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"SHARP"
A ONE-DIMENSIONAL HYDRODYNAMICS CODE
FOR THE IBM 704

Olen Nance, Mark Wilkins, Isabel Blandford, and Hugh Smith

April 1958

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SHARP CODE FOR IBM 704

The code described here was designed to handle calculations of hydrodynamic motion in one-dimensional form, including provision for the disruption of a sample by "spallation". The term spallation refers to the rupture of the material by tension, induced by a rarefaction wave proceeding from a free surface. SHARP. was prepared by means of the IBM logical coding scheme, FORTRAN.* The difference equations, time interval control, and stability calculations for this code rely heavily on contributions by Mark Wilkins of this Laboratory.

Generation of SHARP requires a set of initial conditions which define an established pressure pulse in the front portion of the sample. SHARP investigates the motion of the pressure pulse and the corresponding effects. The generating conditions may be obtained from any suitable code which will yield information on the initial effects of an energy source on the material in question, or by the introduction of an arbitrary pulse consistent with the equation of state.

The input to SHARP consists of (a) the location of zone boundaries (b) the velocity of zone boundaries, (c) values of the internal energy and relative volume for "active zones", (d) the density of the material, and (e) the constants required to establish the equation of state. It is necessary to supply values only for "active" zones, and a model for the rest of the zones. The last zone for which complete data is supplied is designated by J*, and that zone number is supplied on a control card. The generator for the problem will duplicate the last zone for a specified number of times to complete the problem input. Thereafter, the calculation advances J* as zones become active, and bypasses unnecessary calculations in quiet zones. Edit routines are provided for a "zero print", as well as for prints on the basis of time intervals, distance of advance of the pressure peak, spallation, and manual control. The inputs and edits are discussed in more detail later in appendices.

The equations of state are provided in the form of polynomials which can be made applicable to any one of a number of materials by the introduction of appropriate constants with the input data.

* FORTRAN terminology has been used freely throughout this report; it is assumed that the reader has access to the appropriate FORTRAN manuals.

The basic equations governing the solution are:

1) Equation of motion: $\rho_0 \frac{\partial U}{\partial t} = - \frac{\partial (p+q)}{\partial x}$

2) Equation of energy conservation: $\frac{\partial E}{\partial t} + (p+q) \frac{\partial V}{\partial t} = 0$

3) Equation of continuity: $\rho_0 \frac{\partial V}{\partial t} = \frac{\partial U}{\partial t}$

4) Equations of state: $E = E(p, V)$
 $p = p(V, E)$

In these equations

U = velocity

V = relative volume (V/V_0)

p = pressure

E = internal energy

ρ_0 = density of normal state

t = time

x = distance

T = temperature

q = "von Neumann dissipation factor" *

Equation of State

The Equation of State exists in two parts, which have the forms

1) $P = \mu (C_1 + C_2 \mu) + (C_3 + C_4 \mu) E$

2) $P = C_5 \mu + (C_6 + C_7 \mu) E$

where $C_1 \dots C_7$ are constant coefficients and μ is defined by

$$\mu = \left(\frac{1}{V} - 1 \right)$$

Control is channeled through 1) or 2) depending on whether μ is positive or negative, respectively.

Zone variables for boundary $J + 1$ for time cycle $n + 1$ are listed below:

$U_{J+1}^{n+1/2}$ velocity (cm/sec)

X_{J+1}^{n+1} position (cm)

$V_{J+1}^{n+1/2}$ volume (relative, i.e. $\frac{V}{V_0}$, where V_0 is original volume)

$q_{J+1}^{n+1/2}$ von Neuman viscosity

$\mathcal{E}_{J+1}^{n+1/2}$ energy (referred to volume of original mass) $\left(\frac{\text{megbar} \times \text{cc}}{\text{cc}} \right)$

* von Neumann, J., and Richtmyer, R. D. "A method for the Numerical Calculation of Hydrodynamic Shocks." Journal of Applied Physics, 21, 232-237 (1950).

