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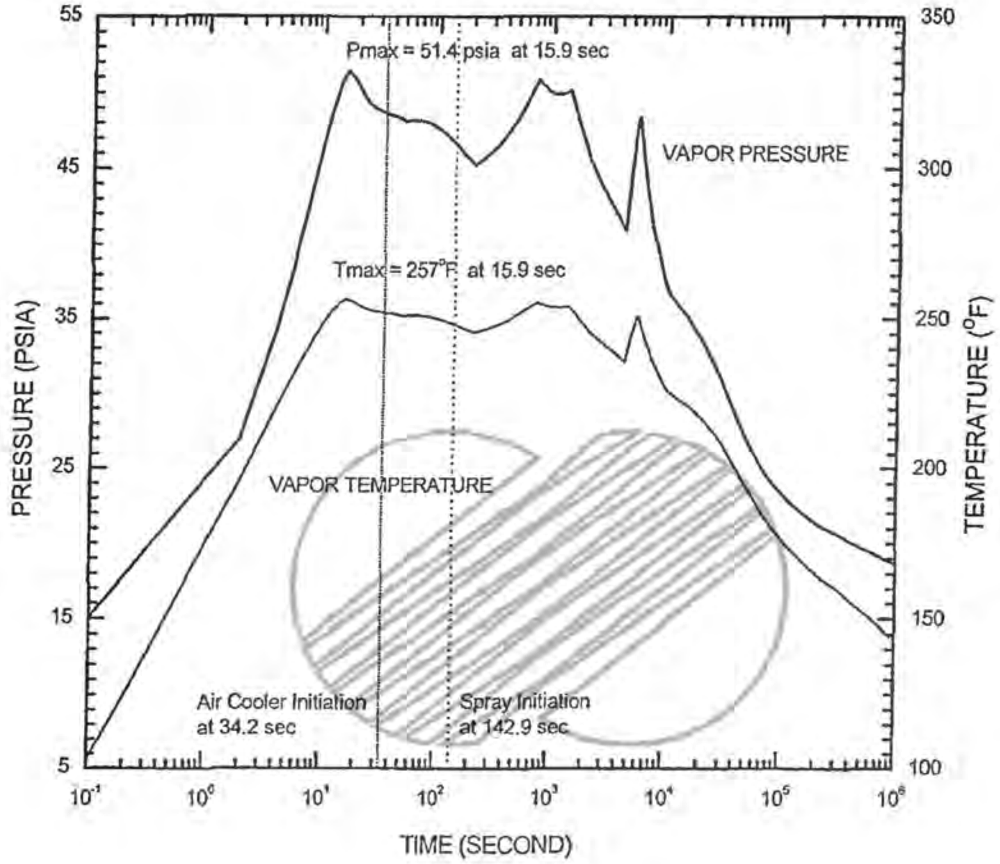
Double-Ended Pump Suction Break Minimum Safety Injection



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KOREA HYDRO & NUCLEAR POWER COMPANY KRN 3 & 4 FSAR
CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK (Sheet 1 of 18) Figure 6.2-1

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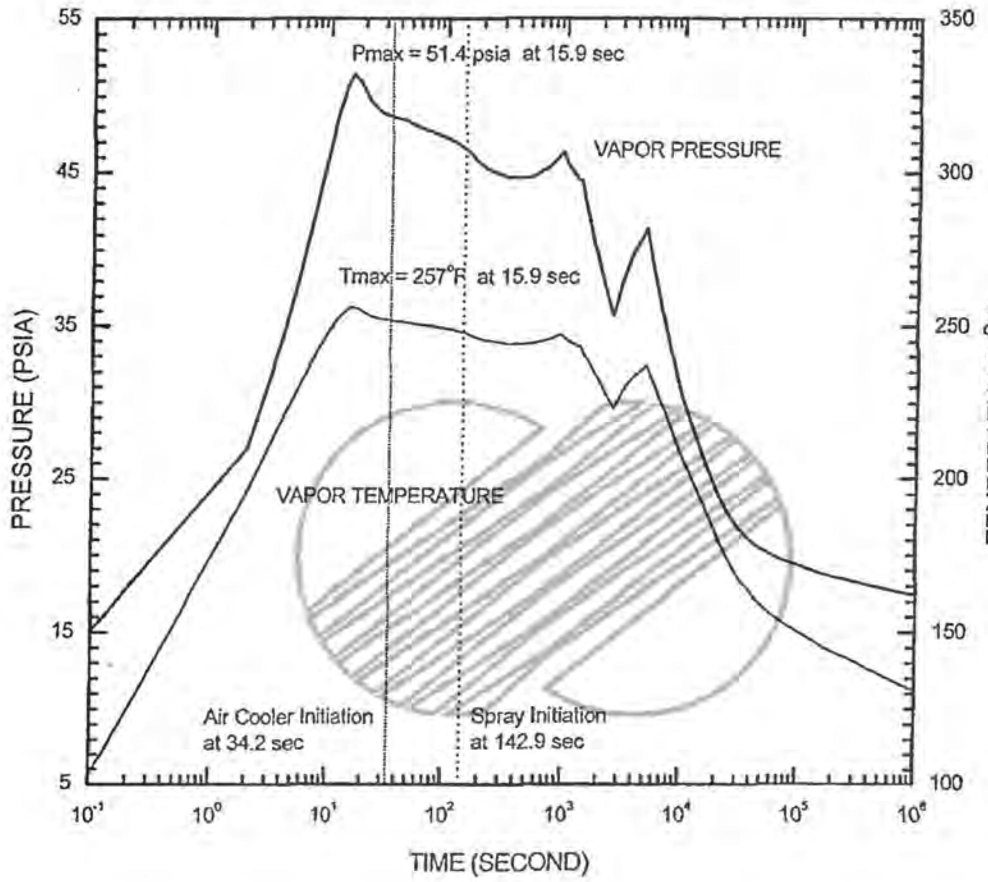

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KOREA HYDRO & NUCLEAR POWER COMPANY
KRN 3 & 4 FSAR

CONTAINMENT PRESSURE AND TEMPERATURE
VS TIME FOLLOWING A PIPE BREAK
(Sheet 2 of 18)
Figure 6.2-1

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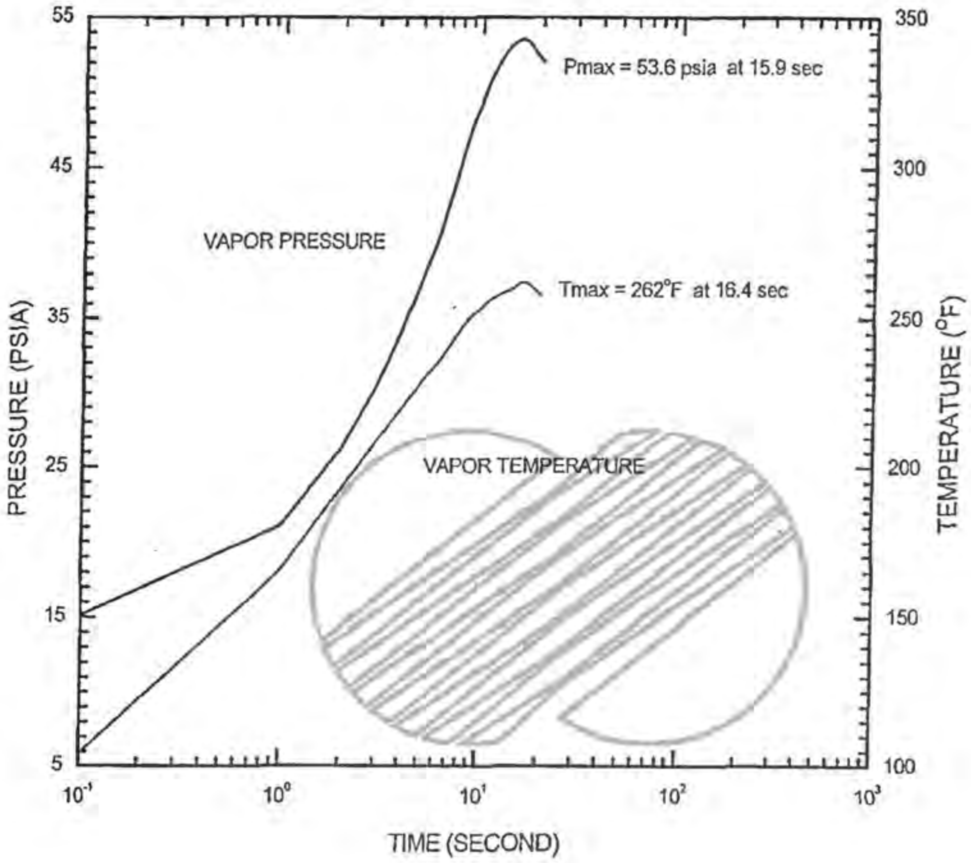
Double-Ended Hot Leg Break



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KOREA HYDRO & NUCLEAR POWER COMPANY

KRN 3 & 4 FSAR

CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK

(Sheet 3 of 18)

Figure 6.2-1

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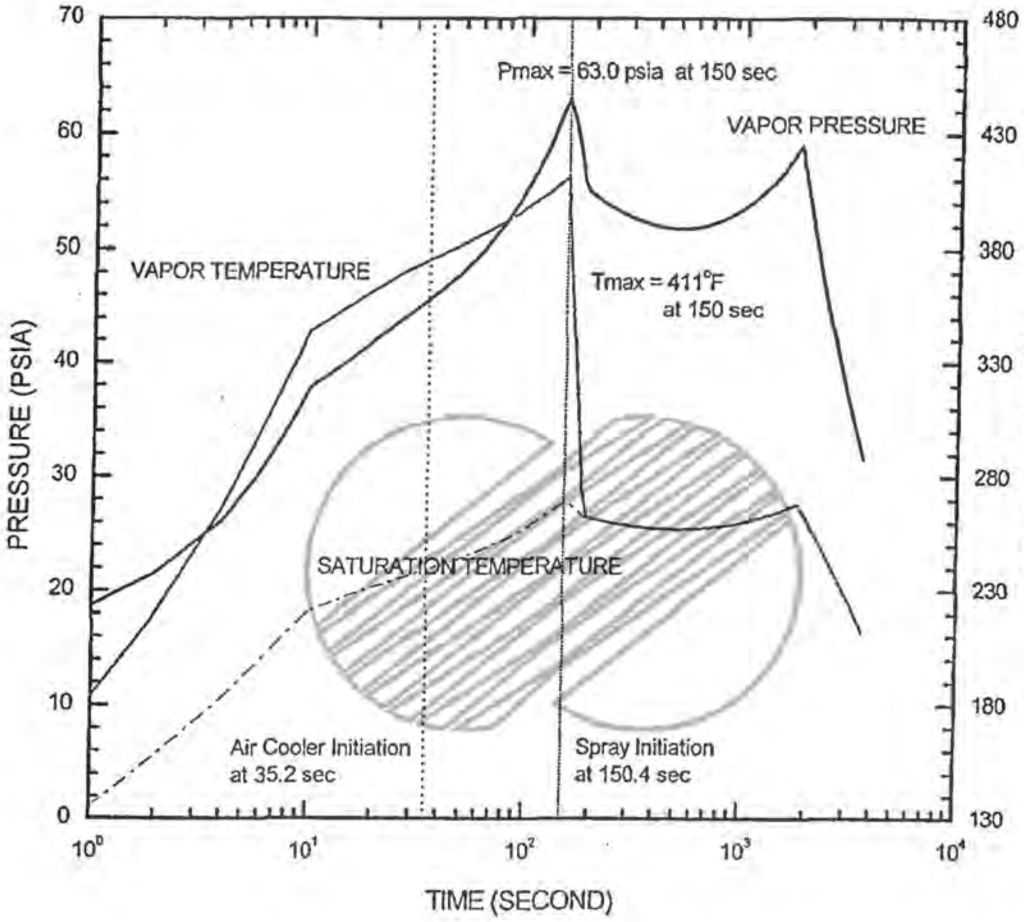
Main Steam Line Break Full Double-Ended Pipe Rupture at 102% Power



KOREA HYDRO & NUCLEAR POWER COMPANY
KRN 3 & 4 FSAR

CONTAINMENT PRESSURE AND TEMPERATURE
VS TIME FOLLOWING A PIPE BREAK
(Sheet 4 of 18)
Figure 6.2-1

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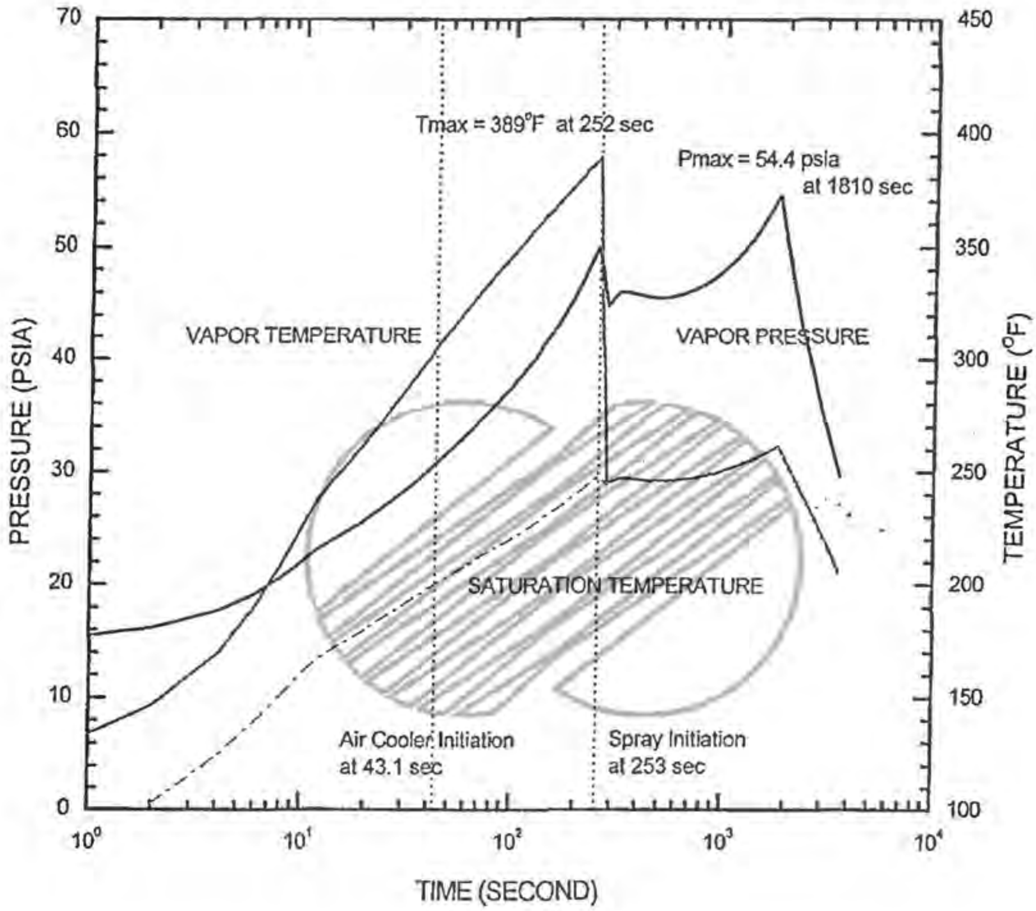

KOREA HYDRO & NUCLEAR POWER COMPANY
KRN 3 & 4 FSAR

CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK
(Sheet 5 of 18)
Figure 6.2-1

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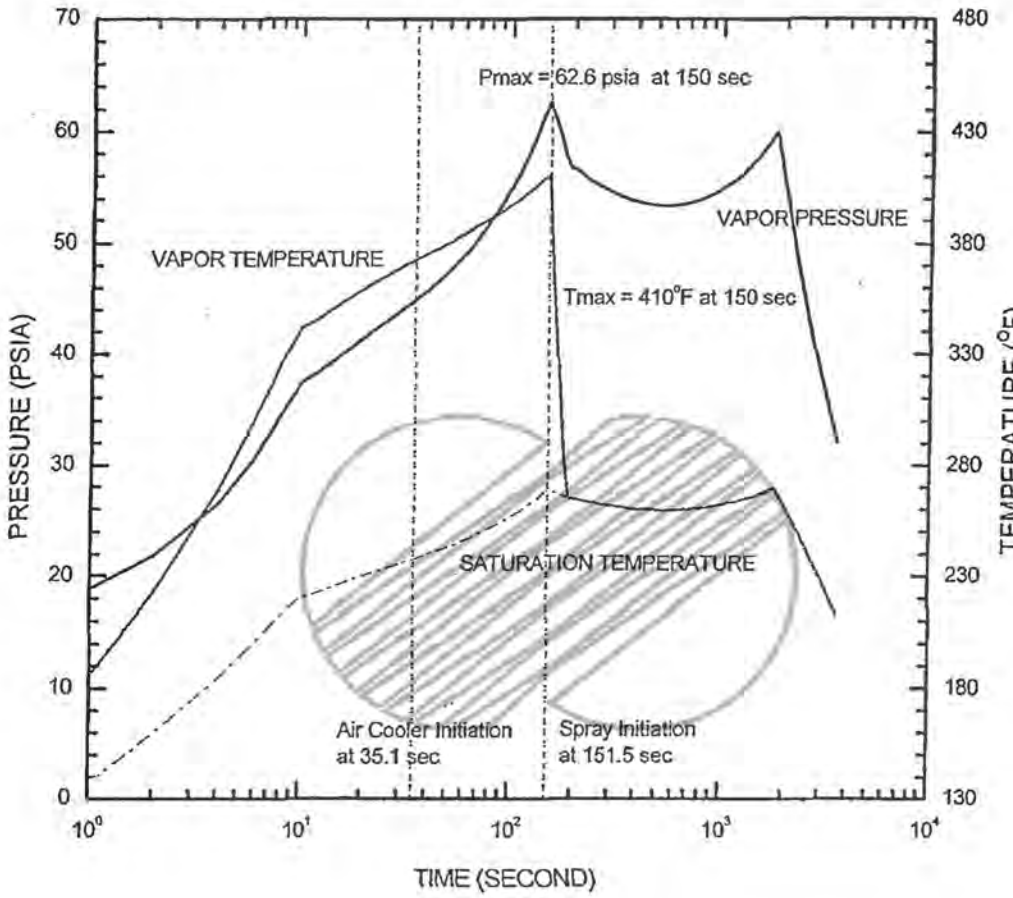
Main Steam Line Break Full Double-Ended Pipe Rupture at 75% Power



KOREA HYDRO & NUCLEAR POWER COMPANY
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CONTAINMENT PRESSURE AND TEMPERATURE
VS TIME FOLLOWING A PIPE BREAK
(Sheet 6 of 18)
Figure 6.2-1

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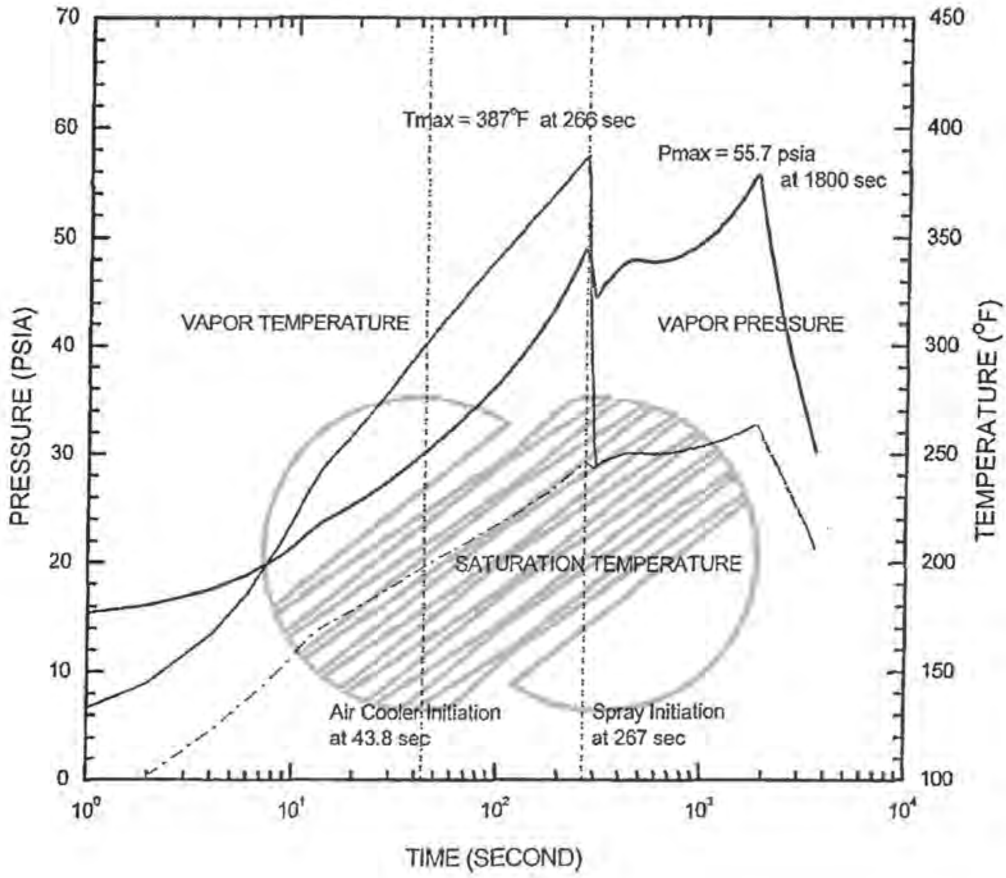
Main Steam Line Break Small Double-Ended Pipe Rupture at 75% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY KRN 3 & 4 FSAR	
CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK (Sheet 7 of 18) Figure 6.2-1	

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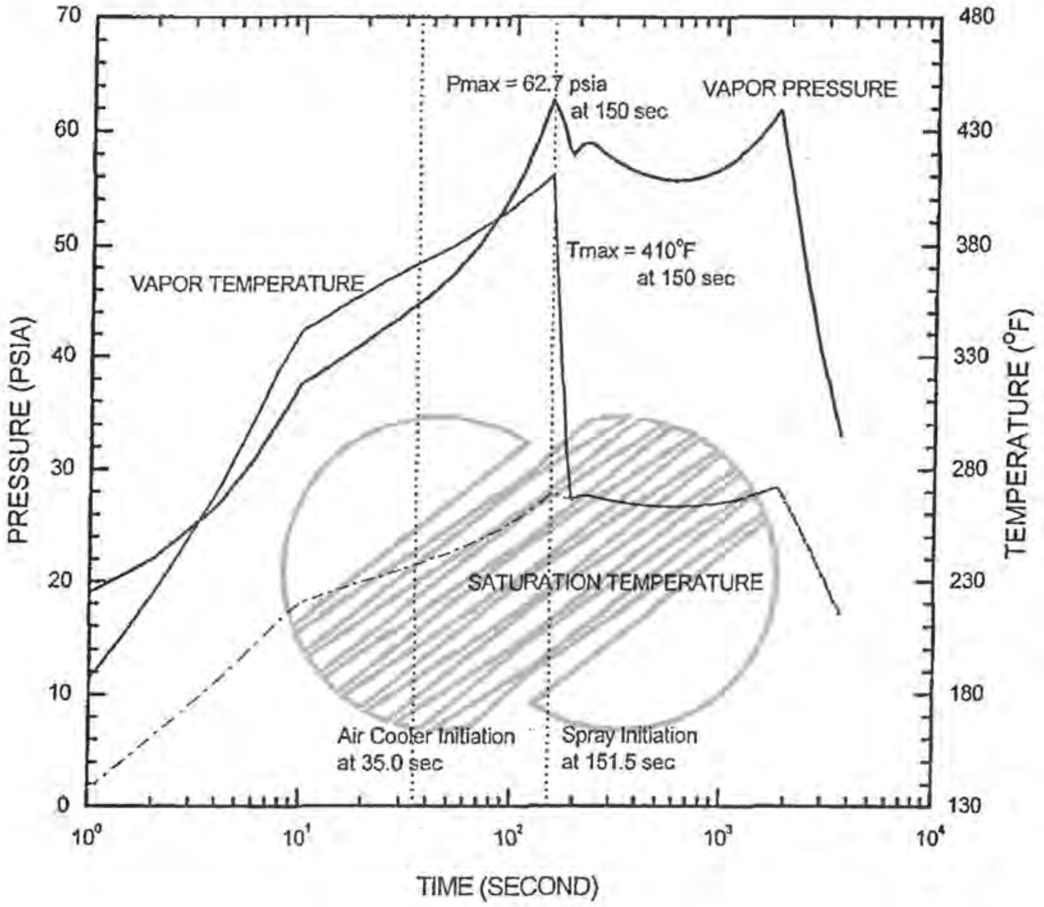
Main Steam Line Break Full Double-Ended Pipe Rupture at 50% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY
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CONTAINMENT PRESSURE AND TEMPERATURE
VS TIME FOLLOWING A PIPE BREAK
(Sheet 8 of 18)
Figure 6.2-1

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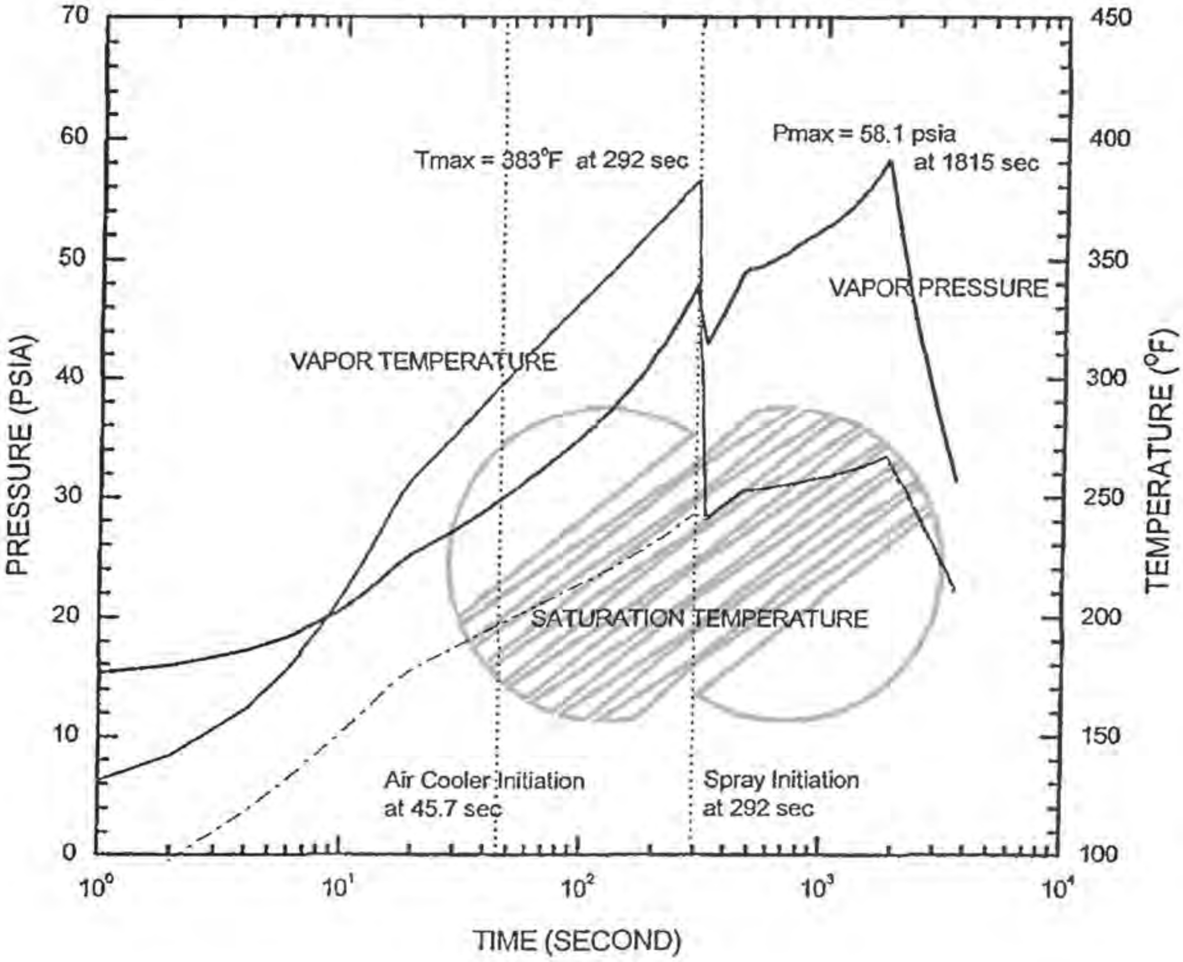
Main Steam Line Break Small Double-Ended Pipe Rupture at 50% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY

KRN 3 & 4 FSAR

CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK

(Sheet 9 of 18)

Figure 6.2-1

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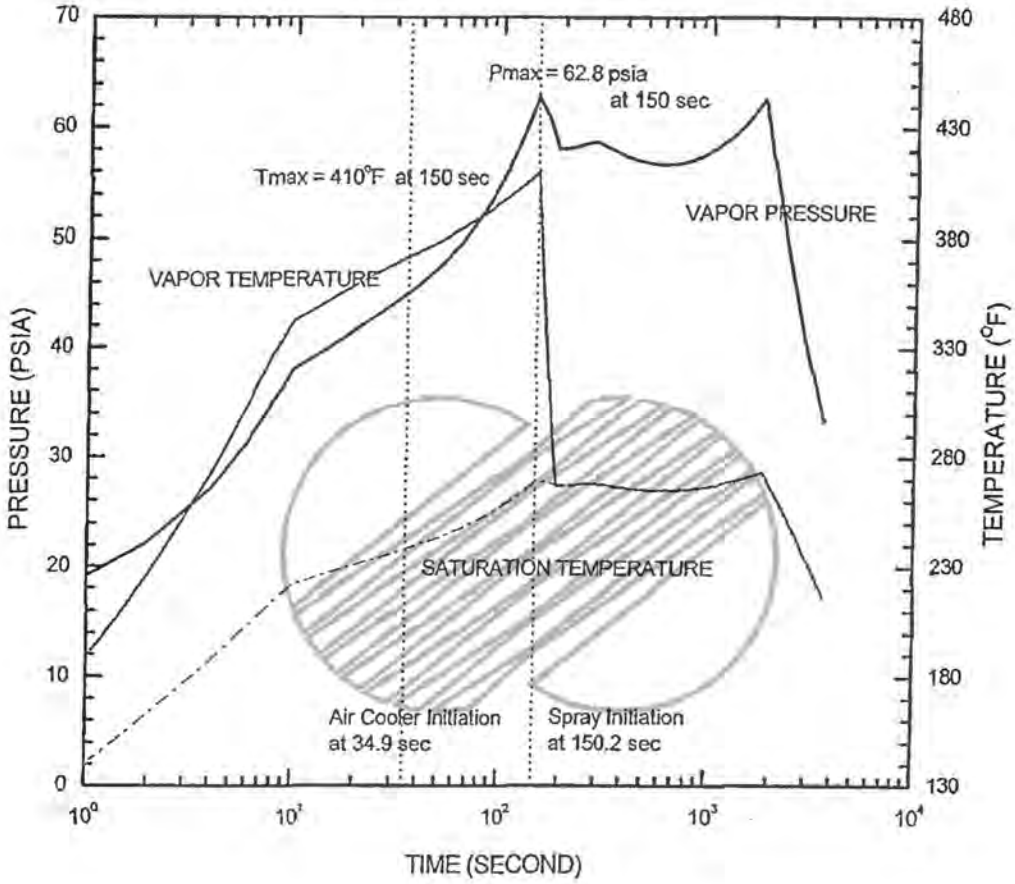
Main Steam Line Break Full Double-Ended Pipe Rupture at 25% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY KRN 3 & 4 FSAR
CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK (Sheet 10 of 18) Figure 6.2-1

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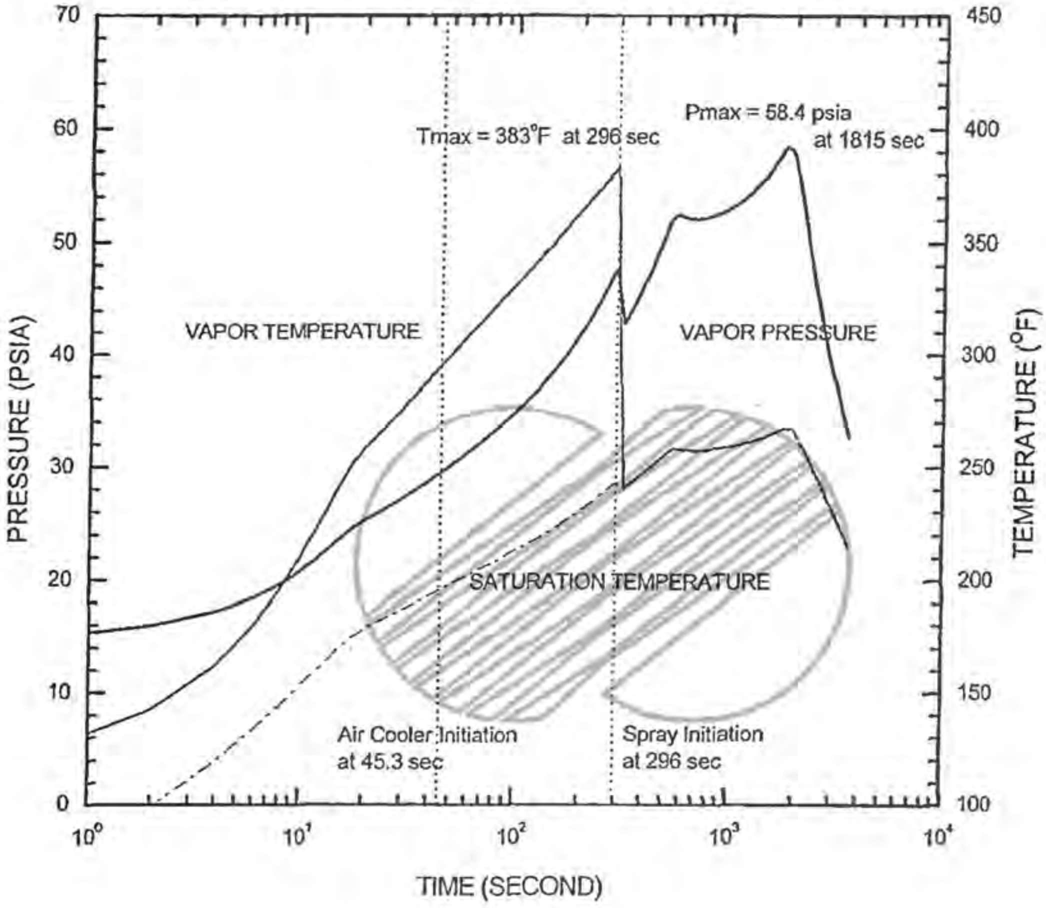
Main Steam Line Break Small Double-Ended Pipe Rupture at 25% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY KRN 3 & 4 FSAR
CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK (Sheet 11 of 18) Figure 6.2-1

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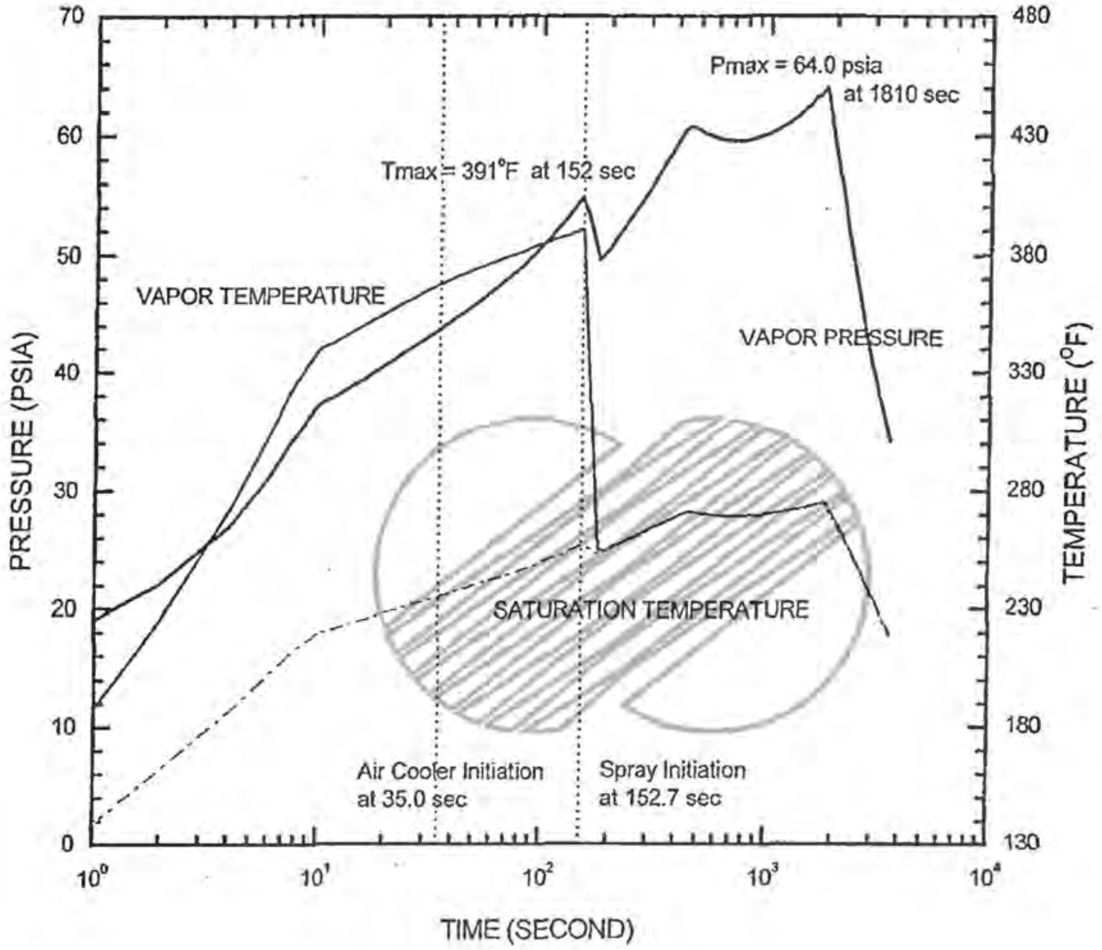
Main Steam Line Break Full Double-Ended Pipe Rupture at 0% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY

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CONTAINMENT PRESSURE AND TEMPERATURE
VS TIME FOLLOWING A PIPE BREAK
(Sheet 12 of 18)
Figure 6.2-1

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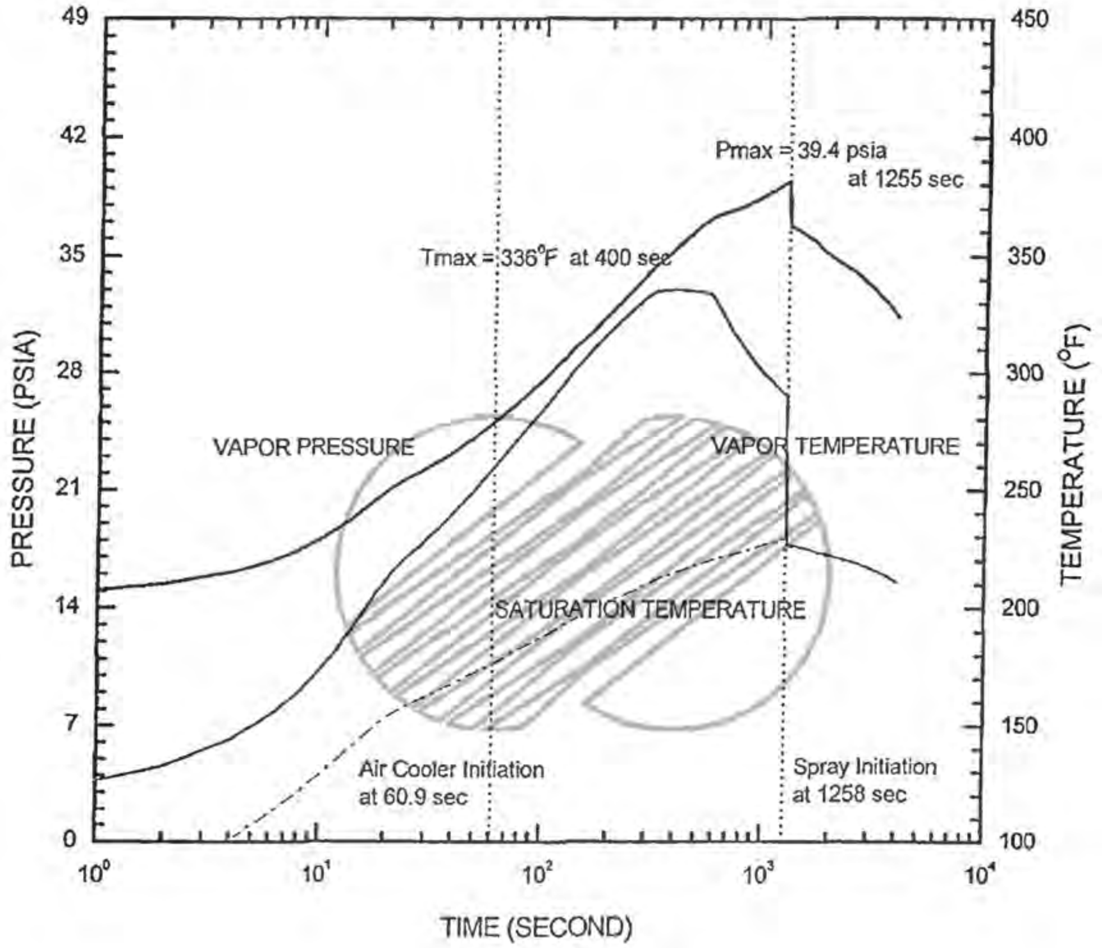
Main Steam Line Break Small Double-Ended Pipe Rupture at 0% Power



KOREA HYDRO & NUCLEAR POWER COMPANY KRN 3 & 4 FSAR
CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK (Sheet 13 of 18) Figure 6.2-1

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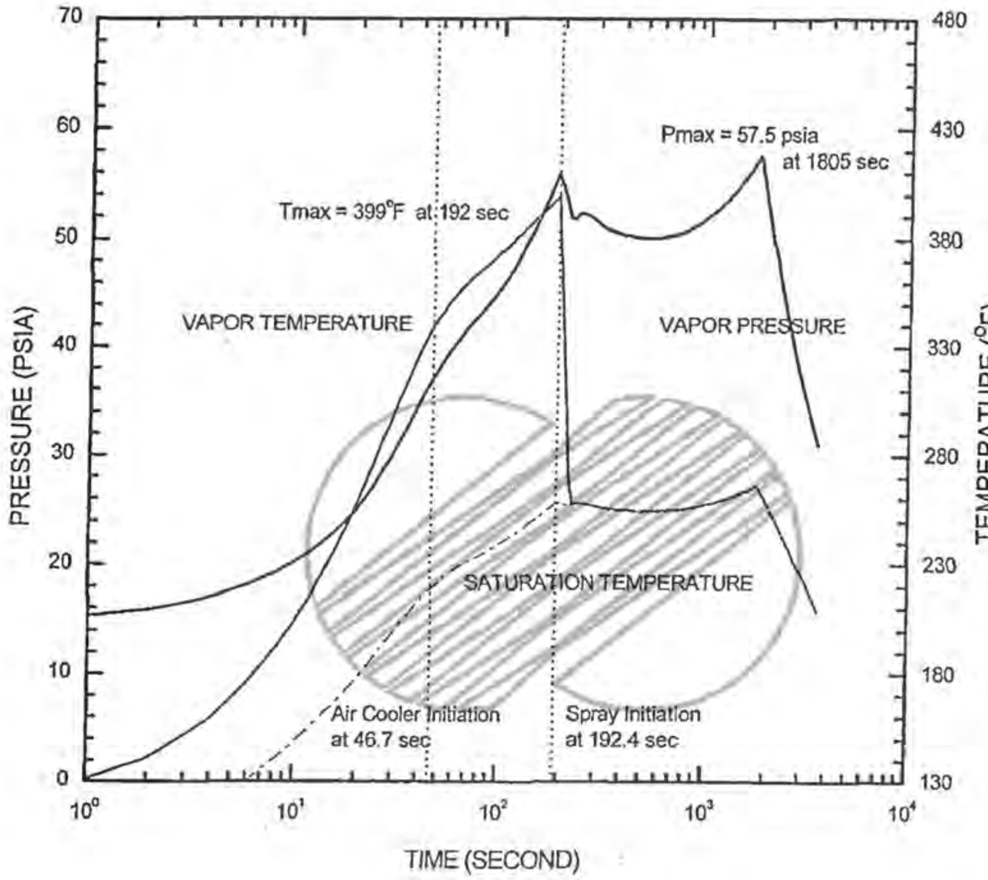
Main Steam Line Break 0.94ft^2 Split Break at 102% Power



KOREA HYDRO & NUCLEAR POWER COMPANY

KRN 3 & 4 FSAR

CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK

(Sheet 14 of 18)

Figure 6.2-1

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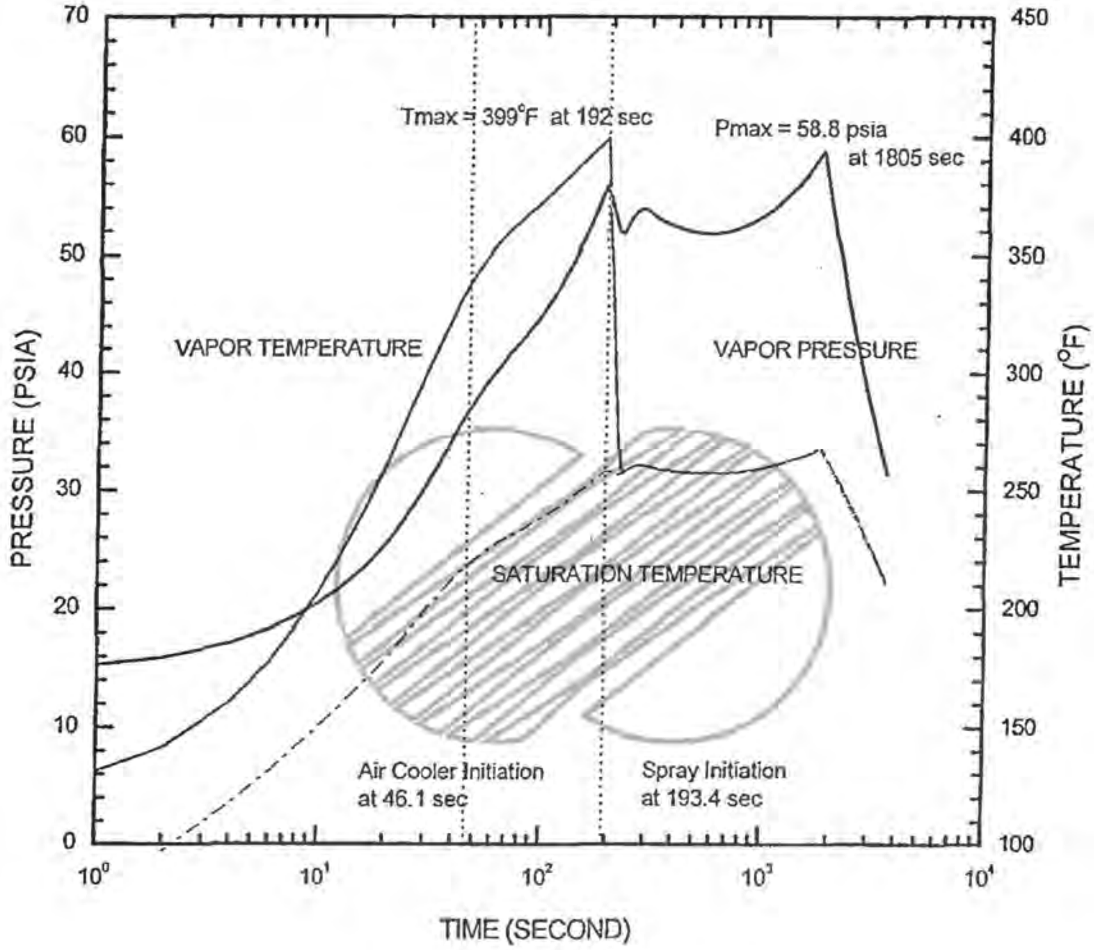
Main Steam Line Break 0.94ft^2 Split Break at 75% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY
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CONTAINMENT PRESSURE AND TEMPERATURE
VS TIME FOLLOWING A PIPE BREAK
(Sheet 15 of 18)
Figure 6.2-1

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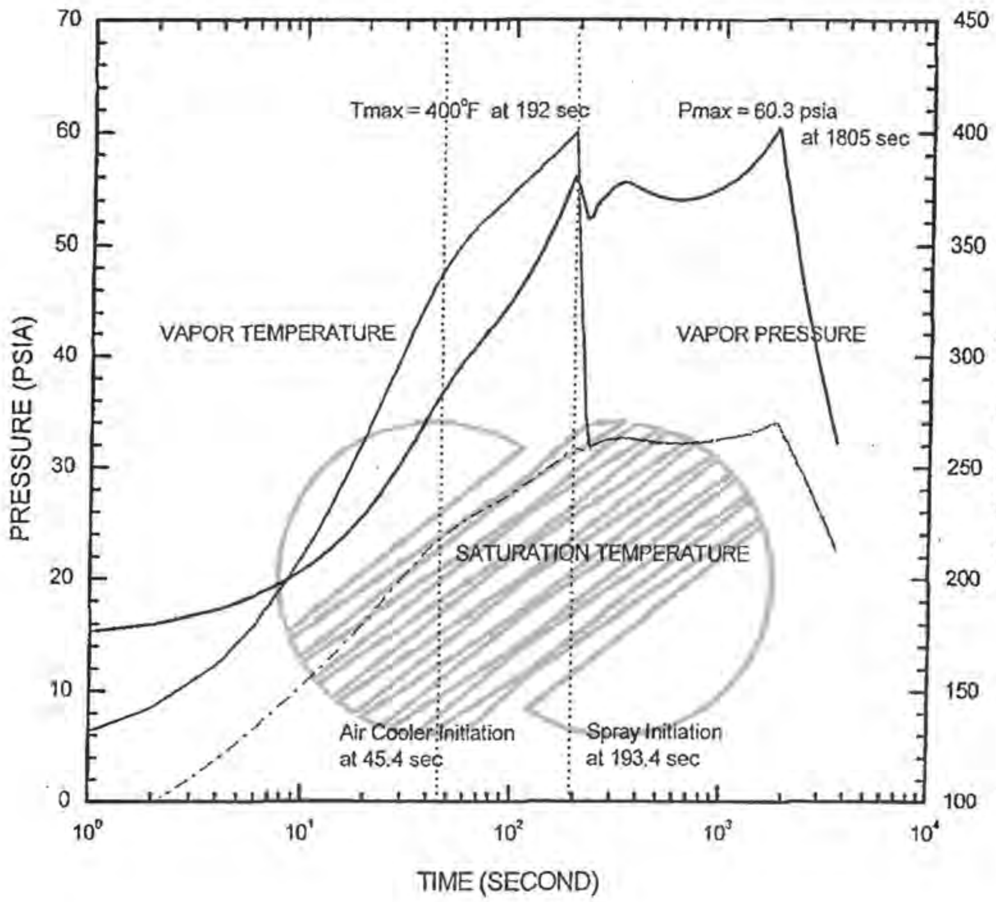
Main Steam Line Break 0.95ft^2 Split Break at 50% Power



KOREA HYDRO & NUCLEAR POWER COMPANY

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CONTAINMENT PRESSURE AND TEMPERATURE
VS TIME FOLLOWING A PIPE BREAK
(Sheet 16 of 18)
Figure 6.2-1

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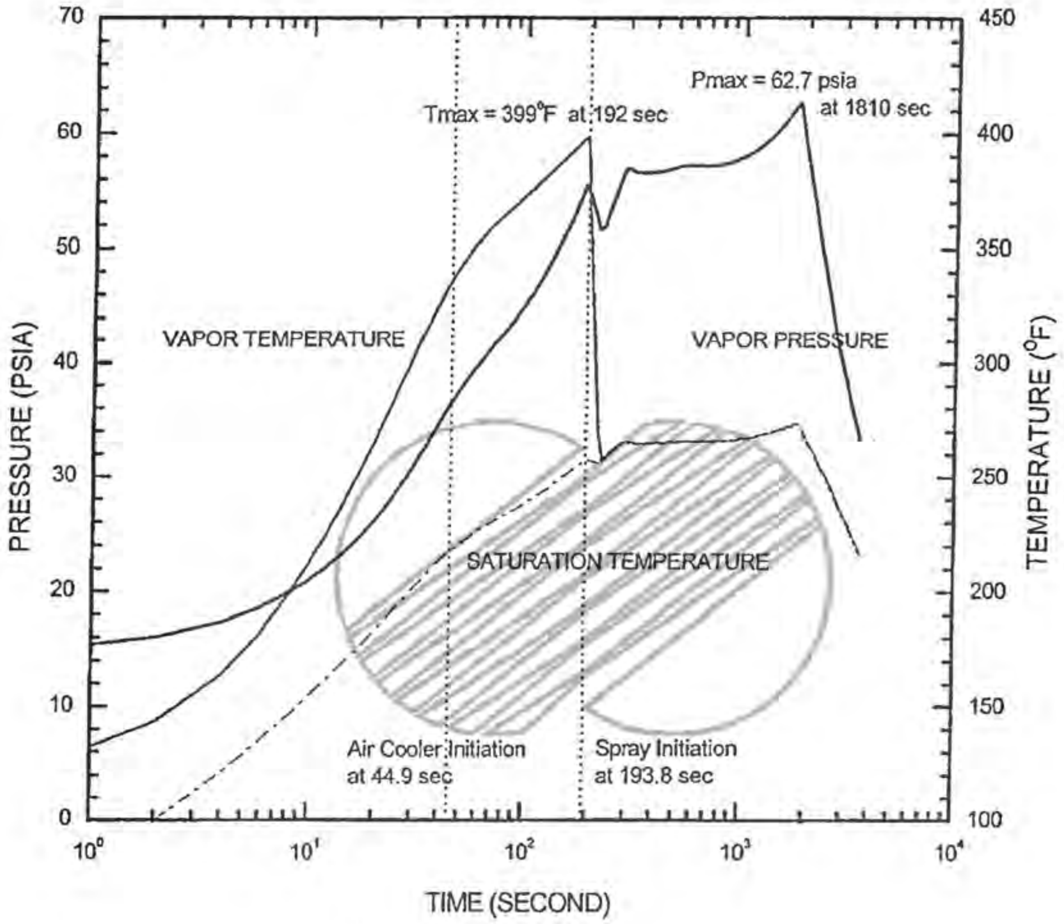
Main Steam Line Break 0.95ft^2 Split Break at 25% Power



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KOREA HYDRO & NUCLEAR POWER COMPANY

KRN 3 & 4 FSAR

CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK

(Sheet 17 of 18)

Figure 6.2-1

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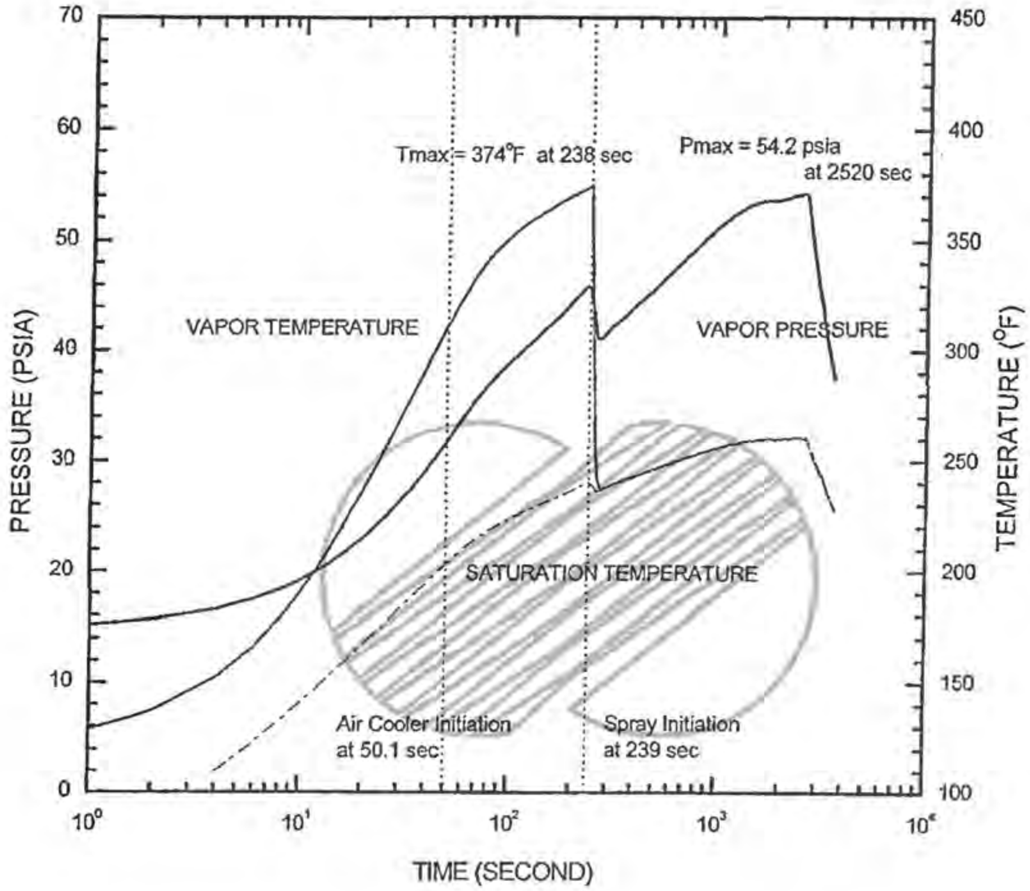
Main Steam Line Break 0.69ft^2 Split Break at 0% Power



KOREA HYDRO & NUCLEAR POWER COMPANY
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CONTAINMENT PRESSURE AND TEMPERATURE VS TIME FOLLOWING A PIPE BREAK (Sheet 18 of 18)
Figure 6.2-1

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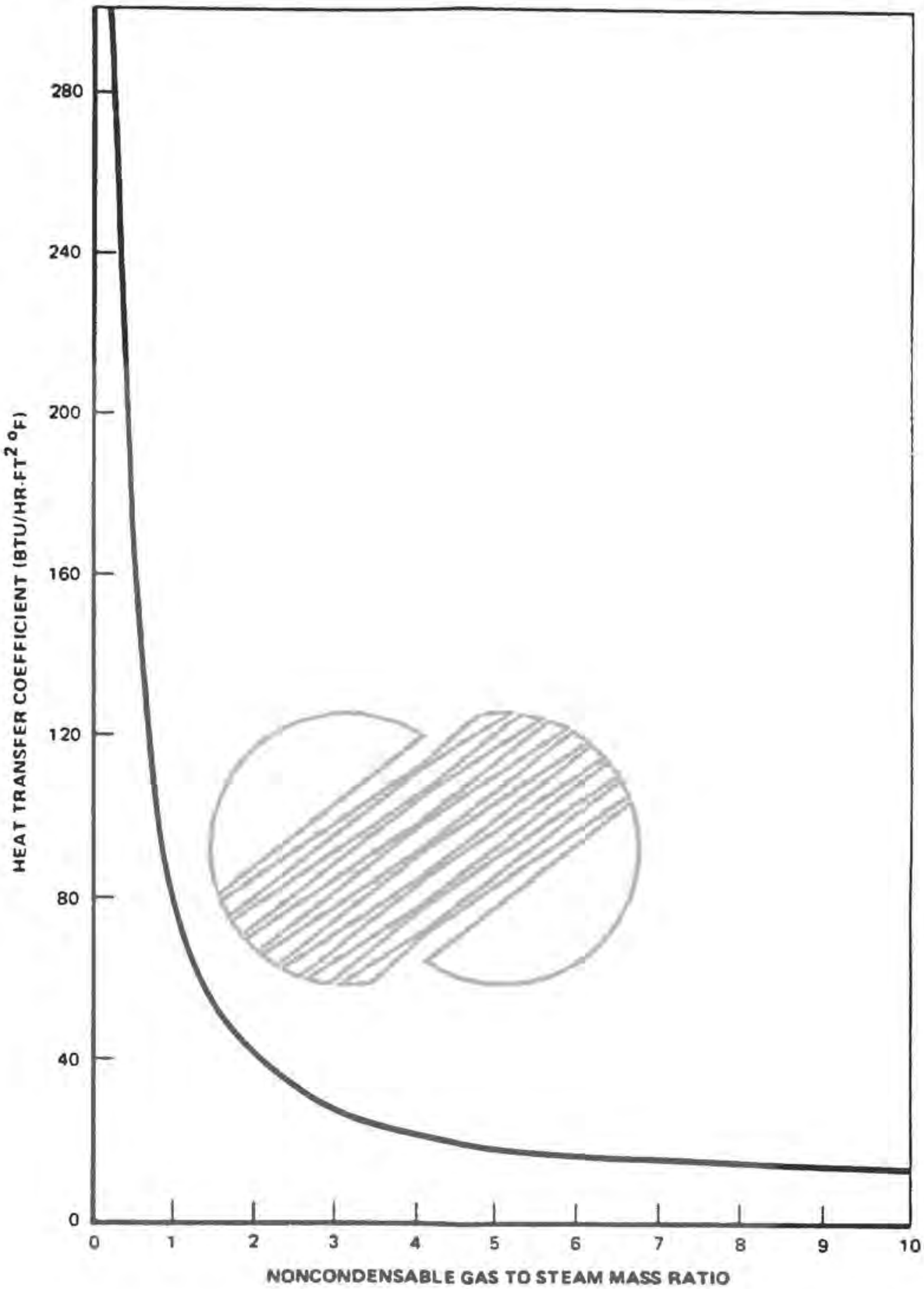

KOREA ELECTRIC POWER CORPORATION
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UCHIDA CONDENSING HEAT TRANSFER COEFFICIENT FOR AIR-STEAM MIXTURES

Figure 6.2-2

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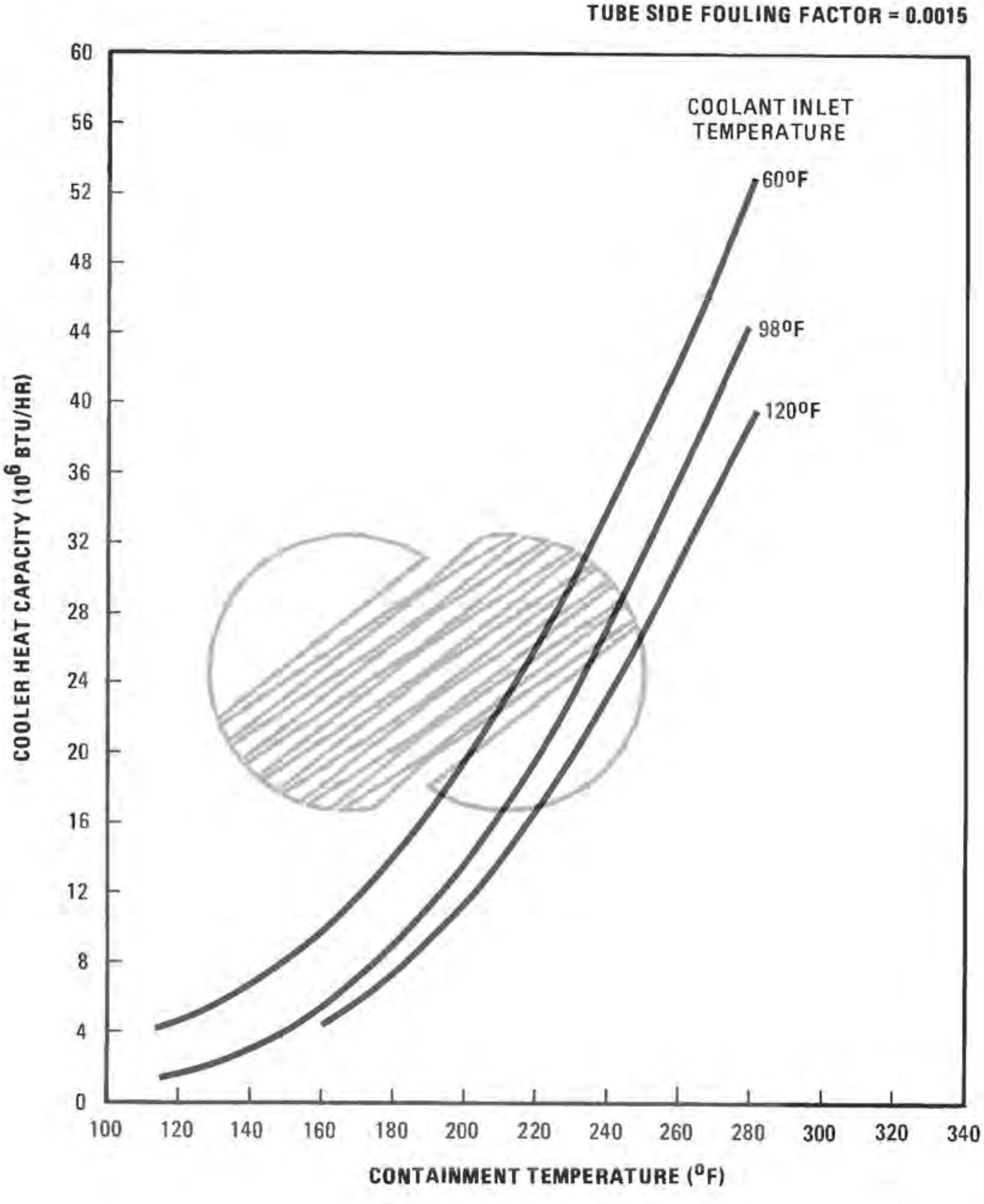

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KOREA NUCLEAR UNITS 5 & 6
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CONTAINMENT FAN COOLER PERFORMANCE CURVE

Figure 6.2-3

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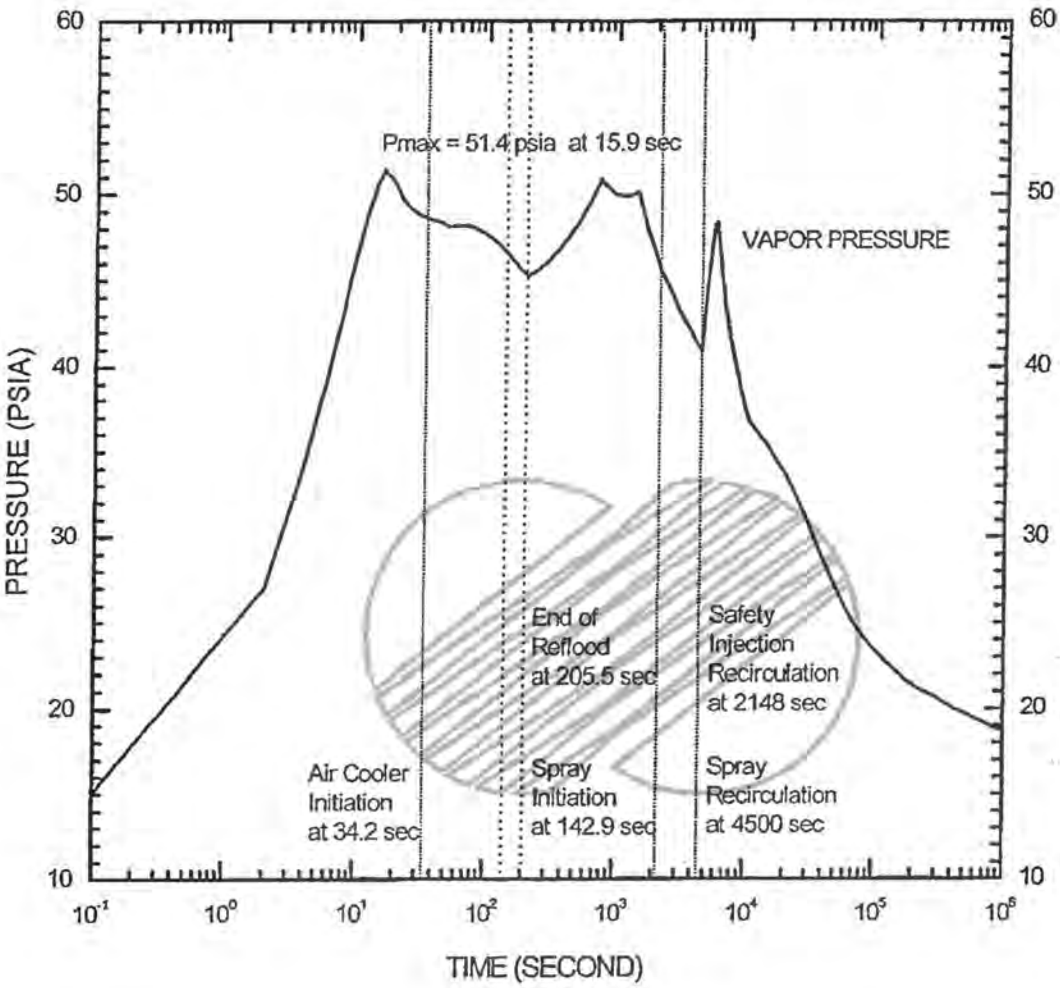
Double-Ended Pump Suction Break Minimum Safety Injection



