RTR-2424

Keywords:
LOCA
Hydraulic
Transient
Core Flow

DAS

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December 19, 1986

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HYDRAULIC TRANSIENTS FOR LOSS OF COOLANT ACCIDENTS

INTRODUCTION

An analysis of the cooling flow transient following a loss of coolant accident (LOCA) was made in 1975 which showed that cooling flow to the reactor would be available for longer periods if credit were taken for the Emergency Cooling System actuation. The calculations have been updated to reflect the increased flow from the Emergency Cooling System as the result of system improvements completed under Project S-1830 (Reference 1). In addition, the calculations were computerized to allow improved accuracy and speed over the manual calculational method.

SUMMARY

The hydraulic transient calculations show that the coolant flow to the core is a direct function of the Emergency Cooling System (ECS) flow to the reactor. The computer program written to calculate transients can be used to predict the effect of increasing ECS flow. Parameters in the program can be easily changed to accommodate future improvements to the ECS or for changes to the input data as the result of newly required empirical data.

The results of the transient calculations should be used with the FLOOD computer program to calculate ECS limits. The leak flow immediately following a double-ended pipe break has been calculated to be 66,500 gpm.

DISCUSSION

The hydraulic transient for a double-ended rupture of a plenum inlet pipe was initially calculated in 1970 (Reference 2). An improved calculation was made in 1975 (Reference 3) to take credit for the addition of cooling water from the ECS. The previous calculations assumed a constant leak rate of 75,000 gpm until the reactor level dropped to a level where the circulating pumps begin to aspirate air, about 60 inches in PL and K Areas and about 72 inches in C Area (Reference 2).

The addition of light water to the circulation system delays the rate at which the reactor level decreases and increases flow to the core during the period immediately following the accident. The leak rate from the reactor plenum is assumed to be proportional to the flow to the plenum from the circulating pumps while the plenum is pressurized (before venting occurs). The leak rate from the plenum after venting, is controlled by the level of water in the plenum directly in front of the broken nozzle. The plenum is assumed to vent when the calculated plenum pressure in front of the broken nozzle is less than the plenum depth (data from the FLOOD computer program).

The hydraulic transient for the double ended rupture of a plenum inlet pipe was calculated using the following assumptions:

- o Constant leak rates of 75,000 and 66,500 gpm until the circulating pumps begin to aspirate air.
- o Total leak rate is proportional to the circulating pump flow rate until the plenum vents.
- o Total leak rate is equal to the pump flow rate plus the plenum leakage after the plenum vents.
- o ECS addition begins one (1) second after the five (5) foot action level for valve [redacted]
- o No credit is taken for dumping of moderator from the plenum to the reactor tank after the plenum vents.
- o No credit is taken for tripping the AC motors and the resulting reduction in flows

The calculations are believed to be conservative. The pump flow rates used in the calculations are the same as used in the FLOOD program which came from the Starved Suction Tests in P Area (Reference 2). Similar tests were performed in L Area in summer of 1985 using more accurate flow measuring instruments. The data from ~~this~~ test have not been analyzed. ~~It~~ is believed that this data will show that the pump flow rates are higher for a given reactor level. Also, a constant pump flow rate to the plenum was used in the calculations. In actuality, the pump flow will increase when the pipe breaks. Using increased pump flow would decrease the ratios of leak rate to pump flow which would result in longer drain times for the reactor. The initial leak rate of 75,000 gpm was calculated for reactor charges used in 1970. Final calculations of the leak rate for modern charges have been completed which give a 66,500 gpm leak rate. The appendix discusses the method for determining the 66,500 gpm value. Calculations also assume the reactor assemblies remain completely full of water for all reactor levels and assembly flow rates.

Credit is taken in the calculations for automatically closing the septifoil header supply valves with automatic incident action (AIA). This assumption is also used in the FLOOD program. Credit is also taken for the ball valve beginning to open 1 second after reaching a reactor level of 60 inches and being fully open 10 seconds later.

The program for calculating the hydraulic transient was written to begin the calculation just prior to air aspiration by the circulating pumps. The Starved Suction Test data from P Reactor showed that the pump flow rate is constant from the time immediately following the pipe break to the time air aspiration begins. Since the leak rate during this time is constant, it is not included in the transient calculation.

The calculation method is based around a material balance with the following equations used:

- o New reactor volume equals old reactor volume minus the volume leaked plus the volume added by the ECS.
- o New reactor level equals the old reactor level minus the volume equivalent for the volume lost by the leak plus the volume equivalent for the volume added by the ECS (Data from DPSOL 105-6122).
- o Pump flow is a function of reactor level (Starved Suction Test Data, Reference 2 and FLOOD CODE).
- o Core flow is six times the pump flow minus the leak flow plus the ECS flow. Leak flow = pump flow + plenum leak
- o Flow from the plenum is a function of core flow as determined from the FLOOD program after plenum venting.
- o Total leakage is a function of pump flow with the initial leak set at 66,500 gpm and the leak at the time the plenum vnets set by the FLOOD program calculations.
- o The total leakage after plenum venting is the sum of the leak from the plenum plus the flow from one pump. Also before venting.
- o ECS flow while the ball valve opens is determined empirically from L-Area test data.

All equations are identified within the program for calculating the hydraulic transients.

The computer program is attached with a sample run for PLK Areas with ECS flows of 5100 and 8000 gpm for initial leak rates of 75,000 and 66,500 gpm. Figure 1 shows the differences between these four cases.

REFERENCES

1. Project S-1830, Improved Supply of Emergency Coolant.

2. Starved Suction Tests, DPSP 70-1-4, pp. 29 - 31.

3. Hydraulic Transient For Loss of Coolant Accident, DPSP 75-1-11, pp. R20-R21.

4. J. L. Steimke, et al., Energy Conservation Survey of 100 Area Cooling Water and Process Water Systems - Phase I: Listing and Evaluation of Conservation Concerns, DPST-78-311, April 11, 1978.

