Nonlinear Filtering in Oil/Gas Reservoir Simulation: Filter Design

**E. M. Arnold
D. A. Voss
D. W. Mayer**

October 1980

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SUMMARY

In order to provide an additional mode of utility to the USGS reservoir model VARGOW, a nonlinear filter was designed and incorporated into the system. As a result, optimal (in the least squares sense) estimates of reservoir pressure, liquid mass, and gas cap plus free gas mass are obtained from an input of reservoir initial condition estimates and pressure history. These optimal estimates are provided continuously for each time after the initial time, and the input pressure history is allowed to be corrupted by measurement error. Preliminary testing of the VARGOW filter was begun and the results show promise. Synthetic data which could be readily manipulated during testing was used in tracking tests. The results were positive when the initial estimates of the reservoir initial conditions were reasonably close. Further testing is necessary to investigate the filter performance with real reservoir data.

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INTRODUCTION

The physical structure of the variable gas-oil-water (VARGOW) reservoir per se model can be described as a zero-dimensional tank-piston model. "Zero-dimensional tank-piston" implies that spatial variations are not considered and the reservoir is treated as a large tank with any inflowing aquifer water forming a piston that pressurizes the reservoir. The "piston" is assumed to be porous to allow entrapment of the reservoir material (oil and gas) by the invading water. The term "reservoir per se" indicates that the model considers only the reservoir itself and does not consider individual wells drilled into the reservoir. The reservoir model was developed by the U.S. Geological Survey with the objective of providing recovery estimates that are suitable for assessment of various reservoir production policies with regard to production regulation.

The purpose of this report is to discuss the modification of VARGOW to employ a nonlinear filter algorithm. The section following the Recommendations and Conclusions discusses the reservoir initial value problem. The next section discusses reservoir tracking using a nonlinear filter algorithm and develops the algorithm as used in the VARGOW model. The final section presents the results obtained from a preliminary test of the filter algorithm.

RECOMMENDATIONS AND CONCLUSIONS

1. The results of preliminary testing indicate that the filtered version of VARGOW can be useful as a reservoir tracking device which reads a noisy pressure record and gives updated optimal estimates of pressure, liquid content, and gas content of the reservoir. This increases the scope and utility of the VARGOW model as a tool for the planning and execution of reservoir operation strategies.
2. The speed of convergence of the filter depends upon the quality of the beginning estimate of the reservoir initial state. This estimate is an input to the filter and must be at least a "ball park" guess if the filter is to converge at all. A testing procedure should be designed which would quantify the effect on filter convergence of initial condition accuracy.
3. It can be advantageous to run the filtered version of VARGOW for some initial segment of the reservoir history to establish an optimal beginning point for a subsequent use of VARGOW without the filter. This would allow an improved prediction capability which should be tested in further research.
4. It is possible to use the filter to estimate parameters characterizing reservoir media properties, entrapment mechanisms and gas migration. If α denotes such a parameter, the equation $d\alpha/dt = 0$ is added to the filter system. In this way an optimal estimate of α is obtained subject to the minimization of the observed and calculated pressure. This procedure should be tested to find out how many parameters can be efficiently estimated. There is a trade off between the number of parameters to be estimated and the size of the resulting filter system.
5. The possibility of using the gas/oil ratio as an auxiliary tracking variable should be investigated.
6. The addition of the estimator equations for the optimal estimate e and the weighting matrix Q adds to the size and complexity of the system. This results in numerical problems with the ordinary differential equation solver in VARGOW. At present it is necessary to use very small time steps

in the filter because of system stiffness (i.e. the system includes both rapidly and slowly varying terms). This is expensive for long simulations. Modification of the Runge-Kutta integration scheme in VARGOW may be necessary.

RESERVIOR INITIAL VALUE PROBLEM

The simulation of oil/gas reservoirs with water entrapment using the VARGOW model proceeds via the solution of an initial value problem. The state of the reservoir at any time is given by the set of quantities $[P(t), N_L(t), N_{FGC}(t)]$ where P , N_L , and N_{FGC} are the reservoir pressure, mass of liquid, and mass of free plus gas-cap gas, respectively. Certainly there are many other intermediate quantities described within the VARGOW model, but these three are the primitive variables in the sense that all the others can be derived from them. The evolution of the reservoir state from an initial state is determined by the solution of a system of three coupled nonlinear ordinary differential equations which can be written as:

$$\frac{dx^i}{dt} = f^i(x_1, x_2, x_3), \quad i=1,2,3 \quad (1)$$

where $x_1=P$, $x_2=N_L$, $x_3=N_{FGC}$ and the functions of f^i are the righthand sides of equation (106), (107), and (108) in SAD section report number 77-10 (USGS 1976) which gives the mathematical description and terminology of the VARGOW model. This simplified notation allows a cleaner discussion of the filtering problem.

The model parameters characterizing the media properties of the reservoir, water entrapment mechanisms, and gas/oil phase properties are estimated by a combination of statistical and physical means. These parameters appear in the functions f^i in Equation (1) and serve to specialize the model equations to a particular reservoir. After the parameters are estimated, the VARGOW model calculates the reservoir state through a numerical solution of Equation (1) from an input of reservoir initial conditions P^0 , N_L^0 and N_{FGC}^0 .

Even when the parameters are accurately estimated, the accuracy of the calculations are limited by the precision with which the initial conditions are determined. The initial conditions are usually obtained from field measurements and laboratory tests. There is enough physical content to these values

that they should not be "floated" in a statistical estimation procedure. On the other hand they are still obscured by measurement errors, and sampling methods which don't represent the bulk properties of the reservoir.

Furthermore, since the simulation proceeds from a fixed initial condition, errors caused by inaccurately determined initial conditions are felt throughout the entire simulation. In effect, if a bad guess at initial conditions is made at the start, one is stuck with it.

As an alternative to the use of VARGOW in a pure initial value problem, as just described, the model can be incorporated into a nonlinear filtering procedure. The filtering algorithm accepts observations (perhaps noisy) on the reservoir state as well as model calculations as ingredients in an optimization scheme which continuously minimizes the least squares difference between the calculated and measured reservoir state. Thus, in the filtering mode, the VARGOW model calculations are influenced, not just by a fixed initial condition, but by a continuous record of noisy measurements on at least one of the state variables P , N_L or N_{FGC} . Roughly speaking, the reservoir state is being continuously updated so that the mean square error between calculated and observed records is minimized.

NONLINEAR FILTERING PROBLEM – RESERVOIR TRACKING

Most of the literature on filtering is specialized to linear systems with complete statistical knowledge of the measurement or observation errors. For example, the celebrated Kalman Filter (Kalman and Bucy 1961) assumes the system model can be expressed as stochastic differential equations with the disturbances being stochastic processes (usually Gaussian) with orthogonal increments.

The approach taken in this study is based upon the invariant imbedding ideas of Bellman (1964). This method is applicable to nonlinear systems, such as VARGOW, and makes no essential use of the statistics (often unknown) of the measurement errors. It should be noted, however, that when statistical information about the disturbances is known, the information may be used to improve the optimization algorithm. For example, these statistics may indicate that an object function other than least squares is appropriate for the minimization.

To simplify the ideas involved in the filtering algorithm, a simple scalar system will be considered first. After this, the filter for VARGOW can be formulated with only minor modifications. This exposition closely follows (Kagiwada 1974, Ch 9) and (Lee 1968, Ch 8) which are basic references for this report.

Consider a scalar system whose state evolves through time t as a solution of the nonlinear ordinary differential equation:

$$\frac{dx}{dt} = f(x,t) \quad (2)$$

The system state is observed from the initial time, taken as $t=0$, up until the present time $t=T$. Due to measurement errors, the true state $x(t)$ is corrupted by a noise component. Thus, the observed state $z(t)$ can be written as $z(t) = x(t) + n(t)$, where $n(t)$ is the noise or disturbance. It is desired to estimate

the state $x(t)$ at time T , based upon observations over the time interval $[0, T]$ in such a way that the mean square difference:

$$\int_0^T [x(t) - z(t)]^2 dt$$

is minimized. In other words, an estimate c of $x(T)$ is required such that if $x(t)$ is the unique solution of Equation (2) satisfying $x(T)=c$, then the mean square difference between $x(t)$ and the observations $z(t)$ is minimized over $[0, T]$.

The above integral object function for minimization can be written as a function of T and the estimate c as follows:

$$\int_0^T [x(t) - z(t)]^2 dt = r(c, T)$$

At this stage, the invariant imbedding idea enters. The original process for fixed T and c is imbedded in a continuous family of processes for $T \geq 0$ and $-\infty < c < +\infty$. The object function is then treated as a differentiable function of T and c . Then, using Taylors theorem along with Equations (1) and (2), the following result is obtained:

$$r_T = [z(t) - c]^2 - f(c, T)f_c \quad (3)$$

where subscripts indicate partial differentiation. This equation is the basis for deriving the estimator equations that constitute the filter algorithm. Also required is a side condition which together with (3) determines r . The

initial data $r(c,0)$ suffices for this purpose. It is assumed that $r(c,0) = k(c - c_0)^2$ where c_0 is an estimate of the initial condition $x(0)$ and k is a scale factor expressing confidence in the estimate c_0 (small k means little confidence). In the preceeding discussion the current time T was fixed for the estimation of $x(T)$.

An estimate for every time $T \geq 0$ is needed. These estimates are denoted by $e(T)$ for $T \geq 0$. Since $e(T)$ are the values of c which minimize $r(c,t)$, it follows that $r_c(e,T) = 0$. Writing out the total derivative $dr_c = 0$ and solving for de/dt , it is found that:

$$\frac{de}{dT} = \frac{-r_{cT}(e,T)}{r_{cc}(e,T)} \quad (5)$$

This equation is an estimator which will be appended to the system equation (1) with the initial condition $e(0) = c_0$, and solved for the optimal estimate $e(T)$ of $x(T)$. First, the functions r_{cT} and r_{cc} appearing in Equation (5) must be determined. Differentiating Equation (3) with respect to c and solving for the expression $-r_{cT}/r_{cc}$, it is seen that the estimator Equation (5) becomes:

$$\frac{de}{dT} = f(e,T) + q(T)(z-e) \quad (6)$$

where the factor $q(T) = 2/\{r_{cc} [e(T),T]\}$. Thus, the estimator equation has the same right-hand side as the original system equation (1) (with the variable T replacing t) except for the addition of the term $z - e$ weighted by $q(T)$. This correction term expresses the weighted difference between observed and calculated values.

Finally, to complete the filter system a differential equation for q is needed. This equation is obtained by differentiation of the expression defining q and further differentiation of Equation (3). The details, which can be

found in Kagiwada (1974, p. 184-186), would add no further understanding to the filter structure. The result is (neglecting f_{ccc}):

$$\frac{dq}{dT} = 2f_c(e,T)(q - q^2) \quad (7)$$

The system Equation (1) (with T replacing t) along with Equations (6) and (7) make up the filter for the scalar example.

In the VARGOW model the governing equation is a vector system for (P, N_L, N_{FGC}) , but the above analysis can be followed without introducing any new ideas. Only notational changes with vectors and matrices appearing in the place of scalars are required. These somewhat tedious modifications can be found in (Lee 1968, pp. 257-260). The final equation will be presented below.

Since data are available only for pressure, only pressure will be observed. The estimates of the reservoir state $[P(T), N_L(T), N_{FGC}(T)]$ for each $T \geq 0$ will minimize the object function:

$$J = \int_0^T [P(t) - P_{ob}(t)]^2 dt$$

where P_{ob} is the observed pressure. Thus, the filter uses the pressure as a tracking variable to obtain estimates of all of the variables (P, N_L, N_{FGC}) minimizing the above object function. Note that this minimization effects all the state variables because the system is coupled.

To write the estimator equations for the VARGOW model we make some notational changes for clarity. The symbols appearing in the definitions are given in SAD section report number 77-10 (USGS 1976).

Let

$$x = (x_1, x_2, x_3)^T, \quad x_1 \equiv P, \quad x_2 \equiv N_L, \quad x_3 \equiv N_{FGC}$$

Superscript T denotes transpose.

$$f_1 = b_1 \frac{(\beta - \rho\gamma)}{W} + \frac{b_2\gamma}{W} - \frac{b_3\beta}{W}$$

$$f_2 = b_1 \frac{(\alpha\gamma - \beta\psi)}{W} - \frac{b_2\gamma}{W} + \frac{b_3\beta}{W}$$

$$f_3 = b_1 \frac{(\rho\psi - \alpha)}{W} + \frac{b_2(1 - \psi)}{W} + \frac{b_3(\alpha - \zeta)}{W}$$

$$F = (f_1, f_2, f_3)$$

Now the VARGOW system can be written in vector form:

$$\dot{x} = (\dot{x}_1, \dot{x}_2, \dot{x}_3)^T = F(x, t) \quad (8)$$

letting

$$r = (0, 0, \int_0^T [x_3^{ob}(\xi) - x_3(\xi)^2 d\xi]$$

where x_3 = pressure and

$$e = (e_1, e_2, e_3)^T$$

$$Q = (q_{ij})$$

$$i, j = 1, 2, 3$$

the estimator equations that are appended to Equation (8) to form the VARGOW filter are:

$$\frac{de}{dT} = F(e,T) + Q(T) [0, 0, 1]^T \left\{ x_3^{ob}(T) - e_3(T) \right\} \quad (9)$$

$$\frac{dQ}{dT} = J_f(e,T) Q(T) + Q(T) J_f(e,T)^T - Q(T) [0, 0, 1]^T [0, 0, 1] Q(T) \quad (10)$$

where e is the vector of optimal estimates of P , N_L , and N_{FGC} at time T , and Q is a matrix of weighting factors analagous to $q(T)$ in Equation (6). Thus, Q is the matrix:

$$Q = 2 \left[\frac{\partial^2 r^{ij}(e,T)}{\partial e^i \partial e^j} \right]^{-1}$$

The term $J_f(e,T)$ is the Jacobian matrix:

$$J_f(e,T) = \left[\frac{\partial f^i}{\partial x^j} \right] \quad (11)$$

The system comprised of Equations (8), (9), and (10) is the VARGOW filter and its corresponding computer program is given in the appendix.

