IAEA REGIONAL WORKSHOP ON DEVELOPMENT AND VALIDATION OF EOP/AMG FOR EFFECTIVE PREVENTION/MITIGATION OF SEVERE CORE DAMAGE

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WWER-440/V-230 Confinement Modernization to Upgrade the Critical Safety Function "Containment Integrity" in Case of SA

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- DESIGN LIMITATIONS OF THE LOCALIZATION SYSTEM
  - SMALL FREE VOLUME
  - UNTIGHTNESS OF THE HERMETIC VOLUMES

- CONSEQUENCE FROM THESE DESIGN LIMITATIONS
  - DBA – PRIMARY BREAK Dn100 WITH VENTURI FLOW RESTRICTION ORIFICE
  - NOT SUFFICIENT PROTECTION IN CASE OF SEVERE ACCIDENTS

- A FEW CONFINEMENT RECONSTRUCTION CONCEPTS FOR OF THIS TYPE OF UNITS WORLDWIDE

- PURPOSE OF THE CONFINEMENT RECONSTRUCTION – TO IMPROVE SIGNIFICANTLY THE ORIGINAL DESIGN, ENSURING (1) LOCALIZATION FOR ALL POSSIBLE PRIMARY BREAKS and (2) LIMITATION OF THE RADIOLOGICAL CONSEQUENCES FOR THE PERSONNEL, THE POPULATION AND THE ENVIRONMENT BELOW THE REGULATORY REQUIREMENTS

- FOR ACHIEVEMENT OF THESE PURPOSES THE CONCEPT FOR MODERNIZATION MUST ENSURE:

1. Protection of the civil structures of the confinement at any size of primary LOCA, including double-sided main coolant pipelines break (2xDn500) to prevent early containment overpressure failure with a consequent uncontrolled release of radioactivity to the environment.

2. Retention of the radioactive products during the accident progression to limit the radiological consequences below the requirements of BNSA as follwos:

    - at DBA – the maximal individual dose limits for the population at the exclusion zone (radius 2.7 km) and beyond it are - effective dose of 50 mSv for the first year after the accident and 150 mGy for the thyroid.

    - at severe accident – the maximal individual dose limits for the population at the border of of the Emergency Plan Area (radius 30 km) and beyond it are - effective dose of 5 mSv for the first year after the accident and 50 mGy for the thyroid.

3. Provision of a heat sink for the decay heat from the FPs inside the confinement and keeping the pressure and temperature below the Plant Limiting Conditions

4. The functional capabilities of the localization system must be preserved in case of loss of external power supply and at a maximal design earthquake.

- PROCESSES INSIDE THE LOCALIZATION SYSTEM IN CASE OF LOCA

  1. Release of steam-air mixture through the flap valves
  2. Consequent steam condensation with sub-atmospheric pressure inside the confinement

  > ***The level of sub-atmospheric pressure depends on the break size and on the operation of the spray system.***
  >
  > ***The duration of the sub-atmospheric pressure depends on that, how leaky is the confinement system.***

- MAIN PROCESSES IN CASE OF SEVERE ACCIDENTS THAT CAUSE PRESSURE INCREASE INSIDE THE LOCALIZATION SYSTEM AND TECHNICAL PROPOSALS FOR RECONSTRUCTION

  1. Generation of non-condensable gases (H_2, CO, CO_2, etc.)
  2. Decay heat and steam generation

For minimization of the radiological consequences it is necessary to suppress all processes that cause pressure increase inside the confinement.

The table below summarizes the main processes that lead to pressure increase inside the localization system and the proposed technical solution to eliminate the pressure increase.

PROCESS FOR PRESSURE INCREASE INSIDE THE CONFINEMENT	PROPOSED TECHNICAL SOLUTION
1. Initial pressure spike due to the blowdown	Pressure Suppression System
2. Decay heat inside the confinement	Spray System; Filtered Venting System
3. Steam generation	Spray System; Filtered Venting System
4. Generation of non-condensable gases	Filtered Venting System
5. Deflagration of combustible gases	Passive Autocatalytic Recombiners (PARs); Filtered Venting System

The proposed technical solutions may compensate the two design limitations of the localization system of Units 1-4 at NPP "Kozloduy".

On the basis of the existing design limitations as well as considering the accumulated international experience, there were defined the following criteria to which the Concept for Confinement Reconstruction should comply:

1. To be considered the specific features and design limitations of the confinement

2. To be considered the specific conditions of the plant site, in particular the General Plant Layout.

3. For the reconstruction to be used systems that are:

   - at a finished stage of development including full scale experiments

   - installed or under implementation at other NPPs

   - the systems must have a clear licensing status

   - optimal from a point of view of investment, amount of civil and erection work and outage of the plant for reconstruction

Considering these criteria and based on the analyses performed by the authors, below is presented an effective technical concept for reconstruction of the confinements of the V-230 type of nuclear units, that comprises the following systems:

SJC – Swirl Jet Condenser for pressure suppression inside the localization system during the initial blowdown and protection of the confinement integrity

PAR – Passive Autocatalytic Recombiners and Hydrogen Monitoring for hydrogen reduction and preventing multiple deflagrations inside the confinement, thus minimizing the radioactive release to the environment

FVS – active Filtered Venting System for controlled release on non-condensable gases during the late phases of a severe accident

SSC – Spray System Controlled/operated by an *ad hock* developed AM procedure that uses the readings from the Hydrogen Monitoring System and used for:

- long term heat removal from the localization system
- inertization of the confinement atmosphere

Most appropriate pressure suppression system is the proposed by "VNIIAES" SJC – it suppresses the pressure at maximal primary LOCA 2xDn500 below the confinement design pressure.

Main features of the concept of this pressure suppression system are:

- possibility to be installed inside the localization system
- sufficient efficiency to protect the civil structures from failure at maximal primary LOCA
- high condensation capacity at small water inventory and minimal water level swelling
- separation of the non-condensable phase in a field of a centrifugal acceleration
- use of jet blade aparatus for increased condensation and scrubbing of the primary coolant passing through the condensation unit

ADVANTAGES OF SJC :

1. The proposed construction is simple and based on a passive principle of operation.
2. SJC resolves the problem with the re-closing of the localization system after the initial opening.
3. SJC eliminates the mechanical construction of the flap valves that may stuck open at LOCA

Most appropriate technical solution for maintaining of a slight continuous underpressure in the confinement in case of a severe accident is the use of an active FVS of KWU - scrubber type with molecular sieve because of its:

(1) Small flow resistance with high retention factors both for aerosols and iodine due to the low submersion of the nozzles as compared to other existing FVSs

(2) High filter loads needed for the proposed mode of operation for these units

(3) Licensing status

(4) Custom tailored design according the requirements – size, configuration (vertical, horizontal), etc.

