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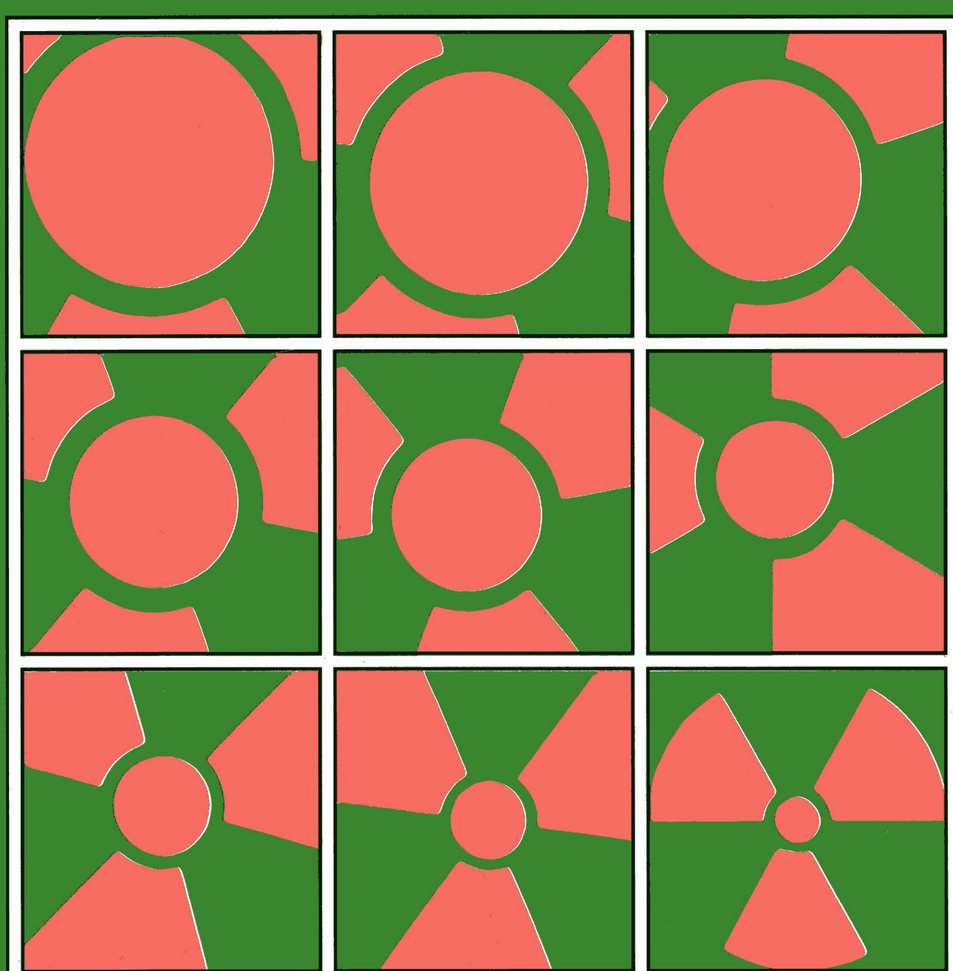
nuclear science and technology

Assessment of management alternatives for LWR wastes

(Volume 4)

Description of a Belgian scenario for PWR waste



Report

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Assessment of management alternatives for LWR wastes

(Volume 4)

Description of a Belgian scenario for PWR waste

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Final report

Work performed as part of the shared cost programme (1985-89) on management and disposal of radioactive waste of the European Communities

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FOREWORD

This report deals with the description of a management route for PWR waste relying to a certain extent on Belgian practises in this particular area. This description is part of an overall assessment study aiming at evaluating a selection of management routes for LWR waste based on economical and radiological criteria.

Actually the assessment study was implemented through complementary contributions provided by nine organisations and companies, i.e.
CEN - Fontenay-aux-Roses, INITEC - Madrid, KAH - Heidelberg, BELGATOM - Brussels, TASK R&S - Ispra, SGN - St. Quentin-en-Yvelines, EDF/SEPTEN - Villeurbanne, FRAMATOME - Paris-la-Défense, GNS - Essen, co-ordinated by the Commission of the European Communities (Brussels).

The main achievements of the assessment study have been summarised by BELGATOM-Brussels.
These different contributions are published as EUR Reports in 1992 (listed as below):

VOLUME N°	MAIN AUTHORS	ORGANISATION	TITLE	EUR REPORT N°
1	R. Glibert	BELGATOM	Assessment of Management Alternatives for LWR Wastes : Main achievements of the joint study	14043 EN/ Vol 1
2	E. de Saulieu C. Chary	SGN EDF	Assessment of Management Alternatives for LWR Wastes : Description of a French scenario for PWR waste	14043 EN/Vol 2
3	S. Santraille K. Janberg H. Geiser	FRAMATOME - GNS	Assessment of Management Alternatives for LWR Wastes : Description of German scenarios for PWR and BWR wastes	14043 EN/Vol 3
4	J. Crustin R. Glibert	BELGATOM	Assessment of Management Alternatives for LWR Wastes : Description of a Belgian scenario for PWR waste	14043 EN/Vol 4
5	B. Centner	BELGATOM	Assessment of Management Alternatives for LWR Wastes : Assessment of the radiological impact to the public resulting from discharges of radioactive effluents	14043 EN/Vol 5
6	G.M. Thiels S. Kowa	TASK R & S KAH	Assessment of Management Alternatives for LWR Wastes : Cost determination of the LWR waste management routes (Treatment/Conditioning/Packaging/ Transport Operations)	14043 EN/Vol 6
7	J. Malherbe	CEA	Assessment of Management Alternatives for LWR Wastes : Cost and radiological impact associated to near surface disposal of reactor waste (French concept)	14043 EN/Vol 7
8	N. Sanchez-Delgado	INITEC	Assessment of Management Alternatives for LWR Wastes : Cost and radiological impact associated to near surface disposal of reactor waste (Spanish concept)	14043 EN/Vol 8

SUMMARY

The objective of this report is to contribute to the implementation of a joint study on management options for LWR wastes by drawing up a route based on the Belgian concepts and industrial practices.

A Belgian radwaste management route is described explaining the way the gaseous and liquid effluents and the solid wastes are fed to treatment systems, purified before release into the environment for the effluents or conditioned for the solid wastes.

The characteristics of processes, major equipment, materials and labour related to the treatment and conditioning units and related buildings are provided in order to carry out the subsequent cost assessment.

The study is completed by sensitivity studies. One study examines the impact of using mobile instead of fixed concreting facilities on capital and operating costs. The other one evaluates the variation of the total disposal cost of low level waste packages as a function of the interim storage capacity.

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CHAPTER I

INTRODUCTION

I.1. Objectives and Scope

During the last few years, reactor waste management practices in the European Community have taken advantage of many improvements as far as processes, organisation and safety are concerned. In order to take stock of these new practices, to compare them on a sound basis and at the end of the process to highlight those aspects which might require some further improvements, the Commission of the European Communities launched a joint theoretical study on the assessment of a selection of management routes for LWR wastes relying to a large extent on the experience gained in France, Belgium and the Federal Republic of Germany. Although emphasis was placed on the evaluation of management routes for PWR wastes, the case of BWR wastes was also looked into.

This study was performed within the framework of the third research programme of the Commission of the European Communities on "Radioactive waste management and disposal" (1985 - 1989).

Actually the whole study consisted of evaluating five management routes (three on PWR waste and two on BWR waste) on the basis of economic and radiological criteria.

Each route was defined as an assembly of all intermediate management stages which are usually occurring from the waste production at the source up to the storage or disposal of waste packages. With the view to make the different routes comparable, whenever possible, it was attempted to fit in national management routes within a joint framework featured by a fixed nuclear capacity, similar primary waste inventories and common discharge limits.

On the basis of an extensive description of the main equipments involved in each route, a cost evaluation was performed using the same methodology. The radiological impact associated to the implementation of each route was mainly quantified for the part of the public living around the nuclear facilities of concern. In addition, possible long term doses to the public resulting from disposal of radioactive waste packages in near surface sites were determined.

I.2. Contents of the Report

The joint study was performed through contributions provided by several organisations according to a breakdown of tasks reported in the foreword. In this respect, the contents of this report deals with the description of a Belgian scenario for the management of PWR waste mainly relying on the experience gained at Tihange.

This report aims at providing input data for the subsequent cost evaluation and radiological impact assessment of this scenario performed by other partners in the study (see volumes 1, 5 and 6 of the series).

Three principal waste categories are considered throughout the report: i.e. gaseous, liquid and solid wastes. After a thorough analysis of the production of these waste categories during normal operation of typical PWRs at Tihange, the different management steps enabling those waste types to be treated, conditioned, packaged and transported to an interim storage facility according to Belgian practices and regulations are extensively described.

This includes data on the size and type of the major equipment involved in the management route needed for the cost evaluation study (detailed in the volume 6 of the series) and also estimates of the radioactive effluents released (analysed and quantified in the volume 5 of the series together with the determination of the radiological impact to the public) as well as the amount of radioactive waste packages to be finally stored. The overall evaluation of the Belgian management scenario for PWR waste is reported in the first volume of the series (main achievement of the joint study).

As disposal of low and medium level PWR waste is not yet operational in Belgium, it was assumed that the characteristics of the different waste packages generated could comply with acceptance criteria defined for near surface disposal facilities.

The report is concluded by sensitivity studies performed on two important parameters: effect of substituting mobile treatment/conditioning units for fixed ones and impact of varying the interim storage capacity on management cost.

CHAPTER II

BASIC ASSUMPTIONS

In order to be able to carry out a comprehensive evaluation of management routes for PWR waste including all intermediate management stages from the waste production at the source up to final disposal, a reference scenario fixing a number of basic assumptions in which each route was supposed to fit in was defined. This reference scenario comprises assumptions in matter of size of the PWR nuclear park, primary waste inventories, discharge limits and several options for the disposal of radioactive waste packages generated in each route.

II.1. Size of the Nuclear Park

As a first approach, a 20 GWe nuclear park entirely composed of standard 900 MWe PWRs was considered for the study. However, in order to be able to determine the radiological impact to the public resulting from discharges of radioactive effluents into the environment, it was additionnally assumed that PWRs were grouped by four 900 MWe units and that their location was somewhere along the Meuse River in the North Europe in a rather populated area upstream large towns.

For all routes, the interim storage capacity of low and medium level wastes pending final disposal was estimated being capable of accommodating the total volume of waste packages normally produced during one year of plant operation (on-site or in a centralised facility).

Arbitrarily, the distance between PWRs and one hypothetical final disposal site was fixed to 500 km.

For the specific case of the Belgian scenario for PWR waste management, it was assumed that all low and medium level waste packages generated during 30 years operation of the 20 GWe nuclear park could be disposed of in one hypothetical near surface disposal site (see section II.4).

II.2. Primary Waste Inventories

In order to be able to compare the different management routes evolving from the study on a sound basis, common primary waste inventories for all routes were previously defined. This concerned gaseous and liquid effluents as well as solid wastes. These inventories (volumes/radionuclide composition) are reported in tables I/II, III/IV/V and VI/VII respectively. It is important noting that the real values indicated in these tables correspond to operating values whereas the design values are used to size treatment units.

TABLE I: GASEOUS EFFLUENT ORIGIN, VOLUME AND ACTIVITY

WASTE ORIGIN	DESIGN VALUE	REAL VALUE
Chem. & volume control system + primary circuit degasing	24 000 Nm^3/a 300 Ci/Nm^3	10 000 Nm^3/a 3 Ci/Nm^3
Ventilation	150 000 Nm^3/h 10^{-4} Ci/Nm^3	150 000 Nm^3/h 5×10^{-7} Ci/Nm^3

TABLE II: RADIONUCLIDE COMPOSITION FOR GAS (PWRs)

Radionuclide	C-14	Kr-85	Kr-85m	Kr-87	Kr-88	Xe-133	Xe-133m
%	0.00001	0.03	1.83	1.25	3.32	80.41	1.75
Radionuclide	Xe-135	I-131	1-132	I-133	I-134	I-135	Aerosol
%	11.31	0.01	0.02	0.03	0.01	0.02	0.00001

The radionuclide composition corresponds to the one to be expected at the entrance of the off gas system. For the sake of easiness, the same composition is applied to ventilation gases.

TABLE III: LIQUID EFFLUENT ORIGIN, VOLUME AND ACTIVITY

WASTE ORIGIN	DESIGN VALUE	REAL VALUE
Primary effluents circuit	24 000 m^3/a 10 Ci/m^3 (without gas) 1 Ci/m^3 (with gas)	10 000 m^3/a 0.1 Ci/m^3 (out of gas)
Secondary drain waste	4 000 m^3/a 10^{-1} Ci/m^3 (on average) 1 Ci/m^3 (peak value)*	2 500 m^3/a 10^{-2} Ci/m^3
Laundry wastes	4 000 m^3/a 10^{-4} Ci/m^3	4 000 m^3/a 10^{-5} Ci/m^3 (on average) 10^{-4} Ci/m^3 (peak value)*
Decontamination operations	500 m^3/a 10^{-1} Ci/m^3	10 m^3/a 10^{-2} Ci/m^3
Chemicals	1 500 m^3/a 10^{-2} Ci/m^3	1 500 m^3/a 10^{-3} Ci/m^3
Building or floor waste	6 000 m^3/a 10^{-3} Ci/m^3	3 000 m^3/a 10^{-3} Ci/m^3

* The peak value corresponds to max. 10% of the operation time.

TABLE IV: PRIMARY COOLANT RADIONUCLIDE COMPOSITION

Radionuclide		Mn-54	Co-58	Co-60	Sr-90	Nb-95	Mo-99	Ag-110m
%		0.44	3.0	0.6	0.018	0.001	0.44	0.44
Radionuclide	Sb-124	I-131	I-132	I-133	I-134	I-135	Cs-134	Cs-137
%	0.44	10.4	18.2	31.2	10.4	20.8	20.8	1.79

TABLE V: RADIONUCLIDE COMPOSITION FOR ALL THE OTHER AUXILIARY LIQUID EFFLUENTS

Radionuclide	H-3	Mn-54	Co-58	Co-60	Sr-90	Nb-95	Mo-99	Ag-110m
%	1	4.75	31.66	6.33	0.19	0.013	4.75	4.75
Radionuclide	Sb-124	I-131	I-132	I-133	I-134	I-135	Cs-143	Cs-137
%	4.75	0.46	0.79	1.38	0.46	0.92	19.00	19.00

TABLE VI: PRIMARY SOLID WASTE ORIGIN, VOLUME AND ACTIVITY

WASTE ORIGIN	DESIGN VALUE		REAL VALUE	
Primary resins:				
- highly active	1.3 m^3/a	700 Ci/m^3	1.3 m^2/a	500 Ci/m^3
- low active	2.6 m^3/a	100 Ci/m^3	2.6 m^3/a	50 Ci/m^3
Primary filters:				
- primary coolant purification	15 filt/a	100 Ci/filt	10 filt/a	50 Ci/filt
- spent fuel pool purification	25 filt/a	2 Ci/filt	20 filt/a	1 Ci/filt
Normal equipment, combustible + compactable	260 m^3/a	0.01 Ci/m^3	260 m^3/a	0.01 Ci/m^3
Normal equipment, non combustible + compactable	100 m^3/a	0.01 Ci/m^3	100 m^3/a	0.01 Ci/m^3
Normal equipment, combustible + non compactable	20 m^3/a	0.01 Ci/m^3	20 m^3/a	0.01 Ci/m^3
Normal equipment, non-combustible + non-compactable	20 m^3/a	0.2 Ci/m^3	20 m^3/a	0.2 Ci/m^3

TABLE VII: PRIMARY SOLID WASTE RADIONUCLIDE COMPOSITION

Radionuclide	Mn-54	Co-58	Co-60	Mb-90	Ag-100m	Sb-124	Cs-134	Cs-137
%	5	33.32	6.58	5	5	5	20	20

TABLE VIII: DISCHARGE LIMITS RELATED TO ONE 900 MWe PWR UNIT

EFFLUENTS	DESIGN VALUES (Ci/a)	OBJECTIVE VALUES (Ci/a)
Liquid effluents		
- Total (Tritium excluded)	9	2
- Tritium	950	750
Gaseous effluents		
- Noble gases	20 000	2 000
- Halogens	0.3	0.02
- Aerosols	0.5	0.02
- Tritium	200	100

II.3. Discharge Limits

In the definition of management routes for LWR waste and especially the drawing-up of flow-sheets, it is obvious that discharge limits play a decisive role. In this context and for the sake of harmonisation between the different management routes investigated throughout the evaluation study, some threshold values were commonly agreed upon for defining discharge limits for liquid and gaseous effluents normally generated during operation of one typical 900 MWe PWR (see table VIII). These values are in line with current discharge limits fixed for PWR inland sites existing within the Community.

II.4. Disposal Options for LWR Waste

Actually, three disposal options were considered for low and medium level waste packages arising during normal operation of LWR, namely:

* near surface site according to the French concept;
* near surface repository based on the Spanish concept;
* deep repository in the disused Konrad iron mine.

The French concept for disposing of low and medium level waste derives from the "Centre de l'Aube" concept which has just started to be operated. This concept involves the use of engineered structures. Although adopting a similar design, the Spanish concept differs from the French one by the fact that it allows a possible waste retrievability in the future. Accordingly, the related investment costs are slightly higher.

As far as the deep repository is concerned, the waste acceptance criteria already defined for the Konrad mine were taken into account. Current cost figures provided by GNS-Essen for disposing of low and medium level waste in this mine were used throughout the study.

However, for the specific case of the Belgian scenario for PWR waste, only the two first options were taken into consideration.

CHAPTER III

MANAGEMENT OF GASEOUS EFFLUENTS

The gaseous effluents treatment systems control the discharge of gaseous effluents into the environment under normal and accidental conditions.

This chapter describes the gaseous effluents treatment systems used till now in the Belgian PWRs. The systems are designed to be able to treat as well the mean gas production as the transcient ones induced by start-up or shut-down of the plant.

Two kinds of gaseous effluents are generated in PWRs :

- primary off-gas;
- ventilation air.

The primary off-gas treatment system provides a storage function allowing the decay of the short-lived radionuclides. The primary off-gas treatment system provides a storage function allowing the decay of the short-lived radionuclides (xenon, krypton, iodine) and a nitrogen source for re-use into the reactor plant, the recombination of hydrogen contained in hydrogenated effluent and aerosol filtration.

Ventilation effluents originate from the annular space, the auxiliary building and purge gases from the reactor buildings. All three streams containing minor amount of gaseous wastes under normal conditions are each filtered through a train consisting of HEPA filters and charcoal absorber. By this way, an aerosol and iodine decontamination of the ventilation effluents is carried out before release through the stack.

III.1. Primary Off-Gas

The primary off-gas consists of :

. N_2 (main constituant)

. H_2

. Fission products produced by the primary circuit

III.1.1. Functional Design

The role of the primary off-gas treatment circuit (TEG) consists of collecting and treating the hydrogenated gaseous effluents of the following circuits :

- hydrogenated gas-vent circuit, sub-circuit of the drain and gas vent circuit (CPE);

- the part of the circuit between the head-tanks of TEP and the compressors of the TEG;

- the part of the circuit between the RCV and the compressor of the TEG with a view to release or re-use of the effluents.

With this aim, the circuit ensures the following functions :

- storage of gases;

- lowering of H_2 content;

- decreasing of the activity of short period isotopes;

- controlled release, through the stack after filtration and dilution by ventilation air;

- re-use of the gaseous effluent, in place of N_2, as sweeping or covering gas;

The main functions of the circuit are detailed hereunder either in normal operation or during start-up and shut-down periods of the nuclear power plant.

Gas storage or filling-up of TEG

As the effluent activity can reach high values, a storage and decay period is necessary previous release or possible re-use. The T.E.G. is designed assuming that the gaseous effluents contain radioactive elements coming from the activation of components and impurities of primary water or from leakage of fission products of 1 % defective combustible elements.

The effluents collected by the "Drain and gas vent circuit (CPE) are evacuated, via the compressors, through a storage and decay vessel : the circuit is thus said functioning in "filling-up" mode (see Fig. 1).

This "filling-up" function cannot absolutely be interrupted during the normal working of the nuclear power plant.

Three compressors are installed. Two of these are necessary to ensure the described function; the third one acts as reserve equipment and can also be used to ensure other functions of the TEG.

Hydrogen content limitation

The TEG is designed in such a way that the hydrogen content of gaseous effluents is kept under 4 %.
This value lies under the lower inflammability limit of the air-H_2 mixture.

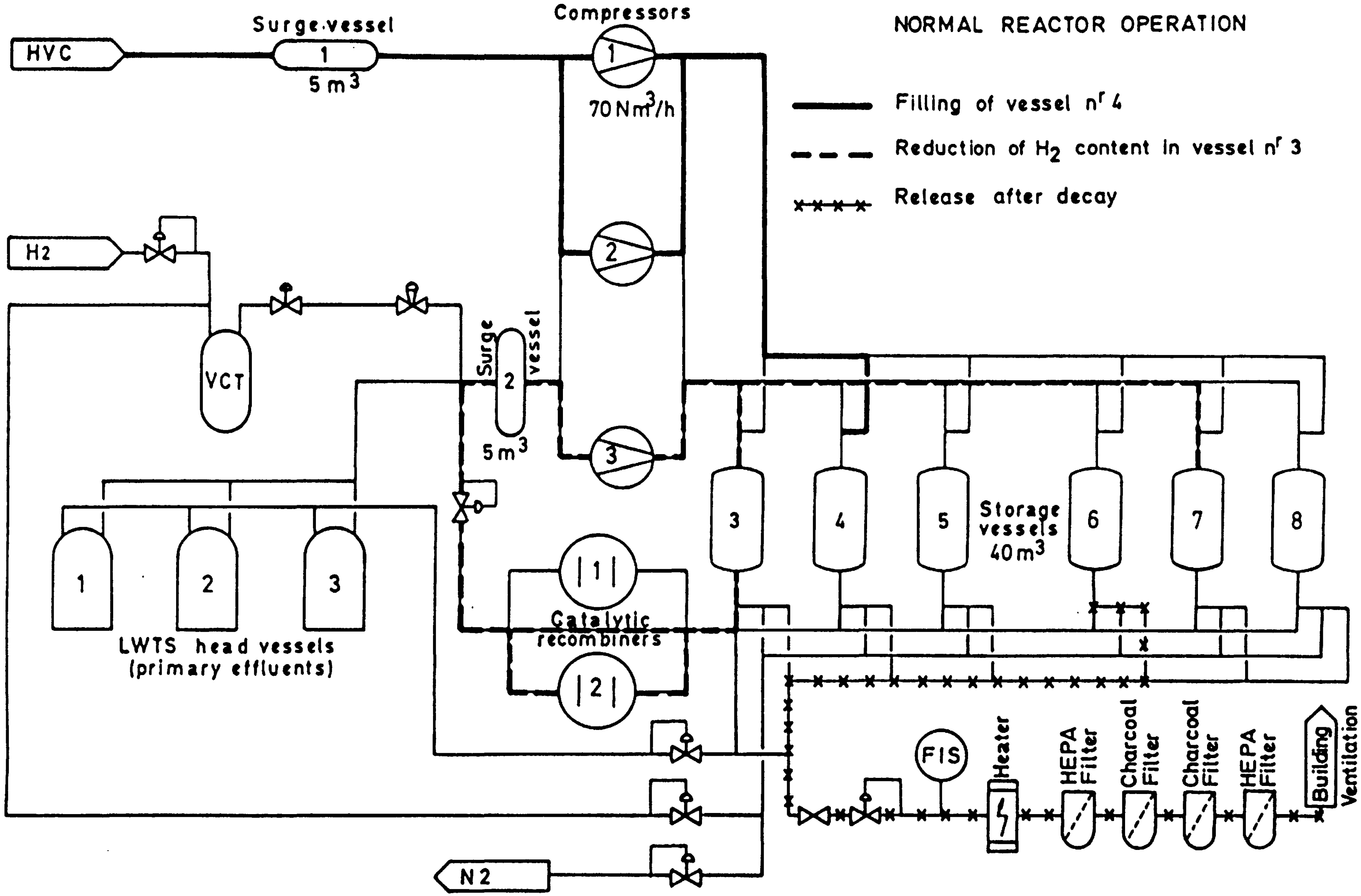


FIGURE 1 : HVC OFF GAS HANDLING

Hydrogen recombiners are installed to this end (Fig.1).

As the hydrogen content of hydrogenated effluents can reach rather high values (even sometimes 100 % during the continuous sweeping with fresh hydrogen), measures are taken in order to limit the fire or explosion risk in the circuits. As first measure to this end, all equipment is explosion proof.

In order to avoid air admission in the circuit the inlet collector of the compressors is functioning with overpressure. The hydrogen and oxygen contents of the storage tank during filling-up is continuously measured via the sampling circuit (CEN).
If any abnormally high value is detected, the vessel is isolated.

In order to avoid any explosion risk, the gaseous effluents do not go directly through the recombiners; they go first through a storage-decay tank where they are diluted.

The operation of the catalytic recombiners is automatically interrupted if:

- a too high H_2-content is measured at the inlet of the recombiners;

- a too high O_2-content is measured at the inlet or at the outlet of the combiners;

If, in spite of these precautions, an explosion does occur in a recombiner, the reaction chamber remains absolutely tight.

Release

The gaseous effluents release can be done as soon as their residual activity lies under the release limits.
To reduce the iode release, without prohibitive increase of the storage time for decay, filtering is foreseen on release collector down-stream of the pressure reducing and of the flow rate limitation devices.
The release is done via the general extraction duct of the building ventilation.

Selective collecting of gaseous effluents (Fig. 2)

The control of volume, chemical parameters and activity of the primary coolant induces the generation of primary effluents (PE).

The transcient functioning conditions, in particular, generate important amounts of primary effluents, which are really considerable at the end of the combustible life-time.

The same situation occurs when the plant is in operation with load follow.

The liquid primary effluents are conducted to the head tanks of the

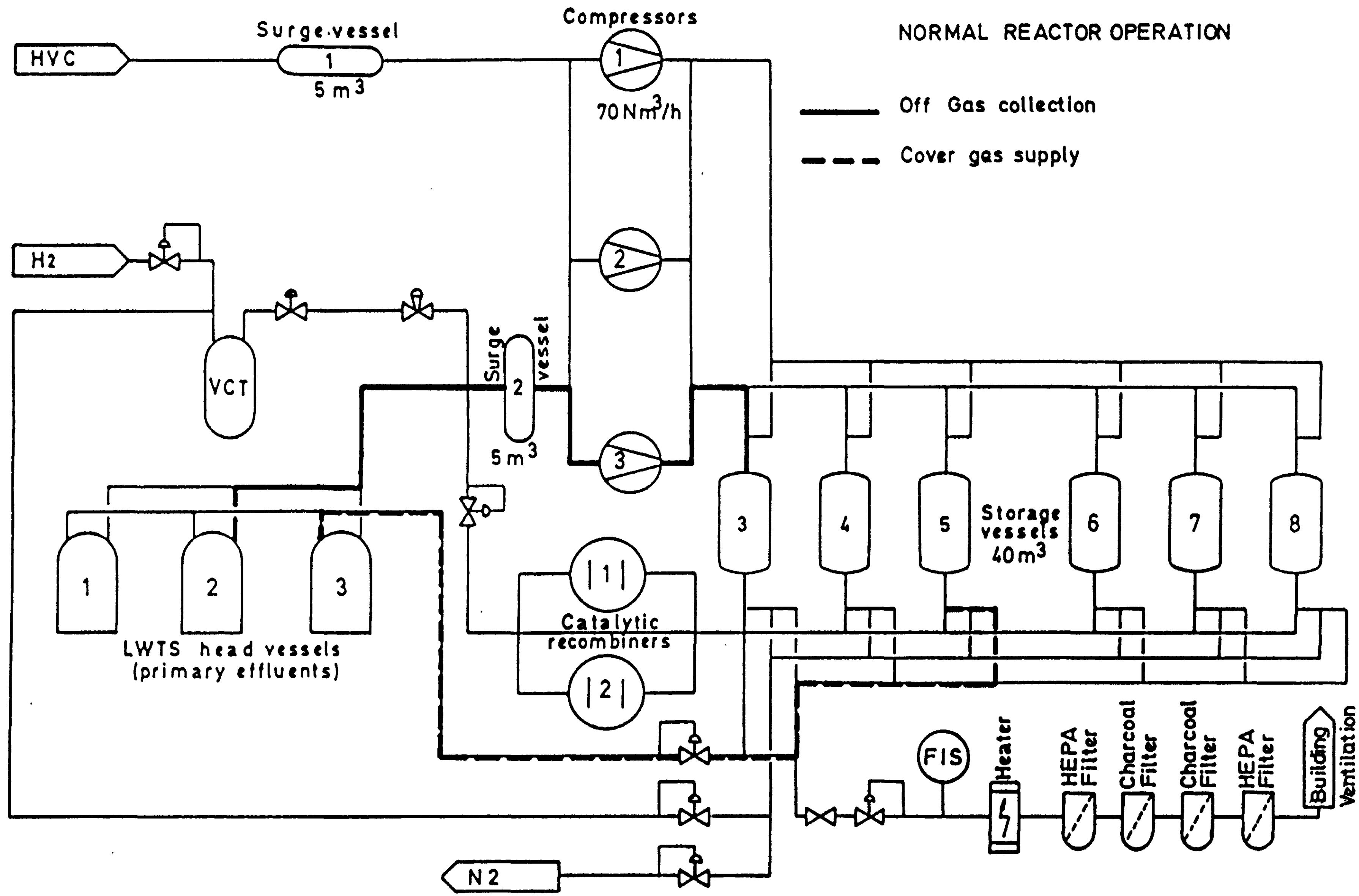


FIGURE 2 : LWTS OFF GAS HANDLING

"Treatment of primary effluents circuit" (TEP).
The gaseous effluents resulting from the filling of these TEP-tanks are relatively low contaminated in comparison with the other hydrogenated effluents.
Direct connections exist between these vessels and the storage-decay tanks of the TEG.

Transfer from one vessel to another

Existing connections allow the transfer from any tank to another via a compressor and the recombiners by-pass line.

Operations simultaneity

Having regard to the availability of the three compressors and also to the constrains of the plant operation, the functions mentioned above (Release) can be performed simultaneously with two of the functions mentioned in (Gas storage or filling-up of TEG), (Hydrogen content limitation), (Selective collecting of gaseous effluents) or (Transfer from one vessel to another).

Operation during start-up and shut-down periods

The gas coming from the fission process and contained in primary water such as the hydrogen must be eliminated to prepare the cold shut-down.
The working of TEG remains unmodified until the reactor is stopped and depressurized.
When the primary circuit is depressurized, the radioactivity in terms of xenon reaches the maximum value. In order to quickly eliminate this activity, the purification pump of the "chemical and volumetrical control circuit" is started. This increases the primary water flow rate to the volumetrical and chemical control tank (RCV).

Two different ways allow the evacuation of the TEG of the gas coming from the fission process from the hydrogen present in the gaseous phase of the RCV.
The first consists in a continuous sweeping of the gas coming from the fission process contained in the RCV with fresh hydrogen and next evacuation of hydrogen by means of continuous sweeping with nitrogen.
The second way consists in alternative draining and filling with nitrogen of the gaseous phase of the RCV.

At the time of the start-up of the plant, the inverse operations must be carried out.

All these operations are illustrated in Fig. 3 and 4.

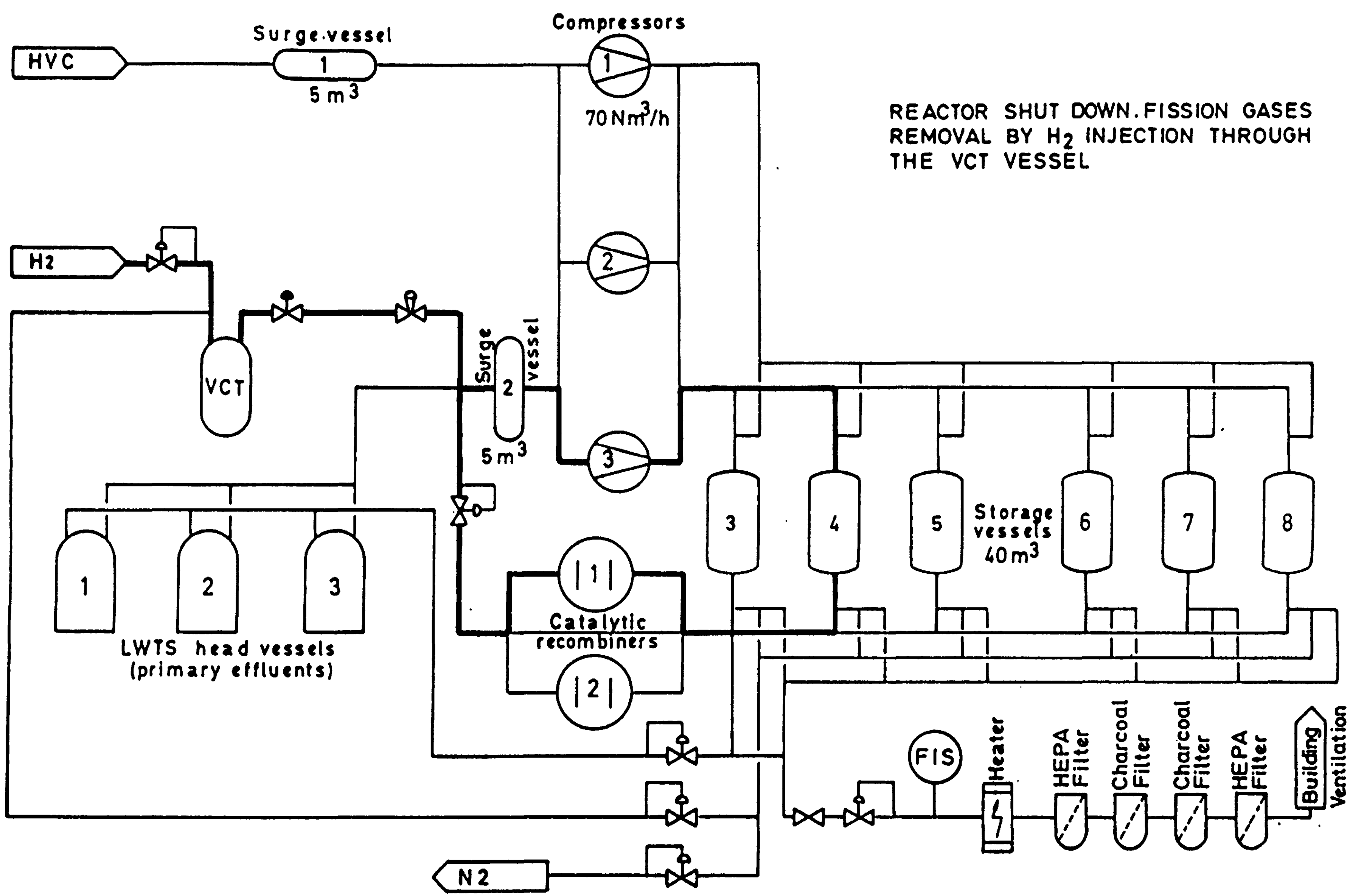


FIGURE 3 : VCT OFF GAS TREATMENT

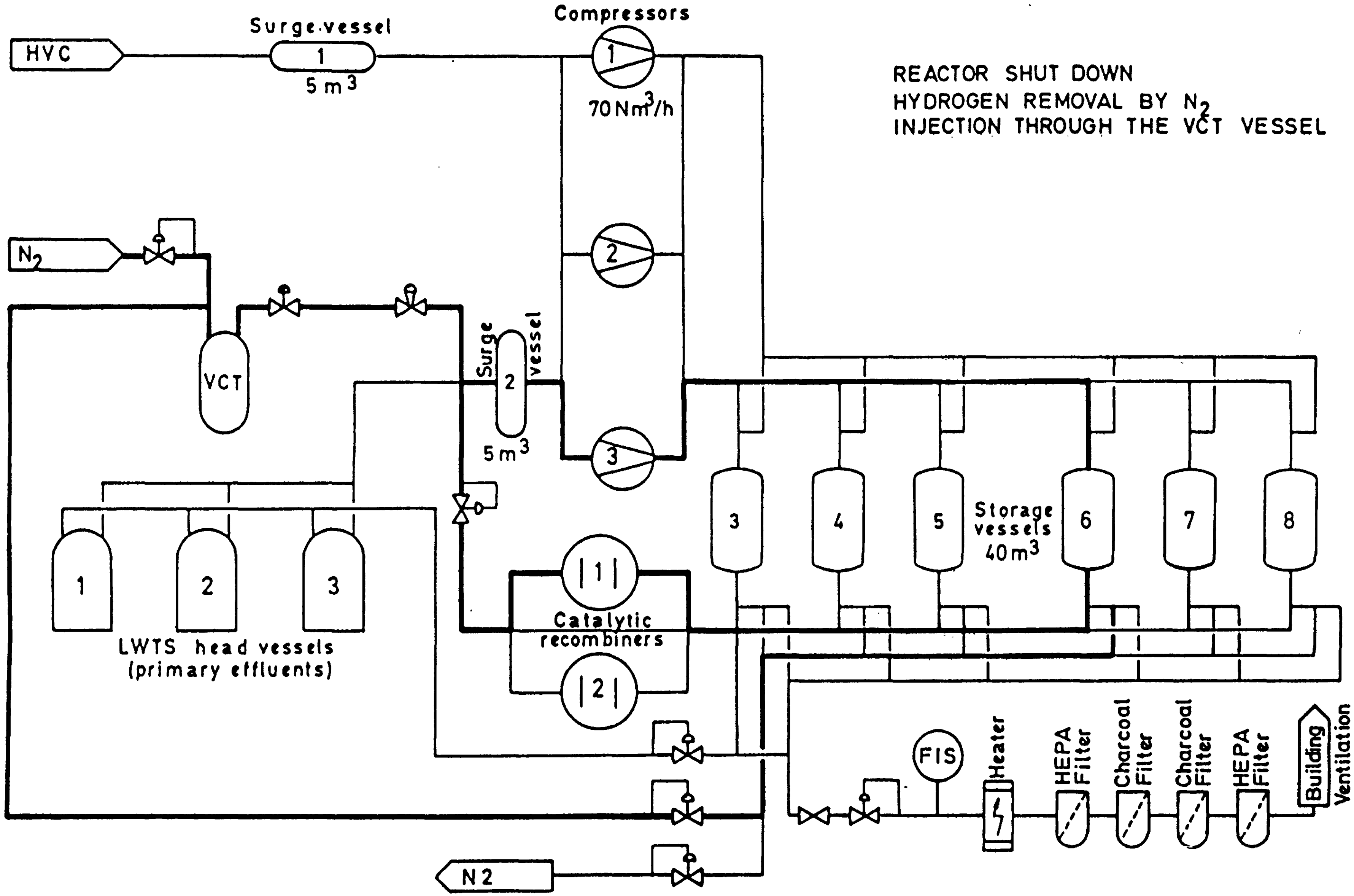


FIGURE 4 : VCT OFF GAS TREATMENT

Retention time of hydrogenated effluents

The main function of the hydrogenated effluents treatment system is the storage of these effluents.

