



# **Lessons Learned from Criticality Accident in Tokai-mura (I) Outline of the Accident**

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**\* Japan Atomic Energy Research Institute (JAERI) and Japan Nuclear Cycle Development Institute (JNC) have been unified and become Japan Atomic Energy Agency (JAEA) on 1 October 2005.**

# Victims

**Nuclear criticality continued for 20 hours!**

**30  
September  
1999**

**C**

**2 - 3 GyEq;  
alive**

**6 - 9  
GyEq;  
died  
210  
days  
later**

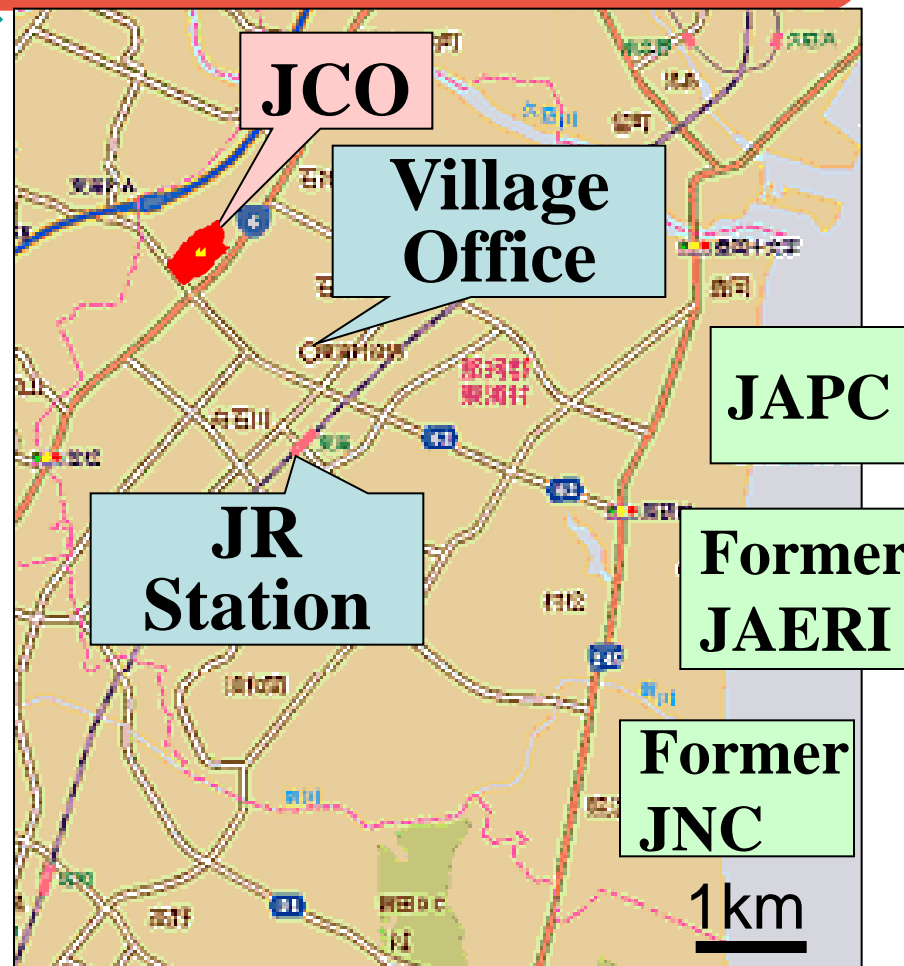
**B**

**A**

**16 - 25 GyEq;  
died 82 days later**

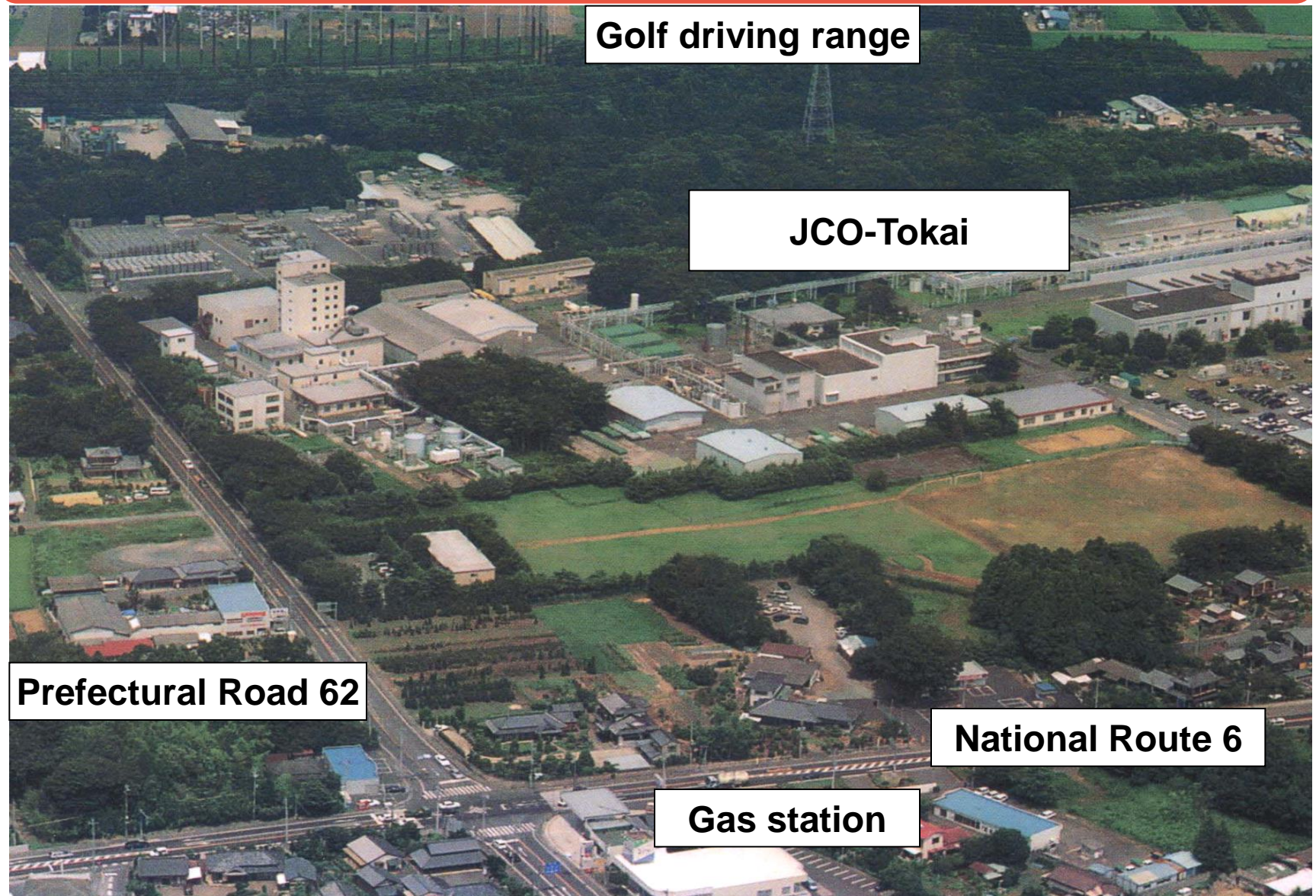
**18.8 wt%-  
enriched U  
in  
 $\text{UO}_2(\text{NO}_3)_2$   
solution,  
370gU/L**