$p_{J+1/2}^{n+1}$ pressure (megbars)

$(1/2)\Delta m_{J+1/2}$ 1/2 zone mass (invariant with time) (gms)

$\pi_{J+1/2}^{n+1}$ "stress" function

$T_{J+1/2}^{n+1}$ temperature (deg. Kelvin)

$C_{pJ+1/2}^{n+1}$ heat capacity ($\frac{\text{megbar} \times \text{cc}}{\text{O}_K}$)

The running index, or subscript, J, is associated with zone boundaries in such a way that the mass, volume, energy, and other extensive properties of the zone are designated by J - 1/2, i.e. are associated with the zone boundary of larger numerical value, or leading zone boundary. Velocities are associated with the zone boundaries in particular and are therefore designated by J. Special values of the variables are associated with the zones bounding voids (see boundary conditions). The superscript, n, is associated with the number of time cycles completed, and the designation n + 1/2 is associated with first approximations as the calculation is advanced in time.

The specific difference equations and variables associated with the code are:

(1) Boundary Conditions

(2) Mass Zoning

$$(1/2)\Delta m_{J+1/2} = \frac{(1/2 \rho_0) (x_{J+1}^0 - x_J^0)}{V_{J+1/2}}$$

(3) Velocity

$$U_{J+1}^{n+1/2} = U_{J+1}^{n-1/2} - \Delta t^n \frac{[(P_{J+3/2}^n + q_{J+3/2}^n) - (P_{J+1/2}^n + q_{J+1/2}^n)]}{(1/2)\Delta m_{J+3/2} + (1/2)\Delta m_{J+1/2}}$$

if $|U_{J+1}^{n+1/2}| \leq U_{\min} = 10^{-6}$, then set $U_{J+1}^{n+1/2} = U_{\min}$

(4) Zone Boundaries

$$x_{J+1}^{n+1} = x_{J+1}^n + \Delta t^{n+1/2} u_{J+1}^{n+1/2}$$

(5) Volume

$$v_{J+1/2}^{n+1} = 1/2 \frac{\rho (x_{J+1}^{n+1} - x_J^{n+1})}{(1/2) \Delta m_{J+1/2}}$$

$$v_{J+1/2}^{n+1/2} = 1/2 (v_{J+1/2}^{n+1} + v_{J+1/2}^n)$$

(6) Viscosity

$$q_{J+1/2}^{n+1/2} = 2 c_0^2 \frac{(1/2 \rho) (u_{J+1}^{n+1/2} - u_J^{n+1/2})^2}{v_{J+1/2}^{n+1/2}} \quad \text{for } (u_{J+1}^{n+1/2} - u_J^{n+1/2}) < 0$$

$$q_{J+1/2}^{n+1/2} = 0 \quad \left\{ \begin{array}{l} \text{for } (u_{J+1}^{n+1/2} - u_J^{n+1/2}) \geq 0 \\ \text{or } p_{J+1/2}^n < 0 \end{array} \right.$$

(7) Energy (first approximation)

$$\tilde{\epsilon}_{J+1/2}^{n+1} = \tilde{\epsilon}_{J+1/2}^n - (p_{J+1/2}^n + q_{J+1/2}^{n+1/2}) (v_{J+1/2}^{n+1} - v_{J+1/2}^n)$$

(8) Pressure (first approximation)

$$p_{J+1/2}^{n+1} = F(\tilde{\epsilon}_{J+1/2}^{n+1}, v_{J+1/2}^{n+1})$$

(9) Energy

$$\epsilon_{J+1/2}^{n+1} = \tilde{\epsilon}_{J+1/2}^{n+1} - 1/2 [(\tilde{p}_{J+1/2}^{n+1} - p_{J+1/2}^n)(v_{J+1/2}^{n+1} - v_{J+1/2}^n)]$$

(10) Pressure

$$p_{J+1/2}^{n+1} = F(\epsilon_{J+1/2}^{n+1}, v_{J+1/2}^{n+1})$$

(11) Spall Conditions

$$\pi_{J+1/2}^{n+1} = \pi_{J+1/2}^n + A (p_{spl} - p_{J+1/2}^{n+1}) \Delta t^{n+1/2}$$

$$\text{for } (p_{spl} - p_{J+1/2}^{n+1}) \geq 0$$

$$\text{if } \pi_{J+1/2}^{n+1} > \pi_{spl}, \text{ then } \underline{\text{spall}}$$

$$\text{if } p_{J+1/2}^{n+1} > p_{spl}, \text{ then reset } \pi_{J+1/2} = 0 \text{ and continue}$$

(12) Energy Calculation

$$\text{Internal Energy} = \sum_J (1/2) \Delta m_{J+1/2} \epsilon_{J+1/2}^{n+1}$$

$$\text{Kinetic Energy} = \sum_J 1/2 [U_{J+1/2}^2 + U_J^2]^{n+1/2} (1/2 \Delta m)_{J+1/2}$$