Most appropriate technical solution for hydrogen recombination is the installation of the PARs and Hydrogen Monitoring System of KWU because:

(1) The PARs have appropriate dimensions and form and are convenient for installation inside the SG box

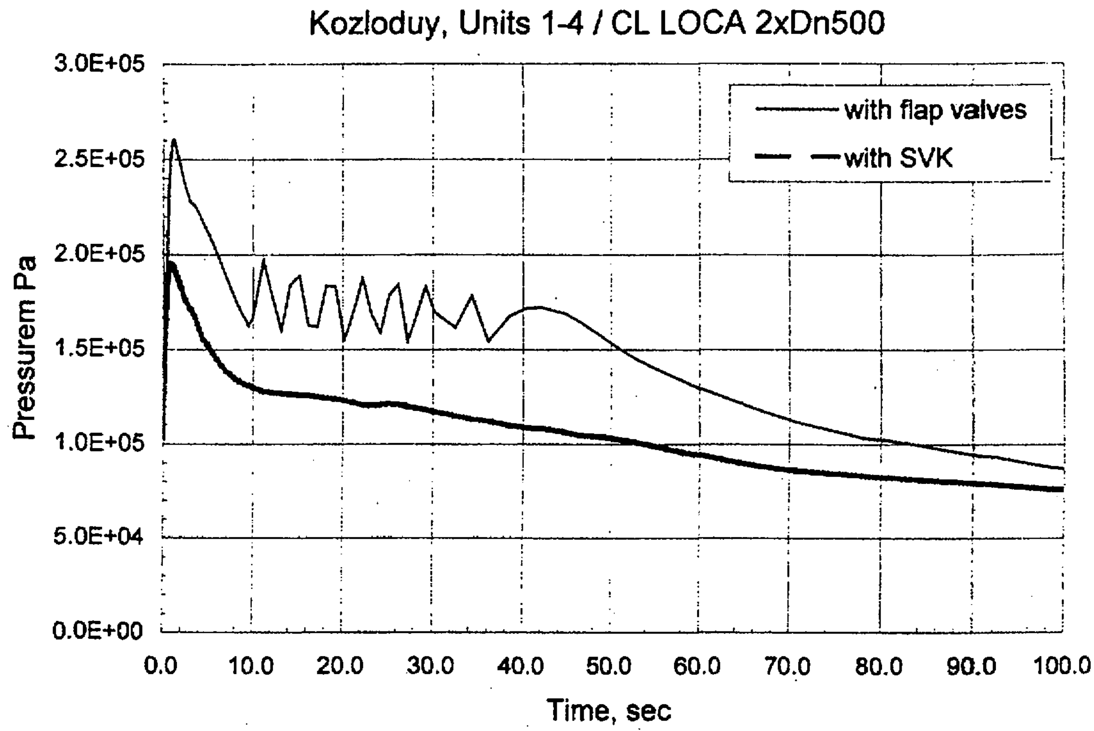
(2) Other advantages of PARs

- special design to prevent clogging of the sumps
- high recombination efficiency
- possibility to operate at high steam concentration and at low hydrogen concentration, etc.

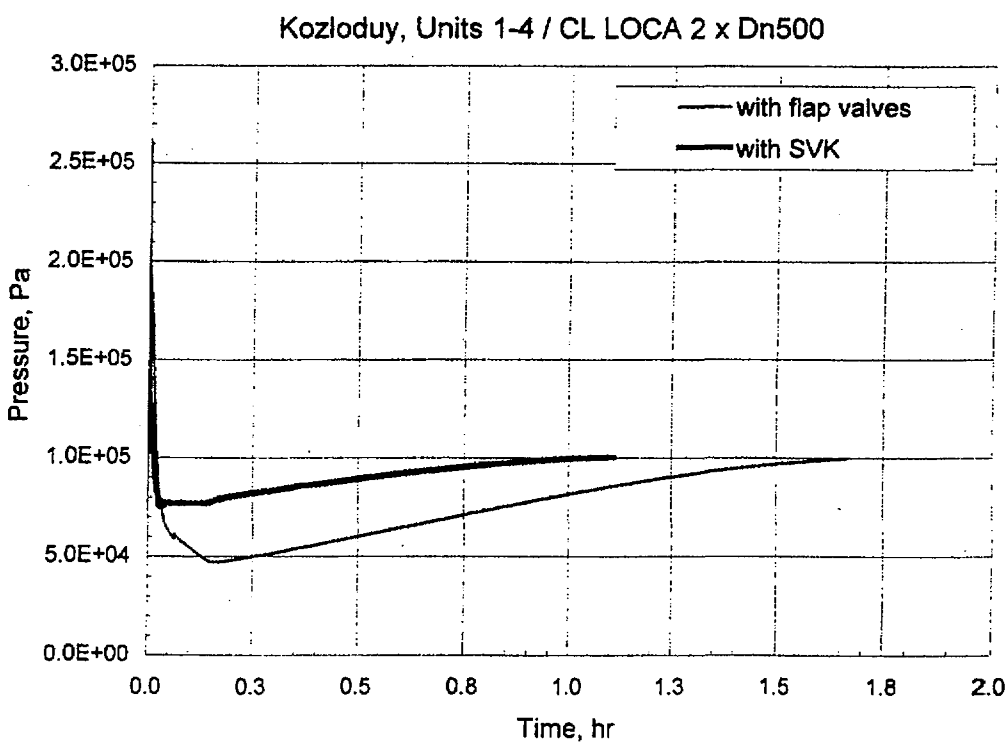
(3) Computerized hydrogen monitoring that provides on-line information for the status of the confinement atmosphere related to possible deflagrations and initiation of SS operation by the safety engineer of the plant

EFFECT AT REALIZATION OF THE PROPOSED TECHNICAL SOLUTIONS

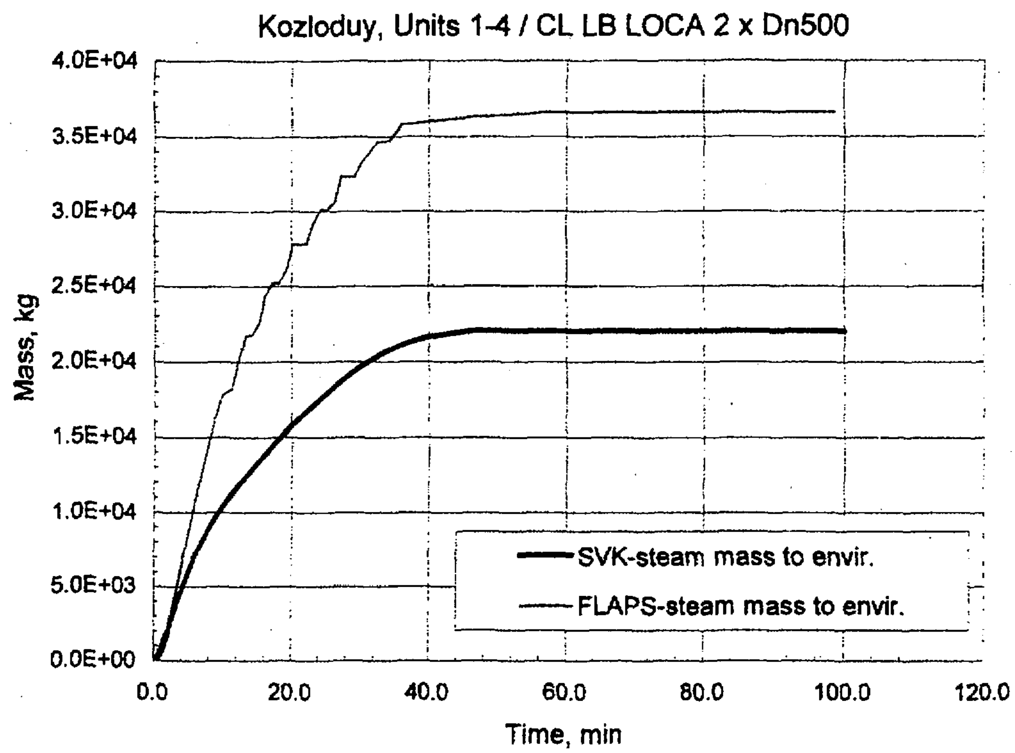
- Retention of the confinement integrity at all possible LOCAs
- Insures radiological consequences both during DBA and in case of SA below the required limits as defined by BNSA.