PRELIMINARY TEST

A preliminary test of the filter algorithm as installed in the VARGOW model has been accomplished by performing a numerical experiment. The basic experiment consist of checking "actual" data with the "filtered" results that are based on a "noisy" input pressure history.

The so-called "actual" data has been generated by the VARGOW model without the filter algorithm in place. The VARGOW model has been run with the input parameters listed in Table 1. The "actual" data is the resulting values for pressure, total gas, and total liquid that are predicted on a yearly basis.

Operation of the VARGOW model with the filter algorithm requires the input of a possibly "noisy" history of one of the state variables. For this experiment the "actual" pressure data was perturbed by a random noise component. The random noise component was taken to be a random value on the range -0.6 psi

TABLE 1. Input Parameter Values (see USGS 1976 for Notation)

<u>Parameter</u>	<u>Value</u>
a	0.0
b	8.0
C	0.0
D	5.0
F	2.0
G	0.4
N_L^0	1.0
P	1000.0
r_{OIL}^0	0.001
S^0	0.65
T^0	400.0
v_L^0	4.0
v_R	1.15
ΔOIL	0.15
MODEL	5

thru 0.6 psi. This results in a noise component that is up to $\pm 0.1\%$ of the "actual" pressure. The resulting pressures have been used as the "noisy" pressure input.

The results using the VARGOW model with the filter algorithm are shown in Figures 1 thru 3. The results labeled "Actual" are the "actual" data previously discussed. The results labeled "Filtered" are the predicted values for pressure, total gas, and total liquid that were generated by tracking the "noisy" pressure data using the VARGOW model with the filter algorithm. The parameter values in Table 1 were used for this simulation also.

FIGURE 1. Actual Versus Filtered Pressure

FIGURE 2. Actual Versus Filtered Total Liquid

ACTUAL VS. FILTERED DATA

TIME* 09:47:44 DATE* 09-SEP-80

FIGURE 3. Actual Versus Filtered Total Gas

REFERENCES

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Lee, E. B. 1968. Quasilinearization and Invariant Imbedding Academic Press, New York.

U.S. Geological Survey, Systems Analysis and Development Section. 1976. A Basic Reservoir Per Se Mathematical Model for Determining Ultimate Recovery Functions for a Variable Withdrawal Rate of a Gas-Oil-Water (VARGOW) System. SAD Section Report No. 77-10, U.S. Geological Survey, Conservation Division, Lakewood, CO.

APPENDIX

PROGRAM LISTING FOR VARGOW FILTER

```

*DECK VARGOW
PROGRAM VARGOW3 (INPUT=65,OUTPUT,TAPE5=INPUT,DATA1,PRES1,
TAPE7=DATA1,TAPE9=PRES1,TAPE20,TAPE21,TAPE22)
C FILE NAME IS VARGOW3
C*** SIMULATE SYSTEM
C
COMMON /PRGDATA/
* YSAV(20)
* ,XSAV ,XEVNT(20) ,DXIN ,XEND
* ,XSTART ,EOINT ,XSOL ,DXSOL
* ,NEQ ,XOUT ,DXPRT ,DXPLT
* ,KPLT ,KPASS ,IOUT ,XCUT
* ,CPLT ,POFLG ,PDPRT ,NOPRNT
COMMON /MARKY/ RRRR
LOGICAL
* EOINT ,KPLT ,CPLT ,PDFLG
* ,PDPRT ,NOPRNT
COMMON /CREOF/
LOGICAL
* EOFCR
COMMON /OUTDATA/
* ITITLE(8) ,IPAGE ,NLINE ,ICASE
* ,IDATE ,OUT(50,63) ,NITEM ,LCASE(8)
COMMON /INTDATA/
* XINT ,Y(20) ,DYDX(20)
COMMON /PRBDAT/
* DSEG ,RINIT ,G ,RT
* ,VINIT ,PINIT ,XNINIT ,SO
* ,VR ,A ,B ,DELOIL
* ,DELGAS ,PLIM ,VLIM ,RLIM
* ,FGL ,TO ,C ,XD
* ,MODEL ,W
C
ICASE=0
CALL DATE(IDATE)
C*** DOUNTIL EOF ON CR
50 CONTINUE
ICASE=ICASE+1
CALL RIU
IF(EOFCR) 100,120
100 CONTINUE
PRINT 6000
6000 FORMAT(*1*,10(1H*),*PROGRAM TERMINATED - NO MORE DATA CARDS*)
GO TO 170
C ELSE
120 CONTINUE
KPASS=0
C DOWHILE NOT END OF SIMULATION
130 CONTINUE
IF(EOINT) 160,140
140 CONTINUE
KPASS=KPASS+1
C PRINT 4444, EOINT,EOFCR,KPASS
4444 FORMAT (1H*,2L4,15)
CALL INTF
C PRINT 4445, EOINT,EOFCR,KPASS
4445 FORMAT (2H*,2L4,15)
GO TO 130
160 CONTINUE
C ENDIF
170 CONTINUE
IF(EOFCR) 180,50

```

```

C      ENDDO
180    CONTINUE
      STOP
      END
*DECK RID
      SUBROUTINE RID
C***  READ INPUT DATA
C
      COMMON /CREOF/
      *   EOFCR
      LOGICAL
      *   EOFCR
      COMMON /OUTDAT/
      *   ITITLE(8)      ,IPAGE      ,NLINE      ,ICASE
      *   ,IDATE          ,OUT(50,63) ,NITEM      ,LCASE(8)
      COMMON /PRG DAT/
      *   YSAV(20)
      *   ,XSAV          ,XEVT(20)   ,DXIN       ,XEND
      *   ,XSTART        ,EOINT       ,XSOL       ,DXSOL
      *   ,NEQ           ,XOUT        ,DXPRT      ,DXPLT
      *   ,KPLLOT        ,KPASS       ,IOUT       ,XCUT
      *   ,CPLLOT        ,PDFLG       ,PDPRNT     ,NOPRNT
      LOGICAL
      *   EOINT          ,KPLLOT      ,CPLLOT      ,PDFLG
      *   ,PDPRNT
C
      READ (5,6000)LCASE
6000  FORMAT(8A10)
      IF(EOF(5)) 100,200
100    CONTINUE
      EOFCR=.TRUE.
      GO TO 300
C
      ELSE
200    CONTINUE
      EOFCR=.FALSE.
      IPAGE=1
      CALL ROPROG
      IF(EOFCR) 240,210
210    CONTINUE
      CALL RDEVAL
230    CONTINUE
240    CONTINUE
C
      ENDIF
300    CONTINUE
      RETURN
      END
*DECK ROPROG
      SUBROUTINE ROPROG
C***  READ PROGRAM DATA
C
      COMMON /OUTDAT/
      *   ITITLE(8)      ,IPAGE      ,NLINE      ,ICASE
      *   ,IDATE          ,OUT(50,63) ,NITEM      ,LCASE(8)
      COMMON /PRG DAT/
      *   YSAV(20)
      *   ,XSAV          ,XEVT(20)   ,DXIN       ,XEND
      *   ,XSTART        ,EOINT       ,XSOL       ,DXSOL
      *   ,NEQ           ,XOUT        ,DXPRT      ,DXPLT
      *   ,KPLLOT        ,KPASS       ,IOUT       ,XCUT
      *   ,CPLLOT        ,PDFLG       ,PDPRNT     ,NOPRNT
      LOGICAL
      *   EOINT          ,KPLLOT      ,CPLLOT      ,PDFLG
      *   ,PDPRNT
      COMMON /CREOF/
      *   EOFCR
      COMMON /INTDAT/
      *   XINT           ,Y(20)      ,DYDX(20)

```

```

LOGICAL
* EOFCR
DIMENSION SEVNT(20)
C
NAMESLIST /PROGIN/
* DXIN,XSTART,XEND,DXPRT,DXPLT,KPLOT,XEVNT,CPLLOT,NOPRNT
DATA BIG /1.0E30/
C
C*** INITIALIZE THE EVENT ARRAY
C
IF(ICASE.EQ.1) 50,60
50 CONTINUE
DO 55 I=1,20
    XEVNT(I)=BIG
55 CONTINUE
GO TO 70
C*** ELSE
60 CONTINUE
DO 65 I=1,20
    XEVNT(I)=SEVNT(I)
65 CONTINUE
C*** ENDIF
70 CONTINUE
C
EOINT=.FALSE.
C*** READ PROGRAM RELATED DATA USING A NAMESLIST.
C
READ (7,PROGIN)
IF(EOP(7)) 120,150
120 CONTINUE
PRINT 6100
6100 FORMAT(1H1,*NO PROGIN DATA FOUND*)
EUFCCR=.TRUE.
GO TO 600
C
ELSE
150 CONTINUE
C
C*** SAVE COPY OF EVENTS.
C
DO 105 I=1,20
    SEVNT(I)=XEVT(I)
C
105 CONTINUE
XSOL=XSTART
XINT=XSTART
PRINT 6011,ITITLE,LCASE,IDATE,ICASE,IPAGE
6011 FORMAT(1H1,8A10/1H0,8A10,10X,A10,5X,*CASE*,I3,5X,*PAGE*,I3)
IF(KPLOT)
* WRITE(20,6021) (LCASE(I),I=1,7),ICASE,IDATE
IF(CPLOT)
* WRITE(21,6021) (LCASE(I),I=1,7),ICASE,IDATE
6021 FORMAT(1X,7A10,/,1X,*CASE*,I3,2X,A10)
PRINT 6000
6000 FORMAT(///5X,*PROGRAM RELATED INPUT DATA*//)
PRINT 6010,XSTART,XEND,DXIN,DXPRT,DXPLT,KPLOT,CPLLOT
6010 FORMAT(5X,*XSTART=*,E9.3,5X,*XEND=*,E9.3,5X,*DXIN=*,E9.3,
* 5X,*DXPRT=*,E9.3,5X,*DXPLT=*,E9.3,5X,*KPLOT=*,L2,/
* 5X,*CPLOT=*,L2/)
PRINT 6030
6030 FORMAT(///5X,*EVENT ARRAY*//)
PRINT 6040,(XEVT(I),I=1,20)
6040 FORMAT(1X,7E16.6)
XDUM=XEND-XSTART
IF(XDUM.LT.1.E-10) 200,300
200 CONTINUE
PRINT 6020
6020 FORMAT(6H0****,*TOTAL TIME INTERVAL IS ZERO, CASE TERMINATED.*)
EOINT=.TRUE.

```

```

300 CONTINUE
600 CONTINUE
RETURN
END
*DECK INTF
SUBROUTINE INTF
C*** INTEGRATE THE FUNCTIONS
C
C
COMMON /PRGDATA/
* YSAV(20)
* ,XSAV ,XEVNT(20) ,DXIN ,XEND
* ,XSTART ,EOINT ,XSOL ,DXSOL
* ,NEQ ,XOUT ,DXPRT ,DXPLT
* ,KPLT ,KPASS ,IOUT ,XCUT
* ,CPLOT ,PDFLG ,PDPRT ,NOPRNT
COMMON /INTDATA/
* XINT ,Y(20) ,DYDX(20)
* LOGICAL
* ,EOINT ,KPLT ,CPLOT ,PDFLG
* ,PDPRT ,NOPRNT
COMMON /RSTRT/
* RESTART
* LOGICAL
* RESTART
C
C EXTERNAL EVAL
C
DIMENSION
* XDIF(20) ,YDIF(20,12) ,FDIF(20,12) ,ALLOW(20)
* ,SIZE(20) ,YS(20) ,ALWNC(20)
C
DATA
* IBLCK/-1/ ,ALWNC/20*1.E-7/
* ,ND/20/
C
IF(KPASS.EQ.1)
* HEST=0.01
C
C*** SET OUTPUT FLAG
IOUT=1
C*** EVALUATE FUNCTIONS
CALL EVAL(XINT,Y,DYDX)
C*** MONITOR TERMINAL CONDITIONS
CALL MONITR
C
PRINT 3334,EOINT,XSOL
3334 FORMAT(3H***,L5,F10.4)
IF(EOINT) 100,120
100 CONTINUE
C*** PRODUCE OUTPUT
IOUT=3
CALL OUTPUT
GO TO 180
C*** ELSE
120 CONTINUE
IF(RESTART) 140,160
140 CONTINUE
C*** RESET INTEGRALS TO PREVIOUS VALUES
CALL RITPV
GO TO 170
C*** ELSE
160 CONTINUE
C*** SAVE INTEGRALS AND X VALUES
CALL SIAX
C*** ENDF
170 CONTINUE
C
C*** OUTPUT DATA AT X=XD FOR MODEL 5.

