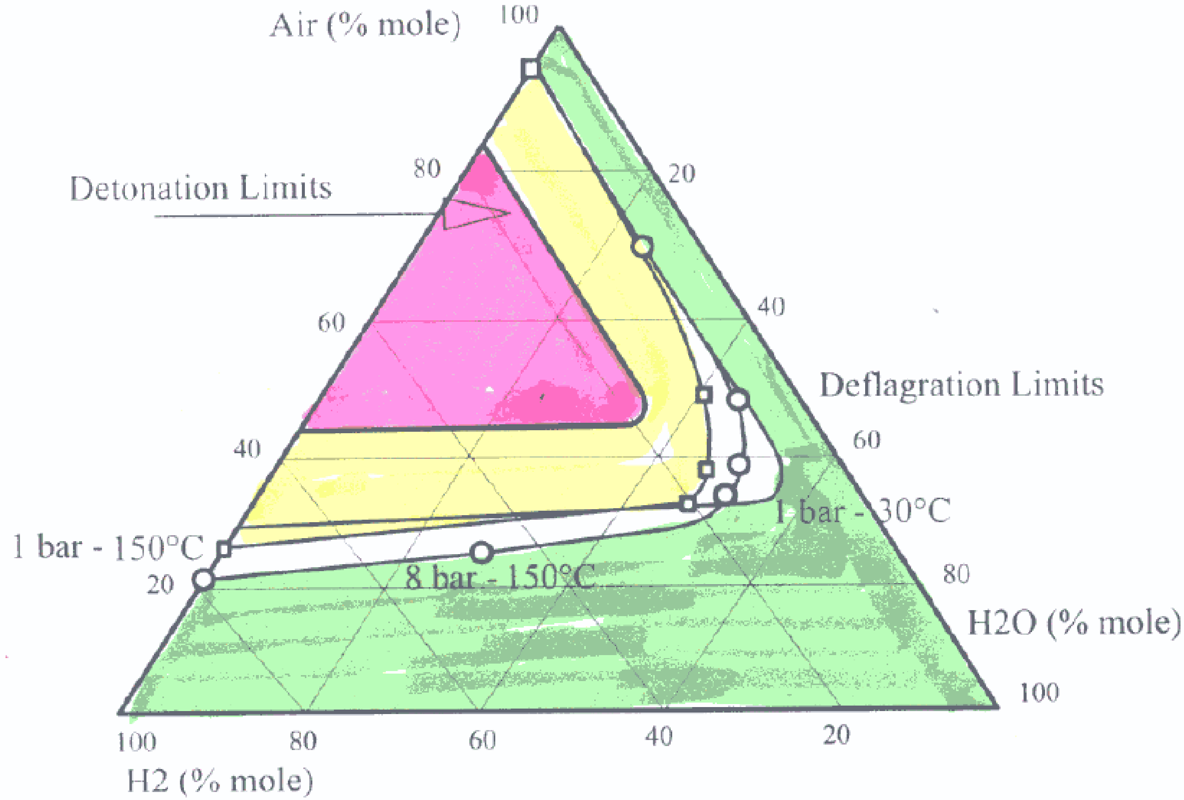
TACIS Project: R1.03/94J Kalinin H2 recombiner - Lot 1 and 2

1. Background: Source of hydrogen hazards

During normal operation the amount of free hydrogen in the containment is negligible. Even in the case of design basis accidents, when the fuel temperature increases and some reactions result in hydrogen releases, the concentration of hydrogen is very small. If the fraction of hydrogen in the air is below 4.1 %, or if the fraction of steam is above 60%, there is no danger of hydrogen ignition of even of flame propagation.



Since the analyses of design basis accidents including LB LOCA show that the generation of hydrogen is small, the NPPs designed and built in the 70- ies and 80-ies were not provided with systems of hydrogen recombination. However, after the severe accident in Three Mile Island, in which the core of the reactor was molten, safety authorities started to study the issue. In the temperatures above 1200 oC the Zircaloy cladding of the fuel rods reacts with water steam producing ZrO_2 and free hydrogen, and releasing in addition some heat, so that the reaction is self sustainable once the fuel cladding temperature exceeds 1200 ^{o}C. Although during DBAs this temperature is not exceeded, it could be exceeded in case of severe accidents.

The consequences of large hydrogen releases from the reactor to the containment can be very serious, including deflagration or even detonation and containment break. Although such an event is utterly improbable, (this is why it is treated as beyond design basis accident) its consequences could be very large.

