

# A Level 1 Fire PRA on PGSR



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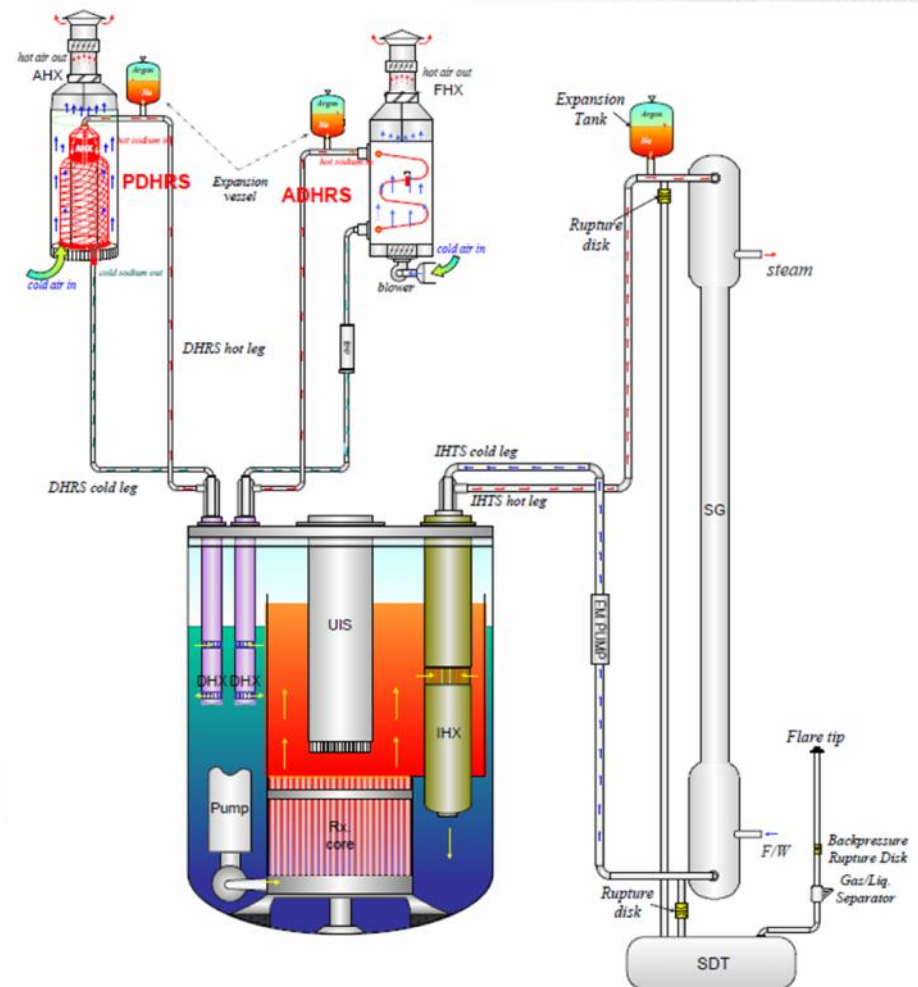
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# Introduction

- **Prototype Generation IV Sodium Fast Reactor (PGSFR)**
- **Characteristics of PGSFR :**
  - Very simple plant
  - PGSFR has sodium which can be an ignition source.
- **Fire Areas**
  - 197 fire areas are determined,
  - Among them, 36 fire areas (including 7 sodium leak areas) are quantitatively in detail analysed.



# Ignition Frequency of PGSFR

- Generic ignition frequencies of the fire areas

NUREG/CR-6850 → NUREG-2169

- Ignition sources:

- fixed source due to the fire of equipment such as pumps, electric cabinets, etc.,
- transient source due to the maintenance work, welding, etc.
- Table 1 are based on the commercial NPPs

- The equipment number

- PGSFR : commercial NPPs = 592 : 1177

→ Small Reactor Factor : (592/1177)

# Table 1: Example of Ignition Frequencies of PGSFR

Fire Area	Fire Area Name	Fixed	Transient	Total
F-C101	REACTOR CAVITY	1.37E-03	1.26E-06	1.37.E-03
F-C206	CONTAINMENT ANNULUS AREA	4.75E-04	5.63E-05	5.31.E-04
F-C303	CONTAINMENT ANNULUS AREA	2.98E-04	5.63E-05	3.54.E-04
F-C311	SP SODIUM SURGE TANK RM	0	1.26E-05	1.26.E-05
F-C312	SP EM PUMP RM	0	1.26E-05	1.26.E-05
F-C313	SP VACCUM PUMP RM	5.44E-04	1.26E-05	5.57.E-04
F-A106A	ESSENTIAL CHILLED WATER PUMP RM	1.09E-03	4.44E-05	1.13.E-03
F-A106B	ESSENTIAL CHILLED WATER PUMP RM	1.09E-03	4.44E-05	1.13.E-03
F-A108A	ESSENTIAL CHILLED WATER PUMP RM	5.44E-04	4.44E-05	5.88.E-04
F-A108B	ESSENTIAL CHILLED WATER PUMP RM	5.44E-04	4.44E-05	5.88.E-04