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CONTAINMENT PRESSURE VS TIME FOR LONG TERM (Sheet 1 of 2) Figure 6.2-4	

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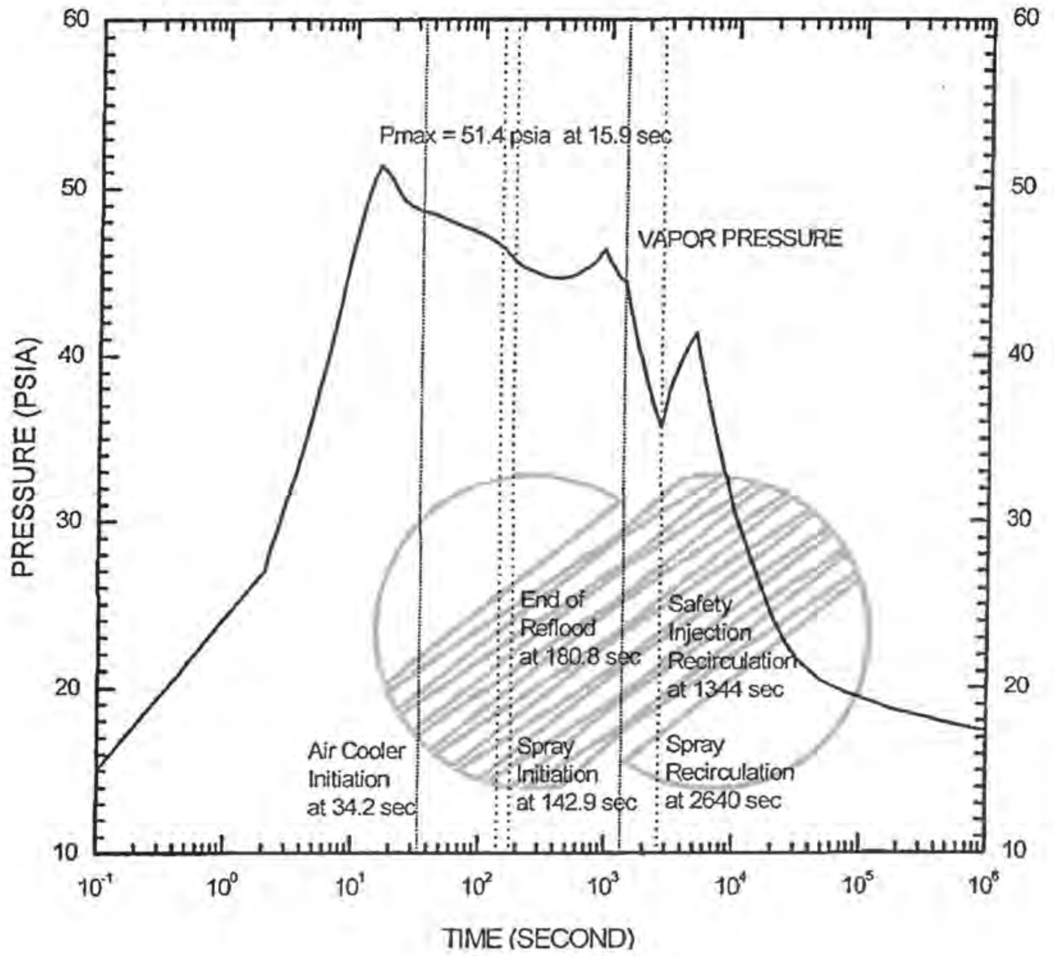

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KOREA HYDRO & NUCLEAR POWER COMPANY KRN 3 & 4 FSAR
CONTAINMENT PRESSURE VS TIME FOR LONG TERM (Sheet 2 of 2) Figure 6.2-4

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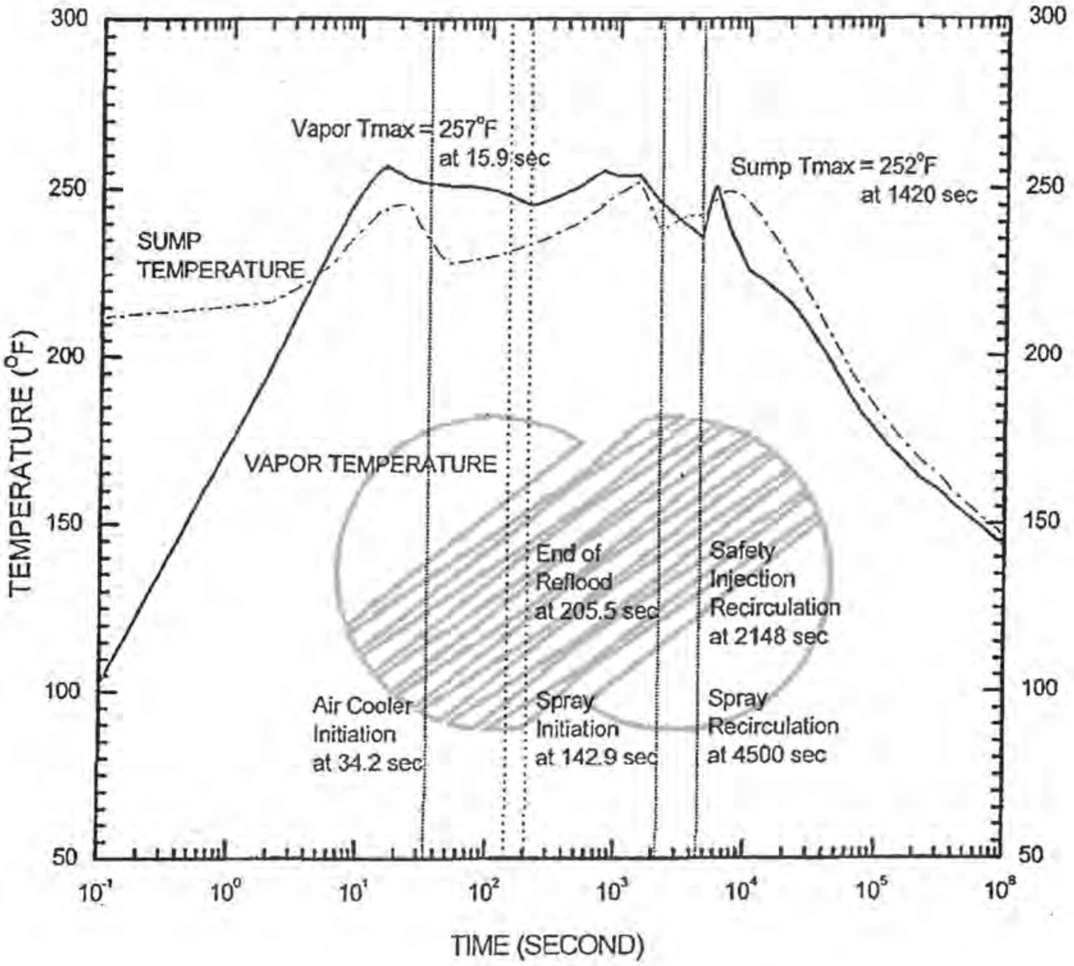

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KOREA HYDRO & NUCLEAR POWER COMPANY
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CONTAINMENT ATMOSPHERE TEMPERATURE
VS TIME FOR LONG TIME
(Sheet 1 of 2)
Figure 6.2-5

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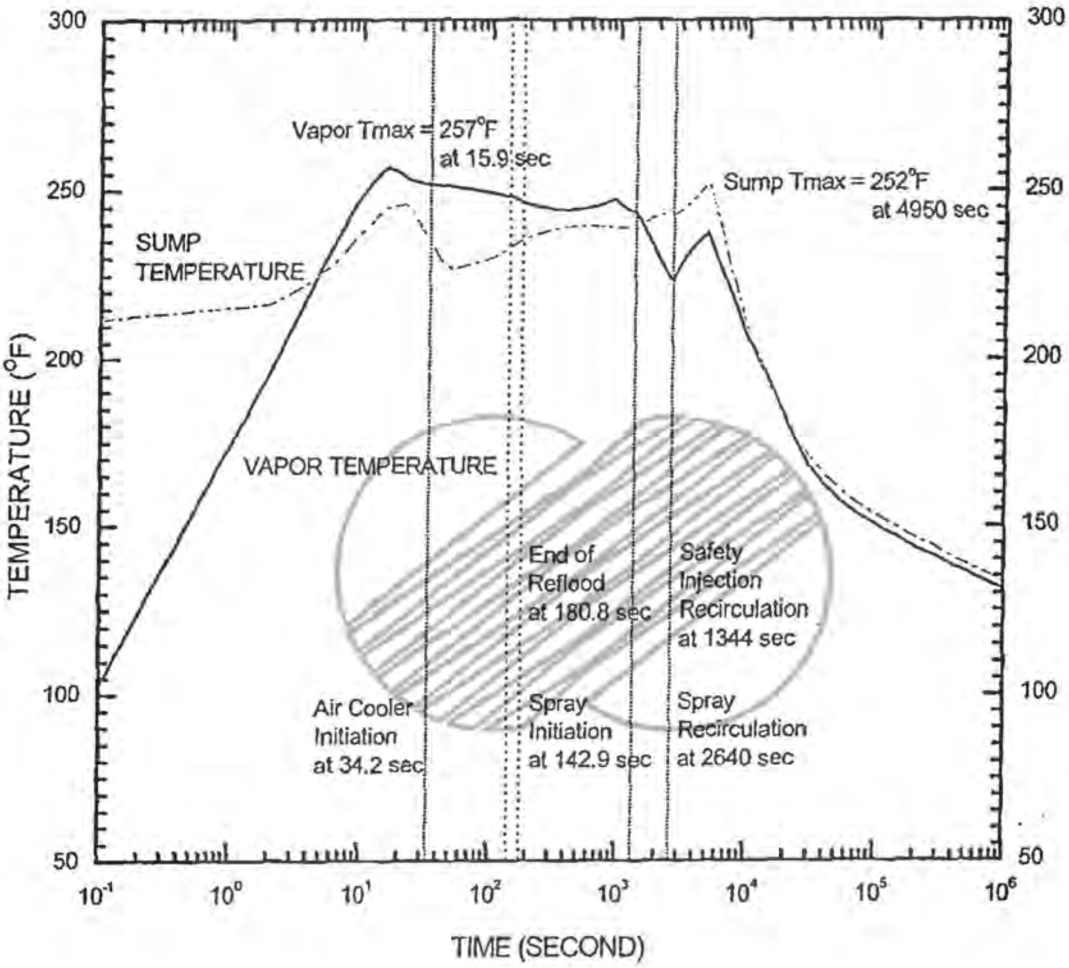

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CONTAINMENT ATMOSPHERE TEMPERATURE VS TIME FOR LONG TIME (Sheet 2 of 2) Figure 6.2-5

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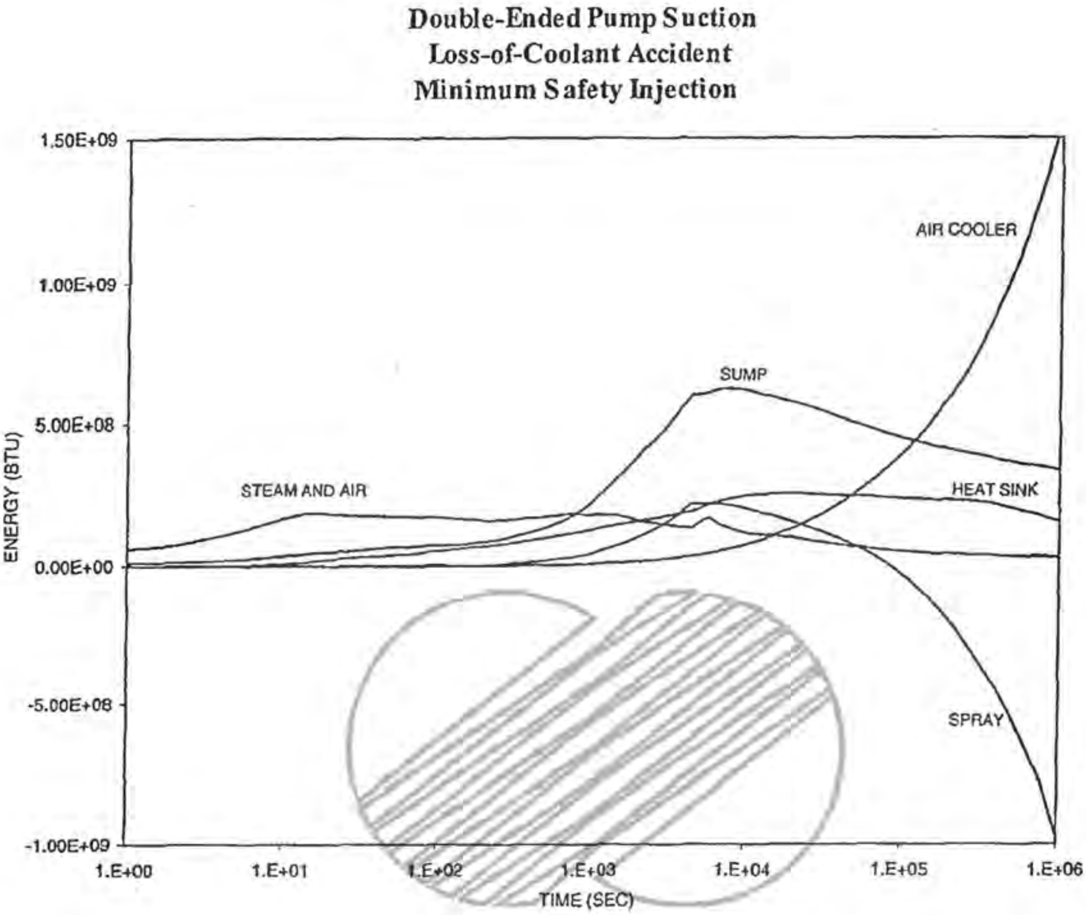

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KOREA HYDRO & NUCLEAR POWER COMPANY
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DISTRIBUTION OF ENERGY INSIDE
CONTAINMENT VS TIME FOR LONG TIME
(Sheet 1 of 4)
Figure 6.2-6

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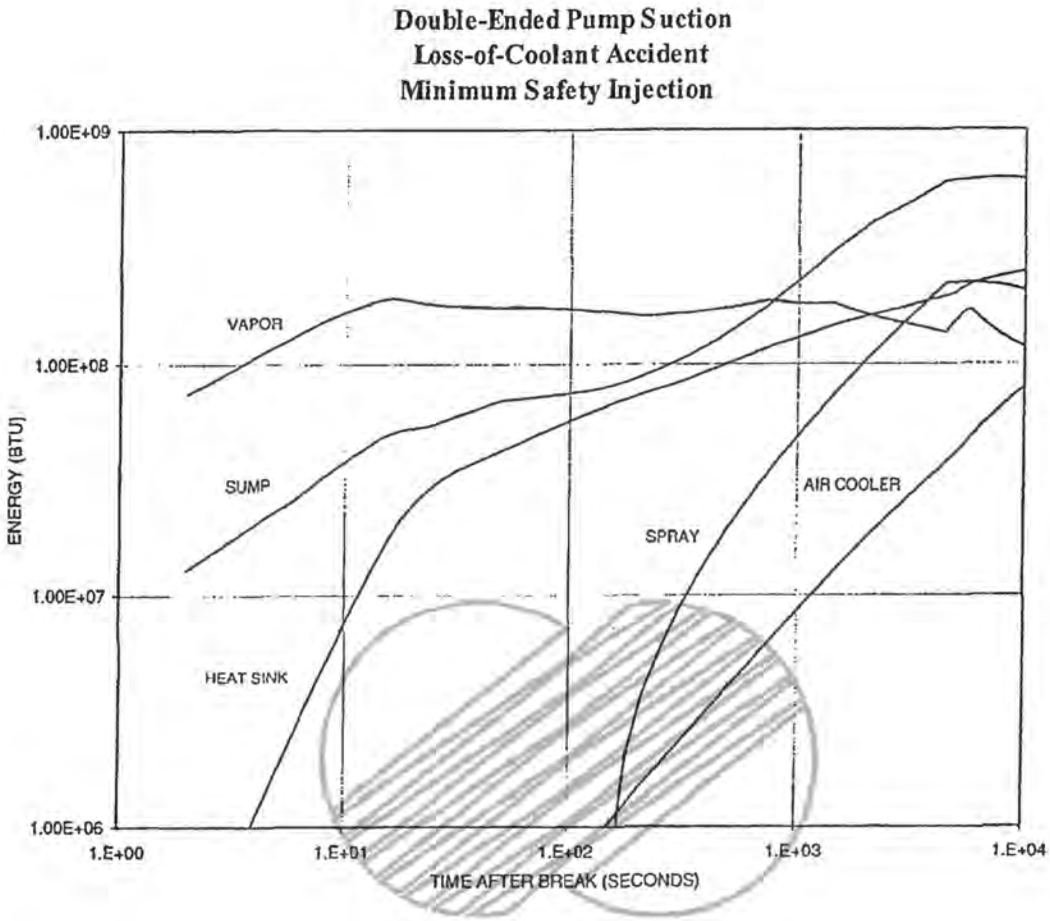

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DISTRIBUTION OF ENERGY INSIDE CONTAINMENT VS TIME FOR LONG TIME
(Sheet 2 of 4)
Figure 6.2-6

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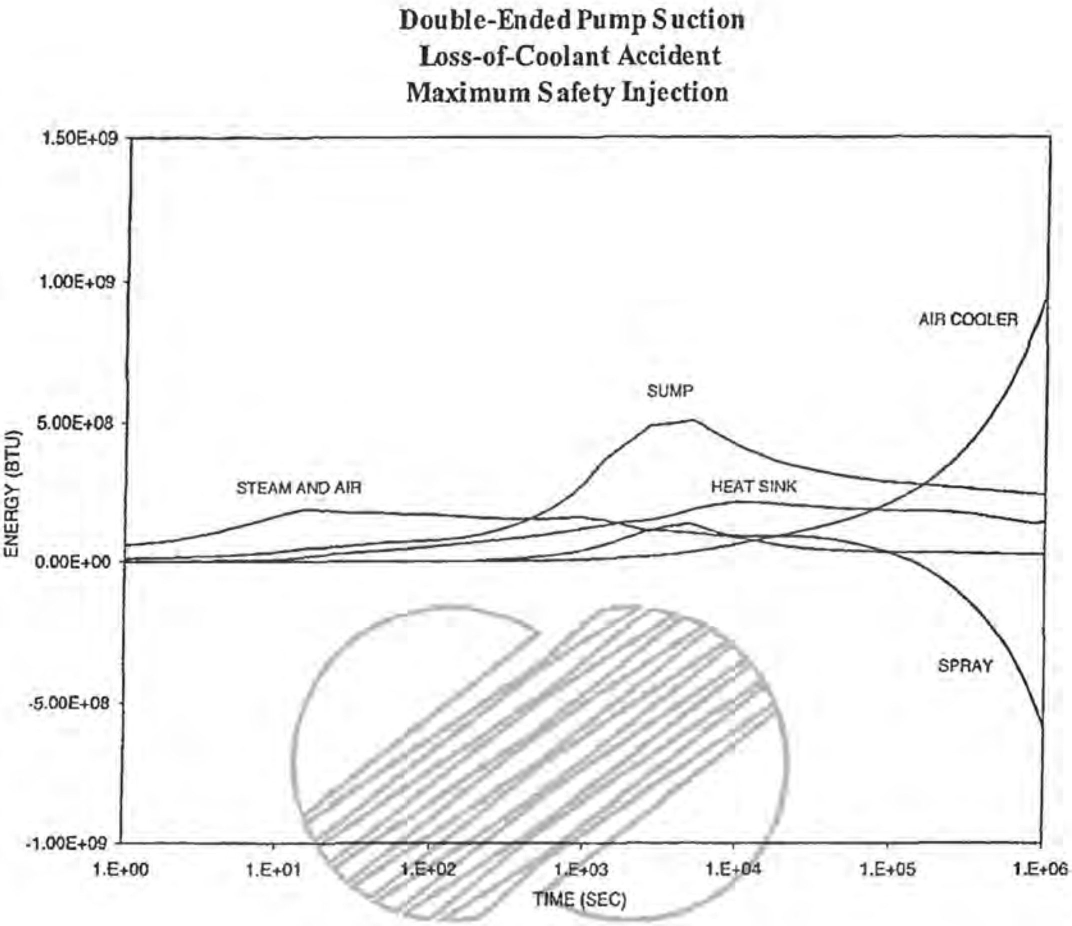

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KOREA HYDRO & NUCLEAR POWER COMPANY
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DISTRIBUTION OF ENERGY INSIDE
CONTAINMENT VS TIME FOR LONG TIME
(Sheet 3 of 4)
Figure 6.2-6

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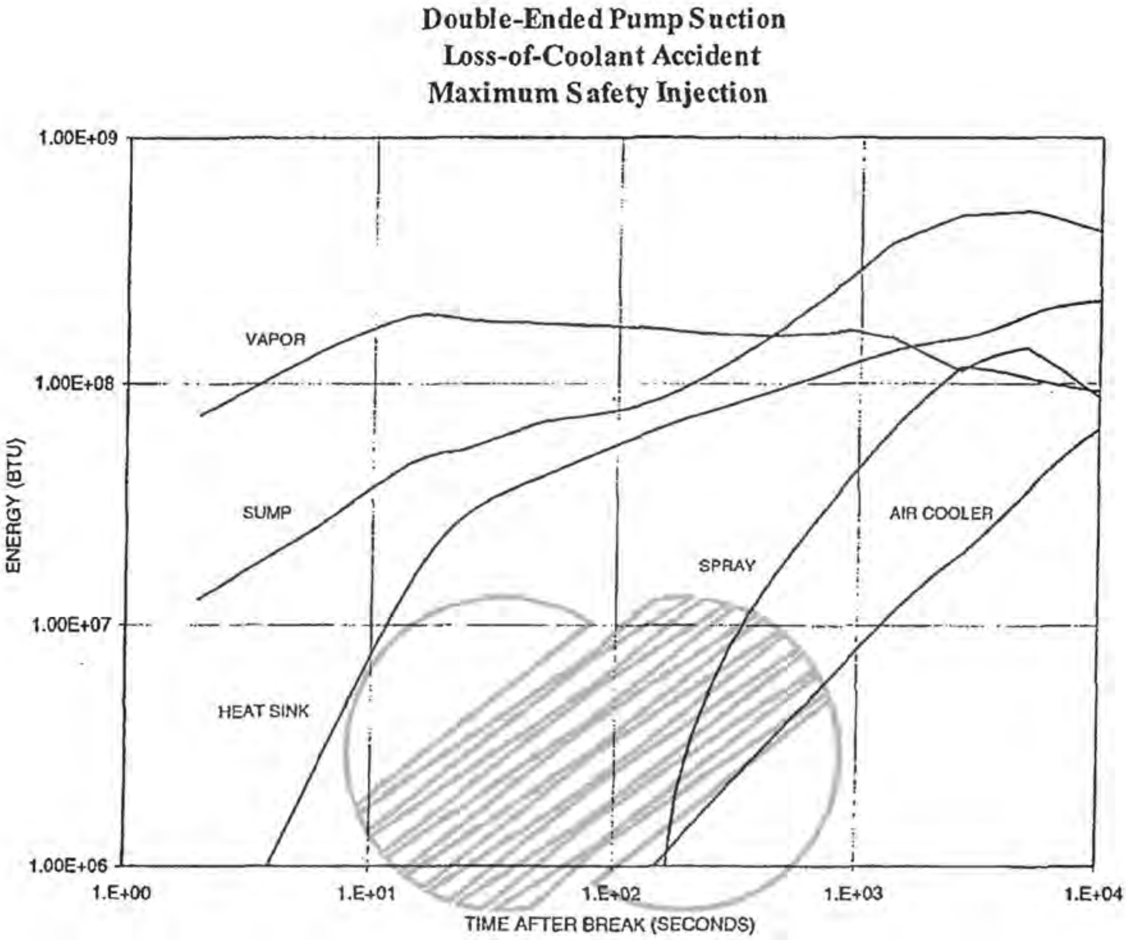

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KOREA HYDRO & NUCLEAR POWER COMPANY KRN 3 & 4 FSAR	
DISTRIBUTION OF ENERGY INSIDE CONTAINMENT VS TIME FOR LONG TIME (Sheet 4 of 4) Figure 6.2-6	

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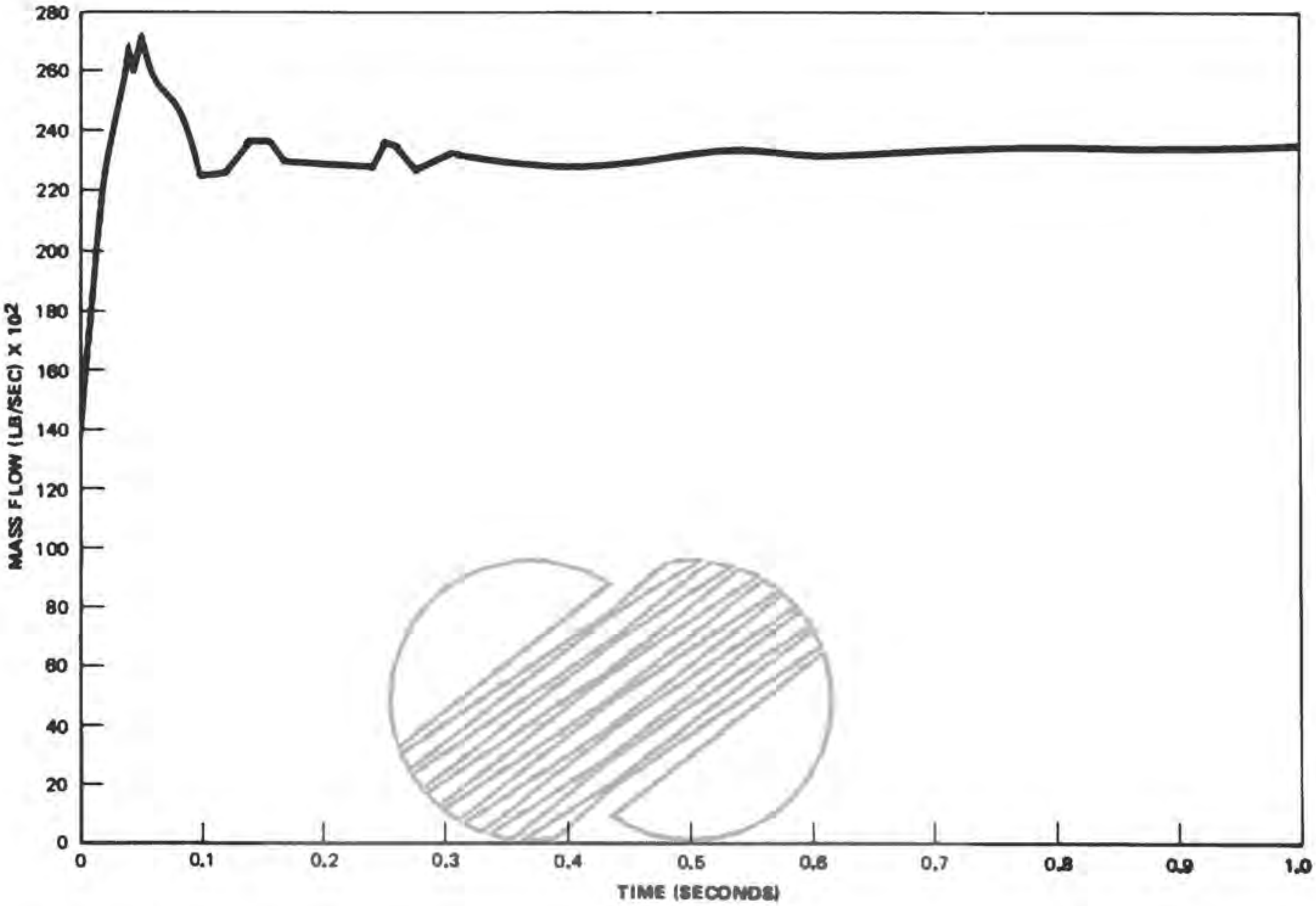

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MASS FLOWRATE VS TIME
150 SQUARE INCH BREAK AT COLD LEG
NOZZLE IN REACTOR CAVITY

Figure 6.2-7

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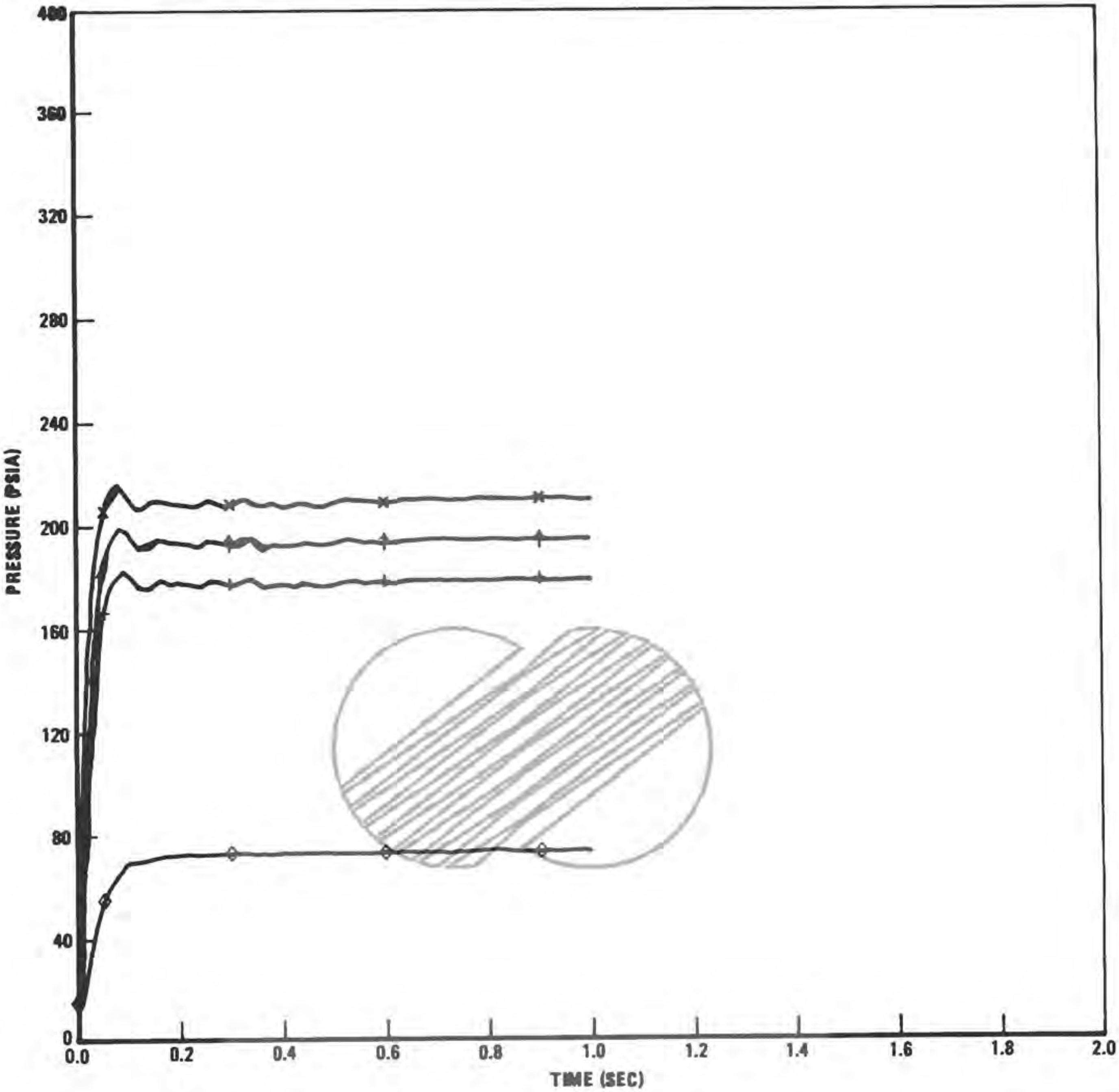

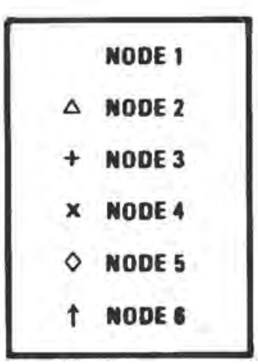

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
FSAR

REACTOR CAVITY
P/T ANALYSIS
(Sheet 1 of 8

Figure 6.2-8

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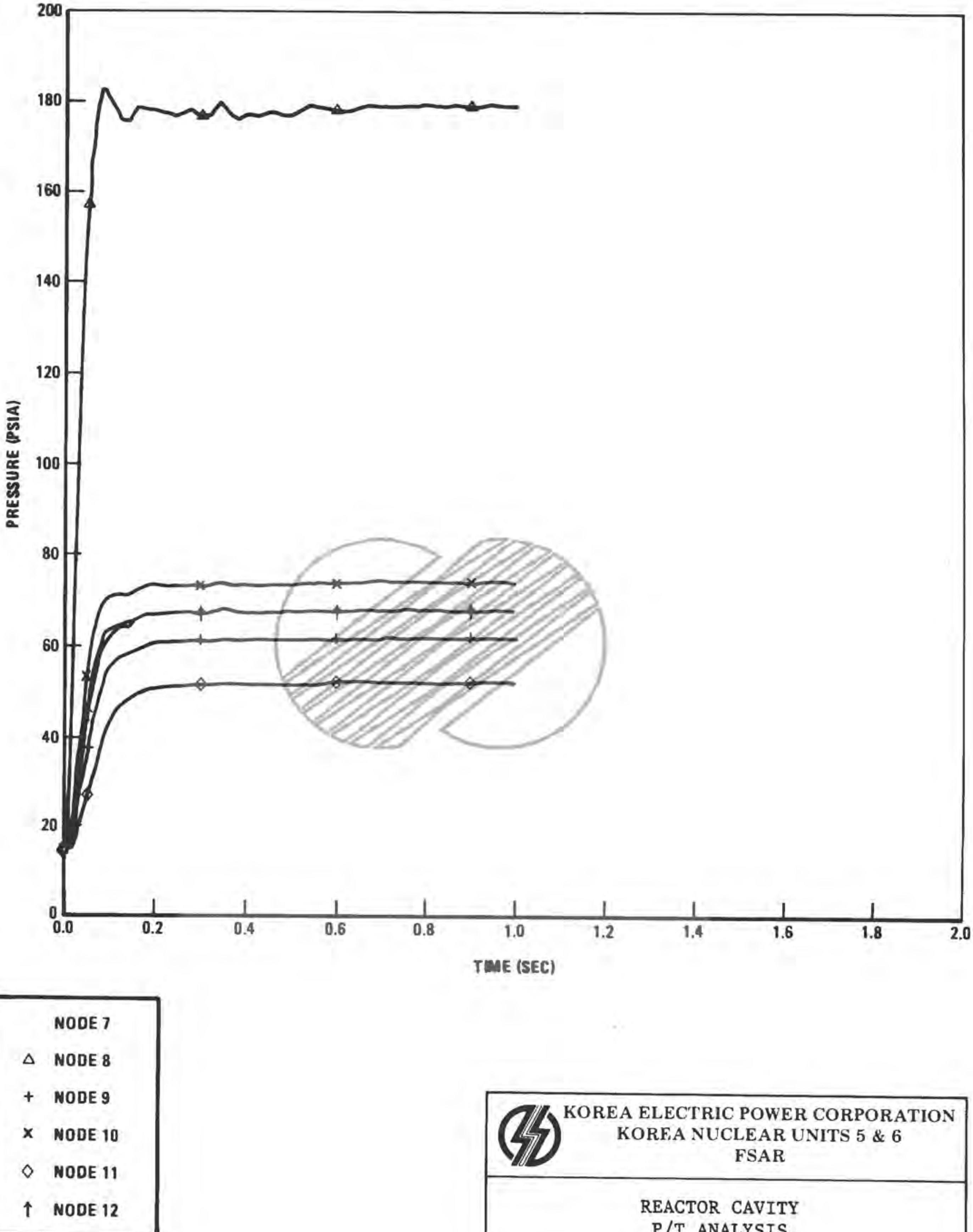
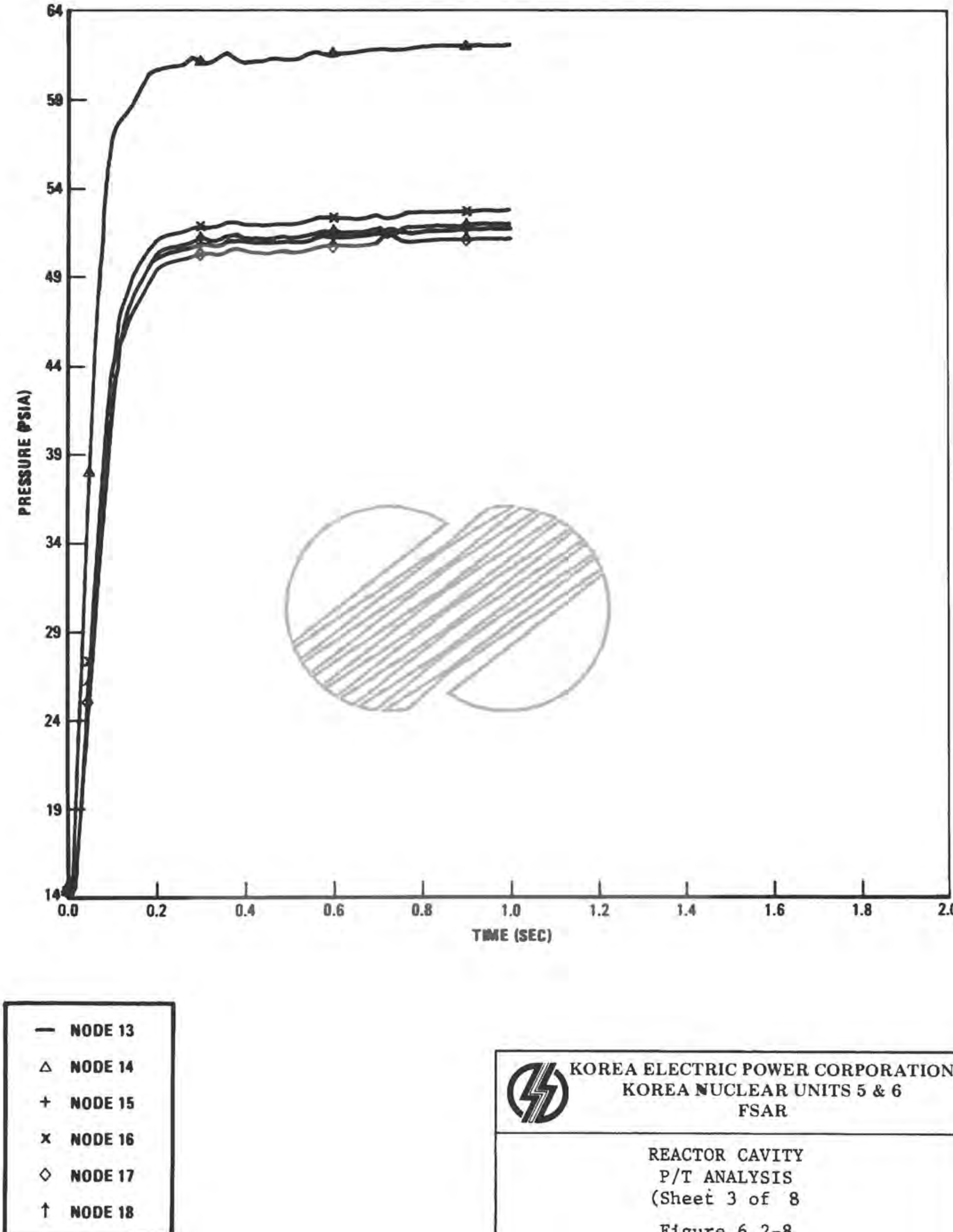


KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
FSAR

REACTOR CAVITY
P/T ANALYSIS
(Sheet 2 of 8)

Figure 6.2-8



KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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REACTOR CAVITY
P/T ANALYSIS
(Sheet 3 of 8

Figure 6.2-8

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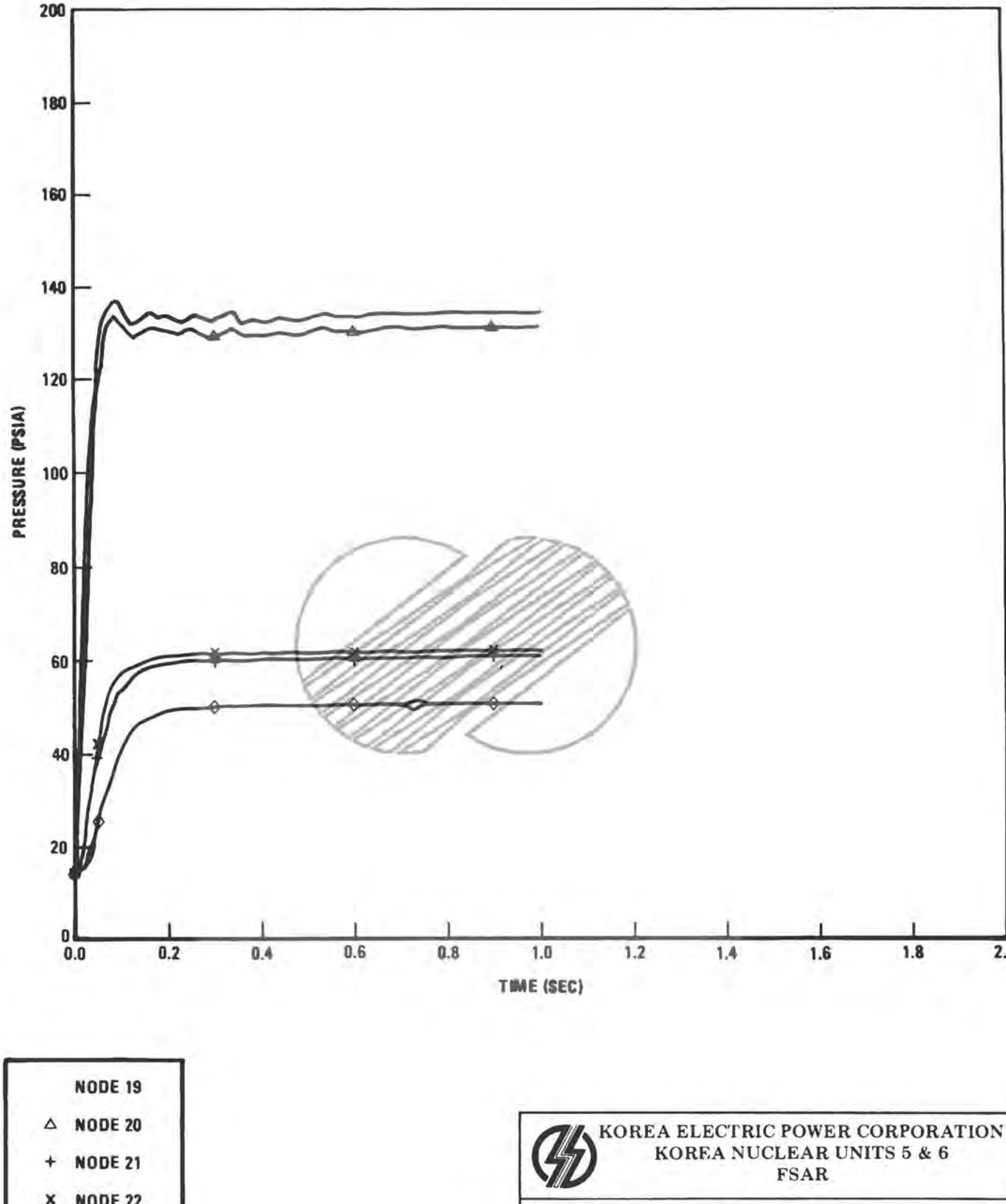

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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REACTOR CAVITY
P/T ANALYSIS
(Sheet 4 of 8)

Figure 6.2-8

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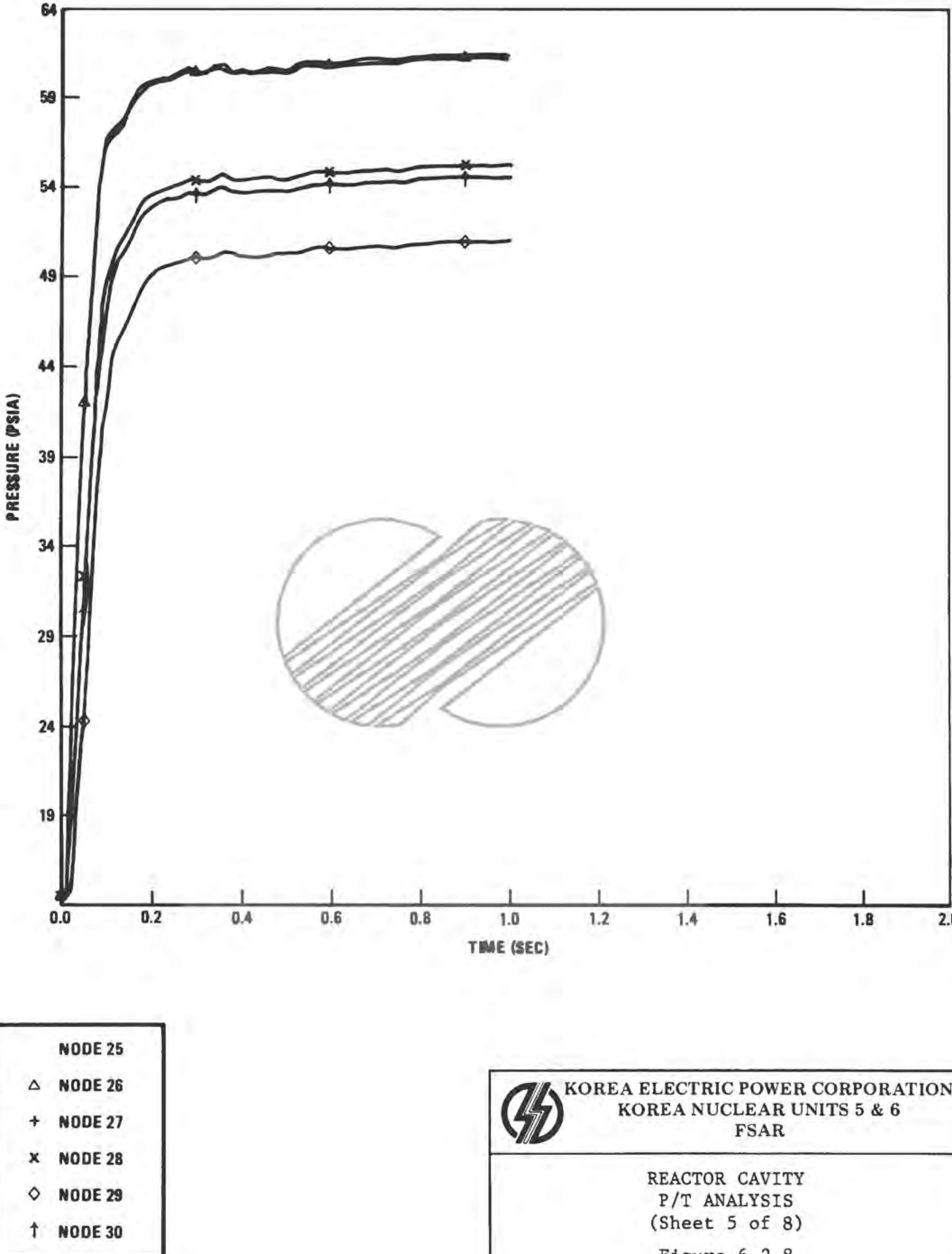

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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REACTOR CAVITY
P/T ANALYSIS
(Sheet 5 of 8)

Figure 6.2-8

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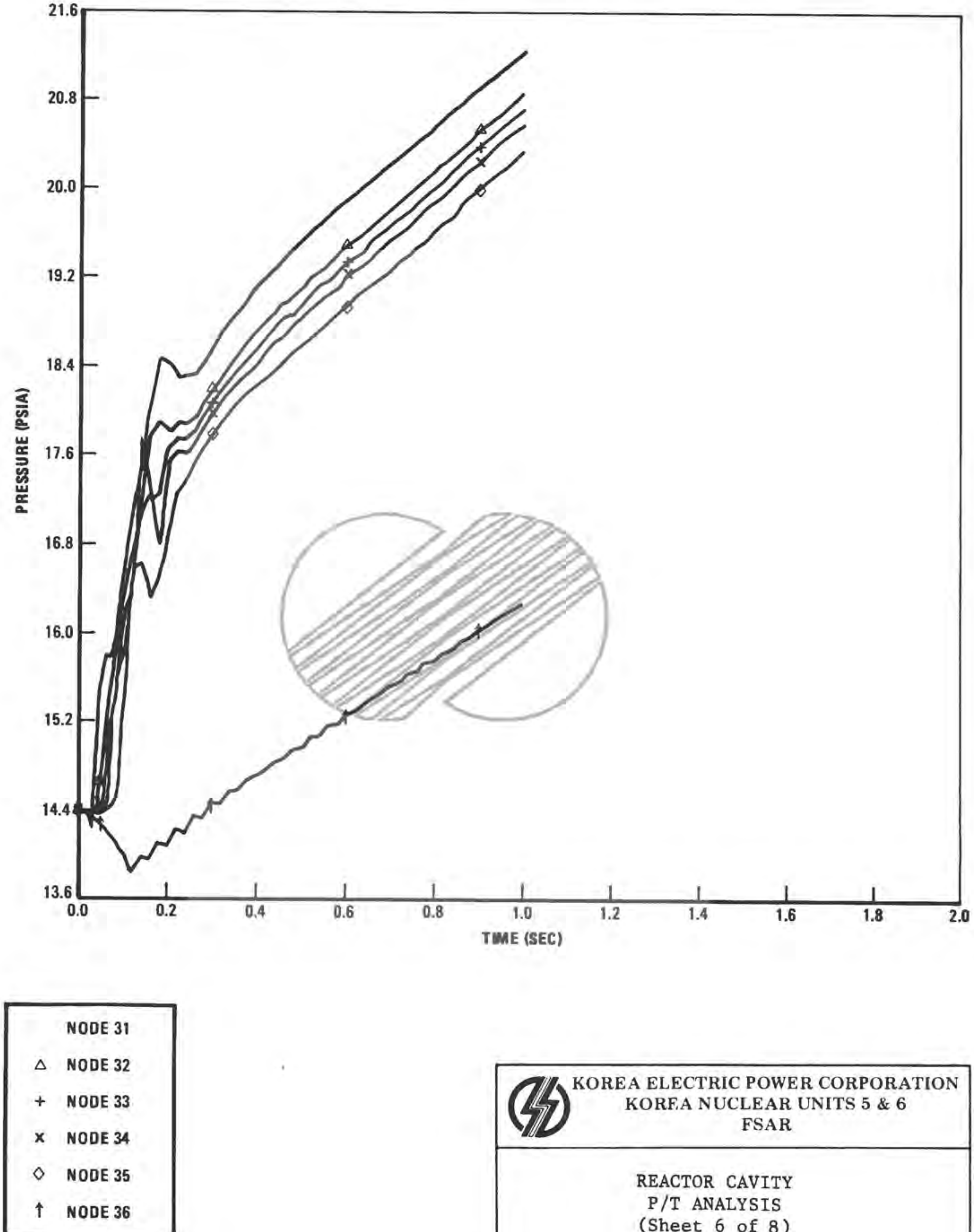

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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REACTOR CAVITY
P/T ANALYSIS
(Sheet 6 of 8)

Figure 6.2-8

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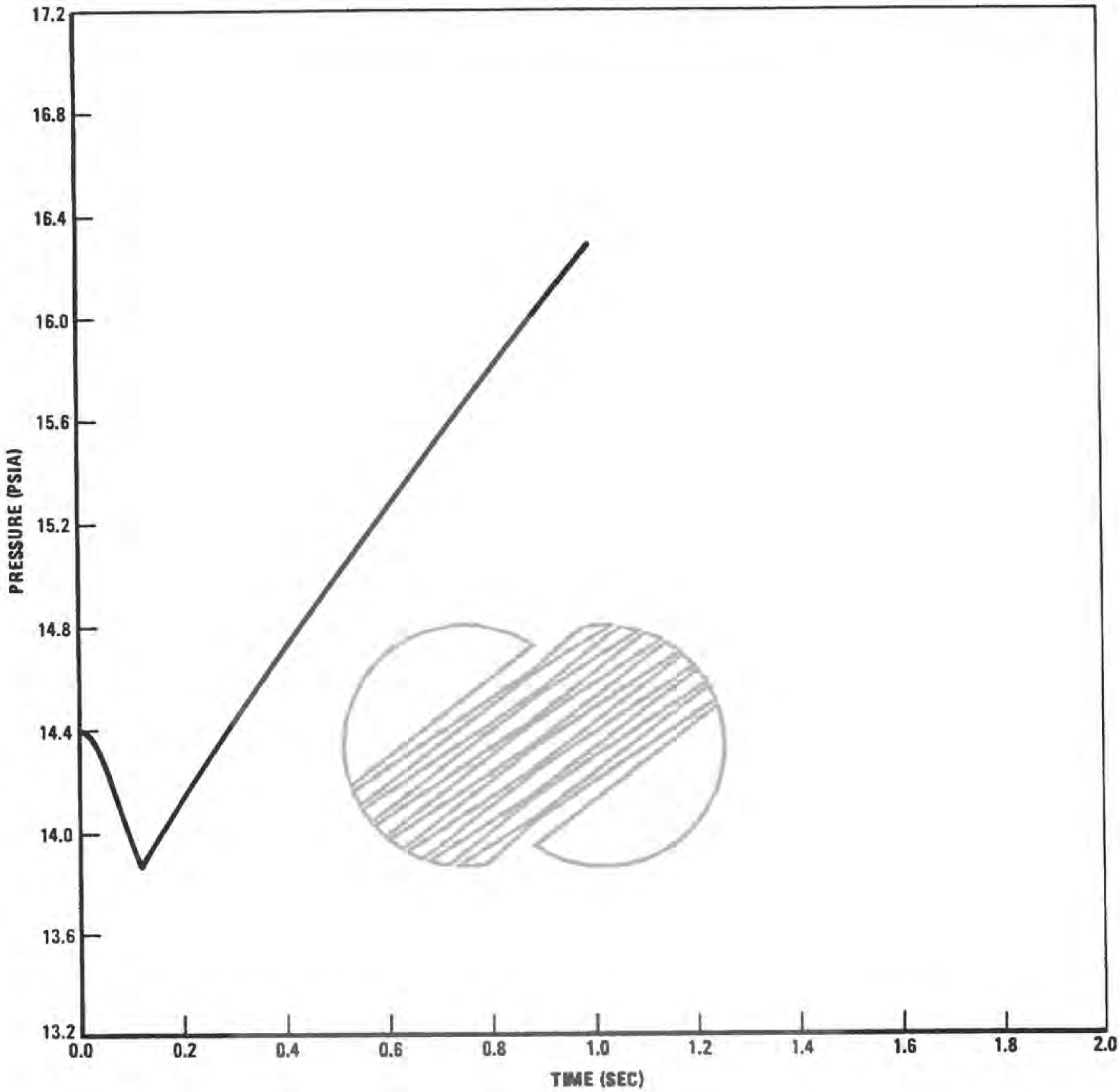

NODE 37

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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REACTOR CAVITY
P/T ANALYSIS
(Sheet 7 of 8)

Figure 6.2-8

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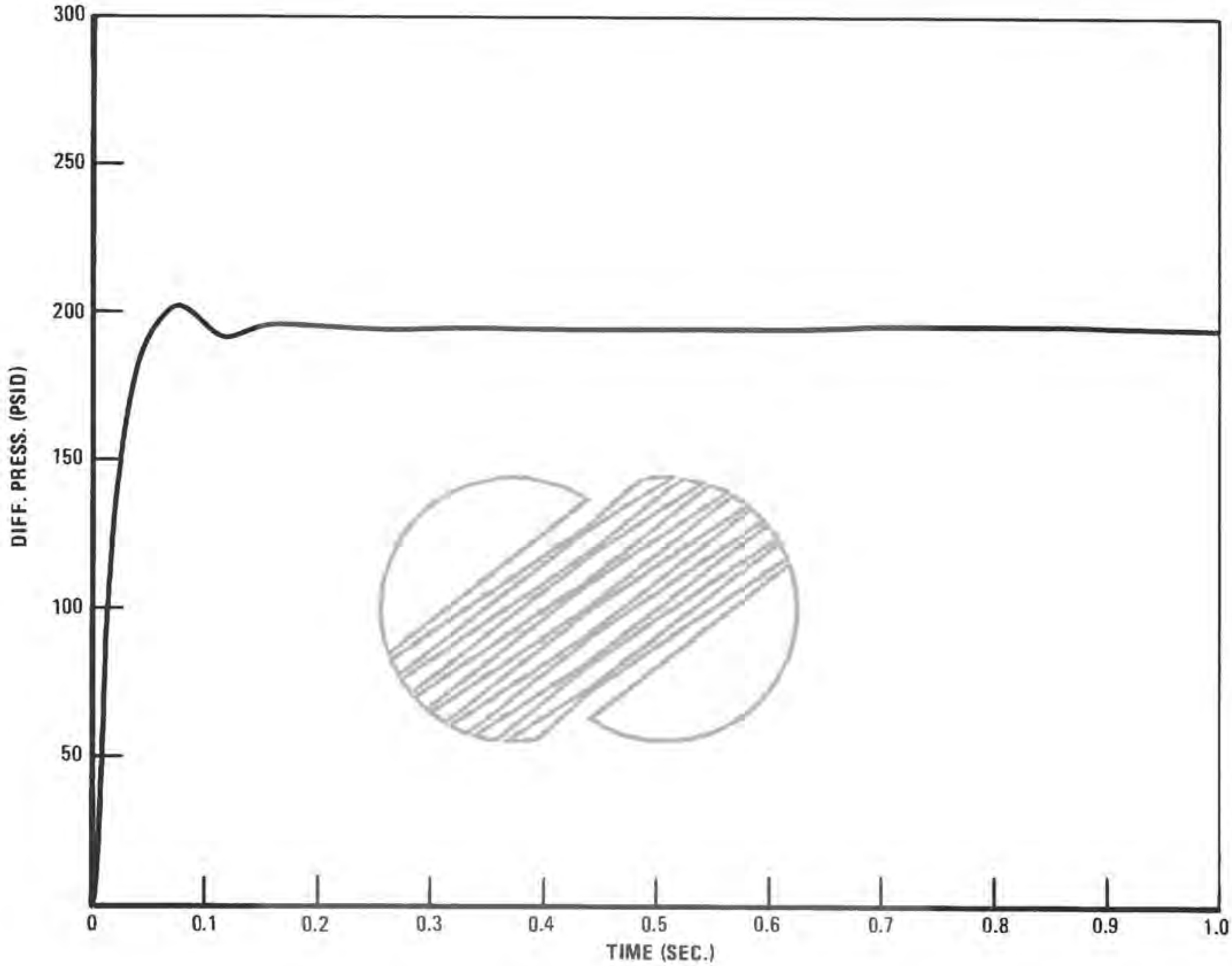

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PRIMARY SHIELD WALL DIFFERENTIAL PRESSURE (BETWEEN NODES 2 AND 37) REACTOR CAVITY P/T ANALYSIS
(Sheet 8 of 8)

Figure 6.2-8

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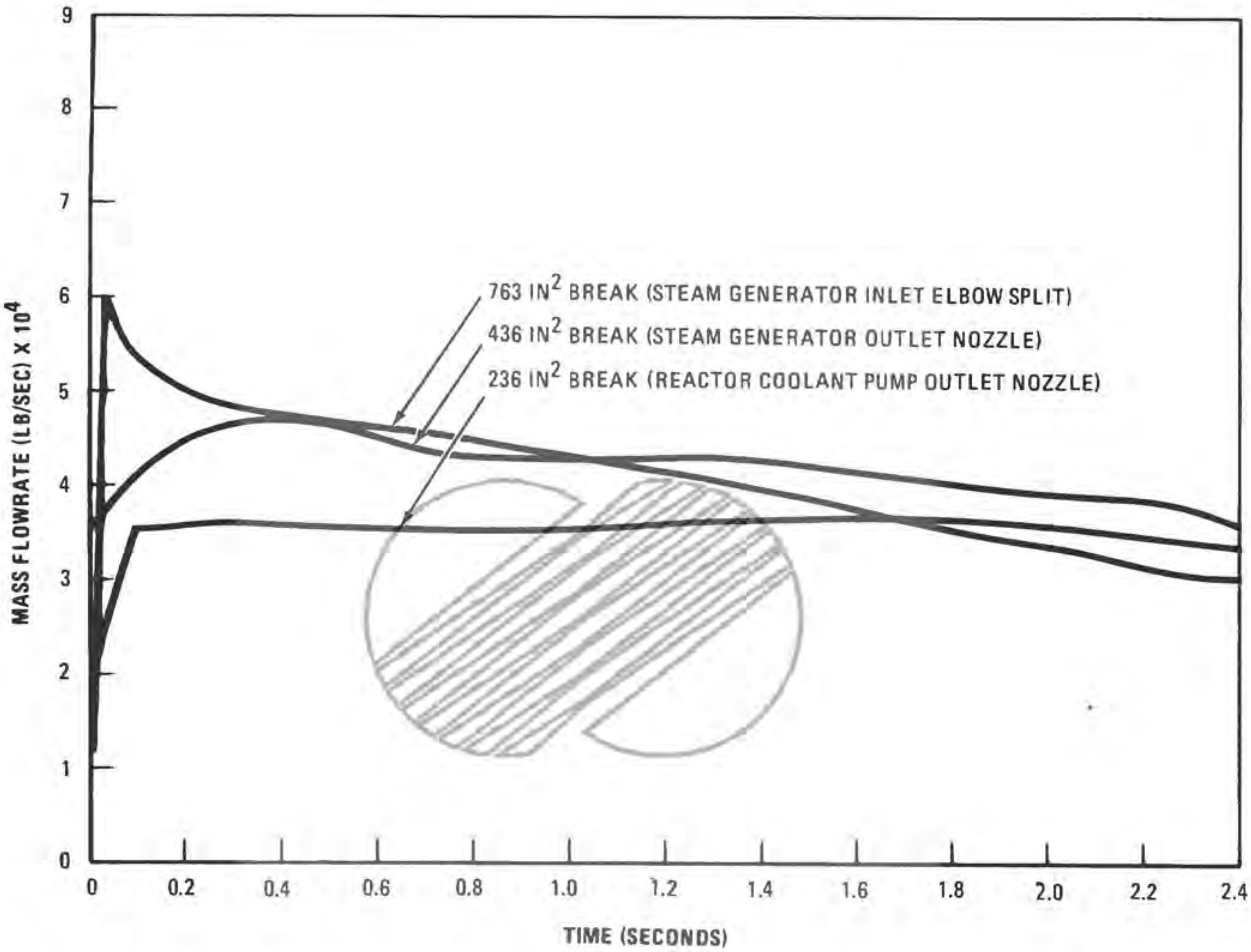

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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MASS FLOWRATE VS TIME
FOR STEAM GENERATOR COMPARTMENT
PRESSURE ANALYSIS

Figure 6.2-11

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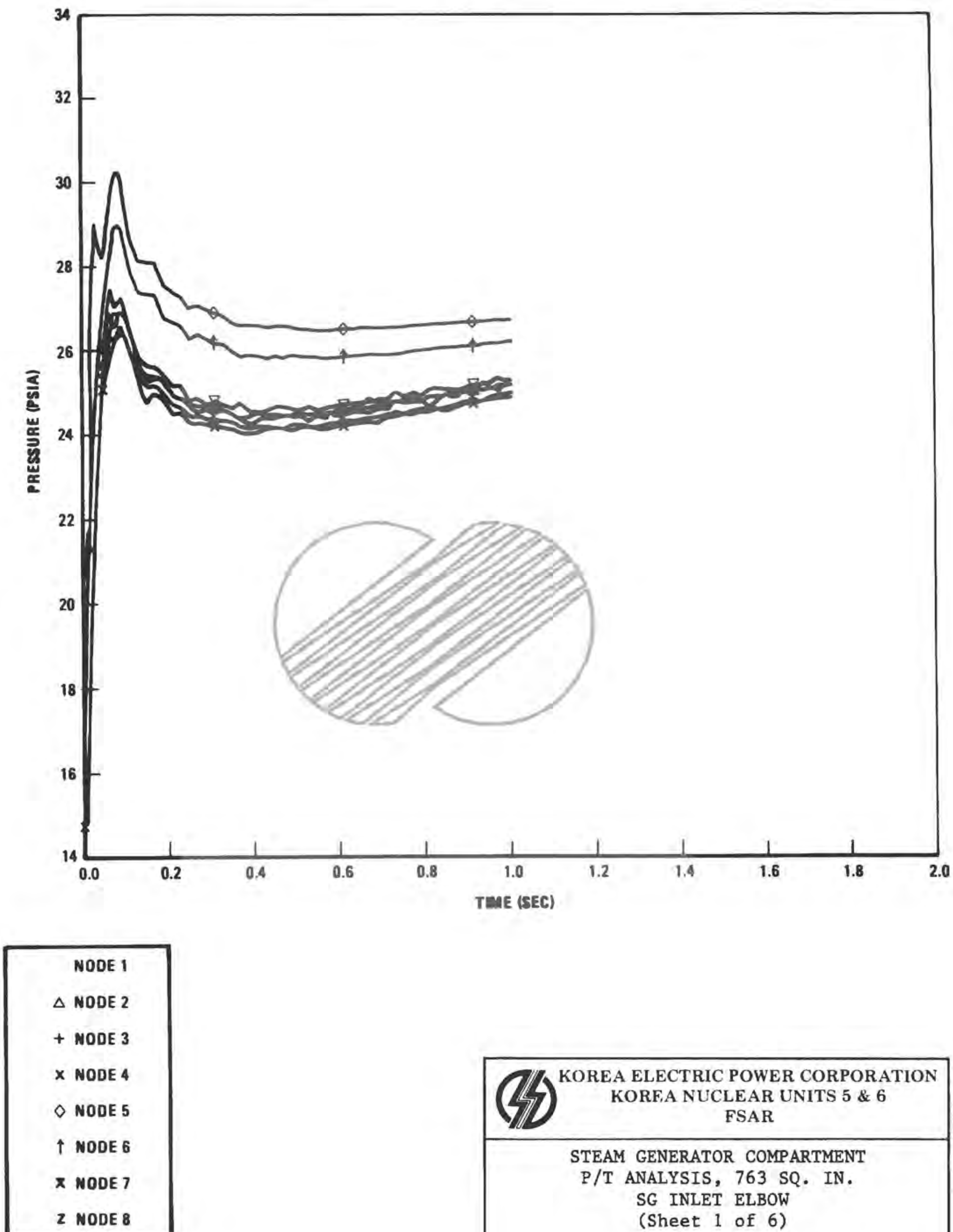

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 763 SQ. IN.
SG INLET ELBOW
(Sheet 1 of 6)

