HTR APPLICATIONS
OF THE AUSTRIAN PCPV

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1. INTRODUCTION

~~1.1 Scope~~

The main scope of the development and experimental verification of a new type of Prestressed Concrete Pressure Vessel (PCPV) was a significant gain in operational safety and, as a consequence, availability. An analysis of possible disturbances and down-times of conventional PCPV's shows two ways to improve the operational safety:

a) to make the working conditions of the liner, the most essential component , safer, thus decreasing the probability of a leak;

b) to improve the possibilities for inspection, leak detection and repair, thus reducing shut-down times.

The Austrian PCPV offers a solution to these requirements.

1.2 Main Features of the Austrian PCPV [1, 2]

The main characteristics of the new vessel concept, developped and tested in Austria, are:

. Elastic hot liner, accessible for inspection and repair;

.. Adjustable wall temperature, matching the respective operating conditions of HTR's optimally;

... Leak limitation and detection, controlled leak evacuation,

By optimization of the working conditions of the liner, especially by balanced liner and concrete temperatures, the probability of leaks is reduced drastically according to scope a);

Scope b) is achieved by the accessability of the hot liner and by the leak limitation and inspection system, installed in the thermal barrier situated between the hot liner and the structural concrete,

1.3 General Realization

Fig. 1 shows a schematic simplified cross section of the vessel wall. The thermal barrier, made of heat resistant concrete, is located between the elastic hot liner and the cooling liner, which is primarily a leak barrier. The liner is anchored in the thermal barrier to prevent buckling, since it undergoes only elastic compression.

In conventional PCPV's a cooling system located between liner and vessel wall, controls the temperature of the structural concrete. This system protects the concrete from high temperatures. In the Austrian vessel a similar system, distributed over the vessel wall, not only protects the concrete but also allows optimal balancing of concrete and liner temperature. With this system the concrete temperature can be adjusted in both directions by cooling or heating.

Fig. 2 illustrates two different systems of leak limitation or / and evacuation. The system as applied with THTR 300 in Schmehausen, limits leaks to a volume somewhat greater than the overaly vessel. In the Austrian concept a steel barrier (cooling liner) between insulating and structural concrete limits leaks to the volume of the insulating concrete.

The advantages of the Austrian system are:

- Possibility to locate leaks;
- Earlier detection of leaks;
- Small contaminated volume;
- Accessible outer surface of vessel;
- Clear separation of thermal barrier from the prestressed concrete, thus no crack propagation from the one to the other - no pressurized cracks;
- No uncontrolled moisture migration between high (insulating) and low temperature concrete.

The experimental verification of the vessel concept and the testing of the first large scale prototype vessel are far advanced. Results are presented in two separate contributions to this Meeting [3, 4] .

2. H T R A P P L I C A T I O N S

By the better temperature control and the high strength martensitic liner [5] this vessel can optimally be adapted to the different steady state and transient working conditions of HTR's. In a series of feasibility studies and investigations the advantages of the vessel were demonstraded for Gas-Cooled Reactors. A detailed reference design for a 1500 MWe PWR vessel showed its applicability for water reactors as well [6].

2.1 HTR - K Vessel

A feasibility study of a multicavity PCPV for a double-circuit HTR (indirect circuit) with steam generators in the vessel wall was based on the following operating conditions:

Liner temperature	
steady state	300°C
emergency	350°C
Helium pressure	60 bar
Main transients	
start-up	17 h
shut-down	24 h
scram	25 min

Fig.3 shows schematically the operating conditions of liner and concrete. It can be seen, that both for steady state and emergency temperature the liner stresses remain below the yield stress. In order to maintain the liner in the elastic compression range a concrete temperature of 140°C is required.

Fig. 4 shows a cross section of this vessel.

2.2 GCFR Vessel

For the multicacity vessel of a Gas-Cooled Fast Reactor (GCFR) a similar study was carried out. The design conditions were:

Liner temperature	
steady state	245°C
emergency	275°C
Helium pressure	
operation	120 bar
design	138 bar

Main transients

start-up	12 h
shut-down	12 h
scram	10 sec

At a maximum vessel wall temperature of 95°C, the compressive stresses in the liner will stay below the yield stress.

A feasibility study for the same conditions and a single cavity design is under work.

2.3 PNP Vessel

For the High Temperature Process Heat Reactor (Prototypanlage Nukleare Prozeßwärme, PNP) the working conditions are

Helium temperature	
outlet	960°C
inlet	300°C
Helium pressure	40 bar

These are the same temperature conditions as for the Austrian Prototyp Vessel in Seibersdorf. For this vessel in the last years extensive theoretical and experimental experience has been accumulated. The coordinated application of this experience for PNP would meet the idea of a common vessel concept for the different HTR's. Furthermore, experimental verification with an existing prototype is possible without delay.