The natural decay of the activity leads to release compatible with the allowed limits.

The retention time is 60 days. It is calculated on the basis of the maximum possible activity in the TEG. This activity is the result of the sum of the activities related with :

- the degasing of primary effluents;
- the sweeping of the gaseous phase of the RCV (two per year);
- the degasing of the primary circuit during a "cold" shut-down of the plant (two per year amoung which one is followed by a "quick refueling").

Filtration efficiency on release circuit

Before release, the hydrogenated effluents are filtered by passing through a filtering chain consisting of absolute filters, active charcoal beds and absolute filters.

This filtering set follows an electrical heater which bring the relative humidity of the gas down under 70 %.

The filtration efficiencies, for mounted filters, are the following :

- Absolute filters :

  . filtration diameter : 0.3 μm
  . efficiency : 99.97 %
  . reference test : DOP

- Active carbon bed :

  . thickness : 5 cm (min.)
  . efficiency : 99.9 % (for I-131 mol. with 90 % relative humidity - 40 °C)
  . efficiency : 99 % (for Iodine as organic compound (methyl Iodide) with 90 % of relative humidity).

III.1.2. Description of the Equipment

The off-gas treatment circuits are given in Fig. 5-6-7.
These circuits consist of :

- two buffer tanks (VO1-VO2);
- three compressors in parallel (KO1, O2, O3);
- six storage and decay vessels (40 m^3; VO3-O8) feeded by two collectors.

Three evacuation collectors for each vessel are foreseen;

- one branch line allows the lowering of H_2 content in the stored effluents. These effluents pass through a catalytic recombiner (two recombiners are mounted in parallel) and a pressure reducing valve in order to bring the effluent pressure down to a value compatible with the suction pressure of the compressors.

Then, a compressor pushes the effluents into the buffer tank or into another. The transfer function from one tank to another is performed by means of a by-pass line of the recombiners;

- a line for the effluents release in a ventilation extraction duct, through a pressure regulating device, a gas reheating unit, an absolute filter, an active charcoal bed and absolute filter again;

- a connection with a pressure reducing valve to the RCV via the hydrogen circuit.
  A direct connection between this tank and the compressor suction is installed upstream of the tank VO2.

- a connection, with pressure reducing valves, to the primary effluent storage tanks, for a direct re-use of these effluents as covering gas.
  A direct connection between these tanks and the compressor suction is installed upstream of the tank TEG VO2;

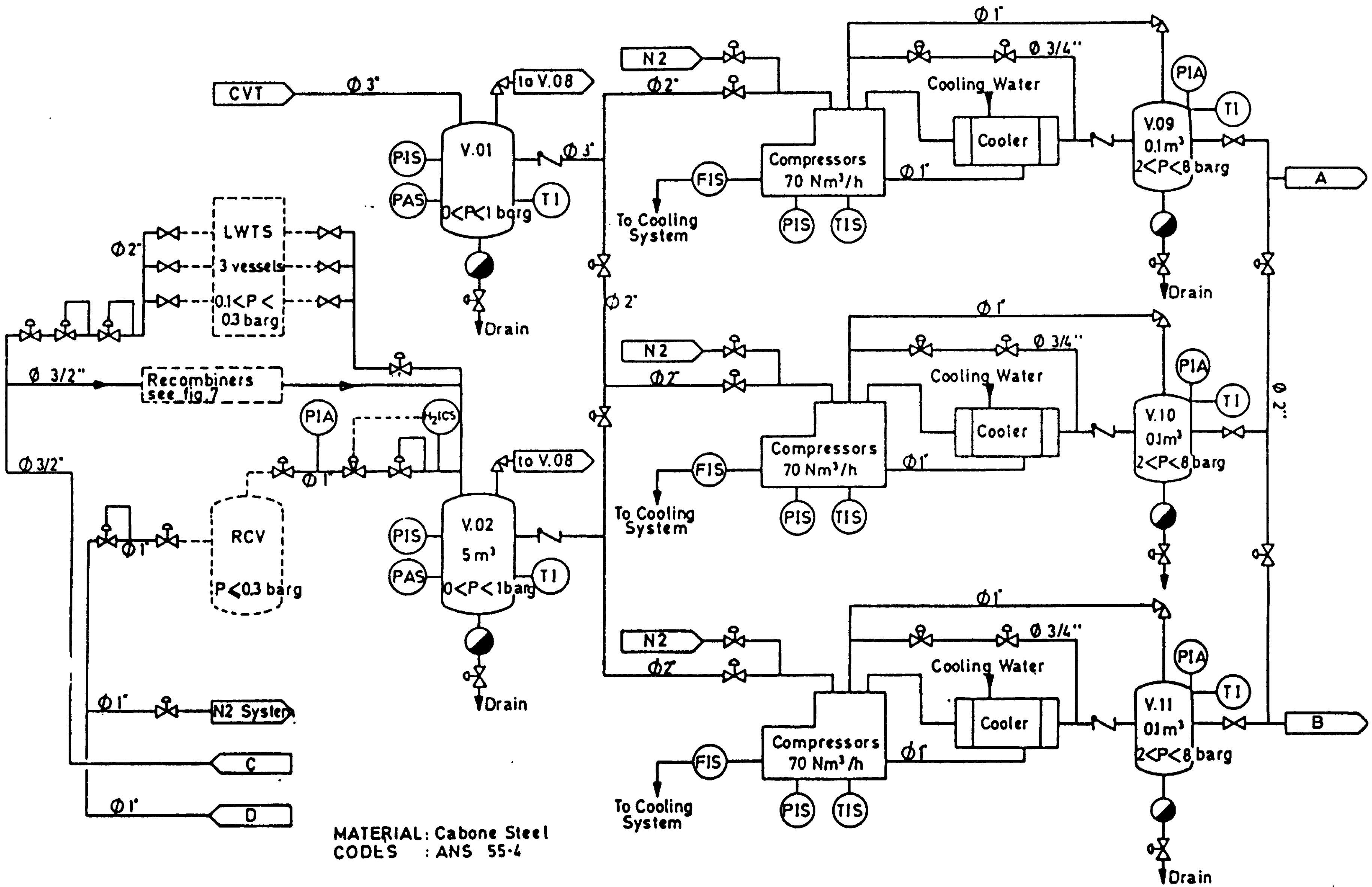
- a by-pass line of the recombiners allowing the simple transfer function from one tank to another;

- a re-use connection, with pressure reducing valve to the N_2 system.

Some characteristics of the main equipment are given here after :

- Compressors upstream lines

  These lines must withstand the vacuum.



MATERIAL: Cabone Steel
CODES : ANS 55-4

FIGURE 5 : OFF GAS SYSTEM COLLECTORS-COMPRESSORS

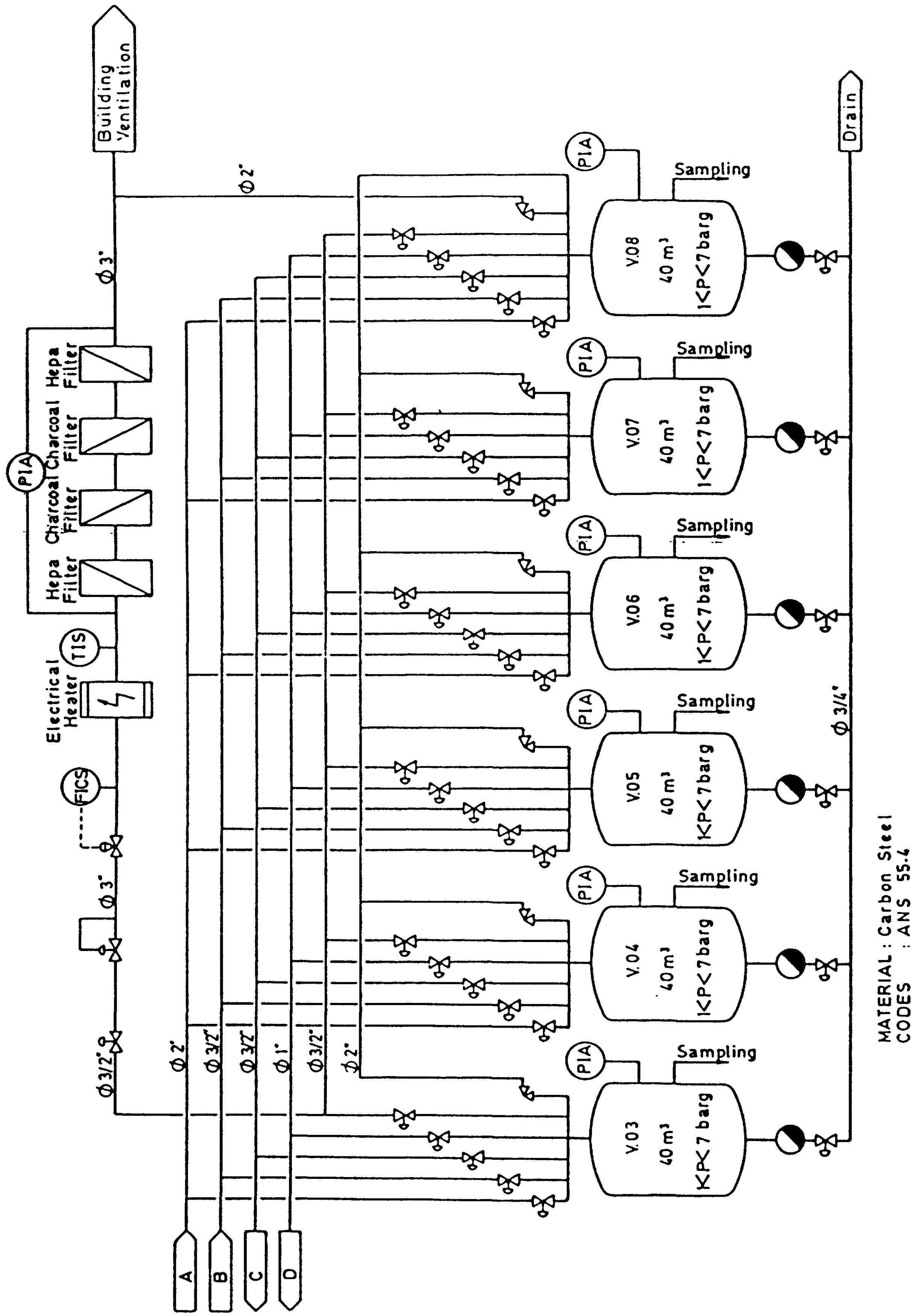
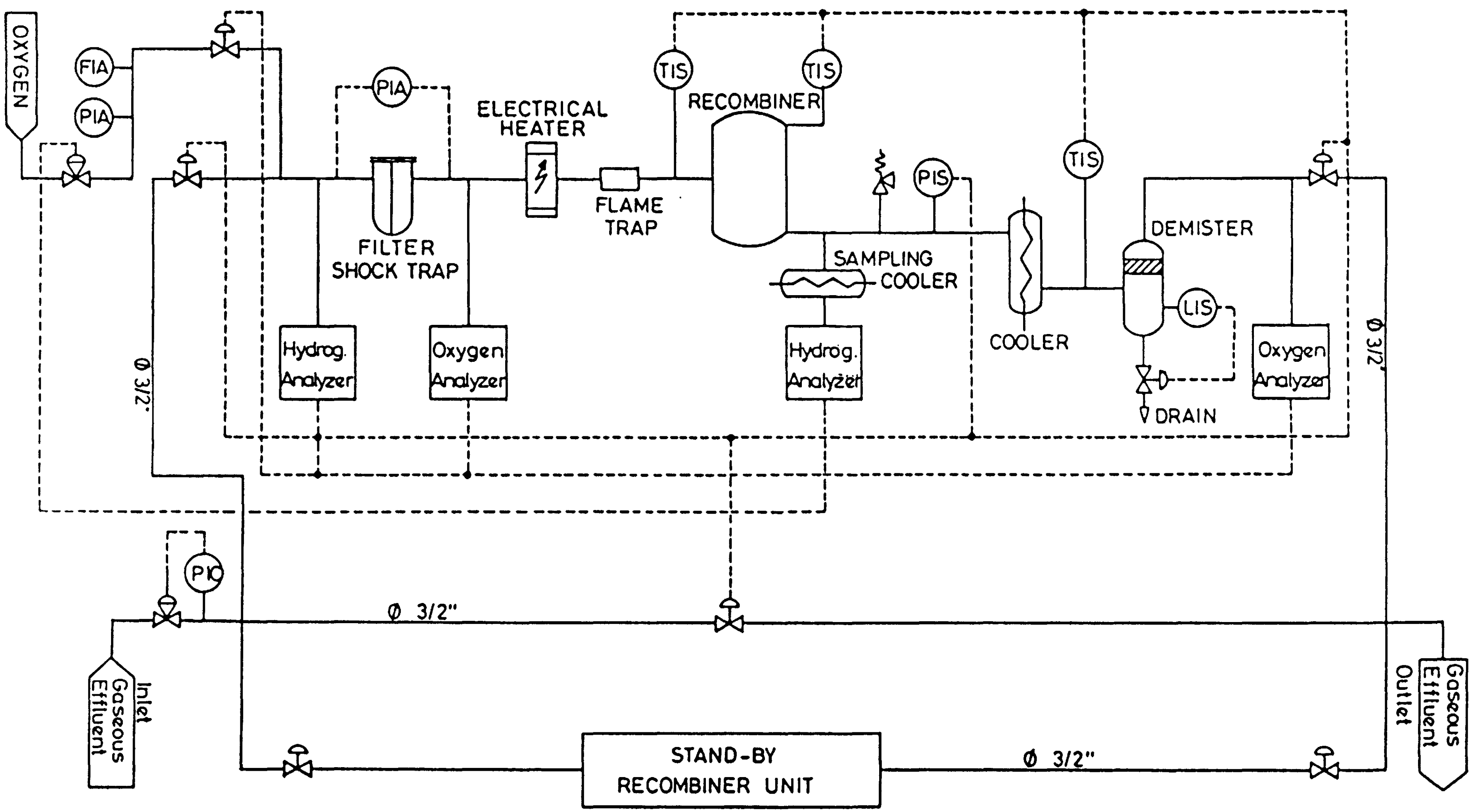


FIGURE 6: OFF GAS SYSTEM STORAGE RELEASE



Material : AISI 304 L
Codes : ANS55.4

FIGURE 7 : RECOMBINER UNIT SIMPLIFIED FLOW DIAGRAM

- Storage-decay vessels

  These vessels are cylindrical-vertical type. The net volume is 40 m^3. These vessels allow the storage of radioactive gas under a maximum pressure of 7.25 bar abs.
  They are located in "bunkers" designed to withstand the accidental failure of one of them.
  Furthermore, the maximum operating pressure in the vessel is limited to 8.25 bar abs.

- Compressors

  - Type with metallic membrane.
  - The maximum temperature of the gas at the outlet is 50°C.

- Catalytic recombiners

  In order to avoid an overheating of the catalytic bed, redundant protections are taken; for example, the limitation of the hydrogen and oxygen contents of the effluents at the inlet of the recombiners.

  To keep the equipment and piping corrosion under limit, it is necessary to maintain the oxygen content as low as possible at the outlet of the recombiner.
  If this oxygen content reaches a too high level, the oxygen injection is automatically stopped.

- Valves

  To avoid a leak of gaseous effluent, all the valves are constructed with diaphragm, direct flow with double tightness at the stem.

  Where the temperature can reach higher values, the valves are provided with a metallic diaphragm or a globe with bellows.

- Safety valves

  The discharge of the safety valves of the TEG is done in a storage-decay tank, and the safety valve of this tank discharges into the release circuit of the TEG.

- Pressure reducing valves

  To keep under limit the eventual activity release in case of failure of a pressure reducing valve of the release circuit, this valve is designed to limit the leak flow rate at a value near of the maximum flow rate (200 Nm^3/h).

- Instrumentation and control

- Operation of the circuit

The command and control of the TEG circuit is not centralized. These functions are performed from the local control room. The selection of the function is performed from the local panel.

Start-up, modifications of flow-rate, normal shut-down are also performed from this local panel.
After reaching of steady-state conditions, the working of the different circuits is continuous and automatic during the necessary time to perform the chosen function (filling-up or treatment of a storage tank).

The operator is only required to perform or survey some time-limited operations or to solve any incident. In particular, the release operations are controlled from the local panel of the control room of the TEG.

To this aim, the main alarms and some auxiliary alarms are transferred into the central control-room.
Depending on the recorded alarm, the operator can check the local panel and, in emergency case, the failing chain is automatically put in a safety position.

- Control of the equipment

The selection of the circuit function is manually performed.

The compressors and valves are actuated from the local control room. The contractors of the motors are installed in the power supply cabinet.

The selection of a circuit is realized by means of motorized valves which limit switches are used in the interlock circuits.

During the operation, the compressors are locked in an operation mode depending on the circuit configuration and the shut-down is coupled with operating securities.

These interlocking and securities electrical circuits are performed by means of electromechanical relay's.

The operating regime of the installation is also manually performed. When this operating regime is reached, the operation of the installation is switched to automatically control and doesn't require the presence of an operator, except if any incident occurs.

- Control and operating panel

  All the indicators, recorders, regulators, signalisations and control of compressors and valves (remote controlled or equipped with limit switches) just like as the corresponding alarms are located in an "active" control-and-operating panel.
  This panel is realized as a schema placed on the front panel of the control boards.
  It comprises all remote instrumentation.

III.2. Ventilation Air

III.2.1. Functional Design

Radioactive or potentially radioactive areas are always operated at pressures lower than atmospheric to insure that any leaks are into rather than out of the area. As there are several different areas in a building, with varying degrees of contamination, pressure staging is used to direct the flow of air : the area of least contamination is just below atmospheric pressure with areas of increasing contamination held at the decreasingly lower pressures until the area with the highest contamination is at the lowest pressure in the building.

Thus, air flow in the building is always from an area of lesser activity to an area of higher activity and the contamination tends to concentrate rather than to diffuse into larger areas.

Ventilation is directed across the surfaces of spent fuel storage pools and reactor pools during refueling to entrain any gases that may be released from the fuel or coolant. In a similar manner, ventilation air is used to cool control rod drive mechanisms and the reactor vessel cavity in a PWR.

In containment structure, 50°C are acceptable if it is coordinated with the operating ambient design temperature of the equipment.

In areas of limited personnel access, 40°C can be tolerated.

In locations of continuous access, temperatures of 35 to 30°C may be considered, depending on the outside air available.

The areas of high design temperature must have facilities for purge cooling to permit personnel occupation for prolonged periods for maintenance and servicing.

All discharges are channelled to exhaust stacks where they are monitored for activity and diluted with copious amounts of outside air. The exhaust monitor is arranged so that it shuts down the exhaust system on high activity levels.

This same monitor is sometimes used to develop a legal, continuous record of plant gaseous effluent. In this exhaust arrangement, highly suspect areas may have their own individual monitors so that one area may be closed off rather than the complete plant. This type of monitoring can be developed as the plant design progresses, in relation with need and cost.

The ventilation air treatment system consists of several ventilation (only circulating and cooling) and purification circuits gathered in 3 main streams :

a) The reactor building ventilation system (VBR)

The reactor containment ventilation systems are intended to :

- provide within the containment, conditions of temperature, hygrometry and pressure making access and operation possible without hindrance from the nuclear boiler;

- in the event of radioactive contamination of the atmosphere within the reactor containment, reduce the activity of the air, thus reducing the start-up interval of the purging ventilation;

- compensate the variations occuring during the full power operation of the power plant, between the pressure within the containment and the atmospheric pressure.

The ventilation of the reactor containment does not fulfill a safety function and is not used in reference accident conditions. It operates in a closed circuit, within the containment, when the conditions of temperature and pressure in the primary circuit are such that they could give rise to a reference accident; the open purging circuit operates only when these conditions are not achieved.

b) The annular space ventilation system (VEA)

It is the space between the two concentric containments around the reactor building.
It also includes the ventilation of the emergency rooms.

The ventilation circuits of the interspace of the double containment are intended to :

- maintain, save for accident conditions, specific temperature, hygrometry and pressure conditions and evacuate possible traces of contamination;

- maintain, in the event of an accident, temperature conditions enabling the normal operation of equipment located in the interspace of the double containment, especially those in the safety rooms;

- maintain, under normal operating conditions and accidents, the underpressure in the interspace of the double containment;

- collect activity leaking from the inner shell and leaks from open pipes to the containment atmosphere in the event of an accident accompanied by overpressure;

- discharge these leaks, after filtration, under conditions ensuring a good atmospheric dilution;

- authorize access to any of the safety rooms in the event of an accident accompanied by overpressure and characterized by a slight release of activity.

c) The auxiliary buildings ventilation systems

which can be subdivided into :

- ventilation of the auxiliary building VBA;
- ventilation of the pool building VBP;
- ventilation of effluents storage building VBA Tihange 2,VBY Tihange 3;
- ventilation of laboratories VBL.

The ventilation circuits of the nuclear auxiliaries buildings are intended to:

- maintain the ambiant temperature and hygrometry within specific limits when the equipment or the staff accessibility so require it;

- limit the concentration in the air of radioactive elements within the buildings and during normal operation of the power plant, to less than a fixed threshold to enable accessibility by staff;

- stop contamination spreading from a contamined room to one slightly or not contaminated;

- keep the rooms in underpressure in relation to the outside atmosphere so as to avoid any unexpected escape of potentially radioactive air;

- ensure the evacuation of the air extracted from the rooms via the unit stack;

- limit the radiological consequences of maintenance accidents in the spent fuel pools.

Moreover, the function of the ventilation system in unit 2, following an accident requiring the isolation of the reactor containment, is to maintain in a state of underpressure the auxiliaries buildings adjacent to the reactor building, collect the radioactive leaks by by-passing the interspace by means of isolation devices and, after filtration, expel the air via the stack.

This function is not required in unit 3 since the by-passing of the interspace is avoided by a system increasing the pressure of the isolation valves thus avoiding leaks through these barriers.

Measures are taken to limit the spread of fire and fumes through the ventilation ducts.

III.2.2. Description of the Circuits and Equipment

These descriptions are based on units 2 and 3 of the Nuclear Power Station located in Tihange - Belgium.

Reactor building

The ventilation circuits of the reactor containment are made up of six sets outlined below (see Figure 8).

- closed circuit ventilation of the containment (Tihange 3)

Three axial fans ensure this ventilation.
One of the units is kept on stand-by. Each fan is linked to a cooling coil (3 x 148,000 m^3/h).
The cooling coils are fed with chilled water.
Cooled air is distributed by ducts to the hot points in the containment. The hot air is taken in at the top of the containment.

An excess of cooled air is forced in at the lower part of the containment to facilitate access to this area.

- Ventilation of the vessel and its cavity (Tihange 3)

  Three centrifugal fans (3 x 14,000 m^3/h), one of which is on stand-by, cool the cavity and ring support of the reactor vessel.

  Air is forced in at the lower part of the cavity, rises the height of the vessel and flows through the ring support.

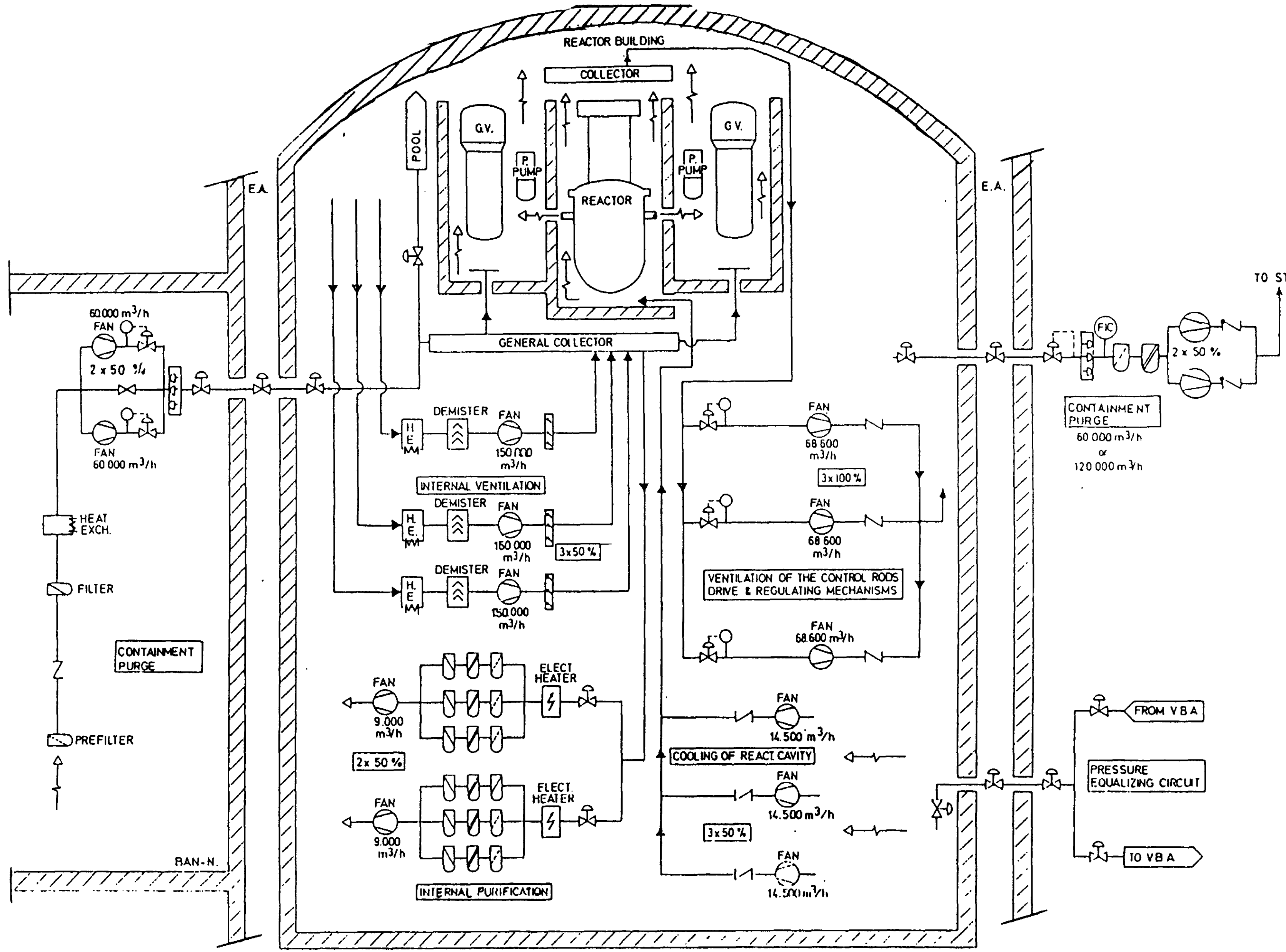


FIGURE 8 : VBR VENTILATION OF THE REACTOR BUILDING

- Ventilation of the control rod cluster mechanisms

  At Tihange 2, three axial fans (3 x about 70,000 m^3/h) are connected to the shroud which envelopes the control mechanisms; two units are on stand-by. Each fan is linked to a cooling coil.

  At Tihange 3, three centrifugal fans (3 x 63,000 m^3/h) are linked to the shroud; ambiant air is aspirated through the shroud and blown towards the top of the BR. Two units are on stand-by. No cooling coils are provided.

- Containment purging ventilation

  The purged air supply is filtered and preheated (at Tihange 3 cooled if necessary); it is forced inside the reactor containment by two centrifugal fans (2 x 60,000 m^3/h) located in one of the nuclear auxiliaries buildings.

  The fresh air intake duct is linked to the fan discharge collector of the closed circuit ventilation system.

  Tapping of this duct means that the access to the reactor containment pool can be ventilated during the cold shut-down of the reactor for reloading.

  At Tihange 2, the exhaust of the purged air is ensured by the BAN's general extraction fans (3 x 81,650 m^3/h).

  At Tihange 3, two specific exhaust fans (2 x 60,000 m^3/h) ensure the exhaust and discharge through the stack, the exhausted air is filtered by pre-filters and absolute filters.

  These fans (TI2 and TI3) expel the air into a leaktight collector linked to the unit stack; the atmospheric releases of the BR occurs at a height of 160 m.

  At Tihange 2, the purged air can be filtered by passing through the filtering devices of the BAN's exhaust ventilation. This is possible only when the purging is done at half capacity. At Tihange 3, separate filters are provided.

  The supply and the exhaust ducts are equipped with containment isolation devices.

- Internal filtration of the reactor containment

  Two centrifugal fans (2 x 9,000 m^3/h) allow the air of the closed circuit ventilation to be drawn into the fans discharge collector prior to discharging it into the containment after filtration.

  This air is filtered by a set made up of pre-filters, absolute filters and charcoal adsorbers.

An electric deshumidifier placed upstream from each filter battery allows the relative humidity of the air to be reduced from 100 % to 70 %..

- Equalization system for pressure variations within the containment

A line connects the reactor containment to the supply or exhaust collectors of the BAN's ventilation system. With this device, air can either be supplied to or purged from the containment with a view to maintaining the pressure as close to the atmospheric pressure as possible. This line is equipped with three containment isolation devices. In the event of air being purged from the BR, the air is filtered prior to being discharged through the stack.

- Annular space

The ventilation circuits of the containment interspace are outlined in Figure 9. These are made up of the three main sets :

a) Ventilation during normal operation

The exhaust fans, which bring the interspace to a state of underpressure, the closed circuit filtration and the safety rooms ventilation fans are at standstill.

During normal operation, the interspace is ventilated by a ventilation circuit which, in the case of Tihange 2 and from an operational angle, is part of the BAN's ventilation circuit and in the case of Tihange 3, is an independent circuit. The air supply and extraction duct shutters of this ventilation system close automatically in phase A in the event of accident. (Phase A corresponds to the safety single providing isolation).

In the case of Tihange 3, two centrifugal fans (2 x 15,000 m^3/h), one on stand-by, allow the air supply.
This air is preheated, pre-filtered, reheated and filtered. Two centrifugal fans (2 x 15,000 m^3/h), one on stand-by allow the air exhaust. Exhausted air is filtered on HEPA filters.
Underpressure is obtained by throttling the air supply.

b) Ventilation in case of accident

The filtration is achieved by three identical systems, one of which on stand-by. Each of them are equipped in series with :

- an electric deshumidifier, intended to reduce the air's hygrometric degree from 100 % to 70 %;

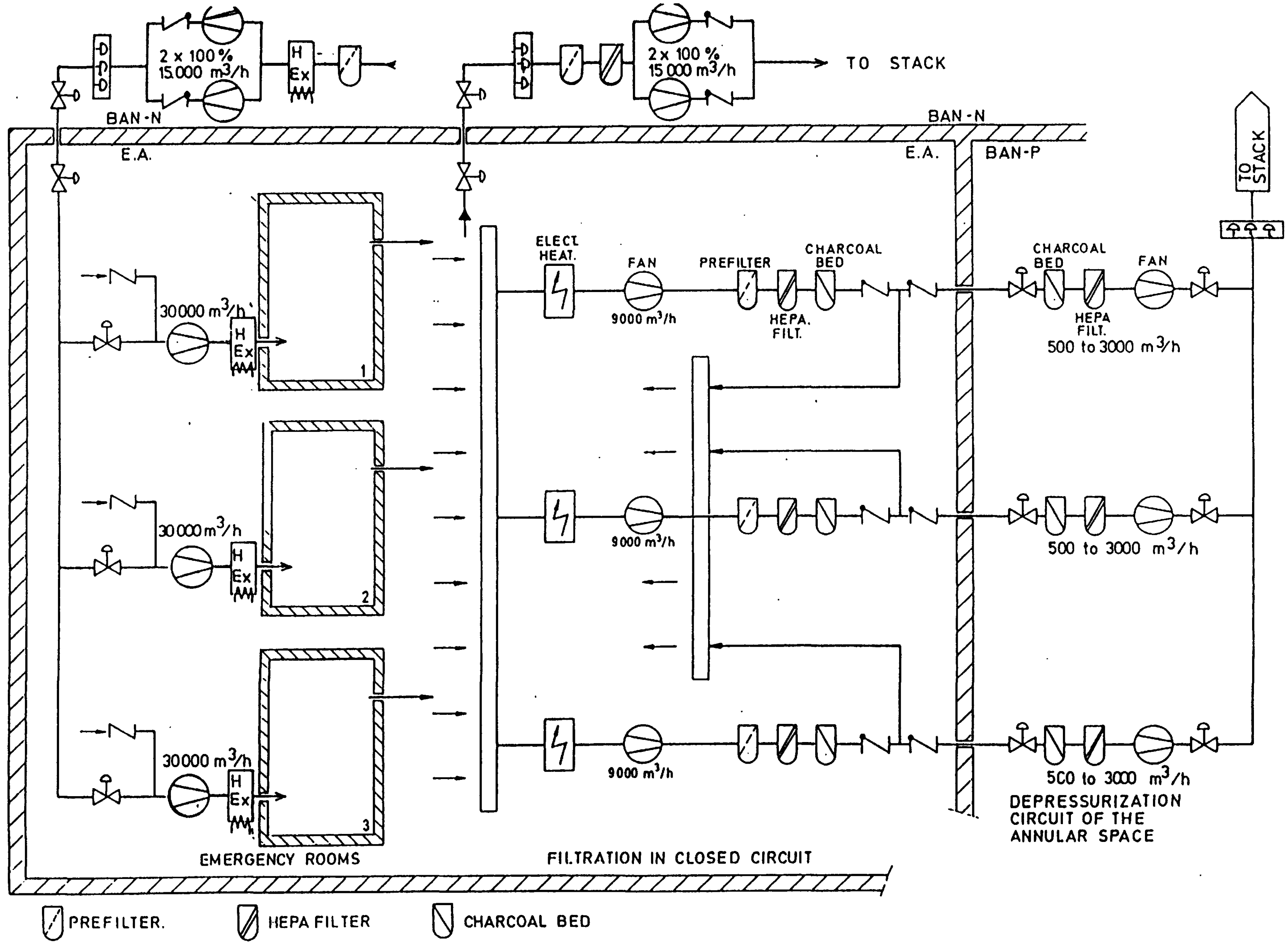


FIGURE 9 : VEA VENTILATION OF THE ANNULAR SPACE

- a centrifugal fan (9,500 m^3/h);

- a filtration battery successively made up of a pre-filter, an absolute filter and a charcoal absorber.

