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REVISION OF AND DOCUMENTATION FOR THE STANDARD VERSION OF THE POISSON GROUP CODES*

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Summary

The Los Alamos Accelerator Theory and Simulation Group (AT-6) maintains and distributes a standard version of the Poisson-Group codes (LATTICE, AUTOMESH, TEKPLOT, POISSON, PANDIRA, MIRT, FORCE, SUPERFISH, and SF01). These codes are the product of man-decades of development under the guidance of R. F. Holsinger and K. Halbach. The main applications are in the design of electromagnets (POISSON and PANDIRA) and rf cavities (SUPERFISH). Other applications include electrostatics, heat transport, and finding mathematical surfaces of minimum area. With special financial support from DOE-HEP, we have revised and corrected the standard version and are writing a comprehensive manual containing many examples and a summary of the theory behind the codes. This paper will illustrate some of the capabilities of the codes and will summarize the manual. The revised codes are available upon request.

Introduction

The Poisson Group of codes really consists of two sets of codes: one for the design of magnets and one for the design of rf cavities. These codes have been developed over a period of 15 years. In the late '60s, John Colonias at Lawrence Berkeley Laboratory (LBL) began modifying a diffusion calculation code written by A. Winslow at Lawrence Livermore National Laboratory (LLNL). The result was the TRIM set of codes (MESH and FIELD) that were capable of solving mathematical models of two-dimensional magnets, including the effects of finite permeability. MESH constructed an irregular triangular mesh to fit the geometry of the magnet. FIELD solved Poisson's equation for the potential function over the mesh.

Ron Holsinger, Klaus Halbach and other associates at LBL found TRIM very useful, and decided to develop a synthesis program that coupled TRIM with PISA (Program for Inversion of System Analysis). This program was called MIRT, which is TRIM spelled backwards. It was decided to completely rewrite TRIM. This task was undertaken by Jim Spoerl, Ron Holsinger, Klaus Halbach, and others. The result was the beginning of the "POISSON Group." Initially there were three codes in the group: LATTICE, TEKPLOT, and POISSON. LATTICE is like MESH; TEKPLOT, which was split from MESH, draws plots of either the mesh or the field lines; and POISSON is like FIELD. Holsinger continued to develop these codes while he was at the Swiss Institute for Nuclear Research (SIN) and CERN (the research center of the European Council for Nuclear Research in Geneva) between early 1972 and mid-1975. By the time he arrived in Los Alamos in 1975, he had completed six programs: LATTICE, POISSON, TEKPLOT, MIRT, FORCE and AUTOMESH. MIRT is an optimization program that iteratively changes the shape of pole faces and current distributions to obtain the field distribution specified by the user. FORCE was created to calculate the magnetic forces and torques on the iron and on the current-carrying coils of the magnet. For many problems, the preparation of input data for LATTICE is very tedious because one must supply both physical and logical coordinates for all points along physical boundaries. AUTOMESH eliminates the need to define the logical coordinates.

While at Los Alamos, Holsinger, in collaboration with Halbach, wrote two more programs: PANDIRA and SUPERFISH. PANDIRA was written in response to the need to solve problems involving permanent magnets, that is, when the B versus H curve is nonzero in the second quadrant. In this case, the algorithm used in POISSON (successive point overrelaxation) was not appropriate. PANDIRA uses the so-called direct method that solves the sparse equations directly.

Halbach and Holsinger recognized that the problem of finding the time-independent amplitudes of the electric and magnetic fields in rf cavities could be solved using methods closely related to those used in magnet problems. SUPERFISH not only calculates the fields but also determines the eigenfrequencies of the cavities. To solve cavity design problems, one uses the codes AUTOMESH, LATTICE, SUPERFISH, and uses TEKPLOT to plot the mesh as fields. One additional set of programs, called SUPERFISH outputs (SFOs), was written to calculate auxiliary quantities from the output file produced by SUPERFISH. Radio-frequency structures [for example, drift-tube linacs (DTLs) and radio-frequency quadrupoles (RFQs)] usually result in the need to calculate different auxiliary quantities.

