FILTERS USED IN POST ACCIDENT CONTAINMENT CLEAN UP SYSTEM FOR INDIAN PHWRS

D. Bhattacharyya & S.S. Bajaj
Nuclear Power Corporation of India Ltd.,
Bombay, India

ABSTRACT

The standardized Indian Pressurized Heavy Water Reactor (PHWR) design incorporate several notable features to minimize the release of radioactive materials under accident conditions. Three of these Engineered Safety Features (ESF) use activated charcoal as the medium for retention of radio iodines. These systems are :

i) Primary Containment Filtration and Pump Back (PCFPB) System to clean up the primary containment atmosphere by removing particulate and Iodine isotopes in various forms so that long term release from containment following an accident can be controlled to a very low value. This will help to initiate depressurization of the primary containment if necessary without appreciable loading on the primary containment controlled discharge system.

ii) Primary Containment Controlled Discharge PCCD) System to initiate controlled depressurization of the Primary Containment if warranted for management of the accident.

iii) Secondary Containment Filtered Recirculation and Purge (SCFRP) System to prohibit/minimise the ground level release by multipass filtered recirculation of the secondary containment atmosphere and maintain a negative pressure.

These three systems make important contribution in controlling the radiological consequences following an accident in the reactor system.

However, the high filtration efficiency charcoal is offset by the problems associated with the post adsorption temperature rise in absence of forced cooling. It may be possible to reduce the iodine loading to a more easily managable level by providing a suitable iodine prefilter. The preliminary studies carried out in this area indicate possibility of use of lead exchanged zeolite as an iodine prefilter.

FILTERS USED IN POST ACCIDENT CONTAINMENT CLEAN UP SYSTEM FOR INDIAN PHWRS

D. BHATTACHARYYA, S.S. BAJAJ

1. INTRODUCTION

Narora Atomic Power Station (NAPS), the first of a series of standardized 235 MWe plants has been provided with a full double containment system. (See Ref.1 for details). The containment system comprises a passive pressure suppression type pressure retaining Prestressed Cement Concrete (PCC) structure known as primary containment with provision for fast isolation, rapid cooling, post accident air clean up and low pressure controlled discharge to environment via filters. The primary containment is surrounded by a Reinforced Cement Concrete (RCC) structure (except at the base raft which is common) called Secondary Containment (Confinement) extended to all penetrations and also to the isolation barriers of pipings open to the primary containment atmosphere. The secondary containment incorporates fast isolation and a multipass filtered recirculation, mixing and purge system with the objective of minimizing the post accident release of radioactive materials to the environemnt. All the three filter systems mentioned above use activated charcoal for adsorption of radio iodines. Schematic of these systems are shown in Figure-1. With the exception of Secondary Containment filtered recirculation and purge system which starts automatically on containment isolation, the other two systems are on manual operation with some time delay.

This paper describes the various filter systems used in Indian PHWR containment for post accident cleanup and gives the results of thermal analysis of these filters. Based on these studies, work has been initiated on development of lead zeolite prefilters to be used along with existing charcoal filters.

2. FILTER SYSTEMS

2.1 Primary Containment Filtration and Pump Back (PCFPB) System

This system has been provided to clean up the primary containment atmosphere by removing particulate and iodine isotopes in various forms so that the long term activity release following an accident involving substantial release of fission products into the containment can be controlled to a very low value.

Because of the long term cleanup provided by this system, the stack releases due to subsequent operation of primary containment discharge (PCCD) (See Section 2.2) would be appreciably reduced due to reduced air concentration of radioiodine. Also the loading of PCCD filter will be reduced. This system also serves to promote mixing of the atmosphere in order to bring down the high hydrogen concentration, if any, in the volume VI of the containment following an accident. The system incorporates several units of standard 1700 m^3/hr High Efficiency Particulate Air (HEPA) Filter and Activated Charcoal Iodine Filter (See Figure-1 and Table-I) with redundant fan and associated valves (See Figure-2). The system is laid out in two physically separated independent trains with independent emergency power supply. The sizing of the filter system is based on the total core inventory of iodines, both active and stable isotopes, in accordance with the USNRC Regulatory Guide 1.52. Each combined HEPA and charcoal filter is preceded by a prefilter. The charcoal filters have good excess capacity for iodine adsorption. However, the capacity of prefilters and HEPA filters are just sufficient for the conservatively estimated aerosol mass expected during a postulated dual failure scenario.

