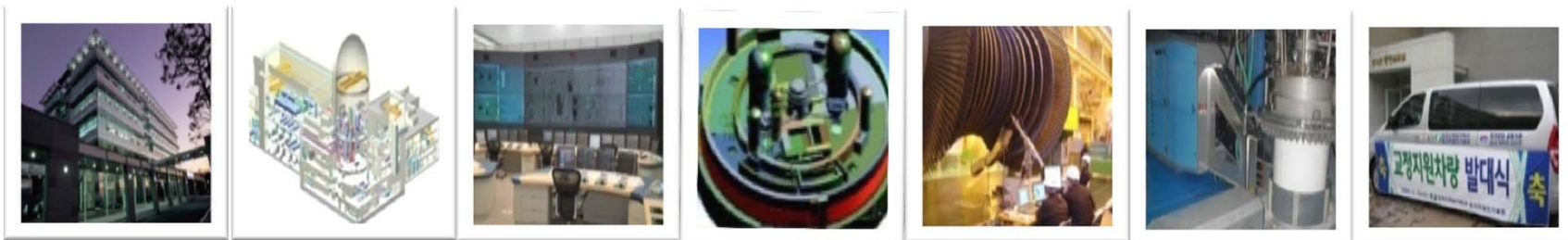


Hanul unit 1&2

# Gaseous Tritium Release Reduction by Evaporation at Fuel Building

Sept. 10, 2015

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- ◆ **Background**
- ◆ **Gaseous Tritium Release Reduction Plan**

## Background (1/2)

| FSAR Gaseous Tritium<br>Expected Release (TBq/yr) | Actual Release of Tritium (TBq/yr) |      |      |      |      |      |
|---|------------------------------------|------|------|------|------|------|
|   | '09                                | '10  | '11  | '12  | '13  | '14  |
| 6.66  | 5.26                               | 6.11 | 6.38 | 6.85 | 6.38 | 5.63 |

- Gaseous tritium release has been increased to expected release
- Expected gaseous release is 40% of those of similar reactor powers
  - Reactor Power( $MW_{th}$ ) : 2,775 (Hanul 1&2, Kori 3&4), 2,900(Hanbit 1&2)
  - Expected gaseous release of Kori unit 3&4, Hanbit unit 1&2 : 15.6 TBq/yr
- Regulatory issues how to manage gaseous tritium release since 2010

