FOIA REQUEST

Presentation to the ACRS Reactor Fuels Subcommittee

Subcommittee Meeting

October 18, 2000

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A/12

Air Ingression and Temperature Criteria For Analysis of Spent Fuel Pool Accidents

- Past evaluations of spent fuel pool accidents have used temperature criteria of 800–900 °C, identified as a temperature criterion for self-sustaining reaction of Zr cladding in air (autoignition/ignition).

- More appropriately, temperature criterion may be thought of as threshold for temperature escalation leading to significant fuel damage.
  - Criterion dependent on system conditions, physical configuration, heat generation and losses.

Air Ingression and Temperature Criteria For Analysis of Spent Fuel Pool Accidents (continued)

- Practically, the temperature criteria was used in draft generic study:

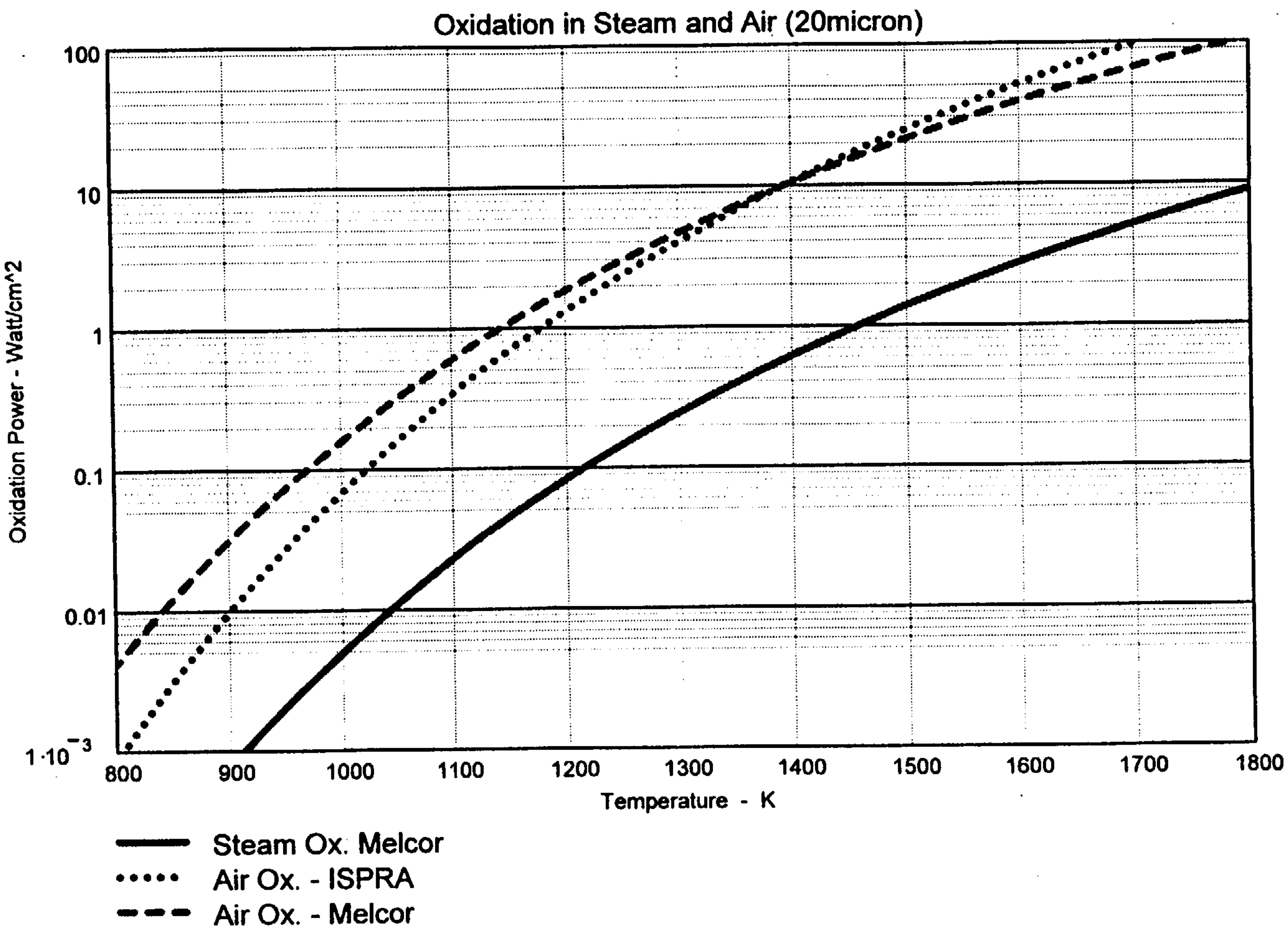
  1) Signal onset of significant fuel pool release for evaluating time for ad hoc evaluation.