Three identical circuits bring the interspace to a state of underpressure; each circuit is linked to a closed circuit filtration system.

Each circuit consists of :

- an intake duct which takes the air out of a closed circuit filtration device of the interspace downstream from the filters;

- an isolating register;

- a filtration battery equipped in series with a charcoal absorber and an absolute filter;

- an exhaust centrifugal fan (3 x 3,000 m^3/h), one on stand-by followed by a motor operated register. The EA's leaks are discharged into the atmosphere via the unit stack.

The operation of the three filtration and exhaust sub-systems is identical.

For each sub-system, an IEA signal actuates the closed circuit filtration fan. A high flow set point in closed circuit filtration starts up :

- the corresponding deshumidifier;

- the associated exhaust fan bringing the interspace in underpressure (if the filtration fan is properly actuated).

c) Ventilation of the safety rooms in case of accident

The start-up of any of the three safeguard equipment leads to start-up of the ventilation fan in the train concerned.

A typical set of ventilation equipment consists of :

- a water cooled heat exchanger;
- an axial fan (30,000 m^3/h).

Auxiliary buildings (see Fig. 10)

The ventilation circuits ensure :

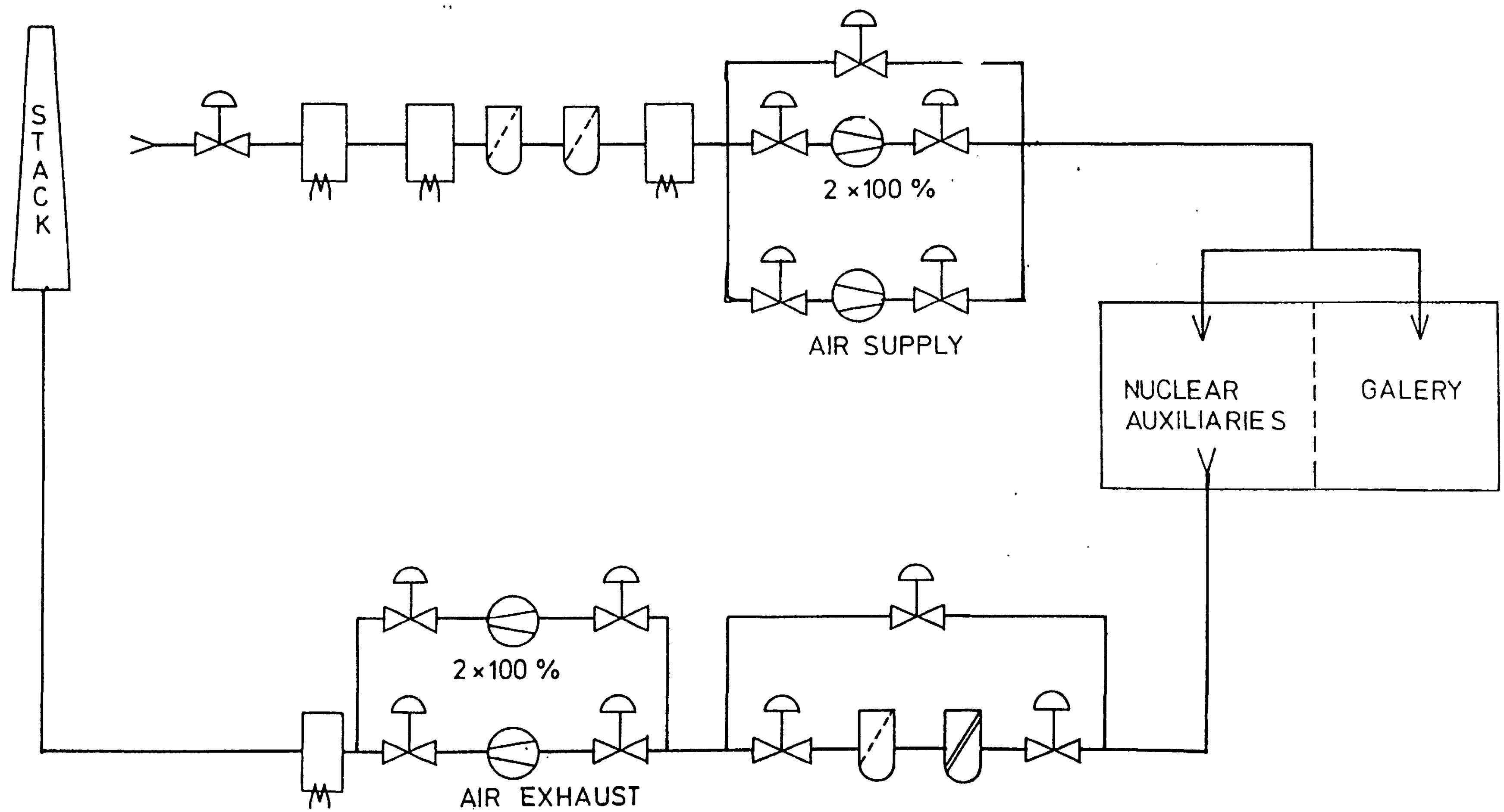


FIGURE 10 : VBA VENTILATION BAN N

- the ventilation of the nuclear auxiliaries building (BAN);

- the ventilation, during normal operation, of the annulus (interspace) in unit 2 whilst that of unit 3 is ensured by a separate circuit;

- equalization of the pressure variations in the reactor containment;

- extraction of the previously examined purging ventilation of the reactor building in unit 2.

The supply air is after preheating, filtering and heating distributed through ducts in the building.

A network of ducts extracts the air from the different rooms.

At Tihange 2, the redundant exhaust air filtration device comprises in series, a pre-filter, a deshumidifier, an absolute filter, a charcoal absorber and an absolute filter. During normal operation, the insertion of filters is done by hand; however, should a high level of activity be detected in the stack or should the phase A containment isolation signal be triggered off, it is then done automatically. In the latter case, the air supply registers close automatically and only one exhaust fan is kept working whilst the superabundant filtration set is isolated by hand.

At Tihange 3, exhaust air is constantly filtered.

In the case of Tihange 2, the equipment is the following :

Three drive fans of 47,200 m^3/h each of a capacity of 50 %.

The common collector at the inlet of these fans is equipped of a pre-heating battery using the heat contained in the extraction air of the BAN, a filter and a heating coil functioning with warm water.

A flow rate of 10,000 m^3/h is directed to the annular space in order to ensure its ventilation in open circuit.

The rest (about 85,000 m^3/h) is pushed in the BAN-N.

A duct to the pressure equalizing system allows to bring the necessary air volume to compensate the possible depression in the containment.

A duct coming from the pressure equalizing system and going to the inlet of the extraction fans of the BAN, through the purification equipment, allows to exhaust from the containment, the corresponding air volume giving air overpressure in the containment.

The purification system is preceeded by three electrical deshumidificators (heaters) in serie, each of 66.5 kW (two of these heaters functioning simultaneously are able to bring the relative humidity from 100 % to 70 %).

Two filtration sets in parallel (each of 100 % capacity) each consisting of:

- 2 sprinklers to protect the filter;
- 2 demisters to prevent the water to reach the filter;
- a filtration battery (capacity 79,800 m^3/h) :
  . pre-filters;
  . absolute filters;
  . charcoal beds;
  . absolute filters;
- a heat recovery system coupled with a demister.

The exhaust of the purging air from the reactor building is directed immediately or after filtration to the inlet collector of the exhaust fans.

Three exhaust fans of 81,650 m^3/h (each of 50 % capacity).

In the case of Tihange 3, the equipment is the following :

Two drive centrifugal fans of 38,100 m^3/h each of a capacity of 100 %. The common collector at the inlet of these fans is equipped of a pre-heating coil using the heat contained in the exhaust air of the BAN, a pre-heating coil functioning with hot water, a filter set and a re-heating coil (hot water).
These two fans assume the air supply in the building.

Two exhaust centrifugal fans of 34,500 m^3/h each of a capacity of 100%. The common collector at the outlet of these fans is equipped of a heat recovery coil.

The exhaust fans are preceeded by a filter set (pre-filters, and absolute filters).

<u>Pool building</u> (VBP) (Fig. 11)

At Tihange 2, the redundant filtering device of the building's extraction air is equipped in series with a pre-filter dehumidifier, an absolute filter, a charcoal adsorber and an absolute filter. During normal operation the filter is inserted by hand; however, should activity in the stack be high, it is done automatically for the air in the spent fuel pool rooms and for the whole building's air when the phase A containment isolation signal is triggered off. In the latter case, the air supply is automatically isolated and only one extraction fan is kept working; the superabundant filtration set is isolated by hand.

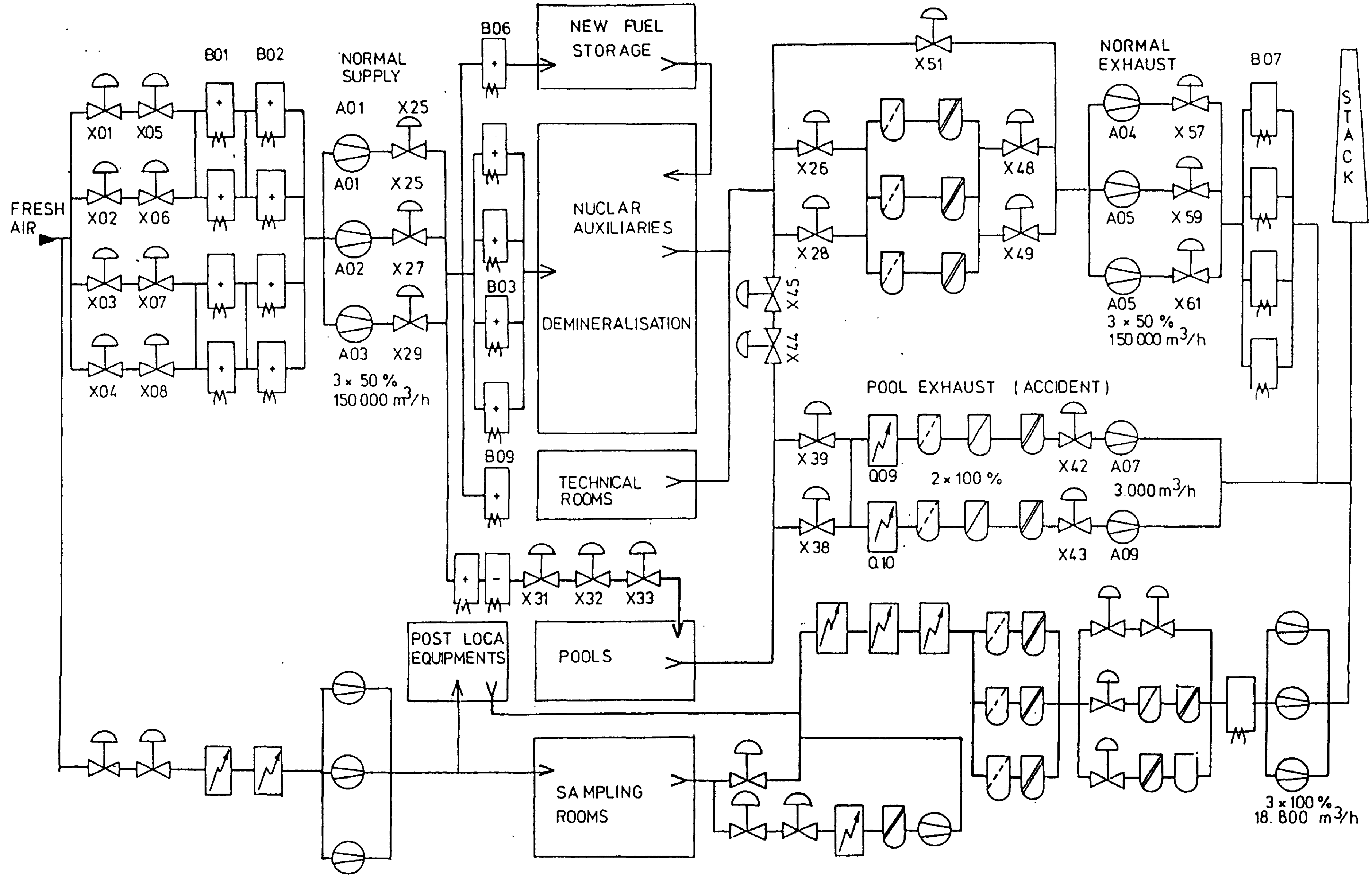


FIGURE 11 : VBP VENTILATION BAN P POOL BUILDING

At Tihange 3, in the event of an accident, the extraction air is filtered and the spent fuel pool hall kept underpressurised, following the shutdown and isolation of the normal ventilation circuits made up of pre-filters and absolute filters, by a special circuit equipped with redundant sets of deshumidifiers, pre-filters, absolue filters, charcoal adsorbers and absolute filters.
Unlike unit 2, the filtration of unit 3's auxiliaries building does not operate in the event of an accident requiring the isolation of the containment; therefore special circuits with filtration facilities are foreseen in the pool building to ensure, in this case, one with complete filtration (pre-filter, absolute filter, charcoal bed) the ventilation of the recombiners'room, the other with pre-filters and absolute filters, the ventilation of the technical rooms working following an accident.

In the case of Tihange 2, the equipment is the following :

- Three drive fans of 44,000 m^3/h, each of 50 % capacity;

- the common collector at the inlet of these fans is equipped of a pre-heating battery using the heat contained in the extraction air of the BAP, a filter and a heating battery supplied with warm water. This equipment as the 3 drive fans are located in the BAN-N;

- The flow-rates in the three separated zones are the following:
  - 6,800 m^3/h for the storage and control room of new combustible;
  - 20,400 m^3/h for the pools' hall;
  - 46,500 m^3/h for the nuclear auxiliary circuits;

- The purification system is preceeded by three electrical deshumidificators (heaters) in line, each of 17 kW (50 % capacity). Two of these heaters simultaneously working are able to bring the relative moisture of the extraction air of the pools' hall (20,400 m^3/h) from 100 % to 70 %;

- Two filtration sets in parallel (each of 100 % capacity) each consisting of:

  - a sprinkler (protection of the filter);
  - a demister (prevent water to reach the filter);
  - a filtration battery:
    - pre-filters;
    - absolute filters;
    - charcoal beds;
    - absolute filters.

  - A heat recovery system coupled with a demister;

- Three extraction fans of 44,000 m^3/h (each of 50 % capacity);

- A connection through the collector of the BAN-N, to the stack.

- In the case of Tihange 3, the equipment is the following :

  - Normal air supply is assumed by three drive fans of 72,370 m^3/h each of 50 % capacity.
    The normal collector at the inlet of these fans is equipped of a heat recovery coil, a heating coil and a pre-filter set.

At the outlet of these fans :

a) a first collector which assumes the flow-rates in three following separated zones :
   - storage zone : 9,600 m^3/h;
   - nuclear auxiliary zone : 98,340 m^3/h;
   - technical rooms : 12,000 m^3/h;

b) a second collector equipped of a filter set, a cooling coil, a heating coil which assumes the air supply of pools'hall 25,000 m^3/h (in case of normal operation).

  - Air supply in case of accident is assumed by three drive fans of 18,800 m^3/h each of 100 % capacity.
    The common collector at the inlet of these fans is equipped of a heat recovery coil, a pre-filter set, a heating coil and a filter set.
    This equipment assumes air supply in rooms where equipment are operating in case of LOCA.

  - Normal air exhaust is assumed by three exhaust fans of 72,370 m^3/h each of 50 % capacity.
    The common collector at the inlet of the fans is equipped of filter battery (pre-filter and absolute filter sets).
    The common collector at the outlet of the fans is equipped of a heat recovery coil and is connected to the stack.

  - Air exhaust in case of accident is assumed by :
    - a common collector equipped of three electrical deshumidifiers in series;
    - a first filter battery equipped of 3 filters sets each of 50 % capacity (filters and absolute filters sets);
    - a second filter battery equipped of 2 filters sets each of 100% capacity (charcoal filter and absolute filter sets);
    - three air exhaust fans of 18,800 m^3/h each of 50 % capacity;
    - a common collector to the stack.

- In case of spent fuel handling accident, exhaust of the poolrooms is assumed by a 2 x 100% redundant system composed of :

  - demister;
  - electrical deshumidifier;
  - pre-filter, HEPA filter, charcoal bed;
  - exhaust fan.

<u>Effluents storage building</u> (Fig. 5)

- In the case of Tihange 2 :

  The effluent storage building is a component of the Nuclear auxiliary building BAN.

- In the case of Tihange 3 :

  Three normal air supply fans of 61,800 m^3/h, each of 50 % of capacity.
  The common collector at the inlet of those fans is equipped of a heat recovery coil, a pre-heating coil, a pre-filter set, a filter set and a re-heating coil.

  Three normal air exhaust fans of 61,600 m^3/h, each of 50 % of capacity. The common collector at the inlet of these fans is equipped of a filter battery (N + 1 filter and absolute filter sets). A common collector at the outlet of the fans is connected to the stack.

  The air exhaust of the Primary Sample Rooms is assumed by two identical air circuits, each of 100 % :
  - the collector at the inlet of the exhaust fan is equipped of an electrical deshumidifier and a filter battery (pre-filter, absolute filter, charcoal filter and absolute filter sets);

  - an exhaust fan of 3,800 m^3/h;

  - the two outlet collectors are connected to the normal exhaust collector.

  In case of failure of a fan, an alarm actuates in the control room and the reserve fan starts up automatically.
  One of the two exhaust fans of sample room is only operating when samples are done.

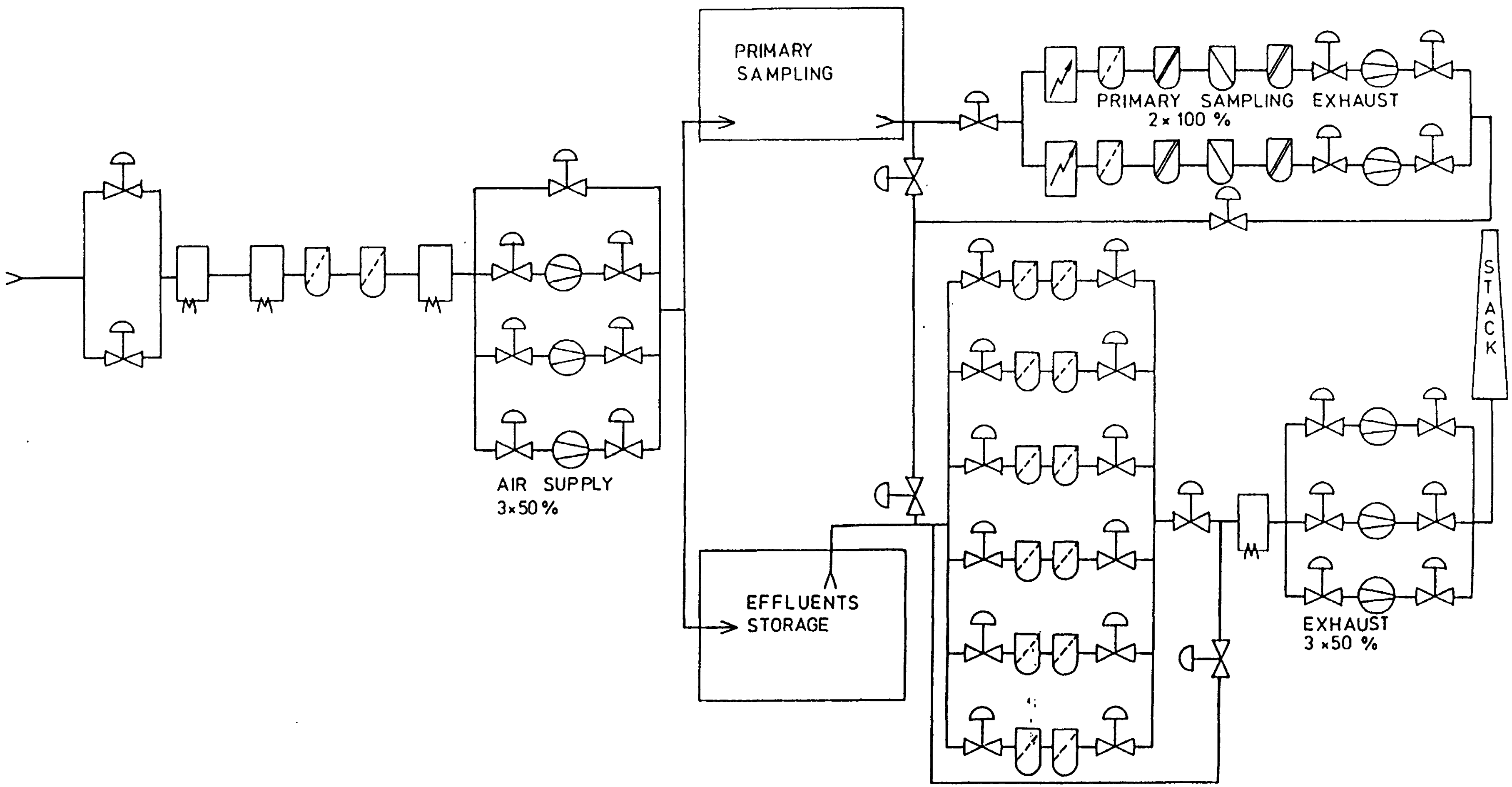


FIGURE 12 : VBY VENTILATION EFFLUENTS STORAGE BUILDING

Laboratories and other contaminable rooms

The laboratories' ventilation circuit treats :

- at unit 2, the laboratories, cloakrooms, washrooms, hot and cold decontamination workshop, BAN's hall, lab and bunker penetrations and offices in building V;

- at unit 3, hot and cold laboratories and associated offices, whilst rooms corresponding to other rooms mentioned for unit 2 are ventilated by the main BAN's circuits.

The function of this installation is :

- to keep the ambiant conditions within the specified limits and ensure the comfort of the occupants and the good working order of the equipment;

- ensure the filtration and discharge at stack of the air extracted from the rooms;

- ensure at Tihange 2 that the rooms housing the circuits from the reactor containment are brought underpressurised.

- At Tihange 3, the following functions are assumed :
  - Air supply of the hot and cold laboratories by 2 air supply fans of 14,750 m^3/h, each of 100 % of capacity.
    The common collector at the inlet of the fans is equipped of a heating coil, a pre-filter set, a filter set, a humidifier, a cooling coil, a re-heating coil.

  - Air exhaust of the cold laboratory by 2 exhaust fans of 8,000 m^3/h, each of 100 % of capacity. The outlet of the fans are connected to out-door.

  - Air exhaust of hoods in the hot laboratory by 2 exhaust fans of 1,600 m^3/h, each of 100 % of capacity. The outlet of the fans are connected to the common collector at the inlet of the exhaust fans of hot laboratory.

  - Air exhaust of hot laboratory by 2 exhaust fans of 6,160 m^3/h, each of 100 % of capacity. Each collector at the inlet of a fan is equipped of an electrical deshumidifier, a 1 x 100 % filter battery (pre-filter, absolute filter, charcoal filter and absolute filter sets).

Features of the filtration equipment for the reactor containment and nuclear auxiliaries buildings

a) Pre-filters and absolute filters

The pre-filters and absolute filters are made of fiberglass. They consist of cells installed in boxes with leaktight lock chambers.

The absolute filters downstream from the charcoal adsorbers are made of cells installed either in boxes with leaktight lock chambers or on a platform according to the space imperatives.

The boxes with leaktight lock chambers have compartments each intended to house a filter cell.

The leaktightness of the boxes and filtration chambers is checked in the factory.

Moreover, the filters are subjected to an efficiency test on site. In the safety calculations, account is taken of a 99.9% efficiency for one single filter and 99.99 % for two filters in serie.

b) Charcoal adsorbers

The charcoal adsorbers are either made up of cells installed in boxes with leaktight lock chambers or are of the rechargeable kind for high flow rates.

In this case, the upper compartment of the iodine filter is filled so as to obtain a layer of activated charcoal above each bed and to avoid any by-pass leak from the iodine filter. The filters are sized so as to obtain an air stream velocity through then > 0.2 m/s.

The charcoal adsorber characteristics are :

1) the sets can fulfil their function under ambiant conditions to which they are exposed; more particularly, necessary measures are taken so as to reduce the hygrometric degree of the air to be filtered to 70 %;

2) the efficiencies attributed to the charcoal adsorbers in the safety calculations are 85 % for molecular iodine and CH_3I and this for a relative humidity of 70 %.

For filters with a 2 inches thick charcoal bed and a relative humidity of the air of 70 %, the efficiency required in situ is greater than the value considered in the event of accident.

III.3. Discharge of Gaseous Effuents into the Environment

Relying on the decontamination performances and the storage capacity of the treatment systems implemented at Tihange for primary off-gas and ventilation air, the discharges of radioactivity as airborne effluents into the environment comply with the discharge limits established in chapter II.

The precise figures of discharges including the radionuclide composition are reported in the volume 5 of the series together with the determination of the radiological impact resulting from releases (individual and collective doses) in the area around Tihange. In order to cope with possible variation in activities and volumes arising during normal operation of the plant, the determination of the radiological impact encompasses several possible discharge cases.

CHAPTER IV

MANAGEMENT OF LIQUID EFFLUENTS

Although most of the radioactive materials originate and are retained within the reactor fuel elements, a small fraction of the radioactive materials may escape from the fuel through cladding defects into the primary coolant.

In addition, radioactive materials may be present in the primary coolant due to the neutron activation of corrosion products and chemical additives such as boric acid.

Small amounts of radioactivity may also be present in the primary coolant from activation products of the primary water itself but this activity may be neglected as far as effluents are concerned because of their very fast decay.

Radioactive materials are transported from the primary system to auxiliary liquid systems through process operations, equipment drains, or equipment leakage. These streams represent the bulk of routine liquid waste effluents generated during reactor operation.

There are many other miscellaneous sources of liquid waste of small routine importance but which under special circumstances can raise significant problems. Examples are the large volumes of water used for shielding during refueling operations, wastes from decontamination operations, the showers for the personnel, the laundry, analytical laboratory, fuel storage pool,...

IV.1. Functional Design

The basic handling of the liquid effluent treatment system essentially consists of two subsystems which handle respectively the recoverable and no recoverable effluents.

The recoverable effluents, i.e. the non-aerated primary effluents, are normally processed to give two recyclable outputs :

- degassed and demineralized water;
- concentrated solution of boric acid.

The non recoverable effluents are discharged into the river, in accordance with the site regulations, either directly or after processing, depending upon their characteristics. Residues from processing are sent to the solid waste treatment system.

Each subsystem is designed in such a way that the following functions are ensured:

- collection of all incoming liquid effluents from all sources;

- segregation of incoming liquid effluents according to their origin and treatment line;

- storage of segregated incoming liquid effluents prior to processing;

- processing of incoming liquid effluents to remove radioactive contaminants (gaseous, soluble, non soluble);

- removal of dangerous or noxious non-radioactive compounds in view of :
  - possible re-use of treated fluids;
  - release of treated fluids to the environment within allowable limits;

- fluids recycling for additional treatment when unsatisfactory results are obtained;

- collection of :
  - concentrated forms of radioactive contaminants;
  - concentrated forms of dangerous or noxious components;
  - secondary wastes;

- transfer of these concentrated forms and secondary wastes to other adequate systems :
  - for further processing and conditioning;
  - in view of their evacuation from the nuclear power plant site.

When selecting the equipment for liquid effluents treatment, consideration must be given to the further processing of concentrated waste before ultimate disposal.

Concentrated radioactive effluents are solidified in the solid radioactive waste management system and prepared for off-site shipment and disposal.

Liquid effluents costs will be affected by the volume reduction requirements that might be necessary to facilitate efficient and economic packaging of these solidified wastes.
Volume reduction equipment will vary, depending on the specific philosophy of the overall radwaste management scheme and might include simple dewatering equipment, evaporators and/or more complex components such as dryers or calcination units.

At Tihange, the maximum concentration of the solid part at the evaporator outlet is 350 g/l.

Further, in the TDS, section (Treatment of Solid Waste) this concentration can reach higher value, by means of a concentrator.

Since the concept of volume reduction can significantly affect the economics of both liquid and solid waste management systems, it should be analyzed in detail during the early stages of radwaste system design.

IV.2. Characterisation of Radioactive Liquid Wastes

Among radioactive liquid wastes generated in a PWR plant, five categories may be distinguished and will be characterized hereafter. As it will be seen, the first category is normally processed in view of its recycling in the reactor.

On the contrary, processing of the other categories leads, on the one hand, to the release of the decontaminated water into the environment and, on the other hand, to the disposal of active residues.

Category 1 (Primary - Recoverable effluents)

This effluent category is constituted by primary water let down or leaking from the Reactor Coolant System or its auxiliaries (chemical and volumetrical control system,...) and collected without contact with air.

These effluents thus contain dissolved boric acid (50-3,000 ppm) and hydrogen (max. 50 cm^3/kg).

They are normally processed for recovering boric acid solution and demineralized/degassed water of such a quality that they can be then recycled in the reactor.

These effluents result essentially from the discharge of excess primary water into the CPU :

- due to the temperature rise of the primary coolant during the start-up period;

- during the boron content modification in the primary coolant circuit.

Radioactive contaminants in these effluents are activated corrosion products, impurities (dissolved or as suspended solids) and possibly fission products, depending on the integrity of the fuel elements cladding.

The maximum activity of the primary effluents is the same as this of the primary coolant (see Table III of Chapter II)

The other characteristics of primary effluents are the following :

- solids in suspension :
  * in normal situation : 10^{-2} to 10^{-1} mg/l
  * in case of start-up : 10^{-2} to 15 mg/l
  * grain size : in the worst case : 70 % are < 1 μm

- H_3BO_3 content : 10 to 3000 ppm

- LiOH content : 0.22 to 2.2 ppm

Category 2 (Primary drain effluents)

This effluent category is constituted by waters similar to the first category but which cannot be collected without aeration; these waters normally do no longer contain any significant amount of hydrogen.

They consist of depressurized waters (draining, emptying, leak-off,...) from the main auxiliary nuclear systems, from the liquid effluents treatment circuits and from the flushing of the ion exchange resins.

They consist, in particular, of effluents produced by :

- de-packing of the demineralizers;
- draining of water used to transport the resins at the time of the charging of a demineralizer;
- the leak of the loading pumps of the CCV;
- the draining of the filters at the time of replacing of the cartridges;
- the overflow and draining of tanks;
- the nuclear sampling circuits;
- etc...

The characteristics and activity of the drains effluents are roughly the same as these of the primary effluents.

In some cases, clear water coming from the chemical treatment of the third category is also added.
The maximum activity level normally remains below 10-15 Ci/m^3.

Category 3 (Chemical effluents)

This effluent category consists of waters loaded with specific but variable chemicals. These solutions are coming from the:

- laboratory drains;

- the decontamination of rooms or systems;

- regeneration of resins (deboration and cationic resins of the demineralizers of the steam generator draining - P.G.V.);

- the chemical circuit rinsing and draining, etc.

Their maximum expected activity lies within a range of a few curies per m^3.
The mean value lies between 10^{-4} and 10^{-1} Ci/m^3.

- The characteristics of these solutions are variable. They can contain, in variable quantities, hydrogen, fission and corrosion products, H_3BO_3, NaOH,

$KMnO_4$,$_2CrO_4$, $(NH_4)_3C_6H_5O_7$.
The maxima contents in these compounds can separately reach the following values :

H_3BO_3	2 to 4 %
Chromates	150 to 200 ppm
NaOH	5 to 10 %
$KMnO_4$	3 to 5 %
$(NH_4)_3C_6H_5O_7$	20 to 25 %

The chemical effluents with the two first compounds or the three last ones are usually gathered

The chemical effluents can consist of the following decontaminating solutions :

Oxidizing solutions

Solution of 240 g/l of :

$KMnO_4$	4.6 %
NaOH	7 %
KOH	67.2 %
various salt of K	10.5 %
chlorides	0.1 ppm

Complexing solution

Solution of 65 g/l of :

oxalic acid	70 %
citric acid	10 %
NH_4OH	20 %

Category 4 (Service effluents)

This effluent category consists of various soiled waters collected in the nuclear system buildings. It groups the effluents from non-active systems, rinsing water circuits, floor drains, floor rinsing operations, accidental leaks from auxiliary nuclear circuits in the sumps of the BR, the BAN-N and BAN-P, etc, located inside the nuclear system buildings.

Among these effluents, we also find detergents and solid particules coming from:
- effluents from the laundry;
- water from the showers and washbasins in changing rooms in the "hot" area.

Normally, these waters are not contaminated but require an activity check before release.

The collected waters in the reactor building have the same maximum activity as the primary coolant, gases excluded.

The waters collected in the auxiliary buildings have a mean activity equal to the tenth of the primary coolant's one, gas excluded.

Furthermore, it is assumed that the production of service effluents in the reactor building is the fifth of the auxiliary buildings'one.

IV.3. Main Features of the Process

IV.3.1. Collection System

The collection system for liquid effluents is mainly characterized by individual headers for their various effluent categories, leading them to separated storage capacities in the Liquid Waste Treatment System (see Fig. 13).

Discharges from the pressurizer relief and safety valves, as well as from the safety valves of other systems located in the Reactor Building are received, condensed and cooled in the pressurizer relief tank, where a nitrogen atmosphere is maintained to avoid oxygenation of the water. The content of the pressurizer relief tank is pumped towards the liquid waste treatment system with further cooling (Tmax = 50°C) in a heat exchanger.

Recoverable primary effluents originated in the Auxiliary Building issued from the CPU, are also received directly in the TEP.

The primary drain effluents originated in the reactor building and in particular valve stem leak-off, are received in a collecting tank, where they are cooled by recirculation through a heat exchanger before to be transferred to the liquid effluent Treatment System (TEU drains).
Other primary drains effluents are collected in two collecting (buffer) tanks located respectively in the auxiliary building (BAN-N) and in the fuel building (BAN-P). These tanks are connected to the headers of the drain effluents circuits located in the BAN-N.

Two headers for chemical effluents are located in the auxiliary building, collecting the chemical drains partly from a buffer tank (about 1 m^3) and partly by gravity and leading them by pumping to the treatment system. These headers (each of 40 m^3) may possibly receive water leaked or drained from the component cooling system. This water containing corrosion inhibitors is prealably collected in two monitoring tanks (one in the reactor building, one in the auxiliary building). Usually, it is sent back to the chemical effluent storage tanks. However, should an abnormally high activity be detected or should the water have become chemically improper for re-use, it is discharged to the chemical effluents headers.

