SARJ 92

1.1 Accident Management in LWR s and Research to Support It

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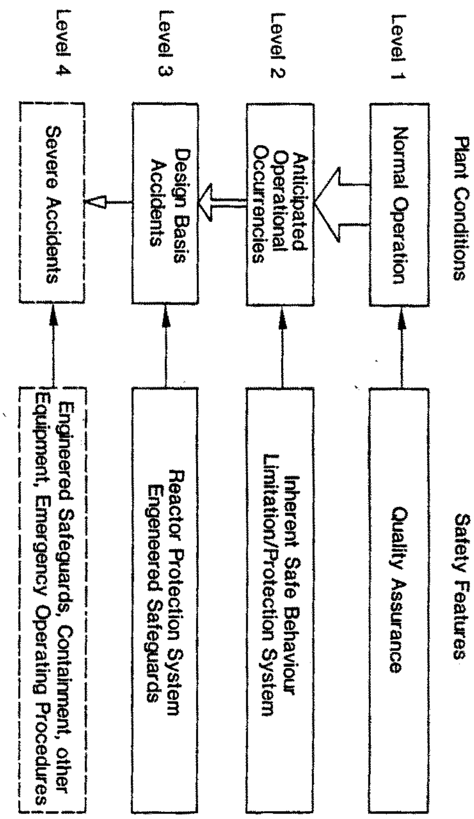
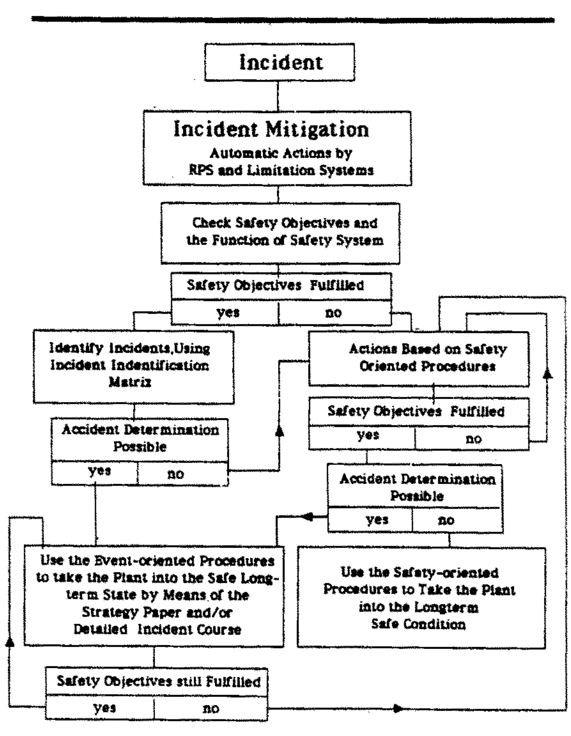


DEFENSE-IN-DEPTH CONCEPT

Priorities in the area of AM

- Priority to preventive measurses
  - Plant response is better predictable and more easily controllable
  - Overall damage within the plant and offsite is minimized
- Preventive AM is achieved by a deterministic approach supplemented by probabilistic safety analysis
- Mitigation measures for severe accident conditions are considered as an additional provision



Emergency Procedure Guideline
Incident Mitigation Based on Event-oriented and Safety-oriented Procedures

PWR-Depressurization Strategies

- German risks study - Phase B - indicates a need to depressurize the reactor coolant system in a PWR
  - Core Damage Frequency W/O AM: $3 \cdot 10^{-5}$/a
    High Pressure states: 98 %
    Low Pressure states: 2 %
  - High Pressure core melt has the potential for early containment failure
- Strategy
  - ■ Secondary Bleed and Feed (prefered actions)
  - Normal way of heat removal
  - Accessibility
  - Sufficient time to prepare actions
  - Passive injection possibility using feedwater tank in addition to mobile pumps
  - ■ Primary Bleed and Feed (back up)

Principles for planning and implementation of AM

The following principles are applied in Germany for planning and implementation of accident management procedures:

- The accident management measures should not impair plant operation under normal or upset conditions nor may they unacceptably interfere with existing procedures
- Possible adverse effects have to be analyzed and assessed
- Accident management measures take credit of all existing systems and equipment
- The usual design criteria for safety systems, such as the "single failure criterion", are not applied
- Analyses should be performed with "best estimate" assumptions
- In view of the limitations and uncertainties in PSAs, the PSA should not be the sole basis for selecting a practicable accident management strategy

Principles for planning and implementation of AM (Continuation)

- The uncertainties that exist should be taken into account during the development of accident management strategies
- Accident management actions are in general considered as manual actions
- Accident management measures may be initiated after a sufficient period of time essential for diagnosis and decision-making
- It must be possible to interrupt and repeat the accident management measures at any time
- Any necessary equipment for initiating accident management measures must be arranged in such a way that operator errors or inadvertant initiation during normal operating are avoided