2.2 Primary Containment Controlled Discharge (PCCD) System

This system has been provided to initiate controlled depressurization of the primary containment via filters if ground level releases are found to take place as a result of the degradation of containment penetration or the secondary containment passive barriers or associated safety feature or in the event of continued slow pressurization of the primary containment after isolation. The sizing of the charcoal filter in PCCD has been based on the consideration that the system would be in service for limited period of time following the postulated Design Basis Accident (DBA) i.e. Loss of Coolant Accident (LOCA) combined with loss of Emergency Core Cooling System (ECCS). No special provision for aerosol filter has been made as the system takes suction from relatively clean area combined with large time delay.

Any operation of PCCD during accident conditions would be subject to clearance given by an 'Emergency Advisory Group' after a through assessment of the situation has been made since the PCCD operation would result in release of radioactive materials through the stack. It is expected that operation of PCCD would not be required earlier than 24 hours into the accident. Beyond this period decision for operation of PCCD would be taken only after the following conditions are satisfied.

(a) Primary containment pressure and its trend. Operation of PCCD is justifiable if in the long term during postulated accident conditions the primary containment pressure shows a continuously increasing trend. (Which could be due to instrument air inleakage, or otherwise).

(b) Meteriological conditions:

Stable conditions (Pasquil´s Category E, F) are preferable. PCCD operation would not be advisable if the weather conditions are characterized by Pasquil´s category A, B etc. or during temperature inversion conditions.

(c) Extent of ground level releases:

In case ground level leakages are detected (possibly due to failure of SCFRP system), it may be advisable to bring down the primary containment pressure by operation of PCCD.

2.3 Secondary Containment Filtered Recirculation and Purge (SCFRP) System

This system has been provided to eliminate or minimise the ground level release by multipass filtered recirculation of the secondary containment air with purge via additional filter in order to clean up the secondary containment atmosphere and maintain a negative pressure with respect to the environment. Even with degraded operation of the primary containment system very little particulates and iodines are expected in the secondary containment and therefore, the system design is based on a minimum possible configuration necessary from other engineering considerations. The SCFRP system takes suction from the secondary containment exhaust header through redundant fan and combined HEPA-Charcoal filters. After filtration most of the air (1500Sm^3/hr) is again filtered using a HEPA filter before discharging via the stack. The purge line has an off-on type isolation valve which opens at vacuum less than 12 mm WC and closes when the vacuum is better than 18 mm WC.

3 THERMAL ANALYSIS

As the charcoal filter performs clean-up operation of containment air at high efficiency, the iodines are largely retained. The temperature rise of charcoal in a plate is influenced by all iodine isotopes (I-131 through I-135). The present analysis considers the heat load from the above mentioned iodine isotopes.

The idoine activity in the containment air and in any particular charcoal system is estimated using the computer code ACTREL (See Figure-3 for physical modelling of various systems in ACTREL) developed earlier for computation of environmental releases following accidents. The code takes the initial pressure transient in primary containment and computes the pressure build up in secondary containments due to leakages, addition of non-condensables etc. It models various Engineered Safety Features (ESF) in the containment, viz. PCFPB, SCFRP & PCCD and can simulate actuation of these systems at pre-selected times with cut off and restart based on monitored parameters. Attenuation of activity on account of radioactive decay, retention in water, plate out on containment surface and in leak paths are allowed. Input also include the containment leakage correlation, filter efficiencies etc.

Temperature rise of the charcoal filters on account of the decay heat of the trapped Iodines is computed using a one dimensional infinite slab model of the charcoal bed which is considered to be adequate for thermal analysis. The filter under analysis is assumed to pass air at its design rate, until the instant of fan failure when only natural cooling mechanisms are available. The heat transfer coefficient on account of natural convection and radiation is assumed to be 1% of that during forced cooling for a filter operating at the rated flow.