According to modern safety philosophy in the EU, the safety systems of the NPPs should be able to mitigate not only DBAs but also severe accidents. This is why the reactors in EU are being provided with hydrogen recombination systems, designed to keep the hydrogen concentration below deflagration limits. Similar upgrading has been undertaken in WWER NPPs within TACIS programme. It meets the current requirements of revised Russian regulations. These imply extensive investigations of severe accidents to ensure that release targets consistent with Emergency Planning can be met at the 10^{-7} per annum level.

As the core melt frequency is probably significantly higher than this value, this implies that there is a need to ensure that the containment is effective in severe accident conditions with a high reliability. In turn this implies that the threat to the containment from hydrogen combustion events should be eliminated.

2. Project description

In comparison with the hydrogen recombination system installed in Rovno NPP, which was mainly designed to cope with Design Basis Accident (Large Break LOCA), the system in Kalinin NPP is more developed, and can cope not only with DBA, but also with severe accidents.

Hydrogen production in case of beyond design basis accident is an important threat to containment integrity. The aim of this project is to provide Unit 1 with a set of catalytic recombiners as well as hydrogen monitoring devices. Passive autocatalytic recombiners (PARs) inside the reactor containment can limit hydrogen concentration so as to avoid generalized deflagrations or detonations after a LOCA or after a severe accident. The number and the locations of PAR modules to be installed depend on the H_2 conditions inside the containment after an accident.

In the WWER-1000 NPP design, the hydrogen removal system was not considered during Design Basis Accident and Severe Accidents. The concentration of hydrogen generated during such accidents inside the containment can reach a detonation level which could damage the containment. One major benefit of PAR is that PARs are efficient in recombining hydrogen even in steam inerted atmosphere. Such PARs are also being installed in the reactor containments of Belgian NPPs.

The equipment for the H_2 monitoring and recombining system has been delivered as follows:

Thermal recombiners by Framatome ANP, (Germany);

Monitoring system by the MGP Instruments (France);

Contract amount : 744 k Euro for lot 1, 286 k Euro for Lot 2.

Organisations involved

- Funding and logistic support: EC
- Beneficiary: Rosenergoatom
- End User: Kalinin NPP
- Procurement Agent: ITALTREND
- Supplier: FRAMATOME ANP GmbH lot 1 (recombiners)

MGP Lot 2 (monitoring system):

- Installation and testing: Kalinin NPP
- On Site Assistance: Tractebel (EC Consultant)

Time Schedule

February-March 1996 - . Technical Specifications ready

Summer 1996 – revision of tender scope to fit the budget

December 1996 – first site visits of suppliers.

1997-1998 Delays due to lack of financial resources at the plant for licensing activities.

1998 - GAN expertise financed by EU utility agreed on the number of recombiners but requested more monitoring systems.