```

```

C
171 IF(PDFLG .AND. PDPKNT) 171,172
    CONTINUE
    IOUT=2
    PDPKNT=.FALSE.
172 CONTINUE
C*** PRODUCE OUTPUT
    CALL OUTPUT
C*** DETERMINE SOLUTION STEP SIZE
    CALL DSSS
C*** PERFORM NUMERICAL INTEGRATION
    ND=NEG
C
    XIN=XSOL
    XOUT=XSOL+DXSOL
    DO 174 I=1,NEQ
        YS(I)=Y(I)
174 CONTINUE
    CALL DIFFEQ(EVAL,NEG,ND,XIN,XOUT,YS,XDIF,YDIF
    * ,FDIF,ALWNC,ALLOW,HEST,SIZE,IBLCK)
    DO 176 I=1,NEQ
        Y(I)=YS(I)
176 CONTINUE
    XINT=XOUT
    XSOL=XINT
    IBLCK=-1

C
C*****
C*** THE FOLLOWING STATEMENT SHOULD HAVE THE C REMOVED IF RESETTING
    HEST FOR EACH INTEGRATION STEP IS DESIRED.
C*****
C
    HEST=0.01
C
C*** ENDIF
180 CONTINUE
    RETURN
    END
*DECK EVAL
    SUBROUTINE EVAL(X,Y,F)
C
C*** EVALUATE INTEGRAND
C
    COMMON /CUTDAT/
    * VU ,PHI ,ZETA ,S
    * ,PSI ,RTOTAL ,TEMP ,SAVV
    * ,SAVP ,SAVR ,SAVT ,VRES
    * ,KOIL ,PRES
    COMMON /PRBDAT/
    * DSEG ,RINIT ,G ,RT
    * ,VINIT ,PINIT ,XNINIT ,SO
    * ,VR ,A ,B ,DELOIL
    * ,DELGAS ,PLIM ,VLIM ,RLIM
    * ,FGL ,TU ,C ,XD
    * ,MODEL ,W
    COMMON /PRGUAT/
    * YSAV(20) ,XEVNT(20) ,DXIN ,XEND
    * ,XSAV ,EOINT ,XSOL ,DXSOL
    * ,XSTART ,XOUT ,DXPRT ,DXPLT
    * ,NEQ ,KPASS ,IOUT ,XCUT
    * ,KPLLOT ,PDFLG ,PDPKNT ,NOPRNT
    LOGICAL
    * EOINT ,KPLLOT ,CPLLOT ,PDFLG
    * ,PDPKNT ,NOPRNT
    COMMON /CREOF/

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```

*      EOFFCR
*      LOGICAL
*      EOFFCR
*      COMMON /OUTDAT/
*      I,ITITLE(8)      ,IPAGE      ,NLINE      ,ICASE
*      ,IDATE      ,OUT(50,63)      ,NITEM      ,LCASE(8)
*      DIMENSION
*      Y(20)      ,F(20)
*      DATA BIG/1.E30/
*      DATA NK/0/

C
C***  CHANGE EVENTS TO THE LARGE VALUE BIG AS THEY ARE REACHED IN
C      THE INTEGRATION.
C
DO 5 I=1,20
  XDUM=ABS(XSOL-XEVNT(I))
  IF(XDUM.LT.1E-5) 2,3
  CONTINUE
  XEVNT(I)=BIG
  IOUT=2
  CONTINUE
  CONTINUE
C***  CALCULATION OF S ***
C
  IF(X.EQ.0)
*    GO TO 10
  ELSE
    RATIO=DSEG/X
  IF(RATIO.GT.230.)
*    GO TO 10
  ELSE
    S=S0/EXP(RATIO)
    GO TO 20
  CONTINUE
  S=0.
  CONTINUE
C***  CALCULATION OF INTERMEDIATE VARIABLES
C
  V0 = VINIT/XNINIT
  PHI = 1./VR+(1.-1./VR)*(Y(3)/PINIT)
  PSI = G*Y(3)/(PINIT+G*Y(3))
  ZETA = RT/Y(3)
  OPHI = (1.-1./VR)/PINIT
  DPSI = (G*PINIT)/((PINIT+G*Y(3))**2)
  DZETA = -RT/(Y(3)**2)
  ALPHA = V0*PHI
  BETA = V0*OPHI*Y(1)+DZETA*Y(2)
  GAMMA = DPSI*Y(1)
  ETA = (1.-S)*Y(2)/Y(1)
  VFG = ZETA*(1.-S)*Y(2)
  VL = V0*PHI*Y(1)
  VRES = VFG+VL
  SIGMA = VFG/VRES
  POWER = A+B*SIGMA
  XKR = 10.**POWER
  TEMP = XKR*V0*PHI/ZETA
  W = BETA*(1.-PSI)+GAMMA*(ALPHA-ZETA)
C
C***  TERMINATE CASE IF W BECOMES VERY SMALL.
C
  WABS=ABS(W)
  IF(WABS.LT.1.E-30) 30,40
  CONTINUE
  PRINT 6010
6010  FORMAT(/1X,* VALUE OF W IS TOO SMALL. CASE TERMINATED.*/)

```

```

      ECINT=.TRUE.
      GO TO 70
C 40  ENDIF
      CONTINUE
C *** RATE EQUATION. THIS CALLS A FUNCTION PIE WHICH NEEDS TO BE
      CHANGED FOR A DIFFERENT MODEL.
      PP= PIE(X,XD,Y,PINIT,DELOIL,MODEL)
C
      RTOTAL = RINIT*((1.+TEMP)/(1.-PSI))*PP
      B0 = ALPHA+ETA*ZETA
      B1 = -RTOTAL-C*FGL*(1.+ETA)*(PINIT-Y(3))/B0
      B2 = -C*(1.+FGL)*(PINIT-Y(3))
      FAC1 = TEMP
      FAC2 = (PSI+FAC1)/(1.+FAC1)
      FAC3 = C*FGL*(PSI+ETA)*(PINIT-Y(3))/B0
      B3 = -FAC2*RTOTAL-FAC3
C
      COEF1= B1*(BETA-GAMMA*ZETA)/W
      COEF2= B2*GAMMA/W
      COEF3= B3*BETA/W
      COEF4= B1*(ALPHA*GAMMA-BETA*PSI)/W
      COEF5= B1*(PSI*ZETA-ALPHA)/W
      COEF6= B2*(1.-PSI)/W
      COEF7= B3*(ALPHA-ZETA)/W
      COEF8= C*FGL*ETA*(PINIT-Y(3))
      COEF9= V0*PHI+ZETA*ETA
      COEF10=C*FGL*PSI*(PINIT-Y(3))
      COEF20=C*FGL*(1.-PSI)*(PINIT-Y(3))
C *** PRIMARY EQUATIONS TO BE INTEGRATED.
C
      F(1) = COEF1+COEF2-COEF3
      F(2) = COEF4-COEF2+COEF3
      F(3) = COEF5+COEF6+COEF7
C *** CALCULATION OF INTERMEDIATE VARIABLES FOR THE
      ESTIMATOR EQUATIONS
C
      DDPSI = -2.*G*G*PINIT/((PINIT+G*Y(3))**3)
      DDZETA = 2.*RT/(Y(3)**3)
      VZ = VRES*VRES
      SIGMA1 = -V0*VFG*PHI/VZ
      SIGMA2 = (1.-S)*ZETA*(VRES-VFG)/VZ
      SIGMA3 = (DZETA*Y(2)*(1.-S)*(VRES-VFG)-VFG*V0*DPhi*Y(1))/VZ
      PT = V0*PHI*XKR*ALOG(10.)*B/ZETA
      TEMP1 = PT*SIGMA1
      TEMP2 = PT*SIGMA2
      TEMP3 = PT*SIGMA3 + V0*XKR*(ZETA*DPhi - PHI*DZETA)/(ZETA*ZETA)
      RTOT1 = RINIT*TEMP1*PP/(1.-PSI)
      RTOT2 = RINIT*TEMP2*PP/(1.-PSI)
      RTOT3 = RINIT*PP*((1.-PSI)*TEMP3 + (1.+TEMP)*DPSI)/((1.-PSI)**2)
      IF(MODEL.EQ.4)41,42
C 41  CONTINUE
      RTOT3 = RTOT3 + RINIT*(1.+TEMP)/(PINIT*(1.-PSI))
C 42  ENDIF
      CONTINUE
      W1 = V0*DPhi*(1.-PSI) + DPSI*(ALPHA-ZETA)
      W2 = DZETA*(1.-PSI)
      W3 = -BETA*DPSI + (1.-PSI)*Y(2)*DDZETA
      * +GAMMA*V0*DPhi - GAMMA*DZETA
      * +(ALPHA-ZETA)*Y(1)*DDPSI
      FB = C*FGL*(PINIT-Y(3))*(1.-S)
      B11 = -RTOT1 - FB*Y(2)*(ZETA-ALPHA)/((Y(1)*B0)**2)
      B12 = -RTOT2 - FB*(ALPHA-ZETA)/(Y(1)*B0**2)
      B13 = -RTOT3 + C*FGL*(1.+ETA)*(B0*(PINIT-Y(3))*(V0*DPhi +
      * ETA*DZETA))/(B0*B0)

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```

FA = -(1.-PSI)/((1. + TEMP)**2)
FAC21 = TEMP1*FA
FAC22 = TEMP2*FA
FAC23 = TEMP3*FA + DPSI/(1.+TEMP)
FAC31 = FB*(ZETA*PSI-ALPHA)*Y(2)/((B0*Y(1))**2)
FAC32 = FB*(ALPHA-ZETA*PSI)/(Y(1)*B0*B0)
FAC33 = C*FGL*(B0*(PINIT-Y(3))*UPSI-PSI-ETA)
      -(PSI+ETA)*(PINIT-Y(3))*(V0*DPHI + ETA*DZETA))/(B0*B0)
*
B31 = -(FAC2*RTOT1 + RTOTAL*FAC21 + FAC31)
B32 = -(FAC2*RTOT2 + RTOTAL*FAC22 + FAC32)
B33 = -(FAC2*RTOT3 + RTOTAL*FAC23 + FAC33)
COEF11 = B1*(V0*DPHI - ZETA*DPSI) + (BETA-GAMMA*ZETA)*B11
COEF12 = B1*DZETA + (BETA-GAMMA*ZETA)*B12
COEF13 = B1*(Y(2)*DDZETA - GAMMA*DZETA - ZETA*Y(1)*DDPSI)
      + (BETA - GAMMA*ZETA)*B13
*
COEF21 = B2*DPSI
COEF23 = B2*Y(1)*DDPSI + GAMMA*C*(1.+FGL)
COEF31 = B3*V0*DPHI + BETA*B31
COEF32 = B3*UZETA + BETA*B32
COEF33 = B3*Y(2)*DDZETA + BETA*B33
COEF41 = B1*(ALPHA*DPSI - PSI*V0*DPHI) + (ALPHA*GAMMA-BETA*PSI)*B11
COEF42 = -B1*PSI*DZETA + (ALPHA*GAMMA - BETA*PSI)*B12
COEF43 = B1*(ALPHA*Y(1)*DDPSI + GAMMA*V0*DPHI -BETA*DPSI
      -PSI*Y(2)*DDZETA) + (ALPHA*GAMMA - BETA*PSI)*B13
*
COEF51 = (PSI*ZETA - ALPHA)*B11
COEF52 = (PSI*ZETA - ALPHA)*B12
COEF53 = B1*(PSI*DZETA+ZETA*DPSI -V0*DPHI)*(PSI*ZETA - ALPHA)*B13
COEF63 = -B2*DPSI + (1.-PSI)*C*(1.+FGL)
COEF71 = (ALPHA-ZETA)*B31
COEF72 = (ALPHA-ZETA)*B32
COEF73 = B3*(V0*DPHI-DZETA) + (ALPHA - ZETA)*B33
C
C*** CALCULATION OF THE JACOBIAN OF F
C
F11 = (COEF11 +COEF21 - COEF31 -F(1)*W1)/W
F12 = (COEF12 +COEF32 - F(1)*W2)/W
F13 = (COEF13 + COEF23 - COEF33 - F(1)*W3)/W
F21 = (COEF41 - COEF21 +COEF31 - F(2)*W1)/W
F22 = (COEF42 + COEF32 - F(2)*W2)/W
F23 = (COEF43 - COEF23 + COEF33 - F(2)*W3)/W
F31 = (COEF51 + COEF71 - F(3)*W1)/W
F32 = (COEF52 + COEF72 - F(3)*W2)/W
F33 = (COEF53 + COEF63 + COEF73 - F(3)*W3)/W
C
C*** OBSERVED PRESSURE
C
C
C
C
C*** SIMULATE OBSERVED PRESSURE
C
IF(NK.GT.0) GO TO 6
IF(X.GT.0.)GO TO 6
TNO=0.
PR0=PINIT
OP=PINIT
PR=1000.
PR1=PINIT
PRINT 223,X,PR,PR1,OP,Y(3)
TN1=TNO+1.
READ(9,*)PR
SUM=0.
DO 18 I=1,12
X1=РАНF(0.)
SUM= SUM+X1
CONTINUE
R=SUM/6.
PR1=PR+.1*R
18