Secondary Bleed and Feed

Objective

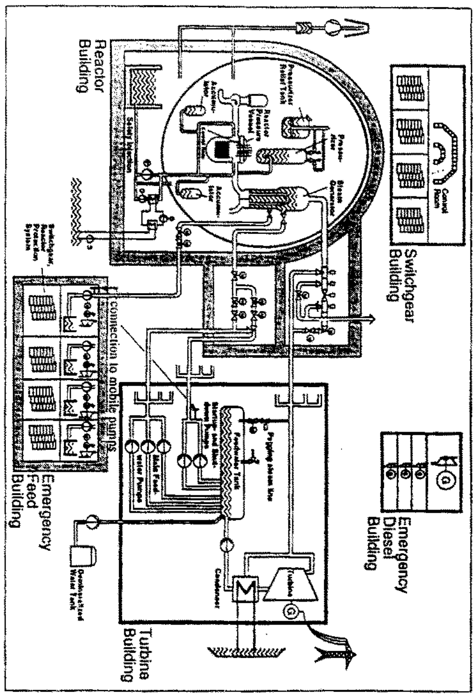
- Restoring Feedwater Supply to maintain core cooling

Transition criteria to AM-Manual

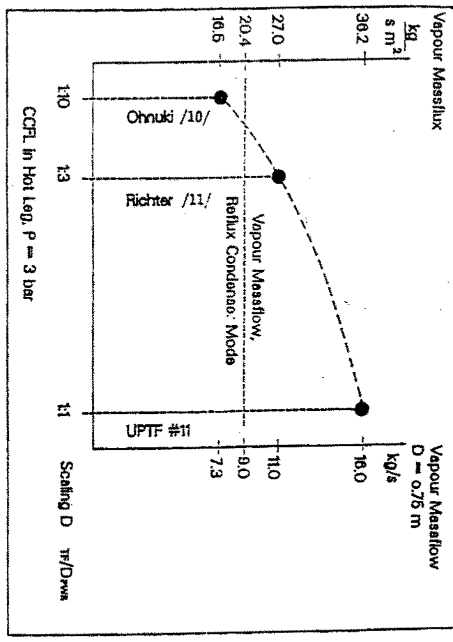
- Emergency Power Supply unavailable for more than 20 min or 4 of 4 SG-Level < 4 m

AM-Measure

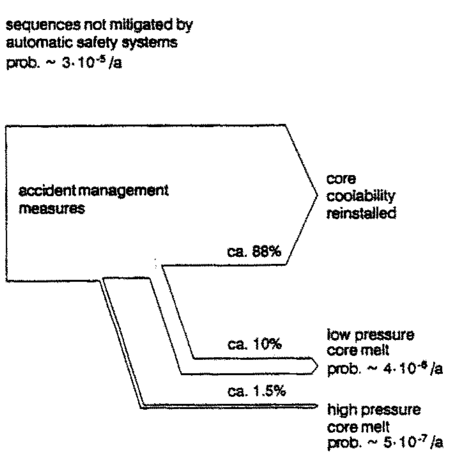
- Bleed: Depressurization of voided SG
- Feed:
  - using water inventory in feedwater line
  - from feedwater tank
  - with mobile pumps
- Water reservoirs:
  - demineralized water tanks
  - cooling water ponds
  - fire water system
  - river



Plant Overview PWR 1300 MW (KONVOI)



Reflux-Boiler-condenser mode:
Counter-current flow limitation in hot leg, scaling influence



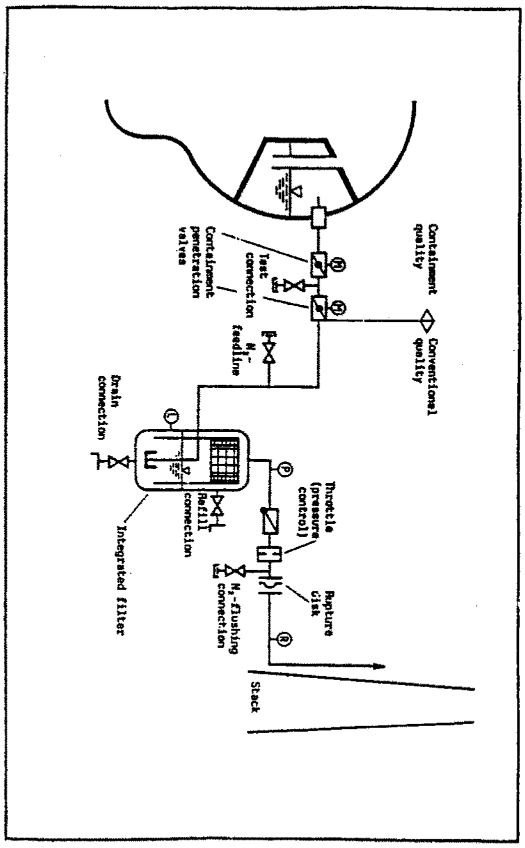
Influence of accident management measures on core melt probability

Mitigation Concepts for PWRs (2)

- **Control of Pressure and Temperature in the Containment**
  - **Containment Spray**
  - **Flooding of Compartments in Containment**
  - **Cooling with RHR**
  - **Filtered Venting**
- **Retention of Fission Product Release in Case of SGTR**
  - **Feed of Defect Steam Generator**

