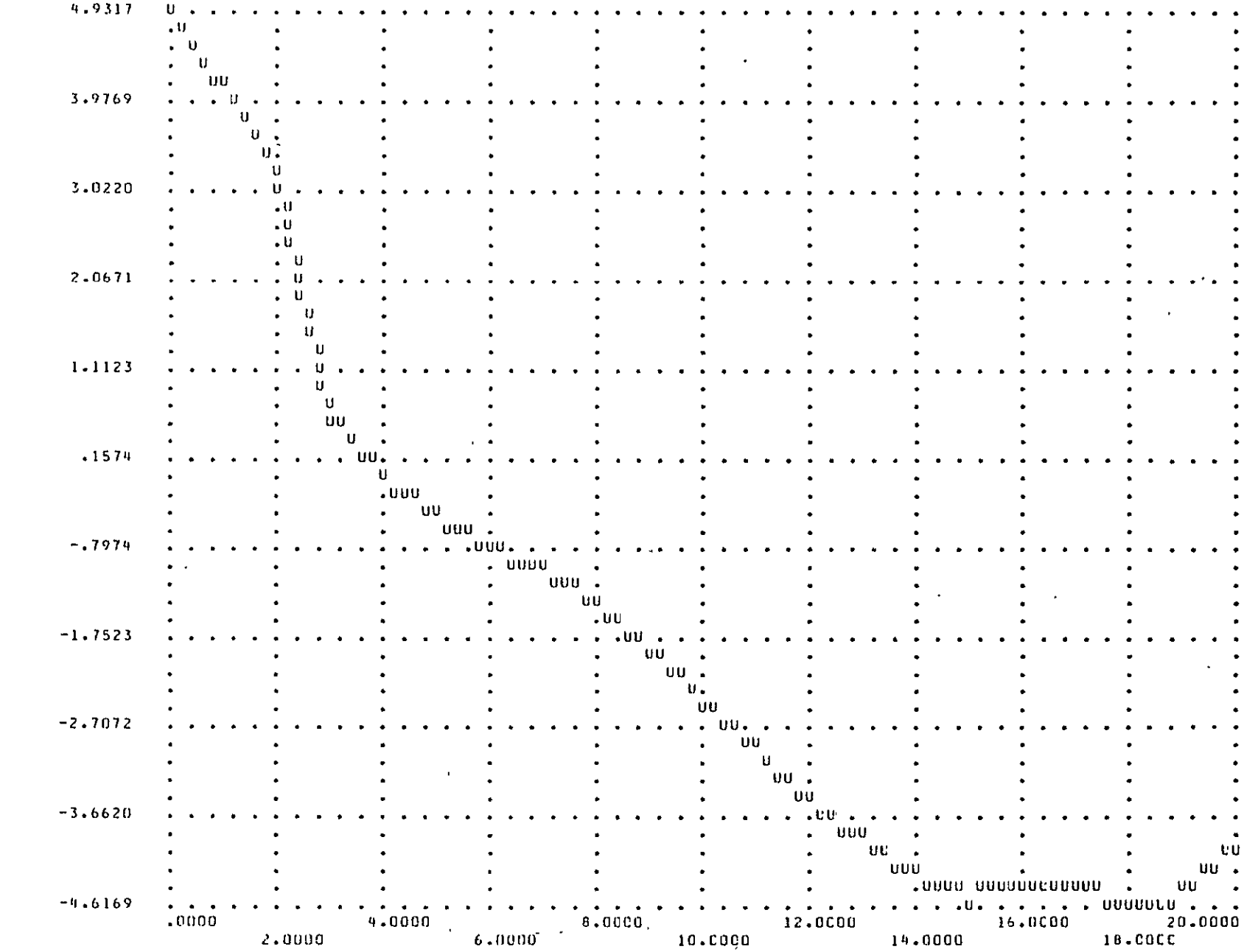
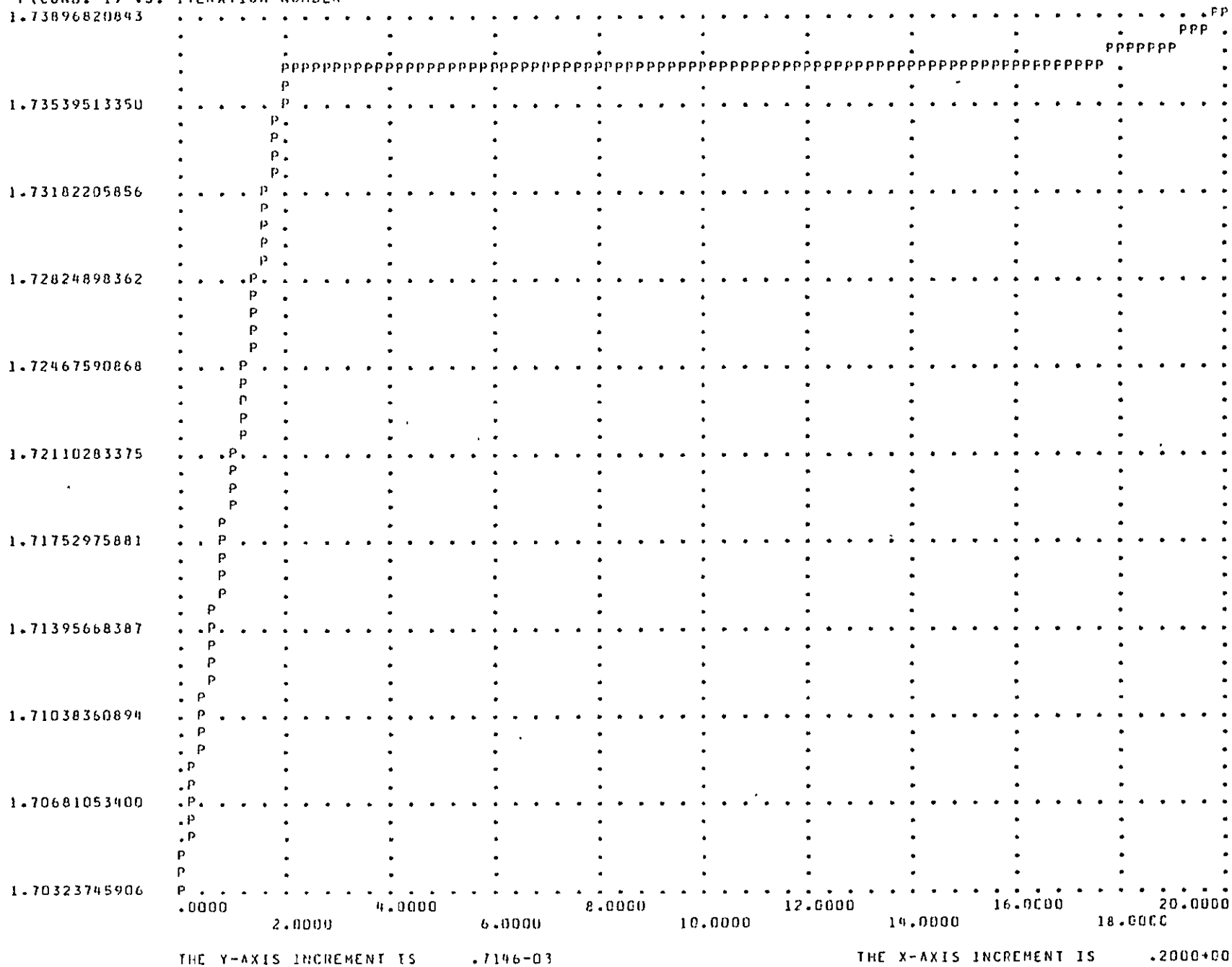
OF POOR QUALITY

ALOG10(UDOTAU) VS. ITERATION NUMBER



THE Y-AXIS INCREMENT IS .1910+00 THE X-AXIS INCREMENT IS .2000+00

P(COND. 1) VS. ITERATION NUMBER



THE Y-AXIS INCREMENT IS .7146-03 THE X-AXIS INCREMENT IS .2000+00

UNIT NO. 14 1 GRIDS

P(I,J, 1, 1)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.E -1 X	2.93	3.05	3.17	3.28	3.39	3.47	3.54	3.58	3.59	3.58	3.54	3.47	3.39	3.28	3.17	3.05	2.93
2	1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05
3	1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17
4	1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28
5	1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39
6	1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47
7	1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54
8	1.E -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58
9	1.E -1 X	3.59	3.82	4.06	4.31	4.54	4.76	4.93	5.04	5.08	5.04	4.93	4.76	4.54	4.31	4.06	3.82	3.59
10	1.E -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58
11	1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54
12	1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47
13	1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39
14	1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28
15	1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17
16	1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05
17	1.E -1 X	2.93	3.05	3.17	3.28	3.39	3.47	3.54	3.58	3.59	3.58	3.54	3.47	3.39	3.28	3.17	3.05	2.93

P(I,J, 2, 1)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05
2	1.E -1 X	3.19	3.35	3.50	3.64	3.77	3.88	3.98	4.04	4.07	4.05	4.00	3.91	3.79	3.66	3.51	3.35	3.19
3	1.E -1 X	3.33	3.50	3.66	3.82	3.97	4.11	4.22	4.30	4.33	4.32	4.25	4.16	4.02	3.87	3.69	3.51	3.33
4	1.E -1 X	3.46	3.64	3.82	4.00	4.18	4.34	4.48	4.57	4.61	4.60	4.53	4.42	4.26	4.08	3.88	3.67	3.46
5	1.E -1 X	3.58	3.77	3.97	4.18	4.39	4.58	4.74	4.85	4.91	4.90	4.83	4.70	4.51	4.29	4.06	3.81	3.58
6	1.E -1 X	3.68	3.88	4.11	4.34	4.58	4.79	4.98	5.12	5.20	5.20	5.12	4.96	4.74	4.49	4.22	3.95	3.68
7	1.E -1 X	3.76	3.98	4.22	4.48	4.74	4.98	5.19	5.36	5.46	5.48	5.38	5.20	4.95	4.67	4.36	4.05	3.76
8	1.E -1 X	3.81	4.04	4.30	4.57	4.85	5.12	5.36	5.56	5.68	5.70	5.60	5.39	5.11	4.79	4.45	4.12	3.81
9	1.E -1 X	3.82	4.07	4.33	4.61	4.91	5.20	5.46	5.68	5.81	5.83	5.72	5.50	5.20	4.86	4.50	4.15	3.82
10	1.E -1 X	3.81	4.05	4.32	4.60	4.90	5.20	5.48	5.70	5.83	5.85	5.74	5.51	5.20	4.85	4.49	4.14	3.81
11	1.E -1 X	3.76	4.00	4.25	4.53	4.83	5.12	5.39	5.60	5.72	5.74	5.63	5.41	5.11	4.78	4.43	4.08	3.76
12	1.E -1 X	3.68	3.91	4.16	4.42	4.70	4.96	5.20	5.39	5.50	5.51	5.41	5.21	4.94	4.63	4.31	4.00	3.68
13	1.E -1 X	3.58	3.79	4.02	4.26	4.51	4.75	4.95	5.11	5.20	5.20	5.11	4.94	4.70	4.44	4.15	3.87	3.58
14	1.E -1 X	3.46	3.66	3.87	4.08	4.29	4.49	4.67	4.79	4.86	4.85	4.78	4.63	4.44	4.21	3.96	3.71	3.46
15	1.E -1 X	3.33	3.51	3.69	3.88	4.06	4.22	4.36	4.45	4.50	4.49	4.43	4.31	4.15	3.96	3.74	3.53	3.33
16	1.E -1 X	3.19	3.35	3.51	3.67	3.81	3.95	4.05	4.12	4.15	4.14	4.08	4.00	3.87	3.71	3.53	3.36	3.19
17	1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05

P(I,J, 3, 1)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17
2	1.E -1 X	3.33	3.49	3.66	3.82	3.97	4.11	4.22	4.29	4.33	4.31	4.25	4.15	4.02	3.86	3.69	3.51	3.33
3	1.E -1 X	3.48	3.66	3.84	4.02	4.19	4.35	4.48	4.58	4.62	4.61	4.55	4.44	4.29	4.11	3.90	3.69	3.48
4	1.E -1 X	3.63	3.82	4.02	4.22	4.42	4.61	4.77	4.90	4.96	4.96	4.89	4.77	4.58	4.37	4.13	3.88	3.63
5	1.E -1 X	3.77	3.97	4.19	4.42	4.66	4.88	5.08	5.24	5.34	5.36	5.29	5.13	4.91	4.65	4.35	4.06	3.77
6	1.E -1 X	3.89	4.11	4.35	4.61	4.88	5.15	5.39	5.60	5.74	5.78	5.71	5.52	5.25	4.92	4.57	4.22	3.89
7	1.E -1 X	3.98	4.22	4.48	4.77	5.08	5.39	5.69	5.96	6.15	6.22	6.13	5.90	5.57	5.18	4.76	4.36	3.98
8	1.E -1 X	4.04	4.29	4.58	4.90	5.24	5.60	5.96	6.28	6.52	6.61	6.51	6.23	5.83	5.37	4.90	4.46	4.04
9	1.E -1 X	4.06	4.33	4.62	4.96	5.34	5.74	6.15	6.52	6.79	6.89	6.77	6.45	6.00	5.50	4.99	4.50	4.06
10	1.E -1 X	4.04	4.31	4.61	4.96	5.36	5.78	6.22	6.61	6.89	6.99	6.85	6.51	6.03	5.51	4.99	4.50	4.04
11	1.E -1 X	3.98	4.25	4.55	4.89	5.29	5.71	6.13	6.51	6.77	6.85	6.70	6.37	5.92	5.42	4.92	4.43	3.98
12	1.E -1 X	3.89	4.15	4.44	4.77	5.13	5.52	5.90	6.23	6.45	6.51	6.37	6.08	5.68	5.23	4.77	4.32	3.89
13	1.E -1 X	3.77	4.02	4.29	4.58	4.91	5.25	5.57	5.83	6.00	6.03	5.92	5.68	5.33	4.95	4.55	4.15	3.77
14	1.E -1 X	3.63	3.86	4.11	4.37	4.65	4.92	5.18	5.37	5.50	5.51	5.42	5.23	4.95	4.63	4.29	3.96	3.63
15	1.E -1 X	3.48	3.69	3.90	4.13	4.35	4.57	4.76	4.90	4.99	4.99	4.92	4.77	4.55	4.29	4.02	3.75	3.48
16	1.E -1 X	3.33	3.51	3.69	3.88	4.06	4.22	4.36	4.46	4.50	4.50	4.43	4.32	4.15	3.96	3.75	3.53	3.33

17 1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17

P(I,J, 4, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28
2 1.E -1 X	3.46	3.64	3.82	4.00	4.17	4.33	4.46	4.55	4.58	4.57	4.50	4.39	4.24	4.06	3.86	3.66	3.46
3 1.E -1 X	3.63	3.82	4.01	4.21	4.41	4.60	4.75	4.87	4.93	4.92	4.85	4.72	4.55	4.34	4.11	3.87	3.63
4 1.E -1 X	3.81	4.00	4.21	4.44	4.67	4.90	5.09	5.25	5.34	5.35	5.27	5.13	4.92	4.66	4.38	4.09	3.81
5 1.E -1 X	3.97	4.17	4.41	4.67	4.95	5.22	5.47	5.67	5.81	5.86	5.79	5.61	5.34	5.02	4.66	4.31	3.97
6 1.E -1 X	4.10	4.33	4.60	4.90	5.22	5.54	5.85	6.14	6.36	6.46	6.39	6.17	5.81	5.39	4.95	4.51	4.10
7 1.E -1 X	4.21	4.46	4.75	5.09	5.47	5.85	6.26	6.65	6.98	7.15	7.07	6.77	6.29	5.75	5.20	4.69	4.21
8 1.E -1 X	4.28	4.55	4.87	5.25	5.67	6.14	6.65	7.18	7.63	7.85	7.74	7.32	6.72	6.05	5.41	4.82	4.28
9 1.E -1 X	4.31	4.58	4.93	5.34	5.81	6.36	6.98	7.63	8.16	8.40	8.24	7.73	7.01	6.24	5.53	4.88	4.31
10 1.E -1 X	4.28	4.57	4.92	5.35	5.86	6.46	7.15	7.85	8.40	8.62	8.41	7.85	7.09	6.29	5.55	4.88	4.28
11 1.E -1 X	4.21	4.50	4.85	5.28	5.79	6.39	7.07	7.74	8.24	8.41	8.18	7.64	6.92	6.17	5.45	4.80	4.21
12 1.E -1 X	4.10	4.39	4.72	5.13	5.61	6.17	6.77	7.32	7.73	7.85	7.64	7.18	6.56	5.90	5.26	4.66	4.10
13 1.E -1 X	3.97	4.24	4.55	4.92	5.34	5.81	6.29	6.72	7.01	7.09	6.92	6.56	6.06	5.52	4.97	4.45	3.97
14 1.E -1 X	3.81	4.06	4.34	4.66	5.02	5.39	5.75	6.05	6.24	6.29	6.17	5.90	5.52	5.09	4.65	4.22	3.81
15 1.E -1 X	3.63	3.86	4.11	4.38	4.66	4.95	5.20	5.41	5.53	5.55	5.45	5.26	4.97	4.65	4.30	3.96	3.63
16 1.E -1 X	3.46	3.66	3.87	4.09	4.31	4.51	4.69	4.82	4.88	4.88	4.80	4.66	4.45	4.22	3.96	3.71	3.46
17 1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28

P(I,J, 5, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39
2 1.E -1 X	3.58	3.76	3.96	4.17	4.37	4.55	4.70	4.80	4.84	4.82	4.75	4.62	4.45	4.25	4.03	3.80	3.58
3 1.E -1 X	3.77	3.96	4.17	4.40	4.63	4.85	5.03	5.16	5.23	5.22	5.14	5.00	4.81	4.57	4.31	4.04	3.77
4 1.E -1 X	3.97	4.17	4.40	4.66	4.93	5.19	5.42	5.60	5.71	5.73	5.65	5.49	5.25	4.95	4.62	4.28	3.97
5 1.E -1 X	4.15	4.37	4.63	4.93	5.24	5.57	5.86	6.12	6.29	6.37	6.30	6.11	5.78	5.39	4.96	4.54	4.15
6 1.E -1 X	4.31	4.55	4.85	5.19	5.57	5.95	6.32	6.67	7.00	7.20	7.17	6.88	6.42	5.88	5.32	4.79	4.31
7 1.E -1 X	4.43	4.70	5.03	5.42	5.86	6.32	6.80	7.39	7.94	8.30	8.27	7.82	7.13	6.38	5.66	5.01	4.43
8 1.E -1 X	4.51	4.80	5.16	5.60	6.12	6.67	7.39	8.21	9.09	9.63	9.48	8.80	7.80	6.82	5.93	5.17	4.51
9 1.E 0 X	.45	.48	.52	.57	.63	.70	.79	.91	1.02	1.07	1.05	.95	.83	.71	.61	.53	.45
10 1.E 0 X	.45	.48	.52	.57	.64	.72	.83	.96	1.07	1.13	1.08	.98	.84	.72	.61	.53	.45
11 1.E 0 X	.44	.47	.51	.57	.63	.72	.83	.95	1.05	1.08	1.04	.94	.82	.70	.60	.52	.44
12 1.E -1 X	4.31	4.62	5.00	5.49	6.11	6.88	7.82	8.80	9.53	9.76	9.38	8.59	7.60	6.63	5.76	4.99	4.31
13 1.E -1 X	4.15	4.45	4.81	5.25	5.78	6.42	7.13	7.80	8.29	8.42	8.17	7.60	6.88	6.12	5.39	4.73	4.15
14 1.E -1 X	3.97	4.25	4.57	4.95	5.39	5.88	6.38	6.82	7.12	7.19	7.01	6.63	6.12	5.56	4.99	4.46	3.97
15 1.E -1 X	3.77	4.03	4.31	4.62	4.96	5.32	5.66	5.93	6.11	6.14	6.02	5.76	5.39	4.99	4.57	4.17	3.77
16 1.E -1 X	3.58	3.80	4.04	4.28	4.54	4.79	5.01	5.17	5.26	5.27	5.17	4.99	4.73	4.46	4.17	3.87	3.58
17 1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39

P(I,J, 6, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47
2 1.E -1 X	3.68	3.88	4.10	4.32	4.54	4.74	4.91	5.02	5.07	5.05	4.96	4.82	4.63	4.40	4.16	3.92	3.68
3 1.E -1 X	3.89	4.10	4.33	4.58	4.83	5.07	5.28	5.43	5.51	5.50	5.41	5.25	5.03	4.77	4.48	4.18	3.89
4 1.E -1 X	4.10	4.32	4.58	4.86	5.17	5.48	5.75	5.95	6.07	6.09	6.00	5.82	5.54	5.20	4.83	4.46	4.10
5 1.E -1 X	4.31	4.54	4.83	5.17	5.55	5.94	6.31	6.60	6.77	6.81	6.77	6.57	6.20	5.74	5.24	4.75	4.31
6 1.E -1 X	4.49	4.74	5.07	5.48	5.94	6.42	6.87	7.28	7.59	7.87	7.87	7.59	7.03	6.35	5.67	5.04	4.49
7 1.E -1 X	4.63	4.91	5.28	5.75	6.31	6.86	7.27	7.54	8.61	9.64	9.71	9.01	8.03	7.01	6.09	5.30	4.63
8 1.E 0 X	.47	.50	.54	.60	.66	.73	.75	.90	1.08	1.21	1.23	1.07	.91	.76	.64	.55	.47
9 1.E 0 X	.48	.51	.55	.61	.68	.76	.86	1.09	1.35	1.51	1.44	1.20	.98	.80	.67	.56	.48
10 1.E 0 X	.47	.51	.55	.61	.68	.79	.96	1.21	1.51	1.61	1.52	1.24	1.00	.82	.67	.56	.47
11 1.E 0 X	.46	.50	.54	.60	.68	.79	.97	1.23	1.44	1.52	1.38	1.17	.96	.79	.66	.55	.46
12 1.E 0 X	.45	.48	.53	.58	.66	.76	.90	1.07	1.20	1.24	1.17	1.03	.86	.74	.62	.53	.45
13 1.E 0 X	.43	.46	.50	.55	.62	.70	.80	.91	.98	1.00	.96	.88	.77	.67	.58	.50	.43
14 1.E -1 X	4.10	4.40	4.77	5.20	5.74	6.35	7.01	7.62	8.04	8.15	7.91	7.38	6.71	6.00	5.31	4.68	4.10
15 1.E -1 X	3.89	4.16	4.48	4.83	5.24	5.67	6.09	6.45	6.68	6.74	6.58	6.25	5.80	5.31	4.81	4.34	3.89

16 1.E -1 X	3.68	3.92	4.18	4.46	4.75	5.04	5.30	5.50	5.63	5.63	5.52	5.30	5.00	4.68	4.34	4.01	3.68
17 1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47

P(I,J, 7, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54
2 1.E -1 X	3.76	3.97	4.20	4.45	4.69	4.90	5.08	5.21	5.26	5.24	5.14	4.98	4.78	4.53	4.28	4.01	3.76
3 1.E -1 X	3.98	4.20	4.45	4.72	5.00	5.27	5.50	5.66	5.75	5.74	5.64	5.46	5.22	4.93	4.61	4.29	3.98
4 1.E -1 X	4.21	4.45	4.72	5.04	5.39	5.74	6.05	6.28	6.40	6.40	6.30	6.09	5.78	5.41	5.00	4.59	4.21
5 1.E -1 X	4.43	4.69	5.00	5.39	5.83	6.31	6.76	7.08	7.21	7.30	7.14	6.93	6.53	6.02	5.45	4.92	4.43
6 1.E -1 X	4.63	4.90	5.27	5.74	6.31	6.93	7.61	8.19	8.28	7.80	8.24	8.17	7.55	6.73	5.94	5.24	4.63
7 1.E 0 X	.48	.51	.55	.60	.68	.76	.81	.88	.89	1.02	1.06	1.03	.89	.75	.64	.55	.48
8 1.E 0 X	.49	.52	.57	.63	.71	.82	.87	.15	.83	1.90	1.54	1.31	1.03	.83	.69	.58	.49
9 1.E 0 X	.49	.53	.57	.64	.72	.83	.89	.83	1.97	2.78	2.05	1.54	1.13	.89	.72	.59	.49
10 1.E 0 X	.49	.52	.57	.64	.73	.78	1.03	1.90	2.78	3.16	2.12	1.60	1.16	.90	.72	.59	.49
11 1.E 0 X	.48	.51	.56	.63	.71	.82	1.06	1.54	2.05	2.13	1.91	1.44	1.10	.87	.70	.58	.48
12 1.E 0 X	.46	.50	.55	.61	.69	.82	1.02	1.31	1.54	1.60	1.44	1.21	.98	.80	.67	.56	.46
13 1.E 0 X	.44	.48	.52	.58	.65	.75	.89	1.03	1.13	1.16	1.10	.98	.85	.72	.61	.52	.44
14 1.E -1 X	4.21	4.53	4.93	5.41	6.01	6.73	7.54	8.31	8.86	9.02	8.70	8.04	7.20	6.35	5.56	4.85	4.21
15 1.E -1 X	3.98	4.28	4.61	5.00	5.45	5.94	6.44	6.87	7.16	7.23	7.05	6.65	6.12	5.56	5.00	4.47	3.98
16 1.E -1 X	3.76	4.01	4.29	4.59	4.92	5.24	5.54	5.78	5.92	5.93	5.80	5.55	5.21	4.85	4.47	4.11	3.76
17 1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54

P(I,J, 8, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58
2 1.E -1 X	3.81	4.03	4.28	4.53	4.78	5.01	5.20	5.33	5.39	5.36	5.26	5.09	4.87	4.61	4.34	4.07	3.81
3 1.E -1 X	4.04	4.28	4.54	4.83	5.13	5.41	5.65	5.83	5.92	5.90	5.79	5.59	5.33	5.02	4.69	4.36	4.04
4 1.E -1 X	4.28	4.53	4.83	5.18	5.55	5.94	6.28	6.53	6.64	6.64	6.49	6.27	5.93	5.54	5.11	4.68	4.28
5 1.E -1 X	4.51	4.78	5.13	5.55	6.05	6.62	7.15	7.50	7.70	7.52	7.50	7.15	6.74	6.18	5.58	5.02	4.51
6 1.E -1 X	4.72	5.01	5.41	5.94	6.62	7.41	8.44	9.05	8.59	9.47	8.24	8.58	7.86	6.96	6.11	5.37	4.72
7 1.E 0 X	.49	.52	.57	.63	.71	.84	.96	1.35	1.35	-.13	1.15	1.11	.94	.79	.66	.57	.49
8 1.E 0 X	.50	.53	.58	.65	.75	.91	1.35	.00	.00	.00	2.19	1.44	1.11	.87	.71	.59	.50
9 1.E 0 X	.50	.54	.59	.66	.77	.86	1.35	.00	.00	.00	3.15	1.78	1.24	.94	.75	.61	.50
10 1.E 0 X	.50	.54	.59	.66	.75	.95	-.13	.00	.00	.00	3.47	1.84	1.28	.96	.75	.61	.50
11 1.E 0 X	.49	.53	.58	.65	.75	.82	1.14	2.19	3.15	3.47	2.27	1.67	1.20	.92	.73	.60	.49
12 1.E 0 X	.47	.51	.56	.63	.72	.86	1.11	1.44	1.78	1.84	1.67	1.33	1.06	.85	.69	.57	.47
13 1.E 0 X	.45	.49	.53	.59	.67	.79	.94	1.11	1.24	1.28	1.20	1.06	.90	.75	.63	.53	.45
14 1.E -1 X	4.28	4.61	5.02	5.54	6.18	6.96	7.86	8.74	9.38	9.56	9.22	8.46	7.51	6.56	5.71	4.95	4.28
15 1.E -1 X	4.04	4.34	4.69	5.10	5.58	6.11	6.65	7.13	7.46	7.54	7.34	6.90	6.32	5.71	5.10	4.55	4.04
16 1.E -1 X	3.81	4.07	4.36	4.68	5.02	5.37	5.69	5.94	6.10	6.12	5.98	5.70	5.35	4.95	4.55	4.17	3.81
17 1.E -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58