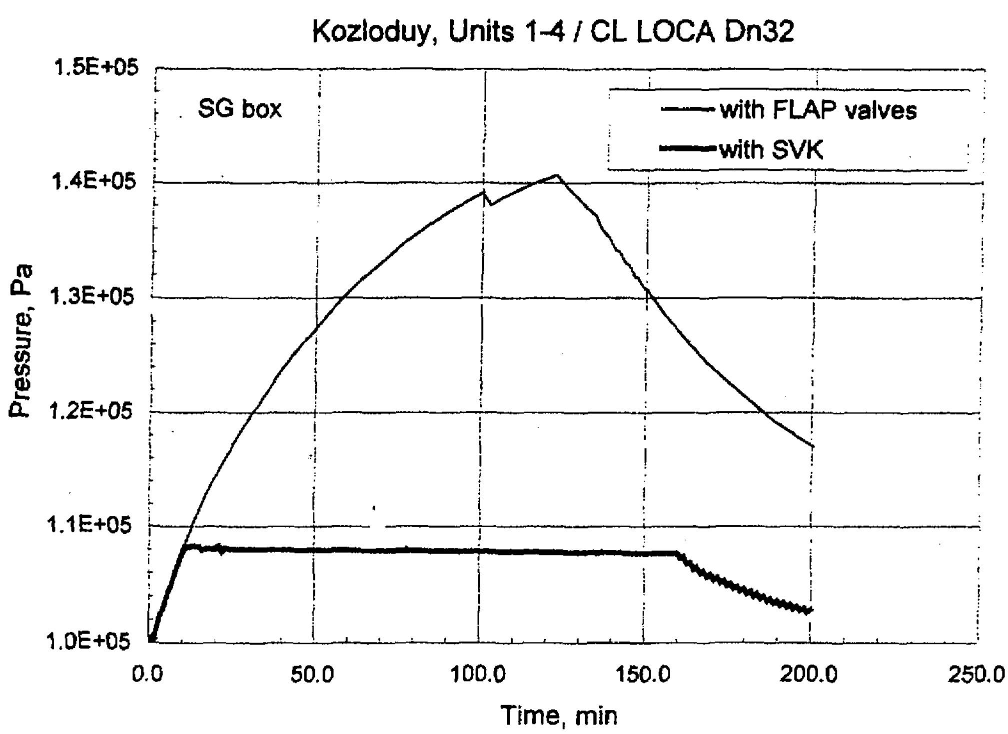
Initial pressure spike in the SG box at LB LOCA (2xDy500)



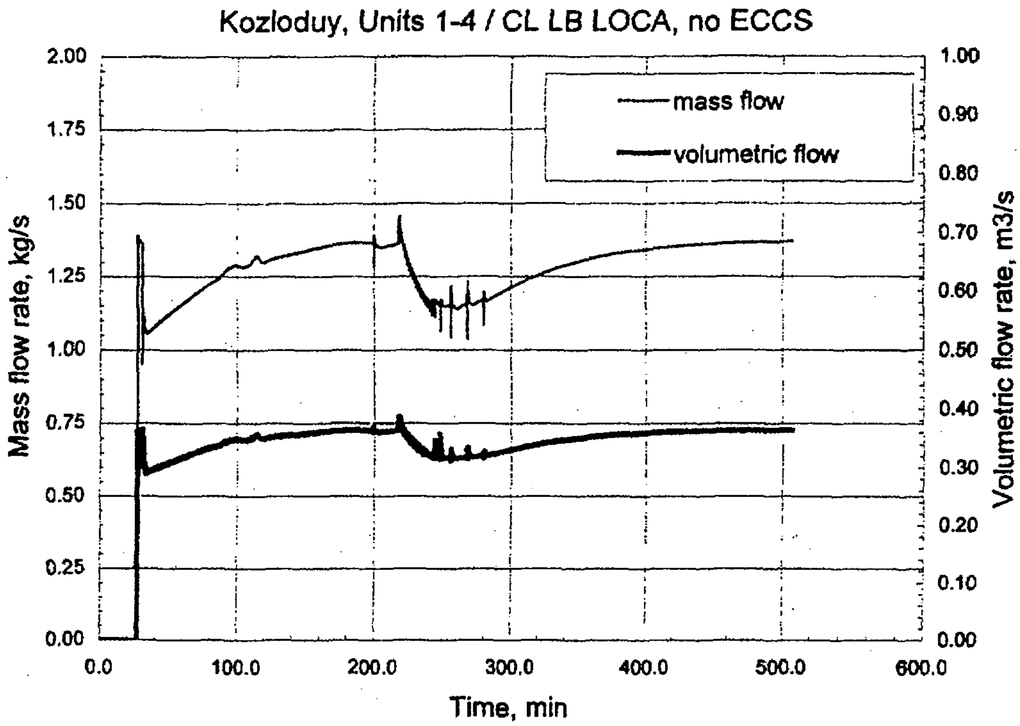
Long-term pressure behavior inside the SG box at LB LOCA (2xDy500)



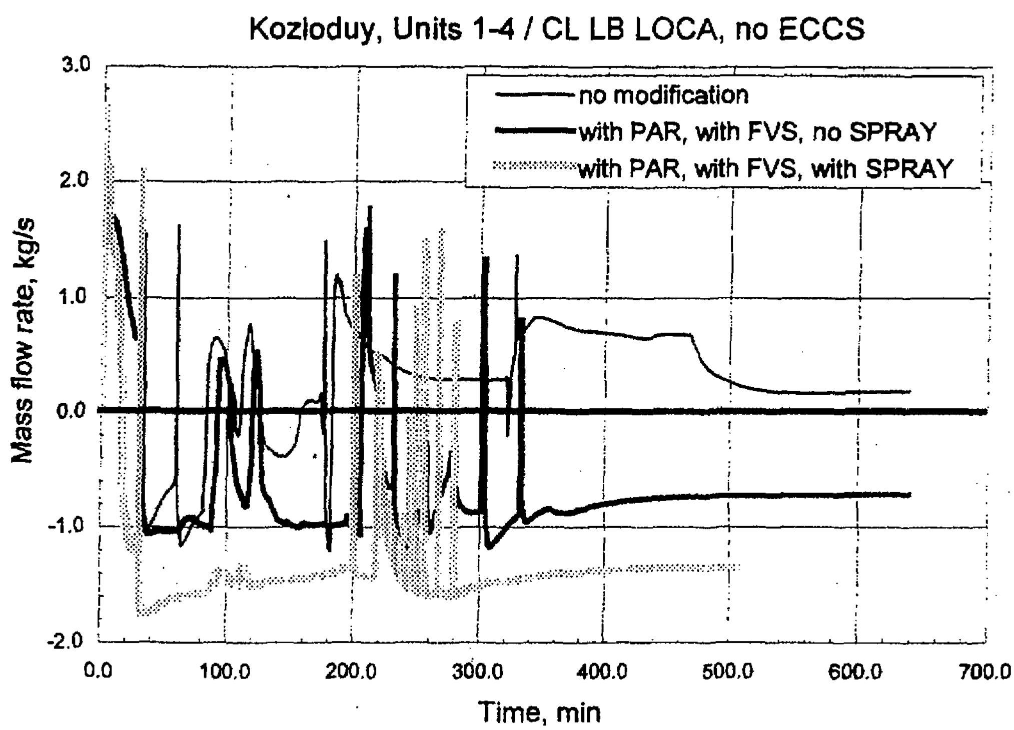
Mass of coolant released to the environment