# Where is Tokai-mura?



**Tokai-mura**

# Vicinity of JCO



Golf driving range

JCO-Tokai

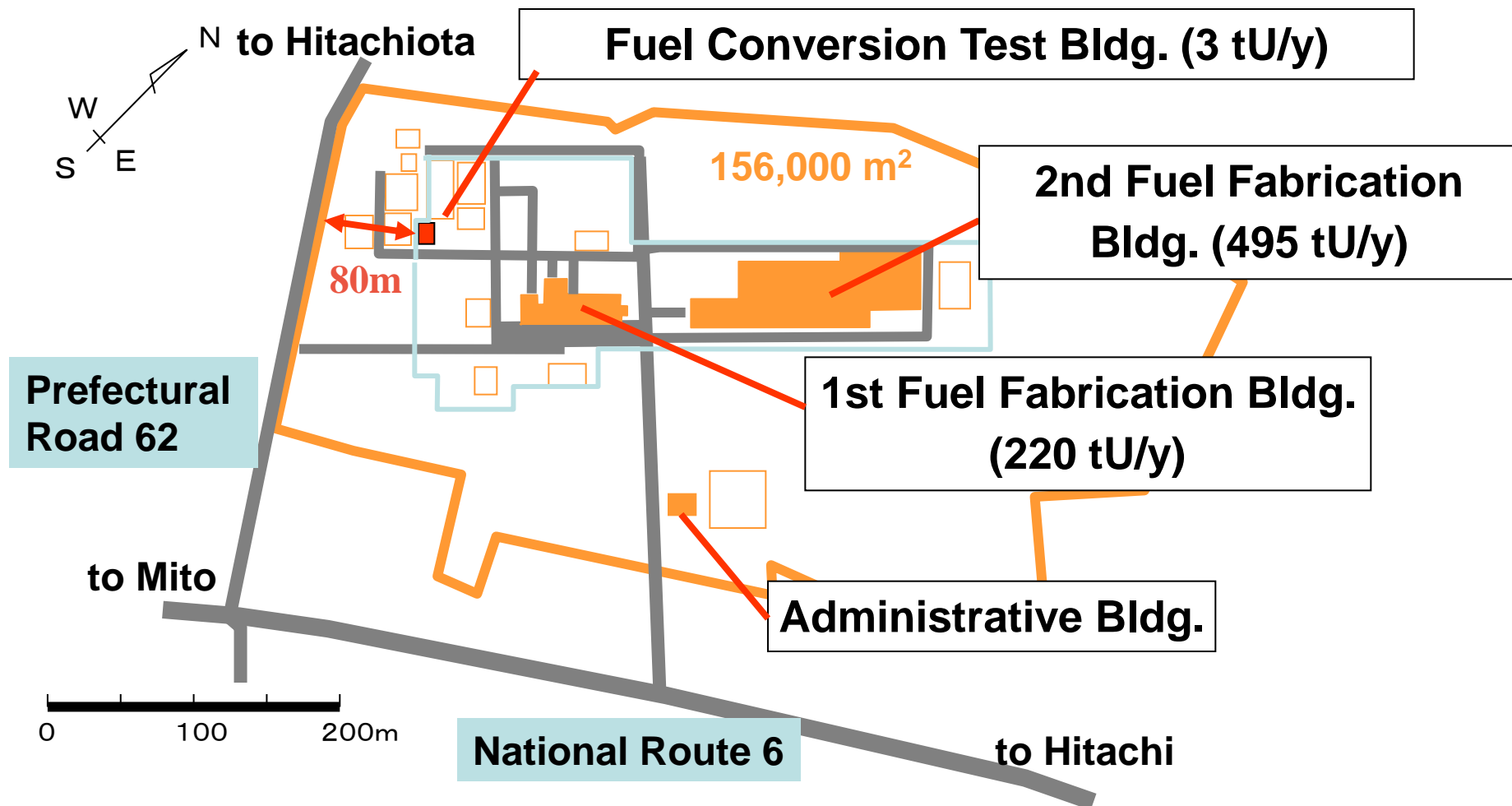
Prefectural Road 62

National Route 6

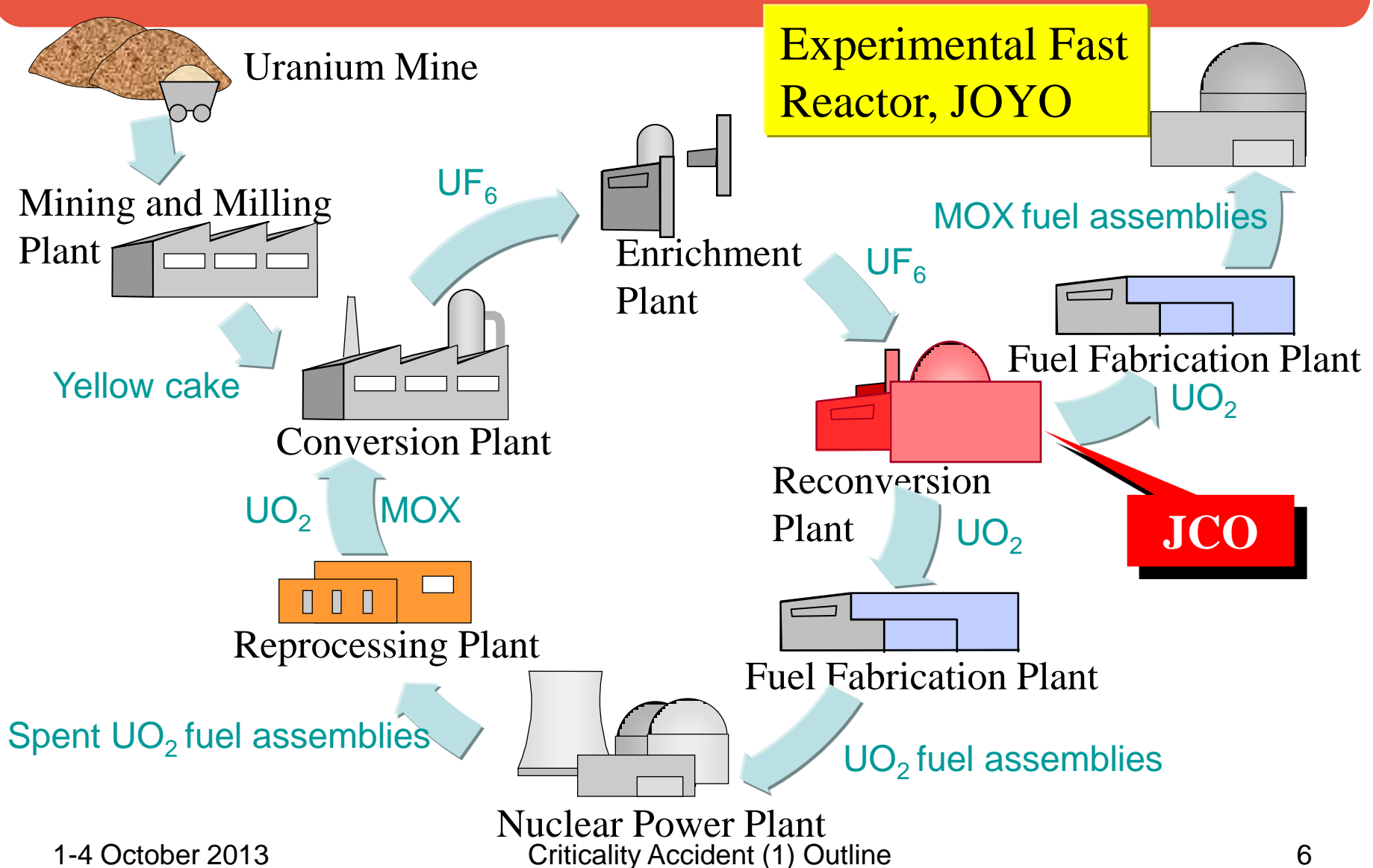
Gas station



# JCO Site



# Main Role of JCO in Nuclear Fuel Cycle

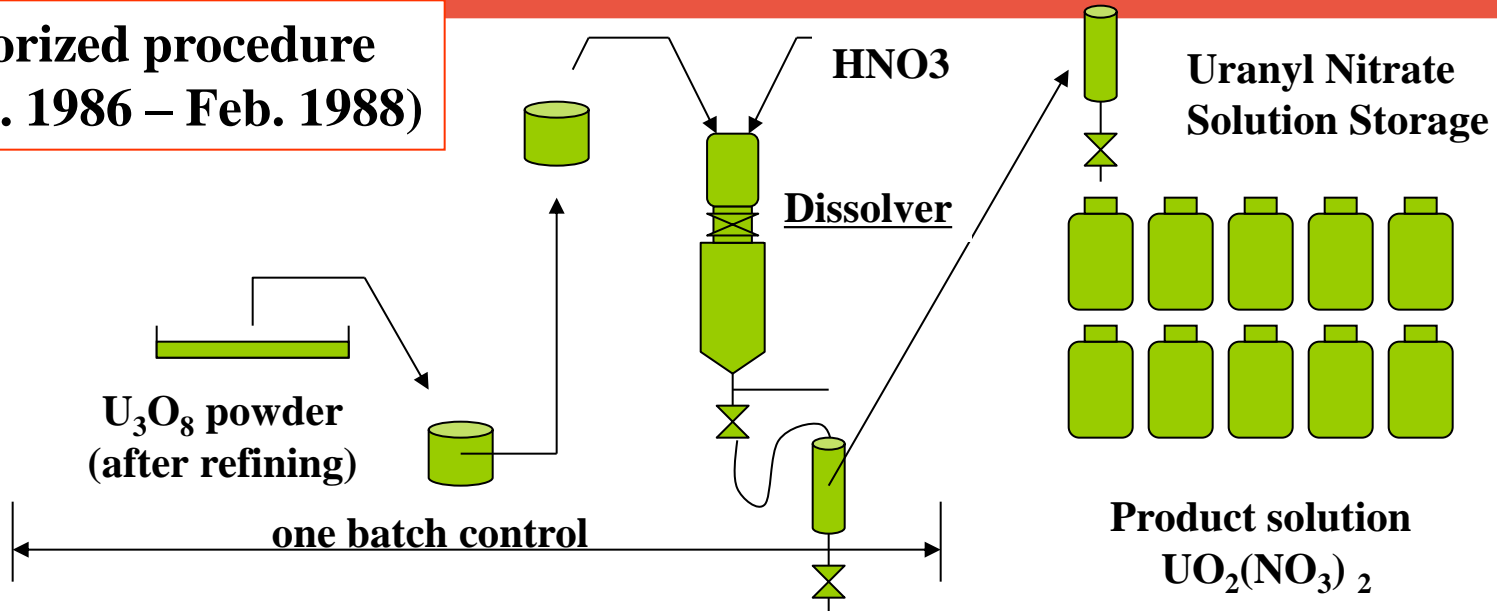


