RASCAL TRAINING

This training covers all the concepts of RASCAL, primarily focusing on the Source Term to Dose tool. It requires no previous RASCAL experience, but a general knowledge of emergency response, reactor operations, and health physics will be beneficial.

Sunday, 25 March	Introduction
	Module 1 – Intro to RASCAL
	Module 2 – RASCAL Fundamentals
Monday, 26 March	Module 3 – RASCAL Tutorials
	-Loss of Coolant Accident
	-Long Term Station Blackout
	-Multi Unit
	-Monitored Mixtures
	-Comparing with Field Measurements
	-Download Meteorology
	-Spent Fuel Pool
	-Containment Rad Monitor
	-Steam Generator Tube Rupture
	-Transportation Accident
Tuesday, 27 March	Module 4 – Advanced Problems
	-Source Term Selection
	-Problem 1 - Confirmatory Calculations
	-Problem 2 - Best Method / Field Team
	-Comparing Models
	-Three Mile Island / Fukushima

Note: This RASCAL tutorial was developed by the U.S. Nuclear Regulatory Commission to support training for its Incident Response Program and the Radiation Protection Computer Code Analysis and Maintenance Program (RAMP). The situations presented may not be realistic or likely and are for training purposes only.

SOURCE TERM TO DOSE WALKTHROUGH (LOCA)

Scenario

Barakah, Unit 1 had been operating at full power. At 10:00am local time the reactor tripped due to an event, causing a major rupture in the primary coolant system (loss-of-coolant accident [LOCA])

The licensee believes the core may become uncovered at 13:00 and are unable to activate the containment spray system. They expect the containment to remain intact and any release to the atmosphere will be at the design leak rate.

At 17:00, operators were able to recover the core. Containment remained at high pressure and wasn't reduced until 21:00.

Weather Data:

Type	Date	Time	Wind Dir (deg)	Wind Spd (m/s)	Stability Class	Precip	Air Temp (°C)
Obs	Today	12:00	210	3	B	None	11

Your Task

Do an assessment of the Unit 1 LOCA and record the TED and Thyroid CED at 0.32 and 6.4 km from the release.

	Dose at 0.32 km	Dose at 4 miles
TED (Sv)		
Child Thyroid CED (Sv)		

LONG-TERM STATION BLACK OUT

Scenario

Barakah Unit 2, was shutdown at the same time as Unit 1, 10:00, due to the event which caused the Unit 1 LOCA. All offsite and onsite AC power was lost. Diesels initially provided power and cooling was maintained. However, a strong aftershock 5 hours after the original quake incapacitated the diesels. The batteries lasted six hours. Fission products leak through a slightly damaged containment at 2.0 percent/d with no sprays available. Finally, power is restored and the core is recovered at 10:00 on the next day. Containment pressure was reduced to atmosphere at noon. Use the following weather data for the BK12 station:

Type	Date	Time	Wind Dir (deg)	Wind spd (m/s)	Stability Class	Precip	Air Temp (Deg C)
Obs	Today	12:00	210	3	B	None	11
Fcst	Today+1	00:00	210	3	B	None	11
Fcst	Today+1	04:00	340	2	D	None	9
Fcst	Today+1	08:00	350	3	C	None	10
Fcst	Today+1	12:00	0	4	B	None	19

Your Task

Do an assessment of the Unit 2 LTSBO and record the TED and Thyroid CED at 0.8 and 8 km from the release.

	Dose at 0.8 km	Dose at 8 km
TED (Sv)		
Child Thyroid CED (Sv)		

MULTI-UNIT ASSESSMENT

Scenario

Combine the Barakah LOCA and LTSBO cases using the Source Term Merge/Export tool.

Your Task

Record the doses below and compare to the individual LOCA and LTSBO cases.

	Dose at 0.8 km	Dose at 8 km
TED (Sv)		
Child Thyroid CED (Sv)		

MONITORED MIXTURES

Scenario

Koeberg Unit 2 had been operating at 100% percent power when a malfunction occurred causing the plant to shutdown at 15:50. Approximately 10 minutes later (16:00), an effluent release through a monitored pathway (stack height 100 ft) was detected by plant operators.