Check:

$$\text{if } |(\varepsilon_i^0 + \varepsilon_k^0) - (\varepsilon_i^{n+1} + \varepsilon_k^{n+1})| > .05 |\varepsilon_i^0 + \varepsilon_k^0|$$

then STOP

(13) Stability Control

$$(S_{J+1/2}^{n+1})^2 = \left| \frac{1/2 (P_{J+1/2}^{n+1} - P_{J+1/2}^n)}{1/2 \rho (V_{J+1/2}^{n+1} - V_{J+1/2}^n)} \right| \text{ for } (V_{J+1/2}^{n+1} - V_{J+1/2}^n) \neq 0$$

$$\text{if } (S_{J+1/2}^{n+1})^2 < .05, \text{ set } (S_{J+1/2}^{n+1})^2 = .05$$

$$(K^{n+1})^2 = \left[\frac{\Delta t^{n+1/2} S_{J+1/2}^{n+1}}{x_{J+1}^{n+1} - x_J^{n+1}} \right] \text{ max over } J$$

$$\lambda^{n+1} = C_0^2 \left| \frac{V_{J+1/2}^{n+1} - V_{J+1/2}^n}{V_{J+1/2}^{n+1}} \right| \text{ for } (V_{J+1/2}^{n+1} - V_{J+1/2}^n) < 0 \text{ max over } J$$

$$\lambda^{n+1} = 0 \text{ for } (V_{J+1/2}^{n+1} - V_{J+1/2}^n) \geq 0$$

$$\text{test: if a) } (K^{n+1})^2 < .136$$

$$\text{or b) } \lambda^{n+1} < .079 \text{ and either}$$

$$\text{c) } (K^{n+1})^2 > .090$$

$$\text{or d) } \lambda^{n+1} > .065 \text{ then } \Delta t^{n+3/2} = \Delta t^{n+1/2}$$

but, if a) or b) fail or both c) and d) fail, calculate $\Delta t^{n+3/2}$ as follows:

$$\Delta t_k^{n+3/2} = \Delta t^{n+1/2} \frac{K}{K^{n+1}}, \text{ where } K = 1/3$$

$$\Delta t_\lambda^{n+3/2} = \Delta t^{n+1/2} \frac{\lambda}{\lambda^{n+1/2}} \text{ where } \lambda = .072 \text{ if } \lambda^{n+1} > .01$$

$$\Delta t_\lambda^{n+3/2} = \infty \text{ if } \lambda^{n+1} \leq .01$$

$$\Delta t_{\min}^{n+3/2} = [\Delta t_k^{n+3/2}, \Delta t_\lambda^{n+3/2}]_{\min}$$

$$\Delta t^{n+3/2} = [\Delta t_{\min}^{n+3/2}, 7/5 \Delta t^{n+1/2}]_{\min}$$

then calculate Δt^{n+1}

$$\Delta t^{n+1} = 1/2 [\Delta t^{n+3/2} + \Delta t^{n+1/2}]$$

(14) Other calculations

$$T_{J+1/2}^{n+1} = CT_2 \left(\frac{\varepsilon_{J+1/2}^{n+1}}{\rho_0} \right)^2 + CT_1 \left(\varepsilon_{J+1/2}^{n+1} \right) + CT_0$$

$$C_{P_{J+1/2}}^{n+1} = F \left(\varepsilon_{J+1/2}^{n+1} \right)$$

$$\begin{aligned} \bar{T}^{n+1} &= \frac{\sum_{\ell} T_{\ell+1/2}^{n+1} \left(\frac{\Delta m}{2} \right) \ell_{+1/2}}{\sum_{\ell} \left(\frac{\Delta m}{2} \right) \ell_{+1/2}} \\ \bar{U}^{n+1/2} &= \frac{\sum_{\ell} U_{\ell+1/2}^{n+1/2} \left(\frac{\Delta m}{2} \right) \ell_{+1/2}}{\sum_{\ell} \left(\frac{\Delta m}{2} \right) \ell_{+1/2}} \end{aligned} \quad \left. \vphantom{\begin{aligned} \bar{T}^{n+1} \\ \bar{U}^{n+1/2} \end{aligned}} \right\}$$

for each piece, where ℓ
has one to one corre-
spondence with J in
the piece.