The results of thermal analysis indicate negligible to insignificant temperature rise of the filter bed as long as the fan is operational. The temperature rise in SCFRP recirculation filter on fan failure is estimated to remain limited to only 4 Deg. C. The purge filter would see even smaller iodine loading and hence has not been analysed. The temperature rise in PCCD iodine filter depends largely on the availability of PCFPB and the time of initiation of controlled discharge. If the depressurization is initiated at 24 hours into the DBA and PCFPB system remains unavailable throughout this period then the maximum temperature rise in charcoal would be about 41 deg. C (see Figure-4). This would not pose any hazard from the point of view of iodine desorption or a charcoal fire. PCFPB filters, inspite of having enormous excess capacity undergoes large amount of iodine loading and the filter temperature increases steeply on cooling failure after most of the iodines have been adsorbed. Based on the analysis a delay of 4 hrs has been imposed on starting of PCFPB so that advantage can be taken of decay of short lived radio iodines and plate out on the containment surfaces. However, even with the delay of 4 hours, the increase in filter temperature upon fan failure is estimated to be about 200 deg. C. Although the peak charcoal temperature on fan failure stays far below the ignition temperature of 350 Deg.C, desorption may occur. However, the iodine source term considered to be 100 % release of core inventory is porobably too conservative and if the releases amounted to only 50% of the core inventory the peak charcoal temperature would not exceed 150 Deg. C (See Figure-4), which is the minimum desorption temperature.

4. DEVELOPMENT WORK

Based on these studies on charcoal filters, it was felt necessary to minimise the radioiodine loading on the charcoal filters in PCFPB & PCCD without significantly increasing the overall dimension of the filter systems. This is necessary as backfitting larger filters would be an extremely difficult task in both operating as well as the plant under construction. Based on the literature studies and the economics of the system, work was initiated to develop a lead exchanged zeolite based iodine prefilter. Lead exchanged 13 X Molecular sieves (Pb-X) were developed using 13 X Na form by ion exchange of Na^{+} by Pb^{++} using Ø.5 M $Pb(NO_3)_2$ solution in a column exchange process. After washing in distilled water and drying in an oven the same was evaluated in laboratoy for its iodine removal efficiency (See Table-II). Further work is in progress in this area to examine the suitability of Pb-X as an iodine prefilter material.

5. ACKNOWLEDGEMENTS

(i) Shri V.K. Sharma, Health Physics Divison, Bhabha Atomic Research Centre, Bombay.

(ii) Shri K.G. Gandhi, Waste Management Division, Bhabha Atomic Research Centre, Bombay.

Reference

1. S.K. Chatterjee, Design of Containment System and Associated Engineered Safety Features in Indian PHWRs.

Table-I

Specification of impregnated activated charcoal

1.	Base material	: Coconut Shell
2.	Activation agent	: Steam air
3.	Mesh size	: - 8 + 16 BSS mesh
4.	Ash content of base charcoal	: 2% or less
5.	BET surface area	: 1050 ± 50 m.sq/g
6.	Hardness number	: 97±2
7.	Moisture content	: 5% or less
8.	Carbontetra chloride (%) activity	: 62 ±2
9.	Iodine number	: 1000
10.	Ignition temperature	: 350 deg. C (min)
11.	Apparent density	: 0.5 ±0.2 g/ml
12.	Impregnants	: KI, KOH in proportions but not exceeding 5% (wt/wt)
13.	Removal efficiency at ambient temperature, 100% RH 2" bed thickness, 0.24 sec contact time carrier free	: Molecular iodine (I_2) 99.98% + Methyliodine (CH_3I)
14.	Desorption of adsorbed iodine species at 180 deg. C (5 hrs. test)	: Less than 1%