# Consignment from Former JNC

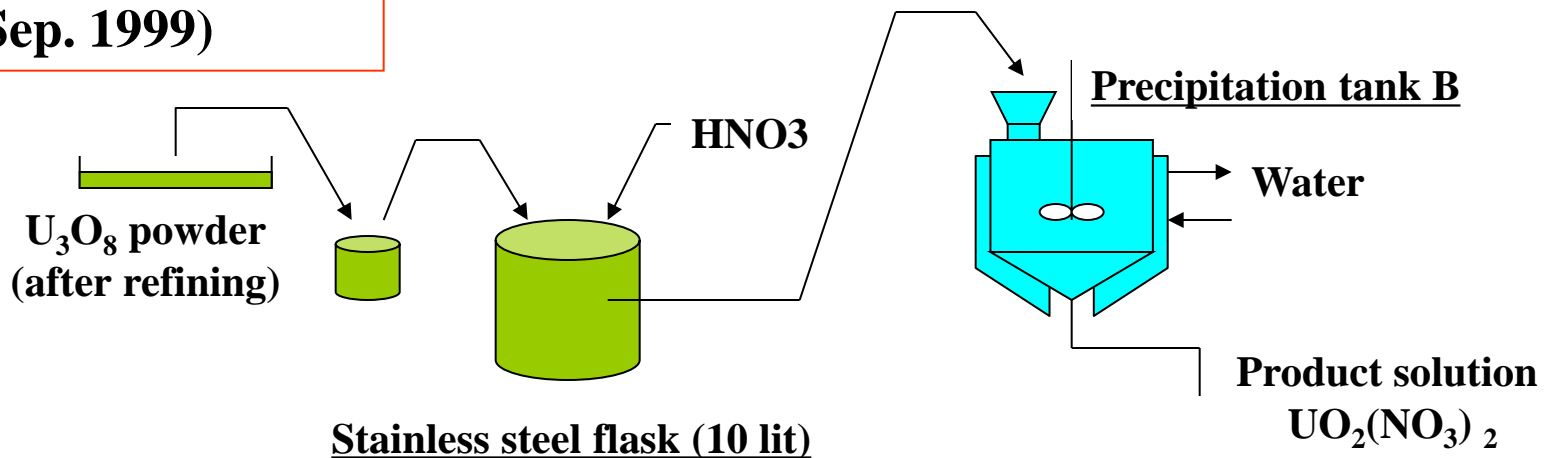
- **To obtain homogeneous uranium nitrate solution from  $\text{U}_3\text{O}_8$  powder of 18.8 uranium enrichment to make a test fuel for the Experiment Fast Breeder, Joyo of the former Japan Nuclear Cycle Development Institute (JNC).**