2.4 HHT Vessel

As far as decided, the lay-out conditions of the multicavity PCPV for the single (direct) circuit HHT Demonstration Plant with integrated gas turbine, are the following:

Liner temperature	
steady state	110° - 150°C
emergency (lay out)	200° - 250°C
Gas pressure	70 bar

These conditions seem to be ideal for a full scale demonstration of a PCPV with hot liner. Fig. 5 shows these temperature conditions and the resulting liner stresses, these stresses being a function of the differnce between liner and concrete wall temperature.

For a ferritic liner and a medium concrete temperature of 50°C the liner undergoes compressive stresses far in excess of its yield stress. Plastification and subsequent tension in the liner are the consequences. In order to avoid plastification a concrete temperature of 120°C, for liner lay out temperature of 200°C, and of 170°C for liner lay out temperature of 250°C respectively would be required.

With a high strength martensitic liner, as used in the Austrian PCPV, significantly lower concrete temperatures keep the liner far below the elastic limit. This solution achieves ideally the scope of our work, i.e. significant increase of operational safety.

3. CONCLUSION

Beyond simplicity and economy of design and construction of a PCPV, its operational safety becomes predominantly important, as demonstrated by the demand of German Utilities for an inspectable and repairable liner. The Austrian PCPV with Hot Elastic Liner and Adjustable Wall Temperature is meant as a contribution to operational safety.

This is the first vessel with elastic hot liner verified experimentally. Its applicability to various HTR's has been studied and demonstrated. With this vessel we offer a common concept for the Gas-Cooled Reactors now in different design stages.

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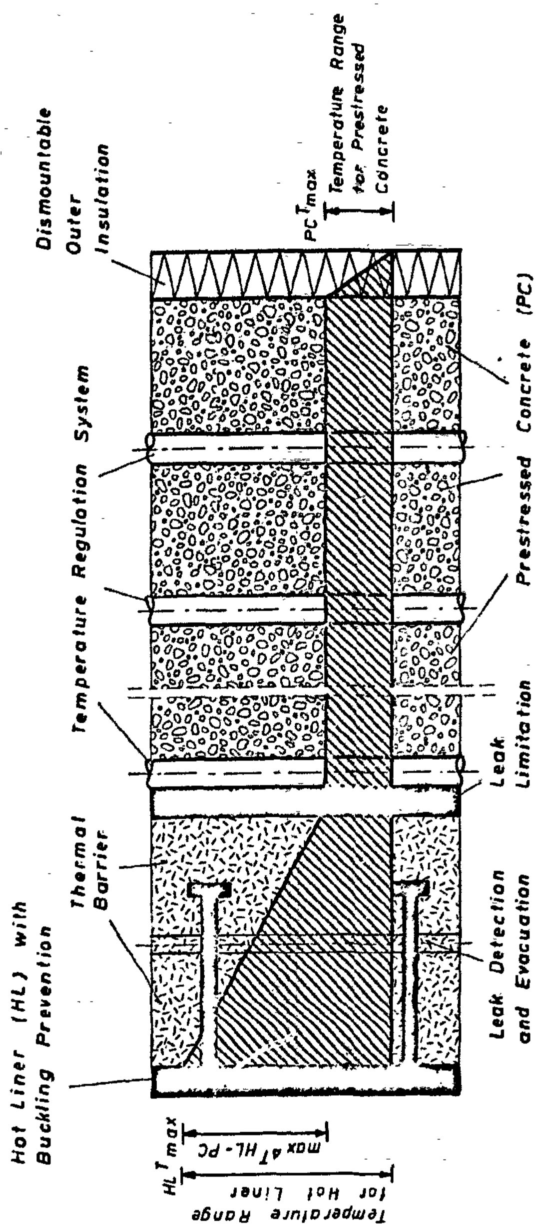
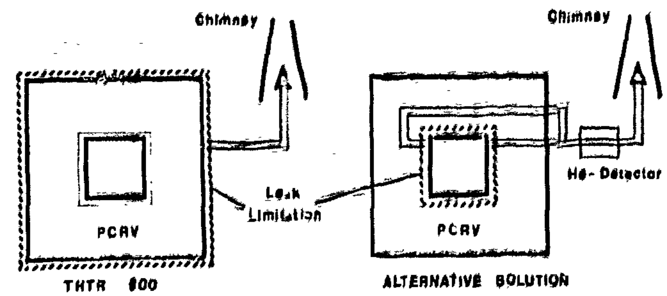


	Pressurized Water Reactor (PWR)	High Temperature Reactor (HTR) Electricity Single Circuit	Electricity Double Circuit	Process Heat	Gas-Cooled Fast Reactor (GCFR)	Prototype Vessel
$_{HL}T_{max}$ [°C]	316	200	350	300	275	300
$_{PC}T_{max}$ [°C]	120	80	140	120	95	120