```

```

      NK = NK + 1
      GO TO 33
      IF (X.GT.TN1) GO TO 7
      OP=PR0+(PR1-PR0)*(X-TN0)
      GO TO 8
      PR0=PR1
      TN0=TN1
      PRINT 223,TN1,X,PR,PR1,OP,Y(3)
      TN1=TN0+1
      READ(9,*)PR
      SUM=0.
      DO 19 I=1,12
      X1=RANF(0.)
      SUM=SUM+X1
      CONTINUE
      R=SUM-6.
      PR1=PR+.1*R
      OP=PR0+(PR1-PR0)*(X-TN0)
      CONTINUE
      PRINT 223,X,PR,PR1,OP,Y(3)
      FORMAT(1X,6F15.7)
      CONTINUE
      SUM = 0.
      DO 43 I=1,12
      X1=RANF(0.)
      SUM= SUM+X1
      CONTINUE
      R=SUM-6.
      OP=Y(3) + .1*R
      C*** ESTIMATOR EQUATIONS
      F(1) = F(1) + Y(12)*(OP + Y(3))
      F(2) = F(2) + Y(15)*(OP - Y(3))
      F(3) = F(3) + Y(18)*(OP - Y(3))
      F(10) = F11*Y(10)+F12*Y(13)+F13*Y(16)+F11*Y(10)+F12*Y(11)
      *      +F13*Y(12)-Y(12)*Y(10)
      F(11) = F11*Y(11)+F12*Y(14)+F13*Y(17)+F21*Y(10)+F22*Y(11)
      *      +F23*Y(12)-Y(12)*Y(11)
      F(12) = F11*Y(12)+F12*Y(15)+F13*Y(18)+F31*Y(10)+F32*Y(11)
      *      +F33*Y(12)-Y(12)*Y(12)
      F(13) = F21*Y(10)+F22*Y(13)+F23*Y(16)+F11*Y(13)+F12*Y(14)
      *      +F13*Y(15)-Y(15)*Y(10)
      F(14) = F21*Y(11)+F22*Y(14)+F23*Y(17)+F21*Y(13)+F22*Y(14)
      *      +F23*Y(15)-Y(15)*Y(11)
      F(15) = F21*Y(12)+F22*Y(15)+F23*Y(18)+F31*Y(13)+F32*Y(14)
      *      +F33*Y(15)-Y(15)*Y(12)
      F(16) = F31*Y(10)+F32*Y(13)+F33*Y(16)+F11*Y(16)+F12*Y(17)
      *      +F13*Y(18)-Y(18)*Y(10)
      F(17) = F31*Y(11)+F32*Y(14)+F33*Y(17)+F21*Y(16)+F22*Y(17)
      *      +F23*Y(18)-Y(18)*Y(11)
      F(18) = F31*Y(12)+F32*Y(15)+F33*Y(18)+F31*Y(16)+F32*Y(17)
      *      +F33*Y(18)-Y(18)*Y(12)
      C*** WATER INVASION EQUATIONS
      F(4) = COEF8/COEF9
      F(5) = COEF10/COEF9
      F(6) = COEF20/COEF9
      C*** ULTIMATE RECOVERY EQUATIONS
      F(7) = (1.-PSI)*RTOTAL/(1.+TEMP)
      F(8) = TEMP*RTOTAL/(1.+TEMP)
      F(9) = PSI*RTOTAL/(1.+TEMP)
      C*** TERMINATE CASE IF F(2) IS NEGATIVE ON THE FIRST PASS.

```

```

C      IF(F(2).LT.0.0 .AND. KPASS.EQ.1) 50,60
C50      CONTINUE
C      PRINT 6020
6020      FORMAT(/1X,* INITIAL VALUE OF THE DERIVATIVE OF TOTAL GAS IS*
*          ,* NEGATIVE. CASE TERMINATED.*/)
C      PRINT 3333, EQINT,EOFCR,KPASS,XSOL
3333      FORMAT (2L4,I4,F10.4)
C      EQINT=.TRUE.
C      PRINT 3333, EQINT,EOFCR,KPASS,XSOL
C      ENDIF
C60      CONTINUE
C
C
70      CONTINUE
      RETURN
      END
*DECK PIE
      FUNCTION PIE(X,XD,Y,PINIT,DELOIL,MODEL)
C
C***      THIS FUNCTION SELECTS THE DESIRED RATE MODEL.
C
      DIMENSION Y(20)
C
      IF(MODEL.EQ.1 .OR. MODEL.EQ.2 .OR. MODEL.EQ.3 .OR. MODEL.EQ.5)
10      *      10,40
      CONTINUE
      IF(X.LT.XD) 20,30
20      CONTINUE
      PIE=1.
      GO TO 100
C
      ELSE
30      CONTINUE
      PIE=1./EXP(DELOIL*(X=XD))
      GO TO 100
C
      ENDIF
C
      ENDIF
40      CONTINUE
      IF(MODEL.EQ.4) 50,60
50      CONTINUE
      PIE=Y(3)/PINIT
      GO TO 100
C
      ENDIF
60      CONTINUE
      PRINT 6000
6000      FORMAT(/* NO RATE MODEL CHOSEN*/)
100      CONTINUE
      RETURN
      END
*DECK RDEVAL
      SUBROUTINE RDEVAL
C***      READ INPUT DATA FOR FUNCTIONS
      COMMON /PRGDAT/
      *      YSAV(20)
      *      ,XSAV      ,XEVRT(20)      ,DXIN      ,XEND
      *      ,XSTART    ,EQINT      ,XSOL      ,DXSOL
      *      ,NEQ      ,XOUT      ,DXPRT      ,DXPLT
      *      ,KPLUT      ,KPASS      ,IOUT      ,XCUT
      *      ,CPLOT      ,PDFLG      ,PDPRT      ,NOPRNT
      *      LOGICAL
      *      ,EQINT      ,KPLOT      ,CPLOT      ,PDFLG
      *      ,PDPRT      ,NOPRNT
      *
      COMMON /PRBDAT/
      *      USEG      ,RINIT      ,G      ,RT
      *      ,VINIT      ,PINIT      ,XNINIT      ,SO
      *      ,VR      ,A      ,B      ,DELOIL
      *      ,DELGAS      ,PLIM      ,VLM      ,RLIM
      *      ,FGL      ,TO      ,C      ,XO

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```

*      ;MODEL      ,W
COMMON /CREOF/
*      EOF CR
LOGICAL
*      EOF CR
COMMON /INTDAT/
*      XINT      ,Y(20)      ,DYDX(20)
NAMELIST /PROBOT/
*      DSEG      ,RINIT      ,G
*      ,VINIT      ,PINIT      ,XNINIT      ,SO
*      ,VR      ,A      ,B      ,DELOIL
*      ,DELGAS      ,PLIM      ,VLIM      ,RLIM
*      ,FGL      ,TO      ,C
*      ;MODEL
DATA NEQ/18/
C
C*** INITIALIZE SWITCHES FOR RATE MODEL S.
C
PDFLG=.FALSE.
PDPRT=.TRUE.
C
READ (7,PROBOT)
IF (EOF(7)) 100,200
100 CONTINUE
PRINT 6100
6100 FORMAT(1H1,*NO PROB DATA FOUND*)
EOF CR=.TRUE.
GO TO 300
C
ELSE
200 CONTINUE
RT=TO*19.330769
C
C*** INITIALIZE MODEL PARAMETERS
C
IF (MODEL.EQ.1 .OR. MODEL.EQ.2)
*      XD=0.
IF (MODEL.EQ.3 .OR. MODEL.EQ.5)
*      XD=1.E+30
C
C*** INITIALIZE INTEGRALS.
C
Y(1)=XNINIT
Y(2)=0.
Y(3)=PINIT
DO 250 I=4,20
250 Y(I)=0.
CONTINUE
C
C*** INITIALIZE Q MATRIX
C
DO 251 I=10,18
251 READ(9,*) Y(I)
CONTINUE
C
PRINT 6005
6005 FORMAT(///5X,*PROBLEM RELATED INPUT DATA*//)
PRINT 6010,DSEG,XNINIT,RINIT,PINIT,VINIT,TO,SO,G,A,B,C,DELOIL
*      ,DELGAS,VLIM,PLIM,RLIM,FGL,VR
6010 FORMAT(5X,*DSEG=*,E9.3,5X,*XNINIT=*,E9.3,5X,*RINIT=*,E9.3,
*      5X,*PINIT=*,E9.3,5X,*VINIT=*,E9.3,5X,*TO=*,E9.3,
*      5X,*SO=*,E9.3,5X,*G=*,E9.3,5X,*A=*,E9.3,
*      5X,*B=*,E9.3,5X,*C=*,E9.3,5X,*DELOIL=*,E9.3,
*      5X,*DELGAS=*,E9.3,5X,*VLIM=*,E9.3,5X,*PLIM=*,E9.3,
*      5X,*RLIM=*,E9.3,5X,*FGL=*,E9.3,5X,*VR=*,E9.3,/)
C
C*** IF PLOT OUTPUT WANTED WRITE PRBLEM DATA RECORD ON DISK
C
IF (KPLT)

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```

* WRITE(20,6040) DSEG,XNINIT,RINIT,PINIT,VINIT,TO,SO,G,A,B,C
* ,DELOIL,DELGAS,VLIM,PLIM,RLIM,FGL,VR,DXPLT,MODEL
* IF(CPLOT)
* WRITE(21,6040) DSEG,XNINIT,RINIT,PINIT,VINIT,TO,SO,G,A,B,C
* ,DELOIL,DELGAS,VLIM,PLIM,RLIM,FGL,VR,DXPLT,MODEL
6040 * FORMAT(5X,* DSEG =*,E9.3,5X,*XNINIT =*,E9.3,5X,*RINIT =*,E9.3,/,
* 5X,*PINIT =*,E9.3,5X,*VINIT =*,E9.3,5X,* TO =*,E9.3,/,
* 5X,* SO =*,E9.3,5X,* G =*,E9.3,5X,* A =*,E9.3,/,
* 5X,* B =*,E9.3,5X,* C =*,E9.3,5X,*DELOIL =*,E9.3,/,
* 5X,*DELGAS =*,E9.3,5X,* VLIM =*,E9.3,5X,* PLIM =*,E9.3,/,
* 5X,* RLIM =*,E9.3,5X,* FGL =*,E9.3,5X,* VR =*,E9.3,/,
* 5X,*DXPLT =*,E9.3,5X,*MODEL =*,12)
C
C*** PRINT DISPLAY OF DESIRED RATE EQUATION.
C
* IF(MODEL.EQ.1)
* PRINT 6020,DELOIL
6020 * FORMAT(/5X,*RATE MODEL 1*,//,10X,*ROIL = RINIT EXP(-*,F4.3,* X)*)
C
* IF(MODEL.EQ.2)
* PRINT 6030,DELOIL
6030 * FORMAT(/5X,*RATE MODEL 2*,//,10X,*ROIL = RINIT EXP(-*,F4.3,* X)*)
C
* IF(MODEL.EQ.3)
* PRINT 6080
6080 * FORMAT(/5X,*RATE MODEL 3*,//,10X,*ROIL = RINIT*)
C
C
C
* IF(MODEL.EQ.4)
* PRINT 6050
6050 * FORMAT(/5X,*RATE MODEL 4*,//,10X,*ROIL = RINIT PRES/PINIT*)
C
* IF(MODEL.EQ.5)
* PRINT 6060,DELOIL
6060 * FORMAT(/5X,*RATE MODEL 5*,//,10X,*ROIL = RINIT*,24X,*WHEN X IS *
* ,*LESS THAN OR EQUAL TO XD.*,//,10X,*ROIL = RINIT EXP(-*
* ,F4.3,* (X-XD))*6X,*WHEN X IS GREATER THAN XD.*,//,46X
* ,*XD IS THE TIME AT WHICH THE PRESSURE EQUALS 0.6 RINIT*)
300 CONTINUE
RETURN
END
*DECK MONITR
SUBROUTINE MONITR
C
C*** MONITOR TERMINAL CONDITIONS
C
COMMON /INTDAT/
* XINT ,Y(20) ,DYDX(20)
COMMON /CUTDAT/
* VO ,PHI ,ZETA ,S
* ,PSI ,RTOTAL ,TEMP ,SAVV
* ,SAVP ,SAVR ,SAVT ,VRES
* ,ROIL ,PRES
COMMON /PRG DAT/
* YSAV(20)
* ,XSAV ,XEVT(20) ,DXIN ,XEND
* ,XSTART ,EQINT ,XSOL ,DXSOL
* ,NEQ ,XOUT ,DXPRT ,DXPLT
* ,KPLOT ,KPASS ,IOUT ,XCUT
* ,CPLOT ,PDFLG ,NOPRNT
LOGICAL
* ,EQINT ,KPLOT ,CPLOT ,PDFLG
* ,NOPRNT
COMMON /PRSDAT/
* DSEG ,RINIT ,G ,RT
* ,VINIT ,PINIT ,XNINIT ,SO
* ,VR ,A ,B ,DELOIL
* ,DELGAS ,PLIM ,VLIM ,RLIM
* ,FGL ,TO ,C ,XD

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```

*      ;MODEL      ;W
COMMON /RSTRT/
*      RESTART
LOGICAL
*      RESTART
COMMON /CREOF/
*      EOFFCR
LOGICAL
*      EOFFCR
DATA BIG/1.E30/
C
C*** INITIALIZE CUTOFFS
C
PDTIME=BIG
C
IF(KPASS.EQ.1) 3,5
3
CONTINUE
PCTIME=BIG
VCTIME=BIG
RCTIME=BIG
C
ENDIF
5
CONTINUE
RESTART=.FALSE.
C
C*** ON FIRST CALL SET OVERSHOOT COUNTS TO ZERO.
C
IF(KPASS.EQ.1) 10,20
10
CONTINUE
PDCOUNT=0
NPCOUNT=0
NRCOUNT=0
NVCOUNT=0
20
CONTINUE
C
C*** PRINT WARNING IF Y(1), Y(2), OR Y(3) BECOMES NEGATIVE.
C
DO 30 I=1,3
IF(Y(I).LT.0.)
*      PRINT 6000,1,Y(I),XSOL
6000 *      FORMAT(/1X,*WARNING Y(*,I1,*) = *,E14.6,* IS NEGATIVE AT TIME*
*      ,* = *,E14.6,/)
C
ENDIF
30
CONTINUE
C
C*** CHECK IF TIME LIMIT IS REACHED
C
XDUM=ABS(XSOL-XEND)
IF(XDUM.LT.1.E-5) 100,200
100
CONTINUE
EOINT=.TRUE.
GO TO 500
C
ELSE
200
CONTINUE
CHECK IF P,V,R CUTOFF IS REACHED
CALL PMON(PCTIME,NPCOUNT)
CALL VMON(VCTIME,NVCOUNT)
CALL RMON(RCTIME,NRCOUNT)
IF(MODEL.EQ.5 .AND. .NOT. PDFLG)
*      CALL PDMON(PDTIME,LPCOUNT)
C
IF(RESTART) 220,225
220
CONTINUE
EOINT=.FALSE.
GO TO 230
C
ELSE
225
CONTINUE
SAVV=VRES
SAVP=PRES
SAVR=RUIL

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```

      SAVT=XSOL
C230  ENDIF
      CONTINUE
C      IGNORE CUTOFF PREDICTIONS FOR PAST TIMES.
C      IF(PCTIME.LE.SAVT)
C*      PCTIME=BIG
C      IF(VCTIME.LE.SAVT)
C*      VCTIME=BIG
C      IF(RCTIME.LE.SAVT)
C*      RCTIME=BIG
C      IF(PDIME.LE.SAVT)
C*      PDIME=BIG
C      XCUT=AMIN1(PCTIME,VCTIME,RCTIME,PDIME)
C      ENDIF
C500  CONTINUE
      RETURN
      END
*DECK PMON
      SUBROUTINE PMON(PCTIME,NPCOUNT)
C***  CALCULATE PRESSURE CUTOFF TIME
C      COMMON /CUTDAT/
C*      VO          ,PHI          ,ZETA          ,S
C*      ,PSI        ,RTOTAL      ,TEMP          ,SAVV
C*      ,SAVP       ,SAVR        ,SAVT          ,VRES
C*      ,KOIL       ,PRES
C      COMMON /INTDAT/
C*      XINT        ,Y(20)        ,DYDX(20)
C      COMMON /PRG DAT/
C*      YSAV(20)
C*      ,XSAV       ,XEVT(20)    ,DXIN          ,XEND
C*      ,XSTART     ,EQINT       ,XSOL          ,DXSOL
C*      ,NEG        ,XOUT        ,DXPRT        ,DXPLT
C*      ,KPLOT      ,KPASS       ,IOUT         ,XCUT
C*      ,CPLOT      ,PDFLG      ,POPRNT        ,NOPRNT
C      LOGICAL
C*      EQINT       ,KPLOT       ,CPLOT         ,POFLG
C*      ,POPRNT     ,NOPRNT
C      COMMON /PRSDAT/
C*      USEG        ,RINIT       ,G            ,RT
C*      ,VINIT      ,PINIT       ,XNINIT      ,SO
C*      ,VR         ,A           ,B            ,DELOIL
C*      ,DELGAS     ,PLIM        ,VLIM        ,RLIM
C*      ,FGL        ,TO         ,C            ,XD
C*      ,MODEL      ,W
C      COMMON /RSTRT/
C*      RESTART
C      LOGICAL
C*      RESTART
C***  CALCULATE PRESSURE
C      PRES=Y(3)
C      IF(KPASS.EQ.1) 10,20
C10    CONTINUE
          SVDXIN=UXIN
          NPCNT=0
          NPCOUNT=0
          GO TO 100
C      ELSE
C20    CONTINUE

