CONF-800415--3

GA-A15800

MASTER

APPLICATION OF AN ARRAY PROCESSOR TO THE ANALYSIS OF MAGNETIC DATA FOR THE DOUBLET III TOKAMAK

by

T. S. WANG and M. T. SAITO

AUGUST 1980

GENERAL ATOMIC COMPANY

GA-A15800

APPLICATION OF AN ARRAY PROCESSOR TO THE ANALYSIS OF MAGNETIC DATA FOR THE DOUBLET III TOKAMAK

by
T. S. WANG and M. T. SAITO

This is a preprint of a paper presented at the Fourth Annual FPS Users Conference, San Francisco, April 28-May 1, 1980, and to be published in the Proceedings.

Work supported by
Department of Energy
Contract DE-AT03-76ET51011

GENERAL ATOMIC PROJECT 3235
AUGUST 1980

GENERAL ATOMIC COMPANY

APPLICATION OF AN ARRAY PROCESSOR TO THE ANALYSIS OF MAGNETIC DATA FOR THE DOUBLET III TOKAMAK

T. S. Wang and M. T. Saito

General Atomic Company
San Diego, California 92138

ABSTRACT

Discussed herein is a fast computational technique employing the Floating Point Systems AP-190L array processor to analyze magnetic data for the Doublet III tokamak, a fusion research device. Interpretation of the experimental data requires the repeated solution of a free-boundary nonlinear partial differential equation, which describes the magnetohydrodynamic (MHD) equilibrium of the plasma. For this particular application, we have found that the array processor is only 1.4 and 3.5 times slower than the CDC-7600 and CRAY computers, respectively. The overhead on the host DEC-10 computer was kept to a minimum by chaining the complete Poisson solver and free-boundary algorithm into one single-load module using the vector function chainer (VFC). A simple "time-sharing" scheme for using the MHD code is also discussed.

Work supported by Department of Energy,
Contract DE-AT03-76ET51011.

I. COMPUTING ENVIRONMENT

The host DEC System-10 computer is the General Atomic Company node of the National Magnetic Fusion Energy Computer Network (see Fig. 1). The largest computers on the network, a CDC-7600 and a CRAY, are located at the Lawrence Livermore Laboratory and are connected to the DEC-10 through a 50K baud link. The DEC-10 is also connected locally to a MODCOMP computer, which collects the Doublet III experimental data. These data are then transferred to the DEC-10 where a complete data base is maintained. The array processor MHD code receives data from and returns results to the DEC-10. Additional data analysis can be done on the CDC-7600 and CRAY.

II. APMHD CODE

One of the major goals of the Doublet III experiment is to maintain and confine a hot (tens of million degrees) ionized gas (plasma) utilizing external magnetic fields. Interpretation of the experimental results requires the repeated solution of a free-boundary nonlinear partial differential equation, which describes the MHD equilibrium of the plasma. The Poisson-like differential equation can be solved iteratively by using the standard Green's function method.

The major portion of the computation is of the form

$$\psi_i = \sum M_{ij} I_j \quad ,$$

where ψ_i is the magnetic flux, I_j is the plasma current, and M_{ij} is the mutual inductance matrix. By storing I_j in RAM TABLE memory and M_{ij} in Main Data memory, by performing the matrix multiplication as a series of dot products, and by coding the program in APAL, we are able to drive the AP-190L very close to the ideal 12 million floating-point operations per second (see Fig. 2). The grid size used in the present code is 27 × 49 and the resulting vector length is 1323. The most time consuming step involves the calculation of the ψ due to the plasma-to-plasma mutual inductance. This entails $2 \times (27 \times 49) \times (27 \times 49) \sim 3.5$ million multiplies and adds. Assuming 100 iterations to produce a fit, this portion of the calculation should take roughly 30 sec. In order to reduce the loading on the host computer and improve the turn-around time, the complete iterative loop, which includes the Poisson solver and free-boundary algorithm, is vectorized using the VFC. This iterative loop is then loaded as a single executable module. The net result is dramatic. Execution of 100 iterations requires only 56 sec on the array processor and a negligible 20 msec overhead on the DEC-10 host. A timing comparison between the DEC-10/AP190L, CDC-7600, and CRAY is given in Table 1. For this particular application, the array processor is only 1.4 and 3.5 times slower than the CDC-7600 and CRAY computers, respectively.