The effluent release rate was reported to be 30,000 GBq/s for noble gases, 400 GBq/s for iodine radioisotopes, and 10 GBq/s for particulates. The plant's Technical Specification (TS) requires that the release duration must be limited to no more than 30 minutes and use predefined Standard Meteorology.

Your Task

Determine the projected TED and Child Thyroid CED at 0.8 km and 8 km.

	Dose at 0.8 km	Dose at 8 km
TED (Sv)		
Child Thyroid CED (Sv)		

COMPARING WITH FIELD MEASUREMENTS

Scenario

Koeberg Unit 2 had been operating at 100% percent power when a malfunction occurred causing the plant to shutdown at 15:50. Approximately 10 minutes later (16:00), an effluent release through a monitored pathway (stack height 100 ft) was detected by plant operators.

The effluent release rate was reported to be 30,000 GBq/s for noble gases, 400 GBq/s for iodine radioisotopes, and 10 GBq/s for particulates. The plant's Technical Specification (TS) requires that the release duration must be limited to no more than 30 minutes and use predefined Standard Meteorology.

Field teams have been dispatched and reported measurements at 18:00 local time. Do these readings confirm that the RASCAL TED and Child Thyroid CED projections are representative of the impact?

Your Task

Do these field team readings confirm that the RASCAL TED and Child Thyroid CED projections are representative of the impact (assuming that the release continues for 4 hours)?

Field Team & Location	Measurement	Field Team Reading	RASCAL Results
Team 1 4 km downwind on the centerline	Gamma	3.1E-02 mSv/h	
	I-131	8.6E-02 kBq/m3	
Team 2 13 km downwind on the centerline	Gamma	8.2E-01 mSv/h	
	I-131	1.7E+01 kBq/m3	

SPENT FUEL POOL

Scenario

The Diablo Canyon, Unit 2, power plant has experienced a loss of water level in the spent fuel pool due to an earthquake. The licensee reports it is the result of a large crack in the pool and postulates that the water is possibly flowing into a sink hole.

Due to a malfunctioning pump, the operators have not been able to make up for the loss of water in the spent fuel pool. Estimates are that the fuel will be fully uncovered by 11:00 and the licensee is attempting to recover the fuel or provide alternate cooling methods. In technical consultation with the licensee and based upon the age of the fuel in the SFP it is estimated that the hottest assemblies experience a gap release (a precursor to a potential zirconium fire) in approximately 22 hours.

The licensee also reports that the pool currently contains three batches of fuel (a batch is defined as one-third of a core): one of which was from the most recent refueling 360 days ago, and 2 from previous refuelings. The licensee anticipates being able to be able to recover the fuel or provide alternate spray flow cooling within 24 hours. The building has been severely damaged and is in many places directly open to the atmosphere. Assume the release point to be unfiltered, 10 meters above ground and Standard Meteorology. Also, use the ICRP 26/30 option.

Your Task

Do an assessment and record the source term and dose information in the tables.

	Activity (Ci)	% of Total
Noble gas		
Iodines		
Other		
Total		

	Dose at 1 mile	Dose at 5 miles	Dose at 10 miles
TEDE (rem)			
Adult Thyroid CDE (rem)			

To what distances are the US EPA PAGs exceeded for TEDE and Adult Thyroid CDE?

If the date of the last refueling changed to 30 days vice the 360 days entered above, how does that change the distances that the change the distance at which the US EPA PAGs are exceeded for TEDE and Adult Thyroid CDE? If so why?

CONTAINMENT RADIATION MONITOR

Scenario

A malfunction occurred at the Fort Calhoun, Nuclear Power Plant causing the plant to shutdown (reactor scram) at 12:00. Approximately 45 minutes later it was determined by the operators that the core was uncovered.

During the course of the event, the operators in the control room receive periodic readings from the containment dome radiation monitor.

Time	Containment Radiation Monitor Reading (R/h)
12:45	14
13:30	50,000
15:00	100,000
+1 day, 15:00	100,000

The release from the core passed into the containment building and the containment sprays are not operating. The operators determined that the containment remained intact and the release from the containment was via design leakage rate.

Use the RASCAL Predefined Data (Non Site-specific) option with Standard Meteorology.