Figure 6.2-12

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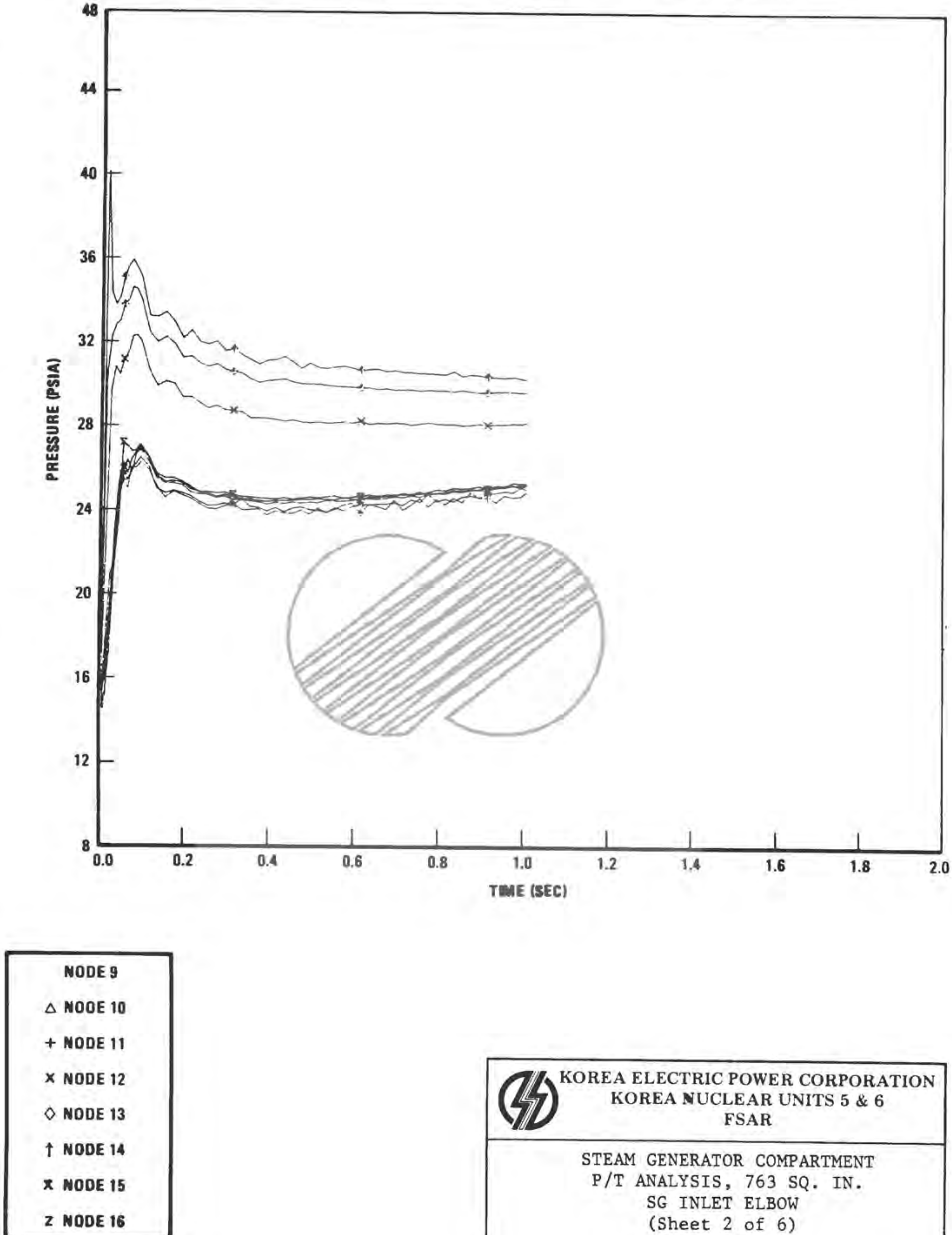

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KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 763 SQ. IN.
SG INLET ELBOW
(Sheet 2 of 6)

Figure 6.2-12

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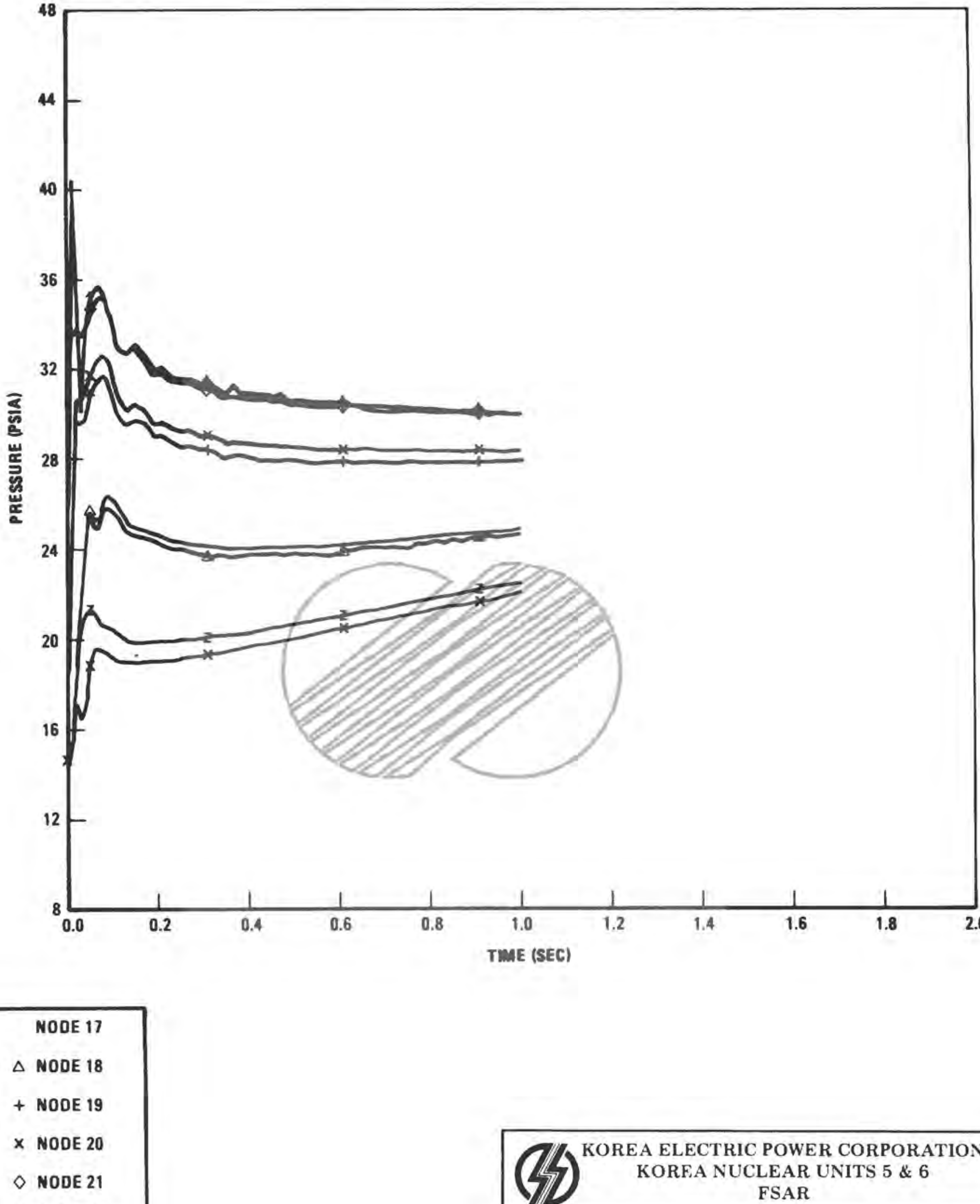

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KOREA NUCLEAR UNITS 5 & 6
FSAR

STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 763 SQ. IN.
SG INLET ELBOW
(Sheet 3 of 6)

Figure 6.2-12

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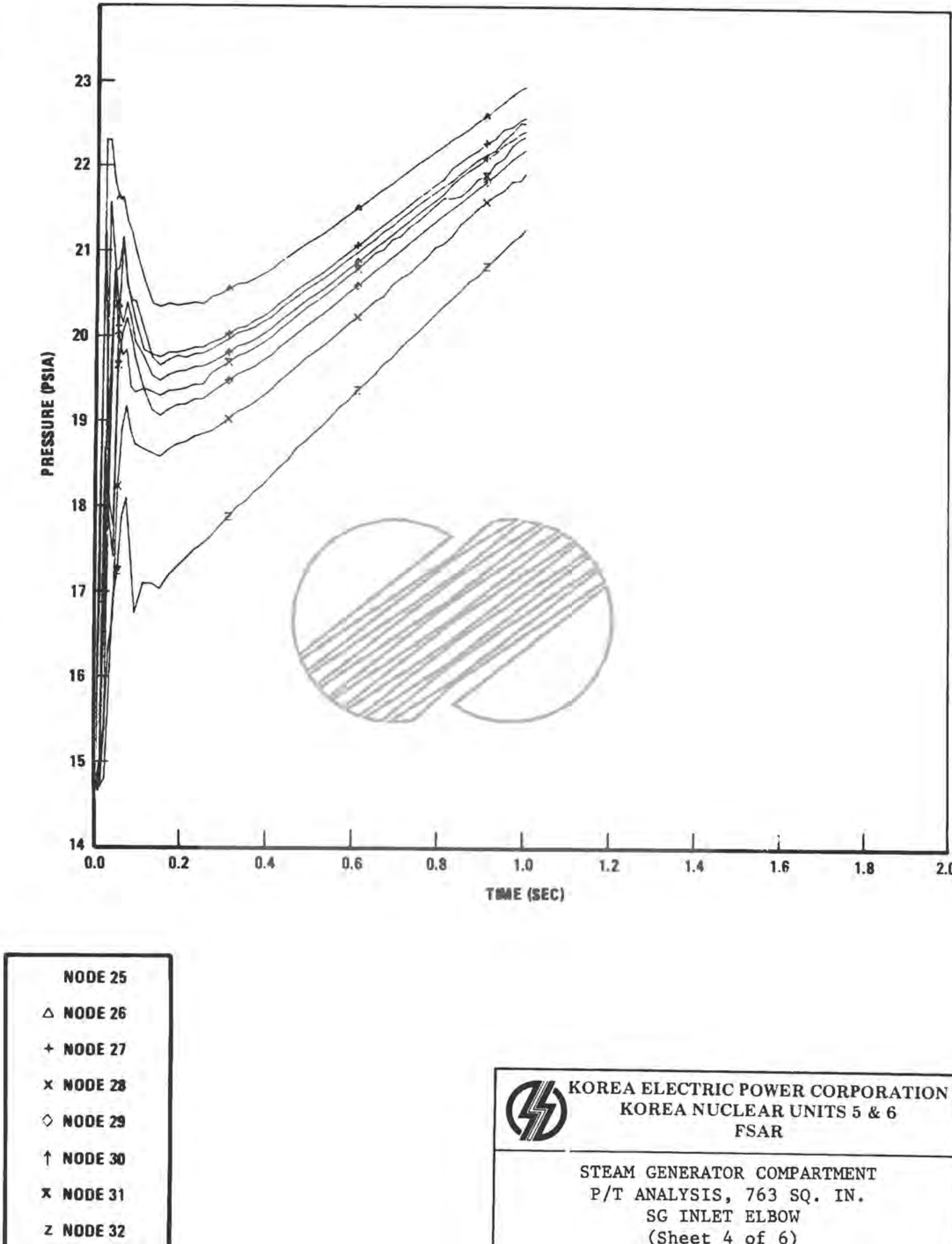

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 763 SQ. IN.
SG INLET ELBOW
(Sheet 4 of 6)

Figure 6.2-12

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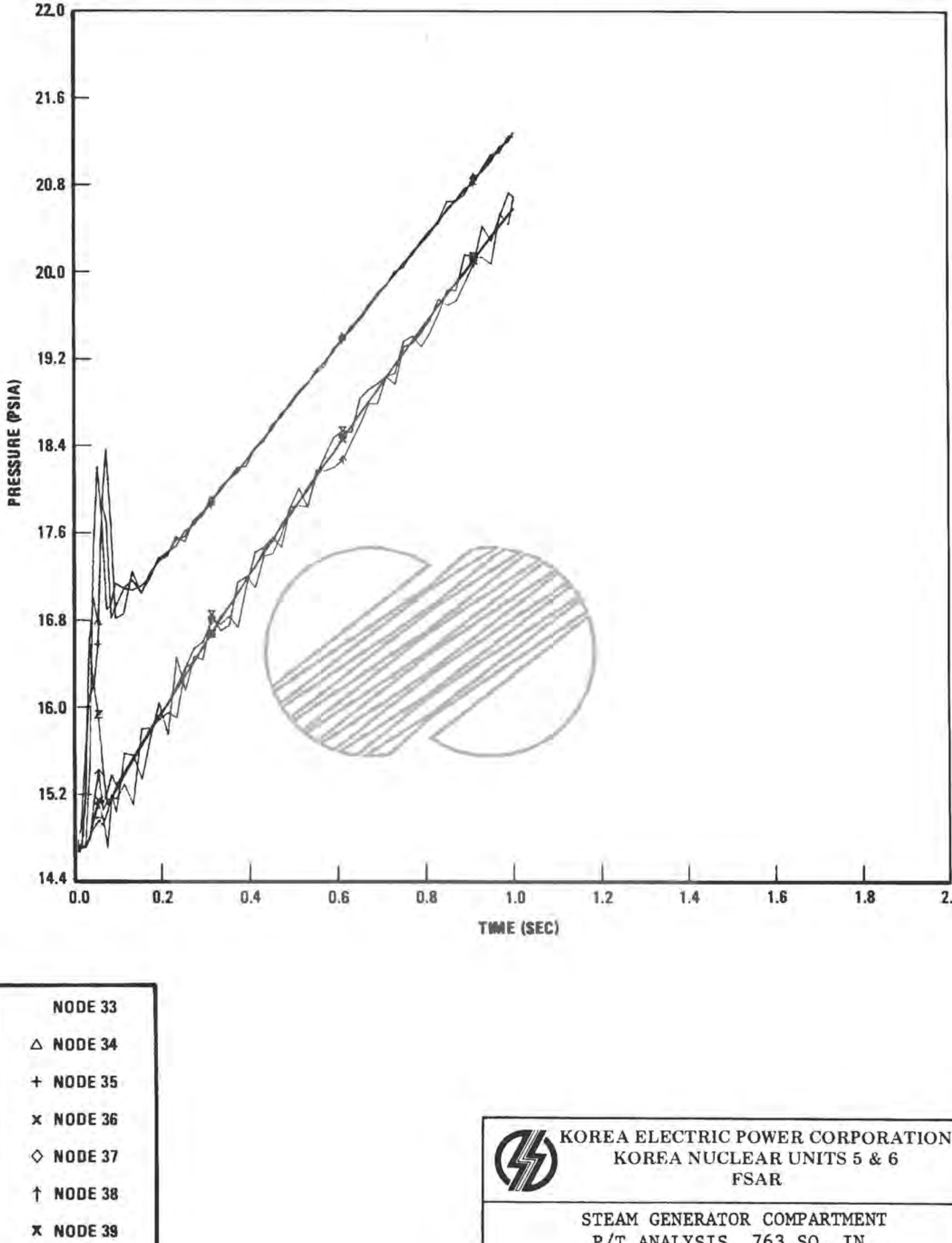

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 763 SQ. IN.
SG INLET ELBOW
(Sheet 5 of 6)

Figure 6.2-12

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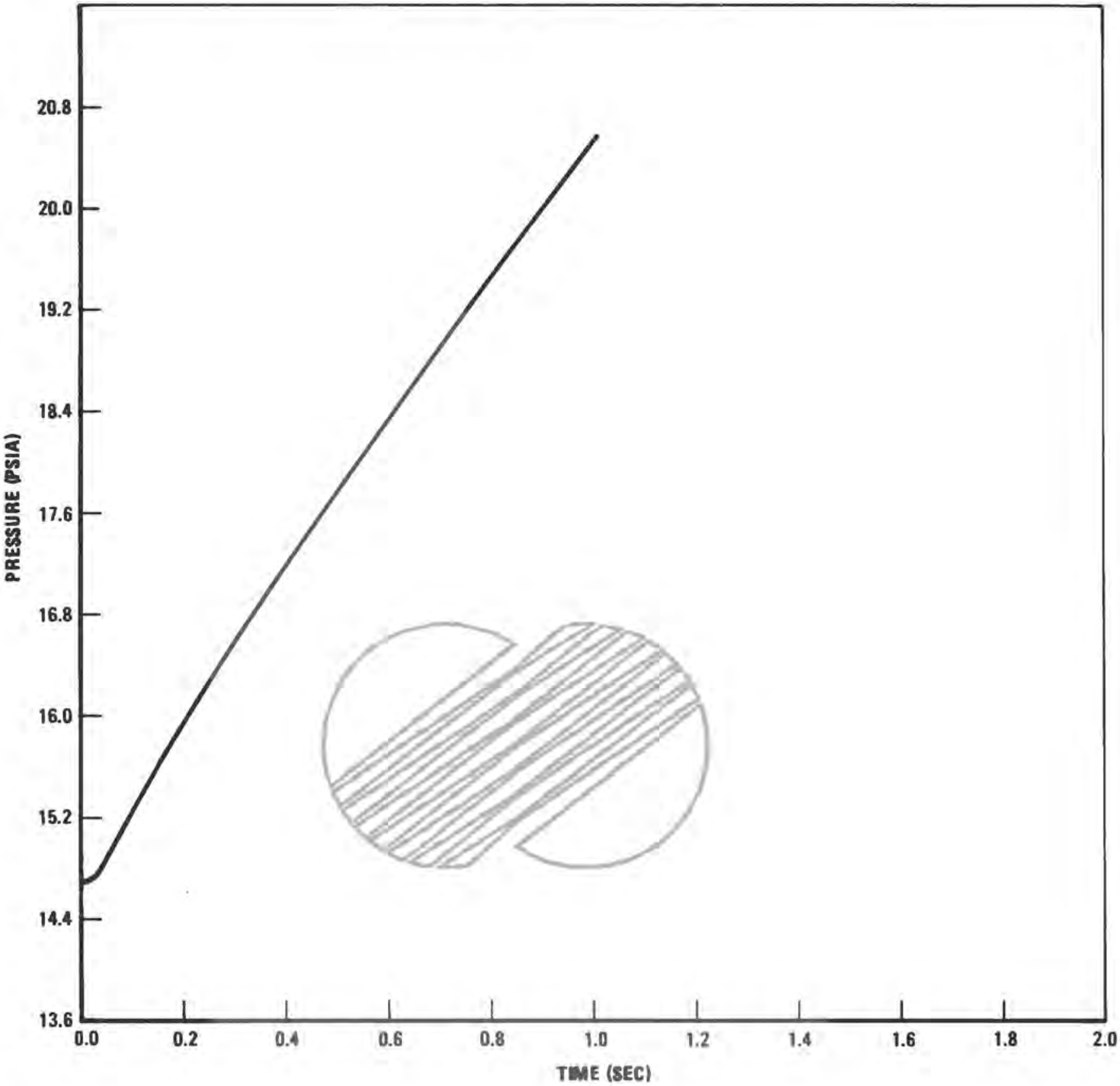

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KOREA NUCLEAR UNITS 5 & 6
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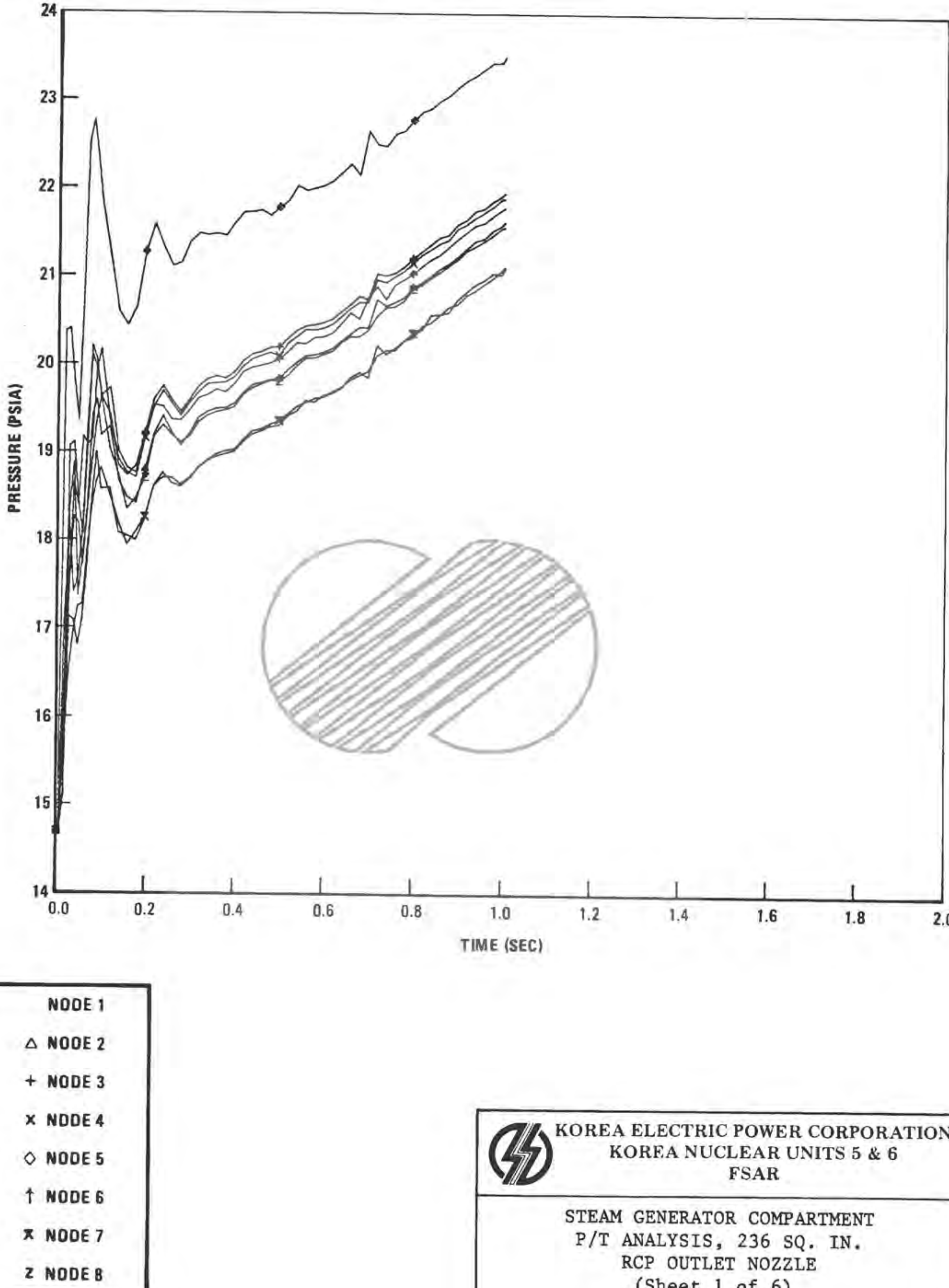
STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 763 SQ. IN.
SG INLET ELBOW
(Sheet 6 of 6)

Figure 6.2-12

본 문서는 한국수력원자력(주)이 정보 공개용으로 작성한 문서입니다.



KOREA ELECTRIC POWER CORPORATION
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 236 SQ. IN.
RCP OUTLET NOZZLE
(Sheet 1 of 6)

Figure 6.2-13

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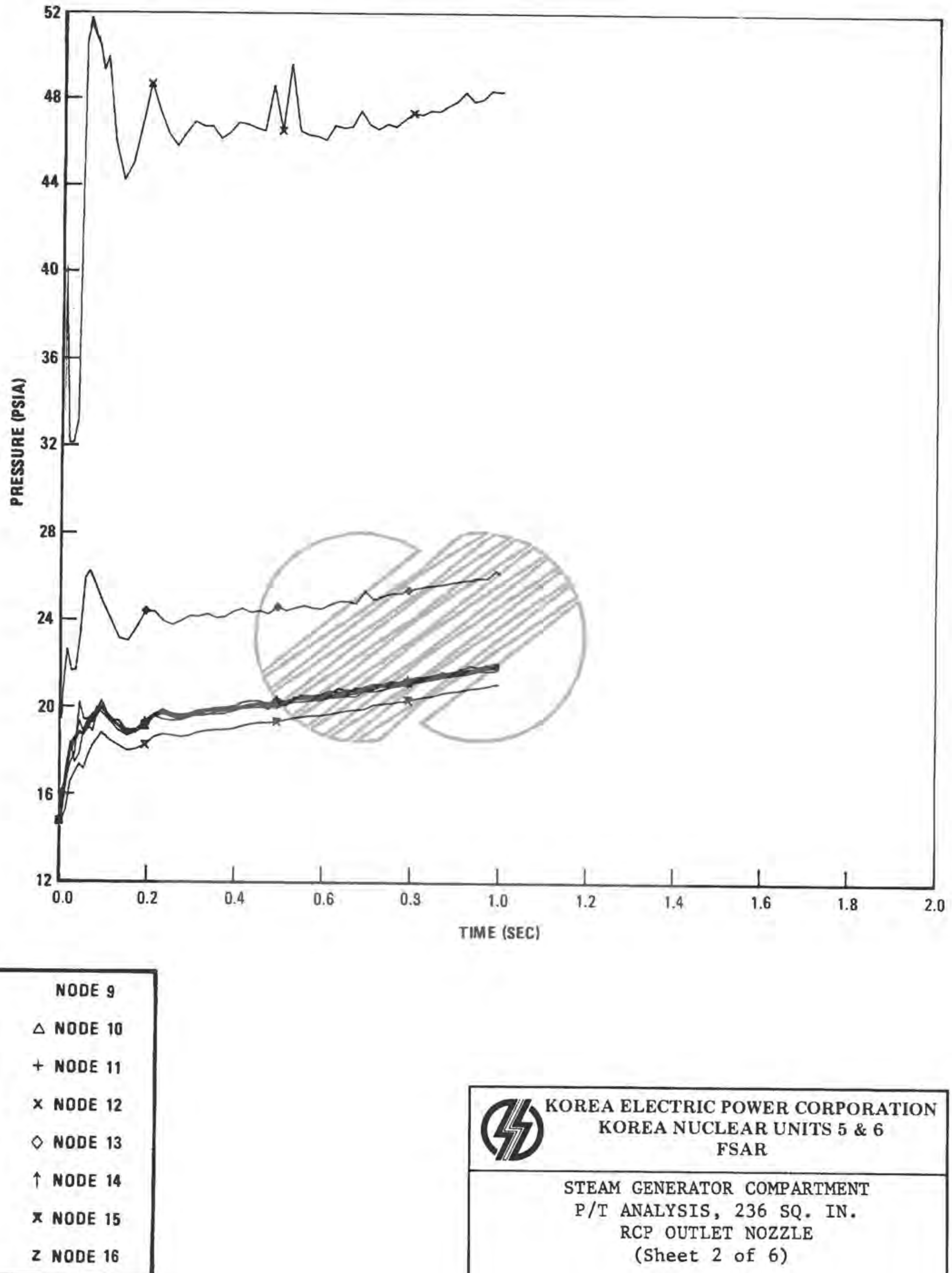

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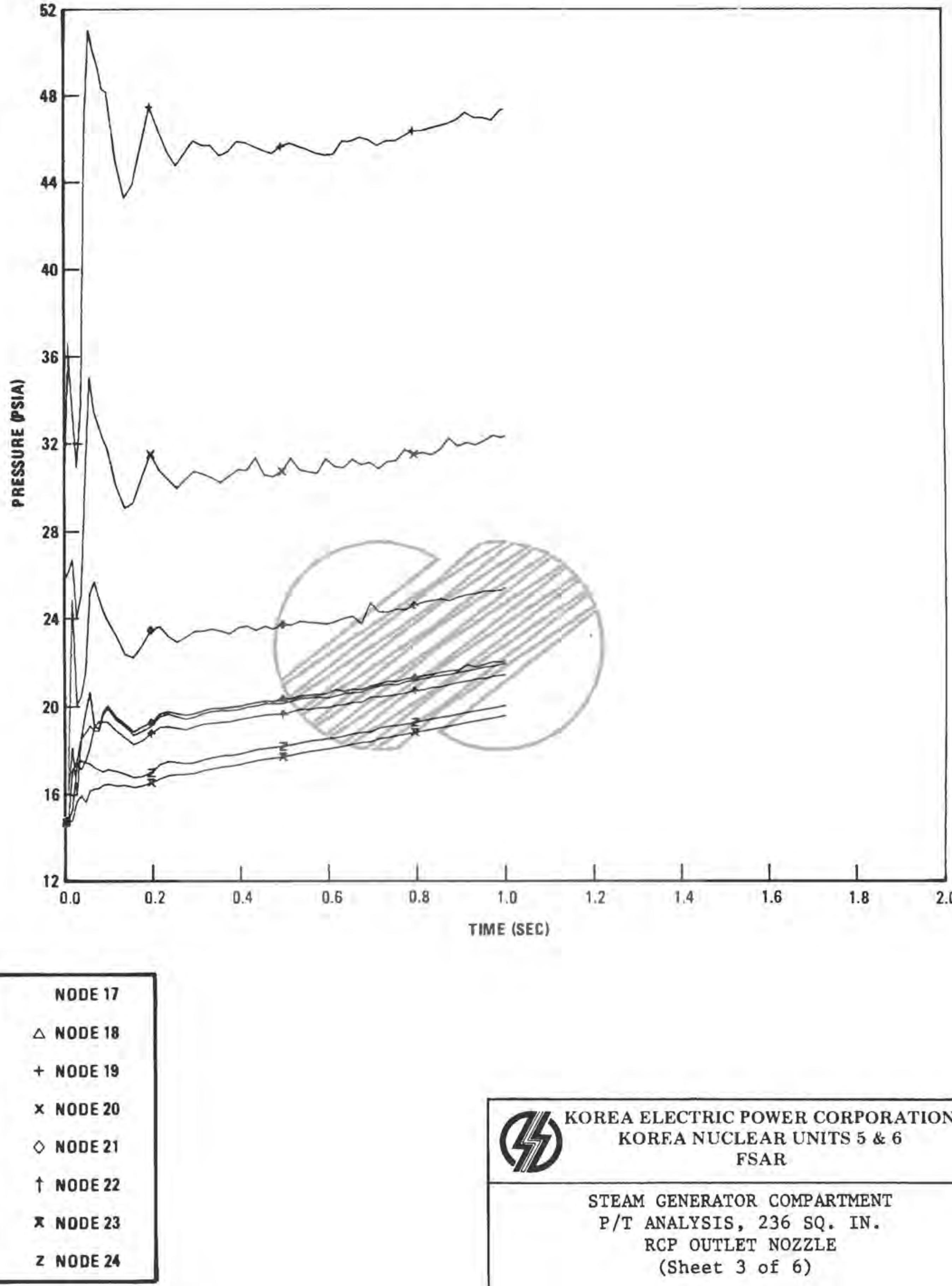
KOREA NUCLEAR UNITS 5 & 6
FSAR

STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 236 SQ. IN.
RCP OUTLET NOZZLE
(Sheet 2 of 6)

Figure 6.2-13

본 문서는 한국수력원자력(주)이 정보 공개용으로 작성한 문서입니다.



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KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 236 SQ. IN.
RCP OUTLET NOZZLE
(Sheet 3 of 6)

Figure 6.2-13

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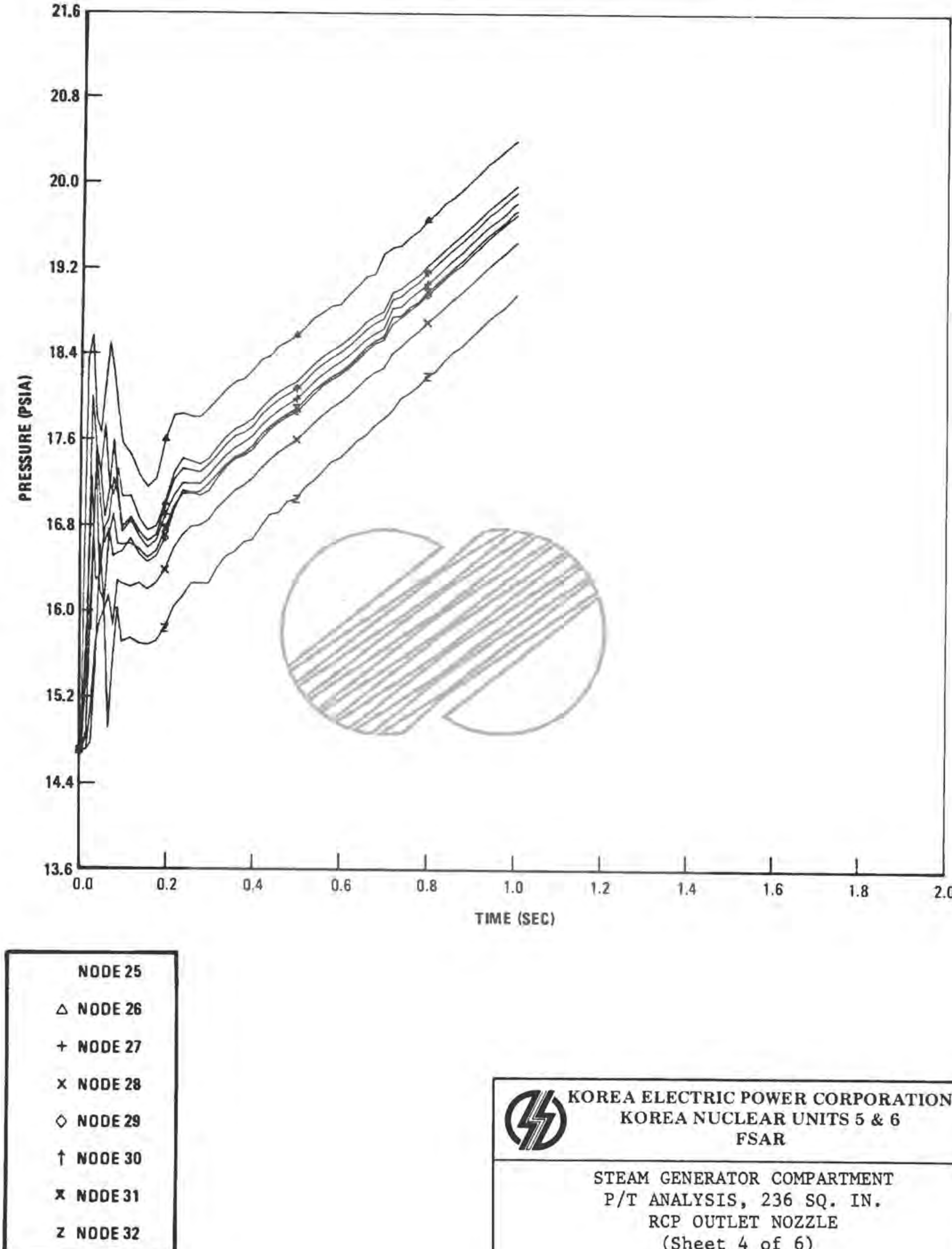

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KOREA NUCLEAR UNITS 5 & 6
FSAR

STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 236 SQ. IN.
RCP OUTLET NOZZLE
(Sheet 4 of 6)

Figure 6.2-13

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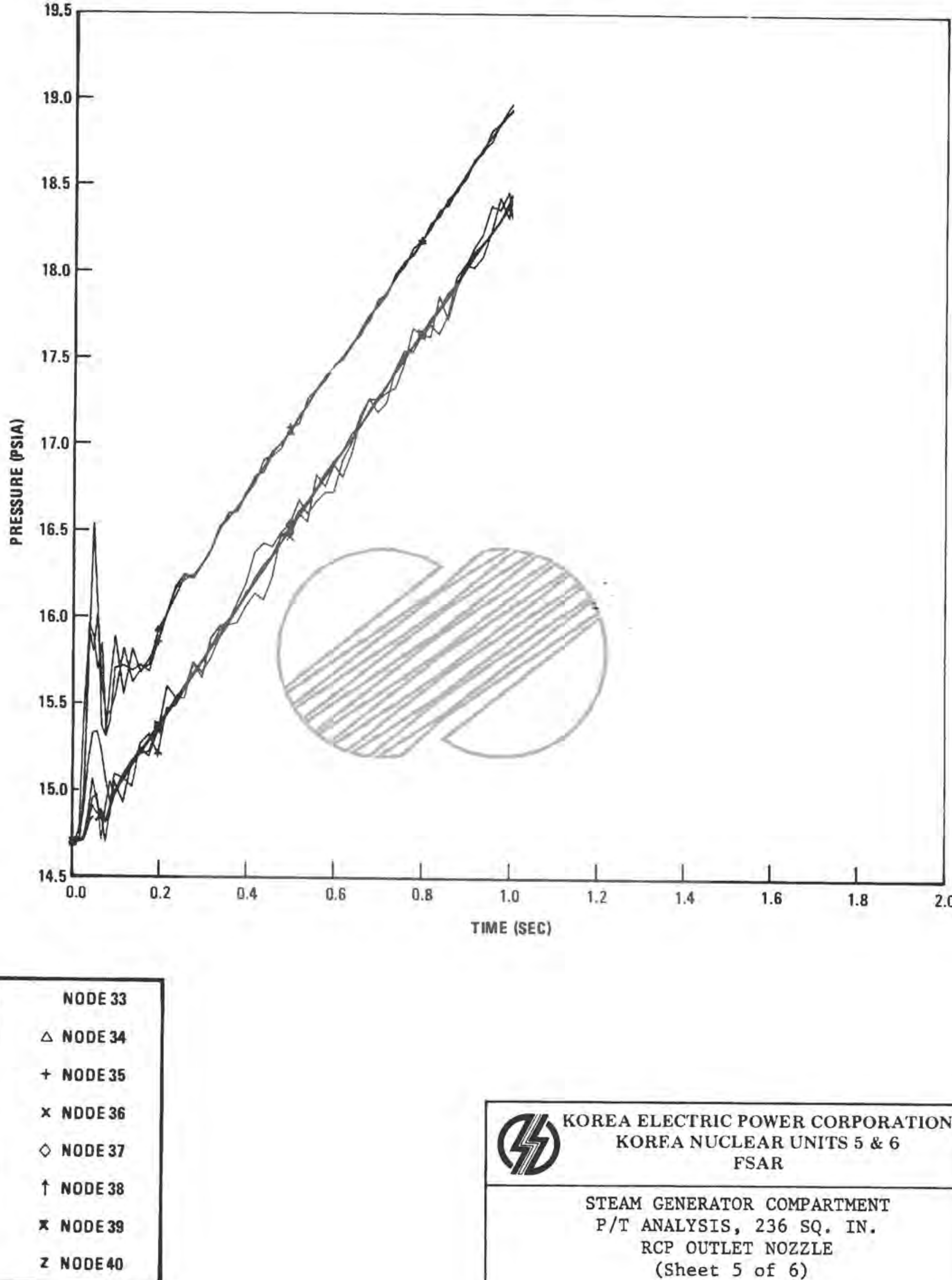

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KOREA NUCLEAR UNITS 5 & 6
FSAR

STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 236 SQ. IN.
RCP OUTLET NOZZLE
(Sheet 5 of 6)

Figure 6.2-13

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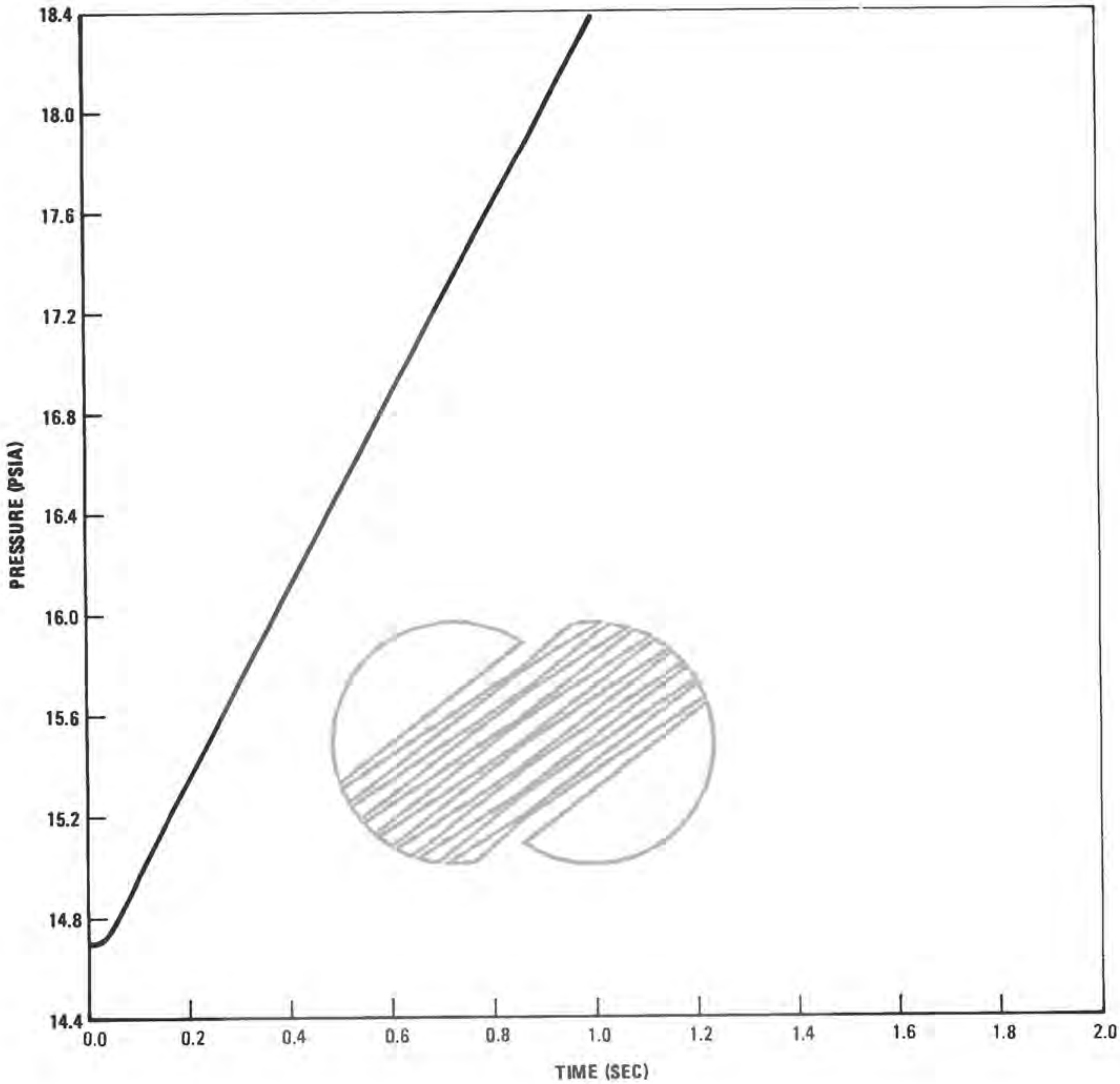

NODE
41

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 236 SQ. IN.
RCP OUTLET NOZZLE
(Sheet 6 of 6)

Figure 6.2-13

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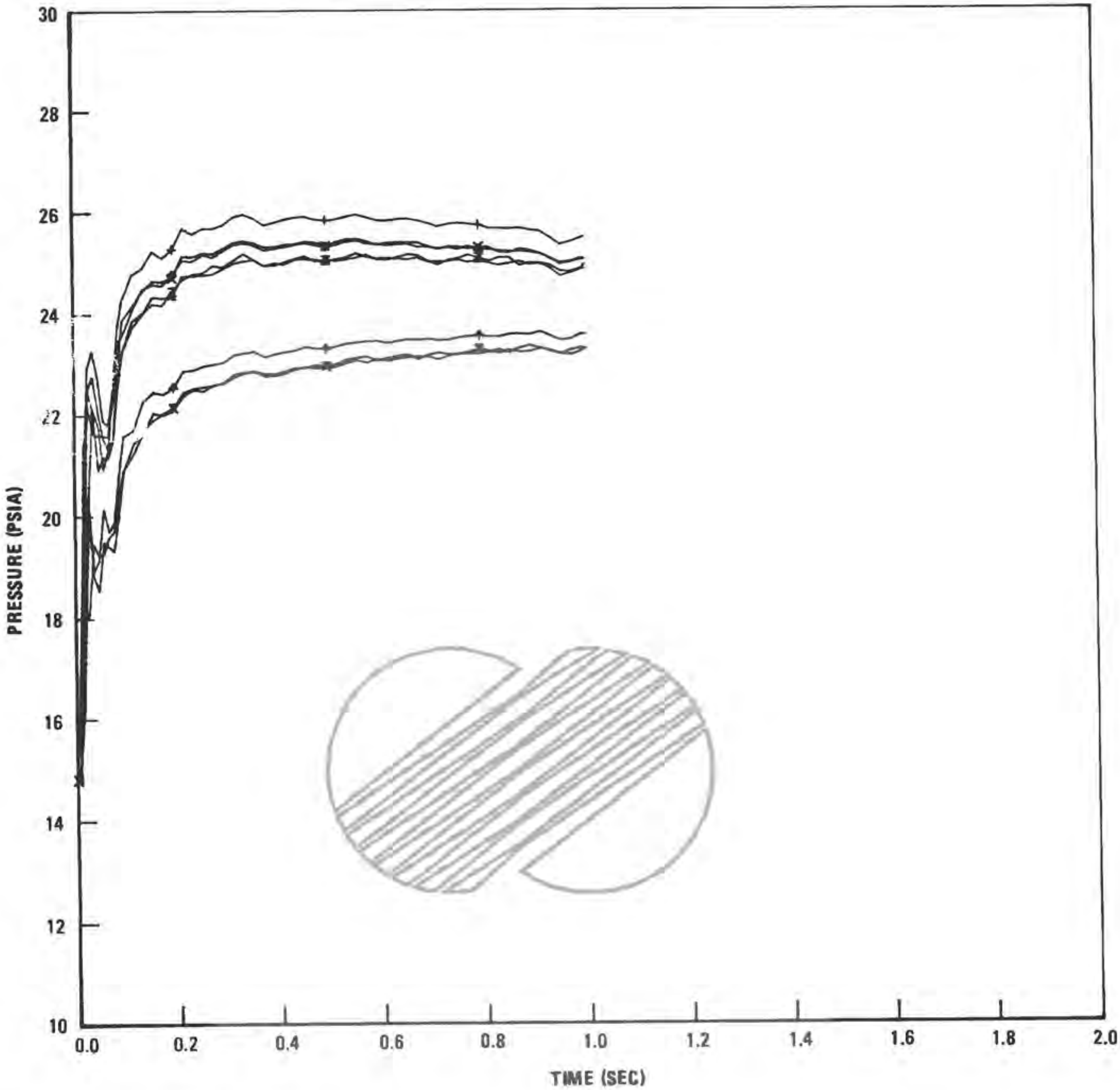

NODE 1
△ NODE 2
+ NODE 3
× NODE 4
◇ NODE 5
† NODE 6
ẋ NODE 7
z NODE 8

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KOREA NUCLEAR UNITS 5 & 6
FSAR

STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 436 SQ. IN.
SG OUTLET NOZZLE
(Sheet 1 of 6)

Figure 6.2-14

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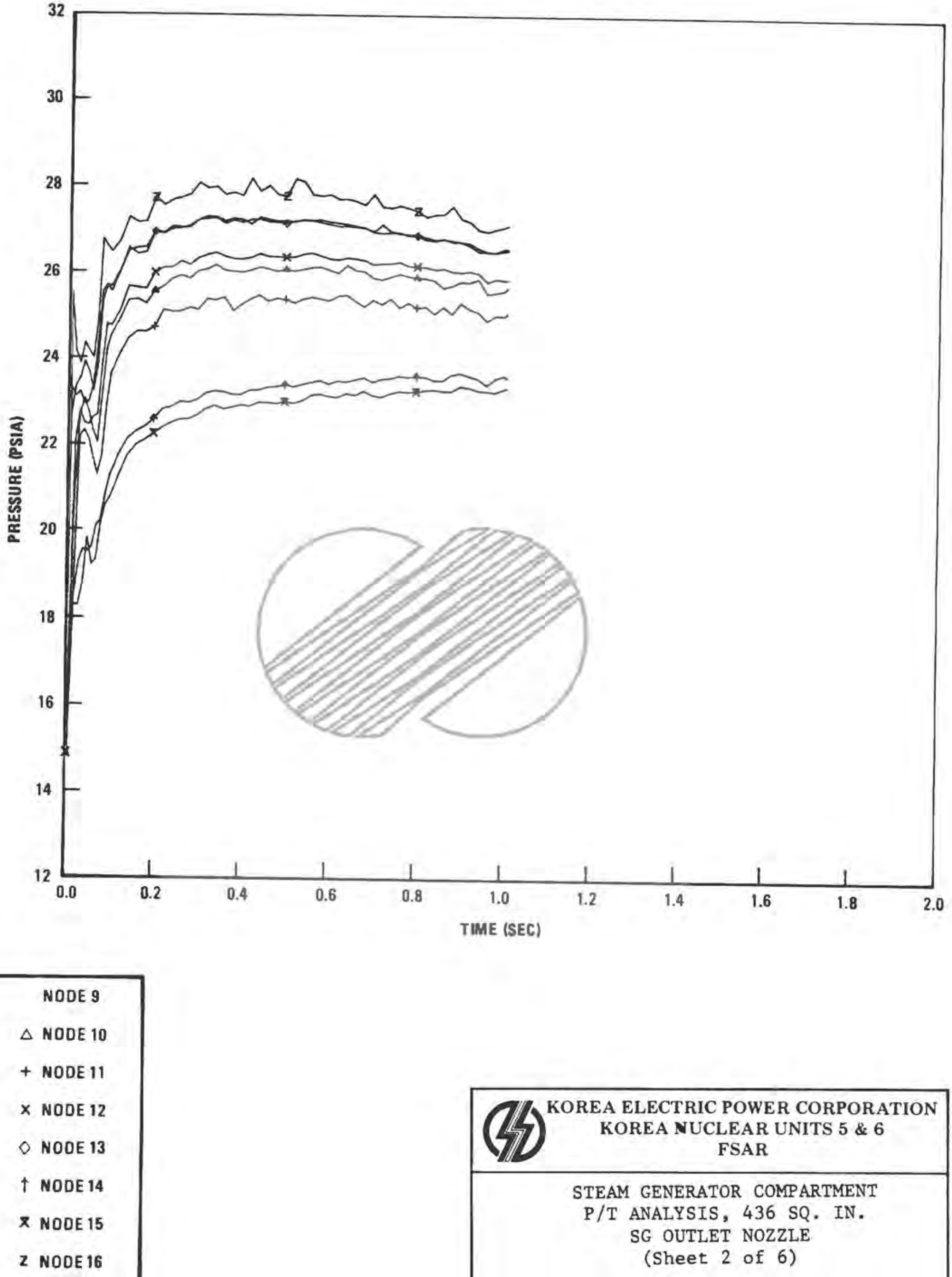

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KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 436 SQ. IN.
SG OUTLET NOZZLE
(Sheet 2 of 6)

Figure 6.2-14

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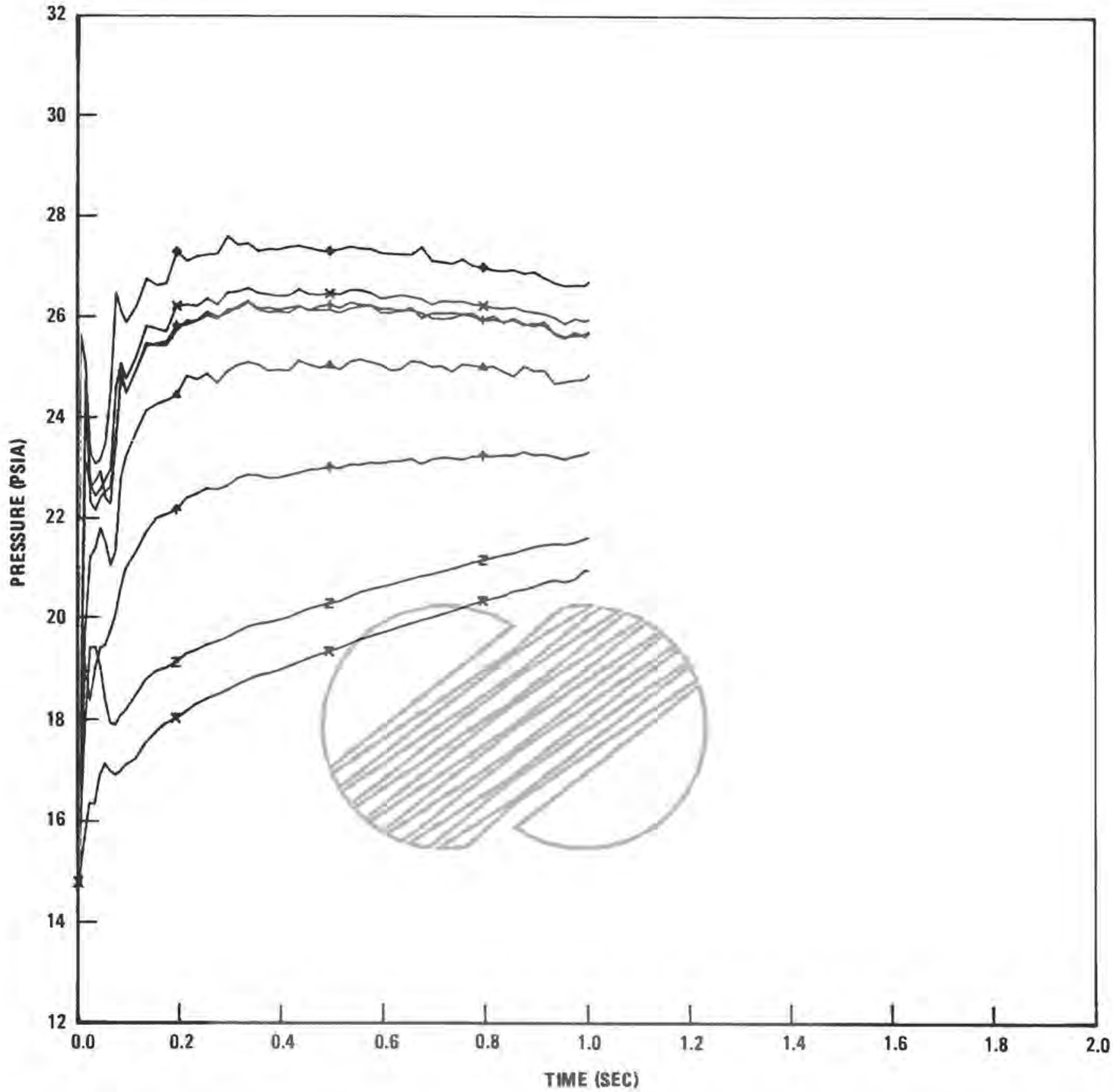

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KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 436 SQ. IN.
SG OUTLET NOZZLE
(Sheet 3 of 6)

Figure 6.2-14

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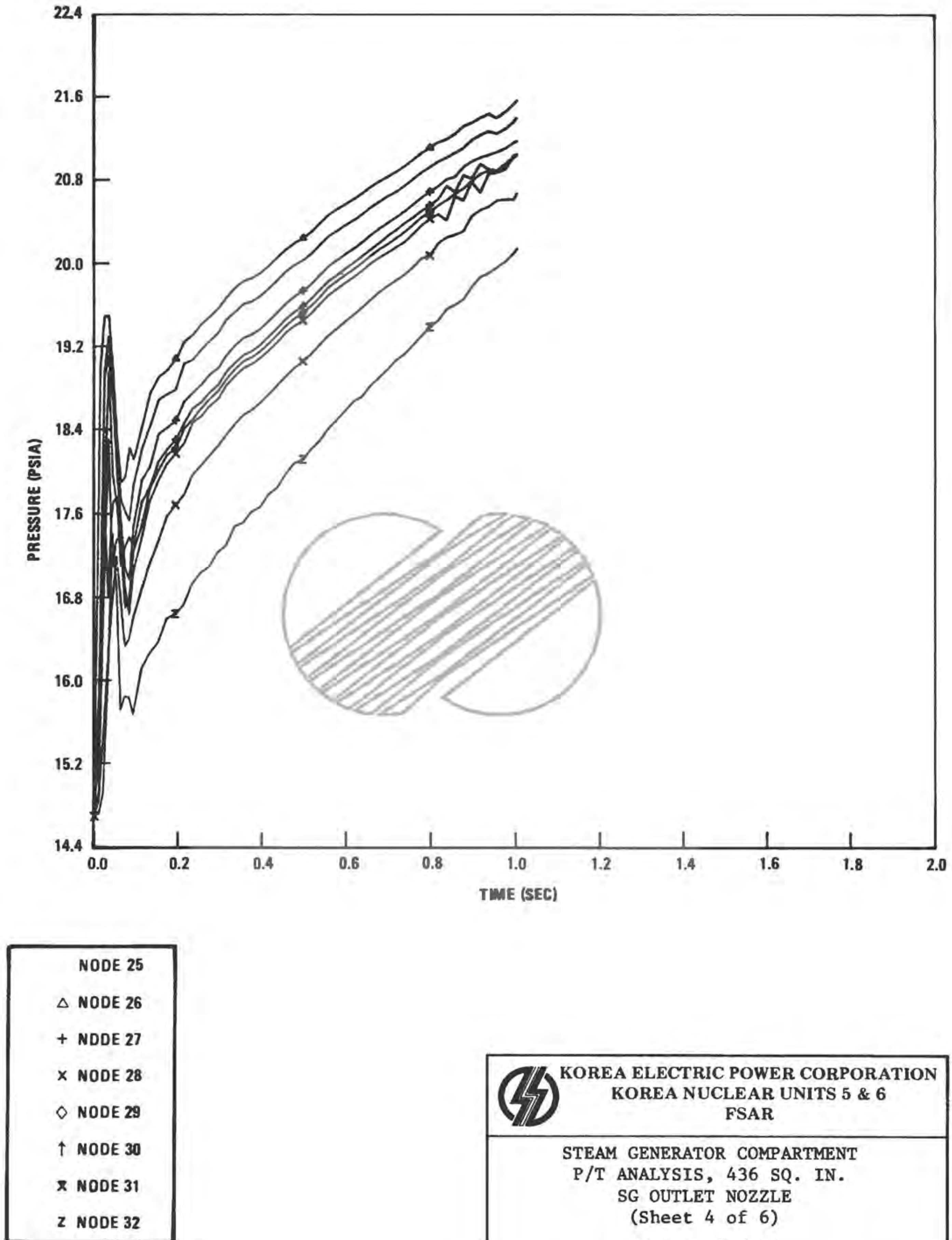

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
FSAR

STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 436 SQ. IN.
SG OUTLET NOZZLE
(Sheet 4 of 6)

Figure 6.2-14

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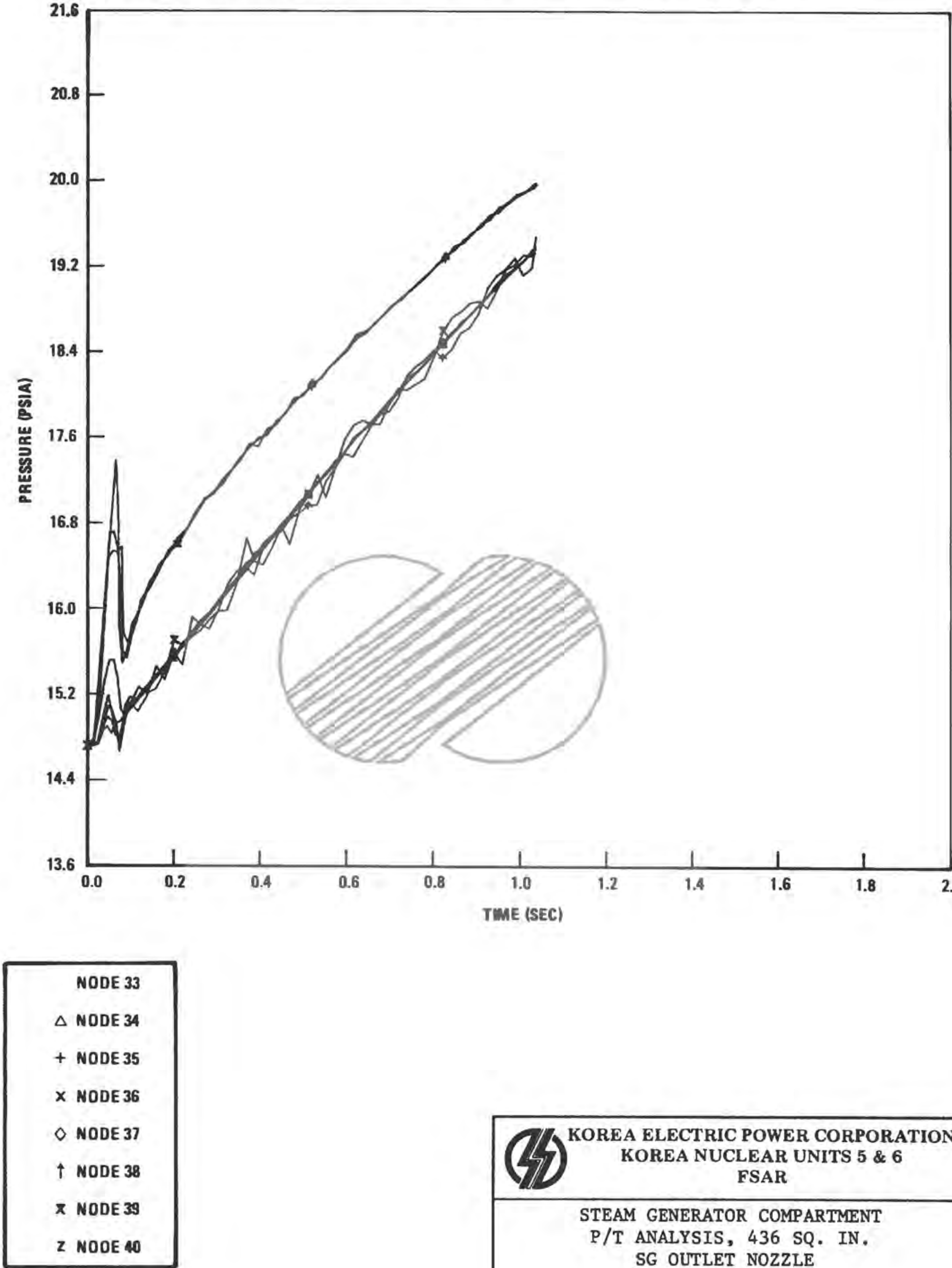

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
FSAR

STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 436 SQ. IN.
SG OUTLET NOZZLE
(Sheet 5 of 6)

Figure 6.2-14

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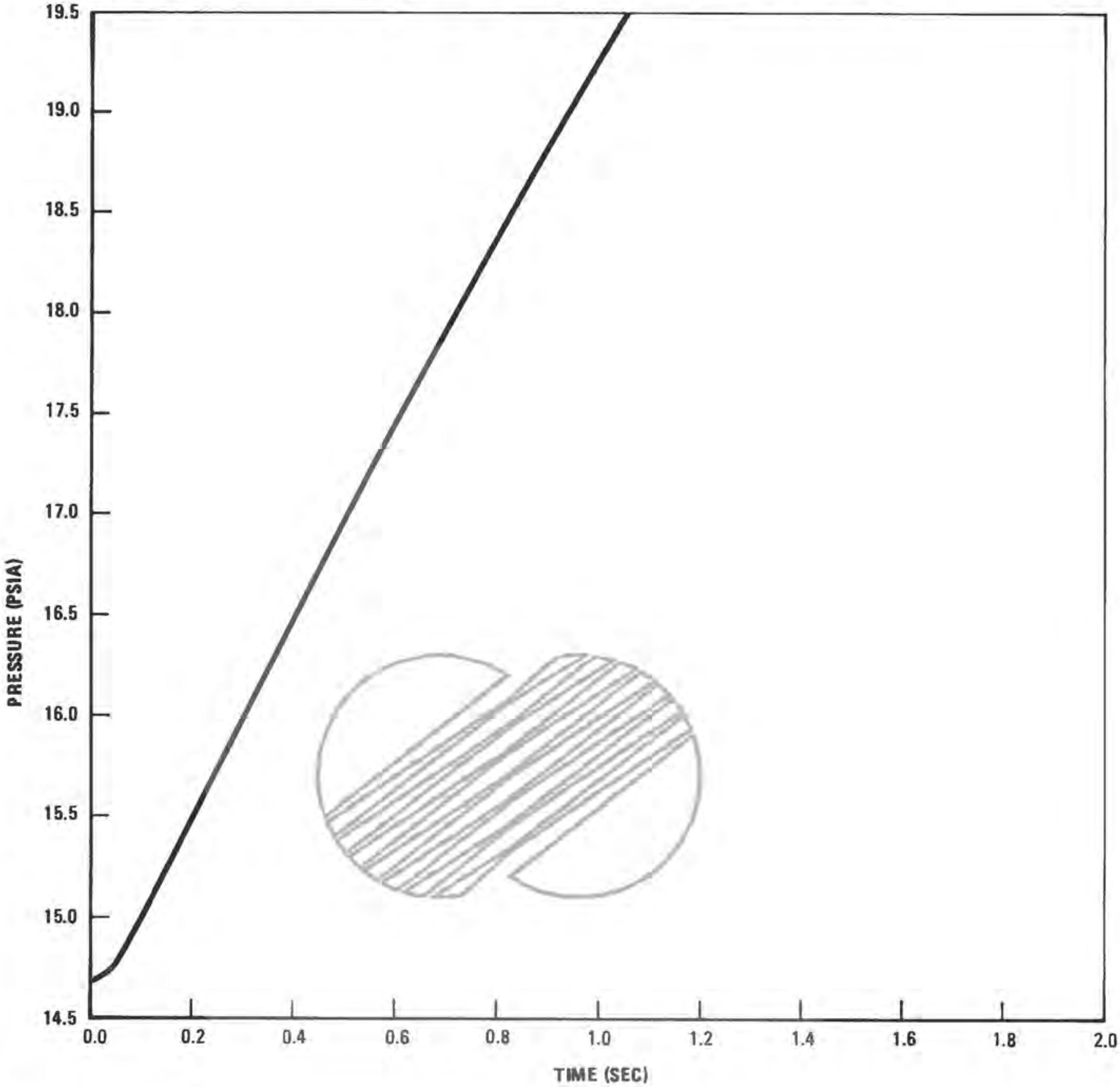

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KOREA NUCLEAR UNITS 5 & 6
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STEAM GENERATOR COMPARTMENT
P/T ANALYSIS, 436 SQ. IN.
SG OUTLET NOZZLE
(Sheet 6 of 6)

Figure 6.2-14

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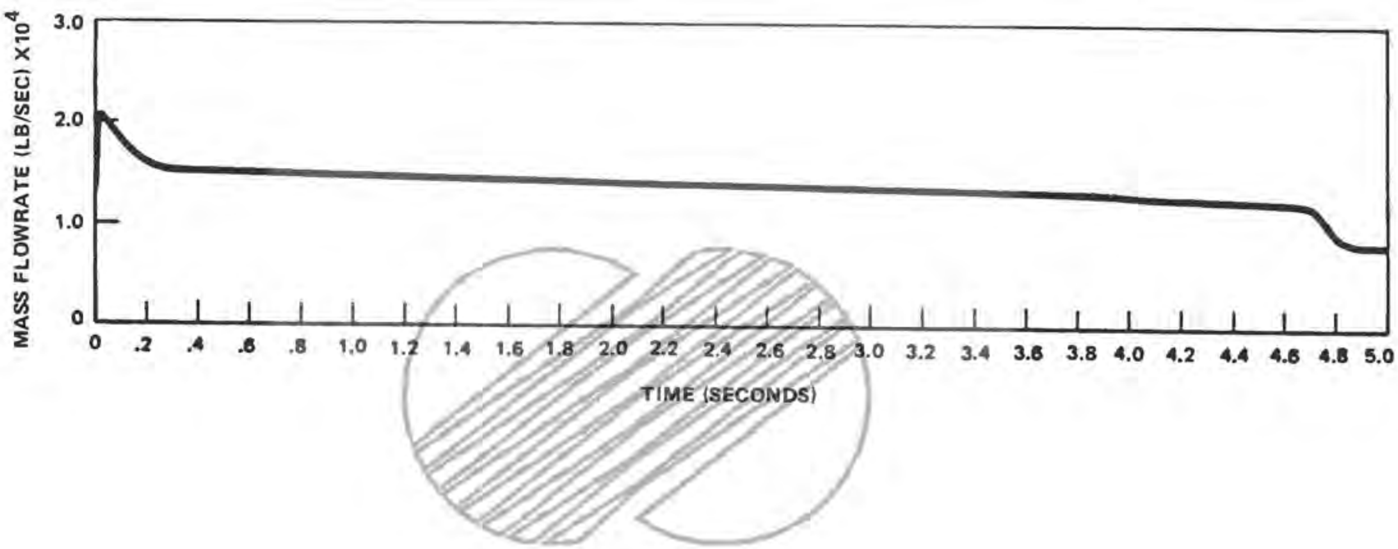