In Fig. 3, a simple block diagram shows the activities that are involved in reducing the magnetic data from Doublet III using the APMHD code.

III. TIME-SHARING OF THE ARRAY PROCESSOR

We have devised a scheme to allow shared usage of the array processor to run the MHD code (Fig. 4). The MHD program and the large Green's function table (≈ 67.5K words) stay loaded in the program source and main data memories. User requests to access the array processor will be queued by a service routine. The service routine also takes care of the rest of the operation including inputting data, running the code, getting data back from the array processor, and updating the user data on the DEC-10. Meanwhile, the DEC-10 remains relatively free to service user terminals through software interrupt. This psuedo time-sharing of the array processor is expected to increase the throughput of the system by a least a factor of two to three.

ACKNOWLEDGMENT

This work was supported by Department of Energy, Contract DE-AT03-76ET51011.

TABLE 1. TIMING COMPARISON OF THE MHD CODE
(Loop time/100 iter.)

	DEC-10/AP190L	CDC7600		CRAY-1	
Grid size	27 × 49	27 × 49	33 × 65	27 × 49	33 × 65
Algorithm	Green's	Green's	Bunemann's	Green's	Bunemann's
Language	DEC-10 FORTRAN AP190L {APAL, VFC}	FORTRAN STACKLIB		FORTRAN CAL	
CPU	AP190L 56 sec DEC-10 50 msec	40	70	16	23
I/O	NONE	40	40	43	39
SYS	NONE	1	1	1	1

FIGURE CAPTIONS

1. General Atomic Company DEC System 10-AP190L computer system.
2. A 12-MFLOPS APAL coded loop for vector calculating of the dot product.
3. APMHD code for tokamak data analysis.
4. Multi-users APMHD code.