```

```

C*** CHECK IF PRESSURE EQUALS PLIM
C
    PDIF=ABS(PLIM-PRES)
    IF (PDIF.LT.0.0001*PLIM) 30,40
30      CONTINUE
        DXIN=SVDXIN
        EOINT=.TRUE.
        GO TO 100
    ELSE
C40      CONTINUE
C*** COMPUTE PRESSURE DERIVED CUTOFF TIME
C
        PDUM=ABS(PRES-SAVP)
        IF (PDUM.GT.1.E-30) 42,44
C42      CONTINUE
            PCTIME=SAVT+(PLIM-SAVP)*(XSOL-SAVT)/(PRES-SAVP)
            GO TO 46
        ELSE
C44      CONTINUE
            PCTIME=1.0E+30
C46      CONTINUE
C*** CHECK IF PRESSURE GREATER THAN PLIM
C
        PCO=0.9999*PLIM
        IF (PRES.GT.PCO) 50,60
50      CONTINUE
            NPCOUNT=0
            NPCNT=0
            GO TO 100
        ELSE
C60      CONTINUE
            RESTART=.TRUE.
            NPCOUNT=NPCOUNT+1
            NPCNT=NPCNT+1
C
C*** CHECK IF PRESSURE OVERSHOOT COUNT LIMIT IS REACHED
C
        IF (NPCNT.GE.10) 62,64
62      DXIN=DXIN/2.
            NPCNT=0
C64      CONTINUE
            IF (NPCOUNT.GE.100) 70,80
70      CONTINUE
            PRINT 6010
6010    FORMAT(/,10X,*PRESSURE OVERSHOOT COUNT LIMIT REACHED*)
            RESTART=.FALSE.
            EOINT=.TRUE.
C80      ENDIF
            CONTINUE
C80      ENDOIF
C80      ENDOIF
C100     ENDOIF
        CONTINUE
        RETURN
    END
*DECK PUMON
    SUBROUTINE PDMON(PDTIME,LPCOUNT)
C*** CALCULATE PRESSURE CUTOFF TIME
C
    COMMON /CUTDAT/
    *      VO      ,PHI      ,ZETA      ,S
    *      ,PSI     ,RTOTAL   ,TEMP     ,SAVV

```

```

*      ,SAVP      ,SAVR      ,SAVT      ,VRES
*      ,KUIL      ,PRES
COMMON /INTDAT/
*      ,XINT      ,Y(20)      ,DYDX(20)
COMMON /PRG DAT/
*      ,YSAV(20)
*      ,XSAV      ,XEVT(20)      ,DXIN      ,XEND
*      ,XSTART      ,EOINT      ,XSOL      ,DXSOL
*      ,NEQ      ,XOUT      ,DXPRT      ,DXPLT
*      ,KPLOT      ,KPASS      ,IOUT      ,XCUT
*      ,CPLOT      ,PDFLG      ,PDPRNT      ,NOPRNT
LOGICAL
*      ,EOINT      ,KPLOT      ,CPLOT      ,PDFLG
*      ,PDPRNT      ,NOPRNT
COMMON /PRBDAT/
*      ,DSEG      ,RINIT      ,G      ,RT
*      ,VINIT      ,PINIT      ,XNINIT      ,SQ
*      ,VR      ,A      ,B      ,DELOIL
*      ,DEL GAS      ,PLIM      ,VLIM      ,RLIM
*      ,FGL      ,TU      ,C      ,XD
*      ,MODEL      ,W
COMMON /RSTRT/
*      ,RESTART
LOGICAL
*      ,RESTART
C
C*** CALCULATE PRESSURE
C
PRES=Y(3)
PU=0.6*PINIT
C
IF(KPASS.EQ.1) 10,20
10 CONTINUE
LPCOUNT=0
SVDXIN=DXIN
LPCNT=0
GO TO 100
C
ELSE
20 CONTINUE
C
C*** CHECK IF PRESSURE EQUALS 0.6*PINIT
C
PDIF=ABS(PU-PRES)
IF(PDIF.LT.0.00006*PINIT) 30,40
30 CONTINUE
DXIN=SVDXIN
PDFLG=.TRUE.
XD=XSOL
GO TO 100
C
ELSE
40 CONTINUE
C
C*** COMPUTE PRESSURE DERIVED CUTOFF TIME
PDUM=ABS(PRES-SAVP)
IF(PDUM.GT.1.E-30)42,44
42 CONTINUE
C
PDTIME=SAVT+(PD-SAVP)*(XSOL-SAVT)/(PRES-SAVP)
GO TO 46
C
ELSE
44 PCTIME=1.0E+30
46 CONTINUE
C*** CHECK IF PRESSURE GREATER THAN PD
C
PCO=0.99994*PD
IF(PRES.GT.PCO) 50,60
50 CONTINUE

```

```

        LPCOUNT=0
        LPCNT=0
        GO TO 100
C
60      ELSE
        CONTINUE
        RESTART=.TRUE.
        LPCOUNT=LPCOUNT+1
        LPCNT=LPCNT+1
C
C*** CHECK IF PRESSURE OVERSHOOT COUNT LIMIT IS REACHED
C
        IF(LPCNT.GE.10) 62,64
62      DXIN=DXIN/2.
        LPCNT=0
64      CONTINUE
C
        IF(LPCOUNT.GE.100) 70,80
70      CONTINUE
        PRINT 6010
6010    FORMAT(/,10X,*INTERMEDIATE PRESSURE OVERSHOOT COUNT LIMIT*,
        *T REACHED*)
        RESTART=.FALSE.
        EOINT=.TRUE.
C
        ENDIF
80      CONTINUE
C
        ENDIF
C
        ENDIF
C
        ENDIF
100     CONTINUE
        RETURN
        END
*DECK VMON
        SUBROUTINE VMON(VCTIME,NVCOUNT)
C
C*** CALCULATE VOLUME CUTOFF TIME
C
        COMMON /CUTDAT/
        *      VO          ,PHI          ,ZETA          ,S
        *      ,PSI        ,RTOTAL       ,TEMP          ,SAVV
        *      ,SAVP       ,SAVR         ,SAVT           ,VRES
        *      ,KOIL
        COMMON /INTDAT/
        *      XINT        ,Y(20)        ,DYDX(20)
        COMMON /PRGDAT/
        *      YSAV(20)
        *      ,XSAV       ,XEVT(20)     ,DXIN          ,XEND
        *      ,XSTART     ,EOINT        ,XSOL          ,DXSOL
        *      ,NEQ        ,XOUT         ,DXPRT         ,DXPLT
        *      ,KPLOT      ,KPASS        ,IOUT          ,XCUT
        *      ,CPLOT      ,PDFLG        ,POPRNT         ,NOPRNT
        LOGICAL
        *      EOINT      ,KPLOT        ,CPLOT          ,PDFLG
        *      ,POPRNT    ,NOPRNT
        COMMON /PRBDAT/
        *      DSEG        ,RINIT        ,G              ,RT
        *      ,VINIT      ,PINIT       ,XNINIT         ,SO
        *      ,VR         ,A           ,B              ,DELOIL
        *      ,DELGAS     ,PLIM        ,VLIM           ,RLIM
        *      ,FGL        ,TO          ,C              ,XO
        *      ,MODEL      ,W
        COMMON /RSTRT/
        *      RESTART
        LOGICAL
        *      RESTART
C
C*** CALCULATE VOLUME
C
        VRES=VO*PHI*Y(1)+ZETA*(1.-S)*Y(2)