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```
C
C
C
C
C  DDDDDDD    RRRRRRR      AAAA    II  NN     NN    000000     222222
C  DDDDDDDD   RRRRRRRR    AAAAAA   II  NNN    NN   00000000   22222222
C  DD    DD   RR    RR   AA    AA  II  NNNN   NN   00    00   22    22
C  DD    DD   RRRRRRR    AAAAAAAA  II  NN NN  NN   00    00         22
C  DD    DD   RRRRRRRR   AAAAAAAA  II  NN  NN NN   00    00       22
C  DD    DD   RR    RR   AA    AA  II  NN   NNNN   00    00     22
C  DDDDDDDD   RR    RR   AA    AA  II  NN    NNN   00000000   22222222
C  DDDDDDD    RR    RR   AA    AA  II  NN     NN    000000    22222222
C
C
C  PROGRAM TO CALCULATE REACTOR FLOW TRANSIENTS FOR LOSS OF COOLANT ACCIDENTS
C  PROGRAM WRITTEN BY J. H. HINTON NOVEMBER 1986, REVISED DECEMBER 1986
C
C  CALCULATIONS WITH AC MOTORS OR DC MOTORS
C
C  ALEV  IS THE REACTOR LEVEL WHEN AIR ASPIRATION BEGINS (70" IN PLK; 82" IN C)
C  BPFLO IS THE EQUILIBRIUM FLOW FROM THE EMERGENCY COOLING SYSTEM
C  COFLO IS THE CALCULATED CORE FLOW
C  COFLOV IS THE CORE FLOW FROM THE FLOOD CODE WHEN THE PLENUM VENTS
C  CECS IS THE CORRECTION TO THE ECS FLOW DURING AC MOTOR COAST DOWN
C  CLEV IS THE REACTOR LEVEL FOR THE AUTOMATIC TRIP OF THE AC MOTORS
C  CT IS THE TIME THE AC MOTORS TRIP
C  DTIME IS THE DIFFERENTIAL TIME FOR THE INCREMENTAL CALCULATION
C  PUFLO1 IS THE CALCULATED PUMP FLOW; STARTS AT 28,200 GPM (FROM FLOOD CODE)
C  PUFL2 IS THE PUMP FLOW RATE WHEN THE PLENUM VENTS (FLOOD CODE DATA)
C  PUMP IS AN IDENTIFIER FOR CHANGING FROM AC TO DC MOTORS
C  RATBP IS ECS FLOW RATE DURING AND AFTER VALVES BEGIN TO OPEN
C  RATLE IS THE CALCULATED LEAK RATE; DESIGNED BASIS IS 75000 GPM
C  RLPV  IS THE RX LEAK RATE WHEN THE PLENUM VENTS (PLENUM + PUMP)
C  RXLEAK IS THE DESIGN BASIS LEAK RATE (75000 GPM)
C  RXLEV1 IS THE REACTOR LEVEL; START AT 70" IN PLK AND 82" IN C
C  RXVOL IS THE VOLUME OF MODERATOR IN THE REACTOR
C  RVOLZ IS THE VOLUME OF MODERATOR IN THE REACTOR WHEN EMPTY; DPSOL 6122
C  RVOL60 IS THE VOLUME OF MODERATOR WITH THE LEVEL AT 60" IN PLK AND 72" IN C
C  RVOL128 IS THE VOLUME OF MODERATOR WITH THE LEVEL AT 12.8 FEET
C  TLEV IS THE AC MOTOR TRIP LEVEL IN FEET (12.8 OR 10.8)
C  TTIME IS THE TIME TO REACH 70 INCHES FOR THE INITIAL LEAK RATE (75000 GPM)
C  TRIP IS AN IDENTIFIER FOR AUTOMATICALLY TRIPPING THE AC MOTORS
C  TVOL  IS THE VOLUME OF MODERATOR IN REACTOR AT THE BEGINNING
C  VECS  IS THE VOLUME ADDED TO THE SYSTEM FROM THE ECS IN THE TIME INCREMENT
C  VENT  IS THE REACTOR LEVEL FOR WHICH THE PLENUM LIQUID LEVEL IS LESS THAN 8.75
C  VLEAK IS THE VOLUME LEAKED FROM THE SYSTEM IN THE TIME INCREMENT
C  VLEV IS THE LEVEL THE VALVES RECEIVE THE SIGNAL TO OPEN (60 IN)
C  VPFT  IS THE REACTOR VOLUME PER FOOT UNDER CIRCULATION
C  VT    IS THE TIME TO REACH THE 5 FOOT LEVEL
C  VTB   IS THE TIME THE BALL VALVE BEGINS TO OPEN; 1 SECOND AFTER 5 FT LEVEL
C  VTE   IS THE TIME THE BALL VALVE IS FULL OPEN; 11 SECONDS AFTER 5 FT LEVEL
C
      DIMENSION RXLEV(9000),COFLO(9000),PUFLO(9000),RATLE(9000)
      DIMENSION VECS(9000),RXVOL(9000),TTIME(9000),VLEAK(9000)
      DIMENSION RATBP(9000),CFLO(9000),CECS(9000),PRAT(9000)
C
C  USE AREA =1.0 FOR PLK CALCULATIONS
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```
C  USE AREA =2.0 FOR C AREA CALCULATIONS
C
C  USE PUMP=1.0 FOR AC MOTORS
C  USE PUMP=2.0 FOR DC MOTORS
C  USE PUMP=3.0 FOR AC MOTORS ON WITH AUTOMATIC TRIP ACTION
C
C  USE TRIP=1.0 FOR AUTOMATIC TRIP OF AC MOTORS AT 12.8 FEET
C  USE TRIP=2.0 FOR AUTOMATIC TRIP OF AC MOTORS AT 10.8 FEET
C
      AREA=1.0
      PUMP=3.0
      TRIP=2.0
      RXLEAK=66500.0
      PUFLO1=28200.0
      BPFLO=10000.0
      ULEV=60.0
      RLPV=9843.0
      COFLOV=33000.0
      PUFL2=7143.0
      RXLEV1=153.6
      DTIME=0.1
      IF(TRIP.EQ.1.0)CLEV=153.6
      IF(TRIP.EQ.1.0)TLEV=12.8
      IF(TRIP.EQ.2.0)CLEV=129.6
      IF(TRIP.EQ.2.0)TLEV=10.8
      IF(PUMP.EQ.2.0) GO TO 5
      GO TO 7
 5    PUFLO1=6875.0
 7    IF (AREA.EQ.1.0) GO TO 10
C
C  DATA FOR C AREA
C
      TVOL=31640.0
      RVOL60=15420.0
      RVOL128=27660
      RVOLZ=4620.0
      VPFT=1800.0
      ALEV=82.0
      GO TO 20
C
C  DATA FOR PLK AREAS
C
10    TVOL=24300.0
      RVOL128=20168.6
      RVOL60=9700.0
      RVOLZ=2990.5
      VPFT=1341.9
      ALEV=70.0
20    CONTINUE
      VPIN=VPFT/12.0
C
C  XP IS THE EXPONENT TO FIT THE LEAK DATA FROM THE FLOOD CODE WHEN THE PLENUM
C     VENTS TO THE INITIAL LEAK RATE (RXLEAK, GPM)
C
      IF(PUMP.EQ.2.0) GO TO 55
      GO TO 58
55    RXLEAK=RXLEAK*0.244
```