Mitigation Concepts for PWRs

- **Control of Containment Isolation**
- **Prevention of High Pressure Scenarios:**
  - **Coolability of Core Debris inside RPV**
  - **Catastrophic Failure of RPV**
  - **Missile Gereration**
  - **Failure of Support Structore**
  - **Direct Containment Heating**
- **Control of Hydrogen in Containment**
  - **Deliberate Ignition**
  - **Catalytic Material**
  - **Passive Igniters**
- **Flooding of Reactor Cavity**
  - **Improving Core Melt Coolability**
  - **Less or even no Melt/Concrete Interaction**



Pressure Relief and filtered Venting System
Containment Vessel of BWR 69

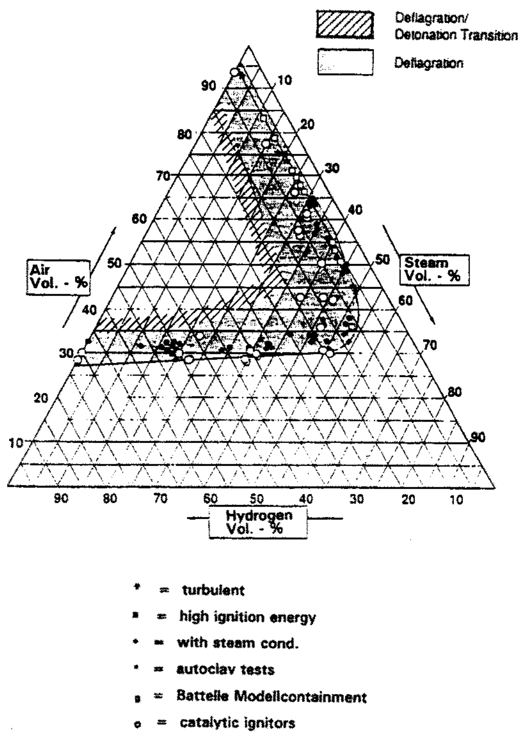
Hydrogen

Evaluation of the Beta - Experiments (KFK) resulted in higher Hydrogen Release than assumed in previous Analyses

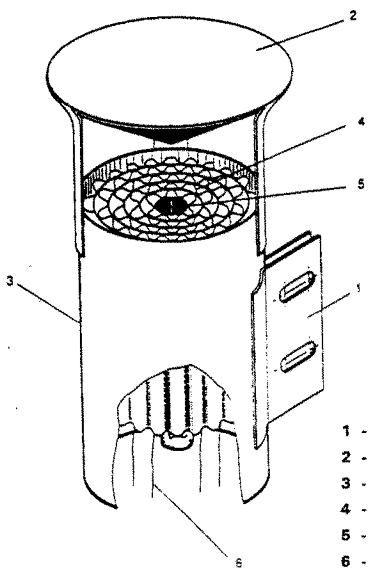
1 - 2 Hours after Melt Through of RPV about 1350 kg of Hydrogen will be released into the Containment

Uncontrolled Hydrogen Burning could lead to Failure of Containment

Counter Measures (Igniting Plugs, Catalytic Foils, Inerting) will be examined presently



Operational results with spark- and catalytic ignitors



Design example of a catalytic igniter

FRG

Research

Program

(excerpt)

TRAM-PROGRAM OBJECTIVES

- Supply experimental data gained from full-scale tests for transients and accident management scenarios, particularly for
  - Intention at depressurization procedures for PWR primary systems before core degradation to avoid high pressure core melt
  - Energy redistribution in reactor systems during degraded core accidents to assess the probability of ex-vessel component failures
- Provide options for full-scale tests on emergency cooling systems of new reactor concepts

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In Vessel Phenomena

- ATHLET -SA
- KESS - III
- RPV Natural convection
- Candling

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Ex Vessel Phenomena

- Hydrogen
  Experiments HDR-III, BMC, LAB
  Code RALOC
- Aerosols
  Experiments BMC (VANAM)
  Code FIPLOC-MAEROS, NAUA
- Iodine
  Experiments LAB
  Code IMPAIR 2
- MCCI
  Experiments BETA, LACE, MACE
  Code WECHSL, CORCON
- Filtered venting
  Experiments KWU, KfK, (ACE)

PKL

- Efficiency of emergeny core cooling for large and small break LOCA's
- Primary and secondary feed and bleed
- Cooldown procedures for beyond design base conditions
- Special thermal hydraulics effects
- Effect of inert gases in primary ciruit

Molten core concrete interaction

- BETA experiments (KfK)
  ACE, MACE participation
  - failure mode of biological shield
  - influence of Zr
  - BWR typical melt (B_4C, Zr)
- WECHSL, CORCON-Codes
  - further development in WECHSL
  - comparison between both codes
  - adaption to VVER-1000

Hydrogen behaviour during severe accidents

General objectives

Improvement of knowledge base on possible phenomena in containment, including accident management measures

Further development of codes to describe the phenomena

Current projects

- Battelle Frankfurt
- GRS
- HDR Phase III
- TU Munich