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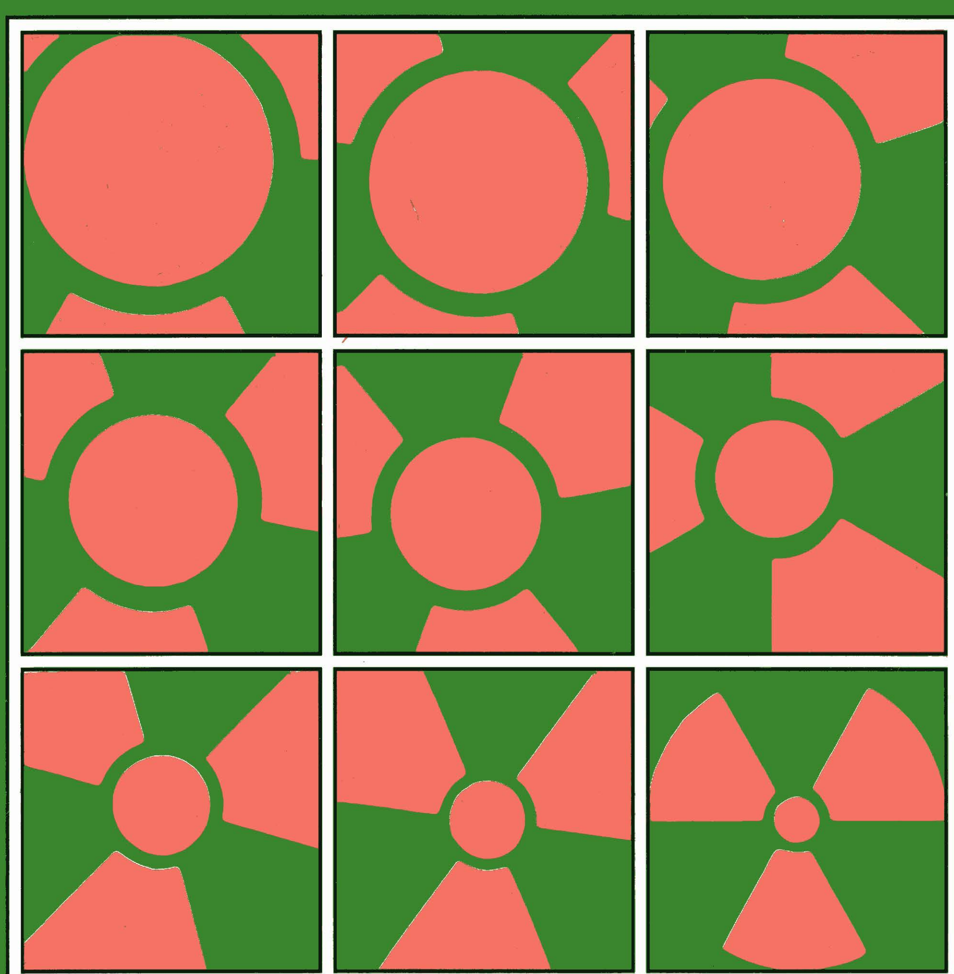
nuclear science and technology

Assessment of management alternatives for LWR wastes

(Volume 2)

Description of a French scenario for PWR waste



Report

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Description of a French scenario for PWR waste

E. De Saulieu
SGN
1, rue des Hérons
Montigny le Bretonneux
F-78182 St Quentin-en-Yvelines

C. Chary
EdF-Septen
12-14, avenue Dutriévoz
F-69628 Villeurbanne

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Final report

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'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 French practices 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 French concepts and industrial practices.

The French treatment systems varie according to the waste activity levels. They include the boron recycle system (TEU), the liquid waste treatment system (TEV) the gaseous waste treatment system (TEG) and the solid waste treatment system (TES) which are described in this report and adapted to common primary waste inventories and discharge limits.

Released activity and related radionuclide spectrum are provided for the assessment of the radiological impact to the public and dose rates to the workers are assessed.

Cost elements are provided such as : characteristics of the major equipment used as based value for the cost determination procedure, estimated volume of the treatment systems building for the assessment of the civil works costs, general information provided by EDF for the French experience, to serve as a basis of comparison for operation cost assessment.

In addition, a part of the study examines the impact of using mobile instead of fixed concreting facilities on the capital and operating costs.

CONTENT

1. ROUGH DESCRIPTION OF TREATMENT CIRCUITS (FOR TWO UNITS)

All waste treatment systems described here are common to two 900 MWe units.

They correspond to the process flow diagrams attached in appendix 1.

Treatment varies according to waste activity level.

The vent and drain system (RPE) collects and routes effluents to the appropriate treatment system :

- The boron recycle system (TEP) separates the non-contaminated reactor coolant effluents into boric acid solution and reactor grade water, both to be reused as make-up to the reactor coolant system (REA), thus limiting the amount of effluents to be discharged to the environment (see TEP 501 to 504 in appendix 1).

- The liquid waste treatment system (TEU) incorporates four functions :

  . storage (see TEU 501, 503, 504 and 505 in appendix 1),

  . demineralization (see TEU 502 in appendix 1),

  . evaporation (see TEU 506 in appendix 1),

  . filtration.

Purified waste is released from the plant after monitoring. Should release conditions not be met (too high radioactive level of the waste), they can be recycled for reprocessing;

- The gaseous waste treatment system (TEG) reduces effluents activity level before monitoring at to the plant stack and release to the atmosphere (see TEG 501 in appendix 1).

- The solid waste treatment system TES receives :

  . spent IERs,

  . concentrates and sludges,

  . filters,

  . technological waste.

The main operations are the following :

* Spent IERs :

  The spent ion exchange resins are backwashed in the demineralizers (RCV, PTR, TEU, TEP), then flused out using the demineralized water distribution system (SED). After which, they are transferred to the storage tanks (see TES 501 in appendix 1) where they are stored under water. They are transferred by gravity to the mobile unit in a metering pot used to dose the resins into concrete containers C4 (see appendix 2).

* Filters :

  The removal of liquid circuits filters occurs either when the pressure drop on the filter reaches the maximum design value or when the accumulated activity on the filter becomes too high.

  The filters are grouted into concrete containers C4 or C1 (see appendix 2).

  Special devices and notably a lead filter cask, allow the transfer of those filters to the drumming station by means of a vertical transfer tube. A vibrating table is used to improve the filling of concrete around the filter.

  After a setting time of about one day, final concrete capping is performed.

* Concentrates and sludges :

  These are mainly generated by the TEU evaporator but a link with the TEP concentrates tank also allows the concentrates to be transferred to the TES when, in upset conditions, they cannot be recirculated to the primary system (REA).

  Concentrates are stored in a stainless steel tank of 5 m3 (see TES 501 in appendix 1).

  A mechanical mixer provides good homogeneity of concentrates before drumming. Electrical tracing is provided to maintain the temperature of the concentrates in the 55 - 60°C range.

  A metering pot (capacity : 120 l) located under the tank is used to dose concentrates in the concrete containers C1.

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

* Miscellaneous waste :

  This waste is generated by work performed in the controlled radioactive area. (Anything likely to have been in contact with radioactive substances : tools, vinyl bags, rags, clothes... and that cannot be decontaminated or washed).

  The wastes are put into metal drums because of their very low activity.

  The compactable ones are previously precompacted in order to divide their volume by 3.

  - The monitoring and release system (KER) is provided to monitor the activity, to take the volumes of the effluents into account and to perform releases to the natural environment through a dilution device when external conditions are favorable (see KER 501 in appendix 1).

2. BASIC ASSUMPTIONS

2.1 Discharge limits for one PWR unit

TABLE I : DISCHARGE LIMITS RELATED TO ONE PWR UNIT (900 MWe)

EFFLUENTS	OBJECTIVE VALUE	DESIGN VALUE
Liquid effluents		
. Total (H-3 excluded)	2 Ci/a	9 Ci/a
. H-3	750 Ci/a	950 Ci/a
Airborne effluents		
. Noble gases	2,000 Ci/a	20,000 Ci/a
. Halogens	0.02 Ci/a	0.3 Ci/a
. Aerosols	0.02 Ci/a	0.5 Ci/a
. Tritium	100 Ci/a	200 Ci/a

The design value is the discharge limit which should necessarily be met by the treatment and conditioning facilities whereas the objective value is the target to be reached during normal operation but without any binding constraint.

2.2 Primary waste inventories for one PWR unit (900 MWe)

TABLE II : PRIMARY WASTE INVENTORIES FOR LIQUIDS

WASTE ORIGIN	DESIGN VALUE	REAL VALUE
Primary system effluents	100 Ci/m3 (with gas) 10 Ci/m3 (without gas) 24,000 m3/a	0.1 Ci/m3 (out of gas) (H_3 excluded) 10,000 m3/a
Secondary drain waste	1 Ci/m3 (peak value)* 10^{-1} Ci/m3 (on average) 4,000 m3/a	10^{-2} Ci/m3 2,500 m3/a
Laundry waste	10^{-4} Ci/m3 4,000 m3/a	10^{-4} Ci/m3 (peak value) 10^{-5} Ci/m3 (on average) 4,000 m3/a
Decontamination operations	10^{-1} Ci/m3 500 m3/a	10^{-2} Ci/m3 10 m3/a
Chemicals	10^{-2} Ci/m3 1,500 m3/a	10^{-3} Ci/m3 1,500 m3/a
Building waste	10^{-3} Ci/m3 6,000 m3/a	10^{-3} Ci/m3 3,000 m3/a

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

TABLE III : PRIMARY WASTE INVENTORIES FOR GAS

WASTE ORIGIN	DESIGN VALUE	REAL VALUE
Chem. & Volume Control. system + Primary System degassing	10,000 Nm3/a 2,000 Nm3/a	6,000 Nm3/a 200 Ci/Nm3 (peak value) 20 Ci/Nm3 (calculation value)
Ventilation	150,000 Nm3/h 10^{-4} Ci/Nm3 *	150,000 Nm3/h 5×10^{-7} Ci/Nm3

* Accidental value.

TABLE IV : PRIMARY WASTE INVENTORIES FOR SOLIDS

WASTE ORIGIN	DESIGN VALUE	REAL VALUE
Primary resins :		
highly active	1.3 m3/a 700 Ci/m3	1.3 m3/a 500 Ci/m3
low active	2.6 m3/a 100 Ci/m3	2.6 m3/a 50 Ci/m3
Primary filters :		
RCV	15 filt/a 100 Ci/filt.	10 filt/a 50 Ci/filt.
PTR	25 filt/a 2 Ci/filt.	20 filt/a 1 Ci/filt.
Normal equipment combustible + compactable (1)	260 m3/a 0.01 Ci/m3	260 m3/a 0.01 Ci/m3
Normal equipment non combustible + compactable(1)	100 m3/a 0.01 Ci/m3	100 m3/a 0.01 Ci/m3
Normal equipement combustible + non compact. (2)	20 m3/a 0.01 Ci/m3	20 m3/a 0.01 Ci/m3
Normal equipment non comb. + non compact. (2)	20 m3/a 0.2 Ci/m3	20 m3/a 0.2 Ci/m3

Notes :

(1) Density before compaction : 0.15

(2) Mean density : 0.75

2.3 Radionuclide composition of the primary waste

TABLE V : RADIONUCLIDE COMPOSITION FOR THE PRIMARY LIQUID EFFLUENTS

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	1.79	1.79

H_3 : 0.60 Ci/m3

TABLE VI : RADIONUCLIDE COMPOSITION FOR THE OTHER LIQUID EFFLUENTS

RADIONUCLIDE	H-3	Mn-54	Co-58	Co-60	Sr-90	Nb-90	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-134	Cs-137
%	4.75	0.46	0.79	1.38	0.46	0.92	19.00	19.00

TABLE VII : RADIONUCLIDE COMPOSITION OF HYDROGENATED GASEOUS WASTE AND VENTILATION GASES

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	I-132	I-133	I-134	I-135	Aerosols
%	11.31	0.01	0.02	0.03	0.01	0.02	0.00001

TABLE VIII : RADIONUCLIDE COMPOSITION FOR SOLIDS

RADIONUCLIDE	Mn-54	Co-58	Co-60	Mo-90	Ag-110m	Sb-124	Cs-134	Cs-137
%	5	33.32	6.68	5	5	5	20	20

3. MATERIAL AND ACTIVITY BALANCES

The material and activity balances have been based on the real values given in § 2.

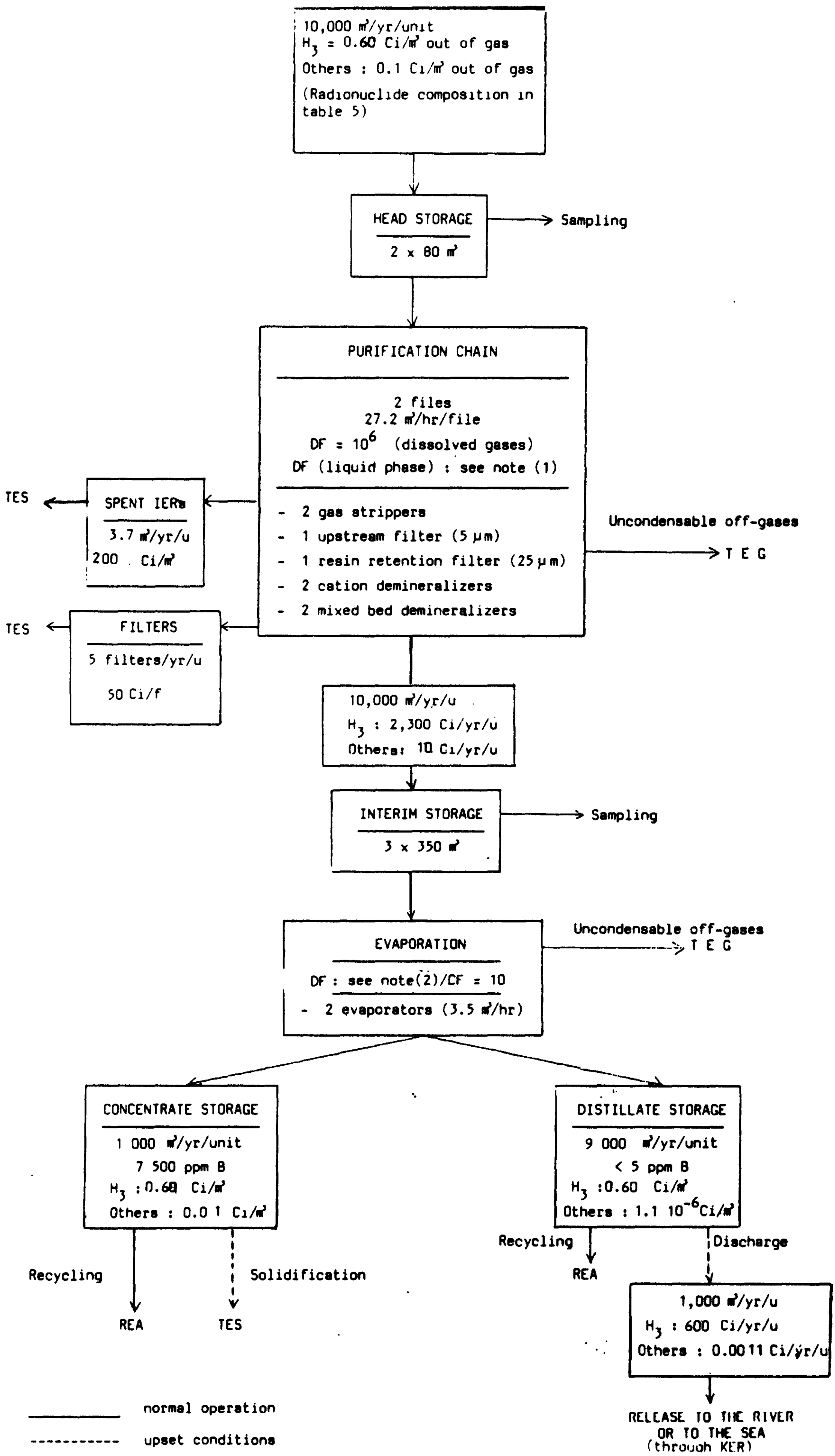
3.1 Boron recycle system : TEP

3.1.1 TEP block diagram

Notes :

1 - The decontamination factor of the demineralization step is about 100 without H_3 ($DF(H_3) = 1$).

2 - The decontamination factor of the evaporation step is about 1,000 without H_3 ($DF(H_3) = 1$).


10,000 m³/yr/unit
H3 = 0.60 Ci/m³ out of gas
Others : 0.1 Ci/m³ out of gas
(Radionuclide composition in table 5)
HEAD STORAGE
2 x 80 m³
Sampling
PURIFICATION CHAIN
2 files
27.2 m³/hr/file
DF = 10⁶ (dissolved gases)
DF (liquid phase) : see note (1)
- 2 gas strippers
- 1 upstream filter (5 μm)
- 1 resin retention filter (25 μm)
- 2 cation demineralizers
- 2 mixed bed demineralizers
Uncondensable off-gases
T E G
TES
SPENT IERs
3.7 m³/yr/u
200 Ci/m³
TES
FILTERS
5 filters/yr/u
50 Ci/f
10,000 m³/yr/u
H3 : 2,300 Ci/yr/u
Others: 10 Ci/yr/u
INTERIM STORAGE
3 x 350 m³
Sampling
EVAPORATION
DF : see note(2)/CF = 10
- 2 evaporators (3.5 m³/hr)
Uncondensable off-gases
T E G
CONCENTRATE STORAGE
1 000 m³/yr/unit
7 500 ppm B
H3 : 0.60 Ci/m³
Others : 0.0 1 Ci/m³
Recycling
REA
Solidification
TES
DISTILLATE STORAGE
9 000 m³/yr/unit
< 5 ppm B
H3 : 0.60 Ci/m³
Others : 1.1 10⁻⁶ Ci/m³
Recycling
REA
Discharge
1,000 m³/yr/u
H3 : 600 Ci/yr/u
Others : 0.0011 Ci/yr/u
RELEASE TO THE RIVER OR TO THE SEA
(through KER)
normal operation
upset conditions

3.1.2 Volume and activity release

Liquid (released to the river or to the sea through KER) :

- 1,000 m3/yr/u
- tritium H_3 : 600 Ci/yr/u
- other radionuclides : 0.0011 Ci/yr/u

Gases (sent to TEG) :

- not detailed here

Solids (sent to TES) :

- ion exchange resins :
  . 3.7 m3/yr/u
  . 200 Ci/m3
- filters :
  . 5 f/yr/u
  . 50 Ci/f

Total activity release from TEP :

- concentrates (recycled) :

. H_3 :	600	Ci/yr/u
. other radionuclides :	9.99	Ci/yr/u
- filters + IERs :	990	Ci/yr/u
- liquid (89% recycled) :		
. H_3	5,400	Ci/yr/u
. other radionuclides :	0.01	Ci/yr/u
	1,000	Ci/yr/u (H_3 excluded)
	+ 6,000	Ci/yr/u H_3

3.2 Liquid waste treatment system : TEU

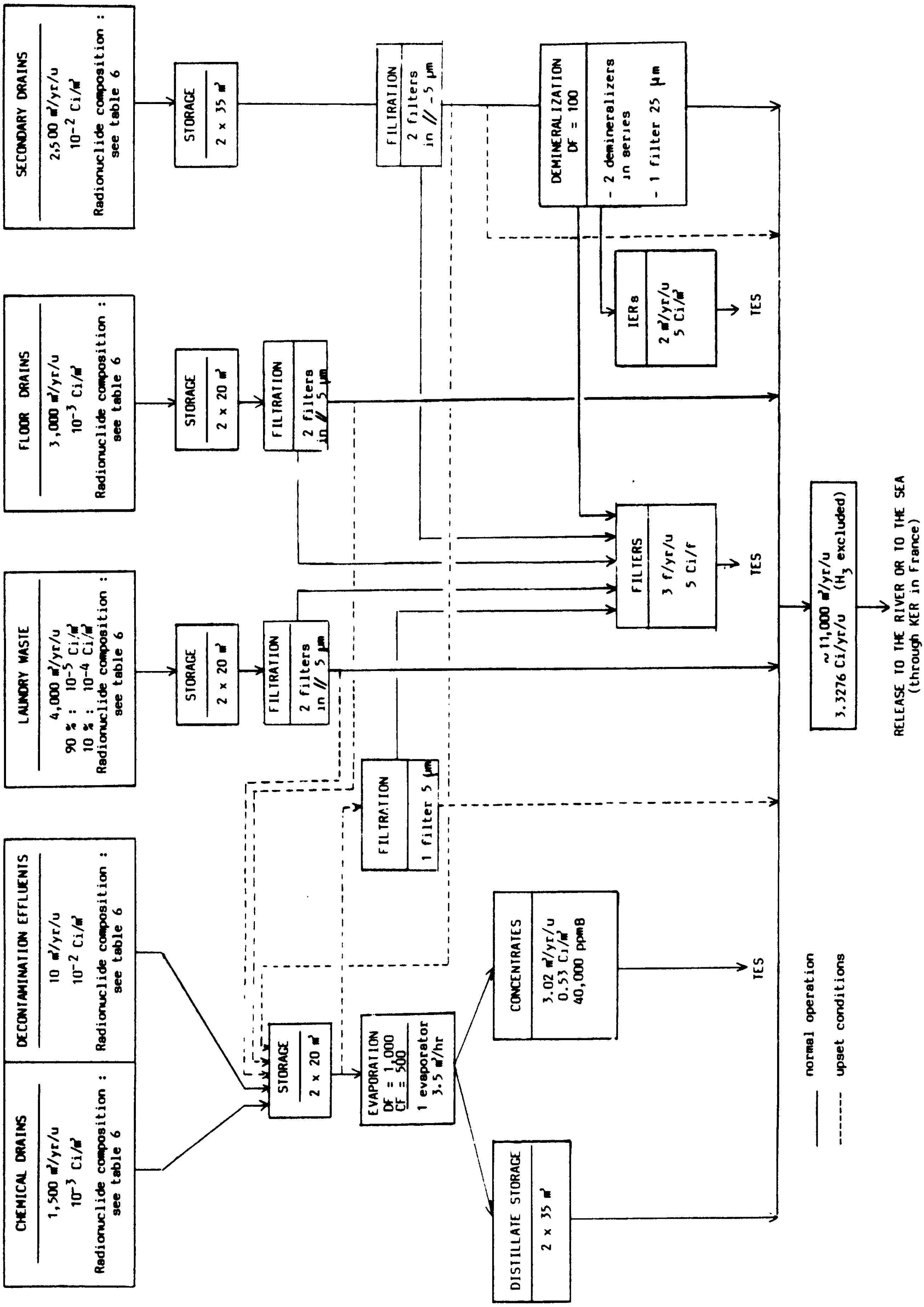
3.2.1 TEU block diagram

The liquid waste can either be treated :