```
58      X=RLPV/RXLEAK
        Y=PUFL2/PUFL01
        XP=(LOG(X))/(LOG(Y))
C
C
        DO 400 I=1,9000
C
C  CALCULATE THE PUMP FLOW RATE FROM REACTOR LEVEL USING FLOOD CODE DATA
C
        RXVOL(1)=RVOL128
        RXLEV(1)=RXLEV1
        RATLE(1)=RXLEAK/60.0
        TTIME(1)=(TVOL-RVOL128)/RATLE(1)
C
C  REACTOR LEVEL TO BEGIN OPENING THE BALL VALVE IS SET AT 59 TO 60 INCHES
C
        IF(RXLEV(I).LE.(VLEV-0.0)) GO TO 62
62      IF(RXLEV(I).GE.(VLEV-1.0)) GO TO 64
        GO TO 66
64      VT=TTIME(I)
        VTB=VT+1.0
        VTE=VT+11.0
66      CONTINUE
C
C  REACTOR LEVEL FOR THE AC MOTOR TRIP SET FOR 10.8 OR 12.8 FEET
C
        IF(RXLEV(I).LE.(CLEV-1.0)) GO TO 72
72      IF(RXLEV(I).GE.(CLEV-1.1)) GO TO 74
        GO TO 76
74      CT=TTIME(I)+1.0
76      CONTINUE
C
C  DETERMINATION OF PUMP COAST DOWN FLOW RATIO
C
        IF(RXLEV(I).GE.(CLEV-1.1)) GO TO 1790
        IF(PUMP.EQ.1.0) GO TO 1790
        IF(PUMP.EQ.2.0) GO TO 1790
        IF(TTIME(I).LE.CT) GO TO 1790
        IF(TTIME(I).LE.(CT+1.07)) GO TO 1800
        IF(TTIME(I).GT.(CT+1.07)) GO TO 1710
1710    IF(TTIME(I).LE.(CT+2.14)) GO TO 1810
        IF(TTIME(I).GT.(CT+2.14)) GO TO 1720
1720    IF(TTIME(I).LE.(CT+3.86)) GO TO 1820
        IF(TTIME(I).GT.(CT+3.86)) GO TO 1730
1730    IF(TTIME(I).LE.(CT+7.71)) GO TO 1830
        IF(TTIME(I).GT.(CT+7.71)) GO TO 1740
1740    IF(TTIME(I).LE.(CT+13.50)) GO TO 1840
        IF(TTIME(I).GT.(CT+13.50)) GO TO 1750
1750    IF(TTIME(I).LE.(CT+21.43)) GO TO 1850
        IF(TTIME(I).GT.(CT+21.43)) GO TO 1760
1760    IF(TTIME(I).LE.(CT+50.36)) GO TO 1860
        IF(TTIME(I).GT.(CT+50.36)) GO TO 1770
1770    IF(TTIME(I).LE.(CT+60.0)) GO TO 1870
        IF(TTIME(I).GT.(CT+60.0)) GO TO 1780
1780    CFLO(I)=0.28
        GO TO 1880
1790    CFLO(I)=1.0
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```
      GO TO 1880
1800  CFLO(I)=(((CT+1.07)-TTIME(I))/10.7)+0.90
      GO TO 1880
1810  CFLO(I)=(((CT+2.14)-TTIME(I))/10.7)+0.80
      GO TO 1880
1820  CFLO(I)=(((CT+3.86)-TTIME(I))/17.2)+0.70
      GO TO 1880
1830  CFLO(I)=(((CT+7.7T)-TTIME(I))/38.5)+0.60
      GO TO 1880
1840  CFLO(I)=(((CT+13.50)-TTIME(I))/57.9)+0.50
      GO TO 1880
1850  CFLO(I)=(((CT+21.43)-TTIME(I))/79.3)+0.40
      GO TO 1880
1860  CFLO(I)=(((CT+50.36)-TTIME(I))/289.3)+0.30
      GO TO 1880
1870  CFLO(I)=(((CT+60.00)-TTIME(I))/482.0)+0.28
1880  CONTINUE
C
C  PUMP FLOW WITH AC MOTORS ON
C
      IF(AREA.EQ.1.0) W=0.0
      IF(AREA.EQ.2.0) W=12.0
      IF(TTIME(I).GE.CT+60.0) GO TO 1000
      IF(PUMP.EQ.2.0) GO TO 1000
      IF(RXLEV(I).GT.70.0+W) GO TO 305
      IF(RXLEV(I).LE.70.0+W) GO TO 550
550   IF(RXLEV(I).GE.60.0+W) GO TO 150
      IF(RXLEV(I).LT.60.0+W) GO TO 560
560   IF(RXLEV(I).GE.50.0+W) GO TO 160
      IF(RXLEV(I).LT.50.0+W) GO TO 570
570   IF(RXLEV(I).GE.40.0+W) GO TO 170
      IF(RXLEV(I).LT.40.0+W) GO TO 580
580   IF(RXLEV(I).GE.30.0+W) GO TO 180
      IF(RXLEV(I).LT.30.0+W) GO TO 590
590   IF(RXLEV(I).GE.25.0+W) GO TO 190
      IF(RXLEV(I).LT.25.0+W) GO TO 600
600   IF(RXLEV(I).GE.24.0+W) GO TO 200
      IF(RXLEV(I).LT.24.0+W) GO TO 610
610   IF(RXLEV(I).GE.23.0+W) GO TO 210
      IF(RXLEV(I).LT.23.0+W) GO TO 620
620   IF(RXLEV(I).GE.22.0+W) GO TO 220
      IF(RXLEV(I).LT.22.0+W) GO TO 630
630   IF(RXLEV(I).GE.21.0+W) GO TO 230
      IF(RXLEV(I).LT.21.0+W) GO TO 640
640   IF(RXLEV(I).GE.20.0+W) GO TO 240
      IF(RXLEV(I).LT.20.0+W) GO TO 650
650   IF(RXLEV(I).GE.19.0+W) GO TO 250
      IF(RXLEV(I).LT.19.0+W) GO TO 660
660   IF(RXLEV(I).GE.18.0+W) GO TO 260
      IF(RXLEV(I).LT.18.0+W) GO TO 670
670   IF(RXLEV(I).GE.15.0+W) GO TO 270
      IF(RXLEV(I).LT.15.0+W) GO TO 680
680   IF(RXLEV(I).GE.10.0+W) GO TO 280
      IF(RXLEV(I).LT.10.0+W) GO TO 690
690   IF(RXLEV(I).GE.5.0+W) GO TO 290
      IF(RXLEV(I).LT.5.0+W) GO TO 300
150   PUFLO(I)=(((RXLEV(I)-(60.0+W))*120)+27000.0)*CFLO(I)
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      GO TO 310
160   PUFLO(I)=(((RXLEV(I)-(50.0+W))*400)+23000.0)*CFLO(I)
      GO TO 310
170   PUFLO(I)=(((RXLEV(I)-(40.0+W))*700)+16000.0)*CFLO(I)
      GO TO 310
180   PUFLO(I)=(((RXLEV(I)-(30.0+W))*720)+8800.0)*CFLO(I)
      GO TO 310
190   PUFLO(I)=(((RXLEV(I)-(25.0+W))*510)+6250.0)*CFLO(I)
      GO TO 310
200   PUFLO(I)=(((RXLEV(I)-(24.0+W))*100)+6150.0)*CFLO(I)
      GO TO 310
210   PUFLO(I)=(((RXLEV(I)-(23.0+W))*50)+6100.0)*CFLO(I)
      GO TO 310
220   PUFLO(I)=(((RXLEV(I)-(22.0+W))*100)+6000.0)*CFLO(I)
      GO TO 310
230   PUFLO(I)=(((RXLEV(I)-(21.0+W))*250)+5750.0)*CFLO(I)
      GO TO 310
240   PUFLO(I)=(((RXLEV(I)-(20.0+W))*650)+5100.0)*CFLO(I)
      GO TO 310
250   PUFLO(I)=(((RXLEV(I)-(19.0+W))*850)+4250.0)*CFLO(I)
      GO TO 310
260   PUFLO(I)=(((RXLEV(I)-(18.0+W))*450)+3800.0)*CFLO(I)
      GO TO 310
270   PUFLO(I)=(((RXLEV(I)-(15.0+W))*308)+2875.0)*CFLO(I)
      GO TO 310
280   PUFLO(I)=(((RXLEV(I)-(10.0+W))*235)+1700.0)*CFLO(I)
      GO TO 310
290   PUFLO(I)=(((RXLEV(I)-(5.0+W))*190)+750.0)*CFLO(I)
      GO TO 310
300   PUFLO(I)=(((RXLEV(I)-(0.0+W))*150)+0.0)*CFLO(I)
      GO TO 310
305   PUFLO(I)=PUFLO1*CFLO(I)
310   CONTINUE
      IF(PUFLO(I).LT.6875.0) GO TO 1000
      GO TO 25
C
C  PUMP FLOWS WITH DC MOTORS ON
C
1000  IF(RXLEV(I).GT.70.0+W) GO TO 1305
      IF(RXLEV(I).LE.70.0+W) GO TO 1550
1550  IF(RXLEV(I).GE.60.0+W) GO TO 1150
      IF(RXLEV(I).LT.60.0+W) GO TO 1560
1560  IF(RXLEV(I).GE.50.0+W) GO TO 1160
      IF(RXLEV(I).LT.50.0+W) GO TO 1570
1570  IF(RXLEV(I).GE.40.0+W) GO TO 1170
      IF(RXLEV(I).LT.40.0+W) GO TO 1580
1580  IF(RXLEV(I).GE.30.0+W) GO TO 1180
      IF(RXLEV(I).LT.30.0+W) GO TO 1590
1590  IF(RXLEV(I).GE.25.0+W) GO TO 1190
      IF(RXLEV(I).LT.25.0+W) GO TO 1600
1600  IF(RXLEV(I).GE.24.0+W) GO TO 1200
      IF(RXLEV(I).LT.24.0+W) GO TO 1610
1610  IF(RXLEV(I).GE.23.0+W) GO TO 1210
      IF(RXLEV(I).LT.23.0+W) GO TO 1620
1620  IF(RXLEV(I).GE.22.0+W) GO TO 1220
      IF(RXLEV(I).LT.22.0+W) GO TO 1630
1630  IF(RXLEV(I).GE.21.0+W) GO TO 1230
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```
      IF(RXLEV(I).LT.21.0+W) GO TO 1640
1640  IF(RXLEV(I).GE.20.0+W) GO TO 1240
      IF(RXLEV(I).LT.20.0+W) GO TO 1650
1650  IF(RXLEV(I).GE.19.0+W) GO TO 1250
      IF(RXLEV(I).LT.19.0+W) GO TO 1660
1660  IF(RXLEV(I).GE.18.0+W) GO TO 1260
      IF(RXLEV(I).LT.18.0+W) GO TO 1670
1670  IF(RXLEV(I).GE.15.0+W) GO TO 1270
      IF(RXLEV(I).LT.15.0+W) GO TO 1680
1680  IF(RXLEV(I).GE.10.0+W) GO TO 1280
      IF(RXLEV(I).LT.10.0+W) GO TO 1690
1690  IF(RXLEV(I).GE.5.0+W) GO TO 1290
      IF(RXLEV(I).LT.5.0+W) GO TO 1300
1150  PUFLO(I)=((RXLEV(I)-(60.0+W))*13.9)+6736.0
      GO TO 1310
1160  PUFLO(I)=((RXLEV(I)-(50.0+W))*13.9)+6597.0
      GO TO 1310
1170  PUFLO(I)=((RXLEV(I)-(40.0+W))*13.9)+6458.0
      GO TO 1310
1180  PUFLO(I)=((RXLEV(I)-(30.0+W))*13.8)+6320.0
      GO TO 1310
1190  PUFLO(I)=((RXLEV(I)-(25.0+W))*14.0)+6250.0
      GO TO 1310
1200  PUFLO(I)=((RXLEV(I)-(24.0+W))*100.)+6150.0
      GO TO 1310
1210  PUFLO(I)=((RXLEV(I)-(23.0+W))*50.)+6100.0
      GO TO 1310
1220  PUFLO(I)=((RXLEV(I)-(22.0+W))*100.)+6000.0
      GO TO 1310
1230  PUFLO(I)=((RXLEV(I)-(21.0+W))*250.)+5750.0
      GO TO 1310
1240  PUFLO(I)=((RXLEV(I)-(20.0+W))*650.)+5100.0
      GO TO 1310
1250  PUFLO(I)=((RXLEV(I)-(19.0+W))*850.)+4250.0
      GO TO 1310
1260  PUFLO(I)=((RXLEV(I)-(18.0+W))*450.)+3800.0
      GO TO 1310
1270  PUFLO(I)=((RXLEV(I)-(15.0+W))*308.)+2875.0