  2) For determination of decay heat level and corresponding time ("critical decay time") at which equilibrium temperature could be maintained, <u>precluding large release</u> (~ 5 years).

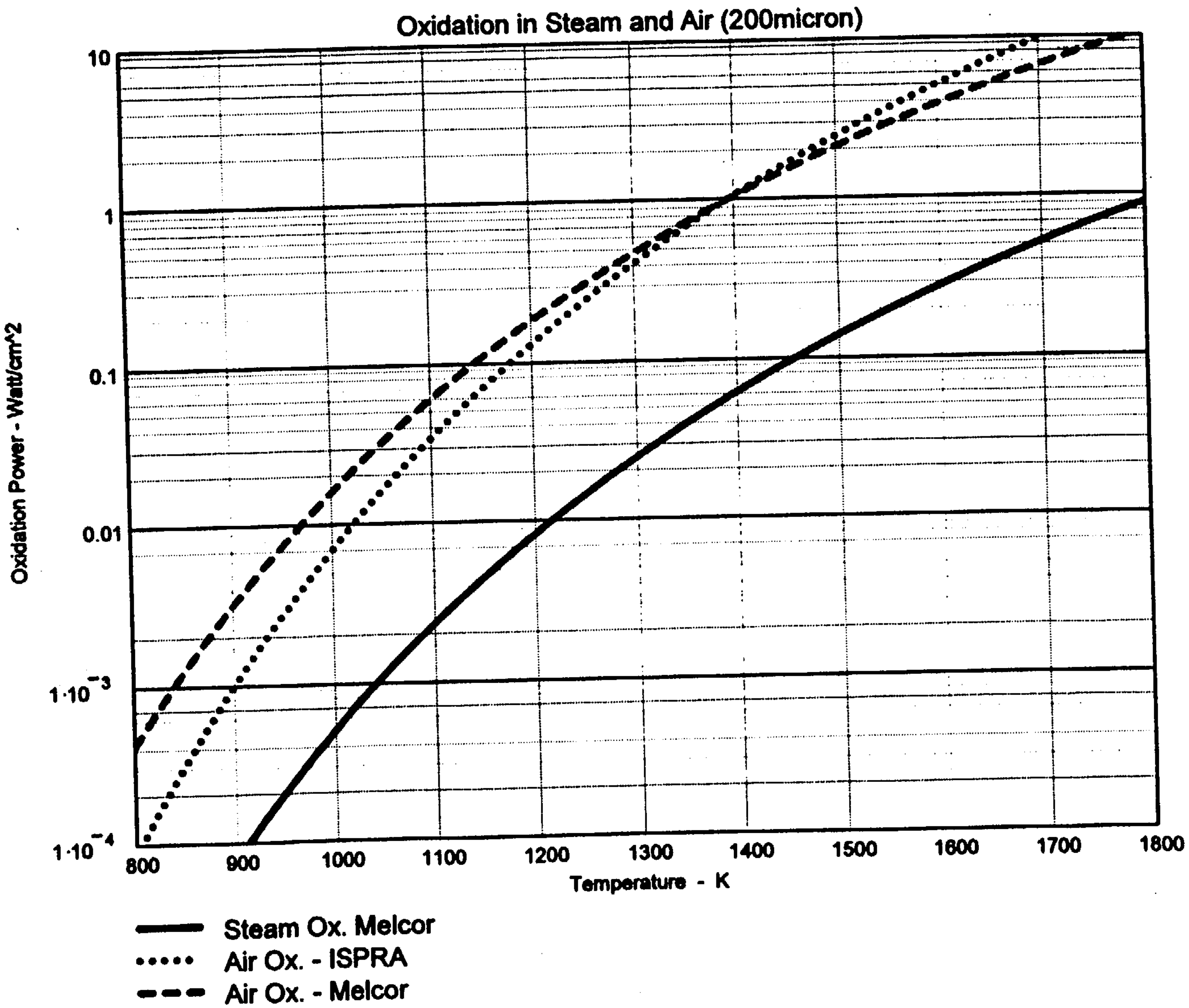
- NRC has reevaluated appropriateness of temperature criteria considering:
  - Zr reaction kinetics
  - Hydriding/autoignition
  - Fuel damage testing
  - Fission product release data (ruthenium)
  - Materials interactions