P(I,J, 9, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.59	3.82	4.06	4.31	4.54	4.76	4.93	5.04	5.08	5.04	4.93	4.76	4.54	4.31	4.06	3.82	3.59
2 1.E -1 X	3.82	4.05	4.30	4.57	4.82	5.06	5.25	5.38	5.44	5.41	5.30	5.12	4.90	4.64	4.37	4.09	3.82
3 1.E -1 X	4.06	4.30	4.58	4.87	5.18	5.47	5.72	5.90	5.98	5.96	5.84	5.63	5.37	5.06	4.72	4.38	4.06
4 1.E -1 X	4.31	4.57	4.87	5.23	5.62	6.03	6.39	6.64	6.77	6.73	6.58	6.32	5.97	5.57	5.13	4.70	4.31
5 1.E -1 X	4.54	4.82	5.18	5.62	6.15	6.76	7.35	7.75	7.87	7.86	7.57	7.25	6.78	6.21	5.61	5.05	4.54
6 1.E -1 X	4.76	5.06	5.47	6.03	6.76	7.69	8.81	9.73	9.84	8.97	9.01	8.61	7.87	6.98	6.14	5.39	4.76
7 1.E 0 X	.49	.52	.57	.64	.74	.86	1.09	1.35	1.34	1.35	1.15	1.09	.94	.79	.67	.57	.49
8 1.E 0 X	.50	.54	.59	.66	.77	.97	1.35	.00	.00	.00	1.71	1.47	1.11	.88	.72	.60	.50
9 1.E 0 X	.51	.54	.60	.68	.79	.98	1.34	.00	.00	.00	3.07	1.81	1.25	.94	.75	.61	.51
10 1.E 0 X	.50	.54	.60	.67	.79	.90	1.35	.00	.00	.00	3.46	1.91	1.29	.96	.76	.62	.50
11 1.E 0 X	.49	.53	.58	.66	.76	.96	1.15	1.71	3.07	3.46	2.39	1.71	1.22	.93	.74	.60	.49
12 1.E 0 X	.48	.51	.56	.63	.72	.86	1.09	1.47	1.81	1.91	1.71	1.36	1.07	.85	.69	.57	.48
13 1.E 0 X	.45	.49	.54	.60	.68	.79	.94	1.11	1.25	1.29	1.22	1.07	.90	.76	.64	.54	.45
14 1.E -1 X	4.31	4.64	5.05	5.57	6.21	6.98	7.88	8.77	9.43	9.64	9.29	8.53	7.56	6.60	5.74	4.98	4.31

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15 1.E -1 X	4.06	4.37	4.72	5.13	5.61	6.14	6.68	7.16	7.49	7.59	7.38	6.94	6.36	5.74	5.13	4.57	4.06
16 1.E -1 X	3.82	4.09	4.38	4.70	5.05	5.39	5.71	5.98	6.14	6.15	6.01	5.74	5.37	4.98	4.57	4.18	3.82
17 1.E -1 X	3.59	3.82	4.06	4.31	4.54	4.76	4.93	5.04	5.08	5.04	4.93	4.76	4.54	4.31	4.06	3.82	3.59

P(I,J,10, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58
2 1.E -1 X	3.81	4.04	4.28	4.54	4.79	5.02	5.21	5.34	5.39	5.37	5.26	5.08	4.86	4.61	4.34	4.06	3.81
3 1.E -1 X	4.04	4.28	4.56	4.85	5.15	5.44	5.68	5.85	5.93	5.90	5.78	5.57	5.31	5.01	4.68	4.35	4.04
4 1.E -1 X	4.28	4.54	4.85	5.20	5.59	5.98	6.34	6.59	6.70	6.67	6.50	6.23	5.89	5.50	5.07	4.66	4.28
5 1.E -1 X	4.51	4.79	5.15	5.59	6.11	6.70	7.27	7.70	7.84	7.74	7.49	7.12	6.64	6.10	5.53	4.99	4.51
6 1.E -1 X	4.72	5.02	5.44	5.98	6.70	7.60	8.69	9.39	9.76	9.46	8.98	8.32	7.60	6.81	6.02	5.32	4.72
7 1.E 0 X	.49	.52	.57	.63	.73	.87	1.04	1.35	1.35	1.35	1.09	1.00	.89	.76	.65	.56	.49
8 1.E 0 X	.50	.53	.59	.66	.77	.94	1.35	.00	.00	.00	1.29	1.29	1.04	.84	.70	.59	.50
9 1.E 0 X	.50	.54	.59	.67	.78	.98	1.35	.00	.00	.00	2.32	1.57	1.16	.90	.73	.60	.50
10 1.E 0 X	.50	.54	.59	.67	.77	.95	1.35	.00	.00	.00	2.93	1.66	1.20	.92	.74	.60	.50
11 1.E 0 X	.49	.53	.58	.65	.75	.90	1.09	1.29	2.32	2.93	2.03	1.55	1.14	.89	.72	.59	.49
12 1.E 0 X	.47	.51	.56	.62	.71	.83	1.00	1.29	1.57	1.66	1.55	1.26	1.02	.82	.68	.56	.47
13 1.E 0 X	.45	.49	.53	.59	.66	.76	.89	1.04	1.16	1.20	1.14	1.02	.87	.73	.62	.53	.45
14 1.E -1 X	4.28	4.61	5.01	5.50	6.09	6.81	7.61	8.42	9.01	9.21	8.91	8.23	7.35	6.46	5.64	4.92	4.28
15 1.E -1 X	4.04	4.34	4.68	5.07	5.53	6.02	6.52	6.97	7.28	7.37	7.18	6.77	6.23	5.64	5.06	4.53	4.04
16 1.E -1 X	3.81	4.06	4.35	4.66	4.99	5.32	5.63	5.87	6.03	6.04	5.91	5.65	5.30	4.92	4.53	4.16	3.81
17 1.E -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58

P(I,J,11, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54
2 1.E -1 X	3.76	3.97	4.21	4.46	4.70	4.92	5.10	5.22	5.27	5.24	5.14	4.97	4.76	4.52	4.27	4.00	3.76
3 1.E -1 X	3.98	4.21	4.47	4.75	5.03	5.31	5.54	5.70	5.77	5.74	5.62	5.43	5.18	4.89	4.58	4.27	3.98
4 1.E -1 X	4.21	4.46	4.75	5.08	5.44	5.81	6.13	6.37	6.47	6.43	6.27	6.02	5.70	5.33	4.95	4.57	4.21
5 1.E -1 X	4.43	4.70	5.03	5.44	5.92	6.45	6.94	7.30	7.45	7.38	7.14	6.79	6.35	5.87	5.35	4.87	4.43
6 1.E -1 X	4.63	4.92	5.31	5.81	6.45	7.22	8.02	8.67	8.89	8.68	8.26	7.72	7.14	6.47	5.79	5.17	4.63
7 1.E 0 X	.48	.51	.55	.61	.69	.80	.95	1.04	1.02	.98	.91	.90	.81	.71	.62	.54	.48
8 1.E 0 X	.49	.52	.57	.64	.73	.87	1.04	1.36	1.36	.33	1.13	1.06	.92	.78	.66	.57	.49
9 1.E 0 X	.49	.53	.58	.65	.74	.89	1.02	1.36	1.73	1.48	1.42	1.26	1.01	.83	.69	.58	.49
10 1.E 0 X	.49	.52	.57	.64	.74	.87	.97	.33	1.48	1.99	1.63	1.35	1.05	.84	.69	.58	.49
11 1.E 0 X	.48	.51	.56	.63	.71	.83	.91	1.13	1.42	1.64	1.57	1.26	1.01	.82	.68	.57	.48
12 1.E 0 X	.46	.50	.54	.60	.68	.77	.90	1.06	1.26	1.35	1.26	1.09	.92	.77	.64	.55	.46
13 1.E 0 X	.44	.48	.52	.57	.63	.71	.81	.92	1.01	1.05	1.01	.92	.80	.69	.60	.51	.44
14 1.E -1 X	4.21	4.52	4.89	5.33	5.87	6.47	7.14	7.78	8.27	8.43	8.19	7.65	6.92	6.17	5.45	4.80	4.21
15 1.E -1 X	3.98	4.26	4.58	4.95	5.35	5.79	6.23	6.61	6.87	6.94	6.78	6.44	5.96	5.45	4.93	4.44	3.98
16 1.E -1 X	3.76	4.00	4.27	4.57	4.87	5.17	5.45	5.66	5.79	5.81	5.69	5.46	5.14	4.80	4.44	4.09	3.76
17 1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54

P(I,J,12, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47
2 1.E -1 X	3.68	3.89	4.11	4.33	4.56	4.76	4.92	5.04	5.08	5.05	4.95	4.80	4.61	4.38	4.15	3.91	3.68
3 1.E -1 X	3.89	4.11	4.34	4.60	4.86	5.11	5.32	5.46	5.52	5.49	5.38	5.20	4.98	4.71	4.44	4.16	3.89
4 1.E -1 X	4.10	4.33	4.60	4.91	5.23	5.55	5.83	6.02	6.11	6.07	5.93	5.71	5.43	5.11	4.76	4.42	4.10
5 1.E -1 X	4.31	4.56	4.86	5.23	5.64	6.07	6.46	6.75	6.87	6.81	6.62	6.33	5.96	5.56	5.12	4.70	4.31
6 1.E -1 X	4.49	4.76	5.11	5.55	6.07	6.66	7.24	7.63	7.74	7.65	7.37	7.05	6.58	6.05	5.49	4.96	4.49
7 1.E -1 X	4.63	4.92	5.32	5.83	6.46	7.24	8.06	8.71	8.72	8.17	8.17	7.88	7.29	6.56	5.84	5.19	4.63
8 1.E 0 X	.47	.50	.55	.60	.67	.76	.87	.96	.96	1.01	.90	.89	.80	.70	.61	.54	.47
9 1.E 0 X	.48	.51	.55	.61	.69	.77	.87	.96	1.06	1.10	1.06	.98	.86	.74	.63	.55	.48
10 1.E 0 X	.47	.50	.55	.61	.68	.76	.82	1.01	1.10	1.18	1.16	1.03	.89	.75	.64	.55	.47
11 1.E 0 X	.46	.49	.54	.59	.66	.74	.82	.90	1.06	1.16	1.12	1.00	.86	.73	.63	.54	.46
12 1.E 0 X	.45	.48	.52	.57	.63	.70	.79	.89	.98	1.03	1.00	.91	.80	.69	.60	.52	.45
13 1.E -1 X	4.31	4.61	4.98	5.43	5.96	6.58	7.29	8.01	8.61	8.85	8.61	8.01	7.20	6.38	5.61	4.92	4.31

14 1.E -1 X	4.10	4.38	4.71	5.11	5.56	6.05	6.56	7.04	7.39	7.51	7.34	6.94	6.38	5.77	5.18	4.62	4.10
15 1.E -1 X	3.89	4.15	4.44	4.76	5.12	5.49	5.84	6.15	6.35	6.40	6.27	6.00	5.61	5.18	4.73	4.30	3.89
16 1.E -1 X	3.68	3.91	4.16	4.42	4.70	4.96	5.19	5.38	5.48	5.49	5.39	5.19	4.92	4.62	4.30	3.99	3.68
17 1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47

P(I,J,13, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39
2 1.E -1 X	3.58	3.77	3.97	4.18	4.38	4.56	4.71	4.81	4.84	4.81	4.73	4.59	4.42	4.22	4.01	3.79	3.58
3 1.E -1 X	3.77	3.97	4.19	4.42	4.65	4.87	5.05	5.18	5.22	5.19	5.09	4.94	4.74	4.51	4.27	4.01	3.77
4 1.E -1 X	3.97	4.18	4.42	4.69	4.97	5.24	5.47	5.63	5.69	5.66	5.55	5.36	5.12	4.84	4.55	4.25	3.97
5 1.E -1 X	4.15	4.38	4.65	4.97	5.31	5.65	5.95	6.17	6.25	6.22	6.07	5.85	5.55	5.21	4.85	4.49	4.15
6 1.E -1 X	4.31	4.56	4.87	5.24	5.65	6.09	6.49	6.77	6.88	6.81	6.66	6.39	6.02	5.60	5.15	4.71	4.31
7 1.E -1 X	4.43	4.71	5.05	5.47	5.95	6.49	7.00	7.38	7.53	7.53	7.28	6.97	6.52	5.99	5.43	4.90	4.43
8 1.E -1 X	4.51	4.81	5.18	5.63	6.17	6.77	7.38	7.85	8.18	8.14	8.01	7.54	6.98	6.32	5.66	5.05	4.51
9 1.E -1 X	4.54	4.84	5.22	5.69	6.25	6.88	7.53	8.18	8.61	8.77	8.56	8.05	7.34	6.55	5.80	5.13	4.54
10 1.E -1 X	4.51	4.81	5.19	5.66	6.22	6.81	7.53	8.14	8.78	9.03	8.84	8.28	7.47	6.63	5.83	5.13	4.51
11 1.E -1 X	4.43	4.73	5.09	5.54	6.07	6.65	7.28	8.01	8.56	8.85	8.70	8.12	7.33	6.50	5.73	5.04	4.43
12 1.E -1 X	4.31	4.59	4.94	5.36	5.85	6.39	6.97	7.55	8.05	8.29	8.12	7.63	6.95	6.21	5.51	4.88	4.31
13 1.E -1 X	4.15	4.42	4.74	5.12	5.55	6.02	6.52	6.98	7.34	7.48	7.33	6.95	6.40	5.80	5.21	4.65	4.15
14 1.E -1 X	3.97	4.22	4.51	4.84	5.21	5.60	5.99	6.32	6.56	6.63	6.51	6.21	5.80	5.34	4.86	4.40	3.97
15 1.E -1 X	3.77	4.01	4.27	4.55	4.85	5.15	5.43	5.66	5.80	5.83	5.73	5.51	5.21	4.86	4.49	4.12	3.77
16 1.E -1 X	3.58	3.79	4.01	4.25	4.49	4.71	4.90	5.05	5.13	5.13	5.04	4.88	4.65	4.40	4.12	3.85	3.58
17 1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39

P(I,J,14, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28
2 1.E -1 X	3.46	3.64	3.82	4.00	4.18	4.34	4.47	4.55	4.58	4.55	4.48	4.36	4.21	4.04	3.85	3.65	3.46
3 1.E -1 X	3.63	3.82	4.02	4.22	4.42	4.62	4.77	4.87	4.91	4.88	4.79	4.66	4.49	4.29	4.08	3.85	3.63
4 1.E -1 X	3.81	4.00	4.22	4.46	4.70	4.93	5.11	5.24	5.29	5.26	5.16	5.00	4.81	4.57	4.32	4.05	3.81
5 1.E -1 X	3.97	4.18	4.42	4.70	4.98	5.25	5.48	5.65	5.72	5.69	5.58	5.39	5.15	4.87	4.56	4.26	3.97
6 1.E -1 X	4.10	4.34	4.62	4.93	5.25	5.58	5.86	6.07	6.16	6.15	6.01	5.79	5.50	5.17	4.80	4.44	4.10
7 1.E -1 X	4.21	4.47	4.77	5.11	5.48	5.86	6.21	6.46	6.60	6.60	6.46	6.20	5.85	5.45	5.02	4.60	4.21
8 1.E -1 X	4.28	4.55	4.87	5.24	5.65	6.07	6.46	6.79	6.98	7.01	6.86	6.56	6.15	5.68	5.18	4.71	4.28
9 1.E -1 X	4.31	4.58	4.91	5.29	5.71	6.16	6.60	6.98	7.24	7.31	7.16	6.83	6.36	5.83	5.28	4.77	4.31
10 1.E -1 X	4.28	4.55	4.88	5.26	5.69	6.15	6.60	7.01	7.31	7.41	7.28	6.92	6.42	5.86	5.30	4.77	4.28
11 1.E -1 X	4.21	4.48	4.79	5.16	5.57	6.01	6.46	6.86	7.16	7.28	7.15	6.80	6.31	5.77	5.22	4.69	4.21
12 1.E -1 X	4.10	4.36	4.66	5.00	5.39	5.79	6.20	6.56	6.83	6.92	6.80	6.49	6.05	5.56	5.05	4.56	4.10
13 1.E -1 X	3.97	4.21	4.49	4.81	5.15	5.50	5.85	6.15	6.36	6.42	6.31	6.05	5.68	5.26	4.81	4.37	3.97
14 1.E -1 X	3.81	4.04	4.29	4.57	4.87	5.17	5.45	5.68	5.83	5.86	5.77	5.56	5.26	4.90	4.53	4.16	3.81
15 1.E -1 X	3.63	3.85	4.08	4.32	4.56	4.80	5.02	5.18	5.28	5.30	5.22	5.05	4.81	4.53	4.23	3.93	3.63
16 1.E -1 X	3.46	3.65	3.85	4.05	4.26	4.44	4.60	4.71	4.77	4.77	4.69	4.56	4.37	4.16	3.93	3.69	3.46
17 1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28

P(I,J,15, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17
2 1.E -1 X	3.33	3.49	3.66	3.82	3.97	4.11	4.22	4.29	4.32	4.29	4.23	4.13	3.99	3.84	3.68	3.50	3.33
3 1.E -1 X	3.48	3.66	3.83	4.02	4.19	4.36	4.49	4.57	4.60	4.58	4.50	4.39	4.24	4.07	3.88	3.68	3.48
4 1.E -1 X	3.63	3.82	4.02	4.23	4.43	4.62	4.77	4.88	4.92	4.89	4.80	4.67	4.50	4.30	4.08	3.85	3.63
5 1.E -1 X	3.77	3.97	4.19	4.43	4.67	4.89	5.07	5.20	5.25	5.23	5.13	4.98	4.78	4.54	4.28	4.02	3.77
6 1.E -1 X	3.89	4.11	4.36	4.62	4.89	5.14	5.35	5.51	5.58	5.56	5.46	5.28	5.04	4.77	4.47	4.17	3.89
7 1.E -1 X	3.98	4.22	4.49	4.77	5.07	5.35	5.60	5.78	5.88	5.87	5.76	5.56	5.29	4.97	4.64	4.30	3.98
8 1.E -1 X	4.04	4.29	4.57	4.88	5.20	5.51	5.78	6.00	6.12	6.13	6.01	5.79	5.48	5.13	4.76	4.39	4.04
9 1.E -1 X	4.06	4.32	4.60	4.92	5.25	5.58	5.88	6.12	6.27	6.30	6.18	5.93	5.60	5.22	4.82	4.43	4.06
10 1.E -1 X	4.04	4.29	4.58	4.89	5.23	5.56	5.87	6.13	6.30	6.33	6.21	5.96	5.62	5.23	4.82	4.42	4.04
11 1.E -1 X	3.98	4.23	4.50	4.80	5.13	5.46	5.76	6.01	6.18	6.21	6.10	5.87	5.53	5.15	4.75	4.35	3.98
12 1.E -1 X	3.89	4.13	4.39	4.67	4.98	5.28	5.56	5.79	5.93	5.96	5.87	5.65	5.35	4.99	4.62	4.25	3.89

13 1.E -1 X	3.77	3.99	4.24	4.50	4.78	5.04	5.29	5.46	5.60	5.62	5.53	5.35	5.08	4.77	4.43	4.10	3.77
14 1.E -1 X	3.63	3.84	4.07	4.30	4.54	4.77	4.97	5.13	5.22	5.23	5.15	4.99	4.77	4.50	4.21	3.92	3.63
15 1.E -1 X	3.48	3.68	3.88	4.08	4.28	4.47	4.64	4.76	4.82	4.82	4.75	4.62	4.43	4.21	3.97	3.73	3.48
16 1.E -1 X	3.33	3.50	3.68	3.85	4.02	4.17	4.30	4.39	4.43	4.42	4.35	4.25	4.10	3.92	3.73	3.53	3.33
17 1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17

P(I,J,16, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05
2 1.E -1 X	3.19	3.34	3.49	3.64	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.78	3.65	3.50	3.35	3.19
3 1.E -1 X	3.33	3.49	3.66	3.82	3.97	4.11	4.22	4.29	4.32	4.29	4.23	4.13	4.00	3.85	3.68	3.50	3.33
4 1.E -1 X	3.46	3.64	3.82	4.01	4.19	4.35	4.47	4.56	4.59	4.56	4.48	4.37	4.22	4.04	3.85	3.65	3.46
5 1.E -1 X	3.58	3.77	3.97	4.19	4.39	4.57	4.72	4.82	4.86	4.83	4.75	4.61	4.44	4.24	4.02	3.79	3.58
6 1.E -1 X	3.68	3.89	4.11	4.35	4.57	4.78	4.95	5.06	5.11	5.09	5.00	4.84	4.64	4.41	4.17	3.92	3.68
7 1.E -1 X	3.76	3.98	4.22	4.47	4.72	4.95	5.14	5.27	5.33	5.31	5.21	5.04	4.82	4.56	4.29	4.02	3.76
8 1.E -1 X	3.81	4.04	4.29	4.56	4.82	5.06	5.27	5.42	5.49	5.48	5.37	5.19	4.94	4.67	4.38	4.09	3.81
9 1.E -1 X	3.82	4.06	4.32	4.59	4.86	5.11	5.33	5.49	5.57	5.56	5.46	5.26	5.01	4.72	4.42	4.11	3.82
10 1.E -1 X	3.81	4.04	4.29	4.56	4.83	5.09	5.31	5.48	5.56	5.56	5.45	5.26	5.01	4.71	4.41	4.10	3.81
11 1.E -1 X	3.76	3.98	4.23	4.48	4.75	5.00	5.21	5.37	5.46	5.45	5.35	5.17	4.93	4.64	4.34	4.04	3.76
12 1.E -1 X	3.68	3.89	4.13	4.37	4.61	4.84	5.04	5.19	5.26	5.26	5.17	5.00	4.78	4.51	4.24	3.95	3.68
13 1.E -1 X	3.58	3.78	4.00	4.22	4.44	4.64	4.82	4.95	5.01	5.01	4.93	4.78	4.58	4.34	4.09	3.83	3.58
14 1.E -1 X	3.46	3.65	3.85	4.04	4.24	4.41	4.56	4.67	4.72	4.71	4.64	4.51	4.34	4.14	3.91	3.69	3.46
15 1.E -1 X	3.33	3.50	3.68	3.85	4.02	4.17	4.29	4.38	4.42	4.41	4.34	4.24	4.09	3.91	3.72	3.52	3.33
16 1.E -1 X	3.19	3.35	3.50	3.65	3.79	3.92	4.02	4.09	4.11	4.10	4.04	3.95	3.83	3.69	3.52	3.36	3.19
17 1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05

P(I,J,17, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	2.93	3.05	3.17	3.28	3.39	3.47	3.54	3.58	3.59	3.58	3.54	3.47	3.39	3.28	3.17	3.05	2.93
2 1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05
3 1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17
4 1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28
5 1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39
6 1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47
7 1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54
8 1.F -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58
9 1.E -1 X	3.59	3.82	4.06	4.31	4.54	4.76	4.93	5.04	5.08	5.04	4.93	4.76	4.54	4.31	4.06	3.82	3.59
10 1.E -1 X	3.58	3.81	4.04	4.28	4.51	4.72	4.89	5.00	5.04	5.00	4.89	4.72	4.51	4.28	4.04	3.81	3.58
11 1.E -1 X	3.54	3.76	3.98	4.21	4.43	4.63	4.79	4.89	4.93	4.89	4.79	4.63	4.43	4.21	3.98	3.76	3.54
12 1.E -1 X	3.47	3.68	3.89	4.10	4.31	4.49	4.63	4.72	4.76	4.72	4.63	4.49	4.31	4.10	3.89	3.68	3.47
13 1.E -1 X	3.39	3.58	3.77	3.97	4.15	4.31	4.43	4.51	4.54	4.51	4.43	4.31	4.15	3.97	3.77	3.58	3.39
14 1.E -1 X	3.28	3.46	3.63	3.81	3.97	4.10	4.21	4.28	4.31	4.28	4.21	4.10	3.97	3.81	3.63	3.46	3.28
15 1.E -1 X	3.17	3.33	3.48	3.63	3.77	3.89	3.98	4.04	4.06	4.04	3.98	3.89	3.77	3.63	3.48	3.33	3.17
16 1.E -1 X	3.05	3.19	3.33	3.46	3.58	3.68	3.76	3.81	3.82	3.81	3.76	3.68	3.58	3.46	3.33	3.19	3.05
17 1.E -1 X	2.93	3.05	3.17	3.28	3.39	3.47	3.54	3.58	3.59	3.58	3.54	3.47	3.39	3.28	3.17	3.05	2.93

IP = 14 IR = 12 IU = 13 ISPARE = 10 IPSAVE = 10

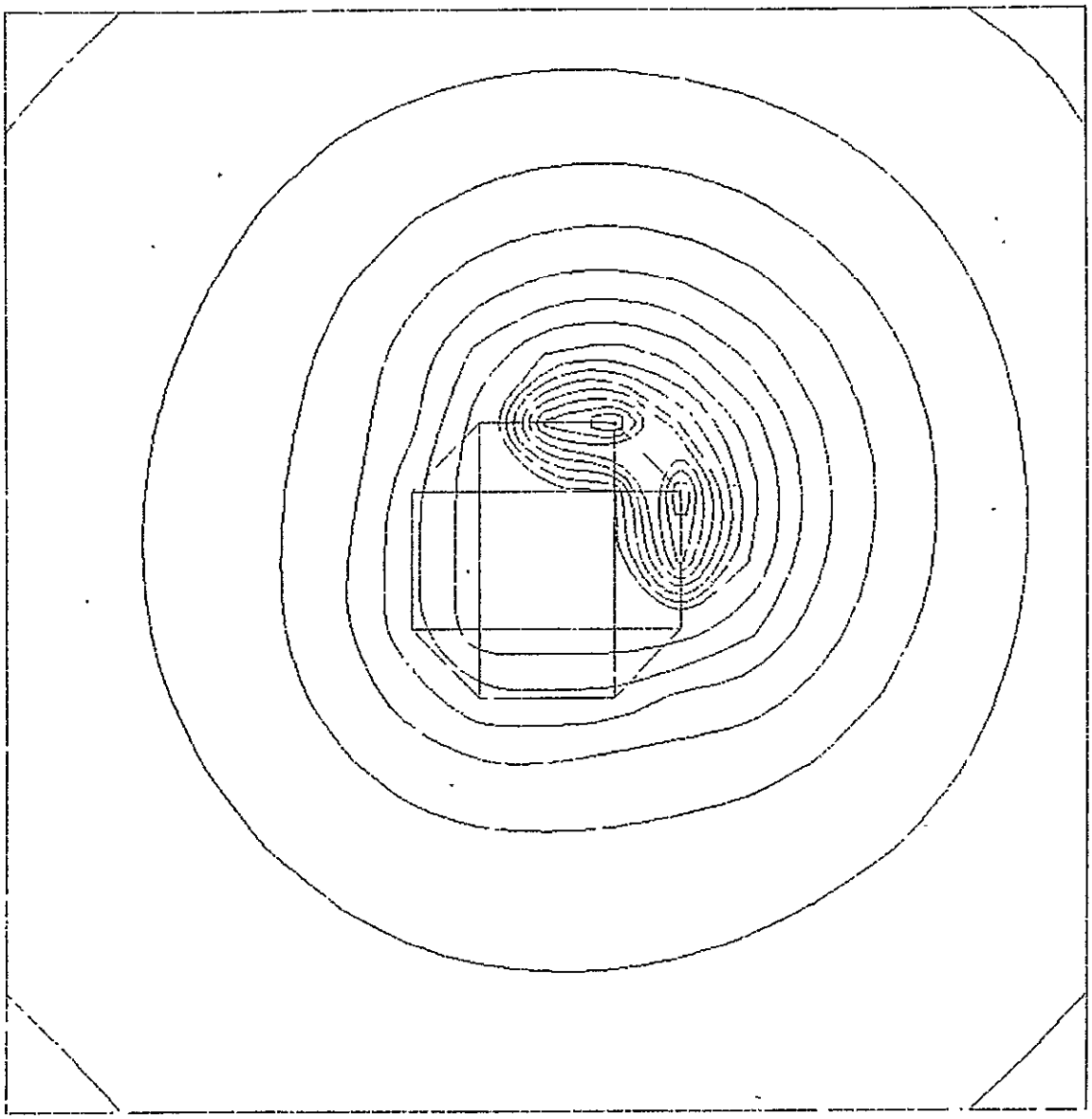
LAST TIMESTEP COMPLETED IS 1

Potential values for all grid points are printed. The requested potential contour plots are generated.