Service effluents are collected by the floor drains systems and flow by gravity to the sumps provided in the reactor building, the auxiliary building and the fuel building. They are taken up by the sump pumps to the service effluents headers (two tanks of 40 m^3 each) which leads them to the liquid effluents

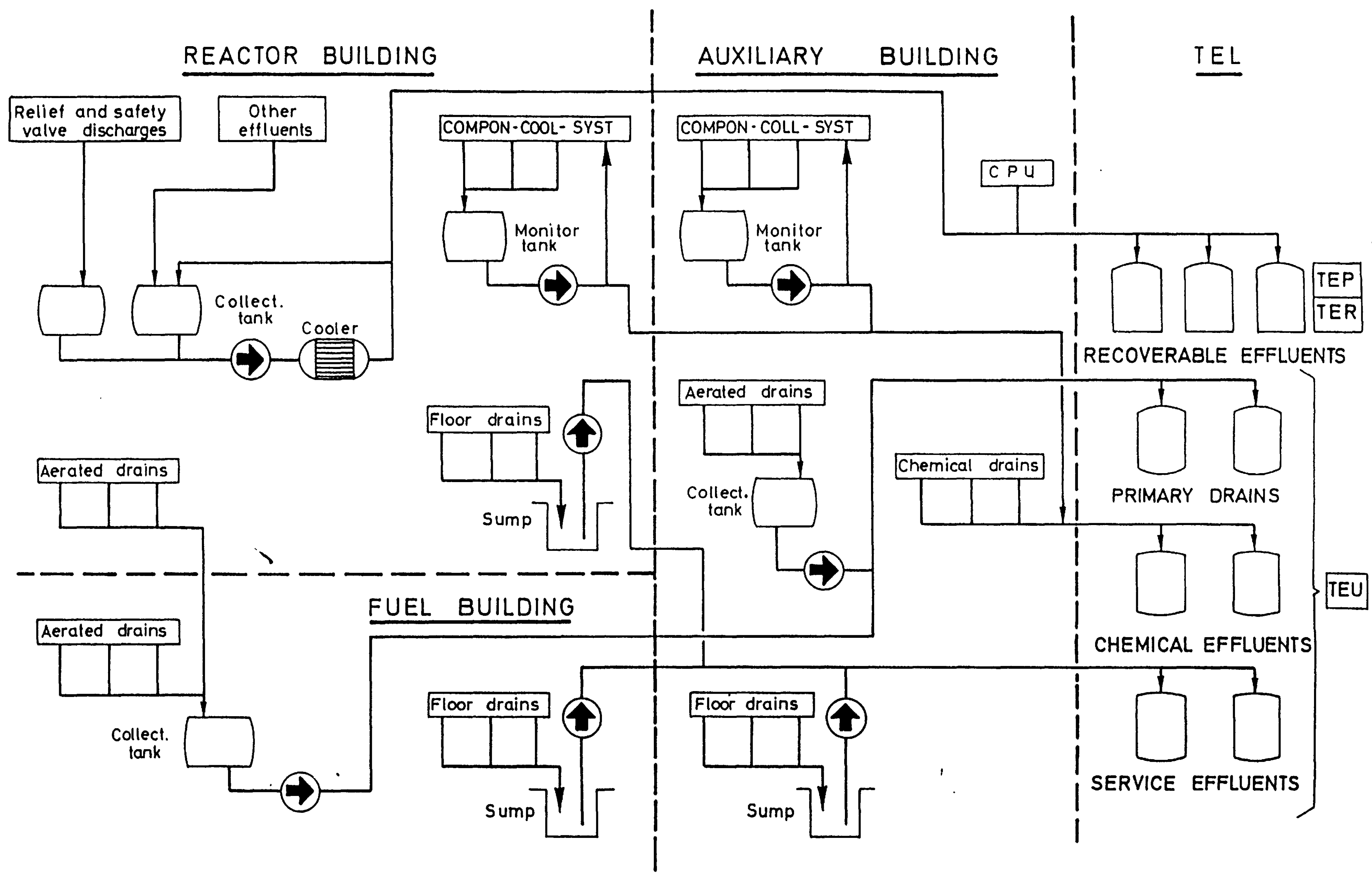


FIGURE 13 : LIQUID RADWASTES COLLECTION SYSTEM

treatment system (TEU).

The liquid effluent treatment system located in the Tihange 2 power plant buildings is designed to treat all the liquid effluents of two plants (Ti2 and Ti3) but the storage of all effluent categories takes place in each plant by means of the respective headers.

Because of this situation the following engineering characteristics are installed:

- for effluents categories 2, 3 and 4, two stainless steel collectors connect the treatment of liquid effluent storage tanks of Tihange 3 to that of Tihange 2;

- the third collector is used solely to transfer primary effluents towards the TEP line at Tihange 2. It is fed by 3 pumps at a nominal flow-rate of 6 m^3/h for transfer;

- the fourth collector is used to transfer effluents, ready for release into the river, from one unit to the other (for example, when the river is at low water). It can thus operate in two directions;

- a single TER collector connects the boric acid recovery line at Tihange 2 to the storage facility at Tihange 3;

- It has the following characteristics :
  - diameter 2";
  - material : stainless steel 304 L;
  - electrical tracing.

IV.3.2. <u>Waste Inputs</u>

The waste amounts mentioned hereafter for each category are typical of a 900 MWe PWR.

<u>Primary effluents</u>

The total volume of the effluents produced in one plant during one cycle of 330 days involving for example :

- 7 hot shut-down extending over 8 hours each;
- 7 hot shut-down extending over 90 hours each;
- 2 cold shut-down;
- 1 refueling shut-down,

can be estimated approximately at 4,000 m^3.

The treatment system equipment is designed to be able to treat 34,500 m^3/y of primary effluents (see Fig. 14).

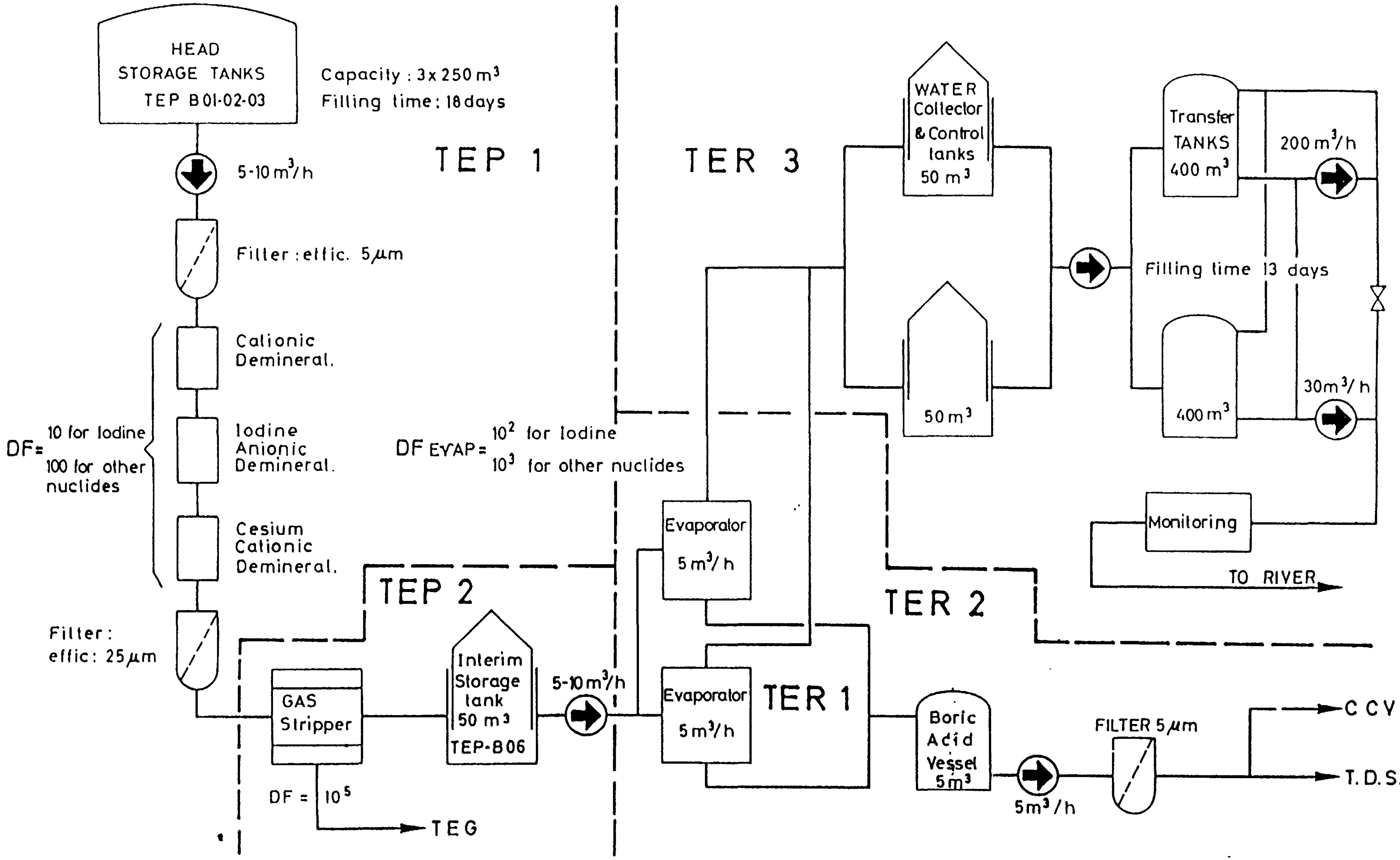


FIGURE 14 : PRIMARY EFFLUENTS PRINCIPLE (TEP-TER)

This treatment capacity takes into account the possibility to follow, in one of the two plants, a load profile 100 % - 50 % of the nominal power as follows :

- 16 hours at 100 % of the nominal power;
- 8 hours at 50 % of the nominal power.

In order to limit the volume of the primary effluents, it is supposed that this "load follow" is only performed when the boron content in the primary coolant circuit is higher than 400 ppm.
The effluent production is then increased of 8,700 m^3/y with a minimum of 30 m^3/day at the beginning of the cycle and a maximum of 65 m^3/day when the boron content reaches the value of 400 ppm.

Under the above conditions, the total amount of produced primary waste in one unit ranges around 17,000 m^3/year.

Drain effluents

The daily production rate of miscellaneous wastes varies between 10 and 12 m^3; the corresponding yearly amount is about 4,000 m^3/unit (see Fig. 15).

Chemical effluents

The yearly production amount of chemical waste is about 2,000 m^3 (see Fig. 16).

Service effluents

The daily production rate of service effluents approaches 20 m^3 during refueling periods (see Fig. 17).

The resulting total amount in a year is equal to 6,000 -10,000 m^3, among which about 1000 m^3 come from laundry alone.

N.B. : the rinsing water used in the laundry are directly transferred in the storage tank before discharge as long as the activity detected in the washing water remains below a fixed unit (about 10^{-5} Ci/m^3).

IV.3.3. Storage Capacities

Primary effluents

In each PWR-unit, the primary effluents are collected in three storage tanks, located in the respective power plant :

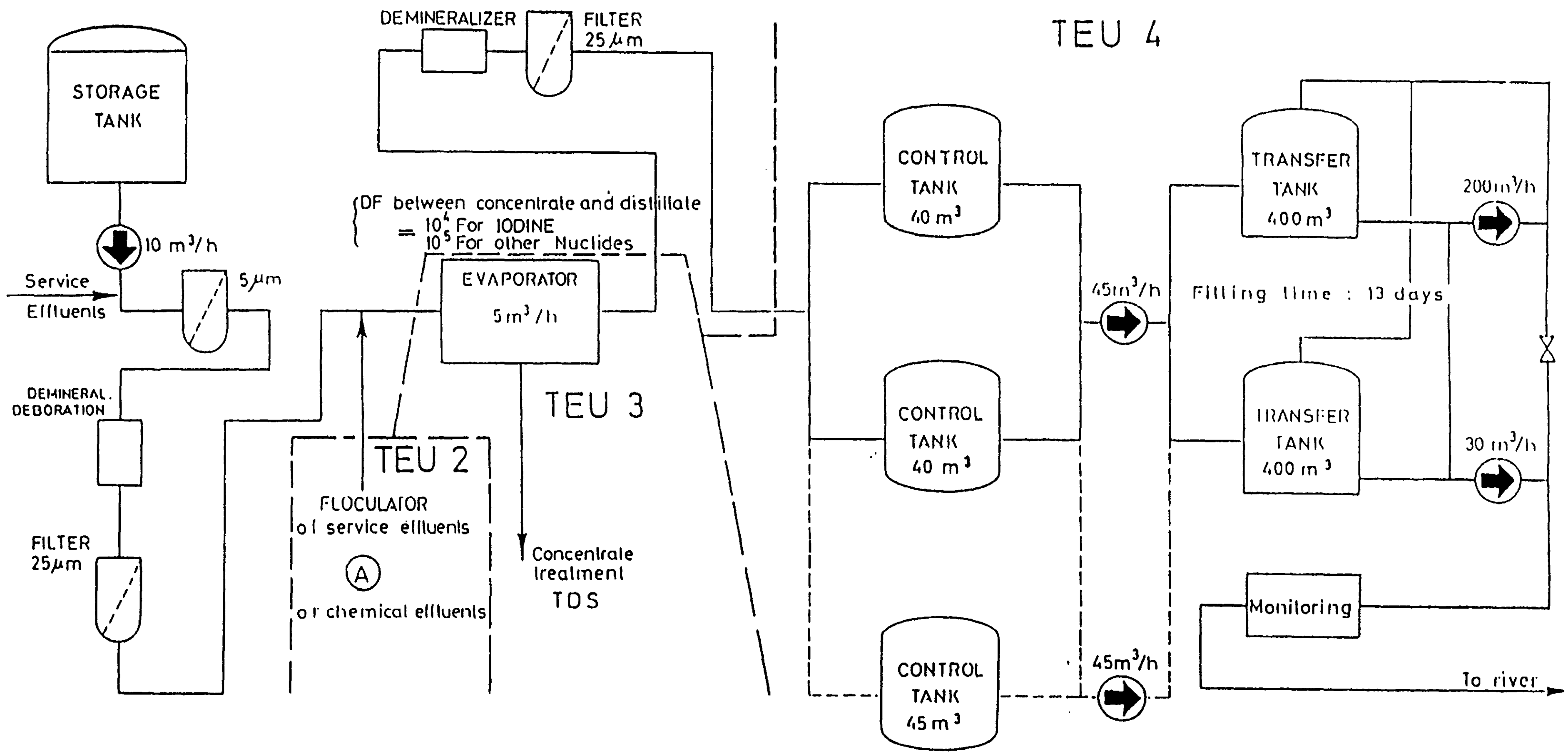


FIGURE 15 : TEU : DRAIN EFFLUENTS PRINCIPLE

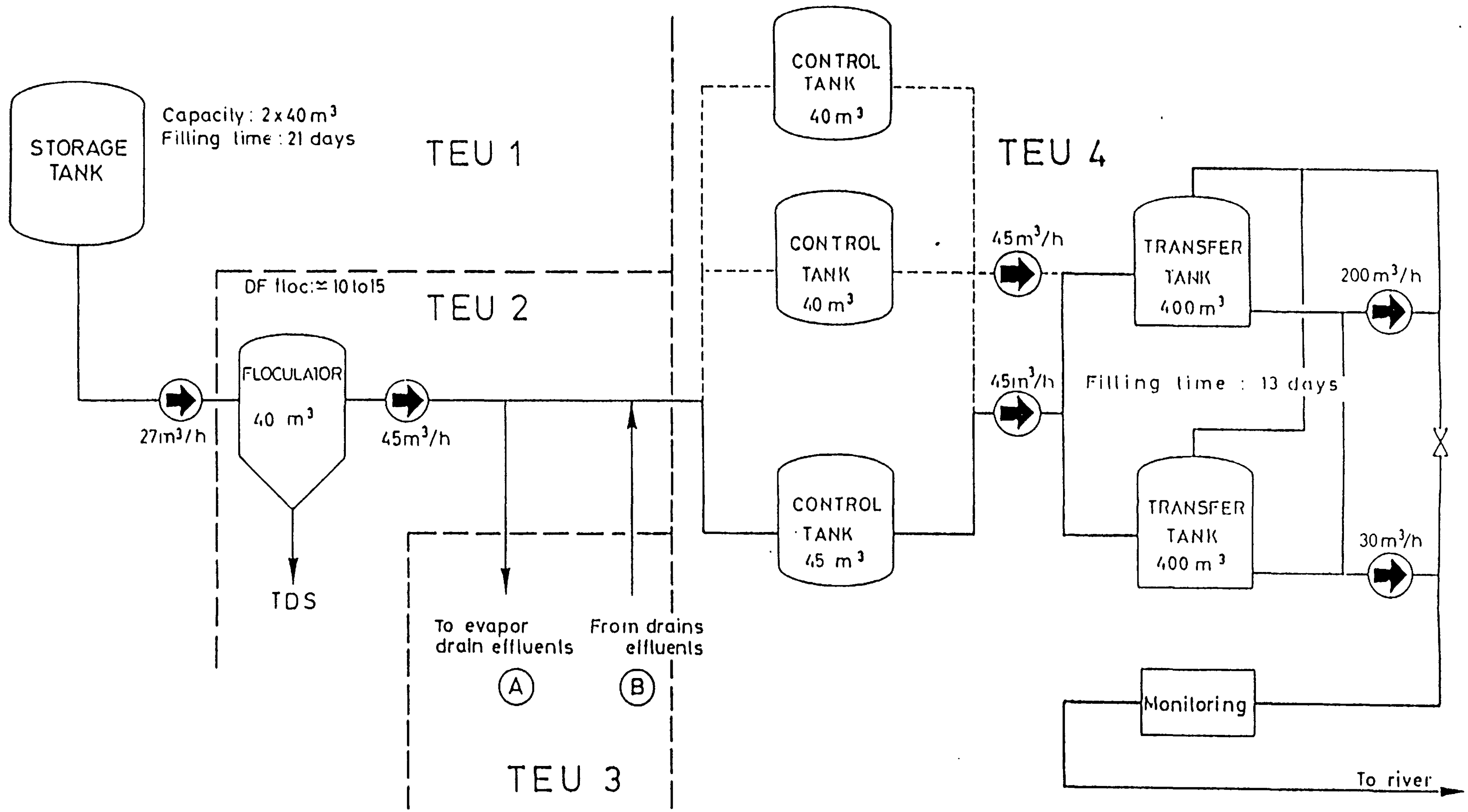


FIGURE 16 : TEU : CHEMICAL EFFLUENTS PRINCIPLE

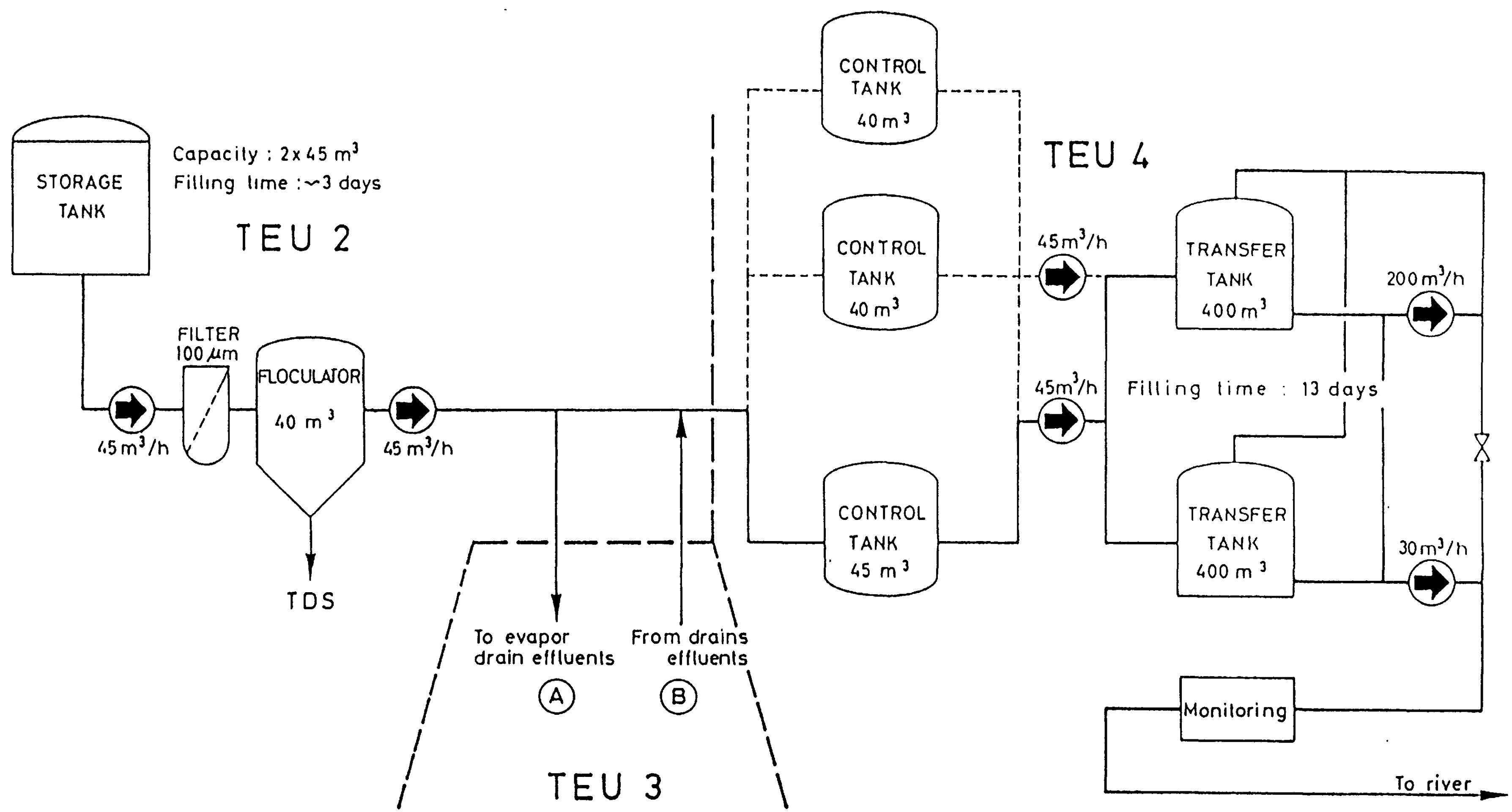


FIGURE 17 : TEU : SERVICE EFFLUENTS PRINCIPLE

- for Tihange 2 : TEP BO1 - BO2 - BO3
- for Tihange 3 : TEP BO1 - BO2 - BO3
  each of 250 m^3 max (200 m^3 useful).

These tanks are the headers of the TEP (Figure 18).

The effluent treatment mode is a batch processing; each batch corresponds to the continuous treatment of one of the header.

The storage capacity for the primary effluents of Tihange 2 is determined as follows :

It must correspond to the quantity of effluents produced during the following plant operations :

- start-up extending over 90 hours after a hot shut-down at a boron content of 280 ppm in the primary coolant;

- 30 days operation following a load profile of 100 % - 50 % of the nominal power respectively 16 hours and 8 hours;

- cold shut-down during 3 days;

- start-up and rising to the nominal power;

quantity of which, the volume treated in this period must be substracted; taking into account that :

- the treatment chains of Tihange 2 operate by halves the effluents produced in Tihange 3;

- the treatment chains are unavailable during 10 days.

In these conditions, the capacity of the TEP headers corresponds to 750 m^3, that is 3 x 250 m^3.

<u>Control tank</u> (interim storage)

Before the transfer of the TER circuit, an intermediate storage tank of 50 m^3 (TEP BO6) is installed which allows to control the efficiency of the TEP treatment (see Fig. 19).

The possibility of recycling via the transfer pumps exists in case of unsatisfactory control results.

<u>Drains and miscellaneous effluents</u>

In each PWR-unit, the drains effluents are collected in two storage tanks

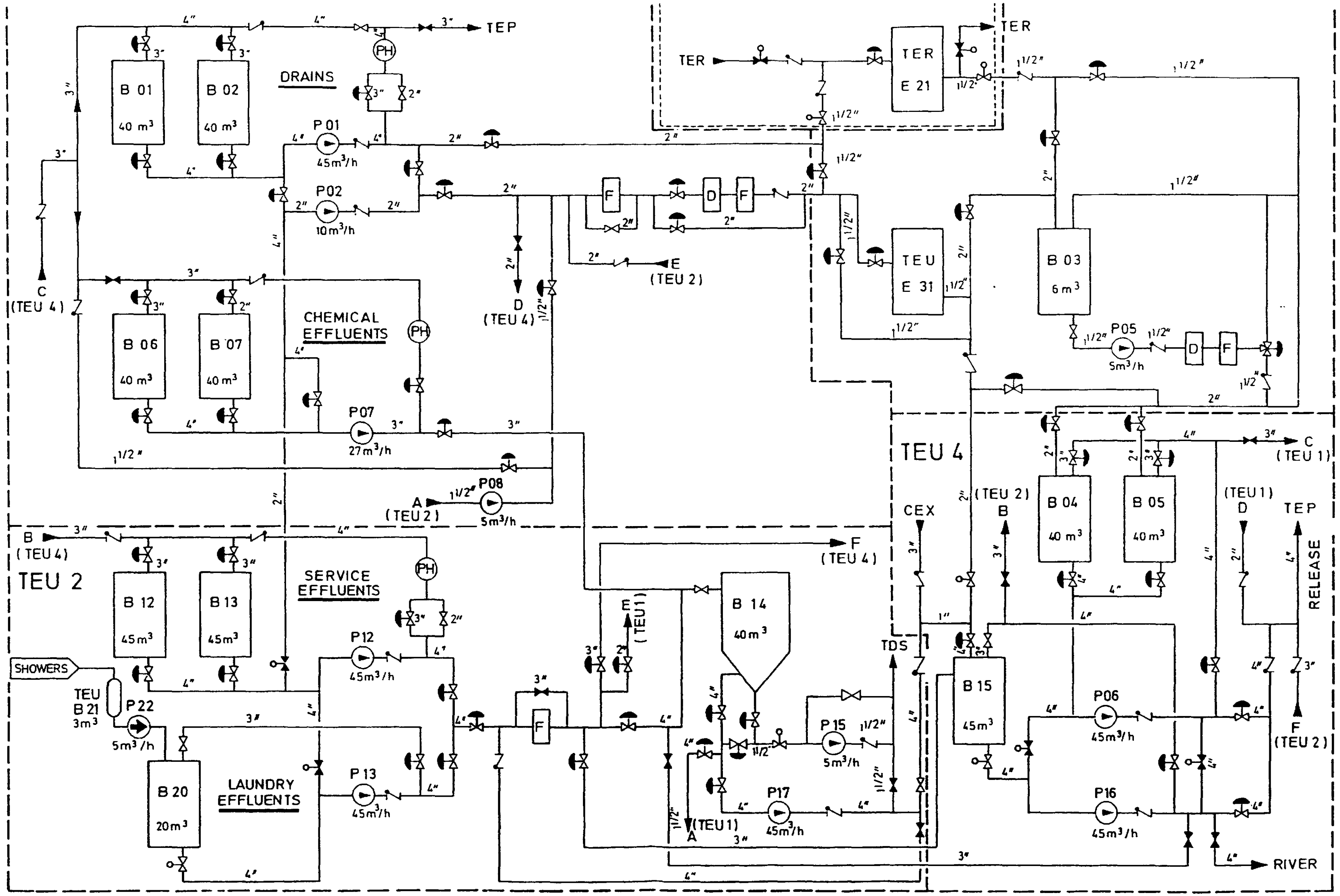


FIGURE 18: LIQUID WASTE TREATMENT TEP 1

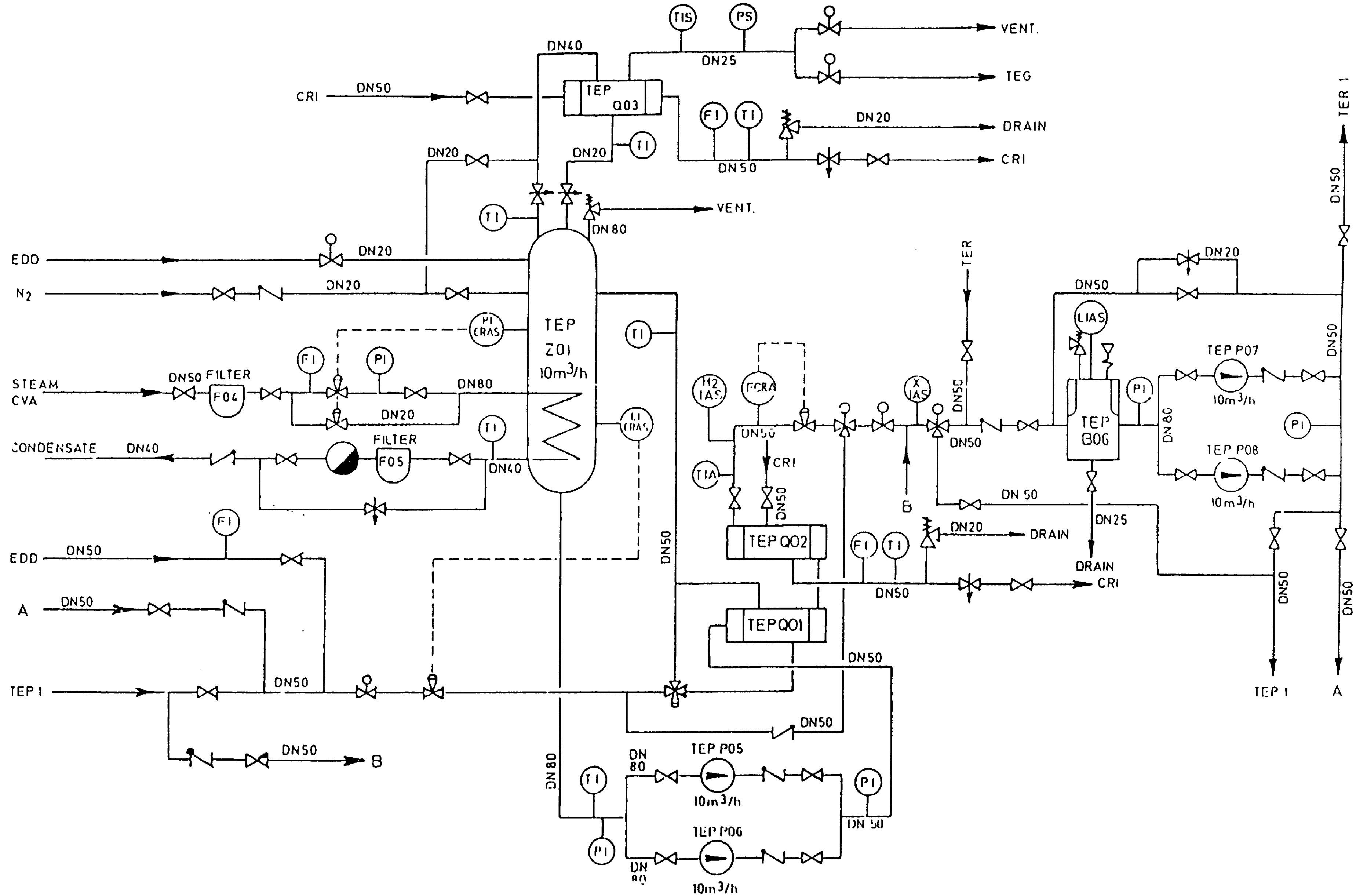


FIGURE 19: LIQUID WASTE TREATMENT TEP 2

(see Fig. 20) :
- for Tihange 2 : TEU BO1 - BO2
- for Tihange 3 : TEU BO1 - BO2
  each of 40 m^3

Chemical effluents

In each PWR-unit, the chemical effluents are collected in two tanks :

- for Tihange 2 : TEU BO6 - BO7
- for Tihange 3 : TEU BO3 - BO4
  each of 40 m^3

Service effluents

In each unit, the service effluents are collected in two tanks:

- for Tihange 2 : TEU B12 - B13
- For Tihange 3 : TEU BO9 - B10
  each of 45 m^3

Showers effluents

In Tihange 2 and 3, the liquid effluents coming from the showers are collected via a buffer tank of 3 m^3 and a pump of 5 m^3/h, in a 20 m^3 tank (TEU B21 for Ti2).

Laundry effluents

In Tihange 2, where is located the only laundry of the two plants site, these effluents are collected directly in the 20 m^3 tank (TEU B20) above mentioned where they are mixed with the showers effluents of Tihange 2.

Monitor tanks

- At the outlet of the treatment unit of recoverable effluents, that is the outlet of the evaporators, the distillate is collected in two monitors tanks (TER BO3 - BO4) where the efficiency of the process can be verified, before recycling in the primary coolant circuit (see Fig. 21 to 23).
  At the other side, the concentrate (Boric Acid) is collected in two 5 m^3 tanks (TER BO1 - BO2).

- At the outlet of the treatment equipment of no recoverable effluents, the treated effluents are stored in three 40 m^3 monitor tanks (TEU BO4-O5-15) where the efficiency of the process is controlled (Figure 24). If the results of this verification are satisfactory, the content of these monitor tanks is discharged via a pump into the two 400 m^3 storage tanks before release (TEP BO4-BO5) - as illustrated in Figure 23).