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
FSAR

MASS FLOWRATE VS TIME
FOR PRESSURIZER SURGE LINE
RUPTURE ANALYSIS

Figure 6.2-17

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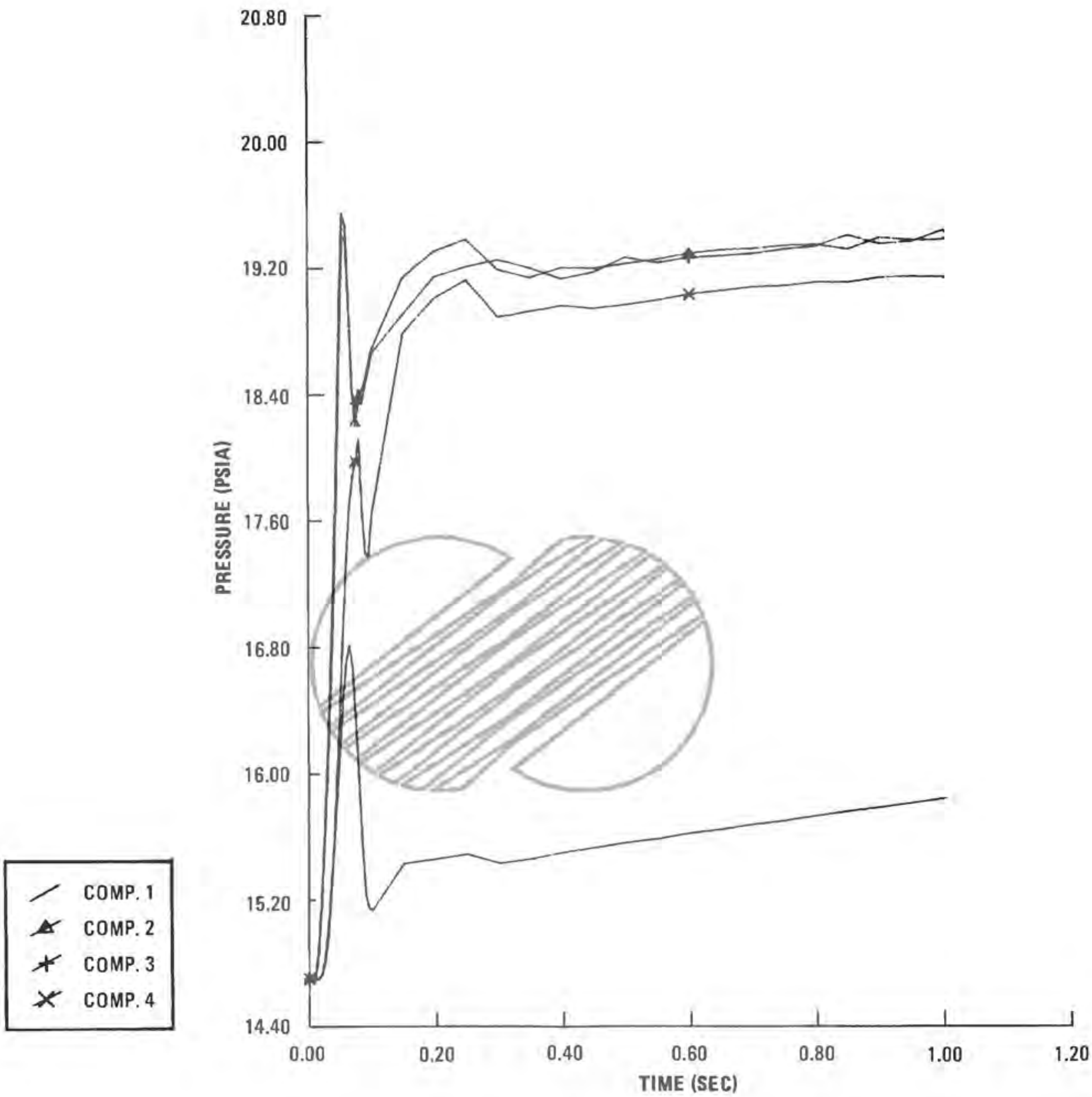

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 1 of 8)]

Figure 6.2-18

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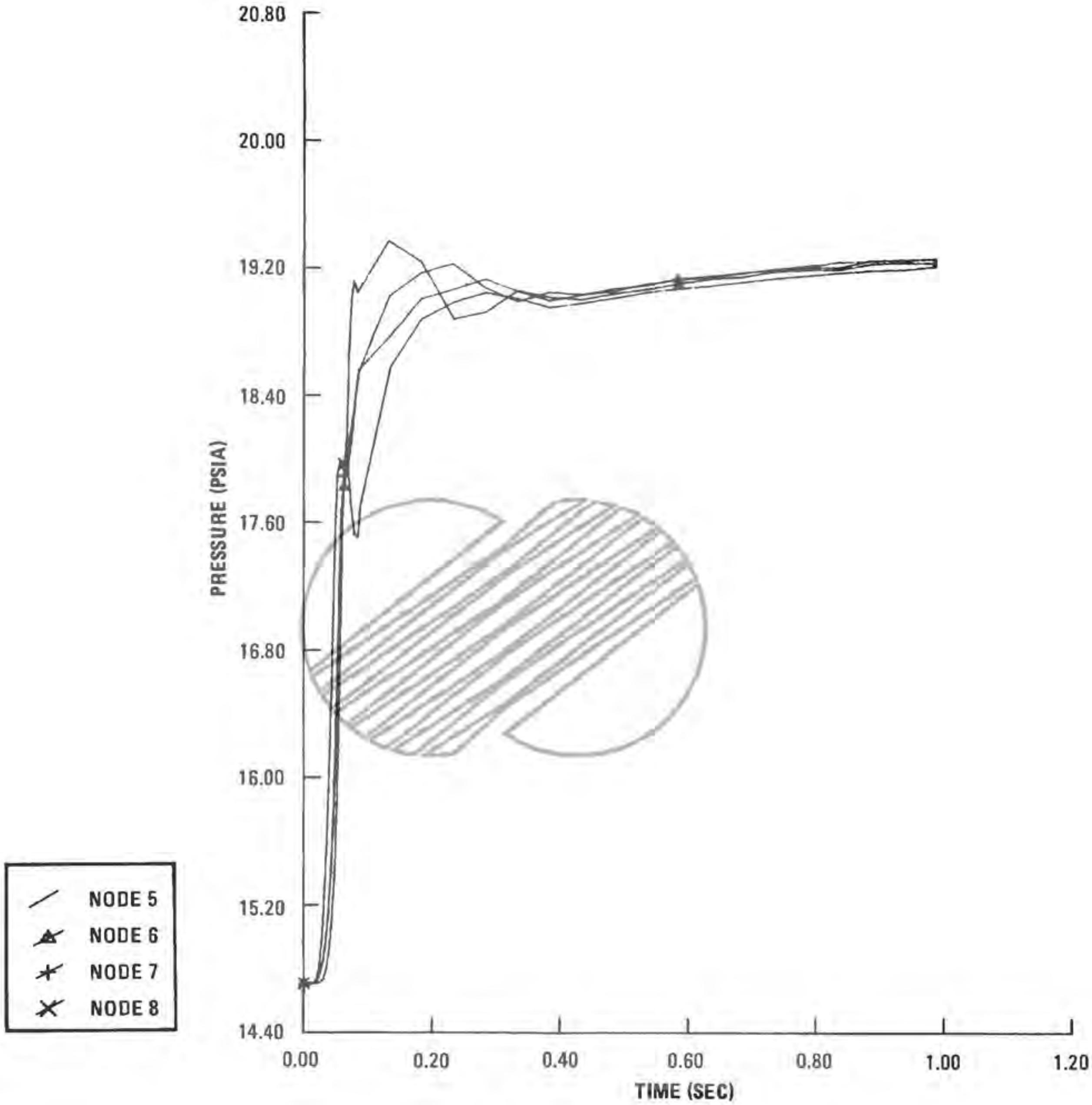

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KOREA NUCLEAR UNITS 5 & 6
FSAR

COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 2 of 8)

Figure 6.2-18

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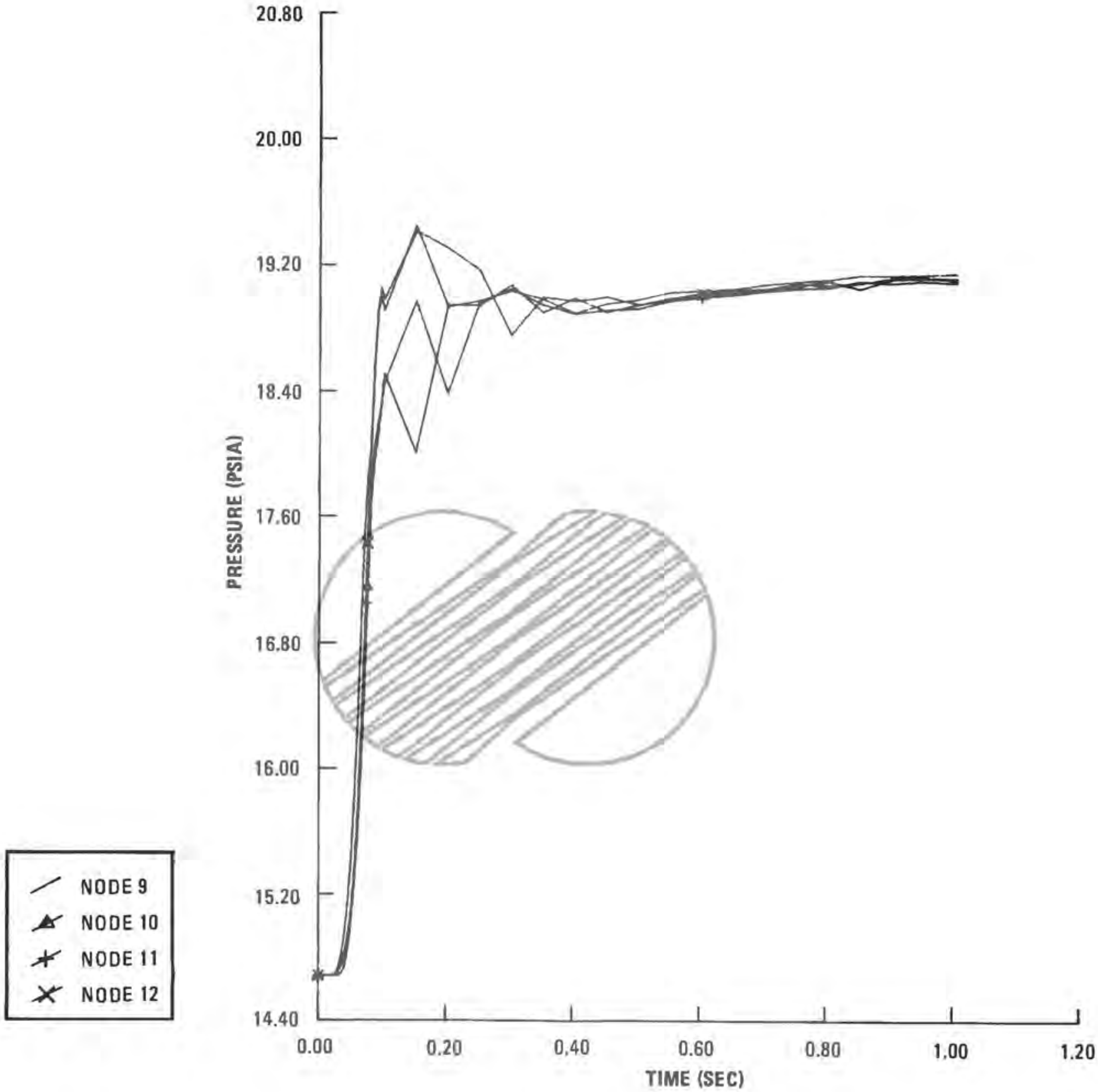

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COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 3 of 8)

Figure 6.2-18

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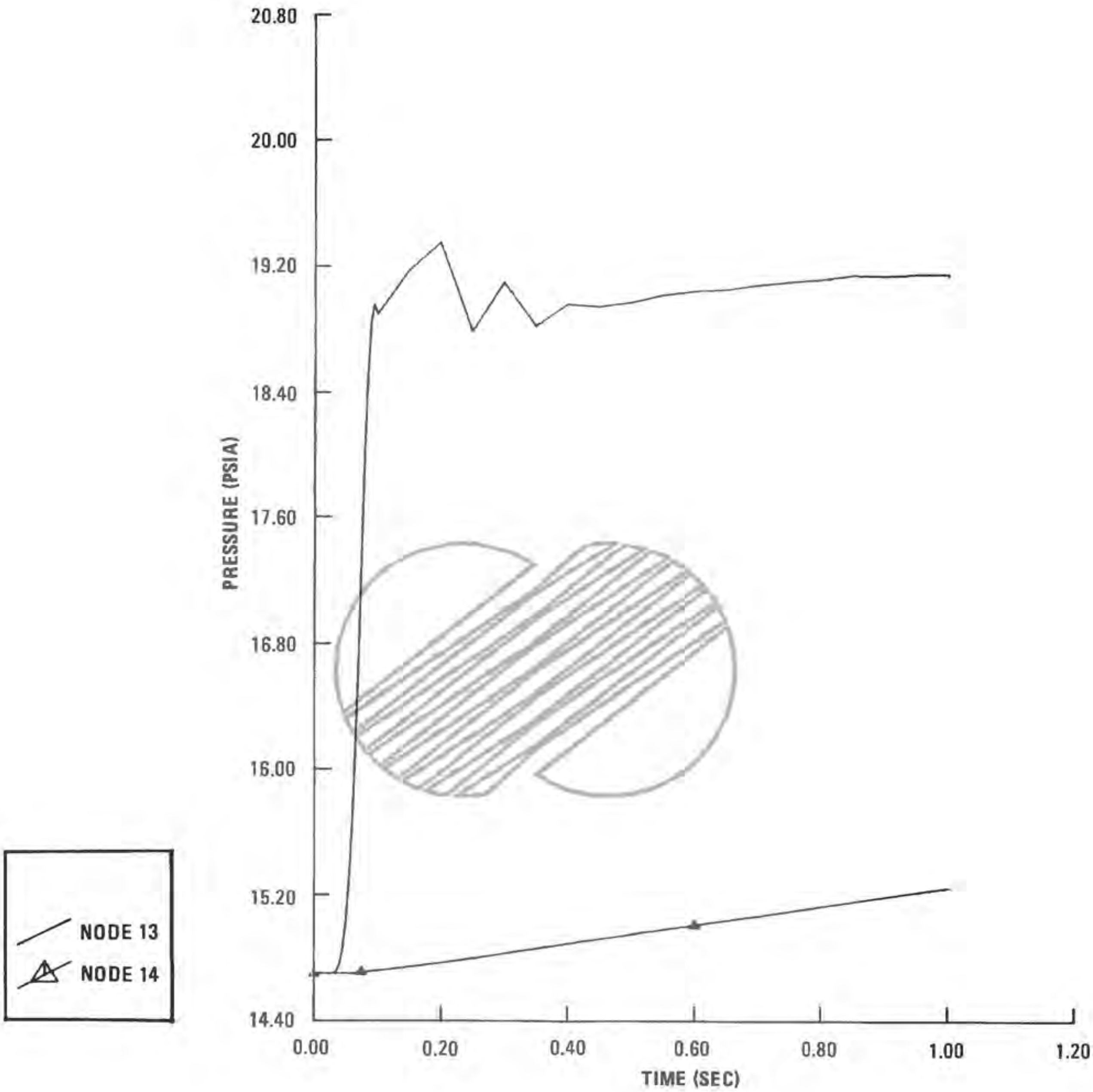

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COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 4 of 8)

Figure 6.2-18

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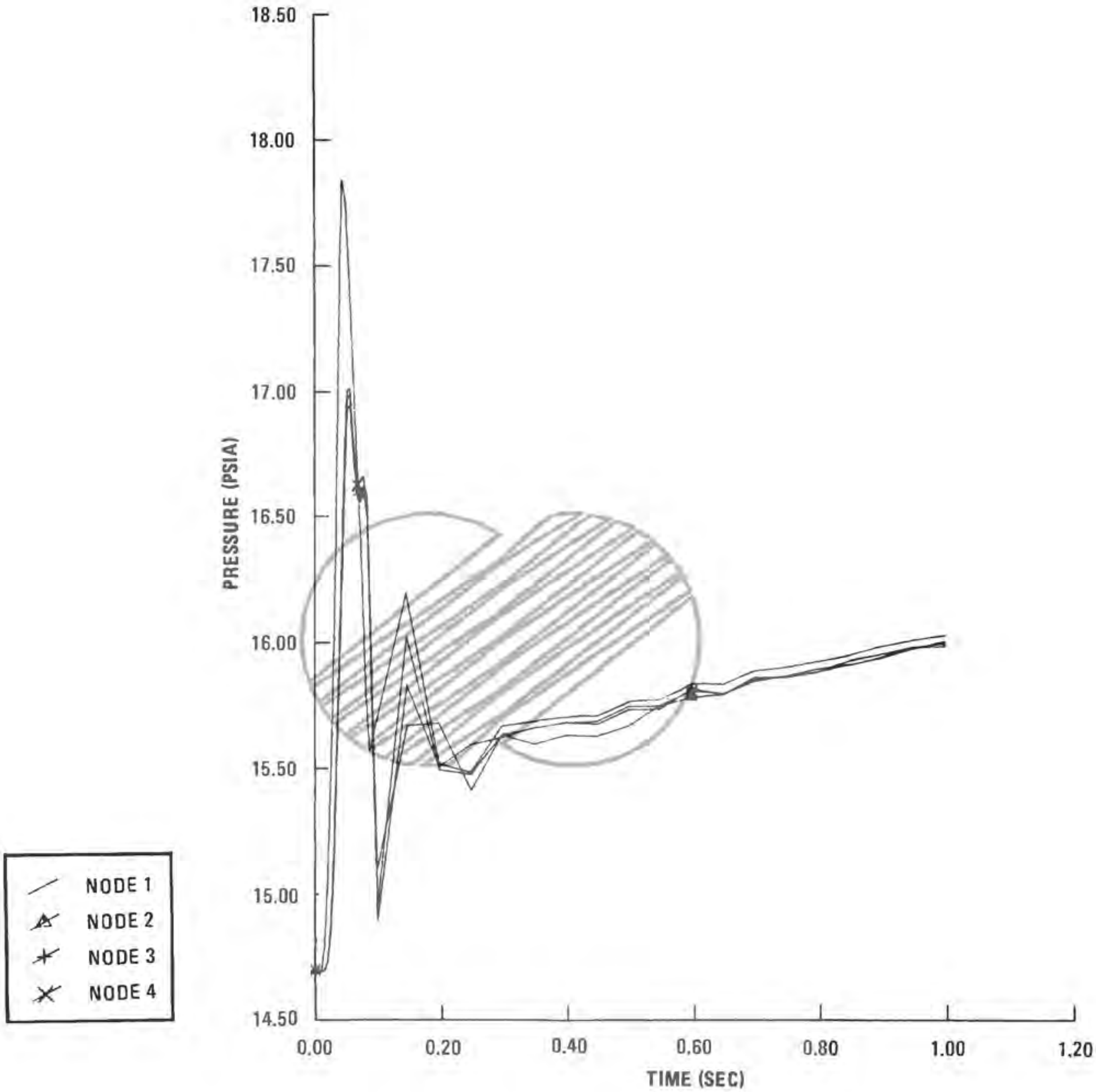

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COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 5 of 8)

Figure 6.2-18

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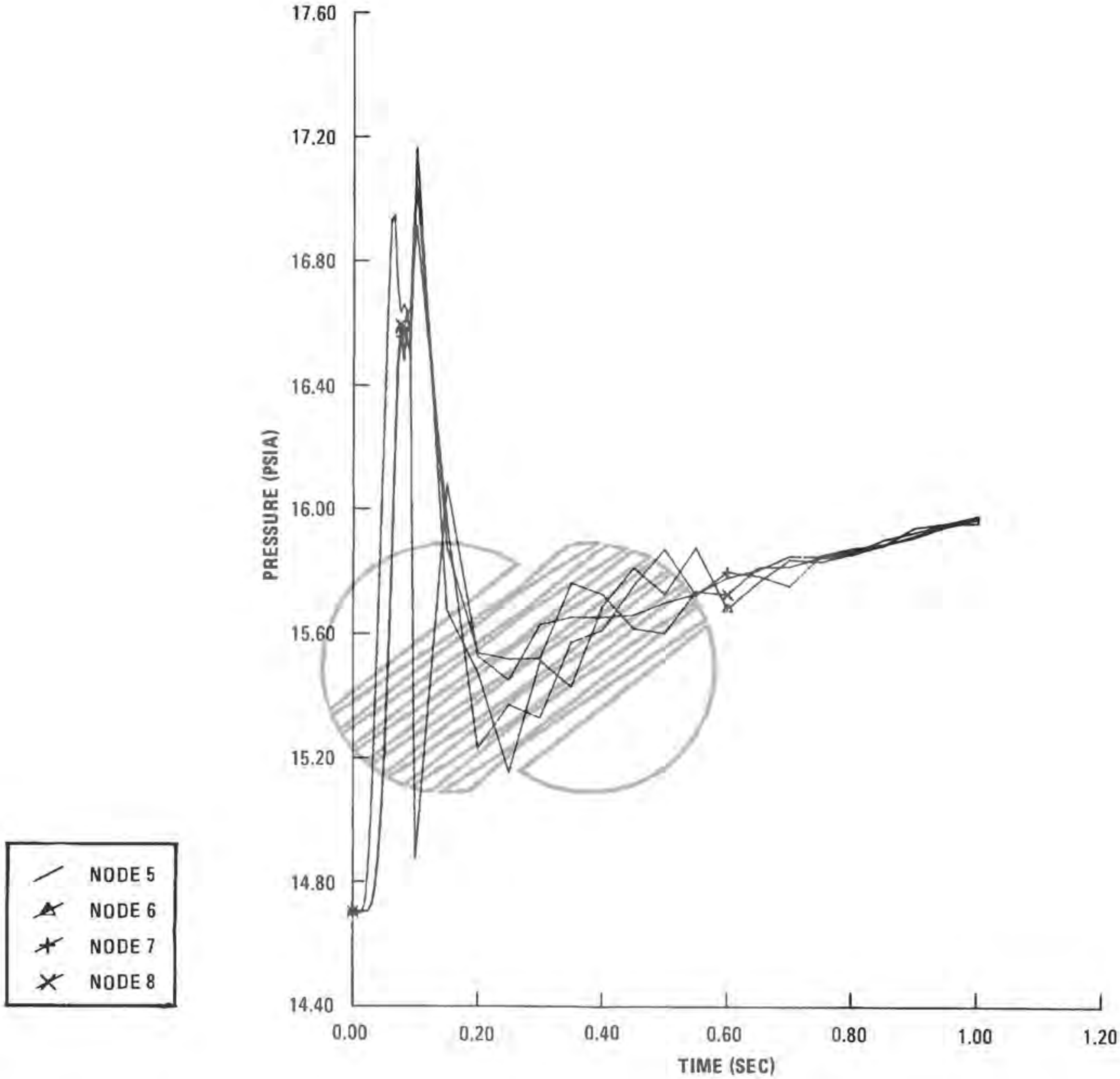

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COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 6 of 8)

Figure 6.2-18

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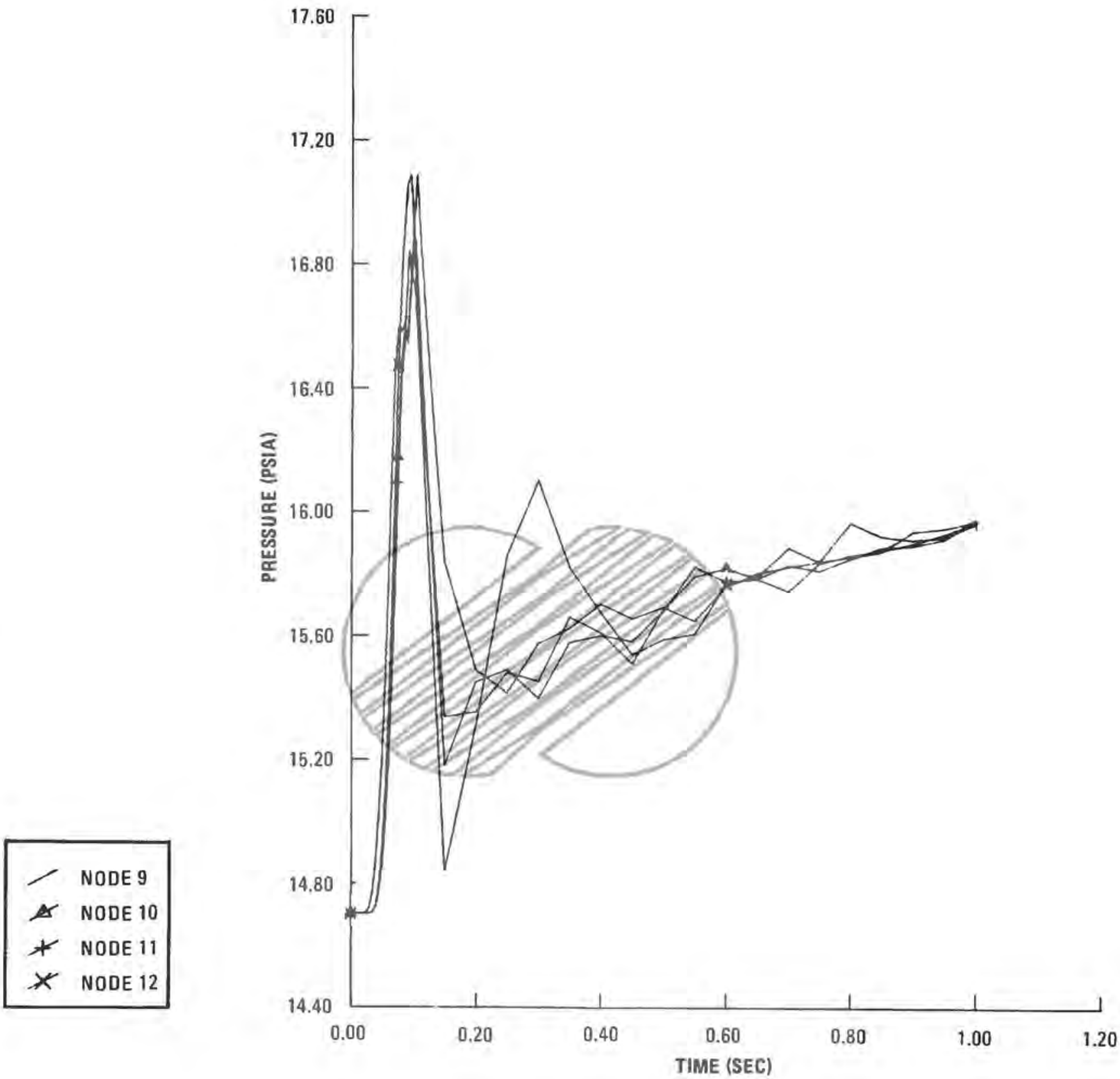

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COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 7 of 8)

Figure 6.2-18

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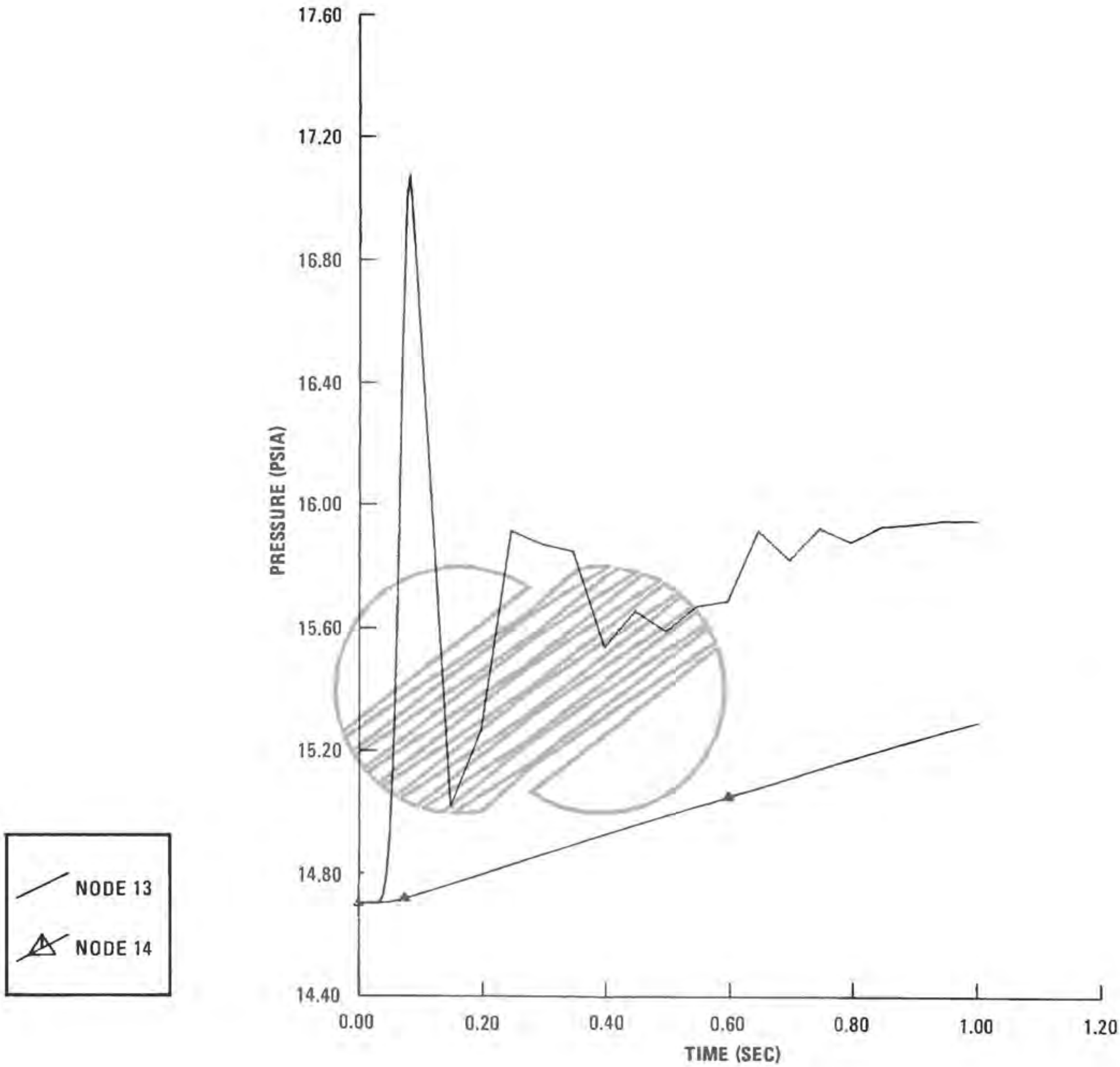

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COMPT PT-BREAK ABOVE 171 FT
PRESSURIZER PRESSURE
(Sheet 8 of 8)

Figure 6.2-18

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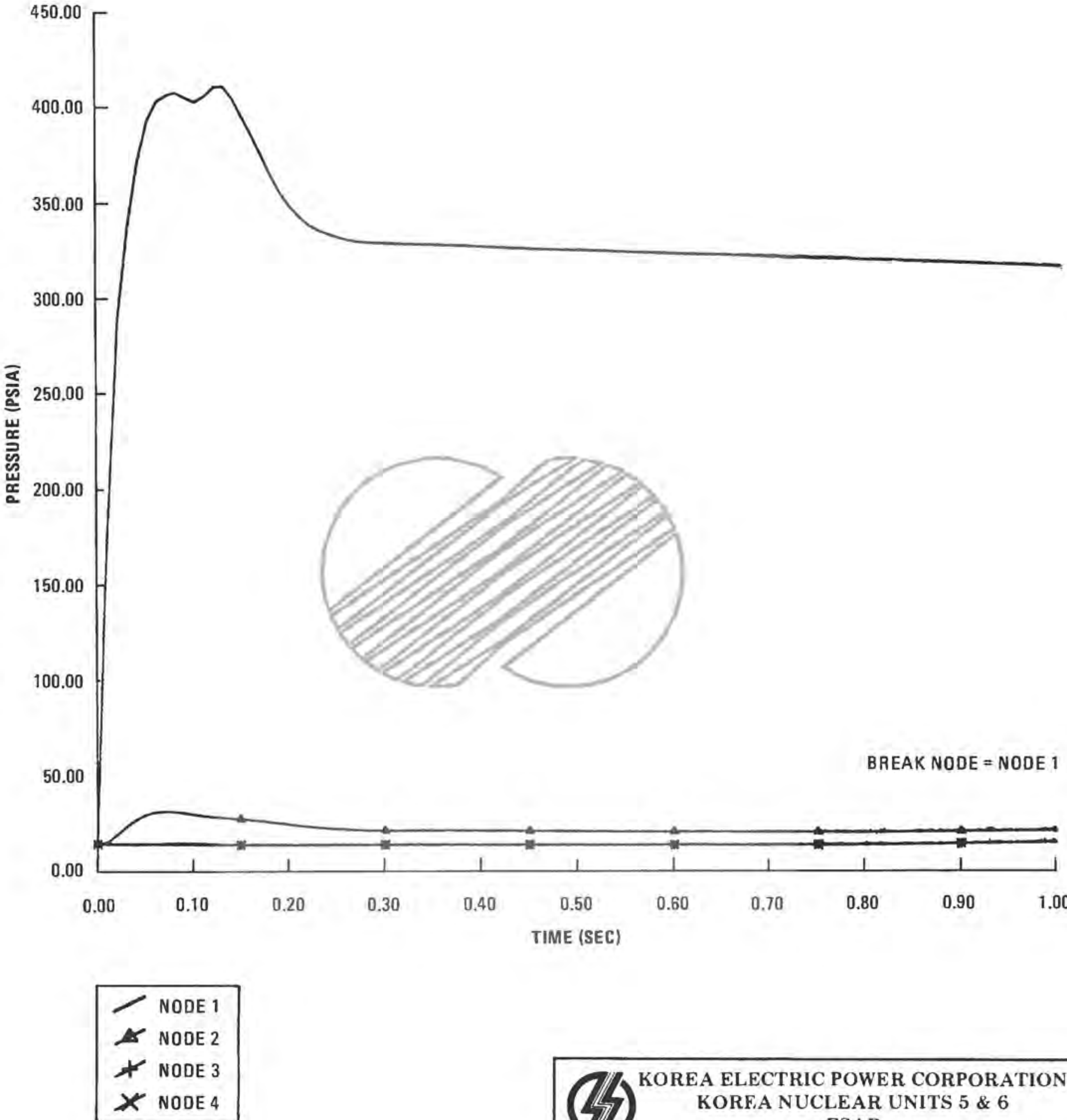

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PRESSURIZER SURGE LINE BREAK
PRESSURE VS. TIME
(Sheet 1 of 2)

Figure 6.2-19

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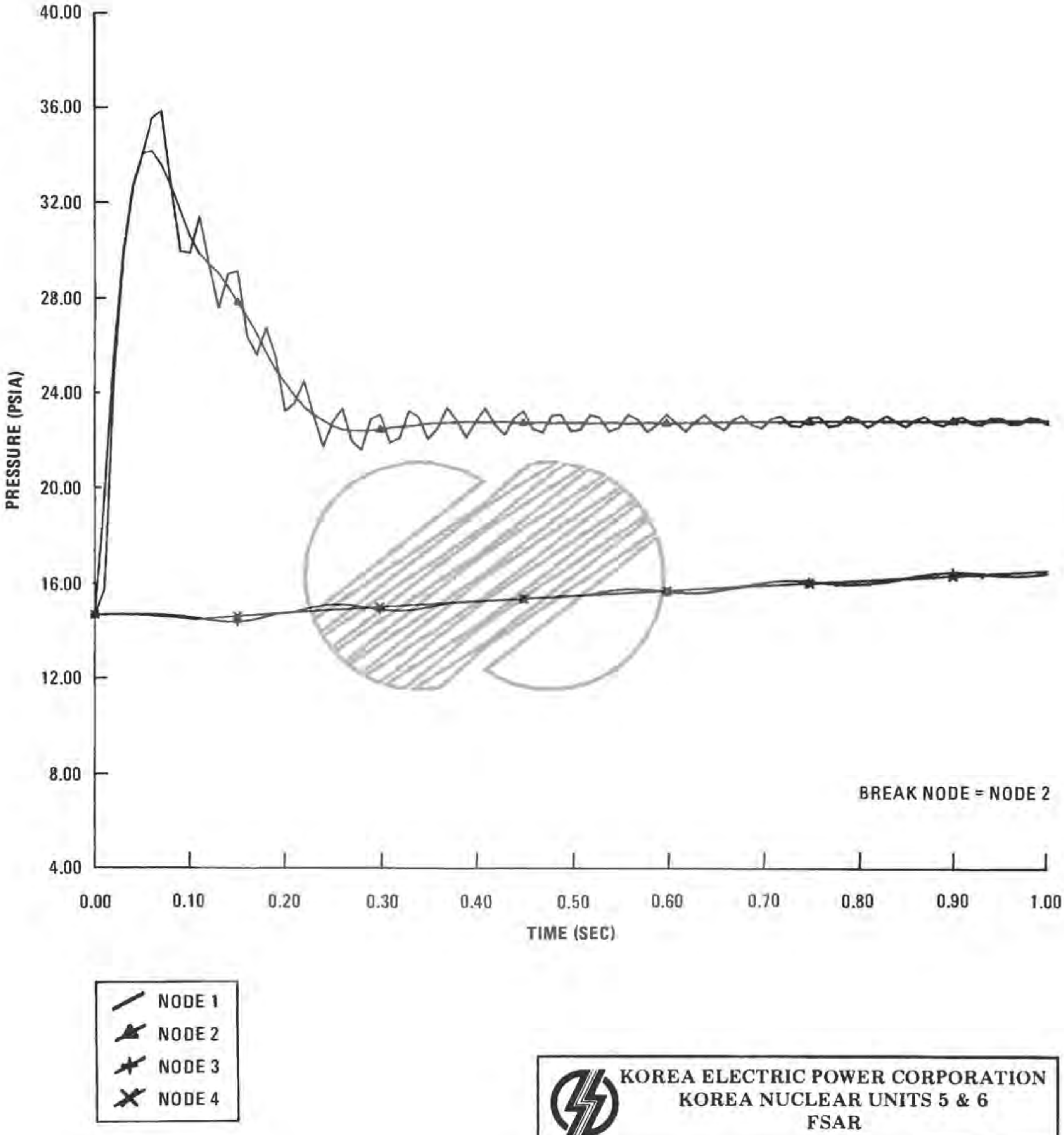

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PRESSURIZER SURGE LINE BREAK
PRESSURE VS. TIME
(Sheet 2 of 2)

Figure 6.2-19

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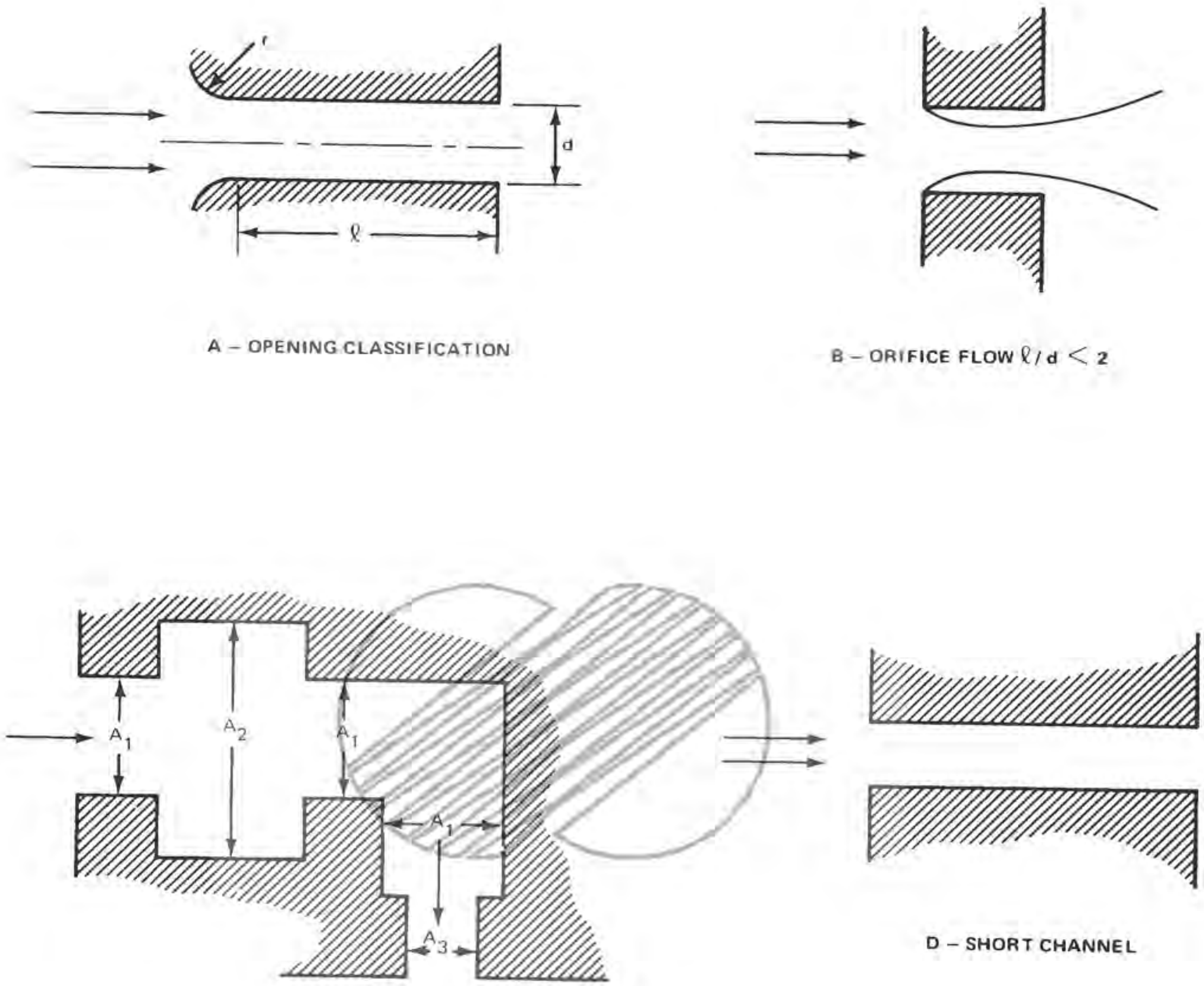

A – OPENING CLASSIFICATION

B – ORIFICE FLOW $\ell / d < 2$

C – AN OPENING HAVING GENERAL GEOMETRY

D – SHORT CHANNEL

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CLASSIFICATION OF OPENINGS

Figure 6.2-20

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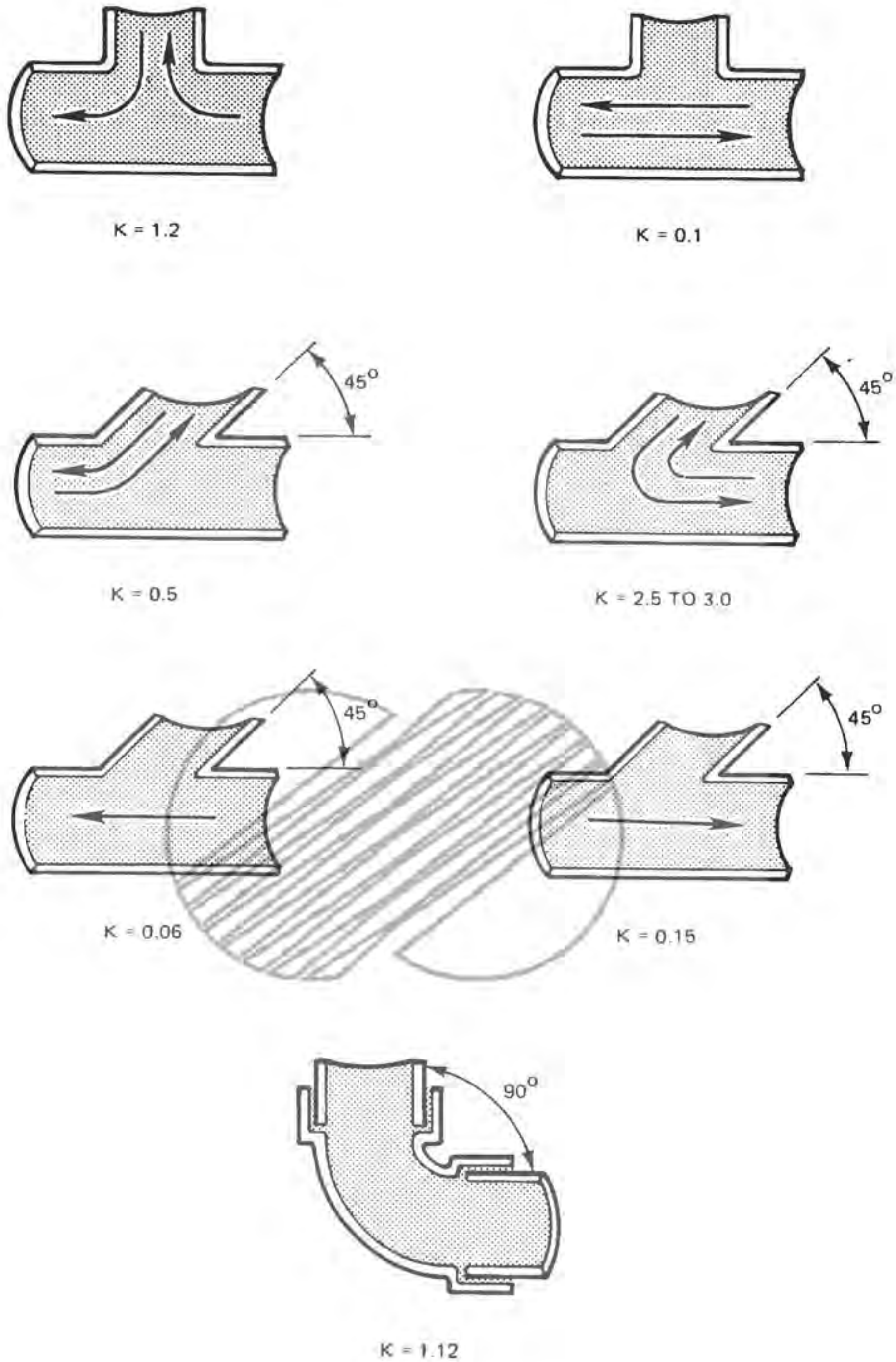

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HEAD LOSS COEFFICIENT DATA - CONDUIT BRANCHES IN TUBING (REFERENCE 12)

Figure 6.2-21

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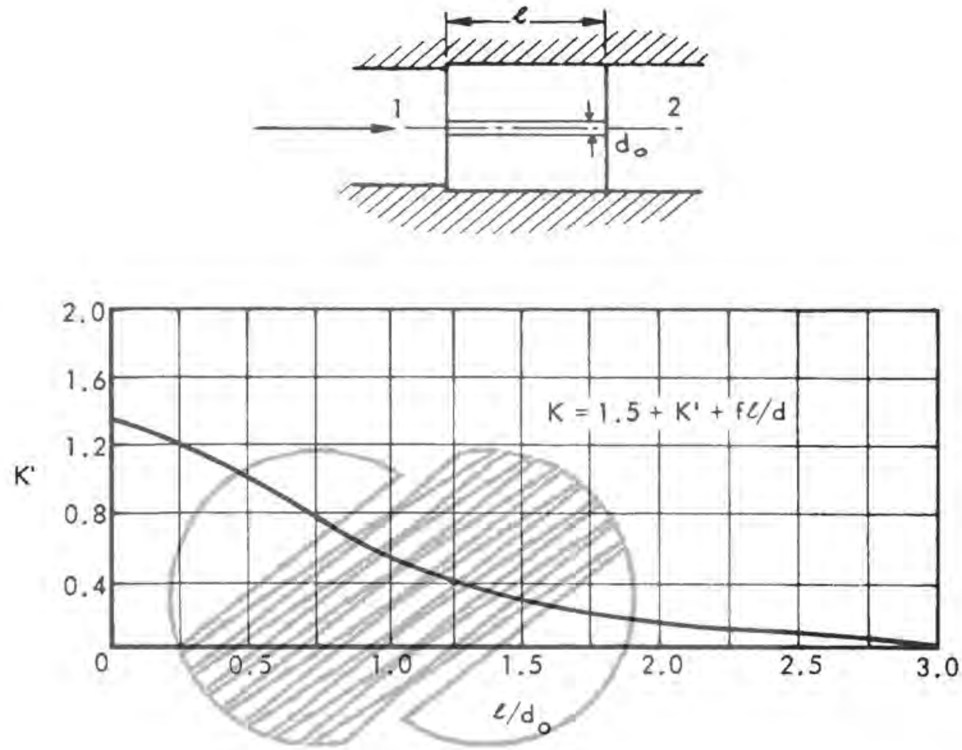

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HEAD LOSS COEFFICIENT DATA - LONG HOLES (REFERENCE 13)

Figure 6.2-22

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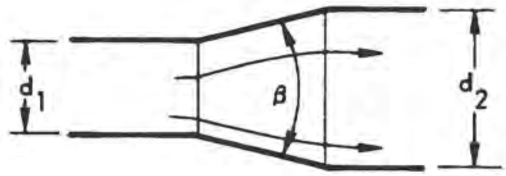

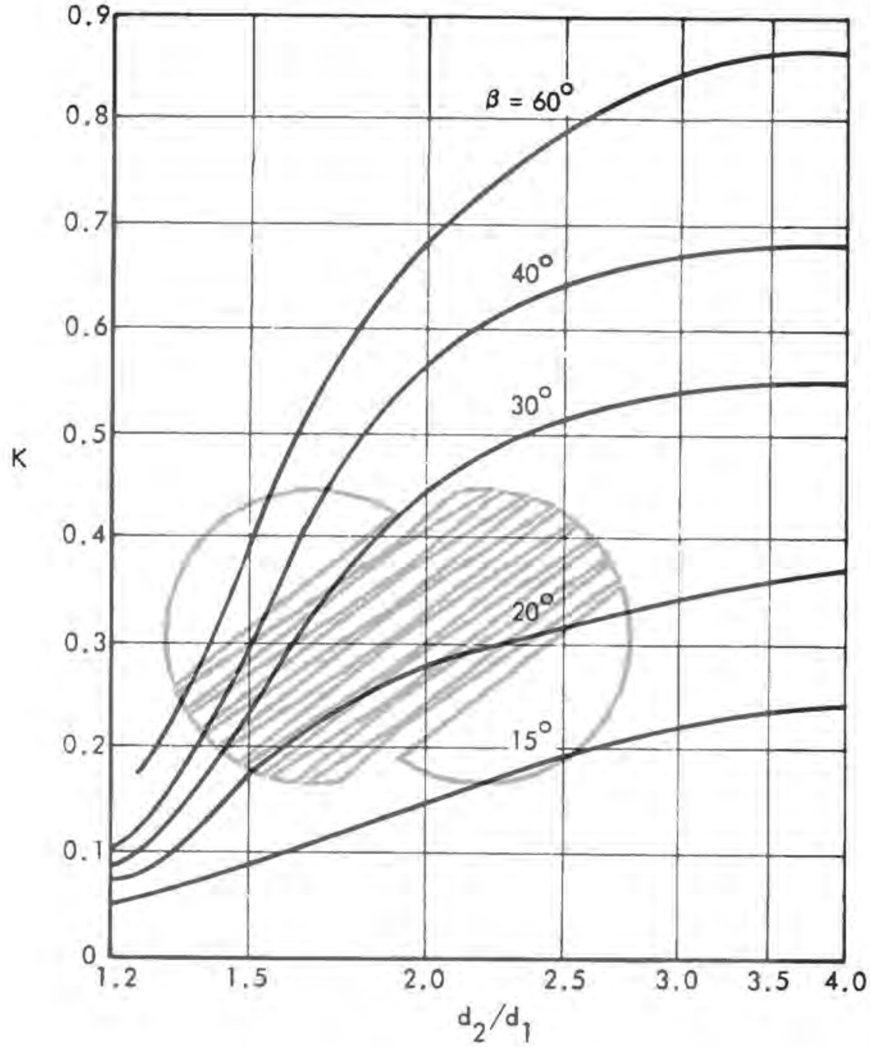

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HEAD LOSS COEFFICIENT DATA - GRADUAL CHANGES IN SECTION (REFERENCE 12)

Figure 6.2-23

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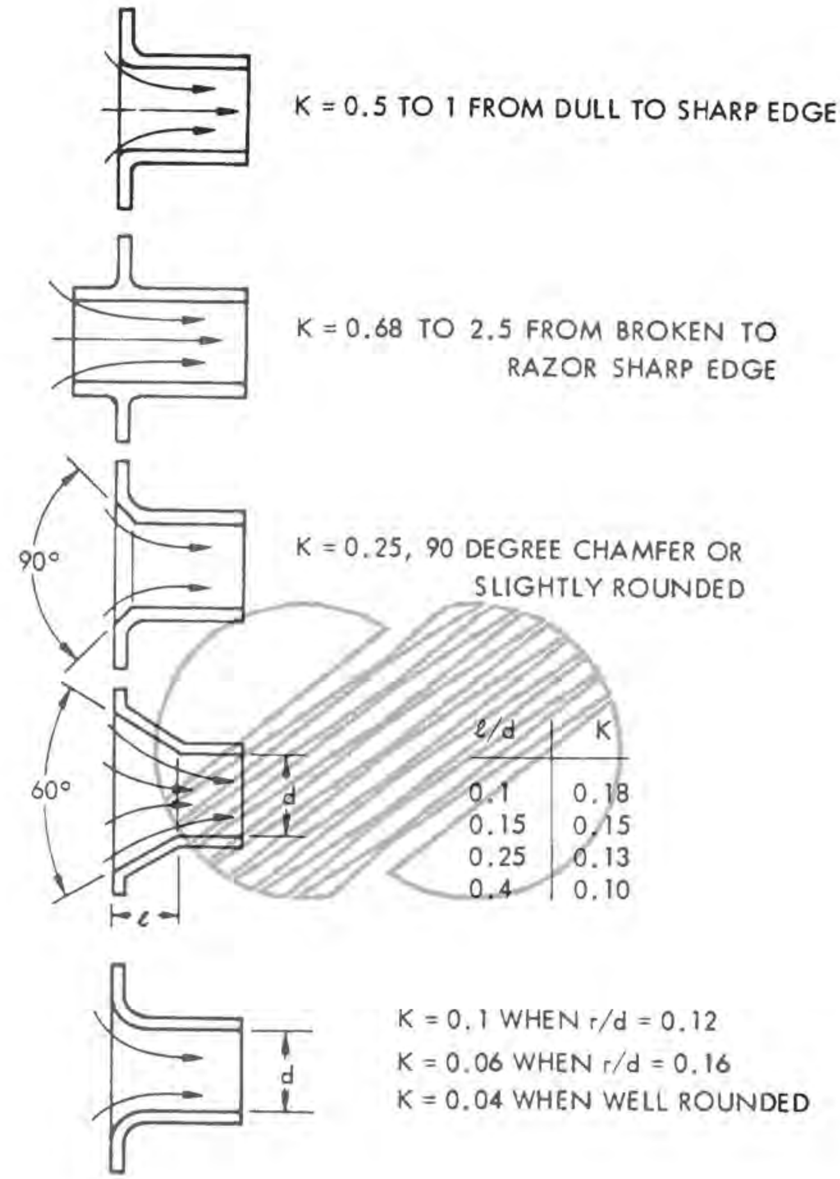

ℓ/d	K
0.1	0.18
0.15	0.15
0.25	0.13
0.4	0.10

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HEAD LOSS COEFFICIENT DATA - ENTRANCE LOSSES (REFERENCE 12)

Figure 6.2-24

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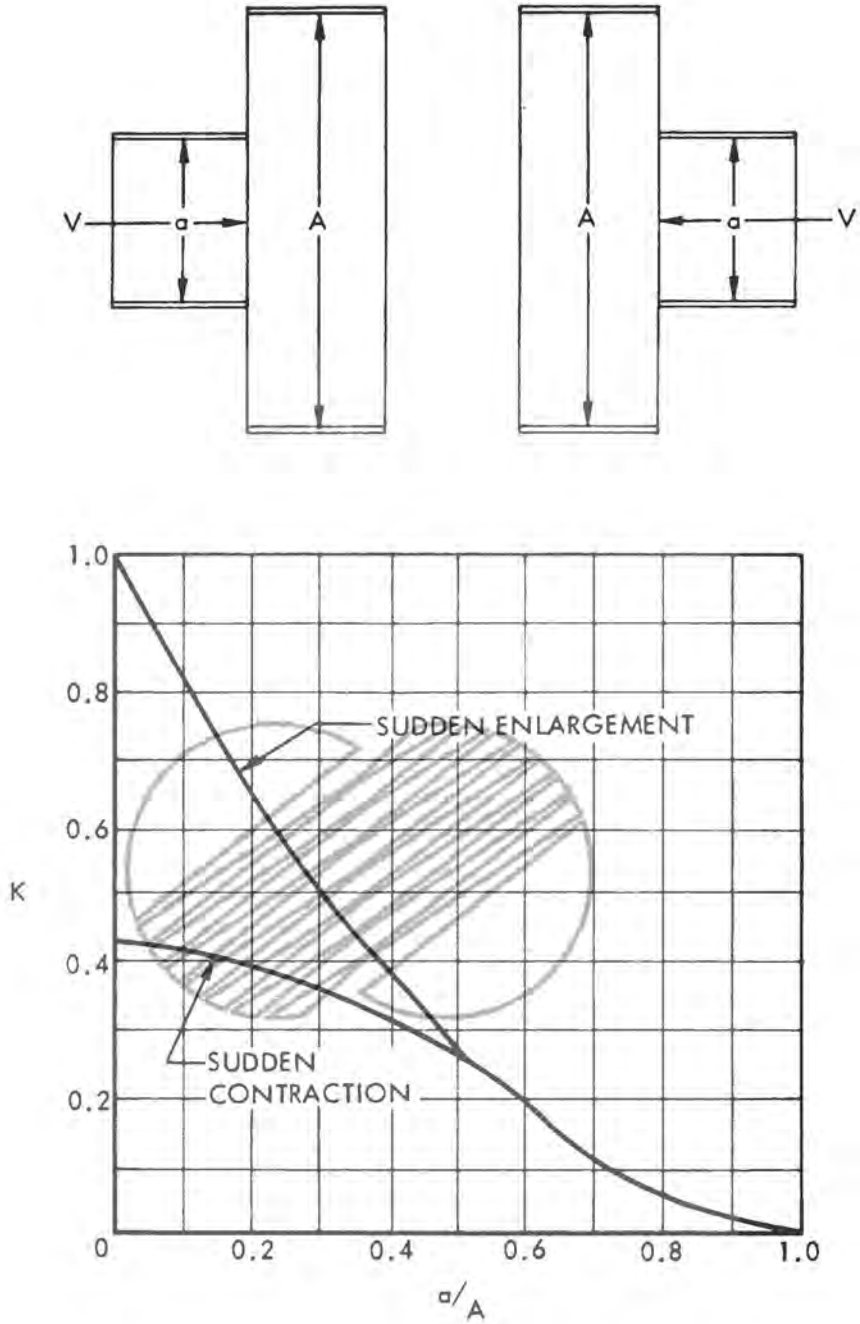

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HEAD LOSS COEFFICIENT DATA -
SUDDEN CHANGES IN SECTION
(REFERENCE 12)

Figure 6.2-25

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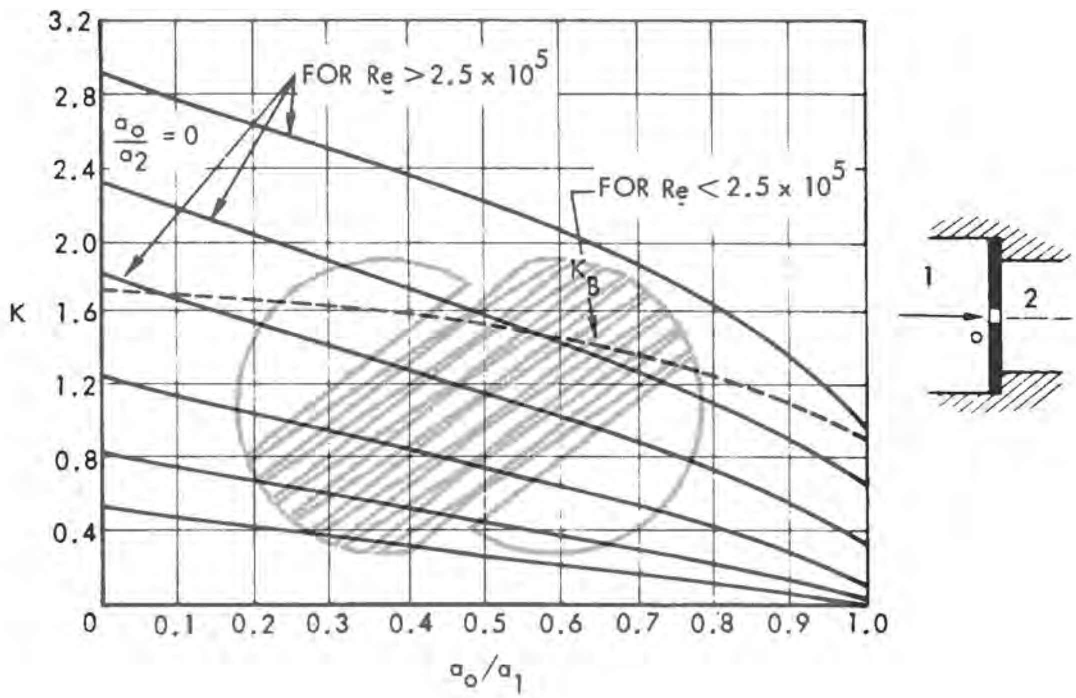

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HEAD LOSS COEFFICIENT DATA -
PIPE DIAMETER CHANGES,
ORIFICE (REFERENCE 13)

Figure 6.2-26

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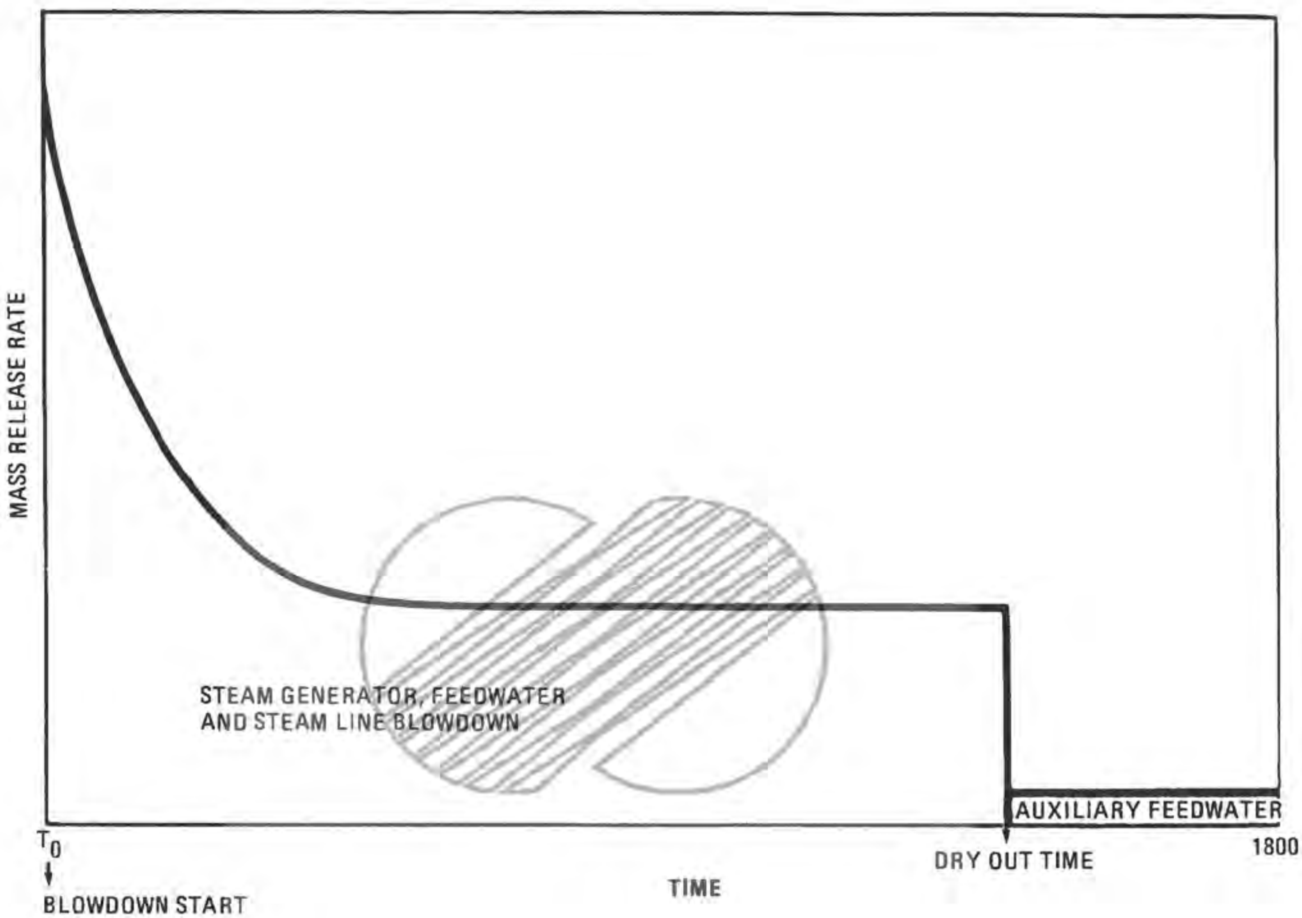

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MASS RELEASE VS TIME
FOR A MAIN STEAM LINE
RUPTURE INSIDE THE CONTAINMENT

Figure 6.2-39

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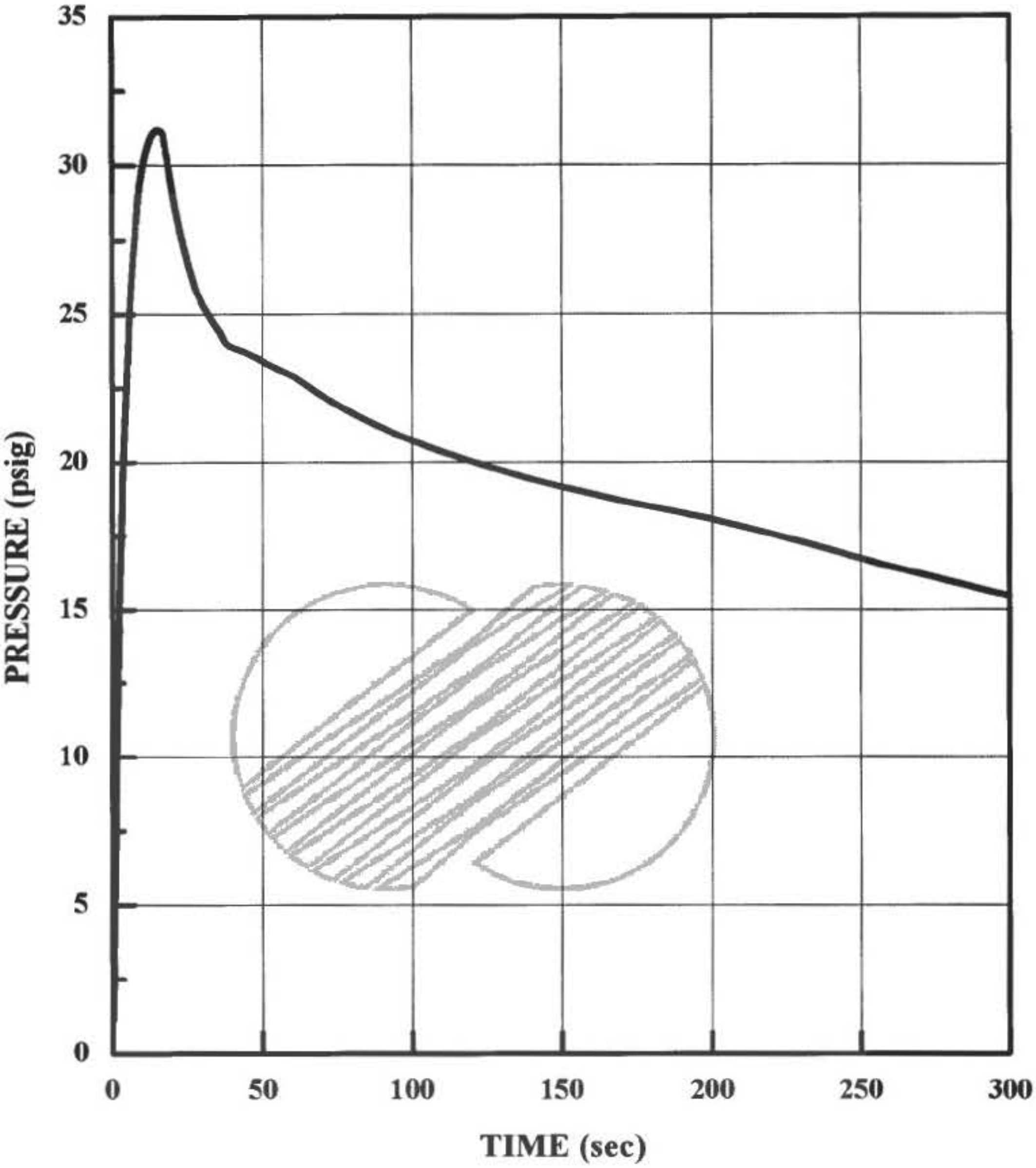