ORIGINAL PAGE IS OF POOR QUALITY

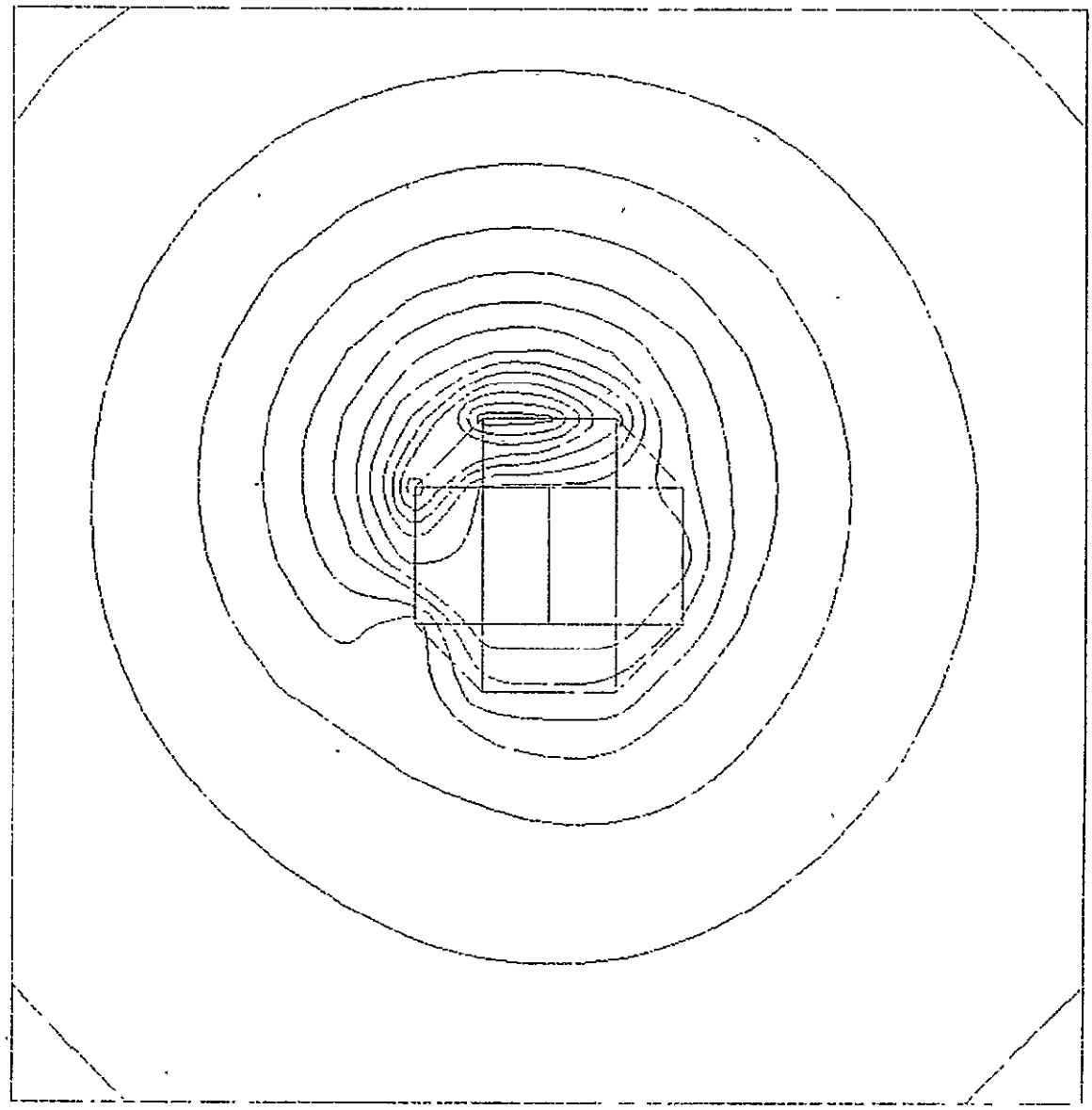
POTENTIAL CONTOURS ALONG THE X-Y PLANE OF Z = 9

ZMIN = .35915+00 ZMAX = .34577+01 ΔZ = .20000+00



POTENTIAL CONTOURS ALONG THE X-Z PLANE OF Y = 9

ZMIN = .35015+00 ZMAX = 31431-01 ΔZ = .20000+00

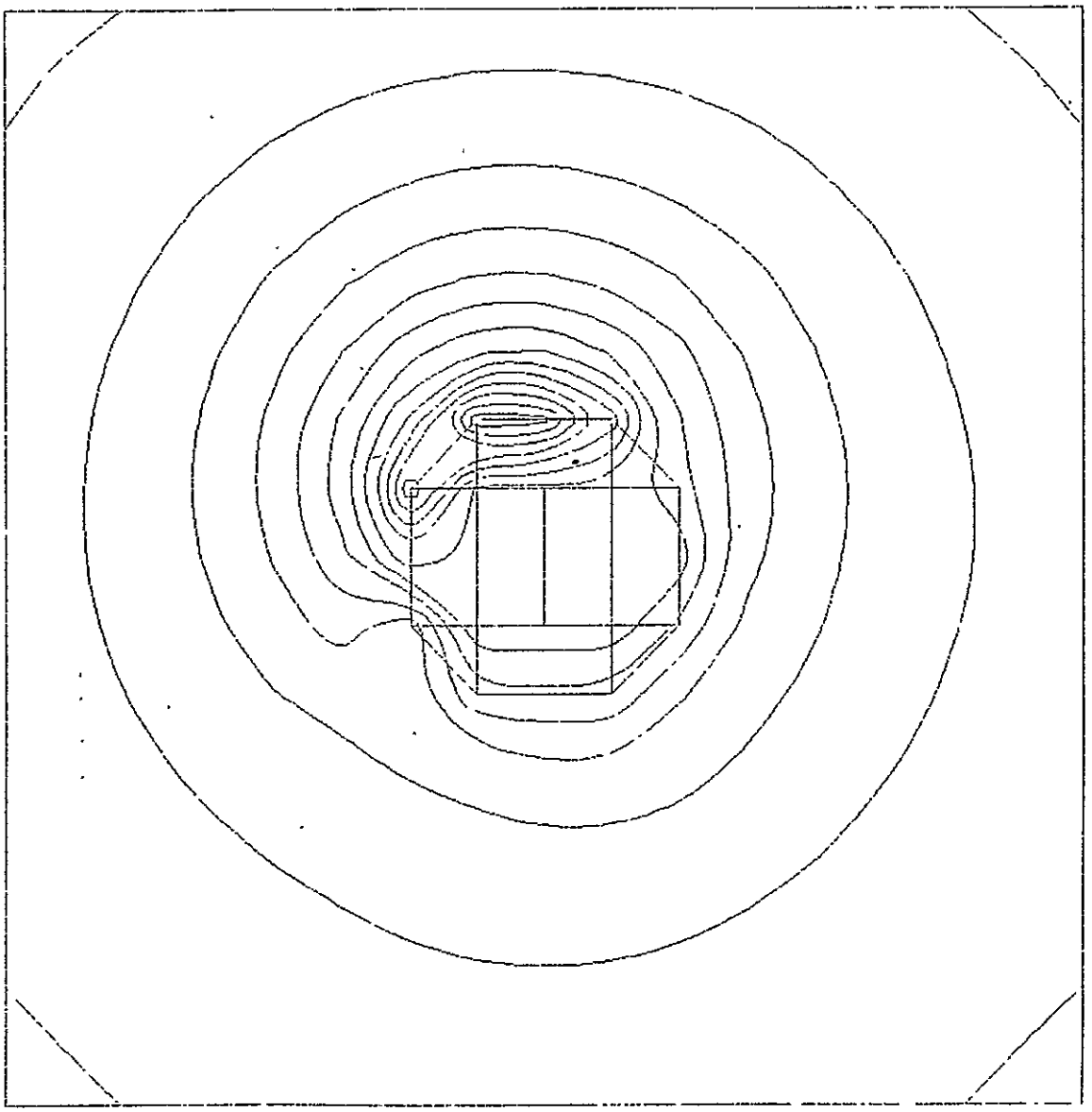


The horizontal axis is the Z axis.

ORIGINAL PAGE IS
OF POOR QUALITY

POTENTIAL CONTOURS ALONG THE Y-Z PLANE OF X = 9

ZMIN = .35915+00 ZMAX = .31421+01 ΔZ = .20000+00

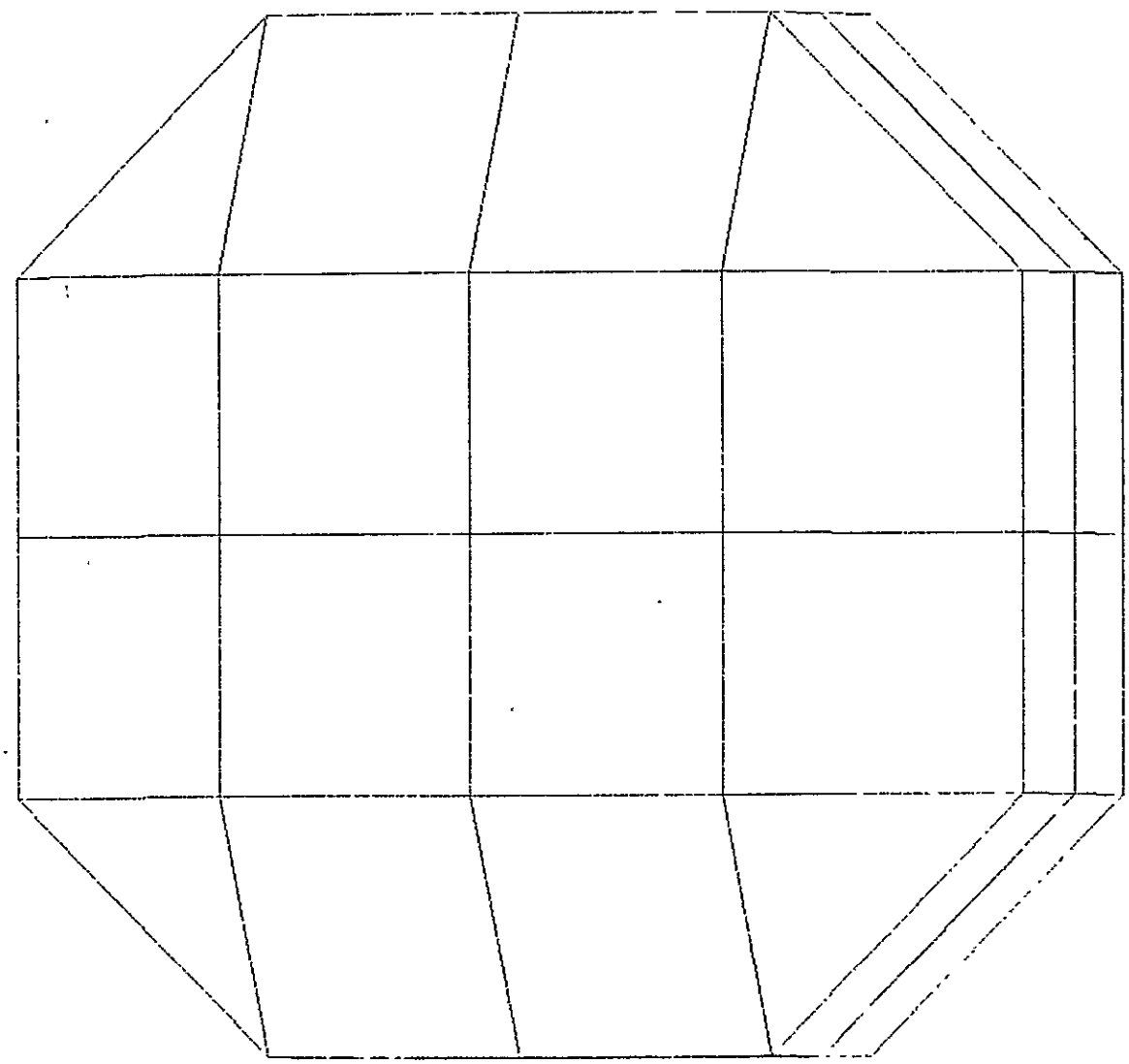


The horizontal axis is the Z axis.

ORIGINAL PAGE IS
OF POOR QUALITY

```
IP = 10  IR = 12  IU = 13  ISPARE = 14  IPSAVE = 10
******ROTATE   5
  TIME =     .1000 SECONDS
     SUN ROTATED TO     1.0000     .1999    -.0054
```

ROTATE moves the sun and calls HIDCEL, which produces a picture of the satellite as it appears from the sun.



From this direction, the quasisphere looks rather flat.

```
 NA1 =    28     NA2 =    18     IP =     0


FINAL NA1 =    28
******TRILIN   0

     FLUX DEFINITION
          TYPE     2
               ELECTRON TEMPERATURE =    2.00+04 ELECTRON VOLTS
               ELECTRON DENSITY =        1.00+06 METER**(-3)
               ION TEMPERATURE =         2.00+04 ELECTRON VOLTS
               ION DENSITY =             1.00+06 METER**(-3)
  POTENTIALS TO BE SET BY SETALL TO    1.00+00/(4*PI*R)
*** CYCLE LOOP FROM CYCLE   1 TO CYCLE   1

          NC DETERMINED BY GETNC TO BE  1
```

TRILIN is called again for the new sun direction.

```
        TIMESTEP NO.    1          TIME =    0.000    SECONDS.

QSUM =  1.0000+00
PCOND =  3.4677-02
QCOND =  0.0000

-----------------------------------------------------------------------------

  SURFACE CELL NO.    1                                   CODE =        010707077742
                                                          LOCATION =     7  7  7
                                                          NORMAL =      -1 -1 -1
                                                          MATERIAL =  TEFLON
                          POTENTIAL =   3.249-02 VOLTS
                          FIELD =   1.724+01 VOLTS/METER
   FLUXES IN A/M**2
        INCIDENT ELECTRONS                          3.78-06
             RESULTING BACKSCATTER                  1.02-06
             RESULTING SECONDARIES                  1.23-06
        INCIDENT PROTONS                            8.83-08
             RESULTING SECONDARIES                  9.15-07
        PHOTOCURRENT                                0.00
                                                 -----------
      NET FLUX                                     -5.34-07

         NET CHARGING CURRENT =   3.11+06 (CODE UNITS/SEC.).

   BADCEL ---    0 OUT OF   53 NODES SET.

   BADCND ---  0 OUT OF  1 CONDUCTORS SET.

   DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02 -7.6+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02 -7.3+02 -6.1+02 -6.8+02
        -4.4+02  4.2+02  4.8+02  1.5+03  1.5+03  1.5+03 -7.4+02 -6.2+02 -7.4+02 -6.8+02 -4.4+02 -5.0+02  1.6+03  1.7+03  3.8+03
         3.9+03  3.7+03  6.8+03  8.2+03  6.7+03  7.9+03  8.0+03  1.1+04  1.1+04  1.1+04  1.1+04  1.3+04  1.5+04  1.3+04  1.8+04
         1.9+04  1.8+04  2.2+04  2.2+04  2.2+04  2.2+04  2.4+04  2.2+04

  ENTERING ICCG1 -- VCTRI =   0.000

  LIST CONTAINS   160 ENTRIES.

    CAPPOT --- RDOTR/RDOTR1 =    2.72-13/   3.33+10

  LEAVING ICCG1 -- VCTRI =   1.078+04

   DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02 -7.6+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02 -7.3+02 -6.1+02 -6.8+02
        -4.4+02  4.2+02  4.8+02  1.5+03  1.5+03  1.5+03 -7.4+02 -6.2+02 -7.4+02 -6.8+02 -4.4+02 -5.0+02  1.6+03  1.7+03  3.8+03
         3.9+03  3.7+03  6.8+03  8.2+03  6.7+03  7.9+03  8.0+03  1.1+04  1.1+04  1.1+04  1.1+04  1.3+04  1.5+04  1.3+04  1.8+04
         1.9+04  1.8+04  2.2+04  2.2+04  2.2+04  2.2+04  2.4+04  2.2+04

   BADCEL ---   31 OUT OF   53 NODES SET.

   BADCND ---  0 OUT OF  1 CONDUCTORS SET.

  ENTERING ICCG1 -- VCTRI =   0.000

  LIST CONTAINS   160 ENTRIES.

    CAPPOT --- RDOTR/RDOTR1 =    1.04-23/   1.48+05

  LEAVING ICCG1 -- VCTRI =  -3.636-01
```

```
 DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02 -7.6+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02 -7.3+02 -6.1+02 -6.8+02
        -4.4+02  4.2+02  4.8+02  1.5+03  1.5+03  1.5+03 -7.4+02 -6.2+02 -7.4+02 -6.8+02 -4.4+02 -5.0+02  1.6+03  1.7+03  3.8+03
         3.9+03  3.7+03  6.8+03  8.2+03  6.7+03  7.9+03  8.0+03  1.1+04  1.1+04  1.1+04  1.1+04  1.3+04  1.5+04  1.3+04  1.8+04
         1.9+04  1.8+04  2.2+04  2.2+04  2.2+04  2.2+04  2.4+04  2.2+04

 DQ
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

ENTERING ICCG1 -- VCTR1 =  -3.636-01

LIST CONTAINS   160 ENTRIES.

  CAPPOT --- RDOTR/RDOTR1 =    1.18-23/   1.48+05

LEAVING ICCG1 -- VCTRI =  -3.636-01

 DQC( 1) = -5.5250+03

 DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02 -7.6+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02 -7.3+02 -6.1+02 -6.8+02
        -4.4+02  7.2+02  5.8+02  7.2+02  6.9+02  7.2+02 -7.4+02 -6.2+02 -7.4+02 -6.8+02 -4.4+02 -5.0+02  6.9+02  4.2+02  6.9+02
         5.6+02  6.9+02  7.2+02  6.9+02  7.2+02  7.2+02  5.8+02  6.9+02  4.2+02  7.2+02  5.8+02  7.2+02  6.9+02  7.2+02  7.2+02
         6.9+02  7.2+02  6.9+02  5.6+02  6.9+02  7.2+02  6.9+02  7.2+02

 VFIX ---   31 OUT OF   53 NODES FIXED.

ENTERING ICCG1 -- VCTR1 =  -3.636-01

LIST CONTAINS   160 ENTRIES.

  CAPPOT --- RDOTR/RDOTR1 =    7.85-21/   1.65+06

LEAVING ICCG1 -- VCTRI =   1.710+00

 DQC( 1) = -5.5250+03

 DQ
        -7.6+02 -7.4+02 -7.6+02 -7.4+02 -6.2+02 -7.4+02 -7.6+02 -7.4+02 -7.6+02 -7.6+02 -7.4+02 -7.6+02 -7.3+02 -6.1+02 -6.8+02
        -4.4+02 -3.7+03 -2.8+03 -2.7+03 -2.6+03 -2.8+03 -7.4+02 -6.2+02 -7.4+02 -6.8+02 -4.4+02 -5.0+02 -2.5+03 -1.0+03 -1.2+03
        -6.7+02 -1.3+03 -2.6+01  5.4+02 -4.1+01  3.9+02  8.1+02  1.2+03  1.7+03  1.2+03  1.5+03  1.7+03  2.2+03  1.7+03  2.8+03
         3.0+03  2.8+03  3.4+03  3.3+03  3.4+03  3.4+03  3.7+03  3.4+03
```


ORIGINAL PAGE IS
OF POOR QUALITY

PREDICTED NODE POTENTIALS

NODE	V-PRED	DO	V-OLD	PTLIST
1	1.32	-763.94	.03	000710100001
2	1.32	-744.22	.04	000710110001
3	1.32	-763.94	.03	000710120001
4	1.32	-744.22	.04	000711100001
5	1.32	-621.18	.04	000711110001
6	1.32	-744.22	.04	000711120001
7	1.32	-763.94	.03	000712100001
8	1.32	-744.22	.04	000712110001
9	1.32	-763.94	.03	000712120001
10	1.32	-763.94	.03	001007100001
11	1.32	-744.22	.04	001007110001
12	1.32	-763.94	.03	001007120001
13	1.33	-733.55	.03	001010070001
14	1.32	-610.85	.03	001010131001
15	1.35	-683.53	.04	001011070001
16	1.34	-436.16	.04	001011131001
17	-.18	-3709.46	.03	001012070001
18	-.06	-2820.86	.03	001012131001
19	.33	-2709.64	.03	001013100001
20	.34	-2602.67	.04	001013110001
21	.30	-2754.78	.03	001013120001
22	1.32	-744.22	.04	001107100001
23	1.32	-621.18	.04	001107110001
24	1.32	-744.22	.04	001107120001
25	1.35	-683.53	.04	001110070001
26	1.34	-436.16	.04	001110131001
27	1.40	-500.05	.04	001111070001
28	.39	-2515.68	.04	001112070001
29	.83	-1025.31	.04	001112131001
30	1.08	-1207.78	.04	001113100001
31	1.29	-669.23	.04	001113110001
32	1.04	-1269.52	.04	001113120001
33	1.69	-25.79	.03	001207100001
34	2.00	543.99	.04	001207110001
35	1.69	-40.76	.03	001207120001
36	1.91	388.84	.03	001210070001
37	2.21	809.30	.03	001210131001
38	2.35	1222.75	.04	001211070001
39	3.19	1717.01	.04	001211131001
40	2.31	1180.78	.03	001212070001
41	2.63	1475.67	.03	001212131001
42	2.59	1730.01	.03	001213100001
43	2.88	2218.99	.04	001213110001
44	2.58	1706.30	.03	001213120001
45	3.13	2795.36	.03	001310100001
46	3.30	3022.33	.04	001310110001
47	3.12	2777.46	.03	001310120001
48	3.48	3372.90	.04	001311100001
49	3.78	3258.25	.04	001311110001
50	3.48	3355.29	.04	001311120001
51	3.44	3404.50	.03	001312100001
52	3.64	3676.02	.04	001312110001
53	3.43	3389.28	.03	001312120001