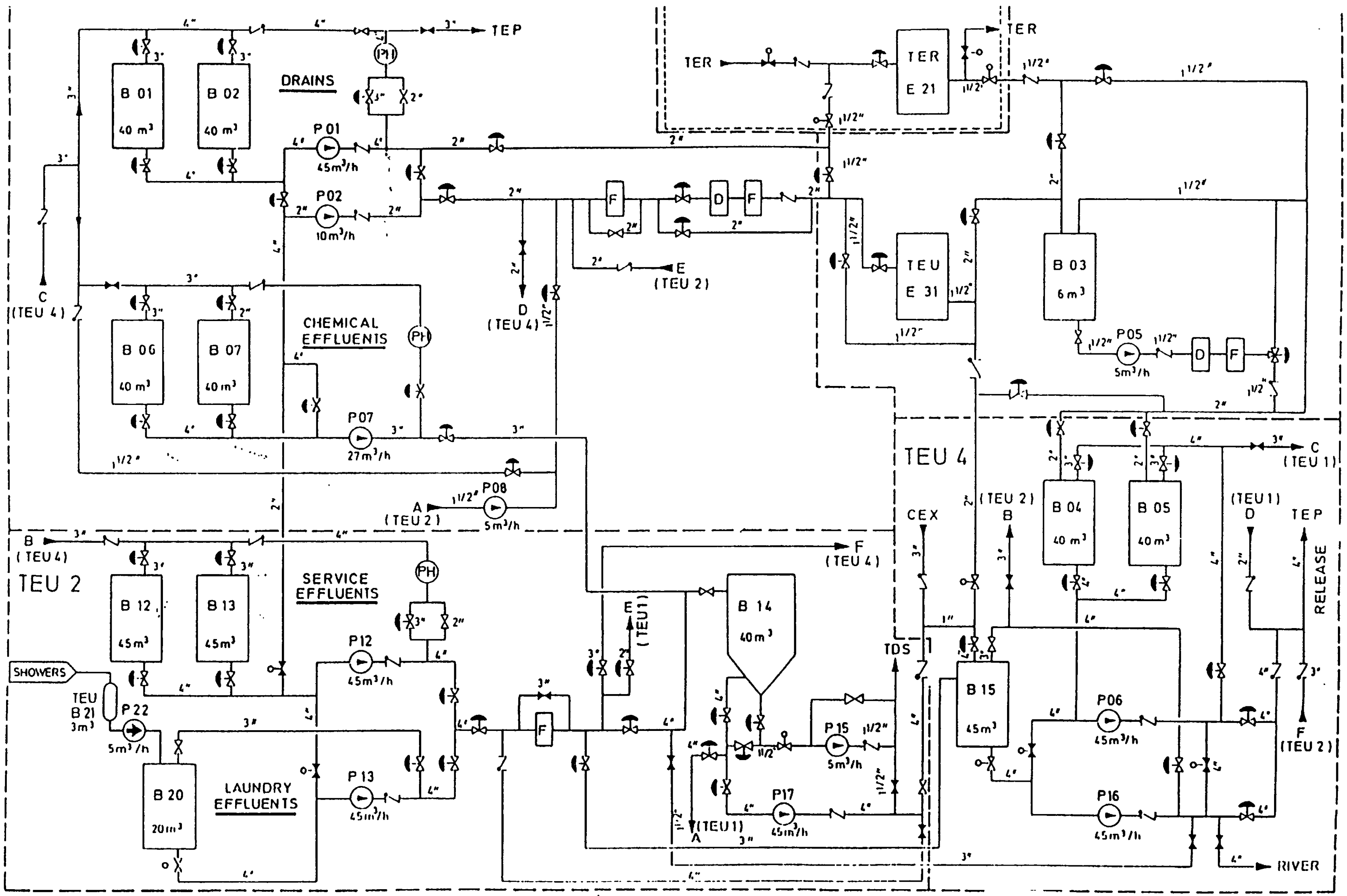


FIGURE 20 : GENERAL FLOW SHEET TEU PROCESS

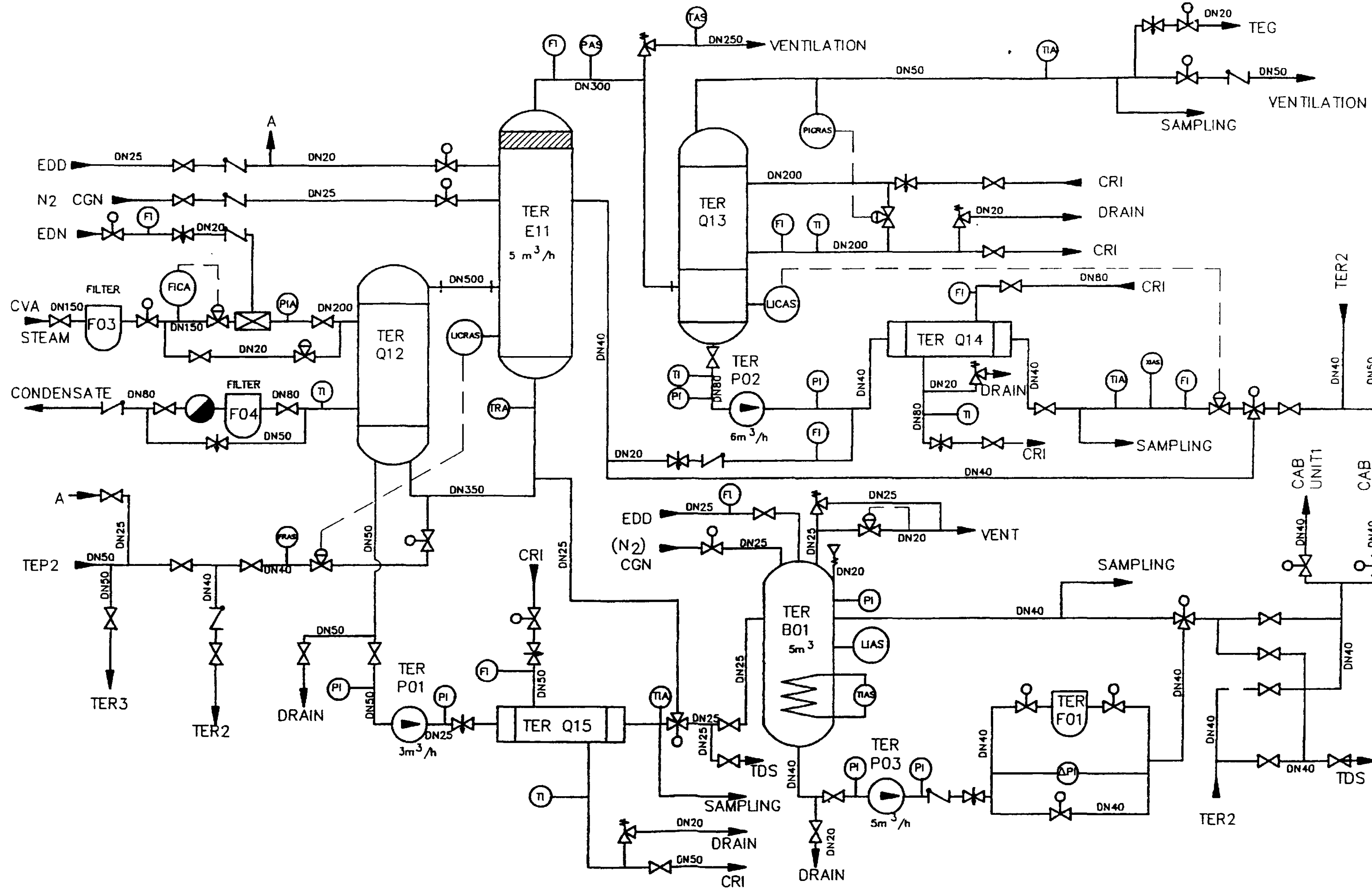


FIGURE 21: LIQUID WASTE TREATMENT TER 1

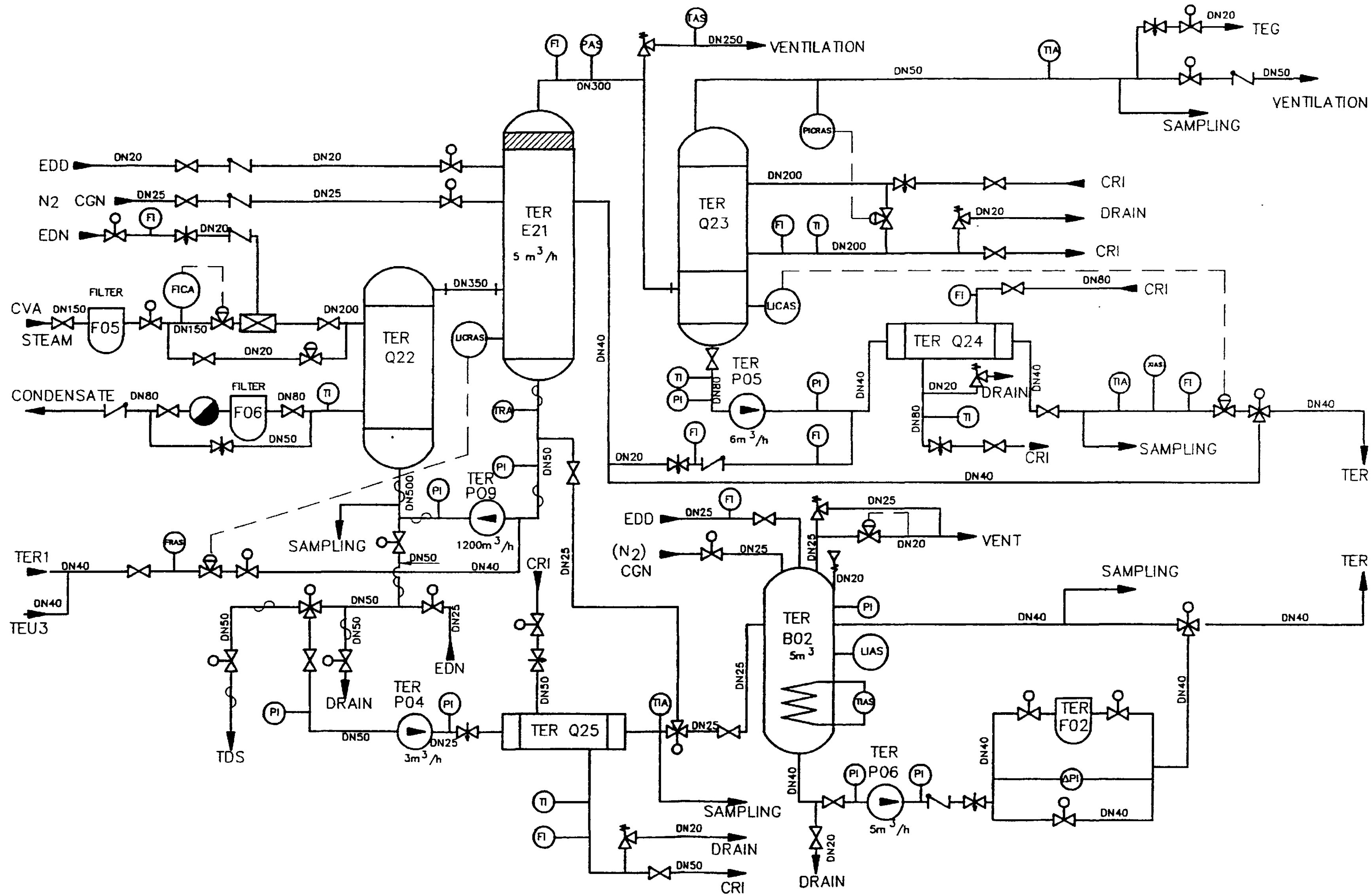


FIGURE 22: LIQUID WASTE TREATMENT TER 2

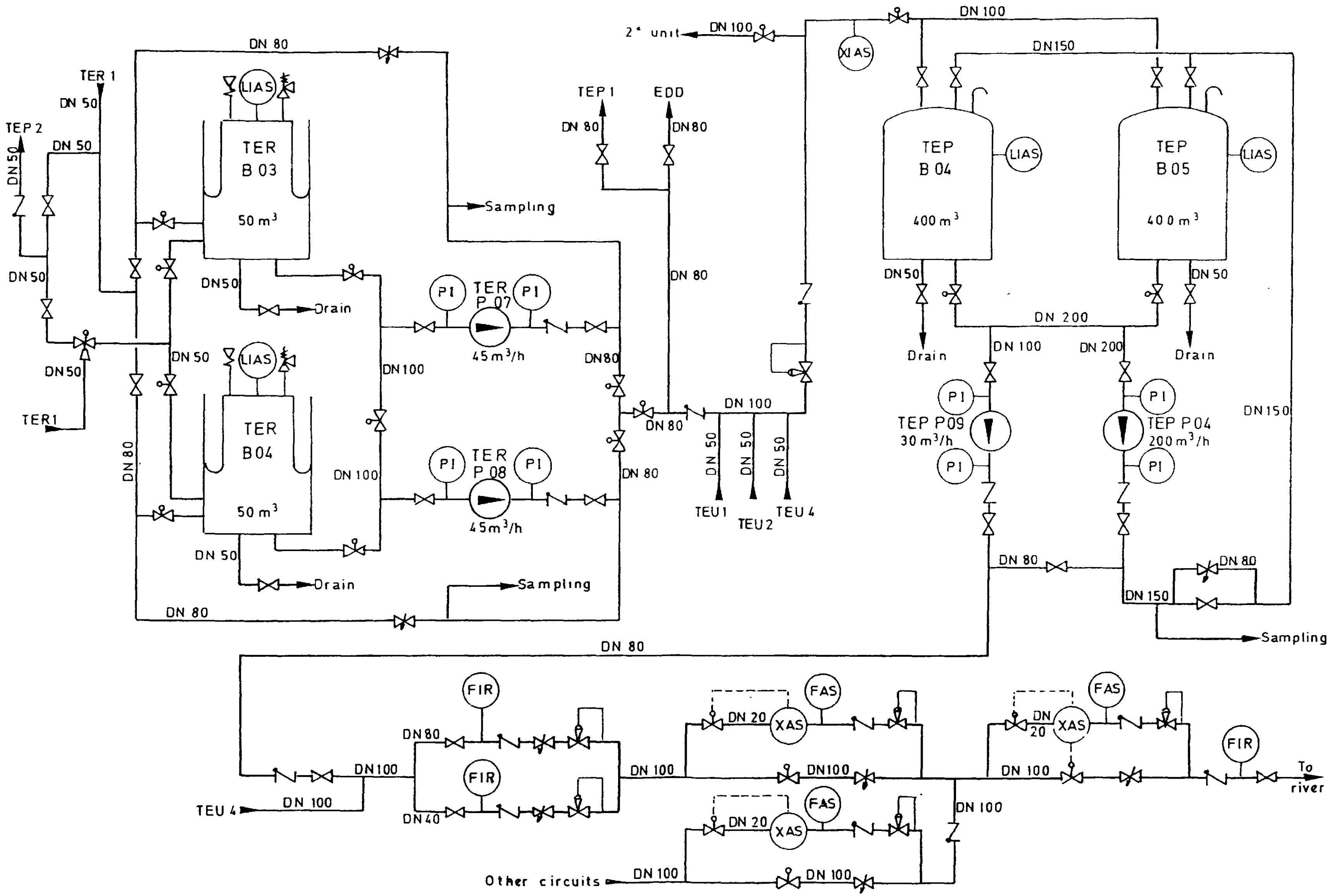


FIGURE 23: LIQUID WASTE TREATMENT TER 3/RELEASE

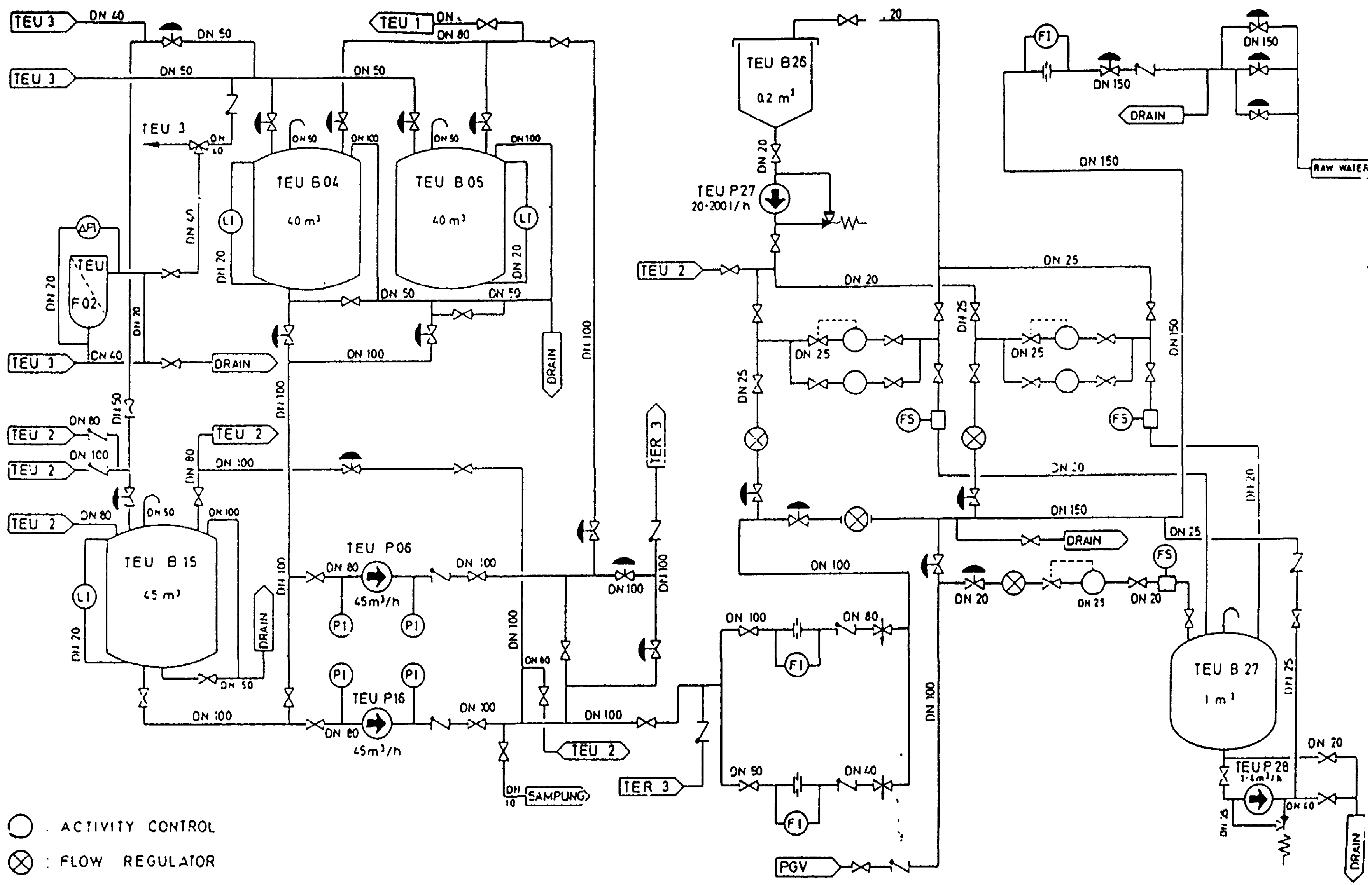


FIGURE 24 : LIQUID WASTE TREATMENT TEU 4

Storage before release

In order to meet the requirement of the release norms, in all particular situations and also to allow the control, by the authorities, of the treated effluents (primary and no-recoverables) during one week before the release in the environment, two 400 m^3 storage tanks are foreseen (TEP BO4-BO5).

IV.4. Description of the Circuits and Equipment

IV.4.1. Recoverable Effluents

The primary effluents treatment system transforms the primary effluents in recoverable ones. With this aim and after analysis, the effluents are filtrated and demineralized in order to remove the solids in suspension and the dissolved fission products.

Next, they are transferred, via a gas stripper unit which removes the gaseous fission products, in the interim storage tank where they can be analyzed to verify the efficiency of the pretreatment (Figure 19).

According to the results obtained, the effluents are transferred whether :

- to the headers of the TEP in order to be reprocessed in this circuit;

or

- to the TER circuit in order to be treated; a continuous monitoring is performed to check the hydrogen content and the activity level;

or

- to the collector of the unit 1 before release in the river via the TER circuit and one of the 400 m^3 storage tanks of this unit;

or

- to the collector of the TEU circuit of the unit 2 before release in the river via the TER circuit and one of the 400 m^3 storage tanks of this unit, in order to meet the requirements (in particular in case of low water in the river) determined by the authorities.

In the TER circuit, the effluents are evaporated (Figures 21-22) :

- the resulting distillate is degased, demineralized water;
- the concentrate is a boric acid concentrated solution at 7,000 ppm boron content.

According to the result of the analysis of the distillate and the concentrate:

- the distillate can be re-used or released;
- the concentrate can be re-used after final filtration or sent to solid waste treatment system.

By-pass lines are provided at each stage and used when the corresponding process step is not necessary.

Recycle lines allow repeated processing of an effluent batch in case of the results of the first treatment would be found unsatisfactory.

The treatment flow-rate of the primary effluents is 10 m^3/h, however the facility is able to work continuously with 6 m^3/h. Subsystems have the following capacities:

- purification demineralizers and gas stripper unit : 10 m^3/h (5 m^3/h when only one evaporator is working);

- evaporator : 5 m^3/h x 2 units.

IV.4.2. Non recoverable Effluents (Figure 20)

Primary drains effluents (Figure 25)

They are collected in the drains effluents headers.

They may contain suspended solids and dissolved matters in various amounts; depending upon their characteristics and after a first step of filtration, it can be chosen between two independent processing lines :

- filtration in a cartridge filter and/or demineralization (specific boron ion resins); the processing capacity is 10 m^3/h;

- concentration in an evaporator, in order to gather all activity emitters in reduced sludge volume; the processing capacity is 5 m^3/h.

The distillate is transferred, directly or via a mixed bed demineralizer to one of the two 40 m^3 monitor tanks (TEU, BO4 and BO5).

The concentrate from the evaporator is directed to the solid waste treatment system.

The treatment quality and efficiency for the filtrate from the cartridge filter and for the distillate from the evaporator are verified in monitor tanks.

After control, the effluents can be:

- recycled at the beginning of the treatment chain for reprocessing;
- directed to the storage tanks before release;
- evacuated in the river via the TEU discharge-collector and the raw water circuit or via the Ti3-storage tanks before release.

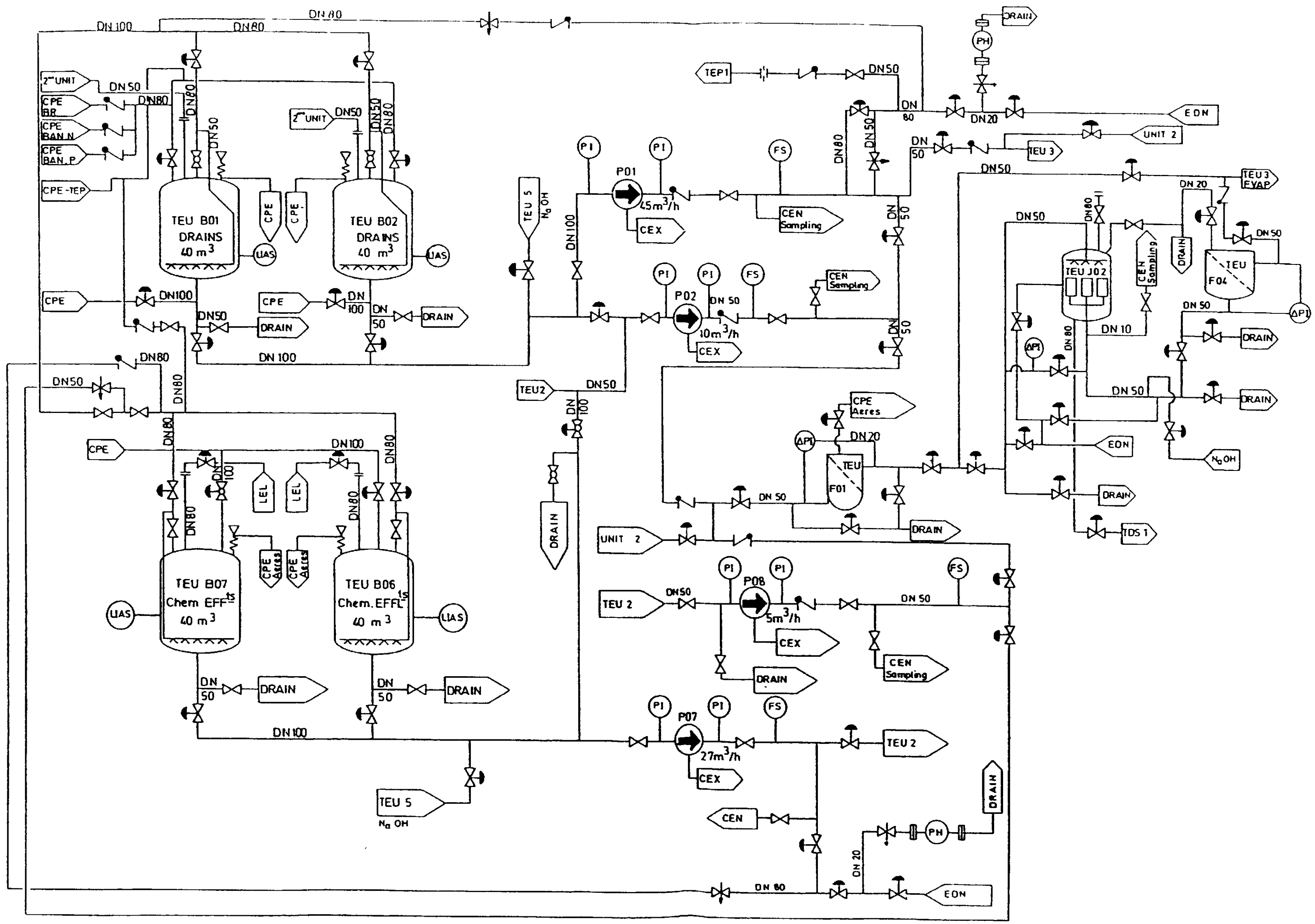


FIGURE 25: LIQUID WASTE TREATMENT TEU 1

According to the amount of effluents to be treated and the availability of the recoverable effluents treatment circuit, it can be decided to put it in service in parallel with the evaporation unit of TEU (Figure 26). In this situation, the feeding pump works with a flow-rate of 10 m^3/h. But, the following filters and demineralizers are designed for a flow-rate of 5 m^3/h.

The same evaporator of the TER circuit can also be substituted, with a flow-rate of 5 m^3/h at the TEU evaporator in case of unavailability of this for a long time. Thus the flow rate of the treatment chain is 5 m^3/h.

In order to increase, without cristallization, the solid matter content in the concentrate, a neutralization of the primary drains is foreseen.

<u>Chemical effluents</u>

They are collected in the chemical effluents headers (see Fig. 25).

An appropriate chemical treatment is performed in a flocculator.

The flocculates are transferred to the TDS for encapsulation, while the purified solution is directed :

- whether to the drain effluents treatment chain;
- or to the filter of the service effluents;
- or to the monitor tank at the end of the treatment chain.

For all the chemical treatments involved in the liquid effluents treatment system, the following equipment is foreseen :

- a 6 m^3 vessel for HNO_3;
- a 15 m^3 vessel for NaOH;
- 6 other 150 1-vessels with additives for the chemical pretreatment;
- all the appropriated pumps.

Connections also exist between these vessels and :

- the flocculator of the chemical and service effluents. The volume of flocculator is determined to be able to treat, in a batch way, all the service effluents produced in a day, that is 40 m^3;

- the storage tank of the drain, chemical and service effluents (HNO_3 and NaOH);

- the deboration demineralizers (NaOH).

Checking of the treatment products (filtrate, distillate, concentrate, uncondensed gases) and their evacuation or transfer are carried out in a similar way as for primary drains.

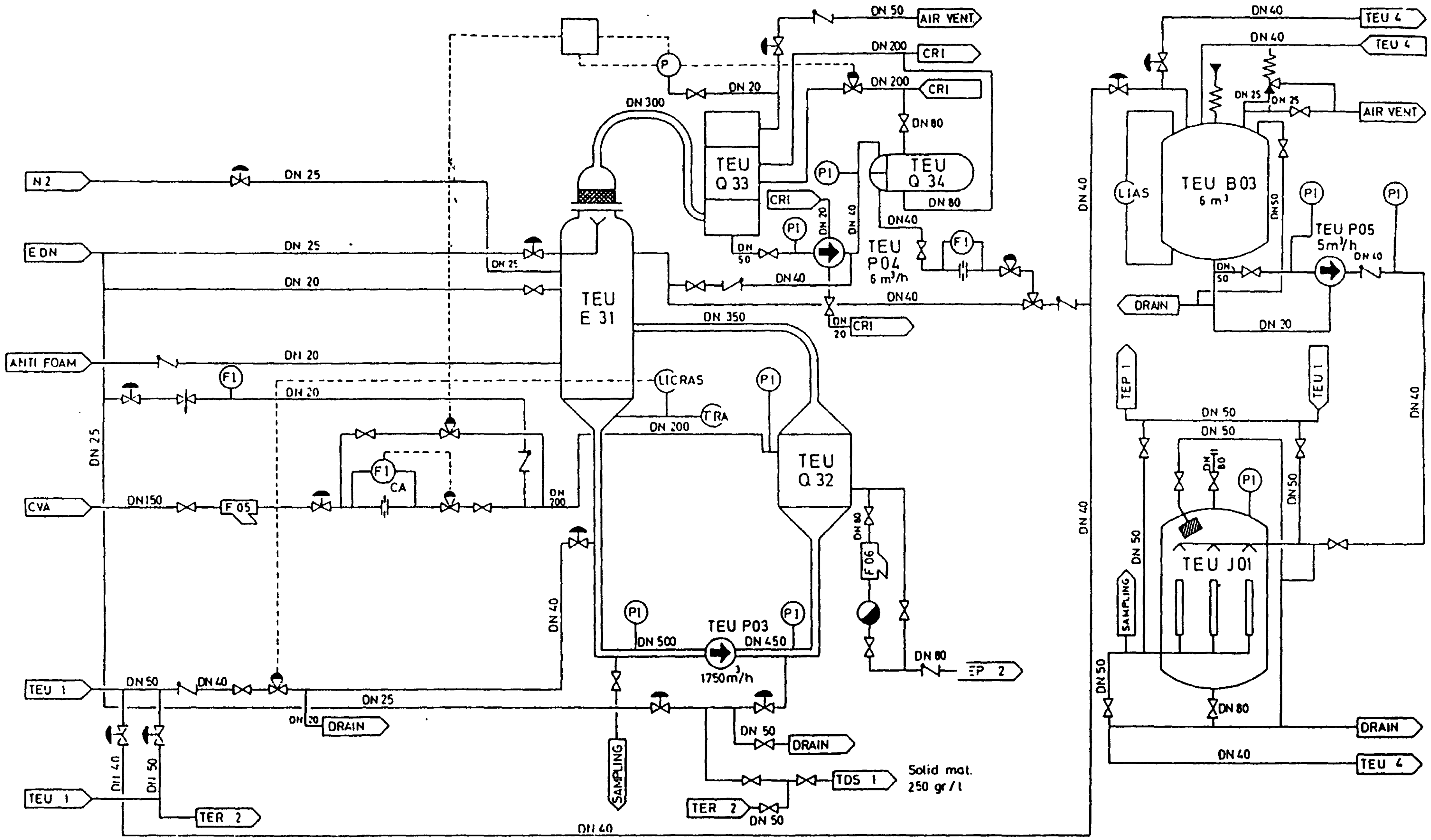


FIGURE 26 : LIQUID WASTE TREATMENT TEU 3

Service effluents and laundry effluents

Usually, these effluents can be released without treatment.

The purification, when necessary, is performed by means of flocculation or filtration (see Fig. 27).

The flocculator has a 40 m^3 capacity, the flocculates are transferred to the TDS encapsulation.

The purified solution is transferred :

- whether to the drain effluents treatment chain;
- or to a monitor tank for control, and then :
  - recycled in the flocculator for reprocessing;
  - directed to the storage tanks before release;
  - evacuated in the river via the TEU discharge collector and the raw water circuit or via the Ti3-storage tanks before release.

  When requested because of the impurities content or the contamination levels, these effluents can be transferred to other category collecting tanks and be treated as chemical or primary drain effluents.

IV.4.3. Equipment Description

IV.4.3.1. Primary Effluents (see Fig. 18-19)

The subsystem comprises, from input to output :

- three large storage tanks for collection of the primary water effluents provided :
  - with nitrogen cover gas devices;
  - with a hydrogenated off-gas discharge;
  - with a recirculation pump for fluids homogenization;
  - with a sampling circuit;
  - with an outtake header towards the process section;
- two process pumps in parallel (one in service, one in stand-by);
- a "filtering" subassembly composed of :
  - two 5 microns-filters in parallel (one in service, one in stand-by);
  - a filter by-pass;

  and means for trapping of cruds and other suspended solids in the effluent stream;

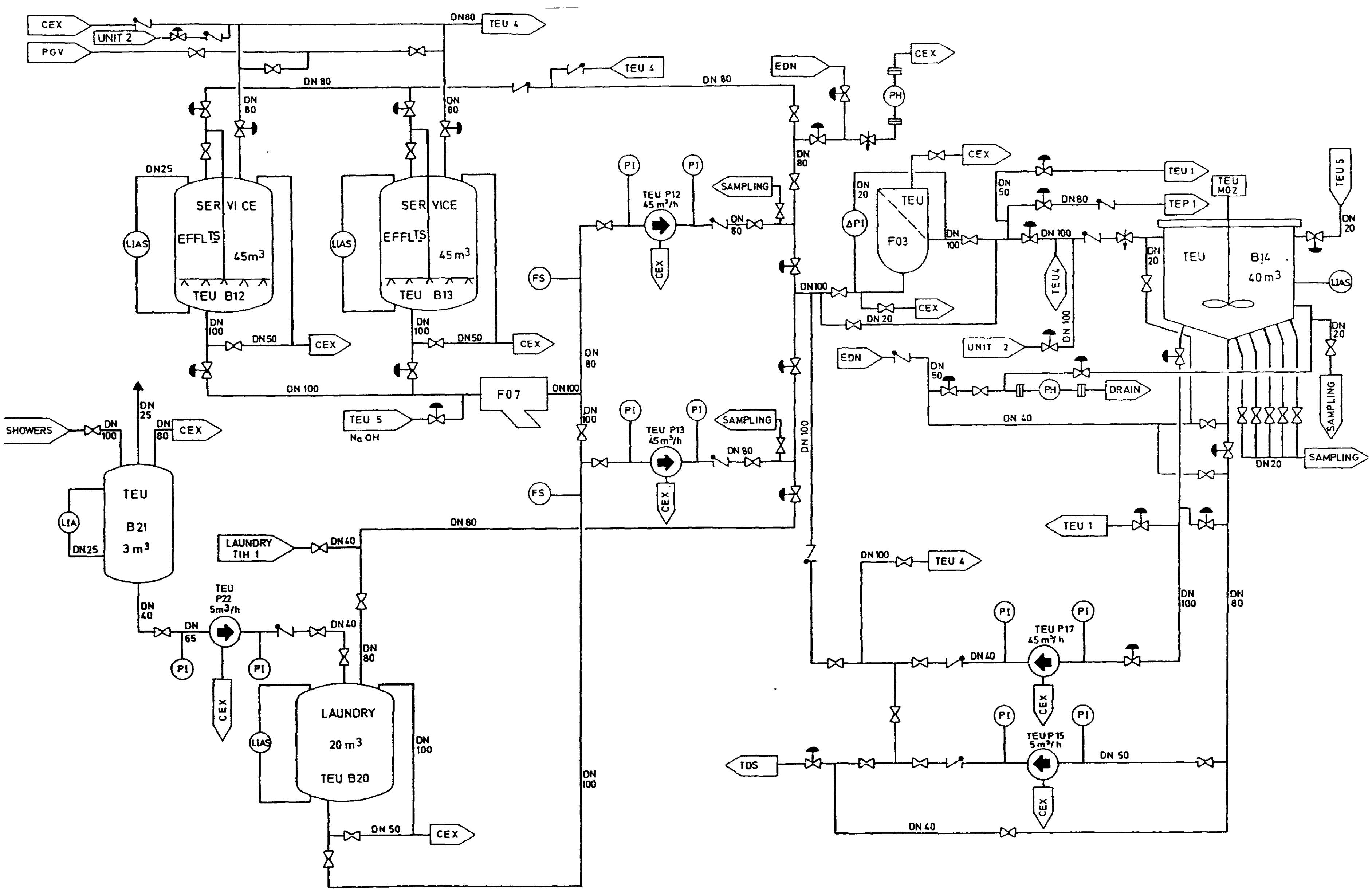


FIGURE 27: LIQUID WASTE TREATMENT TEU 2

- a "demineralization" subassembly composed of :

  - an anionic ion exchanger (boron saturated resins) (mean DF = 100);
  - a cationic ion exchanger (mean DF = 100);
  - a cesium specific cationic ion exchanger;

  with a possible by-pass of each abover demineralization step;

- a 25 microns filter for mechanical retention of possible resin beads escaped from the ion exchange beds;

- a line allowing the return of the effluents towards the head tanks, the content of which must be processed; this line opened before the processing itself starts, allows the loading of the resins;
- a "gas stripping" subassembly provided with (Figure 19) :

  - recuperative heat exchangers (2);
  - heater;
  - stripping column;
  - circulating pumps (2);
  - vent cooler and extraction towards the hydrogenated gaseous radwaste system;

  and which removes the dissolved hydrogen and the possible gaseous radioactive nuclides (flow-rate : 10 m^3/h; DF : about 10^6 for hydrogen).

  N.B. : if not needed, the gas stripping step can also be by-passed.

- A monitoring device for the control of the activity of the demineralized, degased effluents;

- a floating roof monitoring tank which collects the processed effluents and enables water quality control before decision on the further required treatments. It is provided with reprocessing line and sampling circuit.

Remarks

From this stage, should the quality results be unsatisfactory, recycling towards one or the other above process step can be decided for repeated treatment.

Leaving the above monitoring tank, one finds downstream :

- two process pumps in parallel (one in service, one in stand-by) for fluids transfer, either to the next process step, i.e., (Figure 19) evaporation, or towards the upstream treatments;

- two evaporator subassemblies (one in service, one as common stand-by with the miscellaneous waste evaporator) provided with (see Figures 21 and 22):

- boiler;
- flashing/separation column with reflux;
- demister;
- distillate condenser;
- vent extraction towards the hydrogenated gaseous radwaste system;
- distillate cooler;
- concentrate pump;
- concentrate cooler.

From this step, one distinguishes two product evacuation lines, i.e. :

1. Distillate composed of :

   - two floating roof monitoring tanks in parallel (Figure 23) :
     - one available for operation in connection with the upstream evaporator;
     - one being emptied after quality of the processed water;

   - two transfer pumps (on in service, one in stand-by) with three possible discharge options :
     - recycling towards the evaporator, should the water quality be unacceptable for the two other following options;
     - return to the plant demineralized water system for possible re-use;
     - evacuation towards the water release to the environment.

2. Concentrate composed of (Figures 21 and 22) :

   - a collecting tank of the concentrated boric acid solution (TER BO1-BO2);

   - a transfer pump which :
     - either recycles the solution to the boron recovery system;
     - or diverts the concentrate to the solid radwaste system for capsulation and conditioning.

   Secondary wastes generated in the primary effluent subsystem, i.e., ion exchange resins, filtering elements or material, etc. are also transferred to the solid radwaste system.

IV.4.3.2. Miscellaneous Effluents

The subsystem comprises, from input to output (Figure 25) :

- an incoming waste header collecting the effluents from the miscellaneous sources;

N.B.: some installation allows further segregation between drains and service wastes.

