SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

FROM MYRRHA DRAFT-2 TO XT-ADS
FROM A SAFETY PERSPECTIVE

Background

The MYRRHA Draft-2 design was produced in 2005, based on the ITGC (International Technical Guidance Committee) evaluation. It resulted in particular from the safety studies carried out with the Draft-1 design.

Objectives

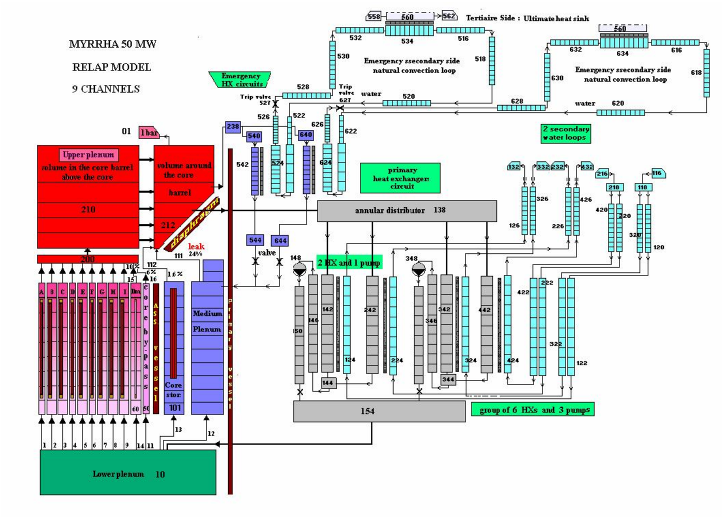
In the IP-EUROTRANS program (EUROpean Research Program for the TRANSmutation of High-Level Nuclear Waste in an Accelerator Driven System), the MYRRHA Draft-2 design was adopted as a basis for the European XT-ADS of 50-100 MWth.

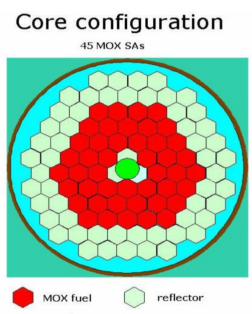
In this view, the results of the MYRRHA Draft-2 safety studies will provide some guidance for the design of the future XT-ADS, especially for the core and the emergency cooling system.

Principal results

The safety studies of the MYRRHA Draft-2 were mainly performed with two thermal-hydraulic computational codes**:** RELAP5 mod 3.2 β, a version adapted by Ansaldo Nucleare for the use of liquid Lead-Bismuth Eutectic and SITHER, a code originally developed by SCK•CEN for simulating the thermal-hydraulic behaviour of core assemblies in LMFBRs, in steady state as well as in transient situations.

We improved the RELAP model of MYRRHA Draft-2 as represented below by increasing, from 3 to 9, the number of thermal-hydraulic channels in the core configuration that comprises 45 MOX fuel assemblies and 54 reflector assemblies; a simple fuel rod (the hottest rod) is also modelled separately





RELAP model of MYRRHA Draft-2

Results of the thermal-hydraulic analysis

The table lists the simulated transients including a brief description and the most relevant results. All starting points of the transients are the nominal conditions with a core power at 50 MW.

Protected transients are accompanied with an automatic cut-off of the proton beam occurring 3 seconds after the accidental initiation. Unprotected transients assume that the accelerator shut down system has failed and that the core power is maintained to its nominal value.

The results for the hottest fuel rod are summarized in the table, the second figure shows the results for a loss of flow with loss of heat sink (LOF&LOH), both in the protected and unprotected cases. In the protected case, the Emergency Cooling System (ECS) is able to remove the residual decay heat. The fuel and cladding temperatures decrease under their nominal values, so the core is kept in safe conditions. At the opposite, a continuous increase of the fuel and cladding temperatures cannot be avoided in the unprotected case, because the ECS is not designed to evacuate the nominal power. The safety criterion for the cladding (700°C) is rapidly exceeded.