SUM(DO)= 5.57422638+03

SUM(CS*DV)= 4.87526698+01

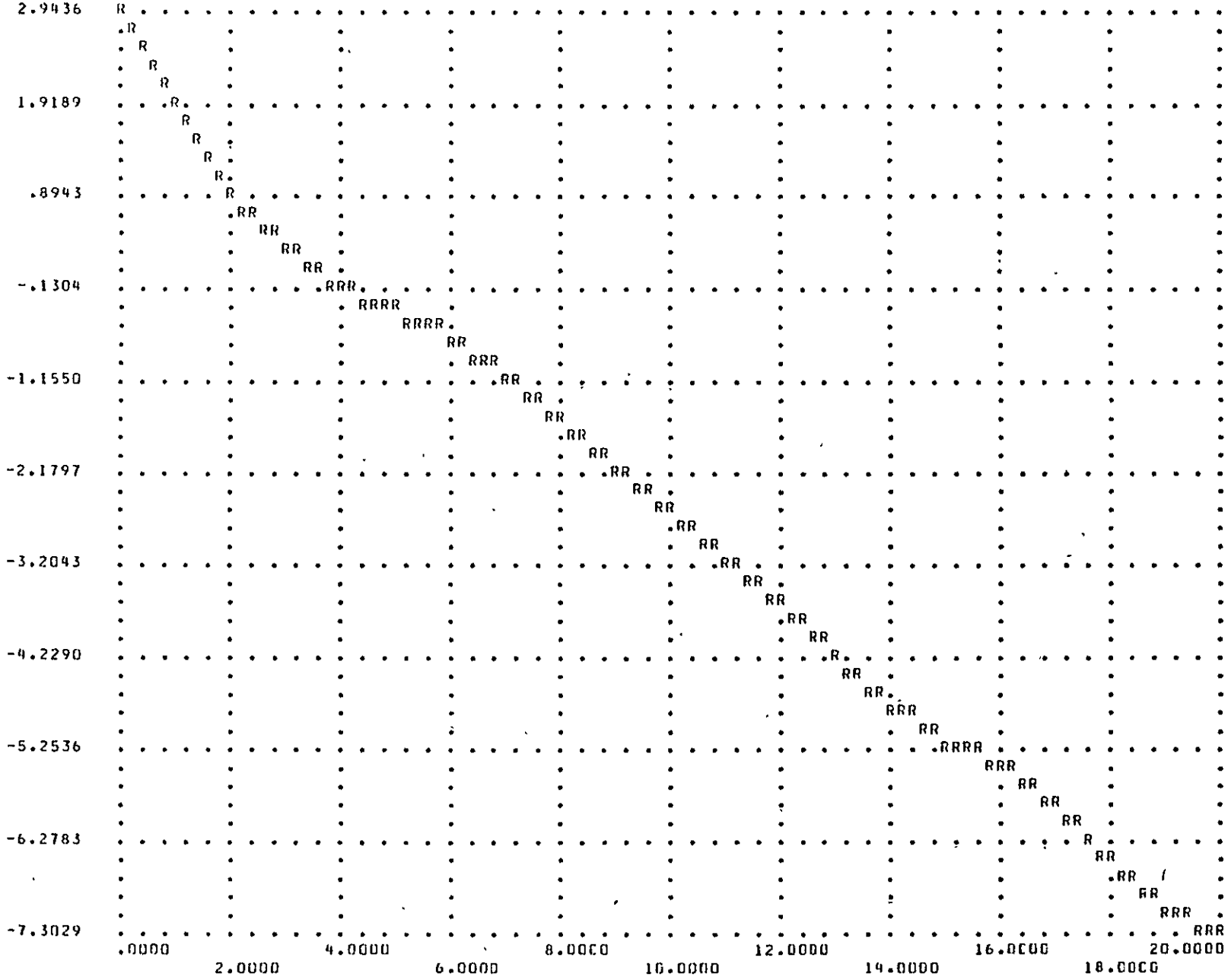
```
DQC = -5.52497308+03
V-C =  1.70983063+00
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
          TIMESTEP NO.                TIME =    1.000-01 SECONDS.

QSUM =  4.9253+01
PCOND =  1.7079+00
QCOND = -5.5250+03
IN POTENT, NC =      1
MBIAS =   1      VBIAS =  0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
CIJSUM =  0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
ROUSCN = -5.5250+03   0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
  ITER =     10C=-5.5250+03  AUNC= 9.9499+02  PC= 1.7079+00  RC=-6.5200+03  UC =-6.7735-02
PCOND =     1.7079+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  8.7818+02  RDOTRS = 9.8145+04

  ITER =     20C=-5.5250+03  AUNC=-1.3041+04  PC= 1.6408+00  RC= 6.4002+03  UC = 6.5885-02
PCOND =     1.6408+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  7.5216+00  RDOTRS = 8.7818+02

  ITER =     30C=-5.5250+03  AUNC= 1.2683+04  PC= 1.6745+00  RC=-8.4683+01  UC =-3.1546-04
PCOND =     1.6745+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  1.9523+00  RDOTRS = 7.5216+00

  ITER =     40C=-5.5250+03  AUNC=-6.0729+01  PC= 1.6740+00  RC= 1.1755+01  UC = 4.0236-05
PCOND =     1.6740+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  7.7208-01  RDOTRS = 1.9523+00

  ITER =     50C=-5.5250+03  AUNC= 7.6357+00  PC= 1.6741+00  RC=-2.2237+00  UC =-7.1895-06
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  3.7648-01  RDOTRS = 7.7208-01

  ITER =     60C=-5.5250+03  AUNC=-1.4111+00  PC= 1.6741+00  RC= 5.4143-01  UC = 2.1192-06
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  2.0451-01  RDOTRS = 3.7648-01

  ITER =     70C=-5.5250+03  AUNC= 3.2239-01  PC= 1.6741+00  RC=-1.1883-01  UC =-8.3372-08
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  7.4561-02  RDOTRS = 2.0451-01

  ITER =     80C=-5.5250+03  AUNC=-8.5410-02  PC= 1.6741+00  RC= 4.4329-02  UC = 4.3013-07
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  2.7254-02  RDOTRS = 7.4561-02

  ITER =     90C=-5.5250+03  AUNC= 1.6796-02  PC= 1.6741+00  RC= 1.7440-02  UC = 3.3840-07
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  7.5703-03  RDOTRS = 2.7254-02

  ITER =    100C=-5.5250+03  AUNC= 3.9749-03  PC= 1.6741+00  RC= 1.0605-02  UC = 2.0417-07
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  2.0492-03  RDOTRS = 7.5703-03

  ITER =    110C=-5.5250+03  AUNC=-1.9513-02  PC= 1.6741+00  RC= 4.2451-02  UC = 4.9628-07
PCOND =     1.6741+00
```

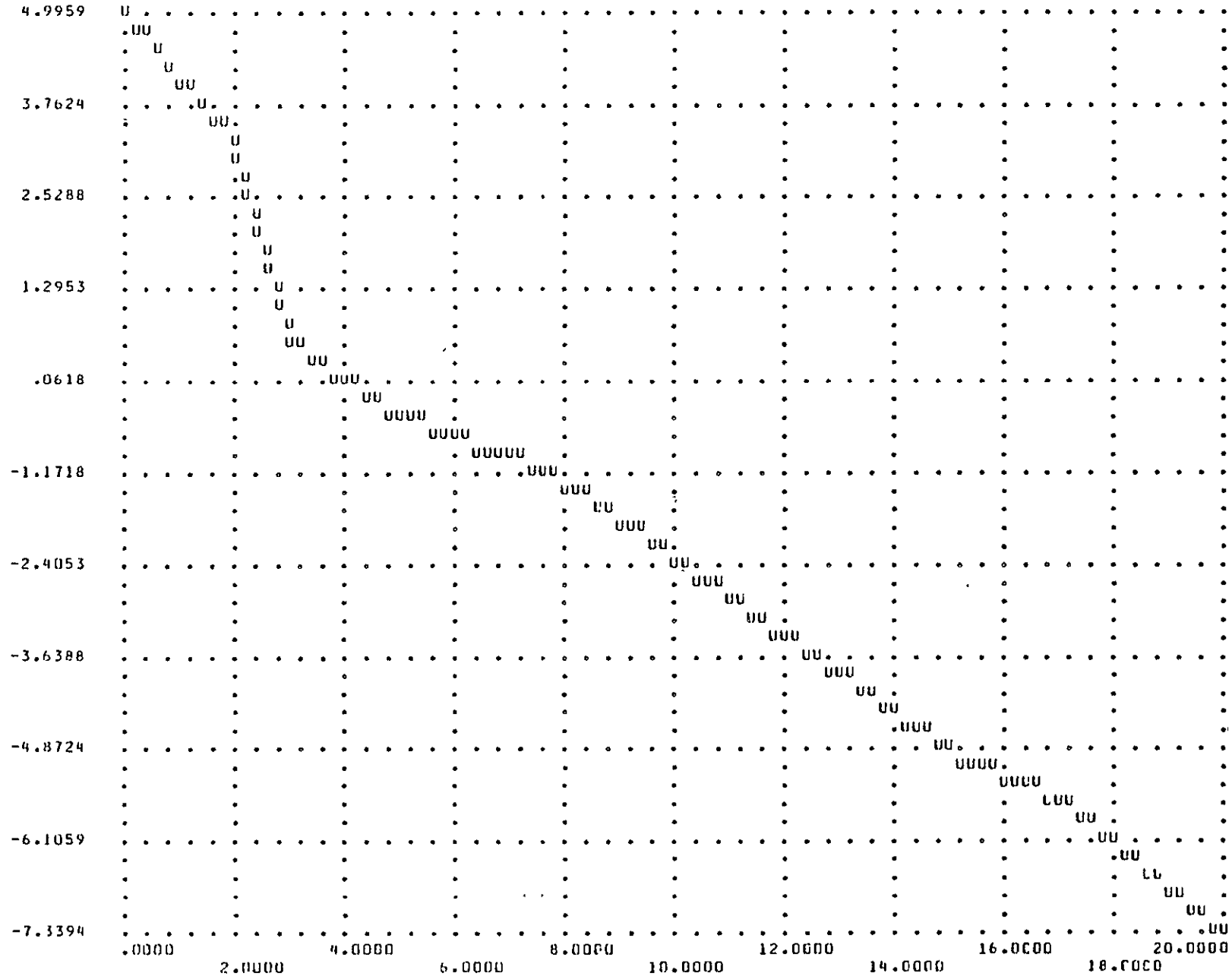
```
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  6.8200-04  RDOTRS = 2.0492-03

  ITER =    120C=-5.5250+03  AUNC= 3.8651-02  PC= 1.6741+00  RC=-1.7649-02  UC =-1.8182-08
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  2.1215-04  RDOTRS = 6.8200-04

  ITER =    130C=-5.5250+03  AUNC=-6.6993-02  PC= 1.6741+00  RC= 9.6396-02  UC = 9.9579-07
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  6.0222-05  RDOTRS = 2.1215-04

  ITER =    140C=-5.5250+03  AUNC= 1.2612-01  PC= 1.6741+00  RC=-1.0848-01  UC =-8.4427-07
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  1.6499-05  RDOTRS = 6.0222-05

  ITER =    150C=-5.5250+03  AUNC=-2.2850-01  PC= 1.6741+00  RC= 2.5689-01  UC = 2.4375-06
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  6.4564-06  RDOTRS = 1.6499-05

  ITER =    160C=-5.5250+03  AUNC= 4.0419-01  PC= 1.6741+00  RC=-3.1151-01  UC =-2.2824-06
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  3.5592-06  RDOTRS = 6.4564-06

  ITER =    170C=-5.5250+03  AUNC=-5.1161-01  PC= 1.6741+00  RC= 3.0375-01  UC = 1.8974-06
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  1.1655-06  RDOTRS = 3.5592-06

  ITER =    180C=-5.5250+03  AUNC= 2.7858-01  PC= 1.6741+00  RC=-4.9556-02  UC = 1.0653-07
PCOND =     1.6741+00
QCOND =    -5.5250+08
AFTER RUPDAT RDOTR =  2.9006-07  RDOTRS = 1.1655-06

  ITER =    190C=-5.5250+03  AUNC=-5.4864-02  PC= 1.6741+00  RC= 3.4526-02  UC = 3.8520-07
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  8.8448-08  RDOTRS = 2.9006-07

  ITER =    200C=-5.5250+03  AUNC= 8.3058-03  PC= 1.6741+00  RC= 2.1690-02  UC = 3.4279-07
PCOND =     1.6741+00
QCOND =    -5.5250+03
AFTER RUPDAT RDOTR =  4.9781-08  RDOTRS = 8.8448-08

PCOND =     1.6741+00
QCOND =    -5.5250+03
```

ALOG10(RDOTR) VS. ITERATION NUMBER

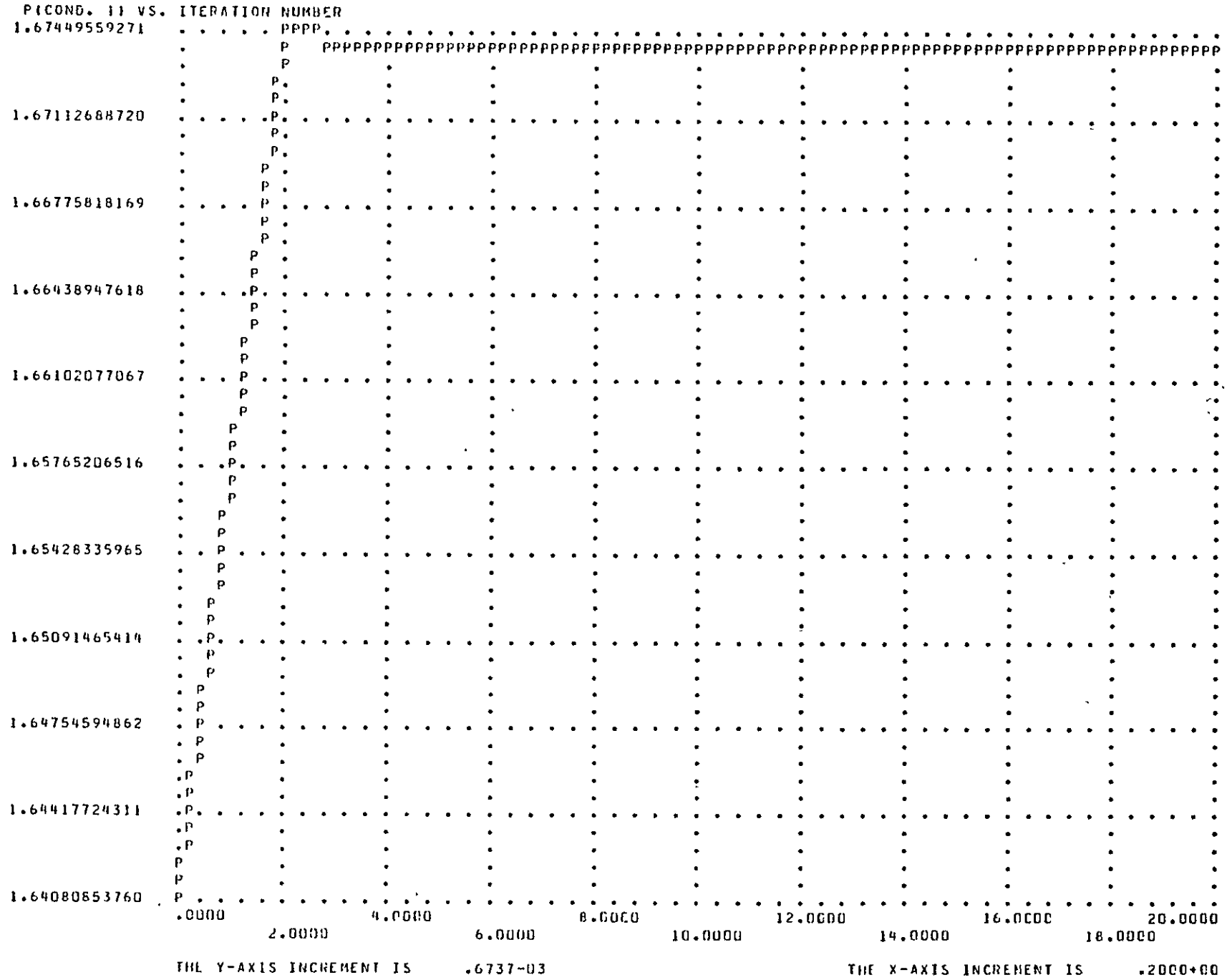


THE Y-AXIS INCREMENT IS .2049+00 THE X-AXIS INCREMENT IS .2000+00

ALOG10(UDOTAU) VS. ITERATION NUMBER



THE Y-AXIS INCREMENT IS .2467+00 THE X-AXIS INCREMENT IS .2000+00



UNIT NO. 14 1 GRIDS

P(I,J, 1, 1)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.E -1 X	2.83	2.95	3.06	3.17	3.27	3.35	3.41	3.45	3.46	3.45	3.41	3.35	3.27	3.17	3.06	2.95	2.83
2	1.E -1 X	2.95	3.08	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95
3	1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06
4	1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17
5	1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27
6	1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35
7	1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41
8	1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45
9	1.E -1 X	3.46	3.69	3.92	4.15	4.38	4.59	4.75	4.86	4.90	4.86	4.75	4.59	4.36	4.15	3.92	3.69	3.46
10	1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45
11	1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41
12	1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35
13	1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27
14	1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17
15	1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06
16	1.E -1 X	2.95	3.08	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95
17	1.E -1 X	2.83	2.95	3.06	3.17	3.27	3.35	3.41	3.45	3.46	3.45	3.41	3.35	3.27	3.17	3.06	2.95	2.83

P(I,J, 2, 1)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.E -1 X	2.95	3.08	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95
2	1.E -1 X	3.08	3.23	3.37	3.51	3.64	3.75	3.84	3.89	3.91	3.88	3.83	3.74	3.63	3.50	3.37	3.22	3.08
3	1.E -1 X	3.21	3.37	3.54	3.70	3.85	3.97	4.07	4.13	4.14	4.12	4.05	3.95	3.82	3.68	3.52	3.37	3.21
4	1.E -1 X	3.34	3.52	3.70	3.89	4.06	4.20	4.31	4.38	4.40	4.36	4.28	4.16	4.02	3.85	3.68	3.51	3.34
5	1.E -1 X	3.45	3.65	3.86	4.07	4.26	4.43	4.56	4.64	4.65	4.61	4.51	4.38	4.21	4.02	3.83	3.64	3.45
6	1.E -1 X	3.55	3.77	4.00	4.23	4.46	4.65	4.80	4.89	4.91	4.85	4.74	4.58	4.39	4.18	3.96	3.75	3.55
7	1.E -1 X	3.62	3.86	4.12	4.37	4.62	4.85	5.02	5.12	5.14	5.08	4.95	4.77	4.55	4.32	4.08	3.84	3.62
8	1.E -1 X	3.67	3.93	4.20	4.48	4.75	5.00	5.19	5.31	5.33	5.27	5.13	4.93	4.68	4.43	4.16	3.91	3.67
9	1.E -1 X	3.69	3.95	4.24	4.53	4.82	5.09	5.30	5.43	5.46	5.40	5.25	5.03	4.77	4.49	4.21	3.94	3.69
10	1.E -1 X	3.67	3.94	4.23	4.53	4.83	5.10	5.32	5.46	5.51	5.44	5.29	5.06	4.79	4.50	4.21	3.93	3.67
11	1.E -1 X	3.62	3.89	4.17	4.47	4.76	5.03	5.25	5.40	5.44	5.39	5.23	5.01	4.74	4.45	4.16	3.89	3.62
12	1.E -1 X	3.55	3.80	4.07	4.35	4.63	4.88	5.09	5.23	5.27	5.22	5.09	4.88	4.62	4.35	4.07	3.80	3.55
13	1.E -1 X	3.45	3.69	3.94	4.19	4.44	4.67	4.85	4.97	5.02	4.98	4.86	4.67	4.44	4.19	3.94	3.69	3.45
14	1.E -1 X	3.34	3.55	3.77	4.00	4.21	4.41	4.56	4.67	4.70	4.67	4.57	4.41	4.22	4.00	3.78	3.55	3.34
15	1.E -1 X	3.21	3.40	3.59	3.78	3.96	4.12	4.25	4.33	4.36	4.34	4.25	4.13	3.97	3.79	3.59	3.40	3.21
16	1.E -1 X	3.08	3.24	3.40	3.56	3.70	3.83	3.93	4.00	4.02	4.00	3.93	3.83	3.71	3.56	3.40	3.24	3.08
17	1.E -1 X	2.95	3.08	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95

P(I,J, 3, 1)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06
2	1.E -1 X	3.21	3.37	3.54	3.70	3.85	3.97	4.07	4.13	4.14	4.11	4.05	3.95	3.82	3.68	3.52	3.37	3.21
3	1.E -1 X	3.36	3.54	3.72	3.90	4.07	4.21	4.32	4.38	4.40	4.36	4.28	4.16	4.02	3.86	3.69	3.52	3.36
4	1.E -1 X	3.51	3.70	3.91	4.12	4.31	4.48	4.60	4.67	4.68	4.63	4.53	4.39	4.23	4.05	3.86	3.68	3.51
5	1.E -1 X	3.64	3.86	4.10	4.34	4.56	4.76	4.91	4.99	4.99	4.92	4.80	4.64	4.45	4.24	4.03	3.83	3.64
6	1.E -1 X	3.75	4.00	4.27	4.54	4.81	5.05	5.22	5.31	5.32	5.23	5.08	4.89	4.67	4.43	4.19	3.96	3.75
7	1.E -1 X	3.84	4.12	4.42	4.73	5.04	5.32	5.53	5.64	5.65	5.55	5.37	5.14	4.88	4.61	4.34	4.08	3.84
8	1.E -1 X	3.90	4.20	4.53	4.88	5.23	5.55	5.81	5.95	5.97	5.86	5.65	5.38	5.08	4.76	4.45	4.16	3.90
9	1.E -1 X	3.92	4.24	4.59	4.97	5.36	5.72	6.01	6.19	6.23	6.12	5.89	5.58	5.23	4.88	4.53	4.21	3.92
10	1.E -1 X	3.90	4.23	4.60	4.99	5.40	5.79	6.11	6.32	6.38	6.27	6.03	5.70	5.32	4.93	4.56	4.21	3.90
11	1.E -1 X	3.84	4.17	4.54	4.93	5.34	5.73	6.06	6.29	6.36	6.26	6.03	5.69	5.30	4.90	4.52	4.17	3.84
12	1.E -1 X	3.75	4.07	4.42	4.80	5.18	5.55	5.87	6.08	6.16	6.08	5.86	5.55	5.18	4.79	4.42	4.07	3.75
13	1.E -1 X	3.64	3.94	4.26	4.59	4.94	5.27	5.54	5.73	5.80	5.74	5.56	5.28	4.95	4.60	4.26	3.94	3.64
14	1.E -1 X	3.51	3.77	4.05	4.35	4.64	4.91	5.14	5.30	5.35	5.31	5.16	4.93	4.66	4.36	4.06	3.78	3.51
15	1.E -1 X	3.36	3.59	3.83	4.07	4.31	4.52	4.70	4.82	4.87	4.83	4.72	4.54	4.32	4.08	3.84	3.59	3.36
16	1.E -1 X	3.21	3.40	3.59	3.79	3.97	4.13	4.26	4.35	4.38	4.35	4.27	4.14	3.98	3.79	3.60	3.40	3.21

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17 1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06

P(I,J, 4, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17
2 1.E -1 X	3.34	3.52	3.70	3.88	4.05	4.19	4.30	4.37	4.39	4.35	4.27	4.15	4.01	3.85	3.68	3.50	3.34
3 1.E -1 X	3.51	3.70	3.91	4.11	4.30	4.47	4.59	4.66	4.67	4.62	4.52	4.38	4.22	4.04	3.86	3.68	3.51
4 1.E -1 X	3.67	3.89	4.12	4.36	4.59	4.78	4.93	5.00	5.00	4.93	4.80	4.64	4.45	4.25	4.05	3.85	3.67
5 1.E -1 X	3.82	4.07	4.34	4.62	4.89	5.13	5.31	5.40	5.38	5.28	5.12	4.92	4.70	4.47	4.24	4.02	3.82
6 1.E -1 X	3.96	4.24	4.55	4.88	5.21	5.51	5.73	5.83	5.80	5.66	5.45	5.21	4.96	4.69	4.43	4.18	3.96
7 1.E -1 X	4.06	4.38	4.74	5.12	5.52	5.89	6.17	6.31	6.27	6.09	5.84	5.54	5.23	4.92	4.61	4.32	4.06
8 1.E -1 X	4.13	4.48	4.88	5.33	5.80	6.25	6.61	6.80	6.78	6.58	6.26	5.90	5.52	5.14	4.76	4.43	4.13
9 1.E -1 X	4.15	4.53	4.97	5.46	5.99	6.52	6.97	7.24	7.27	7.07	6.70	6.26	5.78	5.32	4.88	4.49	4.15
10 1.E -1 X	4.13	4.53	4.99	5.51	6.08	6.66	7.18	7.52	7.60	7.41	7.03	6.51	5.96	5.42	4.94	4.51	4.13
11 1.E -1 X	4.06	4.47	4.93	5.45	6.03	6.62	7.15	7.53	7.65	7.50	7.10	6.57	5.99	5.42	4.91	4.46	4.06
12 1.E -1 X	3.96	4.35	4.79	5.29	5.83	6.38	6.88	7.24	7.37	7.25	6.90	6.40	5.84	5.30	4.80	4.35	3.96
13 1.E -1 X	3.82	4.19	4.59	5.03	5.51	5.98	6.40	6.71	6.83	6.73	6.45	6.03	5.55	5.06	4.61	4.20	3.82
14 1.E -1 X	3.67	3.99	4.34	4.72	5.11	5.49	5.82	6.06	6.15	6.08	5.86	5.53	5.15	4.75	4.36	4.00	3.67
15 1.E -1 X	3.51	3.78	4.07	4.37	4.68	4.97	5.21	5.38	5.44	5.39	5.24	5.00	4.71	4.40	4.08	3.79	3.51
16 1.E -1 X	3.34	3.56	3.79	4.02	4.24	4.45	4.62	4.73	4.77	4.74	4.63	4.46	4.26	4.03	3.79	3.56	3.34
17 1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17

P(I,J, 5, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27
2 1.E -1 X	3.45	3.65	3.85	4.05	4.24	4.41	4.53	4.61	4.63	4.58	4.49	4.35	4.19	4.01	3.82	3.63	3.45
3 1.E -1 X	3.64	3.85	4.08	4.31	4.53	4.72	4.86	4.94	4.95	4.89	4.76	4.60	4.41	4.21	4.01	3.82	3.64
4 1.E -1 X	3.82	4.06	4.33	4.60	4.86	5.10	5.27	5.36	5.35	5.25	5.09	4.89	4.66	4.44	4.22	4.01	3.82
5 1.E -1 X	4.00	4.27	4.58	4.91	5.24	5.54	5.77	5.87	5.83	5.67	5.45	5.20	4.94	4.68	4.44	4.20	4.00
6 1.E -1 X	4.15	4.47	4.83	5.23	5.65	6.04	6.34	6.46	6.37	6.10	5.81	5.53	5.24	4.95	4.66	4.39	4.15
7 1.E -1 X	4.28	4.64	5.06	5.54	6.06	6.57	6.99	7.13	6.95	6.65	6.23	5.91	5.58	5.23	4.87	4.55	4.28
8 1.E -1 X	4.35	4.76	5.25	5.81	6.44	7.10	7.66	7.90	7.82	7.32	6.89	6.40	5.99	5.52	5.08	4.68	4.35
9 1.E -1 X	4.38	4.83	5.37	6.00	6.74	7.54	8.29	8.71	8.72	8.26	7.70	7.02	6.41	5.80	5.25	4.77	4.38
10 1.E -1 X	4.35	4.83	5.40	6.08	6.89	7.79	8.68	9.33	9.48	9.15	8.38	7.57	6.73	5.98	5.34	4.80	4.35
11 1.E -1 X	4.28	4.76	5.34	6.02	6.83	7.75	8.68	9.39	9.66	9.37	8.69	7.75	6.83	6.01	5.32	4.75	4.28
12 1.E -1 X	4.15	4.63	5.18	5.82	6.57	7.41	8.23	8.89	9.17	8.98	8.35	7.51	6.65	5.86	5.20	4.63	4.15
13 1.E -1 X	4.00	4.44	4.93	5.50	6.14	6.83	7.49	7.99	8.20	8.06	7.60	6.94	6.23	5.56	4.97	4.45	4.00
14 1.E -1 X	3.82	4.21	4.63	5.11	5.62	6.14	6.62	6.97	7.12	7.02	6.70	6.23	5.69	5.16	4.67	4.22	3.82
15 1.E -1 X	3.64	3.96	4.30	4.67	5.06	5.44	5.77	6.00	6.09	6.03	5.81	5.49	5.11	4.71	4.33	3.97	3.64
16 1.E -1 X	3.45	3.70	3.97	4.24	4.51	4.77	4.98	5.13	5.19	5.14	5.01	4.79	4.54	4.26	3.98	3.71	3.45
17 1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27