# Simplified Process

**Authorized procedure  
(Oct. 1986 – Feb. 1988)**

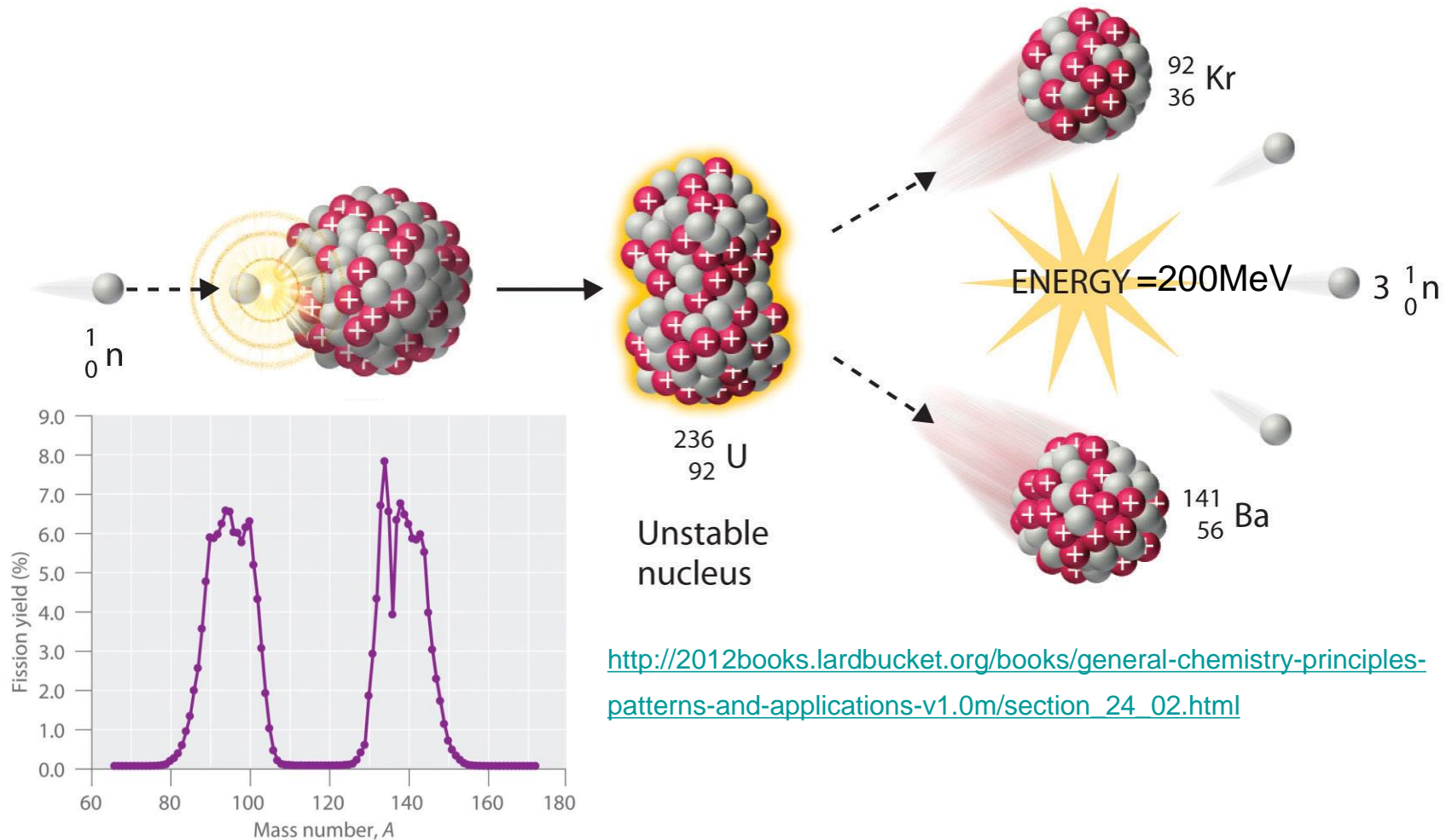


**Actual procedure  
(Sep. 1999)**