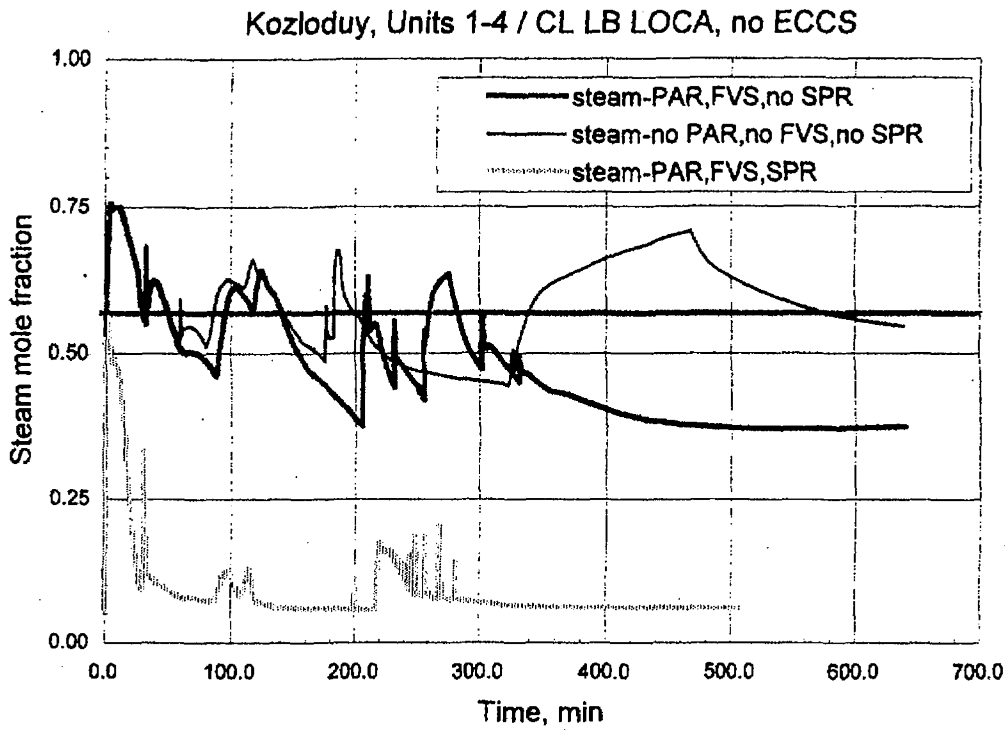
Pressure in the SG box at LOCA Dn32



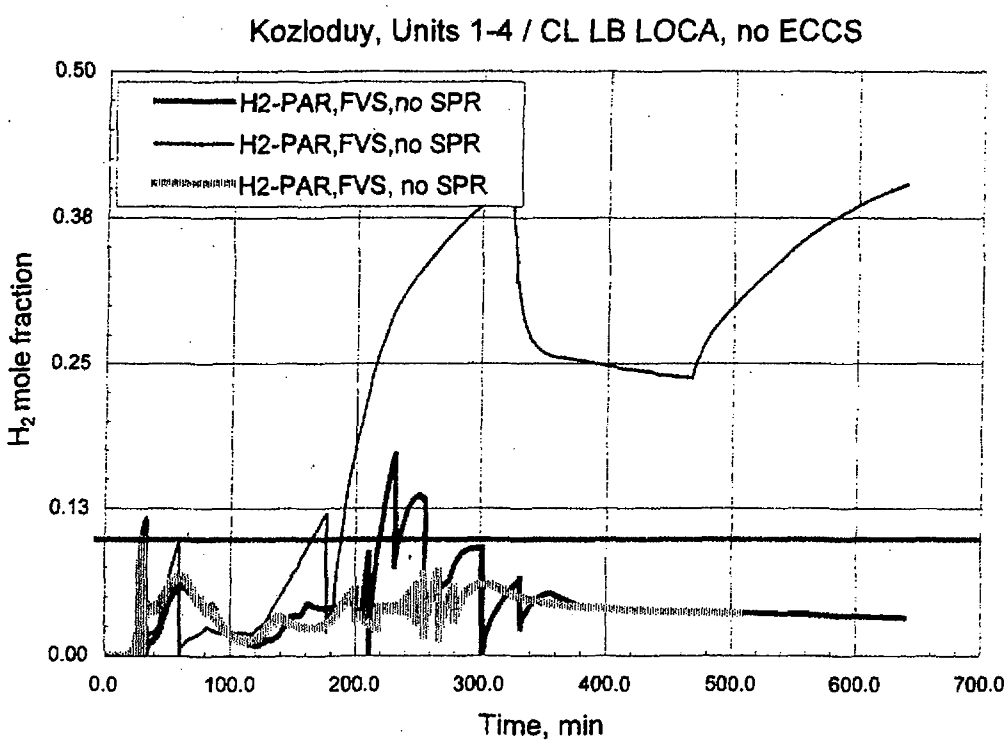
Mass and volumetric flows through the FVS



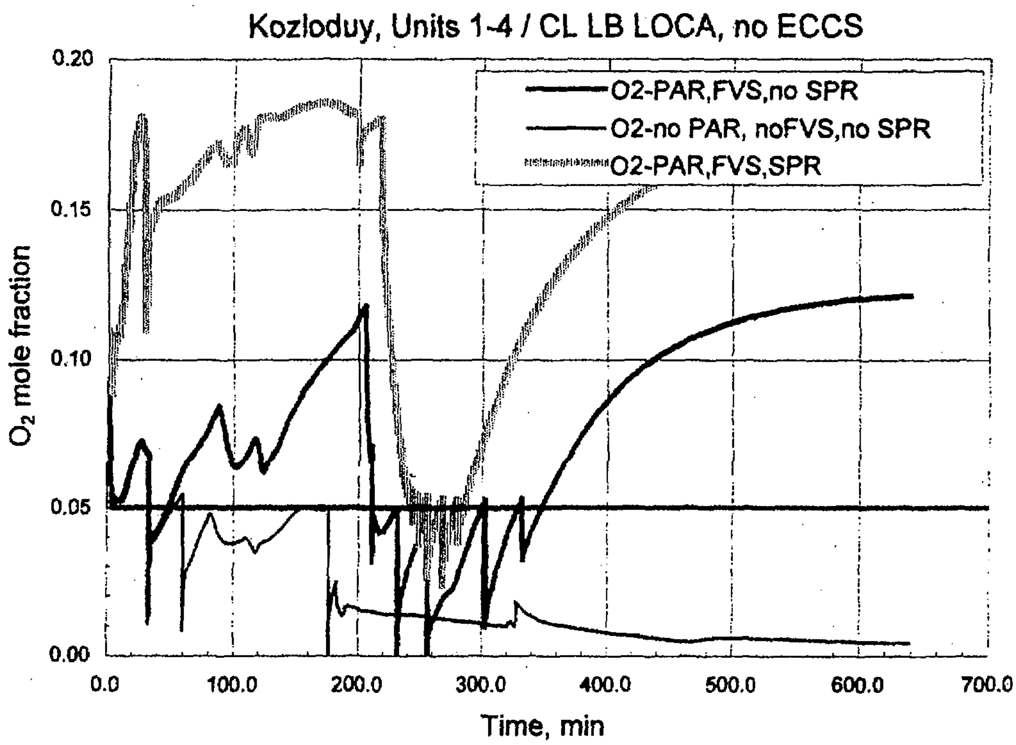
Mass flow rate through the confinement untightness in case of a SA