## Background (2/2)

### < Expected release of gaseous and liquid tritium in PWRs >

| Plant (unit) |   | Reactor         | Core Power (MW <sub>th</sub> ) | FSAR Gaseous Release (TBq/yr) | FSAR Liquid Release (TBq/yr) | Gaseous Fraction (%) | Liquid Fraction (%) | NUREG-0017 Gaseous Release (TBq/yr) | NUREG-0017 Liquid Release (TBq/yr) |
|--------------|---|-----------------|--------------------------------|-------------------------------|------------------------------|----------------------|---------------------|-------------------------------------|------------------------------------|
| Kori         | 1 | Westinghouse    | 1,724                          | 25.90                         | 30.90                        | 46                   | 54                  | 2.55                                | 22.96                              |
|              | 2 | Westinghouse    | 1,876                          | 3.03                          | 25.90                        | 10                   | 90                  | 2.78                                | 24.99                              |
|              | 3 | Westinghouse    | 2,775                          | 7.81                          | 67.71                        | 10                   | 90                  | 4.11                                | 36.96                              |
|              | 4 | Westinghouse    | 2,775                          | 7.81                          | 67.71                        | 10                   | 90                  | 4.11                                | 36.96                              |
| Shin-Kori    | 1 | OPR-1000        | 2,815                          | 33.67                         | 37.40                        | 47                   | 53                  | 4.17                                | 37.50                              |
|              | 2 | OPR-1000        | 2,815                          | 33.67                         | 37.40                        | 47                   | 53                  | 4.17                                | 37.50                              |
| Shin-Wolsong | 1 | OPR-1000        | 2,815                          | 33.67                         | 37.40                        | 47                   | 53                  | 4.17                                | 37.50                              |
|              | 2 | OPR-1000        | 2,815                          | 33.67                         | 37.40                        | 47                   | 53                  | 4.17                                | 37.50                              |
| Hanbit       | 1 | Westinghouse    | 2,900                          | 7.81                          | 67.71                        | 10                   | 90                  | 4.29                                | 38.63                              |
|              | 2 | Westinghouse    | 2,900                          | 7.81                          | 67.71                        | 10                   | 90                  | 4.29                                | 38.63                              |
|              | 3 | PWR (System 80) | 2,815                          | 4.07                          | 37.40                        | 10                   | 90                  | 4.17                                | 37.50                              |
|              | 4 | PWR (System 80) | 2,815                          | 4.07                          | 37.40                        | 10                   | 90                  | 4.17                                | 37.50                              |
|              | 5 | OPR-1000        | 2,815                          | 18.87                         | 22.60                        | 46                   | 54                  | 4.17                                | 37.50                              |
|              | 6 | OPR-1000        | 2,815                          | 18.87                         | 22.60                        | 46                   | 54                  | 4.17                                | 37.50                              |
| Hanul        | 1 | PWR-Framatome   | 2,775                          | 3.33                          | 27.75                        | 11                   | 89                  | 4.11                                | 36.96                              |
|              | 2 | PWR-Framatome   | 2,775                          | 3.33                          | 27.75                        | 11                   | 89                  | 4.11                                | 36.96                              |
|              | 3 | OPR-1000        | 2,815                          | 26.64                         | 14.80                        | 64                   | 36                  | 4.17                                | 37.50                              |
|              | 4 | OPR-1000        | 2,815                          | 26.64                         | 14.80                        | 64                   | 36                  | 4.17                                | 37.50                              |
|              | 5 | OPR-1000        | 2,815                          | 4.07                          | 37.37                        | 10                   | 90                  | 4.17                                | 37.50                              |
|              | 6 | OPR-1000        | 2,815                          | 4.07                          | 37.37                        | 10                   | 90                  | 4.17                                | 37.50                              |

# Gaseous Tritium Release Reduction Plan (1/10)

## < Tritium Reduction Technology >

- Tritium Removal Facility
- Combined Electrolysis Catalytic Exchange
- Bithermal Hydrogen-Water Process
- Molecular Separation
- EPRI Tritium Management Model(TR-1009903, 2005)

# Gaseous Tritium Release Reduction Plan (2/10)

Source of Gaseous Tritium Release (% of Total)

| <u>Plant</u>                 | <u>Auxiliary Building</u> | <u>Refueling Area</u> | <u>Containment Building</u> |
|------------------------------|---------------------------|-----------------------|-----------------------------|
| Ginna (Ref. 7)               | 31                        | 69                    | NM                          |
| Calvert Cliffs 1 (Ref. 7)    | 38                        | 46                    | 16                          |
| Three Mile Is. 1 (Ref. 7)    | 5                         | 43                    | 52                          |
| Zion 1/2 (Ref. 5)            | 79                        | NA                    | 21                          |
| Turkey Point 3/4 (Ref. 6)    | 75                        | 17                    | 8                           |
| Rancho Seco (Ref. 43)        | 92                        | NA                    | 8                           |
| Prairie Island 1/2 (Ref. 43) | <u>7.2</u>                | <u>91.8</u>           | <u>1.0</u>                  |
| Average                      | 32                        | 50                    | 18                          |

※ Reference: NUREG-0017(Rev.1, 1985 )

# Gaseous Tritium Release Reduction Plan (3/10)

< Hanul 3&4, Gaseous Tritium Release (% of Total, 2004~ 2013)

