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Severe Accident Mitigation

A Unified Concept to Protect Nuclear Facilities

Framatome's high expertise and integrated and unified concept improves the severe accident resistance and mitigation capacity of your nuclear facility.

Challenge

In response to nuclear accidents with unacceptable release of radioactive fission products, regulatory institutions worldwide strengthen their requirements not only on prevention but also mitigation of such events. For an effective accident mitigation, the following aspects are paramount:

- Ensuring containment integrity for an appropriate duration
- Reducing the environmental impact as far as reasonably possible
- Protecting plant personnel and emergency crews.

Solution

We at Framatome offer an integrated and unified concept to strengthen the severe accident resistance and mitigation capacity of nuclear facilities (including nuclear power plants, research reactors, as well as front-end and back-end facilities).

It encompasses the following methods and products, presented here exemplarily for a nuclear power plant:

Identification of plant challenges and analysis of possible accidents

As a first step, the current severe accident resistance and mitigation capacity of the plant is determined in a strength and weakness assessment by comparing the performance of installed systems according to their design basis (or their expected design exceeding behavior) against possible loads. This assessment can also encompass a structural containment analysis and the evaluation of potentially endangered instrumentation and control hardware.

Next, facility-specific relevant accident types are identified according to criteria like probability of occurrence and severity of consequences, including the impact of recommended backfitting measures identified in the previous step.

This plant screening procedure can be supported by a comprehensive state-of-the-art probabilistic safety analysis, which helps to balance the facility design, to reduce conservatisms, and to economize possible backfitting measures.

> **Your performance**
> is **our** everyday **commitment**

For those severe accident scenarios that are identified as being representative and conservatively enveloping, the following phenomena, which could endanger the retention of fission products within the plant, are then investigated:

- Containment failure by high static overpressure
- Design-exceeding temperatures and their impact on containment penetrations
- Transient loads from phenomena like hydrogen combustion or high-pressure failure of the reactor pressure vessel
- Containment penetration by core melt attack
- Loss of building stability by basemat erosion through molten corium concrete interaction.

The associated loads can be quantitatively predicted by computer simulations of severe accidents with specialized and validated codes like MELCOR, MAAP, COCOSYS, ANSYS CFX, GASFLOW and COM3D. Here, a realistic and detailed model of the plant is employed, which includes any applicable backfittings.

Customer benefits

Our experience in all aspects of severe accident mitigation allows you to:

- Improve the overall safety of your facility
- Obtain optimal solutions for specific needs
- Fulfill all safety criteria set by regulators
- Ensure an efficient interplay of hardware systems and plant operation
- Mitigate and minimize the consequences in the very unlikely event of an accident.

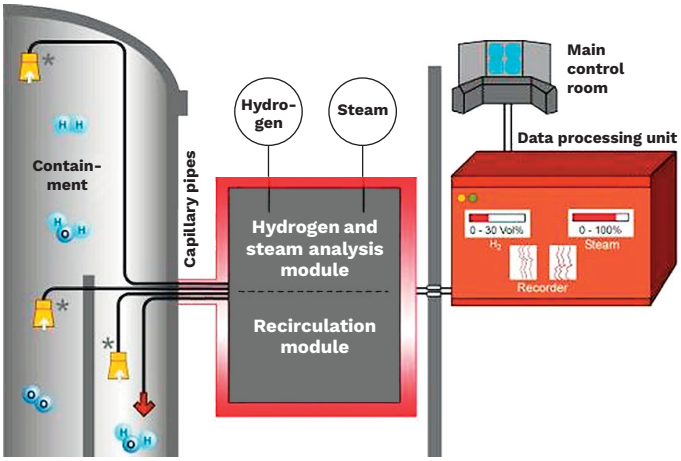
Backfitting hardware

To avert or reduce the loads onto the containment during a severe accident, we offer a variety of backfitting hardware like cooling circuit depressurization valves, combustible gas control systems (passive autocatalytic recombiners, igniters, inertization, mixing), containment venting systems with or without filters, dedicated emergency pumps, and core melt stabilization systems within the containment.