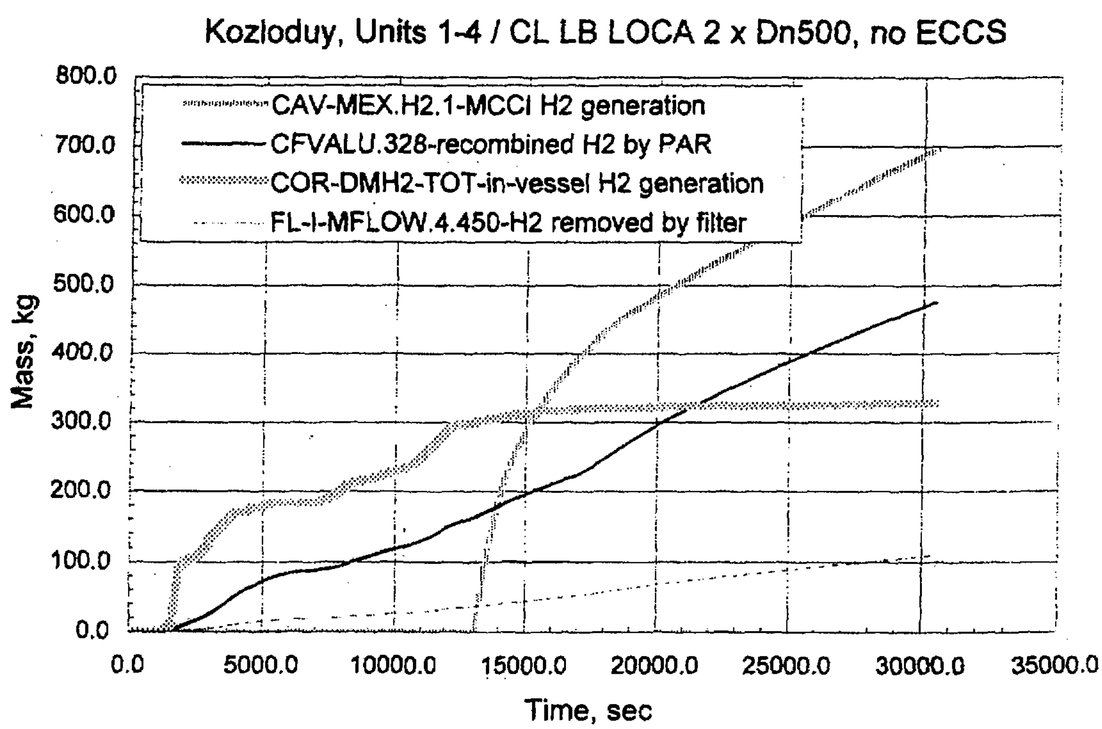
Steam concentration inside the confinement



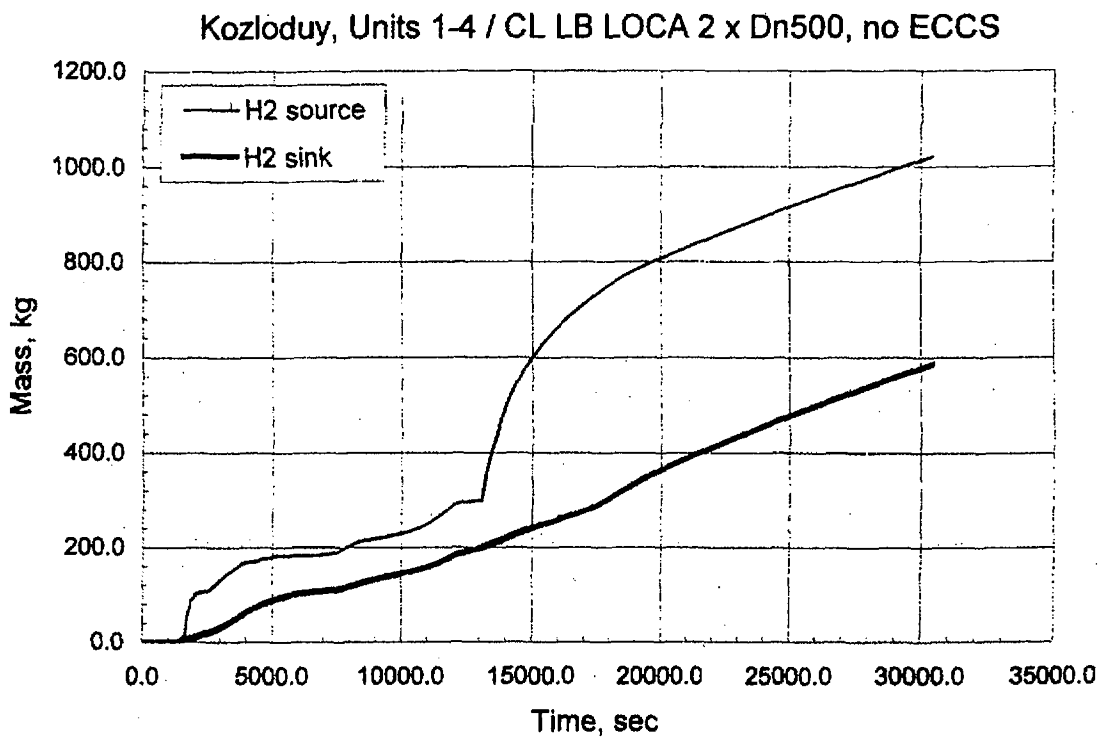
Hydrogen concentration inside the confinement



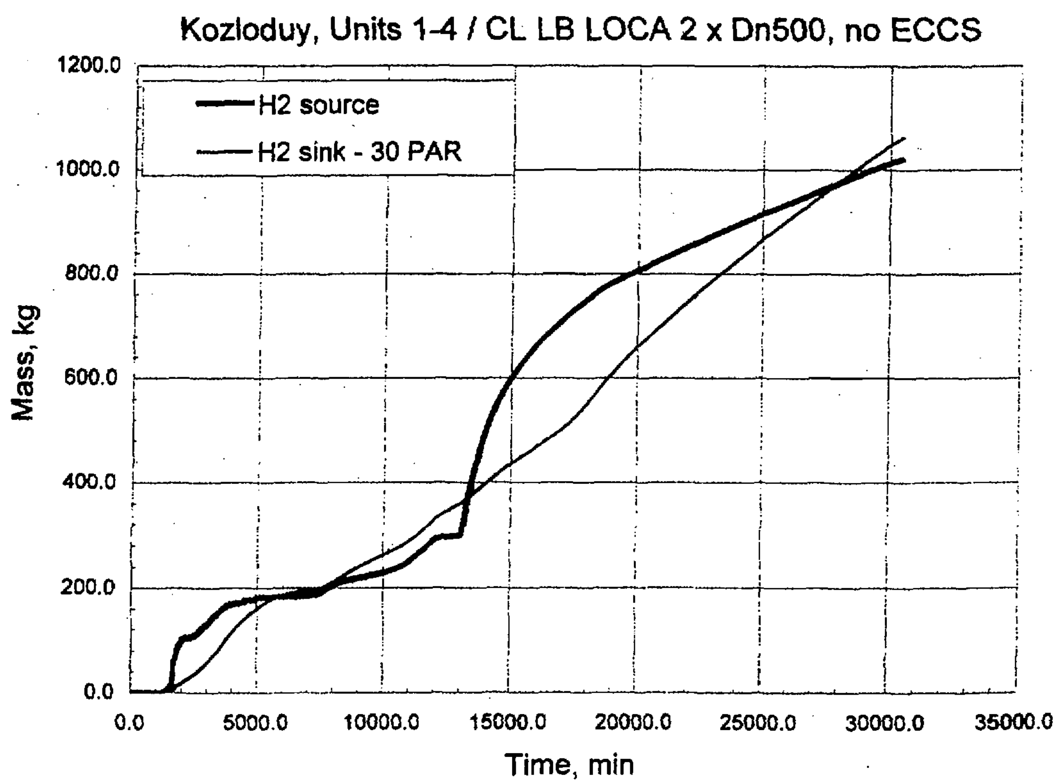
Oxygen concentration inside the confinement