# Increased Fire Frequency By Sodium Leak

- There would be a fire caused by sodium leak.
- Assumed conservatively that there is a sodium fire if there is a leak from sodium piping.
- History data of BN-600
  - 30 years(1980~2010)
  - 0.2/yr

# Ignition Frequencies of PGSFR Due To Sodium Leak Fire

	<u>Fire Area</u>	<u>Piping length (%)</u>	<u>Ignition freq. (/y)</u>
F-C304	HEAD ACCESS AREA	0.228	0.046
F-C303	CONTAINMENT ANNULUS AREA	0.1	0.02
F-A122A	Steam Generator room	0.102	0.02
F-A122B	Steam Generator room	0.102	0.02
F-A316A	PIPE CHASE	0.055	0.011
F-A316B	PIPE CHASE	0.055	0.011
F-A123A	SWRPR SODIUM DUMP TANK RM	0.09	0.018
F-A123B	SWRPR SODIUM DUMP TANK RM	0.09	0.018
F-A518A	AHX RM	0.038	0.008
F-A518B	AHX RM	0.038	0.008
F-A519A	FHX RM	0.051	0.01
F-A519B	FHX RM	0.051	0.01
	<b>SUM</b>	<b>1</b>	<b>0.2</b>

# An Example Screen of PGSFR PSA Model

The screenshot displays the PGSFR PSA Model software interface. On the left is the Project Explorer showing a hierarchical tree structure for the project 'PGSFR\_PSA-2015'. The main window shows a table of results for various scenarios.

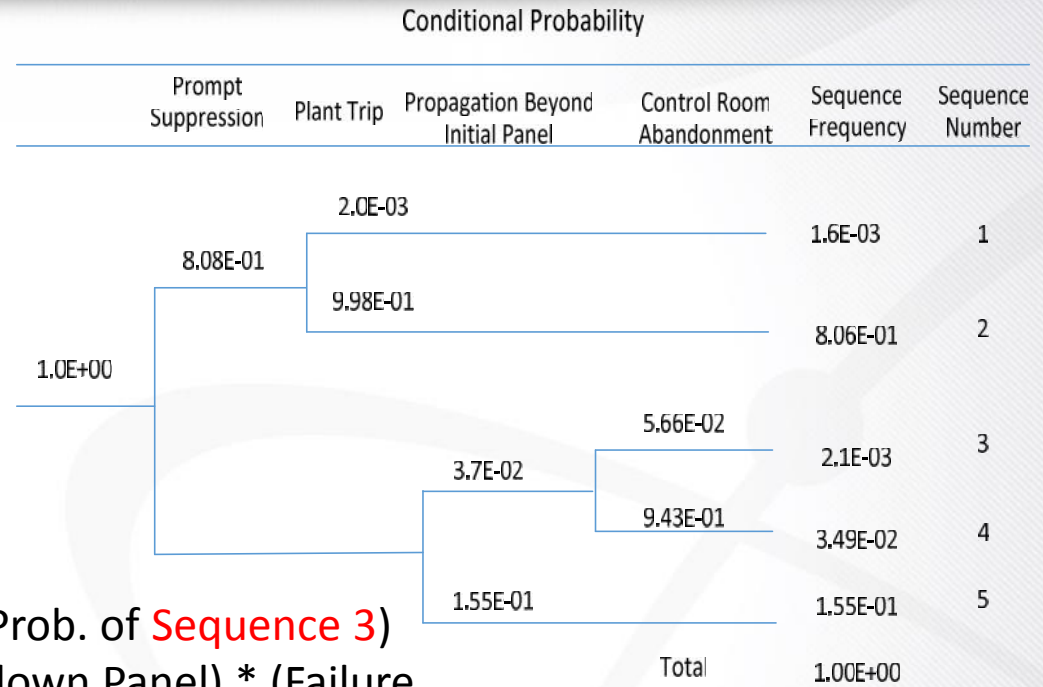
ProjectC	Refe	Sima	CutOff	Result	Remark
27	F-A401B	Base Set GPD-TRAIN-D True Set GPD-TRAIN-D_PAS Tr Set SWRVO-TK True Set PDTWF-D True DeleteExistingIEs	1e-17	SFR-CDF = 4.8	I&C EQUIPMENT
28	F-A402A	Base Set %GTRN True Set GPD-TRAIN-A True Set GPD-TRAIN-C True Set GPD-TRAIN-C_PAS Tr Set SWRVO-TK True Set PDTWF-C True DeleteExistingIEs	1e-17	SFR-CDF = 4.0	I&C EQUIPMENT
29	F-A402B	Base Set %GTRN True Set GPD-TRAIN-B True Set GPD-TRAIN-D True Set GPD-TRAIN-D_PAS Tr Set SWRVO-TK True Set PDTWF-D True DeleteExistingIEs	1e-17	SFR-CDF = 4.8	I&C EQUIPMENT
30	F-A404A	Base Set %LOSF True Set %LOOP True Set EPDGW-01AB True Set EPGTS-AAC True Set PDMPK-CD True DeleteExistingIEs Set PDFSF-SIG True Set RPFSS-SIG True Value PDOPH-DHRS 0.01 Value RPOPH-SIG 0.01	1e-17	SFR-CDF = 1.0	(MAIN CONTROL I
31	F-A515A	Base Set %GTRN True Set GPD-TRAIN-A True DeleteExistingIEs	1e-17	SFR-CDF = 1.4	
32	F-A515B	Base Set %GTRN True Set GPD-TRAIN-B True DeleteExistingIEs	1e-17	SFR-CDF = 1.4	
		Base Set %GTRN True Set GPD-TRAIN-C True	1e-17	SFR-CDF = 1.4	