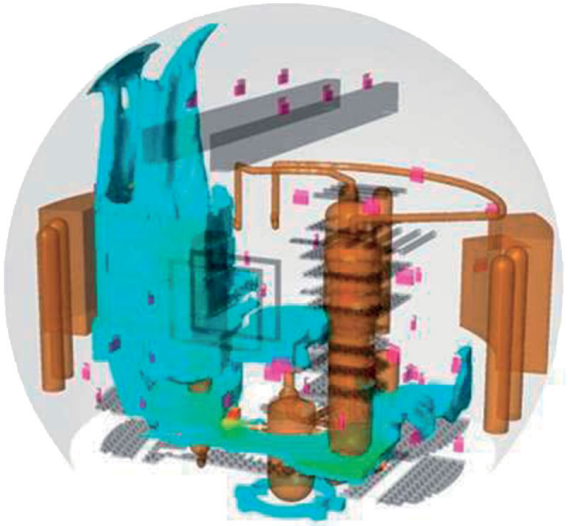
To monitor the accident progression, and to appropriately initiate mitigation measures and check their effectiveness, reliable instrumentation is essential. As existing instrumentation will most likely fail or produce incorrect data in severe accident conditions, it must be strengthened (and qualified) or replaced by new hardware specifically designed for severe accidents. Here, we offer solutions like activity monitoring systems (PEGASUS and PASS) or containment atmosphere monitoring systems (HERMETIS, WS85 and WS85Plus).

A special severe accident instrumentation assessment establishes minimal requirements as well as technically and economically optimal solutions for instrumentation. This could also include erecting a bunkered emergency control room (e.g. in response to regulatory requests).

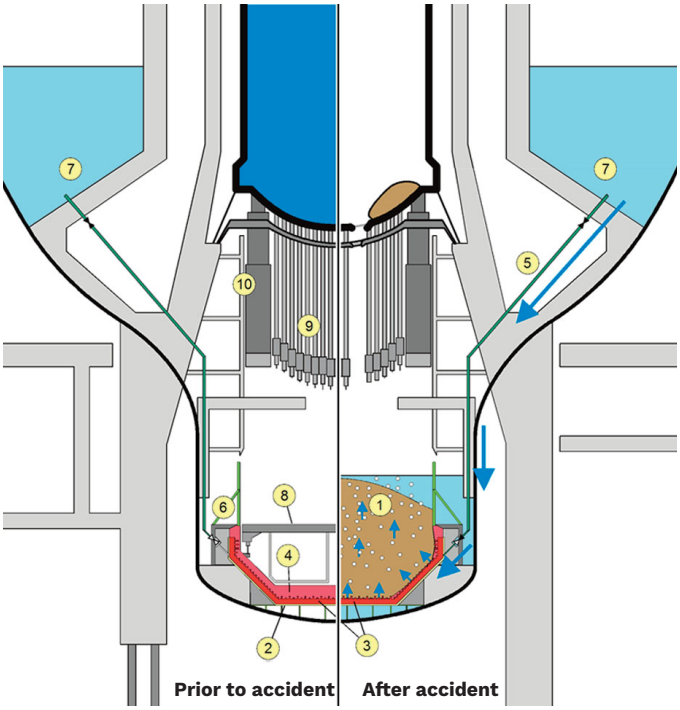
Any backfitting hardware for severe accidents is rigorously tested against the expected ambient conditions such as high radiation, high temperatures or aerosol clogging.



Containment Atmosphere Monitoring System HERMETIS



Computational fluid dynamics simulation of hydrogen distribution in a containment



1 Porous solidified core melt
2 Plan and lower support structure
3 Porous concrete layer
4 Sacrificial concrete layer
5 Downcomer pipes
6 Mobile radial support walls
7 Pressure suppression pool
8 Service platform
9 Control rod drives
10 External circulation pumps

Concept for backfitted core melt stabilization system in a boiling water reactor

Passive autocatalytic recombiner

Cooling circuit depressurization valve

Severe accident management guidelines

During a beyond-design accident with excessive plant damage, the emergency response crew must be able to

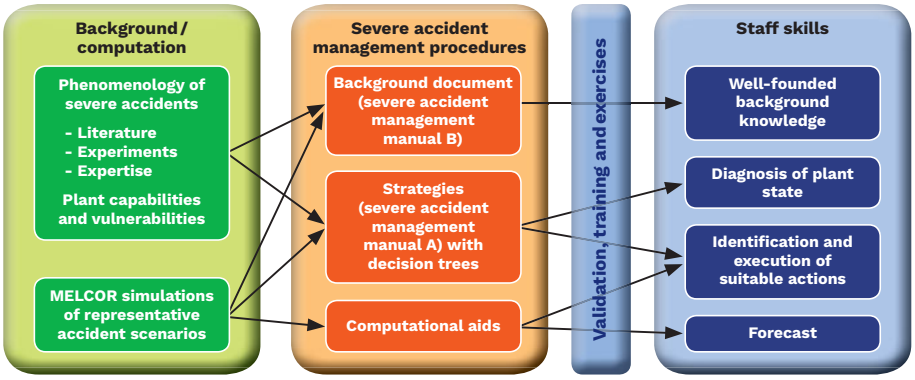
- evaluate the current plant status,
- identify efficient actions to prevent further damage and to mitigate the consequences,
- execute these actions under the given constraints, and
- communicate with on-site and off-site institutions and governmental agencies.