```

```

C
10 IF(KPASS.EQ.1) 10,20
   CONTINUE
   SVDXIN=DXIN
   NVCNT=0
   NVCOUNT=0
   GO TO 100
C
20 ELSE
   CONTINUE
C*** CHECK IF VOLUME EQUALS VLIM
   VDIF=ABS(VLIM-VRES)
   IF(VDIF.LT.0.0001*VLIM) 30,40
30   CONTINUE
   DXIN=SVDXIN
   EQINT=.TRUE.
   GO TO 100
C
40 ELSE
   CONTINUE
C*** COMPUTE VOLUME DERIVED CUTOFF TIME
   VDUM=ABS(VRES-SAVV)
   IF(VDUM.GT.1.E-30) 42,44
42   CONTINUE
   VCTIME=SAVT+(VLIM-SAVV)*(XSOL-SAVT)/(VRES-SAVV)
C
   GO TO 46
C
44   ELSE
   CONTINUE
46   VCTIME=1.0E+30
   CONTINUE
C*** CHECK IF VOLUME GREATER THAN VLIM
   VCO=0.9999*VLIM
   IF(VRES.GT.VCO) 50,60
50   CONTINUE
   NVCOUNT=0
   NVCNT=0
   GO TO 100
C
60   ELSE
   CONTINUE
   RESTART=.TRUE.
   NVCOUNT=NVCOUNT+1
   NVCNT=NVCNT+1
C*** CHECK IF VOLUME OVERSHOOT COUNT LIMIT IS REACHED
   IF(NVCNT.GE.10) 62,64
62   DXIN=DXIN/2.
   NVCNT=0
64   CONTINUE
C
   IF(NVCOUNT.GE.100) 70,80
70   CONTINUE
   PRINT 6010
6010  FORMAT(/,10X,*VOLUME OVERSHOOT COUNT LIMIT REACHED*)
   RESTART=.FALSE.
   EQINT=.TRUE.
C
   ENDIF
80   CONTINUE
C
   ENDIF
C
   ENDIF
100  CONTINUE

```

```

RETURN
END
*DECK RMUN
SUBROUTINE RMUN(RCTIME,NRCOUNT)
C
C*** CALCULATE RATE CUTOFF TIME
C
COMMON /CUTDAT/
*   VU          ,PHI          ,ZETA          ,S
*   ,PSI        ,RTOTAL      ,TEMP         ,SAVV
*   ,SAVP       ,SAVR        ,SAVT         ,VRES
*   ,ROIL       ,PRES
COMMON /INTDAT/
*   XINT        ,Y(20)       ,DYDX(20)
COMMON /PRG DAT/
*   YSAV(20)
*   ,XSAV       ,XEVT(20)    ,DXIN         ,XEND
*   ,XSTART     ,EOINT       ,XSOL         ,DXSOL
*   ,NEQ        ,XOUT        ,DXPRT       ,DXPLT
*   ,KPLOT      ,KPASS       ,IOUT        ,XCUT
*   ,CPLUT      ,PDFLG      ,PDPRNT      ,NOPRNT
LOGICAL
*   EOINT       ,KPLOT      ,CPLUT       ,PDFLG
*   ,PDPRNT    ,NOPRNT
COMMON /PRBDAT/
*   USEG       ,RINIT       ,G           ,RT
*   ,VINIT     ,PINIT      ,XNINIT      ,SO
*   ,VR        ,A          ,B           ,DELOIL
*   ,DELGAS    ,PLIM       ,VLIM       ,RLIM
*   ,FGL       ,TO        ,C           ,XC
*   ,MODEL     ,W
COMMON /RSTRT/
*   RESTART
LOGICAL
*   RESTART
C
C*** CALCULATE RATE
C
ROIL=(1.-PSI)*RTOTAL/(1.+TEMP)
C
IF(KPASS.EQ.1) 10,20
10  CONTINUE
    NRCOUNT=0
    GO TO 100
C
ELSE
20  CONTINUE
C
C*** CHECK IF RATE EQUALS RLIM
C
RDIF=ABS(RLIM-ROIL)
IF(RDIF.LT.0.0001*RLIM) 30,40
30  CONTINUE
    EOINT=.TRUE.
    GO TO 100
C
ELSE
40  CONTINUE
C
C*** COMPUTE RATE DERIVED CUTOFF TIME
C
RDUM=ABS(ROIL-SAVR)
IF(RDUM.GT.1.E-30) 42,44
42  CONTINUE
    RCTIME=SAVT+(RLIM-SAVR)*(XSOL-SAVT)/(ROIL-SAVR)
C
    GO TO 46
C
ELSE
44  CONTINUE

```

```

      RCTIME=1.0E+30
46      CONTINUE
C
C*** CHECK IF RATE GREATER THAN RLIM
C
      RCU=0.9999*RLIM
      IF(RCUI.GT.RCU) 50,60
50      CONTINUE
      NRCOUNT=0
      GO TO 100
C
      ELSE
60      CONTINUE
      RESTART=.TRUE.
      NRCOUNT=NRCOUNT+1
C
C*** CHECK IF RATE OVERSHOOT COUNT LIMIT IS REACHED
C
      IF(NRCOUNT.GE.100) 70,80
70      CONTINUE
      PRINT 6010
6010     FORMAT(/,10X,*RATE OVERSHOOT COUNT LIMIT REACHED*)
      RESTART=.FALSE.
      EOINT=.TRUE.
C
      ENDIF
80      CONTINUE
C
      ENDOIF
C
      ENDOIF
C
      ENDOIF
100     CONTINUE
      RETURN
      END
*DECK SIAX
      SUBROUTINE SIAX
C*** SAVE INTEGRALS AND X VALUE
C
      COMMON /PRGDATA/
      *      YSAV(20)
      *      ,XSAV          ,XEVT(20)      ,DXIN          ,XEND
      *      ,XSTART      ,EOINT          ,XSOL          ,DXSOL
      *      ,NEG          ,XOUT          ,UXPRT          ,DXPLT
      *      ,KPLOT        ,KPASS          ,IOUT          ,XCUT
      *      ,CPLOT        ,PDFLG          ,PDPRT          ,NOPRNT
      COMMON /INTDATA/
      *      XINT          ,Y(20)          ,DYDX(20)
      LOGICAL
      *      EOINT        ,KPLOT          ,CPLOT          ,PDFLG
      *      ,PDPRT        ,NOPRNT
C
      DO 100 I=1,NEG
100     YSAV(I)=Y(I)
      CONTINUE
      XSAV=XSOL
      RETURN
      END
*DECK RITPV
      SUBROUTINE RITPV
C*** RESET INTEGRALS TO PREVIOUS VALUES
C
      COMMON /PRGDATA/
      *      YSAV(20)
      *      ,XSAV          ,XEVT(20)      ,DXIN          ,XEND
      *      ,XSTART      ,EOINT          ,XSOL          ,DXSOL
      *      ,NEG          ,XOUT          ,UXPRT          ,DXPLT
      *      ,KPLOT        ,KPASS          ,IOUT          ,XCUT
      *      ,CPLOT        ,PDFLG          ,PDPRT          ,NOPRNT
      LOGICAL

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      *      EOINT      ,KPL0T      ,CPL01      ,PDFLG
      *      ,P0PRNT      ,NOPRNT
      *      COMMON /INTDAT/
      *      XINT      ,Y(20)      ,DYDX(20)
C
      DO 100 I=1,NEG
      Y(I)=YSAV(I)
100    CONTINUE
      XINT=XSAV
      XSOL=XSAV
      RETURN
      END
*DECK DSSS
SUBROUTINE DSSS
C***  DETERMINE SOLUTION STEP SIZE
C
C      COMMON /PRG DAT/
      *      YSAV(20)
      *      ,XSAV      ,XEVT(20)      ,DXIN      ,XEND
      *      ,XSTART      ,EOINT      ,XSOL      ,DXSOL
      *      ,NEG      ,XOUT      ,DXPRT      ,DXPLT
      *      ,KPL0T      ,KPASS      ,IDUT      ,XCUT
      *      ,CPL0T      ,PDFLG      ,P0PRNT      ,NOPRNT
      LOGICAL
      *      EOINT      ,KPL0T      ,CPL0T      ,PDFLG
      *      ,P0PRNT      ,NOPRNT
      DATA BIG/1.E10/
C
      IF(KPASS.EQ.1) KNTZRO=0
      DXMIN=BIG
      DO 100 I=1,20
      DX=XEVT(1)-XSOL
      DXMIN=AMIN1(DXMIN,DX)
100    CONTINUE
      DXEND=XEND-XSOL
      DXOUT=XOUT-XSOL
      DXCUT=XCUT-XSOL
      DXSOL=AMIN1(DXMIN,DXEND,DXOUT,DXIN,DXCUT)
C
      IF (DXSOL,LT. 1.E-5 ) 200,300
200    CONTINUE
      KNTZRO=KNTZRO+1
      IF(KNTZRO.GE.3) 220,240
220    CONTINUE
      PRINT 6000,DXEND,DXOUT,DXMIN,XSOL,XEVT
6000   FORMAT(1H1,*INTEGRATION STEP IS ZERO*/
      *      1H0,*DXEND=*,E12.6/
      *      1H0,*DXOUT=*,E12.6/
      *      1H0,*DXMIN=*,E12.6/
      *      1H0,*XSOL=*,E12.6/
      *      1H0,*EVENT ARRAY*/
      *      (1X,E12.6))
      EOINT=.TRUE.
      IDUT=3
240    CONTINUE
      GO TO 320
C
      ELSE
300    CONTINUE
      KNTZRO=0
320    CONTINUE
      RETURN
      END
*DECK OUTPUT
SUBROUTINE OUTPUT
C***  PRODUCE OUTPUT
C
C

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```

C      IOUT=1      STORE OUTPUT DATA IF X EQUALS XOUT
C      IOUT=2      STORE OUTPUT DATA UNCONDITIONALLY
C      IOUT=3      STORE OUTPUT DATA UNCONDITIONALLY AND PRINT
C                  THE STORED DATA

COMMON /OUTDAT/
*      ITITLE(8)      ,IPAGE      ,NLINE      ,ICASE
*      ,IDATE      ,OUT(50,63)      ,NITEM      ,LCASE(8)
COMMON /PRGDAI/
*      YSAV(20)
*      ,XSAV      ,XEVT(20)      ,DXIN      ,XEND
*      ,XSTART      ,EOINT      ,XSOL      ,DXSOL
*      ,NEQ      ,XOUT      ,DXPRT      ,DXPLT
*      ,KPLOT      ,KPASS      ,IDUT      ,XCUT
*      ,CPLUT      ,PDFLG      ,PDPRNT      ,NOPRNT
LOGICAL
*      ,EOINT      ,KPLOT      ,CPLUT      ,PDFLG
*      ,PDPRNT      ,NOPRNT
LOGICAL KSAV
DATA BIG/1.E30/,ENDMRK/-1./

C      IF(KPASS.EQ.1) 100,160
100      CONTINUE
        NLINE=0
        XPRT=XSTART
        IF(KPLUT) 120,130
120      CONTINUE
        XPLT=XSTART
        GO TO 140
C      ELSE
130      CONTINUE
        XPLT=BIG
C      ENDIF
140      CONTINUE
C      ENDIF
160      CONTINUE
C
        KSAV=.FALSE.
        XDUM=ABS(XSOL-XPRT)
        IF(XDUM.LT. 1.E-5) 200,220
200      CONTINUE
        NLINE=NLINE+1
C      SAVE OUTPUT DATA
        CALL SAVOUT
        KSAV=.TRUE.
        XPRT=XSOL+DXPRT
        GO TO 280
C      ELSE
220      CONTINUE
        IF(IOUT.GT.1) 240,260
240      CONTINUE
        NLINE=NLINE+1
        CALL SAVOUT
        KSAV=.TRUE.
C      ENDIF
260      CONTINUE
C      ENDIF
280      CONTINUE
C
        IF(KPLOT) 390,580
390      CONTINUE
        XDUM=ABS(XSOL-XPLT)
        IF(XDUM.LT.1.E-5 .OR. IOUT.GT.1) 400,580
400      CONTINUE
        IF(KSAV) 440,420
420      CONTINUE
        NLINE=NLINE+1
        CALL SAVOUT

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        CALL STRPLT
        NLINE=NLINE-1
        GO TO 460
440      CONTINUE
        CALL STRPLT
460      CONTINUE
        IF(XDUM.LT.1.E-5)
          * XPLT=XSOL+DXPLT
C
C***  ADD END OF DATA MARK TO DISK FILE OF A CASE.
C
        IF(IOUT.EQ.3)
          * WRITE(20,6000) ENDMRK
6000      FORMAT(E13.6,/////////)
C
560      CONTINUE
        IF(NLINE.GE.50 .OR. IOUT.EQ.3) 300,320
300      CONTINUE
        PRINT OUTPUT DATA
        IF(.NOT. NOPRNT)
          * CALL PRNT
          * IF(IOUT.EQ.3 .AND. CPLOT)
            * CALL STCPLT
            NLINE=0
320      CONTINUE
C
C      XOUT=AMINI(XPRT,XPLT)
C
        RETURN
        END
*DECK SAVOUT
        SUBROUTINE SAVOUT
C***  SAVE DATA FOR PRINTING
C
        COMMON /CUTDAT/
          * VU          ,PHI          ,ZETA          ,S
          * ,PSI        ,RTOTAL      ,TEMP          ,SAVV
          * ,SAVP       ,SAVR        ,SAVT          ,VRES
          * ,RULL
        COMMON /OUTDAT/
          * ITITLE(8)   ,IPAGE        ,NLINE         ,ICASE
          * ,IDATE      ,OUT(50,63)   ,NITEM        ,LCASE(8)
        COMMON /PRG DAT/
          * YSAV(20)
          * ,XSAV       ,XEVT(20)     ,DXIN          ,XEND
          * ,XSTART     ,EOINT        ,XSOL          ,DXSOL
          * ,NEW        ,XOUT         ,DXPRT        ,DXPLT
          * ,KPLDT      ,KPASS       ,IOUT         ,XCUT
          * ,CPLOT      ,PDFLG       ,PDPRNT        ,NOPRNT
        COMMON /INTDAT/
          * XINT        ,Y(20)        ,DYDX(20)
        LOGICAL
          * ,EOINT      ,KPLOT        ,CPLOT         ,PDFLG
          * ,PDPRNT     ,NOPRNT
        COMMON /PRBDAT/
          * DSEG        ,RINIT        ,G             ,RT
          * ,VINIT      ,PINIT        ,XNINIT       ,SO
          * ,VR         ,A            ,B            ,DELOIL
          * ,DELGAS     ,PLIM         ,VLIM         ,RLIM
          * ,FGL        ,TO          ,C            ,XD
          * ,MODEL      ,W
        I=NLINE
        XNRES = Y(1)+(1.-S)*Y(2)
        XNOIL = (1.-PSI)*Y(1)
        XNOG  = PSI*Y(1)
        XNFG  = (1.-S)*Y(2)