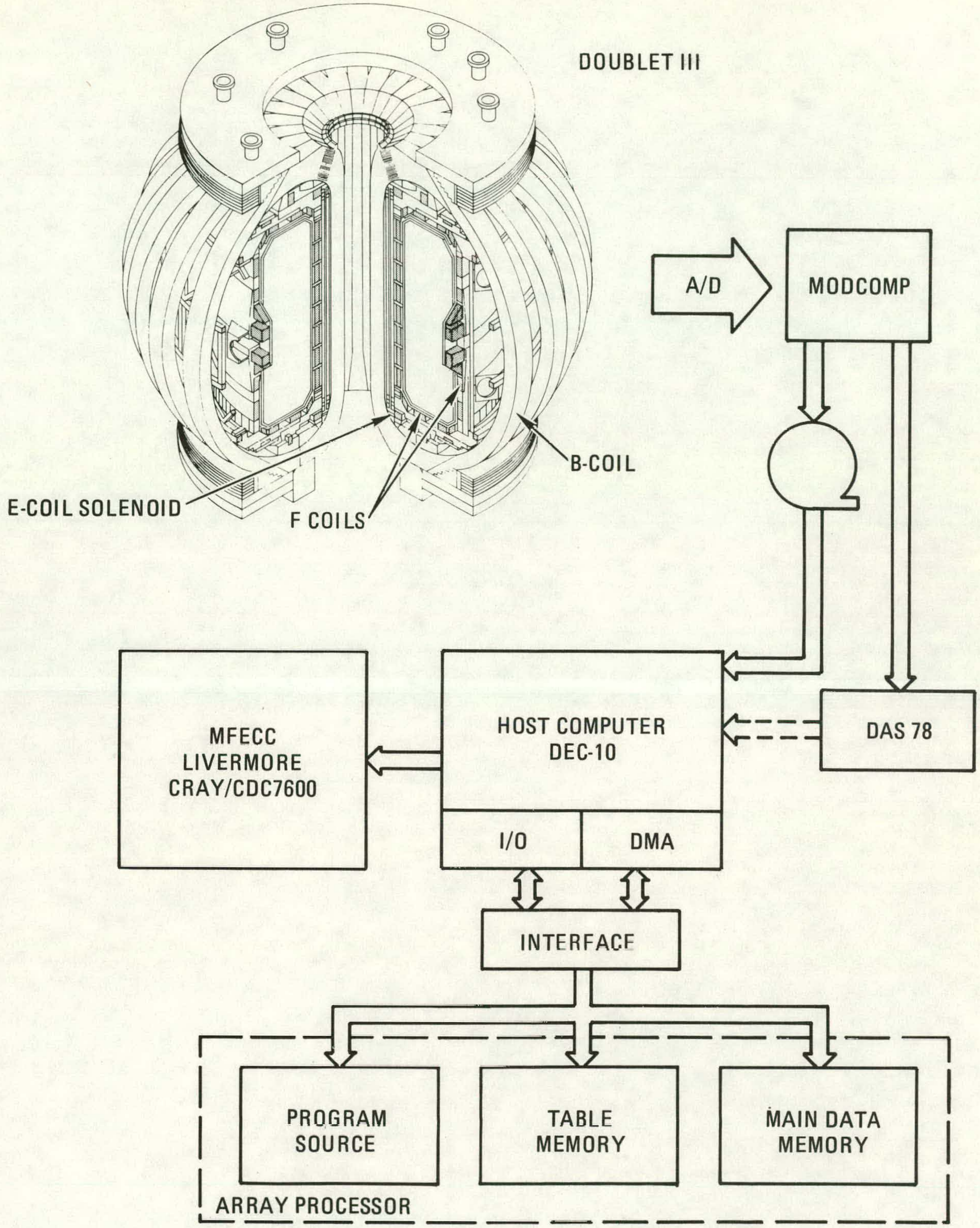

Fig. 1. General Atomic Company DEC System 10-AP190L computer system.

$$\psi_i = \sum_j M_{ij} I_j$$

```
LOOP:  [INCMA;]  [INCTMA;]
       [FMUL TM, MD;]
       [FADD FM, FA;]  [DEC N;]
       BGT LOOP
```