- by evaporation (DF = 1,000)
- by demineralization (global DF for the given radionuclide composition = 100)

or :

- by filtration (DF = 1)


SECONDARY DRAINS
2,500 m³/yr/u
10-2 Ci/m³
Radionuclide composition : see table 6
FLOOR DRAINS
3,000 m³/yr/u
10-3 Ci/m³
Radionuclide composition : see table 6
LAUNDRY WASTE
4,000 m³/yr/u
90 % : 10-5 Ci/m³
10 % : 10-4 Ci/m³
Radionuclide composition : see table 6
DECONTAMINATION EFFLUENTS
10 m³/yr/u
10-2 Ci/m³
Radionuclide composition : see table 6
CHEMICAL DRAINS
1,500 m³/yr/u
10-3 Ci/m³
Radionuclide composition : see table 6
STORAGE
2 x 35 m³
STORAGE
2 x 20 m³
STORAGE
2 x 20 m³
STORAGE
2 x 20 m³
FILTRATION
2 filters in // - 5 µm
FILTRATION
2 filters in // 5 µm
FILTRATION
2 filters in // 5 µm
FILTRATION
1 filter 5 µm
DEMINERALIZATION
DF = 100
- 2 demineralizers in series
- 1 filter 25 µm
IERs
2 m³/yr/u
5 Ci/m³
TES
FILTERS
3 f/yr/u
5 Ci/f
TES
EVAPORATION
DF = 1,000
CF = 500
1 evaporator
3.5 m³/hr
CONCENTRATES
3.02 m³/yr/u
0.53 Ci/m³
40,000 ppmB
TES
DISTILLATE STORAGE
2 x 35 m³
~ 11,000 m³/yr/u
3.3276 Ci/yr/u (H3 excluded)
RELEASE TO THE RIVER OR TO THE SEA
(through KER in France)
normal operation
upset conditions

3.2.2 Volume and activity release

Liquid (released to the river or to the sea through KER) :

- volume : 11,007 m3/yr/u

- activity : see table IX below.

TABLE IX : LIQUID VOLUME AND ACTIVITY RELEASE FROM TEU

TYPE OF WASTE	TYPE OF TREATMENT	INLET VOLUME (m3/yr/u)	INLET ACTIVITY	DF	ACTIVITY RELEASE (Ci/yr/u)
Chemical drains	EVAPO.	1,500	10^{-3} Ci/m3	1,000	0.0015
Decontamination effluents	EVAPO.	10	10^{-2} Ci/m3	1,000	0.0001
Laundry waste	FILTR.	400	10^{-4} Ci/m3	1	0.0400
	FILTR.	3,600	10^{-5} Ci/m3	1	0.0360
Floor drains	FILTR.	3,000	10^{-3} Ci/m3	1	3.000
Secondary drains	DEMINE.	2,500	10^{-2} Ci/m3	100	0.2500
TOTAL		11,010	29.6760 Ci/yr/u		3.3276

Gases (through the ventilation system) : 0

Solids (sent to TES) :

- concentrates :
  . about 3.02 m3/yr/u
  . 0.53 Ci/m3
- filters :
  . 3 f/yr/u
  . 5 Ci/f
- ion exchange resins :
  . 2 m3/yr/u
  . 5 Ci/m3

Total activity release from TEU :

- concentrates :	1.5984 Ci/yr/u
- filters + IERs :	24.7500 Ci/yr/u
- liquid :	3.3276 Ci/yr/u
	29.6760 Ci/yr/u

3.3 Gaseous waste treatment system : TEG

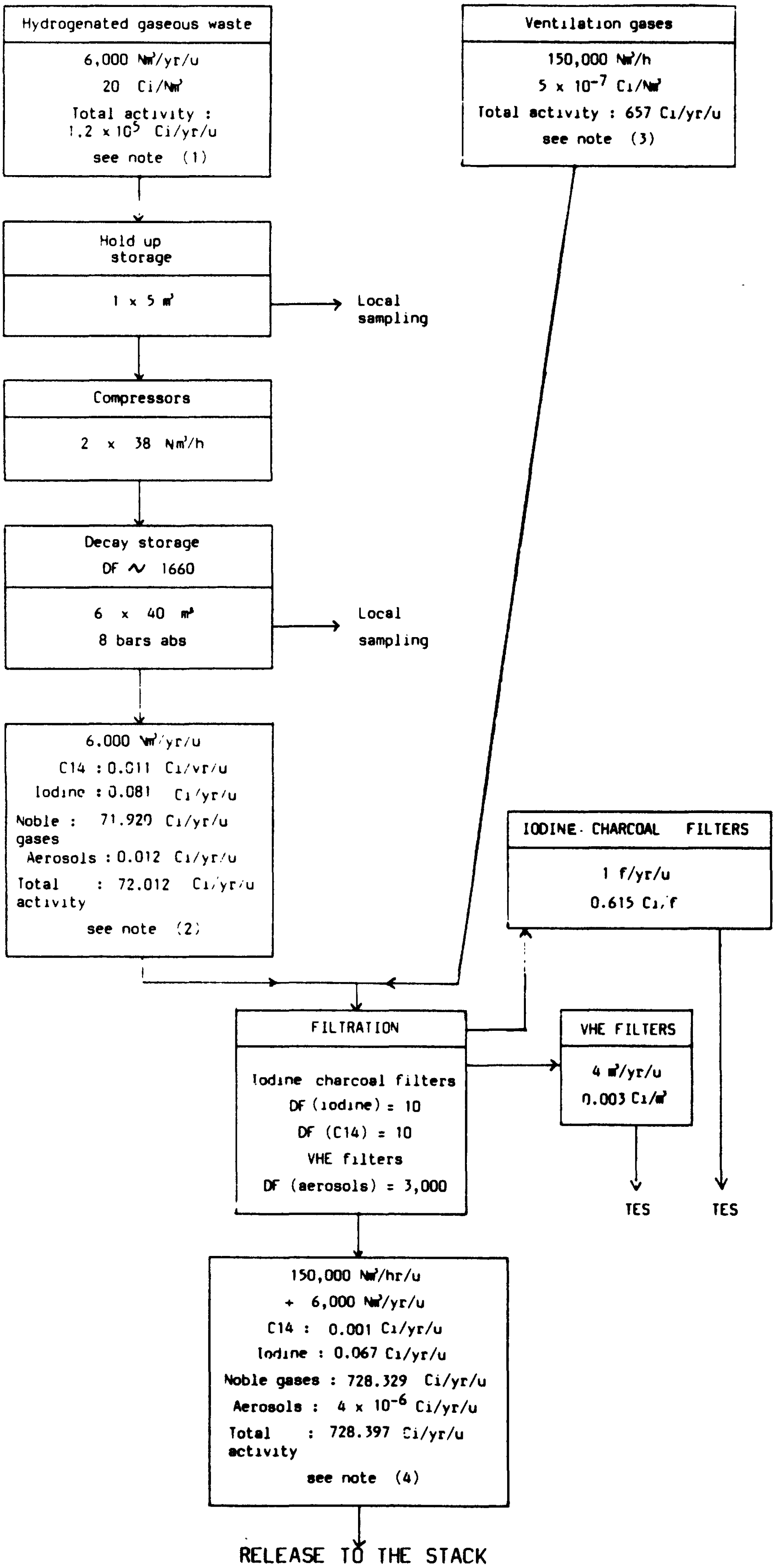
3.3.1 TEG block diagram

Waste origin :

- primary coolant uncondensable off-gas stripping and evaporation,
- pressurizer relief tank,
- storage tanks (RCV, TEP).

TABLE X : RADIONUCLIDE COMPOSITION OF HYDROGENATED GASEOUS WASTE AFTER 60 DAYS OF DECAY

RADIONUCLIDE	C-14	Kr-85	Kr-85m	Kr-87	Kr-88	Xe-133	Xe-133m
%	0.016	50.925	-	-	-	48.947	0.001
RADIONUCLIDE	Xe-135	I-131	I-132	I-133	I-134	I-135	
%	-	0.112	-	-	-	-	



Hydrogenated gaseous waste
6,000 Nm³/yr/u
20 Ci/Nm³
Total activity : 1.2 x 10⁵ Ci/yr/u
see note (1)
Ventilation gases
150,000 Nm³/h
5 x 10⁻⁷ Ci/Nm³
Total activity : 657 Ci/yr/u
see note (3)
Hold up storage
1 x 5 m³
Local sampling
Compressors
2 x 38 Nm³/h
Decay storage
DF ~ 1660
6 x 40 m³
8 bars abs
Local sampling
6,000 Nm³/yr/u
C14 : 0.011 Ci/yr/u
Iodine : 0.081 Ci/yr/u
Noble gases : 71.920 Ci/yr/u
Aerosols : 0.012 Ci/yr/u
Total activity : 72.012 Ci/yr/u
see note (2)
IODINE CHARCOAL FILTERS
1 f/yr/u
0.615 Ci/f
FILTRATION
Iodine charcoal filters
DF (iodine) = 10
DF (C14) = 10
VHE filters
DF (aerosols) = 3,000
VHE FILTERS
4 m³/yr/u
0.003 Ci/m³
TES
TES
150,000 Nm³/hr/u
+ 6,000 Nm³/yr/u
C14 : 0.001 Ci/yr/u
Iodine : 0.067 Ci/yr/u
Noble gases : 728.329 Ci/yr/u
Aerosols : 4 x 10⁻⁶ Ci/yr/u
Total activity : 728.397 Ci/yr/u
see note (4)
RELEASE TO THE STACK

NOTES

(1) 6,000 (Nm3/yr/u) x 20 (Ci/Nm3) = 120,000 Ci/yr/u

including : aerosols : 0.012 Ci/yr/u (see table VII)

(2) 6,000(Nm3/yr/u) x 0.012* (Ci/Nm3) + 0.012(Ci/yr/u) = 72.012 Ci/yr/u

broken down as follows :

C14 : $0.016 \times 10^{-2} \times 72.012 = 0.011$ Ci/yr/u (table X)

iodine : $0.112 \times 10^{-2} \times 72.012 = 0.081$ Ci/yr/u (table X)

noble gases : $99.872 \times 10^{-2} \times 72.012 = 71.920$ Ci/yr/u (table X)

aerosols = 0.012 Ci/yr/u (table VII)

* 0.012 Ci/Nm3 = activity after 60 days decay, excluding aerosols.

(3) 150,000(Nm3/hr) x 8,760(hr/yr) x 5 x 10^{-7}(Ci/Nm3) = 657 Ci/yr/u

broken down as follows :

C14 : $10^{-7} \times 657 = 6.57 \times 10^{-5}$ Ci/yr/u (table VII)

iodine : $0.09 \times 10^{-2} \times 657 = 0.591$ Ci/yr/u (table VII)

noble gases : $99.91 \times 10^{-2} \times 657 = 656.409$ Ci/yr/u (table VII)

aerosols : $10^{-7} \times 657 = 6.57 \times 10^{-5}$ Ci/yr/u (table VII)

(4) The final activity is broken down as follows :

C14 = $(0.011 + 6.57 \times 10^{-5})/10 = 0.001$ Ci/yr/u

iodine = $(0.081 + 0.591)/10 = 0.067$ Ci/yr/u

noble gases = $71.920 + 656.409 = 728.329$ Ci/yr/u

aerosols = $(0.012 + 6.57 \times 10^{-5})/3{,}000 = 4 \times 10^{-6}$ Ci/yr/u

3.3.2 Volume and activity release

Gases : 150,000 Nm3/yr/u

- C14 : 0.001 Ci/yr/u
- iodine : 0.067 Ci/yr/u
- noble gases : 728.329 Ci/yr/u
- aerosols : 4×10^{-6} Ci/yr/u

728.397 Ci/yr/u

Solids :

- VHE filters :
  . density = 0.3
  . 10^{-2} Ci/t ===> 0.003 Ci/m3
  . 4 m3/yr/u

  TOTAL = 0.012 Ci/yr/u (aerosols)

- iodine charcoal filters :
  . hypothesis : 1 filter/yr/u
  . activity : 0.615 Ci/f (from C14 and iodine)

Total activity released from TEG :

- VHE filters : 0.012 Ci/yr/u
- iodine charcoal filters : 0.615 Ci/yr/u
- gases : 728.397 Ci/yr/u

729.024 Ci/yr/u

3.4 Solid waste treatment system : TES

3.4.1 Waste inventories

TABLE XI : SECONDARY WASTE INVENTORIES FOR SOLIDS

i.e. waste resulting from TEU, TEP, TEG and TES operation

WASTE ORIGIN		REAL VALUE
Resins	TEU	2 m3/yr/u - 5 Ci/m3
	TEP	3.7 m3/yr/u - 200 Ci/m3
Filters	TEU	3 f/yr/u - 5 Ci/f
	TEP	5 f/yr/u - 50 Ci/f
	TEG iodine filters	1 f/yr/u - 0.6 Ci/f
	TEG VHE filters	4 m3/yr/u - 0.003 Ci/m3
Concentrates and sludges		3.02 m3/yr/u - 0.53 Ci/m3

Please note that :

- APG resins (0.01 Ci/m3 - 6 m3/yr/u)
- technological waste resulting from unit operation

are already included in primary waste inventories (see table IV).

3.4.2 Material and activity balance

3.4.2.1 IERs

TABLE XII : IERs INVENTORY

ORIGIN	VOLUME m3/yr/u	ACTIVITY	TYPE OF CONCRETE CONTAINER	VOLUME OF RESINS PER CONTAINER (m3)	MAXIMUM NUMBER OF CONTAINERS	OVERALL VOLUME (m3)	MAXIMUM ACTIVITY PER CONTAINER (Ci)
RCV	1.3	500 Ci/m3	C4 (1)	0.260	5	6.2	130
PTR	2.6	50 Ci/m3	C4	0.260	10	12.4	13
TEU	2.0	5 Ci/m3	C4	0.260	8	9.9	1.3
TEP	3.7	200 Ci/m3	C4	0.260	14	17.3	52
TOTAL (2)	9.6	1,530 Ci	C4	0.260	37	45.7	AVERAGE ACTIVITY : 41.4 (3)

Notes :

(1) The C4 containers shown in appendix 2 are equipped with steel liners and internal shieldings.

(2) APG resins (6 m3/yr/u) are included into technological waste.

(3) IER batches (9 m3) can be homogeneized in the storage tanks before being sent to the mobile unit. The activity per container therefore varies between 1.3 Ci and 130 Ci and the average activity is about 41.4 Ci.

3.4.2.2. Filters

TABLE XIII : FILTERS INVENTORY

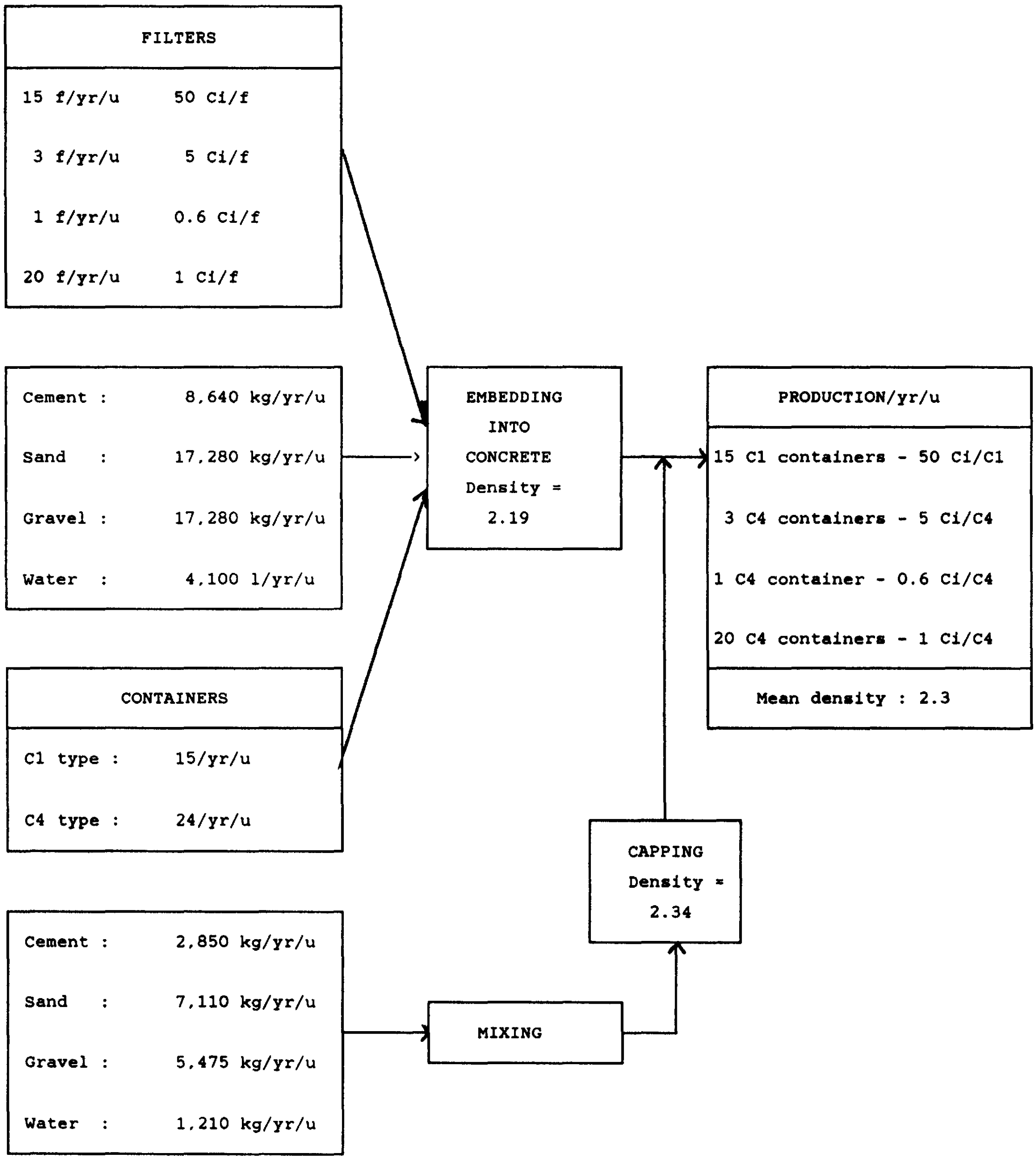
ORIGIN	NUMBER (f/yr/u)	ACTIVITY (Ci/f)	TYPE OF CONCRETE CONTAINER	NUMBER OF CONTAINER	OVERALL VOLUME (m3/yr/u)	ACTIVITY CONTAINER (Ci)
RCV	10	50	C1 (2)	10	20	50
PTR	20	1	C4	20	24.7	1
TEU	3	5	C4	3	3.7	5
TEP	5	50	C1	5	10	50
TEG	1 (1)	0.6	C4	1	0.6	0.6
TOTAL (3)	39	785.6		39	59.6	

Notes :