Your Task

Perform an assessment and consult the case summary report to see how much core damage RASCAL estimated for each reading

Time	Containment Radiation Monitor Reading (R/h)	RASCAL Calculated Core Damage (%)
12:45	14	
13:30	50,000	
15:00	100,000	
+1 day, 15:00	100,000	

STEAM GENERATOR TUBE RUPTURE

Scenario

The St. Lucie, Unit 1, Nuclear Power Plant experienced a sudden drop in primary system pressure and a sudden rise in secondary pressure at 00:36. The resulting drop in primary system pressure caused the reactor to automatically shutdown at the same time.

The control room operators assume that a steam generator tube rupture (SGTR) had occurred and estimate that the makeup flow (including safety injection) to be about 500 gpm.

The increase in steam generator pressure caused the high-pressure safety relief valves to open briefly, but subsequently the increased steam generator pressure is released through the condenser off-gas exhaust.

The control room operators have indications to assume that the SGTR break is above the water line (worst case) and that the steaming rate is at the default value.

The release point is the top of the turbine building, about 15 meters above ground. Use the Predefined Data (Non Site-specific) option with Standard Meteorology.

Your Task

Determine the projected TED and Child Thyroid CED at 0.32 km, assuming that a Protective Action couldn't be ordered until about 8:30am.

	Dose at 0.32 km
TED (Sv)	
Child Thyroid CED (Sv)	

TRANSPORTATION ACCIDENT

Scenario

At 02:00 a tractor trailer truck crashed in central Pennsylvania near the intersection of I-80 and I-180 when the driver lost control on the icy road.

The truck manifest says it was carrying 5,000 TBq of tritium gas and was bound for the Safety Light facility in Bloomsburg, PA. State highway patrol reports that the trailer slid at high speed into a bridge support and split open.

Reports from the scene are that the weather is cold, but the precipitation had stopped and the winds are very light.

	Nearby Population
City	Milton
County	Northumberland
State	Pennsylvania
Country	United States

	Accident Location Info
Time Zone	Eastern
Latitude	41.0495° (+ is north)
Longitude	-76.8400° (- is west)
Elevation	153 meters

The licensee estimates that 10 percent of the containers may have ruptured and that most of their contents are likely to leak out within 10-20 minutes and would quickly volatilize and become airborne.

Your Task

What are the doses (TED) to persons and the first responders in the immediate vicinity of the crash (0.16 and 0.32 km)?

What are the doses (TED) to nearby residents in the vicinity of the crash (0.8 and 1.6 km)?

	0.1 km	0.2 km	0.5 km	1 km
TED (Sv)				

CONFIRMATORY CALCULATIONS - ARKANSAS NUCLEAR ONE

Scenario

In response to an event report at Arkansas Nuclear One, you are called in to provide an initial assessment of potential offsite consequences.

You are provided the initial notification message and asked if the PARs are appropriate. DO NOT USE THE FOLLOWUP NOTIFICATION SHEET YET.

30 minutes later, you receive a follow-up notification from ANO.

Again, you are asked if the PARs are appropriate, as well as being asked to confirm if ANO's offsite dose projection is reasonable.

EMERGENCY CLASS INITIAL NOTIFICATION MESSAGE E-DOC NO: 1903.011-Y CHANGE NO. 042

Initial Notification Message

Use this form for Emergency Class Declarations, Changes (Upgrade or Downgrade), Protective Action Recommendations (PARs) or Terminations.

1. Message Number 6

2. Message:

This is at Arkansas Nuclear One.

My telephone number is

This is ☒ **A Drill.**

☐ **A NOTIFICATION OF UNUSUAL EVENT was DECLARED**
☐ **An ALERT was DECLARED**
☐ **A SITE AREA EMERGENCY was DECLARED**
☒ **A GENERAL EMERGENCY was DECLARED**

on ☒ **Unit 1 and** ☒ **Unit 2** on 8/17/2016 at 1038 based on

EAL: **FG1** Description: **Loss of ANY two Barriers AND Loss or Potential Loss of the third barrier**

The wind is **AT 3.0 miles per hour** and **FROM 98 degrees.**

☒ There is **A GASEOUS RADIOACTIVE RELEASE** due to this event, which **does not** exceed federally approved operating limits.