Main conclusions

Despite the high power density in the core, MYRRHA can face most of the protected accidents (exception for severe SA blockages, but with limited damages);
For the unprotected accidents, major problems will occur at the cladding in case of
total LOF and/or total LOH (for total LOH, grace time ~10 min). The Emergency system is not able to remove the total power;
Even if very unlikely, the consequences of unprotected transients must be mitigated as much as possible.

List of transients

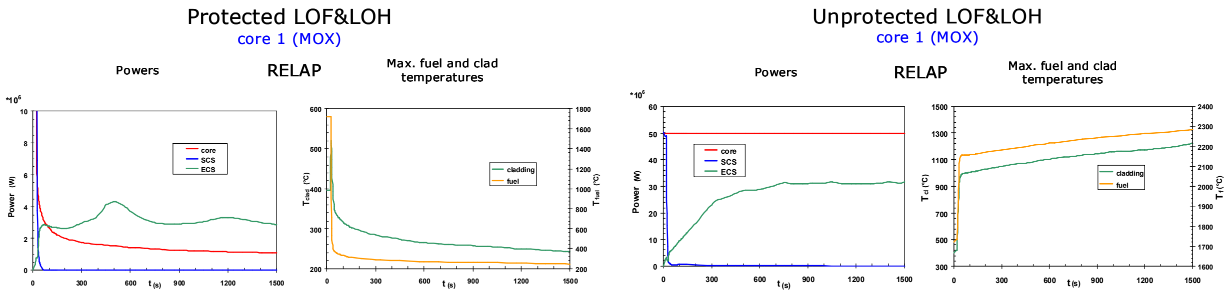
Transient	Description	Code	Protected (1MOX)				Unprotected (1MOX)			
			Fuel	Clad	LBE	Concl.	Fuel	Clad	LBE	Concl.
Protected and Unprotected LOF	loss of forced circulation in primary cooling system	RELAP	OK	OK	OK	☺	OK	T > 1000°C T > 700°C after 7s	OK	☹
Protected and Unprotected LOH	loss of secondary cooling system	RELAP	OK	OK	OK	☺	OK	T > 700°C after 10 min	OK	☹
Protected and Unprotected LOF&LOH	loss of SCS and loss of forced convection in PCS	RELAP	OK	OK	OK	☺	T > 1200°C T > 700°C after 7s	OK		☹
Protected and Unprotected overcooling	SCS inlet temperature drops to 40° in 0 s	RELAP	OK	OK	Partial freezing after 3 min	😐	OK	OK	Freezing after 14 min	😐
Protected and Unprotected TOP	jump in reactivity at HFP	SITHER	Max Dr = 2500 pcm	Id.	OK	😐	Max Dr = 2000 pcm	Id.	OK	😐
Protected and Unprotected SA blockage	flow area reduction in the hottest SA	SITHER	OK	Max FR = 30%	OK	😐	OK	Max F_R = 40%	OK	😐

Main consequences on the XT-ADS design

Owing to the fact that the ECS of the MYRRHA Draft-2 design is unable to cover unprotected accidents, it was decided to remove the emergency heat exchangers and to promote natural convection via the primary heat exchangers.
This can be achieved by:

- reducing the pressure drop through the core (increase of the pitch between the rods in the assemblies);
- increasing the difference between the core level and the primary heat exchangers level;
- improving the Secondary Cooling System (SCS) with an additional emergency secondary cooling circuit connected to the primary heat exchangers; moreover the SCS will work at a lower pressure that in the MYRRHA Draft-2 to enhance the efficiency of the primary heat exchangers.

Finally an ultimate emergency cooling is insured by a Reactor Vessel Air Cooling System (RVACS) able to remove the residual decay heat through the vessel walls.



Results for the protected and unprotected LOF&LOH

Future developments

Safety studies on XT-ADS will be undertaken in the framework of IP-EUROTRANS. In particular a thermal-hydraulic RELAP model will be developed for the XT-ADS design

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Main reference

B. Arien, S. Heusdains, H. Aït Abderrahim, E. Malambu
"Safety analysis of the MYRRHA facility with different core configurations". PHYSOR 2006 -September 10-14, Vancouver.