(1) Iodine charcoal filter

(2) See appendix 2

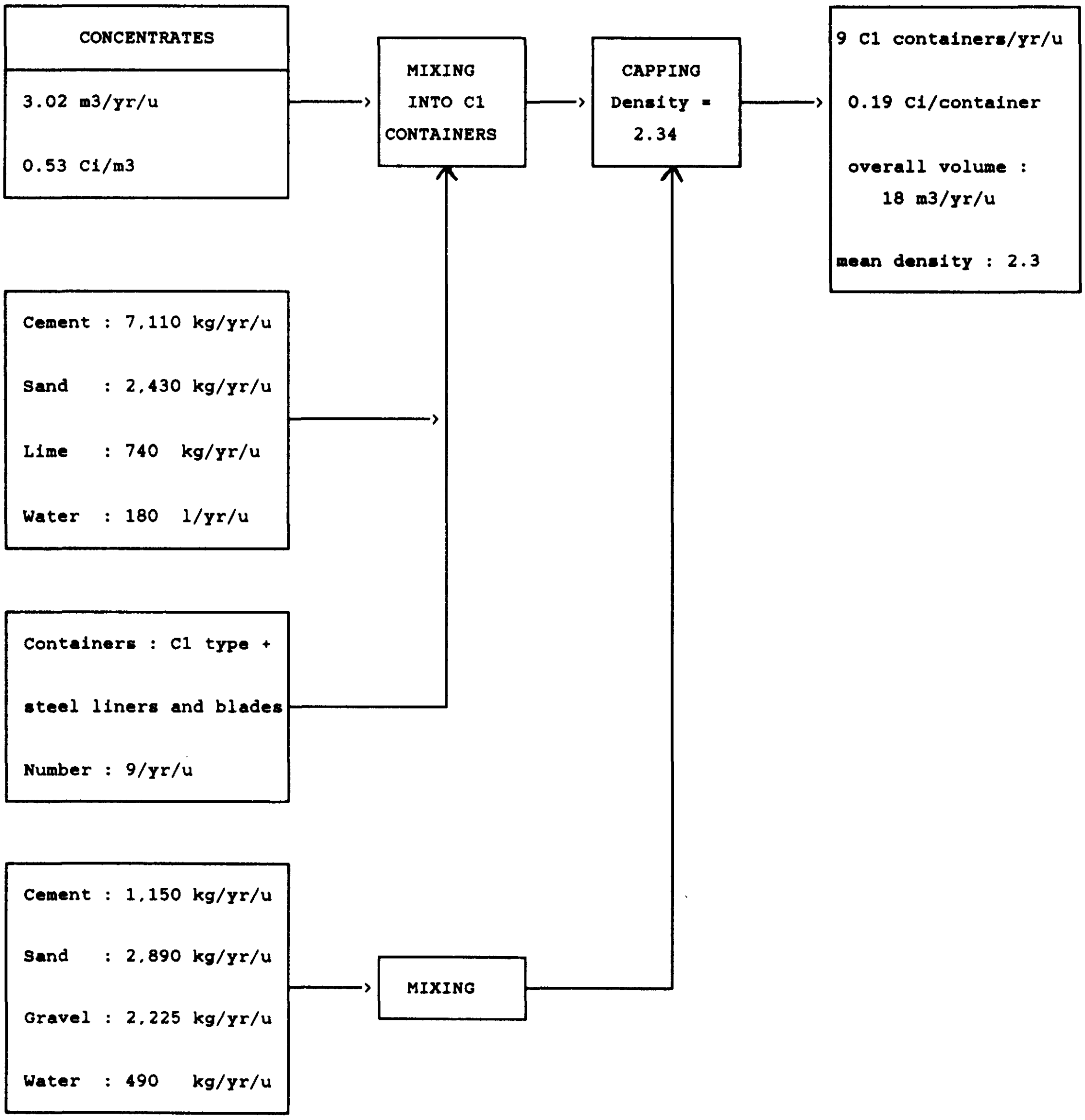
(3) VHE filters are included into technological compactable waste (see table XV)


FILTERS
15 f/yr/u 50 Ci/f
3 f/yr/u 5 Ci/f
1 f/yr/u 0.6 Ci/f
20 f/yr/u 1 Ci/f
Cement : 8,640 kg/yr/u
Sand : 17,280 kg/yr/u
Gravel : 17,280 kg/yr/u
Water : 4,100 l/yr/u
CONTAINERS
C1 type : 15/yr/u
C4 type : 24/yr/u
Cement : 2,850 kg/yr/u
Sand : 7,110 kg/yr/u
Gravel : 5,475 kg/yr/u
Water : 1,210 kg/yr/u
EMBEDDING INTO CONCRETE Density = 2.19
MIXING
CAPPING Density = 2.34
PRODUCTION/yr/u
15 C1 containers - 50 Ci/C1
3 C4 containers - 5 Ci/C4
1 C4 container - 0.6 Ci/C4
20 C4 containers - 1 Ci/C4
Mean density : 2.3

3.4.2.3 Concentrates and sludges

TABLE XIV : CONCENTRATES AND SLUDGES INVENTORY

ORIGIN	VOLUME m3/yr/u	ACTIVITY Ci/m3	TYPE OF CONTAINER	VOLUME OF CONCENTRATE PER CONTAINER (m3)
TEU	3.02	0.53	C1	0.360
Number of containers	Overall volume (m3)	Activity per container (Ci)	Overall activity (Ci/yr/u)	
9	18	max. 0.19	1.6	


CONCENTRATES
3.02 m3/yr/u
0.53 Ci/m3
MIXING INTO C1 CONTAINERS
CAPPING Density = 2.34
9 C1 containers/yr/u
0.19 Ci/container
overall volume : 18 m3/yr/u
mean density : 2.3
Cement : 7,110 kg/yr/u
Sand : 2,430 kg/yr/u
Lime : 740 kg/yr/u
Water : 180 l/yr/u
Containers : C1 type +
steel liners and blades
Number : 9/yr/u
Cement : 1,150 kg/yr/u
Sand : 2,890 kg/yr/u
Gravel : 2,225 kg/yr/u
Water : 490 kg/yr/u
MIXING

3.4.2.4 Technological waste

TABLE XV : TECHNOLOGICAL WASTE INVENTORY

TYPE OF WASTE	TYPE OF DRUM	VOLUME OF WASTE PER DRUM	VOLUME OF WASTE (m3/yr/u)	ACTIVITY OF WASTE (Ci/m3)	NUMBER OF DRUMS	OVERALL VOLUME (m3)	ACTIVITY PER DRUM (Ci)
Compactable waste (2)	200 l drums	200 l	360 4	0.01 0.003	600 (1) 7	120 1.3	6×10^{-3}
Non compactable waste (3)	200 l drums	200 l	20	0.01	100	20	2×10^{-3}
Non compactable waste	200 l drums	200 l	20	0.20	100	20	0.04
TOTAL (3)			404	7.812 Ci/yr/u	807 drums	161	

Notes :

(1) 360 m3 before compaction

===> 120 m3 after compaction

===> 120/0.2 = 600 drums

(2) Including VHE filters : 4 m3/yr/u - 0.003 Ci/m3

(3) Including APG resins and technological waste resulting from the operation of the treatment units.

3.5 Overall balance

The overall balance is presented in the general block diagram attached.

3.5.1 Liquid discharge

3.5.1.1 Origin

TEP - TEU.

3.5.1.2 Volume

12,000 m3/yr/u.

3.5.1.3 Activity

- Tritium H_3 : 600 Ci/yr/u i.e. 99.45 of the total activity (DF(H_3) = 1).

  The tritium activity is mostly due to the distillate released from the TEP, in order to keep the tritium concentration at a constant level in the primary system.

  The quantity of tritium generated in the primary system is constant in a given configuration. It depends on :

  . fuel clad nature (diffusion coefficient of H_3 in the material),

  . fuel nature (B and Li content).

  It is about 200 to 300 Ci/yr/u in France whereas it has been considered to be 600 Ci/yr/u within the scope of this study.

  Even though, the tritium activity is lower than the objective value defined in table I.

- Other radionuclides : 3.33 Ci/yr/u i.e. 0.55% of the total activity.

TABLE XVI : RADIONUCLIDE COMPOSITION (H3 EXCLUDED) FOR THE LIQUID DISCHARGE (3.33 Ci/yr/u)

RADIONUCLIDE	Mn-54	Co-58	Co-60	Sr-90	Nb-95	Mo-99	Ag-110m	
%	4.80	31.98	6.36	0.19	0.013	4.80	4.80	
RADIONUCLIDE	Sb-124	I-131	I-132	I-133	I-134	I-135	Cs-134	Cs-137
%	4.80	0.46	0.80	1.39	0.46	0.93	19.19	19.19

The discharge value is lower than the design value defined in table I.

This design value would even be met without the evaporation step which do not comply with the French management route.

On the other hand, the objective value would easily be reached by increasing the volume of effluents treated by evaporation (about half the volume of floor drains).

The volume of concentrates would be increased accordingly : + 3 m3 (1500 : 500).

3.5.2 Gaseous discharge

3.5.2.1 Origin

TEG

3.5.2.2 Volume

150,000 Nm3/hr/u.

3.5.2.3 Activity

- C14 : 0.001 Ci/yr/u i.e. 10^{-4}% of the total activity

- Iodine : 0.067 Ci/yr/u i.e. 0.009% of the total activity

  This value is lower than the design value given in table I.

  The objective value could be met by increasing the amount of iodine charcoal filters or by changing their type (higher DF).

- Aerosols : 4×10^{-6} Ci/yr/u

  The aerosol activity is far below the objective value due to the type of VHE filters used in the plant.

- Noble gases : 728.329 Ci/yr/u i.e. 99.99% of the total activity

  The radionuclide contribution of each noble gas is assumed, conservatively, to be the same as that given in table VII, C14, iodine and aerosols excluded :

TABLE XVII : NOBLE GASES COMPOSITION FOR THE GASEOUS RELEASE

RADIONUCLIDE	Kr-85	Kr-85m	Kr-87	Kr-88	Xe-133	Xe-133m	Xe-135
%	0.03	1.83	1.25	3.32	80.49	1.75	11.33

The activity discharged to the stack is far below the objective value defined in table I.

3.5.3 Solid waste

3.5.3.1 Origin

TES

3.5.3.2 Volume

See table XVIII below

TABLE XVIII : ANNUAL PRODUCTION OF CONTAINERS FOR ONE UNIT

TYPE OF CONTAINER	NUMBER OF CONTAINERS	VOLUME PER CONTAINER (m3)	TOTAL VOLUME (m3/yr/u)
200 l drums	807	0.2	161
C1	24	2	48
C4	61	1.235	75
TOTAL			284

3.5.3.3 Activity

IERs : 1,530 Ci/yr/u

Filters : 785.6 Ci/yr/u

Concentrates and sludges : 1.6 Ci/yr/u

Technological waste : 7.8 Ci/yr/u

Total : 2,325 Ci/yr/u

For sake of simplification it has been assumed that both primary and secondary waste have the same radionuclide composition (see table VIII).

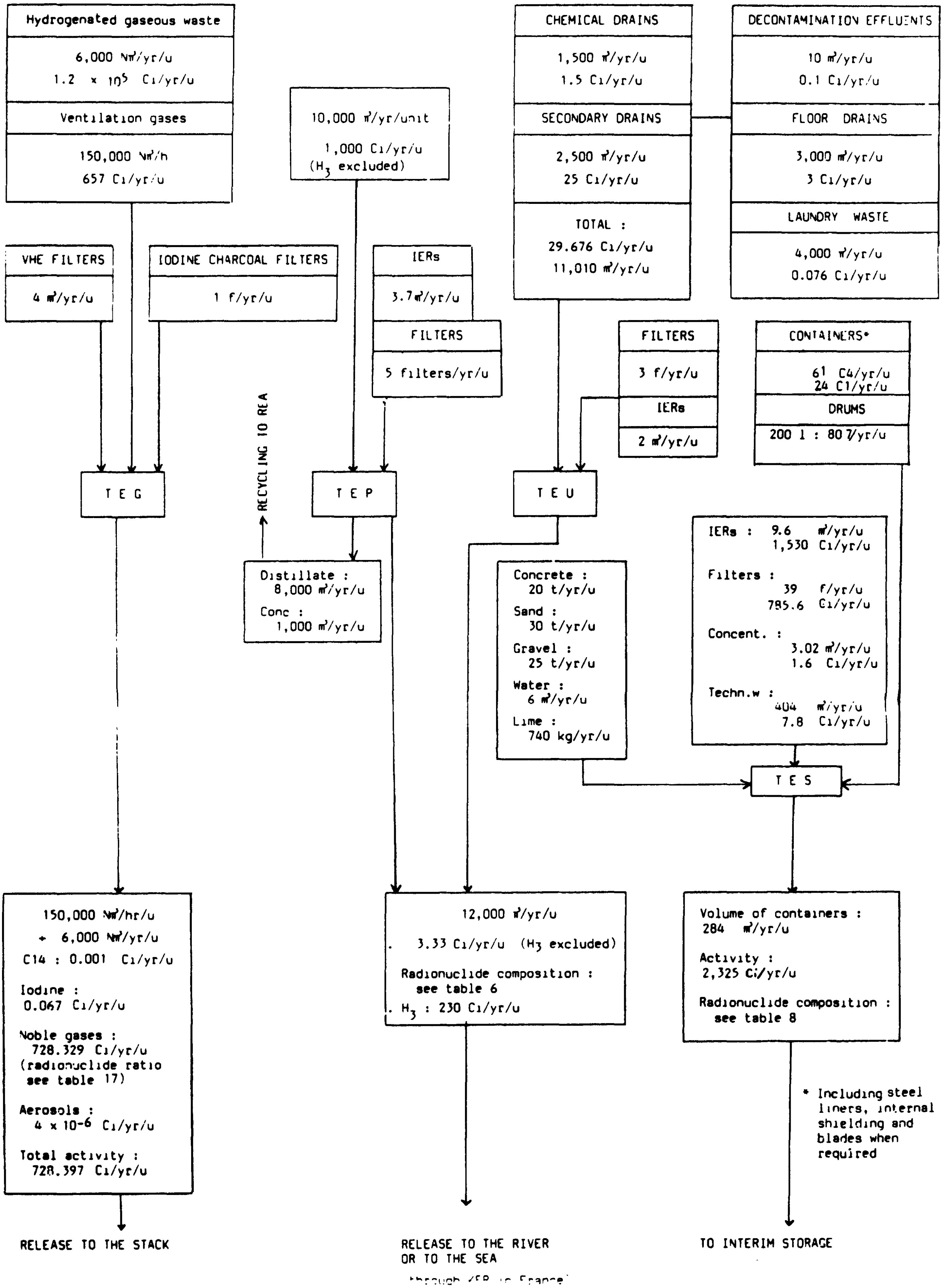
It should be stressed that the contribution of the TEP is very important due to the activity considered at the TEP inlet, within the scope of this study, which does not correspond to actual conditions in France (EDF).

The activity considered is an intermediate value between the activity of the primary system (1 Ci/m3 in the French case) or the RCV inlet and that of the TEP inlet or the RCV outlet (10^{-2} Ci/m3 in the French case). RCV consists of filters and demineralisers which reduce the activity by a factor 100, so that almost all the activity of the primary system is also present in RCV ion exchange resins.

This activity has already been considered in the study, i.e., 500 Ci/m3 (see table IV).

It should be emphasized that, due to the very high activity value at TEP inlet, the volume and activity of the resins and filters generated by TEP are markedly higher than in actual conditions (EDF) :

	EDF	PRESENT PROJECT
Resins	2.8 m3/yr/u - 2 Ci/m3	3.7 m3/yr/u - 200 Ci/m3
Filters	5 f/yr/u - 5 Ci/f	5 f/yr/u - 50 Ci/f


Hydrogenated gaseous waste
6,000 Nm³/yr/u
1.2 × 10⁵ Ci/yr/u
Ventilation gases
150,000 Nm³/h
657 Ci/yr/u
10,000 m³/yr/unit
1,000 Ci/yr/u
(H3 excluded)
CHEMICAL DRAINS
1,500 m³/yr/u
1.5 Ci/yr/u
SECONDARY DRAINS
2,500 m³/yr/u
25 Ci/yr/u
TOTAL :
29.676 Ci/yr/u
11,010 m³/yr/u
DECONTAMINATION EFFLUENTS
10 m³/yr/u
0.1 Ci/yr/u
FLOOR DRAINS
3,000 m³/yr/u
3 Ci/yr/u
LAUNDRY WASTE
4,000 m³/yr/u
0.076 Ci/yr/u
VHE FILTERS
4 m³/yr/u
IODINE CHARCOAL FILTERS
1 f/yr/u
IERs
3.7m³/yr/u
FILTERS
5 filters/yr/u
FILTERS
3 f/yr/u
IERs
2 m³/yr/u
CONTAINERS*
61 C4/yr/u
24 C1/yr/u
DRUMS
200 l : 80 l/yr/u
RECYCLING TO REA
T E G
T E P
T E U
Distillate :
8,000 m³/yr/u
Conc :
1,000 m³/yr/u
Concrete :
20 t/yr/u
Sand :
30 t/yr/u
Gravel :
25 t/yr/u
Water :
6 m³/yr/u
Lime :
740 kg/yr/u
IERs : 9.6 m³/yr/u
1,530 Ci/yr/u
Filters :
39 f/yr/u
785.6 Ci/yr/u
Concent. :
3.02 m³/yr/u
1.6 Ci/yr/u
Techn.w :
404 m³/yr/u
7.8 Ci/yr/u
T E S
150,000 Nm³/hr/u
+ 6,000 Nm³/yr/u
C14 : 0.001 Ci/yr/u
Iodine :
0.067 Ci/yr/u
Noble gases :
728.329 Ci/yr/u
(radionuclide ratio
see table 17)
Aerosols :
4 × 10⁻⁶ Ci/yr/u
Total activity :
728.397 Ci/yr/u
12,000 m³/yr/u
3.33 Ci/yr/u (H3 excluded)
Radionuclide composition :
see table 6
H3 : 230 Ci/yr/u
Volume of containers :
284 m³/yr/u
Activity :
2,325 Ci/yr/u
Radionuclide composition :
see table 8
* Including steel liners, internal shielding and blades when required
RELEASE TO THE STACK
RELEASE TO THE RIVER
OR TO THE SEA
TO INTERIM STORAGE

4. COST ASSESSMENT

This part provides all information necessary for TASK to determine the capital cost of the treatment systems of 900 MWe PWR units :

- characteristics of the Major Equipment used as base value in the TASK cost determination procedure (see TASK 10-EN-114-115/023),

- estimated volume of the treatment systems building, necessary for the determination of the Civil Works cost,

- cost information (prices of 1987) provided by EDF on the basis of French Experience, for purposes of comparison.

It also gives all necessary information for operating cost assessment.

4.1 Capital cost assessment

4.1.1 Major equipment

4.1.1.1 Characteristics of the major equipment

The characteristics of the major equipment of the effluent treatment systems are given in appendix 3.

This equipment is common to two 900 MWe units, as already mentioned.

4.1.1.2 French cost assessment

- Pumps..	3,000,000 FF
- Tanks..	20,000,000 FF
- Filters and demineralizers..................	4,000,000 FF
- Gas strippers and evaporators*...............	35,000,000 FF
- Drumming equipment..........................	11,000,000 FF
- IERs mobile conditioning unit**.............	1,000,000 FF
	74,000,000 FF

* TEU evaporator : 5,000,000 FF
TEP evaporator + gas stripper : 15,000,000 FF

** One mobile unit costs 10,000,000 FF and is required for the conditioning of the spent IERs of 20 units is France.

broken down as follows :

- TEP : 56 %
  TEU : 19 %
  TEG : 8 %
  TES : 17 % (IERs mobile conditioning unit excluded)

Note that the cost of major equipment includes complete services, i.e. :

- construction studies,

- assembly,

- commissioning,

- quality assurance.

4.1.2 Bulk material

The EDF cost assessment is the following :

- piping : 23,000,000 FF,

- valves : 4,000,000 FF,

- I & E equipment : 25,000,000 FF

  broken down as follows :

  TEP : 56 %
  TEU : 19 %
  TEG : 8 %
  TES : 17 %

4.1.3 Ventilation

This item is not taken into account in the TASK cost determination procedure. It includes ventilation ducts with iodine charcoal filters, filters and extractors.

It has been assessed at 10,000,000 FF on the basis of French experience.

Note :

- Gases treated in TEG are released together with all ventilation off-gases, the total design flow rate of which is 150,000 Nm3/h (see table III).

However the ventilation fans of the effluent treatment building are only the following :

- 2 x 25,000 m3/hr,
- 3 x 33,000 m3/hr.

4.1.4 Civil Works

4.1.4.1 Effluent treatment building

The French cost assessment of 42,600,000 FF is given for a total volume of building of 66,500 m3 including :

- concrete,

- shielded door,

- shop window construction.

This building includes all treatment systems common to two 900 MWe units.

The resulting price per m3 of building is 640 FF/m3, i.e. about 91 ECU/m3 which is far below the price given in the TASK cost evaluation methodology 10-EN-114-115/023.

We note that is has finally been agreed to use an average value of 135 ECU/m3, on the basis of the data supplied by the different parties involved in the study.

4.1.4.2 Interim storage for one year

The annual production of drums and concrete containers of one unit has been detailed in table XVIII.

The volume of interim storage building will be assessed by TASK, knowing that the number of concrete containers or drums that can be piled up is the following :

- 8 drums (200 l),

- 3 C1 containers (external volume : 2 m3),

- 3 C4 containers (external volume : 1.235 m3).