Recommended Protective Action are:
☒ **Evacuate Zones: G,N,O,R**
☐ **Shelter Zones:**
☒ **Remainder of the EPZ to go indoors: H,I,J,K,L,M,P,Q,S,T,U**
☐ **Beyond 10 Mile EPZ:**

Comments: Unit 2 has been tripped.
Unit 1 is offline

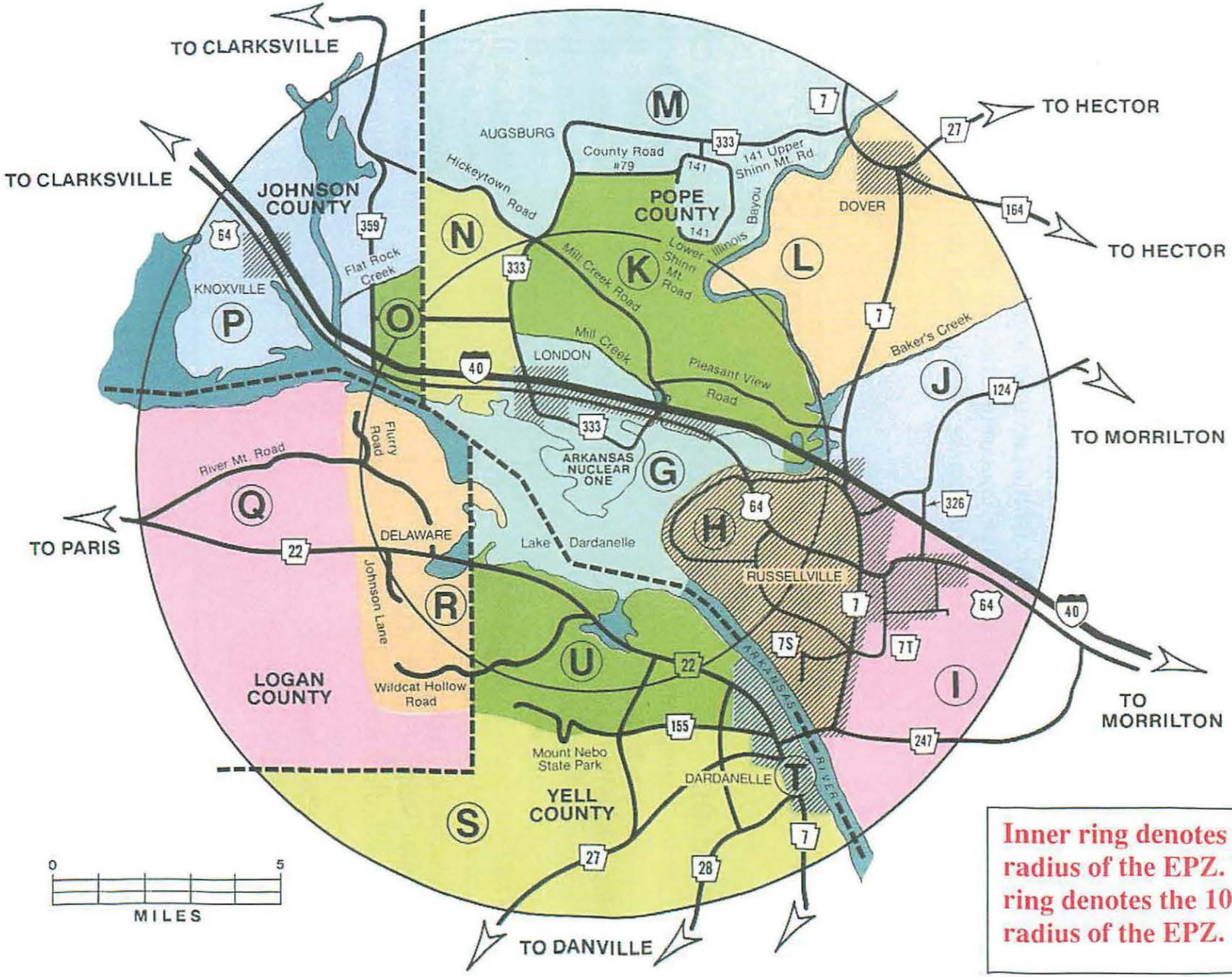
More Information will follow shortly.

3. Approved By: _____

☐ **Shift Manager** ☒ **EOF Director**

Emergency Planning Zone

10 MILE RADIUS AND 5 MILE RADIUS



Inner ring denotes the 5-mile radius of the EPZ. The outer ring denotes the 10-mile radius of the EPZ.