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KORI UNITS 3 & 4 FSAR

CONTAINMENT BACKPRESSURE
LIMITING ANALYSIS (100% DECLG)
Figure 6.2-40

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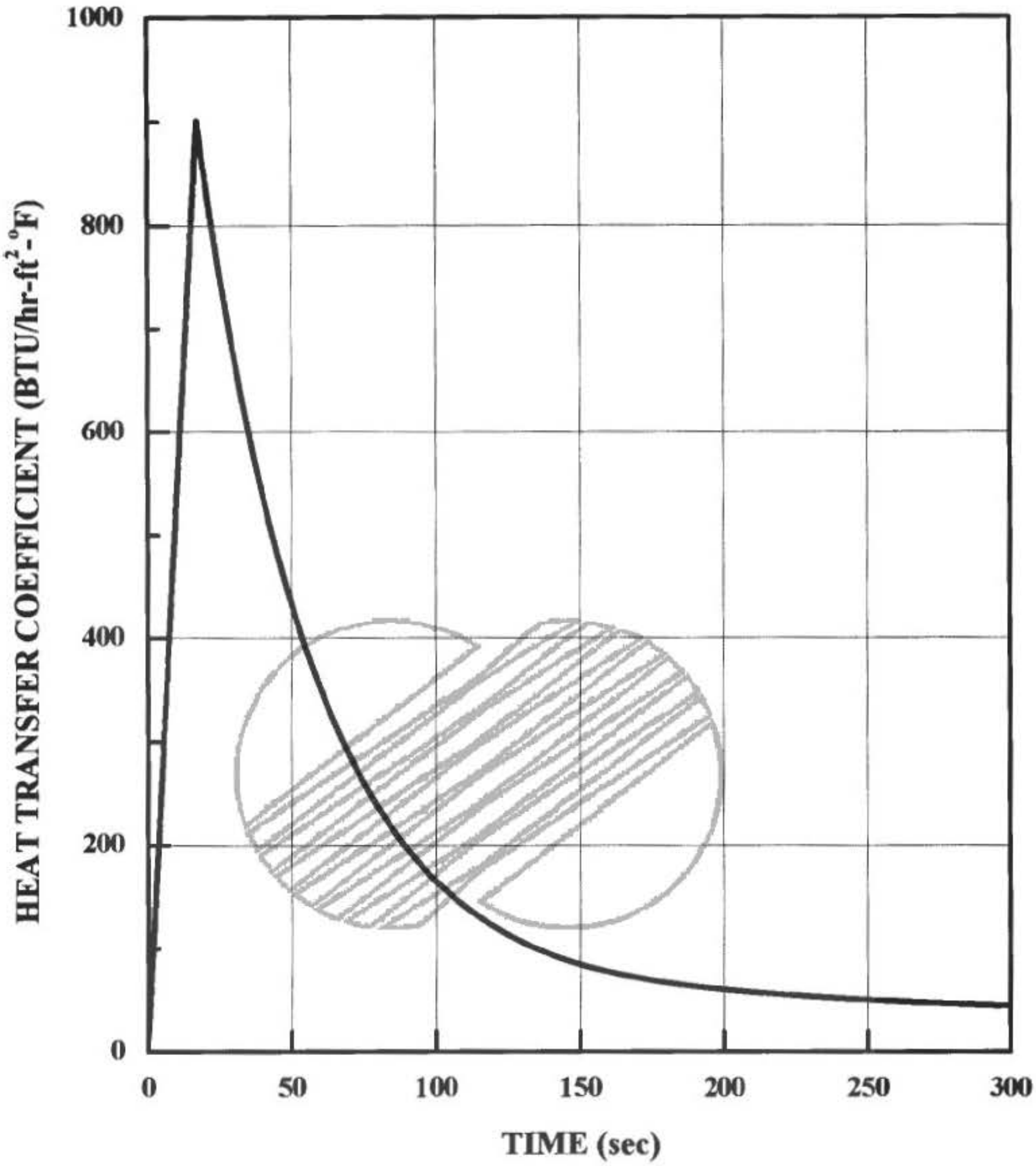

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HEAT TRANSFER COEFFICIENT FOR
HEAT TRANSFER TO CONTAINMENT
Figure 6.2-41

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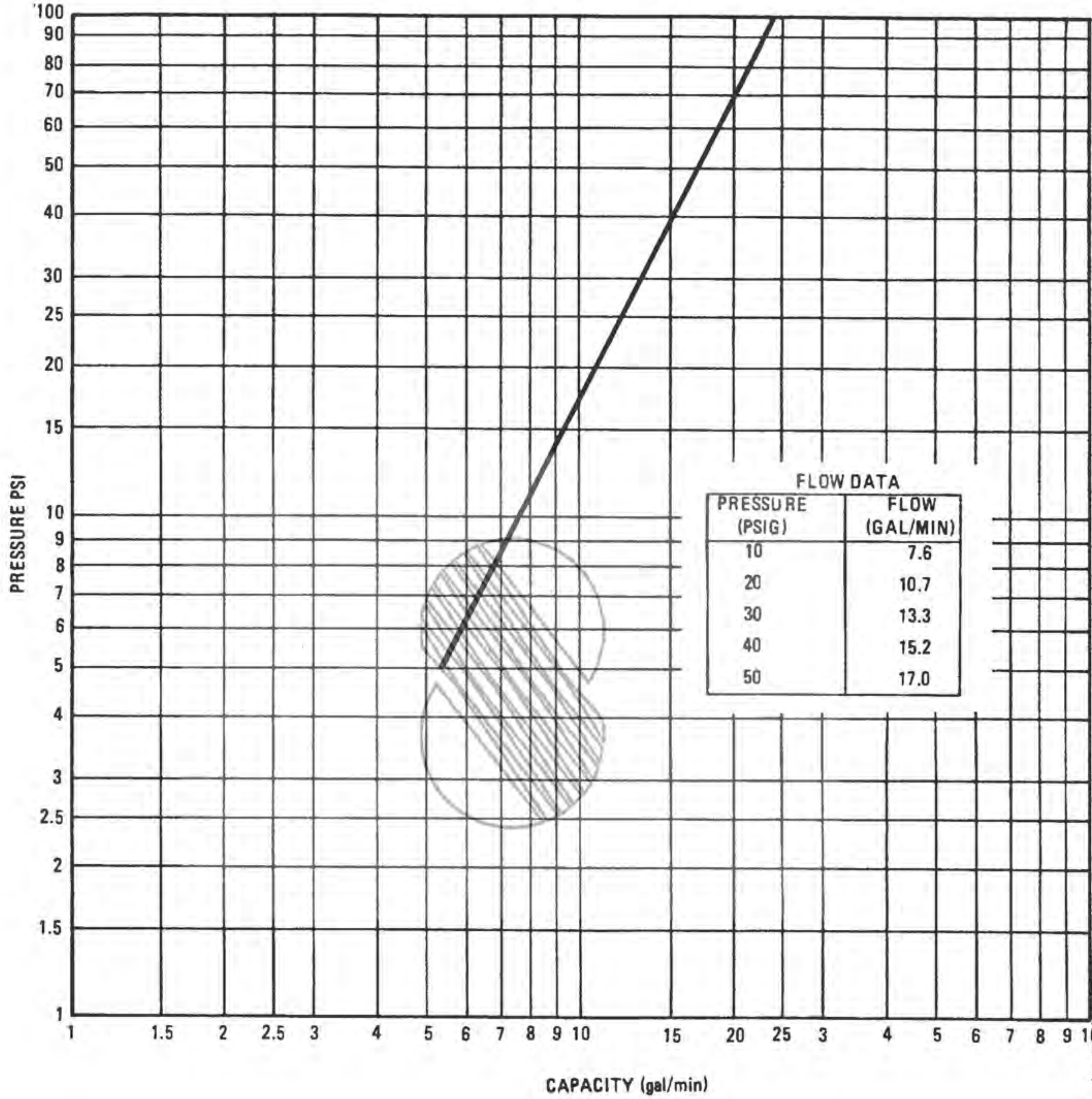

FLOW DATA

PRESSURE (PSIG)	FLOW (GAL/MIN)
10	7.6
20	10.7
30	13.3
40	15.2
50	17.0

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CONTAINMENT SPRAY
NOZZLE CAPACITY CURVE

Figure 6.2-43

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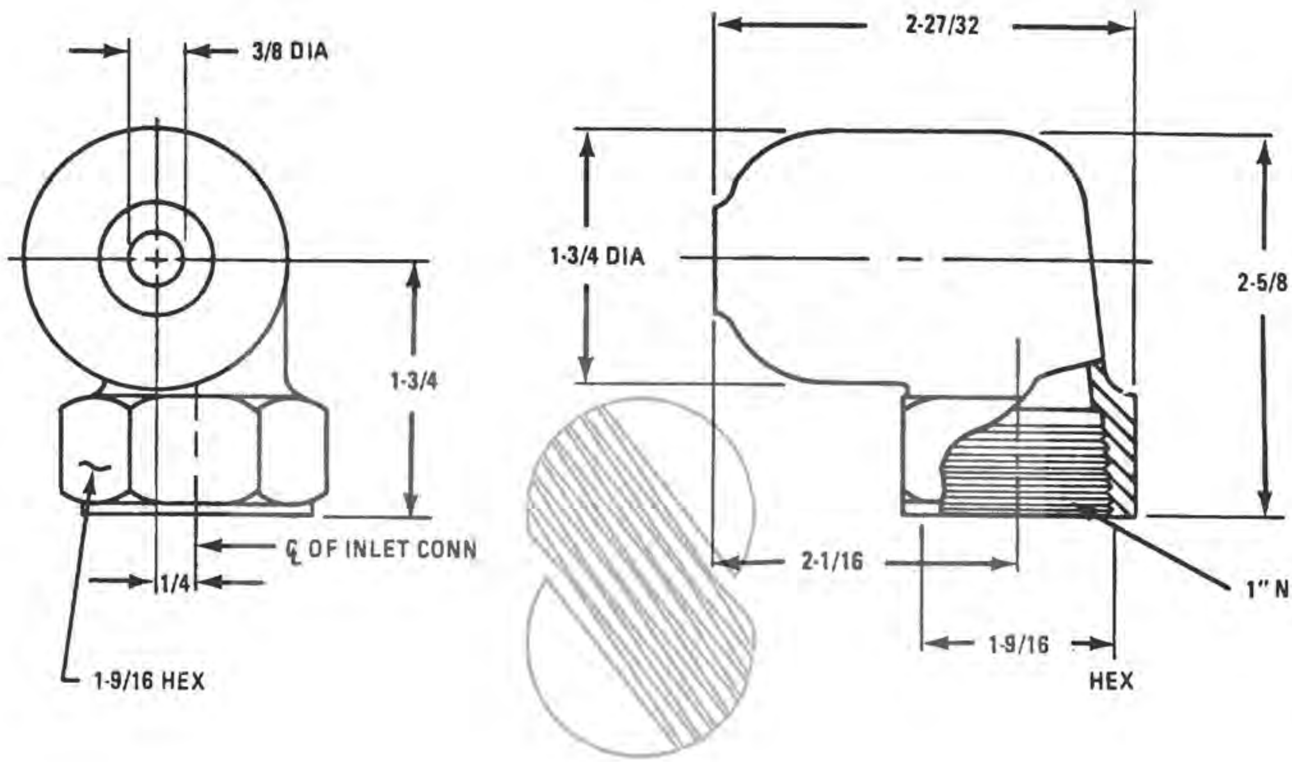

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CONTAINMENT SPRAY NOZZLE
(1713A NOZZLE)

Figure 6.2-44

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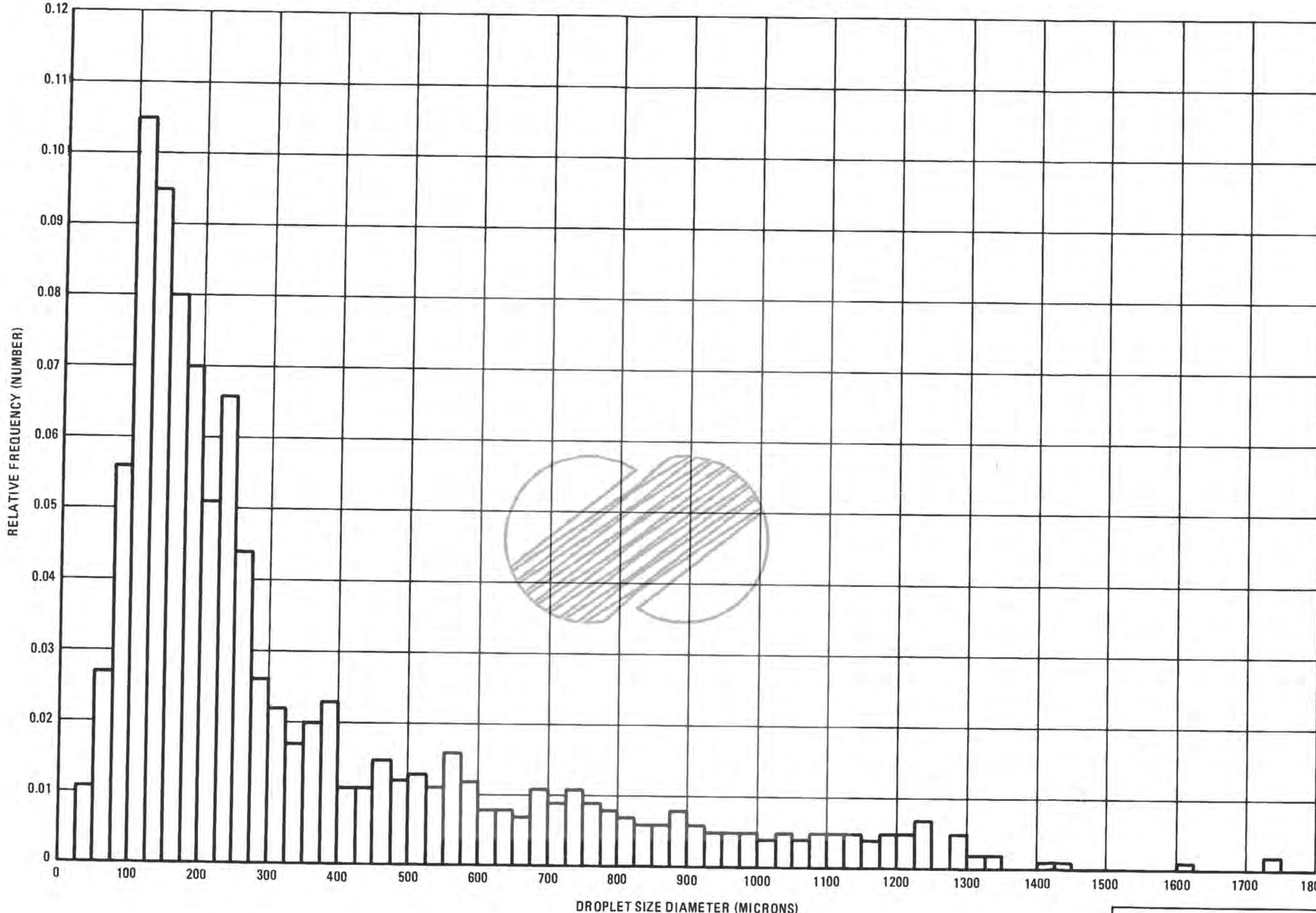

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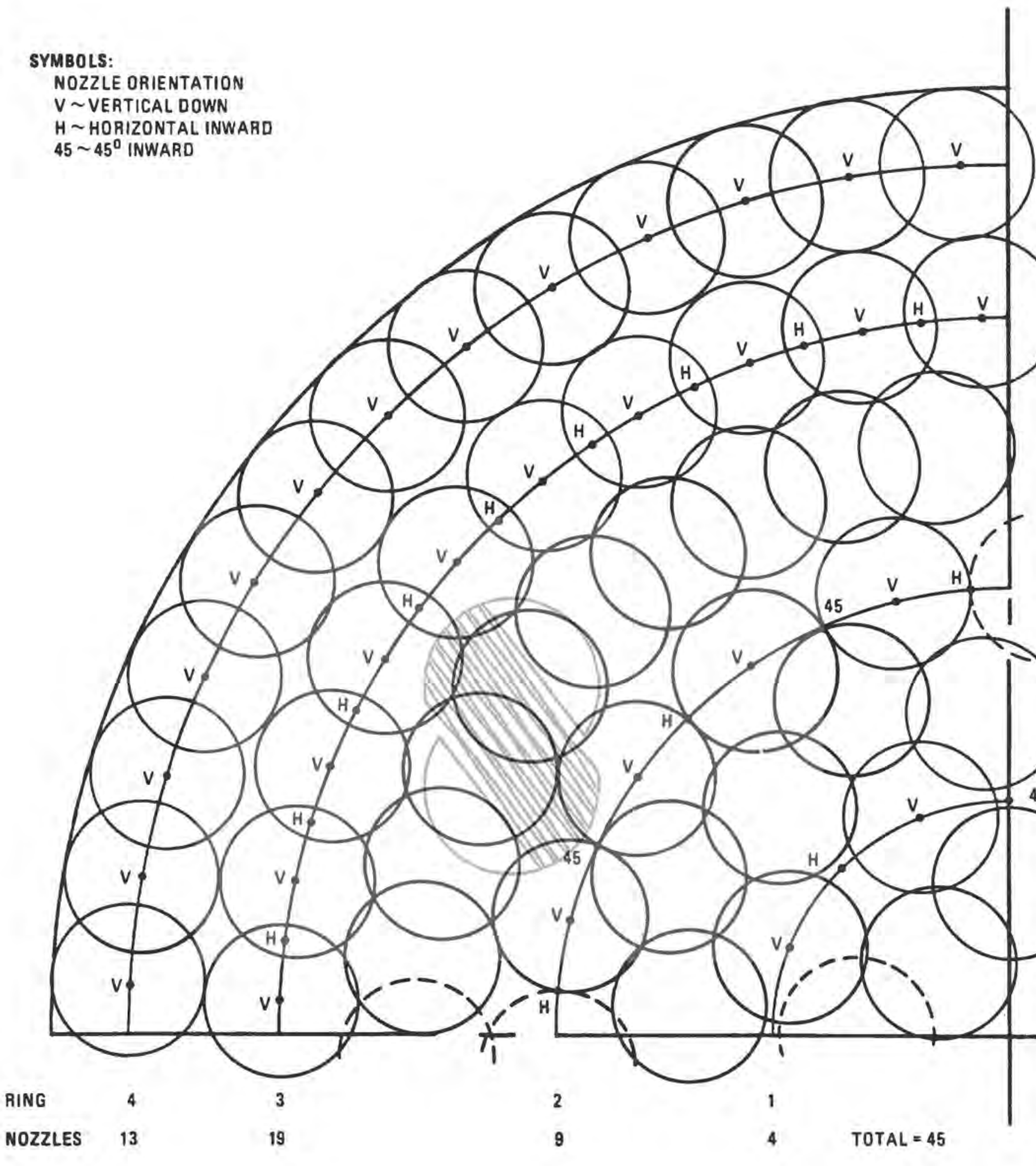
MEAN DROPLET
SIZE DISTRIBUTION

Figure 6.2-45



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CONTAINMENT SPRAY
COVERAGE PATTERN
AT OPERATING FLOOR

Figure 6.2-46

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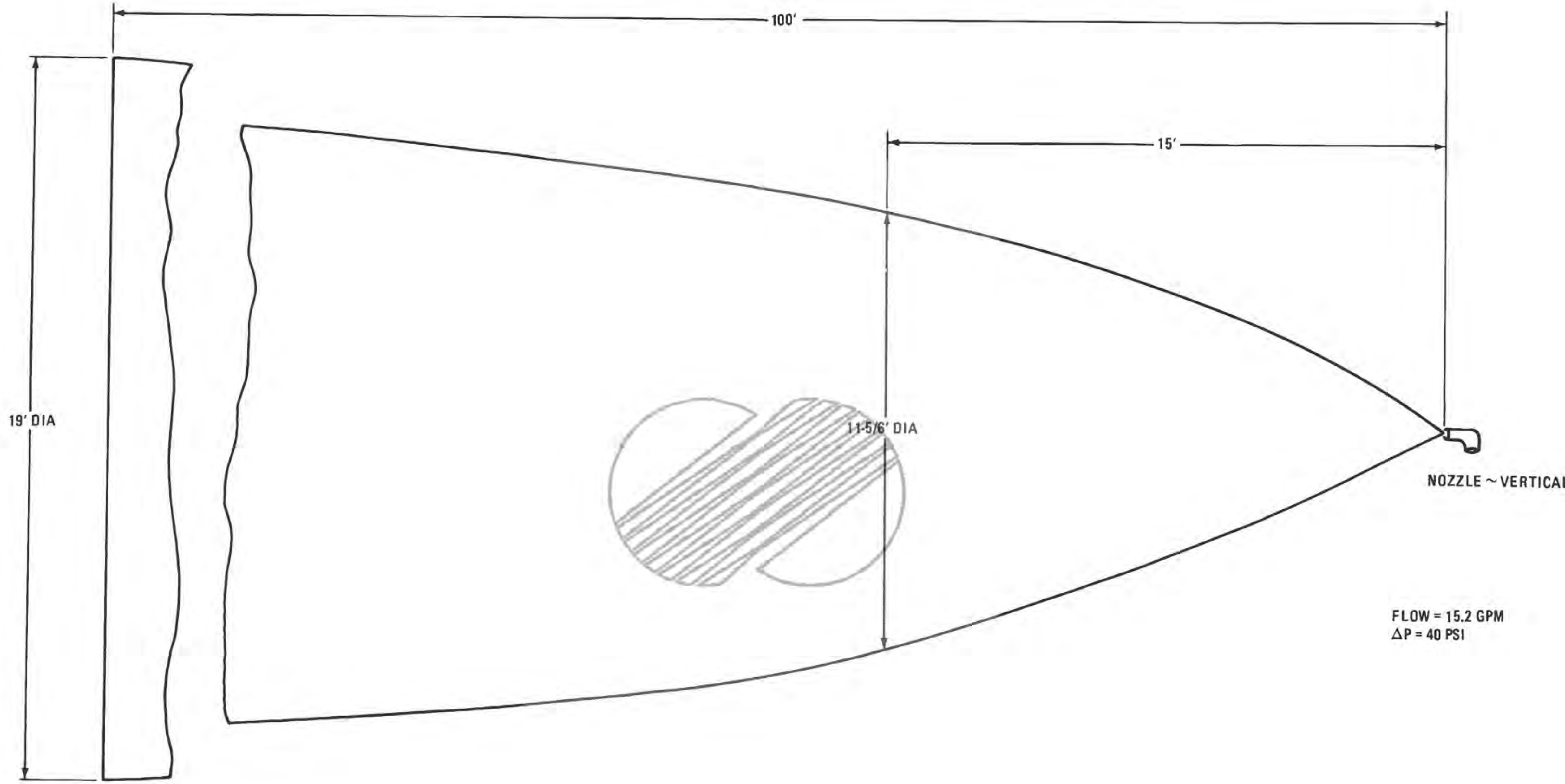

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NOZZLE SPRAY
PATTERN (VERTICAL)

Figure 6.2-49

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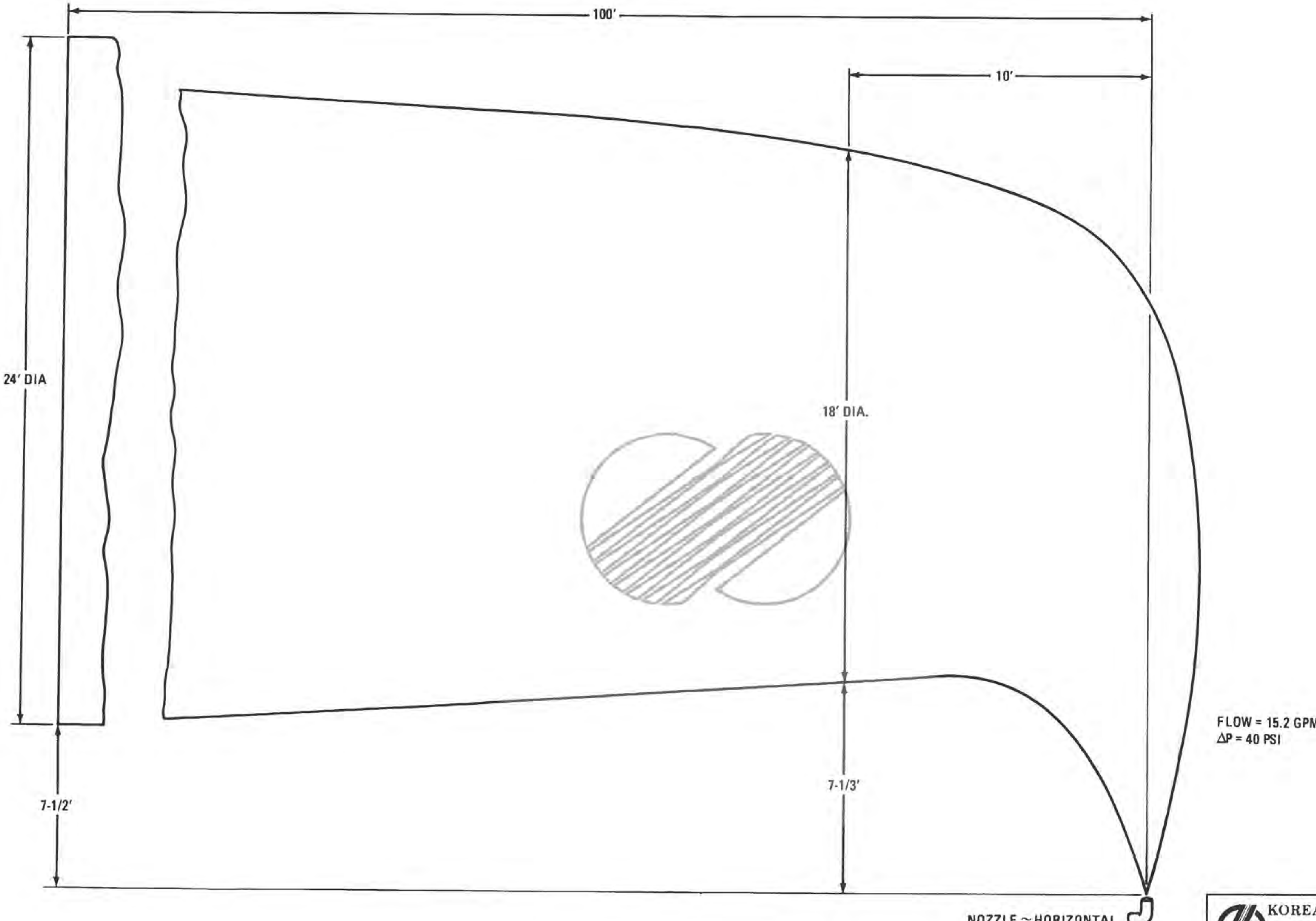

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NOZZLE SPRAY
PATTERN (HORIZONTAL)

Figure 6.2-50

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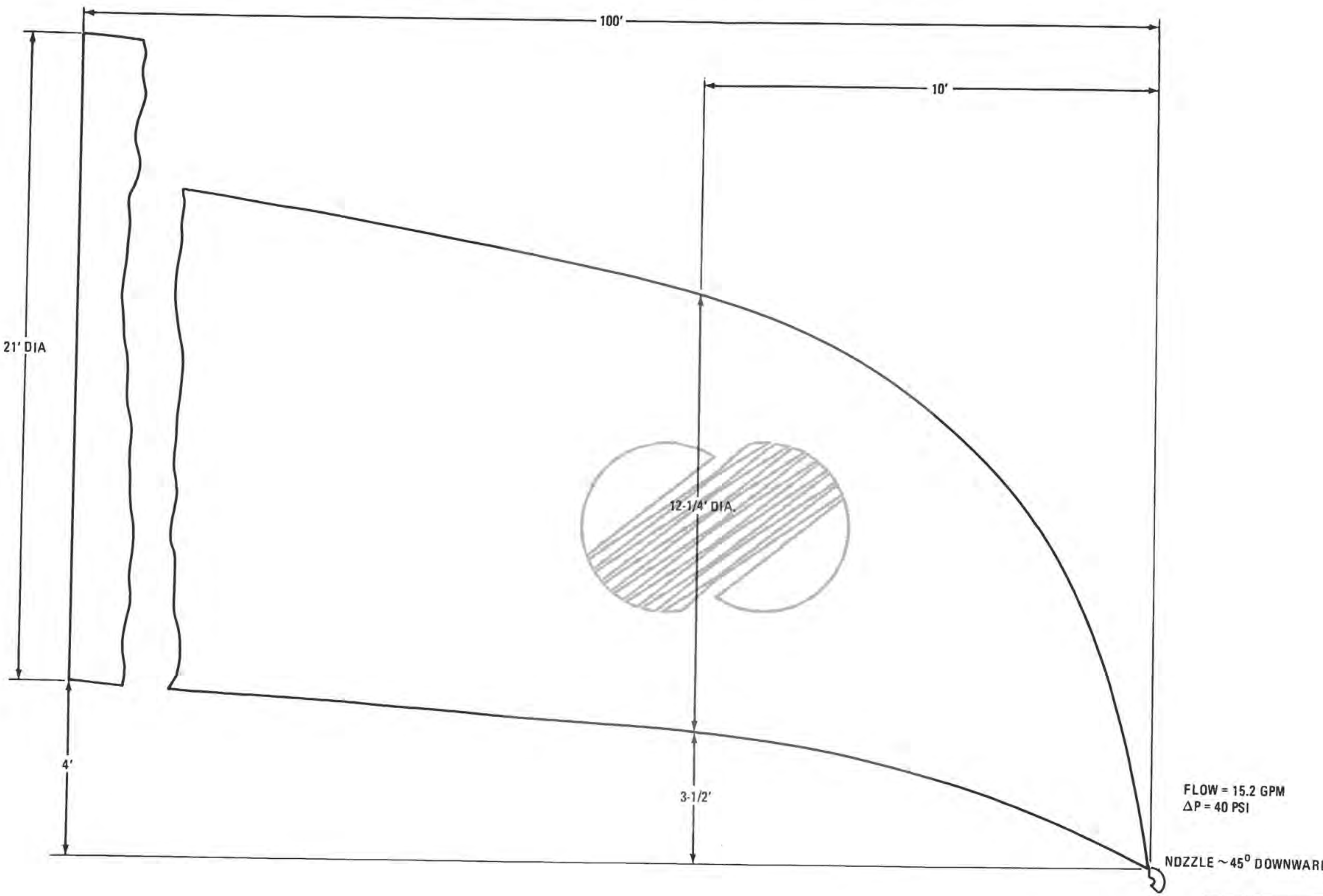

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NOZZLE SPRAY
PATTERN (DOWNWARD)

Figure 6.2-51

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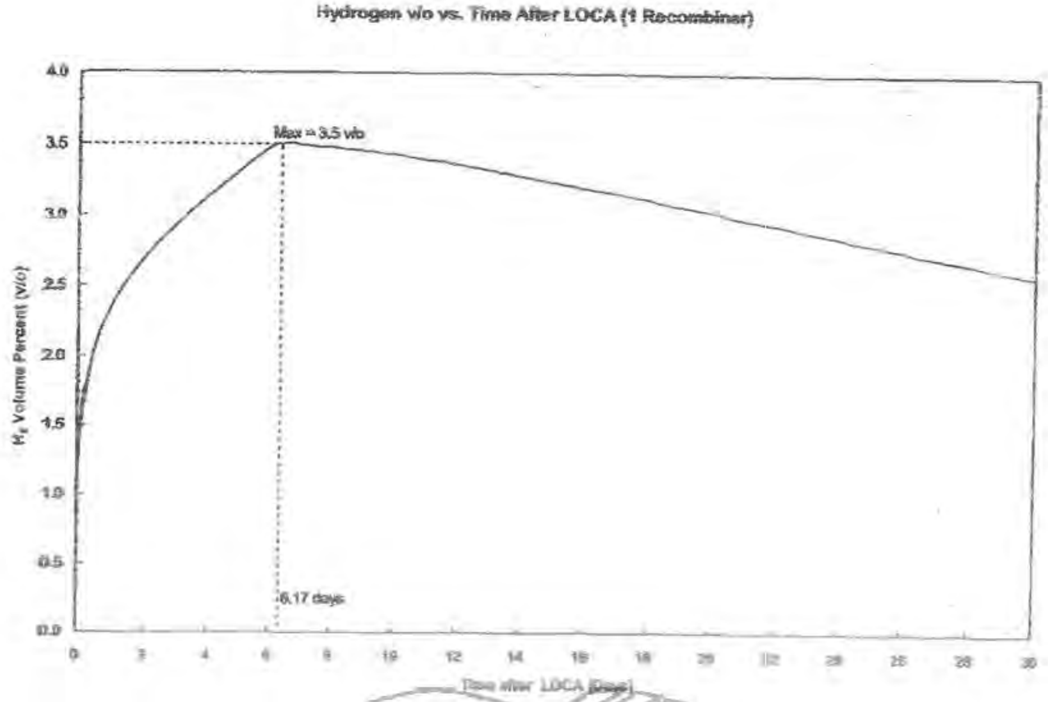

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KOREA HYDRO & NUCLEAR POWER COMPANY
KRN 3 & 4 FSAR

HYDROGEN V/O VS TIME
AFTER LOCA-POWER UPRATE (1 RECOMBINER)
(Sheet 1 of 3)

Figure 6.2-55

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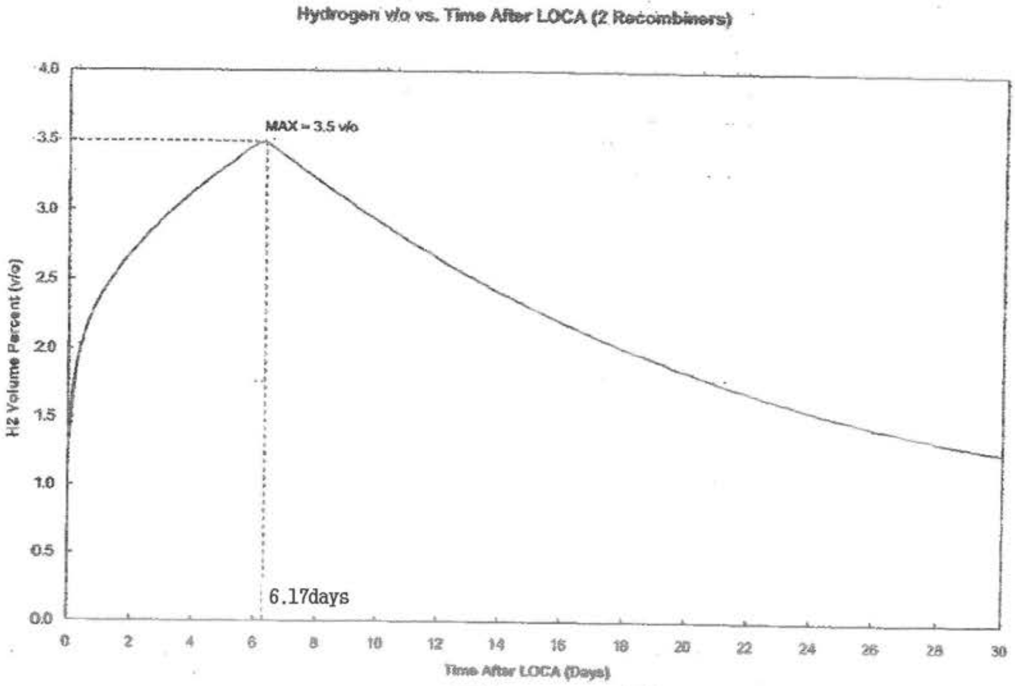

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KRN 3 & 4 FSAR

HYDROGEN V/O VS TIME
AFTER LOCA-POWER UPRATE (2 RECOMBINERS)
(Sheet 2 of 3)

Figure 6.2-55

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Amendment 469
2012. 10. 29

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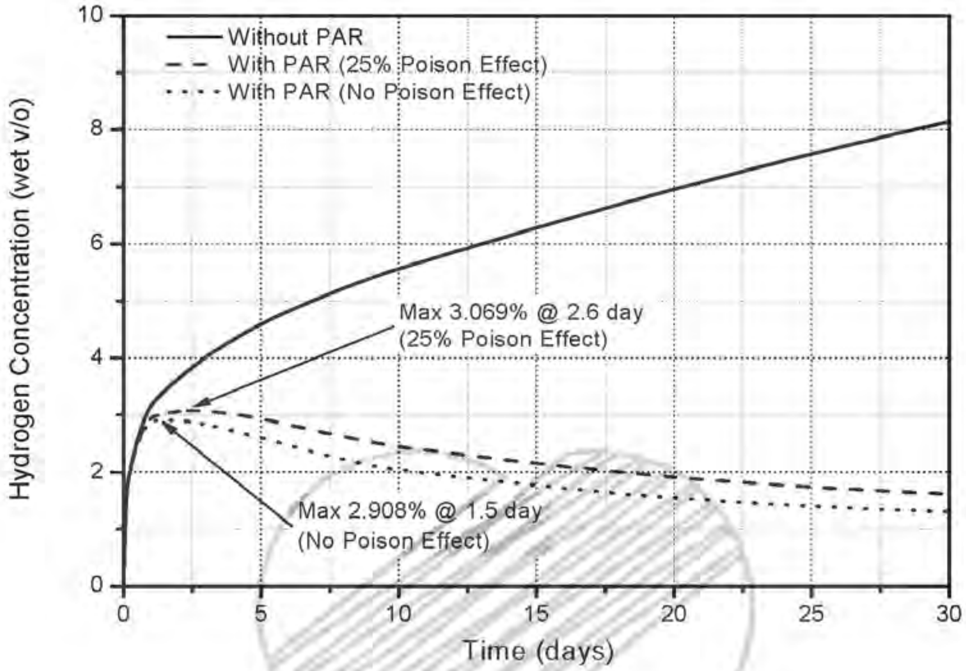

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HYDROGEN V/O VS TIME
AFTER LOCA (1 PAR)
(Sheet 3 of 3)
Figure 6.2-55

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Amendment 475
2013. 02. 08

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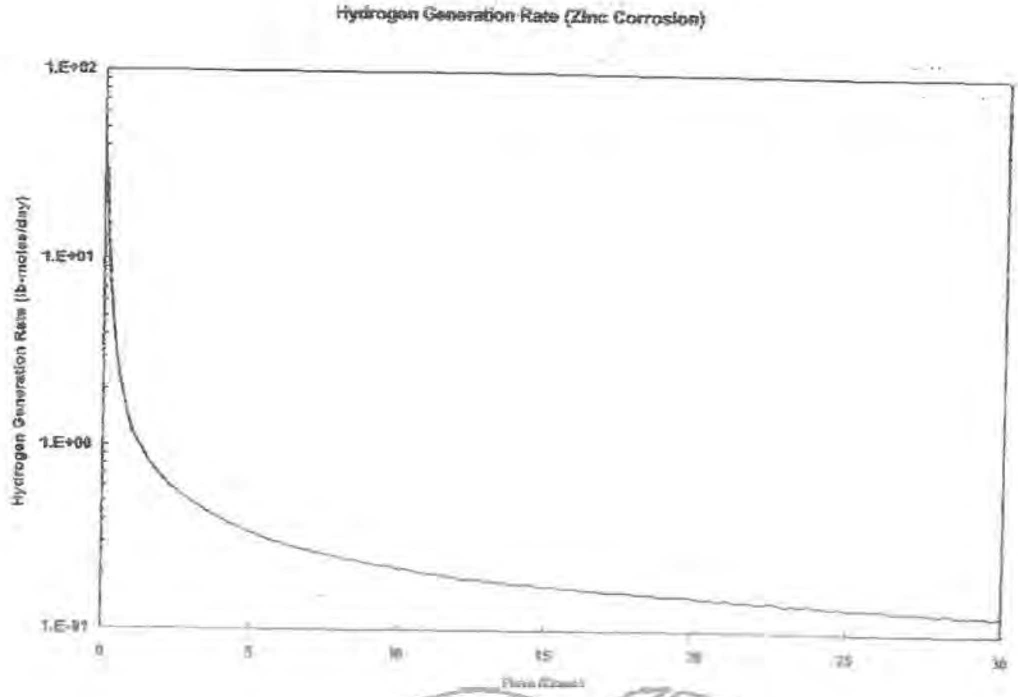

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HYDROGEN GENERATOR RATE-POWER UPRATE
(FROM ZINC CORROSION)
(Sheet 1 of 5)

Figure 6.2-56

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2012. 10. 29

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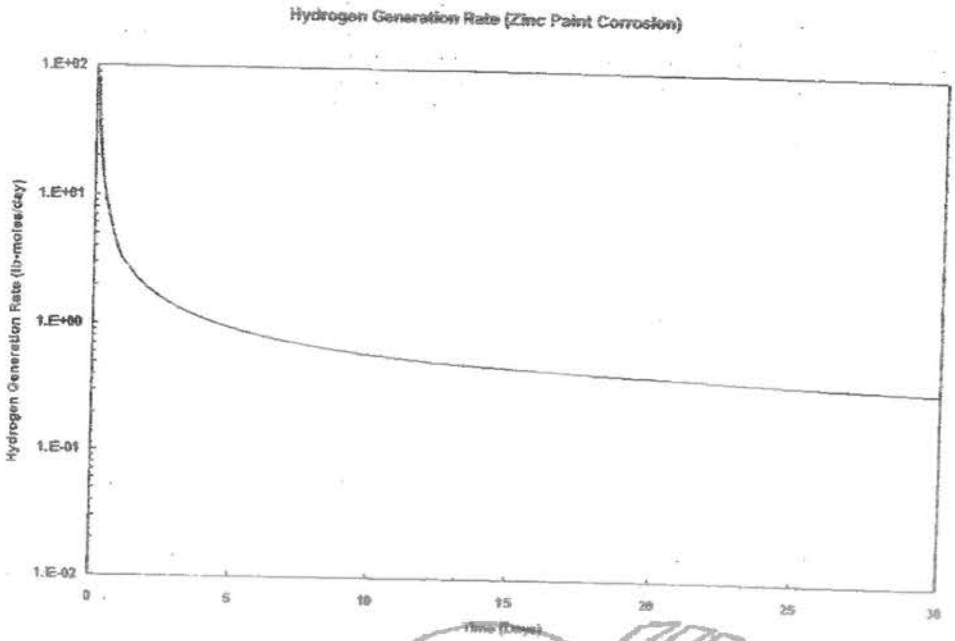

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KRN 3 & 4 FSAR

HYDROGEN GENERATOR RATE-POWER UPRATE
(FROM ZINC PAINT CORROSION)
(Sheet 2 of 5)

Figure 6.2-56

Amendment 469
2012. 10. 29

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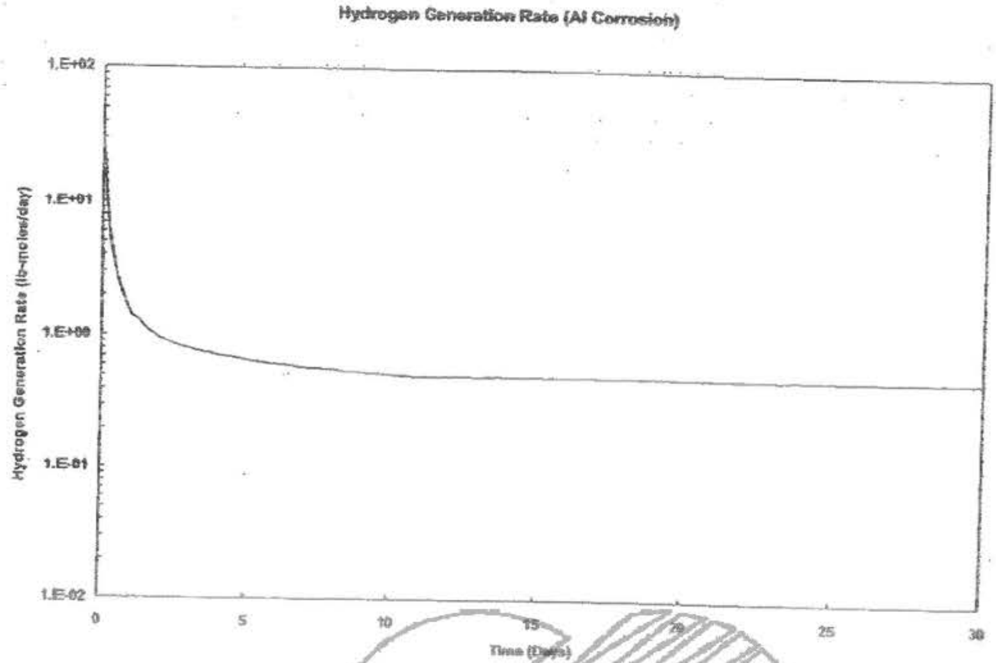

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KRN 3 & 4 FSAR

HYDROGEN GENERATOR RATE-POWER UPRATE
(FROM ALUMINUM CORROSION)
(Sheet 3 of 5)

Figure 6.2-56

Amendment 469
2012. 10. 29

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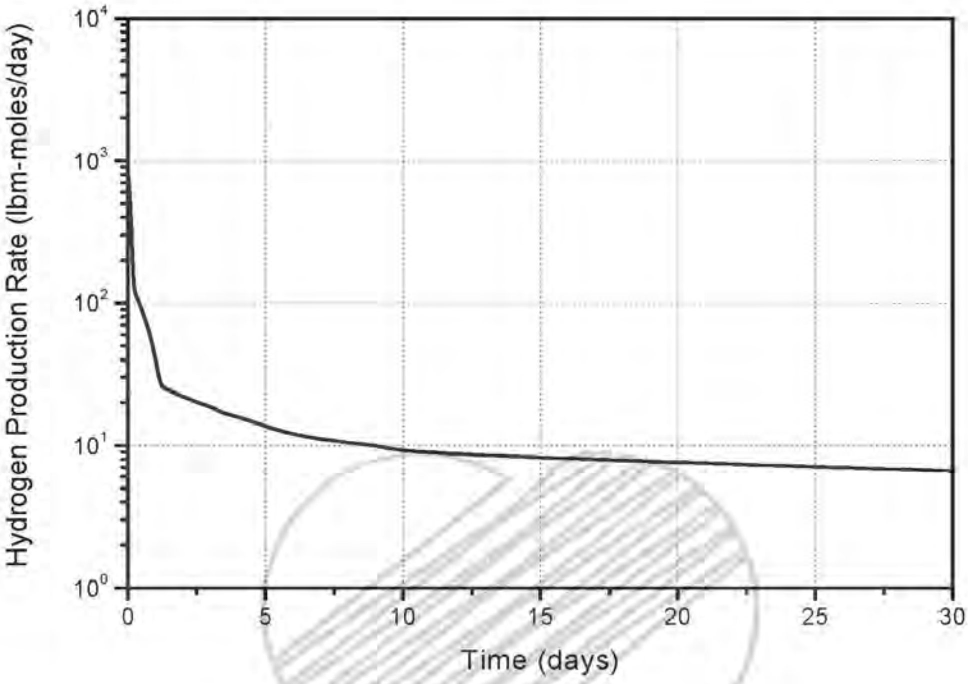

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KOREA HYDRO & NUCLEAR POWER COMPANY
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HYDROGEN PRODUCTION RATE
(FROM ZINC CORROSION)
(Sheet 4 of 5)
Figure 6.2-56

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Amendment 475
2013. 02. 08

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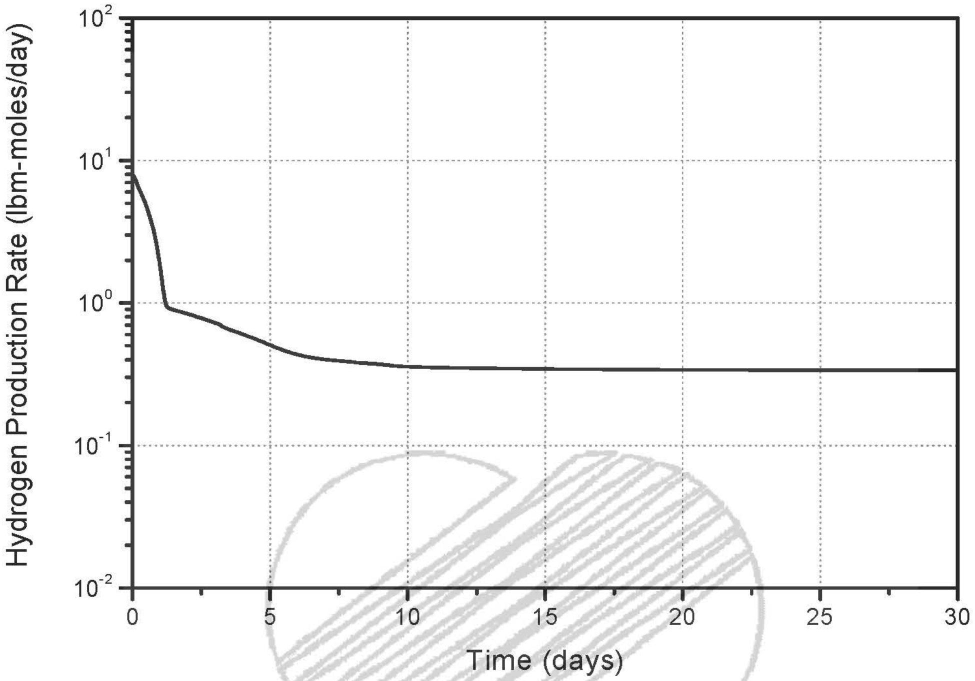

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KOREA HYDRO & NUCLEAR POWER COMPANY
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HYDROGEN PRODUCTION RATE
(FROM ALUMINUM CORROSION)
(Sheet 5 of 5)
Figure 6.2-56

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Amendment 475
2013. 02. 08

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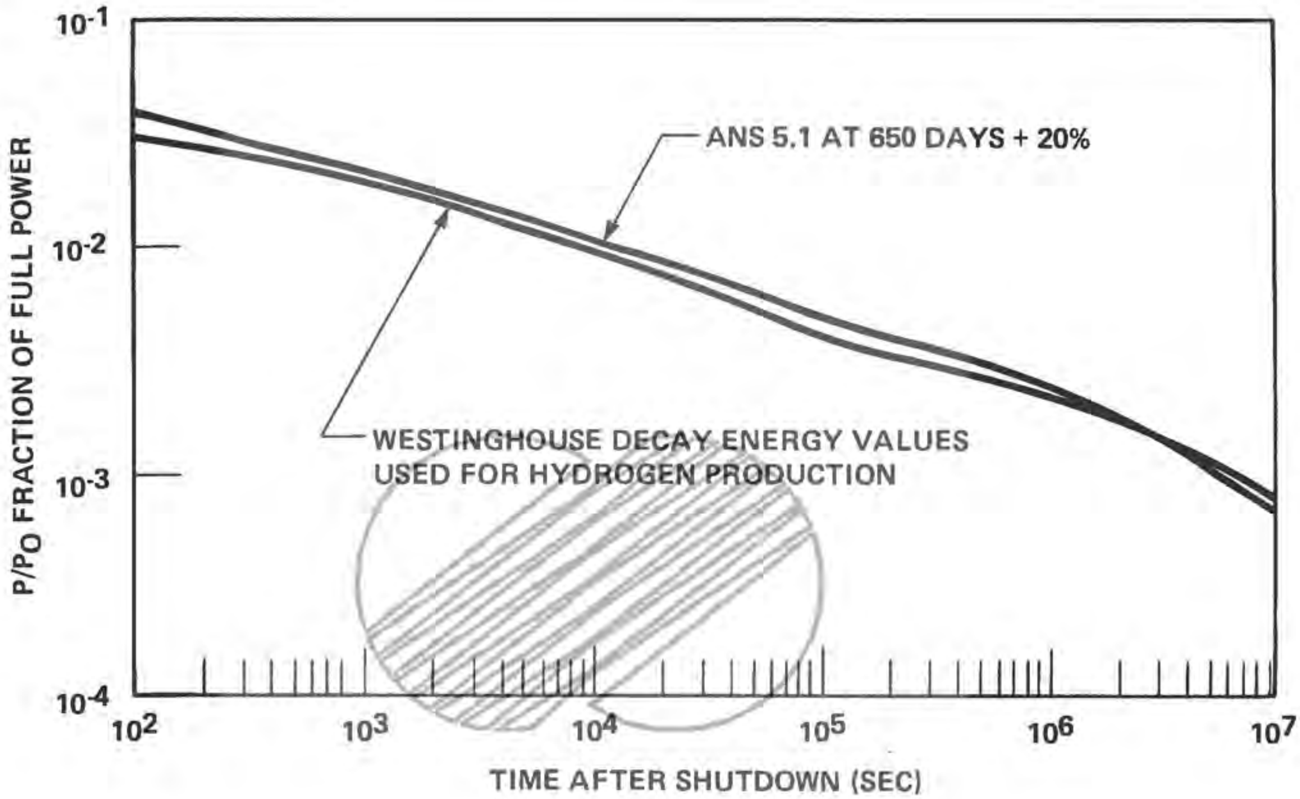
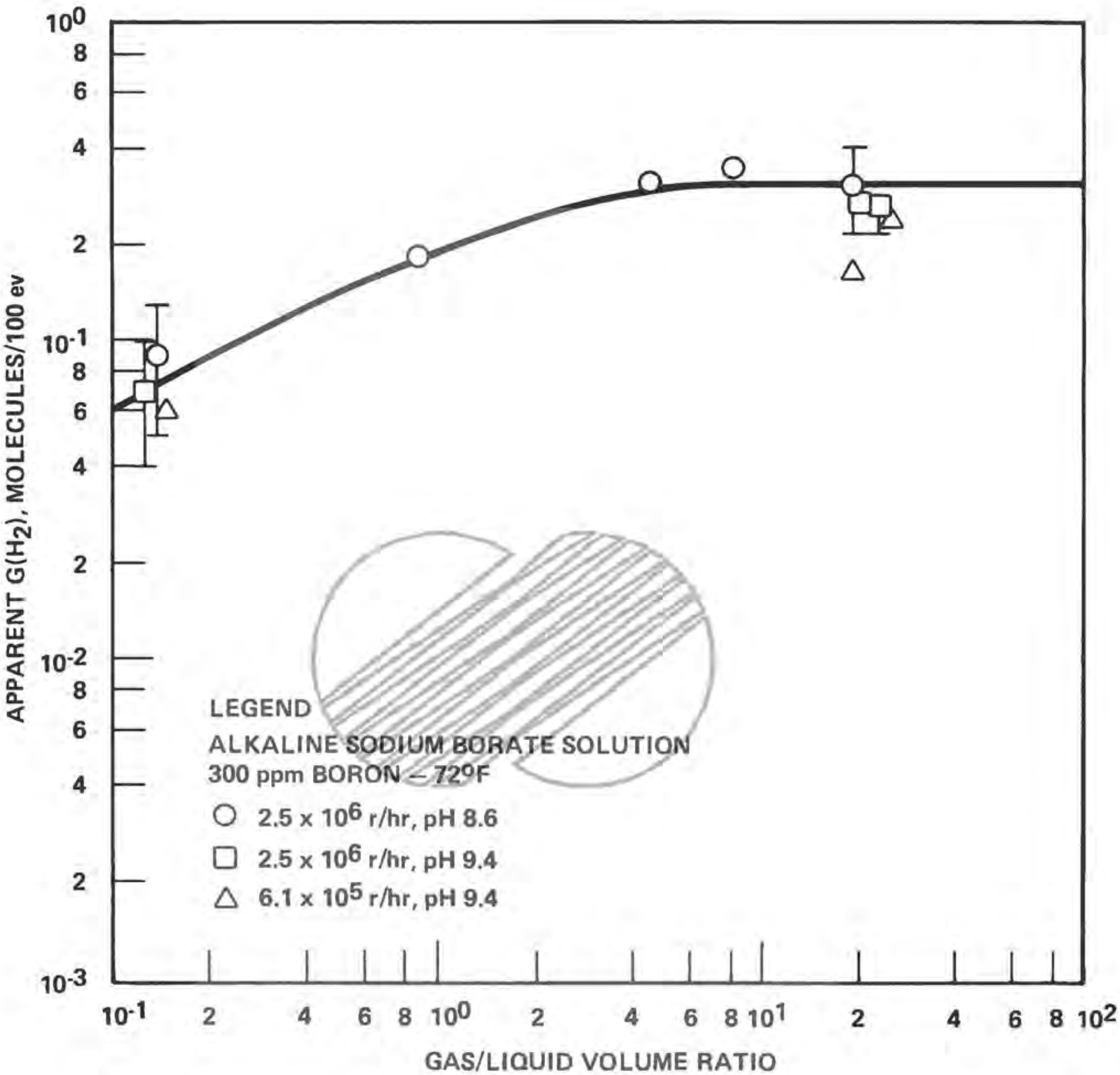


KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
FSAR

COMPARISON OF ANS 5.1 DECAY ENERGY CURVE AT 650 DAYS IRRADIATION + 20% TO DECAY ENERGY VALUES USED FOR H_2 PRODUCTION CALCULATION

Figure 6.2-57



KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
FSAR

RESULTS OF WESTINGHOUSE
CAPSULE IRRADIATION TESTS

Figure 6.2-58

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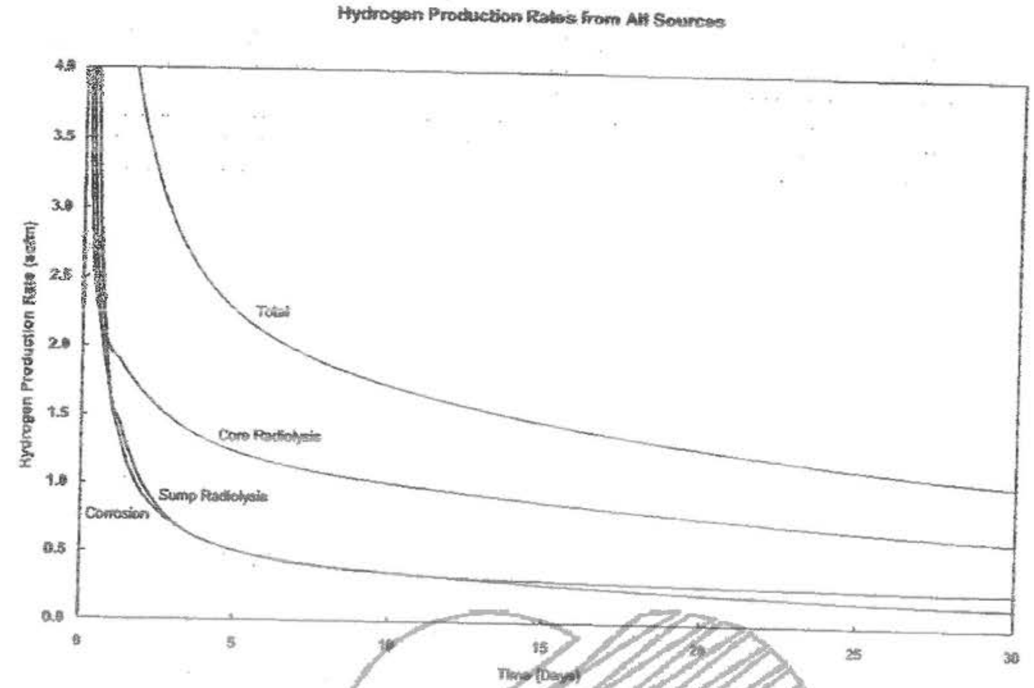

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KOREA HYDRO & NUCLEAR POWER COMPANY
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HYDROGEN PRODUCTION RATE
FROM ALL SOURCES-POWER UPRATE
(Sheet 1 of 2)
Figure 6.2-59

Amendment 469
2012. 10. 29

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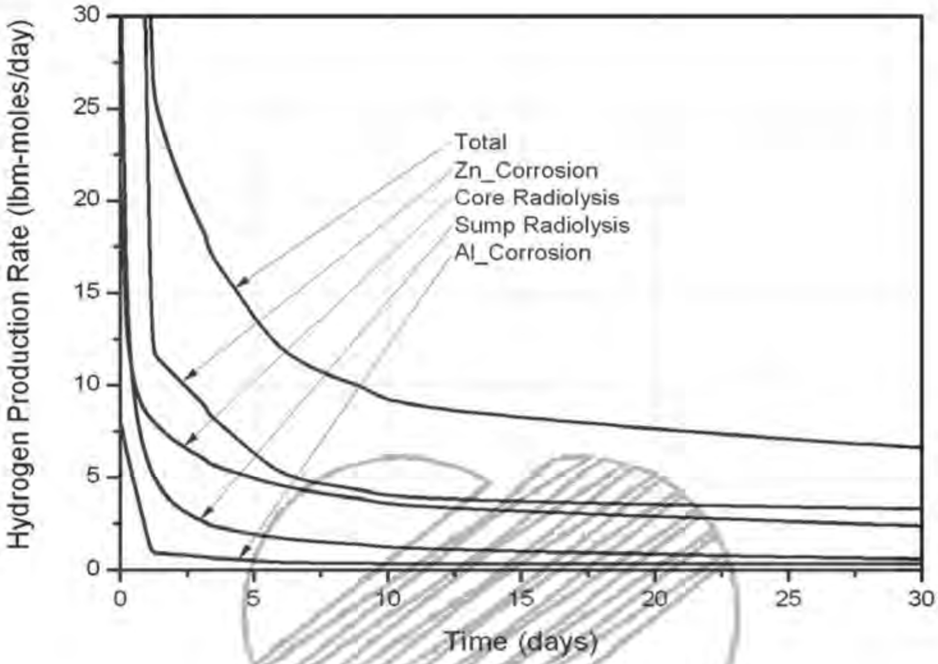

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KOREA HYDRO & NUCLEAR POWER COMPANY
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HYDROGEN PRODUCTION RATE
FROM ALL SOURCES
(Sheet 2 of 2)
Figure 6.2-59

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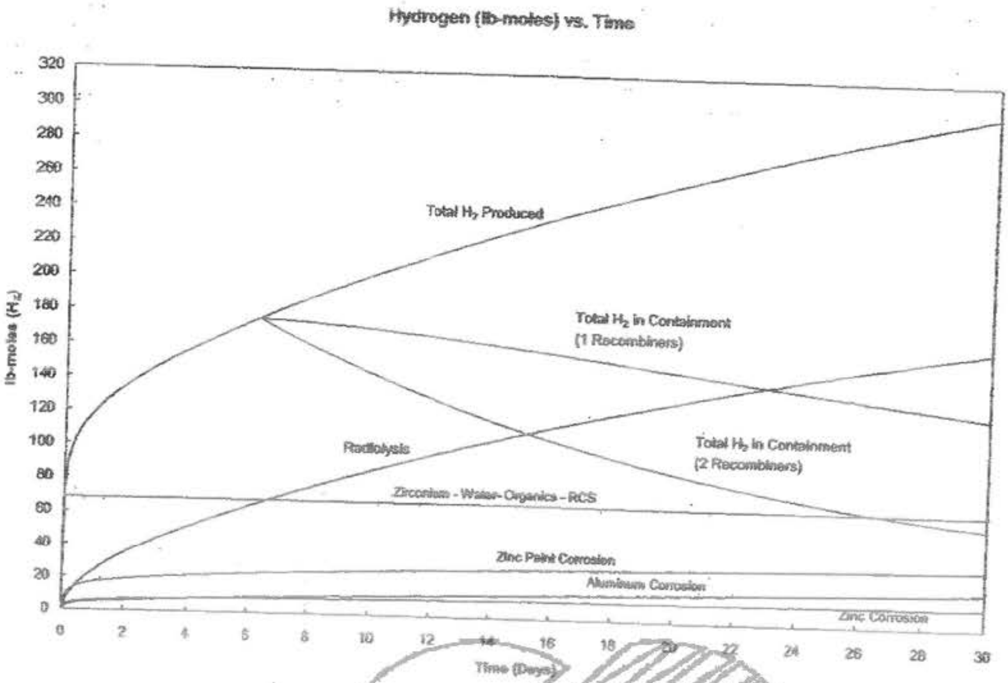

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KRN 3 & 4 FSAR

HYDROGEN (LB.-MOLES) VS TIME
(POWER UPRATE)
(Sheet 1 of 2)
Figure 6.2-60

Amendment 469
2012. 10. 29

469

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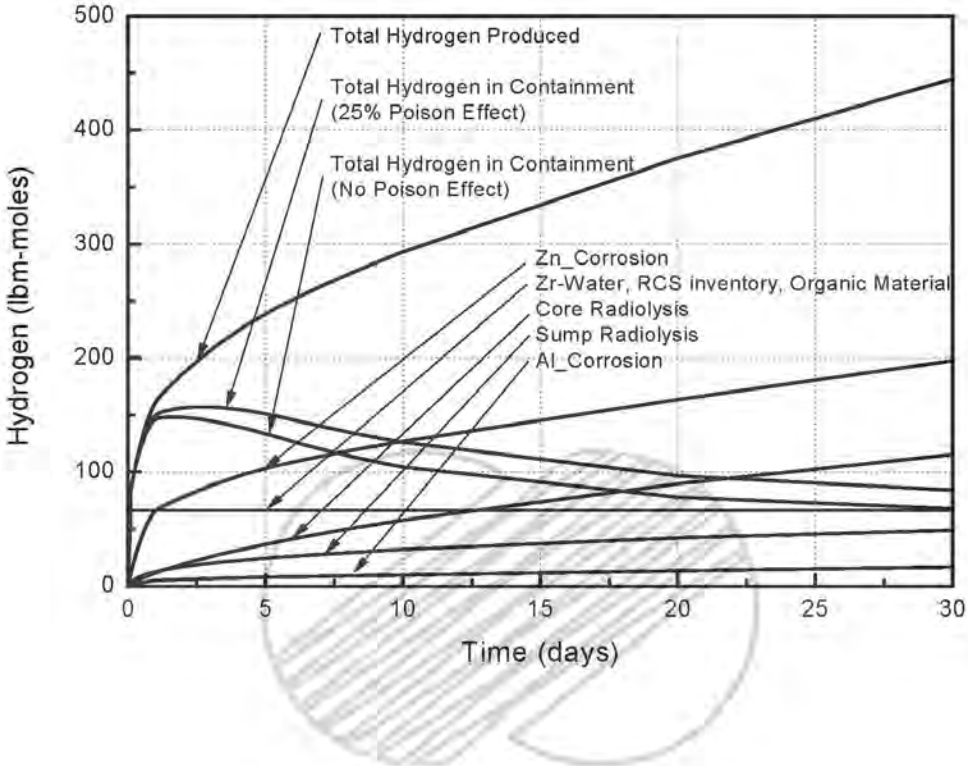

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HYDROGEN(LB.-MOLES) VS TIME
(Sheet 2 of 2)
Figure 6.2-60

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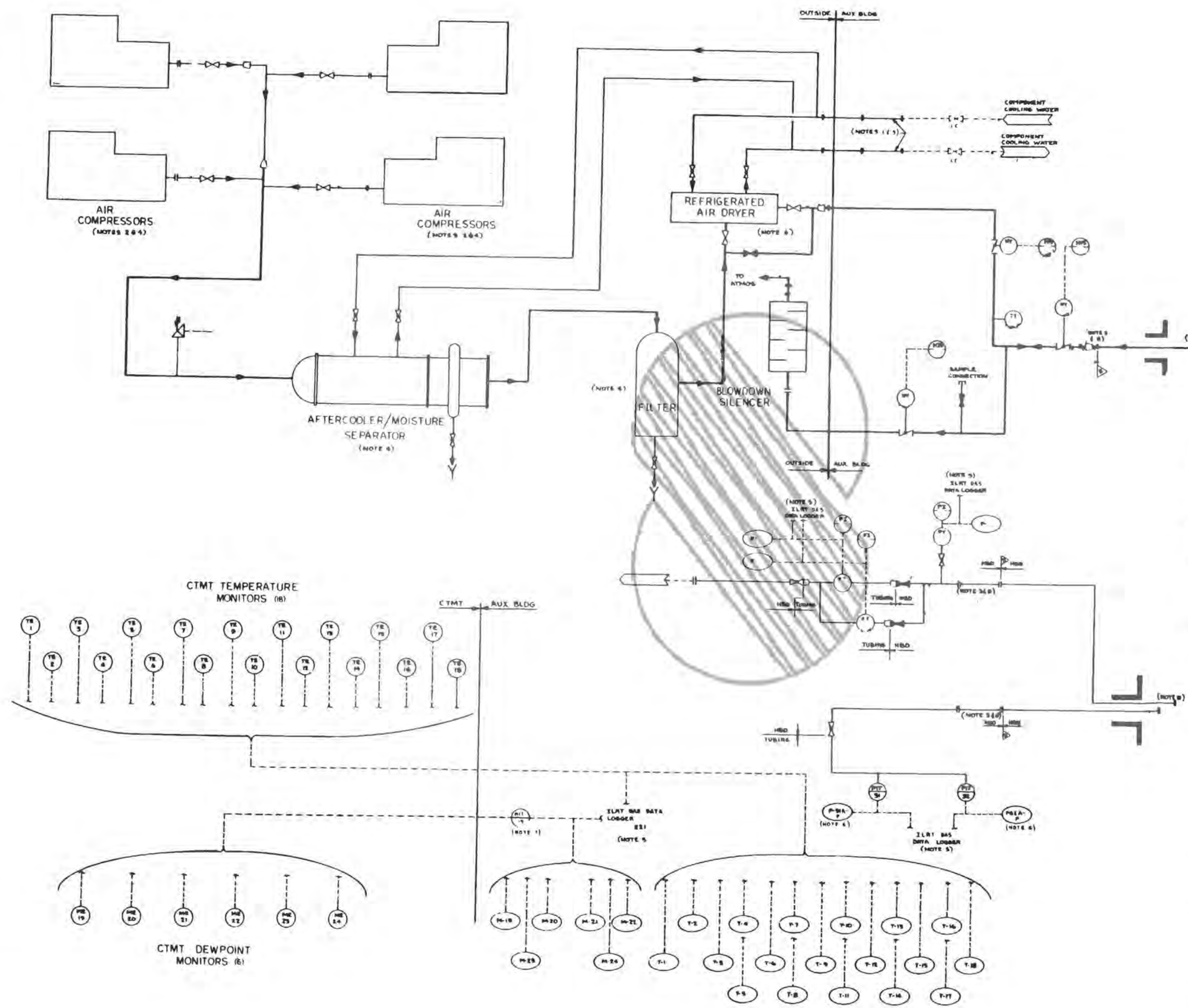

NOTES:

1. COOLING WATER REQUIREMENTS TO BE DETERMINED LATER BASED ON MOISTURE SEPARATOR AND DRYER NEEDS. COOLING WATER TO BE TEMPORARILY CONNECTED TO COMPONENT COOLING WATER SYSTEM.
2. AIR COMPRESSORS (4), MOISTURE SEPARATOR, FILTER, AND DRYER, SILENCER, ASSOCIATED PIPING AND VALVES ARE SUPPLIED BY TPC.
3. SPOOL PIECE INSTALLED ONLY DURING ILRT.
4. ALL INSTRUMENTATION WILL BE MOUNTED ON THE EQUIPMENT BY THE SUPPLIER.
5. ONE ILRT DATA ACQUISITION SYSTEM (DAS) DATA LOGGER/PRINTER IS SHARED AMONG ALL UNITS. THE DAS DATA LOGGER/PRINTER IS USED AS A BACK UP TO THE BOP COMPUTER AND WILL BE UTILIZED ONLY IF THE BOP COMPUTER IS NOT AVAILABLE.
6. SIXTEEN (16) DIGITAL INPUTS (A THRU P) FOR 8-4-2-1 BINARY CODED DECIMAL INPUT TO COMPUTER.
7. A DEWPOINT HYDROMETER (MIT) IS PROVIDED FOR EACH LOOP (19 THRU 24) LOOP MIT-19 IS SHOWN.
8. BLIND FLANGERS TO BE INSTALLED FOR NORMAL PLANT OPERATION.