| Unit | Exhaust        | 2004        | 2005        | 2006        | 2007        | 2008        | 2009        | 2010        | 2011        | 2012        | 2013        | Avg.        |
|------|----------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 3    | CV             | 1.1         | 1.6         | 0.4         | 0.6         | 0.5         | 0.2         | 0.2         | 0.2         | 0.3         | 0.5         |             |
|      | PAB            | 0.0         | 0.0         | 0.0         | 0.6         | 2.9         | 2.5         | 3.6         | 5.3         | 0.8         | 2.6         | 1.8         |
|      | SAB            | 0.0         | 0.0         | 0.0         | 1.0         | 2.6         | 5.6         | 13.1        | 3.8         | 1.5         | 0.0         | 2.8         |
|      | Hot Leg        | 0.0         | 0.3         | 0.5         | 0.4         | 1.5         | 1.3         | 2.4         | 1.4         | 0.6         | 0.3         | 0.9         |
|      | Primary Lab    | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
|      | <b>Fuel BD</b> | <b>87.0</b> | <b>48.7</b> | <b>25.9</b> | <b>46.2</b> | <b>31.2</b> | <b>33.3</b> | <b>37.7</b> | <b>42.1</b> | <b>47.4</b> | <b>45.5</b> | <b>44.5</b> |
|      | Condenser      | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
|      | Steam Seal     | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
|      | Gas stripper   | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
| 4    | CV             | 1.9         | 1.5         | 1.5         | 0.6         | 0.8         | 0.3         | 0.2         | 1.0         | 0.9         | 0.9         | 0.9         |
|      | PAB            | 0.0         | 0.0         | 0.0         | 5.8         | 7.8         | 1.6         | 0.0         | 0.0         | 0.6         | 0.0         | 1.6         |
|      | SAB            | 1.3         | 5.1         | 6.0         | 7.5         | 21.2        | 9.6         | 3.0         | 1.1         | 0.6         | 1.3         | 5.7         |
|      | Hot Leg        | 0.5         | 5.4         | 7.1         | 5.3         | 7.6         | 3.5         | 2.0         | 0.9         | 0.5         | 0.4         | 3.3         |
|      | Primary Lab    | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
|      | <b>Fuel BD</b> | <b>1.1</b>  | <b>33.3</b> | <b>40.1</b> | <b>24.8</b> | <b>12.7</b> | <b>23.5</b> | <b>33.6</b> | <b>44.2</b> | <b>46.8</b> | <b>48.6</b> | <b>30.9</b> |
|      | Condenser      | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
|      | Steam Seal     | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
|      | Gas stripper   | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         | 0.0         |
| -    | RWB            | 7.1         | 4.1         | 18.5        | 7.2         | 11.2        | 18.5        | 4.3         | 0.0         | 0.0         | 0.0         | 7.1         |

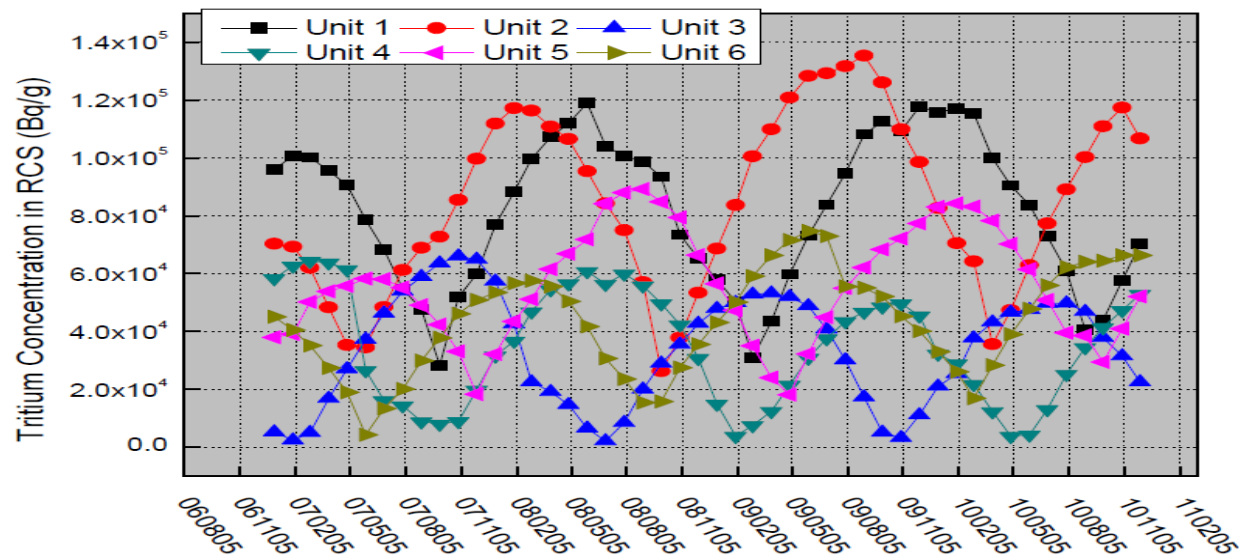
# Gaseous Tritium Release Reduction Plan (4/10)