P(I,J, 6, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35
2 1.E -1 X	3.55	3.76	3.98	4.20	4.42	4.60	4.75	4.83	4.85	4.80	4.69	4.53	4.35	4.14	3.94	3.74	3.55
3 1.E -1 X	3.75	3.98	4.23	4.49	4.74	4.96	5.12	5.22	5.22	5.14	4.99	4.80	4.59	4.36	4.15	3.94	3.75
4 1.E -1 X	3.96	4.22	4.51	4.82	5.13	5.41	5.62	5.73	5.71	5.58	5.37	5.12	4.86	4.61	4.37	4.15	3.96
5 1.E -1 X	4.15	4.45	4.80	5.18	5.58	5.96	6.26	6.40	6.35	6.12	5.80	5.47	5.17	4.88	4.61	4.36	4.15
6 1.E -1 X	4.33	4.68	5.09	5.57	6.09	6.62	7.06	7.24	7.06	6.65	6.16	5.81	5.50	5.18	4.86	4.57	4.33
7 1.E -1 X	4.47	4.87	5.36	5.95	6.62	7.35	8.00	8.34	7.85	6.64	6.36	6.18	5.91	5.52	5.12	4.76	4.47
8 1.E -1 X	4.56	5.02	5.59	6.29	7.13	8.07	9.06	9.51	8.32	7.99	6.65	6.89	6.45	5.91	5.38	4.92	4.56
9 1.E 0 X	.46	.51	.57	.65	.75	.87	1.00	1.12	1.07	1.00	.83	.79	.71	.63	.56	.50	.46
10 1.E 0 X	.46	.51	.58	.67	.78	.92	1.09	1.23	1.27	1.16	1.07	.90	.77	.66	.57	.51	.46
11 1.E 0 X	.45	.50	.57	.66	.77	.92	1.09	1.25	1.34	1.30	1.12	.94	.78	.66	.57	.50	.45
12 1.E 0 X	.43	.49	.55	.64	.74	.86	1.01	1.13	1.19	1.16	1.05	.90	.76	.65	.56	.49	.43
13 1.E 0 X	.42	.47	.53	.60	.68	.78	.86	.96	1.00	.98	.90	.80	.70	.61	.53	.47	.42
14 1.E -1 X	3.96	4.40	4.90	5.48	6.13	6.83	7.50	8.01	8.23	8.09	7.63	6.97	6.25	5.57	4.96	4.43	3.96
15 1.E -1 X	3.75	4.12	4.52	4.96	5.43	5.91	6.34	6.65	6.76	6.69	6.41	5.99	5.51	5.02	4.56	4.14	3.75

16 1.E -1 X	3.55	3.83	4.13	4.44	4.77	5.07	5.34	5.52	5.59	5.54	5.37	5.11	4.80	4.47	4.15	3.84	3.55
17 1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35

P(I,J, 7, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41
2 1.E -1 X	3.62	3.85	4.08	4.32	4.55	4.76	4.92	5.01	5.03	4.97	4.85	4.68	4.47	4.25	4.03	3.82	3.62
3 1.E -1 X	3.84	4.09	4.35	4.63	4.91	5.15	5.34	5.45	5.45	5.36	5.18	4.97	4.73	4.48	4.25	4.04	3.84
4 1.E -1 X	4.06	4.34	4.65	5.00	5.35	5.67	5.93	6.07	6.05	5.89	5.63	5.32	5.03	4.75	4.49	4.26	4.06
5 1.E -1 X	4.28	4.60	4.98	5.41	5.87	6.34	6.73	6.94	6.89	6.59	6.16	5.73	5.35	5.04	4.75	4.49	4.28
6 1.E -1 X	4.47	4.84	5.30	5.85	6.48	7.17	7.82	8.23	8.16	7.54	6.70	6.05	5.71	5.37	5.03	4.72	4.47
7 1.E 0 X	.46	.51	.56	.63	.71	.81	.93	1.00	.91	.77	.62	.64	.62	.58	.53	.49	.46
8 1.E 0 X	.47	.52	.59	.67	.78	.91	1.04	1.30	1.31	-.22	.65	.71	.69	.62	.56	.51	.47
9 1.E 0 X	.48	.53	.61	.70	.83	1.00	1.20	1.31	1.36	.35	.96	.90	.78	.68	.59	.53	.48
10 1.E 0 X	.47	.53	.61	.72	.86	1.07	1.35	1.87	2.32	2.27	1.39	1.12	.86	.71	.61	.53	.47
11 1.E 0 X	.46	.53	.61	.71	.86	1.07	1.42	1.77	2.03	1.89	1.59	1.15	.89	.72	.61	.53	.46
12 1.E 0 X	.45	.51	.59	.68	.82	1.00	1.24	1.50	1.62	1.56	1.31	1.06	.85	.70	.59	.51	.45
13 1.E 0 X	.43	.48	.55	.64	.74	.88	1.02	1.15	1.21	1.17	1.06	.91	.77	.65	.56	.49	.43
14 1.E -1 X	4.06	4.56	5.13	5.80	6.59	7.47	8.35	9.04	9.35	9.17	8.55	7.69	6.77	5.92	5.20	4.59	4.06
15 1.E -1 X	3.84	4.24	4.69	5.20	5.75	6.32	6.85	7.24	7.41	7.30	6.95	6.44	5.85	5.27	4.74	4.27	3.84
16 1.E -1 X	3.62	3.93	4.26	4.61	4.98	5.33	5.64	5.86	5.95	5.88	5.68	5.38	5.02	4.65	4.28	3.94	3.62
17 1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41

P(I,J, 8, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45
2 1.E -1 X	3.67	3.90	4.15	4.40	4.64	4.86	5.03	5.13	5.15	5.09	4.96	4.77	4.55	4.32	4.10	3.87	3.67
3 1.E -1 X	3.90	4.15	4.43	4.73	5.02	5.29	5.49	5.61	5.61	5.51	5.32	5.08	4.82	4.56	4.32	4.10	3.90
4 1.E -1 X	4.13	4.42	4.75	5.12	5.50	5.86	6.15	6.31	6.30	6.11	5.81	5.47	5.14	4.84	4.57	4.33	4.13
5 1.E -1 X	4.35	4.69	5.09	5.56	6.08	6.62	7.08	7.38	7.34	7.01	6.45	5.93	5.49	5.15	4.84	4.57	4.35
6 1.E -1 X	4.56	4.95	5.45	6.05	6.76	7.57	8.49	9.02	9.14	8.21	7.30	6.28	5.84	5.50	5.14	4.81	4.56
7 1.E 0 X	.47	.52	.58	.66	.75	.87	1.02	1.28	1.28	1.28	.69	.64	.64	.59	.55	.50	.47
8 1.E 0 X	.48	.54	.61	.70	.82	.97	1.28	.00	.00	.00	.29	.76	.72	.65	.58	.52	.48
9 1.E 0 X	.49	.55	.63	.74	.89	1.10	1.28	.00	.00	.00	1.04	1.04	.84	.71	.61	.54	.49
10 1.E 0 X	.48	.55	.64	.76	.93	1.19	1.66	.00	.00	.00	2.55	1.27	.95	.75	.63	.55	.48
11 1.E 0 X	.47	.54	.63	.75	.92	1.21	1.71	3.10	3.45	3.41	1.97	1.37	.98	.77	.64	.54	.47
12 1.E 0 X	.46	.52	.61	.72	.87	1.11	1.47	1.80	2.03	1.89	1.60	1.20	.93	.74	.62	.53	.46
13 1.E 0 X	.44	.50	.57	.67	.79	.95	1.14	1.31	1.38	1.34	1.19	1.00	.83	.69	.58	.50	.44
14 1.E 0 X	.41	.47	.53	.60	.69	.79	.90	.98	1.02	1.00	.93	.82	.71	.62	.54	.47	.41
15 1.E -1 X	3.90	4.33	4.81	5.36	5.97	6.62	7.22	7.68	7.87	7.75	7.35	6.76	6.10	5.45	4.87	4.35	3.90
16 1.E -1 X	3.67	3.99	4.34	4.72	5.12	5.51	5.85	6.09	6.19	6.12	5.90	5.57	5.17	4.76	4.37	4.01	3.67
17 1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45

P(I,J, 9, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.46	3.69	3.92	4.15	4.38	4.59	4.75	4.86	4.90	4.86	4.75	4.59	4.38	4.15	3.92	3.69	3.46
2 1.E -1 X	3.69	3.92	4.17	4.43	4.68	4.90	5.07	5.18	5.20	5.13	5.00	4.81	4.58	4.35	4.12	3.89	3.69
3 1.E -1 X	3.92	4.18	4.46	4.76	5.06	5.34	5.55	5.67	5.67	5.56	5.37	5.12	4.86	4.59	4.35	4.12	3.92
4 1.E -1 X	4.15	4.45	4.76	5.16	5.55	5.93	6.23	6.41	6.40	6.20	5.89	5.53	5.19	4.88	4.60	4.36	4.15
5 1.E -1 X	4.38	4.72	5.14	5.62	6.16	6.72	7.23	7.55	7.52	7.16	6.58	6.01	5.55	5.19	4.88	4.60	4.38
6 1.E -1 X	4.59	4.99	5.50	6.12	6.87	7.74	8.72	9.47	9.71	8.80	7.54	6.41	5.90	5.55	5.18	4.85	4.59
7 1.E 0 X	.48	.52	.59	.66	.76	.90	1.06	1.28	1.28	1.28	.75	.64	.64	.60	.55	.51	.48
8 1.E 0 X	.49	.54	.62	.71	.84	1.01	1.28	.00	.00	.00	.31	.76	.74	.66	.59	.53	.49
9 1.E 0 X	.49	.55	.64	.75	.91	1.15	1.28	.00	.00	.00	1.25	1.07	.87	.72	.62	.55	.49
10 1.E 0 X	.49	.55	.65	.77	.96	1.23	1.96	.00	.00	.00	2.84	1.38	.98	.77	.64	.55	.49
11 1.E 0 X	.48	.55	.64	.77	.95	1.27	1.87	3.26	3.74	3.61	2.21	1.46	1.01	.79	.65	.55	.48
12 1.E 0 X	.46	.53	.61	.73	.90	1.19	1.56	1.99	2.24	2.09	1.70	1.26	.96	.76	.63	.53	.46
13 1.E 0 X	.44	.50	.58	.68	.81	.98	1.19	1.37	1.46	1.41	1.25	1.04	.85	.70	.59	.51	.44
14 1.E 0 X	.42	.47	.53	.61	.70	.81	.93	1.02	1.06	1.03	.95	.84	.73	.63	.54	.47	.42

15 1.E -1 X	3.92	4.36	4.85	5.42	6.06	6.73	7.37	7.85	8.05	7.93	7.50	6.88	6.19	5.52	4.91	4.39	3.92
16 1.E -1 X	3.69	4.02	4.37	4.76	5.17	5.57	5.93	6.18	6.29	6.22	5.98	5.64	5.23	4.81	4.40	4.03	3.69
17 1.E -1 X	3.46	3.69	3.92	4.15	4.38	4.59	4.75	4.86	4.90	4.86	4.75	4.59	4.38	4.15	3.92	3.69	3.46

P(I,J,10, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45
2 1.E -1 X	3.67	3.90	4.15	4.40	4.65	4.87	5.04	5.14	5.16	5.09	4.96	4.78	4.56	4.33	4.10	3.88	3.67
3 1.E -1 X	3.90	4.15	4.43	4.73	5.03	5.29	5.50	5.62	5.62	5.52	5.33	5.09	4.83	4.57	4.32	4.10	3.90
4 1.E -1 X	4.13	4.42	4.75	5.12	5.51	5.87	6.17	6.33	6.32	6.13	5.84	5.49	5.16	4.85	4.58	4.33	4.13
5 1.E -1 X	4.35	4.69	5.10	5.57	6.09	6.64	7.11	7.41	7.38	7.05	6.49	5.96	5.51	5.16	4.85	4.58	4.35
6 1.E -1 X	4.56	4.96	5.46	6.06	6.78	7.60	8.52	9.05	9.19	8.27	7.36	6.34	5.88	5.52	5.15	4.82	4.56
7 1.E 0 X	.47	.52	.58	.66	.75	.88	1.02	1.28	1.28	1.28	.71	.64	.64	.60	.55	.51	.47
8 1.E 0 X	.48	.54	.61	.70	.83	.98	1.28	.00	.00	.00	.27	.77	.73	.65	.58	.53	.48
9 1.E 0 X	.49	.55	.63	.74	.89	1.11	1.28	.00	.00	.00	1.01	1.05	.85	.71	.61	.54	.49
10 1.E 0 X	.48	.55	.64	.76	.93	1.21	1.65	.00	.00	.00	2.54	1.28	.96	.76	.64	.55	.48
11 1.E 0 X	.47	.54	.63	.75	.93	1.22	1.73	3.09	3.44	3.40	2.00	1.39	.98	.77	.64	.54	.47
12 1.E 0 X	.46	.52	.61	.72	.88	1.12	1.49	1.83	2.06	1.91	1.61	1.21	.94	.75	.62	.53	.46
13 1.E 0 X	.44	.50	.57	.67	.79	.96	1.15	1.32	1.40	1.36	1.20	1.01	.83	.69	.58	.50	.44
14 1.E 0 X	.41	.47	.53	.60	.69	.80	.91	.99	1.03	1.01	.93	.83	.72	.62	.54	.47	.41
15 1.E -1 X	3.90	4.33	4.81	5.37	5.99	6.64	7.26	7.71	7.91	7.79	7.38	6.78	6.11	5.46	4.87	4.36	3.90
16 1.E -1 X	3.67	3.99	4.35	4.73	5.13	5.52	5.86	6.11	6.21	6.14	5.92	5.58	5.18	4.77	4.37	4.01	3.67
17 1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45

P(I,J,11, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41
2 1.E -1 X	3.62	3.85	4.09	4.33	4.56	4.77	4.93	5.02	5.04	4.98	4.86	4.68	4.48	4.26	4.04	3.82	3.62
3 1.E -1 X	3.84	4.09	4.36	4.64	4.92	5.17	5.36	5.47	5.47	5.38	5.21	4.98	4.74	4.50	4.26	4.04	3.84
4 1.E -1 X	4.06	4.34	4.66	5.01	5.36	5.70	5.96	6.10	6.09	5.93	5.67	5.36	5.05	4.77	4.50	4.27	4.06
5 1.E -1 X	4.28	4.60	4.99	5.43	5.90	6.37	6.78	7.00	6.96	6.66	6.23	5.79	5.40	5.07	4.77	4.50	4.28
6 1.E -1 X	4.47	4.85	5.32	5.88	6.52	7.22	7.89	8.32	8.26	7.66	6.82	6.16	5.78	5.42	5.06	4.73	4.47
7 1.E 0 X	.46	.51	.56	.63	.72	.82	.94	1.01	.93	.79	.65	.65	.63	.58	.54	.49	.46
8 1.E 0 X	.47	.52	.59	.68	.78	.92	1.06	1.29	1.30	-.10	.71	.73	.70	.63	.57	.51	.47
9 1.E 0 X	.48	.53	.61	.71	.84	1.01	1.24	1.30	1.67	.79	1.06	.93	.80	.68	.60	.53	.48
10 1.E 0 X	.47	.54	.62	.73	.87	1.09	1.41	2.18	3.15	2.60	1.48	1.15	.88	.72	.61	.53	.47
11 1.E 0 X	.46	.53	.61	.72	.87	1.09	1.47	1.89	2.18	2.02	1.65	1.18	.91	.73	.61	.53	.46
12 1.E 0 X	.45	.51	.59	.69	.83	1.02	1.27	1.54	1.67	1.60	1.35	1.08	.86	.71	.60	.51	.45
13 1.E 0 X	.43	.49	.56	.64	.75	.89	1.04	1.17	1.23	1.20	1.08	.93	.78	.66	.56	.49	.43
14 1.E -1 X	4.06	4.57	5.14	5.83	6.64	7.55	8.45	9.16	9.48	9.29	8.66	7.77	6.82	5.96	5.22	4.60	4.06
15 1.E -1 X	3.84	4.25	4.70	5.22	5.78	6.37	6.91	7.31	7.48	7.37	7.01	6.48	5.89	5.30	4.76	4.27	3.84
16 1.E -1 X	3.62	3.93	4.26	4.62	4.99	5.35	5.66	5.89	5.97	5.91	5.71	5.40	5.04	4.66	4.29	3.94	3.62
17 1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41

P(I,J,12, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35
2 1.E -1 X	3.55	3.76	3.98	4.21	4.42	4.61	4.76	4.84	4.86	4.81	4.70	4.54	4.36	4.15	3.94	3.74	3.55
3 1.E -1 X	3.75	3.99	4.24	4.50	4.75	4.98	5.15	5.24	5.25	5.17	5.02	4.82	4.61	4.38	4.16	3.95	3.75
4 1.E -1 X	3.96	4.22	4.52	4.83	5.15	5.44	5.66	5.78	5.77	5.64	5.42	5.17	4.90	4.64	4.39	4.16	3.96
5 1.E -1 X	4.15	4.46	4.81	5.20	5.61	6.01	6.32	6.48	6.44	6.22	5.89	5.55	5.22	4.92	4.63	4.37	4.15
6 1.E -1 X	4.33	4.69	5.11	5.60	6.14	6.69	7.16	7.37	7.21	6.82	6.32	5.94	5.59	5.24	4.90	4.59	4.33
7 1.E -1 X	4.47	4.88	5.39	6.00	6.69	7.45	8.15	8.53	8.11	6.99	6.68	6.40	6.04	5.60	5.17	4.78	4.47
8 1.E -1 X	4.56	5.03	5.63	6.35	7.23	8.23	9.30	9.91	9.10	8.82	7.27	7.22	6.62	6.01	5.43	4.95	4.56
9 1.E 0 X	.46	.51	.58	.66	.77	.90	1.04	1.23	1.22	1.13	.93	.84	.73	.64	.57	.51	.46
10 1.E 0 X	.46	.51	.58	.67	.79	.94	1.15	1.35	1.41	1.33	1.16	.94	.79	.67	.58	.51	.46
11 1.E 0 X	.45	.51	.56	.67	.79	.94	1.14	1.36	1.48	1.41	1.18	.98	.80	.67	.58	.51	.45
12 1.E 0 X	.43	.49	.56	.64	.75	.89	1.04	1.18	1.25	1.21	1.09	.92	.77	.65	.56	.49	.43
13 1.E 0 X	.42	.47	.53	.60	.69	.79	.90	.99	1.03	1.01	.93	.82	.71	.61	.54	.47	.42

14 1.E -1 X	3.96	4.41	4.93	5.52	6.19	6.92	7.62	8.16	8.39	8.24	7.76	7.08	6.32	5.61	4.98	4.44	3.96
15 1.E -1 X	3.75	4.13	4.53	4.98	5.47	5.96	6.40	6.73	6.86	6.77	6.48	6.05	5.55	5.05	4.57	4.14	3.75
16 1.E -1 X	3.55	3.83	4.14	4.46	4.78	5.10	5.37	5.55	5.63	5.57	5.40	5.14	4.82	4.49	4.16	3.84	3.55
17 1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35

P(I,J,13, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27
2 1.E -1 X	3.45	3.65	3.85	4.06	4.25	4.42	4.55	4.62	4.64	4.60	4.50	4.36	4.20	4.01	3.82	3.63	3.45
3 1.E -1 X	3.64	3.86	4.09	4.32	4.54	4.74	4.89	4.97	4.98	4.92	4.79	4.63	4.43	4.23	4.02	3.82	3.64
4 1.E -1 X	3.82	4.07	4.34	4.62	4.89	5.13	5.31	5.41	5.41	5.31	5.14	4.93	4.70	4.47	4.24	4.02	3.82
5 1.E -1 X	4.00	4.28	4.60	4.94	5.28	5.59	5.83	5.95	5.92	5.77	5.54	5.28	5.00	4.73	4.46	4.22	4.00
6 1.E -1 X	4.15	4.48	4.85	5.27	5.70	6.12	6.45	6.60	6.53	6.27	5.97	5.65	5.33	5.01	4.69	4.40	4.15
7 1.E -1 X	4.28	4.65	5.09	5.59	6.14	6.69	7.15	7.36	7.25	6.96	6.50	6.11	5.72	5.31	4.92	4.57	4.28
8 1.E -1 X	4.35	4.78	5.28	5.87	6.55	7.27	7.93	8.31	8.32	7.82	7.31	6.68	6.16	5.63	5.14	4.71	4.35
9 1.E -1 X	4.38	4.85	5.41	6.08	6.87	7.76	8.68	9.27	9.40	8.96	8.23	7.37	6.61	5.91	5.31	4.80	4.38
10 1.E 0 X	.44	.49	.54	.62	.70	.80	.91	1.00	1.03	.99	.89	.79	.69	.61	.54	.48	.44
11 1.E 0 X	.43	.48	.54	.61	.70	.80	.91	1.00	1.03	1.00	.92	.81	.70	.61	.54	.48	.43
12 1.E -1 X	4.15	4.64	5.22	5.89	6.69	7.60	8.53	9.30	9.64	9.41	8.68	7.75	6.80	5.95	5.25	4.66	4.15
13 1.E -1 X	4.00	4.45	4.97	5.56	6.23	6.97	7.68	8.23	8.47	8.31	7.81	7.10	6.34	5.63	5.01	4.47	4.00
14 1.E -1 X	3.82	4.22	4.66	5.15	5.68	6.23	6.74	7.11	7.27	7.17	6.82	6.33	5.76	5.21	4.70	4.24	3.82
15 1.E -1 X	3.64	3.97	4.32	4.70	5.10	5.49	5.83	6.08	6.18	6.11	5.89	5.55	5.15	4.74	4.35	3.98	3.64
16 1.E -1 X	3.45	3.71	3.97	4.25	4.53	4.79	5.01	5.16	5.22	5.18	5.04	4.82	4.56	4.27	3.99	3.71	3.45
17 1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27

P(I,J,14, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17
2 1.E -1 X	3.34	3.52	3.70	3.88	4.05	4.20	4.31	4.38	4.40	4.36	4.28	4.16	4.02	3.85	3.68	3.51	3.34
3 1.E -1 X	3.51	3.71	3.91	4.12	4.32	4.49	4.61	4.69	4.70	4.65	4.55	4.41	4.24	4.05	3.87	3.68	3.51
4 1.E -1 X	3.67	3.89	4.13	4.38	4.61	4.81	4.97	5.05	5.05	4.98	4.85	4.68	4.48	4.27	4.06	3.86	3.67
5 1.E -1 X	3.82	4.08	4.36	4.64	4.93	5.18	5.37	5.47	5.47	5.36	5.20	4.98	4.75	4.50	4.26	4.03	3.82
6 1.E -1 X	3.96	4.25	4.57	4.91	5.26	5.58	5.83	5.95	5.94	5.80	5.58	5.32	5.03	4.74	4.46	4.19	3.96
7 1.E -1 X	4.06	4.39	4.76	5.17	5.59	6.00	6.32	6.49	6.49	6.31	6.03	5.69	5.34	4.99	4.65	4.34	4.06
8 1.E -1 X	4.13	4.50	4.91	5.38	5.89	6.39	6.81	7.07	7.08	6.89	6.53	6.10	5.65	5.22	4.81	4.45	4.13
9 1.E -1 X	4.15	4.55	5.01	5.53	6.10	6.70	7.22	7.58	7.66	7.45	7.02	6.49	5.94	5.41	4.94	4.52	4.15
10 1.E -1 X	4.13	4.55	5.03	5.58	6.20	6.85	7.45	7.88	8.01	7.82	7.36	6.75	6.12	5.52	4.99	4.53	4.13
11 1.E -1 X	4.06	4.49	4.97	5.52	6.14	6.80	7.41	7.86	8.03	7.86	7.41	6.79	6.13	5.51	4.96	4.48	4.06
12 1.E -1 X	3.96	4.37	4.83	5.35	5.92	6.53	7.09	7.50	7.66	7.53	7.13	6.57	5.96	5.38	4.84	4.37	3.96
13 1.E -1 X	3.82	4.20	4.62	5.08	5.58	6.09	6.55	6.89	7.03	6.93	6.61	6.15	5.64	5.12	4.65	4.21	3.82
14 1.E -1 X	3.67	4.00	4.37	4.76	5.16	5.57	5.92	6.17	6.27	6.20	5.97	5.62	5.21	4.79	4.39	4.02	3.67
15 1.E -1 X	3.51	3.79	4.08	4.40	4.71	5.01	5.27	5.45	5.51	5.46	5.30	5.05	4.74	4.42	4.10	3.80	3.51
16 1.E -1 X	3.34	3.56	3.79	4.03	4.26	4.47	4.64	4.76	4.80	4.77	4.66	4.49	4.28	4.04	3.80	3.57	3.34
17 1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17

P(I,J,15, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06
2 1.E -1 X	3.21	3.38	3.54	3.70	3.85	3.98	4.07	4.13	4.15	4.12	4.06	3.95	3.83	3.68	3.53	3.37	3.21
3 1.E -1 X	3.36	3.54	3.73	3.91	4.08	4.23	4.34	4.40	4.42	4.38	4.30	4.18	4.03	3.87	3.70	3.53	3.36
4 1.E -1 X	3.51	3.71	3.92	4.13	4.33	4.50	4.63	4.71	4.72	4.67	4.57	4.42	4.25	4.07	3.88	3.69	3.51
5 1.E -1 X	3.64	3.87	4.11	4.35	4.59	4.80	4.95	5.04	5.05	4.98	4.86	4.69	4.48	4.27	4.05	3.84	3.64
6 1.E -1 X	3.75	4.01	4.28	4.57	4.85	5.10	5.29	5.40	5.41	5.33	5.17	4.96	4.72	4.47	4.22	3.98	3.75
7 1.E -1 X	3.84	4.13	4.44	4.76	5.09	5.39	5.63	5.77	5.78	5.69	5.49	5.24	4.95	4.66	4.37	4.09	3.84
8 1.E -1 X	3.90	4.21	4.55	4.92	5.29	5.65	5.94	6.11	6.15	6.04	5.81	5.51	5.17	4.82	4.49	4.18	3.90
9 1.E -1 X	3.92	4.25	4.62	5.02	5.43	5.83	6.17	6.39	6.44	6.33	6.07	5.73	5.34	4.94	4.57	4.23	3.92
10 1.E -1 X	3.90	4.24	4.62	5.04	5.48	5.91	6.27	6.52	6.60	6.49	6.22	5.85	5.42	5.00	4.60	4.23	3.90
11 1.E -1 X	3.84	4.19	4.57	4.98	5.42	5.84	6.22	6.47	6.56	6.47	6.20	5.83	5.40	4.97	4.56	4.18	3.84
12 1.E -1 X	3.75	4.09	4.45	4.84	5.25	5.65	6.00	6.24	6.33	6.24	6.01	5.66	5.26	4.85	4.45	4.09	3.75

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13 1.E -1 X	3.64	3.95	4.28	4.63	4.99	5.34	5.64	5.85	5.93	5.86	5.66	5.37	5.02	4.65	4.29	3.95	3.64
14 1.E -1 X	3.51	3.78	4.07	4.37	4.68	4.96	5.21	5.37	5.44	5.39	5.23	4.99	4.70	4.39	4.08	3.79	3.51
15 1.E -1 X	3.36	3.60	3.84	4.09	4.33	4.56	4.74	4.87	4.92	4.88	4.76	4.58	4.35	4.10	3.85	3.60	3.36
16 1.E -1 X	3.21	3.40	3.60	3.79	3.98	4.15	4.28	4.37	4.40	4.38	4.29	4.16	3.99	3.80	3.60	3.41	3.21
17 1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06