```

```

XNGAS = XNDG+XNFG
XNGC  = S*Y(2)
GOR   = XNFG/XNOIL
XFG   = TEMP*RTOTAL/(1.+TEMP)
RDG   = PSI*RTOTAL/(1.+TEMP)
RGAS  = RFG+RDG
GOR1  = RDG/ROIL
GOR2  = RFG/ROIL
GOR3  = RGAS/ROIL
GASWI = Y(4)+Y(5)
XLIQWI = Y(5)+Y(6)
VLIQ  = V0*PHI*Y(1)
VFG   = ZETA*XNFG
VGC   = ZETA*XNGC
VFGC  = VFG+VGC
SIGMA = VFG/VRES
XKN   = 10.** (A+8*SIGMA)
RLIQ  = ROIL+RDG
RGAS  = RFG+RDG
UGAS  = Y(8)+Y(9)
ULIQ  = Y(7)+Y(9)
XNPROD = ULIQ+Y(8)
GRATIO = UGAS*(1.+G)/G
ORATIO = Y(7)*(1.+G)
TRATIO = XNPROD/XNINIT
GASZ  = G*RINIT
TOTALZ = (1.+G)*RINIT
RATEZ = RINIT

C
10 IF(KPASS.EQ.1) 10,20
    CONTINUE
    ACGAS=0
    GO TO 30
C
20 ELSE
    CONTINUE
    ACGAS=VFGC/Y(2)-ZETA
C
30 ENDIF
    CONTINUE
C
    ACLIQ = VLIQ/Y(1)+V0*PHI
    ACOIL = XNOIL-(1.-PSI)*Y(1)
C
    OUT(I,1) = XSOL
    DO 40 J=2,10
        OUT(I,J)=Y(J-1)
        OUT(I,J+9)=DYDX(J-1)
40 CONTINUE
C
    OUT(I,20) = XNRES
    OUT(I,21) = VRES
    OUT(I,22) = XNOIL
    OUT(I,23) = XNDG
    OUT(I,24) = XNFG
    OUT(I,25) = XNGAS
    OUT(I,26) = XNGC
    OUT(I,27) = GOR
    OUT(I,28) = RFG
    OUT(I,29) = RDG
    OUT(I,30) = ROIL
    OUT(I,31) = RGAS
    OUT(I,32) = GOR1
    OUT(I,33) = GOR2
    OUT(I,34) = GOR3
    OUT(I,35) = GASWI
    OUT(I,36) = XLIQWI
    OUT(I,37) = VLIQ
    OUT(I,38) = VFG
    OUT(I,39) = VGC

```

```

OUT(I,40) = VFGC
OUT(I,41) = SIGMA
OUT(I,42) = XKR
OUT(I,43) = RLQ
OUT(I,44) = RGAS
OUT(I,45) = ACGAS
OUT(I,46) = ACLIQ
OUT(I,47) = ACOIL
OUT(I,48) = UGAS
OUT(I,49) = ULIQ
OUT(I,50) = XNPROD
OUT(I,51) = GRATIO
OUT(I,52) = UKRATIO
OUT(I,53) = TRATIO
OUT(I,54) = GASZ
OUT(I,55) = TOTALZ
OUT(I,56) = RATEZ
OUT(I,57) = W
RETURN
END
*DECK
PRNT
SUBROUTINE PRNT
C*** PRINT OUTPUT DATA
C
COMMON /OUTDAT/
* ITITLE(8) , IPAGE , NLINE , ICASE
* , IDATE , OUT(50,63) , NITEM , LCASE(8)
COMMON /PRGDATA/
* YSAV(20)
* , XSAV , XEVNT(20) , OXIN , XEND
* , XSTART , EOINT , XSOL , DXSOL
* , NEG , XOUT , OXPRT , DXPLT
* , KPLOT , KPASS , IOUT , XOUT
* , CPLUT , PDFLG , POPRNT , NOPRNT
LOGICAL
* , EOINT , KPLOT , CPLUT , PDFLG
* , POPRNT , NOPRNT
C
IPAGE=IPAGE+1
PRINT 6000, ITITLE, LCASE, IDATE, ICASE, IPAGE
6000 FORMAT(1H1,8A10/1H0,6A10,10X,A10,5X,*CASE*,13,5X,*PAGE*,13)
PRINT 6030
PRINT 6040
DO 10 I=1,NLINE
10 PRINT 6010, (OUT(I,J), J=1,4), (OUT(I,J), J=11,13)
C CONTINUE
IPAGE=IPAGE+1
PRINT 6000, ITITLE, LCASE, IDATE, ICASE, IPAGE
PRINT 6050
PRINT 6060
DO 20 I=1,NLINE
20 PRINT 6010, OUT(I,1), OUT(I,20), OUT(I,21), OUT(I,4), OUT(I,2)
* , OUT(I,22), OUT(I,23)
C CONTINUE
IPAGE=IPAGE+1
PRINT 6000, ITITLE, LCASE, IDATE, ICASE, IPAGE
PRINT 6070
PRINT 6080
DO 30 I=1,NLINE
30 PRINT 6010, OUT(I,1), (OUT(I,J), J=45,47), OUT(I,57)
C CONTINUE
IPAGE=IPAGE+1
PRINT 6000, ITITLE, LCASE, IDATE, ICASE, IPAGE
PRINT 6090

```

```

PRINT 6100
DO 40 I=1,NLINE
  PRINT 6010,OUT(I,1),(OUT(I,J),J=23,26),OUT(I,3),OUT(I,4)
40 CONTINUE
C
  IPAGE=IPAGE+1
  PRINT 6000,ITITLE,LCASE,IDATE,ICASE,IPAGE
  PRINT 6110
  PRINT 6120
  DO 50 I=1,NLINE
    PRINT 6010,OUT(I,1),OUT(I,27),(OUT(I,J),J=32,34),OUT(I,4)
50 CONTINUE
C
  IPAGE=IPAGE+1
  PRINT 6000,ITITLE,LCASE,IDATE,ICASE,IPAGE
  PRINT 6130
  PRINT 6140
  DO 60 I=1,NLINE
    CONTINUE
60 C
  IPAGE=IPAGE+1
  PRINT 6000,ITITLE,LCASE,IDATE,ICASE,IPAGE
  PRINT 6150
  PRINT 6160
  DO 70 I=1,NLINE
    PRINT 6010,OUT(I,1),OUT(I,21),(OUT(I,J),J=37,40),OUT(I,4)
70 CONTINUE
C
  IPAGE=IPAGE+1
  PRINT 6000,ITITLE,LCASE,IDATE,ICASE,IPAGE
  PRINT 6170
  PRINT 6180
  DO 80 I=1,NLINE
    PRINT 6020,OUT(I,1),(OUT(I,J),J=41,42),(OUT(I,J),J=28,31)
    * CONTINUE,OUT(I,43),OUT(I,4)
80 C
  IPAGE=IPAGE+1
  PRINT 6000,ITITLE,LCASE,IDATE,ICASE,IPAGE
  PRINT 6190
  PRINT 6200
  DO 90 I=1,NLINE
    PRINT 6010,OUT(I,1),OUT(I,9),OUT(I,10),OUT(I,8)
    * CONTINUE,OUT(I,J),J=48,50
90 C
C*** PRINT CUTOFF VALUES.
C
100 IF(IOUT.EQ.3) 100,130
  CONTINUE
  IPAGE=IPAGE+1
  I=NLINE
  PRINT 6000,ITITLE,LCASE,IDATE,ICASE,IPAGE
  PRINT 6210
  FORMAT(1X,*CUTOFF VALUES OF VARIABLES.*)
6210 PRINT 6220
6220 FORMAT(1X)
C
  PRINT 6030
  PRINT 6040
  PRINT 6010,(OUT(I,J),J=1,4),(OUT(I,J),J=11,13)
C
  PRINT 6050
  PRINT 6060
  PRINT 6010,OUT(I,1),OUT(I,20),OUT(I,21),OUT(I,4),OUT(I,2)
  * ,OUT(I,22),OUT(I,23)
C
  PRINT 6070

```



```

*      *      TRAPPED *      *      TOTAL TRAPPED *      *      TRAPPED *
*      *      W1 FREE GAS *      *      W1 DISS GAS *      *      W1 OIL *)
6140  FORMAT( 1X*      *      TIME *      *      FREE GAS *      *      DISSOLVED GAS*
*      *      OIL *      *      GAS *      *      LIQUID *
*      *      DERIVATIVE *      *      DERIVATIVE *      *      DERIVATIVE*/)
6150  FORMAT(/3X*      *      X **2X*      *      VRES **2X*      *      VLIQ *
*      *      **2X*      *      VGC **2X*      *      VOLUME *
*      *      Y(3) *)
6160  FORMAT( 3X*      *      TIME **2X*      *      RES VOLUME **2X*      *      LIQUID VOLUME*
*      *      **2X*      *      FREE GAS VOL **2X*      *      GAS CAP VOL **2X*      *      FREE GAS+CAP *
*      *      PRESSURE **/)
6170  FORMAT(/1X*      *      X *      *      GAS *      *      KSUBR *
*      *      RFG *      *      RDG *      *      ROIL *
*      *      RGAS *      *      RLQ *      *      Y(3) *)
6180  FORMAT( 1X*      *      TIME *      *      SATURATION *      *      GAS-OIL PERM *
*      *      FREE GAS RATE *      *      DISS GAS RATE *      *      OIL RATE *
*      *      GAS RATE *      *      LIQUID RATE *      *      PRESSURE*/)
6190  FORMAT(/3X*      *      X **2X*      *      FREE GAS **2X*      *      DISS GAS *
*      *      **2X*      *      TOTAL GAS **2X*      *      LIQUID *
*      *      RES MATERIAL *)
6200  FORMAT( 3X*      *      TIME **2X*      *      PRODUCTION **2X*      *      PRODUCTION *
*      *      **2X*      *      PRODUCTION **2X*      *      PRODUCTION *
*      *      PRODUCTION **/)
6230  FORMAT(/3X*      *      **2X*      *      GASZ **2X*      *      TOTALZ *
*      *      **2X*      *      GRATIO **2X*      *      ORATIO *
*      *      TRATIO *)
6240  FORMAT( 3X*      *      **2X*      *      RGAS/INIT **2X*      *      ROIL/INIT *
*      *      **2X*      *      RTOTAL/INIT **2X*      *      UGAS/NGASINIT **2X*      *      UOIL/NOILINIT*
*      *      **2X*      *      U/NINIT **/)