EMERGENCY CLASS FOLLOWUP NOTIFICATION MESSAGE

E-DOC NO: 1903.011-Z CHANGE NO. 041

Follow Up Notification Message

1. MESSAGE NO. 7

2. Reported By: _____ Tel. No. _____

3. This is ☒ **A DRILL**

4. EMERGENCY CLASSIFICATION:

☐ NOTIFICATION OF UNUSUAL EVENT ☐ SITE AREA EMERGENCY ☐ TERMINATION
☐ ALERT ☒ GENERAL EMERGENCY

5. DECLARED ON: ☒ **Unit 1** ☒ **Unit 2** Date: 8/17/2016 Time: 1038

6. PROGNOSIS: **Unit 1:** ☐ Degrading ☒ Stable ☐ Improving ☐ N/A
Unit 2: ☐ Degrading ☒ Stable ☐ Improving ☐ N/A

7. RECOMMENDED PROTECTIVE ACTIONS:

☒ **Evacuate Zones:G,N,O,R**
☐ **Shelter Zones:**
☒ Remainder of the EPZ to go indoors: **H,I,J,K,L,M,P,Q,S,T,U**
☐ **Beyond 10 Mile EPZ:**

8. INCIDENT DESCRIPTION/COMMENTS:

EAL: FG1 **EAL CONDITION:** Loss of ANY two Barriers AND Loss or Potential Loss of the third barrier

COMMENTS: Unit 2 has been tripped.
Unit 1 is offline

9. REACTOR SHUTDOWN? Unit 1: ☐ No ☑ Yes
Unit 2: ☐ No ☑ Yes

10. STATUS: Unit 1: ~~43% and lowering~~ off line

Unit 2:

11. MET DATA: Wind **AT** 3.0 MPH **FROM** 98 Degrees

Stability Class: ☐ A ☐ B ☐ C ☒ D ☐ E ☐ F ☐ G
Precipitation: ☒ None ☐ Rain ☐ Sleet ☐ Snow

12. RADIOLOGICAL RELEASE:

☒ There is **A GASEOUS RADIOACTIVE RELEASE** due to this event, which ☒ **does not** exceed federally approved operating limits.

Start Time: 1029 **Duration (hrs):**
Expected Duration (hrs): 4

RELEASE RATE (Ci/sec): PARTICULATE: 3.14E-06 IODINE: 9.59E-05 NOBLE GAS: 3.43E-06

ESTIMATE OF PROJECTED OFF-SITE DOSE:

TEDE DOSE (mRem)		CHILD THYROID DOSE (CDE) (mRem)	
0.62 miles: 0	3.00 miles: 0	0.62 miles: 1.37	3.00 miles: 0.311
1.00 miles: 0	7.00 miles: 0	1.00 miles: 0.784	7.00 miles: 0.170

13. LIQUID RELEASE? ☐ Yes ☒ No

Approved: EOF Director

BEST METHOD / FIELD TEAM COMPARISON – WATTS BAR

Scenario

In response to an event report at Watts Bar, you are called in to provide an initial assessment of potential offsite consequences.

After reporting to duty, you have compiled some data from several sources. Run RASCAL to determine an initial assessment based on the data you have.

After completing your assessment, determine how your results compare with the field team readings that are being reported.

Additionally, other organizations are providing independent model runs. How do your results compare?

Watts Bar – Significant Events Timeline

Date/Time	Description	Reported By	
10/19/2011 10:13:29	At 0955 the Joint Information Center is activated.	CECC PAT	Edit
10/19/2011 09:58:25	All Control Rods have been inserted manually	WBN TSC Ops Comm	Edit
10/19/2011 09:49:01	Operations entered E-3, SG Tube Rupture	WBN TSC Ops Comm	Edit
10/19/2011 09:51:29	An attempt to transfer the steam supply for the TDAFW Pump from #1 SG (ruptured) to #4 SG (Intact) has failed. Team to be dispatched to locally close the steam supply.	CECC PAT	Edit
10/19/2011 09:49:13	At 0938 a Site Area Emergency was declared on EAL 2.3, Failure of Reactor Protection.	CECC PAT	Edit
10/19/2011 09:46:44	Indication of SG #1 Tube Rupture	WBN TSC Ops Comm	Edit
10/19/2011 09:33:27	Safety Injection has occurred	WBN TSC Ops Comm	Edit
10/19/2011 09:31:26	ATWAS Unit One	WBN TSC Ops Comm	Edit
10/19/2011 09:30:46	At 0930, WBN U1 lost Feed Water flow to SG #1. The reactor failed to trip from the Control Room.	CECC PAT	Edit