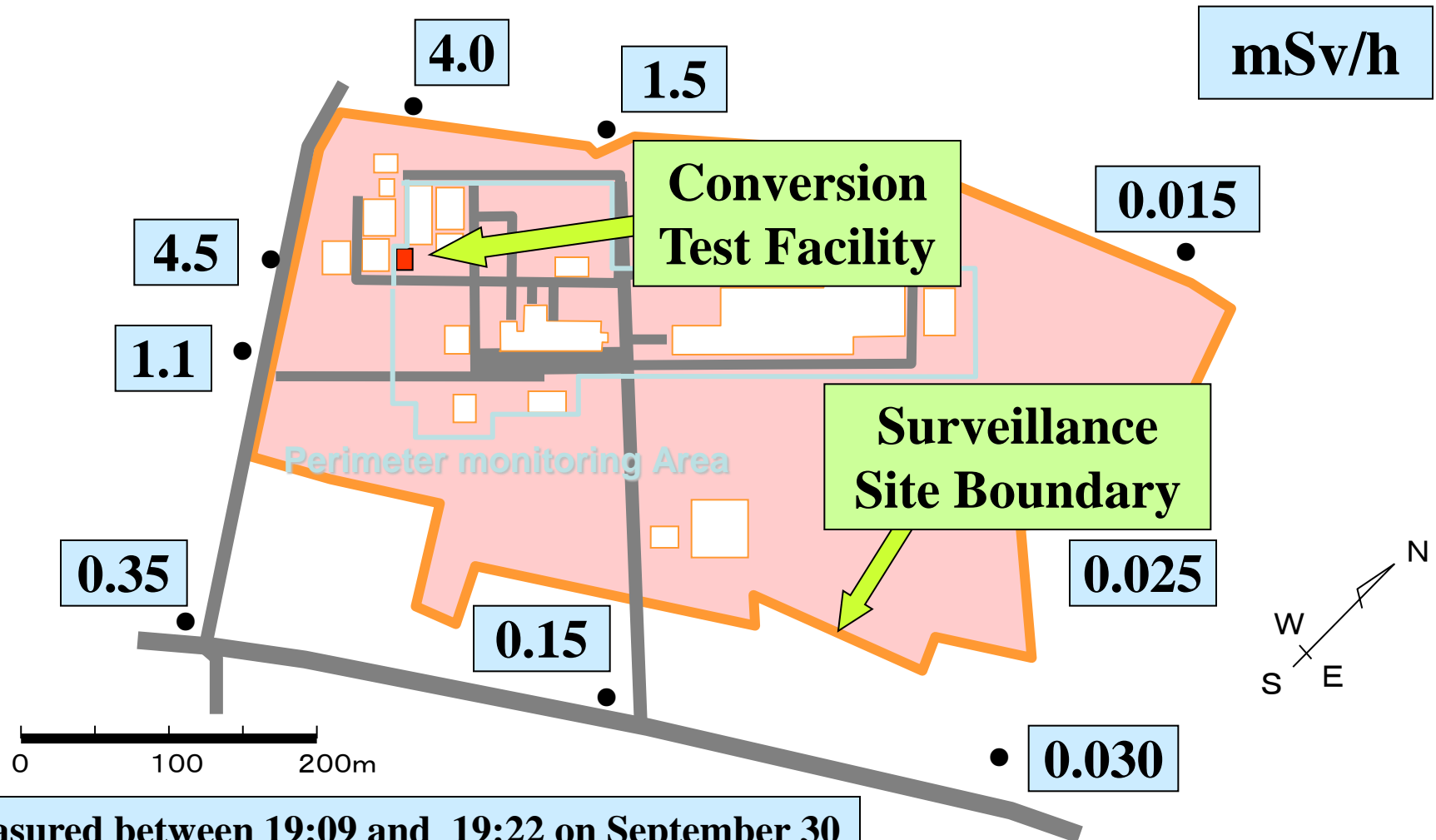




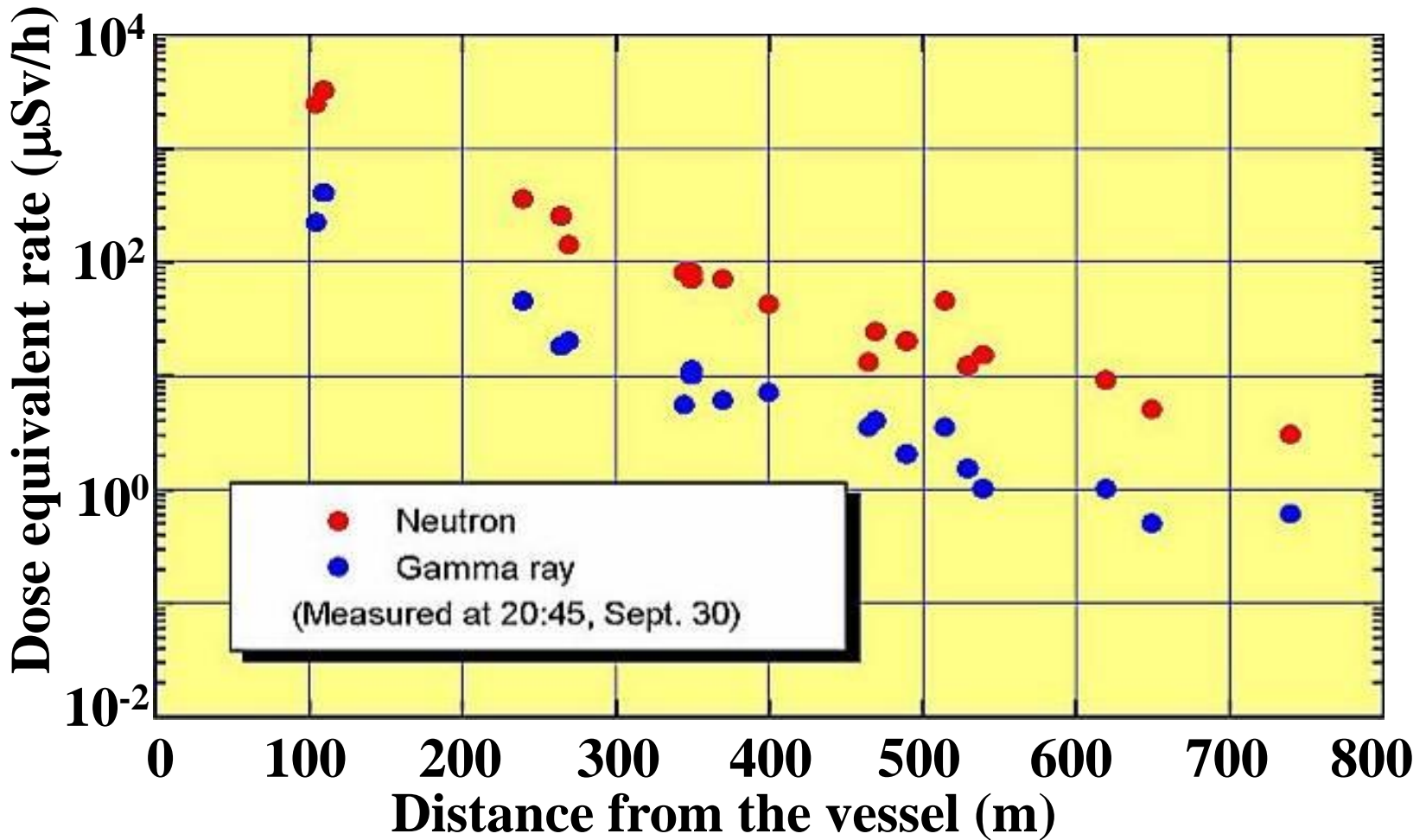
# What is Induced by a Fission?