P(I,J,16, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	2.95	3.08	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95
2 1.E -1 X	3.08	3.23	3.37	3.52	3.65	3.76	3.84	3.89	3.91	3.89	3.83	3.75	3.64	3.51	3.37	3.22	3.08
3 1.E -1 X	3.21	3.38	3.54	3.70	3.85	3.96	4.08	4.14	4.15	4.13	4.06	3.96	3.83	3.68	3.53	3.37	3.21
4 1.E -1 X	3.34	3.52	3.71	3.89	4.07	4.21	4.33	4.40	4.41	4.38	4.30	4.18	4.03	3.86	3.69	3.51	3.34
5 1.E -1 X	3.45	3.65	3.87	4.08	4.28	4.45	4.58	4.67	4.68	4.64	4.54	4.40	4.23	4.04	3.84	3.64	3.45
6 1.E -1 X	3.55	3.77	4.01	4.25	4.48	4.68	4.84	4.93	4.95	4.90	4.79	4.62	4.42	4.20	3.98	3.76	3.55
7 1.E -1 X	3.62	3.87	4.13	4.39	4.65	4.88	5.07	5.18	5.20	5.15	5.01	4.82	4.59	4.34	4.09	3.85	3.62
8 1.E -1 X	3.67	3.93	4.21	4.50	4.78	5.04	5.25	5.38	5.42	5.35	5.20	4.99	4.73	4.46	4.18	3.92	3.67
9 1.E -1 X	3.69	3.96	4.25	4.56	4.86	5.14	5.37	5.52	5.56	5.49	5.33	5.10	4.82	4.52	4.23	3.95	3.69
10 1.E -1 X	3.67	3.95	4.25	4.56	4.87	5.16	5.40	5.56	5.61	5.54	5.38	5.13	4.84	4.54	4.23	3.94	3.67
11 1.E -1 X	3.62	3.90	4.19	4.49	4.80	5.09	5.32	5.48	5.54	5.48	5.32	5.08	4.79	4.49	4.18	3.89	3.62
12 1.E -1 X	3.55	3.81	4.09	4.38	4.66	4.93	5.15	5.30	5.35	5.30	5.15	4.93	4.67	4.38	4.09	3.81	3.55
13 1.F -1 X	3.45	3.69	3.95	4.21	4.47	4.70	4.90	5.03	5.08	5.04	4.91	4.71	4.48	4.22	3.95	3.70	3.45
14 1.E -1 X	3.34	3.56	3.78	4.01	4.23	4.43	4.60	4.71	4.75	4.71	4.61	4.44	4.24	4.02	3.79	3.56	3.34
15 1.E -1 X	3.21	3.40	3.60	3.79	3.97	4.14	4.27	4.36	4.39	4.36	4.28	4.15	3.98	3.80	3.60	3.40	3.21
16 1.E -1 X	3.08	3.24	3.40	3.56	3.71	3.84	3.94	4.01	4.03	4.01	3.94	3.84	3.71	3.57	3.41	3.24	3.08
17 1.E -1 X	2.95	3.06	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95

P(I,J,17, 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 1.E -1 X	2.83	2.95	3.06	3.17	3.27	3.35	3.41	3.45	3.46	3.45	3.41	3.35	3.27	3.17	3.06	2.95	2.83
2 1.E -1 X	2.95	3.08	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95
3 1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06
4 1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17
5 1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27
6 1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35
7 1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41
8 1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45
9 1.E -1 X	3.46	3.69	3.92	4.15	4.38	4.59	4.75	4.86	4.90	4.86	4.75	4.59	4.38	4.15	3.92	3.69	3.46
10 1.E -1 X	3.45	3.67	3.90	4.13	4.35	4.56	4.72	4.82	4.86	4.82	4.72	4.56	4.35	4.13	3.90	3.67	3.45
11 1.E -1 X	3.41	3.62	3.84	4.06	4.28	4.47	4.62	4.72	4.75	4.72	4.62	4.47	4.28	4.06	3.84	3.62	3.41
12 1.E -1 X	3.35	3.55	3.75	3.96	4.15	4.33	4.47	4.56	4.59	4.56	4.47	4.33	4.15	3.96	3.75	3.55	3.35
13 1.E -1 X	3.27	3.45	3.64	3.82	4.00	4.15	4.28	4.35	4.38	4.35	4.28	4.15	4.00	3.82	3.64	3.45	3.27
14 1.E -1 X	3.17	3.34	3.51	3.67	3.82	3.96	4.06	4.13	4.15	4.13	4.06	3.96	3.82	3.67	3.51	3.34	3.17
15 1.E -1 X	3.06	3.21	3.36	3.51	3.64	3.75	3.84	3.90	3.92	3.90	3.84	3.75	3.64	3.51	3.36	3.21	3.06
16 1.E -1 X	2.95	3.08	3.21	3.34	3.45	3.55	3.62	3.67	3.69	3.67	3.62	3.55	3.45	3.34	3.21	3.08	2.95
17 1.E -1 X	2.83	2.95	3.06	3.17	3.27	3.35	3.41	3.45	3.46	3.45	3.41	3.35	3.27	3.17	3.06	2.95	2.83

IP = 14 IR = 12 IU = 13 ISPARE = 10 IPSAVE = 10

LAST TIMESTEP COMPLETED IS 1

Another set of contour plots is generated.

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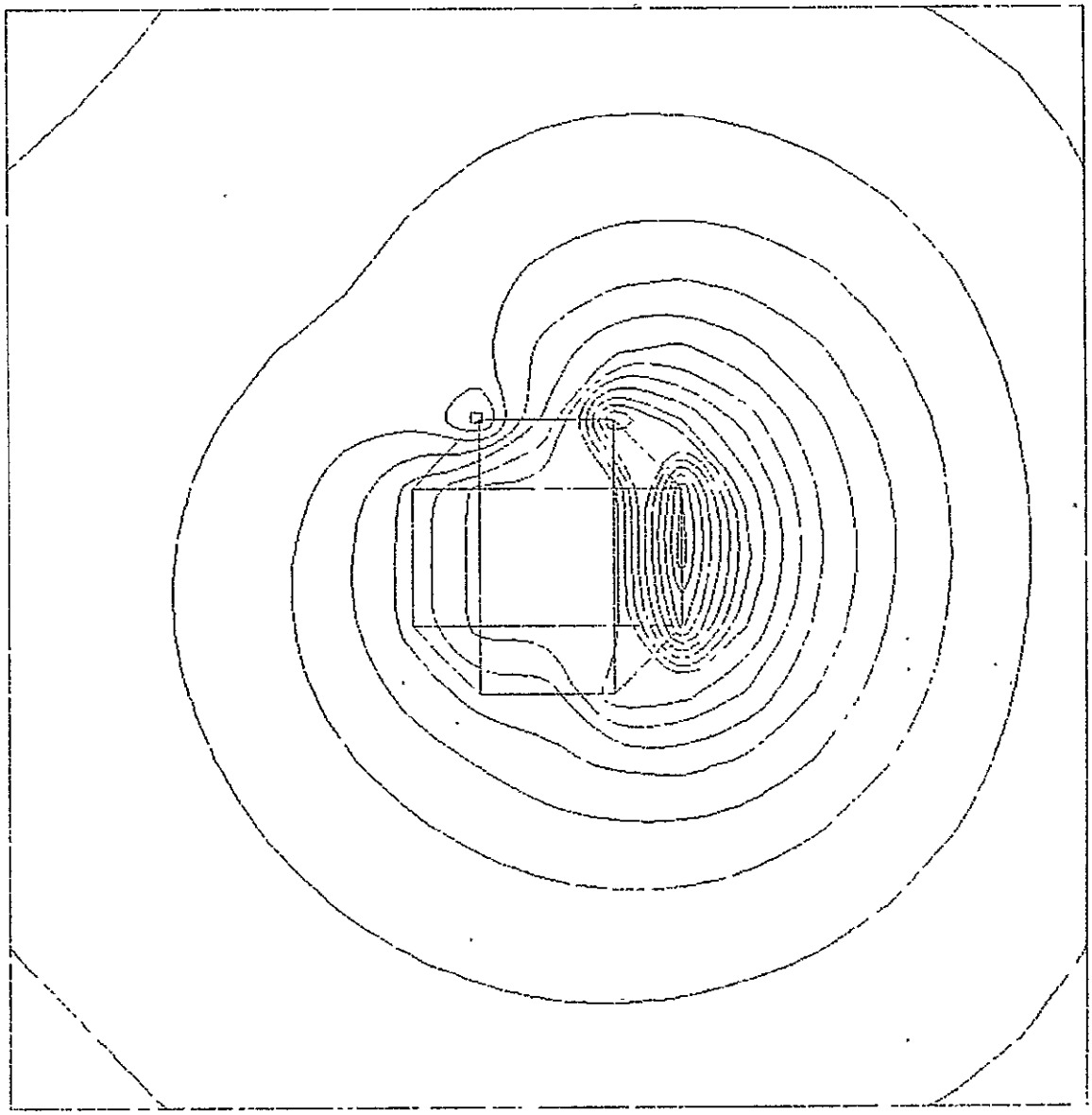
C-3

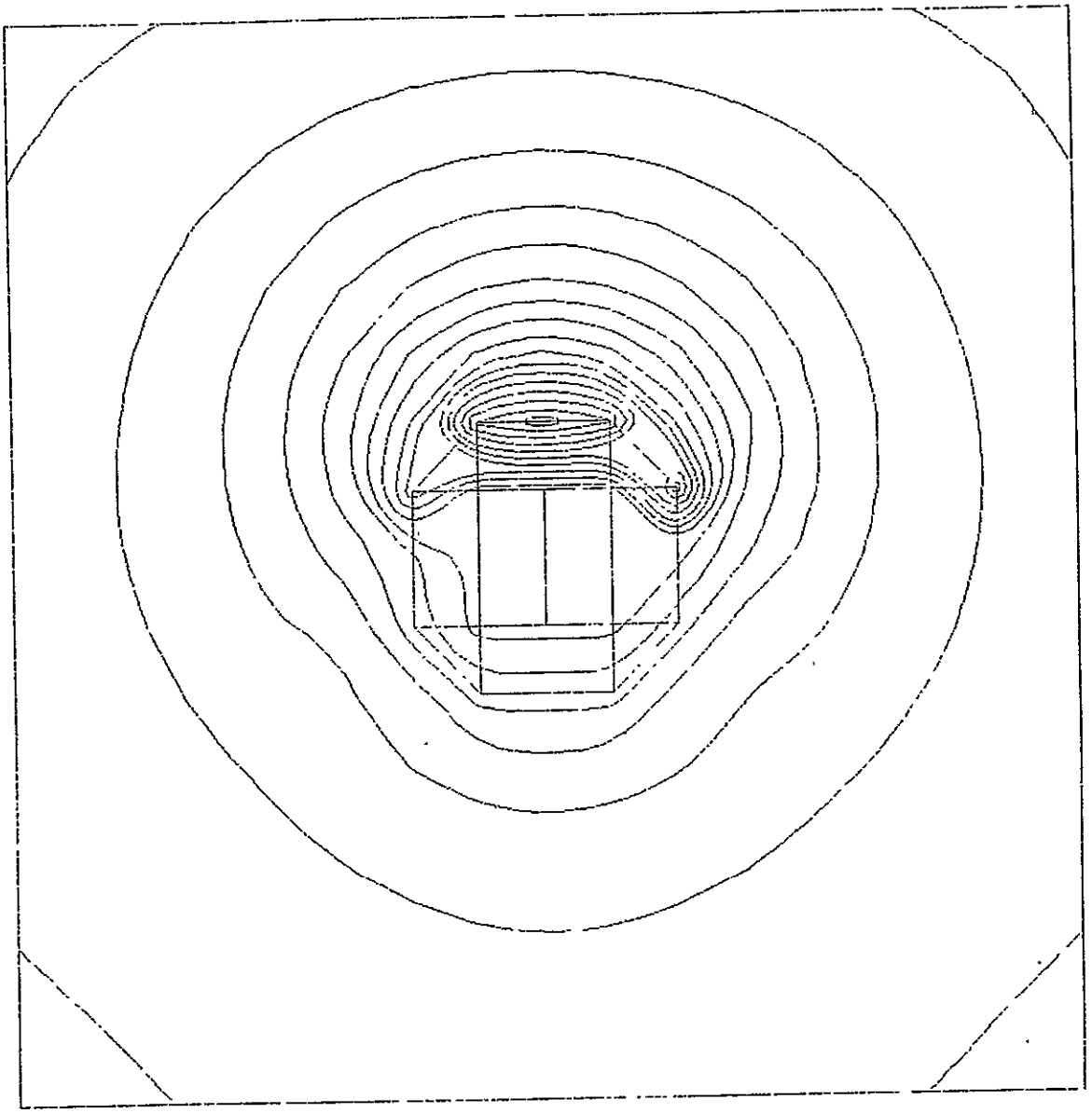
POTENTIAL CONTOURS ALONG THE X-Y PLANE OF Z = 9

ZMIN = .20540+00 ZMAX = .37412+01 ΔZ = .20000+00



POTENTIAL CONTOURS ALONG THE X-Z PLANE OF Y = 9

ZMIN = .3643+00 ZMAX = .0741S+01 ΔZ = .20000+00



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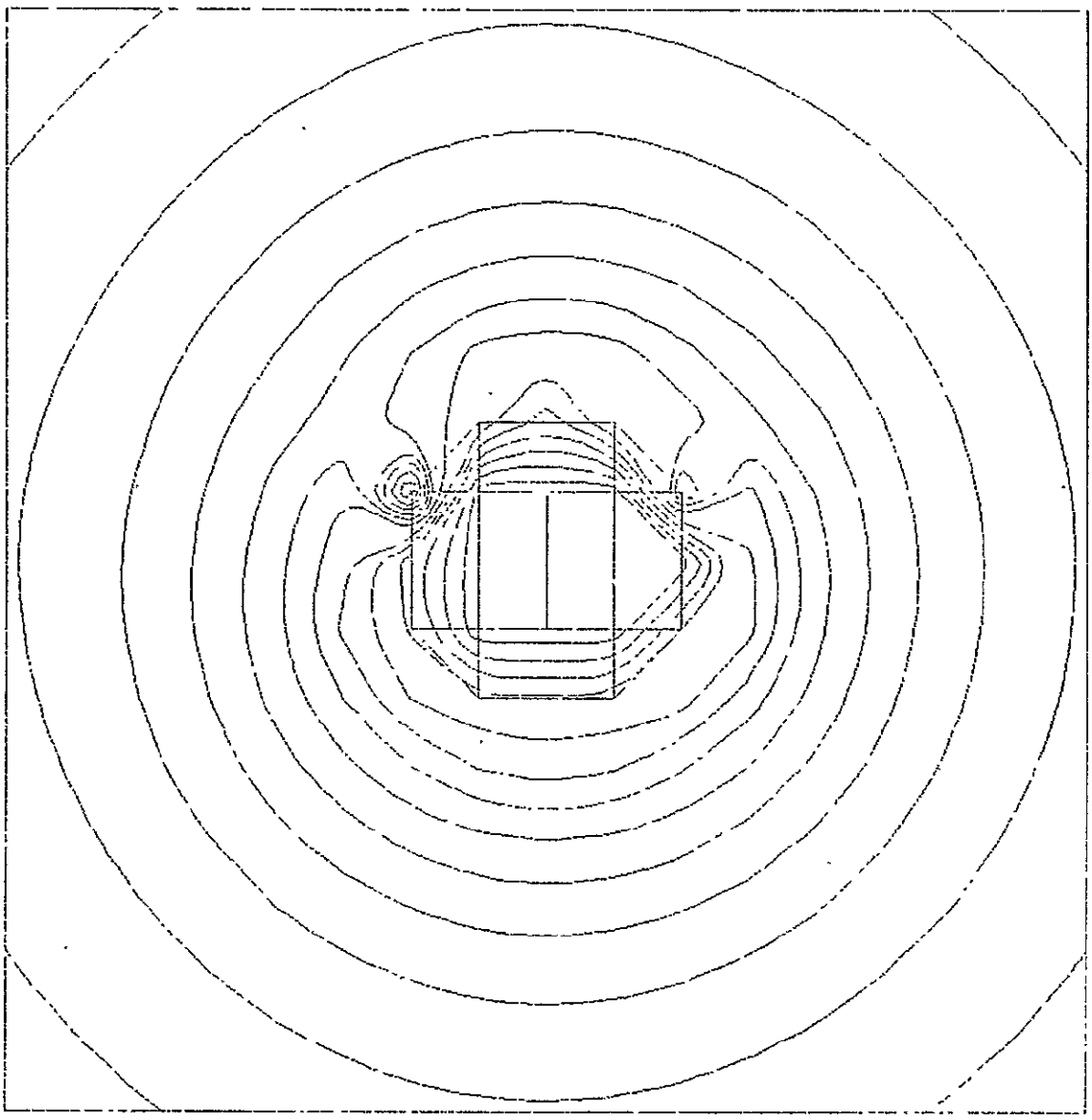
POTENTIAL CONTOURS ALONG THE Y-Z PLANE OF X = 9

ZMIN = .3443+00 ZMAX 1.671+01 ΔZ = .1000+00



```
IP = 10  IR = 12  IU = 13  ISPARE = 14  IPSAVE = 10
******END      0

@PMD.RED
```

The "END" control word is read. Program terminates normally. A dump is requested in case of abnormal termination.

10. SUBROUTINE DESCRIPTIONS

In this section, subroutine descriptions are arranged according to program modules. The modules vary in complexity from ROTATE with only one subroutine, to SATPLT — HIDCEL with over forty. The descriptions vary in detail, but each includes the name of the calling subroutine and at least a sentence about the subroutine purpose.

Figures 10.1 through 10.4 give the general code structure for sections with many subroutines. Each subroutine is indented below the subroutine that calls it. Subroutines at the same level of indentation are at the same level in the calling hierarchy. Subroutines enclosed in a box all share the same level.

```
NASCAP
   GETIGF  }
   DEFOPT  }   Initialization

   RDOPT   )
   OBJDEF  |
   TRILIN  |
   SATPLT  }   Program Modules
   HIDCEL  |
   CAPACI  |
   ROTATE  )

   RDOBJ   —   Restart subroutine

   FINSHV  —   Termination
```

Figure 10.1. Partial hierarchical outline of NASCAP.

10.1 NASCAP

DEFOPT

Called by NASCAP.
Sets all keyword variables to default values. These are subject to modification by RDOPT.

FINSHV

Called by NASCAP.
Closes the plot file if one was opened.

GETIGF

Called by NASCAP.
Opens a plot file if needed.

NASCAP

Main routine of NASCAP code.
Reads control word input and calls program modules as directed.
Performs initialization and termination tasks.

RDOBJ

Called by NASCAP.
Reads object definition information for restart run. Object was completely defined in previous run and should not be re-defined.

10.2 RDOPT

RDOPT

Called by NASCAP.
Reads keyword file. Changes default values to user-specified values. Calls SUMOPT to print summary. Calls REVERT under certain conditions.

REVERT

Called by RDOPT.
In case of internal restart (successive TRILIN calls with some options changed in between) translates some variables from code units back to input units.

SUMOPT

Called by RDOPT.
Prints out a summary of keyword options, including default values for those not specified by the user.

OBJDEF

INPUT

RECTAN	WEDGE	TETRAH
CONDUC	FIL111	CMPRSS
OCTGON	QSPHER	DELETE

CMPRSS

LORDEQ

TRNGLS

DIAGNO

MATPRO

SPECEL

NUMLTB

Figure 10.2. Partial hierarchical outline of OBJDEF module.

10.3 OBJDEF

An outline of OBJDEF is shown in Figure 10.2. The three main functions are: (1) determine the geometrical configuration and surface cell list from user input, (2) perform preprocessing of the material properties, and (3) determine the surface points, special points and their potential coefficients. The subroutine writeups which follow are divided into (1) general and miscellaneous routines, (2) geometrical object routines, (3) material routines, and (4) point and potential coefficient routines.

10.3.1 General and Miscellaneous Routines

CMPRSS

Called by INPUT, OBJDEF, QSPHER.
Eliminate superfluous or redundant surface cells.
Calling Sequence: SUBROUTINE CMPRSS (LTBL,NX,NY,NZ).

CONDUC

Called by INPUT.
Places conductor indices in surface cell array.
Calling Sequence: SUBROUTINE CONDUC (NCON).

DIAGNO

Called by OBJDEF.
Prints list of surface cells.
Calling Sequence: SUBROUTINE DIAGNO.

DELETE

Called by INPUT, FIL111.
Deletes a volume cell and all associated surface cells.
Calling Sequence: INPUT, FIL111.

INPUT

Called by OBJDEF.
Reads ISAT input file and calls object definition routines.
Calling Sequence: SUBROUTINE INPUT (IOFF,LTBL,NX,NY,NZ,ISAT).

LORDEQ

Called by OBJDEF.
Identical to LORDER (q.v.).
Calling Sequence: SUBROUTINE LORDEQ (LIST,W)

NUMLTB

Called by OBJDEF.
Number volume cells (LTBL) adjacent to object for purpose of calculating low energy electron flux.
Calling Sequence: SUBROUTINE NUMLTB (LTBL,NX,NY,NZ).

OBJDEF

Called by NASCAP.
Primary routine for object definition section of NASCAP code. (See Figure 10.2.)
Calling Sequence: SUBROUTINE OBJDEF (NX,NY,NZ,NC).

10.3.2 Geometrical Object Routines

CFLICT

Called by several geometrical object routines and CMPRSS.
Determines if a right-triangular surface cell is valid, superfluous or illegal.
Calling Sequence: SUBROUTINE CFLICT (N100,NORM,IB5,IRET).

CUBE34

Called by FIL111.
Defines a truncated cube volume cell.
Calling Sequence: SUBROUTINE CUBE34 (IOFF,LTBL,NX,NY,NZ,STUFF).

FIL111

Called by INPUT.
Defines a wedge with (111)-type surface normal.
Calling Sequence: SUBROUTINE FIL111 (IOFF,LTBL,NX,NY,NZ,ISAT).

NIOOBJ

Called by NIOOCT.
Defines a rectangular parallelepiped with parameters passed in array JSTUFF.
Calling Sequence: SUBROUTINE NIOOBJ (LTBL,NX,NY,NZ,JSTUFF).

NIOOCT

Called by OCTGON, QSPHER.
Defines an octagonal right cylinder as two RECTAN's and four WEDGE's from parameters passed in array JSTUFF.
Calling Sequence: SUBROUTINE NIOOCT (IOFF,LTBL,NX,NY,NZ,JSTUFF).

NIOTET

Called by QSPHER.
Defines a tetrahedron from parameters passed in array JSTUFF.
Calling Sequence: SUBROUTINE NIOTET (IOFF,LTBL,NX,NY,NZ,JSTUFF).

NIOWGE

Called by OCTGON, QSPHER.
Defines a right triangular cylinder (WEDGE) from parameters passed in array JSTUFF.
Calling Sequence: SUBROUTINE NIOWGE (LTBL,NX,NY,NZ,JSTUFF).

OCTGON

Called by INPUT.
Defines an octagonal right cylinder from input data as two rectangular parallelepipeds and four wedges.
Calling Sequence: SUBROUTINE OCTGON (IOFF,LTBL,NX,NY,NZ,ISAT).

QSPHER

Called by INPUT.
Defines a quasi-sphere from input data.
Calling Sequence: SUBROUTINE QSPHER (IOFF,LTBL,NX,NY,NZ,ISAT).

RECTAN

Called by INPUT.
Defines a rectangular parallelepiped from input data.
Calling Sequence: SUBROUTINE RECTAN (IOFF,LTBL,NX,NY,NZ,ISAT).

TETRAH

Called by INPUT.
Defines a tetrahedron from input data.
Calling Sequence: SUBROUTINE TETRAH (IOFF,LTBL,NX,NY,NZ,ISAT).

TRNGLS

Called by OBJDEF.
Performs further processing of right triangle surface cells, including determination of right angle corner location and elimination of redundant cells.
Calling Sequence: SUBROUTINE TRNGLS (LTBL,NX,NY,NZ).

WEDGE

Called by INPUT.
Defines a right triangular cylinder (WEDGE) from input data.
Calling Sequence: SUBROUTINE WEDGE (IOFF,LTBL,NX,NY,NZ,ISAT).

10.3.3 Materials Routines

ELSEC1

Called by INEIMP
Identical to ELSEC (q.v.).
Calling Sequence: SUBROUTINE ELSEC1 (YIELD,E,THETA,IOPT).

INEIMP

Called by MATPRO.
Preprocesses material parameters associated with electron secondary emission.
Calling Sequence: SUBROUTINE INEIMP (MPRM).

MATPRO

Called by OBJDEF.
Preprocessing of material property parameters
Calling Sequence: SUBROUTINE MATPRO.

QEQN

Called by INEIMP through ZSYSTM.
Routine used in preprocessing of electron-produced secondary material parameters.
Calling Sequence: FUNCTION QEQN (Z,K,Q).

QEQN2

Called by INEIMP through ZSYSTM.
Routine used in preprocessing of electron-produced secondary material parameters.
Calling Sequence: FUNCTION QEQN2 (Z,K,Q).

ZSYSTM

Called by INEIMP.
Modified version of IMSL routine to solve a system of non-linear equations.
Calling Sequence: SUBROUTINE ZSYSTM (F,EPS,NSIG,N,X,ITMAX,
WA,PAR,IER).

10.3.4 Point and Potential Coefficient Routines

IBIT

Called by PERMU, SPECEL, others.
Extracts N bits from word I, with bit NO the rightmost bit. (The rightmost bit of a word is bit 0.) Substitute for FLD functions for machine independence.
Calling Sequence: FUNCTION IBIT (I,NO,N).

SPECEL

Called by OBJDEF.
Identifies special cells and puts LTBL in its final form except for numbering by NUMLTB.
Calling Sequence: SUBROUTINE SPECEL (LTBL,NX,NY,NZ).

SATPLT

MATCAL

MATPLT

HIDCEL

PPJSET (see PRSPPJ)

A2PLOT

A1GEN

A2GEN

AREA

SHIELD

INSIDD	PRSPPJ	PTCOMP
PRSPPK	OLAP	INSIDE
LINPLN	INTCHK	FINVER

ADDA1

A1COMP

(plot package)

Figure 10.3. Partial hierarchical outline of SATPLT—HIDCEL module.

10.4 SATPLT — HIDCEL

SATPLT calls all routines responsible for satellite illustration plots. HIDCEL creates three-dimensional perspective plots, while MATPLT produces the shaded area silhouettes. CONPLT plots potential contours, ROUSP plots ROUS charge contours, and PARPLT plots particle trajectories.

Only the three-dimensional hidden-line plots are complex enough to warrant an algorithm description. Following is a description of the HIDCEL algorithm and documentation of all plot-related subroutines.