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CONTAINMENT
INTEGRATED
LEAK RATE TEST

Figure 6.2-61

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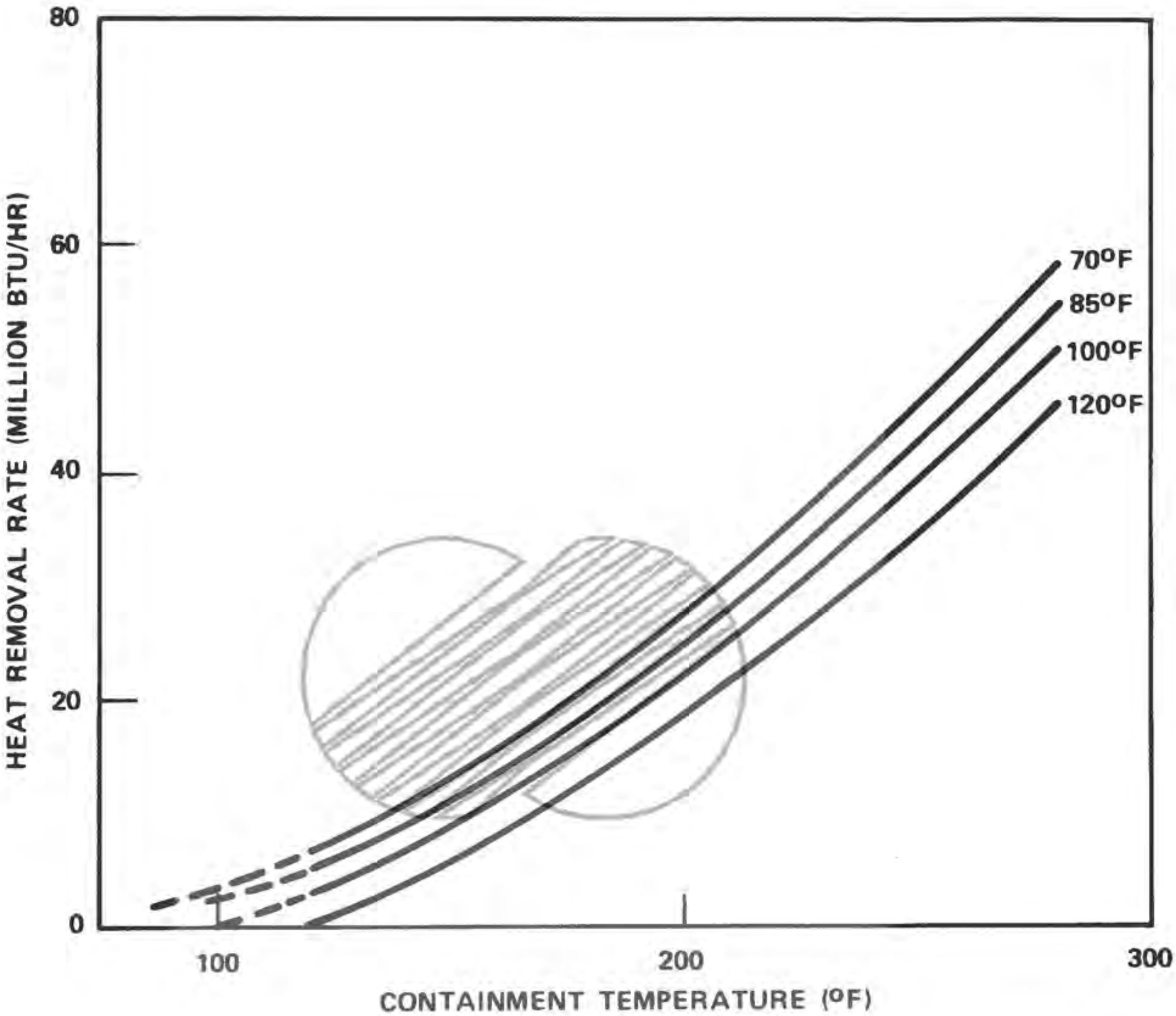

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Fan Cooler Performance

Figure 6.2-62

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6.3 EMERGENCY CORE COOLING SYSTEM

6.3.1 DESIGN BASES

The emergency core cooling system (ECCS) is a Seismic Category I safety-related system. It consists of the centrifugal charging pumps; the boron injection tank (BIT); the refueling water storage tank (RWST); the residual heat removal (RHR) pumps; the accumulators; and the associated valves, piping, and instrumentation.

Nuclear plants employing a similar ECCS design are given in section 1.3.

The primary function of the ECCS following an accident is to remove the stored and fission product decay heat from the reactor core such that fuel rod damage, to the extent that it would impair effective cooling of the core, is prevented.

The ECCS is designed to cool the reactor core, as well as to provide additional shutdown capability following initiation of the following accident conditions:

A. Loss of reactor coolant accident including a pipe break or a spurious relief or safety valve opening in the reactor coolant system (RCS) which would result in a discharge larger than that which could be made up by the normal makeup system

B. Loss of secondary coolant accident including a pipe break or a spurious relief, dump, or safety valve opening in the secondary steam system which would result in an uncontrolled steam release or a pipe break in the secondary feedwater system

C. Steam generator tube rupture accident

D. Rod ejection accident caused by the rupture of a control rod drive mechanism which would result in a loss of coolant from the reactor vessel upper plenum to the containment.

The acceptance criteria for the consequences of each of these accidents are described in the respective accident analyses sections of chapter 15.

The bases used in the design and selection of ECCS functional requirements are derived from Appendix K, Limits for Fuel Cladding Temperature, etc. following any of the above accidents as delineated in 10 CFR 50.46. The subsystem functional parameters are selected so that, when integrated, the Appendix K requirements are met over the range of anticipated accidents and single failure assumptions.

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The ECCS also operates in conjunction with the other systems of the cold shutdown design. The primary function of the ECCS during a safety grade cold shutdown is to ensure a means for injecting and throttling boration and makeup flow. Details of the cold shutdown design are discussed in subsection 5.4.7.

The reliability of the ECCS has been considered in selection of the functional requirements, selection of the particular components, and location of components and connected piping. Redundant components are provided where the loss of one component would impair reliability. Valves are provided in series where isolation is desired and in parallel when flow paths are to be established for ECCS performance. Redundant sources of the safety injection actuation signal are available so that the proper and timely operation of the ECCS will be ensured. Sufficient instrumentation is available so that a failure of an instrument will not impair readiness of the system. The active components of the ECCS are powered from separate buses which are energized from offsite power supplies. In addition, redundant sources of auxiliary onsite power are available through the use of the emergency diesel generators to ensure adequate power for all ECCS requirements. Each generator is capable of driving all pumps, valves, and necessary instruments associated with one train of the ECCS.

All valves required to be actuated during ECCS operation are located to prevent vulnerability to flooding or have been evaluated to ensure the consequences are acceptable. Repositioning of valves due to spurious actuation coincident with an accident has been analyzed and is not considered credible for a design basis.

The environmental qualification of active ECCS equipment is discussed in section 3.11.

Protection of the ECCS from missiles is discussed in section 3.5; dynamic effects associated with ruptures of piping in section 3.6; and protection from flooding in section 3.4.

The elevated temperature of the sump solution during recirculation is well within the design temperature of all ECCS components. In addition, consideration has been given to the potential for corrosion of various types of metals exposed to the fluid conditions prevalent immediately after the accident or during long-term recirculation operations.

6.3.2 SYSTEM DESIGN

The ECCS components are designed such that a minimum of two accumulators, one charging pump, and one RHR pump, together with their associated valves and piping, will ensure adequate

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core cooling in the event of a design basis accident. The redundant onsite emergency diesels ensure adequate emergency power to all electrically operated components in the event that a loss of offsite power occurs simultaneously with an accident, even assuming a single failure in the emergency power system.

6.3.2.1 Schematic Piping and Instrumentation Diagrams

Flow diagrams of the ECCS are shown in figures 6.3-1 and 6.3-2. Pertinent design and operating parameters for the components of the ECCS are given in table 6.3-1. The codes and standards to which the individual components of the ECCS are designed are listed in table 3.2-1.

The components of the ECCS are interlocked as listed below:

A. The safety injection (S) signal is interlocked with the following components and initiates the indicated actions:

1. The charging pumps start
2. The RHR pumps start
3. The BIT isolation valves open
4. The RWST to charging pump valves open
5. The boron injection recirculation isolation valves close
6. Normal charging line isolation valves close
7. The volume control tank (VCT) to charging pump suction isolation valves close
8. The boron injection recirculation pumps stop
9. The RWST to spent fuel pool cooling system (SFPCS) valves close. 3

B. The containment isolation phase A (T) signal is interlocked with the following valves and initiates the indicated actions:

1. The N_2 supply header isolation valve closes
2. The accumulator fill line isolation valve closes

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3. The check valve test line header isolation valves close

4. The check valve test line isolation valves close.

C. The sump suction isolation valves are interlocked to open upon receipt of a signal generated by a concurrent S signal and RWST low-low level signal.

D. The RWST to RHR pump isolation valves close upon receipt of an "open" signal generated by the sump suction isolation valves.

E. The accumulator isolation valves open upon receipt of an S signal or when the RCS pressure exceeds a predetermined value.

6.3.2.2 Equipment and Component Descriptions

The component design and operating conditions are specified as the most severe conditions to which each respective component is exposed during either normal plant operation or operation of the ECCS. For each component, these conditions are considered in relation to the code to which it is designed. By designing the components in accordance with applicable codes, and with due consideration for the design and operating conditions, the fundamental assurance of structural integrity of the ECCS components is maintained. Components of the ECCS are designed to withstand the appropriate seismic loadings in accordance with their safety class as given in table 3.2-1. Specific equipment parameters are shown in table 6.3-1.

The major mechanical components of the ECCS are:

6.3.2.2.1 Accumulators

The accumulators are pressure vessels partially filled with borated water and pressurized with nitrogen gas. During normal operation, each accumulator is isolated from the RCS by two check valves in series. Should the RCS pressure fall below the accumulator pressure, the check valves open and borated water is forced into the RCS. One accumulator is attached to each of the cold legs of the RCS. Mechanical operation of the swingdisc check valves is the only action required to open the injection path from the accumulators to the core via the cold legs.

Connections are provided for remotely adjusting the level and boron concentration of the borated water in each accumulator during normal plant operation as required. Accumulator water level may be adjusted either by draining to the RWST or by

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pumping borated water from the RWST to the accumulator. Samples of the solution in the accumulators are taken periodically to check boron concentration.

Accumulator pressure is provided by a supply of nitrogen gas, and can be adjusted as required during normal plant operation; however, the accumulators are normally isolated from this nitrogen supply. Gas relief valves on the accumulators protect them from pressures in excess of design pressure.

The accumulators are located within the containment but outside of the secondary shield wall which protects them from missiles. Since the accumulators are located within the containment, a release of the nitrogen gas in the accumulators would cause an increase in normal containment pressure. Containment pressure increase following release of the gas from all accumulators has been calculated and is well below the containment pressure setpoint for ECCS actuation. Accumulator level and pressure are monitored by indicators and alarms. Thus, the operator could take action promptly as required to maintain plant operation within the requirements of the technical specification covering accumulator operability.

6.3.2.2.2 Boron Injection Tank

The BIT contains a nominal 12 weight percent (21,000 ppm boron) concentrated boric acid solution and is connected to the discharge of the charging pumps. Upon actuation by an S signal, the charging pumps provide pressure to inject the boric acid solution into the RCS when the isolation valves associated with the BIT open automatically.

To prevent cold spots and stratification within the tank during normal operation, the contents of the BIT are continuously recirculated with the boron injection surge tank via a boron injection recirculation pump. The BIT incorporates a sparger type inlet which distributes the incoming boric acid in a 360-degree fan as it enters the tank. This prevents channeling and also ensures homogeneity of the boric acid solution. This recirculation path is automatically isolated on receipt of an S signal.

Redundant tank heaters and line heat tracing are provided to ensure that the solution will be stored at a temperature in excess of its solubility limit (135F at a nominal 12 weight percent concentration of boric acid).

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6.3.2.2.3 Boron Injection Surge Tank

The boron injection surge tank provides surge capacity for the BIT recirculation loop. The boron injection surge tank contains the same concentration of boric acid as the BIT during normal plant operation. The recirculation lines to and from the boron injection surge tank are automatically closed and the boron injection recirculation pumps stopped by the S signal.

A boron injection surge tank heater, which is not required for normal system operation, is provided as a backup heat source in the event the surge tank is isolated for maintenance.

6.3.2.2.4 Residual Heat Removal Pumps

The RHR pumps function as the low head safety injection pumps.

In the event of an accident the RHR pumps are started automatically on receipt of an S signal. The RHR pumps deliver water to the RCS from the RWST during the injection phase and from
the containment recirculation sump during the recirculation phase. 253
Each RHR pump is a single-stage vertical position centrifugal pump.

A minimum flow bypass line is provided for the pumps to recirculate and return the pump discharge fluid to the pump suction should these pumps be started with their normal flow paths blocked. Once pump discharge flow greater than 1000 gal/min is established, the bypass line is automatically closed. This line prevents deadheading of the pumps and permits pump testing during normal operation.

The RHR pumps are discussed further in subsection 5.4.7. A pump performance curve is given in figure 6.3-3.

6.3.2.2.5 Centrifugal Charging Pumps

The charging pumps function as the high head safety injection pumps.

In the event of an accident, the charging pumps are started automatically on eeceipt of an S signal and are automatically aligned to take suction from the RWST during injection. During recirculation, suction is provided via the RHR pumps.

These pumps deliver flow through the BIT to the RCS at the prevailing RCS pressure. Each charging pump is a multistage diffuser design, barrel-type casing with vertical suction and discharge nozzles.

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A minimum flow bypass line is provided on each pump discharge to recirculate flow to the pump suction after cooling via the seal water heat exchanger during normal plant operation. Each minimum flow bypass line and common bypass line contains respectively a valve which is close manually to prevent safety injection flow degradation when the actual RCS pressure drops to the calculated pressure for manual reactor coolant pump trip and is reopened manually to avoid deadheading of charging pumps should the wide range RCS pressure subsequently rise to greater than 2,000 psig. These operator manual actions are dictated by plant emergency operating procedures. The S signal closes the valves to isolate the normal charging line and VCT, and opens the charging pump suction valves from the RWST to align the high head portion of the ECCS for injection. During normal plant operation, at least one charging pump is containuously in service. The other charging pumps may be tested during power operation via the minimum flow bypass lines. 3

A pump performance requirement curve is given in figure 6.3-4.

Required net positive suction head (NPSH) for ECCS pumps are shown in table 6.3-1. The safety intent of Regulatory Guide 1.1 is met by the design of the ECCS such that adequate NPSH is provided to system pumps. In addition to considering the static head and suction line pressure drop, the calculation of available NPSH in the recirculation mode assumes that the vapor pressure of the liquid in the sump is equal to the containment ambient pressure. This ensures that the actual available NPSH is always greater than the calculated NPSH.

6.3.2.2.6 Boron Injection Recirculation Pumps

These pumps are provided to recirculate the nominal 12 weight percent concentrated boric acid solution continuously around a closed loop consisting of the BIT, the boron injection surge tank and associated piping. One pump is in continuous operation while the other pump provides a maintenance spare. The pumps are automatically stopped on receipt of an S signal.

6.3.2.2.7 Positive Displacement Hydrostatic Test Pump

This pump serves two functions, neither of which is safety-related. Permanent connections are provided to the accumulators to allow addition of borated water from the RWST. Temporary connections permit the use of this pump in hydro-testing the plant piping systems.

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6.3.2.2.8 Residual Heat Exchangers

The residual heat exchangers are conventional shell and U-tube type units. During normal cooldown operation, the RHR pumps circulate reactor coolant through the tube side while component

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cooling water flows through the shell side. During emergency core cooling recirculation operation, water from the containment sump flows through the tube side. The tubes are seal welded to the tubesheet.

A further discussion of the residual heat exchangers is found in subsection 5.4.7.

6.3.2.2.9 Valves

Design parameters for motor-operated valves used in the ECCS are given in table 6.3-1.

Design features employed to minimize valve leakage include:

A. Where possible, packless valves are used.

B. Other valves which are normally open, except check valves and those which perform a control function, are provided with backseats to limit stem leakage.

C. Normally closed globe valves are installed with recirculation fluid pressure under the seat to prevent stem leakage of recirculated (radioactive) water.

D. Relief valves are enclosed; i.e., they are provided with a closed bonnet.

6.3.2.2.10 Motor-Operated Gate Valves

The seating design of all motor-operated gate valves is of the crane flexible wedge design. These designs release the mechanical holding force during the first increment of travel so that the motor operator works only against the frictional component of the hydraulic unbalance on the disc and the packing box friction. The discs are guided throughout the full disc travel to prevent chattering and to provide ease of gate movement. The seating surfaces are hard faced to prevent galling and to reduce wear.

Where a gasket is employed for the body to bonnet joint, it is either a fully trapped, controlled compression, spiral wound asbestos gasket with provisions for seal welding, or it is of the pressure seal design with provisions for seal welding. The valve stuffing boxes are designed with a lantern ring leakoff connection with a minimum of a full set of packing below the lantern ring and a minimum of one-half of a set of packing above the lantern ring. A full set of packing is defined as a depth of packing equal to one and one-half times the stem diameter.

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The motor operator incorporates a "hammer blow" feature that allows the motor to impact the discs away from the backseat upon opening or closing. This "hammer blow" feature not only impacts the disc but allows the motor to attain its operational speed prior to impact.

6.3.2.2.11 Manual Globe, Gate and Check Valves

Gate valves are either wedge design or parallel disc and are straight through. The wedge is either split or solid. All gate valves have backseat and outside screw and yokes.

Globe valves, T and Y style, are full ported with outside screw and yoke construction.

Check valves are spring-loaded, lift-piston types for sizes 2 inches and smaller, swing type for sizes 2-1/2 inches to 4 inches, and tilting disc type for sizes 4 inches and larger. Stainless steel check valves have no penetration welds other than the inlet, outlet, and bonnet. The check hinge is serviced through the bonnet.

The stem packing and gasket of the stainless steel manual globe and gate valves larger than 2 inches are similar to those described above for motor-operated valves. Carbon steel manual valves are employed to pass nonradioactive fluids only and therefore do not contain the double packing and seal weld provisions.

6.3.2.2.12 Accumulator Check Valves (Swing-disc)

The accumulator check valve is designed with a low pressure drop configuration with all operating parts contained within the body.

During normal operation, the check valves are in the closed position with a nominal differential pressure across the disc of approximately 1650 psi. Since the valves remain in this position except for testing or when called upon to open following an accident, and are, therefore, not subject to the abuse of flowing operation or impact loads caused by sudden flow reversal and seating, they do not experience significant wear of the moving parts, and are expected to function with minimal back-leakage. This back-leakage can be checked via the test connection as described in subsection 6.3.4.

6.3.2.2.13 Relief Valves

Relief valves are installed in various sections of the ECCS to protect lines which have a lower design pressure than the RCS. The valve stem and spring adjustment assembly are isolated from the system fluids by a bellows seal between the valve disc and spindle. The closed bonnet provides an additional barrier for enclosure of the relief valves. Table 6.3-2 lists the system relief valves with their capacities and setpoints.

6.3.2.2.14 Butterfly Valves

Each main residual heat removal system (RHRS) discharge line has an air-operated butterfly valve which is normally open and is designed to fail in the open position. The actuator is arranged such that air pressure on the diaphragm overcomes the spring force, causing the linkage to move the butterfly to the closed position. Upon loss of air pressure, the spring returns the butterfly to the open position. These valves are left in the full-open position during normal operation to maximize flow from this system to the RCS during the injection mode of the ECCS operation. These valves are used during normal RHRS operation to control cooldown flowrate.

Each residual heat exchanger bypass line has an air-operated butterfly valve which is normally closed and is designed to fail closed. These valves are used during normal cooldown to avoid thermal shock to the residual heat exchangers, and limit the maximum temperature in the component cooling water system.

6.3.2.2.15 Accumulator Motor-Operated Valve Controls

As part of the plant shutdown administrative procedures, the operator is required to close these valves. This prevents a loss of accumulator water inventory to the RCS and is done after the RCS has been depressurized below the safety injection unblock setpoint. The redundant pressure and level alarms on each accumulator would remind the operator to close these valves, if any were inadvertently left open. Power is disconnected after the valves are closed.

During plant startup, the operator is instructed, via procedures, to energize and open these valves when the RCS pressure reaches the safety injection unblock setpoint. Monitor lights in conjunction with an audible alarm will alert the operator should any of these valves be left inadvertently closed once the RCS pressure increases beyond the safety injection unblock setpoint. Power is disconnected after the valves are opened.

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The accumulator isolation valves are not required to move during power operation. For a discussion of limiting conditions for operationation and surveillance requirements of these valves, refer to ITS Chapter 1 3.5.1. 1 357

The accumulator isolation valves receive an S signal to ensure that they are open, in the event of an accident which initiates safety injection. For further discussions of the instrumentation associated with these valves, refer to subsection 6.3.5, subparagraph 7.3.1.1.2, and subsection 7.6.4.

6.3.2.2.16 Valve Position Controls

Remotely operated motor-operated valves for the injection mode which are under manual control (i.e., valves which normally are in their ready position and do not require an S signal) have their positions indicated on a common portion of the control board. If a component is out of its proper position, its monitor light will indicate this on the control panel. At any time during operation when one of these valves is not in the ready position for injection, this condition is shown visually on the board, and an audible alarm is sounded in the control room.

Inadvertent mispositioning of a motor-operated valve due to a malfunction in the control circuitry in conjunction with an accident has been analyzed and found not to be credible for consideration in design.

Table 6.3-3 provides information on various motor-operated valves such as valve position indication, valve interlocks, and alarms.

6.3.2.3 Applicable Codes and Classifications

See subsection 3.9.3 for a discussion of the applicable codes and standards which apply to individual ECCS components.

6.3.2.4 Materials Specifications and Compatibility

Materials employed for engineered safety feature (ESF) components are discussed in subsection 6.1.1. Materials for ECCS components are selected to meet the applicable material requirements of the codes in table 3.2-1 and the following additional requirements:

A. All parts of components in contact with borated water are fabricated of, or clad with, austenitic stainless steel or equivalent corrosion-resistant material.

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B. All parts of components in contact (internal) with sump solution during recirculation are fabricated of austenitic stainless steel or equivalent corrosion-resistant material.

C. Valve seating surfaces are hard faced with Stellite No. 6 or equivalent to prevent galling and to reduce wear, except soft seat valves; i.e., accumulator gas supply/isolation valve.

D. Valve stem materials are selected for their corrosion resistance, high tensile properties, and resistance to surface scoring by the packing.

The elevated temperature of the sump solution during recirculation is well within the design temperature of all ECCS components. In addition, consideration has been given to the potential for corrosion of various types of metals exposed to the fluid conditions prevalent immediately after the accident or during long-term recirculation operations.

Table 6.3-4 summarizes the materials employed for ECCS components.

Environmental testing of ECCS equipment inside the containment and required to operate following an accident is discussed in section 3.11.

6.3.2.5 System Reliability

Reliability of the ECCS is considered in all aspects of the system from initial design to periodic testing of the components during plant operation. The ECCS is a two-train, fully redundant, safety-related system. The system has been designed and proven by analysis to withstand any single credible active failure during injection or any single active or passive failure during recirculation or operator error and maintain the performance objectives desired in subsection 6.3.1. Separate trains of pumps, heat exchangers, and flow paths are provided for redundancy as only one train and flow path is needed to satisfy the performance requirements. The initiating signals for the ECCS are derived from independent sources as measured from process (e.g., pressurizer low pressure) or environmental (e.g., containment high pressure) variables. Redundant, as well as functionally independent, variables are measured to initiate the safeguards signal. Each train is physically separated and protected, where necessary, so that a single event cannot initiate a common failure. Power sources for the ECCS are divided into two independent trains supplied from the separate emergency buses supplied from offsite power.

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Sufficient diesel generating capacity is maintained onsite to provide required power to each train. The diesel generators and their auxiliary systems are completely independent and dedicated to one of the two ECCS trains.

The preoperational testing program ensures that the systems, as designed and constructed, will meet the functional requirements as calculated in design. The ECCS is designed with the ability for on-line testing of most components so the availability and operational status can be readily determined. In addition to the above, the integrity of the ECCS is ensured through examination of critical components during the routine inservice inspection.

The reliability program extends to the procurement of ECCS components such that only designs which have been proven by past use in similar applications are acceptable for use. The quality assurance program as described in chapter 17 ensures receipt of components only after manufacture and test to the applicable codes and standards.

6.3.2.5.1 Active Failure Criteria

The failure of a powered component, such as a piece of mechanical equipment, component of the electrical supply system, or instrumentation and control equipment to act on command to perform its design function is considered an active failure. Examples include the failure of a motor-operated valve to move to its correct position, the failure of an electrical breaker or relay to respond, the failure of a pump, fan, or diesel generator to start, etc.

The failure mode and effects analysis (FMEA), provided in table 6.3-5, demonstrates the ability of the ECCS to withstand any single active failure. The analysis illustrates that the ECCS can sustain an active failure in either the short or long term and still meet the required level of performance for core cooling.

Since the short-term operation of the active components of the ECCS following a secondary side rupture or a steam generator tube rupture is similar to that following a LOCA, the same analysis is applicable and the ECCS can sustain the failure of any single active component and still meet the level of performance for the addition of shutdown reactivity.

Portions of the ECCS are also relied on to provide boration and makeup during a safety grade cold shutdown. The capability of the ECCS to sustain an active failure and still perform in conjunction with other systems of the cold shutdown design is provided in table 5.4-7, RHRS - Safety Grade Cold Shutdown Operations - FMEA.

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6.3.2.5.2 Passive Failure Criteria

The structural failure of a static component that limits the component's effectiveness in carrying out its design long-term function is considered a passive failure. Examples include cracks in pipes, sprung flanges, valve packing leaks, or pump seal failures.

A single passive failure analysis is presented in table 6.3-6. It demonstrates that the ECCS can sustain a single passive failure during the long-term phase and still retain an intact flow path to the core to supply sufficient flow to maintain the core covered and effect the removal of decay heat. The procedure followed to establish the alternate flow path also isolates the component which failed.

The following philosophy provides for necessary redundancy in component and system arrangement to meet the intent of the general design criterion on single failure as it specifically applies to failure of passive components in the ECCS. Thus, for the long term, the system design is based on accepting either a passive or an active failure, assuming no failures in the short-term.

6.3.2.5.2.1 Redundancy of Flow Paths and Components for Long-Term ECCS Operation. The following criteria are utilized to establish redundancy of ECCS flow paths and components for long term ECCS operation.

A. During the long-term cooling period following an accident, the emergency core cooling flow paths shall be separable into subsystems, either of which can provide minimum core cooling functions and return spilled water from the floor of the containment back to the RCS.

B. Either of the two subsystems can be isolated and removed from service in the event of a leak outside the containment.

C. Adequate redundancy of check valves is provided to tolerate failure of a check valve during the long-term as a passive component.

D. Should one of these two subsystems be isolated in this long-term period, the other subsystem remains operable.

E. Provisions are also made in the design to detect leakage from components outside the containment, collect this leakage, and provide for maintenance of the affected equipment.

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For the long-term emergency core cooling function, adequate core cooling capacity exists with one flow path removed from service.

6.3.2.5.2.2 Subsequent Leakage from ECCS Components. Provisions to detect, isolate, and handle ECCS component leakage are incorporated into the plant design. With respect to piping and mechanical equipment outside the containment, considering the provisions for visual inspection and leak detection, leaks will be detected before they propagate to major proportions. A review of the equipment in the system indicates that the largest sudden leak potential would be the sudden failure of a pump shaft seal. Evaluation of leak rate, assuming only the presence of a seal retention ring around the pump shaft, showed flows less than 50 gal/min. would result. Piping leaks, valve packing leaks, or flange gasket leaks have been of a nature to build up slowly with time and are considered less severe than the pump seal failure.

Larger leaks in the ECCS are prevented by the following:

A. The piping is classified in accordance with American Nuclear Society (ANS) Safety Class 2 and receives the ASME Class 2 quality assurance program associated with this safety class.

B. The piping, equipment, and supports are designed to ANS Safety Class 2 seismic classification permitting no loss of function for the design basis earthquake (DBE).

C. The system piping is located within a controlled area on the plant site.

D. The piping system receives periodic pressure tests and is accessible for periodic visual inspection.

E. The piping is austenitic stainless steel which, due to its ductility, can withstand severe distortion without failure.

The design of the auxiliary building and related equipment is based upon handling of leaks up to a maximum of 50 gal/min. Means are also provided to detect and isolate such leaks in the emergency core cooling flow path within 30 minutes.

6.3.2.5.3 Lag Times

Lag times for initiation and operation of the ECCS is limited by pump startup time and consequential loading sequence of

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these motors onto the safeguard buses. Most valves are normally in the position conducive to safety; therefore, valve operation time is not considered for these valves. If there is no loss of offsite power, all pump motors and valve motors are loaded immediately onto the safeguards buses according to the sequencer. The charging pumps and all valves are applied to the buses in 5 seconds and the RHR pumps in 10 seconds. Safeguards pumps are capable of obtaining operating speed and rated flow within 5 seconds of receipt of the start signal. In the case of loss of offsite power, an additional 10 seconds delay is assumed for the diesel to start and to obtain operating speed and voltage prior to the safeguards pumps and valves being sequenced onto the safeguards buses. These lag times refer to the time after initiation of the S signal.

6.3.2.5.4 Potential Boron Precipitation

In the event of a cold leg break loss of coolant accident, boron precipitation ation in the reactor vessel can be prevented by a backflush of ECCS water through the core. This is accomplished by the switchover from cold leg to hot leg recirculation at approximately 7 hours following an accident. In addition to preventing boron prcipitation by backflushing the core, hot leg recirculation provides subcooled water to maintain core cooling. Approximately, 10.5 hours after realigning the ECCS to the RCS hot legs, the ECCS should be realigned to
51 the RCS cold legs, to preclude boron precipitation in the reactor vessel in the event of a hot leg break loss of coolant accident. Thereafter, the ECCS should cycle between hot and cold leg injection every 10.5 hours to control the boric acid concentration in the reactor vessel. No cycling is required if the 8889 MOV fails, where the procedure is to align the RHR to the RCS cold legs while the high head SI is realigned to the RCS hot legs. In that instance, simultaneous hot and cold leg injection flow precludes boron precipitation.

Three flow paths are available for hot leg recirculation of sump water. Each charging pump can discharge individually to the hot legs with suction taken from the RHR pump discharge. The RHR pump can also be aligned to deliver flow directly to the hot legs via a common hot leg recirculation header.

Loss of one pump or one flow path will not prevent hot leg recirculation since redundant methods are available for use.

6.3.2.5.5 Safety Grade Cold Shutdown Function

During a safety grade cold shutdown, the ECCS is relied on to provide an injection path for boration and makeup. The ECCS high head safety injection headers provide this function. Two independent subsystems, each consisting of a charging pump and the associated valves and piping, are provided and are powered by redundant emergency buses in a manner that ensures that at least one subsystem is always operable. A solenoid valve provided in each subsystem ensures that the remote throttling capability necessary for RCS inventory control and shutdown is available. Also, provisions are made to ensure that the accumulators can always be either isolated or vented so that RCS depressurization can be accomplished. Details of the cold shutdown design are discussed in subsection 5.4.7.

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6.3.2.6 Protection Provisions

The provisions taken to protect the system from damage that might result from dynamic effects are discussed in section 3.6 from missiles in section 3.5, and from seismic damage in sections 3.7, 3.9, and 3.10; thermal stresses on the RCS are discussed in section 3.9.

6.3.2.7 Provisions for Performance Testing

Test lines are provided for performance testing of the ECCS system as well as individual components. These test lines and instrumentation are shown in figure 6.3-1. All pumps have miniflow lines for use in testing operability. Additional information on testing can be found in paragraph 6.3.4.2.

6.3.2.8 Manual Actions

The ECCS is automatically actuated following those accidents identified in subsection 6.3.1. Following actuation, the ECCS continues to operate in the injection mode until its operation is terminated by the operator or until its operation is switched to the recirculation mode. During the injection mode, no manual actions are required for proper operation of the ECCS. For the loss of secondary coolant accident and the tube rupture accident, the operator should stabilize plant conditions and terminate ECCS operation after satisfying the criteria for ECCS termination. For the LOCA accident, the operator may not be able to terminate ECCS operation and may have to initiate manual actions to align the ECCS for the recirculation mode. The following discussion addresses the limited manual actions that are required of the operator to realign the system for the cold leg recirculation mode of operation, and, after approximately 7 hours, for the hot leg recirculation mode of 51
operation. These actions are delineated in table 6.3-7.

The switchover from the injection mode to recirculation mode is initiated automatically and completed manually by operator action from the main control room. Protection logic is provided to automatically open the ECCS recirculation sump isolation valves when two out of four RWST level channels indicate a low-low level in conjunction with an S signal. This automatic action aligns the two RHR pumps to take suction from the con- 253
tainment recirculation sump and to deliver directly to the RCS. The RHR pumps continue to operate during this automatic switchover from the injection mode to the recirculation mode.

The two charging pumps continue to take suction from the refueling water storage tank until manual operator action is taken to align these pumps in series with the RHR pumps.

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The RWST level protection logic consists of four level channels with each level channel assigned to a separate process control protection set. Four RWST level transmitters provide level signals to corresponding normally deenergized level channel bistables. Each level channel bistable would be energized on receipt of a RWST level signal less than the low-low level setpoint.

A two-out-of-four coincident logic is utilized in both protection cabinets A and B to ensure a signal in the event that two out of the four level channel bistables are energized. This signal, in conjunction with the S signal, provides the actuation signal to automatically open the corresponding containment recirculation sump isolation valves and CCW isolation valve to RHR heat exchanger. 253

The RWST low-low level signal is also alarmed to inform the operator to initiate the manual action required to realign the charging pumps for the recirculation mode. The manual switchover sequence that must be performed by the operator is delineated in table 6.3-7. During the automatic switchover action, the two RHR pumps are aligned to take suction from the containment sump and deliver directly to the RCS cold legs. The RHR pumps are then manually aligned to provide suction to the two charging pumps which also deliver directly to the RCS cold legs.

The switchover from the cold leg recirculation mode to the hot leg recirculation mode requires further manual actions. The manual switchover sequence that must be performed by the operator is delineated in table 6.3-7. Following completion of the manual switchover actions, the RHR pumps and charging pumps are aligned to deliver directly to the RCS hot legs.

Refer to subsection 9.2.8 for a discussion of the sequence of events in completing the switchover from the injection to the recirculation phase.

6.3.3 PERFORMANCE EVALUATION

The accidents identified in subsection 6.3.1 result in ECCS actuation and are mitigated within acceptance criteria by ECCS operation. For the purpose of evaluation in chapter 15, the accidents that result in ECCS actuation are categorized as follows:

A. Increase in heat removal by the secondary system

   1. Inadvertent opening of a steam generator relief, dump, or safety valve

   2. Steam system piping failure.

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B. Decrease in heat removal by the secondary system

   1. Feedwater system piping failure.

C. Decrease in RCS inventory

   1. Steam generator tube rupture

   2. Loss of coolant accident from a spectrum of postulated RCS piping failures

   3. Pressurizer safety or relief valve open.

Each of these accidents will result in generation of an S signal and ECCS operation. The S signal can be generated by any of the following.

A. Pressurizer low pressure (two-out-of-three logic)

B. Steam line low pressure (two-out-of-three logic in any one loop)

C. Containment high pressure (two-out-of-three logic)

D. Manual actuation.

In addition to initiating ECCS operation, the S signal initiates other safeguards automatic actions, including reactor trip, auxiliary feedwater system initiation, feedwater and containment isolation.

Upon receipt of an S signal, the actions in paragraph 6.3.2.1 are automatically initiated and the ECCS is aligned to operate in the injection mode. The charging pumps are aligned to the BIT and deliver its contents to the RCS cold legs. The RHR pumps and the accumulators are aligned to deliver to the RCS cold legs should RCS pressure drop below pump shutoff head or tank static pressure, respectively. The ECCS pumps and the accumulator flowrates will vary depending on the type of accident and its characteristic pressure transient.

6.3.3.1 Increase in Heat Removal by the Secondary System

A number of events have been postulated which could result in an increase in heat removal from the RCS by the secondary system. Detailed analyses of these events are presented in section 15.1. For those events which result in ECCS actuation, the following summarizes ECCS performance.

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6.3.3.1.1 Inadvertent Opening of a Steam Generator Relief, Dump, or Safety Valve

The most severe core conditions resulting from an accidental depressurization of the main steam system are associated with an inadvertent opening of a single steam dump, relief or safety valve. Refer to subsection 15.1.4 for a detailed description of this accident, including acceptance criteria and analytical results.

For this accident, the ECCS is actuated upon generation of an S signal and the charging pumps function to inject high concentration boric acid solution from the BIT into the RCS cold legs. This high concentration boric acid provides sufficient negative reactivity to maintain the reactor below criticality. The charging pump flow also functions to increase RCS inventory and to repressurize the RCS. For this accident, the RCS does not depressurize sufficiently to permit the RHR pumps or accumulators to deliver to the RCS. Subsequent to stabilizing plant conditions and satisfying ECCS termination criteria, the operator terminates ECCS operation and initiates plant shutdown operations.

6.3.3.1.2 Steam System Pipe Failure

The most severe core conditions resulting from a steam system piping failure are associated with a double ended rupture of a main steamline which occurs at zero power. Effects of smaller piping failures at higher power levels are bounded by the double ended rupture at zero power. Refer to subsection 15.1.5 for a detailed description of this accident, including acceptance criteria and analytical results.

For this accident, the ECCS functions as described in paragraph 6.3.3.1 for the inadvertent opening of a steam generator relief, dump, or safety valve. However, this piping failure constitutes a more severe cooldown transient and the negative reactivity provided by operation of the charging pumps may not be sufficient to prevent the reactor from returning to criticality during the transient. The core is ultimately shut down by the high concentration boric acid solution provided by operation of the charging pumps.

6.3.3.2 <u>Decrease in Heat Removal by the Secondary System</u>

A number of events have been postulated which could result in a decrease in heat removal from the RCS by the secondary system. Detailed analyses of these events are presented in section 15.2. For those events which result in ECCS actuation, the following summarizes ECCS performance.

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6.3.3.2.1 Feedwater System Pipe Failure

The most severe core conditions resulting from a feedwater system piping failure are associated with a double-ended rupture of a feedline at full power. Depending on break size and power level, a feedwater system pipe failure could cause either a RCS cooldown transient or RCS heatup transient. Only the RCS heatup transient is evaluated as a feedwater system pipe failure since the spectrum of cooldown transients is bounded by the steam system pipe failure analyses. The heatup transient effects of smaller piping failures at reduced power levels are bounded by the double ended feedline rupture at full power. Refer to subsection 15.2.8 for a detailed description of this accident, including acceptance criteria and analytical results.

For this accident, the ECCS is actuated upon generation of an S signal and the charging pumps inject high concentration boric acid solution from the BIT into the RCS cold legs. The charging pump flow functions to increase RCS inventory to ensure that sufficient inventory exists to keep the core covered with water. Since the accident is characterized by a heatup transient, the high concentration boric acid solution from the BIT is not required, and is not taken credit for in the analysis, to control core reactivity. The RCS does not depressurize to permit the RHR pumps or accumulators to deliver to the RCS. Subsequent to stabilizing plant conditions and satisfying ECCS termination criteria, the operator terminates ECCS operation and initiates plant shutdown operations.

6.3.3.3 Decrease in Reactor Coolant System Inventory

A number of events have been postulated which could result in a decrease in RCS inventory. Detailed analyses of these events are presented in section 15.6. For those events which result in ECCS actuation, the following summarizes ECCS performance.

6.3.3.3.1 Steam Generator Tube Rupture

Although a steam generator tube rupture is an accident which results in a decrease in RCS inventory, severe core conditions are not associated with a steam generator tube rupture. The accident analyzed is a complete severance of a single steam generator tube that occurs at power with the reactor coolant contaminated with fission products corresponding to continuous operation with a limited amount of defective fuel rods. Effects of smaller breaks are bounded by the complete severance. Refer to subsection 15.6.3 for a detailed description of this accident, including acceptance criteria and analytical results.

For this accident, the ECCS is actuated upon generation of an S signal and the charging pumps inject high concentration boric acid solution from the BIT into the RCS cold legs. The

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charging pump flow functions to replace RCS inventory that is being lost through the ruptured steam generator tube, to provide a heat sink which helps absorb decay heat, and to repressurize the RCS. Subsequent to stabilizing plant conditions and satisfying ECCS termination criteria, the operator terminates ECCS operation and initiates plant shutdown operations.

6.3.3.3.2 Loss-of-Coolant Accident

A LOCA is defined as a rupture of the RCS piping or branch piping which results in a decrease in RCS inventory that exceeds the flow capability of the normal makeup system. Ruptures which result in break flow within the capability of the normal makeup system will not result in decreasing RCS pressure and ECCS actuation. The maximum break size for which the normal makeup system can maintain RCS pressure is obtained by comparing the calculated flow from the RCS through the postulated break against the charging pump makeup flow at the normal RCS pressure of 2250 psia. A makeup flowrate from one charging pump is adequate to sustain pressurizer pressure at 2250 psia for a break through a 0.375 inch diameter hole. This break results in a loss of approximately 17.5 lb/s (i.e., 127 gal/min. at 130F and 2250 psia). For breaks less than a 0.375 inch diameter hole, the normal makeup system can maintain RCS pressure and permit the operator to execute an orderly shutdown.

For the purpose of evaluation, the spectrum of postulated piping breaks in the RCS is divided into major pipe breaks (large break) and minor pipe breaks (small break). The large break is defined as a rupture with a total cross-sectional area equal to or greater than 1.0 ft^2. The small break is defined as a rupture with a total cross-sectional area less than 1.0 square feet but larger than the 0.375-inch diameter hole. Refer to subsection 15.6.5 for a detailed description of this accident, including acceptance criteria and analytical results.

For this accident, the ECCS is actuated upon receipt of an S signal. Once actuated, the ECCS will mitigate the spectrum of LOCA accidents but its performance will vary, depending on the LOCA transient. The charging pumps function to immediately inject high concentration boric acid solution from the BIT followed by the lower concentration borated water from the RWST. The RHR pumps function to start delivering borated water from the RWST when the RCS depressurizes to approximately 200 psia. The accumulators begin to inject when the RCS depressurizes to approximately 600 psia. During the LOCA transient, flow to the RCS is dependent on the RCS pressure transient. The ECCS water injected into the RCS provides for heat transfer from the core, prevents excessive fuel clad temperatures and eventually accomplishes core reflood (large break) or core recovery (small break). The LOCA analyses do not take credit for the boron content of the injected water.

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Following completion of core reflood (large break) or core recovery (small break), the ECCS continues to supply water to the RCS for long term cooling. After the water level in the RWST reaches the low-low level setpoint, switchover to cold leg recirculation is initiated automatically and completed by manual operator action as discussed in paragraph 6.3.2.8. This permits continued cooling of the core by recirculation of the spilled water in the containment recirculation sumps. | 253
At approxlmately 7 hours after initiation of the LOCA, the ECCS is manually realigned in the hot leg recirculation mode to | 51
control boric acid concentration in the reactor vessel, "In the event of a cold leg break. Approximately, 10 hours after switching to hot leg recirculation mode, the ECCS is realigned to the RCS cold legs to control boric acid concentration in the reactor vessel in the event of a hot leg break. 382
After that, at 10 hour intervals, the ECCS is cycled back and forth from cold to hot leg recirculation mode. Note, that in the event of a failure of the 8889 MDV, and the RHR pumps are realigned to inject to the RCS cold legs while the charging pumps are aligned to the RCS hot legs, there is no requirement to cycle. Simultaneous hot and cold leg injection will preclude boron precipitation and ensure long term cooling." 51

Figure 6.3-2 provides process flow diagrams which illustrate ECCS performance for the various modes of system operation.

6.3.3.4 Use of Dual function Components

The ECCS contains components which have no other operating function, as well as components which are shared with other systems. Components in each category are as follows.

A. Components of the ECCS which perform no other function are:

1. One accumulator for each loop which discharges borated water into its respective cold leg of the reactor coolant loop piping | 462

2. Two boron injection recirculation pumps, one of which continuously circulates the 12 weight percent boric acid solution through the BIT

3. One BIT

4. One boron injection surge tank

5. Associated piping, valves and instrumentation

6. One positive displacement hydrostatic test pump.

B. Components which also have a normal operating function are as follows:

1. Two RHR pumps and two residual heat exchangers

These components are normally used for core decay heat removal during the latter stages of normal plant shutdown and when the reactor is held at cold shutdown or refueling conditions. During all other plant operating modes, they are aligned to perform the low head injection function.

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2. Three charging pumps

   These pumps are normally aligned for charging service with suction from the VCT. As a part of the CVCS, the normal operation of these pumps is discussed in subsection 9.3.4.

3. One refueling water storage tank

   This tank is used to fill the refueling canal for refueling operations and to provide makeup to the spent fuel pool. However, during all other plant operating periods it is aligned to the suction of the RHR pumps. The charging pumps are automatically aligned to the suction of the RWST upon receipt of an S signal or a VCT low level signal.

Under safety grade conditions, portions of the ECCS may be used for boration and makeup. All actions required to align the ECCS for safety grade cold shutdown operations are accomplished remotely by the operator from the control room. For a safety grade cold shutdown, the charging pumps are aligned to deliver borated water from the boric acid tanks or the RWST to the RCS cold legs, via one of the high head safety injection headers. For ECCS operation, the charging pump suction is automatically aligned to take suction from the RWST and inject the water via the BIT header. The extent to which the ECCS is used as part of the cold shutdown design is discussed in more detail in subsection 5.4.7.

An evaluation of all components required for operation of the ECCS demonstrates that either:

A. The component is not shared with other systems, or

B. If the component is shared with other systems, it is either aligned during normal plant operation to perform its accident mitigation function or if not aligned to perform its accident mitigation function, two valves in parallel are provided to align the system for injection, and two valves in series are provided to isolate portions of the system not utilized for injection. These valves are automatically actuated by the S signal.

Table 6.3-8 provides a shared function evaluation that indicates the alignment of components during normal operation, and the realignment required to perform the accident function.

In all cases of component operation, safety injection has the priority usage such that an S signal will override all other signals and start or align systems for injection.

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6.3.3.5 Limits on System Parameters

The analyses show that the design basis performance characteristic of the ECCS is adequate to meet the requirements for core cooling following an accident with the minimum ESF equipment operating. In order to ensure this capability in the event of the simultaneous failure to operate any single active component, technical specifications are established for reactor operation.

Normal operating status of ECCS components is given in table 6.3-9.

The ECCS components are available whenever the coolant energy is high and the reactor is critical. During low temperature physics tests there is a negligible amount of stored energy in the coolant and low decay heat; therefore, an accident comparable in severity to accidents occurring at operating conditions is not possible and ECCS components are not required.

The principal system parameters and the number of components which may be out of operation in test, quantities, and concentrations of coolant available, and allowable time in a degraded status are provided in ITS Chapter 1 3.5.1 ~ 3.5.6. 357
If efforts to restore the operable status of the ECCS is not accomplished within technical specification requirements, the plant is required to be placed in a lower operational mode (i.e., hot standby to hot shutdown, hot shutdown to cold shutdown, etc.)

6.3.4 TESTS AND INSPECTIONS

6.3.4.1 ECCS Performance Tests

Preoperational testing of the ECCS can be conducted during the hot-functional testing of the RCS following flushing and hydrostatic testing, with the system cold and the reactor vessel head removed. The ECCS would be aligned for normal power operation. During the test, the pumps would inject into the reactor vessel, via the RCS cold legs, with the overflow from the reactor vessel spilling into the refueling canal. Simultaneously, the safety injection block switch is reset and the breakers on the lines supplying offsite power are tripped manually so that operation of the emergency diesels is tested in conjunction with the ECCS. This test should provide information including the following facets:

A. Satisfactory S signal generation and transmission

B. Proper operation of the emergency diesel generators, including sequential load pickup

C. Pump starting times

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D. Pump delivery rates at runout conditions (one point on the operating curve)

E. Valve operating times.

Separate flow tests of the ECCS RHR and charging pumps are conducted during the operational startup testing (with the reactor vessel head off) to check capability for sustained operation. Each pump would be aligned to take suction from the RWST and to discharge into the reactor vessel through the injection lines, with the overflow from the reactor vessel spilling into the refueling canal. Data will be taken to determine pump head and flow at this time. Pumps will then be run with only the miniflow circuits open and data taken to determine a second point on the head/flow characteristic curve.

Each accumulator is filled with water from the RWST and pressurized with nitrogen with the motor-operated valve on the discharge line closed. The valve is opened and the accumulator allowed to discharge into the reactor vessel as part of the operational startup testing with the reactor cold and the vessel head off.

See chapter 14 for a description of the testing program.

6.3.4.2 Reliability Tests and Inspections - Description of Tests Planned

Routine periodic testing of the ECCS components and all necessary support systems at power is planned. Valves which operate after a LOCA are operated through a complete cycle, and pumps are operated individually in this test on their miniflow lines except the charging pumps which are tested by their normal charging function. If such testing indicates a need for corrective maintenance, the redundancy o equipment in these systems permits such maintenance to be performed without shutting down or reducing load under certain conditions. These conditions include considerations such as a period within which the component should be restored to service and the capability of the remaining equipment to provide the minimum required level of performance during such a period.

The series check valves between the accumulator and the RCS are tested to verify that each of the series check valves can independently sustain differential pressure across its disc, and also verify that the valve is in its closed position. The required periodic tests are performed after each refueling just prior to plant startup, after the RCS has been pressurized.

The series check valves in the RHR pump cold leg injection lines form the high pressure to low pressure isolation barrier between the RCS and ECCS piping outside the reactor containment.

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Periodic testing of these check valves must be performed to provide assurance that certain postulated failure modes will not result in a loss of coolant from the low pressure system outside containment with a simultaneous loss of ECCS pumping capacity. The tests performed verify that each of the series check valves can independently sustain differential pressure across its disc, and also verify that the valve is in its closed position. The required periodic tests are to be performed after each refueling just prior to plant startup, after the RCS has been pressurized.

To implement the periodic component testing requirements, ITS Chapter 1 3.5.1 ~ 3.5.6. have been established. During periodic system testing, a visual inspection of pump seals, valve packings, flanged connections, and relief valves is made to detect leakage. Inservice inspection provides further confirmation that no significant deterioration is occurring in the ECCS pressure boundary. 357

Design measures have been taken to assure that the following testing can be performed:

A. Active components may be tested periodically for operability (e.g., pumps on miniflow, certain valves, etc.).

B. An integrated system actuation test can be performed when the plant is cooled down and the RHRS is in operation. The ECCS will be arranged so that no flow will be introduced into the RCS for this test. Detailed discussion of S signal testing provisions is provided in section 7.2.

C. An initial flow test of the full operational sequence can be performed.

The design features which ensure this test capability are specifically:

A. Power sources are provided to permit individual actuation of each active component of the ECCS.

B. The RHR pumps are used every time the RHRS is put into operation. They can also be tested periodically when the plant is at power using the miniflow recirculation lines.

C. The charging pumps are either normally in use for charging service or can be tested periodically on miniflow.

D. Remote-operated valves can be exercised during routine plant maintenance.

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E. Level and pressure instrumentation is provided for each accumulator tank, for continuous monitoring of these parameters during plant operation.

F. Flow from each accumulator tank can be directed through a test line in order to verify isolation valve position. The test line can be used, when the RCS is pressurized, to ascertain backleakage through the accumulator check valves.

G. A flow indicator is provided in the RHR pump headers. Pressure instrumentation is also provided in these lines.

H. An integrated system test can be performed when the plant is cooled down and the RHRS is in operation. This test does not introduce flow into the RCS but does demonstrate the operation of the valves, pump circuit breakers, and automatic circuitry including diesel starting and the automatic loading of ECCS components on the diesels (by simultaneously simulating a loss of offsite power to the vital electrical buses).

ITS Chapter 1 3.5.1 ~ 3.5.6. specify requirements for test frequency, acceptability of testing, and measured parameters. A description of the inservice inspection program is also included in the technical specifications. ECCS components and systems are designed to meet the intent of ASME B&PV Code, Section XI, for inservice inspection. 357

6.3.5 INSTRUMENTATION REQUIREMENTS

Instrumentation and associated analog and logic channels employed for initiation of ECCS operation is discussed in section 7.3. This section describes the instrumentation employed for monitoring ECCS components during normal plant operation and also ECCS post-accident operation. All alarms are annunciated in the control room.

6.3.5.1 Temperature Indication

6.3.5.1.1 Boron Injection Tank Temperature

Duplicate temperature control channels are provided for the BIT electric strip heaters. Both actuate high and low temperature alarms on the main control board and provide local indication.

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6.3.5.1.2 Residual Heat Exchanger Temperature

The fluid temperature at the inlet and outlet of each residual heat exchanger is recorded on the main control board. The temperatures are recorded by a dual-point recorder to indicate the delta temperature reduction of RHR flow.

6.3.5.1.3 Boron Injection Surge Tank Temperature

The tank is supplied with one temperature detector which provides heater control for the immersion heater and both indication and high and low temperature alarms in the control room.

6.3.5.2 Pressure Indication

6.3.5.2.1 Boron Injection Tank Pressure

Boron injection tank outlet pressure is indicated in the control room. A high pressure alarm is provided in the control room.

6.3.5.2.2 Accumulator Pressure

Duplicate pressure channels are installed on each accumulator. Pressure indication and high and low pressure alarms are provided by each channel in the control room.

6.3.5.2.3 Test Line Pressure

Local pressure indication in the common check valve test line provides indication of RCS back leakage during the check valve leakage test.

6.3.5.2.4 Hydrotest Pump Discharge Pressure

Local pressure indication is provided to monitor hydrotest pump discharge pressure.

6.3.5.2.5 Residual Heat Removal Pump Discharge Pressure

RHR discharge pressure for each pump is indicated in the control room. A high pressure alarm is actuated by each channel.

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6.3.5.2.6 Residual Heat Removal Pump Inlet Pressure

A pressure indicator is locally mounted in each RHR pump suction line to be used for pump performance evaluation and evaluation of suction conditions when required.

6.3.5.2.7 Centrifugal Charging Pump Discharge Pressure

A local pressure indicator is mounted in each centrifugal charging pump's discharge line.

6.3.5.2.8 Centrifugal Charging Pump Inlet Pressure

A local pressure indicator is mounted in each centrifugal charging pump's inlet line.

6.3.5.2.9 Boron injection Recirculation pump inlet pressure

1 A local pressure indicator is mounted in each pump's inlet line

6.3.5.2.10 Boron injection Recirculation Pump Discharge Pressure

A local pressure indicator is mounted in each pump's discharge line.

6.3.5.3 Flow Indication

6.3.5.3.1 Boron Injection Tank Recirculation Flow

Recirculation flow through the BIT is indicated locally. A low flow alarm is provided on the main control board.

6.3.5.3.2 Charging Pump Injection Flow

Charging pump injection and recirculation header flow is indicated on the main control board.

6.3.5.3.3 Residual Heat Removal Return Line Flow

A flow switch with local indication is provided in the discharge of each RHR pump. This switch controls the miniflow isolation valve to assure adequate pump protection.

A flow transmitter is provided in each of the RHR cold leg discharge lines. These transmitters control the flow control valves downstream of the RHR heat exchangers to maintain a constant RCS return flow during normal cooldown. A main control board mounted indicator with a low flow alarm is provided for each to monitor cooldown flow.

6.3.5.3.4 Test Line Flow

There are two locally mounted flow indicators provided in the common check valve test line to indicate RCS back leakage during check valve leakage test.

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6.3.5.3.5 Residual Heat Removal Pump Hot Leg Recirculation Flow

The hot leg recirculation header flow from the RHR pumps to the RCS hot legs is indicated in the control room.

6.3.5.3.6 Residual Heat Removal Pump Minimum Flow

A flowmeter installed in each RHR pump discharge line provides control for the valve located in the pump minimum flow line. Each flowmeter has an indicator and low flow alarm in the control room to monitor cooldown flow.

6.3.5.4 Level Indication

6.3.5.4.1 Refueling Water Storage Tank Level

Six water level indicating channels, two narrow range (non-safety related) and four wide range (safety related) with indicators and alarms in the main control room, are provided for the RWST. One narrow range indicator monitors and alarms the high and low level setpoints. The second narrow range indicator monitors the empty level setpoint. The four wide range level indicating channels monitor the RWST water level from below the empty level setpoint to above the high level setpoint. In addition, these four wide range indicating channels alarm the low-low level setpoint and the empty level setpoint (see figure 9.2-18 for alarm setpoints).

The low level alarm is provided to ensure that a sufficient volume of water is always available in the RWST in conformance with the technical specifications.

The low-low level signal initiates the semi-automatic ECCS switchover and the alarm alerts the operator to perform the manual action required to realign the ECCS system from the injection mode to the recirculation mode. The empty alarm indicates that the usable tank inventory is almost exhausted and alerts the operator to manually realign the containment spray pumps from the RWST to the containment emergency sumps. For additional discussion on RWST level instrumentation and water volumes see section 9.2.8.

6.3.5.4.2 Accumulator Water Level

Duplicate water level channels are provided for each accumulator. Both channels provide indication and actuate high and low water level alarms in the control room.

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6.3.5.4.3 Boron Injection Surge Tank Level

Two level indicators give local indication and provide high and low level alarms in the control room.

6.3.5.5 Operating Status Indication

6.3.5.5.1 Pumps

The operating status of ECCS pumps is indicated on the control board by red (running) and green (stopped) lights that are integral with the pump switch assembly for each pump. Pump operating status is also indicated by monitor lights which are grouped in a common portion of the control board. The operating status of each ECCS pump is indicated by its monitor light which is dark (stopped) or bright (running), depending on pump operating status.

6.3.5.5.2 Valves

The position of ECCS valves is indicated on the control board by red (open) and green (closed) lights that are integral with the valve switch assembly for each valve. Valve position is also indicated by monitor lights which are grouped in a common portion of the control board. The position of each valve is indicated by its monitor light which is dark (valve in proper position of ECCS operation) or bright (valve in improper position for ECCS operation). The position indication lights for motor-operated valves are controlled by motor operator limit switches. For air-operated valves, these lights are controlled by stem-mounted limit switches.

The accumulator motor-operated valves have additional position indication. For each valve, an alarm annunciator point is activated by both a motor operator limit switch and a stem-mounted limit switch whenever an accumulator valve is not fully open for any reason with the system at pressure (the pressure at which the safety injection block is unblocked is approximately 1950 psig). A separate annunciator point is used for each accumulator valve. The alarm activated by the stem-mounted limit switch will be recycled at approximately one-hour intervals to remind the operator of the improper valve lineup, until corrective action is taken.

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Table 6.3-1

EMERGENCY CORE COOLING SYSTEM
COMPONENT PARAMETERS (Sheet 1 of 4)

Accumulators		
Number	3	
Design pressure, psig	700	
Design temperature, °F	300	
Operating temperature, °F	100-150	
Nominal operating pressure, psig	660	
Total volume, ft^3	1,450 each	
Nominal water volume, ft^3	1,000 each	
Nominal volume N_2 gas, ft^3	450 each	
Boron concentration, nominal ppm	2,525	51 178
Centrifugal Charging Pumps		
Number	3	
Design pressure, (outlet) psig	2,800	
Design temperature, (outlet) °F	300	
Design flowrate, gal/min.	150	
Design head, ft	5,800	
Maximum flowrate, gal/min	675	
NPSH required at maximum flowrate from RWST, ft	30	159
NPSH available, at maximum flowrate from RWST, ft	30.95	
Design discharge head at shutoff, ft	6,200	
Motor rating, bhp	900	

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Table 6.3-1

EMERGENCY CORE COOLING SYSTEM
COMPONENT PARAMETERS (Sheet 2 of 4)

Hydrotest Pump		
Number	1	
Design pressure, psig	3,300	
Design temperature, °F	300	
Normal operating temperature, °F	Ambient	
Design flow rate, gal/min	24.5	
Developed head at design flow rate, ft	7,188	
Motor rating, bhp	60	
Residual Heat Removal Pumps		
Number	2	
Design pressure, (outlet) psig	600	
Design temperature, (outlet) °F	400	
Design flow rate, gal/min	3,000	
Design head, ft	270	
Maximum flow rate, gal/min	4,500	
Design head at maximum flow rate, ft	200	
Sump NPSH required at maximum flow rate from sump, ft	20	479
Sump NPSH available, at maximum flowrate from sump, ft	27.5	479
Design discharge head at shutoff, ft	325	
Motor rating, bhp	335	

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Table 6.3-1

EMERGENCY CORE COOLING SYSTEM
COMPONENT PARAMETERS (Sheet 3 of 4)

Residual Heat Exchangers	
See subsection 5.4.7 for design parameters)	
Boron Injection Tank	
Number	1
Total volume, gal	900
Usable volume at operating conditions (solution), gal	900
Boron concentration nominal, ppm	21,000
Design pressure, psig	2,735
Operating pressure, ft	100
Design temperature, °F	300
Operating temperature, °F	155-175
Heaters	
Number of channels	2
Capacity, each channel, kW	6
Type	Strip
Boron Injection Surge Tank	
Number	1
Total volume, gal	75
Boron concentration nominal, ppm	21,000
Design pressure, psig	Atm
Operating pressure, psig	Atm
Design temperature, °F	200

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Table 6.3-1

EMERGENCY CORE COOLING SYSTEM
COMPONENT PARAMETERS (Sheet 4 of 4)

Boron Injection Surge Tank (Cont)	
Operating temperature, °F	155-175
Heaters	
Number of channels	1
Capacity, kW	6
Type	Immersion
Boron Injection Recirculation Pump	
Number	2
Design pressure, psig	150
Design temperature, °F	250
Design flowrate, gal/min	20
Design head, ft	100
Normal operating temperature, °F	155-175
Motor rating, bhp	4
Refueling Water Storage Tank	
(See subsection 9.2.8)	
Motor-Operated Valves	
	<u>Maximum Opening or Closing Time</u>
Up to and including 8 inches, time (sec)	15
Over 8 inches, rate (in/min)	49
Air-operated valves maximum closing time (sec)	10

Table 6.3-2

EMERGENCY CORE COOLING SYSTEM RELIEF VALVE DATA

Description	Fluid Discharged	Fluid Inlet Temperature Normal	Set Pressure (psig)	Back Pressure (psig) Constant	Back Pressure (psig) Buildup	Capacity
N_2 supply to accumulators	N_2	120	700	0	0	2743 **standard** ft^3**/min**
BIT relief	12% boric acid	165	2,735	3	12	20 **gal/min**
RHR pump safety injection lines	Water	120	600	7	50	20 **gal/min**
Accumulator to containment	N_2 gas	120	700	0	0	1500 **standard** ft^3**/min**
Hydrotest pump discharge	Water	100	700	5	20	25 **gal/min**

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Table 6.3-3

MOTOR-OPERATED ISOLATION VALVES IN THE
EMERGENCY CORE COOLING SYSTEM (Sheet 1 of 2)

Location	Valve ID	Interlocks	Automatic Features	Position Indication	Alarms
Accumulator	8808A,B,C	S signal, RCS pressure > unblock	Opens on S signal if closed and RCS pressure > unblock	Main control board (MCB)	Yes - out of position
Recirculation sump	8811A,B 8812A,B	S signal, RWST low-low signal	Opens on coincident S and RWST low-low signals	MCB	Yes - out of position
Charging pump suction from RWST	LCV-115B,D	S signal	Opens on S signal	MCB	Yes - out of position
Charging pump normal suction	LCV-115C,E	S signal	Closes on S signal if charging pump suction from RWST open	MCB	Yes - out of position
Charging pump discharge	8107, 8108	S signal	Closes on S signal	MCB	Yes - out of position
BIT suction	8803A,B	S signal	Opens on S signal	MCB	Yes - out of position
	8892	None	None	MCB	Yes - out of position
BIT discharge	8801A,B	S signal	Opens on S signal	MCB	Yes - out of position
RWST to RHR pump suction	8809A,B	Sump suction valves	Closes on "open" signal from valves 8811A,B and 8812A,B	MCB	Yes - out of position
Charging pump miniflow	8109A,B,C 8106	S signal	Closes on S signal	MCB	Yes - out of position
Charging pump hot leg recirculation	8884, 8886	None	None	MCB	Yes - out of position
Charging pump cold leg recirculation	8885, 8891	None	None	MCB	Yes - out of position
RHR pump crossover	8887A,B	None	None	MCB	Yes - out of position
RHR pump cold leg recirculation	8888A,B	None	None	MCB	Yes - out of position

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Table 6.3-3

MOTOR-OPERATED ISOLATION VALVES IN THE
EMERGENCY CORE COOLING SYSTEM (Sheet 2 of 2)

Location	Valve ID	Interlocks	Automatic Features	Position Indication	Alarms
RHR pump hot leg recirculation	8889	None	None	MCB	Yes - out of position
RHR discharge to charging pump suction	8706A,B	Cannot be opened unless at least one RHR HL suction isolation valve in corresponding subsystem is closed	None	MCB	Yes - out of position
Charging pump suction crossover	8130A,B 8131A,B	None	None	MCB	Yes - out of position
Charging pump discharge crossover	8132A,B 8133A,B	None	None	MCB	Yes - out of position

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Table 6.3-4

MATERIALS EMPLOYED FOR
EMERGENCY CORE COOLING SYSTEM COMPONENTS (Sheet 1 of 2)

Component	Material
Accumulators	Carbon steel, clad with stainless steel
Boron injection tank	Stainless steel
Boron injection surge tank	Stainless steel
Pumps	
Centrifugal charging pump	Stainless steel
Residual heat removal pump	Stainless steel
Boron injection recirculation pump	Stainless steel
Residual heat exchangers	
Shell	Carbon steel
Sheel end cap	Carbon steel
Tubes	Stainless steel
Channel	Stainless steel
Channel cover	Stainless steel
Tubesheet	Stainless steel
Valves	
Motor-operated valves containing radioactive fluids	
Pressure-containing parts	Stainless steel or equivalent
Body-to-bonnet bolting and nuts	Low alloy steel

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Table 6.3-4

MATERIALS EMPLOYED FOR
EMERGENCY CORE COOLING SYSTEM COMPONENTS (Sheet 2 of 2)

Component	Material
Seating and surfaces	Stellite Number 6 or equivalent
Stems	Stainless steel or 17-4 PH stainless
Diaphragm valves	Stainless steel
Accumulator check valves	
Parts contacting borated water	Stainless steel
Clapper arm shaft	17-4 PH stainless
Relief valves	
Stainless steel bodies	Stainless steel
Carbon steel bodies	Carbon steel
All nozzles, discs, spindles, and guides	Stainless steel
Bonnets for stainless steel valves without a balancing bellows	Stainless steel or plated carbon steel
All other bonnets	Carbon steel
Piping	
All piping in contact with borated water	Stainless steel

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Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 1 of 13)

Component(a)	Failure Mode	Function(b)	Effect on System Operation(b)	Failure Detection Method(c)	Remarks(b)
1. Motor-operated gate valve LVC-115C (LCV-115E analogous)	Fails to close on demand	Provides isolation of fluid discharge from the VCT to the suction of charging pumps.	Failure reduces redundancy of providing tank discharge isolation. Negligible effect on system operation. Alternate isolation valve LCV-115E (LCV-115C) provides backup VCT discharge isolation.	Valve open/close position indication and valve close position monitor light and alarm for group monitoring of components at MCB.	Valve is electrically interlocked with isolation valve LCV-115B (LCV-115D) and the instrumentation that monitors fluid level of the VCT. Valve closes upon receipt of an S signal or upon receipt of a VCT low water level signal, providing that isolation valve LCV-115B (LCV-115D) is at full open position.
2. Motor-operated gate valve LCV-115B (LCV-115D analogous)	a. Fails to open on demand	Provides isolation of fluid discharge from the RWST to the suction of charging pumps, and an electrical interlock to the closing of isolation valve LCV-115C (LCV-115E).	a. Failure reduces redundancy of providing fluid flow from RWST to suction of charging pumps. Negligible effect on system operation. Alternate isolation valve LCV-115D (LCV-115B) opens to provide backup flow path to suction of charging pumps.	Valve open/close position indication and valve open position monitor light and alarm for group monitoring of components at MCB.	Valve is electrically interlocked with the instrumentation that monitors fluid level of the VCT. Valve opens upon receipt of an S signal or upon receipt of a VCT low water level signal.

a. See notes at end of table.

b. See list at end of table for definition of acronyms and abbreviations used.

c. As part of plant operation, periodic tests, surveillance inspections, and instrument calibrations are made to monitor equipment and performance. Failures may be detected during such monitoring of equipment in addition to detection methods noted.