## < Factors generating tritium >

### ➤ RCS recycle and fuel defect

- Most US PWRs discontinued the use of boron recycle and waste evaporators
- During refueling operations, reactor cavity water is linked with RCS/RWST
- Purification system (ion exchange, filtration) : Fission Products
- Fuel defects (10 times) : #1 ('00.6, '04.10, '10.8, '10.10), #2 ('90.10, '97.5, '01.6, '02.9, '05.11, '10.10)

### ➤ RCS Management Policy





# Gaseous Tritium Release Reduction Plan (5/10)

## < Theoretically Evaporation Calculation >

$$Q_m = A (x_1 - x_2) a_e$$

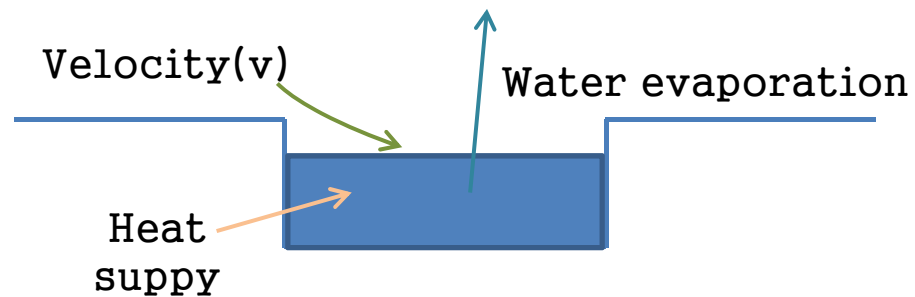
$Q_m$  : mass of water evaporated (kg/hr)

$A$  : the surface area of SFP (m<sup>2</sup>)

$x_1$  : the specific humidity directly above the pool (kg H<sub>2</sub>O/kg Air)

$x_2$  : the specific humidity of the fuel building (kg H<sub>2</sub>O/kg Air)

$a_e$  : evaporation coefficient (kg/m<sup>2</sup>hr),  $a_e = (25+19v)$ ,  $v$  : air velocity (m/s)



$$Q_m = A (x_1 - x_2) a_e$$
$$= 25A(x_1 - x_2)$$

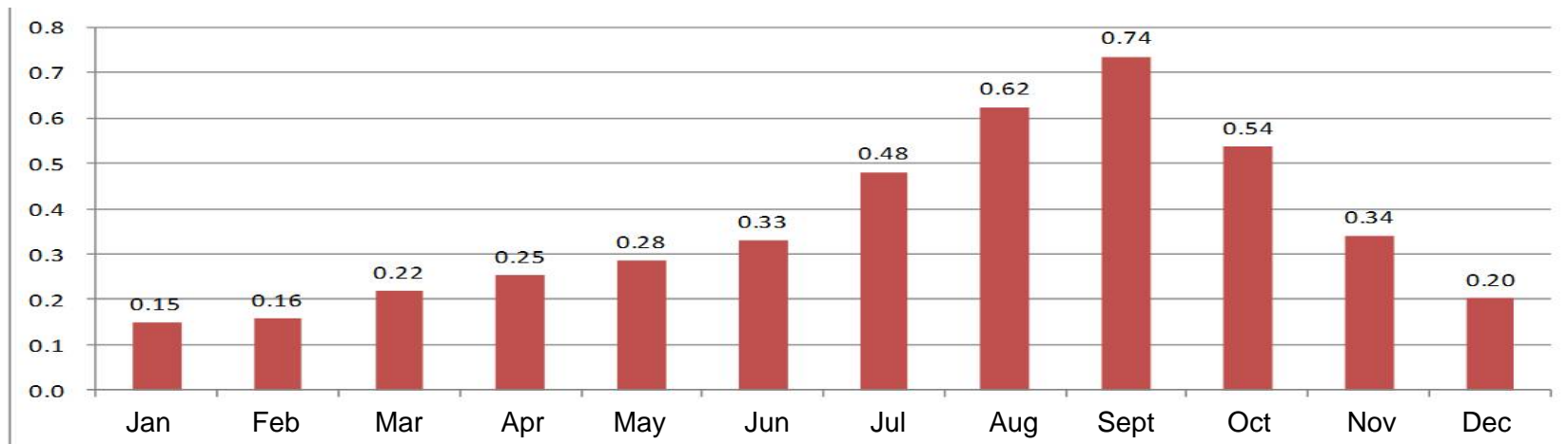
# Gaseous Tritium Release Reduction Plan (6/10)