4.1.5 Handling

This item is not taken into account in the TASK cost determination procedure.

It has been assessed at 5,000,000 FF on the basis of French experience.

4.1.6 Laboratory

This item involves minimal cost because waste treatment facilities require a very small number of analyses.

4.1.7 Cost of KER

The cost of the KER is assessed at 8,000,000 FF.

4.2 Operating cost assessment

4.2.1 Rough evaluation of utilities consumptions

- RRI (chilling water - 35°C - 8.1 to 8.8 bars eff.)

  . TEP : 760,000 m3 RRI/yr i.e.

  380,000 m3 RRI/yr/u

  or 38 m3 RRI/m3 effluent

  . TEU : 120,000 m3 RRI/yr i.e.

  60,000 m3 RRI/yr/u

  or 40 m3 RRI/m3 effluent

- SVA (steam - 136°C to 139°C - 4.5 bars eff. except for gas stripper : 9 bars eff.)

  . TEP : 24,300 t SVA/yr i.e.

  12,150 t SVA/yr/u

  or 1.2 t SVA/m3 effluent

  . TEU : 4,050 t SVA/yr i.e.

  2,025 t SVA/yr/u

  or 1.3 t SVA/m3 effluent

- Electricity

  . TEP : 6.5 kWh/m3 effluent

  . TEU : 5.0 kWh/m3 effluent

  . TEG : 0.5 kWh/m3 effluent

- SED : negligible

- Reagents (TES) - polymers excluded

  . water : 6 m3/yr/u

  . cement : 20 t/yr/u

  . sand : 30 t/yr/u

  . gravel : 25 t/yr/u

  . lime : 740 kg/yr/u

  . caustic soda : negligible

  . acid : negligible

- Price of 1 kWh : 3.048 FF to be multiplied by the number of operating hours.

- Price of 1 kWh of steam : 1.17 FF to be multiplied by the number of operating hours.

4.2.2 Operating cost based on EDF French experience

4.2.2.1 IERs

Characteristics :

- mobile unit,

- embedding into a polymer matrix,

- use of concrete containers C4 equipped steel with liners and internal shieldings depending on the activity of the resins.

Average cost : 200,000 FF/m3 of IERs, broken down as follows :

- transport : 9%
- storage : 7.75% (see § 4.2.2.5)
- reagents : 10.00%
- equipped concrete containers (+ shielding) : 47.00%
- operating cost + depreciation cost : 26.25%

4.2.2.2 Filters

Characteristics :

- fixed drumming station,
- embedding into concrete,
- use of concrete containers C1 or C4.

TABLE XIX : AVERAGE COST

TYPE OF CONTAINER	C1 + SHIELDING	C4
Cost of container	Container : 3,500 FF Shielding : 8,300 FF* (average cost)	2,200 FF
Cost of transport (see § 4.2.2.5)	2,350 FF	1,400 FF
Cost of storage	4,470 FF	2,750 FF
Cost of reagents	**	**

Notes :

* Thickness : 5 cm lead

** The cement, sand, gravel and water consumptions have been given in § 3.4.

4.2.2.3 Concentrates and sludges

Characteristics :

- fixed drumming station,
- embedding into concrete,
- use of steel liners into concrete containers C1.

Average cost : 38,000 FF/m3 of concentrates brokendown as follows :

- storage : 37.0%
- transport : 20.4% (see § 4.2.2.5)
- steel liners + blades : 9.4%
- concrete containers : 25.6%
- reagents : 7.6%

4.2.2.4 Miscellaneous waste

Cost of one drum : 200 FF

Transport : 150 FF (see § 4.2.2.5)

Storage : 900 FF

Cost of compaction : included into the operating labour cost.

4.2.2.5 Transport costs

In actual conditions (EDF), the transport costs are calculated on the following bases :

- transport by truck,
- 26 t of packaged waste per truck,
- 660 km (return is not included),
- cost per type of packaged waste :
  . IERs :
    * 18,000 FF/m3
    * 0.260 m3 IERs/C4
    * C4 = 1.235 m3
    * density = 2.3

    ===> 1,648 FF/t

. Filters :

* 2,350 FF/m3

* 1,400 FF/C4

* C4 = 1.235 m3

* C1 = 2 m3

* density = 2.3

===> 500 FF/t

. Concentrates :

* 7,750 FF/m3

* 0.360 m3/C1

* C1 = 2 m3

* density = 2.3

===> 607 FF/t

. Miscellaneous waste :

* 150 FF/drum

* 200 l/drum

* Compactable waste = 0.45 x 200 = 90 kg/drum

* Non compactable waste = 0.75 x 200 = 150 kg/drum

* Drum = 20 kg

===> 1,364 FF/t of compactable waste

822 FF/t of non compactable waste

In actual conditions (EDF), the resulting transport costs per tonne are given below :

TABLE XX : TRANSPORT COSTS OF THE CONTAINERS

TYPE OF WASTE	TYPE OF CONTAINER	NUMBER OF CONTAINERS	VOLUME (m3)	DENSITY	WEIGHT (t)	COST (FF/t)
IERs	C4	37	45.7	2.3	105.1	1,648
Filters	C1 C4	39	59.6	2.3	137.1	500
Concentrates	C1	9	18	2.3	41.4	607
Techn. waste	200 1	607	121.4	0.55	66.8	1,364
	200 1	200	40	0.85	34	882
					384.4	1,009

The average transport cost is therefore about 764 FF/t for a 500 km return journey, which corresponds to the scope of this study.

4.3 Operating staff

The treatment units are able to run in 3 x 8 hour-shifts but normally run in day shift.

Personnel requirements :

- 3 chief operators,
- 16 operators.

Salary scale (basic assumptions for the study) :

- operators : 17 ECU/h
- chief operators : 35 ECU/h

5. DOSE RATES TO WORKERS

The radiological exposure of operating personnel in the Effluent Treatment Units of two 900 MWe nuclear power plant units is assessed on the basis of the French experience : total dose rates are calculated so that no distinction can be made between treatment units.

However, it should be noted that the dose integrated by workers mostly arises from the Solid Waste Treatment System (TES) where all operations are manual.

The mean individual dose integrated by the operators of the Effluent Treatment Units of two 900 MWe power plant units is 0.5 Rem/year.

The collective dose of the 19 operators is therefore approx. 10 m.rem/year.

6. SENSITIVITY STUDY

This part of the study examine the impact of using mobile concreting facilities on the capital and operating costs given in the reference study (see § 4).

The mobile concreting units are used for the conditioning of IER's, concentrates and filters.

These waste inventories are those of the reference study (see table IV and XI).

6.1. Material and activity balance

6.1.1. Spent IERs

6.1.1.1. IERs inventory

TABLE XXI : IERs INVENTORY

ORIGIN	VOLUME	ACTIVITY	TYPE OF CONCRETE CONTAINER	VOLUME OF RESINS PER CONTAINER (m3)	MAXIMUM NUMBER OF CONTAINERS	OVERALL VOLUME (m3)	MAXIMUM ACTIVITY PER CONTAINER (Ci)
RCV	1.3	500 Ci/m3	C4 (1)	0.11	12	14.8	54.2
PTR	2.6	50 Ci/m3	C4	0.11	24	29.6	5.4
TEU	2.0	5 Ci/m3	C4	0.11	18	22.2	0.55
TEP	3.7	200 Ci/m3	C4	0.11	34	42	21.8
TOTAL	9.6	1,530 Ci	C4	0.11	88	108	AVERAGE ACTIVITY 17.4

Notes :

(1) See C4 container in appendix 2

The C4 containers are equipped with steel liners and internal lead shieldings, 7 cm thick for the average activity.

(2) The activity per container varies between 0.55 Ci and 54.2 Ci and the average activity is about 17.4 Ci.

6.1.1.2. Waste conditioning

. Receipt of spent IERs

The annual production of spent IERs is homogeneized in the storage tank before being pumped into the mobile facility.

The average activity of resins is therefore constant.

. Receipt of dry batches and reagents

All operations associated with the procurement of :

- cement for concreting itself,

- reagents for resins,

- dry batches (cement, sand, gravel) for final capping,

are performed outside the BTE.

. Pretreatment of resins :

Before being embedded in concrete, the spent IERs are pretreated using the following reagents :

- caustic soda,
- calcium nitrate.

. Metering of resins

Suspended resins are transferred from the fixed storage tanks to a metering pot where a given water content (100 % in settled equivalent) and a given volume of resins at this concentration are obtained.

. Mixing

A concrete batch corresponding to the volume of the C4 container to be filled is prepared in the GUEDU 350 batch mixer.

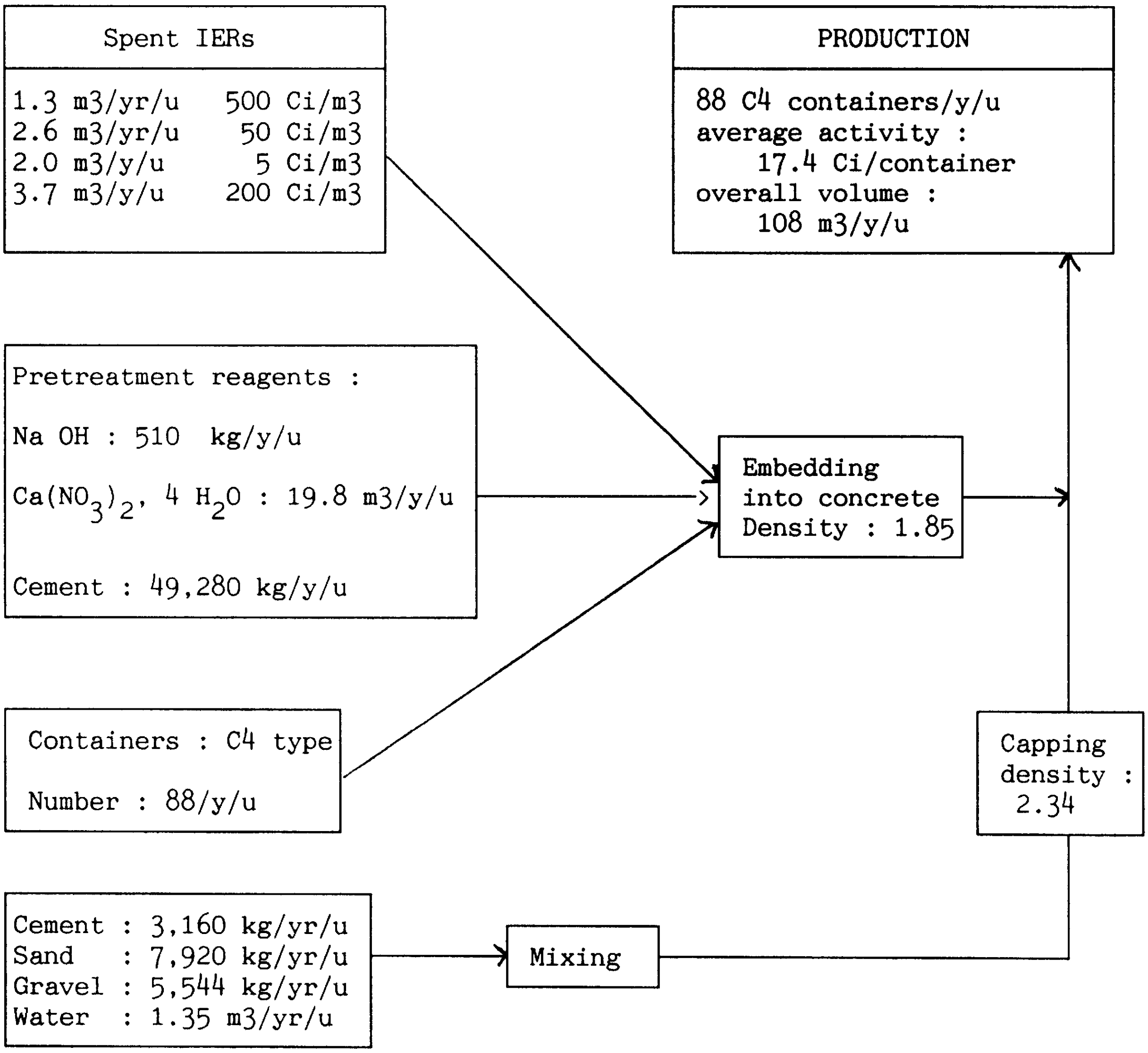
Embedding ratio : 110 l of resins (100 % in settled equivalent) per container C4.

The quantity of resins and solid product needed to prepare a batch is automatically weighed by placing the mixer on a weight scale. The resulting homogeneous mix of resins and cement is emptied by gravity into a C4 container by opening a side gate located at the lower part of the mixer.

. <u>Final capping</u>

A second GUEDU 350 mixer is used for the preparation of inactive concrete for the capping of C4 containers.

6.1.1.3. Effluents and dry batches quantities



6.1.2. Filters

6.1.2.1. Filters inventory

TABLE XXII : FILTERS INVENTORY

ORIGIN	NUMBER (f/yr/u)	ACTIVITY (Ci/f)	TYPE OF CONCRETE CONTAINER	NUMBER OF CONTAINERS	OVERALL VOLUME (m3/yr/u)	ACTIVITY CONTAI-NER (Ci)
RCV	10	50	C4 (2)	10	12.4	50
PTR	20	1	C4	20	24.7	1
TEU	3	5	C4	3	3.7	5
TEP	5	50	C4	5	6.2	50
TEG	1(1)	0.6	C4	1	1.2	0.6
TOTAL (3)	39	785.6		39	48.2	

Notes

(1) Iodine charcoal filter

(2) For filters whose activity is 50 Ci, containers of the C4 type are used with a 5 cm thick internal lead shielding around the filter

(3) VHE filters are classed as technological compactable waste

6.1.2.2. Filters conditioning

. Receipt of filters :

A lead cask is used to transfer the filter cartridges from the concrete bunkers to the drumming station. The filter is dropped through a vertical transfer tube into the C4 container which is covered by a provisional iron plug.

Containers and plugs are then transferred into the hall where the mobile concreting facility is installed.

A 78-filter buffer storage is planned for the annual production of filters (2 x 39 filters/yr/BTE).

This storage is considered as part of the interim storage building (see § 6.4.1.4).

. Receipt of dry batches :

All operations associated with the procurement of dry batches are performed outside the BTE.

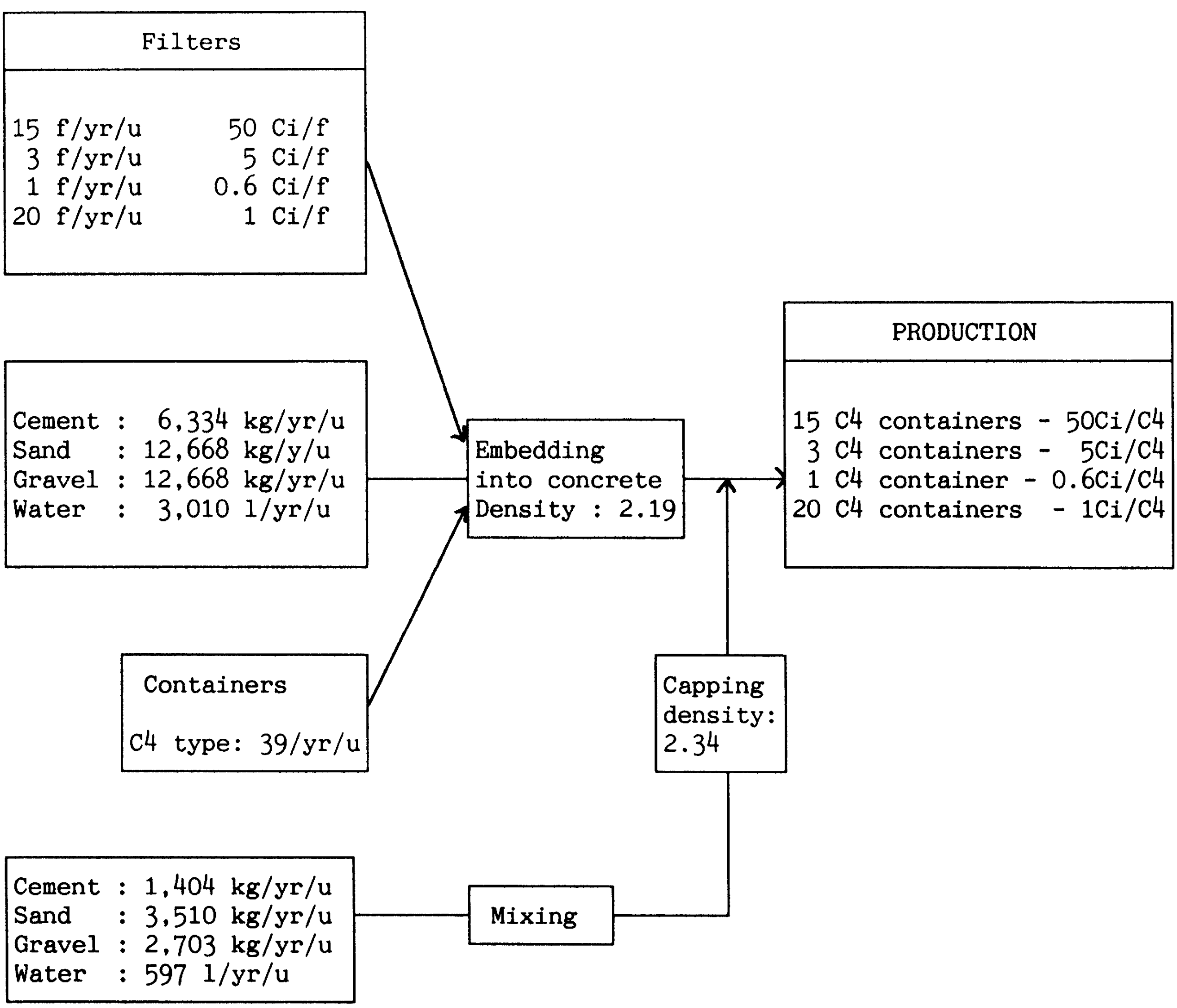
. Stabilization of filters :

Inactive concrete grout is prepared in a GUEDU 350 mixer to stabilize and embed filters in C4 containers. The embedding ratio is 1 filter per C4 container.

. Capping :

The same GUEDU 350 mixer is used to prepare and mix inactive concrete grout so as to cap C4 containers.

6.1.2.3. Filters and dry batches quantities



6.1.3. Concentrates and sludges

6.1.3.1. Concentrates and sludges inventory

Identical to that of the reference study.

TABLE XIV : CONCENTRATES AND SLUDGES INVENTORY

ORIGIN	VOLUME	ACTIVITY	TYPE OF CONTAINER	VOLUME OF CONCENTRATE PER CONTAINER (m3)
TEU	3.02	0.53	C1 (1)	0.360
Number of containers	Overall volume (m3)	Activity per Container (Ci)	Overall activity (Ci/yr/u)	
9	18	max. 0.19	1.6	

Note :

(1) See appendix 2.

6.1.3.2. Concentrates and sludges conditioning

. Receipt of concentrates and sludges

Concentrates and sludges are transferred from the fixed storage tanks to the mobile concreting facility.

All operations with the procurement of dry batches are performed outside the BTE.

. Mixing

A concrete batch corresponding to the volume of the C1 container to be filled is prepared in the GUEDU 350 batch mixer.

Embedding ratio : 360 l of concentrates and sludges per C1 container.