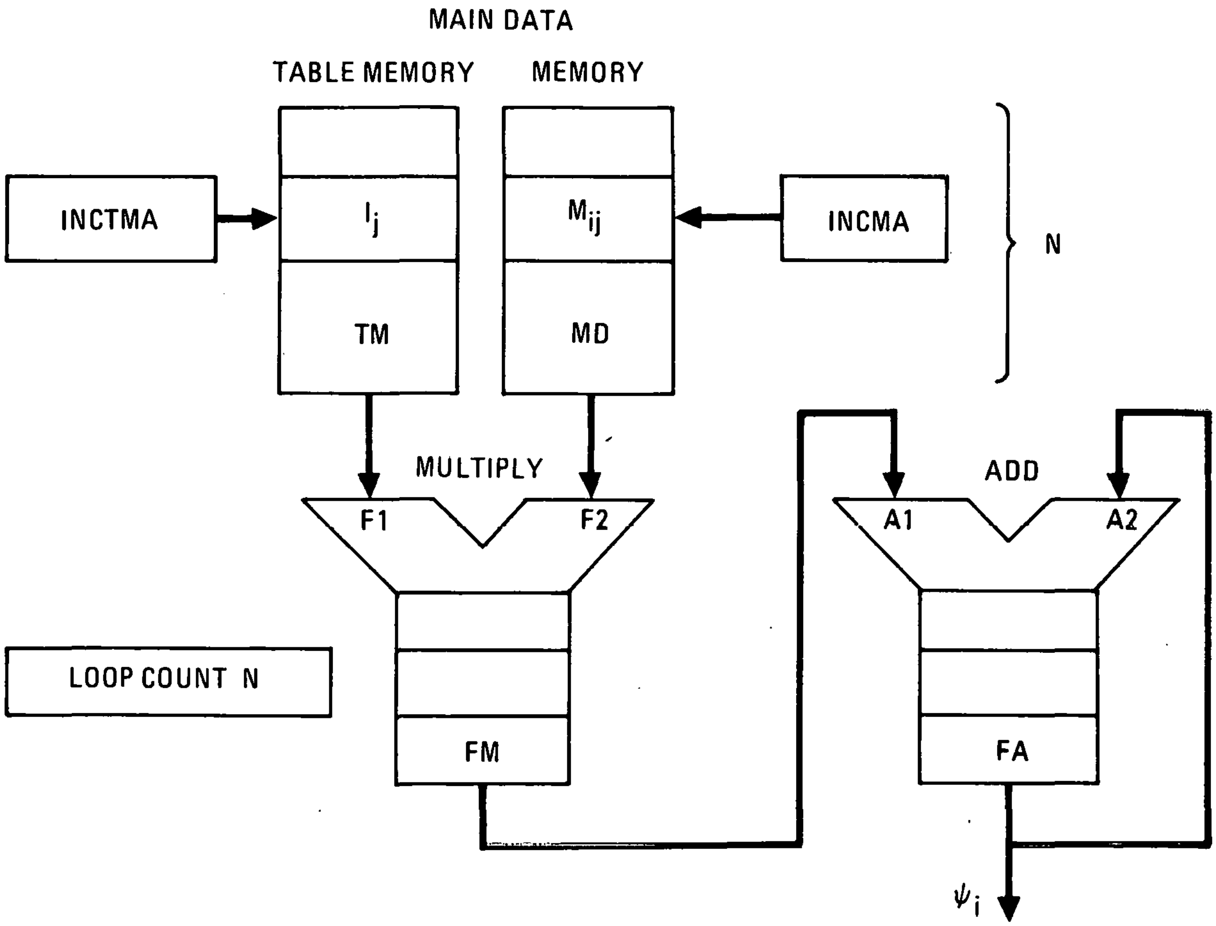

Fig. 2. A 12-MFLOPS APAL coded loop for vector calculating of the dot product.