$$V = \sum_{\ell} V_{\ell+1/2}$$

$$M = \sum_{\ell} \left(\frac{\Delta m}{2} \right) \ell_{+1/2}$$

for each piece

$$t^{n+1} = t^n + \Delta t^{n+1}$$

KEY TO SHARP TERMINOLOGY

X(J)	= X_J
U(J)	= U_J
V(J)	= $V_J - 1/2$
E(J)	= $\mathcal{E}_J - 1/2$
PNUM	= problem number
JFIN	= number of zones desired in sample
JSTAR	= (J*), zone number of model for quiet zones
PSPL	= P_{spl} (negative)
PISP	= π_{sp}
A	= A
C0	= C_0
RHO	= $1/2 \rho_0$
C1,C2..C7	= $C_1, C_2, \dots C_7$, equation of state constants
X(1),U(1)	= position and velocity of front surface of sample
N	= n (cycle number)
KFIN	= total number of pieces
PMAX	= maximum pressure in piece
JPMAX	= zone number of peak pressure location
EM	= $\mathcal{E}/\rho_0$
K	= piece number
EI(K)	= $\mathcal{E}_i$ total internal energy in a piece
EK(K)	= $\mathcal{E}_k$ total kinetic energy in a piece
ZMSUM	= M total mass
UBAR	= $\bar{U}$
TBAR	= $\bar{T}$
S2	= S^2
S2M(K)	= maximum value of S^2 in a piece
JS2M(K)	= zone location of S2M(K)
VSUM	= V total volume
X(M-1) U(M-1)	} = position and velocity of front surface of a piece.

XVOID(J) = position and velocity of boundary at spall
UVOID(J)
Q(J) = $q_J - 1/2$
P(J) = $p_J - 1/2$
PI(J) = $\pi_J - 1/2$
TIME = t^{n+1}
DTN = Δt^n
DTNH = $\Delta t^{n+1/2}$
SK2M = $\Delta t_k^{n+3/2}, \Delta t_{\min}^{n+3/2}$
SLMDA = $\Delta t_{\lambda}^{n+3/2}, 7/5 \Delta t^{n+1/2}$
ETW = $\tilde{\epsilon}_{J+1/2}^{n+1}$
PTW = $\tilde{p}_{J+1/2}^{n+1}$
EQS1F } = $P = P(\mathcal{E}, V)$
EQS2F } = $E = E(p, V)$
EQMU = $\gamma = (\frac{1}{V} - 1)$
PAB(J) = $|p_J - 1/2|$
ECK = $\mathcal{E}_i + \mathcal{E}_k$
 c_p = appears as the set of constants (CT1, CT2, CT ϕ)

Calculating Procedure

Preliminary

The quantities $\mathcal{A}(J)$ and $P(J)$ are first calculated for all active zones, and the quiet zones are defined using J^* as a model. If any $\mathcal{E}(J) = 0$, the corresponding $P(J)$ is set equal to zero. The half mass, internal energy, and kinetic energy are calculated for each zone, and a "zero print" is written on output tape.

Initialization

The code then enters an initialization routine for $J = 1$, clearing storage locations as necessary, and defining the equation of motion for $X(1)$.

Calculations

The body of the calculations are carried on inside two "loops" in the code. A series of calculations is carried out for each zone, J , from $J = 1$ to J^* , J^* being advanced as necessary. After a series is completed for all zones, the time is advanced by a Δt , and the series is repeated. This series of calculations for any given time, t , is referred to as the "main loop, or "J loop". The time "loop" contains series of "J loops".

Spallation

A major concern of the code is the determination of spall. When any pressure goes more negative than the constant P_{spl} , the code tests for possible spall. The quantity π is defined by

$$\pi^{n+1} = \pi^n + A \int (P_{spl} - P) dt$$

If π^{n+1} becomes larger than the constant π_{sp} , spall is indicated, and control is shifted into the proper channel in the code, determining U and X at the spall interface and calling for an edit routine. The quantities $XVOID$ and $UVOID$ are used to determine the difference in velocity of the two pieces, and the space between them. In addition they are employed in initializing the succeeding zone in the J loop.

After each spall, the code calculates the average temperature, $\bar{T}$, and the average velocity, $\bar{U}$, for each piece, K . The code searches for and finds the position and value of the maximum pressure in each piece. These and other values are recorded on output tape and will be considered more completely in the explanation of the edit routine.

Energy Check

At the end of each time cycle the code goes through an energy check routine. The total energy is computed as the sum of the internal and kinetic energies in the sample. If, during the course of the problem, the total energy varies by more than 5% from the original energy input, the problem will stop. The energy check may be bypassed (see operating instructions).