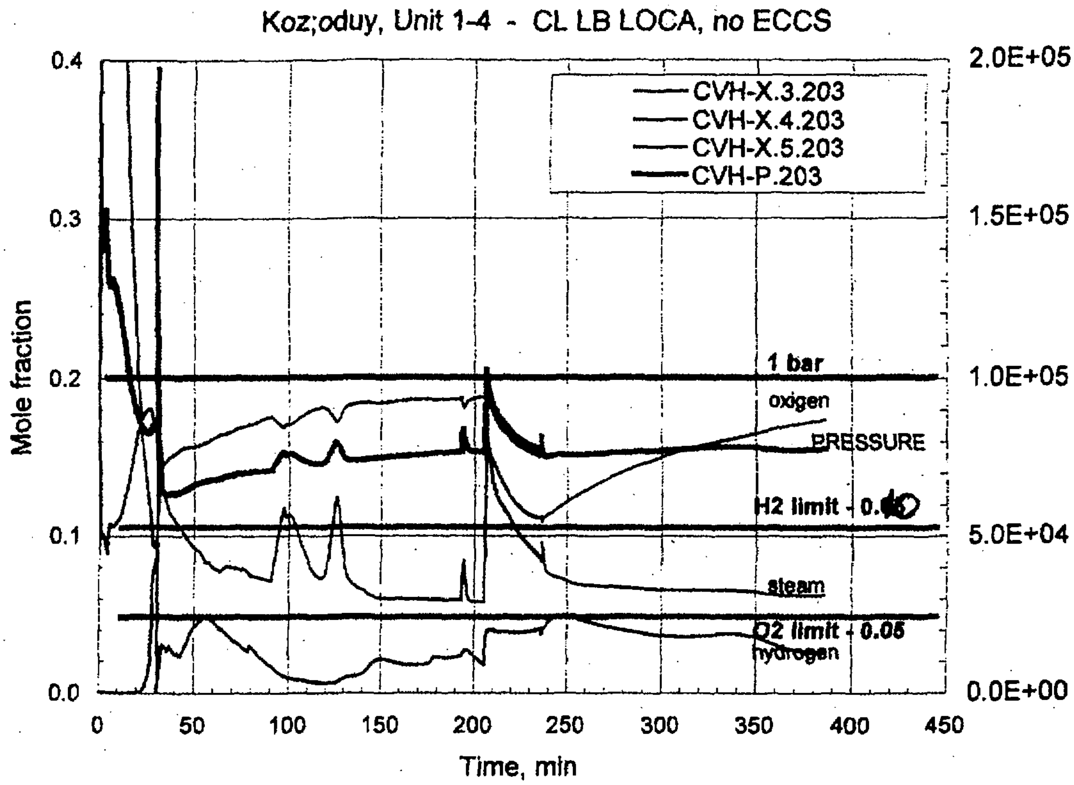
Hydrogen sources and sinks inside the confinement



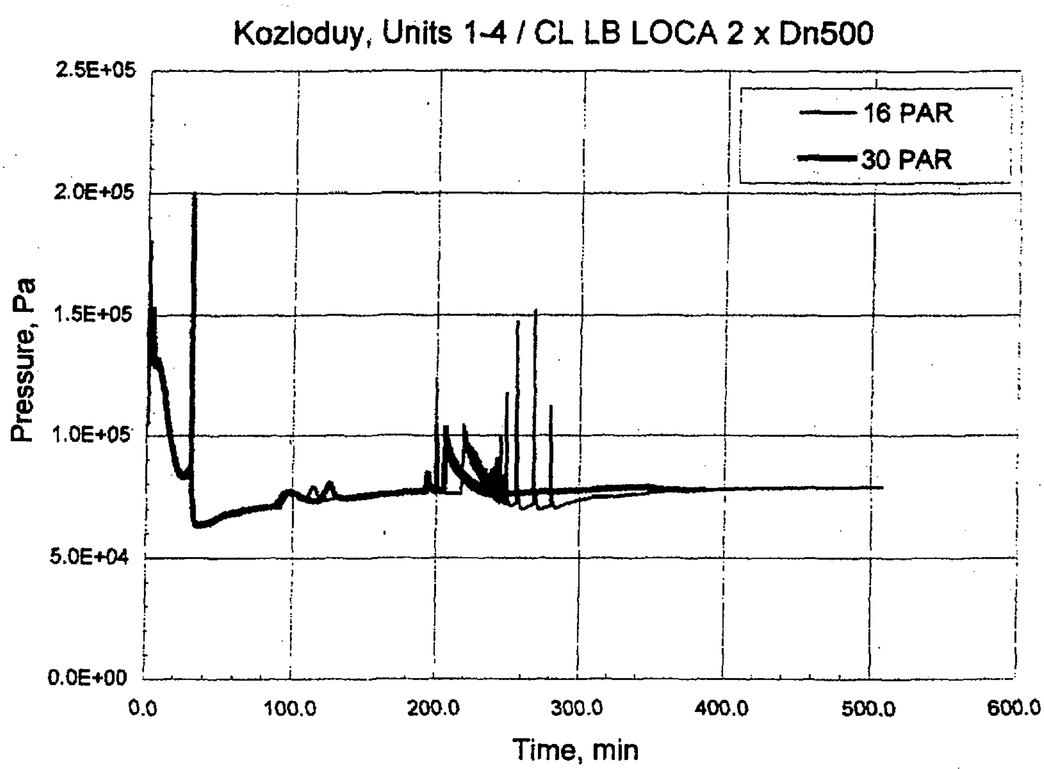
Balance of hydrogen inside the confinement – 16 PARs type FR90/1-1500



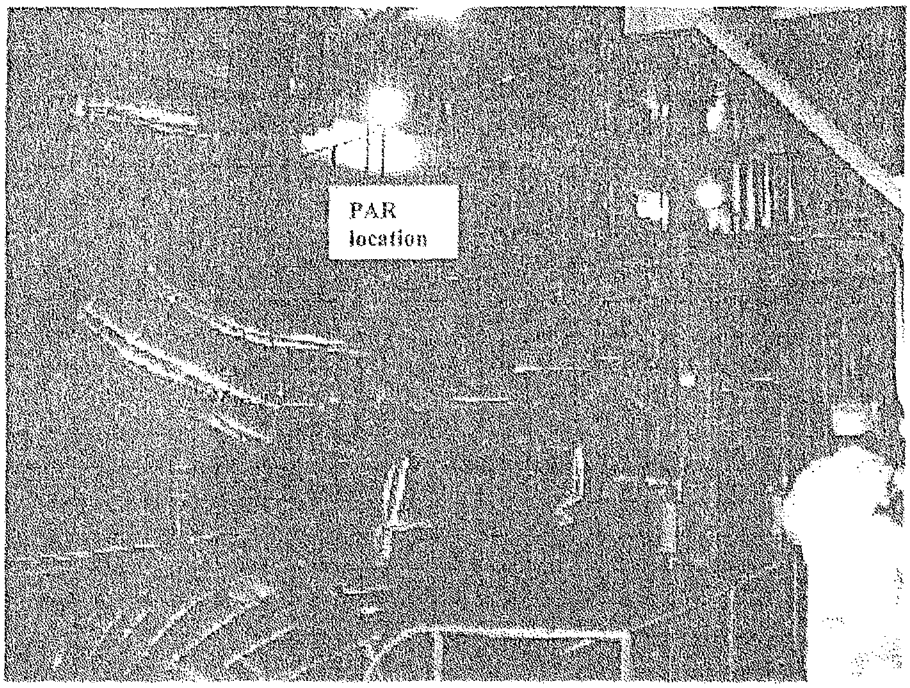
Balance of hydrogen inside the confinement – 30 PARs type FR90/1-1500