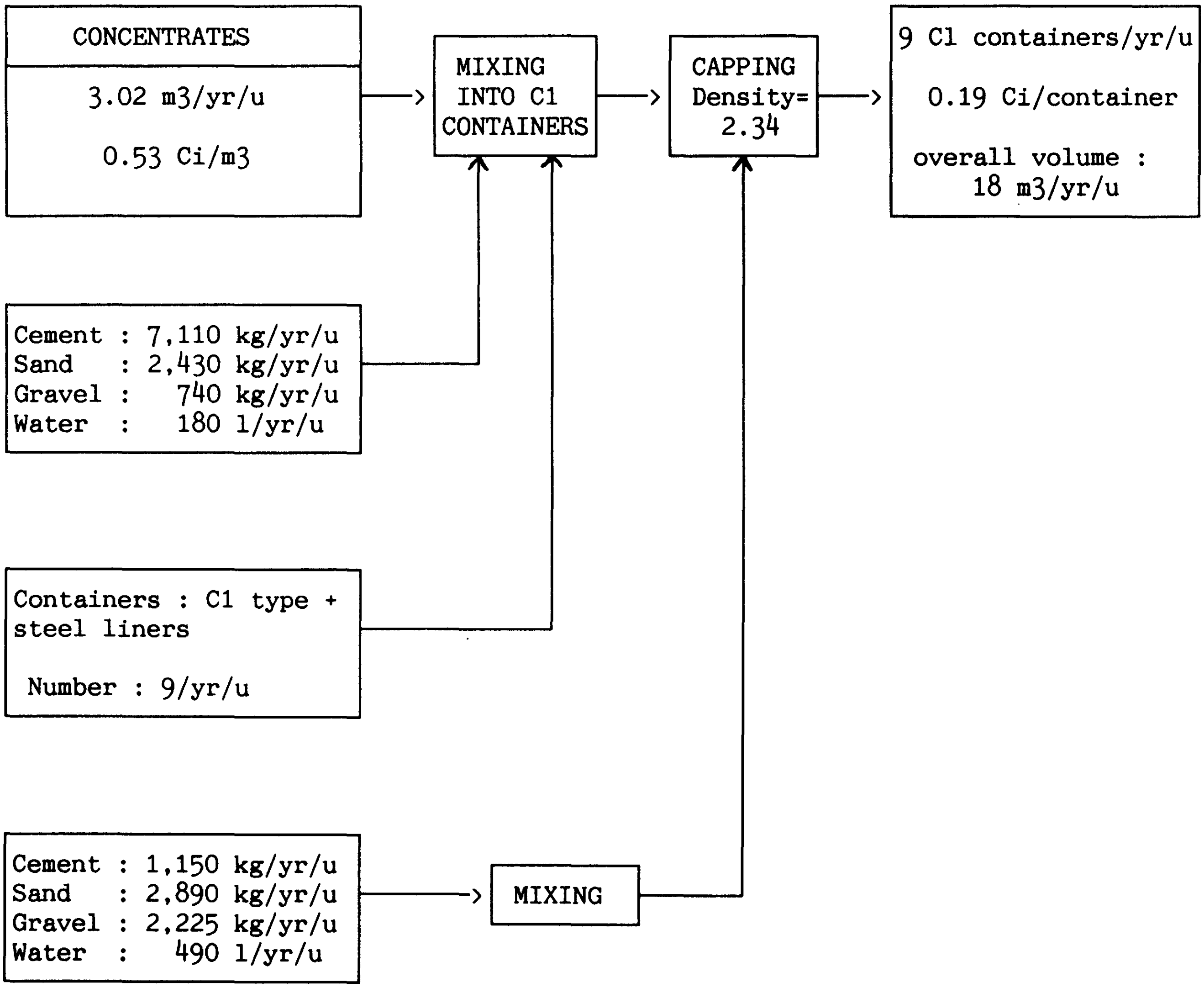
The quantity of concentrates and dry batches needed to prepare a batch is automatically weighed by placing the mixer on a weight scale. The embedded product is emptied by gravity into a C1 container by opening a side gate located at the lower part of the mixer.

. Final capping

A second GUEDU 350 mixer is used for the preparation of inactive concrete for the capping of C1 containers.

6.1.3.2. Concentrates and dry batches quantities

(Identical to that of the reference study).



6.1.4. APG resins

APG resins, whose level of activity is very low, come from the stream generator blowdown systems. Up to now, the annual production of ion exchange resins, i.e. 6 m3/year/unit, was considered as technological waste. At present, APG resins are embedded in cement in 200 l drums.

6.1.4.1. APG Resins inventory

TABLE XXIII : APG RESINS INVENTORY

TYPE OF WASTE	TYPE OF DRUM	VOLUME OF WASTE/DRUM m3/yr/u	ACTIVITY OF WASTE (Ci/m3)	VOLUME OF RESINS PER DRUM (m3)	NUMBER OF DRUM	OVERALL VOLUME (m3)	ACTIVITY PER DRUM (Ci)
APG	200 l drums	6	0.01	0.075	80	16	7.5×10^{-4}

6.1.4.2. APG resins conditioning

. Receipt of resins

APG resins are transferred in a mobile tank in which they are stored under water until they are sent into the mobile facility.

The mobile tank is installed inside the BTE.

. Receipt of ciment

All the operations associated with the procurement of cement are performed outside the BTE.

. Resins pretreatment

Before being embedded into concrete, the APG resins are pretreated using the following reagents :

- caustic soda 30 %,
- sodium nitrate,
- additives,
- water,

in order to remove their ammonia content.

. Metering of resins

The pretreated resins are transferred to a metering pot where a given water content (100 % in settled equivalent), and a given volume of resins at this concentration are obtained.

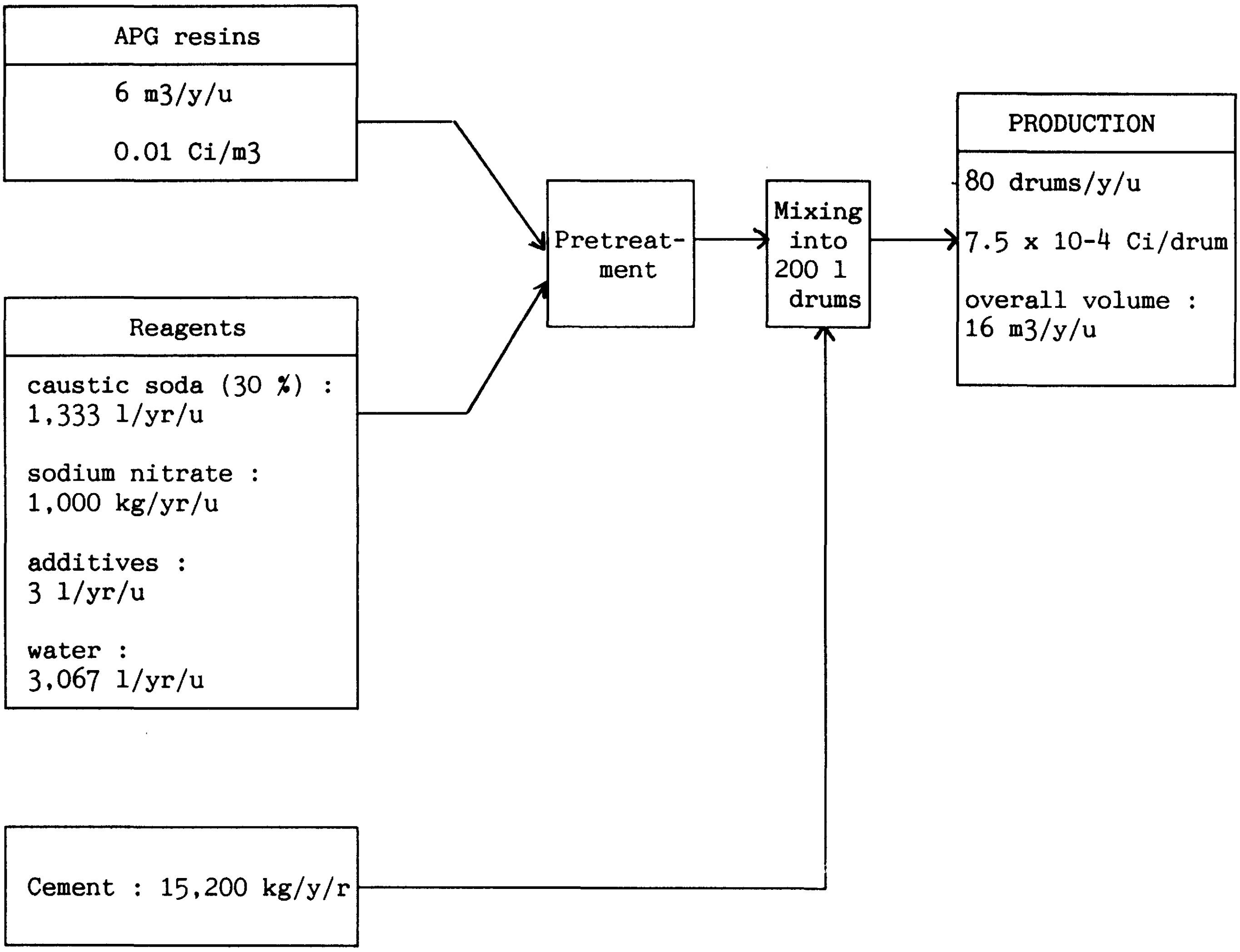
. Mixing

A concrete batch corresponding to the volume of the drum to be filled is prepared in the GUEDU 350 batch mixer.

Embedding ratio : 75 l of APG resins per 200 l drum.

The quantity of resins and cement needed to prepare a batch is automatically weighed by placing the mixer on a weight scale. The final product is emptied by gravity in a drum by opening a side gate located at the lower part of the mixer.

6.1.4.3. APG resins and cement quantities



6.2. Production capacity

The following assumptions were made so as to determine the number of mobile concreting facilities needed to treat all the solid waste (except technological waste) corresponding to the whole 20 GWe nuclear capacity :

- operating period : 250 days/year,
- load factor : 0.66,
- production period : 165 days/year,
- operation of mobile facilities in one day shift, on the basis of 6.5 effective working hours per shift, exclusively dedicated to active waste concreting,
- working time : 5 days/week,
- execution of all the assembly-disassembly operations within 4 days, once for each site.

Note :

The basic data are provided for a 2 x 0.9 GWe unit ; the adjustment factor to 20 GWe is therefore 11.11.

6.2.1. IERs

Production :

. 9.6 m3/year/unit,

. 110 l per C4 container.

Concreting capacity :

. Nine C4 containers daily,

. 12 caps daily.

Operating period of the facility and production of C4 containers per BTE :

The 19.2 m3 of resins generated annually by the two power plant units are processed within 35 working days, of which 20 days are dedicated to active concreting and 15 days to container capping, with a production of 175 C4 containers, i.e. 88 containers/year/unit.

Operating period of the facility for the whole nuclear capacity :

. Operating period of the facility per BTE : 35 days
. Assembly-disassembly : 4 days.

The total operating period of the facility is 429 days for the whole nuclear capacity.

Three mobile concreting facilities are needed to condition the 212 m3 of resins generated annually by the whole nuclear capacity.

6.2.2. Filters :

Production :

. 39 filters/year/unit,
. 1 filter per C4 container.

Concreting facility :

. Nine C4 containers daily,
. 12 caps daily.

Operating period of the facility and production of C4 containers per BTE :

The 78 filters produced annually by two units of the site are processed within 16 days, of which 9 days are dedicated to concreting and 7 days to capping, with a production of 78 C4 containers, i.e. 39 containers/year/unit.

Operating period of the facility for the whole nuclear capacity :

. Operating period of the facility per BTE : 16 days

. Assembly-disassembly : 4 days.

The operating period of the facility of the whole nuclear capacity is 220 days.

Two mobile facilities are required to condition the 858 filters generated annually by the whole nuclear capacity.

6.2.3. Concentrates and sludges

Production :

. 3.02 m3/year/unit
. 360 l concentrates per C1 container.

Concreting capacity :

. Six C1 containers daily
. 12 caps daily.

Operating period of the facility per BTE and production of containers :

The 6.04 m3 of concentrates and sludges generated annually by two 900 MWe units are processed within 5 working days of which 3 dedicated to concreting and 2 to the capping of C1 containers, i.e. 9 containers/year/unit.

Operating period of the facility for the whole nuclear capacity :

. Operating period of the facility/BTE : 5 days
. Assembly-disassembly : 4 days.

The operating period of the facility for the whole nuclear capacity is 99 days.

The 67 m3 of concentrates and sludges generated annually by the whole nuclear capacity requires only one mobile concreting facility.

6.2.4. APG resins

Production :

- 6m3/year/unit

- 75 litres per 200 l container.

Concreting capacity :

. Ten 200 l drums daily.

The time dedicated to the production of final product drums is 4 days per week, the first day being devoted to resins pretreatment.

Operating period of the facility per BTE and production of drums :

The 12 m3 of APG resins generated annually by two 900 MWe units are processed within 20 working days, with a production of 160 drums, i.e. 80 drums/year/unit.

Operating period of the facility for the whole nuclear capacity :

Operating period of the facility per BTE : 20 days.
Assembly-disassembly : 4 days.

The operating period of the facility is 264 days for the whole nuclear capacity.

The 132 m3 of APG resins generated annually by the whole nuclear capacity require two mobile concreting facilities.

6.2.5. Number of mobile concreting facilities

A maximum of 8 mobile concreting facilities is required to treat all the waste generated by the 20 MGe nuclear capacity (see Table 24 below). This presupposes that a given type of facility is assigned to a single type of waste.

TABLE XXIV : MAXIMUM NUMBER OF MOBILE CONCRETING FACILITIES REQUIRED

	TYPE OF CONTAINER	NUMBER OF CONTAINERS OR DRUMS/UNIT	NUMBER OF OPERATING DAYS OF THE FACILITY	NUMBER OF MOBILE CONCRETING FACILITIES
Concentrates and sludges	C 1	9	99	1
IERs	C 4	88	429	3
Filters	C 4	39	220	2
APG resins	200 1 drums	80	264	2

However, the design of the IER concreting facility is such that it can be used to condition active filters (utilization of the inactive mixer only). This double utilization helps to reduce the number of mobile concreting facilities.

Waste type	Operating days of the facility
IERs	429 days
Filters	220 days
Total	649 days

Production period : 165 days/year

The number of mobile concreting facilities is therfore :

$$\frac{649}{165} = 4 \text{ mobile facilities}$$

As a consequence, 7 mobile concreting facilities are required to condition all the solid waste generated annually by all the 20 GWe nuclear power plants (see following table XXV). One of the facilities is used for the conditioning of both IERs and filters.

TABLE XXV : OPTIMIZED NUMBER OF MOBILE FACILITIES REQUIRED

	TYPE OF CONTAINER	NUMBER OF CONTAINERS OR DRUMS/ YEAR/UNIT	OPERATING PERIOD OF THE FACILITIES (IN DAYS)	NUMBER OF MOBILE FACILITIES
Concentrates and sludges	C 1	9	99	1
IER's	C 4	88	429	3*
Filters	C 4	39	220	1*
APG resins	200 1 drums	80	264	2

* Conditioning of IERs : 2 facilities
Conditioning of filters : 1 facility
Conditioning of IERs and filters : 1 facility

6.3. Overall balance

The overall balance takes technological waste into account.

6.3.1. Volume

TABLE XXVI : ANNUAL PRODUCTION OF CONTAINERS FOR ONE UNIT

TYPE OF CONTAINER	NUMBER OF CONTAINERS	VOLUME OF A CONTAINER (m3)	TOTAL VOLUME (m3/yr/u)
200 l drums	887	0.2	177
C1	9	2	18
C4	127	1.235	157
TOTAL			352*

* or 336 m3/yr/u if APG resins are only included into technological waste as in the reference study

6.3.2. Activity

IERs : 1,530 Ci/yr/u

Filters : 783.6 Ci/yr/u

Concentrates and sludges : 1.6 Ci/yr/u

Technological waste : 7.92 Ci/yr/u

APG resins : 0.00075 Ci/yr/u

Total : 2,325 Ci/yr/u

6.4. Cost assessment

This paragraph indicates both the capital and operating costs associated with the use of a mobile concreting facility, and emphasizes the cost reduction obtained with respect to the reference case.

6.4.1. Capital cost assessment

6.4.1.1. Capital cost of the mobile facilities

The capital cost of the mobile facilities required for one BTE is as follows :

- Spent IER's	FF	3,240,000
- Filters	FF	787,500
- Concentrates and sludges	FF	990,000
- APG resins	FF	900,000

These costs include complete services, i.e. :

- construction studies,
- equipment procurement and control,
- assembly,
- commissioning,
- quality assurance,

without export margin.

The seven mobile concreting facilities needed to cover the whole nuclear capacity cost FF 5,917,500 for two units.

If the treatment of APG resins as indicated in the reference study is not considered, this cost is only FF 5,017,500 for two units.

6.4.1.2. Cost reduction due to the deletion of fixed equipment and of part of the building

The cost reduction due to the deletion of certain fixed equipment items of the reference treatment systems and of a part of the building corresponding to a concrete bunker has been estimated : FF 5,000,000 are saved, to which FF 1,000,000 should be added, corresponding to the cost of the mobile facility used to embed resins in polymers, which is no longer used.

The use of mobile concreting facilities can therefore involve a slight decrease in capital cost.

6.4.1.3. Ventilation

The ventilation cost is identical to that of the reference study.

6.4.1.4. Civil works

* Effluents treatment building :

  see § 6.4.1.2.

* Interim storage for one year :

  The annual production of drums and concrete containers of one unit has been detailed in table XXVI.

  The volume of waste to be stored is higher than in the reference study, due to the increase in the number of containers and to the filter buffer storage.

6.4.1.5. Handling cost

Identical to that of the reference study.

6.4.1.6. Laboratory cost

Identical to that of the reference study.

6.4.2. <u>Operating cost assessment</u>

6.4.2.1. Cost of containers, transport and storage

The following table indicates, for each waste type, the cost of one container with associated transport and storage cost per container.

TABLE XXVII : COST OF CONTAINER, TRANSPORT AND STORAGE

	TYPE OF CONTAINER	COST OF ONE CONTAINER	TRANSPORT COST	STORAGE COST	TOTAL PER CONTAINER
IERs resins	C4(*)(1)	8,380 FF	1,400 FF	2,750 FF	12,530 FF
Filters activity ≤ 5 Ci	C4	2,200 FF	1,400 FF	2,750 FF	6,350 FF
activity = 50 Ci	C4(*)(1)	6,620 FF	1,400 FF	2,750 FF	10,770 FF
Concentrates and sludges	C1	3,500 FF	2,350 FF	4,470 FF	10,320 FF
APG resins	200 1 drum	200 FF	150 FF	900 FF	1,250 FF

Notes :

(*) C4 containers equipped with steel liners and internal shieldings :

(1) thickness : 7 cm lead

(2) thickness : 5 cm lead (for filters whose activity is 50 Ci), like in the reference case but in a C4 container smaller than the C1 container.

* **IER's** :

It should be stressed that container cost is drastically reduced when using a mobile concreting facility.

. Cost of one container in the initial case : FF 24,440

. Cost of one container within the framework of the sensitivity study : FF 8,380.

Relating this cost to the number of containers involved in the two cases yields a decrease of FF 166,840 in the operating cost of one unit.

* **Filters** :

For filters whose activity is 50 Ci (15 filters/yr/u) the operating cost due to transport and storage is lower than in the case of C1 containers (see table XXVII).

Cost reduction is FF 40,050 per unit, to which the reduction in container cost should be added :

- Reference case	: C1 container + internal shielding (5 cm lead)	11,800 FF
- Sensitivity study	: C4 container + internal shielding (5 cm lead)	6,620 FF

i.e. a saving of FF 77,700 per unit.

The total decrease in operating cost is therefore FF 117,750 per unit.

* **APG resins** :

The total operating cost of APG resins concreting facilities had not been considered at all in the reference study.

* **Concentrates** :

The operating cost is identical to that of the reference study, for the following reasons :

- utilization of identical containers,

- same production of containers.

6.4.2.2. Evaluation of utility consumption :

- **Reagents** :

  . water : 8.7 m3/yr/u

  . cement : 83.6 t/yr/u

  . sand : 21.5 t/yr/u

  . gravel : 17.6 t/yr/u

  . lime : 1.25 t/yr/u

  . caustic soda (30 %) : 1,3 m3/yr/u

  . calcium nitrate : 19.7 m3/yr/u

  . ammonium nitrate : 1 t/yr/u

  . additives : 3 kg/yr/u

6.4.2.3. Operating personnel :

The following operating personnel is required for one mobile concreting facility :

- 1 chief operator,

- 3 operators,

i.e., 2 or 3 operators per BTE depending on whether the APG resins concreting facility is being considered.

Irrespective of the APG resins mobile concreting facilities, two operators are assigned to concreting and one to the polymer mobile unit in two 900 MWe units.

A saving of one operator per BTE is thus obtained, but the same number of operators as in the reference study is obtained if the APG resins concreting facility is being considered.

6.5. Conclusion

The use of mobile concreting facilities reduces both capital and operating costs :

- capital cost without APG mobile units : FF 982,500 per BTE (2 units).

  The investment cost is still decreased by FF 82,500 per BTE (2 units when APG mobile units are being considered.

- operating cost (APG mobile units excluded) :

  A saving of about FF 284,590/unit is obtained due to the costs of containers, transport and storage. The operating cost is also decreased because of the saving of one operator per BTE and because less equipment items are to be maintained and replaced.

  The saving due to the costs of containers, transport and storage is still FF 184,590/unit when APG mobile units are being considered.