- Two storage tanks in parallel :

  - one available for collection of the incoming effluents;
  - one which, after content homogenization, analysis and possible adjustment, is operating as upstream feed tank.

- Two process pumps in parallel :
  - one which serves :
    - preferably to the homogenization recirculation;
    - as spare for the process feed;

  - one which normally assures the feed to the subsystem process section.

  Transfer to other storage tanks is also foreseen;

- A filter meant for trapping of cruds and other suspended solids in the effluent stream and provided with a by-pass line.

  From this stage, two different types of treatment can be chosen according to the effluent content and the corresponding process needed to achieve the specified water quality.

  a) <u>Evaporation</u> composed of (Figure 26) :

  - an evaporator subassembly provided with :
    - boiler;
    - circulation pump (e.g. for forced circulation evaporator type);
    - flashing/separation column with reflux;
    - demister;
    - distillate condenser;
    - vent extraction towards the aerated off-gas;
    - distillate cooler;
    - distillate pump;
    - bottom (or concentrate) discharge towards the solid radwaste system.

  - a distillate collecting tank;

  - a distillate transfer pump;

  - a possible polishing demineralization (mixed bed) of the distillate followed by a final filtration of it.

  b) <u>Demineralization</u> composed of (Figure 26) :

  - a mixed bed ion exchanger;
  - a 25 microns-filter for trapping of (possibly) carried over resin beads.

N.B.: From there, diverting towards the evaporator is also feasible.

After processing, treated waters are :

- collected in either one of two final monitoring tanks in parallel where water quality control can take place, possibly after homogenization of the tank content :
  - one tank should always be available to receive processed waters
  - the other can then be under checking and thereafter emptied.
- From above tanks, directed by pump :
  - either upstream of one or the other above process step for recycling;
  - or towards the water release to the environment.

As for the secondary waste generated in the subsystem, these are similarly transferred to the solid radwaste system for further treatment and conditioning.

IV.4.3.3. Chemical Effluents and Detergent Wastes (Figures 25 and 27)

In general, "chemical" effluents are collected separately from the "detergent" waste, because their processings are different. However, several process components are, for economical reasons, common to both treatment lines.

Usually, these subsystems at least comprise, from input to output :

- two incoming waste collecting tanks in parallel;
  - one available for the incoming effluents storage;
  - one which, after content homogenization and analysis, serves as upstream feed tank.
- Process pumps which take above effluents and ensure :
  - either homogenization recirculation of the collecting tanks content;
  - or their transfer to other subsystems storage;
  - or the feed to the subsystem process section.
- An upstream filter for removal of the suspended solids in the effluent stream;
- A neutralizer/flocculator (or batch type chemical reactor) where operators can perform (as required by the effluent composition):
  - pH adjustment;
  - chemical precipitation;
  - decanting;

  separating, on the one hand, sludges with most of the contaminated materials, and, on the other hand, clarified waters.

These sludges, as well as the secondary wastes (mainly filtering materials) are again directed towards the solid radwaste system for encapsulation and conditioning.

The treated clear waters are collected in a set of final monitoring tanks having the same functions as in the miscellaneous effluent case and from these, they are directed by the pump :

- either to the "miscellaneous effluent" storage in view of an additional treatment, should the clear water quality and/or content require it;

- or to the water release to the environment.

CHAPTER V

MANAGEMENT OF SOLID WASTES

Variable amounts of miscellaneous radwastes are generated in PWR power plants both in normal operation or during shut-down periods.

When dealing with the problem of PWR radwaste solidification, the designer has to take several specifications into consideration which often differ from one power plant to the other. The definition of the input fluids to be processed may considerably vary in terms of:

- nature of the contained materials or compounds;
- specific radionuclides in presence;
- respective physical or chemical concentrations;
- respective activity levels;
- dissolved or suspended form of the content;
- suspended particles and sedimentation properties;
- daily, weekly and yearly production rates,

each of those characteristics being specified within rather broad limits. This means that a given solidification plant should have the capability of processing a wide variety of fluids.

V.1. Functional Design

The solid waste treatment system in a Belgian PWR permits :

- collection and selective storage for decay of all the solid radioactive wastes produced at the power plant (slurry/wet or dry solids);

- removal and transfer of filter cartridges and spent ion exchange resins from the liquid waste filter-demineralizer section;

- conditioning prior to storage on- or off-site, or removal without conditioning for off-site treatment (combustion, compaction).

V.2. Categories of Solid Radioactive Wastes

The wastes to be treated comprise :

- evaporation concentrates produced at the power plant as a result of treatment of liquid effluents;
- flocculates produced at the power plant following treatment of liquid effluents;
- spent ion-exchange resins from the demineralizers in the auxiliary nuclear circuits and from the liquid effluent processing unit;
- residues from magnetic filtration of steam generator blowdowns;
- filter cartridges from liquid circuits;
- solid wastes of various origins (ventilation filters, contaminated clothes, bags, rags, ...).

The solid radwastes are grouped into wet and dry types.

V.2.1. Slurry/Wet solids

- concentrates from evaporator's bottom produced by treatment of liquid effluents;
- suspensions (I.E.R. beads) from demineralizers in auxiliary and effluents circuits;
- sludges (decanted flocculates, iron oxides from magnetic filters,...).

V.2.2. Dry Solids

- filter cartridges from liquid effluents treatment circuits;
- ventilation and off-gas filters;
- burnable solids (paper, plastics, ...): contaminated clothes, bags, rags, ...
- non-burnable solids;
  - compactable type
  - non-compactable type (too heavy or too big to be inserted in a standard 200 l drum).

V.3. Treatment and Conditioning of Wet Solid Wastes

The facilities comprise six major units, namely :

- a unit for collection, concentration and transfer of evaporator concentrates (sodium borate);
- a unit for collection and concentration of flocculates;
- a unit for collection and transfer of resins;
- a unit for collection of iron oxide;
- a drumming station;
- a plugging station.

V.3.1. Collection, Concentration and Transfer of Evaporator Concentrates

According to the scheme reported in Fig. 28, the concentrates produced by the liquid wastes evaporators may be stored in tank BO2 (15 m^3) or B10 (25 m^3). Each tank is fitted with a dismountable stirring device. BO2 is electrically traced at 75°C, as well as the borate feed line coming from the evaporators, in order to avoid cristallisation up to 250 g/l borates concentration.

B10 is fitted with a steam heating allowing either to keep 75°C or to concentrate the solutions up to 350 g/l dry matter by reaching 90°C and sweeping the cover gas (wet air). The cover gas is recirculated by ventilator A10 (1600 m^3/h) through condenser L33 acting as a dryer.

Rate of water extracted by this method averages 200 kg/h.

The pH is adjusted to 11.5 by liquid soda injection into the tanks.
Following control of the pH by sampling or through recirculating via the pump P10, the concentrates are ready to be gravity fed to the drumming station via the volumetric doser B12 (40 l or 5 l).

The pump can also be used for tank to tank transfer, and also to remove the concentrates to be treated off-site in case of overproduction.

V.3.2. Collection and Transfer of Resins

The spent ion-exchange resins that are unloaded from the demineralizers are placed in the BO7 and BO8 (13 m^3) storage and decay tanks (see Fig. 29).

Each tank is fitted with 10 resin/water interface detectors along its height.

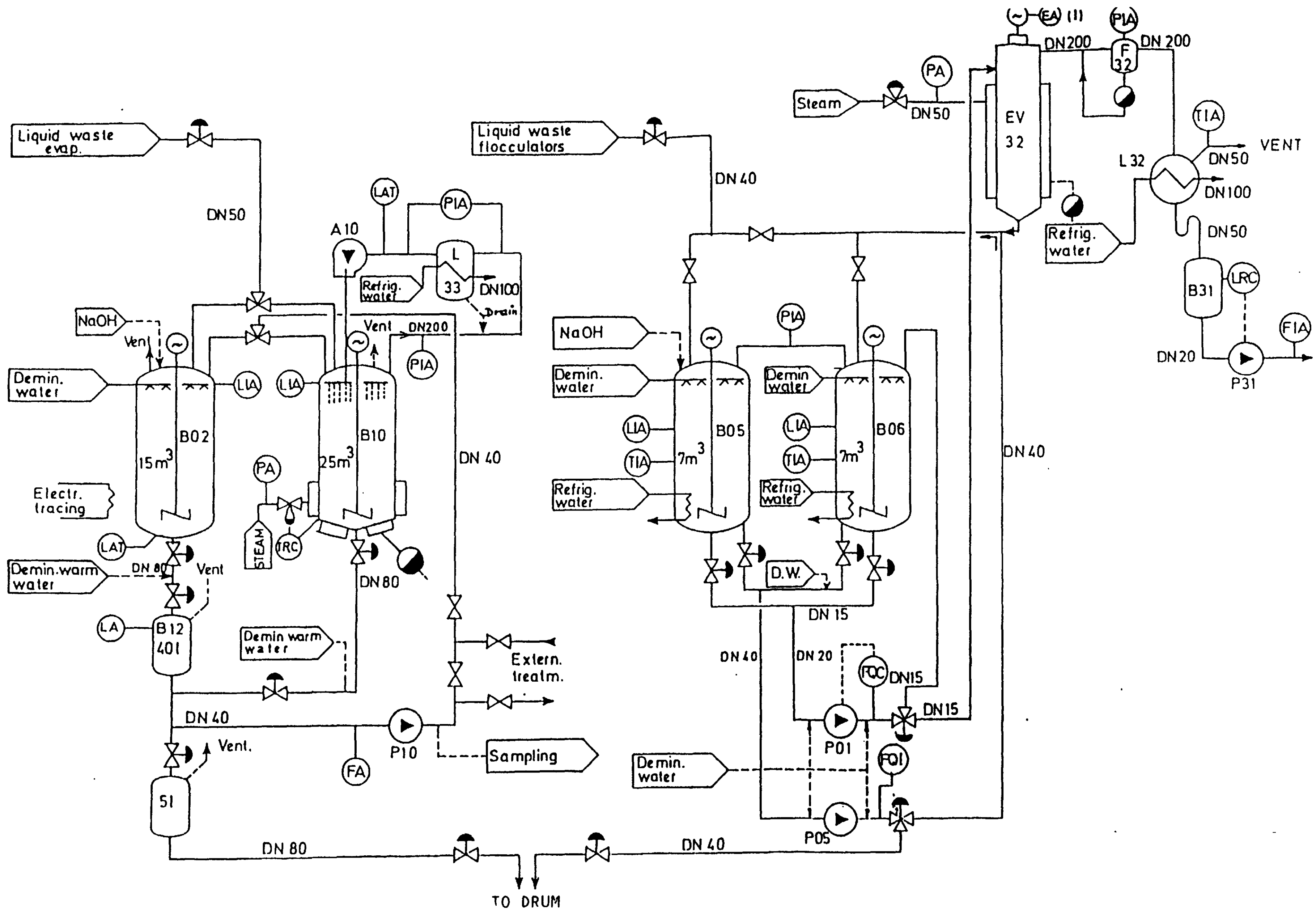


FIGURE 28 : SOLID WASTES HANDLING CONCENTRATES AND FLOCCULATES

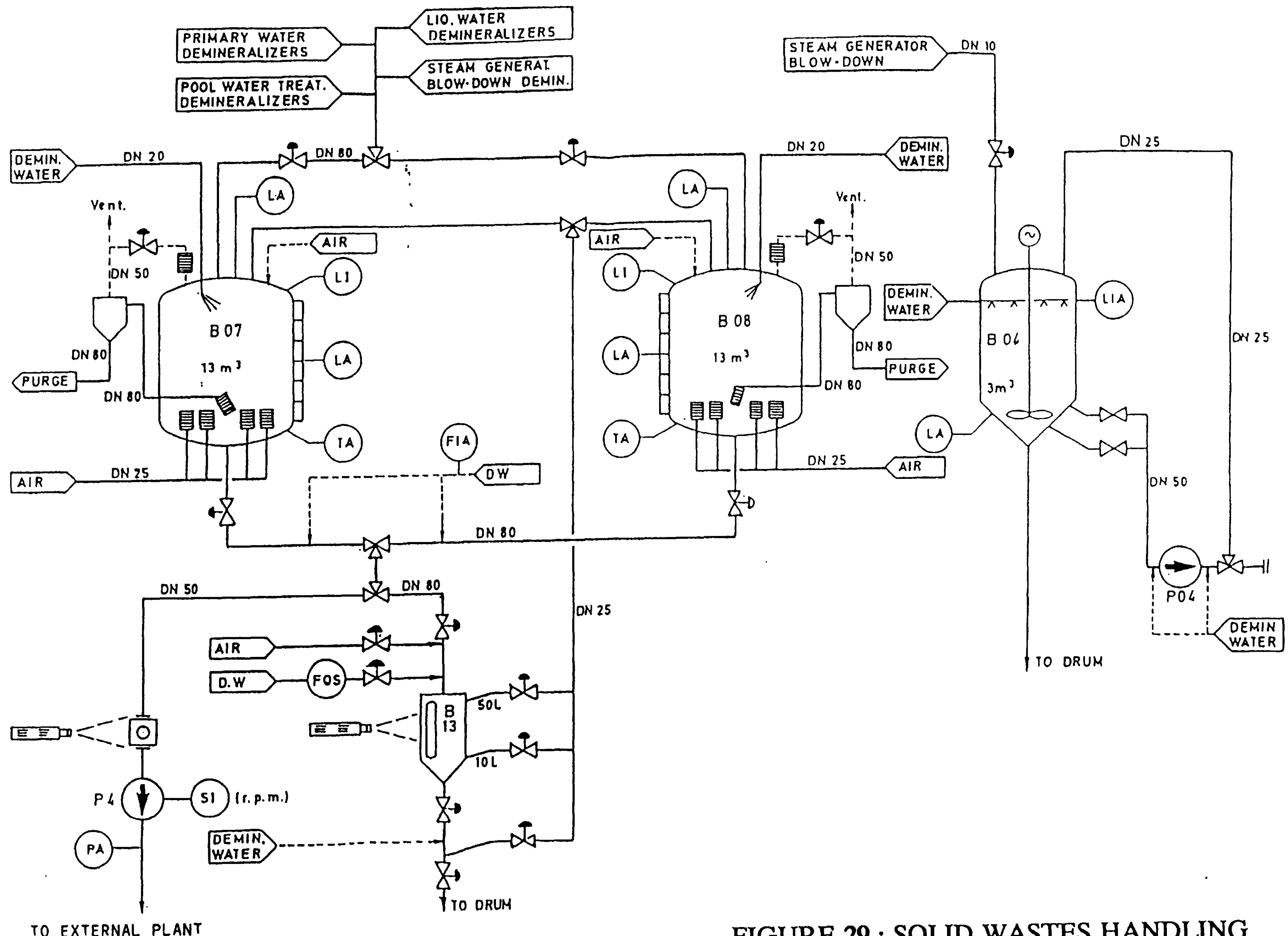


FIGURE 29 : SOLID WASTES HANDLING RESINS AND IRON OXIDES

The transfer waters are sent to a purging circuit through an overflow fitted with a strainer (100 mn); four base strainers (100 mn) enable the resin bed to be loosened using compressed air; the excess cover water from the resins is removed passing afterwards through the same base strainers, but in opposite direction.

So as to limit the consequence of equipment failure in any of the tanks, a possibility exists for transferring the resins pneumatically from one tank to the other; a sprayer placed in the tank dome ensures optimal cleaning of the tank, once it is empty.

For encapsulation in concrete, the resins are gravity fed to the B13 doser, in which they are dosed volumetrically following decanting (50 l or 10 l); the dosing excess is returned to the tank by pneumatic transfer.

The doser pot is shielded. A glass-sight viewed by a TV camera system allows to survey the resin level.
The resins can also be transferred to an adjoining building by means of the P40 screw pump for encapsulation in a matrix other than concrete.

V.3.3. Flocculates Collecting and Concentrating Unit

As illustrated in Fig. 28, the 2% weight flocculates are collected in the BO5 tank (7 m^3) which is fitted with a stirrer. They are concentrated to 12% weight using the thin film evaporator EV32 fed by PO1 pump. The mass flow to EV32 is measured continuously and compared to a set value adjusted by the operator. The controller output acts on the speed of rotation of PO1 (nominal flow rate: 250 kg/h).

The flocculates thus concentrated in the bottom of the evaporator are gravity fed into the BO6 tank (7 m^3), where they are stored with continue stirring for subsequent drumming.

The vapours generated by the EV32 evaporator pass through a droplet separator F32, and are condensed in the L32 condensor. The condensates are collected in a small buffer tank B31, the level of which is kept constant by acting n extraction pump P31. Measurement of the flow through this pump provides continuous monitoring of performance and allows to calculate the concentration in the bottom of the evaporator.

The concentrated flocculates are transferred to the drumming station via the doser pump PO5 (normal flow : 1.5 m^3/h). The instantaneous flow and total quantity transferred are monitored.

In order to keep the evaporator operational and to allow its draining to tank BO6, it is very important to control the dry matter amount in the bottom. Tests show that an amount of 20 % weight if dry matter should never be exceeded. Therefore, to keep a safe margin, the parameters are adjusted in order to get 12% weight dry matter in the concentrate.

V.3.4. Collection of Iron Oxides

The residues from magnetic filtration of the steam generators blowdown (iron oxide) are gravity fed into the BO4 tank (3 m^3), where they are concentrated by successive decantations of several loads (see Fig. 29). Once the mean oxide contents under the overflow reaches 50 w/o, the solution which is homogeneized by stirring is gravity fed into a metallic drum.

V.3.5. Filter Cartridges from Liquid Circuits Unloading

Filter cartridges are removed from vessels in a special lead cask fitted with a remote handled hook. The lead cask is then moved by help of a crane to the head of a 30 cm diameter vertical pipe in which the filter cartridge is lowered tot he drumming station. Care is taken to allow water drops collection during eachs step of the filter cartridge manipulation and to allow rinsing afterwards.

V.3.6. Drumming Station

The drumming station is described in Fig. 30. This includes the following equipment:

- a concrete preparation station, where dry or wet concrete is prepared (for further encapsulation).
  Note : wet concrete is used for filter cartridges encapsulation.

- a sealing concrete preparation station (for drum plug confection).

- a mixing station for waste/concrete "in drum" mixing.

- a self-driven carriage, on rails, taking the drum to the different discharge points for wastes and for concrete.

Encapsulation concrete preparation station

This facility allows to prepare a well known quantity of concrete between 125 and 250 litres with predetermined composition.
The main parts are :

- the cement hopper S1 (7 m^3) fed pneumatically from an external storage S7.

- the argex hopper S2 (2.5 m^3) fed pneumatically from an external storage S8.
  Note : S1 and S2 are fitted with air blowing and vibration facilities.

- two endless screw conveyors V11 and V21 feeding the weighting hopper DO4 respectively from S1 and S2.

- the mixer B15 (375 l) for dry or wet concrete preparation from the products mentioned. The inner wall is made of renewable wearing plates. A water

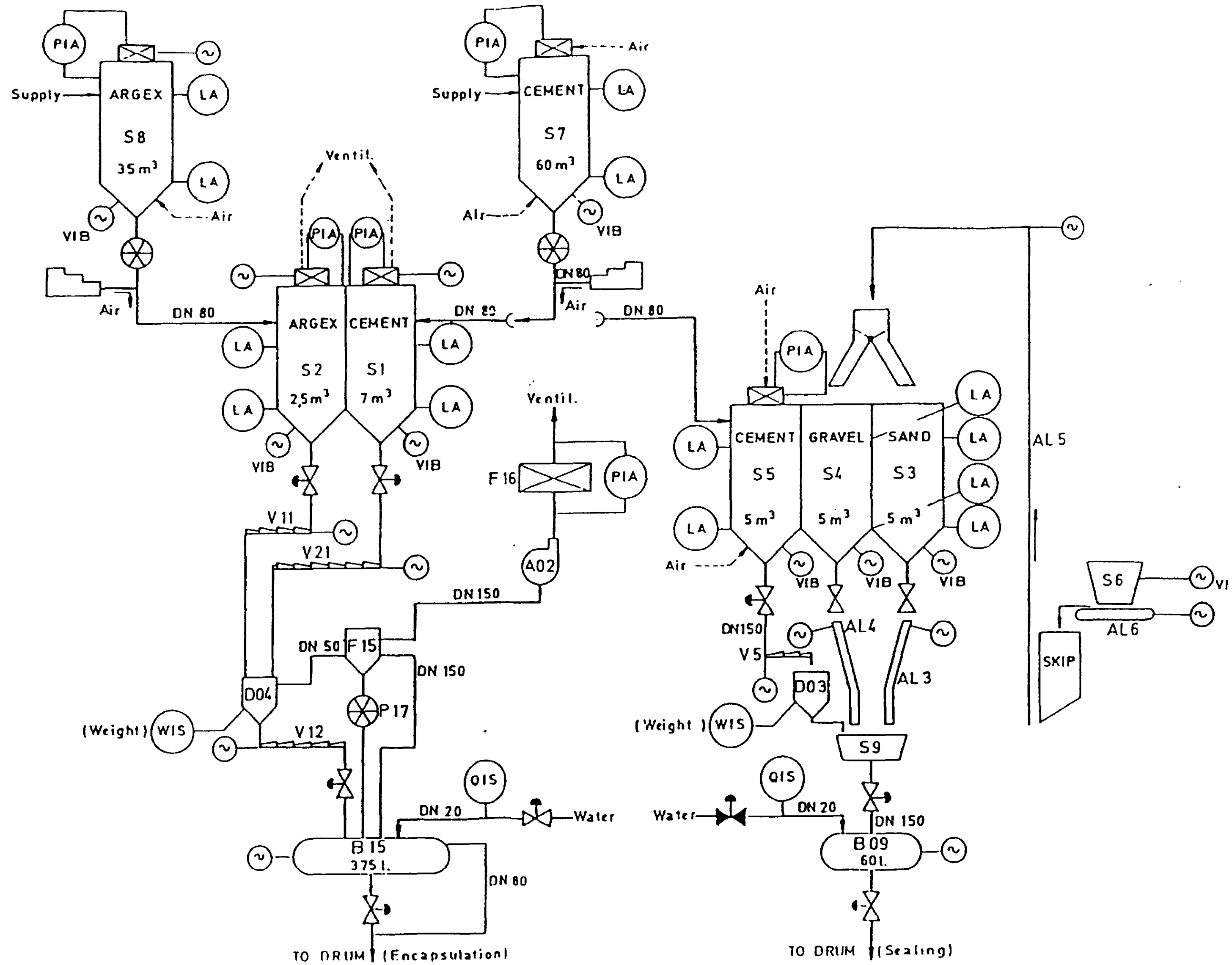


FIGURE 30: SOLID WASTES HANDLING ENCAPSULATION AND SEALING CONCRETE PREP.

injection with meter is foreseen.

- the vertical discharge tube from the mixer into the drum.
  Note : A pneumatically actuated drip-pan for collection of flushing water is foreseen, as well as an antisplashing cover adaptable to the different drum types.
  A ventilator keeps the whole unit (DO4, B15 and drum) under depressure during unloading, so as to avoid external losses of the dust.

Sealing concrete preparation station (if necessary)

The filled drums are closed with a conventional concrete (sand 24 w/o, water 9 w/o, cement 14 w/o, gravel 53 w/o).

The sealing concrete preparation station includes:

- a sand hopper S3 (5 m^3) fed by a skip AL5 (1 m^3).

- a gravel hopper S4 (5 m^3) fed alternatively by the same skip AL5.

- a cement hopper S5 (5 m^3) fed pneumatically from the external storage S7.

- two belt conveyors AL3 and AL4 feeding the mixer BO9 respectively from S3 and S4.

- a sand or gravel external receiving hopper S6 (6 m^3) feeding the skip AL5 through the belt conveyor AL6.

- an endless screw conveyor V5 feeding the weighting hopper DO3 with cement.

- the mixer BO9 (60 l or 100 kg) for seal concrete preparation from the products mentioned.
  Note : the hoppers are fitted with vibrators. Air blowing is foreseen on S5.

"In drum" mixing station

Once the wastes and the concrete mixture have been unloaded, after weighting, into the drum, the carriage takes the drum to the mixing station, for homogeneization (see Fig. 31).

- The drum mixing unit is comprised of:

  - a mixing shaft, the blades of which are designed so as to permit efficient mixing with minimum clogging of the blades.

  - a reducing motor which rotates the shaft at 25 rpm in automatically programmed alternate directions.

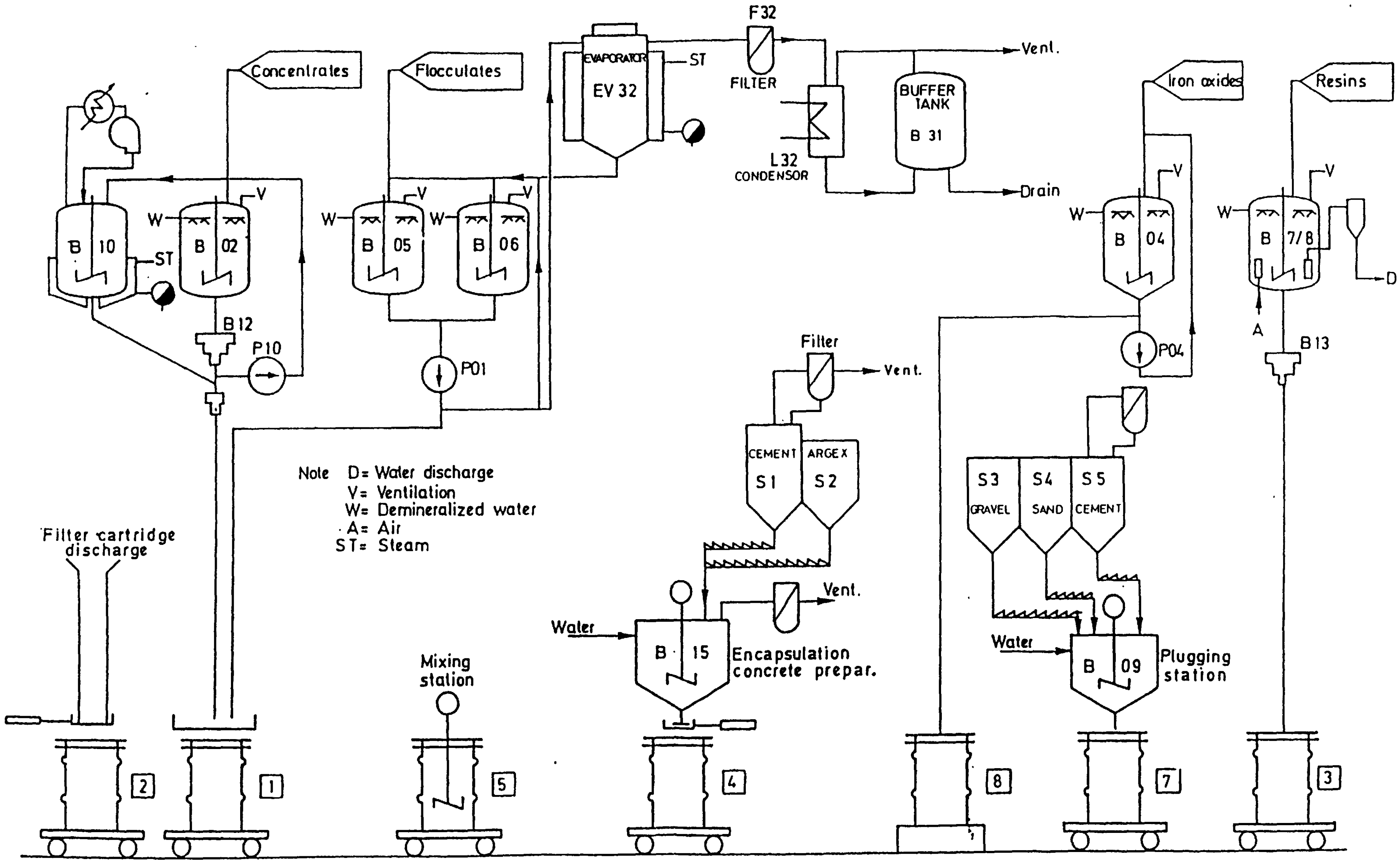


FIGURE 31 : SOLID WASTES HANDLING GENERAL DESIGN

- the upward and downward movements of the shaft in the drum are controlled by a pneumatic actuator with a reserve of compressed air in case of accidental loss of supply.

- the mixing shaft is fixed by a mandrel which can, if required, be disconnected by remote control.

- a drop collector to recover any droplets or mortar that may be spilled during removal of the drum.

All operations are monitored by a videocamera. The current of the mixer motor is also monitored.

Drum carriage

The self-driven carriage brings the drum to the different stations for wastes and concrete reception or mixing :

Station 1: discharge of concentrates and flocculates.
Station 2: discharge of filter cartridges.
Station 3: discharge of resins.
Station 4: discharge of dry or wet concrete.
Station 5: indrum mixing.
Station 6: discharge of iron oxides.
Station 7: plugging station.
Station 8: loading of incoming empty drum and unloading filled drum.

The carriage is able to move a load of 5.5 ton corresponding to a full special drum of 0.9 m^3 useful volume.

The carriage installation includes:

- the rails fixed on the ground;
- the electric propelling allowing 6 m/min speed.
- the lifting platform, raising the drum against the discharge duct.
- locking and centering devices of the carriage, namely for mixing and filter cartridge discharge;
- protected electrical limit switches for control or safety and namely for carriage stops.

V.4. Treatment and Conditioning of Combustible and Compactable Solid Wastes

In addition to the installations on-site previously described, some solid radioactive waste are transfered to a central treatment facility located in Mol-Dessel, which collects all the technological waste produced in the belgian nuclear power stations. The central treatment facility consists of incineration and compaction units completed by a conditioning unit for the residues.

V.4.1. Incineration

The incineration unit (so called "at low temperature" i.e. 850 to 1000°C) consist of an EVENCE-COPPEE furnace with feeding device, gas purification and ashes conditioning device (see Fig. 32).

The furnace itself is composed of two combustion chambers, each with a sloping fixed grid, and a post-combustion chamber. The wastes are conditioned in polyethylene bags which are weighted and transported by a transport belt to the upper part of the combustion chambers where they are introduced through a lock. The combustion of the waste on the grid is sustained by a gas burner, one in each combustion chamber. The ashes are collected in 200 l drums, water cooled and closed before storage.
The combustion gases are cooled successively in an air reheater and then in a water injection cooler. They are purified by washing in a venturi-scrubber followed by a demister. A fan ensures the transfer of the purified off-gases through the stack into the environment.

The water used for the cooling and the washing of the combustion gases is stored in a 2000 m^3 decantation pond, and finally treated after extraction of the sludges.

The feeding of the incinerator is performed from 1 m^3 capacity containers.

V.4.2. Compaction

The compaction unit consists of a press located in a wood wall local, and provided with a lock system for the entrance and outlet transfer of the drums.
The installation is able to compact a drum in such a way that it is possible to pile up 5 or 6 compacted drums in another drum or cylindrical container filled with concrete.

The work rythm allows the compaction of 5 to 6 drums per hour, taking into account the whole handling and conditioning operations.

The handling of the drum for and after compaction is manually performed.

The press has a maximum force of $\sim 10^5$ kg and is equipped of a ventilation hood.

The feeding of the compaction unit is performed from 200 l capacity drums (standard petroleum barrel).

The output overpacking is a normalized 400 l drums.

V.4.3. Conditioning Unit for the Residues

The conditioning unit illustrated in Fig. 30 essentially consists of :

- a mixer where takes place the mixing between cement, sand and water used

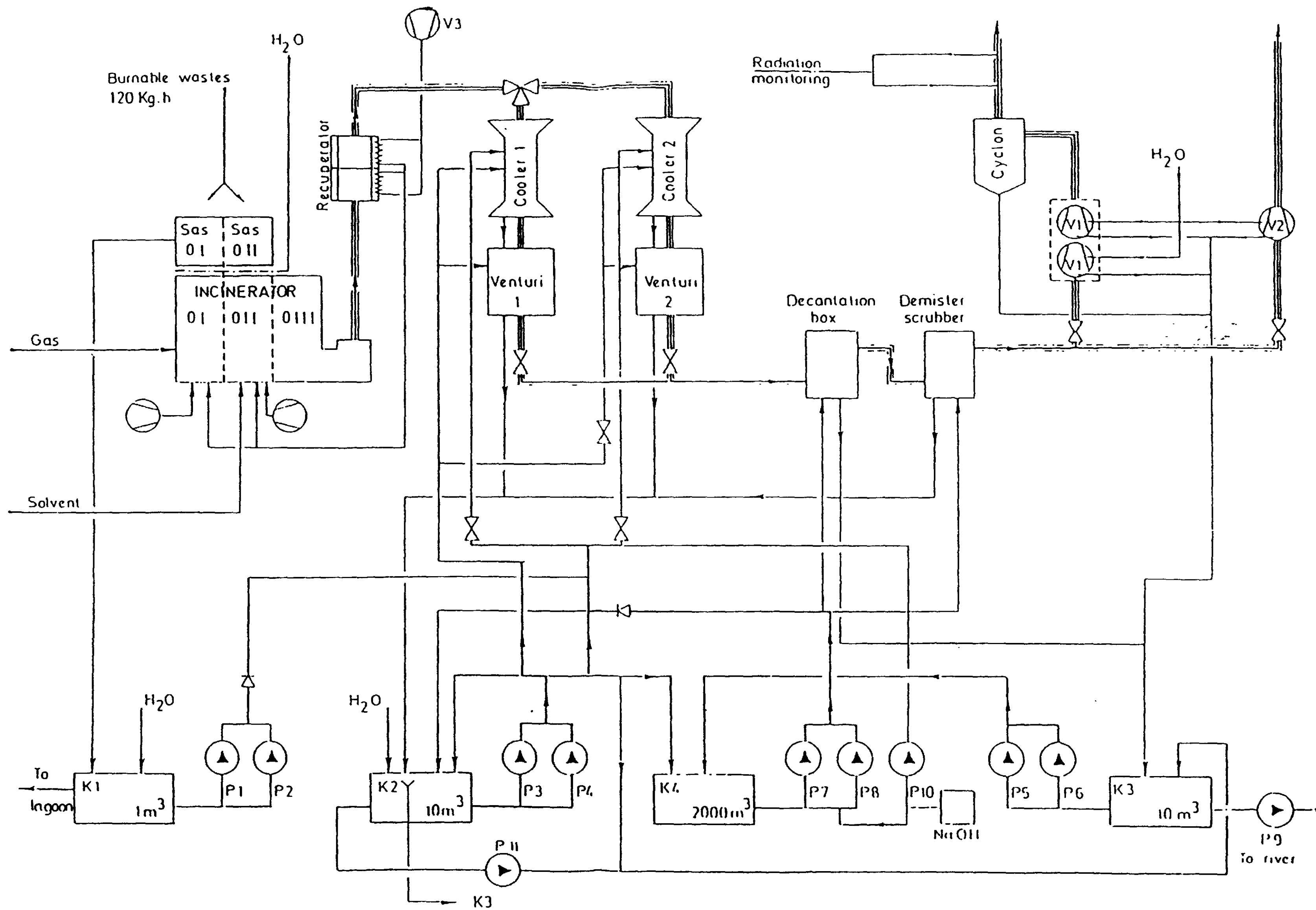


FIGURE 32: GENERAL FLOW SHEET

for embedding the solid radwastes.

- two feeding hoppers: one for cement, the other for sand.

- two transport screws to transfer the cement and the sand in the weighting device.

- a weighting device.

- a drum handling system.

- a ventilation system.

The main characteristics of the equipment are the following :

- the feeding hoppers are two 5 m^3 - silos, equipped with adequate support structure, manhole, safety valve, feeding pipe, butterfly valve and filtration set.

- the transport screw is equipped with a motor-gear group of 3 kW.

- the weighting device with inlet and outlet valves is equipped with flexible joints in order to avoid any influence of all the connections and piping on the registered value of the weight of the materials contained in the device.

- water feeding with preselection of water quantity.

- a completely tight mixer cone-shaped ended in which the water is distributed by means of injectors; and provided at the outlet with a special tight slide-valve.