< Monthly avg. Temperatures of SFP (2010.8~2014.5) >

Unit : °C

| 구분 | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sept | Oct  | Nov  | Dec  | Avg  |
|----|------|------|------|------|------|------|------|------|------|------|------|------|------|
| #1 | 22.0 | 19.9 | 20.8 | 23.4 | 23.6 | 25.0 | 28.4 | 30.3 | 30.8 | 30.5 | 25.5 | 22.8 | 25.3 |
| #2 | 24.8 | 19.1 | 19.5 | 20.6 | 21.5 | 23.6 | 28.3 | 32.0 | 31.8 | 33.1 | 25.7 | 23.6 | 25.3 |
| -  | 24.8 | 19.1 | 19.5 | 20.6 | 21.5 | 23.6 | 28.3 | 32.0 | 31.8 | 33.1 | 25.7 | 23.6 | 25.3 |

< Monthly avg. Gaseous Tritium Release (TBq) (2003~2012) >



# Gaseous Tritium Release Reduction Plan (7/10)

## < Evaporation Calculation of SFP (Theory) >

| Item                     |      | Temp(°C) |        | SH(kg)         |                | Evaporation (kg) |         | Activity (Bq) |          |
|--------------------------|------|----------|--------|----------------|----------------|------------------|---------|---------------|----------|
| Date                     | Unit | SFP      | FuelBD | x <sub>1</sub> | x <sub>2</sub> | Date             | Week    | Week          | Total    |
| Feb<br>3 <sup>rd</sup> W | #1   | 20.0     | 28.1   | 14.7           | 2.3            | 750.0            | 5,249.7 | 6.84E+09      | 1.43E+10 |
|                          | #2   | 18.7     | 28.3   | 13.6           | 2.4            | 677.4            | 4,741.6 | 7.43E+09      |          |
| May<br>2 <sup>nd</sup> W | #1   | 22.1     | 27.0   | 16.7           | 4.4            | 743.9            | 5,207.3 | 6.99E+09      | 1.45E+10 |
|                          | #2   | 20.6     | 28.1   | 15.5           | 4.7            | 653.2            | 4,572.3 | 7.47E+09      |          |

※ SFP S.A of Tritium : Feb 18, 2014 (unit 1) 1,303 Bq/g, (unit 2) 1,568 Bq/g

May 8, 2014 (unit 1) 1,343 Bq/g, (unit 2) 1,633 Bq/g

※ Relative Humidity : 10% (Feb 18, 2014), 20% (May 8, 2014)