TEP	Boron recycle system
TEU	Liquid waste treatment system
TES	Solid waste treatment system

SYMBOLS

BA	Tank
CO	Compressor
CS	Condenser
DE	Demineralizer
DI	Diaphragm
EV	Evaporator
EX	Regenerative heat exchanger
EZ	Gas stripper
FI	Filter
HT	Heating heat exchanger
LD	Rotameter
PO	Pump - C Centrifugal - V Metering
RF	Chilling heat exchanger
V	Valves - VA Instrument or service air - VD Demineralized water - VK Liquid effluent - VP Primary effluent - VS Solid effluent - sludge - VV Auxiliary steam - VY Hydrogenated gases

APPENDIX I

PROCESS FLOW DIAGRAMS

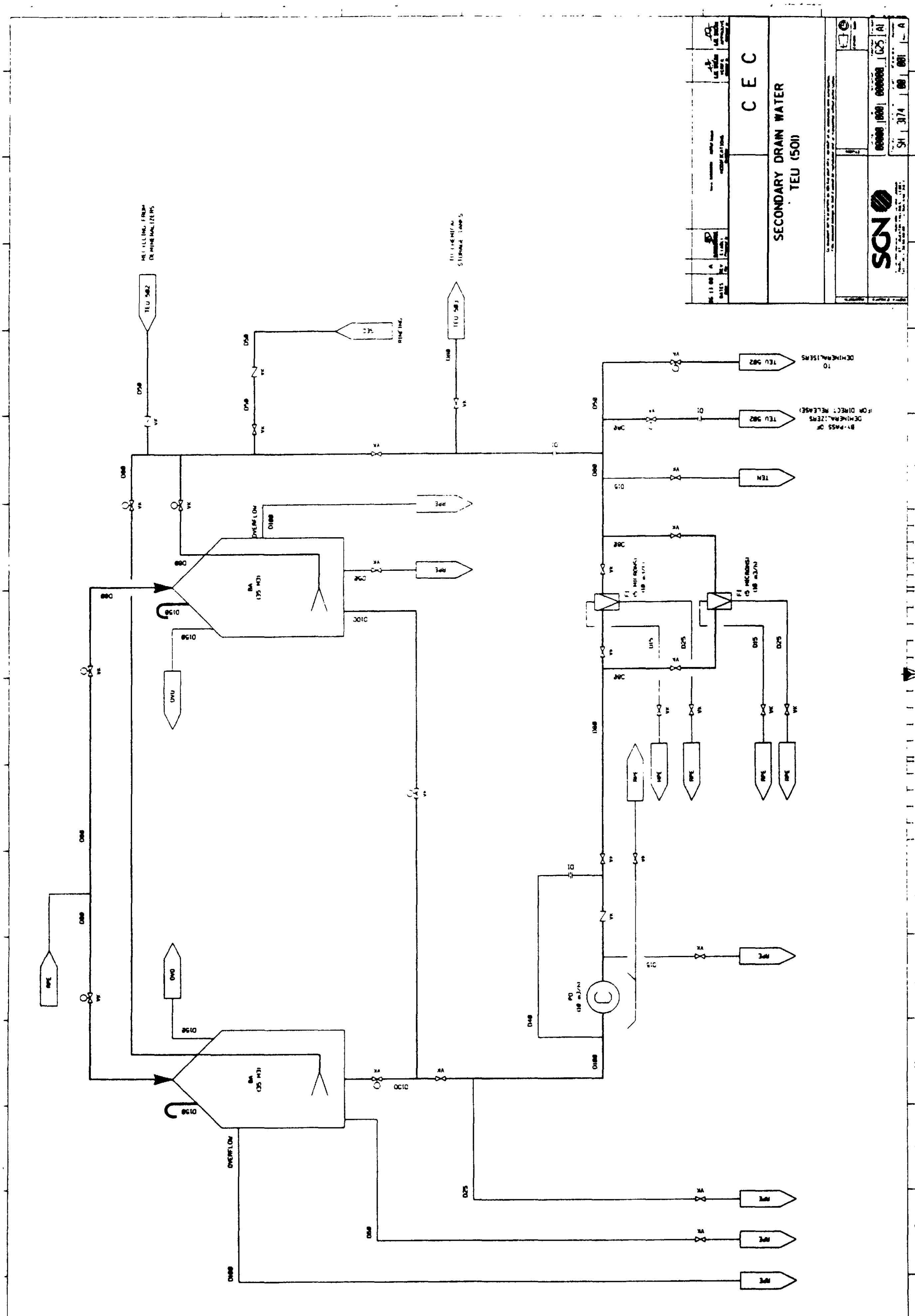
The waste treatment systems are sized according to the design values defined in tables II, III and IV.

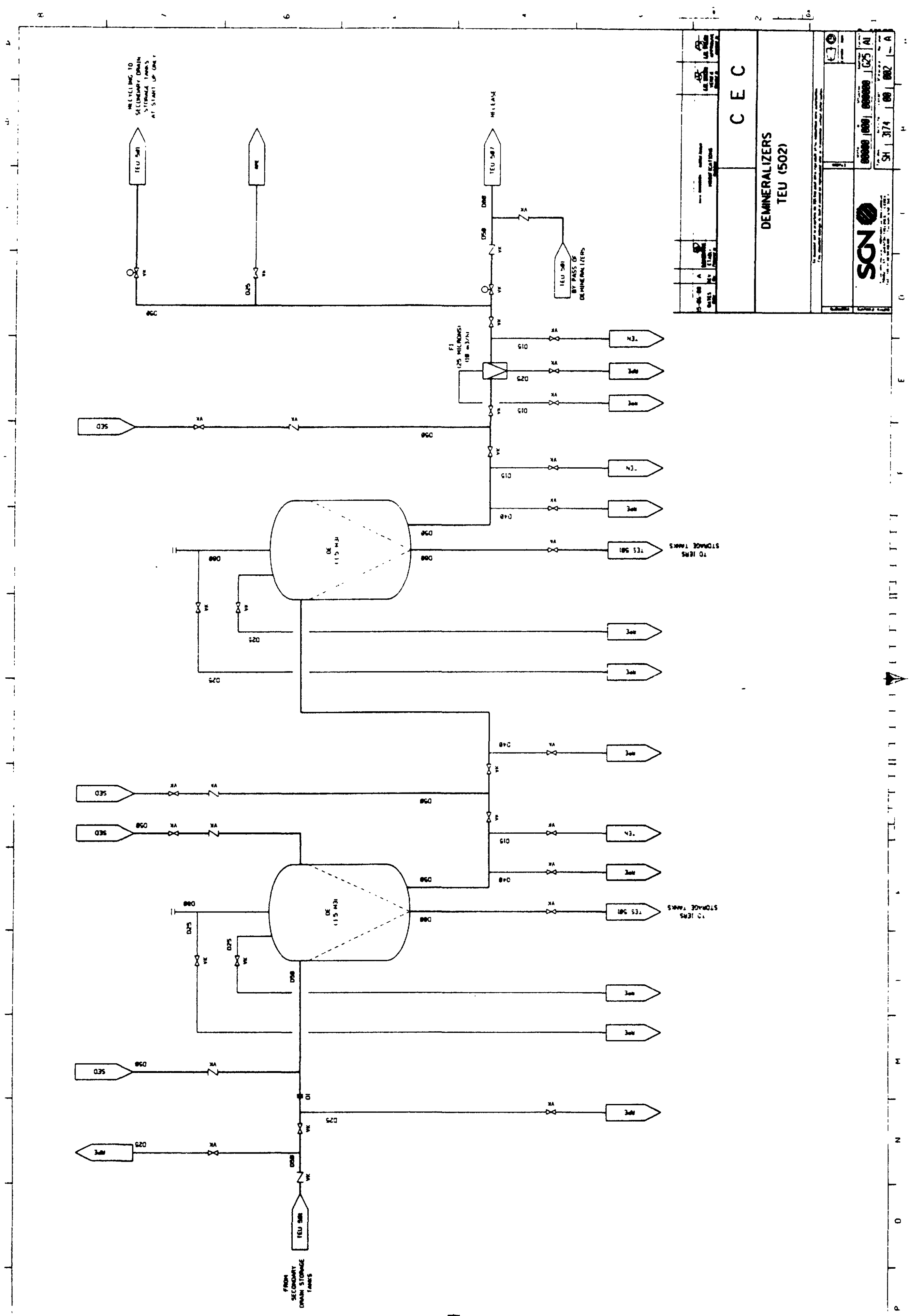
As already mentioned, they are common to two 900 MWe units.

The list of abbreviations and symbols used in the process flow diagrams also attached to this appendix are given below :

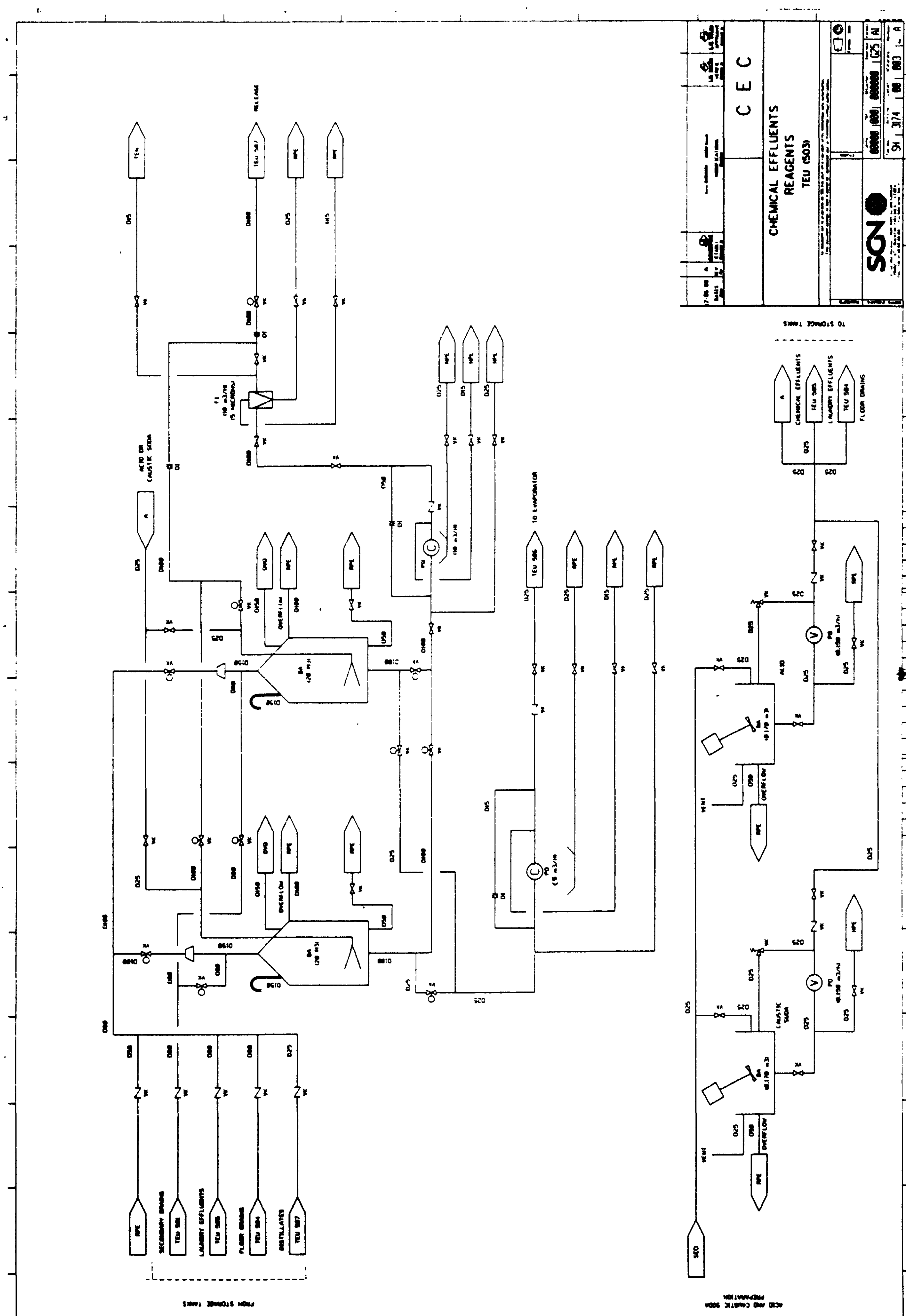
LIST OF ABBREVIATIONS

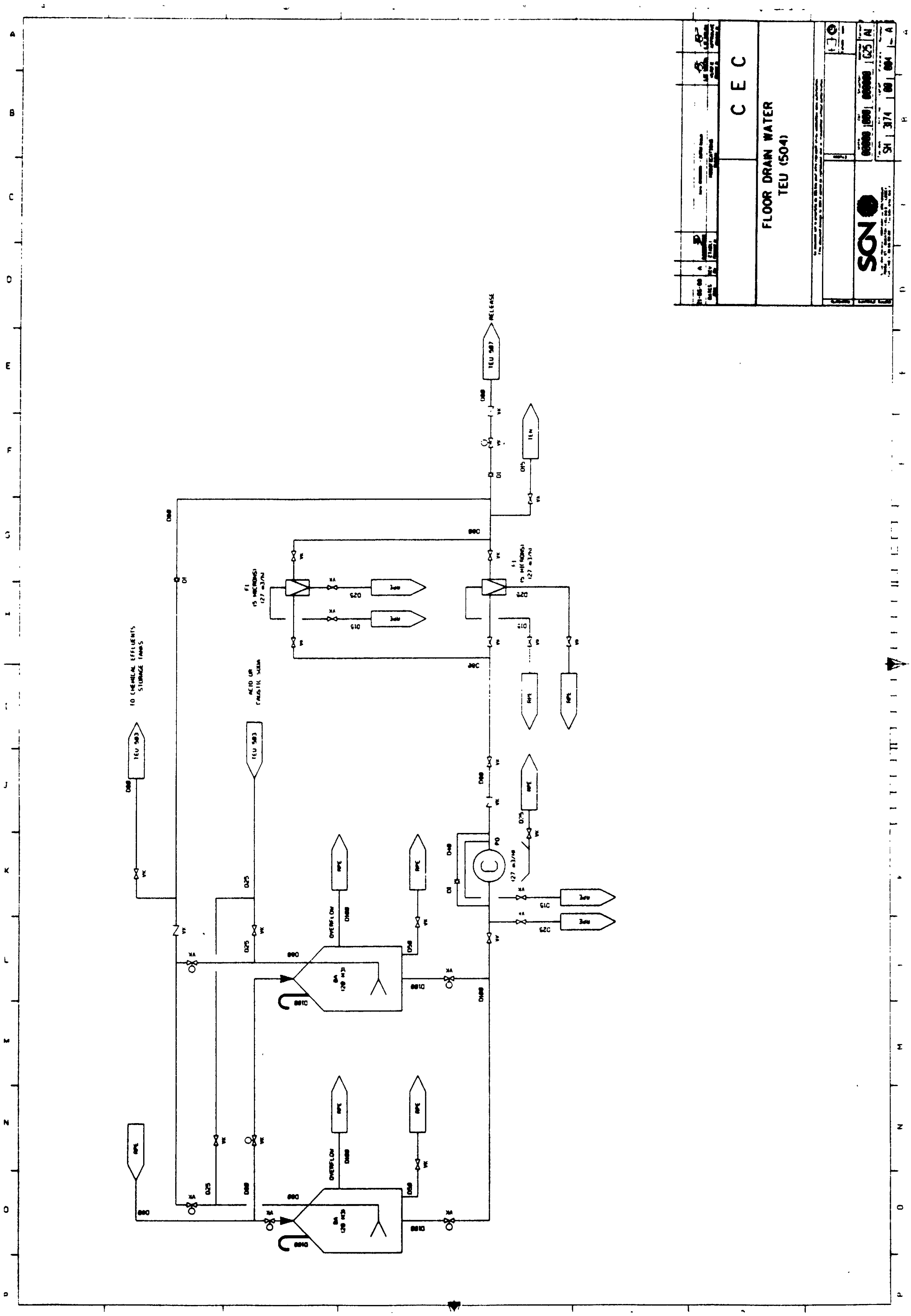
APG	Steam generator blowdown system
BAN	Nuclear auxiliary building
BTE	Effluent treatment building
DVN or DVQ	Ventilation system
DVQ	Ventilation system
KER	Liquid waste discharge system
KRT	Radiation monitoring system
PTR	Reactor cavity and spent fuel pit cooling & treatment system
RAZ	Gaseous nitrogen system
RCV	Chemical and volume control system
REA	Reactor make-up system
REN or TEN	Nuclear sampling system
RPE	Vent and drain system
RRI	Intermediate cooling system (component cooling water system)
SAT	Instrument air system
SED	Demineralized water system
SVA	Auxiliary steam system
TEG	Gaseous waste treatment system
TEN	Sampling system