Watts Bar – Technical Data

PAG Release Rates			Current Release Rates (16)			Comments:
Noble Gas	2.8E+08	uCi/s	Noble Gas	1.3E+07	uCi/s	This is a drill! PAG Release Rates determined using FRED
I-131	3.5E+05	uCi/s	I-131		uCi/s	
Tritium		uCi/s	Tritium		uCi/s	

Basis: (•) Monitor Reading ( ) Plant Personnel ( ) BRED Estimate using field measurement

FRED Projected Radiological Impact Time at 10/19/11 15:00 — FRED or EPIP-1

Time Generated: 10/19/11 11:18 Time of Release (15): 10/19/11 11:00 Projected Through (15): 10/19/11 15:00

Distance (19)	Direction (19)	TEDE (rem) (19)	Thyroid CDE (rem) (19)	Milk Ingestion Dose (rem) (19)
Site Boundary	SSE	2.5E-01	4.1E+00	1.3E+03
5 Miles	SSE	9.1E-03	1.4E-01	4.3E+01
10 Miles	SSE	2.1E-03	3.2E-02	1.0E+01

Comments (20): CORRECTED *** SEGMENT 4 @1100 DUE TO STABILITY CLASS D ---DRILL

Meteorological Data	15 min data (B)	Forecasts (D)				EPIP 17
Conditions at	1114	1200	1300	1500	1700	1900
Wind Direction (Deg/Sector)	344./NNW	347./NNW	345./NNW	350./ N	5./ N	3./ N
Plume Direction (Deg/Sector)	164./SSE	167./SSE	165./SSE	170./ S	185./ S	183./ S
Wind Speed (mph)	4.2	5.3	5.3	5.8	7.8	8.9
Stability Class	B	B	A	A	C	D
Precipitation(mm)	0.00	NONE	NONE	NONE	NONE	NONE

Comments(E): THIS IS A DRILL.

State Update Form

AIRBORNE RELEASES--FRED MODEL
RADIOLOGICAL DOSE ASSESSMENT - PERIODIC STATE INFORMATION

Time: 19-OCT-11 11:37 (Eastern)

15. The release being assessed begins at 10:00 Eastern time on 19-OCT-11
and is estimated to continue through 14:00 Eastern time on 19-OCT-11
and is based upon ongoing measured release (i.e., radiation monitor),
with a GAP release.

16. Release Rates: Noble Gas: 1.3E+07 uCi/sec
Iodine-131: 9.3E+04 uCi/sec
Particulates: 1.7E+04 uCi/sec
Gross Activity: 1.4E+07 uCi/sec

17. Release Path: SGTR (below) Effective Release Height: 0. meters
Release Type: GAP (0 meters = ground level)

18. Meteorological Conditions: Wind Speed: 2.1 meters/sec
4.6 miles/hr
Wind Direction
(from): 339:NNW (degrees:sector)
Stability Class: B
Precipitation: 0.0 mm/hr
Affected Sector: 159:SSE (degrees:sector)

THIS IS A DRILL

19. Projected Doses (rem) (Does not include previously received dose)

Distance	Sector	TEDE	Sector	Thyroid CDE
0.62 miles	SSE	3.0E-01	SSE	4.5E+00
2 miles	SSE	3.2E-02	SSE	4.4E-01
5 miles	SSE	1.0E-02	SSE	1.5E-01
10 miles	SSE	3.6E-03	SSE	5.3E-02