TABLE-II

Preliminary Test Results of Lead Exchanged Zeolite

Adsorbent : PbX

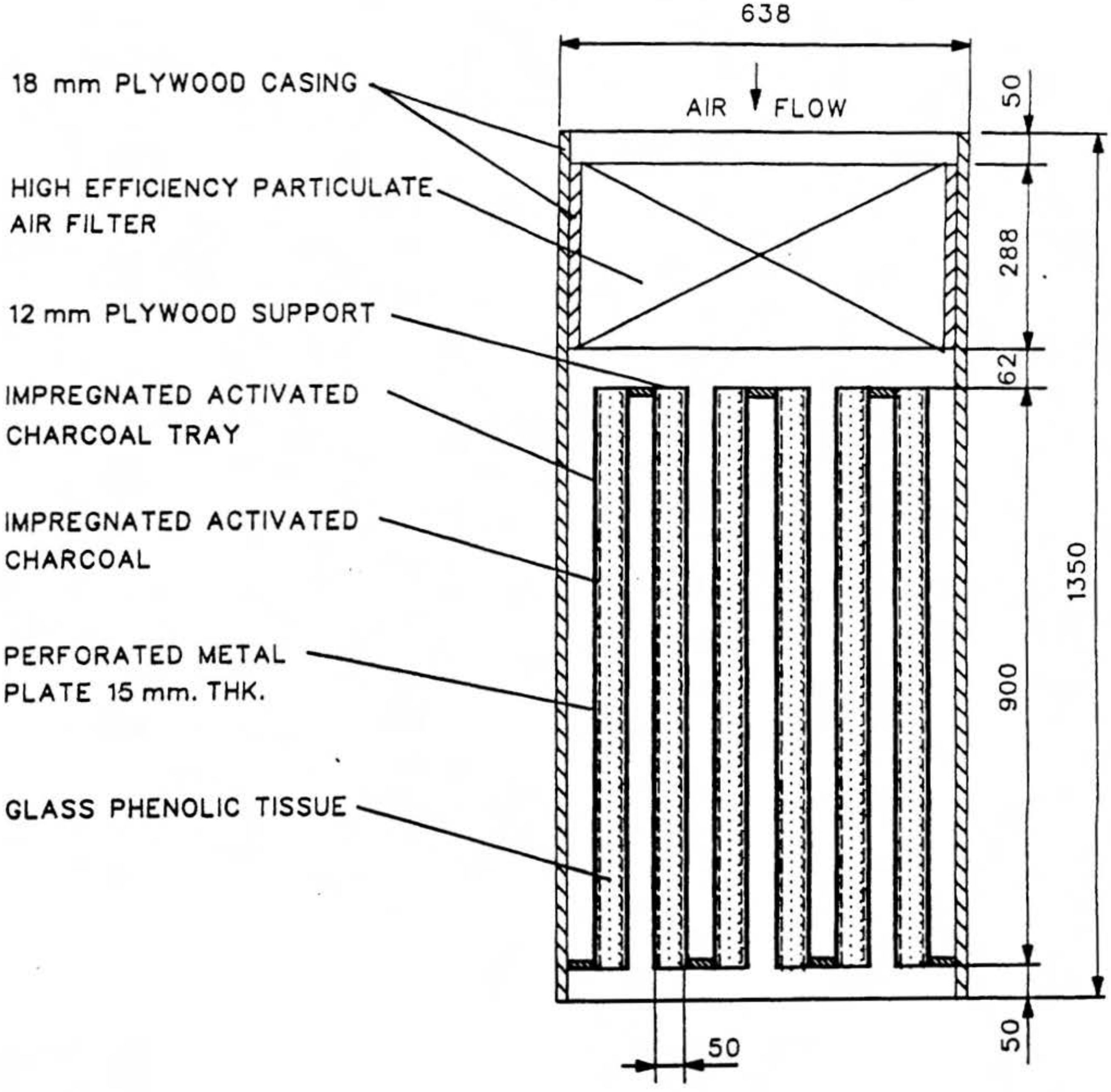
Bed thickness : 2"

Adsorbate : Molecular Iodine $(I_2)^{131}$ carrier free

Temperature : Ambient

Humidity : 100% RH

Sl. No.	Air Velocity fpm	Contact time Sec	% removal efficiency
1.	71.50	0.14	64.50
2.	57.10	0.17	73.40
3.	47.60	0.21	81.20
4.	40.80	0.24	88.00



NOTE :-
ALL DIMENSIONS ARE IN m m.