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Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 2 of 13)

Component[a]	Failure Mode	Function[b]	Effect on System Operation[b]	Failure Detection Method[c]	Remarks[b]
	b. Fails to close on demand		b. Failure reduces redundancy of providing isolation of fluid discharged from residual heat exchanger 1 (exchanger 2) to RWST. No immediate effect on system operation during recirculation. Alternate isolation check valve 8926 (8927) in line from RWST provides backup tank isolation.		
3. Centrifugal charging pump 1 (pump 3 analogous)	Fails to deliver working fluid	Provides fluid flow of emergency coolant through the BIT to the RCS at the prevailing incident RCS pressure.	Failure reduces redundancy of providing emergency coolant to the RCS at high RCS pressures. Fluid flow from charging pump 1 (pump 3) will be lost. Minimum flow requirements for HHSI will be met by charging pump 3 (pump 1).	Charging pump discharge header pressure and flow indication at MCB. Open/close pump switchgear circuit breaker indication on MCB. Circuit breaker close position monitor light for group monitoring of component at MCB. Common breaker trip alarm at MCB.	Two charging pumps start upon receipt of an S signal. Charging pump 2 is lined up on solid-state protection system (SSPS) train A when replacing pump 1, or on SSPS train B when replacing pump 3. Replacement requires operator action for the line up of pump and isolation valves.
4. Motor-operated gate valve 8106	Fails to close on demand	Provides isolation of fluid flow from the charging pump minimum-flow bypass line to the seal water heat exchanger minimum-flow bypass line.	Failure reduces redundancy of providing isolation of charging pump mini-flow line. Negligible effect on system operation. Alternate isolation valves 8109A and 8109C in charging pump minimum flow bypass lines provide backup mini-flow line isolation.	Same as item 1.	Valve closes upon receipt of an S signal.

Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS
OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 3 of 13)

Component[a]	Failure Mode	Function[b]	Effect on System Operation[b]	Failure Detection Method[c]	Remarks[b]
5. Motor-operated globe valve 8109A (8109C analogous)	Fails to close on demand	Provides isolation of fluid flow from charging pump 1 (pump 3) to the seal water heat exchanger via minimum-flow bypass line.	Failure reduces redundancy of providing isolation of charging pump miniflow line. Negligible effect on system operation. Alternate isolation valve 8106 provides backup miniflow line isolation.	Same as item 1.	Valve closes upon receipt of an S signal. Valve 8109B provides isolation to miniflow line if charging pump 2 is on line. Analysis for this valve being in service is analogous to that presented for valves 8109A and 8109C.
6. Motor-operated gate valve 8107 (8108 analogous)	Fails to close on demand	Provides isolation of fluid flow from the charging pump discharge header to the CVCS normal charging line to the RCS.	Failure reduces redundancy of providing isolation of HHSI charging pump discharge to normal charging line of CVCS. Negligible effect on system operation. Alternate isolation valve 8108 (8107) provides backup normal CVCS charging line isolation.	Same as item 1 except no valve close monitor alarm for group monitoring.	Same as item 4.
7. Motor-operated gate valve 8130A (8130B analogous).	Fails to close on demand	Provides isolation barrier to form two independent flow paths in the event of a single passive failure.	No effect on system operation. Isolation barrier is provided by closing of alternate isolation valve 8130B (8130A).	Same as item 1.	The normal operating position of the valve during recirculation is open.
8. Motor-operated gate valve 8131A (8131B analogous).	Fails to close on demand	Provides isolation barrier to form two independent flow paths in the event of a single passive failure.	No effect on system operation. Isolation barrier is provided by closing of alternate isolation valve 8131B (8131A).	Same as item 1.	The normal operating position of the valve during recirculation is open.

Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 4 of 13)

Component[a]	Failure Mode	Function[b]	Effect on System Operation[b]	Failure Detection Method[c]	Remarks[b]
9. Motor-operated gate valve 8132A (8132B analogous).	Fails to close on demand	Provides protection against charging pump runout. Also provides an isolation barrier to form two independent flow paths in the event of a single passive failure.	No effect on system operation. Charging pump runout protection is provided by closing of alternate isolation valve 8132B (8132A).	Same as item 1.	The normal operating position of the valve during recirculation is closed if charging pump 1 and charging pumps 2 or 3 are on line and are in operation.
10. Motor-operated gate valve 8133A (8133B analogous).	Fails to close on demand	Provides protection against charging pump runout. Also provides an isolation barrier to form two independent flow paths in the event of a single passive failure.	No effect on system operation. Charging pump runout protection is provided by closing of alternate isolation valve 8133B (8133A).	Same as item 1.	The normal operating position of the valve during recirculation is closed if charging pump 3 and charging pumps 1 or 2 are on line and are in operation.
11. Motor-operated gate valve 8803A (8803B analogous)	a. Fails to open on demand	Provides isolation of fluid flow from the charging pump discharge header to the inlet of the BIT.	a. Failure reduces redundancy of providing fluid flow from charging pump discharge header to BIT. Negligible effect on system operation. Alternate isolation valve 8803B (8803A) opens to provide backup flow path to BIT.	Same as item 2. In addition, pressure of BIT discharge line indicated at MCB.	a. Valve opens upon receipt of an S signal.
	b. Fails to close on demand		b. Failure reduces redundancy of providing isolation of fluid flow from charging pump discharge header to BIT negligible effect on system operation. Alternate isolation valves 8801A and 8801B provide backup isolation of fluid flow.		b. Valves are closed by the reactor operator for recirculation into hot legs of RCS coolant loops, and valve 8803B (8803A) is opened by the operator when recirculation into cold legs of RCS coolant is desired during long term incident recovery period.

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Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 5 of 13)

Component(a)	Failure Mode	Function(b)	Effect on System Operation(b)	Failure Detection Method(c)	Remarks(b)
12. Motor-operated gate valve 8801A (8801B analogous)	a. Fails to open on demand	Provides isolation of fluid discharge from the BIT to high head injection header connected to the cold legs of RCS coolant loops.	a. Failure reduces redundancy of providing fluid low from BIT to high head injection header feeding the cold legs of RCS loops. Negligible effect on system operation. Alternate isolation valve 8801B (8801A) opens to provide backup flow path to header.	Same as item 2.	a. Same as item 11.
	b. Fails to close on demand		b. Failure reduces redundancy of providing isolation of fluid flow from BIT to cold legs of RCS coolant loops. Negligible effect on system operation. Alternate isolation valves 8803A and 8803B provide backup isolation of fluid flow from BIT to RCS cold legs.		b. Valves are closed by the reactor operator for recirculation into hot legs of RCS coolant loops and valve 8801B (8801A) is opened by the operator when recirculation into cold legs of RCS coolant is desired during long term incident recovery period.
13. Air-operated globe valve 8945A (8945B analogous)	Fails to close on demand	Provides isolation of fluid discharge from the BIT discharge line to the inlet line of the boron injection surge tank (BIST).	Failure reduces redundancy of providing isolation of fluid flow from BIT to the BIST. Negligible effect on system operation. Alternate isolation valve 8945B (8945A) provides backup BIST isolation.	Same as item 6.	Valves designed to fail closed and are electrically wired so that electrical solenoid of air diaphragm operator is energized to open the valves. Electrical solenoid is deenergized upon receipt of an "S" signal.

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Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS
OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 6 of 13)

Component[a]	Failure Mode	Function[b]	Effect on System Operation[b]	Failure Detection Method[c]	Remarks[b]
14. Air-operated globe valve 8942	Fails to close on demand	Provides isolation of fluid discharge from the BIT inlet line to the discharge header of the boron injection recirculation (BIR) pumps.	Failure reduces redundancy of providing isolation of fluid flow from BIT inlet line to header of BIR pumps. Negligible effect on system operation. Alternate isolation check valves 8940A and 8940B in discharge lines from BIR pumps provide backup isolation against fluid flow from the BIT inlet line.	Same as item 6.	Same as item 13.
15. Motor-operated gate valve FCV-602A (FCV-602B analogous)	a. Fails open	Provides regulation of fluid flow through miniflow bypass line to suction of residual heat removal (RHR) pump 1 (pump 2) to protect against overheating and loss of the pump.	a. Failure reduces working fluid delivered to RCS from RHR pump 1 (pump 2). Minimum flow requirements for RHR pump 2 (pump 1) delivering working fluid to RCS.	Same as item 1. In addition, pump discharge header pressure and flow indication at MCB.	Valves are regulated by signals from a flow transmitter located in each pump discharge header. The control valves open when a RHR pump discharge flow is less than 500 gal/min and close when the flow exceeds 1,000 gal/min.
	b. Fails closed		b. Failure results in an insufficient fluid flow through RHR pump 1 (pump 2) for a small LOCA or steam break, resulting in possible pump damage. Minimum flow requirements will be met by RHR pump 2 (pump 1) and charging pump 3 (pump 1) delivering coolant fluid to RCS.		

Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS
OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 7 of 13)

Component(a)	Failure Mode	Function(b)	Effect on System Operation(b)	Failure Detection Method(c)	Remarks(b)
16. Residual heat removal pump 1 (pump 2)	Fails to deliver working fluid	Provides fluid flow to the RCS when the incident RCS loop pressure drops below shutoff head of pump (N160 psig), and provides long term recirculation capability for core cooling following the injection phase of LOCA.	Failure reduces redundancy of providing emergency coolant to the RCS at low RCS pressure. Fluid flow from RHR pump 1 (pump 2) will be lost. Minimum flow requirement for LHSI will be met by RHR pump 2 (pump 1).	Same as that stated for item 3 except RHR pump discharge pressure and flow indication at MCB.	The RHR pumps are used to deliver reactor coolant through the residual heat exchanger to meet the plant cooldown requirements, and are used during plant cooldown and startup operation. The RHR pumps start upon receipt of an S signal.
17. Motor-operated gate valve 8811A (8811B analogous)	Fails to open on demand	Provides isolation of fluid flow from containment sump to suction line of RHR pump 1 (pump 2).	Failure reduces redundancy of providing fluid flow from the containment sump to the RCS. RHR pump 1 (pump 2) not available for recirculation. Minimum flow requirements will be met by RHR pump 2 (pump 1) through opening of isolation valves 8811B and 8812B (8811A and 8812A). Negligible effect on system operation.	Same as item 2.	Valves open automatically on receipt of a 2/4 RWST low-low level signal in coincidence with S signal being present (i.e., latched in). Administrative procedures require reactor operator to verify opening of sump isolation valves.
18. Motor-operated gate valve 8812A (8812B analogous)	Fails to open on demand	Same as item 17.	Same as item 17.	Same as item 2.	Same as item 17.
19. Motor-operated gate valve 8809A (8809B) analogous)	Fails to close on demand	Provides isolation of fluid discharge from the RWST to suction line of RHR pump 1 (pump 2).	Failure reduces redundancy of providing RWST isolation from suction line of RHR pump 1 (pump 2). Negligible effect on system operation.	Same as item 1.	Valve closes automatically on receipt of "open" signal from both valves 8811A and 8812A (8811B and 8812B).

Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 8 of 13)

Component[d]	Failure Mode	Function[b]	Effect on System Operation[b]	Failure Detection Method[c]	Remarks[b]
			A series check valve 8958A (8958B) provides backup isolation against fluid flow from the suction of RHR pump 1 (pump 2) to the RWST.		
20. Motor-operated gate valve 8887A (8887B analogous)	a. Fails to close on demand	Controls the LHSI system resistance to prevent RHR pump runout by blocking flow paths. Provides separation between two independent flow paths outside containment during cold leg recirculation. Directs LHSI flow to hot legs during hot leg recirculation.	a. Failure reduces redundancy to prevent excessive pump runout during cold leg recirculation effect on system operation. Isolation valve 8887A (8887A) provide backup isolation to limit RHR pump runout flow.	Same as item 15.	a. During the first 7 hours of long term phase incident recovery, RHR pumps are aligned for injection into cold legs of RCS coolant loops. After 7 hours, pumps are aligned by operator for recirculation flow into the hot legs. "On 10.5 hour intervals following switchover to hot leg recirculation, ECCS cycles from hot to cold leg injection mode unless valve 8889 fails. In that event, RHR injection to cold legs and HHSI pump injection to hot legs precludes the requirement to cycle." 51
	b. Fails to open on demand		b. Failure reduces redundancy of providing fluid flow from RHR pumps for injection into hot legs of RCS loops. Minimum flow requirements will be met by opening of isolation valve 8887B (8887A) and flow from RHR pump 2 (pump 1).		b. Hot leg RCS coolant loop recirculation required to prevent boron precipitation during long term core cooling.
21. Motor-operated gate valve 8888A (8888B analogous)	Fails to close on demand	Provides isolation of fluid flow from RHR pump 1 (pump 2) to cold leg injection header of RCS coolant loops.	Failure reduces flow of recirculation coolant to hot legs of RCS coolant loops from RHR pump 1 (pump 2). Minimum flow requirements to hot leg of RCS coolant loops will	Same as item 15.	

Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 9 of 13)

51

Component[a]	Failure Mode	Function[b]	Effect on System Operation[b]	Failure Detection Method[c]	Remarks[b]
			be met by delivery of coolant from RHR pump 2 (pump 1) and charging pump 3 (pump 1) to the hot legs.		
22. Motor-operated gate valve 8889	a. Fails to open on demand	Provides isolation of fluid flow from RHR pumps to hot leg injection header of RCS coolant loops.	a. Failure prevents fluid flow from RHR pumps to hot leg injection header of RCS coolant loops. Minimum flow requirements to hot legs of RCS coolant loop will be met by delivery of coolant from two charging pumps to the hot legs. "RHR may also be realigned to cold legs to provide additional ECCS flow for core cooling purposes."	Same as item 15.	Same as item 20.
	b. Fails to close on demand		b. Failure reduces redundancy of providing isolation of recirculation fluid into hot legs of RCS coolant loops by RHR pumps. Negligible effect on recirculation into cold legs of RCS coolant loops. Alternate fluid flow isolation provided by closing of isolation valves 8887A and 8887B.		
23. Motor-operated gate valve 8706A (8706B analogous)	Fails to open on demand	Provides isolation of fluid flow from RHR pump 1 (pump 2) via RHR heat exchanger 1 (exchanger 2) to suction line of charging pump 1 (pump 3).	No effect on system operation. Charging pumps 1 and 3 will be provided suction head by RHR pump 2 (pump 1) via valve 8706B (8706A) and the common charging pump suction header.	Same as item 2. In addition, charging pump 1 (pump 3) flow indication at MCB.	Valve cannot be opened unless at least one RHR HL suction isolation valve in corresponding subsystem is closed.

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Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 10 of 13)

Component[(a)]	Failure Mode	Function[(b)]	Effect on System Operation[(b)]	Failure Detection Method[(c)]	Remarks[(b)]
24. Motor-operated gate valve 8885	a. Fails to open on demand	Provides isolation of fluid flow from charging pump 1 discharge line to cold legs of RCS coolant loops.	a. Failure reduces redundancy of providing fluid flow from charging pumps to cold legs of RCS coolant loops. Minimum flow requirements will be met by charging pump 3 providing flow to cold legs via BIT cold leg injection line.	Same as item 2. In addition, charging pump 1 flow indication at MCB.	Valve is positioned open by reactor operator for recirculation into cold legs of RCS coolant loops, and closed by the operator when recirculation into hot legs of RCS coolant loops is desired during long term incident recovery periods.
	b. Fails to close on demand		b. Failure prevents flow delivery of charging pump 1 to RCS hot legs. Minimum flow will be met by charging pump 3 providing flow to its hot leg recirculation flow path.		
25. Motor-operated gate valve 8884 (8886 analogous)	a. Fails to open on demand	Provides isolation of fluid flow from charging pump 1 (pump 3) discharge line to hot legs of RCS coolant loops.	a. Failure reduces redundancy of providing fluid flow from charging to hot legs of RCS coolant loops. Minimum flow requirements will be met by charging pump 3 (pump 1) and RHR pump flow to hot legs of RCS coolant loops.	Same as item 2. In addition charging pump 1 (pump 2) flow indication at MCB.	Valve is positioned open by reactor operator for recirculation into hot legs of RCS coolant loops, and closed by the operator when recirculation into cold legs of RCS coolant loops is desired during long term incident recovery period.

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Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS
OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 11 of 13)

Component[(a)]	Failure Mode	Function[(b)]	Effect on System Operation[(b)]	Failure Detection Method[(c)]	Remarks[(b)]
	b. Fails to close on demand		b. Failure reduces redundancy of providing fluid flow from charging pumps to cold legs of RCS coolant loops during long term incident recovery. Minimum flow requirements will be met by charging pump 3 (pump 1) and RHR pump flow to cold legs of RCS coolant loops.		
26. Air-operated globe valve 8800A (8800B analogous)	Fails to close on demand	Provides isolation of fluid from the RWST outlet to the spent fuel pit cooling system (SFPCS).	Failure reduces redundancy of providing isolation of fluid flow from the RWST. Negligible effect on system operation. Alternate isolation valve 8800B (8800A) provides backup RWST isolation.	Same as item 2, except no valve open monitor alarm for group monitoring.	Same as item 13.
27. Solenoid-operated globe valve HCV-937A	b. Fails to open on demand	Permits throttling of boration flow from charging pumps to cold legs of RCS coolant loops during long term incident recovery.	a. Failure reduces redundancy of providing throttling capability of boration flow. Flow requirements will be met by alternate throttling path through HVC-937B to the cold legs.	Variable setpoint and feedback position indication at MCB. In addition, charging pump flow indication at MCB.	Valve is positioned by reactor operator to throttle boration flow during long term recirculation phase as part of the safety grade cold shutdown function.
	b. Fails to close on demand.		b. No effect on system operation. Containment isolation barrier will be provided by closing of valve 8891.		

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Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS
OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 12 of 13)

Component[(a)]	Failure Mode	Function[(b)]	Effect on System Operation[(b)]	Failure Detection Method[(c)]	Remarks[(b)]
28. Solenoid-operated globe valve HCV-937B	a. Fails to open on demand	Same as item 27.	a. Same as item 27, except for alternate boration path through valve HCV-937A.	Same as item 27.	Same as item 27.
	b. Fails to close on demand		b. Failure reduces redundancy of providing isolation of fluid flow from charging pump discharge header to BIT. Negligible effect on system operation. Alternate isolation valves 8801A and 8801B provide backup isolation of fluid flow.		
29. Motor-operated gate valve 8891	a. Fails to open on demand	Same as item 27.	a. Same as item 27.	Same as item 24.	Valve was added as part of the safety grade cold shutdown function, and is used in conjunction with valve HCV-937A.
	b. Fails to close on demand		b. No effect on system operation. Isolation of fluid flow will be provided by valve HCV-937A. Containment isolation will be provided by check valves 8995A, B, and C.		

Table 6.3-5

EMERGENCY CORE COOLING SYSTEM - SAFEGUARDS OPERATIONS - FAILURE MODES AND EFFECTS ANALYSIS (Sheet 13 of 13)

Component[a]	Failure Mode	Function[b]	Effect on System Operation[b]	Failure Detection Method[c]	Remarks[b]
30. Motor-operated gate valve 8892	Fails to close on demand	Provides capability of isolating BIT following a train A failure. Closure permits throttling of boration flow from charging pump discharge header through valve HCV-937B to cold legs of RCS coolant loops during long term incident recovery.	Negligible effect on system operation. Failure reduces effectiveness of providing throttling capability for boration flow.	Same as item 11.	Valve was added as part of the safety grade cold shutdown function, and permits throttling of boration flow in the event of a Train A failure.

NOTES

1. List of acronyms and abbreviations

BIR - Boron injection recirculation
BIT - Boron injection tank
BIST - Boron injection surge tank
CVCS - Chemical and volume control system
HHSI - High head safety injection
LHSI - Low head safety injection
LOCA - Loss of coolant accident
MCB - Main control board
RCS - Reactor coolant system
RHR - Residual heat removal
RHRS - Residual heat removal system
RWST - Refueling water storage tank
SSPS - Solid state protection system
VCT - Volume control tank

2. Components 1 through 10 are components of the CVCS that perform an ECCS safeguards function.

3. Components 15, 16, and 23 are components of the RHRS that perform an ECCS safeguards function.

4. Components 3, 11, 24, and 27 through 30 are components that perform a safety grade cold shutdown function.

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Table 6.3-6

EMERGENCY CORE COOLING SYSTEM RECIRCULATION PIPING PASSIVE FAILURE ANALYSIS
LONG TERM PHASE

Flow Path	Indication of Loss of Flow Path	Alternate Flow Path
Low Head Recirculation		
From containment sump to low head injection header via the RHR pumps and the residual heat exchangers.	Accumulation of water in a RHR pump compartment or auxiliary building sump.	Via the independent, identical low head flow path utilizing the second residual heat exchanger and RHR pump.
High Head Recirculation		
From containment sump to the high head injection header via RHR pump, residual heat exchanger, and the charging pumps.	Accumulation of water in a RHR pump compartment, the auxiliary building sump, or charging pump compartments.	From containment sump to the high head injection headers via alternate RHR pump, residual heat exchanger, or charging pump.

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Table 6.3-8

EMERGENCY CORE COOLING SYSTEM SHARED FUNCTIONS EVALUATION

Component	Normal Operating Arrangement	Accident Arrangement
Refueling Water Storage Tank	Lined up to suction of RHR pumps.	Lined up to suction of charging and RHR pumps. Valves for alignment to charging pumps meet single failure criteria.
Centrifugal Charging Pumps	Lined up for charging service.	Lined up to inlet of BIT. Valves for realignment meet single failure criteria.
RHR Pumps	Lined up to cold legs of reactor coolant piping.	Lined up to cold-legs of reactor coolant piping.
Residual Heat Exchangers	Lined up to cold legs of reactor coolant piping.	Lined up to cold legs of reactor coolant piping.

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Table 6.3-9

NORMAL OPERATING STATUS OF EMERGENCY CORE COOLING SYSTEM COMPONENTS FOR CORE COOLING

Number of charging pumps operable	2	
Number of RHR pumps operable	2	
Number of residual heat exchangers operable	2	
RWST volume, min. usable gal	514,000	
Boron concentration in RWST, nominal, ppm	2,525	51 178
Boron concentration in BIT, nominal, ppm	21,000	
Boron concentration in accumulator, nominal, ppm	2,525	51 178
Number of accumulators	3	
Nominal accumulator pressure, psig	660	
Nominal accumulator water volume, ft^3	1,000	
System valves, interlocks, and piping required for the above components which are operable	All	

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NOTES

The ECCS process flow diagrams are provided for illustrative purposes only and are intended to represent the flow rates used in various accident analyses; such flow rates are provided in chapter 15, where appropriate. The process flow diagrams are developed to provide representative system performance data. This data consists of process flow data (i.e., pressure, temperature, and flow) for three principal modes of ECCS operation and valve alignments for an expanded set of ECCS operation modes. The flow rates in the FSAR accident analyses are developed based on pump test curves degraded by 5 percent and worst case assumptions pertaining to spilling line system resistances (e.g., maximum allowable resistances in lines connected to unbroken loops and minimum allowable resistances in the line connected to the broken loop) and RCS pressure.

The following general assumptions were utilized to develop the process flow data for the principal modes of ECCS operation.

1. The system operating conditions presented for the injection and recirculation modes are based on the assumption that the RCS is fully depressurized and is in equilibrium with the containment at zero psig.

2. The accumulator delivery is considered as an independent mode of operation and the process conditions presented are based on the assumption that the accumulators are fully discharged and depressurized to zero psig.

MODES OF OPERATION

MODE A - PLANT POWER OPERATION WITH ECCS IN STANDBY MODE

This mode represents the case of plant power operation with the ECCS in the standby mode with the BIT isolated and one boron injection recirculation pump operating.

The boron injection recirculation pump takes suction from the boron injection surge tank and delivers through the BIT returning to the surge tank. This process circulates the 12 percent boric acid and maintains a uniform fluid temperature.

MODE B - INJECTION/MAXIMUM SAFEGUARDS

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This mode represents the case of maximum safeguards where all safeguards pumps operate, following accumulator delivery. RHR pumps 1 and 2 and charging pumps 1 and 3 are operating, taking suction from the RWST and delivering to the reactor through three cold leg connections.

MODE C - INJECTION/MINIMUM SAFEGUARDS (TRAIN A OPERATING)

This mode represents the case of minimum safeguards with RHR pump 1 and charging pump 1 taking suction from the RWST and delivering to the reactor through three cold leg connections.

MODE D - INJECTION/MINIMUM SAFEGUARDS (TRAIN B OPERATING)

This mode represents the case of minimum safeguards with RHR pump 2 and charging pump 3 taking suction from the RWST and delivering to the reactor through three cold leg connections.

MODE E - COLD LEG RECIRCULATION/MAXIMUM SAFEGUARDS

This mode represents the case of cold leg recirculation with RHR pumps 1 and 2, and charging pumps 1 and 3 operating.

In this mode the safeguards pumps operate in series, with only the RHR pumps capable of taking suction from the containment recirculation sump. 253
The recirculated coolant is then delivered by RHR pumps 1 and 2 to charging pumps 1 and 3, which deliver to the reactor through three cold leg connections. The RHR pumps also deliver flow directly to the same three cold leg connections.

MODE F - COLD LEG RECIRCULATION/MINIMUM SAFEGUARDS (TRAIN A OPERATING)

This mode represents the case of cold leg recirculation with RHR pump 1 and charging pump 1 operating.

In this mode the safeguards pumps operate in series with only RHR pump 1 capable of taking suction from the containment recirculation sump. 253
The recirculated coolant is then delivered by RHR pump 1 to charging pump 1, which delivers to the reactor through three cold leg connections. The RHR pump also delivers flow directly to the reactor through the same three cold leg connections. The RHR pump also delivers flow directly to the reactor through the same three cold leg connections.

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MODE K - HOT LEG RECIRCULATION/MINIMUM SAFEGUARDS (TRAIN B OPERATING)

his mode represents the case of hot leg recirculation with RHR pump 2 and charging pump 3 operating.

In this mode, the safeguards pumps again operate in series with only RHR pump 2 taking suction from the containment recirculation sump. 253
The recirculated coolant is then delivered by RHR pump 2 to charging pump 3, which deliver to the reactor through three hot leg connections. The RHR pump also delivers directly to the reactor through two hot leg connections.

MODEL L - HOT LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

This mode represents the case of hot leg recirculation, assuming RHR pump 1 and charging pumps 1 and 3 operating.

In this mode, the safeguards pumps again operate in series with only RHR pump 1 taking suction from the containment recirculation sump. 253
The recirculated coolant is then delivered by RHR pump 1 to charging pumps 1 and 3, which deliver to the reactor through three hot leg connections. The RHR pump also delivers directly to the reactor through two hot leg connections.

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MODE G - COLD LEG RECIRCULATION/MINIMUM SAFEGUARDS (TRAIN B OPERATING)

This mode represents the case of cold leg recirculation with RHR pump 2 and charging pump 3 operating.

In this the safeguards pumps operate in series, with only RHR pump 2 capable of taking suction from the containment sump. The recirculated coolant is then delivered by RHR pump 2 to charging pump 3, which delivers to the reactor through three cold leg connections. The RHR pump also delivers flow directly to the reactor through the same three cold leg connections.

MODE H - COLD LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

This mode represents the case of cold leg recirculation with RHR pump 1 and charging pumps 1 and 3 operating.

In this mode the safeguards pumps operate in series, with only RHR pump 1 capable of taking suction from the containment sump. The recirculated coolant is then delivered by RHR pump 1 to charging pumps 1 and 3, which deliver to the reactor through three cold leg connections. The RHR pump also delivers flow directly to the reactor through the same cold leg connections.

MODE I - HOT LEG RECIRCULATION/MAXIMUM SAFEGUARDS

This mode represents the case of hot leg recirculation with RHR pumps 1 and 2, and charging pumps 1 and 3 operating.

In this mode, the safeguards pumps again operate in series with RHR pumps 1 and 2 taking suction from the containment sump. The recirculated coolant is then delivered by RHR pumps 1 and 2 to charging pumps 1 and 3, which deliver to the reactor through three hot leg connections. The RHR pumps also deliver directly to the reactor through two hot leg connections.

MODE J - HOT LEG RECIRCULATION/MINIMUM SAFEGUARDS (TRAIN A OPERATING)

This mode represents the case of hot leg recirculation with RHR pump 1 and charging pump 1 operating.

In this mode, the safeguards pumps again operate in series with only RHR pump 1 taking suction from the containment sump. The recirculated coolant is then delivered by RHR pump 1 to charging pump 1, which delivers to the reactor through three hot leg connections. The RHR pump also delivers directly to the reactor through two hot leg connections.

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EMERGENCY CORE COOLING SYSTEM
PROCESS FLOW DIAGRAM
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Figure 6.3-2

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MODE K - HOT LEG RECIRCULATION/MINIMUM SAFEGUARDS (TRAIN B OPERATING)

This mode represents the case of hot leg recirculation with RHR pump 2 and charging pump 3 operating.

In this mode, the safeguards pumps again operate in series with only RHR pump 2 taking suction from the containment sump. The recirculated coolant is then delivered by RHR pump 2 to charging pump 3, which deliver to the reactor through three hot leg connections. The RHR pump also delivers directly to the reactor through two hot leg connections.

MODEL L - HOT LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

This mode represents the case of hot leg recirculation, assuming RHR pump 1 and charging pumps 1 and 3 operating.

In this mode, the safeguards pumps again operate in series with only RHR pump 1 taking suction from the containment sump. The recirculated coolant is then delivered by RHR pump 1 to charging pumps 1 and 3, which deliver to the reactor through three hot leg connections. The RHR pump also delivers directly to the reactor through two hot leg connections.

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EMERGENCY CORE COOLING SYSTEM
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Figure 6.3-2

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VALVE ALIGNMENT CHART
OPERATIONAL MODES

VALVE NO.	A	B	C	D	E	F	G	H	I	J	K	L
1A	O	O	O	O	C	C	O	C	C	C	O	C
1B	O	O	O	O	C	O	C	C	C	O	C	C
2A	O	O	O	O	O	O	O	O	O	O	O	O
2B	O	O	O	O	O	O	O	O	O	O	O	O
3A	C	C	C	C	C	C	C	C	C	C	C	C
3B	C	C	C	C	C	C	C	C	C	C	C	C
4A	O	C	C	O	C	C	O	C	C	C	O	C
4B	O	C	O	C	C	O	C	O	C	O	C	O
5A	C	C	C	C	O	O	C	O	O	O	C	O
5B	C	C	C	C	O	C	O	C	O	C	O	C
6A	O	O	O	O	C	C	O	C	O	O	O	O
6B	O	O	O	O	C	O	C	C	O	O	O	O
7A	O	O	O	O	O	O	O	O	C	C	C	C
7B	O	O	O	O	O	O	O	O	C	C	C	C
8	C	C	C	C	C	C	C	C	O	O	O	O
9A	C	C	C	C	O	O	C	O	O	O	C	O
9B	C	C	C	C	O	C	O	O	O	C	O	O
10A	C	C	C	C	O	O	C	O	O	O	C	O
10B	C	C	C	C	O	C	O	O	O	C	O	O
11A	C	C	C	C	C	C	C	C	C	C	C	C
11B	C	C	C	C	C	C	C	C	C	C	C	C
12A	C	C	C	C	C	C	C	C	C	C	C	C
12B	C	C	C	C	C	C	C	C	C	C	C	C

O = OPEN
C = CLOSED

KOREA ELECTRIC POWER CORPORATION
KOREA NUCLEAR UNITS 5 & 6
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EMERGENCY CORE COOLING SYSTEM
PROCESS FLOW DIAGRAM
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Figure 6.3-2

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VALVE ALIGNMENT CHART
OPERATIONAL MODES

VALVE NO.	A	B	C	D	E	F	G	H	I	J	K	L
13A	C	O	O	C	C	C	C	C	C	C	C	C
13B	C	O	C	O	C	C	C	C	C	C	C	C
14A	O	C	C	O	C	C	O	C	C	C	O	C
14B	O	C	O	C	C	O	C	C	C	O	C	C
15A	O	O	O	O	O	O	O	O	O	O	O	O
15B	O	O	O	O	O	O	O	O	O	O	O	O
16A	O	O	O	O	O	O	O	O	O	O	O	O
16B	O	O	O	O	O	O	O	O	O	O	O	O
17A	O	O	O	O	C	O	O	C	C	O	O	C
17B	O	O	O	O	C	O	O	C	C	O	O	C
18A	O	O	O	O	C	O	O	C	C	O	O	C
18B	O	O	O	O	C	O	O	C	C	O	O	C
19A	O	C	O	C	C	O	C	C	C	O	C	C
19B	O	C	O	C	C	O	C	C	C	O	C	C
19C	O	C	O	C	C	O	C	C	C	O	C	C
20	O	C	C	O	C	C	O	C	C	C	O	C
21A	O	C	C	O	C	C	O	C	C	C	O	C
21B	O	C	O	C	C	O	C	C	C	O	C	C
22A	C	O	O	C	O	O	C	O	C	C	C	C
22B	C	O	C	O	O	C	O	O	C	C	C	C
23A	C	O	O	C	O	O	C	O	C	C	C	C
23B	C	O	C	O	O	C	O	O	C	C	C	C
24	C	C	C	C	C	C	C	C	O	C	O	O
25	C	C	C	C	C	C	C	C	O	O	C	O
26	C	C	C	C	O	C	C	O	C	C	C	C
27A	O	C	C	C	C	C	C	C	C	C	C	C
27B	O	C	C	C	C	C	C	C	C	C	C	C
28	O	C	C	C	C	C	C	C	C	C	C	C
29A	O	O	O	O	O	O	O	O	O	O	O	O
29B	O	O	O	O	O	O	O	O	O	O	O	O
29C	O	O	O	O	O	O	O	O	O	O	O	O
30A	C	C	C	C	C	C	C	C	C	C	C	C
30B	C	C	C	C	C	C	C	C	C	C	C	C
31	C	C	C	C	C	C	C	C	C	C	C	C
32	O	O	O	O	O	O	O	O	O	O	O	O

O = OPEN
C = CLOSED

KOREA ELECTRIC POWER CORPORATION
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EMERGENCY CORE COOLING SYSTEM
PROCESS FLOW DIAGRAM
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Figure 6.3-2

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MODE C - INJECTION MINIMUM SAFEGUARDS (TRAIN A OPERATING)
Runout conditions following accumulator delivery

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
1	Refueling water	ATM TANK	100	-	350,000
2	Refueling water	-	100	7,200[b]	-
3	Refueling water	-	100	4,200	-
4	Refueling water	-	100	3,550	-
5A	Refueling water	20	100	3,550	-
5B	Refueling water	-	100	0	-
6A	Refueling water	122	100	3,550	-
6B	Refueling water	-	100	0	-
7A	Refueling water	-	100	3,550	-
7B	Refueling water	-	100	0	-
8A	Refueling water	-	100	3,550	-
8B	Refueling water	-	100	0	-
9A	Refueling water	-	100	0	-
9B	Refueling water	-	100	0	-
10A	Refueling water	-	100	0	-
10B	Refueling water	-	100	0	-

[a] At reference conditions 100F and 0 psig.
[b] Includes 3,000 gpm for one containment spray pump.

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Figure 6.3-2

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MODE C - INJECTION MINIMUM SAFEGUARDS (TRAIN A OPERATING)
Runout conditions following accumulator delivery

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
11A	Refueling water	69	100	3,550	-
11B	Refueling water	-	100	0	-
12	Refueling water	0	100	1,417	-
13	Refueling water	0	100	1,383	-
14	Refueling water	0	100	1,350	-
15	Refueling water	-	100	0	-
16	Refueling water	0	100	0	-
17	Refueling water	0	100	0	-
20A	Reactor coolant	0	212	0	-
20B	Reactor coolant	0	212	0	-
22A	Recirculating water	0	212	0	-
22B	Recirculating water	0	212	0	-

KOREA ELECTRIC POWER CORPORATION
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Figure 6.3-2

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MODE C - INJECTION MINIMUM SAFEGUARDS (TRAIN A OPERATING)
Runout conditions following accumulator delivery

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
30	Refueling water	-	100	3,000	-
40	Refueling water	-	100	650	-
41A	Refueling water	-	100	650	-
41B	Refueling water	-	100	0	-
42	Refueling water	-	100	0	-
43A	Refueling water	16	100	650	-
43B	Refueling water	-	100	0	-
43S	Refueling water	-	100	0	-
44	Refueling water	-	100	0	-
45A	Refueling water	1,069	100	650	-
45S	Refueling water	-	100	0	-
45B	Refueling water	-	100	0	-
46	Refueling water	-	100	0	-
47	Refueling water	929	100	50	-
48	Refueling water	915	100	60	-

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Figure 6.3-2

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MODE C - INJECTION MINIMUM SAFEGUARDS (TRAIN A OPERATING)
Runout conditions following accumulator delivery

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)(a)	Volume (gallons)
49	Refueling water	-	100	600	900
50A	Refueling water	-	100	0	-
50B	Refueling water	575	100	600	-
51A	Refueling water	-	100	0	-
52A	Refueling water	-	100	0	-
53A	Refueling water	-	100	0	-
51B	Refueling water	13	100	200	-
52B	Refueling water	13	100	200	-
53B	Refueling water	13	100	200	-
54A	Refueling water	-	100	0	-
55A	Refueling water	-	100	0	-
54B	Refueling water	-	100	0	-
55B	Refueling water	-	100	0	-
56	Refueling water	-	100	0	-
57A	Refueling water	-	100	0	-
57B	Refueling water	-	100	0	-

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Figure 6.3-2

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MODE C - INJECTION MINIMUM SAFEGUARDS (TRAIN A OPERATING)
Runout conditions following accumulator delivery

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
60	Nitrogen	0	100	0	(c)
61	Nitrogen	0	100	0	(c)
62	Nitrogen	0	100	0	(c)
70	12 weight % boric acid	0	165	0	-
71	-	0	165	0	(d)
72	12 weight % boric acid	0	165	0	(d)
73	12 weight % boric acid	0	165	0	-
74A	12 weight % boric acid	0	165	0	-
74B	12 weight % boric acid	0	165	0	-
75	12 weight % boric acid	0	165	0	-

c. Total accumulator volume - 1,450 ft^3.
d. Total BI surge tank capacity - 75 gallons.

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Figure 6.3-2

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MODE H - COLD LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
1	Refueling water	atm tank	100	-	-
2	Refueling water	-	100	0	-
3	Refueling water	-	100	0	-
4	Refueling water	-	100	0	-
5A	Recirculating water	12	< 212	4,500	-
5B	Recirculating water	-	-	0	-
6A	Recirculating water	95	< 212	4,500	-
6B	Recirculating water	-	-	0	-
7A	Recirculating water	93	< 212	4,500	-
7B	Recirculating water	-	-	0	-
8A	Recirculating water	49	180	4,500	-
8B	Recirculating water	-	-	0	-
9A	Recirculating water	< 49	180	1,300	-
9B	Recirculating water	-	-	0	-
10A	Recirculating water	-	-	0	-
10B	Recirculating water	-	-	0	-
11A	Recirculating water	61	180	3,200	-
11B	Recirculating water	-	-	0	-
12	Recirculating water	0	180	1,484	-

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PROCESS FLOW DIAGRAM
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Figure 6.3-2

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MODE H - COLD LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
13	Recirculating water	0	180	1,484	-
14	Recirculating water	0	180	1,484	-
15	Refueling water	< 31	100	0	-
16	Refueling water	0	100	0	-
17	Refueling water	0	100	0	-
20A	Recirculating water	0	< 212	0	-
20B	Recirculating water	0	< 212	0	-
22A	Recirculating water	0	< 212	4,500	-
22B	Recirculating water	0	< 212	0	-
30	Refueling water	-	100	0	-
40	Refueling water	-	100	0	-
41A	Recirculating water	-	100	0	-
41B	Recirculating water	-	100	0	-
42	Recirculating water	-	100	0	-
43A	Recirculating water	46	180	650	-
43B	Recirculating water	45	180	650	-
43S	Recirculating water	45	180	0	-

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Figure 6.3-2

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MODE H - COLD LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
44	Refueling water	-	100	0	-
45A	Recirculating water	1,090	180	650	-
45B	Recirculating water	1,090	180	650	-
45S	Recirculating water	-	-	0	-
46	Recirculating water	-	100	0	-
47	Recirculating water	1,035	180	50	-
48	Recirculating water	1,035	180	600	-
49	Recirculating water	800	180	600	900
50A	Recirculating water	668	180	650	-
50B	Recirculating water	722	180	600	-
51A	Recirculating water	>100	180	217	-
52A	Recirculating water	>100	180	217	-
53A	Recirculating water	>100	180	217	-
51B	Recirculating water	>100	180	200	-
52B	Recirculating water	>100	180	200	-
53B	Recirculating water	>100	180	200	-

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EMERGENCY CORE COOLING SYSTEM
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Figure 6.3-2

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MODE H - COLD LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
54A	Refueling water	-	100	0	-
55A	Refueling water	-	100	0	-
54B	Refueling water	-	100	0	-
55B	Refueling water	-	100	0	-
56	Refueling water	-	100	0	-
57A	Refueling water	-	100	0	-
57B	Refueling water	-	100	0	-
60	Nitrogen	0	100	0	(c)
61	Nitrogen	0	100	0	(c)
62	Nitrogen	0	100	0	-
70	12 weight % boric acid	0	165	0	-
71	-	0	165	0	(d)
72	12 weight % boric acid	0	165	0	(d)
73	12 weight % boric acid	0	165	0	-
74A	12 weight % boric acid	0	165	0	-
74B	12 weight % boric acid	0	165	0	-
75	12 weight % boric acid	0	165	0	-

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Figure 6.3-2

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MODE L - HOT LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
1	Refueling water	ATM TANK	100	-	-
2	Refueling water	-	100	0	-
3	Refueling water	-	100	0	-
4	Refueling water	-	100	0	-
5A	Recirculating water	12	< 212	4,000	-
5B	Recirculating water	-	-	0	-
6A	Recirculating water	108	< 212	4,000	-
6B	Recirculating water	-	-	0	-
7A	Recirculating water	106	< 212	4,000	-
7B	Recirculating water	-	-	0	-
8A	Recirculating water	71	180	4,000	-
8B	Recirculating water	-	-	0	-
9A	Recirculating water	<71	180	1,300	-
9B	Recirculating water	-	-	0	-
10A	Recirculating water	-	180	0	-
10B	Recirculating water	-	-	0	-
11A	Recirculating water	58	180	2,700	-
11B	Recirculating water	-	-	0	-
12	Recirculating water	0	180	0	-
13	Recirculating water	0	180	0	-

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Figure 6.3-2

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MODE L - HOT LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
14	Recirculating water	0	180	0	-
15	Recirculating water	< 58	180	2,700	-
16	Recirculating water	0	180	1,767	-
17	Recirculating water	0	180	1,767	-
20A	Recirculating water	0	< 212	0	-
20B	Recirculating water	0	< 212	0	-
22A	Recirculating water	0	< 212	4,000	-
22B	Recirculating water	0	< 212	0	-
30	Refueling water	-	100	0	-
40	Refueling water	-	100	0	-
41A	Recirculating water	-	100	0	-
41B	Recirculating water	-	100	0	-

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EMERGENCY CORE COOLING SYSTEM
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Figure 6.3-2

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MODE L - HOT LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[(a)]	Volume (gallons)
42	Recirculating water	-	100	0	-
43A	Recirculating water	68	180	650	-
43B	Recirculating water	67	180	650	-
43S	Recirculating water	67	180	0	-
44	Refueling water	-	100	0	-
45A	Recirculating water	1,112	180	650	-
45B	Recirculating water	1,112	180	650	-
45S	Recirculating water	-	180	0	-
46	Recirculating water	-	100	0	-
47	Recirculating water	1,057	180	50	-
48	Recirculating water	1,057	180	600	-
49	Recirculating water	-	180	0	-
50A	Recirculating water	-	100	0	-
50B	Recirculating water	-	180	0	-
51A	Recirculating water	-	180	0	-
52A	Recirculating water	-	180	0	-
53A	Recirculating water	-	180	0	-
51B	Recirculating water	-	180	0	-
52B	Recirculating water	-	180	0	-
53B	Recirculating water	-	180	0	-

KOREA ELECTRIC POWER CORPORATION
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EMERGENCY CORE COOLING SYSTEM
PROCESS FLOW DIAGRAM
(Sheet 22 of 23)

Figure 6.3-2

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MODE L - HOT LEG RECIRCULATION/RHR PUMP NO. 2 NOT OPERATING

Location	Fluid	Pressure (psig)	Temperature (°F)	Flow (gal/min)[a]	Volume (gallons)
54A	Recirculating water	> 100	180	217	-
55A	Recirculating water	> 100	180	217	-
54B	Recirculating water	> 100	180	200	-
55B	Recirculating water	> 100	180	200	-
56	Recirculating water	> 100	180	417	-
57A	Recirculating water	873	180	650	-
57B	Recirculating water	900	180	600	-
60	Nitrogen	0	100	0	(c)
61	Nitrogen	0	100	0	(c)
62	Nitrogen	0	100	0	-
70	12 weight % boric acid	0	165	0	-
71	-	0	165	0	(d)
72	12 weight % boric acid	0	165	0	(d)
73	12 weight % boric acid	0	165	0	-
74A	12 weight % boric acid	0	165	0	-
74B	12 weight % boric acid	0	165	0	-
75	12 weight % boric acid	0	165	0	-

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EMERGENCY CORE COOLING SYSTEM
PROCESS FLOW DIAGRAM
(Sheet 23 of 23)

Figure 6.3-2

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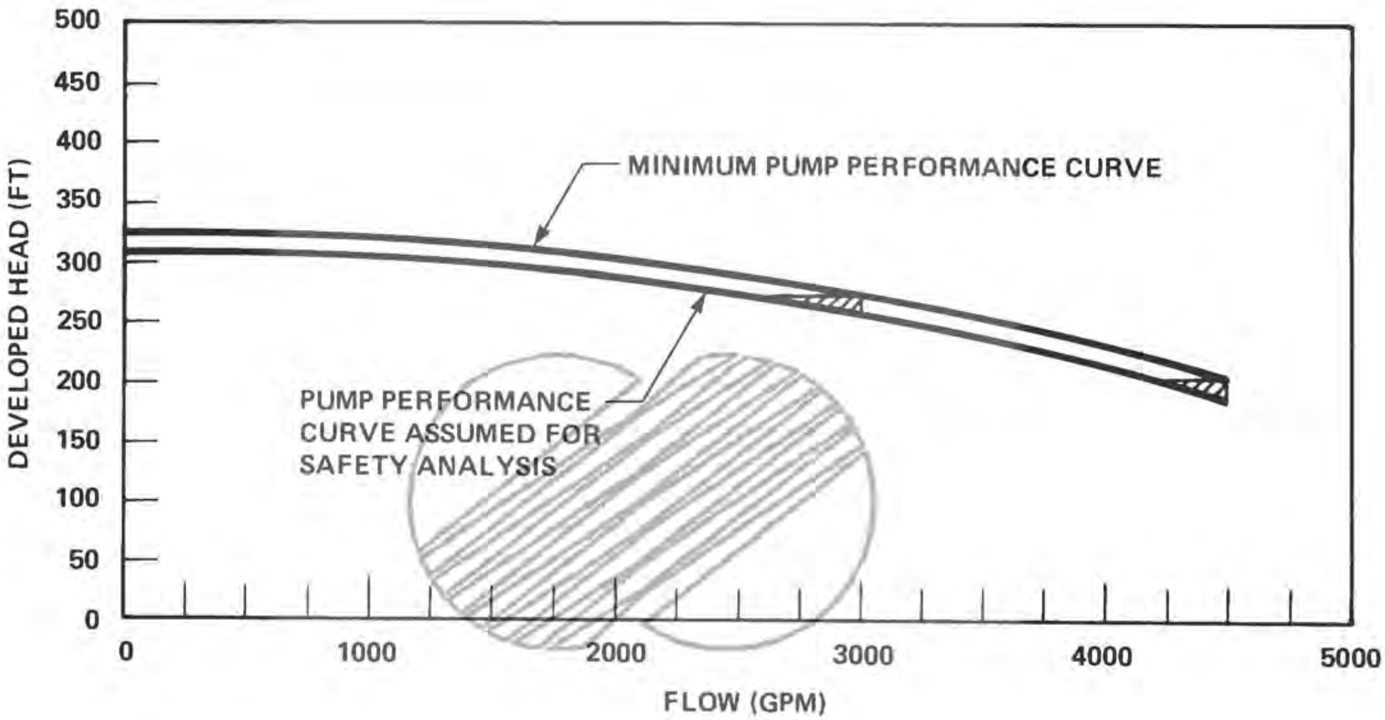

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RESIDUAL HEAT REMOVAL PUMP
PERFORMANCE CURVE

Figure 6.3-3

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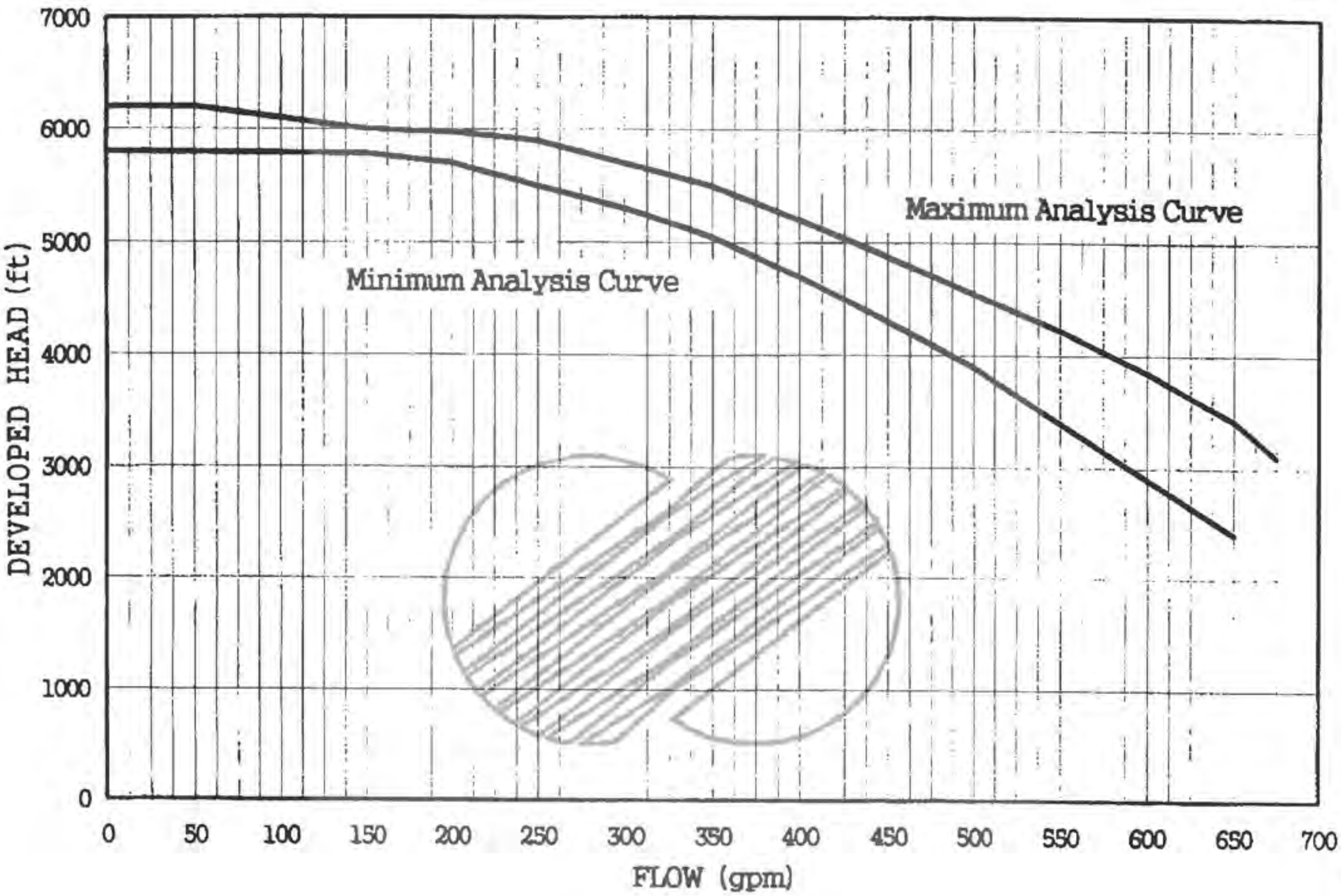

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CENTRIFUGAL CHARGING PUMP
PERFORMANCE CURVE

Figure 6.3-4

6.4 HABITABILITY SYSTEMS

The control room habitability systems include missile protection, radiation shielding, radiation monitoring, smoke detection capability, control room filtration, air conditioning, lighting, and manual fire protection. These habitability systems are provided to permit access to and occupancy of the control room during normal plant operations, as well as during and following emergency conditions.

The normal control room ventilation and air-conditioning system is discussed in subsection 9.4.1, Control Building HVAC System. This section only addresses emergency service requirements and responses, including operation of control room ventilation and air-conditioning equipment under emergency conditions, see table 6.4-2. Lighting systems are discussed fully in subsection 9.5.3, and are not discussed herein. Other equipment and systems are described only as necessary to define their connection with control room habitability and, accordingly, reference is made to other appropriate sections.

6.4.1 DESIGN BASES

6.4.1.1 Safety Design Bases

The control room filtration, air-conditioning systems, the radiation monitoring systems, the emergency lighting system, the isolation dampers in the control building supply air, and exhaust ducting are treated as safety-related items and are required to function under emergency conditions. These habitability systems are required to function following a design basis accident (DBA) and to enable the plant operators to achieve and/or maintain the plant in a safe shutdown condition. The following safety design bases are met.

6.4.1.1.1 Safety Design Basis One

The habitability systems are housed within a structure capable of withstanding the effects of natural phenomena, such as earthquakes, typhoons, floods, and external missiles.

6.4.1.1.2 Safety Design Basis Two

The habitability systems are designed to remain functional after a safe shutdown earthquake (SSE) and to perform their intended function following a postulated hazard, such as fire, toxic chemical release, internal missiles, or pipe break.

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6.4.1.1.3 Safety Design Basis Three

Habitability system redundancy is provided so that safety functions can be performed, assuming a single active component failure coincident with a loss of offsite power.

6.4.1.1.4 Safety Design Basis Four

The habitability systems are designed so that the active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of appropriate components of the control room air-conditioning system.

6.4.1.1.5 Safety Design Basis Five

The habitability systems are designed and fabricated according to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

6.4.1.1.6 Safety Design Basis Six

The control room ventilation system is capable of automatic transfer from its normal operational mode to its emergency mode upon detection of conditions which could result in accidental radiation exposure of control room personnel in excess of General Design Criterion 19 limits.

The radiation exposure of control room personnel throughout the duration of any postulated DBA discussed in chapter 15 does not exceed the guideline values of General Design Criterion 19 of Appendix A to 10 CFR 50.

6.4.1.1.7 Safety Design Basis Seven

Throughout the duration of any one of the postulated hazardous chemical releases discussed in section 2.2 or postulated accidents discussed in chapter 15, the habitability systems maintain the control room atmosphere at environmental conditions suitable for occupancy per General Design Criterion 19.

6.4.1.1.8 Safety Design Basis Eight

Sufficient food, water, medical supplies, and sanitary facilities will be furnished to allow continuous occupancy of the control room by the emergency team for a minimum of 5 days.

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A 6-hour onsite bottled air supply provided with self-contained breathing apparatus will be available in the main control room with offsite replenishment available from nearby locations.

6.4.1.2 Power Generation Design Bases

The control room ventilation and air-conditioning system power generation design bases are discussed in paragraph 9.4.1.1.1.2.

6.4.1.3 Codes and Standards

Codes and standards applicable to the control building HVAC systems are listed in table 3.2-1.

6.4.2 SYSTEM DESIGN

6.4.2.1 Definition of Control Room Envelope

The control room envelope includes the control room and all areas in or adjacent to the control room containing plant information and equipment that may be needed during an emergency. The control room habitability boundary is indicated on figures 6.4-1 and 6.4-2. The control room emergency air-conditioning outside air intakes are indicated on figure 6.4-3.

6.4.2.2 Ventilation System Design

6.4.2.2.1 General Description

The normal control room HVAC system is described in subsection 9.4.1 and shown in figure 9.4-1.

The control room ventilation and air-conditioning system is designed to control the level of airborne contamination in the control room atmosphere and to control the temperature and humidity for personnel safety and comfort.

Upon actuation of the system to the emergency mode of operation, as outlined in subsection 6.4.3, the control room exhaust isolation dampers and the control room normal supply air isolation dampers close; the air-conditioning system switches to emergency recirculation and supply. The control room emergency air-conditioning unit is supplemented by the control room emergency air filtration unit. The control room emergency air filtration unit has provision for removal of airborne radioactivity by filtering inlet air and circulating part of the control room air through charcoal adsorbers. Particulates are removed by high-efficiency particulate air (HEPA) filters and moisture by the moisture air separator. Moderate

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efficiency filter and cooling coil in the recirculation unit removes the particulates and cools the air. Supply air and exhaust system isolation dampers close in 5 seconds following receipt of an isolation signal.

Redundant radiation monitors are provided to control ventilation system operation. The radiation monitors are located in the control room normal intake air system ductwork.

6.4.2.2.2 Component Description

Design data for major components of the control room emergency HVAC system are listed in table 6.4-1.

Emergency mode intake air flow is processed by one of two identical, physically separated, emergency filtration trains. Each emergency train includes a moisture separator, an electric heating coil, a fan, an upstream HEPA filter, a carbon adsorber, and a downstream HEPA filter. The emergency supply/recirculation unit consists of moderate efficiency filters, cooling coil, electric heating coil, fan and associated ductwork and controls. Except for certain controls, all components are located outside of the control room.

6.4.2.2.2.1 Moisture Separator. A moisture separator of the woven pad type at the inlet to each filter train serves to remove entrained water droplets from the air stream in order to protect the downstream filter components from moisture saturation.

6.4.2.2.2.2 Heater. An electric heating coil is provided to lower the relative humidity of the incoming air to 70 percent or less in order to maximize carbon adsorber efficiency.

6.4.2.2.2.3 High Efficiency Particulate Air Filters. The HEPA filter elements are of the pleated fiberglass with aluminum insert design, measure 24 x 24 x 11.5 inches, and are capable of handling a nominal flowrate of 1000 ft^3/min each. The filter medium is cased in stainless steel, is equipped with face guards on both sides, and is water and fire resistant.

The HEPA filter element are manufactured and tested prior to installation in accordance with ASME-AG1-1997 as modified by AEC Health and Safety Information Issue 306. The filter element minimum acceptance criterion is removal of 99.97 percent of 0.3 micron thermally generated monodisperse challenge gas(e.g., DOP, PAO) particles. 437

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6.4.2.2.2.4 Carbon Adsorbers. The carbon adsorbers are of the gasketless type, 2 inches deep, and have an all welded design.

The gasketless type charcoal adsorber is enclosed within a type 304 stainless all welded construction design. The filter beds are permanently installed by welding to the support frame and housing.

The acceptance criterion for the carbon adsorbers include a requirement for greater than 95 percent removal of all iodine species at a controlled relative humidity of 70 percent.

Spray nozzles and distribution piping is installed to allow flooding of the charcoal beds in case of bed ignition.

6.4.2.2.2.5 Emergency Train Fans. The emergency train fans are Seismic Category I and are capable of delivering the design flowrate with all filters at their maximum anticipated pressure drop. Fans are chosen with a steeply rising pressure-flow characteristic to maintain a reasonably constant air flow over the full filter train life.

6.4.2.2.2.6 Emergency Supply/Recirculation Units. Each emergency supply/recirculation unit includes a moderate efficiency filter, a cooling coil, a heating coil, a fan, associated ductwork, and controls.

6.4.2.2.2.7 Control Room Access Doors. To minimize inleakage, the access doors have airtight seals and are equipped with self-closing devices which shut the doors automatically following the passage of personnel.

6.4.2.2.2.8 Isolation Dampers. The system normal supply and exhaust isolation dampers are capable of shutting fully within 5 seconds following receipt of an isolation signal. The dampers are bubble tight at 1 psi differential pressure.

6.4.2.2.2.9 Radiation Detectors. Redundant radiation detectors are installed in the control room normal outside air intake. The unit is responsive to radioactivity concentrations between 10^{-6} and 10^{-1} $\mu Ci/cm^3$. The detectors are described in subsection 12.3.4.

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6.4.2.2.2.10 Moderate Efficiency Filters. The moderate efficiency filter elements are of the replaceable dry type with media composed of fiberglass. The face area is 24 x 24 inches and each element is capable of handling a nominal flow rate of 1000 $ft.^3/min$. The average atmospheric dust spot efficiency is not less than 45 percent.

6.4.2.2.2.11 Cooling Coil. The cooling coil is of the extended surface type arranged for horizontal air flow. The chilled water cooling media is circulated inside tubes constructed of copper with copper fins permanently bonded to the tubes.

6.4.2.3 Leaktightness

During the emergency mode of operation, isolation of the normal control room HVAC exhaust ensures a minimum overpressure of the control room by the emergency HVAC system to prevent infiltration of unfiltered air from surrounding areas. This is accomplished by sealing of potential leak paths, such as cable, pipe and ducting penetrations.

Refer to section 15.6 for an analysis of the radiological consequences to the control room occupants in the unlikely event of a loss-of-coolant accident (LOCA).

6.4.2.4 Interaction With Other Zones and Pressure-Containing Equipment

The control room envelope is isolated during any accident involving the release of significant quantities of radioactive gases in the vicinity of the control room. The control room air-conditioning system is operated in the emergency recirculation mode, with outside filtered air used to maintain control room pressure.

The control room HVAC system maintains the control room at a slight positive pressure. If smoke is detected in the control building supply air system, it is alarmed in the control room.

Although those doors which form a part of the control room pressure boundary open outward, they are designed to maintain a slight positive control room pressure.

The use of fire extinguishers located in the control room envelope will not yield a hazardous concentration of toxic gas. All piping not connected or related to control room equipment is routed outside the boundary.

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6.4.2.5 Shielding Design

A description of the radiation sources and shielding required to maintain the habitability of the control room during normal operations and during the course of postulated accidents is provided in subsection 12.3.2. The shielding design is based on the requirements specified in General Design Criterion 19.

6.4.3 SYSTEM OPERATION

6.4.3.1 Normal and Smoke Removal Modes

Control room HVAC system operation in the normal and smoke removal modes is described in subsection 9.4.1.

6.4.3.2 Emergency Mode

Upon receipt of an engineered safety feature actuation signal, or control room outside air intake high radiation signal, the control room emergency HVAC system is automatically started. The emergency HVAC system may also be initiated manually from the control room.

Transfer to the emergency mode consists of closing of all normal supply and exhaust isolation dampers, opening the outside air damper to the emergency filtration trains, and starting the fans in the emergency filtration trains and the emergency supply/recirculation units. The emergency filtration train fan discharges into the emergency supply/recirculation air handling unit. Thus, the emergency filtration train fan draws outside air and recirculation through HEPA filters and carbon adsorbers and discharges into the control room. Since there is no control room exhaust, the pressurized control room atmosphere leaks from the control room enclosure.

To cool the control room air, it is recirculated at a rate of 21,000 ft^3/min through the emergency supply/recirculation air handling unit. The processing of outside air through the emergency filtration train allows 350 ft^3/min of outside air to be introduced into the control room. In addition, 1650 ft^3/min of the recirculated air is processed through the emergency filtration train to aid in the removal of particulates and iodines which have built up in the control room atmosphere. The temperature of the control room is maintained between 68 and 78F.

6.4.4 SAFETY EVALUATIONS

Safety evaluations are numbered to correspond with the safety design bases.

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6.4.4.1 Safety Evaluation One

The safety-related portions of the control room habitability systems are located in the control building. This building is designed to withstand the effects of earthquakes, typhoons, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7, and 3.8 provide the bases for the adequacy of the structural design of these buildings.

6.4.4.2 Safety Evaluation Two

The safety-related portions of the habitability systems are designed to remain functional after an SSE. Sections 3.7 and 3.9 provide the design loading conditions that were considered. Sections 3.5, 3.6, and subsection 9.5.1 provide hazards analyses to assure that a safe shutdown, as outlined in section 7.4, can be achieved and maintained.

6.4.4.3 Safety Evaluation Three

The system design for the safety-related portions of the habitability systems provides for complete redundancy, and no single failure will compromise the systems' safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in chapter 8.

6.4.4.4 Safety Evaluation Four

The habitability systems are initially tested with the program given in chapter 14. Periodic inservice functional testing is done in accordance with subsection 6.4.5 and ITS Chapter 1 3.7.10 and 3.7.11. 357

6.4.4.5 Safety Evaluation Five

Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portions of these systems and supporting systems. All the power supplies and control functions necessary for safe functioning of the safety-related portions of the habitability systems are Class 1E, as described in chapters 7 and 8.

6.4.4.6 Safety Evaluation Six

Upon detection of high radiation in the normal control room HVAC intake duct, the control room ventilation system is capable of automatic transfer from normal to emergency mode.

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The direct radiation exposure of a control room occupant throughout the duration of any one of the postulated DBAs discussed in chapter 15 does not exceed 0.5 mr/h whole-body, and thus will not exceed General Design Criterion 19 requirements. A detailed discussion of the dose calculation model for control room operators is discussed in appendix 15A. Control room shielding design, based on the most limiting design basis LOCA fission product release, is discussed in section 12.3.

6.4.4.7 Safety Evaluation Seven

Throughout the duration of any of the postulated hazardous chemical releases discussed in section 2.2 or DBAs discussed in chapter 15, the habitability system maintains the control room environmental conditions below those established by General Design Criterion 19. Control Room HVAC system design data are provided in table 6.4-1.

6.4.4.8 Safety Evaluation Eight

Food, water, medical supplies, and sanitary facilities are provided for a minimum occupancy of five persons for 5 days. Storage locations provided ensure that the above supplies will not be contaminated as a result of postulated accidents.

6.4.4.9 Safety Evaluation Nine

There are not significant quantities of hazardous chemicals stored or transported within 5 miles of the site, as discussed in section 2.2, which require a hazards analysis in accordance with Regulatory Guides 1.78 or 1.95.

6.4.5 TESTS AND INSPECTIONS

Prior to acceptance by the manufacturer, moisture separator sections are qualified for water droplet removal at the design air flowrate, temperature, pressure, droplet size, and liquid loading. Inservice testing of performance is by a pressure drop determination across the mat.

The HEPA filter banks are tested in-place prior to operation and periodically thereafter to verify efficiency of at least 99.97 percent with a cold generated polydisperse 0.7 micron DOP aerosol. Testing is in accordance with ANSI Standard N101.1. The emergency mode of the control room HVAC system will undergo preoperational testing to verify that the system will maintain a slightly positive pressure in the control room.