      GO TO 1310
1280  PUFLO(I)=((RXLEV(I)-(10.0+W))*235.)+1700.0
      GO TO 1310
1290  PUFLO(I)=((RXLEV(I)-(5.0+W))*190.)+750.0
      GO TO 1310
1300  PUFLO(I)=((RXLEV(I)-(0.0+W))*150.)+0.0
      GO TO 1310
1305  PUFLO(I)=PUFLO1
1310  CONTINUE
C
C  CALCULATE THE LEAK RATE FROM PUMP FLOW AND INITIAL LEAK RATE
C
25    IF(RXLEV(I).GE.ALEV) RATLE(I)=RXLEAK/60
C
C  LEAK IS PROPORTIONAL TO PUMP FLOW UNTIL PLENUM VENTS
C  AIR ASPIRATION CAUSES THE PUMP FLOW TO DECREASE
C
      IF(RXLEV(I).LT.ALEV) GO TO 30
30    IF(PUFLO(I).LE.PUFL2) GO TO 40
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      RATLE(I)=(RXLEAK/60.0)*((PUFLO(I)/PUFLO1)**XP)
      GO TO 45
C
C  CALCULATE THE LEAK RATE FROM FLOOD CODE DATA AFTER PLENUM VENTING
C
40    RATLE(I)=(RLPV/60.0)*(PUFLO(I)/PUFL2)
45    CONTINUE
      VLEAK(I)=RATLE(I)*DTIME
C
C  CALCULATE REDUCTION IN ECS FLOW WITH VALVES OPENING BEFORE 5 FEET
C
      IF(PUMP.EQ.2.0) GO TO 1985
      IF(PUMP.EQ.3.0) GO TO 1890
      PRAT(I)=PUFLO(I)/PUFLO1
      IF(CFLO(I).GE.0.80) GO TO 2190
      IF(CFLO(I).LT.0.80) GO TO 2095
2095  IF(CFLO(I).GE.0.70) GO TO 2155
      IF(CFLO(I).LT.0.70) GO TO 2100
2100  IF(CFLO(I).GE.0.60) GO TO 2160
      IF(CFLO(I).LT.0.60) GO TO 2105
2105  IF(CFLO(I).GE.0.50) GO TO 2165
      IF(CFLO(I).LT.0.50) GO TO 2110
2110  IF(CFLO(I).GE.0.40) GO TO 2170
      IF(CFLO(I).LT.0.40) GO TO 2115
2115  IF(CFLO(I).GE.0.30) GO TO 2175
      IF(CFLO(I).LT.0.30) GO TO 2120
2120  IF(CFLO(I).GE.0.28) GO TO 2180
      IF(CFLO(I).LT.0.28) GO TO 2185
2155  CECS(I)=0.490-(0.490*((PRAT(I)-0.70)/0.10))
      GO TO 2195
2160  CECS(I)=0.673-(0.183*((PRAT(I)-0.60)/0.10))
      GO TO 2195
2165  CECS(I)=0.798-(0.125*((PRAT(I)-0.50)/0.10))
      GO TO 2195
2170  CECS(I)=0.886-(0.088*((PRAT(I)-0.40)/0.10))
      GO TO 2195
2175  CECS(I)=0.951-(0.065*((PRAT(I)-0.30)/0.10))
      GO TO 2195
2180  CECS(I)=0.961-(0.010*((PRAT(I)-0.28)/0.02))
      GO TO 2195
2185  CECS(I)=1.0
      GO TO 2195
2190  CECS(I)=0.0
2195  CONTINUE
C
C  CALCULATE THE REDUCTION IN ECS FLOW WHILE PUMPS ARE IN COAST DOWN
C
1890  IF(CFLO(I).GE.0.80) GO TO 1990
      IF(CFLO(I).LT.0.80) GO TO 1895
1895  IF(CFLO(I).GE.0.70) GO TO 1955
      IF(CFLO(I).LT.0.70) GO TO 1900
1900  IF(CFLO(I).GE.0.60) GO TO 1960
      IF(CFLO(I).LT.0.60) GO TO 1905
1905  IF(CFLO(I).GE.0.50) GO TO 1965
      IF(CFLO(I).LT.0.50) GO TO 1910
1910  IF(CFLO(I).GE.0.40) GO TO 1970
      IF(CFLO(I).LT.0.40) GO TO 1915
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1915    IF(CFLO(I).GE.0.30) GO TO 1975
        IF(CFLO(I).LT.0.30) GO TO 1920
1920    IF(CFLO(I).GE.0.28) GO TO 1980
        IF(CFLO(I).LT.0.28) GO TO 1985
1955    CECS(I)=0.490-(0.490*((CFLO(I)-0.70)/0.10))
        GO TO 1995
1960    CECS(I)=0.673-(0.183*((CFLO(I)-0.60)/0.10))
        GO TO 1995
1965    CECS(I)=0.798-(0.125*((CFLO(I)-0.50)/0.10))
        GO TO 1995
1970    CECS(I)=0.886-(0.088*((CFLO(I)-0.40)/0.10))
        GO TO 1995
1975    CECS(I)=0.951-(0.065*((CFLO(I)-0.30)/0.10))
        GO TO 1995
1980    CECS(I)=0.961-(0.010*((CFLO(I)-0.28)/0.02))
        GO TO 1995
1985    CECS(I)=1.0
        GO TO 1995
1990    CECS(I)=0.0
1995    CONTINUE
C
C  CALCULATE THE ECS FLOW INTO SYSTEM DURING AND AFTER VALVE OPENING
C
        IF(RXLEV(I).GE.(VLEV-1.0)) GO TO 110
        IF(TTIME(I).LE.VTB) GO TO 110
        IF(TTIME(I).GT.VTB) GO TO 790
790     IF(TTIME(I).LT.VTE) GO TO 120
        IF(TTIME(I).GE.VTE) GO TO 130
110     RATBP(I)=0.0
        GO TO 140
120     IF(RXLEV(I).LT.59.0) CECS(I)=1.0
        RATBP(I)=((TTIME(I)-VTB)**2.0)*CECS(I)
        GO TO 140
130     IF(RXLEV(I).LT.59.0) CECS(I)=1.0
        RATBP(I)=100.0*CECS(I)
140     CONTINUE
C
C  CALCULATE CORE FLOW FROM FLOOD CODE DATA AND REACTOR LEVEL
C
        COFLO(I)=6*(PUFLO(I))+(BPFLO*RATBP(I)/100.0)-(RATLE(I)*60.0)
C
        A=COFLOV+100
        B=COFLOV-100
        IF(COFLO(I).LE.A) GO TO 450
450     IF(COFLO(I).GE.B) GO TO 460
        GO TO 470
460     VENT=RXLEV(I)
        TVENT=TTIME(I)
        PUFL3=PUFLO(I)
470     CONTINUE
        VECS(I)=(BPFLO/60.0)*(RATBP(I)/100)*DTIME
        TTIME(I+1)=TTIME(I)+DTIME
        RXVOL(I+1)=RXVOL(I)-VLEAK(I)+VECS(I)
        RXLEV(I+1)=(RXVOL(I+1)-RVOLZ)/VPIN
C
C  CALCULATION WILL TERMINATE WHEN THE REACTOR LEVEL REACHES 5 INCHES OR
C  WHEN THE ECS INPUT EQUALS THE LEAK
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C
      IF(RXLEV(I+1).LE.5.0) GO TO 410
      Z=VLEAK(I)-VECS(I)
      IF(ABS(Z).LE.0.001) GO TO 410
      NR=I
400   CONTINUE
410   CONTINUE
      WRITE(6,380)
      WRITE(6,390)RXLEAK
      WRITE(6,320)BPFLO
      IF(AREA.EQ.1.0) GO TO 800
      WRITE(6,740)
      GO TO 810
800   WRITE(6,330)
810   CONTINUE
      IF(PUMP.EQ.1.0) GO TO 850
      IF(PUMP.EQ.2.0) GO TO 860
      IF(PUMP.EQ.3.0) GO TO 870
850   WRITE(6,880)
      GO TO 910
860   WRITE(6,890)
      GO TO 910
870   WRITE(6,900)
910   CONTINUE
      WRITE(6,700)TVENT
      IF(PUMP.NE.3.0) GO TO 915
      WRITE(6,820)CT
      WRITE(6,830)TLEV
915   WRITE(6,750)PUFL3
      VLEVF=VLEV/12
      WRITE(6,840)VLEVF
      WRITE(6,710)VT
      WRITE(6,720)VTB
      WRITE(6,730)VTE
      WRITE(6,340)
      WRITE(6,350)
      WRITE(6,360)
      DO 420 I=1,1000,10
      WRITE(6,370)TTIME(I),RXLEV(I),RXVOL(I),VECS(I),
     1 VLEAK(I),COFLO(I),PUFLO(I)
420   CONTINUE
      DO 425 I=1001,NR,50
      WRITE(6,370)TTIME(I),RXLEV(I),RXVOL(I),VECS(I),
     1 VLEAK(I),COFLO(I),PUFLO(I)
425   CONTINUE
380   FORMAT(6X,'CODE TO CALCULATE REACTOR TRANSIENTS FOR LOCAS')
390   FORMAT(6X,'INITIAL LEAK RATE,GPM=   ',F10.1)
320   FORMAT(6X,'ECS FLOW RATE,GPM=        ',F8.1)
330   FORMAT(6X,'CALCULATIONS ARE MADE FOR PLK REACTOR AREAS')
740   FORMAT(6X,'CALCULATIONS ARE MADE FOR C REACTOR')
340   FORMAT(6X,'    ',5X,'REACTOR',5X,'REACTOR',5X,'ECS',5X,'LEAK')
350   FORMAT(6X,'TIME',5X,' LEVEL ',5X,'VOLUME ',5X,'VOL',5X,'VOL ',5X,
     1 'CORE FLOW',5X,'PUMP FLOW')
360   FORMAT(6X,'SEC.',5X,'INCHES ',5X,'GALLONS',5X,'GAL',5X,'GAL ',5X,
     1 '   GPM   ',5X,'  GPM')
370   FORMAT(4X,F5.1,5X,F7.2,5X,F7.0,4X,F5.2,4X,F6.2,4X,F9.0,5X,F9.0)
700   FORMAT(6X,'THE TIME THE REACTOR PLENUM VENTS, SEC.=       ',F8.2)
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710   FORMAT(6X,'TIME VALVE OPEN LEVEL IS REACHED, SEC.=        ',F8.2)
720   FORMAT(6X,'THE TIME THE BALL VALVE BEGINS TO OPEN,SEC.=  ',F8.2)
730   FORMAT(6X,'THE TIME THE BALL VALVE IS FULL OPEN,SEC.=    ',F8.2)
750   FORMAT(6X,'THE PUMP FLOW RATE WHEN THE PLENUM VENTS, GPM=',F8.0)
820   FORMAT(6X,'TIME AC MOTORS TRIP, SEC.=                     ',F8.2)
830   FORMAT(6X,'LEVEL AC MOTORS ARE TRIPPED, FEET=             ',F8.2)
840   FORMAT(6X,'LEVEL VALVES RECEIVE SIGNAL TO OPEN,FEET=      ',F8.2)
880   FORMAT(6X,'TRANSIENT CALCULATIONS FOR AC MOTOR DRIVE ONLY')
890   FORMAT(6X,'TRANSIENT CALCULATIONS FOR DC MOTOR DRIVE ONLY')
900   FORMAT(6X,'CALCULATIONS FOR AC MOTORS WITH AUTOTOMATIC TRIP')
      END
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CODE TO CALCULATE REACTOR TRANSIENTS FOR LOCAS
INITIAL LEAK RATE,GPM= 75000.0
ECS FLOW RATE,GPM= 8000.0
CALCULATIONS ARE MADE FOR PLK REACTOR AREAS
THE TIME THE REACTOR PLENUM VENTS, SEC.= 190.79
THE PUMP FLOW RATE WHEN THE PLENUM VENTS, GPM= 5806.
THE TIME THE 5 FOOT LEVEL IS REACHED, SEC.= 11.79
THE TIME THE BALL VALVE BEGINS TO OPEN,SEC.= 12.79
THE TIME THE BALL VALVE IS FULL OPEN,SEC = 22.78