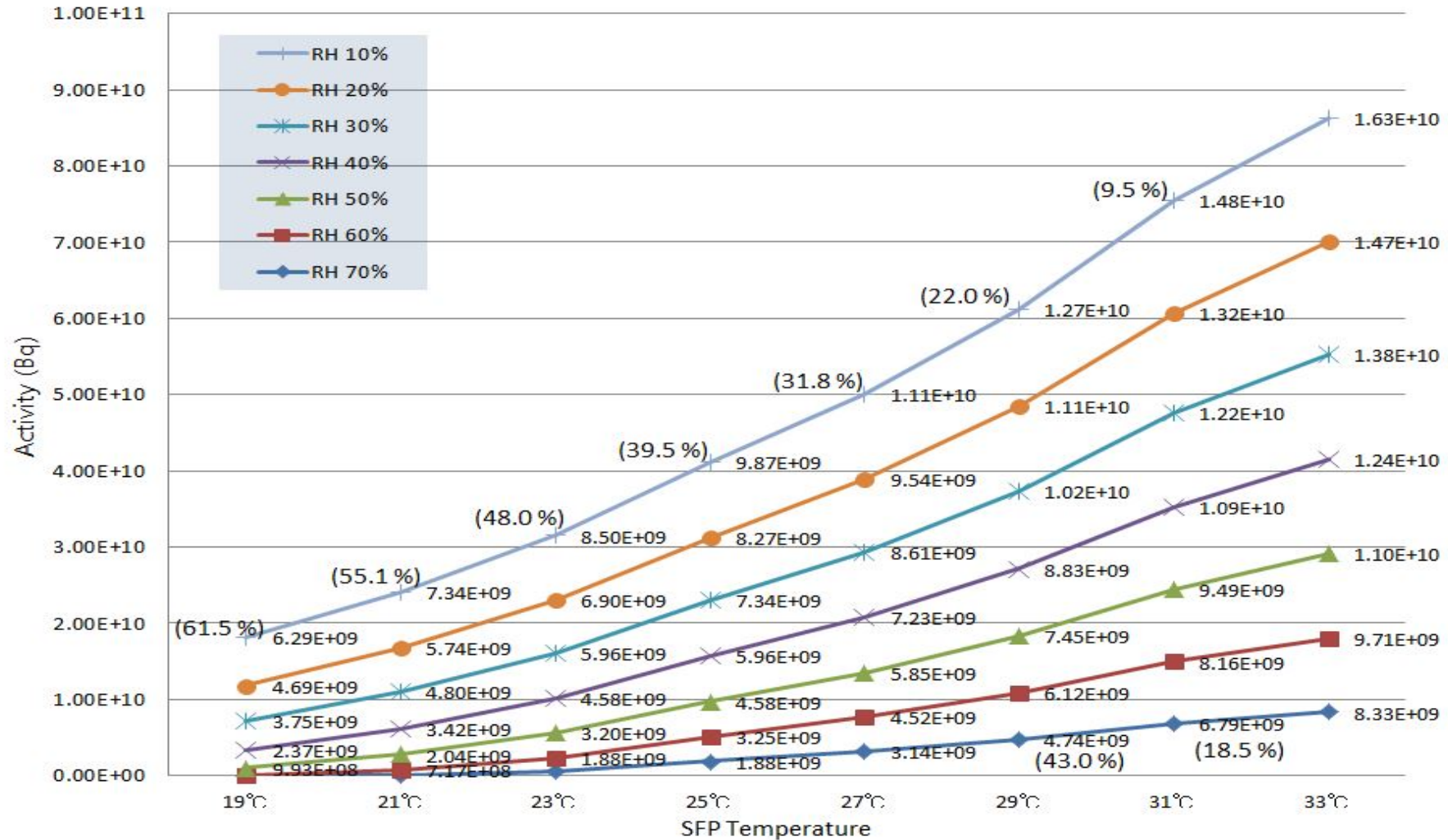
## < Actual Gaseous Release Data >

| Year | M | W | Start      | Termination | Release(m <sup>3</sup> ) | S.Activity (Bq/m <sup>3</sup> ) | Activity (Bq) |
|------|---|---|------------|-------------|--------------------------|---------------------------------|---------------|
| 2014 | 2 | 3 | 2014.02.12 | 2014.02.18  | 53,280,000               | 5.18E+02                        | 2.76E+10      |
| 2014 | 5 | 2 | 2014.05.08 | 2014.05.14  | 51,936,000               | 6.92E+02                        | 3.60E+10      |

※ Comparison(Cal/Data) : 51.7%(Feb 3<sup>rd</sup>), 40.2%(May 2<sup>nd</sup>) → OK with NUREG-0017

# Gaseous Tritium Release Reduction Plan (8/10)

## Expected Release by Evaporation



# Gaseous Tritium Release Reduction Plan (9/10)

(1) Temperature of SFP 

(2) Humidity of FB 

## **Future Works**

A) Replacement of chillers

B) Installation of humidistat

# Gaseous Tritium Release Reduction Plan (10/10)