To facilitate these tasks, we provide severe accident management guidelines. These are based on extensive screening simulations with system codes like MELCOR. Well-defined and unambiguous indicators are identified that permit to determine the current core and containment status, using a minimum set of instrumentation.

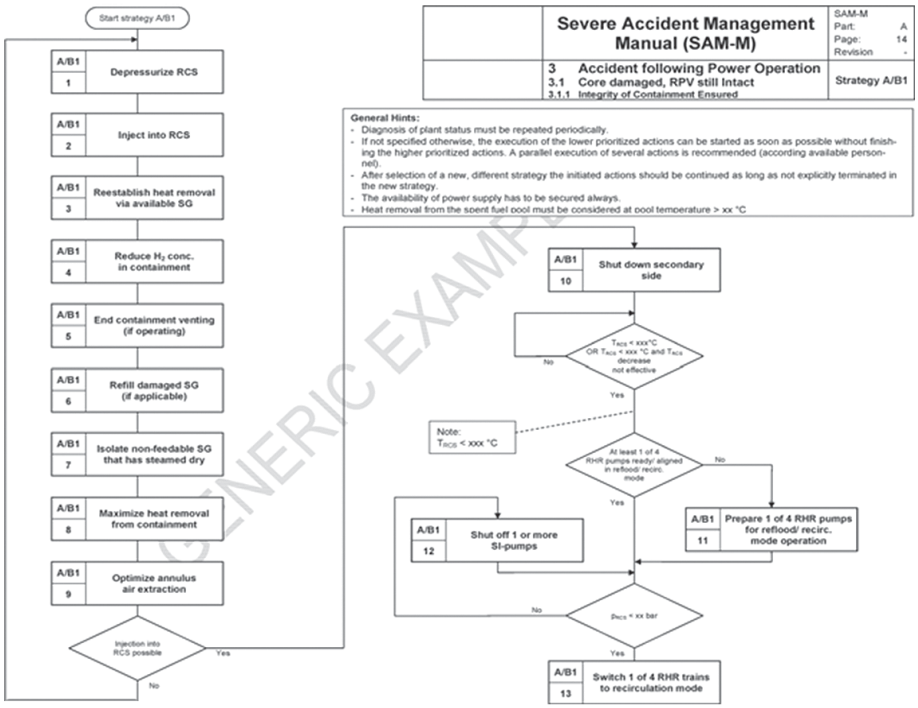
The intended beneficial impact and possible side effects of existing safety systems as well as possible backfittings are assessed. Based on their effectiveness mitigation strategies are developed. To evaluate grace periods, support tools for forecasting the anticipated accident progression are also supplied.

Plant status identification and mitigation strategies are formulated in clear flow charts, allowing fast and reliable usage. The reduction of plant information to the minimum required level promotes efficient communication between the various emergency response organizations, even via a single telephone line.

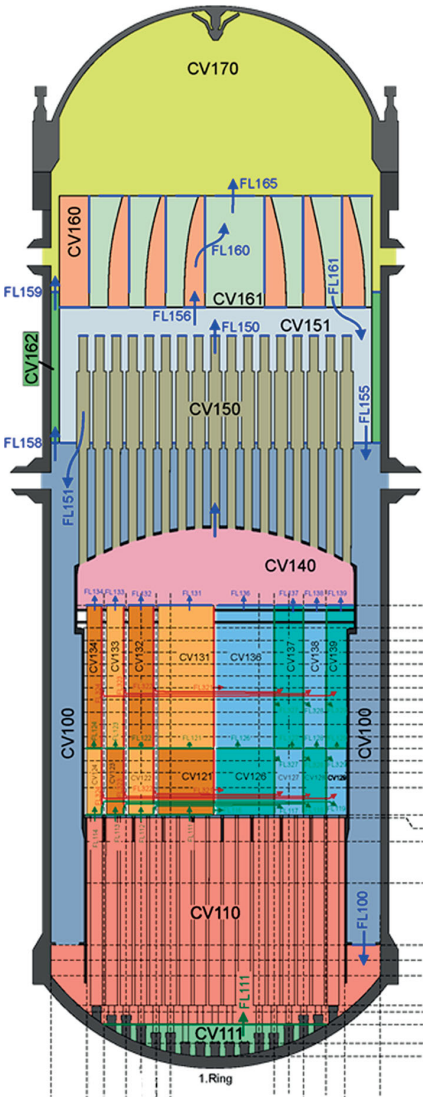
Our approach is highly flexible, applicable to all plant designs and compatible with existing plant manuals, which minimizes the training effort for the operating staff, increases execution safety due to the use of practiced procedures, and leads to an integrated safety concept. According to customer needs, the guidelines can be either fully incorporated into existing manuals, or compiled as a dedicated manual, such that the already existing (and licensed) manuals need not be modified.