TIME SEC.	REACTOR LEVEL INCHES	REACTOR VOLUME GALLONS	ECS VOL GAL	LEAK VOL GAL	CORE FLOW GPM	PUMP FLOW GPM
10.8	70.00	10820.	.00	125.00	94200.	28200.
11.8	59.18	9608.	.00	115.12	90964	26673.
12.8	49.86	8566.	0.00	91.39	82292.	22903.
13.8	42.85	7783.	.13	64.34	69459.	17997.
14.8	37.89	7227.	.53	46.65	59212	14480.
15.8	34.30	6826.	1.20	34.88	51166.	11895.
16.8	31.66	6531.	2.13	26.97	45083.	9998.
17.8	29.72	6314.	3.33	21.80	40863.	8657.
18.8	28.24	6149.	4.80	19.05	38869.	7903.
19.8	27.12	6023.	6.53	17.05	37680.	7332.
20.9	26.31	5933.	8.53	15.89	37104.	6920.
21.8	25.77	5873.	10.80	15.26	37189.	6644.
22.8	25.49	5841.	13.33	14.93	38041.	6500.
23.8	25.35	5826.	13.33	14.77	37720.	6430.
24.8	25.23	5812.	13.33	14.62	37432.	6368.
25.8	25.12	5800.	13.33	14.50	37172.	6312.
26.8	25.02	5789.	13.33	14.38	36938.	6261.
27.8	24.93	5778.	13.33	14.34	36855.	6243.
28.8	24.84	5768.	13.33	14.32	36814.	6234.
29.8	24.75	5759.	13.33	14.30	36774.	6225.
30.8	24.67	5749.	13.33	14.28	36734.	6217.
31.8	24.58	5740.	13.33	14.26	36696.	6208.
32.8	24.50	5731.	13.33	14.24	36658.	6200.
33.8	24.42	5722.	13.33	14.22	36621.	6192.
34.8	24.34	5713.	13.33	14.20	36584.	6184.
35.8	24.27	5704.	13.33	14.19	36549.	6177.
40.8	23.90	5663.	13.33	14.11	36403.	6145.
45.8	23.56	5625.	13.33	14.07	36324.	6128.
50.8	23.24	5589.	13.33	14.04	36250.	6112.
55.8	22.93	5555.	13.33	13.99	36163.	6093.
60.8	22.65	5524.	13.33	13.93	36033.	6065.
65.8	22.40	5495.	13.33	13.87	35916.	6040.
70.8	22.17	5470.	13.33	13.82	35810.	6017.
75.8	21.96	5447.	13.33	13.76	35690.	5991.
80.8	21.80	5428.	13.33	13.66	35495.	5949.
85.8	21.67	5413.	13.33	13.59	35345.	5916.
90.8	21.56	5402.	13.33	13.53	35229.	5891.
95.8	21.49	5393.	13.33	13.49	35139.	5872.
100.8	21.43	5387.	13.33	13.45	35069.	5857.
105.8	21.38	5381.	13.33	13.42	35016.	5845.
110.8	21.34	5377.	13.33	13.40	34974.	5836.
115.8	21.32	5374.	13.33	13.39	34942.	5829.
120.8	21.29	5372.	13.33	13.38	34917.	5824.
125.8	21.28	5370.	13.33	13.37	34898.	5820.
130.8	21.27	5369.	13.33	13.36	34883.	5816.