Originally, the programs were written for the CDC 6600 computers. In 1977 when Holsinger left Los Alamos, he converted all the programs to run on the VAX 11/780. He continued to update and maintain the programs until 1982. At that time he transferred the maintenance and distribution responsibility to AT-6 in Los Alamos. The programs have had tremendous popularity since the early '70s, and this has resulted in a proliferation of versions of the codes. The documentation for these codes was adequate but incomplete. Until recently, Los Alamos has had very limited resources for documentation, maintenance, distribution, and consultation services. In October of 1983, the DOE-NP provided financial support with which we have undertaken the writing of a comprehensive user's manual and the standardization of the codes into one version that will run on both the CRAY and the VAX computers. Certain lines of the code can be switched in and out, depending on which computer one is using. The switching is done quickly--requiring only two commands to a text editor. With continued DOE support, we plan to complete the documentation, establish a user's group to direct improvements of the codes, and establish a system for distributing updated versions of the codes and documentation.

The remainder of this paper describes some typical output produced by these programs and mentions some of the features of the documentation.

Magnet Codes

A typical problem in magnet design is the specification of the pole-tip shape and the current strength necessary to produce a uniform field over a given region. Figure 1 is a TEKPLOT output showing the cross section of a typical H-shaped dipole magnet with field lines for a flat pole tip. Column 3 in Table I lists the magnitude of the field $|B|$ as a function of position in a rectangular region ($x = 0$ to 2.5 cm, $y = 0$ to 2.0 cm) at the center of the pole. Column 4 shows the result of exercising the option to automatically adjust the current to produce a specified field (16 kG in the example) at the center of the gap ($x = 0$, $y = 0$). The initial current is multiplied by the variable xjfact (calculated by the program) to get the adjusted current. Column 5 is the

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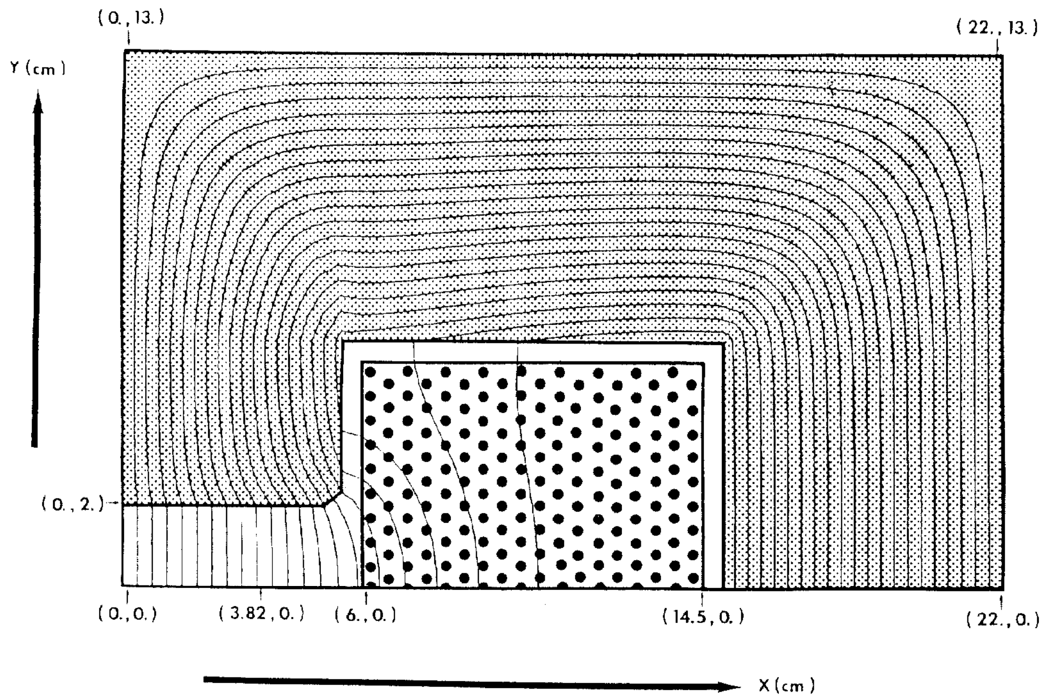

Fig. 1. A TEKPLOT output showing the geometry and field lines for one-fourth of an H-shaped magnet with uncorrected pole-tip shape produced by POISSON.