# Neutron Dose Equivalent Rate Measured at the Site Boundary

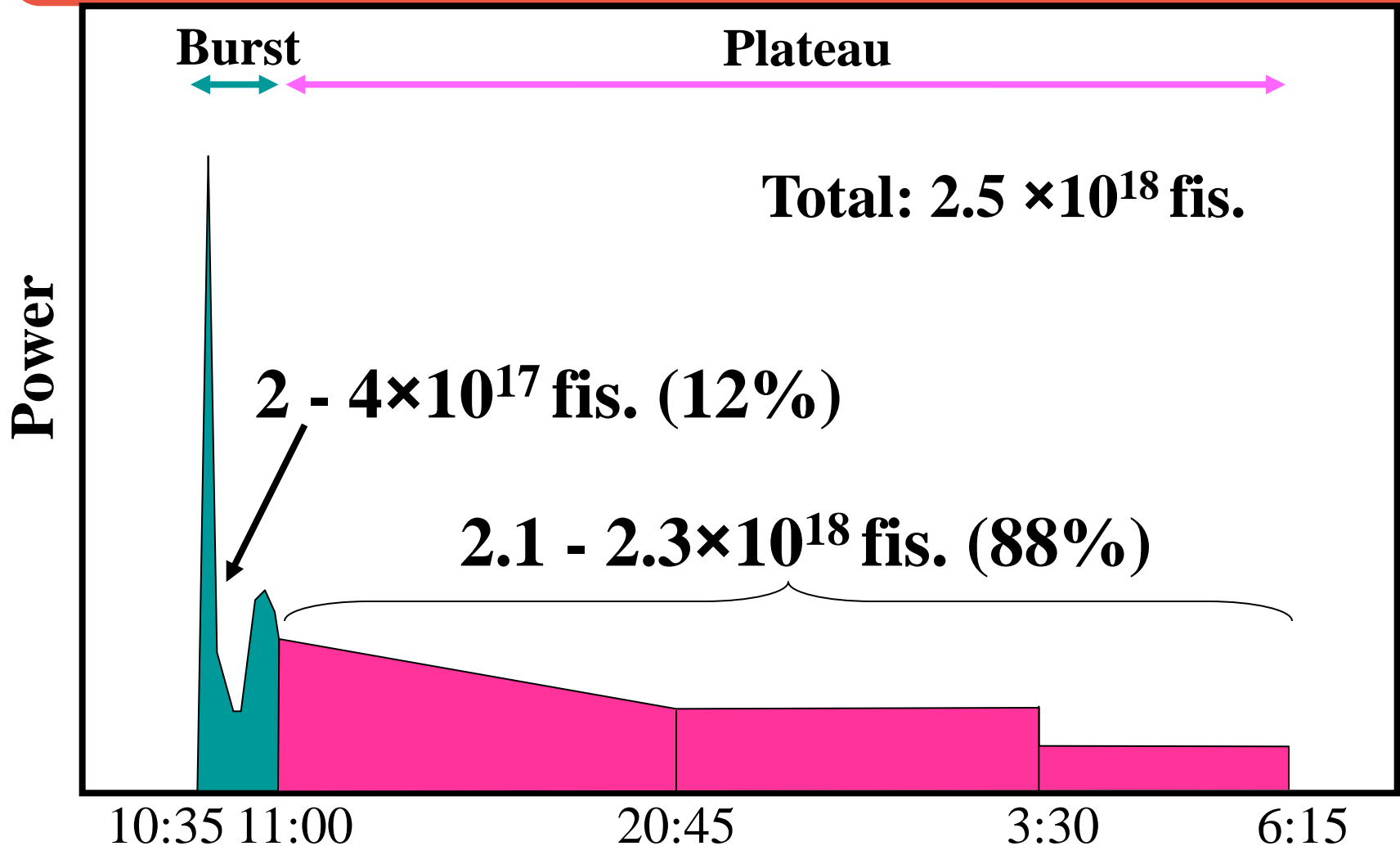


# Neutron/Gamma Dose Equivalent Rates Measured near JCO



<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAERI-Tech-2000-074.pdf> [in Japanese]

# Estimation of Fission Behavior



# Radioactivity Discharged into the Atmosphere

	Released amount (Bq)
<b>Noble gases</b>	<b><math>1.6 \times 10^{14}</math></b>
<b>Iodines</b>	<b><math>1.3 \times 10^{10}</math></b>

# Emergency Response by JCO

Time	Action
<b>10:35</b>	<b>Gamma-ray area monitors alarmed in JCO.</b>
<b>10:40</b>	<b>Collected workers on the playing ground and called over.</b>
<b>10:43</b>	<b>Called 119, telling “Looks like by <i>tenkan</i>*.”</b>
<b>~11:15</b>	<b>Sent FAX to STA, Ibaraki Pref., Tokai-mura, etc. reporting the event with a comment “nuclear criticality might occur.”</b>
<b>13:56</b>	<b>Visited Tokai-mura and requested evacuation of the nearby residents.</b>
<b>14:40</b>	<b>Same as above.</b>

\* In Japanese, both conversion and epilepsy are pronounced *tenkan*.



# Emergency Response by Firefighters

Time	Action
<b>10:46</b>	<b>Arrived at the main gate of JCO.</b>
<b>11:02</b>	<b>Informed by JCO that the patients suffered radiation exposure.</b>
<b>11:33</b>	<b>Requested National Mito Hospital (NMH) to accept the radiation casualties.</b>
<b>12:07</b>	<b>Arrived at NMH.</b>
<b>13:02</b>	<b>Requested the police helicopters to transfer the casualties to the NIRS.</b>
<b>13:43</b>	<b>Left the police heliport in Mito.</b>
<b>15:23</b>	<b>The casualties arrived at the NIRS.</b>

# Emergency Response by Former JNC

Time	Action
<b>12:30</b>	<b>Received a call for help from JCO.</b>
<b>12:35</b>	<b>Established the JNC Support Headquarters.</b>
<b>After 14:30</b>	<b>Arrived at JCO and made a plan for counter-measuring the event.</b>
<b>16:30</b>	<b>Measured the neutron dose level as 0.6mSv/h in the administrative building of JCO.</b>
<b>19:30</b>	<b>Made gamma screening for JCO workers at Ishigami Community Center.</b>
<b>Next day</b>	<b>A hundred workers participated in making sand bags and piling them up for shielding.</b>

M. Kanamori, "JCO Criticality Accident Termination Operation," JAEA-Technology 2009-079 (2010).

# Emergency Response by Former JAERI

Time	Action
12:18	Received a call from STA.
13:10	Established the emergency Headquarters at Tokai Establishment.
14:10	Dispatched specialists in criticality safety and health physics to STA-Tokai.
~18:10	Received information on the precipitation tank of JCO.
~22:00	Estimated that the tank might become subcritical when water would be drained out from the water jacket of the tank.

# Emergency Response by Local Residents

Time	Action
12:30	The residents of Tokai-mura were announced over the community system that they should be stayed indoors, because radiological material was seemingly released from JCO where an accident was occurred at 10:35.
~15:00	The residents within 350-m-radius area were requested by Tokai-mura to evacuate.
22:30	The residents within 10-km-radius area were requested by the Governor of Ibaraki-Prefecture to stay indoors.