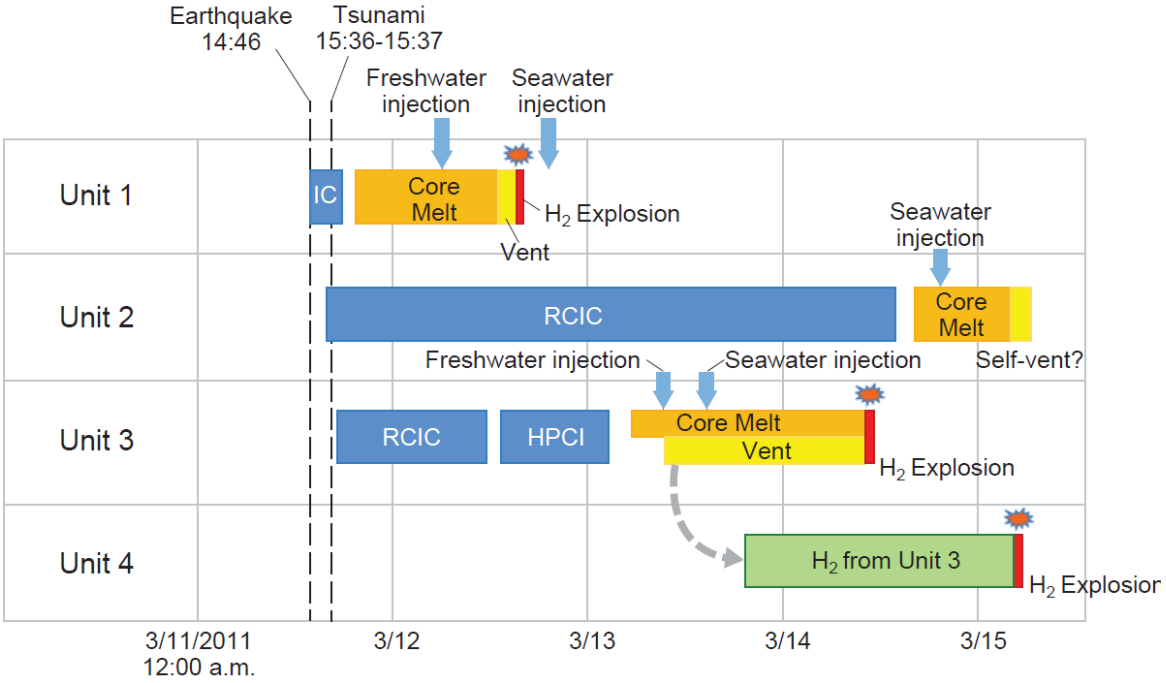
USNRC Chronology

Date/Time	Entry
2011/10/19 10:27	Current MET is 4.7 mph; stability C from wind direction 1 degree. Noble gas release rate 3.66E5 uCi/s
2011/10/19 10:42	Current MET is 4.5 mph; stability C from wind direction 344 degrees. Noble gas release rate 2.12E6 uCi/s
2011/10/19 10:55	Current MET is 5.8 mph; stability A from wind direction 344 degrees. Noble gas release rate 1.62E6 uCi/s
2011/10/19 11:12	Current MET is 4.8 mph; stability D from wind direction 341 degrees. Noble gas release rate 1.47E6 uCi/s
2011/10/19 11:25	Field readings reported @ site boundary: 4.5 mR/h, Iodine 3.6E-8 uCi/cc. Field readings @ 4.4 miles: 0.04 mR/h.
2011/10/19 11:33	Current MET is 4.6 mph; stability B from wind direction 339 degrees. Noble gas release rate 1.28E7 uCi/s
2011/10/19 11:42	Field reading update @ site boundary: 6.1 mR/h, Iodine 3.6E-8 uCi/cc.

FUKUSHIMA & THREE MILE ISLAND

Scenario

For two of the large NPP accidents that have actually occurred, many of the dose assessment challenges were more complex than what is often practiced during exercises.



Lessons Learned from the Fukushima Nuclear Accident for Improving Safety of U.S. Nuclear Plants, 2014. National Academy of Sciences.

FUKUSHIMA DAI-ICHI ACCIDENT, 2011

March 11
14:46 A 9.0 Magnitude earthquake strikes off the coast. Units 1, 2, and 3 are automatically shut down. Units 4, 5, and 6 had been shut down earlier for maintenance. Site loses power, but diesels start up.

15:30 Unit 1 emergency condenser fails.

15:46 A 46 ft (14 m) tsunami overtops the site seawall and disabled all diesels except one and washes away fuel tanks.

18:00 Unit 1 water level reaches top of fuel.

19:30 Unit 1 water level reaches bottom of fuel.

21:00 Unit 1 containment pressure twice normal levels.