TABLE I

EXAMPLE USING POISSON AND MIRT TO PRODUCE A UNIFORM FIELD IN AN H-SHAPED MAGNET

x	xjfact= y	POISSON 1.000000 |B|(G)	POISSON 1.080663 |B|(G)	MIRT 1.092228 |B|(G)
0.000	0.000	15205.6	15998.6	16003.4
0.857	0.000	15200.3	15991.6	16000.9
1.714	0.000	15178.4	15963.8	15997.0
2.571	0.000	15112.4	15885.3	16002.4
0.000	0.666	15208.4	16002.5	16005.1
0.869	0.666	15204.5	15996.9	16001.6
1.714	0.666	15189.5	15976.8	15993.9
2.567	0.667	15147.3	15924.1	15999.0
0.000	1.333	15215.3	16012.2	16011.0
0.867	1.333	15214.9	16010.6	16006.1
1.709	1.333	15214.7	16006.9	15987.6
2.560	1.333	15222.8	16009.6	15950.2
0.000	2.000	15222.5	16023.7	16021.8
0.850	2.000	15225.6	16026.2	16018.8
1.700	2.000	15236.7	16034.4	15997.1
2.550	2.000	15274.8	16073.4	15879.5

result of a MIRT run in which two parameters were varied. One parameter was xjfact and the second was related to the height of a bump at the edge of the pole tip. Figure 2 shows the new pole-tip shape. The parameters were varied, subject to the constraint that the field be uniformly 16 kG in the small circular region, shown in the figure by a dotted line. MIRT will handle much more complicated sets of parameters and constraints.

Cavity Codes

As an example of what SUPERFISH can do, consider the problem of refining the design of a DTL cavity by optimizing the face angle of the drift tube to decrease the gap between drift tubes and thus increase the transit-time factor T. It is assumed that dimensions and shape of the cavity already have been determined in such a way that the TM_{010} mode of the cavity is at the frequency of the power source. Figure 3 is a TEKPLOT output of one-fourth the cross section of a DTL cavity. A picture of the full cavity is obtained by rotating the figure about the horizontal z-axis and reflecting the result through the vertical plane containing the r-axis. The figure shows the pattern of electric-field lines in the TM_{010} mode. Figure 4 identifies the face angle α. Table II shows the type of useful numbers that can be obtained from the SUPERFISH output for four different face angles α. Although increasing the face angle does increase T, it also increases the maximum electric field E_{max}. One must balance increased T against the possibility of electrical breakdown caused by high fields. The quantity P is the power dissipated in the cavity; Z is the impedance per unit length. The parameter ZT^2 is a measure of cavity efficiency.

Features of the Manual

The Poisson-Group codes are fairly complicated and require some effort on the users' part before they can be mastered. The manual is intended to give a quick introduction to the beginner, to be a useful reference for persons simply needing reminders of how the programs work, and to be an in-depth summary of the theory that went into the writing of the codes. The manual has been divided into three sections: a general introduction, a section for magnet problems, and a section for rf cavities. The codes AUTOMESH, LATTICE, and TEKPLOT are common to both magnet and cavity problems. For the convenience of the reader, each section has its own description of these programs. The sections of the manual can be physically separated without destroying the continuity of each section.

To help the beginner get a general understanding of the codes, we have started each section with a brief summary of the theory followed by a simple example. The examples do not demonstrate all the options of the programs. Details of these options are contained in subsequent subsections, which describe the input and output of each program arranged in the sequence used to solve a magnet or cavity problem.