# Lessons Learned (I)

- 1. The accident was happened where it was not assumed to happen.**
  - Not at a nuclear power plant nor at a fuel reprocessing plant!**
  - Processing uranium, not plutonium!**
  - Nuclear criticality continued!**
- 2. Emergency response can be made within his/her usual habit and ability.**
  - Many workers for JCO and some first responders did not carry a personal dosimeter.**
  - Criticality calculation was performed by a JAERI researcher who used the code in his research.**

# Lessons Learned (2)

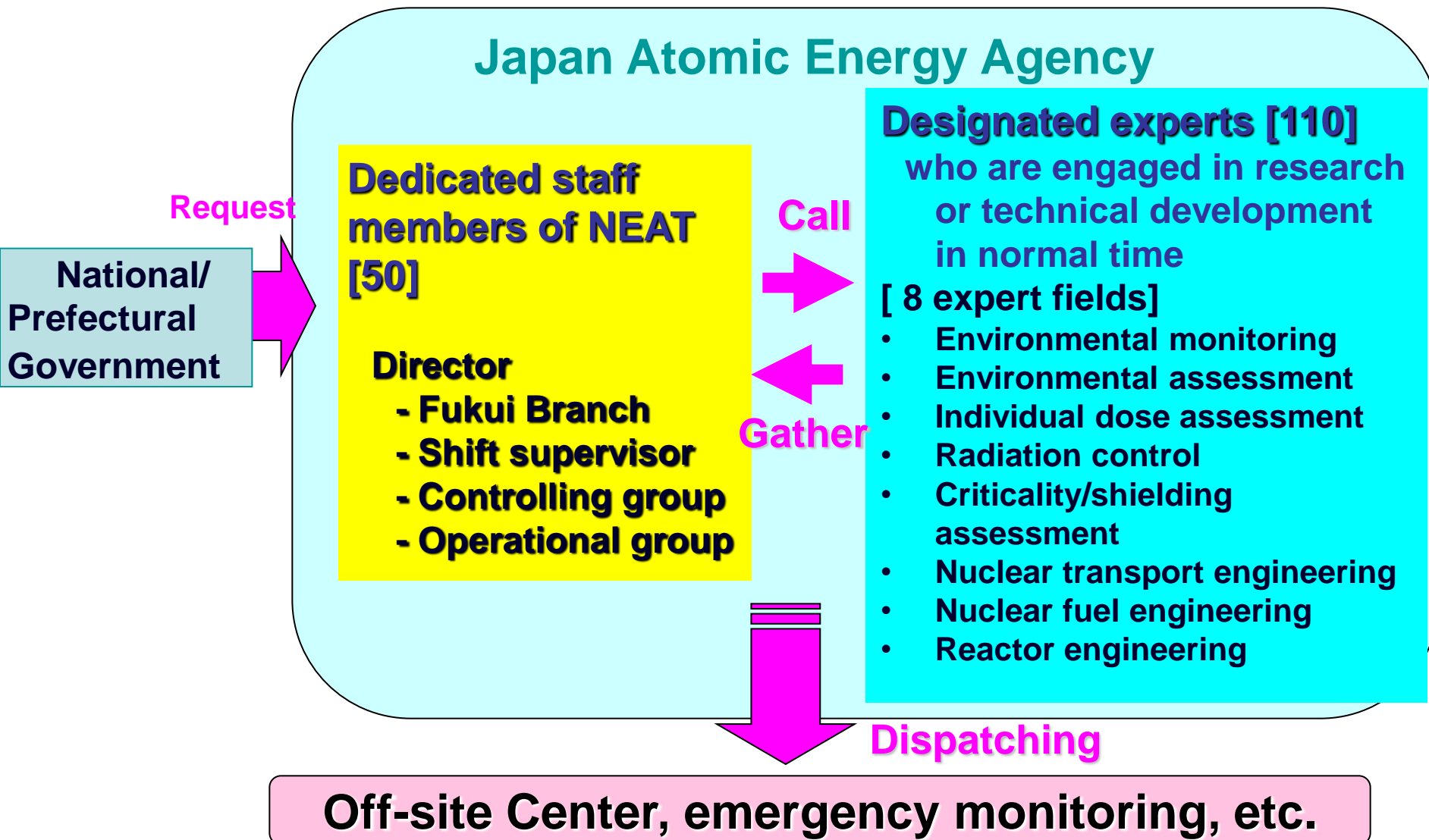
- 3. Information sharing among emergency response headquarters is important.**
  - The emergency HQs of Tokai-mura was not informed of the Governor's request.
- 4. Mass communication, esp. TV broadcast, is a fast publication tool in emergency.**
  - JCO workers watched TV during the accident, not knowing what to do.
  - People at the Emergency HQs of Tokai-mura knew the Governor's request through TV news.
  - However, the national broadcast does not join the emergency exercise, because of the independence of mass media.