Summary and implementation of the Framatome Severe Accident Management Concept



Severe accident management strategy flow chart



MELCOR model for the reactor pressure vessel of a boiling water reactor

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Protection of personnel and environment

Combining the previously listed methods with radiation protection calculations, locations can be identified that must or can be accessed or inhabited by plant personnel and emergency crews during accident progression (e.g. the control rooms).

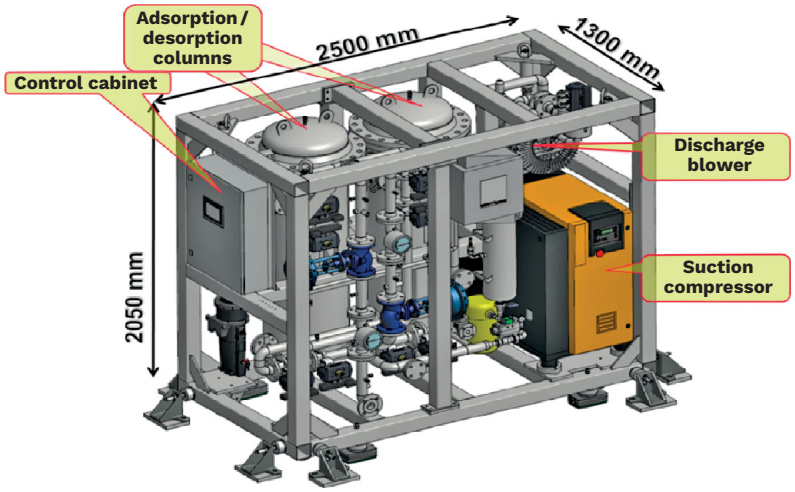
Additional hardware can reduce radiation exposure, for example by protecting control rooms from iodine and noble gas ingress using the CRAFT filtering system.

Radiological and meteorological analyses (e.g. utilizing the proven Central Radiological Computer System) can predict the consequences of radioactive release during a severe accident in terms of activity for relevant radionuclide groups, spatial and temporal distribution, and dose to humans. Such analyses can also provide information for optimizing mitigative measures like e.g. the activation time for filtered containment venting.

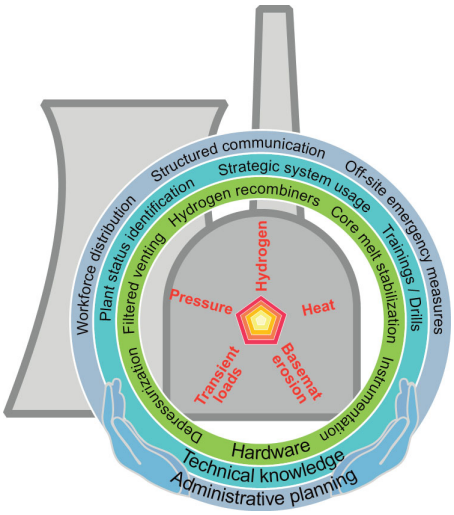
Education and training

To familiarize plant personnel and emergency crews with a possible emergency situation, we offer a variety of training courses (covering e.g. the basics of severe accident phenomenology, the current understanding of the Fukushima Dai'ichi accident, and the efficient use of backfittings and accident management) as well as computer-assisted emergency simulations and drills.

This knowledge and practice enables the personnel to make informed decisions in a severe accident situation, thereby optimizing the mitigation efforts. Understanding the progression and consequences of a severe accident also helps them to assess their personal risk, reducing the individual stress level and thus increasing work reliability.



Control Room Filtering System CRAFT



Framatome Severe Accident Mitigation Concept

Regulatory acceptance

To acquire regulatory acceptance for backfitting measures, their effectiveness and avoidance of negative side effects must be demonstrated to the regulatory institution. This can for instance be accomplished by convincing technical documentation, if necessary supported by customized computer simulations of severe accidents.

We have extensive experience with supporting customers to accelerate and economize such acceptance processes. Our integrated approach using reliable and qualified methods, hardware and simulation software has been successfully applied in many international licensing processes. It is also flexible enough to build upon existing systems or analyses.

Your partner

As the world-leading company in nuclear engineering, Framatome has cutting edge competence and long-time experience in all severe accident topics and concepts as well as in safety hardware.

We have built as original equipment manufacturer (OEM) a large fleet of reactors, but also provide services for non-OEM nuclear power plants, research laboratories and reactors, and other types of nuclear facilities.

Our staff work in a customer-oriented and cost-effective way, are internationally recognized experts in their field, have expertise in safety licensing, and actively participate in international severe accident research.

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