For purposes such as calculating photoemission effects it is desirable to be able to calculate the shadowing effects of the satellite upon itself for an arbitrary angle of incident sunlight. A subroutine called HIDCEL computes for each surface grid cell the area of that part of the cell which remains exposed when partially or completely shadowed by some other portion of the satellite (or, of course, when not shadowed at all). The program is completely general: For any satellite which NASCAP can treat, any incident angle may be specified as a vector from the center of the satellite out towards the viewer (sun). In addition to calculating the cell-by-cell areas needed for code computations, HIDCEL plots a diagnostic (and informative) hidden line 3-D plot of the satellite as viewed from the incident angle requested.

The code accomplishes both the area calculations and 3-D plots by a long series of polygon maskings. The set of cell faces whose normals produce positive dot products with the vector pointing towards the viewer are selected and projected into 2-D polygons. We call this set of individual cell polygons the A1 polygons. A second but much shorter set of polygons is selected and projected into 2-D by finding those faces of each parallelepiped, wedge, tetrahedron, octagon, etc. forming the satellite (as determined by user input), which meet the dot product criterion. We call this set the A2 polygons.

The cell-by-cell (A1) set of 2-D polygons is then masked one at a time against each of the larger "building-block" (A2) polygons, and at each step we discard any polygon which is partially or completely shielded and replace it, if necessary, with the polygon (or polygons) representing that part of the original cell which remains visible.

An A1 polygon which is completely shadowed, but is masked by several different surfaces, will then be "whittled down" a bit at a time, each masking leaving an appropriately smaller polygon until the last masking for that cell finally removes it from the system. A polygon whose middle is masked but whose ends remain visible will be split into two or more new polygons; the code maintains records, however, indicating which original cell has generated each new polygon. Consequently, when all maskings have been completed and a finalized set of masked A1 polygons exists, we may calculate areas of each polygon and add into the appropriate cell area the area of each polygon contributing to that cell.

The areas stored for further NASCAP calculations are fractional areas with the dot product (2-D projection) effect removed. We do this by calculating the areas of each cell's 2-D projection before any masking takes place and then computing the fraction of this area which remains visible following all maskings. This procedure also precludes any area normalization problems.

As is evident, for a satellite of this complexity, we may be masking on the order of 500 cell faces against on the order of 150 building-block faces for a total of about 75,000 individual maskings. Computing time (including plot generation) on S^3's UNIVAC 1100/81 varies from 5 to 60 seconds per view, depending on satellite complexity.

Subroutine descriptions follow.

ADDA1

Called by HIDCEL.

ADDA1 adds a new polygon and its associated information to the end of the A1 polygon list.

Calling Sequence: SUBROUTINE ADDA1 (A3,N3,A1,NA1,NV1,IFFS, IFF1,A1RS,A1R,A1BS,A1FS,A1B,A1F,XMIN1, XMAX1,YMIN1,YMAX1,IA1).

AREA

Called by HIDCEL, FINVER.

AREA's value is the area of polygon A.

Calling Sequence: FUNCTION AREA (A,N).

Local Variables: A(2,N): Vertices of a 2-D polygon
N: Number of vertices

A1COMP

Called by HIDCEL.

A1COMP is called following masking of all A1 polygons against one A2 polygon. A1COMP removes all flagged A1 polygons (any which have been partially or wholly shielded), and compresses the list by inserting polygons from the end of the list into those spaces occupied by the removed ones.

Calling Sequence: SUBROUTINE A1COMP (A1,NA1,NV1,IFF1,A1R, A1B,A1F,XMIN1,XMAX1,YMIN1,YMAX1,IREMOV).

A1GEN

Called by HIDCEL.

A1GEN generates the vertices in 3-D of all A1 individual cell faces whose normals have positive dot product with the direction of viewing. Each of these 3-D polygons is then projected into 2-D by calling PRSPPJ. The final set of 2-D vertices is stored in the A1 array. In addition, 2-D XMIN's, XMAX's, YMIN's, and YMAX's are calculated and stored for use in rough masking and behindness tests.

Calling Sequence: SUBROUTINE A1GEN (DIR,A1,A1B,A1F,NA1,NV1,
DV1,A1R,IFF1,XMIN1,XMAX1,YMIN1,YMAX1,NSURF,
JSURF,IP).

A2GEN

Called by HIDCEL.

A2GEN generates the 3-D and 2-D projected coordinates for the "building-block" face A2 surfaces whose normals have a positive dot product with the direction of viewing. A2GEN also computes and saves minima and maxima for use in behindness tests.

Calling Sequence: SUBROUTINE A2GEN (DIR,A2,A2B,A2F,IFAC,NA2,
IFF2,DV2,A2R,NV2,NBLK,NPBLK,IPER,XMIN2,
XMAX2,YMIN2,YMAX2,IP).

Internal Organization: We start with a loop over all building blocks making up the satellite as defined by user input to OBJDEF. The number of points in the block (NPBLK(IBLK)) tells us which type block it is of the five possible types: rectangular parallelepiped, wedge, tetrahedron, octagon, or "FIL111" type. From the type, we know how many faces this block has, and we loop over each face for the current block.

Using face normal data stored in the IFAC array (see SETFAC), we find the normal for the current face and place it in IFF(3). We compute the dot product of this face normal with the direction of viewing, and skip this face if its dot product is less than or equal to 1.E-10.

If we keep this face we must find its 3-D vertices. We pick the vertices for this face in order out of array IPER according to the face index, the type of block, and the vertex index data stored in IV (see SETFAC).

Next, we project the 3-D vertex set into 2-D by calling PRSPPJ for each vertex. We also store the distance to the viewer for each vertex in DV2. The closest and furthest points to the viewer are found and stored in A2F and A2B. The 2-D minima and maxima are calculated and stored, and the first vertex is appended to the vertex list. All faces of all blocks are looped through in this manner.

A2PLOT

Called by HIDCEL.

A2PLOT plots the non-hidden line plots of the building block faces when HIDCEL is called with IAREA = 1. If drastic errors have been made in defining the building blocks which make up the satellite, A2PLOT plots will reveal them in an obvious manner.

Calling Sequence: SUBROUTINE A2PLOT (NBLK,NPBLK,IPER,A2P).

CONPLT

Called by TRILIN.

CONPLT plots potential contours for the inner one or two grids. The 3-D plane at which the potentials are plotted is specified by a fixed x, y, or z. IXYZ determines which dimension is fixed, and IND is the fixed value.

IND is an index in the outer grid if two grids are used.

Calling Sequence: SUBROUTINE CONPLT (IXYZ,IND,NX,NY,NZ,P1,P2, IPER,PER,IOBPLT).

Local Variables:

IXYZ:	IXYZ = 1, 2, or 3 specifies contours through a fixed x, y, or z plane
IND:	Fixed value of x, y, or z
P1:	Inner grid potentials
P2:	Next-to-inner grid potentials

Internal Organization: CONPLT fills in a two-dimensional array P with the potential values at the specified cut. P has the fineness of the inner grid, but encompasses both grids. Potential values at the new finer points in the outer grid area of P are found by linear interpolation, while the values for the inner grid are simply those already present in P1.

CONTOR is called to plot the potential contours and titles.

The satellite silhouette is plotted by reading in the building block data from file IPLT = IABS(IOBPLT) and plotting the block perimeters in IPER = PER projected into the appropriate plane and translated according to the new cooordinate system.

CONPOT

Called by TRILIN.
CONPOT sets the potentials at points in the interior of the satellite (otherwise untreated) equal to the potential on conductor one.
Calling Sequence: SUBROUTINE CONPOT (BUF1,NX,NY,NZ,PCOND).

FINVER

Called by SHIELD.
FINVER completes the vertex set of a new polygon consisting of one or more A1 vertices and two points where A1 intersects the A2 perimeter, by adding those A2 vertices which fall between the two intersection points and which are inside the original A1 polygon.
Calling Sequence: SUBROUTINE FINVER (INEW,NEW,A3,A2,N2,N3, N3INT,NA2SG3,IA2SG3,INS2,IN2,NJOIN,IJOIN, IP).

Local Variables:

INEW:	Number of points currently in the new polygon
NEW:	Index of new polygon being considered
N2:	Number of vertices in the current A2 polygon
N3(12):	Number of vertices (final) in each of the new polygons
N3INT(12):	Number of intersection points for each of the new polygons
NA2SG3(2,12):	Number of A2 segments intersected by up to two intersection points per new polygon, for up to twelve new polygons

IA2SG3(2,2,12):	Indices of A2 segments intersected for the intersection points indexed by NA2SG3
INS2(9):	INS2(I) is 0 or 1 if the Ith vertex of A2 is outside or inside A1
IN2:	Number of A2 vertices inside A1
NJOIN:	Not used
IJOIN:	Not used
IP:	Print flag

Internal Organization: First we determine if the first and last points of the new polygon are the same. If they are not, we proceed to the normal loops of the routine. If they are, we check if INEW = 3. If so, we have two points different to the finer accuracy of the intersection routine, but the same to the coarser accuracy of PTCOMP. We keep the finer accuracy polygon and return. If INEW $\neq$ 3, we have a redundant last vertex and remove it to yield an already complete polygon. We return with this polygon.

If the two intersection points are on the same A2 segment, we are done already.

The normal section of the routine marches around the vertices of A2 between the two intersection points, first in one direction, and then, if necessary, in the other. It searches until it finds a complete set of A2 vertices between the two points which are <u>all within A1</u>. This is the set of points we need. If any point in the first direction is outside A1, we skip out and search in the other direction. If no such set is found in the second direction, we error return.

For some very complex cases, we may need to calculate the area of the new polygon taken with each of the two possible vertex sets. The set providing the lesser area is the correct set.

HIDCEL

Called by NASCAP, SATPLT.

HIDCEL calls all routines associated with the 3-D plots. There are two modes of calling HIDCEL: (1) IAREA = 0 implies that this call is merely for satellite illustration, and both a "building block" non-hidden line plot and a cell-by-cell hidden line plot will be plotted. In this case, no areas will be calculated; (2) IAREA $\neq$ 0 implies that this call is to generate hidden-cell fractional areas for each of the (up to 1024) surface cells. These areas will be written onto unit IAREA at the end of HIDCEL. A cell-by-cell hidden line plot is also plotted in this case, but no building block plot is generated.

Calling Sequence: SUBROUTINE HIDCEL (PDIR,IPLOT,NX,NY,NZ, IAREA).

Local Variables: PDIR(3): Vector (not necessarily normalized) indicating direction from center of satellite to viewer (or sun, for shadowing).

Internal Organization: HIDCEL first normalizes the PDIR(3) vector pointing from the center of the satellite towards the viewer. The normalized data is placed in DIR(3). PPJSET is then called to set up the 3-D to 2-D (PRSPPJ calls) and 2-D to 3-D (PRSPPK calls) conversion matrices. Data is read in from file IPLOT = IABS(IOBPLT) holding the building block information which defines the satellite. If we are in mode IAREA = 0, subroutine A2PLOT is called to generate the 3-D non-hidden-line plot of the building blocks.

Next, A2GEN is called to generate all A2 polygons and all data associated with them. The set of A2 polygons is the set of building block faces whose normals have a positive dot product with DIR, projected into the 2-D focal plane perpendicular to the direction of viewing as set up by PPJSET.

A1GEN is called to generate the set of A1 polygons and their associated data. The set of A1 polygons is the set of

surface cell faces whose normals have a positive dot product with DIR, projected similarly into 2-D. The 2-D area of each A1 polygon is calculated and the information written onto file IAREA. These areas reflect the angle of a cell relative to the direction of view, and represent the entire 2-D area of each cell before shielding.

Two nested loops march through every combination of each A1 polygon with each A2 polygon. The outer loop loops through the A2 polygons. Thus, for one building block face polygon, each cell face polygon is checked against it one at a time.

If the A2 vertex closest to the viewer is at least as far as the farthest A1 vertex, A2 is behind A1 and this combination is skipped.

2-D XMIN's, XMAX's, YMIN's, and YMAX's are generated in A1GEN and A2GEN for each A1 and A2 polygon. If A2's in XMAX is greater than or equal to A1's XMIN, or if A2's XMIN is less than or equal to A1's XMAX, or similarly for the YMIN's and YMAX's, we skip this combination.

A variable called IMASK, initially set to 0, indicates whether we have yet determined if A1 is behind A2 and must be masked. If the A2 vertex furthest from the viewer is at least as close as the A1 vertex closest to the viewer, A1 is behind A2 and IMASK is set to 1. If IMASK is 0 at this point, however, several possibilities still exist as to whether the complex shielding algorithm must be executed for this combination (e.g., A1 may be <u>on</u> A2 in which case it must not be masked against A2). Subroutine SHIELD is called to make the final determination of whether masking is to be done, and to do it if so, or, if IMASK is already 1, to simply execute the shielding algorithm, skipping any further tests on behindness.

ISHLD is the main output indicator from SHIELD. ISHLD = -1 implies that no changes need be made in any of

the polygon bookkeeping arrays. This occurs when it is determined that the polygons need not be masked against one another due to A1's being in front of or on A2, or when the polygons <u>are</u> masked against one another but there is no overlap. ISHLD $\geq$ 0 implies that the polygons were masked, that there is overlap, and that ISHLD <u>new</u> A1 polygons have been created and are currently in array A3 waiting to be transferred to array A1. Thus, if ISHLD = 0, the current A1 polygon was completely shielded by A2 and zero new polygons have been created. Regardless of whether any new polygons have been created or not, the current A1 polygon is flagged for removal by subroutine A1COMP by setting IREMOV(IA1) equal to 1.

If new polygons <u>have</u> been created (ISHLD $\geq$ 1), subroutine ADDA1 is called for each of them to add their respective information to the tail end of the A1 polygon arrays.

Next we loop back around to the beginning of the A1 polygon loop to begin checking of the next A1 polygon against the current A2 polygon.

When all A1 polygons (except those new ones created by comparison to the current A2 polygons) have been checked against the current A2 polygon, subroutine A1COMP compresses the arrays containing A1 polygon information by removing each polygon flagged in IREMOV, and replacing its data with data from the end of the list (starting with the last new A1 polygon created). Thus, when checking against the next A2 polygon begins, the list of A1 polygons which we check it against is exactly what we want it to be; the most current set of A1 polygons containing some already partially masked by previous A2's and containing no superfluous polygons.

When all A2 polygons have been checked against all A1 polygons, we are left with a final set of non-overlapping A1 polygons representing those parts of all surface cells remaining visible when viewed from direction DIR. We loop over this

finalized set of A1 polygons calculating an overall 2-D XMIN, XMAX, YMIN and YMAX. We also calculate the area of each polygon and add it into the appropriate location in array AREA1. The index in AREA1 is the index of the original surface cell whose 2-D projection was the parent polygon of the current A1 polygon. This index is stored in bits 6-15 of IFF1(IA1). A given surface cell can generate two or more partially shielded new polygons if some thin part of the satellite crosses over the middle of the surface cell. For diagnostic purposes, a message to this effect is pointed out along with the A1 polygon area whenever such a situation is encountered.

Next, the original unshielded areas of all surface cells are read back in from unit IAREA. (Cells which did not face the viewer have this area already set to zero and hence, in this sense, have already been shielded.) A second loop over the surface cells computes the fractional areas for each cell: final shielded 2-D area/initial unshielded 2-D area. In this way, the effect of the dot product on the area is removed.

Next, a user area for plotting is set up using the 2-D overall minima and maxima just calculated. A last loop over all final A1 polygons plots the perimeter of each polygon by simply connecting its vertices.

Finally, the IAREA file is rewound, the set of 1024 fractional areas is written onto it, and IAREA is rewound again for use by the rest of the code.

INSIDD

Called by SHIELD.

INSIDD determines if point P is inside polygon A. If P is on the perimeter of A, it is considered inside. INSIDD = 0 implies P is not inside A. INSIDD = 1 implies P is inside A.

INSIDD is used instead of INSIDE for determining if vertices of a polygon are inside the other and for resetting them to be exactly on the polygon perimeter if they are off by only some epsilon. This resetting is accomplished by calling PROLIN to do a double-precision calculation finding the projection of point P on the segment of A which it is almost on.

Calling Sequence: FUNCTION INSIDD (A,AD,P,PD,N,IP).

Local Variables:

A(2,10):	Single-precision polygon vertices
AD(2,10):	Double-precision polygon vertices
P:	Single-precision point
PD:	Double-precision point
N:	Number of vertices in polygon
IP:	Point flag

INSIDE

Called by SHIELD

INSIDE determines if point P is inside polygon A. If P is on the perimeter of A, it is considered inside. INSIDE = 0 implies P is not inside A. INSIDE = 1 implies P is inside A. INSIDE is a single-precision function.

Calling Sequence: FUNCTION INSIDE (A,P,N,IP).

Local Variables:

A(2,10):	Vertices of a polygon
P(2):	Point
N:	Number of vertices of polygon
IP:	Print flag

INTCHK

Called by SHIELD.

Given the I1th segment of A1, INTCHK checks for any and all intersections of this segment with all A2 segments. INTCHK also keeps track of which A2 segments are intersected, eliminates duplicate intersection points, and orders those kept according to how close to the start of the I1th A1 segment they are.

Calling Sequence: SUBROUTINE INTCHK (I1,A1,A1D,A2,A2D,INT, N2,INDINT,XINT,NA2SEG,IA2SEG,INS2,IP).

Local Variables:

I1:	Index of current A1 polygon segment
A1D:	Double-precision copy of A1
A2D:	Double-precision copy of A2
INT:	(output) number of intersections of segment I1 of A1 with A2 perimeter
N2:	Number of A2 segments
INDINT:	Not used
XINT(2,10):	(output) intersection points found
NA2SEG(10):	(output) number of A2 segments intersected by up to 10 intersection points
IA2SEG(2,10):	(output) indices of A2 segments intersected by up to 10 intersection points
INS2(9):	INS2(I) = 0 or 1 if vertex I of A2 is outside or inside A1
IP:	Print flag

Internal Organization: INTCHK starts with a loop over the A2 segments. INTSEC is called to find any intersections of the A1 segment with the current A2 segment. If there were none, we go on to the next A2 segment. If there was one, we increment INT and record the A2 segment information in NA2SEG and

IA2SEG (INTSEC has already placed the intersection point in XINT). The distance of this point to the start of the A1 segment is computed and stored in D for sorting purposes. If there has been at least one previous intersection, we check to see if we have a redundant intersection and eliminate it if so.

If the A1 segment does not "intersect" the A2 segment, but partially or wholly overlaps it, we do not need to count the intersection but we must record the A2 segment information in NA2SEG and IA2SEG for use by FINVER.

When all A2 segments have been checked, we sort all intersection points (if more than one) according to their distance from the start of A1, so that the closest ones will be treated first.

INTSEC

Called by INTCHK.
INTSEC determines if segment X1 intersects segment X2, and if so, calculates the intersection in double-precision.

INTSEC finds the equations of the two lines, finds their intersection, and determines if that intersection is on both of the line segments by calling PTLINE.

Calling Sequence: SUBROUTINE INTSEC (X1,X2,PXI,INTFLG,IP).

Local Variables:

X1(2,2):	First double-precision line segment
X2(2,2):	Second double-precision line segment
PXI(2):	(output) single-precision intersection of X1 and X2, if any
INTFLG:	(output) INTFLG = 0 implies no intersection; INTFLG = 1 implies an intersection; INTFLG = -1 implies the segments overlap.
IP:	Print flag

LINPLN

Called by SHIELD.

LINPLN finds the intersection XINT of a 3-D line with a 3-D plane.

Calling Sequence: SUBROUTINE LINPLN (XL1,DIR,XP,INB,XINT).

Local Variables:

XL1(3):	Start point of line
DIR(3):	XL1 + DIR forms finish point of line
XP(3):	Point on the plane
INB:	Word containing bit-encoded normal to plane
	Bits 0,1: x-component of normal
	Bits 2,3: y-component of normal
	Bits 4,5: z-component of normal
XINT(3):	(output) intersection of the line with the plane

MATCAL

Called by SATPLT.

MATCAL reads the satellite surface cell and material information from unit IOBPLT and calls MATPLT to plot the satellite material composition silhouettes.

Calling Sequence: SUBROUTINE MATCAL (NX,NY,NZ,IOBPLT).

MATPLT

Called by MATCAL.

MATPLT plots satellite silhouettes illustrating surface material composition via fifteen different shadings. The default mode is to plot six views from the plus or minus z, y, and z directions, plotting all cells whose normal has a component in the direction of viewing. In cases where a cell face is partially or completely shielded by other cells in front of it, only the visible part of that cell (if any) is plotted and shaded. The sacrifice here is that inner surfaces hidden by outer surfaces may never be seen via the default views.

Hence, additional input allows the user to specify for any of the six basic viewing directions, additional plots showing only those cells within a specific range of x, y, or z values according to the view involved.

Calling Sequence: SUBROUTINE MATPLT (NX,NY,NZ).

MOVEA1

Called by A1COMP.

MOVEA1 moves the information for the I1th A1 polygon into the I2th position in all the A1 information arrays.

Calling Sequence: SUBROUTINE MOVEA1 (I1,I2,A1,NV1,IFF1,A1R, A1B, A1F, XMIN1,XMAX1,YMIN1,YMAX1).

PARPLT

Called by TRILIN.

PARPLT plots particle trajectories generated by subroutine PUSH projected onto either of the y-z, x-z, or x-y planes. Separate plots are made for electrons and protons (species one and two).

The particle data is read from file IPART and plotted by connecting each successive location for one particle to the next.

The satellite silhouette is plotted by reading in the building block data from file IPLT = IABS(IOBPLT), and plotting the block perimeters in IPER = PER projected onto the appropriate plane.

Calling Sequence: SUBROUTINE PARPLT (IXYZ,IPART,IOBPLT,NX,NY, NZ).

Local Variables: IXYZ: IXYZ = 1, 2, or 3 specifies particle trajectories projected onto the y-z, x-z, or x-y plane (fixed x, fixed y, or fixed z).

PROLIN

Called by INSIDD.

PROLIN computes the projection XP of point X on line segment A.

Calling Sequence: SUBROUTINE PROLIN (A,X,XP,IP).

Local Variables: A(2,2): Double-precision line segment
X(2): Double-precision point
XP(2): (output) projection of X on A
IP: Print flag

PRSPPJ

Called by HIDCEL (PPJSET); A1GEN, A2GEN (PRSPPJ);
SHIELD (PRSPPJ, PRSPPK).

PPJSET sets up the 3-D to 2-D to 3-D projection matrices. PRSPPJ projects from 3-D to 2-D; PRSPPK projects from 2-D to 3-D. The method is as follows:

Imagine a camera properly oriented to take a picture of a collection of points and line segments. Let P_v be the point at the center of the lens of the camera and let P_q be a point that is directly in front of the lens so that its image is focused on the center of the plate. The line lying on the points P_v and P_q is the optic axis of the camera. Unless the optic axis is parallel to the z-axis, the camera will be rotated about the optic axis until the image of a vector pointing in the +z direction points straight up on the plate. If the camera is pointed straight up (or down), then the image of a vector pointing in +x direction will point to the right and the image of a vector pointing in the +y direction will point up (or down).

The plane perpendicular to the optic axis at the lens is the principal plane and the plane in which the plate lies is the focal plane. The distance between the focal plane and the principal plane is the focal length. The focal length determines the magnification of the camera. In fact, if a

segment is perpendiculr to the optic axis and if

H = the length of the segment

h = the length of the image of the segment

D = the distance between the segment and the principal plane

d = the focal length of the camera

then

h = d*H/D.

Calling Sequence: Entry Point PPJSET: SUBROUTINE PPJSET (X1Q,Z2Q,X3Q,X1V,X2V,X3V,D).

Entry Point PRSPPJ: SUBROUTINE PRSPPJ (X,Y,Z,XP,YP,ZP).

Entry Point PRSPPK: SUBROUTINE PRSPPK (XJ,YJ,ZJ,XI,YI,ZI).

Local Variables:

X1Q: x coordinate of satellite center (inner grid center)

X2Q: y coordinate of satellite center (inner grid center)

X3Q: z coordinate of satellite center (inner grid center)

X1V: x coordinate of camera lens

X2V: y coordinate of camera lens

X3V: z coordinate of camera lens

D: camera focal length

X:, Y:, Z: coordinates of 3-D point to be projected into 2-D

XP:, YP:, ZP: (output) coordinates of 2-D projection and (ZP) distance to viewer

XJ:, YJ:, ZJ: (output) coordinates of 3-D reverse-projection point

XI:, YI:, ZI: coordinates of 2-D point to be reverse-projected and (ZP) distance to viewer of 3-D point to be found

PTCOMP

Called by SHIELD, INTCHK, FINVER.

PTCOMP determines if the points X1 and X2 are the same point.

Calling Sequence: SUBROUTINE PTCOMP (X1,X2,ISAM).

Local Variables:

X1(2):	Point 1
X2(2):	Point 2
ISAM:	(output) ISAM = 0 implies X1 and X2 are different points; ISAM = 1 implies X1 and X2 are the same point.

PTLINE

Called by INTSEC.

PTLINE determines if point XP (which must lie on the line formed by X1 and X2) is on the line segment bounded by X1 and X2.

Calling Sequence: SUBROUTINE PTLINE (X1,X2,XP,IONFLG).

Local Variables:

X1(2):	Start of double-precision line segment
X2(2):	End of double-precision line segment
XP(2):	Double-precision point which may or may not lie on the line segment
IONFLG:	(output) IONFLG = 0 implies XP is not on the segment; IONFLG = 1 implies XP is on the segment.

ROUSP

Called by TRILIN.

ROUSP plots contours of the charge array, ROUS, at a specified cut. ROUS is only defined for the inner grid, and the 3-D plane at which the ROUS values are plotted is specified by a fixed x, y, or z. IXYZ determines which dimension is fixed, and IND is the fixed value.

ROUSP also plots the satellite silhouette by reading in the building block data from file IPLT = IABS(IOBPLT) and plotting the block perimeters in IPER = PER projected onto the appropriate plane.

Calling Sequence: SUBROUTINE ROUSP (IXYZ,IND,IROUS,BUF1, IOBPLT,IPER,PER,NX,NY,NZ).

Local Variables:

IXYZ: IXYZ = 1, 2, or 3 specifies contours through a fixed x, y, or z plane

IND: Fixed value of x, y, or z; index in grid at which cut is to be taken

SATPLT

Called by NASCAP.

SATPLT is called when IOBPLT is greater than zero indicating satellite illustration plots are desired.

SATPLT first calls MATCAL to set up for and call MATPLT to generate the material composition satellite silhouettes.

Next, HIDCEL is called to generate 3-D plots for each of three default views, and for any additional views requested by user input.

Calling Sequence: SUBROUTINE SATPLT (NX,NY,NZ,IOBPLT).

SETFAC

Called by SETFWG, SETFOC, SETFTH, SETFFL.
The IFAC(80) array stores block face normal information for up to 64 building blocks plus extra face storage for up to 16 octagons (which would already be part of the set of 64). For rectangular blocks, the faces are indexed 1 through 6 and face I will always have the same orientation and normal.