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6.4.5.1 Efficiency Testing of Air-Cleaning Systems Containing Devices for Removal of Particles

Impregnated, activated carbon is batch tested prior to loading into the adsorber bed. Acceptance criteria are those
6 described in ASTM D3803. Tests include particle size distribution, hardness, density, moisture content, impregnant content, ash content, impregnant leach-out, and elemental iodine and methyl iodine removal efficiencies at postulated accident conditions. Post-installation testing is in accordance with DP-1082, Standardized Nondestructive Test of Carbon Beds for Reactor Confinement Applications. The carbon adsorber vessel is filled with carbon in a manner to ensure a uniform packing density and to minimize dusting. The adsorber vessel is Freon leak tested prior to operation and periodically thereafter to verify less than 0.05 percent bypass. In addition, a periodic laboratory test of a representative sample of the impregnated activated carbon is performed at intervals not exceeding 18 months to
6 determine iodine removal efficiencies as outlined in ASTM-D3803. If such efficiencies are found to be lower than 95 percent, the charcoal will be replaced. A design comparison to Regulatory Guide 1.52 is given in table 6.5-1.

Performance of fans is initially verified in accordance with Air Moving and Conditioning Association (AMCA) test codes at the maximum anticipated system pressure drop.

The emergency mode of the control room HVAC system will undergo an acceptance test to verify that the system will maintain a slight positive pressure in the emergency zone.

The control room emergency and isolation capability and the ability to recirculate inside air and process outside air through one of the two high efficiency filter trains will be tested periodically. The filtration trains will be tested periodically in conformance with Regulatory Guide 1.52. Refer to 357
ITS Chapter 1 3.7.10 for additional details.

6.4.6 INSTRUMENTATION REQUIREMENT

Safety-related instrumentation and isolation signals are discussed in paragraph 9.4.1.2.3 and section 7.3.

Indication of all fan operational status is provided in the control room.

An indication of the position of all isolation dampers is provided in the control room.

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The filter differential pressure transmitter and heater moisture controller associated with filtration units complies with Regulatory Guide 1.52.

A discussion of the range, isolation setpoint, and minimum sensitivity for the redundant radiation monitors installed in the normal control room HVAC intake duct is presented in section 11.5.

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Table 6.4-1

CONTROL ROOM HVAC SYSTEM DESIGN DATA (Sheet 1 of 3)

Control Room Environmental Conditions			
	Normal	Maximum	Minimum
Temperature, °F	75	78	68
Emergency Supply/Recirculation Air Handling Units			
Quantity Flowrate, ea, ft³/min	2 @ 100 percent ea 21,000		
Emergency Supply/Recirculation Unit Moderate Efficiency Filters			
Type Quantity, per unit Filter media Capacity, ea, ft³/min Pressure drop, clean, in. WG	Dry, disposable 1 bank Glass fiber 21,000 0.5		
Emergency Supply/Recirculation Air Handling Unit Heating Coil			
Type Quantity, per unit Heating capacity, kw Power Supply	Electric 1 133 460V/3Ø/60Hz		
Emergency Supply/Recirculation Unit Cooling Coils			
Type Quantity, per unit Heat transfer, ea, BTU/h	Fin-tube 1 769,200		
Emergency Supply/Recirculation AHU Fans			
Type Quantity, per unit Flowrate, ea, ft³/min Static pressure, in. WG Drive	Centrifugal 1 21,000 4.5 Direct		

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Table 6.4-1

CONTROL ROOM HVAC SYSTEM DESIGN DATA (Sheet 2 of 3)

Emergency Supply/Recirculation AHU Fan Electric Motor	
Motor classification, Class Quantity, per unit Rated horsepower, hp Rated speed, r/min Power supply Full-load current, amps Drive coupling, type	1E 1 40 1,765 460V/3Ø/60Hz 51 Flexible
Emergency Filtration Trains	
Quantity Flowrate, ea, ft³/min	2 @ 100 percent ea 2,000
Emergency Train Fans	
Type Quantity, per train Flowrate, ea, ft³/min Static pressure, in. WG Drive	Centrifugal 1 2,000 15.0 Direct
Emergency Train Fan Electric Motor	
Motor classification, Class Quantity, per unit Rated horsepower, hp Rated speed, r/min Power supply Full-load current, amps Drive coupling, type	1E 1 25 3,535 460V/3Ø/60Hz 30 Direct
Emergency Train HEPA Filters	
Type Quantity, upstream/ downstream per train Filter media Capacity, ea, ft³/min Pressure drop, clean, in. WG Efficiency, percent	Dry, high efficiency 2/2 Glass fiber 1,000 1.0 99.97

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Table 6.4-1

CONTROL ROOM HVAC SYSTEM DESIGN DATA (Sheet 3 of 3)

	Emergency Train Carbon Adsorbers	
	Type	Gasketless
	Media	Activated carbon
	Bed depth, in.	2
28	Minimum gas stream residence time, s	0.25
	Pressure drop, clean, in. WG	1.3
	Efficiency, percent	
28	Elemental iodine	99 @ 70 percent RH
28	Organic iodine	99 @ 70 percent RH
	Emergency Train Heating Coil	
	Type	Electric
	Quantity, per unit	1
36	Heating capacity, kw	9.3
	Power supply	460V/3Ø/60HZ
	Emergency Train Moisture Separator	
	Quantity, per unit	1
	Capacity, standard ft^3/min	2,000
	Pressure drop, in. WG	1

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Table 6.4-2

HABITABILITY SYSTEMS

Component	Failure	Comments
1. Emergency Supply/ Recirculation Air Handling Unit	Fails to start on automatic signal or fails to start manually	Two, 100 percent capacity redundant trains are provided.
2. Emergency Filtration Train	Fails to start on automatic signal or fails to start manually	Two, 100 percent capacity redundant trains are provided.
3. Power Supply	Failure of both normal and preferred power supplies	All Class 1E component automatically switch over to emergency diesel generator power supply.
4. Power Supply	Failure of power supply to one train	Two independent and physically separated buses of 100 percent capacity are provided.

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6.5 FISSION PRODUCT REMOVAL AND CONTROL SYSTEMS

6.5.1 ENGINEERED SAFETY FEATURE (ESF) FILTER SYSTEMS

The ESF filter systems include the fuel building emergency exhaust system (subsection 9.4.6) and the control room habitability system (section 6.4). The fuel building emergency exhaust system will operate following a loss-of-coolant accident (LOCA) to remove fission product releases from the auxiliary building ESF pump rooms. It would also operate after a fuel | 2 handling accident to remove fission product releases from the fuel building. The control room emergency heating, ventilating, and air-conditioning (HVAC) systems operate to maintain control room habitability by removing fission products from air entering the control room following postulated accidents. This section discusses the design basis and safety evaluation of the functional requirements of the ESF filter systems.

6.5.1.1 Design Bases

Criteria for the selection of safety design bases are found in subparagraph 1.1.2.2.1.

6.5.1.1.1 Safety Design Bases

6.5.1.1.1.1 Safety Design Basis One. The fuel building emergency exhaust system is provided to reduce the fission product release from the plant, following a fuel handling accident in the fuel building or a LOCA that could potentially result in radioactive leakage into the auxiliary building.

6.5.1.1.1.2. Safety Design Basis Two. A control room emergency HVAC system is provided to isolate the habitability area (control room) from other parts of the control building and to provide the habitability area with a filtered supply of fresh air.

6.5.1.1.2 Power Generation Design Bases

The ESF filter systems have no power generation design bases.

6.5.1.1.3 Codes and Standards

Codes and standards applicable to the ESF filter systems are listed in table 3.2-1.

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6.5.1.2 System Description

6.5.1.2.1 General Description

The fuel building emergency exhaust system is shown in figure 9.4-6, and the control building HVAC system is shown in figure 9.4-1. A detailed description of these systems is provided in subsections 9.4.1, 9.4.2, and 9.4.6.

The ESF filter systems comply with Regulatory Guide 1.52, as discussed in table 6.5-1.

Table 6.5-2 lists the system design parameters used in the radiological consequences of postulated accidents presented in chapter 15.

6.5.1.2.2 Component Description

The fuel building emergency exhaust system components are described in subsection 9.4.6. The control room HVAC system components are described in subsection 9.4.1.

6.5.1.2.3 System Operation

In the event of a LOCA, the fuel building emergency exhaust system functions to limit and reduce the potential release of fission products from the auxiliary building. Specific details of system operation following a LOCA are provided in subsection 9.4.2.

In the event of a fuel handling accident in the fuel building, the fuel building emergency exhaust system functions to reduce the fission product release from the fuel building. Specific details of system operation following a fuel handling accident are provided in subsection 9.4.6.

In the event of a LOCA or fuel handling accident, the control room HVAC system isolates the normal control room intake and provides the control room with a filtered supply of air. Specific details of system operation following a LOCA are discussed in section 6.4.

6.5.1.3 Safety Evaluation

Safety evaluations are numbered to correspond to the safety design bases given in subparagraph 6.5.1.1.1.

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6.5.1.3.1 Safety Evaluation One

Table 6.5-2 lists the ESF filter systems design parameters used to determine the radiological consequences for the postulated accidents analyzed in chapter 15. The results of these analyses demonstrate that the fuel building emergency exhaust system reduces and controls fission products released from the offsite radiation exposures are within the guidelines of 10 CFR 100. The functional requirements for the design and construction of the fuel building emergency exhaust system filters are provided in subsection 9.4.6.

6.5.1.3.2 Safety Evaluation Two

The results of the analyses described in chapter 15 demonstrate that the control room HVAC systems reduce fission product concentrations to the control room following a LOCA to within the guidelines of General Design Criterion 19. The functional requirements for the design and construction of the control room filter systems are provided in section 6.4 and subsection 9.4.1.

6.5.1.4 Tests and Inspections

Tests and inspections for the ESF filter systems are described in section 6.4 and subsection 9.4.6.

6.5.1.5 Instrumentation Requirements

High pressure differential alarms and indicators are provided in the control room to monitor filter condition. Instrumentation and controls are provided to facilitate automatic operation and remote control of the system and to provide continuous indication of system parameters. Further descriptions are provided in section 6.4 and subsection 9.4.6.

Design details and logic of the instrumentation are discussed in chapter 7.

6.5.1.6 Materials

The materials used for ESF filter systems were chosen considering the environmental conditions and compatibility with the filter materials.

The quantity and chemical composition of materials used are shown in tables 6.4-1 and 9.4-11.

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6.5.2 CONTAINMENT SPRAY SYSTEM FISSION PRODUCT REMOVAL

The containment spray system (CSS) is an ESF system, the functions of which are to reduce pressure and temperature in the containment atmosphere following a postulated loss-of-coolant-accident (LOCA), and to remove radioactive fission products from the containment atmosphere. These functions are performed by spraying water into the containment atmosphere through a large number of nozzles on spray headers located in the containment dome. Reduction of pressure and temperature in the containment with the CSS is discussed in subsection 6.2.1 and paragraph 6.2.2.1.

Radioiodine in its various forms is the fission product of primary concern in the evaluation of a LOCA. It is absorbed by the containment spray from the containment atmosphere. To enhance this iodine absorption capacity of the spray, the spray solution is adjusted to an alkaline pH that promotes iodine hydrolysis, in which iodine is converted to nonvolatile forms.

The physical characteristics of the CSS are discussed in paragraph 6.2.2.1. Discussed herein are the spray additive portion of the system and the containment spray system's fission product removal capability following a LOCA.

6.5.2.1 Design Bases

6.5.2.1.1 Safety Design Bases

6.5.2.1.1.1 Safety Design Basis One. The CSS is designed to provide a spray solution while the spray additive portion of the system is in operation in the pH range of 9.0 to 11.0, and a final containment recirculation sump solution with a pH of at least 8.5.

6.5.2.1.1.2 Safety Design Basis Two. The CSS is capable of reducing the iodine and particulate fission product inventories in the containment atmosphere such that the offsite radiation exposures resulting from a design basis LOCA are within the plant siting dose guidelines of 10 CFR 100.

Additional safety design bases are included in paragraph 6.2.2.1, in which the capability of the spray system to remove heat from the containment atmosphere is discussed.

6.5.2.1.2 Power Generation Design Bases

The CSS has no power generation design bases. 462

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6.5.2.2 System Design

6.5.2.2.1 General Description

The containment spray additive portion of the CSS provides for eduction of a nominal 30 weight percent sodium hydroxide

spray mixture with a pH of 9.86 to 11.40 during the initial period of operation when radioiodine is being removed from the containment atmosphere. A pH of spray mixture exceeds value of 11.00 for a period of 30 minutes during sodium hydroxide injection.

The spray additive subsystem of the CSS, shown schematically in figure 6.2-44, consists of one spray additive tank, two eductors, valves, and connecting piping. The system uses the containment spray pumps and spray headers, as described in paragraph 6.2.2.1, to deliver and distribute the spray additive solution to the containment atmosphere. Initially, water from the refueling water storage tank (RWST) is used as the water source for containment spray. Sodium hydroxide is educted from the spray additive tank into the water from the RWST or the containment sump, and pumped to the spray ring headers and nozzles.

Parts of the CSS in contact with borated water or the sodium hydroxide spray additive, or mixtures of the two, are stainless steel or an equivalent corrosion-resistant material.

The stainless steel spray additive tank contains sufficient 30 weight percent sodium hydroxide spray additive solution to bring the containment sump fluid to a minimum pH of 8.5 after mixing with the borated water from the RWST, boron injection tank, accumulators, and reactor coolant. This assures continued iodine retention effectiveness of containment sump water during the recirculation phase.

The two spray additive eductors mix 30 weight percent sodium hydroxide spray additive solution with the spray solution discharged by the containment spray pumps, as their motive flow.

The spray header design, including the number of nozzles per header, nozzle spacing, and nozzle orientation is provided in paragraph 6.2.2.1 and shown in figures 6.2-46 through 6.2-50. Each spray header layout is oriented to provide more than 95 percent area coverage at the operating deck of the containment building.

Total containment free volume, unsprayed containment free volume, specific unsprayed regions and volumes, and post-accident ventilation between sprayed and unsprayed volumes are provided in table 6.2-75.

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6.5.2.2.2 Component Description

The mechanical components of the spray additive subsystem are described in paragraph 6.2.2.1. Spray additive subsystem component design parameters are given in table 6.2-72.

6.5.2.2.3 System Operation

Summary of the design basis LOCA chronology for the CSS is presented in table 6.2-76.

System flow rates and the duration of operational modes are presented in subsection 6.2.2.

Operation of the CSS and the containment spray additive subsystem ensures that iodine removal requirements are fulfilled during the injection phase. The amount of NaOH added is sufficient to ensure long-term iodine retention in the sump water. Operation of the containment spray additive subsystem is terminated manually following the addition of the prescribed quantity of NaOH to assure a minimum long-term sump pH of at least 8.5. The containment iodine removal credit assumed in the calculation of offsite doses following a LOCA is provided in section 15.6.

6.5.2.3 Design Evaluation

6.5.2.3.1 Safety Evaluation

The safety evaluations are numbered to correspond to the safety design bases.

6.5.2.3.1.1 Safety Evaluation One. The system's capability to reduce the airborne fission product inventory is based on the pH of the spray solution for removal during injection and for retention during recirculation, and on the system's capability to provide spray for essentially all regions of the containment.

The pH calculations for containment spray and sump water following a LOCA have been made for the following two cases:

A. Maximum pH

B. Minimum pH.

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In calculating the maximum pH, the following assumptions are made:

A. Minimum safety injection system flow rates

B. Minimum CSS flow rates.

C. Minimum RWST and accumulator boron concentration

D. Minimum RWST volume

E. Maximum spray additive tank volume content and NaOH concentration. NaOH is injected into one of the two CSS trains.

F. No pH reduction due to consumption of hydroxyl ions as a result of corrosion of metals.

In calculating the minimum pH, the following assumptions are made:

A. Maximum safety injection system flow rates

B. Maximum CSS operation

C. Maximum RWST and accumulator boron concentration

D. Maximum RWST volume

E. Minimum spray additive tank volume content and NaoH concentration

The results of the analysis for the maximum pH case are presented in figure 6.5-1. These results show that for full safety injection and containment spray operation, the injection phase of operation will last approximately 35.0 minutes. The spray water pH during the injection phase will be approximately 9.86. The spray flow rate into the containment will be approximately 6010.0 gal/min from two spray trains, of which 40.0 gal/min will be from the sodium hydroxide tank via the eductors. This addition of sodium hydroxide to the sump water during the injection phase increases sump pH to approximately 8.16. During the first 75.0 minutes of recirculation, sodium hydroxide will continue to be added to the spray water. A maximum spray pH of 11.4 is reached after approximately 4400 gallons of 30.0 weight percent sodium hydroxide have been injected into the containment.

The results of the analysis for the minimum pH case are presented in figure 6.5-2. These results show that for full safety injection and one-half containment spray operation, 433

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the injection phase of operation will last for 38 minutes. The spray water pH during the injection phase will be approximately 9.13. A larger RWST volume and smaller spray additive tank volume is assumed for this case than the previous case. In this case, the RWST will empty prior to the spray additive tank. The spray additive tank will empty approximately 82 minutes after recirculation phase begins. During this time, the sump water pH will continually increase to a maximum value of 8.66. The minimum long term recirculation sump water pH is 8.66.

The above analyses show that the spray water pH is always greater than 9.06 and the sump water pH will not fall below 8.66 for long term recirculation.

6.5.2.3.1.2 Safety Evaluation Two. The spray iodine removal analysis is based on the assumption that:

A. Only one out of the two spray pumps is operating

B. The emergency core cooling system (ECCS) is operating at its maximum capacity.

The later assumption includes operation of two high and two low pressure injection pumps.

The ECCS pumps are switched to the recirculation mode when the low-low alarm level is reached in the RWST. The containment spray pumps are switched over to the recirculation mode when the RWST water reaches the empty alarm level.

The input parameters and results of the containment spray iodine removal analysis are given in table 6.5-3.

The spray system directly sprays approximately 79 percent of the total containment net free volume. The remaining 21 percent of the total containment volume does not get sprayed directly because of obstructions to the falling spray drops. However, the major portion of the containment not directly sprayed still has good communication with directly sprayed volumes while a minor portion has restricted communication. A description of the spray obstructions, the sprayed and unsprayed volumes, and the communication between sprayed and unsprayed volumes is presented in paragraph 6.2.2.1.

For the spray iodine removal analysis, the assumption was made that the directly sprayed volumes and those volumes not directly sprayed (even those having good communication with directly sprayed regions) should be considered separately.

The former was designated as the sprayed volume and the latter was designated as the unsprayed volume. Thus, the sprayed volumes make up 79 percent of the containment free volume, while the unsprayed volumes make up the remaining 21 percent of the containment free volume for the determination of the effective iodine removal constant for the entire containment volume.

Sodium hydroxide is added to the spray solution to ensure efficient and rapid removal of the iodine from the containment atmosphere. The containment spray pump flow rate of 2,985 gal/min per pump is used in the calculations for conservatism.

The sump/spray pH results corresponding to the assumptions stated above are illustrated in figure 6.5-1. Sodium hydroxide is added to the containment spray solution during the injection mode resulting in a minimum containment recirculation sump water pH value of 8.66. Although the iodine removal capability remains high under these conditions, no credit is taken for iodine removed after the decontamination factor (DF) of 100 is reached during the injection phase.

6.5.2.3.2 Iodine Removal Models

Based on Regulatory Guide 1.4, three species of iodine are postulated to exist airborne in the containment atmosphere following a LOCA. These are the elemental, particulate, and organic species. It has been conservatively assumed in these evaluations of spray removal effectiveness that organic iodine forms are not removed by the sodium hydroxide spray.

The spray washout model for aerosol particles is represented in equation form as follows (reference 1):

$$\lambda_\rho = \frac{3hEF}{2dV} \qquad (1)$$

where:

λ_ρ = spray removal constant for particles, (hr^{-1})

h = fall height, (cm)

E = total collection efficiency for a single drop,

F = spray flowrate, (ft^3/hr)

d = mean drop diameter, (cm)

V = volume of gas space, (ft^3)

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The capture of particles by falling drops results from Brownian diffusion, diffusiophoresis, interception, and impaction. Early in the injection phase particles are removed mainly by impaction. Following injection when the larger particles have already been removed, the removal rate is controlled by diffusiophoresis, which is the collection of particulates by steam condensing on the spray drops. The single drop collection efficiency, E, is taken as 0.0015 the minimum value observed in the CSE experimental tests (reference 2). In those experimental results, the minimum collection efficiency, 0.0015, was only attained after the major fraction of airborne particles was removed. For early time periods, the removal rates were much higher than the minimum values ultimately reached.

Based on equation (1) and the conservative assumptions indicated in this subsection, the resulting spray removal constant for particulate iodine has been calculated to be 0.715 (hr^{-1}). This 462
provides a significant margin of conservatism over the value of 0.45 (hr^{-1}) that was used in the analysis in section 15.6.

Particle spray removal constants considerably larger and of longer duration than those conservatively chosen above have been reported from the Battelle Northwest Containment Systems Experiment (reference 2) and by the Oak Ridge National Laboratories Nuclear Safety Pilot Plant (reference 3).

The spray system, by virtue of the large surface area provided between the droplets and the containment atmosphere, will afford an excellent means of absorbing elemental radioactive iodine released as a consequence of a LOCA. Sodium hydroxide will be added to the spray fluid to increase the solubility of iodine in the spray to the point where the rate of absorption is largely dependent on the concentration of radioiodine in the air surrounding the drops. The conservatively calculated removal constant for elemental iodine is 23.1 hr^{-1}. This removal constant is calculated based on the assumptions and model which follow. The assumptions used in the analyses are conservative in comparison with actual values.

Assumptions:

A.	Containment free volume, ft^3	2.15×10^6
B.	Sprayed volume fraction, %	79.0
C.	Spray flow rate (single train), gal/min	2,700
D.	Spray droplet (mean drop diameter), microns	1,000 max.
E.	Fall height, ft	100

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F.	Sherwood number, Sh	1.5292
G.	Drop residence time	
H.	Accident temperature, °F	248
I.	Partition coefficient	5,000

Model:

The basic model of the containment atmosphere and spray system is given by Parsley (reference 3). The containment atmosphere is viewed as a "black box" having a sprayed volume, V, and containing iodine at some uniform concentration Cg. Liquid enters at a flow of F volumes per unit time, containing iodine at a concentration of CL1, and leaves at the same flow at concentration CL2. A material balance for the containment vessel as a function of time is given by:

$$-(V)dCg = F(CL2 - CL1)\ dt \qquad (2)$$ 462

where:

CL1 = the iodine concentration in the liquid entering the dispersed phase, g/cm^3

CL2 = the iodine concentration in the liquid leaving the dispersed phase, g/cm^3

V = sprayed volume of containment, cm^3

Cg = the iodine concentration in the containment atmosphere, g/cm^3

F = the spray flow rate, cm^3/s

t = spray time, s

An absorption efficiency, E, which may be described as the fraction of saturation, is defined as:

$$E = (CL2 - CL1)/(CL^* - CL1) \qquad (3)$$

In addition the equilibrium distribution of iodine between the vapor and liquid phases is given by:

$$H = CL^*/Cg \qquad (4)$$

where:

H = the iodine partition coefficient (g/l of liquids)/(g/l of gas)

CL* = the equilibrium concentration in the liquid, g/cm^3

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Substitution of equation (4) into equation (3) yields

$$E = (CL2 - CL1)/(HCg - CL1) \quad (5)$$ 462

Solving equation (5) for (CL2 - CL1) and inserting the result into equation (2) gives

$$-(V)dCg = EF(HCg - CL1)dt \quad (6)$$ 462

During the injection phase, CL1 = 0, so that

$$-(V)dCg = (EFHCg)dt \quad (7)$$ 462

Equation (7) can be integrated to solve for Cg. The concentration of iodine in the containment atmosphere during injection as a function of time is given by:

$$Cg = Cg_o \exp\,[-EHFt/V] \quad (8)$$

where:

Cg_o = the initial iodine concentration in the containment atmosphere, g/cm^3

Equation (8) is applicable up to the time the spray solution is recirculated and is based on the following assumptions:

A. Cg is uniform throughout the containment.

B. There are no iodine sources after the initial release.

C. The concentration of iodine in the spray solution entering the containment is zero.

From equation (8), the spray removal constant, λ_e, is given by:

$$\lambda_e = \frac{EHF}{V} \quad (9)$$

The above equation for λ_e is independent of the models on which the numerical evaluation of the drop absorption efficiency, E, and the iodine partition coefficient, H, may be based.

Absorption efficiency for elemental iodine may be calculated from the time-dependent diffusion equation for a rigid sphere, with the gas film mass transfer resistance as a boundary condition. This mass transfer model was suggested by Parsley (reference 3), who gives the solution to the diffusion equation with the above mentioned boundary condition as:

$$E = 1 - \sum_{n=1}^{\infty} \frac{6Sh^2 \exp(-\alpha_n^2\theta_f)}{\left[\alpha_n^2 + (Sh)\,(Sh-1) \quad \alpha_n^2\right]} \quad (10)$$

where:

Sh = the dimensionless group = $k_g\ a/HD_L$

a = the drop radius, cm

k_g = the gas film mass transfer coefficient, cm/s

D_L = the liquid diffusivity, cm^2/s

θ_f = the dimensionless drop residence time

α_n = the eigenvalues of the solution

It should be noted that this solution, which applies to the rigid drop model, is based on the assumption that molecular diffusion occurs from the surface to the interior of the drop. Since a high degree of mixing is expected in the drops, particularly in the presence of sizeable temperature and concentration gradients, it is apparent that this stagnant drop model presents a conservative approach to the calculation of iodine absorption by the drops.

The gas film mass transfer coefficient required for the above calculation is computed by the equation of Ranz and Marshall (reference 4),

$$k_g = \frac{D_g}{d} (2 + 0.6\ Re^{0.5}\ Sc^{0.33}) \qquad (11)$$

where:

d = drop diameter, cm

D_g = diffusion coefficient in vapor, cm^2/s

R_e = Reynold's number

Sc = Schmidt number

The absorption efficiency is a function of the drop size, the gas phase mass transfer coefficient, diffusion in the liquid phase, the partition coefficient, and the drop fall time.

The distribution of drop sizes is expected to follow a log-normal distribution as described in reference 5. For conservatism, a Sauter mean drop size of 1000 microns was considered in the spray analysis. L. F. Parsley, in Design Considerations of Reactor Containment Spray Systems, Part VII (reference 3), recommends that the diameter be increased by 25 percent for calculational purposes. This increase, along with the dispersion effect, leads to overestimating the iodine removal

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half-life by a factor of 2. This allows adequate margin for effects on spray performance due to drop coalescence (reference 5). As a result, a drop diameter of 1250 microns is conservatively assumed in the spray analysis. The actual mean drop size is 230 microns. Refer to subparagraph 6.2.2.1.2.2 for data on the containment spray nozzles and drop size tests. Considering all drops to be 1250 microns will produce conservative results as compared to using the actual drop size distribution. This is based on conclusions of ORNL-TM-2412, Part 1 (reference 6).

The equations given by Eggleton (8) were used to calculate the partition coefficient.

Although the iodate reaction, i.e.,

$$3(I_2) + 3H_2O = IO_3^- + 5\ (I^-) + 6(H^+)$$

is expected to contribute significantly to the iodine partition at the high sump pH values, this reaction is conservatively neglected in these calculations.

The equilibrium elemental iodine decontamination factor is given by:

$$DF = 1 + H\ (VL)/(VG) \qquad (12)$$

where:

H = equilibrium partition coefficient

VG = gaseous volume of the containment

VL = liquid volume of the containment

The liquid volume in the containment is given in table 6.5-3. The gaseous volume is determined by subtracting the liquid volume from the containment net free volume given in table 6.5-3.

Section 15.6 utilizes a maximum decontamination factor of 100 to determine the offsite thyroid doses following a LOCA. To achieve this DF, an equilibrium partition coefficient of 5.0×10^3 must be maintained throughout the accident. Based on the temperature and pH values for the containment sump, the equilibrium partition coefficient for full safety injection system with full spray system operation is 4.76×10^4 at the end of sodium hydroxide injection. For full safety injection system with one-half spray system operation, the equilibrium partition coefficient is 5.0×10^4 at the end of sodium hydroxide injection.

In both cases the calculated value of the iodine decontamination factor, based on the conservative set of equations given by Eggleton (reference 7), is larger than the value used to evaluate offsite thyroid doses in section 15.6. It can be concluded, therefore, that no re-evolution of iodine will occur as a result of changes in sump pH and temperature.

In order to conservatively compute the value of the removal constant for elemental iodine, λe, a single value of 5000, Postma and Pasedag (reference 1), was assumed for the iodine partition coefficient. The mass transfer parameters were evaluated for a single conservative containment temperature of 248F.

6.5.2.4 Tests and Inspections

The testing and inspection capability and the preoperational testing program for the CSS are discussed in paragraph 6.2.2.1.

6.5.2.5 Instrumentation Applications

The CSS instrumentation applications are discussed in paragraph 6.2.2.1.

6.5.2.6 Materials

The CSS materials are discussed in paragraph 6.2.2.1.

6.5.3 FISSION PRODUCT CONTROL SYSTEMS

6.5.3.1 Primary Containment

The primary containment consists of a prestressed, post-tensioned, reinforced concrete structure with cylindrical walls, hemispherical dome, and base slab, lined with welded 6 mm steel plates, forming a continuous leaktight pressure boundary. Details of the containment structural design are discussed in section 3.8. Layout drawings of the containment structure and the hydrogen purge system are given in the general arrangement drawings of section 1.2.

The containment walls, liner plate, mechanical and electrical penetrations, isolation valves, hatches, and locks function to limit release of radioactive materials, subsequent to postulated accidents, such that the resulting offsite doses are less than the guideline values of 10 CFR 100. Containment parameters affecting fission product release accident analyses are given in table 6.5-4. Containment isolation system design is discussed in subsection 6.2.4.

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Long-term containment pressure response to the design basis accidents are shown in subsection 6.2.1. Relative to this time period, the containment spray system is operated to reduce iodine concentrations and containment atmospheric temperature and pressure from the time commencing with system initiation, until containment pressure has returned to normal. Containment spray system actuation times are discussed in section 8.3 and paragraph 6.2.2.1.

The containment low volume purge system operates continuously during power operation to allow personnel access to the containment. Operation of the low volume purge system is considered in the analysis of radiological releases following a design basis accident as described in chapter 15. The low volume purge system will terminate and the containment will isolate within 5 seconds upon receipt of either a containment isolation signal or containment high radiation signal as indicated in subsection 6.2.4.

Redundant, safety-related hydrogen recombiners are provided for the containment atmosphere as the primary means of controlling post-accident hydrogen concentrations. A hydrogen purge system is provided for backup hydrogen control. Containment combustible gas control systems are discussed in detail in subsection 6.2.5.

6.5.3.2 Secondary Containment

This section is not applicable to KNU 5 & 6.

6.5.4 ICE CONDENSER AS A FISSION PRODUCT CLEANUP SYSTEM

This section is not applicable to KNU 5 & 6.

6.5.5 REFERENCES

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Table 6.5-1

DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.52, REVISION 2, DATED MARCH 1978, TITLED "DESIGN, TESTING, AND MAINTENANCE CRITERIA FOR POST-ACCIDENT ENGINEERED SAFETY FEATURE ATMOSPHERE CLEANUP SYSTEM AIR FILTRATION AND ADSORPTION UNITS OF LIGHT-WATER-COOLED NUCLEAR POWER PLANTS"
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NOTE

Design requirements of this Regulatory Guide are applicable to the following power plant exhaust systems:

Fuel building emergency exhaust
Control room emergency filtration

Regulatory Guide 1.52 Position	KNU 5 & 6 Design
1. Environmental Design Criteria	
a. The design of an ESF atmosphere cleanup system should be based on the maximum pressure differential, radiation dose rate, relative humidity, maximum and minimum temperature, and other conditions resulting from the postulated DBA and on the duration of such conditions.	1. a. Complies as per paragraphs 6.4.2.2 and 6.4.4.6, and subparagraph 9.4.6.3.1
b. The design of each ESF system should be based on the radiation dose to essential services in the vicinity of the adsorber section, integrated over the 30-day period following the postulated DBA. The radiation source term should be consistent with the assumptions found in Regulatory Guides 1.3, 1.4 and 1.25. Other ESFs including pertinent components of essential services such as power, air, and control cables should be adequately shielded from the ESF atmosphere cleanup systems.	b. Complies.

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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
c. The design of each adsorber should be based on the concentration and relative abundance of the iodine species (elemental, particulate, and organic), which should be consistent with the assumptions found in Regulatory Guides 1.3, 1.4, and 1.25.	c. Designed for: 1. Maximum loading of 2.5 mg of iodine per gram of activated carbon 2. 50 mg of impregnant per gram of carbon.
d. The operation of any ESF atmosphere cleanup system should not deleteriously affect the operation of other engineered safety features such as a containment spray system, nor should the operation of other engineered safety features such as a containment spray system deleteriously affect the operation of any ESF atmosphere cleanup system.	d. The operation of both the fuel building emergency exhaust and the control room emergency systems does not affect the operation of other ESF systems.
e. Components of systems connected to compartments that are unheated during a postulated accident should be designed for post-accident effects of both the lowest and highest predicted temperatures.	e. All systems are designed to operate over a temperature range as shown in tables 3.11-1 and 3.11-2.
2. System Design Criteria	
a. ESF atmosphere cleanup systems designed and installed for the purpose of mitigating accident doses should be redundant. The systems should consist of the following sequential components: (1) demisters, (2) prefilters (demisters may serve this function), (3) HEPA filters before the adsorbers, (4) iodine adsorbers (impregnated activated	2. a.1. Control room emergency filtration system complies. a.2. Fuel building emergency exhaust system complies, except that demisters are not required since

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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
carbon or equivalent adsorbent such as metal zeolites), (5) HEPA filters after the adsorbers, (6) ducts and valves, (7) fans, and (8) related instrumentation. Heaters or cooling coils used in conjunction with heaters should be used when the humidity is to be controlled before filtration.	water droplets are not entrained in the airstream following an accident.
b. The redundant ESF atmosphere cleanup systems should be physically separated so that damage to one system does not also cause damage to the second system. The generation of missiles from high-pressure equipment rupture, rotating machinery failure, or natural phenomena should be considered in the design for separation and protection.	b. Complies as per subparagraph 9.4.6.3.3 and sections 3.5 and 3.6.
c. All components of an ESF atmosphere cleanup system should be designated as Seismic Category I (see Regulatory Guide 1.29) if failure of a component would lead to the release of significant quantities of fission products to the working or outdoor environments.	c. Complies as per subparagraph 9.4.6.3.4 and section 3.2.
d. If the ESF atmosphere cleanup system is subject to pressure surges resulting from the postulated accident, the system should be protected from such surges. Each component should be protected with such devices as pressure relief valves so that the overall system will	d. Not applicable. The systems are located outside of the containment and not exposed to pressure surges.

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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
perform its intended function during and after the passage of the pressure surge.	
e. In the mechanical design of the ESF system, the high radiation levels that may be associated with buildup of radioactive materials on the ESF system components should be given particular consideration. ESF system construction materials should effectively perform their intended function under the postulated radiation levels. The effects of radiation should be considered not only for the demisters, heaters, HEPA filters, adsorbers, and fans, but also for any electrical insulation, controls, joining compounds, dampers, gaskets, and other organic-containing materials that are necessary for operation during a postulated DBA.	e. The ESF equipment is located in areas where the normal 40 years and post-accident integrated radiation dosage is not significant.
f. The volumetric air flow rate of a single cleanup train should be limited to approximately 30,000 ft^3/min. If a total system air flow in excess of this rate is required, multiple trains should be used. For ease of maintenance, a filter layout three HEPA filters high and ten wide is preferred.	f. The fuel building emergency exhaust system air flow is 5,000 ft^3/min, with HEPA filters 6 ft wide by 4 ft high. The control room HVAC system air flow is 2,000 ft^3/min with HEPA filters 2 ft wide by 4 ft high.
g. The ESF atmosphere cleanup system should be instrumented to signal, alarm, and record pertinent pressure drops and flow rates at the control room.	g. Complies as shown in figures 9.4-1 and 9.4-6.

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DESIGN COMPARISON TO REGULATORY POSITIONS OF
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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
h. The power supply and electrical distribution system for the ESF atmosphere cleanup system described in regulatory position 2.a above should be designed in accordance with Regulatory Guide 1.32. All instrumentation and equipment controls should be designed to IEEE Standard 279. The ESF system should be qualified and tested under Regulatory Guide 1.89. To the extent applicable, Regulatory Guides 1.30, 1.100, and 1.118 and IEEE Standard 334 should be considered in the design.	h. The design complies with Regulatory Guides 1.32, 1.89, 1.30, 1.100 and IEEE Standards 279, 323, 334, 344.
i. Unless the applicable ESF atmosphere cleanup system operates continuously during all times that a DBA can be postulated to occur, the system should be automatically activated upon the occurrence of a DBA by (1) a redundant ESF signal (i.e., temperature, pressure) or (2) a signal from redundant Seismic Category I radiation monitors.	i. Complies as shown in figures 9.4-1 and 9.4-6.
j. To maintain radiation exposures to operating personnel as low as is reasonably achievable during plant maintenance, ESF atmosphere cleanup systems should be designed to control leakage and facilitate maintenance in accordance with the guidelines of Regulatory Guide 8.8. The ESF atmosphere cleanup train should be totally enclosed. Each train should be designated and	j. Sections of the cleanup units are welded or bolted to prevent leakage in accordance with Regulatory Guide 8.8.

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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
installed in a manner that permits replacement of the train as an intact unit or as a minimum number of segmented sections without removal of individual components.	
k. Outdoor air intake openings should be equipped with louvers, grills, screens, or similar protective devices to minimize the effects of high winds, rain, snow, ice, trash, and other contaminants on the operation of the system. If the atmosphere surrounding the plant could contain significant environmental contaminants, such as dusts and residues from smoke cleanup systems from adjacent coal burning power plants or industry, the design of the system should consider these contaminants and prevent them from affecting the operation of any ESF atmosphere cleanup system.	k. Complies as shown in figure 9.4-1.
l. ESF atmosphere cleanup system housings and ductwork should be designed to exhibit on test a maximum total leakage rate as defined in Section 4.12 of ANSI N509-1976. Duct and housing leak tests should be performed in accordance with the provisions of Section 6 of ANSI N510-1975.	l. The filter-fan unit meets ANSI N509 and N510 requirements.
3. Component Design Criteria and Qualification Testing	
a. Demisters should be designed, constructed, and tested in accordance with the requirements of	3. a.1. Not applicable to fuel building emergency exhaust

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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
Section 5.4 of ANSI N509-1976. Demisters should meet Underwriters' Laboratories (UL) Class 1 requirements.	system. See response to regulatory position 2.a above. a.2. Demisters meet UL Class 1 and ANSI N509. a.3. Control room emergency filtration system complies.
b. Air heaters should be designed, constructed, and tested in accordance with the requirements of Section 5.5 of ANSI N509-1976.	b. Air heaters meet ANSI N509 requirements.
c. Materials used in the prefilters should withstand the radiation levels and environmental conditions prevalent during the postulated DBA. Prefilters should be designed, constructed, and tested in accordance with the provisions of Section 5.3 of ANSI N509-1976.	c. Complies except that no prefilters are used for control room emergency filtration units. Prefilters meet ANSI N509 requirements.
d. The HEPA filters should be designed, constructed, and tested in accordance with section 5.1 of ANSI N509-1976. Each HEPA filter should be tested for penetration of dioctylphthalate (DOP) in accordance with the provisions of MIL-F-51068 and MIL-STD-282.	d. HEPA filters meet ANSI N509 requirements (see subsection 6.4.5). HEPA filters meet DOP testing in accordance with MIL-F-51068 and MIL-STD-282.
e. Filter and adsorber mounting frames should be constructed and	e. Filter and adsorber mounting

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designed in accordance with the provisions of Section 5.6.3 of ANSI N509-1976.	frames meet ERDA-76-21 requirements.
f. Filter and adsorber banks should be arranged in accordance with the recommendations of Section 4.4 of ERDA 76-21.	f. Filter and adsorber banks meet ERDA-76-21 requirements.
g. System filter housings, including floors and doors, should be constructed and designed in accordance with the provisions of Section 5.6 of ANSI N509-1976.	g. The design meets ERDA-76-21 requirements.
h. Water drains should be designed in accordance with the recommendations of Section 4.5.8 of ERDA 76-21.	h. The design meets ERDA-76-21 requirements.
i. The adsorber section of the ESF atmosphere cleanup system may contain any adsorbent material demonstrated to remove gaseous iodine (elemental iodine and organic iodides) from air at the required efficiency. Since impregnated activated carbon is commonly used, only this adsorbent is discussed in this guide.	i. The adsorbent material used is impregnated activated carbon.
Each original or replacement batch of impregnated activated carbon used in the adsorber section should meet the qualification and batch test results summarized in Table 5.1 of ANSI N509-1976. In this table, a "qualification test" should be interpreted to mean a test that establishes the suitability of a product for a	Batch tests on the raw and impregnated materials meet ASTM D3803 requirements (see subparagraph 6.4.5.1). 6

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DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.52 (Sheet 9 of 17)

Regulatory Guide 1.52 Position	KNU 5 & 6 Design
general application, normally a one-time test reflecting historical typical performance of material In this table, a "batch test" should be interpreted to mean a test made on a production batch of product to establish suitability for a specific application. A "batch of activated carbon" should be interpreted to mean a quantity of material of the same grade, type, and series that has been homogenized to exhibit, within reasonable tolerance, the same performance and physical characteristics and for which the manufacturer can demonstrate by acceptable tests and quality control practices such uniformity. All material in the same batch should be activated, impregnated, and otherwise treated under the same process conditions and procedures in the same process equipment and should be produced under the same manufacturing release and instructions. Material produced in the same charge of batch equipment constitutes a batch; material produced in different charges of the same batch equipment should be included in the same batch only if it can be homogenized as above. The maximum batch size should be 350 ft^3 of activated carbon. If an adsorbent other than impregnated activated carbon is proposed or if the mesh size distribution is different from the	

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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
specifications in Table 5.1 of ANSI N509-1976, the proposed adsorbent should have demonstrated the capability to perform as well as or better than activated carbon in satisfying the specifications in Table 5.1 of ANSI N509-1976.	
If impregnated activated carbon is used as the adsorbent, the adsorber system should be designed for an average atmosphere residence time of 0.25 sec per two inches of adsorbent bed. The adsorption unit should be designed for a maximum loading of 2.5 mg of total iodine (radioactive plus stable) per gram of activated carbon). No more than 5 percent of impregnant (50 mg of impregnant per gram of carbon) should be used. The radiation stability of the type of carbon specified should be demonstrated and certified (see regulatory position 1.b above for the design source term).	The average atmosphere residence time is 0.25 seconds per two inches of adsorbent bed. The maximum loading is 2.5 mg of iodine per gram of activated carbon. Maximum of 5 percent of impregnant is used.
j. Adsorber cells should be designed, constructed, and tested in accordance with the requirements of Section 5.2 of ANSI N509-1976.	j. The adsorbers meet ANSI N509 requirements (see paragraph 6.4.5.1).
k. The design of the adsorber section should consider possible iodine desorption and adsorbent autoignition that may result from radioactivity-induced heat in the adsorbent and concomitant temperature rise. Acceptable designs	k.1. Fuel building emergency exhaust system complies. Charcoal bed temperature will be maintained below desorption range by

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include a low-flow air bleed system, cooling coils, water sprays for the adsorber section, or other cooling mechanisms. Any cooling mechanism should satisfy the single-failure criterion. A low-flow air bleed system should satisfy the single failure criterion for providing low-humidity (less than 70 percent relative humidity) cooling air flow.	assuring a minimum air flow across the loaded bed. k.2. Control room emergency filtration and fuel building emergency exhaust systems comply. Anticipated charcoal bed loading is not sufficient to raise bed temperature to the desorption range. However, minimum air flow can be maintained across the bed to prevent excessive heating, if required.
l. The system fan, its mounting, and the ductwork connections should be designed, constructed, and tested in accordance with the requirements of Sections 5.7 and 5.8 of ANSI N509-1976.	l. The design meets Sections 5.7 and 5.8 of ANSI N509 requirements.
m. The fan or blower used on the ESF atmosphere cleanup system should be capable of operating under the environmental conditions postulated, including radiation.	m. The system can operate under all postulated environmental conditions. The expected radiation is negligible (refer to section 3.11).
n. Ductwork should be designed, constructed, and tested in accordance with the provisions of Section 5.10 of ANSI N509-1976.	n. Complies.

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o. Ducts and housings should be laid out with a minimum of ledges, protrusions, and crevices that could collect dust and moisture and that could impede personnel or create a hazard to them in the performance of their work. Straightening vanes should be installed where required to ensure representative air flow measurement and uniform flow distribution through cleanup components.	o. Complies.
p. Dampers should be designed, constructed, and tested in accordance with the provisions of Section 5.9 of ANSI N509-1976.	p. Leakage criteria meets ANSI N509, Class 2 requirements.
4. Maintenance	
a. Accessibility of components and maintenance should be considered in the design of ESF atmosphere cleanup systems in accordance with the provisions of Section 2.3.8 of ERDA 76-21 and Section 4.7 of ANSI N509-1976.	4. a. Complies.
b. For ease of maintenance, the system design should provide for a minimum of three feet from mounting frame to mounting frame between banks of components. If components are to be replaced, the dimension to be provided should be the maximum length of the component plus a minimum of three feet.	b. Not applicable for gasketless type charcoal adsorber cells as used in the control room emergency filtration system and the fuel handling emergency exhaust system.

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c. The system design should provide for permanent test probes with external connections in accordance with the provisions of Section 4.11 of ANSI N509-1976.	c. The design meets Section 4.11 of ANSI N509 requirements.
d. Each ESF atmosphere cleanup train should be operated at least 10 hours per month, with the heaters on (if so equipped), in order to reduce the buildup of moisture on the adsorbers and HEPA filters.	d. The filtration trains will be operated in this manner.
e. The cleanup components (i.e., HEPA filters, prefilters, and adsorbers) should not be installed while active construction is still in progress.	e. Complies.
5. In-Place Testing Criteria	
a. A visual inspection of the ESF atmosphere cleanup system and all associated components should be made before each in-place airflow distribution test, DOP test, or activated carbon adsorber section leak test in accordance with the provisions of Section 5 of ANSI N510-1975.	5. a. The in-place HEPA DOP test complies with ANSI N101.1-1972, see subsection 6.4.5.
b. The airflow distribution to the HEPA filters and iodine adsorbers should be tested in place for uniformity initially and after maintenance affecting the flow distribution. The distribution should be within ± 20 percent of the average flow per unit. The testing should be conducted in accordance	b. Complies.

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DESIGN COMPARISON TO REGULATORY POSITIONS OF
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Regulatory Guide 1.52 Position	KNU 5 & 6 Design
with the provisions of Section 9 of "Industrial Ventilation" and Section 8 of ANSI N510-1975.	
c. The in-place DOP test for HEPA filters should conform to Section 10 of ANSI N510-1975. HEPA filter sections should be tested in place (1) initially, (2) at least once per 18 months thereafter, and (3) following painting, fire, or chemical release in any ventilation zone communicating with the system to confirm a penetration of less than 0.05 percent at rated flow. An ESF air filtration system satisying this condition can be considered to warrant a 99 percent removal efficiency for particulates in accident dose evaluations. HEPA filters that fail to satisfy this condition should be replaced with filters qualified pursuant to regulatory position 3.d above. If the HEPA filter bank is entirely or only partially replaced, an in-place DOP test should be conducted.	c. Complies, except that HEPA filters are tested for efficiency, initially at the factory and at the USNRC Quality Assurance station, in accordance with MIL-STD-282.
If any welding repairs are necessary on, within, or adjacent to the ducts, housing, or mounting frames, the filters and adsorbers should be removed from the housing during such repairs. The repairs should be completed prior to periodic testing, filter inspection, and in-place testing. The use of silicone sealants or any other temporary patching material on filters, housing,	

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mounting frames, or ducts should not be allowed.	
d. The activated carbon adsorber section should be leak tested with gaseous halogenated hydrocarbon refrigerant in accordance with Section 12 of ANSI N510-1975 to ensure that bypass leakage through the adsorber section is less than 0.05 percent. After the test is completed, air flow through the unit should be maintained until the residual refrigerant gas in the effluent is less than 0.01 ppm. Adsorber leak testing should be conducted (1) initially, (2) at least once per 18 months thereafter, (3) following removal of and adsorber sample for laboratory testing if the integrity of the adsorber section is affected, and (4) following painting, fire or chemical release in any ventilation zone communicating with the system.	d. Complies, except that additional testing is provided to demonstrate efficiency. Samples from the initial charcoal batch and samples from the installed charcoal will be tested with radiomethyl iodine tracers to establish efficiency. Testing will be in accordance with ANSI N-510-1980 and will be conducted within 18 months.
6. Laboratory Testing Criteria for Activated Carbon	
a. The activated carbon adsorber section of the ESF atmosphere cleanup system should be assigned the decontamination efficiencies given in table 2 for elemental iodine and organic iodides if the following conditions are met: (1) The adsorber section meets the conditions given in regulatory position 5.d of this Guide.	6. a. Complies. The control room system activated carbon adsorber section has a 95 percent efficiency at 70 percent relative humidity and the fuel building emergency carbon adsorber has a 95 percent efficiency at 70 percent relative humidity.

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(2) New activated carbon meets the physical property specifications given in Table 5.1 of ANSI N509-1976, and (3) Representative samples of used activated carbon pass the laboratory tests given in Table 2 of this Guide. If the activated carbon fails to meet any of the above conditions, it should not be used in ESF adsorbers.	
b. The efficiency of the activated carbon adsorber section should be determined by laboratory testing of representative samples of the activated carbon exposed simultaneously to the same service conditions as the adsorber section. Each representative sample should be not less than two inches in both length and diameter, and each sample should have the same qualification and batch test characteristics as the system adsorbent. There should be a sufficient number of representative samples located in parallel with the adsorber section to estimate the amount of penetration of the system adsorbent throughout its service life. The design of the samplers should be in accordance with the provisions of Appendix A of ANSI N509-1976. Where the system activated carbon is greater than two inches deep, each representative sampling station should consist of enough two-inch samples in series to	b. Complies, at least eight test canisters, each containing a representative sample of charcoal, are installed across each filter bank.

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equal the thickness of the system adsorbent. Once representative samples are removed for laboratory test, their positions in the sampling array should be blocked off. Laboratory tests of representative samples should be conducted, as indicated in Table 2 of this Guide, with the test gas flow in the same direction as the flow during service conditions. Similar laboratory tests should be performed on an adsorbent sample before loading into the adsorbers to establish an initial point for comparison of future test results. The activated carbon adsorber section should be replaced with new unused activated carbon meeting the physical property specifications of Table 5.1 of ANSI N509-1976 if (1) testing in accordance with the frequency specified in footnote c of Table 2 of this Guide results in a representative sample failing to pass the applicable test in Table 2 of this Guide, or (2) no representative sample is available for testing.	

[1]The pertinent quality assurance requirements of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR 50 apply to all activities affecting the safety-related functions of HEPA filters.

[2]The U.S. Department of Energy (USDOE) operates a number of filter test facilities qualified to perform HEPA filter efficiency tests. These facilities are listed in the current USDOE Environmental Safety and Health Information Bulletin for Filter Unit Inspection and Testing Service.

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Table 6.5-2

ESF FILTER SYSTEMS INPUT PARAMETERS TO
CHAPTER 15 ACCIDENT ANALYSIS

Fuel building emergency exhaust filter adsorber unit efficiencies (%)	95
Fuel building emergency exhaust system flowrate standard ft^3/min	5,000
Control room filter adsorber unit efficiency (%)	95
Control room ac system flowrate standard ft^3/min	
Maximum outside air	350
Minimum recirculated air	1,650

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Table 6.5-3

INPUT PARAMETERS AND RESULTS OF CONTAINMENT
SPRAY IODINE REMOVAL ANALYSIS
(Sheet 1 of 2)

Core power (MWt)	2,775
Total containment free volume (ft^3) Sprayed containment free volume (ft^3)	2.15×10^6 1.70×10^6
Area coverage at the operating deck	95%
Mixing rate between sprayed and unsprayed volumes (ft^3/min)	33,000
Droplet fall distance assumed (ft)	100
Net spray flow rate per train (gal/min) (a)	2,985
Design NaOH flow rate per eductor (gal/min)	35 ± 5
Number of spray trains operating Maximum pH Minimum pH	 2 1
RWST Volume (gal): Maximum pH Minimum pH	433,000 530,000
Spray/Sump solution pH: Maximum Minimum	Figure 6.5-1 Figure 6.5-2
Liquid volume of the containment (ft^3): Maximum Minimum	 84720.0 71890.0
Elemental iodine removal coefficient, λe, used in accident calculations (hr^{-1}/train)	23.1
a. During injection phase	

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Table 6.5-3

INPUT PARAMETERS AND RESULTS OF CONTAINMENT SPRAY IODINE REMOVAL ANALYSIS
(Sheet 2 of 2)

Expected λe (hr^{-1}/train)	34.5
Particulate iodine removal coefficient, λp, used in accident calculations (hr^{-1}/train)	0.4
Calculated λp (hr^{-1}/train)	0.715
Spray drop size, design (cm)	0.125
Partition coefficient	5000

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Table 6.5-4

PRIMARY CONTAINMENT OPERATION FOLLOWING
A DESIGN BASIS ACCIDENT

General	
Type of structure	Reinforced concrete cylindrical containment with hemispherical dome. Interior wall lined with 6mm liner plate
Internal fission product removal systems	Containment spray system with NaOH additive
Free volume of containment	2.15×10^6 ft^3
Unsprayed Region Fraction	0.21
Sprayed Region Fraction	0.79
Transfer rate between sprayed and unsprayed regions	3.30×10^4 ft^3/min
Time-Dependent Parameters	
Containment Leakage Rate	
0 - 24 hrs	0.1 percent vol/d
1 - 30 days	0.05 percent vol/d
Sprayed Region Parameters	
Iodine spray removal coefficients[(a)]	
Elemental	23.13
Particulate	0.45

a. The spray removal coefficients are assumed to be zero when a decontamination factor of 100 is reached in the sprayed region.

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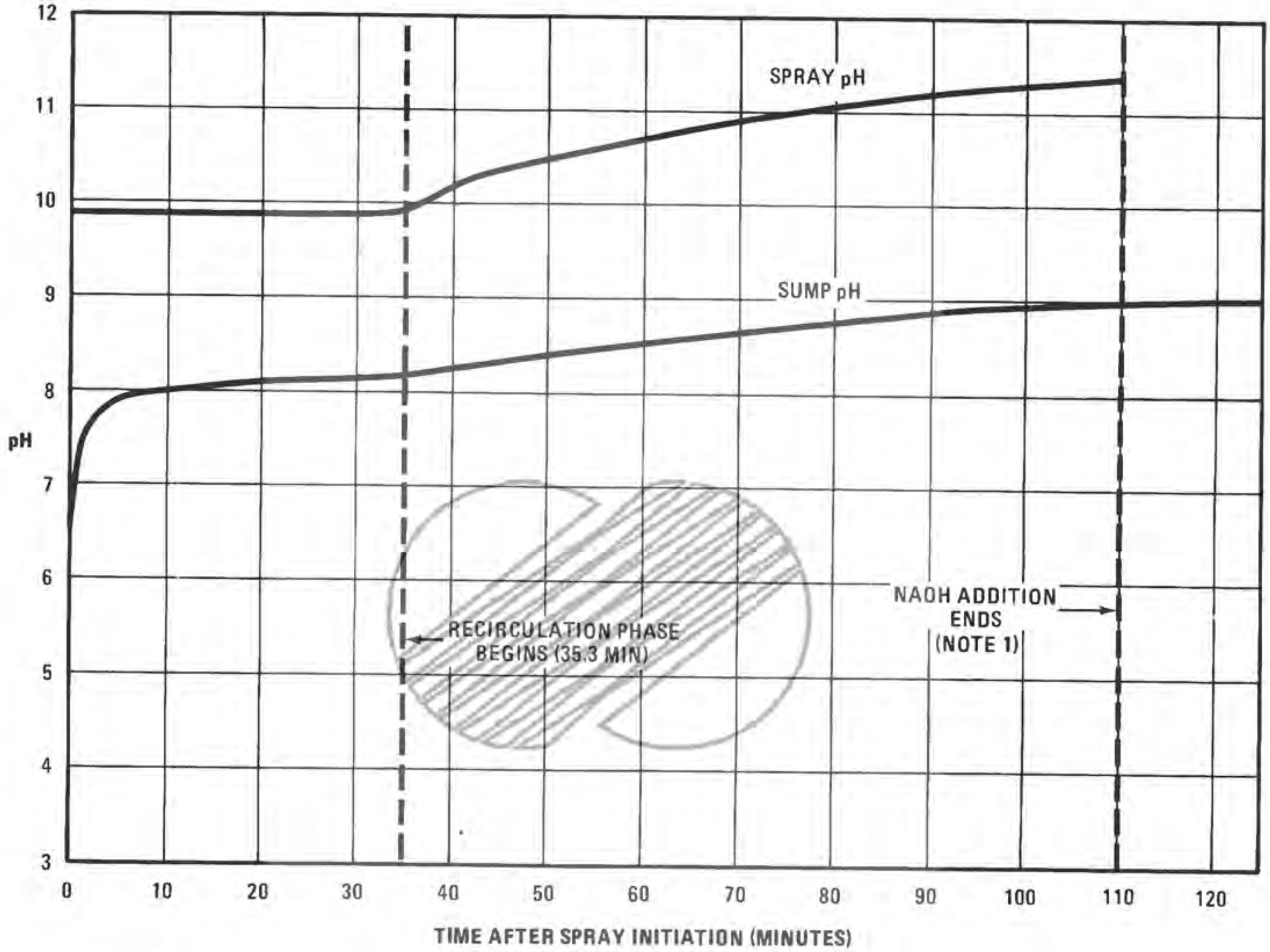

NOTES: 1 FOLLOWING THE COMPLETION OF NAOH ADDITION, SPRAY pH AND SUMP pH ARE IDENTICAL.

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MAXIMUM SPRAY AND SUMP pH VERSUS TIME

Figure 6.5-1

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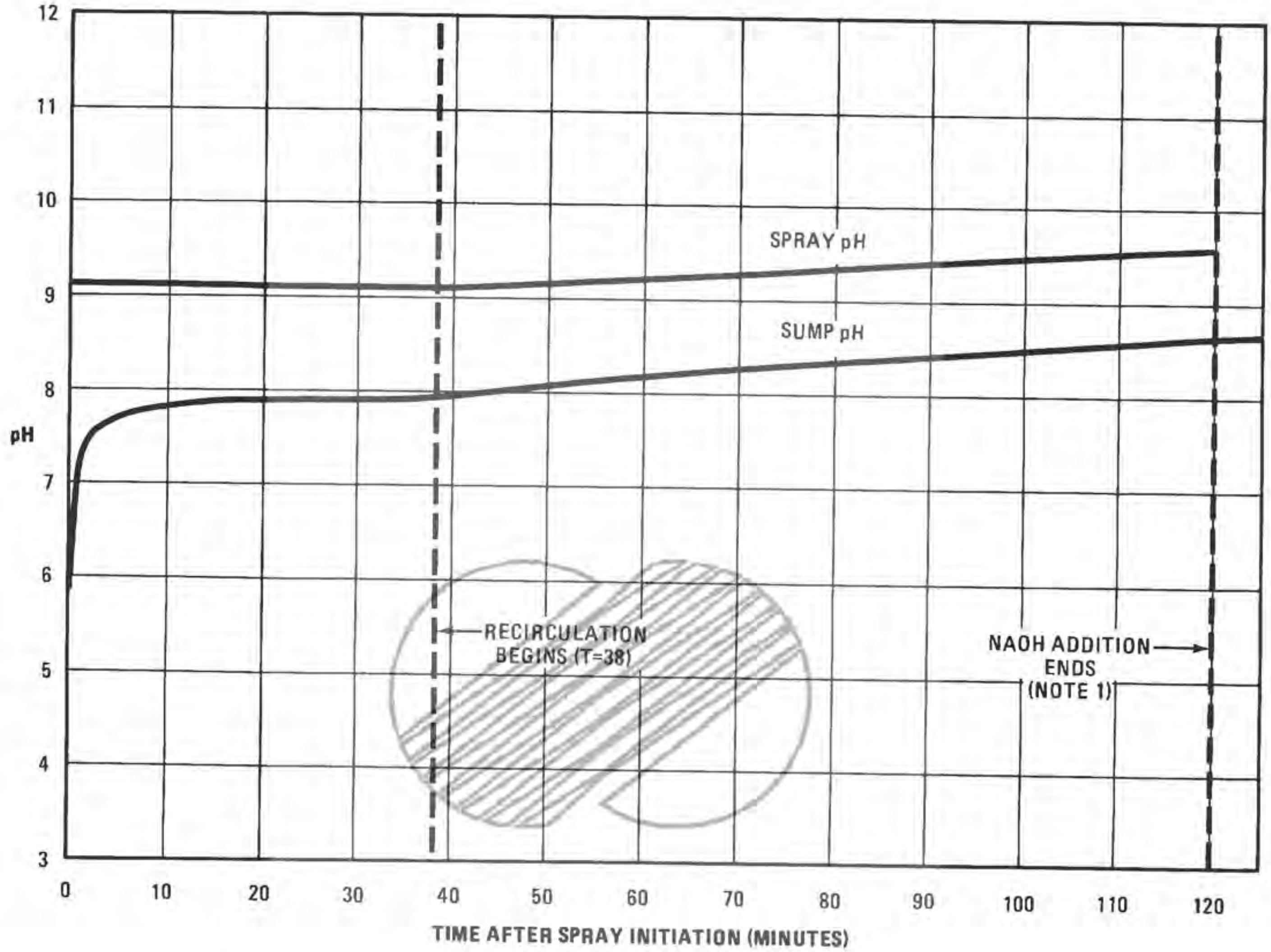

NOTES: 1 FOLLOWING THE COMPLETION OF NAOH ADDITION, SPRAY pH AND SUMP pH ARE IDENTICAL.

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MINIMUM SPRAY AND
SUMP pH VERSUS TIME

Figure 6.5-2

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6.6

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6.6 INSERVICE INSPECTION OF CLASS 2 AND 3 COMPONENTS

This section addresses the preservice and inservice inspection of Quality Group B and C (ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Class 2 and 3) components requiring inspection by ASME B&PV Code, Section XI, 1977 Edition through Summer 1978 addendum, Subsections IWC and IWD. The applicable edition of Section XI is based on the requirements of 10CFR50.55 a(b)(2), 10 CFR 50.55a(g)3 and 10 CFR 50.55a(g)4 for both preservice and inservice inspection. Exceptions identified after plant operation will be reported to the ROK-AEB, as specified in 10 CFR 50.55 (g)(5)(iv).

6.6.1 COMPONENTS SUBJECT TO INSPECTION

All Class 2 components, other than those exempted by Paragraph IWC-1220, will be inspected in accordance with the requirements of Subsection IWC. All Class 3 components will be inspected in accordance with the technical requirements of Subsection IWD of Section XI.

6.6.2 ACCESSIBILITY

The physical arrangement of the components (such as piping systems, pumps, valves, tanks, and vessels) and supports is designed to allow personnel access to welds requiring inservice inspection. Modifications to the initial plant design have been incorporated to provide proper examination access. Removable insulation has been provided on those piping systems requiring volumetric and surface examination of welds. In addition, the location of pipe hangers and supports has been reviewed and modifications made where necessary to facilitate the required examinations of piping welds that would otherwise be inaccessible.

Working platforms have been provided in many areas to facilitate the inservice testing requirements of pumps and valves. Temporary platforms, scaffolding, and ladders will be provided to gain access to the piping and vessel welds and welds in Code Class 1 pumps and valves. The surface of the welds requiring ultrasonic or surface examination have been prepared to permit effective examination.

A preservice inspection design review was undertaken to evaluate access requirements with subsequent design modifications and/or examination technique development to ensure Code compliance. The provisions for suitable access for inservice examinations will minimize the time required for these inspections to be performed and reduces the amount of radiation exposure to both plant and examination personnel.

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Controlled space is provided to handle and store calibration standard blocks, insulation, structural members, shielding, and similar material related to the inspection. Suitable hoists and other handling equipment have also been provided. Lighting and sources of power for the inspection equipment are provided at appropriate locations.

6.6.3 EXAMINATION TECHNIQUES AND PROCEDURES

Inspection locations, inspection techniques, inspection frequencies, and evaluation of Class 2 examination data will be in accordance with the technical requirements of the ASME B&PV Code, Section XI 1977 Edition through the Summer 1978 addendum. The visual, surface, and volumetric examination techniques and procedures are written in accordance with the requirements of Section XI, Subarticle IWA-2200. The liquid penetrant (PT) or magnetic particle (MT) methods will be used for surface examinations and ultrasonic (UT) methods (manual or remote) for volumetric examinations. Manual ultrasonic examination techniques will be used for most volumetric examinations of Class 2 components. All reportable indications will be mapped, and records will be made of maximum signal amplitude, depth below the scanning surface, and length of the reflector. The data compilation format will provide for comparison of data from subsequent examinations. For areas where manual surface examinations or direct visual examinations are to be performed, all reportable indications are to be mapped with respect to size and location in a manner to allow comparison of data to subsequent examinations.

Class 3 components will be examined in accordance with the requirements of Subsection IWD during hydrostatic testing and during operations, without removing insulation.

6.6.4 INSPECTION INTERVALS

The inservice inspection schedule for Class 2 system components will be developed in accordance with the requirements of Subarticles IWA-2400 and IWC-2400 and 10 CFR 50.55a(g)4.

The inservice inspection schedule of Class 3 system components will be developed in accordance with the requirements of Subarticles IWA-2400 and IWD-2400 and 10 CFR 50.55a(g)4.

Pressure testing of Class 2 and 3 systems will be conducted during plant outages and at or near the end of each 10-year interval.

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The inspection interval, as defined in Subarticle IWA-2400 of Section XI, is a 10-year interval of service. These inspection intervals represent calendar years after the reactor facility has been placed into commercial service. The interval may be extended by as much as 1 year to permit inspections to be concurrent with plant outages. All of the examinations required by Subarticles IWC-2400 and IWD-2400 will be performed completely, once, prior to initial plant startup. It is intended that inservice examinations be performed during normal plant outages, such as refueling shutdowns or maintenance shutdowns occurring during the inspection interval.

6.6.5 EXAMINATION CATEGORIES AND REQUIREMENTS

Inservice inspection categories and requirements for Class 2 components comply with Subarticle IWC-2500.

The examination requirements for Class 3 components comply with Subarticle IWD-2600, and Articles IWA-5000 and IWD-5000.

Preservice examinations for Class 2 and 3 components meet the requirements of Subarticles IWC-2200 and IWD-2200, respectively.

6.6.6 EVALUATION OF EXAMINATIONS

Evaluation of examination results of Class 2 components will be in accordance with Article IWA-3000 and IWC-3000. Evaluation of examination results of Class 3 components will be in accordance with Article IWD-3000.

Repairs of defects discovered by the examinations in Class 2 components will be in accordance with Article IWC-4000. Repairs of defects in Class 3 components will be in accordance with Article IWD-4000.

6.6.7 SYSTEM PRESSURE TEST

Class 2 systems subject to hydrostatic and operational pressure tests will be tested in accordance with Articles IWA-5000 and IWC-5000.

Class 3 systems subject to pressure tests will be tested in accordance with the requirements of Article IWA-5000, Article IWD-5000, and Subarticle IWD-2600.

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6.6.8 AUGMENTED INSERVICE INSPECTION TO PROTECT AGAINST POSTULATED PIPING FAILURES

Longitudinal and circumferential welds in high energy fluid system piping that penetrates containment (discussed in subsection 3.6.2) will receive an augmented inservice inspection when they are within a no break zone. This augmented inservice inspection program satisfies the requirements set forth in Standard Review Plan 3.6.1, Branch Technical Position APCSB 3-1, B.2.d. High energy fluid piping systems are defined as those fluid systems that, during normal plant conditions (i.e., reactor startup, operation at power, hot standby, and reactor cooldown to cold shutdown conditions), are in operation or maintained pressurized under either or both of the following conditions:

A. Maximum operating temperature exceeds 200F

B. Maximum operating pressure exceeds 275 psig

The augmented inservice examination completed during each 10-year inspection interval will include 100 percent volumetric examination of the entire length of the circumferential and longitudinal pipe welds in the no break zone.

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6.7

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6.7 MAIN STEAM LINE ISOLATION VALVE LEAKAGE CONTROL SYSTEM

This section is not applicable to pressurized water reactors.