CODE TO CALCULATE REACTOR TRANSIENTS FOR LOCAS
INITIAL LEAK RATE,GPM= 75000.0
ECS FLOW RATE,GPM= 5100.0
CALCULATIONS ARE MADE FOR PLK REACTOR AREAS
THE TIME THE REACTOR PLENUM VENTS, SEC.= 27.28
THE PUMP FLOW RATE WHEN THE PLENUM VENTS, GPM= 6015.
THE TIME THE 5 FOOT LEVEL IS REACHED, SEC.= 11.78
THE TIME THE BALL VALVE BEGINS TO OPEN,SEC.= 12.78
THE TIME THE BALL VALVE IS FULL OPEN,SEC.= 22.78

TIME SEC.	REACTOR LEVEL INCHES	REACTOR VOLUME GALLONS	ECS VOL GAL	LEAK VOL GAL	CORE FLOW GPM	PUMP FLOW GPM
10.8	70.00	10820.	.00	125.00	94200.	28200.
11.8	59.18	9608.	.00	115.12	90964.	26673.
12.8	49.86	8566.	0.00	91.39	82282.	22903.
13.8	42.85	7782.	.09	64.33	69428.	17996
14.8	37.88	7226.	.34	46.61	59075.	14473.
15.8	34.27	6823.	.77	34.79	50830.	11873.
16.8	31.59	6523.	1.36	26.77	44438.	9947.
17.8	29.59	6299.	2.13	21.55	39881.	8589.
18.8	28.01	6123.	3.06	18.63	37366.	7785.
19.8	26.75	5982.	4.17	16.41	35520.	7144.
20.8	25.76	5871.	5.44	15.24	33938.	6637.
21.8	24.98	5784.	6.89	14.35	33008.	6248.
22.8	24.38	5717.	8.50	14.21	33700.	6188.
23.8	23.87	5660.	8.50	14.11	33496.	6144.
24.8	23.37	5604.	8.50	14.05	33381.	6119.
25.8	22.88	5549.	8.50	13.98	33238.	6088.
26.8	22.39	5495.	8.50	13.87	33014.	6039.
27.8	21.92	5441.	8.50	13.73	32737.	5979.
28.8	21.46	5390.	8.50	13.47	32209.	5865.
29.8	21.03	5342.	8.50	13.22	31707.	5757.
30.8	20.63	5297.	8.50	12.65	30555.	5507.
31.8	20.28	5258.	8.50	12.13	29505.	5280.
32.8	19.97	5224.	8.50	11.66	28561.	5076.
33.8	19.71	5195.	8.50	11.15	27535.	4854.
34.8	19.49	5170.	8.50	10.72	26674.	4668.
35.8	19.31	5150.	8.50	10.36	25953.	4512.
40.8	18.72	5084.	8.50	9.47	24165.	4125.
45.8	18.37	5045.	8.50	9.11	23437.	3967.
50.8	18.15	5020.	8.50	8.88	22980.	3868.
55.8	18.01	5005.	8.50	8.74	22693.	3806.
60.8	17.92	4995.	8.50	8.67	22550.	3775.
65.8	17.86	4987.	8.50	8.62	22457.	3755.
70.8	17.81	4982.	8.50	8.59	22388.	3740.
75.8	17.78	4978.	8.50	8.57	22339.	3730.
80.8	17.75	4975.	8.50	8.55	22303.	3722.
85.8	17.73	4973.	8.50	8.53	22277.	3716.
90.8	17.72	4972.	8.50	8.53	22257.	3712.
95.8	17.71	4971.	8.50	8.52	22243.	3709.
100.8	17.70	4970.	8.50	8.51	22233.	3707.
105.8	17.70	4969.	8.50	8.51	22226.	3705.
110.8	17.69	4969.	8.50	8.51	22220.	3704.
115.8	17.69	4969.	8.50	8.51	22217.	3703.
120.8	17.69	4968.	8.50	8.50	22214.	3703.
125.8	17.69	4968.	8.50	8.50	22212.	3702.
130.8	17.68	4968.	8.50	8.50	22210.	3702.

CODE TO CALCULATE REACTOR TRANSIENTS FOR LOCAS
INITIAL LEAK RATE,GPM=   56500.0
ECS FLOW RATE,GPM= 5100.0
CALCULATIONS ARE MADE FOR PLK REACTOR AREAS
THE TIME THE REACTOR PLENUM VENTS, SEC.=   29.66
THE PUMP FLOW RATE WHEN THE PLENUM VENTS, GPM=   6017.
THE TIME THE 5 FOOT LEVEL IS REACHED, SEC.=   13.26
THE TIME THE BALL VALVE BEGINS TO OPEN,SEC.=   14.26
THE TIME THE BALL VALVE IS FULL OPEN,SEC.=   24.26