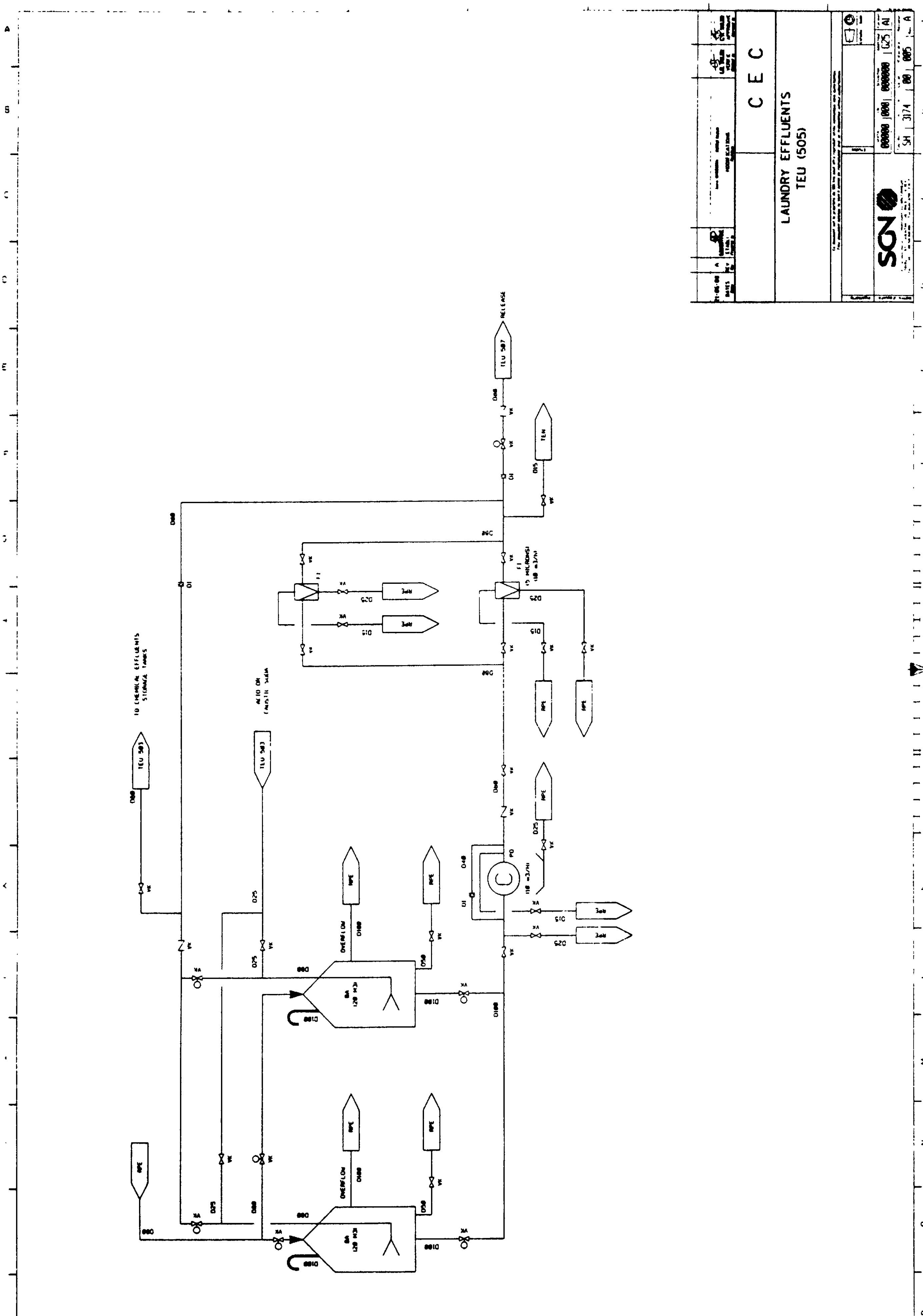

CEC
SECONDARY DRAIN WATER
TEU (501)
SGN

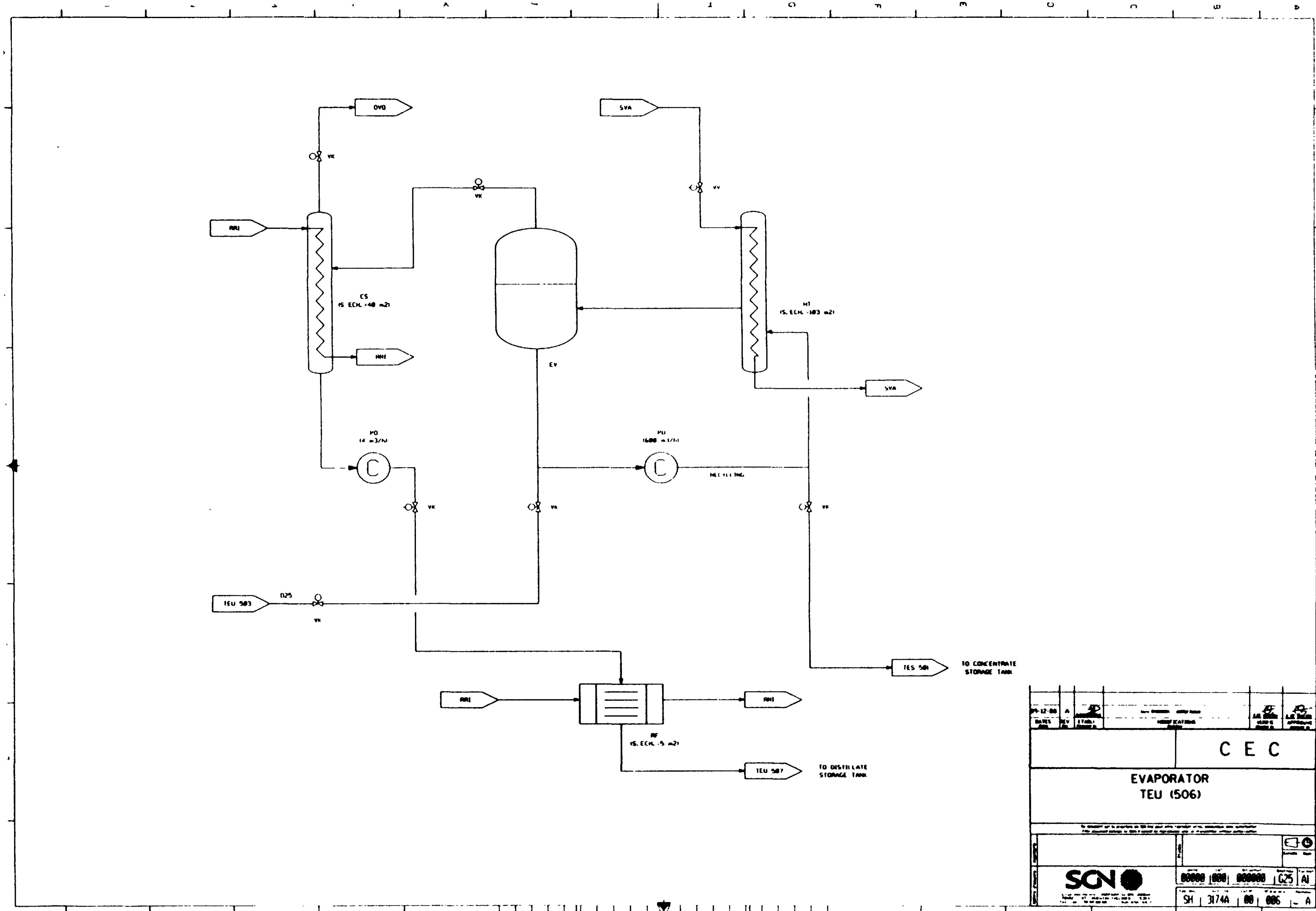


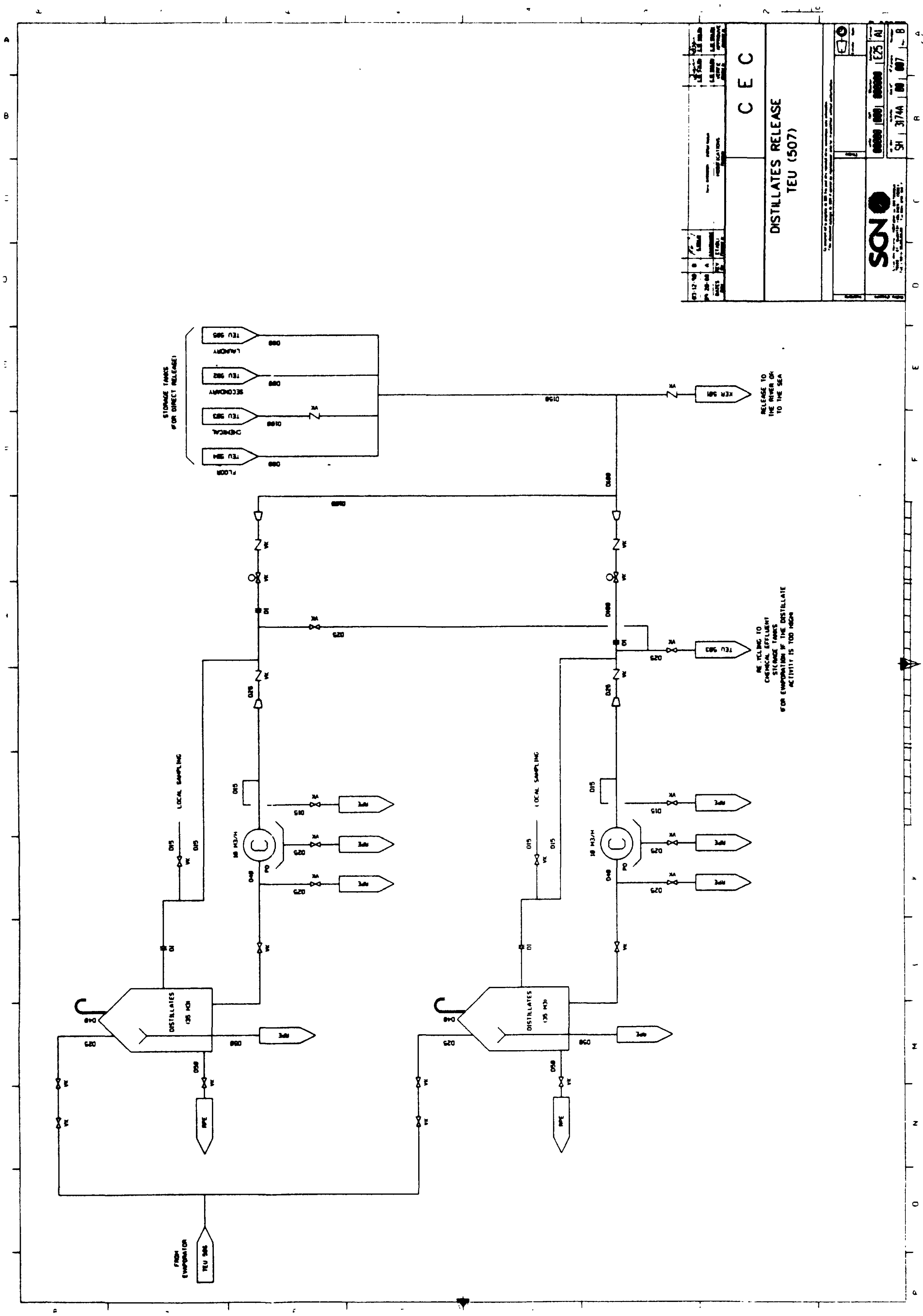
C E C
DEMINERALIZERS
TEU (502)
RECYCLING TO SECONDARY DRAIN STORAGE TANKS AT START UP ONLY
RELEASE
BY PASS OF DEMINERALIZERS
TO IERS STORAGE TANKS
TO IERS STORAGE TANKS
FROM SECONDARY DRAIN STORAGE TANKS

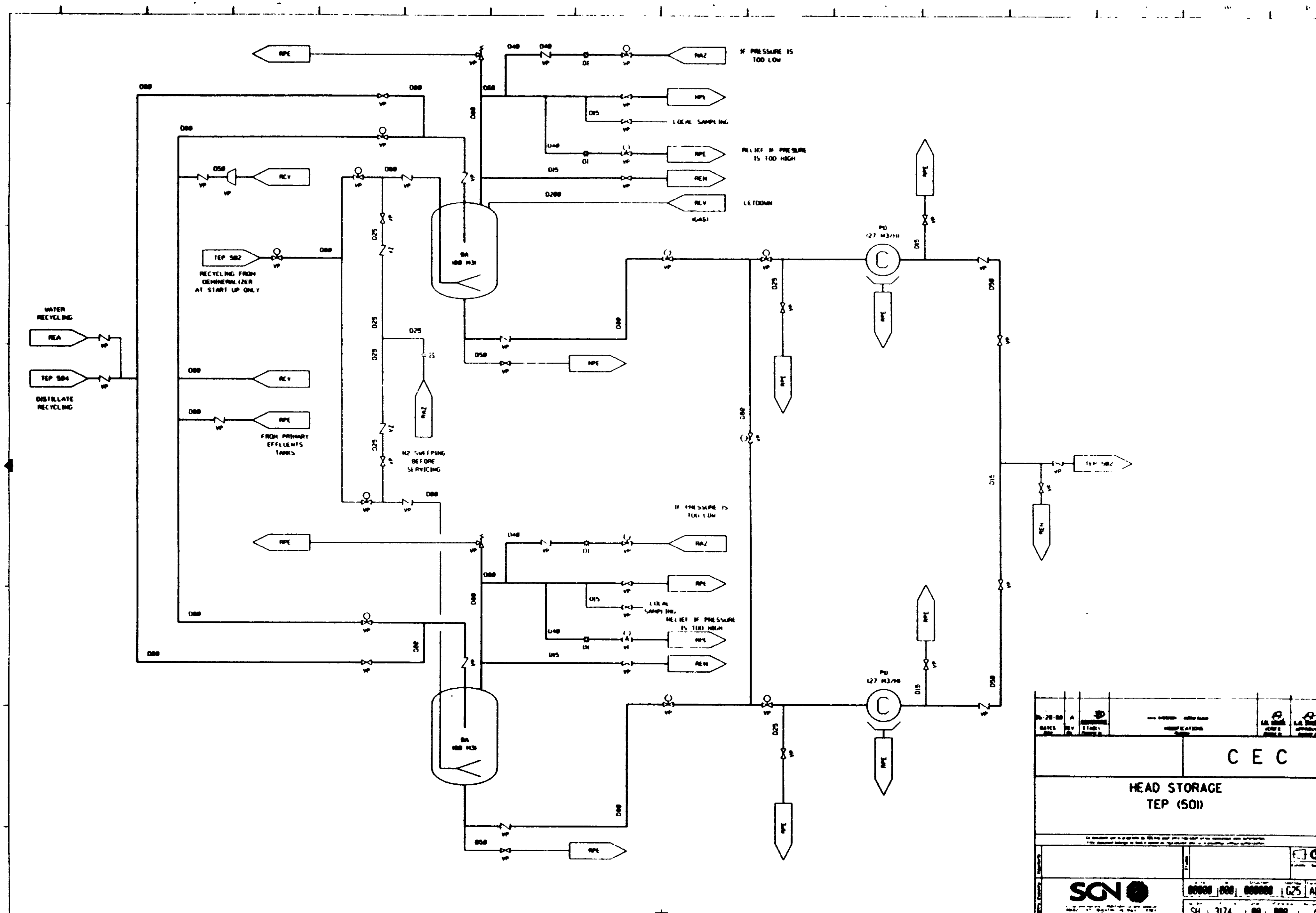

CEC
CHEMICAL EFFLUENTS
REAGENTS
TEU (503)
FROM STORAGE TANKS
TO STORAGE TANKS
TO EVAPORATOR
ACID AND CAUSTIC SODA PREPARATION

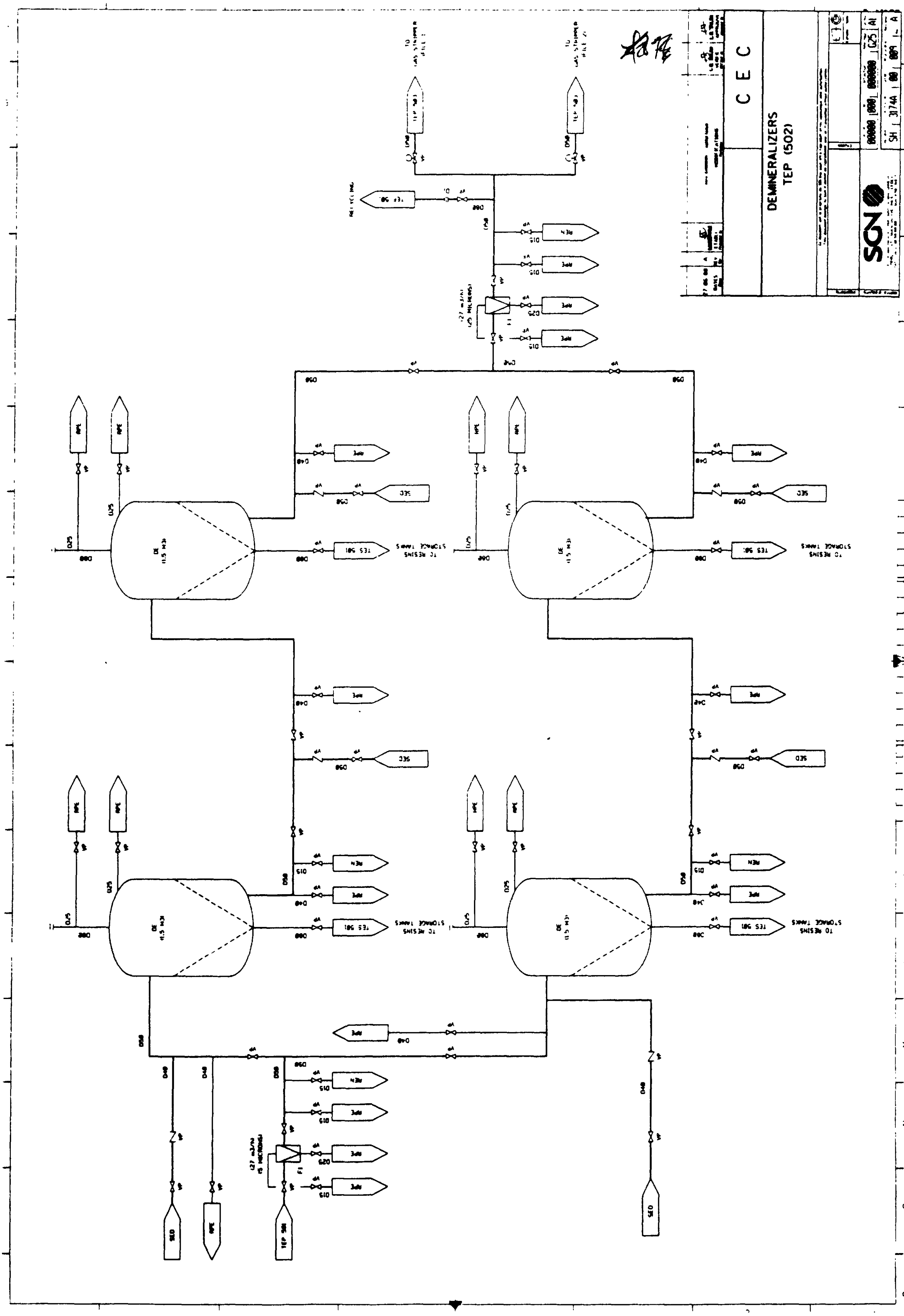

CEC
FLOOR DRAIN WATER
TEU (504)
SGN
TEU 507
RELEASE
TEN
TO CHEMICAL EFFLUENTS
STORAGE TANKS
ACID OR
CAUSTIC SODA
TEU 503
OVERFLOW
RPE

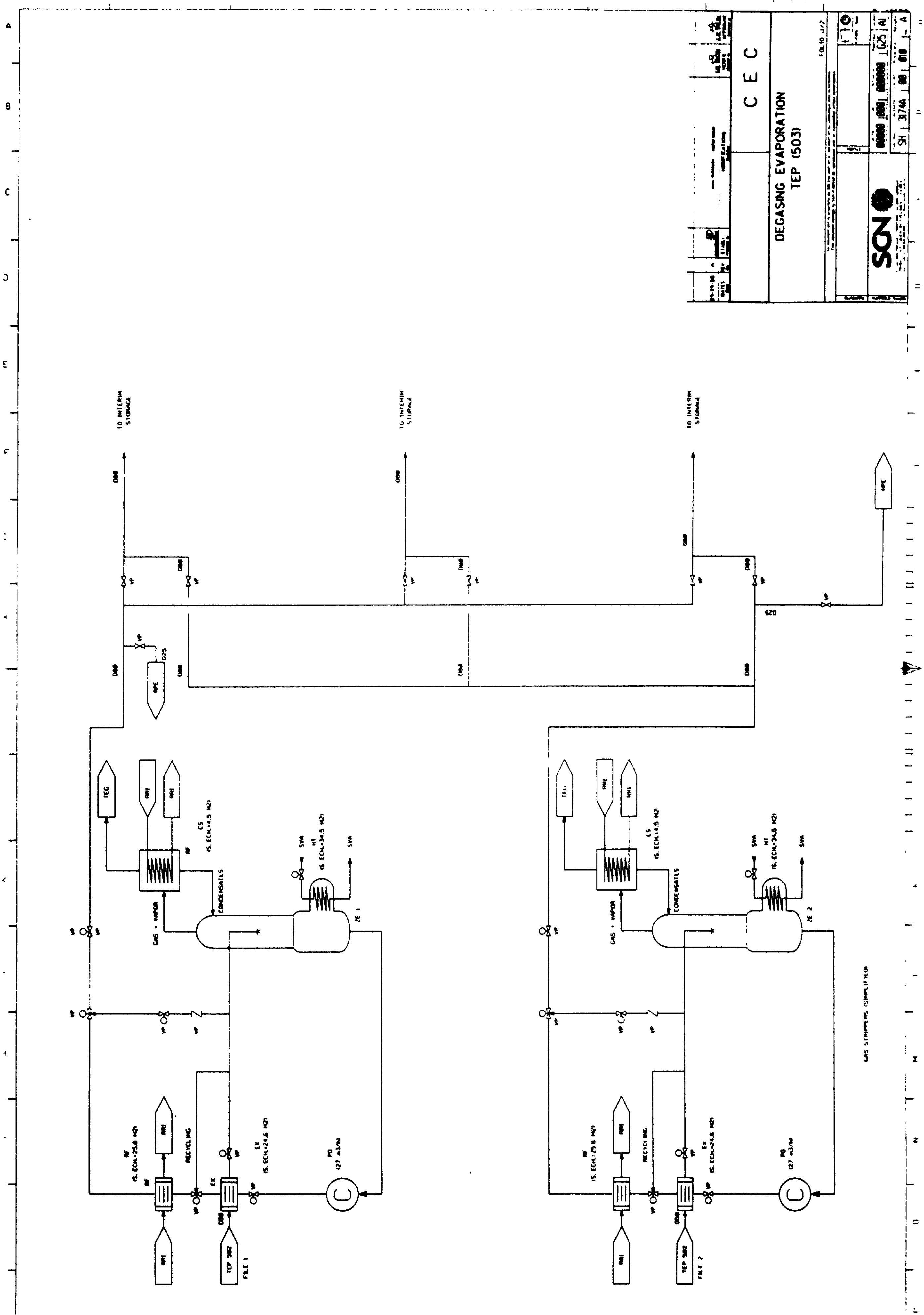

C E C
LAUNDRY EFFLUENTS
TEU (505)
RELEASE
TEU 507
TEN
TEU 503
TO CHEMICAL EFFLUENTS STORAGE TANKS
OVERFLOW
RPE

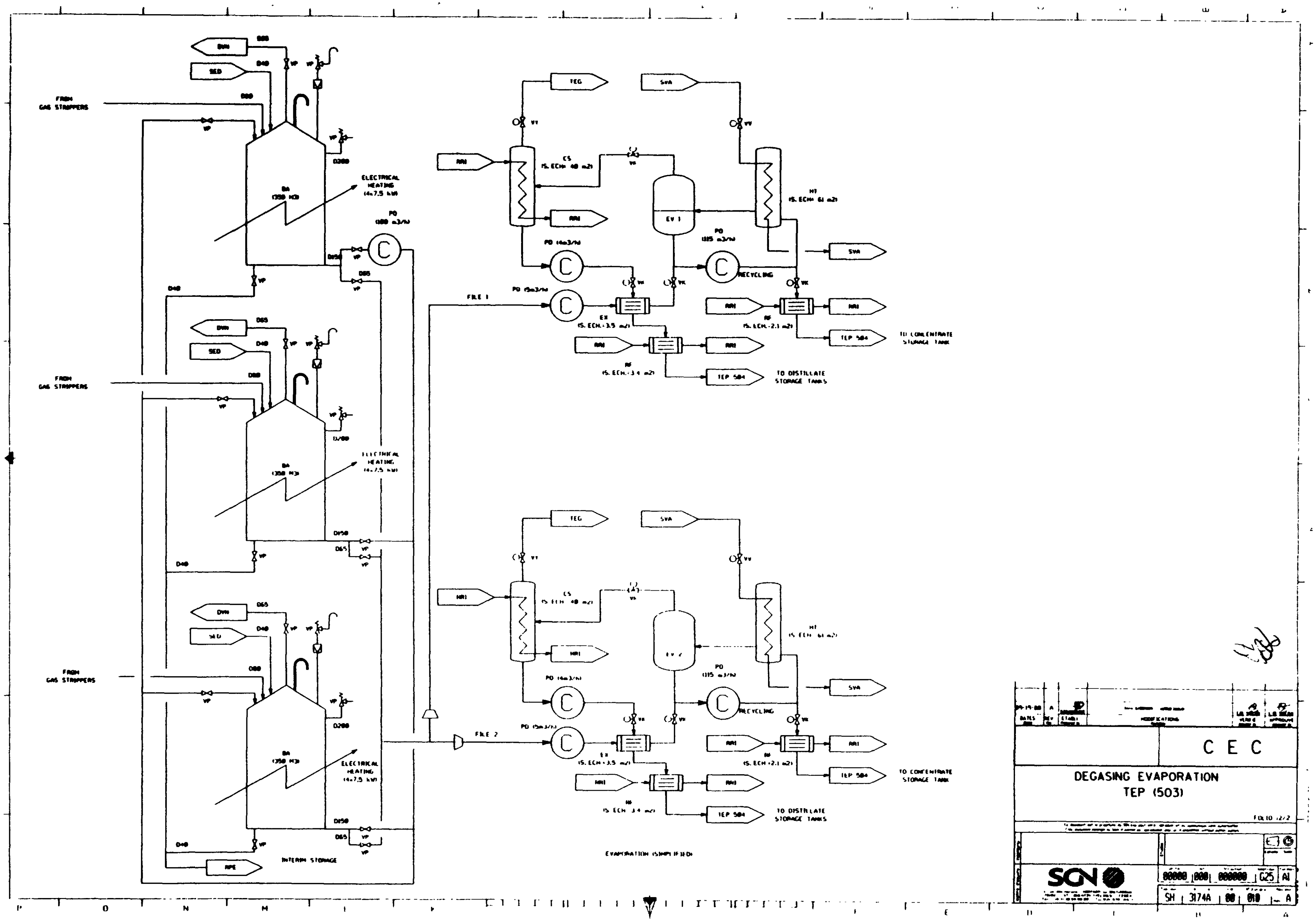

OVG
SVA
VK
VV
RRI
CS
(S. ECH. =40 m2)
RRI
HT
(S. ECH. =103 m2)
SVA
EV
PO
(4 m3/h)
PU
(600 m3/h)
RECYCLING
TEU 503
D25
TES 504
TO CONCENTRATE
STORAGE TANK
RRI
RF
(S. ECH. =5 m2)
TEU 507
TO DISTILLATE
STORAGE TANK
C E C
EVAPORATOR
TEU (506)
SGN
SH 3174A 00 006 A