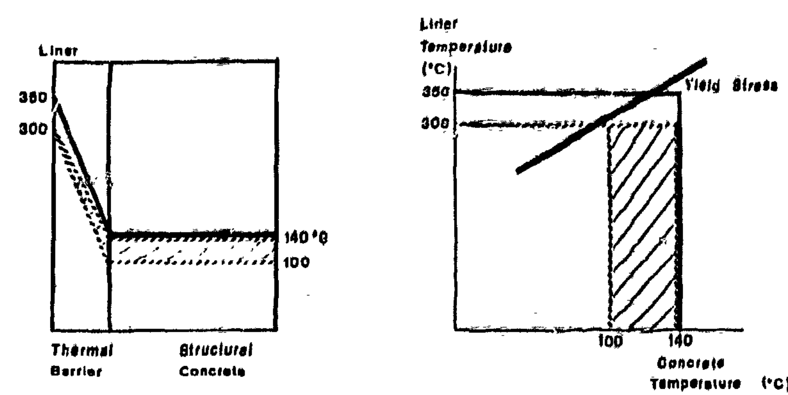
Fig.1



Volume of Leak Extension:
12 000 m³ 500 m³
Material for Leak Limitation:
2 400 m² 1300 m²

LEAK LIMITATION AND EVACUATION

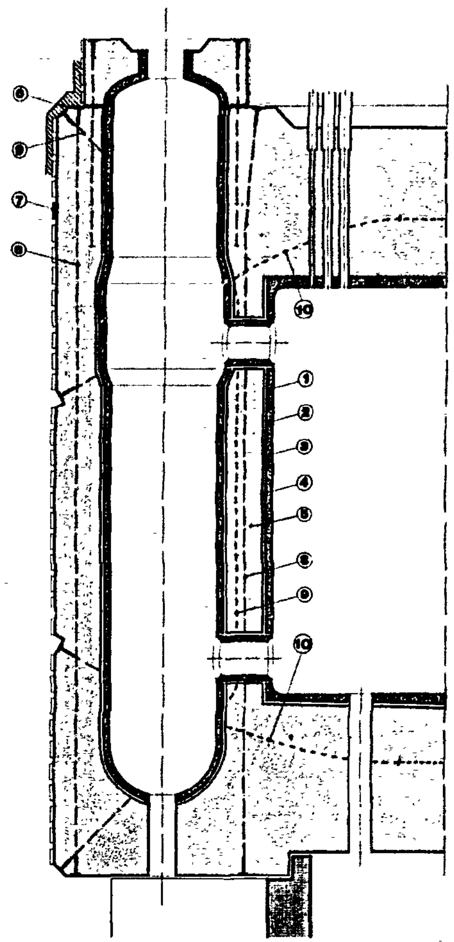
Fig. 2



PCPV FOR HTR-DOUBLE CIRCUIT
Martensitic Liner

Fig. 3

PCRV WITH HOT LINER HTR-K



LEGEND

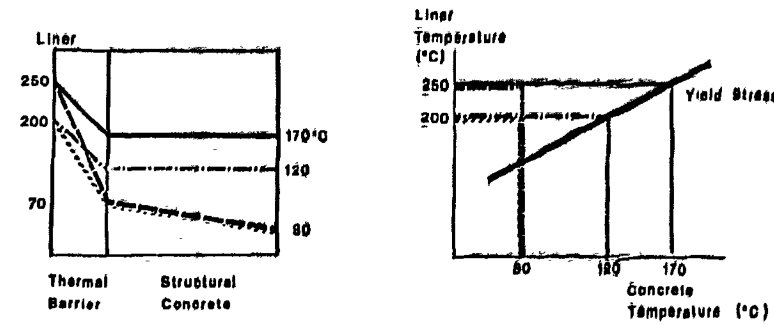
1 Hot liner with anchor bolts
2 Insulating concrete with leak detection and venting system
3 Injected mortar
4 Cooling liner for leak limitation and temperature distribution
5 Prestressed concrete with temperature regulation system
6 Insulation dismountable

7 Hoop wire winding
8 Axial tendons
9 Helical tendons
10 Dome tendons

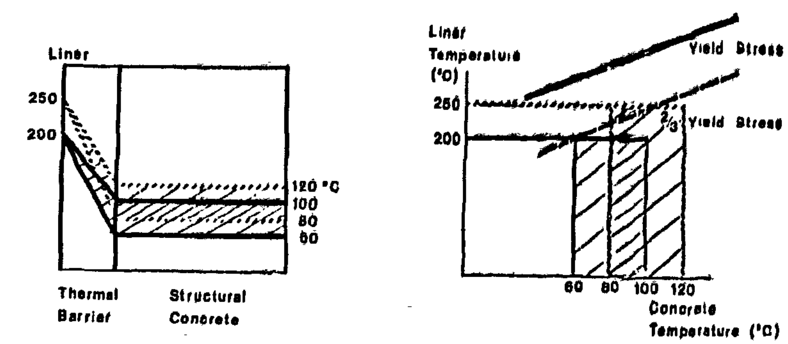
0 1 2 3 4 5 m

RFB REAKTORBAU FORSCHUNGS UND BAUGESELLSCHAFT MBH & CO

Fig. 4



PCPV FOR HTR-SINGLE CIRCUIT
Ferritic Liner



PCPV FOR HTR-SINGLE CIRCUIT
Martensitic Liner

Fig. 5