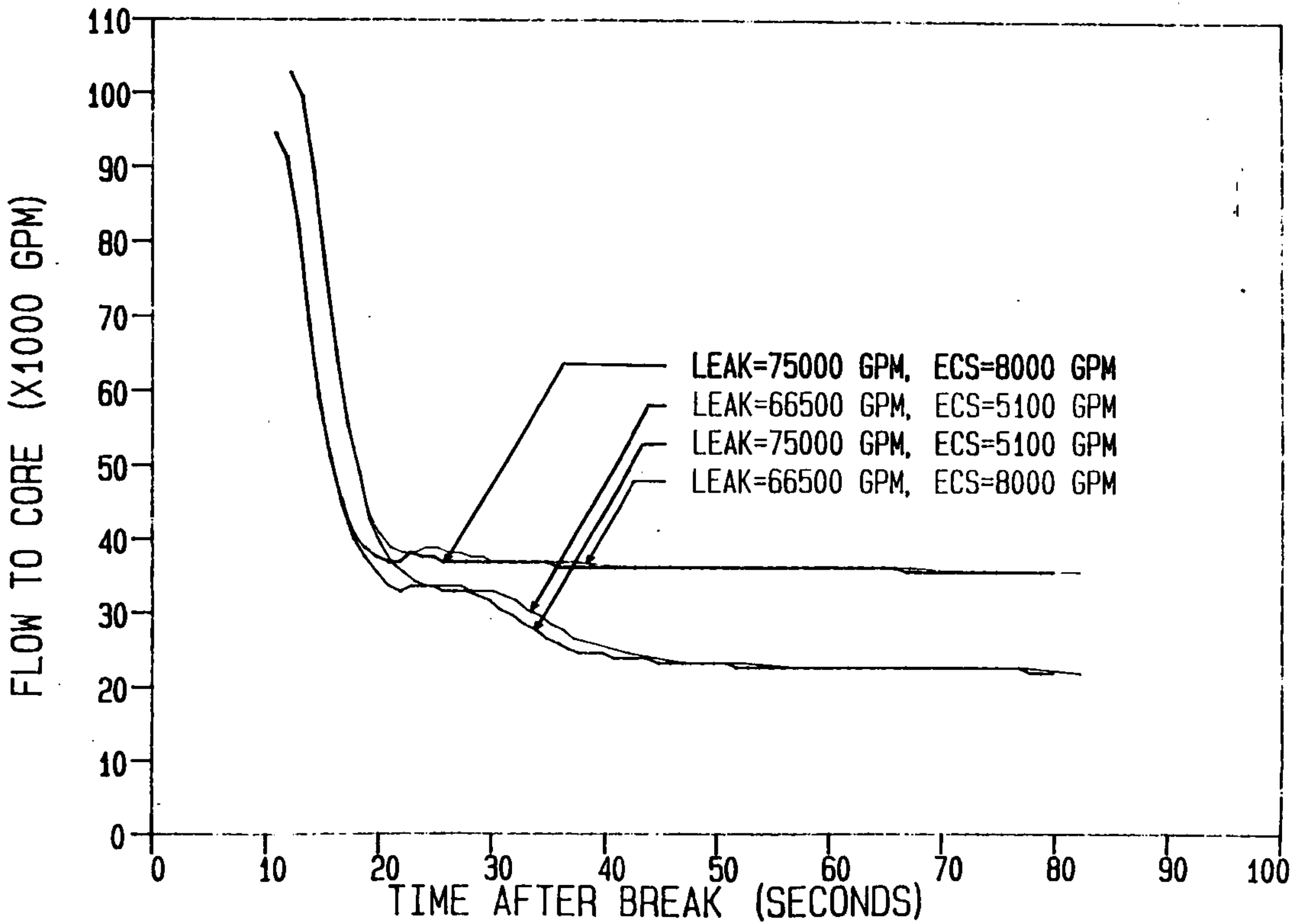
TIME SEC.	REACTOR LEVEL INCHES	REACTOR VOLUME GALLONS	ECS VOL GAL	LEAK VOL GAL	CORE FLOW GPM	PUMP FLOW GPM
12.2	70.00	10820.	.00	110.83	102700.	29200.
13.2	60.36	9740.	.00	104.56	99524.	27043.
14.2	51.72	8775.	.00	96.99	89960.	23691.
15.2	44.79	7999.	.07	65.63	76751.	19350
16.2	39.63	7423.	.31	49.23	65067.	15737.
17.2	35.77	6991.	.71	37.57	55635.	12958.
18.2	32.85	6664.	1.29	29.36	48281.	10854.
19.2	30.62	6415.	2.04	23.50	42611.	9247.
20.2	28.90	6222.	2.96	20.31	39201.	8238.
21.2	27.52	6067.	4.05	17.66	37027.	7533.
22.2	26.42	5945.	5.30	16.02	35421.	6975.
23.2	25.56	5849.	6.73	15.01	34251.	6536.
24.2	24.92	5777.	8.33	14.33	33847.	6242.
25.2	24.40	5719.	8.50	14.22	33709.	6190.
26.2	23.89	5662.	8.50	14.11	33500.	6145.
27.2	23.39	5606.	8.50	14.05	33385.	6120.
28.2	22.90	5551.	8.50	13.99	33247.	6090.
29.2	22.41	5497.	8.50	13.87	33022.	6041.
30.2	21.94	5443.	8.50	13.74	32757.	5984.
31.2	21.48	5392.	8.50	13.48	32228.	5869.
32.2	21.04	5344.	8.50	13.23	31725.	5760.
33.2	20.64	5299.	8.50	12.67	30597.	5516.
34.2	20.29	5259.	8.50	12.14	29541.	5288.
35.2	19.98	5225.	8.50	11.68	28603.	5085.
36.2	19.72	5196.	8.50	11.17	27570.	4861.
37.2	19.50	5171.	8.50	10.73	26704.	4674.
42.2	18.82	5095.	8.50	9.57	24363.	4168.
47.2	18.43	5052.	8.50	9.17	23562.	3994.
52.2	18.19	5025.	8.50	8.92	23058.	3885.
57.2	18.04	5008.	8.50	8.77	22742.	3817.
62.2	17.94	4997.	8.50	8.68	22573.	3780.
67.2	17.87	4989.	8.50	8.63	22474.	3759.
72.2	17.82	4983.	8.50	8.60	22401.	3743.
77.2	17.78	4979.	8.50	8.57	22348.	3732.
82.2	17.75	4976.	8.50	8.55	22309.	3723.
87.2	17.73	4974.	8.50	8.54	22281.	3717.
92.2	17.72	4972.	8.50	8.53	22261.	3713.
97.2	17.71	4971.	8.50	8.52	22246.	3710.
102.2	17.70	4970.	8.50	8.51	22235.	3707.
107.2	17.70	4969.	8.50	8.51	22227.	3706.
112.2	17.69	4969.	8.50	8.51	22221.	3704.
117.2	17.69	4969.	8.50	8.51	22217.	3703.
122.2	17.69	4968.	8.50	8.50	22214.	3703.
127.2	17.69	4968.	8.50	8.50	22212.	3702.
132.2	17.68	4968.	8.50	8.50	22210.	3702.

CODE TO CALCULATE REACTOR TRANSIENTS FOR LOCAS
INITIAL LEAK RATE,GPM= 56500.0
ECS FLOW RATE,GPM= 3000.0
CALCULATIONS ARE MADE FOR PLK REACTOR AREAS
THE TIME THE REACTOR PLENUM VENTS, SEC.= 195.07
THE PUMP FLOW RATE WHEN THE PLENUM VENTS, GPM= 5806.
THE TIME THE 5 FOOT LEVEL IS REACHED, SEC.= 13.26
THE TIME THE BALL VALVE BEGINS TO OPEN,SEC.= 14.26
THE TIME THE BALL VALVE IS FULL OPEN,SEC = 24.26