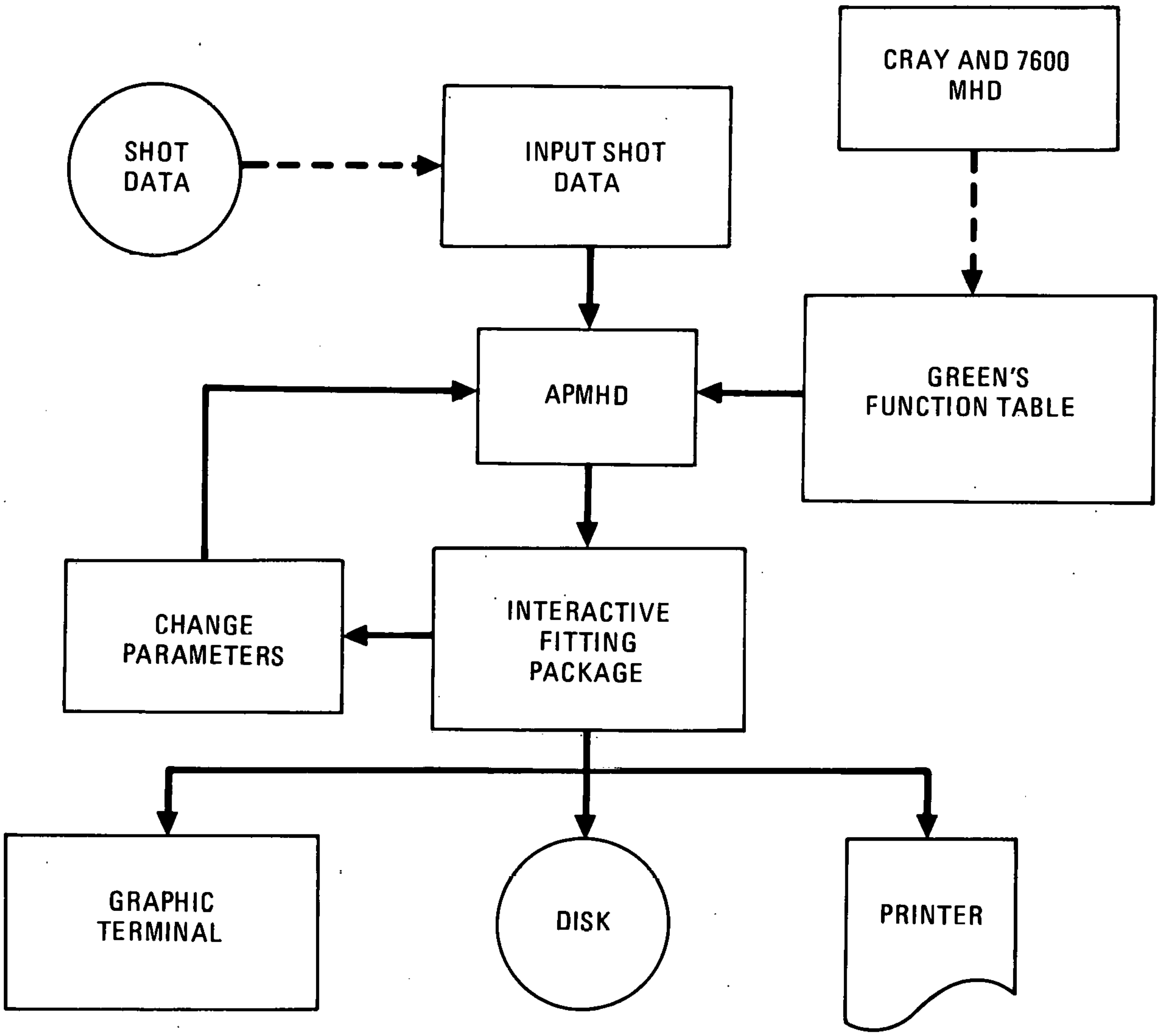

Fig. 3. APMHD code for tokamak data analysis.