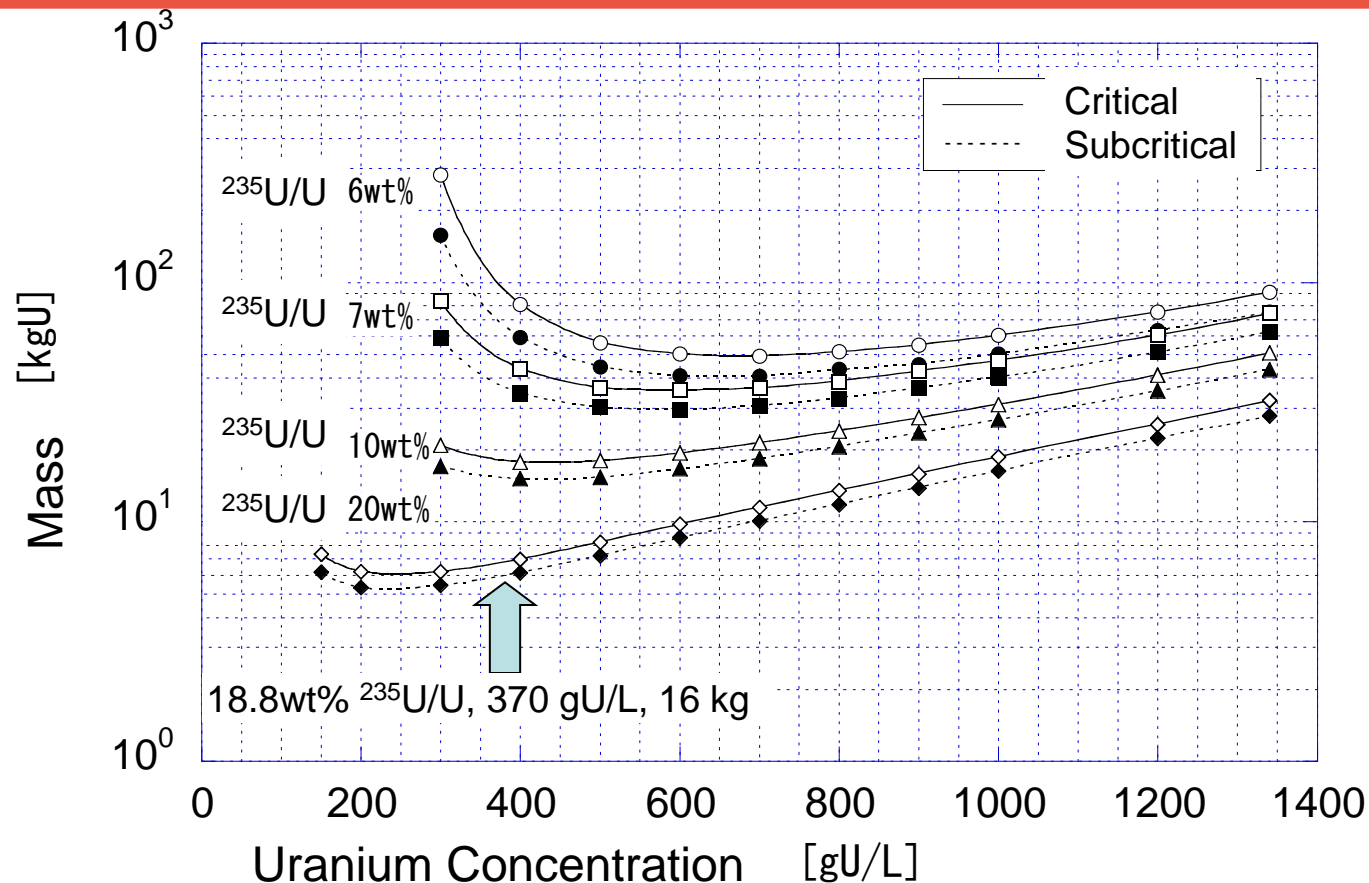
# Appendices

- **JAEA/NEAT**
- **Criticality mass curves**
- **Drawing for countermeasure**
- **Memo on calculation results**

# Emergency Response Structure of the Japan Atomic Energy Agency as a Designated Institute



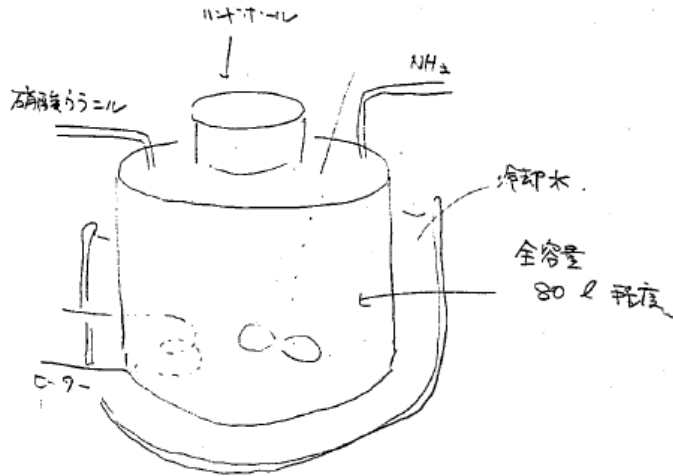
# Criticality Mass Curves



**Criticality mass curves for uranium nitrate solution**

<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Data-Code-2009-010.pdf> [in Japanese]

# Drawing for Stopping Criticality



1. タンク内で瞬発が起るといふと考えられる。
2. 本来 26kg 投入するところ、16kg 投入した。
3. 流量は不明。
4. タンク周囲の冷却水が、中性子反射材となつてゐる可能性が有る。

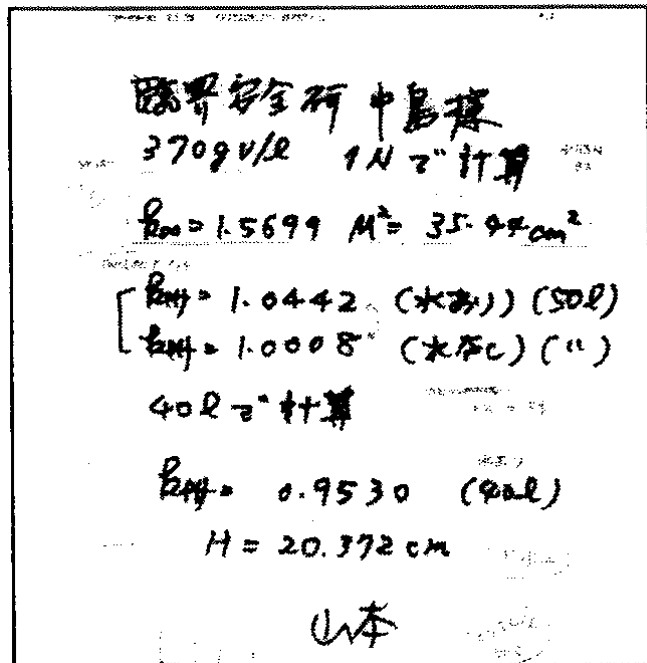
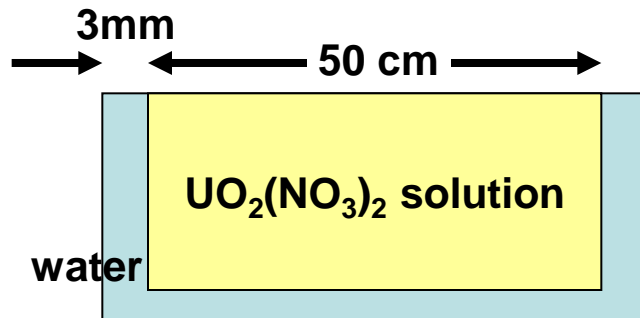
対策

1. 中性子反射材である冷却水を抜く。
2. 中性子吸収剤を含む水（ホウ酸水）をタンク内に入れる。
3. NH3ラインから入れることは可能か？

- **Outline drawing of the precipitation tank and planning of countermeasures to stop criticality**
  1. To draw cooling water outside of tank
  2. To inject neutron absorber into the tank
  3. Is it possible to inject from NH<sub>3</sub> line?
- **The paper was faxed to JAERI's Emergency HQs by the dispatched expert of JAERI.**

<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JNC-TN8440-2001-018.pdf> [in Japanese]

# Criticality calculation made for stopping criticality on 30th September



- **Calculation assumptions**
  - Uranium conc.: 370 gU/L
  - Free nitric acid: 1 N
  - Liquid volume: 50 L
- **Calculation results**
  - Infinite multiplication factor  $k_{\infty} = 1.5699$
  - Migration area  $M^2 = 35.44 \text{ cm}^2$
  - $k_{\text{eff}} = 1.0442$  w/ water reflector
  - $k_{\text{eff}} = 1.0008$  w/o water reflector

<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAERI-Tech-2000-074.pdf>  
[inJapanese]