Stability

The code contains a stability routine which determines the Δt for each time cycle. Tolerances are set up on the stability parameters, which depend upon the pressures and volumes of the zones. If these tolerances are met, the Δt remains unchanged for the succeeding time cycle. If not, a new Δt will be calculated which will prevent the numerical approximation routine from becoming unstable. The conditions are described in the difference equations.

Dump

The code contains an instruction which periodically causes it to write the entire memory on tape 1. This memory dump occurs automatically after each 100 cycle interval. The dump can be forced at any time by the operator.

Edit

At various times during the problem the code goes through an edit routine. This routine is initiated after the first cycle, after each microsecond of problem time, each time J^* has advanced an additional thirty zones, and after each spall. In addition, the operator may force an edit at any time. As previously mentioned, the edit routine calculates $\bar{T}$ and $\bar{U}$ and locates the peak pressure for each piece.

An example on line print is shown in Fig. 1. Fig. 2 gives the form of the zero print, while Fig. 3 is a typical edit written on tape after the first cycle.

GENERAL FLOW

GENERATOR

J=1 LOOP

DO 461
NN = 1, 10,000

MAIN LOOP

DO 118
J = 1, 505

MAIN LOOP (CONT.)

(CONT.)

MAIN LOOP (CONT.)

END OF CYCLE : CONTROL & CALCULATION

EDIT

APPENDIX I

Operating Instructions

Input

Input to SHARP is supplied initially on cards and consists of SHARP binary deck followed by a number of decimal load cards. Input data must be punched on the cards according to a definite format, and each quantity must be pushed to the extreme right in its allotted space.

The first three cards contain problem parameters, followed by the cards containing the $X(J)$, $U(J)$, $V(J)$, and $E(J)$ for $J = 2$ to J^* . A sample data input sheet containing the form and format for these inputs is shown in Fig. 4. The cards must be punched in exactly the same format or error will result.

Note: C_0 has been selected on the basis of performance and should be entered as 1.8.

Manual Control

Tapes

The code requires two magnetic tapes. Memory dumps are written on tape one and output is written on tape two.

Sense Switches

- a) Edit when SS #1 is down
- b) Dump when SS #2 is down
- c) Stop when SS #2 and SS #3 are down
- d) Bypass energy check when SS #4 is down

Printer Board:

SHARP uses printer board SHARE #2.

APPENDIX II

FIGURE 1
ON LINE EDIT

TIME	N	DTNH	KFIN	PMAX	JPMAX	JSTAR
1.000E-04	1	1.000E-04	1	0.345E-00	7	11
0.118E-00	25	0.108E-01	2	0.458E-00	10	13
0.148E-00	28	0.962E-02	3	0.387E-00	10	13
0.415E-00	53	0.101E-01	5	0.492E-00	14	17
0.493E-00	60	0.112E-01	6	0.466E-00	15	18

FIGURE 2
ZERO PRINT

SHARP		PNUM				
ZERO PRINT		1001.0328				
J	X(J)	P(J)	E(J)	V(J)	U(J)	ZM(J)
1	2.200E-01				3.000E-02	
2	2.300E-01	7.200E-04	3.600E-02	1.000E 00	3.500E-02	3.000E-02
3	2.425E-01	4.470E-02	3.610E-02	9.500E-01	4.000E-02	3.947E-02
4	2.570E-01	1.453E-01	3.244E-02	9.000E-01	5.000E-02	4.833E-02
5	2.725E-01	2.231E-01	3.512E-02	8.750E-01	6.200E-02	5.314E-02
6	2.900E-01	2.805E-01	3.960E-02	8.600E-01	7.500E-02	6.105E-02
7	3.100E-01	3.454E-01	3.035E-02	8.450E-01	9.000E-02	7.101E-02
8	3.350E-01	2.806E-01	4.027E-02	8.600E-01	5.600E-02	8.721E-02
9	3.650E-01	4.426E-02	2.540E-02	9.500E-01	1.250E-02	9.474E-02
10	4.000E-01	0.	0.	1.000E 00	3.000E-04	1.050E-01
11	4.400E-01	0.	0.	1.000E 00	0.	1.200E-01
12	4.800E-01	0.	0.	1.000E 00	0.	1.200E-01
13	5.200E-01	0.	0.	1.000E 00	0.	1.200E-01
14	5.600E-01	0.	0.	1.000E 00	0.	1.200E-01
15	6.000E-01	0.	0.	1.000E 00	0.	1.200E-01
16	6.400E-01	0.	0.	1.000E 00	0.	1.200E-01
17	6.800E-01	0.	0.	1.000E 00	0.	1.200E-01
18	7.200E-01	0.	0.	1.000E 00	0.	1.200E-01
19	7.600E-01	0.	0.	1.000E 00	0.	1.200E-01
20	8.000E-01	0.	0.	1.000E 00	0.	1.200E-01