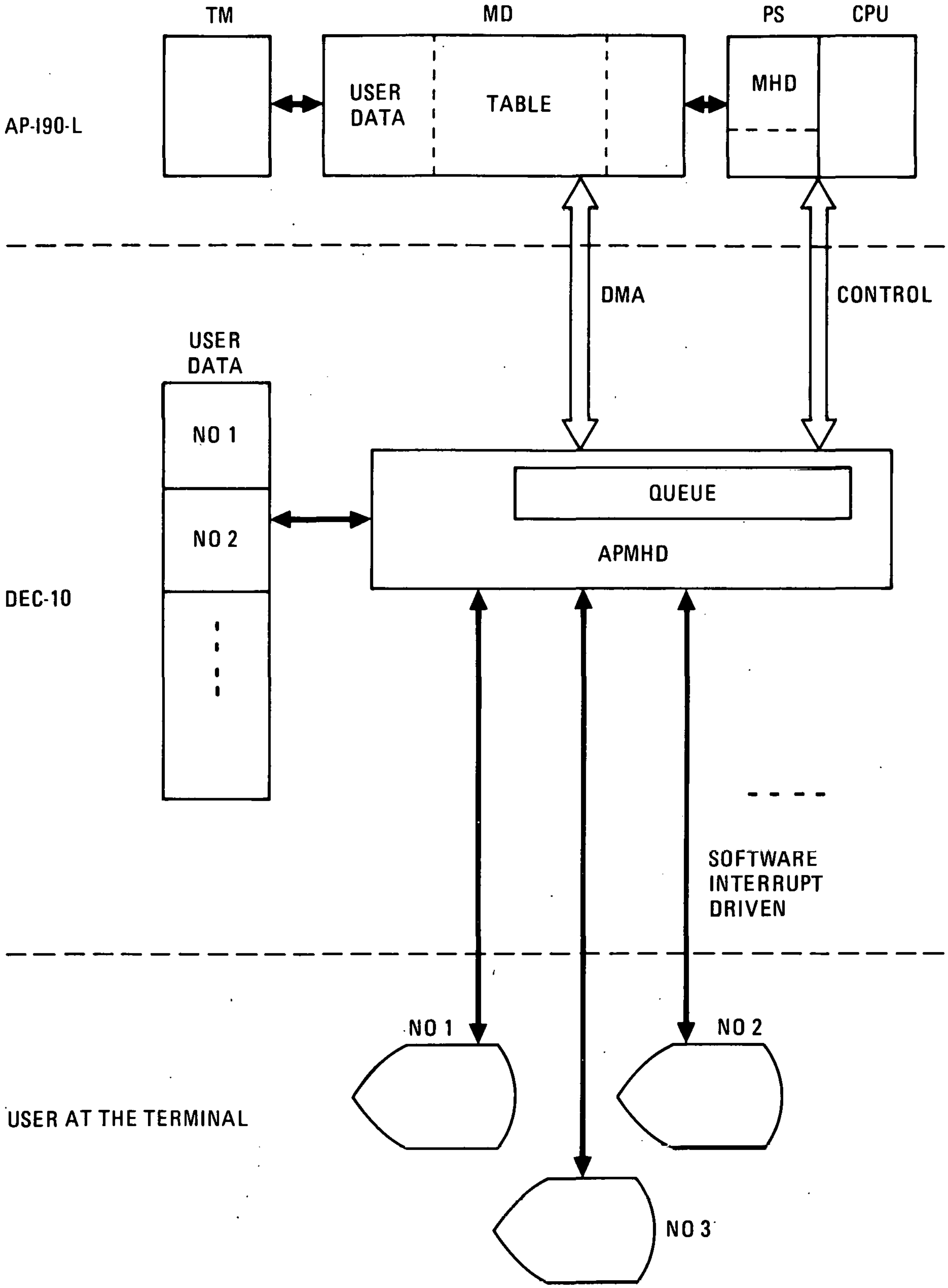

Fig. 4. Multi-users APMHD code.

GENERAL ATOMIC COMPANY

INTERNAL DISTRIBUTION

Armentrout, Charles
Baker, Dan
Beal, Jack
Bernard, L. Chris
Bhadra, Dilip K.
Blau, Frederick P.
Burke, John M.
Burnett, Sibley
Burrell, Keith H.
Callis, Richard W.
Chan, Vincent
Chang, Choong S.
Chen, Wilkie
Chiu, Shiu-Chu
Chu, Cheng
Chu, Ming Sheng
Colleraine, A. P.
D'Aoust, J.
DeBoo, James C.
Dobrott, Don R.
Document Center
Dominguez, Rene
Ejima, Seiki
Ensberg, Earl S.
Fisher, Raymond K.
Freeman, Richard L.
George, Joan
Gilleland, John R.
Guest, Gareth E.
Guss, William
Harder, C. Ross
Harvey, Robert W.
Helton, F. Joanne
Hino, Tomoaki
Hopkins, George R.
Hsieh, Chung-Lih
Hsu, Jang Y.
Hunt, Rose
Jahns, Gary L.
Jensen, Torkil H.
Kamperschroer, James H.
Kohli, James
Lee, Jae Koo
Lee, Shu-Tso
Levy, Martin
Luxon, James L.
McHarg, Bill
Mahdavi, M. Ali
Marcus, Frederick B.
Matsuda, Kyoko
Miller, Park H.
Miller, Robert L.
Moeller, Charles P.
Moore, Reagan W.
Ohkawa, Tihiro
Ohyabu, Nobuyoshi
Parks, Paul
Petersen, Peter I.
Peuron, Alex
Pfeiffer, Wayne
Prater, Ron
Rawls, John M.
Rosenberg, Marlene
Schaffer, Mike
Smith, Joe N., Jr.
Stambaugh, Ronald
Tamano, Teruo
Toffolo, Walter
Vaslow, Dale F.
Waltz, Ron
Wang, Tun-Soo
Wesley, John C.
Wong, Seung Kai
Yamagishi, Tomejiro

EXTERNAL DISTRIBUTION

Mr. Edwin E. Kintner
Dr. David B. Nelson
Dr. Robert E. Price
Dr. Walter Sadowski
Dr. Dale M. Meade
Dr. Robert A. Dory
Dr. William E. Drummond
Dr. Lawri Mann
Dr. Steve Hui
Dr. N. Maron
Dr. M. Okabayashi
Dr. Chris Thomas
Dr. Charles C. Baker
Max Planck Institut fur Plasmaphysik
Dr. Shogo Seki
Dr. H. Toyama
Dr. T. Kamimura