```

```

C      END
*DECK STRPLT
SUBROUTINE STRPLT
C
C*** WRITE OUTPUT ON DISK FOR PLOTTING.
C
COMMON /OUTDAT/
*      ITITLE(8)      ,IPAGE      ,NLINE      ,ICASE
*      ,IDATE      ,OUT(50,63)      ,NITEM      ,LCASE(8)
C
WRITE(20,6000) (OUT(NLINE,J),J=1,50),OUT(NLINE,57)
6000  FORMAT(6E13.6)
RETURN
END
*DECK STCPLT
SUBROUTINE STCPLT
C
C*** WRITE CUTOFF OUTPUT ON DISK FOR PLOTTING.
C
COMMON /OUTDAT/
*      ITITLE(8)      ,IPAGE      ,NLINE      ,ICASE
*      ,IDATE      ,OUT(50,63)      ,NITEM      ,LCASE(8)
C
COMMON /MARKY/ RRRRR
WRITE(21,6000) (OUT(NLINE,J),J=1,57)
6000  FORMAT(6E13.6)
C*****
C
WRITE(22,6789) OUT(NLINE,1),(OUT(NLINE,J),J=51,54),OUT(NLINE,56)
1,RRRRR
6789  FORMAT (F10.2,4F10.7,F10.4,F10.8)
C
C*****
RETURN
END
BLOCK DATA
C
C

```



```

10  ALWNC(1)=AMAX1(ALWNC(1),.1E-8)
    Y(I,1)=YS(I)
    CALL FCN(X(1),Y(1,1),F(1,1))
    IOLCK=0
    H=ABS(HEST)*S
    MODE=1
    FRAC=AMCON(3)*32.
    MOD=1
20  FRC=ABS(H)/DX
    DO 30 I=1,NEG
30  ALLOW(I)=AMAX1((SIZE(I)*ALWNC(I)*FRC),ABS(Y(I,MOD)*FRAC))
    IF(MODE-1)81,50,81
50  CONTINUE
    H=RNDOFF(H)

```

PURPOSE OF ABOVE STATEMENT IS TO FORCE ROUNDOFF INTO H, SO THAT
 X(I) AND H WILL ADD EXACTLY

```

51  DO 51 J=1,NEW
    Y(J,2)=Y(J,1)+H*F(J,1)
    X(2)=X(1)+H
    CALL FCN(X(2),Y(1,2),F(1,2))
    DO 52 J=1,NEG
52  Y(J,2)=Y(J,1)+.5*H*(F(J,1)+F(J,2))
    CALL FCN(X(2),Y(1,2),F(1,2))
    DO 53 J=1,NEG
53  Y(J,3)=Y(J,1)+2.*H*F(J,2)
    X(3)=X(2)+H
    CALL FCN(X(3),Y(1,3),F(1,3))
    DO 54 J=1,NEG
54  Y(J,2)=Y(J,1)+H*(5.*F(J,1)+8.*F(J,2)-F(J,3))/12.
    CALL FCN(X(2),Y(1,2),F(1,2))
    DO 55 J=1,NEG
55  Y(J,3)=Y(J,1)+H*(F(J,1)+4.*F(J,2)+F(J,3))/3.
    CALL FCN(X(3),Y(1,3),F(1,3))
    X(4)=X(3)+H
    DO 56 J=1,NEG
56  Y(J,4)=Y(J,1)+.75*H*(F(J,1)+3.*F(J,3))
    CALL FCN(X(4),Y(1,4),F(1,4))
    DO 57 J=1,NEG
57  Y(J,2)=Y(J,1)+H*(9.*F(J,1)+19.*F(J,2)-5.*F(J,3)+F(J,4))/24.
    CALL FCN(X(2),Y(1,2),F(1,2))
    DO 58 J=1,NEG
58  Y(J,3)=Y(J,1)+H*(F(J,1)+4.*F(J,2)+F(J,3))/3.
    CALL FCN(X(3),Y(1,3),F(1,3))
    DO 59 J=1,NEG
59  Y(J,4)=Y(J,1)+.375*H*(F(J,1)+3.*F(J,2)+3.*F(J,3)+F(J,4))
    CALL FCN(X(4),Y(1,4),F(1,4))
    DO 60 J=1,NEG
60  Y(J,5)=Y(J,1)+8.*H*((F(J,2)+F(J,4))-.5*F(J,3))/3.
    X(5)=X(4)+H
    CALL FCN(X(5),Y(1,5),F(1,5))
    DO 61 J=1,NEG
61  Y(J,2)=Y(J,1)+H*(251.*F(J,1)+646.*F(J,2)-264.*F(J,3)+106.*F(J,4)-
    119.*F(J,5))/720.
    CALL FCN(X(2),Y(1,2),F(1,2))
    DO 62 J=1,NEG
62  Y(J,3)=Y(J,1)+H*(29.*F(J,1)+124.*F(J,2)+24.*F(J,3)+4.*F(J,4)
    1-F(J,5))/90.
    CALL FCN(X(3),Y(1,3),F(1,3))
    DO 63 J=1,NEG
63  Y(J,4)=Y(J,1)+H*(9.*F(J,1)+34.*F(J,2)+24.*F(J,3)+14.*F(J,4)
    1-F(J,5))*0.375
    CALL FCN(X(4),Y(1,4),F(1,4))
    DO 64 J=1,NEG
64  Y(J,5)=Y(J,1)+H*(7.*F(J,1)+F(J,5)+32.*F(J,2)+F(J,4)+12.*F(J,3)

```

```

1)/22.5
CALL FCN(X(5),Y(1,5),F(1,5))
X(6)=X(5)+H
DO 65 J=1,NEQ
65 Y(J,6)=Y(J,1)+5.*H*(19.*F(J,1)-10.*F(J,2)+120.*F(J,3)-70.*F(J,4)+
185.*F(J,5))/144.
CALL FCN(X(6),Y(1,6),F(1,6))
DO 66 J=1,NEQ
66 Y(J,2)=Y(J,1)+H*(475.*F(J,1)+1427.*F(J,2)-798.*F(J,3)+482.*F(J,4)
1-173.*F(J,5)+27.*F(J,6))/1440.
CALL FCN(X(2),Y(1,2),F(1,2))
DO 67 J=1,NEQ
67 Y(J,3)=Y(J,1)+H*(28.*F(J,1)+129.*F(J,2)+14.*(F(J,3)+F(J,4))=6.*
1F(J,5)+F(J,6))/90.
CALL FCN(X(3),Y(1,3),F(1,3))
DO 68 J=1,NEQ
68 Y(J,4)=Y(J,1)+H*(51.*F(J,1)+219.*F(J,2)+114.*(F(J,3)+F(J,4))=21.*
1F(J,5)+3.*F(J,6))/160.
CALL FCN(X(4),Y(1,4),F(1,4))
DO 69 J=1,NEQ
69 Y(J,5)=Y(J,1)+H*(7.*(F(J,1)+F(J,5))+32.*(F(J,2)+F(J,4))+12.*F(J,3)
1)/22.5
CALL FCN(X(5),Y(1,5),F(1,5))
DO 70 J=1,NEQ
70 Y(J,6)=Y(J,1)+H*(19.*(F(J,1)+F(J,6))+75.*(F(J,2)+F(J,5))+50.*
1(F(J,3)+F(J,4)))/57.6
CALL FCN(X(6),Y(1,6),F(1,6))
X(7)=X(6)+H
DO 71 J=1,NEQ
71 Y(J,7)=Y(J,1)+.3*H*(11.*(F(J,2)+F(J,6))-14.*(F(J,3)+F(J,5))+26.*
1F(J,4))
CALL FCN(X(7),Y(1,7),F(1,7))
DO 72 J=1,NEQ
72 Y(J,2)=Y(J,1)+H*(19067.*F(J,1)+65112.*F(J,2)-46461.*F(J,3)+37504.*
1F(J,4)-20211.*F(J,5)+6312.*F(J,6)-863.*F(J,7))/60460.
CALL FCN(X(2),Y(1,2),F(1,2))
DO 73 J=1,NEQ
73 Y(J,3)=Y(J,1)+H*(1139.*F(J,1)+5640.*F(J,2)+33.*F(J,3)+1328.*F(J,4)
1-807.*F(J,5)+264.*F(J,6)-37.*F(J,7))/3780.
CALL FCN(X(3),Y(1,3),F(1,3))
DO 74 J=1,NEQ
74 Y(J,4)=Y(J,1)+H*(685.*F(J,1)+3240.*F(J,2)+1161.*F(J,3)+2176.*
1F(J,4)-729.*F(J,5)+216.*F(J,6)-29.*F(J,7))/2240.
CALL FCN(X(4),Y(1,4),F(1,4))
DO 75 J=1,NEQ
75 Y(J,5)=Y(J,1)+H*(286.*F(J,1)+1392.*F(J,2)+384.*F(J,3)+1504.*
1F(J,4)+174.*F(J,5)+48.*F(J,6)-8.*F(J,7))/945.
CALL FCN(X(5),Y(1,5),F(1,5))
DO 76 J=1,NEQ
76 Y(J,6)=Y(J,1)+5.*H*(743.*F(J,1)+3480.*F(J,2)+1275.*F(J,3)+3200.*
1F(J,4)+2325.*F(J,5)+1128.*F(J,6)-55.*F(J,7))/12096.
CALL FCN(X(6),Y(1,6),F(1,6))
DO 77 J=1,NEQ
77 Y(J,7)=Y(J,1)+H*(41.*(F(J,1)+F(J,7))+216.*(F(J,2)+F(J,6))+27.*
1(F(J,3)+F(J,5))+272.*F(J,4))/140.
CALL FCN(X(7),Y(1,7),F(1,7))
ISWIT=0
IS1=1
IS2=2
IS3=3
IS4=4
IS5=5
IS6=6
IS7=7
GO TO 89
81 ISWIT=0
82 ISWIT=ISWIT+1
IS0=ISWIT-1

```

```

      IS1=ISWIT+1
      IS2=ISWIT+2
      IS3=ISWIT+3
      IS4=ISWIT+4
      IS5=ISWIT+5
      IS6=ISWIT+6
      IS7=ISWIT+7
      X(IS7)=X(IS6)+H
      DO 83 J=1,NEU
83      Y(J,IS7)=Y(J,ISWIT)+7.*H*(751.*F(J,ISWIT)-840.*F(J,IS1)+8547.*
1      F(J,IS2)-11648.*F(J,IS3)+14637.*F(J,IS4)-7224.*F(J,IS5)+4417.*
2      F(J,IS6))/8640.
      CALL FCN(X(IS7),Y(1,IS7),F(1,IS7))
      DO 84 J=1,NEQ
84      Y(J,IS7)=Y(J,IS1)+H*(41.*(F(J,IS1)+F(J,IS7))+216.*(F(J,IS2)+
1      F(J,IS6))+27.*(F(J,IS3)+F(J,IS5))+272.*F(J,IS4))/140.
      CALL FCN(X(IS7),Y(1,IS7),F(1,IS7))
89      RATIO=0.
      DO 90 J=1,NEQ
      EST=ABS(.55*H*H*(F(J,IS1)-6.*(F(J,IS2)+F(J,IS6))
1      +15.*(F(J,IS3)+F(J,IS5))-20.*F(J,IS4)+F(J,IS7)))
90      RATIO=AMAX1(RATIO,(EST/ALLOW(J)))

      RATIO IS THE WORST ERROR RELATIVE TO ITS ALLOWANCE

      IF(RATIO=1.)93,91,91

      REDO WITH DECREASED H

91      H=H/AMIN1(.2E1,(SQRT(SQRT(SQRT(RATIO*10.)))))
      IF(ISWIT)50,50,92
92      MODE=-ISWIT-6
      GO TO 97
93      IF(RATIO=.01)95,94,94
94      IF(ISWIT=5)82,96,96
95      H=H/AMAX1(.5E00,SQRT(SQRT(SQRT(RATIO*10.)))))
      MODE=-ISWIT-7
      GO TO 97
96      MODE=12
97      HH=H
      IBLCK=IBLCK+1
      MOD=IABS(MODE)
      DO 136 I=1,NEQ
136      SIZE(I)=.8*SIZE(I)+.2*ABS(Y(I,MOD))
140      CALL LOOKAT(X,Y,F,MOD,S,NEQ,NU,XOUT,IRET)
      IF(IRET)141,141,150
141      MO=MOD-7
      JM=7
      IF(MODE)142,142,143
142      JM=1
      MO=MOD-1
143      DO 145 J=1,JM
      DO 144 I=1,NEQ
      Y(I,J)=Y(I,J+MO)
144      F(I,J)=F(1,J+MO)
145      X(J)=X(J+MO)
      MODE=MAXV(MODE,1)
      GO TO 20
150      J=((XOUT-X(1))*(MOD-1))/(X(MOD)-X(1))
      K=MAXV(0,(J-1))
      K=MINV(K,(MOD-4))
      XO=XOUT
      DO 173 J=1,4
      HR=1.

```

```

A=0.
JK=J+K
XJ=X(JK)
DO 172 L=1,4
LK=L+K
XI=X(LK)
IF(LK=JK) 171,172,171
171 HR=HR*(X0-XI)/(XJ-XI)
A=A+1./(XJ-XI)
172 CONTINUE
SHR(J)=HR*HR
173 SA(J)=A
DO 175 I=1,NEQ
ANS=0.
DO 174 J=1,4
JK=J+K
174 ANS=ANS+SHR(J)*((X(JK)-X0)*(2.*SA(J)*Y(I,JK)-F(I,JK))+Y(I,JK))
175 YS(I)=ANS
HEST=H
RETURN
END

```


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