TIME SEC.	REACTOR LEVEL INCHES	REACTOR VOLUME GALLONS	ECS VOL GAL	LEAK VOL GAL	CORE FLOW GPM	PUMP FLOW GPM
12.2	70.00	10820.	.00	110.83	102700.	28200.
13.2	60.36	9740.	.00	104.56	99524.	27043.
14.2	51.73	8775.	.00	86.98	89960.	23691.
15.2	44.79	7999.	.11	65.63	75787.	19350.
16.2	39.64	7424.	.48	49.25	65192.	15743.
17.2	35.80	6994.	1.12	37.55	55951.	12979.
18.2	32.92	6672.	2.03	29.54	48900.	10901.
19.2	30.75	6429.	3.20	23.82	43661.	9339.
20.2	29.12	6247.	4.64	20.39	40657.	8351.
21.2	27.87	6107.	6.35	18.25	39134.	7713.
22.2	26.95	6004.	8.32	16.73	38415.	7243.
23.2	26.32	5934.	10.56	15.90	38341.	6924.
24.2	25.96	5894.	13.07	15.48	38997.	6741.
25.2	25.78	5873.	13.33	15.25	38719.	6646.
26.2	25.61	5855.	13.33	15.07	38331.	6562.
27.2	25.46	5838.	13.33	14.90	37981.	6487.
28.2	25.33	5823.	13.33	14.74	37667.	6419.
29.2	25.21	5810.	13.33	14.60	37383.	6357.
30.2	25.10	5798.	13.33	14.47	37129.	6302.
31.2	25.00	5787.	13.33	14.36	36899.	6252.
32.2	24.91	5777.	13.33	14.33	36848.	6241.
33.2	24.83	5767.	13.33	14.31	36807.	6233.
34.2	24.74	5757.	13.33	14.29	36767.	6224.
35.2	24.65	5747.	13.33	14.27	36727.	6215.
36.2	24.57	5738.	13.33	14.26	36689.	6207.
37.2	24.49	5729.	13.33	14.24	36651.	6199.
42.2	24.10	5686.	13.33	14.15	36473.	6160.
47.2	23.75	5647.	13.33	14.10	36368.	6138.
52.2	23.42	5609.	13.33	14.06	36291.	6121.
57.2	23.10	5574.	13.33	14.02	36218.	6105.
62.2	22.81	5541.	13.33	13.97	36105.	6081.
67.2	22.54	5511.	13.33	13.90	35981.	6054.
72.2	22.30	5484.	13.33	13.85	35869.	6030.
77.2	22.08	5459.	13.33	13.80	35768.	6008.
82.2	21.88	5438.	13.33	13.71	35599.	5971.
87.2	21.73	5421.	13.33	13.63	35425.	5934.
92.2	21.62	5408.	13.33	13.56	35291.	5904.
97.2	21.53	5398.	13.33	13.51	35187.	5882.
102.2	21.46	5390.	13.33	13.47	35106.	5865.
107.2	21.40	5384.	13.33	13.44	35044.	5851.
112.2	21.36	5379.	13.33	13.41	34996.	5841.
117.2	21.33	5376.	13.33	13.40	34959.	5833.
122.2	21.31	5373.	13.33	13.38	34931.	5827.
127.2	21.29	5371.	13.33	13.37	34908.	5822.
132.2	21.27	5369.	13.33	13.36	34891.	5819.

FIGURE 1

CORE FLOW AFTER LOCA



APPENDIX

Leak Rate Calculation

The leak rate for a double-ended pipe break adjacent to the plenum inlet nozzle is calculated in this appendix. The total leak rate comes from two sources. First, the Bingham pump in the broken line is a supply source. Second, the flow from the plenum at the broken nozzle is the remaining supply source.

The leak rate is a function of the components in the reactor. In the following calculations, data from the K-12.3 subcycle were used. The K-12.3 subcycle had the largest plenum pressure for the subcycles considered.

Leak From Pump

The leak rate from the broken plenum inlet pipe is determined by summing the pressure losses from the pump to the break location and using the pump head curve from Reference 4 to determine the pump flow. The pressure loss is

$$P_L = h_B + h_L \tag{1}$$

where P_L = total head loss, ft of D_2O
h_B = head at point of line break, ft of D_2O
h_L = loss from broken pipe, taken as one velocity head, ft of D_2O

The pump head for the system flow is 430 ft of D_2O. For the K-12.3 subcycle, total pump flow for six systems is 149,400 gpm and is split as:

Fuel flow = 141,400 gpm
S-Foil flow = 6,600 gpm
Sparger flow = 1,400 gpm

The individual system flow is 149,400/6 or 24,900 gpm at 430 ft of D_2O. For this subcycle, the plenum pressure is 71.9 psig (no blanket gas) or 151 ft D_2O. The plenum gradient of 20 ft of D_2O is added to 151 to obtain the head at the edge of the plenum. The value for h_B is

$$h_B = 430 - 171$$

$$= 259 \text{ ft of } D_2O \text{ at } 24{,}900 \text{ gpm}$$

For a reference point, the loss for one velocity head is calculated for 25,000 gpm and is

$$V = 25{,}000/(60 \times 7.483 \times 1.23)$$

$$= 45.3 \text{ ft/sec}$$

$$h_L = 1.0\ V^2/2g_c$$

$$= 31.85 \text{ ft of } D_2O \text{ at } 25{,}000 \text{ gpm}$$

where 60 = conversion from minutes to seconds
7.483 = conversion from gallons to cubic feet
1.23 = area of 16 inch pipe, square feet

At this point, the total head loss for a number of flows is calculated using equation 1:

$$P_L = (FLOW/24.9)^2 \times 259 + (FLOW/25)_2 \times 31.85$$

where FLOW = system flow in thousands of gpm

The point at which the total head loss and pump flow matched the pump head curve from Reference 4 is 28,500 gpm. The septifoil flow must be subtracted from this value. It is assumed that the septifoil pressure supply is proportional to flow to obtain:

$$(28.5/24.9) = 1{,}100 = 1{,}260 \text{ gpm}$$

The flow to the line break is:

$$FLOW = 28{,}500 = 1{,}260 = 27{,}240 \text{ gpm}$$

Leak From Plenum

In calculating the plenum leak rate, the pumps must work against the head from the piping leading to the plenum (h_B), the plenum pressure (151 ft of D_2O for this example), and the leak loss (h_L). The calculational technique first calculates a flow equation coefficient from

$$C = P/(FLOW)^2 \qquad (2)$$

For each of the three items contributing to the head loss:

Plenum Leak $C_l = 31.85/25^2 = 0.05096$ (3)

Core Flow $C_c = 151/(142.8)^2 = 0.007405$ (4)

System Flow $C_s = 259/(149.4/6)^2 = 0.41774$ (5)

The next step is to assume a core flow and calculate the appropriate head losses. For an assumed core flow of 92,000 gpm, equation 2 gives a pressure at the plenum centerline of 63 ft. The pressure gradient from the plenum centerline to the plenum leak location must be added to the 63 ft. The plenum gradient value estimated to be 16 ft to give a delta-P value of 79 ft. For the plenum head at the plenum leak location, equation 2 calculated a plenum leak of 39,300 gpm. The total plenum flow is 39,300 + 92,000 or 131,300 gpm. For the K-12.3 subcycle, the septifoil flow was 6,600 gpm at a total core flow of 142,800 gpm (fuel and sparger flow). The septifoil flow for the 131,300 flow was determined from

$$\text{Septifoil flow} = (131,300/142,800) \times 6,600$$

$$= 6,060 \text{ gpm}$$

The total pump flow is 6,060 + 131,300 or 137,360 gpm which gives an individual pump flow of 27,500 gpm. The system delta-P as determined from equation 2 is 315.3 ft. The plenum gradient can be calculated and compared to the assumed value of 16 ft. The plenum gradient was 20 ft at the full flow of 142,800 gpm. For the reduced plenum flow of 131,300 gpm, the plenum gradient was determined by

$$\text{Gradient} - 20/(142,800/131,300)^2$$

to be 16.9 ft which is close enough to the assumed 16 ft value. The total delta-P is then

$$pT = 315.3 + 16.9 + 63$$

$$= 395.2 \text{ ft}$$

The flow and total delta-P (head) are then compared to what is possible from the pump head curves. Iterations are continued if agreement is poor.

For the K-12.3 subcycle, the plenum-to-break leak is calculated to be 39,300 gpm.

Total Leak

The total leak rate is:

$$\text{Total leak} = 39,300 + 27,240$$

$$= 66,500 \text{ gpm}$$

This leak rate is lower than the previously assumed value of 75,000 gpm because the plenum leak rate in this calculation depends on the pump head curves. The previous value of 75,000 gpm was determined by assuming a constant plenum pressure and using the Vernoulli equation with loss terms to calculate flow from the plenum nozzle. With this assumption, the previous leak rate from the plenum was approximately 47,000 gpm which combined with the line break flow gave the 75,000 gpm value.

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