FIG. 1 COMBINED HEPA AND IODINE FILTER

OF 1700 m^3 / hr CAPACITY

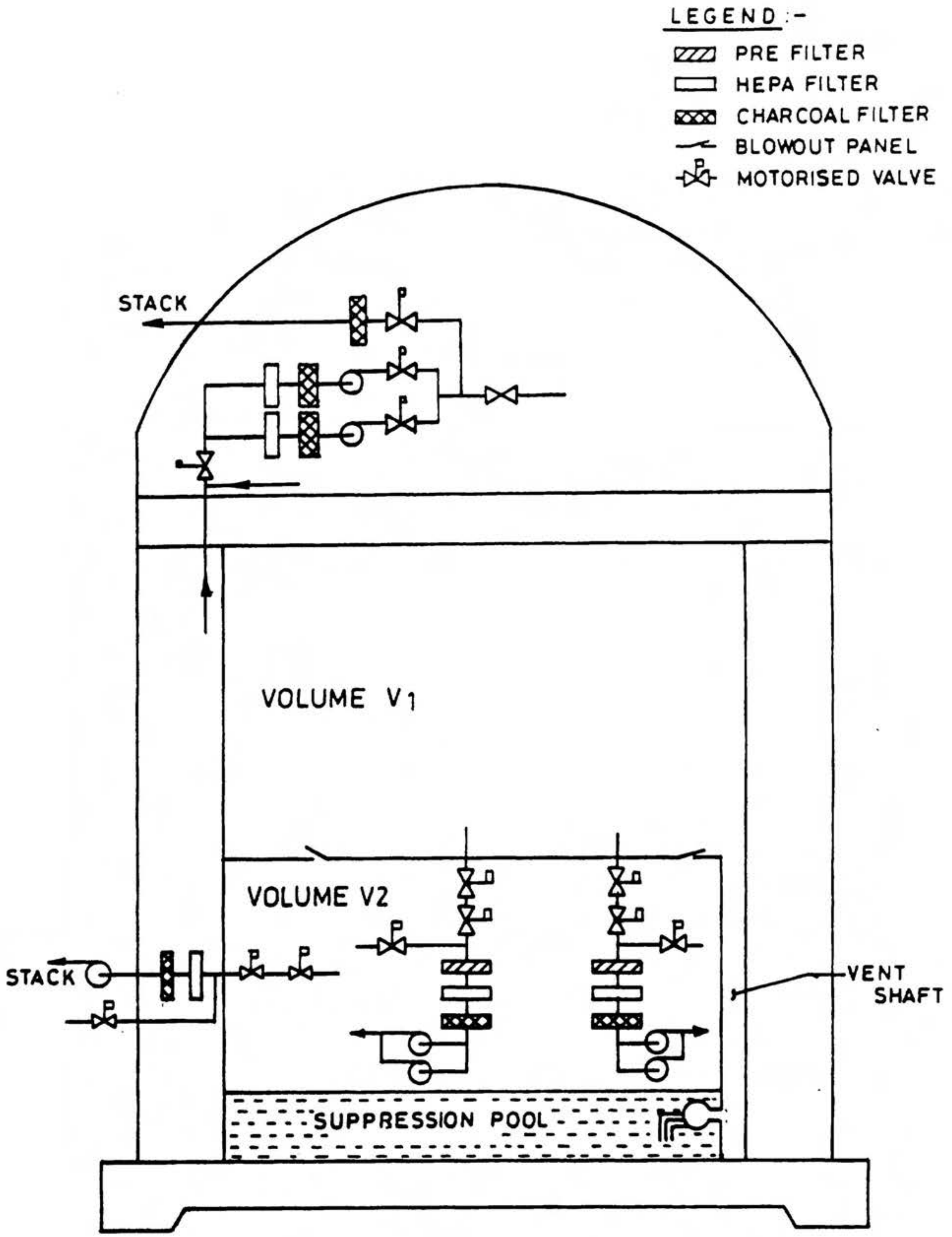
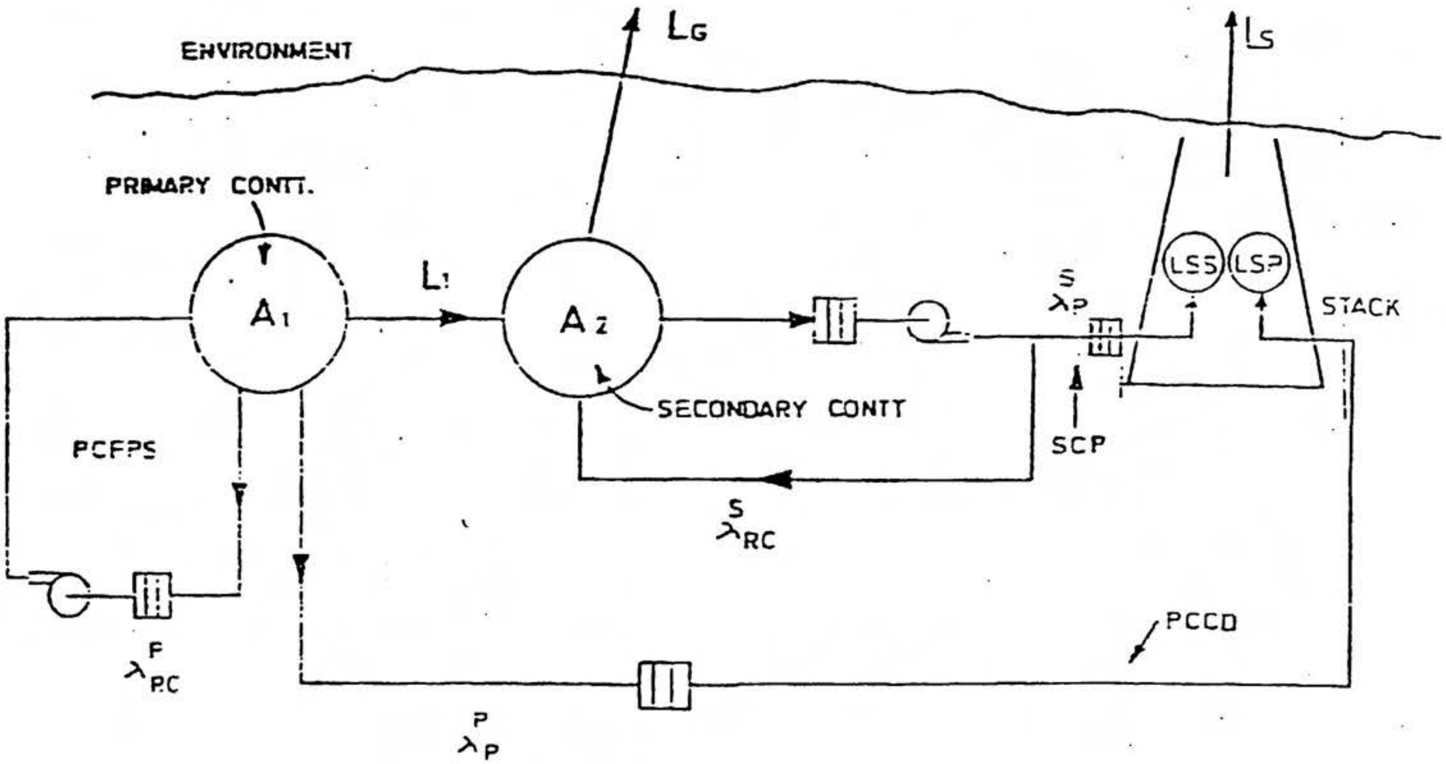