- a roll-way and handling system to carry the empty and full drums and to exactly place them under the mixer during the filling operation. A vribrating table located under the drum being filled allows a good homogenization of the conditioned waste.

- an air purification and ventilation system consisting of:
  - a bag filter located above the mixer and the related cleaning system by means of pulsed air;
  - a motorized lock between mixer and filter;
  - an absolute filter;
  - a fan located between bag filter and absolute filter in order to maintain an underpressure of 20 mm water column at the outlet of the bag filter.
  - ventilation ducts for connections :

  - A remote control system for:
    - the mixer
    - the drum handling system and the vibration table
    - the bag filter

- the transfer screws
- the weighting device
- the water injection
- the ventilation and air purification system
- the motorized and pneumatic valves
- the alarm system.

V.4.4. Characteristics of the Embedding Matrix and Waste Category

In Belgium, the materials and values indicated in Table 9 are used for the conditioning/embedding of the waste.

Two installations are considered; either on-site or in a centralised facility while wet wastes are generally conditioned on-site, solid dry wastes (combustible, compactable...) are processed in the centralised treatment unit located in MOL.

All type of waste are mixed with a corresponding matrix and the mixture is conditioned in 400 l - drums.

TABLE 9
Characteristics of the embedding matrix and waste category

CENTRAL TREATMENT UNIT			ON SITE INSTALLATIONS		
Waste Category	**Embedding Matrix**	**Max. volume concentration of the waste in the mixture/drum**	**Waste Category**	**Embedding Matrix**	**Max. volume concentration of the waste in the mixture/drum**
Combustible and compactable	MORTAR	Ashes : 50% vol.*	Spent ion exchange resins (incl. high-active ones)	Cement + Sand (the water is contained in the resins)	30% vol.
Combustible and non-compactable (included charcoal beds)	MORTAR	Ashes : 50% vol.*	Filter cartridge	(cement, sand, gravel, water)	1 cartridge/ 400 l drum
Non-combustible and compactable (included absolute filters)	MORTAR	50% vol.	Evaporator concentrates (at 250 g/l)	Cement + Sand + Argex	33% vol. (pH non adjusted)
Non-combustible and non-compactable	MORTAR	50% vol.	Flocculates (at 12% concent.)	Cement + Sand + Argex	25% vol.

* For the ashes resulting of an incineration process, various processes are under investigation, but up to now, the value "50% vol." corresponds to an encapsulation rather than an embedding. In fact a 200 l-drum filled with 100 % ashes is put in a 400 l-drum with a mean shielding thickness of 5 to 7 cm mortar.

CHAPTER VI

INTERIM STORAGE

Regarding the storage, the low and medium level wastes include, in addition to the wastes coming from the Nuclear Power Plants, those in the nuclear fuel cycle, the industry and medical applications.

In Belgium, the sea dumping was applied until September 1982 for the disposal of low level solid wastes.

Low level wastes and medium level wastes generated from 1975 onwards were conditioned in various types of containers, namely :

- metallic container of 220 l;
- metallic container of 400 l;
- metallic container of 400 l with internal shielding of 18 cm thickness concrete;
- metallic container of 600 l;
- metallic container of 1800 l;
- concrete container of 1000 l;
- concrete container of 1500 l;
- concrete container of 1600 l.

Some examples are shown in figures 33, 34 and 35.

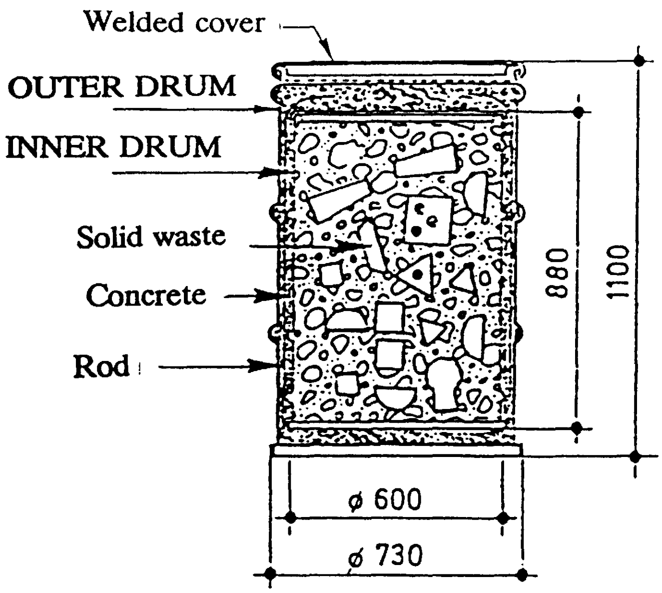
But now and for the future, the standard conditioning, for both types of waste, is a 400 l-drum so long as the direct contact dose rate remains below 300 mSv/h (see Figure 31).

The conditioned product has a mechanical withstanding greater than 150 kg/cm^2.

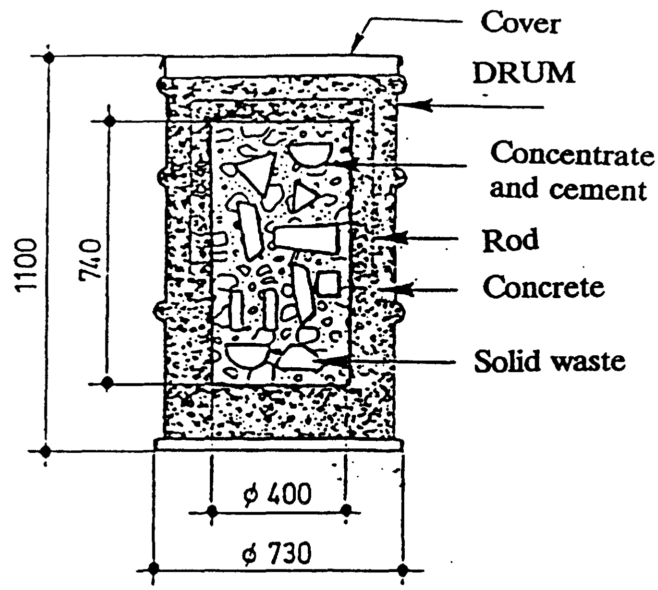
Sometimes it is technically necessary to store the waste during several years in a non-conditioned form. This is among other things due to the necessity to accumulate a sufficient amount of waste to allow rational treatment.

In anticipation of the opening of a disposal site, the conditioned waste packages are stored in buildings specially contructed for this purpose on the site of Dessel, operated by Belgoprocess.

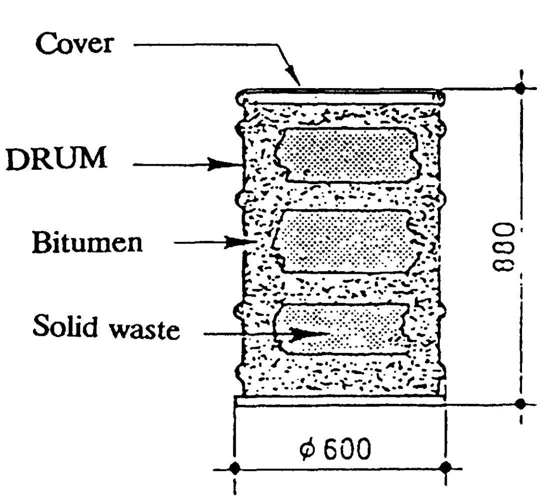
The waste is transferred to storage bunkers under the supervision of those responsible for the subsequent operations.



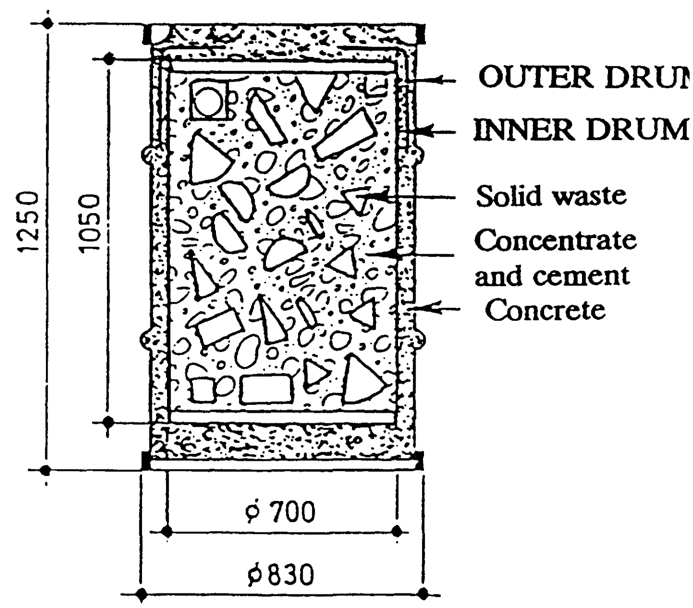
CONTAINER 400 / 75



CONTAINER 400/125



CONTAINER 220 / 0



CONTAINER 600 / 65

FIGURE 33 : VARIOUS TYPES OF DRUMS

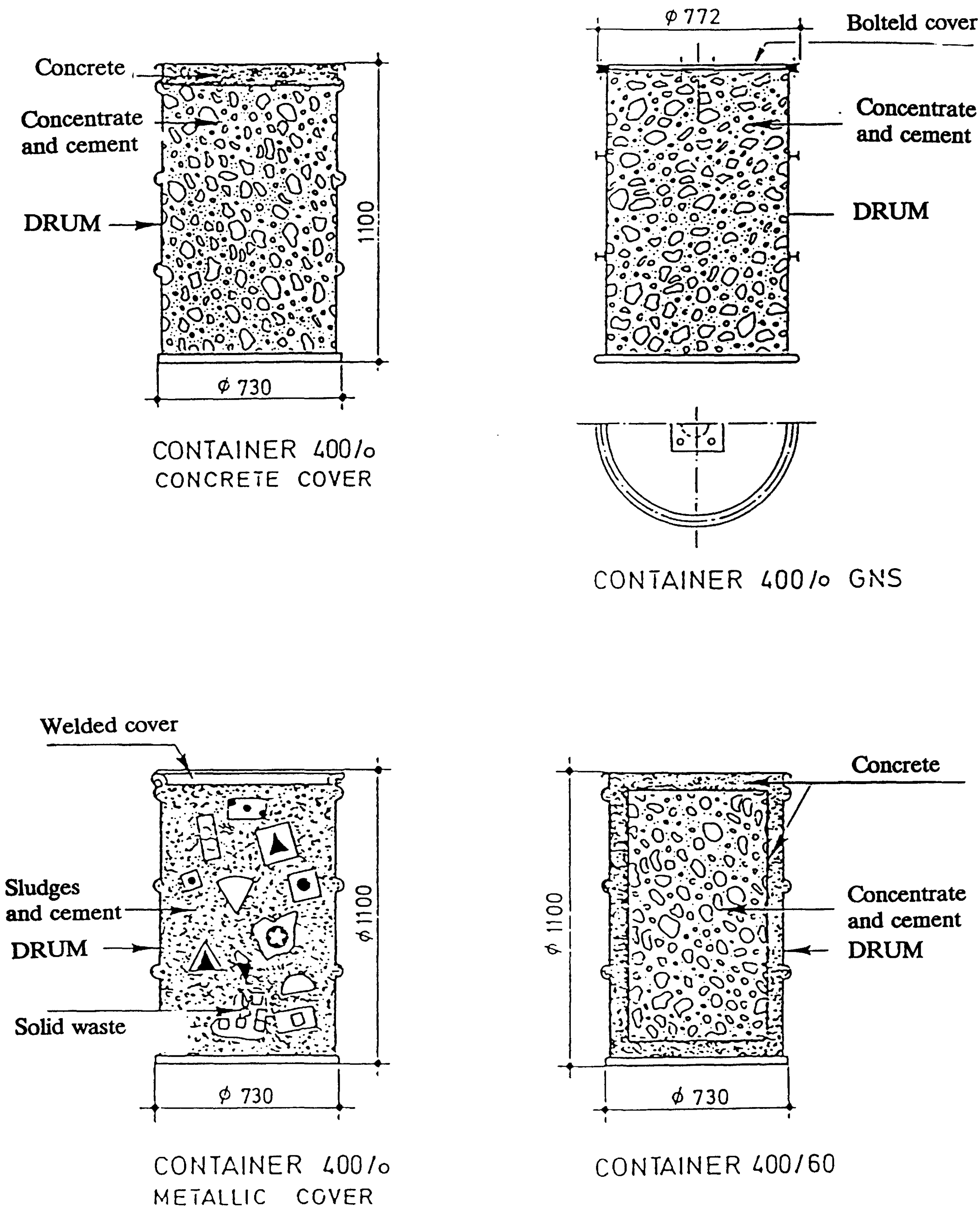
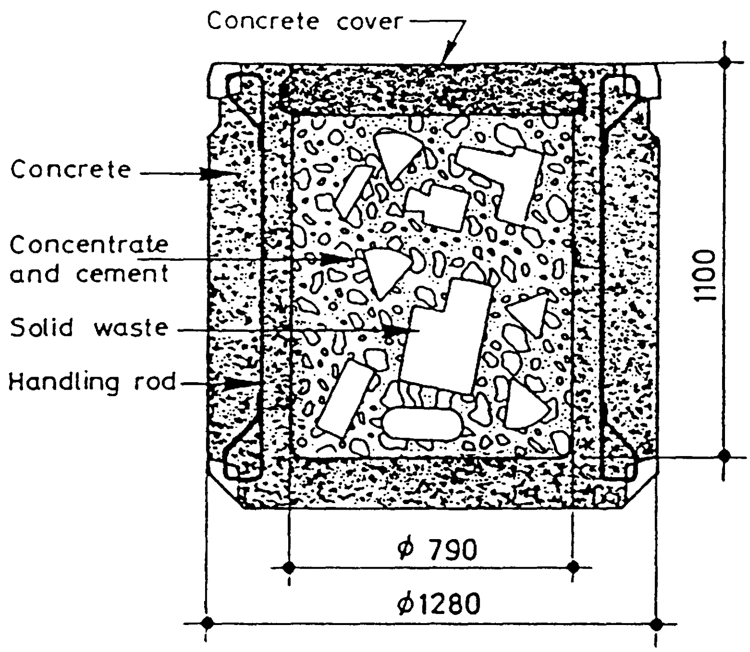
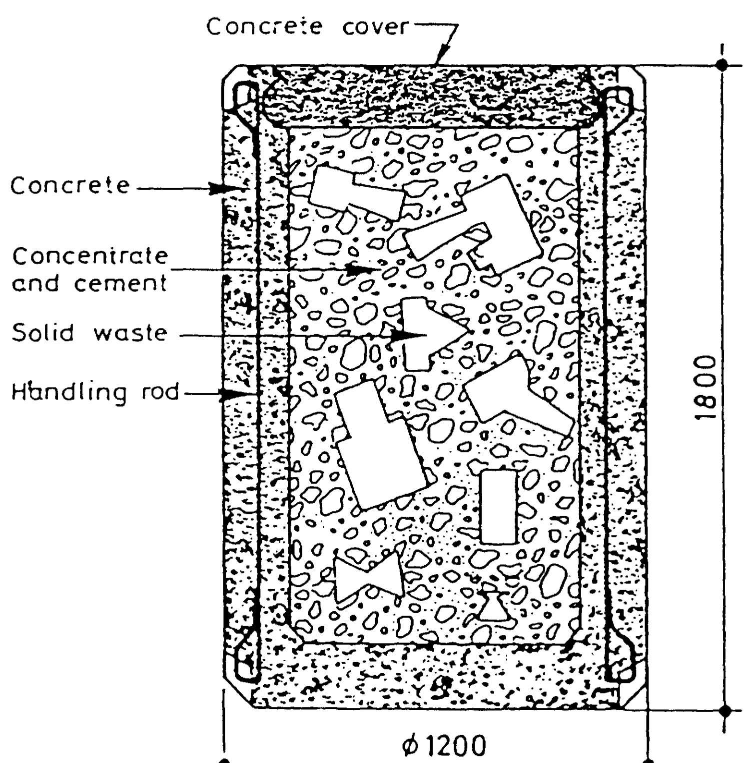


FIGURE 34 : VARIOUS TYPES OF DRUMS



CONTAINER 1600/200



CONTAINER 1500/200

FIGURE 35 : VARIOUS TYPES OF DRUMS

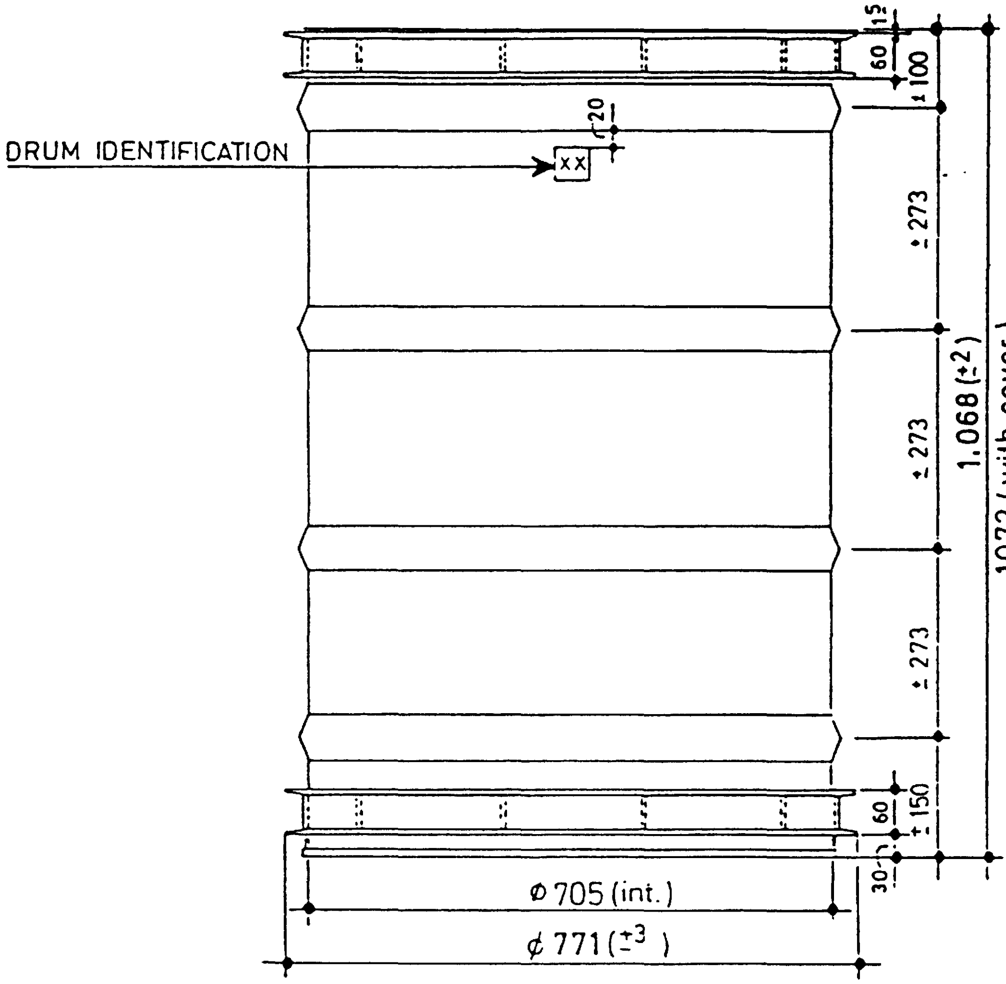


FIGURE 36 : DRUM STANDARD ONDRAF 400 l.

VI.1. Low Level Waste

The waste packages with a direct contact dose rate lesser than 4 mSv/h are defined as low-level waste.

Since the interruption of the sea dumping, low-level waste are temporary stored in a building (Nr. 51 ONDRAF - BELGOPROCESS) designed for ten year-storage waiting for a decision of the Authorities about definitive disposal.

Building
Material: prefabricated concrete
Shielding: 25 cm wall thickness
15 cm roof thickness

Handling
Standard drums: overhead crane 4 T with telescopic guide and automatic working.
Non-standard drums: overhead crane - 10 T.

Design specification
- vertical storage up to 6 layers;
- outside inspection corridor;
- segregation according to drum type;
- each drum individually retrievable.

VI.2. Medium Level Waste

Waste packages with a direct contact dose rate comprised between 4 mSv/h and 300 mSv/h are defined as medium level waste.

Since 1975, the medium level waste are temporary stored in a building (Nr. 27 ONDRAF - BELGOPROCESS) designed for twenty year-storage waiting for a decision of the Authorities about definitive disposal.

Building
Material: concrete.
Shielding: 80 cm wall thickness.
40 cm roof thickness.

Handling : overhead crane with telescopic guide and automatic working.

CHAPTER VII

TRANSPORT

Storage of radioactive waste is nomally performed by the waste producers themselves on site. Raw, still untreated wastes are stored out, classified and inventoried, on the spot, according to radiation and physical-chemical characteristics. In a subsequent step, the main producers themselves take care of the treatment and conditioning of a large part of their waste. The resulting waste packages are directly transferred to the centralised storage buildings on the Dessel site operated by Belgoprocess.

The following types of radioactive waste are transported :

- waste treated and conditioned by the producers themselves and directly transferred to the storage buildings on the site of Dessel;

- non-conditioned waste collected from the producers and to be transferred to the treatment and conditioning installations of the Dessel site;

The transportation of conditioned waste was entrusted by ONDRAF-NIRAS to TRANSNUBEL.

ONDRAF-NIRAS also organized and subcontracted to TRANSNUBEL the transportation of non-conditioned waste to the treatment and conditioning installations of Dessel site.

VII.1. Transportation Methods

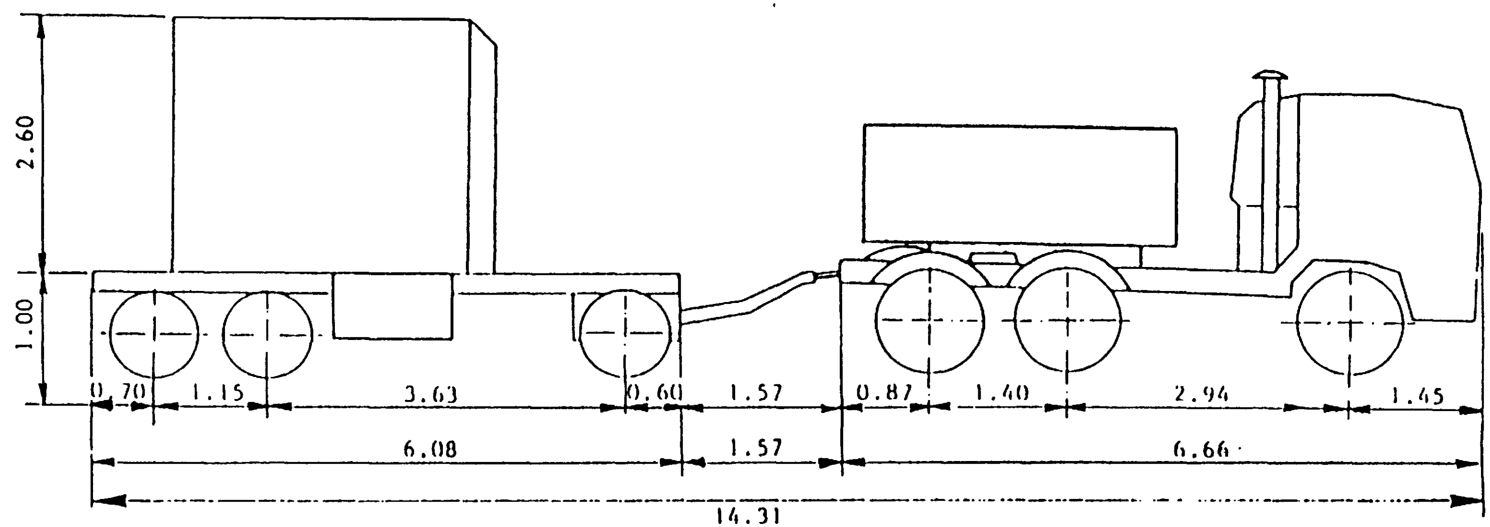
VII.1.1. Liquids (Sludges)

Some liquids (sludges) are transported from nuclear power plants to a central processing plant located on the Dessel site. These liquids are essentially composed of evaporator concentrates (sludges) containing mainly : Co-60, Mn-54, Fe-59, Cr-51, Cs-137.

For this purpose, container TNB 0165 (Figure 37) has been put into service.

This container with a double wall is placed in an external metallic structure specially strengthened of ISO-10 feet - type. The internal volume is 6 m^3.

The steel and lead shielding, and the specific accessories were foreseen to allow a safe execution of the handling and transport operations.



Truck weight	:	14 500 kg
Trailer weight	:	5 190 kg
Container weight (empty)	:	13 950 kg
Maximum payload	:	10 050 kg

FIGURE 37 : TRANSPORTATION OF LIQUIDS TNB 0165 CONTAINER

The outer dimensions of the 10 feet ISO container are :

- length: 2991 mm
- width: 2438 mm
- height: 2591 mm
- tare: 13,950 metric tons
- maximum gross weight: 24 metric tons
- maximum payload: 10,05 metric tons
- nominal capacity: 6850 lit.
- design temperature: 100°C
- design pressure: 3 bars

The container is transported on a 3 axle trailer having a pneumatic suspension and a weight of 5190 kg.

The main dimentions of such a trailer are as follows :

- length : 6080 mm
- width : 2500 mm
- heigth : 1000 mm

VII.1.2. Solids

These wastes are transported from nuclear power plants to central processing installations or interim storage in Dessel.

Conditioned wastes are placed 400l-drums. This standardization allowed the conception of a fitted transport-container.

Medium level waste package

The container TNB 0167 (Figure 38) was especially designed for the transportation of conditioned radioactive waste with a contact dose rate up to 0.3 Sv/h (30 rem/h).

To meet the requirements of the road transport regulations, the external dimensions are these of an ISO-20 feet type container taking into account the maximum allowed weight related to the shielding necessary to limit the irradiation during the transportation of radioactive materials.

The design takes into account the two following possibilities :

- transportation of drums with a dose rate lower than 50 mSv/h;
- transportation of drums with a dose rate lower than 300 mSv/h.

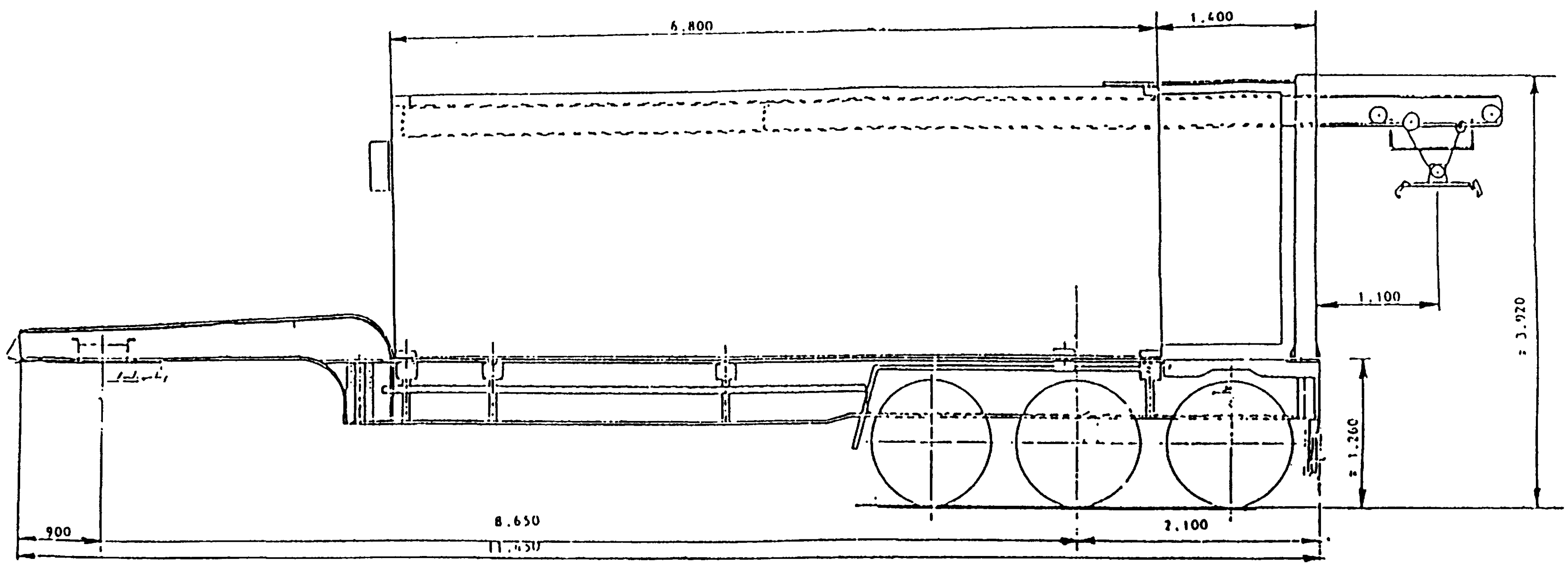


FIGURE 38 : TRAILER AND CONTAINER TNB 167

In the first case the container can transport up to 14 drums. The weight of the empty container including the corresponding shielding amounts to 19 metric tons.

In the second case the container can only transport 7 drums. The weight of the empty container including the corresponding shielding is then 26 metric tons.

Total lenght of the container on its truck = 14.5 m.

Height of the container: 2.36 m
Width of the container : 2.44 m

Total weight of the container and its truck = 73 metric tons.

With such a dose rate, the drums are remote handled from the truck cabin equipped with a video system.

The container is equipped with a crane with a hanging grip device able to lift up to 2500 kg.

Low level waste package

Until September 1982, when the sea dumping was practised, drums were loaded in an ISO-20 feet container transport by road to the next train station and then transferred by train to the shipping harbour.

This method had a negative impact on the occupational exposure of the personnel during the handling of the drums.

The ALARA principle (As Low As Reasonably Achievable) was the basis of the design of the container TNB 178 suitable for low level waste up to a direct contact dose rate of 4 mSv/h (400 mrem/h).

To meet the requirements of the road transport regulations the external dimensions are these of an ISO 40 feet type container.

This container has a lead shielding on the walls and on the floor allowing a safe transportation until 20 drums of 400 l (contact dose rate up to 4 mSv/h).

The container is equipped with a remote controlled pneumatic fastening system allowing an easy loading of the container and easy handling of the drums through an open roof.

Main data of TNB 178 :

- lenght:	12.2 m
- height:	2.44 m
- width:	2.54 m
- empty weight:	15.5 metric tons
- total weight with 20 drums:	33.5 metric tons

Non-conditioned waste

Non-conditioned solid wastes are also transported in a closed container of ISO 40 feet or ISO 20 feet types between the producer sites and the treatment installations.

VII.2. Waste Volumes to be transported

Table 10 gives for one year waste production of one 900 MWe unit PWR the following information::

- volume of the different types of waste before treatment;
- final volume of the different types of waste after treatment and embedding conditioning;
- final volume of waste packages (400 l-drums);
- splitting after transportation in function of the container type: TNB 167 - normal (14 drums/transport);
- with special shielding (7 drums/transport): TNB 178 - (20 drums/transport).
- splitting of the storage in function of the activity level.

For one year waste production the following transportations are necessary :

- 3 transportations/year with the container TNB 167 with its special shielding;
- 5 transportations/year with the container TNB 167;
- 26 transportations/year with the container TNB 178.

TABLE 10 : WASTE VOLUMES TO BE TRANSPORTED

WASTE TYPE	ANNUAL VOLUME (m3) PRIM. +SEC. =TOTAL	CONDITIONING/ EMBEDDING	MOD. VOL. COEF. TREATxEMB= GLOBAL	FINAL VOLUME (m3)	400 l DRUMS	TRANSPORT			STORAGE	
						TNB 167 S	TNB 165 NS	TNB 178	BUNKER	BAT.51
ION EXCHANGE RESINS		30 % VOLUME IN CEMENT+SAND (Activity after conditioning < 30 rem contact)								
-High Active (500 Ci/m3)	1.3 + 0 = 1.3		1 X 3.33 = 3.33	4.33	11	7 + 4	-	-	11	-
-Medium Active (50 Ci/m3)	2.6 + 4 = 6.6		(30 % VOLUME)	22	55	-	(3x14) +13	-	55	-
FILTER CARTRIDGES										
-Medium Active (50 Ci/F)	10 + 10 = 20	CONCRETE	20 x 400 l	8	20	-	20 (14+6)	-	20	-
-Low Active (1 Ci/F)	20 + 10 = 30	(1 Cartridge/Drum)	30 x 400 l	12	30	-	-	20+10	15	15
COMBUSTIBLE + COMPACTIBLE	260 + 0 = 260	ASHES 50 % VOLUME IN CONCRETE	$\frac{1}{28} \times 2 = \frac{1}{14}$	18.6	47	-	-	(2x20) + 7	-	47
COMBUSTIBLE + NON COMPACTIBLE	20 + 10 = 30	ASHES 50 % VOLUME IN CONCRETE	$\frac{1}{28} \times 2 = \frac{1}{14}$	2.14	6	-	-	6	-	6

TABLE 10 : WASTE VOLUMES TO BE TRANSPORTED (CONTINUED)

WASTE TYPE	ANNUAL VOLUME (m3) PRIM. +SEC. =TOTAL	CONDITIONING/ EMBEDDING	MOD. VOL. COEF. TREATxEMB= GLOBAL	FINAL VOLUME (m3)	400 l DRUMS	TRANSPORT			STORAGE	
						TNB 167 S	TNB 165 NS	TNB 178	BUNKER	BAT.51
NON COMBUSTIBLE + COMPACTIBLE	100 100.+ 20 = 120 20	50 % VOLUME IN CONCRETE	$\frac{1 X 2}{4} = \frac{1}{2}$ $\frac{1 x 2}{6} = \frac{1}{3}$	50 7	143	-	-	(7x20) + 3	-	143
NON COMBUSTIBLE + NON COMPACTIBLE	20 + 0 = 20	50 % VOLUME IN CONCRETE (10 CFR 61)	1 x 2 = 2	40	100	-	-	5x20	-	100
CONCENTRATES (at 250g/l)	0 + 10 =10	33 % VOLUME IN CEMENT+ SAND+ARGEX (PH non adjusted)	1 x 3 = 3	30	75	-	-	(3x20) + 15	-	75
FLOCCULATES (at 12 %)	0 + 12.5 = 12.5	25 % VOLUME IN CEMENT+SAND +ARGEX	1 x 4 = 4	50	125	-	-	(6x20) + 5	-	125
TOTAL	N.B. : A 400 l-DRUM HAS A NET VOLUME OF 400 l WASTE BUT TAKES A 500 l VOLUME (ALONE) AND A 560 l VOLUME IN PILE.			244.07	612	7 + 4	(5x14) + 5	(26x20) + 6	101 drums (40.4m3)	511 drums (204.4m3)

CHAPTER VIII

SENSITIVITY STUDIES

VIII.1. Mobile Treatment Units Versus Fixed Facilities

In the assumption of an installed park of 20 GWe PWRs distributed among 5 sites, two types of liquid radwaste treatment facilities are compared on the technical and economical points of view.

The first one is a fixed treatment facility located on each site of the installed nuclear park.

The second one is based on mobile treatment facilities which provides conditioning services for the liquid radwastes produced on the 5 sites.

VIII.1.1 Short Description of the existing Solid Waste Treatment Circuit

The solid waste treatment is included in a general radwaste system. It depends on the design of the other radwaste treatment circuits. However, the general design is similar for all PWRs considered.

Route N° PWR 1 (French scenario)

Initially, the process selected for the 900 MWe units was the embedding into cement in fixed cells. Each solid waste treatment system was common to two 900 PWR units. Troubles have appeared during start-up of the facilities. In the same time, new technologies of conditioning radwastes by mobile units based on the use of polymer matrix have become available. In addition, the level of retention of the embedded waste (leaching rate) of radioisotopes such as Cs-137 has been upgraded by the Safety Authorities.

These elements have lead to the choice of mobile units using thye polymer matrix for the embedding of Ion Exchange Resins (I.E.Rs) and concrete matrix for the concentrates and sludges. These liquid radwastes are treated in the following way:

Spent ion exchange resins originate from the demineralizers where they are backwashed before being flushed out of storage tanks. They are stored under water. They are transferred by gravity to a mobile unit in a metering pot and embedded into a polymer matrix.