Zr Oxidation Kinetics

- Review of steam and air oxidation data
  - CORA, QUENCH, PHEBUS, and CODEX data on temperature escalation.
  - Determination of temperatures for equivalent heat generation between air and steam.
- Temperature of 1200 °C, representative of temperature escalation in steam core damage tests corresponds to an equivalent heat generation in air at ~ 925 °C using ISPRA's best fit to CODEX data.
- Above approach produces a threshold for temperature escalation quite close to CODEX observation.



Oxidation in Steam and Air (20micron)
100
10
1
0.1
0.01
1·10⁻³
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
Temperature - K
Oxidation Power - Watt/cm^2
Steam Ox. Melcor
Air Ox. - ISPRA
Air Ox. - Melcor



Oxidation in Steam and Air (200micron)
10
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1·10⁻⁴
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Temperature - K
Oxidation Power - Watt/cm^2
Steam Ox. Melcor
Air Ox. - ISPRA
Air Ox. - Melcor

Zr Oxidation Kinetics (continued)

- Autoignition of clean metal or hydride.
  - Normally oxidized but exposed on ballooning/burst small surface area.
  - Hydrides dissolution prior to reaching conditions for ignition.
- Breakaway oxidation.
  - Reported in isothermal tests (Leistikow, Evans).
  - Instability of nitride layer.
  - Deviation from parabolic rate kinetics.
  - Incubation time of 4–10 hours at 800 °C.
    - Not limiting for transient heatup but would be limiting for long-term equilibrium criterion.

Temperature Criteria and Fission Product Releases

- Fission product releases
  - Initial release of fission products upon cladding failure.
  - High-temperature release of volatiles
  - Release of Ru after oxidation of fuel. (Under what low temperature conditions might fuel oxidize leading to large ruthenium releases?)
  - To avoid rapid releases of Ru, in draindown scenarios temp should be maintained less than 600 °C

Summary

	Adequacy of 10 hrs for Evacuation	Precluding Large Release Fuel <5yrs	Precluding Large Release Fuel >5yrs
Dominant Air Environment	900 °C	600 °C	800 °C
Dominant Steam Environment	1200 °C	N/A	N/A

- Use of temperature criteria must be supported by analysis of all significant heat generation and loss mechanisms.
- Determination of an acceptable long term condition requires confirmation of equilibrium temperature condition.
- Integrated modeling of thermal hydraulics, cladding reactions and fuel heatup and fission product release would provide consistent consideration of conditions for sequence specific analysis. Would provide means for more realistic estimates.

$$K_{H2O}(T) := 29.6e^{\frac{-16820 \cdot K}{T}} \cdot \left(\frac{kg}{m^2}\right)^2 \cdot sec^{-1}$$

rate of Zr metal reacted in steam (MELCOR Code)

$$K_{O2}(T) := 50.4e^{\frac{-14630K}{T}} \cdot \left(\frac{kg}{m^2}\right)^2 \cdot sec^{-1}$$

rate of Zr metal reacted in oxygen (MELCOR Code)

$$K_{ISPRA}(T) := 52.67 \cdot 10^4 \cdot e^{\frac{-17597K}{T}} \cdot \left(\frac{mg}{cm^2} \cdot \frac{91 \cdot gm}{32 \cdot gm}\right)^2 \cdot sec^{-1}$$

rate of O_2 mass (converted to Zr) produced cited as "best fit" by ISPRA.

The following figure show the temperature dependence of the above three rate constants graphically...

... with units expressed as $(mg/cm^2)^2\ sec^{-1}$.