For blocks which are wedges, octagons, tetrahedra, or "FIL111" types, the input block is not symmetric in three dimensions, and a given face I of some block may have a normal different from the face I normal for a previous block of the same type if the two blocks are input with different orientations. (The array IPER = PER contains for each block a list of vertices, some of which are duplicated, which when traced out sequentially in 3-D draws the entire perimeter of the block. Face I for a given block type is defined as a particular subset of the vertices stored in PER for that block; e.g., vertices 4, 3, 8, and 5 might define face 2 of block type 2, which is a wedge. These face-definition data are stored in array IV in subroutine A2GEN.)

A block face normal may be defined by six bits; 0 and 1, 2, and 3, and 4 and 5 define three bit pairs for the x, y, and z components of the normal, each pair of which can represent either a 1(01), 0(00) or -1(11). All block types except the octagon have at most six faces. Consequently, the first 64 words of IFAC contain, one word (36 bits) per block, normal information for up to six faces per block. The last 16 words contain, for a satellite with up to 16 octagons, the normal information for the last four octagon faces in bits 0-23.

For rectangles, because due to their 3-D symmetry of general shape, their orientation in the code is always the same, the specification of IFAC is a constant set of 36 bits. This constant is called IFACR and is defined in RECTAN in a

data statement. For each rectangular block encountered, RECTAN is called and sets IFAC for this block equal to IFACR.

For the other four block types, however, a somewhat complex decoding of input orientation information must be made in order to correctly specify the face normal for each block in IFAC. For wedges, octagons, tetrahedra and FIL111 type blocks, the routines which fill in the set of PER perimeter vertices are WEDGES, NIOOCT, TETRAH, and FIL111. Each of these routines calls, just after PER has been defined, one of SETFWG, SETFOC, SETFTH, or SETFFL. Each of these routines defines the cell face normal for its block type by filling in IFAC(NBLK) with a series of calls to SETFAC. SETFAC fills in a particular field of two bits with an 01, 00, or 11, according to whether IDIR equals 1, 0, or -1. Which pair of bits of the set of six for a given face is determined by I; I = 1, 2, or 3 implies the x, y, or z component is being defined. Which face is being treated (which field of 6 bits) is defined by INDFAC.

The building block cell face normals and vertex sets are necessary for the definition and sorting of A2 surface polygons in subroutine A2GEN.

Calling Sequence: SUBROUTINE SETFAC (I,IDIR,INDFAC,IWORD).

Local Variables:

I:	I = 1, 2 or 3 implies an x, y, or z component of the block face normal.
IDIR:	IDIR = 1, 0, or -1 implies set 01, 00, or 11 bit pattern for this component.
INDFAC:	INDFAC specifies what face of the current block we are defining a normal for.
IWORD:	Word currently being filled in with normal bit set patterns; following completion of this block's face normal definitions, IFAC(NBLK) will be set equal to IWORD.

SETFFL

Called by FIL111.

SETFFL defines the block face normals in array IFAC for input blocks which are FIL111 type blocks. A series of calls to SETFAC fills in IWORD, and IFAC(NBLK) is set equal to IWORD (see SETFAC).

Calling Sequence: SUBROUTINE SETFFL.

SETFOC

Called by NIOOCT.

SETFOC defines the block face normals in array IFAC for input blocks which are octagons. A series of calls to SETFAC fills in IWORD and IFAC(NBLK) is set equal to IWORD for the first six faces, while IFAC(64 + NOCT) is set equal to a second IWORD for the last four faces (see SETFAC).

Calling Sequence: SUBROUTINE SETFOC (NBLK,NOCT,IFAC,I1,I2,I3).

Local Variables:

- NBLK: Index of current block being defined.
- NOCT: Number of octagons including current one, which have been encountered (defines which word of last 16 of IFAC will be used in storing normals for last 4 faces of this octagon).
- I1: I2: I3: Some combination of 1, 2, and 3, specifying x, y, and z components of block face normals.

SETFTH

Called by TETRAH.

SETFTH defines the block face normals in array IFAC for input blocks which are tetrahedra. A series of calls to SETFAC fills in IWORD, and IFAC(NBLK) is set equal to IWORD (see SETFAC).

Calling Sequence: SUBROUTINE SETFTH (NBLK,IFAC,ID).

Local Variables:

- NBLK: Index of current block being defined.
- ID(3): 1, 0 or -1 for normal specification.

SETFWG

Called by WEDGES.

SETFWG defines the block face normals in array IFAC for input blocks which are wedges. A series of calls to SETFAC fills in IWORD, and IFAC(NBLK) is set equal to IWORD (see SETFAC).

Calling Sequence: SUBROUTINE SETFWG (NBLK,IFAC,ID,I1,I2,I3).

Local Variables:

NBLK: Index of current block being defined.

ID(3): 1, 0, or -1 for normal specification.

I1: I2: I3: Some combination of 1, 2, and 3, specifying x, y, and z components of block face normals

SHIELD

Called by HIDCEL.

SHIELD finishes deciding if an A1 polygon is behind the current A2 polygon. If so, it masks the A1 polygon against the A2 polygon, placing new polygons created (representing the unshielded portion(s) of the original A1) into the A3 array. ISHLD indicates the number of new polygons created by this masking. ISHLD = 0 implies A1 was completely shielded by A2. ISHLD = -1 implies no shielding took place, either because there was no overlap or because A1 was in front of A2.

Calling Sequence: SUBROUTINE SHIELD (N1,N2,A1,A2,ISHLD,N3,A3, IMASK,IFF1,IFF2,DV1,DV2,DIR,IA1,IA2,A1R, A2R,IP).

Local Variables:

N1: Number of vertices in A1.

N2: Number of vertices in A2.

N3(12): Number of vertices in up to 12 new polygons.

Internal Organization: SHIELD first generates A1D and A2D, double precision copies of the A1 and A2 vertices for use in INSIDD and INTCHK calculations demanding double precision accuracy.

A loop over the A1 vertices determines whether each A1 vertex is inside A2 or not by calling INSIDD (on the perimeter

is inside). Within this loop we also perform a behindness-checking algorithm if IMASK = 0 and if the current vertex is inside A2. PRSPPK finds a 3-D point on the line between the 3-D surface cell vertex and its 2-D focal plane projection (see PRSPPJ). The 3-D line defined by the 3-D lens point (see PRSPPJ) and this new 3-D point is the line between the 3-D vertex and the 2-D projection. LINPLN recaptures and places in XINTA1 the original 3-D coordinates of the A1 vertex by finding the intersection of the line with the plane of the A1 polygon as determined by its normal in IFF1(IA1), bits 0-5, and point A1R. A1R is one 3-D vertex of A1; we cannot store all 3-D vertices for the A1's due to storage considerations. (Note: We do store all 3-D coordinates for the A2 polygons in A2R, since there are far fewer of these.) LINPLN is also called to find the 3-D point on the plane of A2 which this line intersects. This point is placed in XINTA2. Since the line from the 3-D vertex through the lens point to the 2-D projected point represents the direction of viewing for this point, the distances to the viewer of XINTA1 and XINTA2 indicate whether A1 is behind or in front of A2. PRSPPJ calculates these two distances, DA1 and DA2.

If the two distances are equal, then this A1 vertex is actually on A2 in 3-D. We keep track of the number of such vertices by incrementing NDA2 for each of these cases. If NDA2 reaches 3, indicating that at least three vertices of A1 are on A2, the two planes are the same and A1 must be on A2. We skip out of shield and skip this polygon combination. (If we masked A1 polygons against the A2's on which they lie, the whole satellite would disappear.)

If DA2 is greater than DA1, then A1 is closer to the viewer than A2 at this point, which implies that all of A1 is closer than A2 due to the A1's being single-cell polygons. ISHLD is set to -1 and we skip this combination.

If DA1 is greater than DA2, then A2 is closer to the viewer than A1, and we must mask A1 by A2. IMASK is set to 1 so no more behindness testing will be done.

The inside testing is done for each A1 vertex, and the behindness algorithm checked for each A1 vertex which is inside A2 until IMASK is set to 1. It may happen either that no A1 vertices are in A2 or that those that are yield only inconclusive behindness tests. In this case IMASK may still equal zero at the end of this loop. If NDA2 equals 2 at this point, we have A1 adjacent to A2 and set ISHLD = -1 to specify skipping this combination. If all vertices of A1 are inside A2, then A1 is completely inside A2 (since A2 polygons <u>must</u> be convex in this code), and we return with ISHLD = 0.

A similar loop on A2 vertices follows. For each A2 vertex, INSIDD determines if the vertex is inside A1. If IMASK = 1, no behindness testing is done. Otherwise, for A2 vertices inside A1 we call LINPLN to find the point on the A1 plane which the line from the current 3-D A2 vertex to the lens point intersects (we need not use PRSPPK to find the 3-D vertex since we save all of these for A2's in A2R). We call PRSPPJ to calculate the distance to the viewer of this A1 plane intersection point. We already have this distance for the A2 vertex stored in DV2 (another example of information stored for A2 polygons but not for A1's).

We compare these two distances, DA1 and DV2. If DA1 = DV2 we increment NDA1. Unless NDA1 reaches three, indicating an error, this information is inconclusive. However, if DA1 is less than DV2, we may return with ISHLD = -1 again, since A1 is in front of A2; and, if DA1 is greater than DV2, we set IMASK = 1 to avoid any further behindness tests.

We determine whether each A2 vertex is inside A1, and if IMASK = 0 at this point, check for behindness for A2

vertices which <u>are</u> in A1, until IMASK is set to 1 or until we finish the set of A2 vertices.

It is possible for IMASK to equal 0 at this point but for masking to still be necessary; for example, if two long rectangles at right angles cross at their middles, neither will have any vertices within the other, hence no behindness testing will have been done in the previous two loops. This and other somewhat pathological cases must be tested for behindness when some intersection point of the two polygons is found by the masking algorithm. In this case, an algorithm identical to that in the first loop is used to determine behindness.

The remainder of the routine masks the A1 polygon by the A2 polygon by following the A1 perimeter around from start to finish, making note of all intersections with the A2 perimeter, and opening and closing new polygons as is appropriate. A "new polygon" is a portion of the A1 polygon which lies completely outside A2 and is composed of one or more A1 vertices and two intersection points with the A2 perimeter (these may, of course, also be A1 vertices in certain cases). The A2 perimeter intersection points mark the start and finish of the "new polygon" at this point, but may or may not lie on the same A2 side. If they <u>do</u> lie on the same A2 side, then the polygon is already complete. If they do not, however, then to complete the new polygon we must find that set of A2 vertices which lie on that part of the A2 perimeter betwen the start and finish points of the new polygon. Whether the start and finish points lie on the same side or not, the task of finishing the vertex set of a new polygon is performed by subroutine FINVER.

Following the inside tests and behindness checking, a loop over the segments of A1 begins. A segment of either polygon is referenced by the vertex starting it: segment 1 goes from vertex 1 to 2, segment 2 from vertex 2 to 3, and

the last segment from vertex N to vertex 1. The last vertex information is appended to all appropriate lists to facilitate handling of the last segment.

If the last vertex of the current A1 segment is outside A2, it is added to the current new polygon vertex list. Next, we call INTCHK which checks the current A1 segment for intersections with all A2 segments. INTCHK returns INT = number of distinct intersections with the A2 perimeter. If INT = 0, we go onto the next A1 segment.

If INT $\neq$ 0, then INTCHK has also returned all intersection points in array XINT, and information (NA2SEG) telling how many A2 segments this A1 segment intersected at each intersection point (if it intersects at an A2 vertex, then it has intersected two A2 segments at that intersection point). It also returns IA2SEG indicating which A2 segment the A1 segment intersects. FINVER will use this information.

A loop over the number of intersection points follows. If the current intersection point is the same as the last one treated, we skip it. (There are certain tests here to avoid skipping such a point if it is needed both to start the first new polygon and end the last one.) If we keep this intersection point, we add it into the current new polygon by incrementing INEW (number of points in the new polygon) and by moving the intersection point into A3 (INEW, NEW).

Before we actually move the point into A3, however, we must check if, for INEW = 2, we have a segment which is completely within A2. If so, we must discard the INEW = 1 point and start our new polygon with the current intersection point. We determine this by finding the midpoint of the segment from the INEW = 1 point to the INEW = 2 point. Since A2 must be convex, if this midpoint is inside A2, we discard this segment, while if it is outside, we keep the segment.

It is at this point that we check for behindness once again if IMASK is still equal to zero.

Since the current point is an intersection point, it must either open or close a new polygon. If INEW is equal to 1, we are opening a new polygon and go on to the next intersection point (if there are no more, we go on to the next A1 segment).

If INEW is greater than 1, we are closing a new polygon. If this is the second intersection point in this new polygon, we may call FINVER at this point to finish its vertex set. (The first and last new polygons may need to be added together to form a complete new polygon with two intersection points, depending on which A1 vertex we started at.)

We close this new polygon by incrementing NEW, the number of new polygons and by resetting INEW to zero.

We then check to see if the current intersection point is an A2 vertex. If so, we must count it not only as the last point of the last new polygon, but also as the opening point of the just-opened new polygon. If this is so, we set INEW = 1, and move the appropriate information into place for the new polygon.

We then loop back to finish any more intersection points for the current A1 segment. When these are exhausted, we loop back to the next A1 segment. When all A1 segment vertices and intersection points have been exhausted, we reach statement label 70. Here we know that there has been at least one intersection, and our task is to determine if either or both of the first and last new polygons are incomplete. If the first one is incomplete, we join it to the last one. If the first one is complete, we either keep or discard the last one depending on whether it is complete or not. A polygon to be discarded might be, for example, a one-point polygon.

If the first and last polygons are added together, FINVER is called to complete the vertex set. We are now finished and jump to 300 to perform final checks and return to HIDCEL.

If we reach the end of the 200 loop, there have been no intersections at all. If this is so, and neither polygon had any vertices inside the other, then there is no overlap and we return with ISHLD = -1.

If all vertices of A1 are inside A2, A1 is completely shielded and we return with ISHLD = 0 (this has already been checked earlier in the routine). If all vertices of A2 are inside A1 and there have been no intersections we error return with a RETURN 0. <u>We do not allow an A2 polygon to be completely enclosed within an A1 polygon with no intersections</u>.

```
TRILIN

     FLXDEF
     INDATA
     CHARGE

        CALFLX

             SOURCE        ELFLUX        SOLFLX
             GETCEL        PRFLUX        IOFLX
             PUSH          BKSCAT

     LIMCEL
     QUPDAT
     QSUMER
     POTENT

             GETDIV        PUPDAT        QCONCP
             COPROD        RUPDAT        CNVPLT
             BIAFIX        UUPDAU
             URSET0        APRT

     (various plotting routines)
```

Figure 10.4. Partial hierarchical outline of TRILIN module.

10.5 TRILIN

APRT

Called by POTENT (most calls are currently commented out), INDATA

APRT prints NGP grids' worth of data for the NX x NY x NZ x NG array stored on file IF.

Calling Sequence: SUBROUTINE APRT (BUF1,IF,NGP,NX,NY,NZ,NG).

Local Variables:
- IF: Unit number of file containing data to be printed
- NGP: Number of grids worth of these data to be printed

BIAFIX

Called by POTENT.

Corrects the ROUS point charge array for points on biased conductors. Also sets ROUSCN — the conductor charge array.

BKSCAT

Called by CALFLX.

Computes flux of backscattered electrons through FUNCTION BSCAT.

Calling Sequence: SUBROUTINE BKSCAT (ICELL,ITYPE,FIN,FOUT).

CALFLX

Called by CHARGE.

Calls SOURCE, PUSH, ETNGUN, ELFLUX, BKSCAT, PRFLUX, GETCEL, IOFLX.

Calling Sequence: SUBROUTINE CALFLX (ITYPE,PCOND,FLUXES,CNET, FLOW,IOBPLT,IPART)

- ITYPE - NASCAP operating mode
- PCOND - Array of conductor potentials
- FLUXES - Array of net fluxes to surface cells
- CNET - Net charging current
- FLOW - Low electron emission for each surface cell
- IOBPLT - LUN of OBJDEF output file
- IPART - LUN of particle trajectory plot scratch file

CHARGE

Called by TRILIN.

Primary routine for charge accumulation, transport and sharing for the NASCAP code.

Calling Sequence: SUBROUTINE CHARGE (NNX,NNY,NNZ,NNG,ITYPE, QCOND,PCOND)

NNX,NNY,NNZ,NNG	- Same as NX,NY,NZ,NG
ITYPE	- NASCAP operating mode
QCOND	- Array of charges on conductors
PCOND	- Array of potentials on conductors

CNVPLT

Called by TRILIN.

Plots potential convergence parameters using printer-plotter routines, i.e., ALOG10(R(I)) versus I, ALOG10(U(I)) versus I, P(I) versus I.

Calling Sequence: SUBROUTINE CNVPLT (R,U,P,NI)

R(NI)	- An array of positive numbers
U(NI)	- An array of positive numbers
P(NI)	- An array assumed to contain potentials of spacecraft ground
NI	- Dimension of arrays R,U,P

COPROD

Called by POTENT (in two places).

COPROD computes the product of the linear equation coefficient array A with either of p^o or u^n, depending on whether the call to COPROD is the initial call in POTENT or the call within the potential iteration loop. COPROD also calculates $u^n \cdot a^n$ adding terms into the dot product one at a time, as it calculates the individual terms of a^n.

Calling Sequence: SUBROUTINE COPROD (IA,IAUN,BUF1,BUF3,NG, NX,NY,NZ,P3,W4,UDOTAU,AUNCON,UPCOND,IOBJ, W,LIST,WPCOND,PMCND,SWPSSC,CIJ,CIJSUM, MBIAS,MFIX).

Local Variables: IA: COPROD takes the product of the coefficient array A with whatever vector is on external storage unit IA. In the initial call to COPROD, IA = IP, the unit storing the (at that time) initial guess for the potentials. In the iteration loop call to COPROD, IA = IU, the unit storing the u^n vector.

ELFLUX

Called by CALFLX.

Calculates incident electron flux and flux of electron-produced secondaries using subroutine ELSEC.

Calling Sequence: SUBROUTINE ELFLUX (ICELL,ITYPE,FIN,FOUT).

ICELL - Current surface cell
FIN - Incident electron flux (output)
FOUT - Flux of secondary electrons (output)
ITYPE - NASCAP operating mode

FLXDEF

Called by TRILIN.

Reads and preprocesses flux definition parameters.

Calling Sequence: SUBROUTINE FLXDEF (ITYPE1,NX,NY,NZ,NG).

GETCEL

Called by CALFLX, SHECAL.

Places geometrical and electrostatic properties of surface cell in common block SRFPRM.

Calling Sequence: SUBROUTINE GETCEL (ICELL,PCOND).

GETDIV

Called by POTENT.

Constructs the inverse of the diagonal term of the coproduct A matrix, for all points. The resulting diagonal matrix D is used in the scaled conjugate gradient algorithm.

INDATA

Called by TRILIN.

Performs data manipulations associated with initialization/restart.

Calling Sequence: SUBROUTINE INDATA (NX,NY,NZ,NG,NC).

IOFLX

Called by CALFLX.

Output of fluxes, potentials and fields across dielectrics for selected surface cells.

Calling Sequence: SUBROUTINE IOFLX (EIN,EOUT,PIN,POUT,EBACK, PCUR,PCND,ICELL).

LIMCEL

Called by TRILIN.

Adjusts the charge arrays for an implicit (LONGTIMESTEP) charging calculation. LIMCEL and its called subroutines are undergoing further development, and are not fully documented at this time.

POTENT

Called by TRILIN.

POTENT uses the iterative conjugate gradient technique described below to solve a set of linear equations whose unknowns are the potentials at all grid points and on each of the conductors, and the charges on each biased or fixed-potential conductor.

Calling Sequence: SUBROUTINE POTENT (BUF1,BUF2,BUF3,ICYC, RITER,UITER,PCITER,NITERP,ROUS,NX,NY,NZ,NG, QCOND,NC,W,LIST,WPCOND,PMCND,PCOND,IWARN, IALG).

Internal Organization: POTENT places fixed-potential conductor potentials (set by input in array VFIX) into PCOND, and then forms some precalculable quantities (for use in OBJSPC)

based on the WPCOND and PMCND weights and on the conductor relative capacitances. The first call to COPROD calculates A times p^o where p^o is the initial guess for the potentials for this run (determined by one of the initial guess options specified by user input, or, in the case of a restart, by the final potentials left over from the previous run).

POTENT then proceeds to make calls as shown in Figure 10.4.

PRFLUX

Called by CALFLX.
Calculates flux of incident protons and resulting secondaries using subroutine PROSEC.
Calling Sequence: SUBROUTINE PRFLUX (ICELL,ITYPE,FIN,FOUT).

PUPDAT

Called by POTENT.
PUPDAT updates the linear equation solution vector P on file IP (containing system potentials) according to the equation

$$p^{n+1} = p^n + \alpha * u^n$$

The updated p^{n+1} data is written onto file ISPARE, one grid at a time, and when all data has been updated, the unit numbers IP and ISPARE are switched.

PUPDAT also updates the conductor potentials in array PCOND.
Calling Sequence: SUBROUTINE PUPDAT (ALPHA,IP,IU,ISPARE,BUF1,
BUF2,NG,NX,NY,NZ,NC,PCOND,UCOND,MBIAS,MFIX).

PUSH

Called by CALFLX.

For a given cell, calculate the incoming particle flux from a given ambient environment by the reverse trajectory technique. All test particles are emitted from the center of the cell. The selection of energies and angles are in common block FLUX. The actual flux densities are from FSPACE. The local flux is filled into F. EPOT(I) is the minimum final kinetic energy that a particle of type I can have upon impacting the object. That is, EPOT(I) = 0 if the object repels type I particles and EPOT equals the absolute value of the local potential if the object attracts particles of type I. (See Figure 10.4.)

Calling Sequence: SUBROUTINE PUSH (F,EPOT,ICELL,IPART).

Local Variables: X(3): Particle position
XO(3): Center of the cell
V(3): Particle velocity

QCONCP

Called by POTENT.

Potentials for any conductors designated as fixed-potential or biased potential conductors are removed as unknowns from the set of linear equations solved by the conjugate gradient potential iteration system. Following convergence upon all other potentials of the system, proper biases are added to conductor 1's new potential and the resultant biased potentials are placed in the appropriate places in array PCOND (this is done in subroutine POTENT). The only unknowns remaining in the system at this point are the new amounts of charge on the biased or fixed conductors. QCONCP finds the amount of charge on conductor i according to the original equation for this conductor:

$$Q_i = \left(- \sum_F W_{Fi} + \sum_{j \neq 1} C_{ij} \right) \phi_i - \sum_{j \neq 1} C_{ij} \phi_j + W_{Fi} \phi_F \ .$$

QCONCP calculates the charge on each conductor and places it in the appropriate location in array QCOND.

Calling Sequence: SUBROUTINE QCONCP (QCOND,PCOND,CIJ,CIJSUM, WPCOND,PMCND,BUF1,IP,NX,NY,NZ,IOBJ,MFIX, MBIAS).

QSUMER

Called by TRILIN, INDATA.

Calculates total charge contained within inner grid.

Calling Sequence: SUBROUTINE QSUMER (IROUS,ROUS,QCOND,NX,NY, NZ,QSUM).

QUPDAT

Called by TRILIN.

Updates the charge array ROUS for surface points.

RUPDAT

Called by POTENT.

RUPDAT updates the conjugate gradient vector r on file IR according to the equation

$$r^{n+1} = r^n - \alpha * a^n$$

The updated r^{n+1} data is written onto file ISPARE one grid at a time, and when all data have been updated, the unit numbers IR and ISPARE are switched.

RUPDAT also updates the conductor r values in array RCOND, and computes two dot product $r^{n+1} \cdot D\, r^{n+1}$.

Calling Sequence: SUBROUTINE RUPDAT (ALPHA,IR,IAUN,ISPARE, BUF1,BUF2,NG,NX,NY,NZ,RDOTR,RDOTRS,NC, RCOND,AUNCON,RDOTAU,MBIAS,MFIX).

SOLFLX

Called by CALFLX.
Calculates flux of photoelectrons from surface cell using material properties and shadowing calculation output.
Calling Sequence: SUBROUTINE SOLFLX (ICELL,PCUR).

SOURCE

Called by CALFLX.
Performs logical and I/O functions relevant to test tank particle tracking.
Calling Sequence: SUBROUTINE SOURCE (IOBPLT).
IOBPLT - LUN of OBJDEF output file.

TRILIN

Called by NASCAP.
Internal Organization: After calling FLXDEF and INDATA for initialization purposes, serves as primary program for NASCAP main loop: alternate calls to CHARGE and POTENT. Calls necessary routines for potential scaling, potential convergence plots and potential contour plots. After end of main loop, calls routines for restart dump, particle trajectory plots and charge density contour plots.

URSET0

Called by POTENT.
Given the set of linear equations for the potential of the system, Ap = ROUS, and given the coefficient product Ap^o of A with the initial guess for the potentials, p^o, and given the diagonal matrix D, URSET0 defines the u^o and r^o arrays on files IU and IR according to the equation

$$r^o = ROUS - Ap^o$$

$$u^o = D\ r^o$$

URSET0 also calculates the initial dot product $r^o \cdot D\, r^o$.

Calling Sequence: SUBROUTINE URSET0 (ROUS,IU,IR,IAUN,BUF1,
BUF2,NG,NX,NY,NZ,RDOTR,NC,AUNCON,UCOND,
RCOND,ROUSCN,MFIX,MBIAS).

UUPDAU

Called by POTENT.

UUPDAU updates the conjugate gradient vector u on file IU according to the equation

$$u^{n+1} = D\, r^{n+1} + \beta * u^n$$

The updated u^{n+1} data are written onto file ISPARE one grid at a time and when all data have been updated, the unit numbers IU and ISPARE are switched.

UUPDAU also updates the conductor u values in array UCOND.

Calling Sequence: SUBROUTINE UUPDAU (BETA,ISPARE,BUF1,BUF2,
NG,NX,NY,NZ,NC,UCOND,RCOND,MBIAS,MFIX).

10.6 ROTATE

ROTATE

Called by NASCAP.
Rotates the satellite by changing the sun direction. If an input file is specified, ROTATE reads user rotation specifications. If no input file or file 0 is specified, existing values (default or previous input) are used. The rotation is specified in terms of spin angular velocity (rad/sec, default is 1 RPM), and sun direction at t = 0 (default is (1.,0.,0.)).

The sun is rotated to the proper direction for the current time, and the subroutine terminates. Upon return to NASCAP, the HIDCEL routine will automatically be called to perform a shadowing calculation for the new sun direction.

10.7 CAPACI

CAPACI

Called by NASCAP.
Forms a capacitor model of the satellite to allow for an implicit charging calculation (LONGTIMESTEP). CAPACI deposits a unit charge on conductor #1 and calls the potential solver POTENT. The resulting potentials are used to construct a lumped-circuit-element model of the spacecraft.

Like the LIMCEL routines, this section of code is still being developed. We are incorporating cell subdivision and surface conductivity as well as other features. The documentation is incomplete.

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