Concentrates and sludges are mainly generated by the liquid waste treatment system and partially by the boron recycle system. Concentrated are stored in a storage tank. A mechanical mixer provides good homogeneity of concentrated before drumming.

Concentrates are mixed with concrete in containers my means of a disposable mixer.

Route N° PWR 2 (German scenario)
The reference PWR unit used for the radwaste definition is a 1300 MWe PWR.

Since the middle of the seventies, the German LWRs have abandoned the installation or the use of already installed conditioning systems within their power stations.
Until 1978/1979 mobile cementation facilities were in use for sludges, concentrates, resins and a polymer facility for resins only.

In 1979 due to a lack of storage (Asse-salt mine closed for the final disposal of nuclear wastes) the applied technology was the direct disposal of liquid radwaste with a mobile installation.

Ion exchange resins

The conditioning was performed in a mobile facility (FAMA). The spent ion-exchange resins was first dewaterred and then embedded with a polystyrene matrix into special casks. These casks have useful volumes ranging from 320 to 500 l depending on the shielding requirements (MOSAIK final disposal cask). The treatment capacity of the unit was up to 10 waste containers per day. To day, the direct disposal of IERs is practiced with a mobile unit called FAFNIR.

Concentrates and sludges

The treatment is performed in a mobile facility (FAVORIT). The concentrates and sludges are totally dried in order to achieve the formation of a solid block inside the special cask (Mosaik final disposal cask).

Treatment capacity is up to 100 l/h.
Remark : it must be noted that a part of the spent resins (lower activity 50Ci/m3) is mixed with the dried concentrates and sludges.

Route PWR-3 (Belgian scenario)

The solid waste treatment is either common to the PWR units (WAB-DOEL) or specific to 2 grouped units (TIHANGE).
It receives the following radwastes :

- spent IERs
- concentrates and sludges
- technological waste.

All these wastes including the liquid radwastes are handled in a fixed cementation facility.

Liquid radwastes are conditioned, possibly after an initial treatment by embedding them into concrete matrix using appropriate mixer (at Doel) or by an in-drum mixing technique at Tihange as described hereafter. The 400 l metallic drum is placed on a self driven carriage, taken ot the various product receiving stations and finally, to the mixing station where, once the carriage had been clamped into position, the mixer-shaft is lowered into the drum, to homogeneize and prepare the active mortar. Each drum is filled to 85-90% capacity in two alternating sequence steps, i.e., cement/wastes/mixing as the first step, and wastes/cement/mixing as the second step.

The incorporation rates depend on the type of waste being treated :

- 500 l of concentrates and flocculates per m3 of cement,
- 300 l of IERs per m3 of cement.

The capacities are the following :

- concentrates : 3 m3/day (DOEL) ; 1.4 m3/day (TIHANGE)
- IERs : 2.5 m3/day (DOEL) ; 0.8 m3/day (TIHANGE).

VIII.1.2. Primary Waste Inventories from PWR Units

During normal plant operation, different types of liquid radwastes are generated. The amount of arising waste is depending on the design of the circuits. In France, for example, low level liquid wastes are generally decontaminated by evaporation or chemical precipitation although ion-exchange is being increasingly used on power plants for liquid waste treatments in preference to evaporation (3).

French references

Per 900 MWe PWR unit, volume and activity release are the following :

Ionic exchange resins

- 7.6 m^3/y 50-500 Ci/m^3
- 2 m^3/y 5 Ci/m^3

Concentrates sludge

- 3.02 m^3 (0.5 Ci/m^3)

Remark : Production of concentrates and sludges was about 20 to 30 m^3/year and per unit (1 Ci/m^3).

After modification of the treatment of the secondary drain wastes this production has become about 6 to 8 m^3/year and per 900 MWe unit including the effluents of decontamination. The volume of concentrates and sludges amounts to 3 m^3/year and per 900 MWe unit.

German reference

The amounts of the different types of liquid radwastes are based on a 1300 MWe PWR Power Plant. There is no significant difference of the equipment kind and size for a 1300 MWe and a 900 Me power plant. The German plants have a separate liquid waste treatment system for each units, which is different compared to the French or Belgian situation.

The amounts of liquid radwaste generated during normal operation are the following:

Ionic exchange resins

- 3.3 m^3/a 200-500 Ci/m^3
- 2.6 m^3/a 200 Ci/m^3

Concentrates-sludges

- 30 m^3/y (1 Ci/m^3)

Belgian reference

The waste amounts mentioned hereafter are typical of a 900 MWe PWR. The incoming liquid radwastes to be considered are the following :

Ion exchange resins

- 7 à 8 m^3/year (150 Ci/m^3)

Concentrate-sludge

- 10 m^3/y (concentrate 250 g/l) (+/-1 Ci/cm^3)
- 12 m^3/y (flocculate 12 w/o)

VIII.1.3. Review of the existing Mobile Treatment Units

In the European countries various mobile treatment units are used for the conditioning of Ion-Exchange Resins (IERs) and concentrates flocculates. A lot of these units have collected a large industrial experience. Others mobile units are under development or have a reduced industrial experience. The first group includes DEWA, MOWA, FAMA, COMET, PRECED mobile units and are extensively described.

Table 11 from (3) summarizes operational experience gained with mobile units at the end of 1987.

The second group includes the SGN, the TECHNICATOME, the FAVORIT-FAFNIR mobile treatment units.

TABLE XI
Operational experience with mobile conditioning plant

Country	Power Plant Site	Plant Design	Waste Stream	Matrix	Quantity processed m3 200 l drums
Belgium	Research Centre (Mol) Power Plant (Tihange)	MOWA (1) FAMA (2)	Powder resin Bead resin	Cement Polystyrene	- 100 20 m^3
France	Power Plants (all 900 MWe units) (all 1300 & 900 MWe units)	COMET 1&2(3) PRECED (4)	Bead resin Bead resin, concentrates, sludge	Polymer Polymer	0.1 m^3 0.4 m^3
Germany	Power Plants (Biblis) (Brunsbuttel) (Gundremmingen) (Neckar-Westheim) (Philippsburg) (Unterweser) (Wurgassen)	DEWA (5) MOWA DEWA FAMA DEWA DEWA/MOWA DEWA MOWA	Concentrates Sludge Concentrate, sludge, decontaminant effluents Bead resin Concentrate Bead, resin, sludge, concentrate Sludge,concent. Sludge	Cement Cement Cement Polymer Cement Cement Cement Cement	340 250 250 650 370 1150 700 820
Italy	Research Centre (Casaccia)	MOWA	Inactive trials	Cement/ polymer	- -
The Netherlands	Power Plant (Borssele)	DEWA/MOWA	Sludge, resin concentrate	Cement	160 1520 (slud.,concent.) 8 121 (resin)

NOTES:
(1) Manufactured by NUKEM
(2) Operated by GNS/STEAG
(3) Manufactured by STMI
(4) Manufactured by PEC
(5) Manufactured by NUKEM, now superseded by MOWA

DEWA-MOWA (Nukem) Mobile Waste conditioning plants

- DEWA - Demountable waste conditioning plant
  DEWA is mobile equipment developed by Nukem in which pumpable and mixable nuclear waste can be bound in cement.

  The main characteristics are the following:

  Capacity : 2-5 m^3 per shift (8h/day)
  Packaging : 200 or 400 l drums or in drums with lost concrete shielding.

- MOWA (Nukem) - Mobile waste conditioning plant (4)
  The MOWA is a mobile waste conditioning plant for treatment of liquid low and intermediate level beta/alpha wastes and ion exchange resins. Based on the operational experience gained with the demountable waste conditioning plant DEWA, MOWA 1 was developed by Nukem and is in active operation since 1982 using cement as binder. In 1983, a second equipment MOWA 2 has been built for Nucleo, S.P.A., Italy. This plant enables the embedding of liquid radwastes into cement or resin-material. The main characteristics are the following :

  Throughput :

  - IERs up to 2 m^3 per 8 hr. shift
  - Concentrate/sludge up to 10 m^3 per 8 hr shift

  The final cemented product contain from 6 to 10 weight % dry waste (6 % concentrate and 10 % IERs).
  The organic polymer products contain 11 to 14 weight % dry waste (13 % IERs and 14 % concentrate).

  MOWA is able to manage drum of several sizes (100-400 L). All the parts of the mobile plants is skidmounted.

  It consists of :

  - two independent dosing and mixing positions for the waste disposal drums;
  - an accessible sealed cell with dosing devices for sludges, concentrates, and IERs;
  - two hydraulic aggregates for the drives of the in drum stirrers.

  For operation with the DOW-process (resin matrix) modifications have been done on the stirrer drive (higher rotational speed 0-500 rpm), the in drum stirrer design, the metering devices and the drum off gas system.

Operating experience with MOWA specifies the following points :

- active operation has been performed with waste materials in the range of 0.01 to 300 Ci/m^3;
- the average dose rate taken by the crew (1 foreman and 3 workers) has been less than 10 mRem per person and day;
- during transportation no technical failures and no problems concerning the radiation exposure and contamination occurred.

FAMA (STEAG) Mobile conditioning unit

The FAMA-Mobile Conditioning Unit has been developed in the FRG by GNS. One unit has been sold to STMI in France. This unit is operated under the name of COMET 1. The unit is devoted to the embedding of IERs by use of polymer matrices (styrene, diphenyl benzene). The IER's and the polymer are mixed in the drum (in-drum process).

The throughput of such an unit is 1-2 m^3/day.

COMET (STMI) - Mobile Conditioning Unit

Since 1982, STMI has designed and operated two mobile conditioning system for spent resins encapsulation using polymerized styrene as encapsulating material. In 1981 COMET I was operating. In 1983, COMET II was manufactured based on the experience gained with COMET I.

The two units are now on the same technical level and have the following main characteristics :

Throughput: 0.1 m^3/hr
Packaging: 110 or 200 l drums with special shielding depending on the level of radioactivity.

The COMET unit includes the following elements :

- a working platform with control board for semi-automatic operation;
- an auxiliary cabin (air compressor, fire extinguising system, vacuum pump and refrigeration unit for the reagents);
- a shielded vessel for spent resin metering allowing accurate level control of both resin and carrier water;
- a shielded pathway for safe transfer of the resin from the metering to the encapsulation vessel.

In addition to characterize the isotopic content of the encapsulated waste STMI has designed a dose rate measurement system which is connected by Modem to STMI headquarters.

Operating experience

The two COMET units have processed more than 450 m^3 in 4 years corresponding to 5,000 drums (110 liters).

The encapsulation process allows for eight drum per shift. In typical operation an STMI crew produces between 18 and 20 drums in a two shifts day.
The drums produced to date have been 110 liters liners containing 95 liters of resin. In 1986 qualification has be given for 200 liters liner.

The average dose for an operator during the process is about 2 mRem per drum, corresponding to an average value for a 5 man crew during 25 working days.

PRECED (PEC-STMI) - Mobile conditioning plant

The PRECED mobile conditioning plant has been design by PEC engineering based on a Dow Chemical Solidification process.

The DOW process is applied in various facilities fixed and mobile. It allows the incorporation of IERs or concentrates into DOW polymer.

Main characteristics :

- Throughput: 0.4 m^3/hr
- Average encapsulation efficiency : 65 %

The PRECED unit includes a five position shielded tunnel into which the liners used for resin encapsulation are introduced.

- PO position
  The liner is loaded into the system with an existing plant crane. Then it moves to the other positions by means of a motorized roller conveyor.

- P1 position
  Above P1 tunnel position a spent ion exchange resins dosing vessel is fed with a membrane pump. The resins are lowered to the liner through a screw conveyor. The loaded resins are then weighed with the drum in order to adjust the right quantity of polymer and catalysts to be added. The polymer and catalysts are poured into the liner and then mixed with a non-recoverable device.

- P2 position
  A first temperature of polymerisation checking is performed.

- P3 position
  After a final polymerisation, the liner is shielded and sealed with a predetermined thickness of leadshot with additional polymer mixture.

- P4 position
  Thirty minutes are needed to achieve a sealed processed drum.

Operating experience

The PRECED started operation in 1985. At the end of 1986, the following campaigns have been carried out :

- Tricastin (IER + concentrate)
- Dampierre (IER)
- St. Alban (concentrate)
- Flamanville (IER)

Concrete packagings are selected depending on level of radioactivity of the spent IERs.

Comparison COMET/PRECED

The two mobile units are operated by STMI in France on the different nuclear sites. COMET units are presently used for 900 MWE PWR units and treats the spent IER's. PRECED is presently used for all 1300 MWe PWR units and some 900 MWe units and enables to treat IER's and concentrates.

Based on the accumulated experience it appears the following comparison elements which are summarized in the table 12.

TABLE 12
COMPARISON OF THE CHARACTERISTICS OF THE COMET-PRECED MOBILE UNITS

ITEM	COMET	PRECED
Throughput	0.1 m^3/h	0.4 m^3/h
Process	simple	more complex
Safety	low risk of leakage (transfer under vacuum)	-
Incorporation rate (weight)	± 100 % (styrene)	max. 70 % (polymer)
Feed product	IER	IER + concentrates
Reagent cost	low (styrene)	DOW polymer = 2.5-3 x styrene
Hardening of the mixture	slow 2 to 10 days	fast a few minutes

Various mobile plants for the treatment of spent resins and concentrates flocculates are under development or have a reduced industrial experience :

SGN Cement Solidification of Spent Fuel Ion Exchange resins

SGN has developped a mobile plant which allows the cement solidification of spent ion exchange resins.

The main characteristics are the following :

Throughput : 1.5 m^3/day and per shift.
The encapsulation ratios (% dry resin mass) : 10-15 %.

The corresponding volumetric ratios (% resin volume settled with respect to overall volume of encapsulated material) are about 40 % and 75 % respectively.

This capacity enables treatment of resins from eighteen 1300 MWe PWR units, i.e. about 180 m^3 of resins with a volumetric encapsulation ratio of 40 to 75 %.

Drum : 55 gallon drum.

The mobile plant is made up of 3 palletizables modules as follows :

- a pretreatment module which comprise an agitated tank linked to a gas processing unit (for removal amoniac);
- a dry load feed module which comprises a hopper and a conveyor screw;
- a process module, which contains a mixer, the IER metering pot, the pour station, the drum handling.

SETH 200 (TECHNICATOME) Mobile conditioning plant

SETH 200 is a mobile conditioning plant for the embedding of radwastes into thermosetting polymer (polyester, epoxy).

The process has been developed by the French Atomic Energy Commission and its subsidiary TECHNICATOME.

The SETH 200 is designed to perform IERs embedding by epoxy process in fifty five gallons standard drums.

The main characteristics are the following :

Throughput: 1 m^3 (IERs) per 8 hr shift
1.5 m^3 (max.) per 8 hr shift

Proportion: 50 % epoxy
50 % IERs weight

Packaging: 220 l drum

The unit is equipped with two working stations, enabling interchange of empty and full drums while processing on the other line.

The embedding sequence is summarized as follows :

- the amount of spent ion exchange resins required to make a drum is transferred into the drum in its transport container;

- after IERs draining in the drum, the reagents forming the embedding matrix are transferred into the drum;

- the constituents are then mixed with an appropriate sequence;

- after interchanging the working places, the package is moved to a temporary storage area;

- when the polymerization has been checked a sealing plug is injected to close the drum.

FAVORIT-FAFNIR - Mobile Treatment Units

The solid waste treatment in German PWR's has been based on the use of mobile conditioning units using cement or polymer as matrix for resins, sludges, concentrates.

Recently due to a lack of storage capacity volume reduction of produced wastes became a prime necessity. A technic of direct disposal which ables dewatering of the resins, sludges, concentrates is applied.

The concentrates and sludges are treated with a mobile installation - FAVORIT -This installation is a drying facility for the volume reduction of radioactive wastes.

The objective is total drying in order to achieve the formation of a solid salt block inside special cast iron packages called MOSAIK. The casks have useful volumes of 320 to 500 l depending on the shielding requirements.

This technique of direct disposal allows to get an improvement of the volume ratio compared to the cementation going up to 20.

Spent resins are treated by this technique with a similar mobile installation called FAFNIR.

VIII.1.4. Advantages/Disadvantages Mobile Versus fixed Treatment Facility

Qualitative

A lot of a qualitative advantages are claimed for the use of mobile treatment facility.

- The operational experience of the existing treatment mobile units have shown that this kind of plant have a good reliability. It results that the station operator can call them for periodical conditioning campaign.

- The station operator is sure to get state of the art conditioning equipment available. If the process of the fixed station becomes obsolete, no investment costs are required to incorporate technical innovations. In the same way, the mobile unit allows a rapid adaptation of a process in compliance with any requirement issued by the safety authorities.

- The skilled personnel who is serving the mobile units reduces the dose up-take of the power station's personnel.

- However the treatment of liquid radwastes by campaign could require additional storage capacities.

Quantitative

The low production of liquid wastes at the level of each power plant favors the design of mobile units ensuring a maximum return on investment as they enable, thanks to rotations between several sites, an optimized management of wastes. In order to quantify this point, the impact of using mobile concreting facilities on the investment and operating costs has been analyzed by comparison between a fixed and mobile treatment facility.

VIII.1.4.1. Main Functions of the 2 Reference Systems

The reference system using mobile units will include a fixed concrete station allowing the embedding of solid wastes (filters, technological wastes, etc. The mobile units will treat liquid radwastes (IER's and the concentrates/sludges) using a cement matrix.

The reference system using fixed facilities is the BELGATOM one previously described in this report.

VIII.1.4.2. Liquid Radwaste Inventory/Production Capacity

The liquid radwaste european inventory retained by the assessment study has been choosen :

- concentrate sludge 30 m^3/a per ± 1000 MWe unit (1 Ci/m^3)
- IER's : 3.9 m^3/a per ± 1000 MWe unit (± = 200 Ci/m^3)

Production capacities

Per site (4000 MWe):
120 m^3 concentrate sludge
15.6 m^3 IER's

For the reference power capacity of 20 GWe (5 sites), the production capacities are the following :

600 m^3 concentrate-sludge
78 m^3 IER's.

VIII.1.4.3. Mobile Treatment Unit Characteristics

The Mowa-mobile waste conditioning plant for treatment of liquid wastes previously described has been selected as mobile unit for this sensibility study.

The main characteristics are the following :
- Standard drum: 400 l useful volume
- Concreting capacities (maximum)

  - 2 m^3 IER/8 hrs shift
  - 10 m^3 concentrate-sludge/8 hrs shift

VIII.1.4.4. Operating Period per Mobile Unit

The following assumptions are made to determine the operating period required to treat the liquid radwaste of one site.

Mobile unit

Effective capacities (6.5. effective working hours per shift) IER's : 2 x 6.5/8 = 1.625 m^3/8 hrs shift (max.)

Concentrate-sludge 10 x 6.5/8 = 8.125 m^3/8 hrs shift (max).

Execution of all the moving assembly-disassembly operation within 6 days
- Working time : 5 days/week

Transfer of the concentrate-sludge conditioning mode to the IER's one: 1 day if one mobile unit is used.

IER's : 2 x 30 m^3

Operating time per site for 2 campaigns

- Concentrate sludge 60/8.125 = 7.35 shifts

- IER's : 7.8/1.625 = 4.8 shifts

Duration of one campaign expressed in working days

Operations : 13 w.days
Moving/assembly/disassembly: 6 w.day or 1 calendar month per site and per campaign.

For the 5 sites and considering 2 campaigns per year, the number of calendar months would be for 10 for one mobile unit.

VIII.1.4.5. Optimized Configuration of the System based on Mobile Units

An operating period per mobile unit of 10 calendar months corresponds to a load factor of 83 % for one mobile unit. This figure of 83 % corresponds to the maximum concreting capacities applied. This value of 83 % does not give a sufficient safety margin: 2 mobile units are required.

The optimized configuration for a system using mobile units based on MOWA type will this include two MOWA facilities. One dedicated to the concentrates-sludges, the other to the IER's.

Each site of 4000 MWe will be specifically equipped with an encapsulation local which comprises :

- an overhead crane for the assembling/disassembling of a mobile unit;
- a decontamination system;
- a ventilation system.

In addition, the site will include the following units which are common to both systems (fixed and mobile units based).

Remark: the same useful storage capacity for the liquid wastes for both systems (fixed and mobile) has been kept in order to provide some decay and maximum flexibility for the operations.

- unit for collection-concentration and transfer of evaporator concentrates;
- unit for collection and concentration of flocculates;
- unit for collection and transfer of resins;
- unit for collection of iron oxide;
- immobilization station for solid waste;
- plugging station;

- drum capping system;
- the building corresponding to the fixed equipment of the common facilities.

VIII.1.4.6. Cost Assessment

The capital and operating costs associated with the use of mobile unit are based on the elements described in the previous paragraph.

Capital cost assessment

Capital cost of the 2 mobile units 2 MECU 88

Per site, the capital cost of the subsystem specifically dedicated to the use of mobile unit has been estimated to 0.23 MECU 88.

The capital cost of the common facilities to the both systems has been evaluated to 8.92 MECU 88.

For the 20 GWe nuclear park the capital cost is:
(8.92 + 0.23) x 5 + 2 = 49.75 MECU 88

The capital cost of the fixed system is estimated to:
10.46 x 5 = 52.30 MECU 88

The reference system for this estimation is the solid waste treatment system previously described which has been adapted to a site of 4 GWe nuclear capacity.

For this reference system, it must be noted a useful storage capacity for concentrate-sludge and IER's of 170 m^3.

It results a slight reduction of the capital cost of 2.55 MECU 88.

Operating cost assessment

a) Operating personnel

The following operating personnel is assumed to operate a mobile concreting facility:

- chief operator
- 3 operators

Each mobile unit will operate during 5 calendar months. The remaining time will be devoted to maintenance, improvement and possible repairs. If we take into account, some partial contribution of personnel of the site, the same number of operators has to be considered.

b) Utility consumptions

The process applied for the two system (concrete technology) being identical, the utility consumption will be the same.

VIII.1.5. Conclusions

The use of mobile unit reduces the capital cost of a radwaste treatment facility corresponding to a 20 GWe nuclear park (reduction factor ± 5 %).

The operating costs are not significantly affected by use of the mobile units.

In addition, radwaste treatment facility based on mobile unit presents a lot of qualitative advantages for the nuclear operator. The main important being the flexibility of such a facility by incorporating technical innovations and improvements to the technology to treat the liquid radwastes.

VIII.2. Economical Impact of Interim Storage Capacity on Management Cost

In the assumption of an installed park of 20 GWe PWRs, the variation of the total cost of the operations of storage (interim + final) is studied as a function of the interim storage capacity.

The reference systems used for this study are respectively a central engineered storage facility for the interim storage and a shallow land burial for final storage.

Regarding the total cost, the study shows an optimized period for the interim storage. This optimized period strongly depends on the financial and economical assumptions selected.

VIII.2.1. Buildings and Operating Costs of the Storage Facilities

Both storage facilities (interim and final) are evaluated as a function of their capacity. The determination of costs, the procedure are based on the methodology described by TASK. The same financial and economical assumptions choosen for the study have been applied.

Interim storage

The interim storage of the packages are carried out on a central storage site. The facility includes :

- the modules of storage depending on the capacity;
- fixed facilities such as reception and dispatching stations, control and inspection of the drums, management and administration building.

The following input data were established to perform the cost actualisation of the interim storage plant.

Construction period of the plant:	4 years
Start of construction:	01.01.1988
Date of actualisation:	01.01.1992
Duration of plant operation:	30 years

For the Belgian route the cost data for an interim storage facility with a capacity of respectively 1 year and 10 years are the following:

Capacity 1 year (building volume = 33.284 m^3)

Investment cost:	13.52 MECU92
Operating cost:	1.05 MECU92/year

Capacity 10 years

Investment cost:	39 MECU92
Operating cost:	1.05 MECU92/year

Remark: The amount of drums handled per year being constant, it is assumed that the operating cost of an interim storage facility does the following relation for the investment cost (I.C.) versus buffer capacity (x) is proposed :

I.C. = 13.52 [79 (%) + 21 (%) x]
O.C. : 1.05 MECU92/year

where IC, OC are expressed in MECU 92

Final storage

The main characteristics of the disposal facility applying the near surface storage technology are those of the Centre de Stockage de l'Aube "C.S.A." and are given in the report (7).

The cost data for this repository have been adapted to the Belgian route (5333 m^3 packages production/year) following the relations given in the document (7). It results the following cost data:

Investment cost:	43 MECU92
Operating cost:	5.47 MECU92

for the case where the operations of disposal start after 1 year.

The following input date were established to perform the cost actualisation of the final storage plant.

Construction period of the plant:	3 years
Start of the construction:	11.01.1990
Date of actualisation:	01.01.1992
Duration of plant operation:	30 years

When the start of operation of the final storage is delayed its yearly processing capacity must be increased as more packages must be processed before the plant lifetime : it is assumed that the plant lifetime is restricted to 1992 + 31 = 2033

Taking into account the distribution of costs between the fixed part and the variable one (7) the following relation for the operating cost versus its annual processing capacity has been considered :

$$O.C. = 5.47\ [78\ (\%) + 22\ (\%)\ y]$$

where y = number of year before the start-up, O.C. expressed in MECU92.

Remark: The cost of the storage modules is included in the operating costs since these modules are built as required.

$$I.C. = 43\ MECU92$$

This value does not depend on the number of year before the start-up.

VIII.2.2. Cost Optimization of the Combined Interim and Final Storage Operations

The sensitivity of the cost of the combined interim and final storage operations has been estimated from the relations defined herebefore.

The total storage cost (investment + operating costs) of both storage facilities for a total duration of 31 years of operation has been calculated as a function of the interim storage capacity. The results of the calculations are shown in Figure 34.

The following financial and economical data have been used for this calculation :

Currency:	ECU92	
Interest rate (i.t.):	8.3 %	
Inflation rate (i.f.):	2.2 %	
Net discount rate:	6 %	$\frac{100+i.t.}{100+i.f.} - 1$

The figure 39 indicates a minimum value for a capacity of interim storage corresponding to 18 years operation.

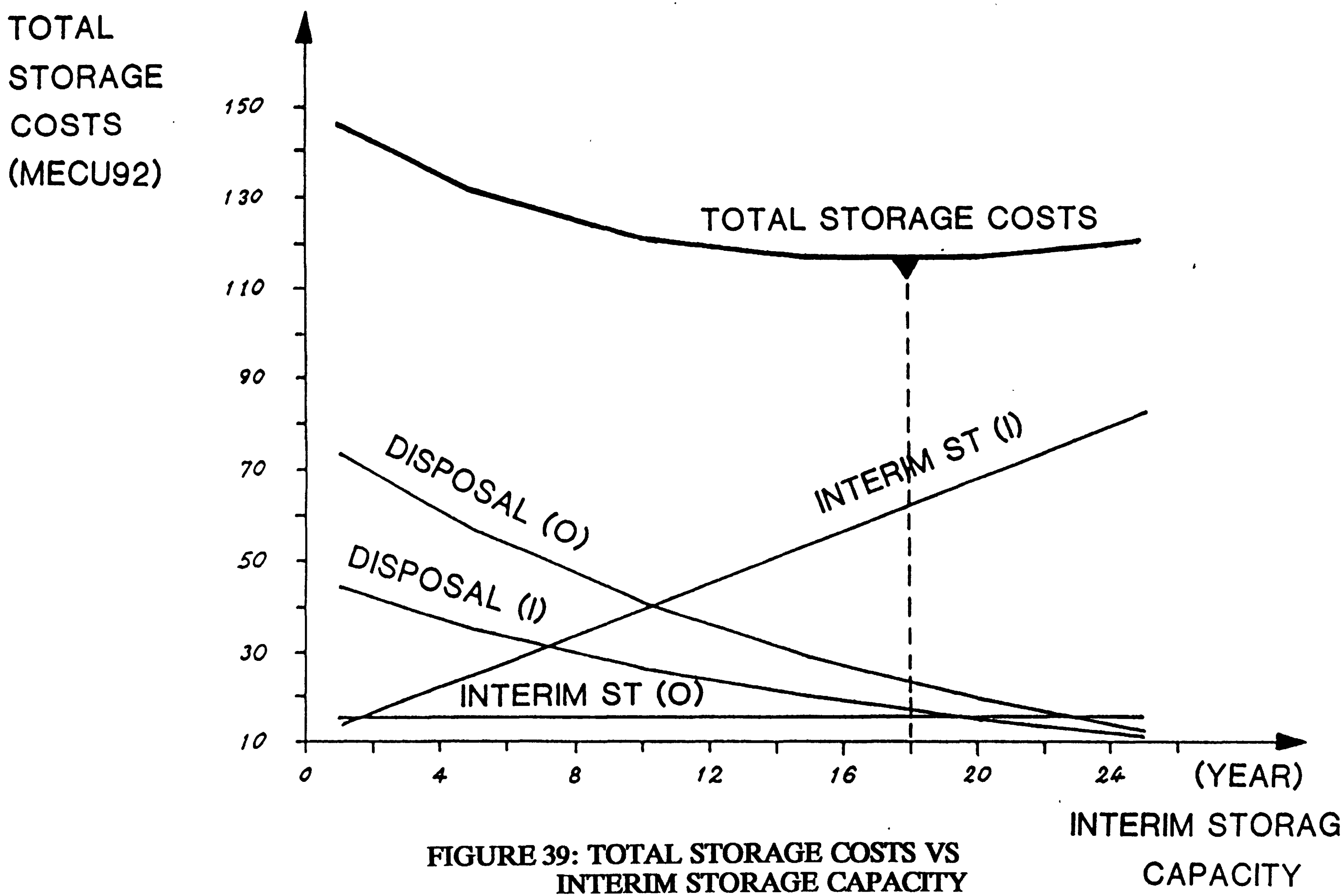


FIGURE 39: TOTAL STORAGE COSTS VS INTERIM STORAGE CAPACITY

Delaying the final storage operations for a period of 18 years will minimized the total costs of the combined interim and final storage operations for the given technical and financial conditions.

VIII.2.3. Sensitivity of the Optimized Interim Storage Capacity with the Financial Conditions

The total cost and consequently the optimized period of delay to start disposal operations has been calculated with constant financial conditions for a period of time of more than 30 years.

The sensitivity of the optimized interim storage capacity with financial conditions has been evaluated.

Various net discount rates have been selected for the calculation of the total storage costs versus interim storage size. The results are shown In figure 40.

The optimized interim storage size is reduced when the net discount rate increases. The optimized interim storage size will vary from 13 years for a net discount rate of 10 % to 22 years for a value of 4 %.

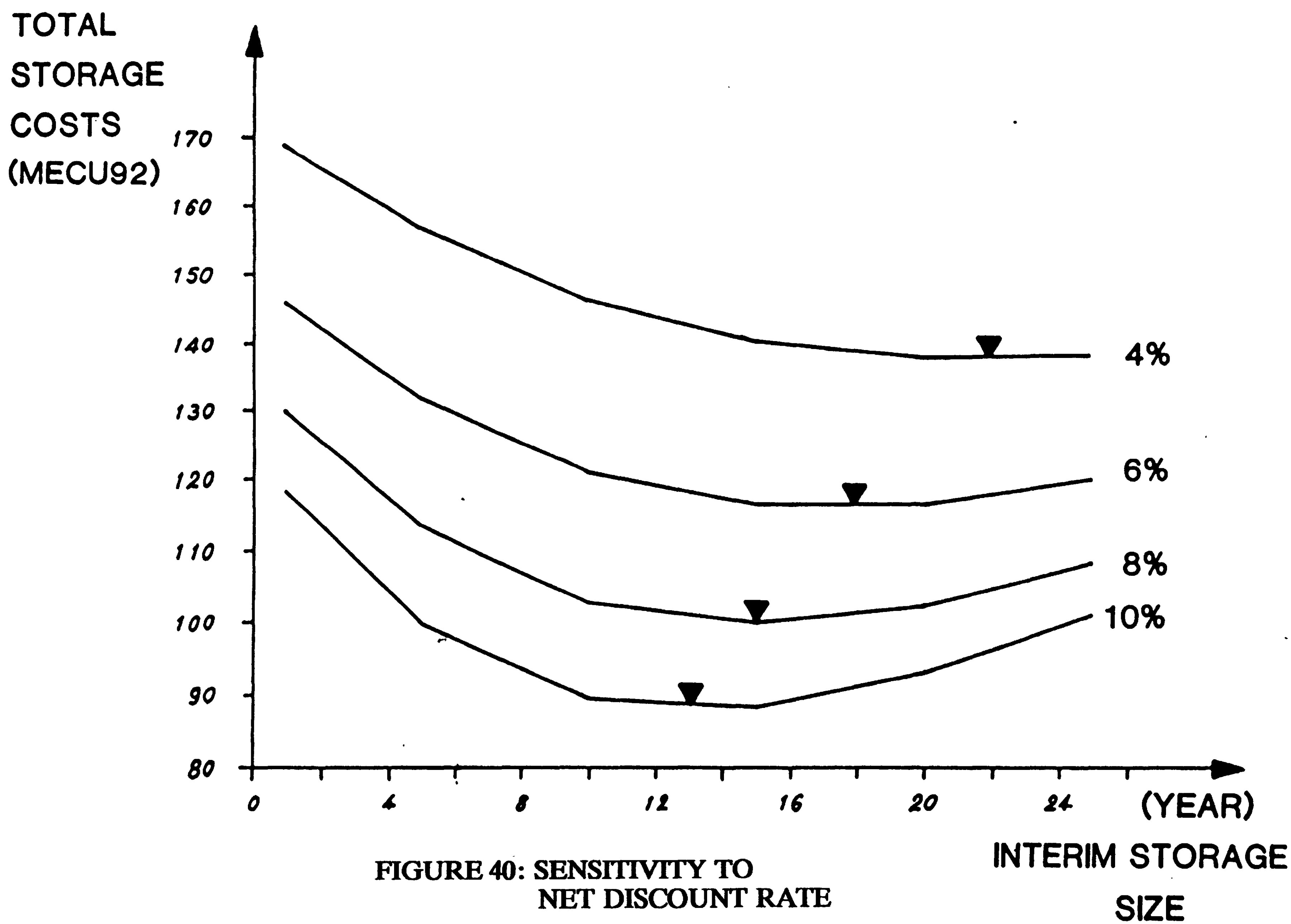


FIGURE 40: SENSITIVITY TO
NET DISCOUNT RATE

CHAPTER IX

REFERENCES

(1) E. de Saulieu (SGN), C. Chary (EDF), "Assessment of Management Alternatives for LWR Wastes : Description of a French scenario for PWR waste", EUR report N° 14043 EN/Vol 2 (1992)

(2) K. Janberg (GNS), Dr. Geiser (GNS), S. Santraille (Framatome), "Assessment of Management Alternatives for LWR Wastes : Description of German scenarios for PWR and BWR wastes", EUR report N° 14043 EN/Vol 3 (1992)

(3) F.H. Passant, Radioactive Waste Management in Western Europe. A review, Unipede - Sorrento Congress, May 30-June 3, 1988

(4) H. Brunner et al., MOWA, the mobile waste conditioning plant, Radioactive Waste Management Conference, London, November 27-29, 1984

(5) Cl. Jaouen, B. Vigreux, Cement solidification of spent ion exchange resins produced by the nuclear industry spectrum, International Meeting on Nuclear and Hazardous Waste Management, Pasco (USA), September 11-15, 1988

(6) G. Thiels (Task R & S), S. Kowa (KAH), "Assessment of Management Alternatives for LWR Wastes : Cost determination of the LWR waste management routes (Treatment/Conditioning/Packaging/Transport Operations)", EUR report N° 14043 EN/Vol 6 (1992)

(7) J. Malherbe (CEA), "Assessment of Management Alternatives for LWR Wastes : Cost and radiological impact associated to near surface disposal of reactor waste (French concept)", EUR report N° 14043 EN/Vol 7 (1992)

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EUR 14043 – Assessment of management alternatives for LWR wastes
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Description of a Belgian scenario for PWR waste

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This report deals with the description of a management route for PWR waste relying to a certain extent on Belgian practices in this particular area. This description, which aims at providing input data for subsequent cost evaluation, includes all management steps which are usually implemented for solid, liquid and gaseous wastes from their production up to the interim storage of the final waste products.

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