FIG. 2 SCHEMATIC OF CONTAINMENT FILTERS



NAPP DOUBLE CONTAINMENT ACTIVITY RELEASE MODEL

FIG 3

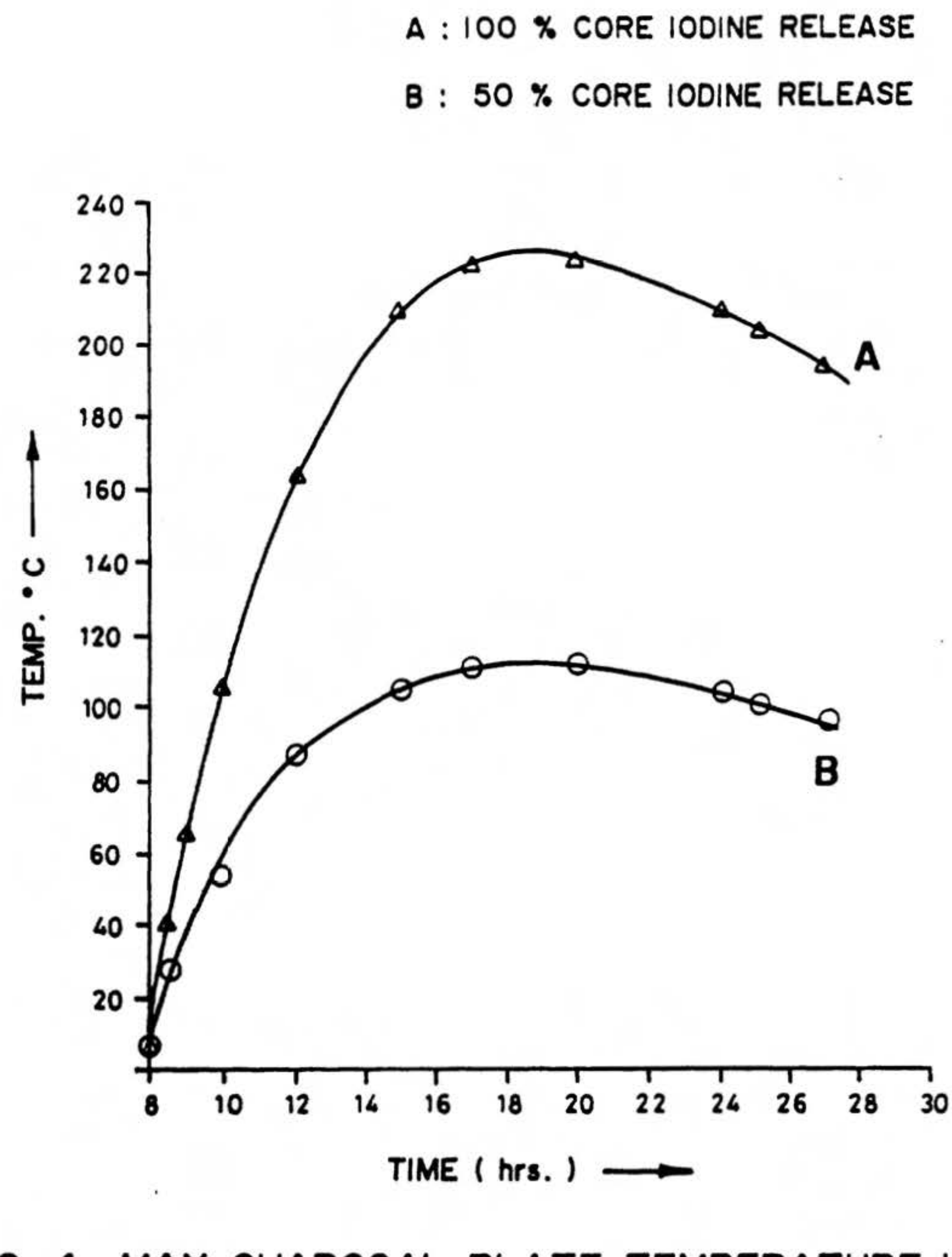


FIG. 4 MAX CHARCOAL PLATE TEMPERATURE IN PCFPB FILTER AFTER COOLING FAILURE