March 12
02:44 Battery power for Unit 3 runs out

04:15 Unit 3 water level below fuel

05:30 Operators decide to vent steam to reduce pressure in Unit 1 (low amount of rad material). Freshwater injection into Unit 1.

10:58 Operators decide to vent high pressure in Unit 2

14:50 Freshwater injection in Unit 1 halted.

15:36 Explosion in secondary containment of Unit 1

19:00 Seawater injection started for Unit 1

March 14
11:00 Unit 3 reactor building explodes

13:15 Cooling system for Unit 2 stops.

18:00 Unit 2 water level reaches top of fuel

20:00 Unit 2 core damage occurs

March 15
11:00 Second explosion of Unit 3

THREE MILE ISLAND UNIT 2 ACCIDENT, 1979

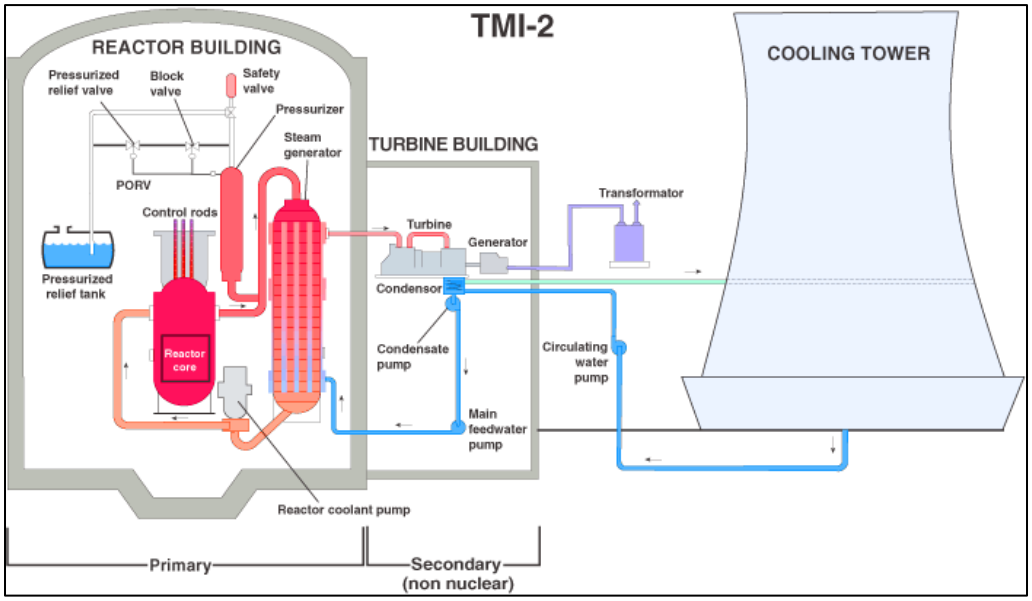
March 28 04:00
Pumps feeding water to the secondary loop shut down. Water pressure and temperature in the reactor core rise. Pressure Relief valve (PORV) automatically opens to vent excess steam into a containment tank. Reactor is shut down and PORV light goes out, indicating valve is closed. When the PORV light goes out the operators incorrectly assume that the valve is closed. In reality the valve is not only open but is also releasing steam and water from the core.

04:02
Emergency Injection Water (EIW) is automatically activated. The instrument checking the radiation has not registered an alarm, and the gauges in the control room are wrongly indicating that the water level is up. In actuality, the water level in primary loop was dropping. Operators shut of the EIW system.

05:20
Primary loop pumps start to shake violently. Steam produced by the lack of cooling water in the core passes through the primary loop pumps and causes them to shake. Assuming they are not functioning correctly the operators turn off two of the four pumps. The remaining two pumps in the primary loop turn off and causes the water within the core to stop circulating. This in turn causes the heated core to convert more water into steam, further reducing the transfer of heat away from the core.

06:15
Water level drops below the top of the core. Since the PORV is still in the open position it allows the hydrogen gas produced to be released along with the steam. Operators receive first indication that containment radiation levels are up.

11:30
Operators pump water into the primary loop and open the PORV backup valve to lower the pressure. Hydrogen within the containment structure explodes. Primary loop pumps are turned on. Water from the primary loop pumps is circulated and the core temperature is finally brought under control.



Text and figure from www.world-nuclear.org.