FIGURE 3

SAMPLE EDIT

CODE	TIME	N	DTNH	KFIN	PNUM			
SHARP	0.415E+00	53	0.101E-01	5	1000.			
K	EI(K)	E K(K)	ZMSUM	UBAR	S2MK	JS2MK	VSUM	TBAR
PIECE 1	3.600E-04 X(M-1)	4.469E-06	3.000E-02	-6.038E-03	8.166E-02	2	1.002E 00 U(M-1)	7.500E 02
1	2.177E-01						-1.617E-02	
2	2.277E-01	-1.015E-04	-1.000E 00	3.600E-02	7.500E 02	1.002E 00	-6.038E-03	0.
PIECE 2	4.627E-04	2.163E-06	3.947E-02	7.777E-04	7.922E-02	3	1.004E 00	7.375E 02
1	2.295E-01						-1.044E-02	
3	2.427E-01	-1.520E-03	-1.000E 00	3.517E-02	7.375E 02	1.004E 00	7.777E-04	0.
PIECE 3	4.359E-04	2.420E-06	4.833E-02	-1.106E-03	8.198E-02	4	1.006E 00	6.214E 02
1	2.451E-01						9.946E-03	
4	2.614E-01	-2.515E-03	-1.000E 00	2.706E-02	6.214E 02	1.006E 00	-1.106E-03	0.
PIECE 4	2.852E-03	3.213E-05	4.721E-01	7.885E-03	2.730E-01	9	5.941E 00	5.121E 02
1	2.612E-01						-3.362E-03	
5	2.790E-01	-2.533E-03	0.	2.518E-02	5.958E 02	1.006E 00	1.819E-03	0.
6	2.991E-01	6.169E-03	0.	2.592E-02	6.058E 02	9.888E-01	-1.778E-03	0.
7	3.225E-01	7.044E-03	0.	1.210E-02	4.312E 02	9.869E-01	7.059E-03	0.
8	3.517E-01	-2.168E-03	0.	2.654E-02	6.143E 02	1.005E 00	7.023E-03	0.
9	3.814E-01	6.021E-02	0.	2.593E-02	6.059E 02	9.394E-01	7.470E-03	0.
10	4.169E-01	-7.072E-03	-1.000E 00	4.923E-05	3.005E 02	1.014E 00	1.821E-02	0.
PIECE 5	1.470E-03	1.648E-03	1.200E 00	2.030E-02	1.001E 00	14	9.578E 00	3.431E 02
1	4.169E-01						1.821E-02	
11	4.532E-01	1.237E-01	0.	4.278E-03	3.441E 02	9.077E-01	3.980E-02	0.
12	4.914E-01	3.774E-02	0.	7.372E-04	2.074E 02	9.541E-01	6.273E-03	0.
13	5.296E-01	3.439E-02	0.	6.185E-04	3.062E 02	9.568E-01	7.866E-02	0.
14	5.623E-01	4.923E-01	0.	2.991E-02	6.612E 02	8.173E-01	7.583E-02	0.
15	6.001E-01	5.290E-02	0.	1.214E-03	3.122E 02	9.434E-01	2.458E-03	0.
16	6.400E-01	5.176E-04	0.	3.238E-07	3.000E 02	9.987E-01	2.086E-05	0.
17	6.800E-01	3.577E-06	0.	1.503E-11	3.000E 02	10.000E-01	0.	0.
18	7.200E-01	0.	0.	0.	3.000E 02	1.000E 00	0.	0.
19	7.600E-01	0.	0.	0.	3.000E 02	1.000E 00	0.	0.
20	8.000E-01	0.	-1.000E 00	0.	3.000E 02	1.000E 00	0.	0.
J	X(J)	P(J)	PI(J)	E(J)	T(J)	V(J)	U(J)	Q(J)

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PROGRAM _____ DATE _____

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FORMATS FOR INPUT

FIG.4.

FIG. 4.