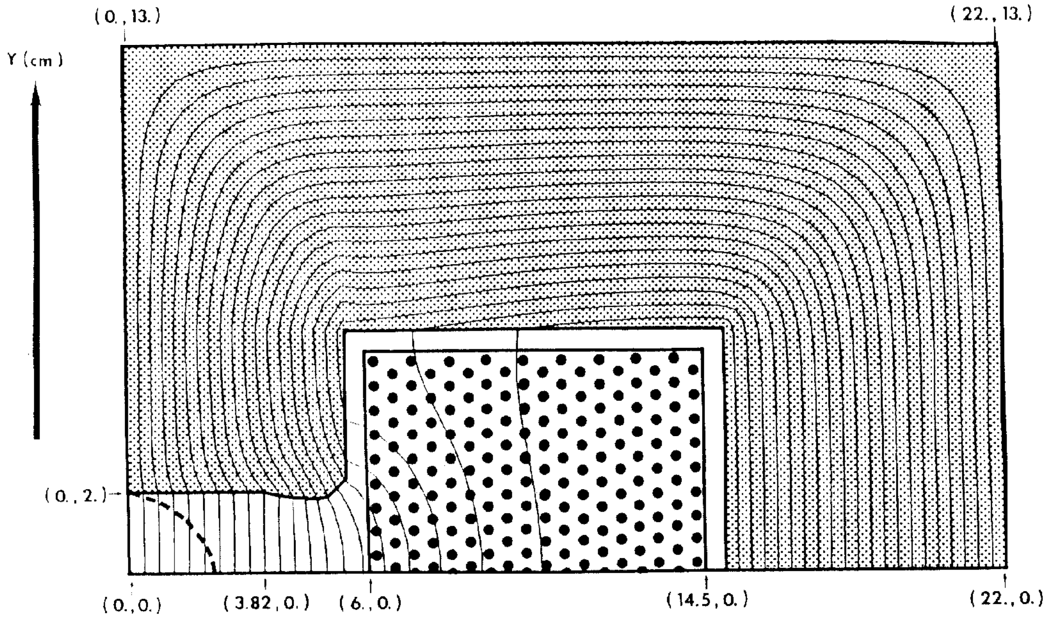

Fig. 2. A TEKPLOT output of H-shaped magnet after correcting the pole-tip shape using MIRT.

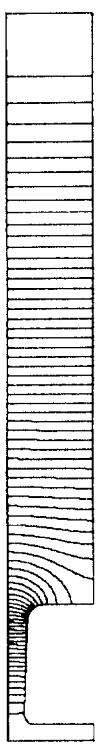

Fig. 3. TEKPLOT output showing one-fourth of a DTL cell with the pattern of field lines for the TM_{010} mode.

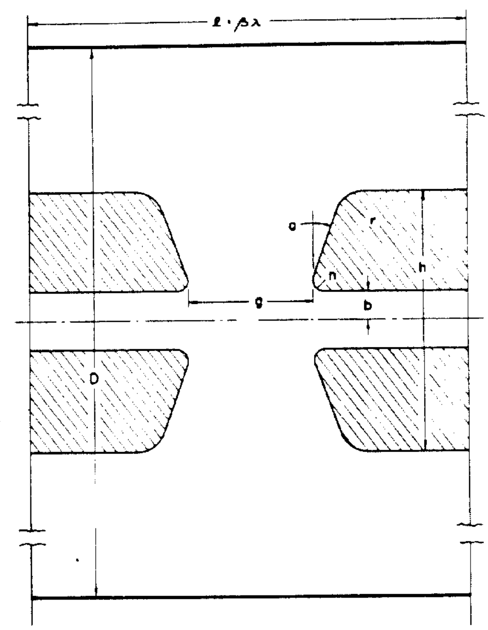

Fig. 4. Schematic picture of a DTL showing the nomenclature for the nose angle α. With exception of the gap g, other symbols on the figure should be ignored.

These subsections contain quick reference tables that summarize the input structure and remind the user of what is contained in the output. We have also included a separate subsection on diagnostic messages produced by the programs and interpretations of these messages. The remaining material in each section will be useful for an indepth understanding of the theory behind the codes and present limitations.

TABLE II

DTL CAVITY PARAMETERS
FOR DIFFERENT DRIFT-TUBE FACE ANGLES

Parameter α	0°	1°	2°	3°
G (cm)[a]	1.127	1.063	1.000	0.939
T	0.817	0.824	0.832	0.839
E_{max} (MV/m)	5.79	5.94	6.35	6.76
P (kW)	0.73	0.72	0.73	0.72
Z (MΩ/m)	72.6	72.9	72.6	72.9
ZT^2 (MΩ/m)	48.4	49.5	50.2	51.3

[a]The gap G has been adjusted to keep the resonant frequency the same for all cases.