The status bar at the bottom shows the command line: C:\Program Files (x86)\Wkaeri\Aims-PSAW\Ftrex.exe "###gen.kir" "#F-A404A.SFR-CDF.raw" /ASSP=0 /SEQ=0 /R\_SWITCH=1...



# CDF By MCR Fire of PGSFR

## ■ MCR abandonment



### MCR Abandonment (Seq. 3)

$CDF_{(abandon)} = (\text{Ignition Freq. in Console}) * (\text{Prob. of Sequence 3})$   
 $* (\text{Operator's Failure to Use Remote Shutdown Panel}) * (\text{Failure of Manually Open of PDRC Damper}) \text{ ----- (1)}$

### MCR Non-abandonment (Seq. 4, 5)

$CDF_{(No\ abandon)} = (\text{Ignition Freq. in Console}) * (1/2) * (\text{Prob. of Sequence 5}) * [\text{CCDP(DHRS)} + \text{CCDP(EPS)}]$   
 $+ (\text{Ignition Freq. in Console}) * (\text{Prob. of Sequence 4}) * [\text{CCDP(EPS + DHRS)}]$   
 ----- (2)

- If HFE increased by Double  
 → *13% More Dangerous With Doubled Operator Error Prob.*

# Table 2. CDF portion of each fire area

	Fire Area	Ignition Fr eq.	Sodium Fi re Freq.	CDF %
<b>F-C304</b>	HEAD ACCESS AREA	1.26E-05	4.56E-02	16.55%
<b>F-C303</b>	CONTAINMENT ANNULUS AREA	3.54E-04	2.01E-02	7.36%
<b>F-A122A</b>	Steam Generator room	1.15E-05	2.05E-02	5.12%
<b>F-A122B</b>	Steam Generator room	1.15E-05	2.05E-02	5.12%
<b>F-A202A</b>	480V CLASS 1E LOAD CENTER & MCC RM	9.50E-04		5.95%
<b>F-A202B</b>	480V CLASS 1E LOAD CENTER & MCC RM	9.50E-04		5.95%
...	...	...		
<b>F-A209A</b>	4.16kV CLASS 1E SWGR RM	1.99E-03		1.25%
<b>F-A209B</b>	4.16kV CLASS 1E SWGR RM	1.99E-03		1.25%
<b>F-A518B</b>	AHX RM	4.52E-04	7.68E-03	9.77%
<b>F-A519A</b>	FHX RM	4.45E-04	1.02E-02	9.76%
<b>F-A519B</b>	FHX RM	4.45E-04	1.02E-02	12.88%
<b>F-D202</b>	SWITCHGEAR ROOM	2.83E-03		1.36%
...	....	....		
<b>F-A433B</b>	MCR			13%
				100%

# Results (1/2)

## ◆ Core Damage Frequency (CDF)

- The 3<sup>rd</sup> column (ignition frequency) of Table 2 is derived by multiplying the small reactor factor (592/1177)
- The 4<sup>th</sup> column is the ignition frequency caused by the sodium piping leak.
- Head access area (F-C304)
  - CDF portion is 16.55%
  - the sodium fire could occur frequently because many sodium piping lines pass through this area.
- MCR (F-A433B)
  - 13%, Eq.(1) + Eq.(2).

# Results (2/2)

## ◆ Sensitivity Analysis

### ● Different sodium fire ignition frequency

- Sodium piping leakage rate (3.0E-9/ft/h)
- Optimistic : 3.4 Times

→ *51% Safer With Sodium piping leakage rate*

### ● Small Reactor Factor

➤ The equipment number

- PGSFR : commercial NPPs = 592 : 1177

→ *27% More Dangerous Without Small Reactor Factor*

### ● Operator Error

- Operator's 'Failure to use Remote Shutdown Panel' and 'Failure of Manually Open of PDRC Damper' in Eq. (1)
- If HFE increased by Double

→ *13% More Dangerous With Doubled Operator Error Prob.*

# Conclusions

- CDF of level 1 fire PSA on PGSFR is **several order lower** than those of commercial NPPs.
- The characteristics of PGSFR are described in this paper; 1) **sodium fire ignition**, 2) **small reactor factor**, 3) a console type MCR and **MCR abandonment** logic.
- The fire area having the highest CDF portion is where a lot of sodium piping lines are passing through.
- The next higher CDF portion fire area is MCR.
- The sensitivity analysis that the result of level 1 fire PSA on PGSFR can be feasible.



**THANK YOU**