June 1998 – revised Work Order with increased budget_obtained from EC

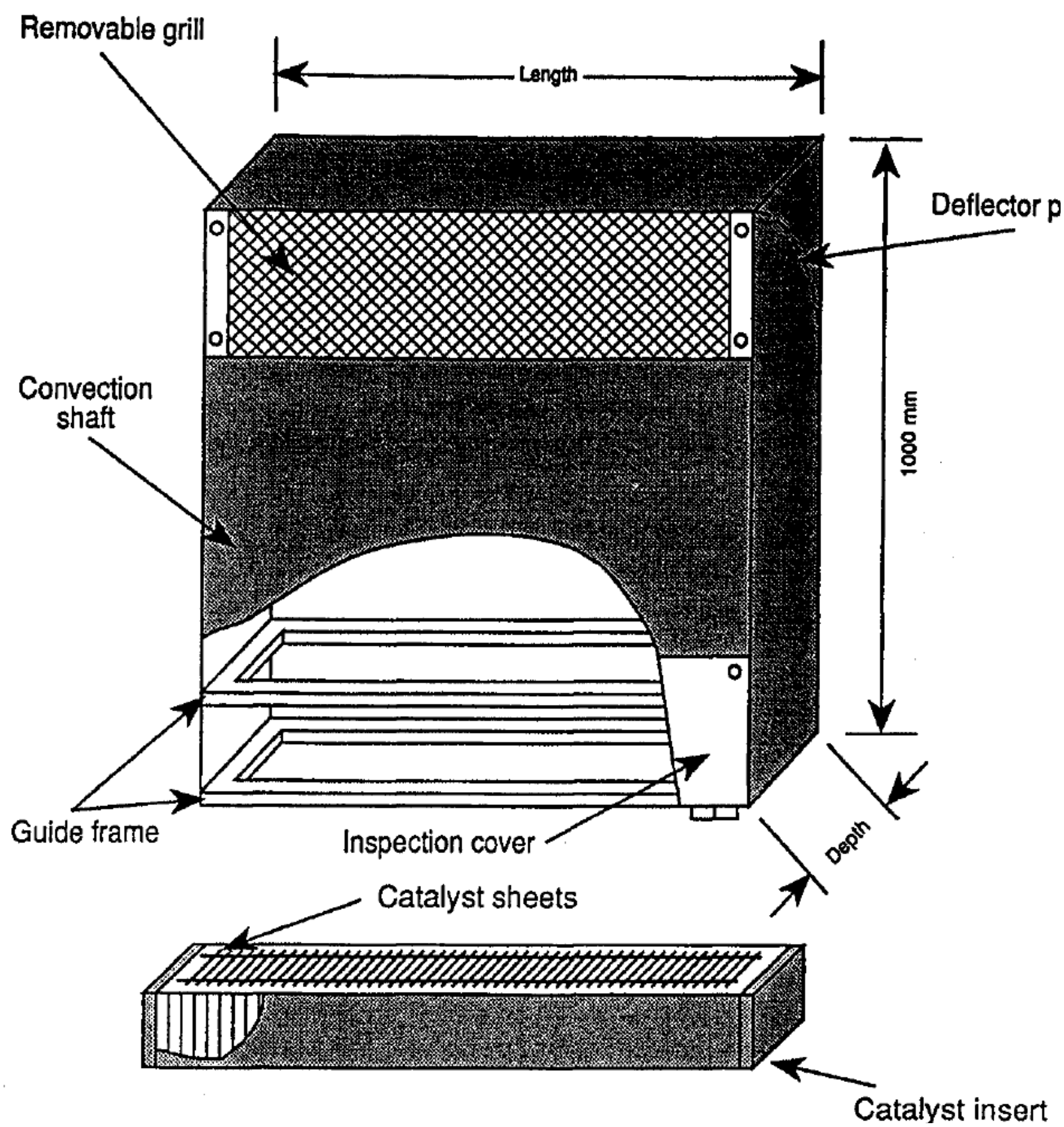
06.11.2000 Signature of the supply contract for Lot 1,

15.12.2000 Signature of the supply contract for Lot 2,

October 2003 - Site acceptance tests of the catalytic plates

13.10.2004 Date of Provisional Acceptance Certificate

FACs were signed for both lots on 13. September 2006



Operation of P.A.R system

The functions of PARs are to prevent fire and explosion loads in the leak tight compartments of the containment under severe accident conditions. Catalytic recombiners use catalysts to oxidise (recombine) hydrogen and are operable outside the limits of flammability. Passive autocatalytic recombiners are units that are situated inside the containment and use the heat of the oxidation reaction to produce flow through the unit by natural convection and thus do not require outside power or operator action. The PARs intended for installation at Kalinin NPP are to enable the recombination of hydrogen and oxygen into steam and to enable the recombination of carbon monoxide and oxygen into carbon dioxide, without ignition, at high capacity and entirely passively.

The function of the hydrogen (H_2) monitoring system is to provide a representative picture of the H_2 concentration evolution at specific locations inside the reactor building, so as:

1. To demonstrate the effectiveness of the H_2 removal system by means of PARs;
2. To assist the operator for implementing the accident management procedures.

Safety improvement

During the project implementation, the "2+2" approach was applied, involving the Western and Russian Regulatory Bodies with their respective Technical Support Organisations. The cooperation of EU/RF experts has yielded good results for improving the work of the RF regulatory organisations. What concerns the safety improvement in Kalinin NPP, the EU/RF experts reached the following conclusions in their analysis:

- The installation of PARs reduces the threat to the containment from hydrogen combustion, without adversely affecting other safety functions, provided that the PARs are mounted adequately.
- It has not been demonstrated that it is practical to avoid combustible mixtures forming in all circumstances. This is more likely to be the case if use of the sprays is restricted, to maintain steam inerting during the main period of hydrogen production. Any restrictions on the use of the sprays need to be evaluated carefully because of their role in design basis accidents.
- The benefits of the gas monitoring system are less obvious, but it is clearly desirable to have some knowledge of hydrogen concentration so that operation of the sprays does not lead to potentially dangerous mixtures of gases.
- The main safety benefit resulting from the installation of passive autocatalytic recombiners (PARs) and improved hydrogen monitoring instrumentation is the capability to handle severe accident loads without threat to the containment through overpressurisation and to equipment through fire and explosion hazard. The TSOs' experts estimated that the above mentioned safety benefits can be achieved.