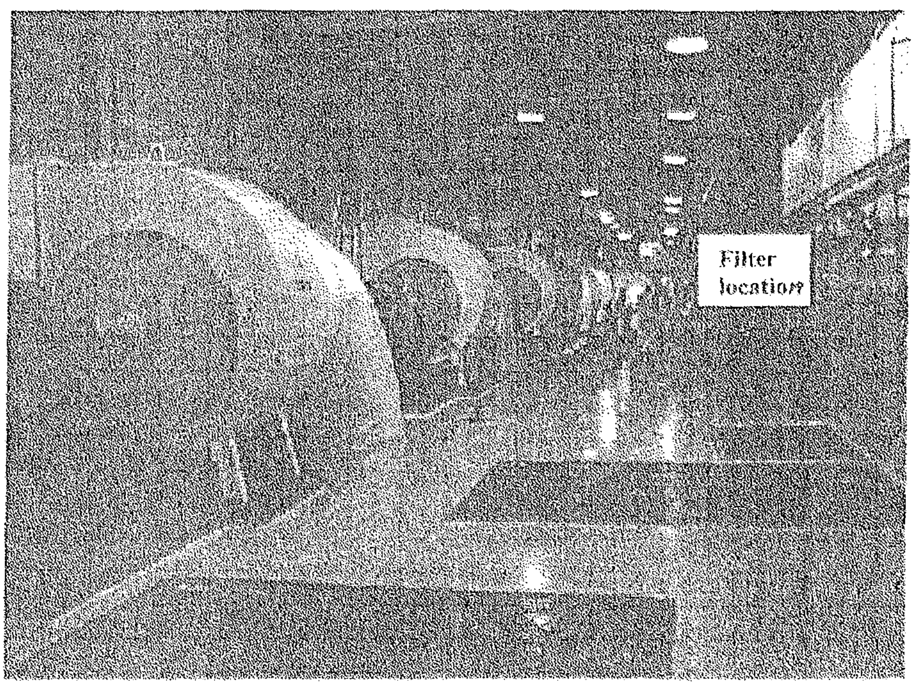
Concentration of gases and pressure inside SG box
with 30 PARs type FR90/1-1500



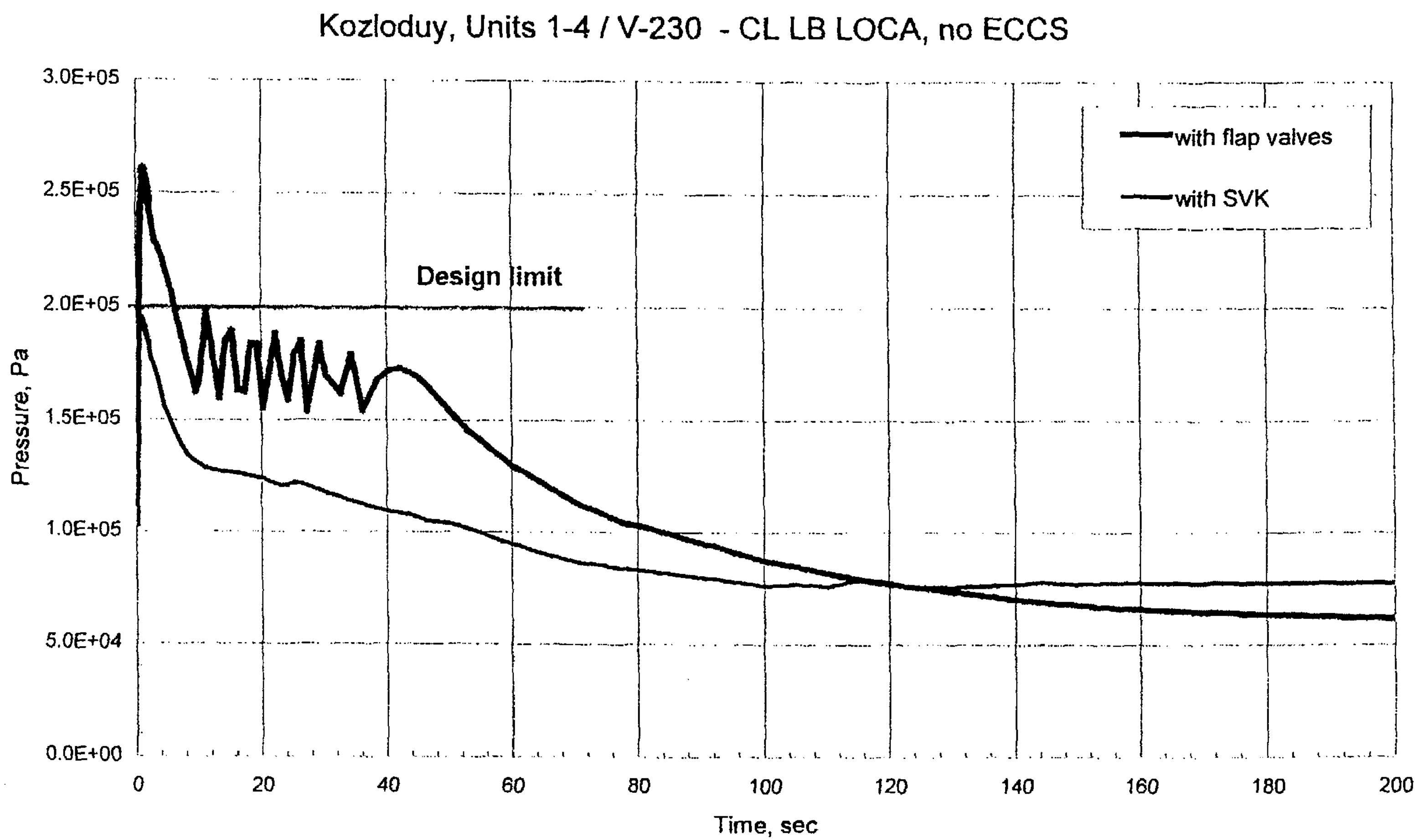
Pressure inside the SG box with 16 and 30 PARs type FR90/1-1500 .



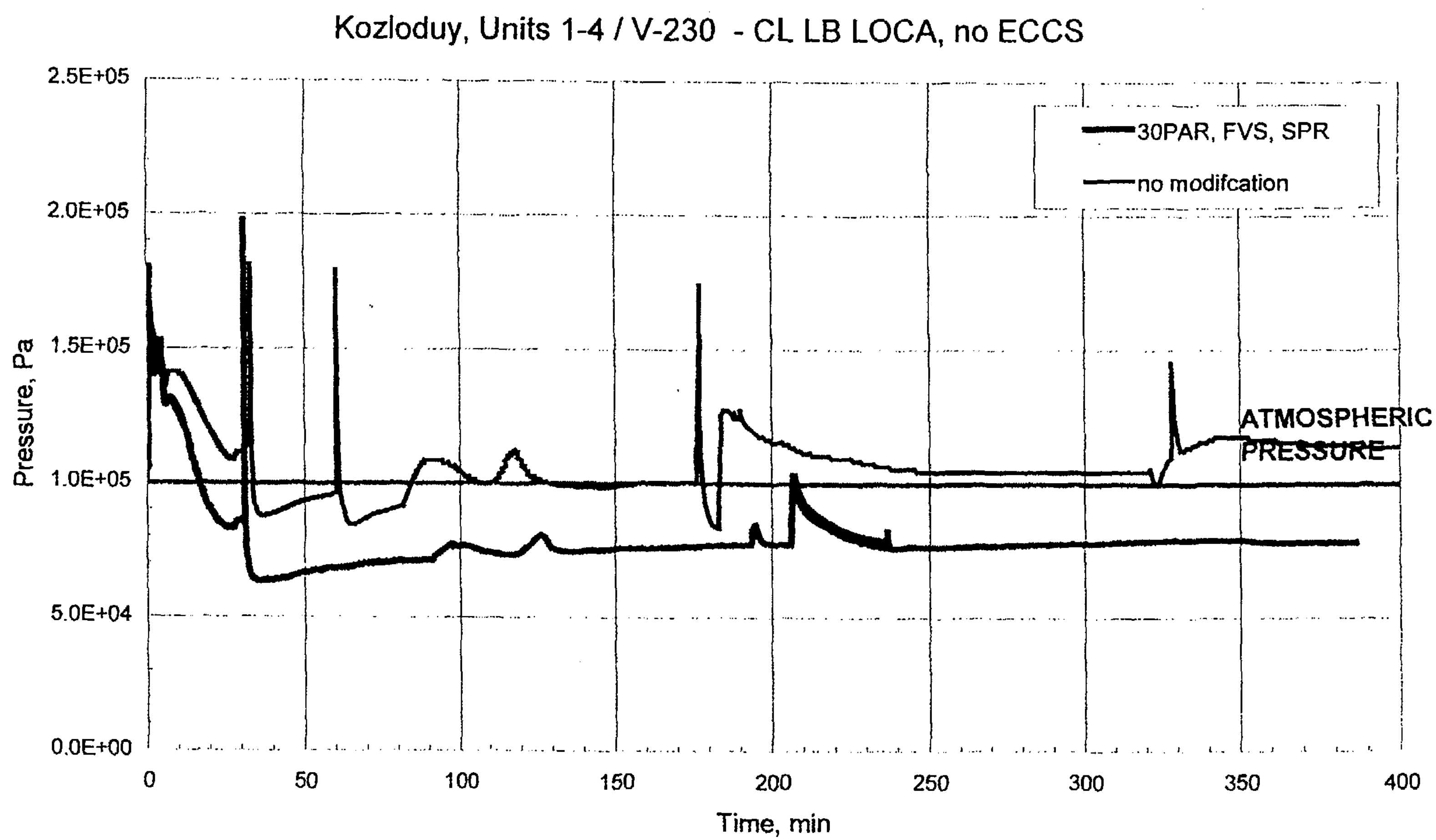
Possible location for installation of PARs - ventilation centre (A002)



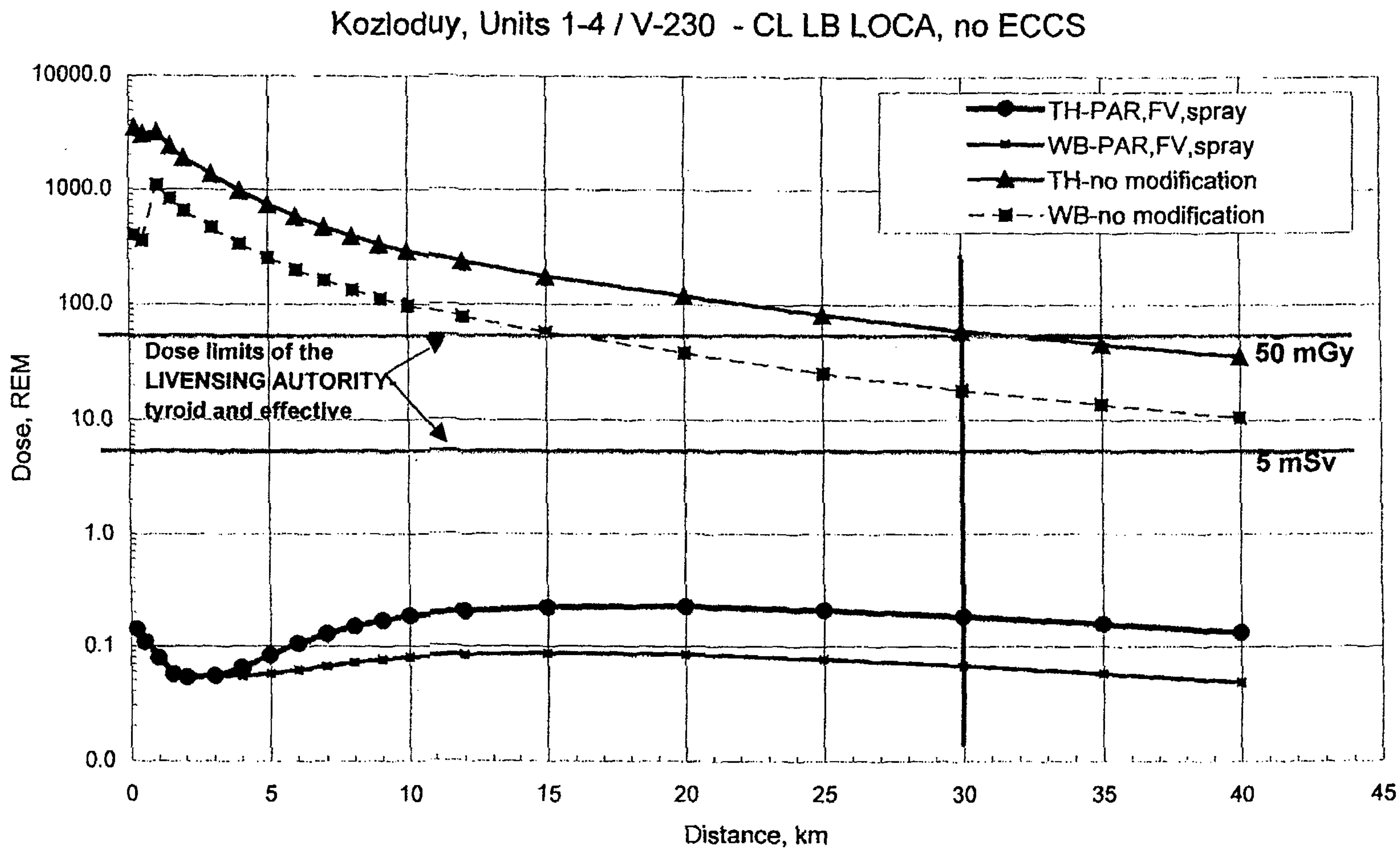
Possible location for installation of FVS (B-304)



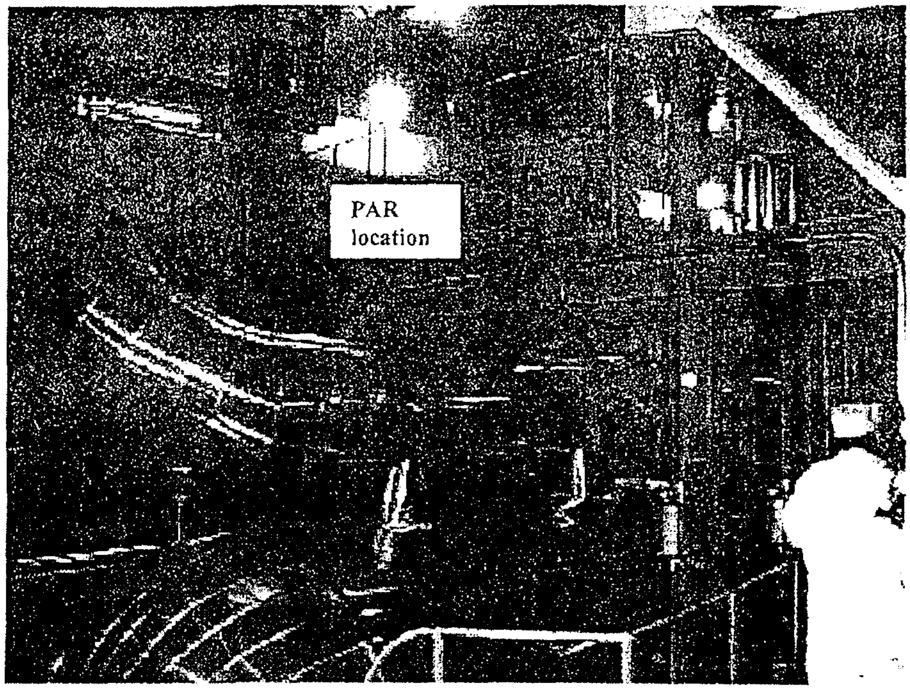
EFFECT OF THE <u>JET CONDENSER</u> ON THE PEAK PRESSURE AT LB CL BREAK (2f)



EFFECT OF THE PARs ON THE PRESSURE IN THE LOCALIZATION SYSTEM AT SEVERE ACCIDENT



OVERALL EFFECT OF THE BACKFITTING CONCEP[T ON THE RADIOLOGICAL CONSEQUENCES AT SEVERE ACCIDENT WITH EX-VESSEL RELEASE



Possible location for installation of PARs - ventilation centre (A002)

Possible location for installation of FVS (B-304)