C E C
DISTILLATES RELEASE
TEU (507)
RELEASE TO THE RIVER OR TO THE SEA
STORAGE TANKS (FOR DIRECT RELEASE)
LAUNDRY
SECONDARY
CHEMICAL
FLOOR
RECYCLING TO CHEMICAL EFFLUENT STORAGE TANKS FOR EVAPORATION IF THE DISTILLATE ACTIVITY IS TOO HIGH
LOCAL SAMPLING
DISTILLATES (35 M3)
FROM EVAPORATOR

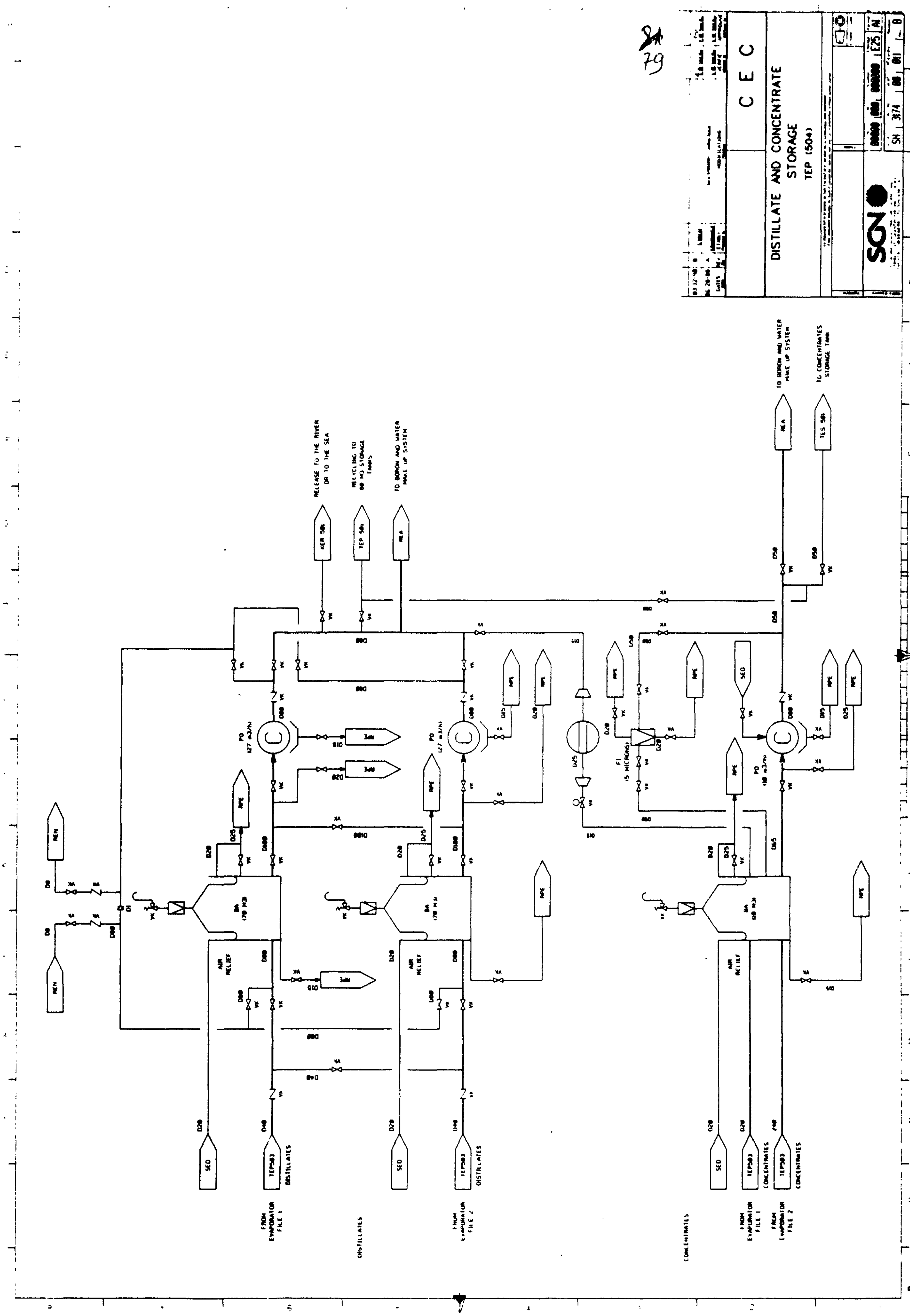

HEAD STORAGE
TEP (501)
C E C
IF PRESSURE IS TOO LOW
LOCAL SAMPLING
RELIEF IF PRESSURE IS TOO HIGH
LETDOWN
(GAS)
RECYCLING FROM DEMINERALIZER AT START UP ONLY
WATER RECYCLING
DISTILLATE RECYCLING
FROM PRIMARY EFFLUENTS TANKS
N2 SWEEPING BEFORE SERVICING
TEP 502
TEP 504
REA
RCV
RPE
RAZ
REN
RLV
BA 100 M3
PO (27 M3/H)
SH 3174

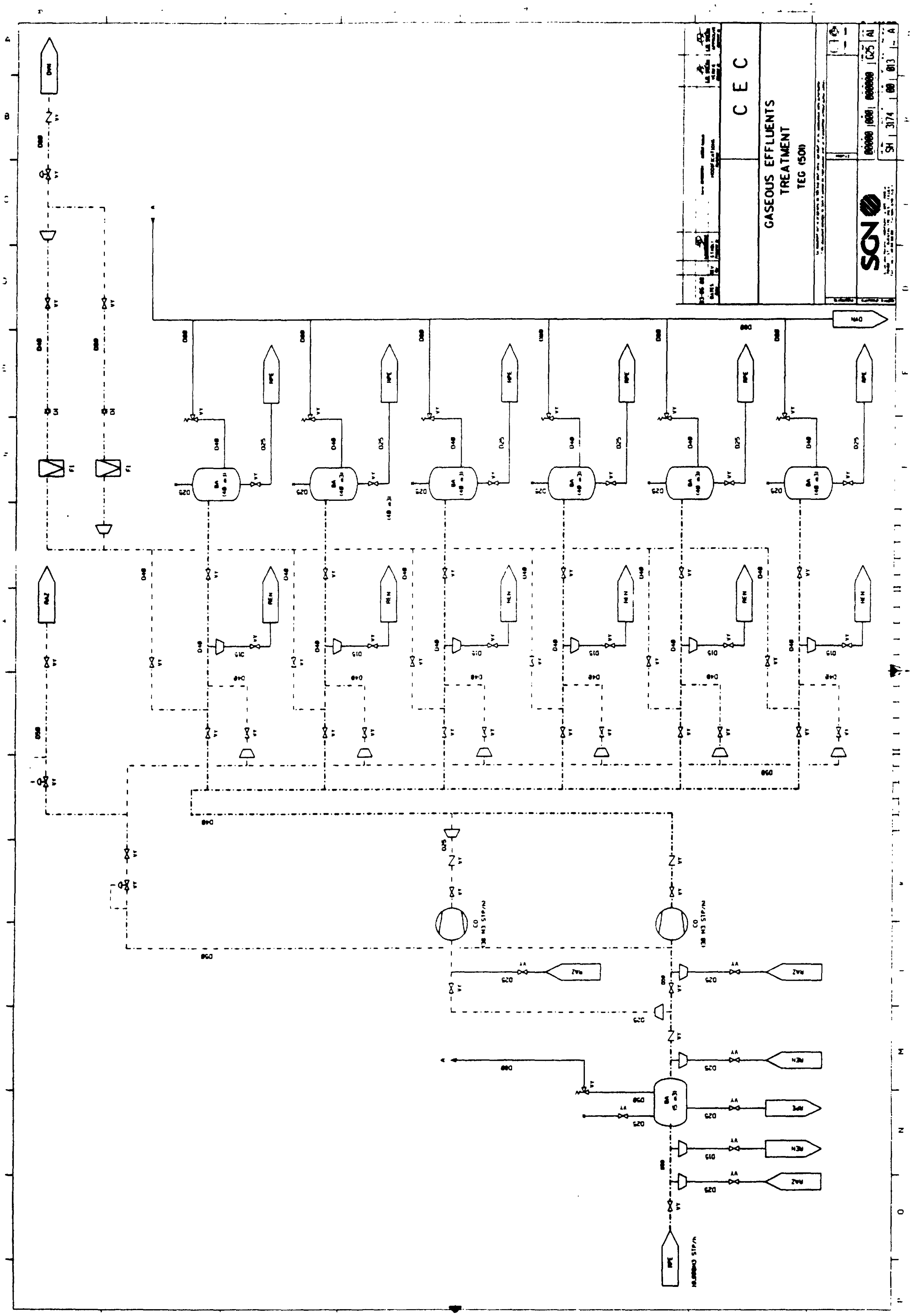

C E C
DEMINERALIZERS
TEP (502)
SGN


C E C
DEGASING EVAPORATION
TEP (503)
GAS STRIPPERS (SIMPLIFIED)
TO INTERIM STORAGE
TO INTERIM STORAGE
TO INTERIM STORAGE
TEG
CONDENSATES
GAS + VAPOR
RECYCLING
TEP 502
FILE 1
FILE 2
ZE 1
ZE 2
SVA
HT
CS
EX
PO
D25

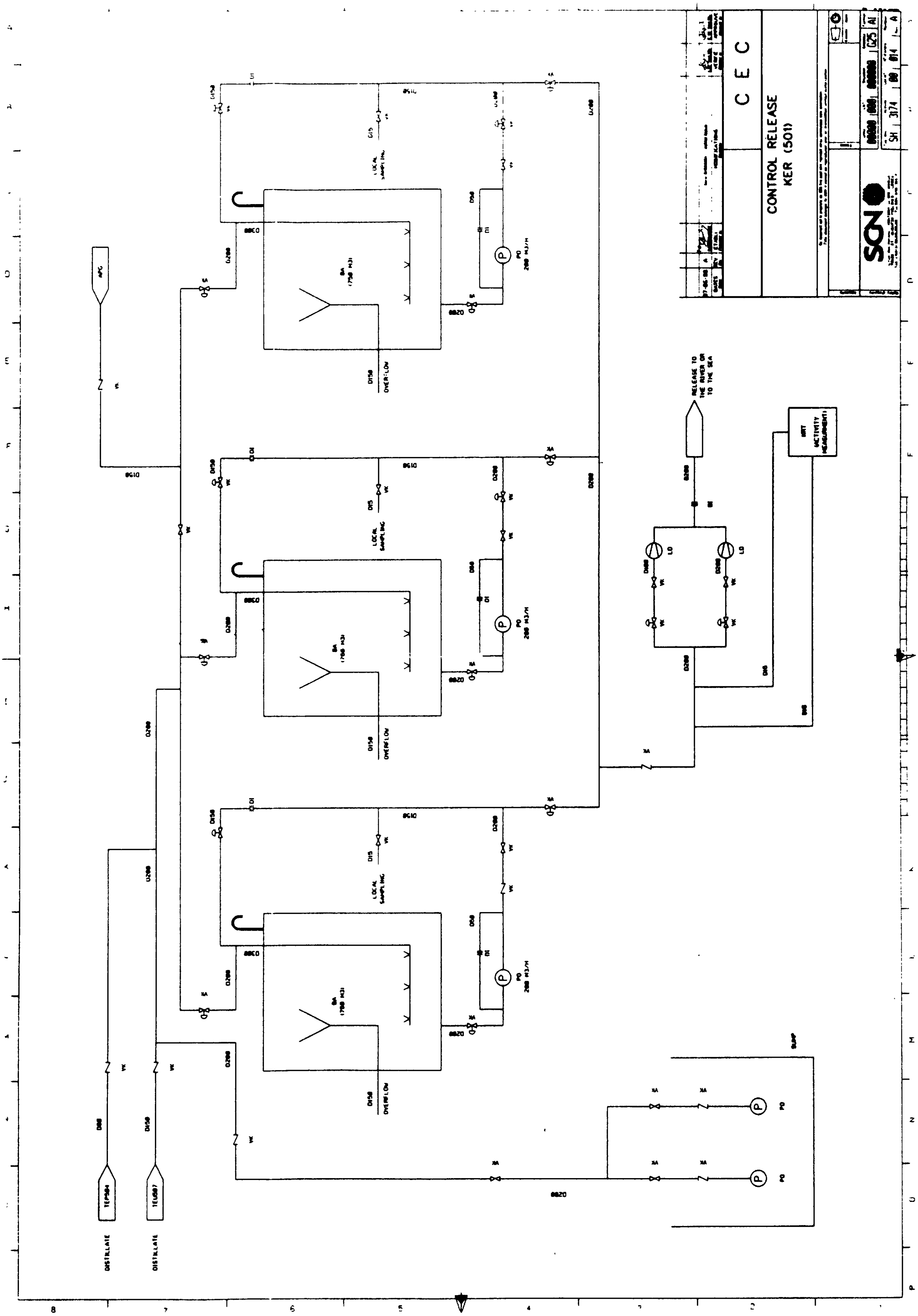


FROM GAS STRIPPERS
ELECTRICAL HEATING (4x7.5 kW)
DVN
SED
RPE
INTERIM STORAGE
FILE 1
FILE 2
TEG
SVA
RAI
NRI
EV 1
EV 2
RECYCLING
TEP 504
TO CONCENTRATE STORAGE TANK
TO DISTILLATE STORAGE TANKS
EVAPORATION (SIMPLIFIED)
C E C
DEGASING EVAPORATION
TEP (503)
SGN
SH 3174A


CEC
DISTILLATE AND CONCENTRATE
STORAGE
TEP (504)
SGN
RELEASE TO THE RIVER OR TO THE SEA
TO BORON AND WATER MAKE UP SYSTEM
DISTILLATES
CONCENTRATES
FROM EVAPORATOR FILE 1
FROM EVAPORATOR FILE 2
AIR RELIEF
KER 501
TEP 501
REA
TES 501
TEP503
SED
RPE
REN



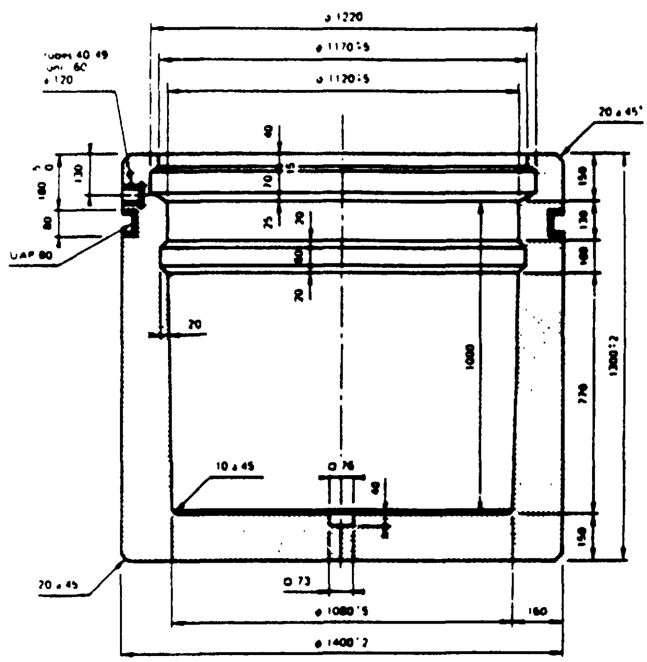
C E C
GASEOUS EFFLUENTS
TREATMENT
TEG (500)

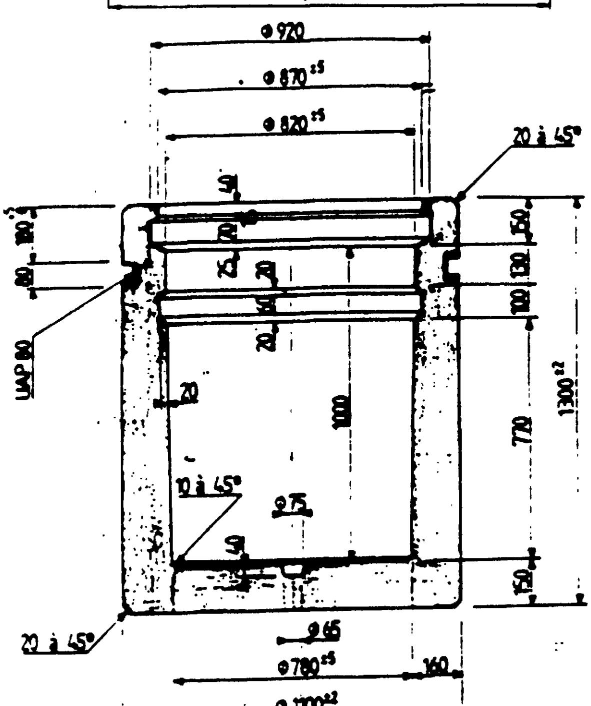

C E C
CONTROL RELEASE
KER (501)
RELEASE TO THE RIVER OR TO THE SEA
LOCAL SAMPLING
OVERFLOW
DISTILLATE
DISTILLATE

APPENDIX 2

DESCRIPTION OF CONCRETE CONTAINERS

C1 CONTAINER





C4 CONTAINER

APPENDIX 3

CHARACTERISTICS OF MAIN EQUIPMENT (TEP, TEU, TEG, TES)

Table I : TANKS

Table II : PUMPS

Table III : OTHER EQUIPMENT

TABLE I

TANKS

ORIGIN	NUMBER	SERVICE CAPACITY (m3)	MATERIAL	OVERALL DIMENSIONS	WEIGHT WHEN EMPTY (t)	DESIGN PRESSURE (bar eff)	DESIGN TEMPERATURE (°C)	OTHER CHARACTERISTICS
TEU 501	2	35	304 L	Ø 4 m L 3.8 m	3.8	atm	50	
TEU 503	2	20	316 L	Ø 3 m L 3.28 m	1.34	atm	50	
	2	0.17	316 L	Ø 0.55 m L 1.3 m		atm	20	Mechanical stirrer
TEU 504	2	20	316 L	Ø 3 m L 3.70 m	2.2	atm	50	
TEU 505	2	20	A 414 grE + paint coating	Ø 3 m L 3.30 m	2.2	atm	70	
TEU 507	2	35	304 L	Ø 3.2 m L 4.96 m	2.2	atm	70	
TEP 501	2	80	304 L	Ø 3.2 m L 11.47 m	10	2.4		

TABLE I (continued)

TANKS

ORIGIN	NUMBER	SERVICE CAPACITY (m3)	MATERIAL	OVERALL DIMENSIONS	WEIGHT WHEN EMPTY (t)	DESIGN PRESSURE (bar eff)	DESIGN TEMPERATURE (°C)	OTHER CHARACTERISTICS
TEP 503	3	350	304 L	Ø 6.9 m L 12.35 m	21	2	50	. Normal working pressure : - 0.05 bar . Electrical heating 4 x 7.5 KW/tank
TEP 504	2	70	304 L	Ø 4.9 m L 4.4 m	4.8	atm	50	floating roof.
	1	10	304 L	Ø 2.5 m L 2.74 m	1.5	atm	50	floating roof.

TABLE I (continued)

TANKS

ORIGIN	NUMBER	SERVICE CAPACITY (m3)	MATERIAL	OVERALL DIMENSIONS	WEIGHT WHEN EMPTY (t)	DESIGN PRESSURE (bar eff)	DESIGN TEMPERATURE (°C)	OTHER CHARACTERISTICS
TEG 501	1	5	304 L	Ø 1.5 m L 3.1 m	0.97	Vacuum tight		He tight Man-hole
	6	40	A 414 grE + paint coating			Vacuum tight	50	Relief valves : 100N m3/h Service pressure: 7 bar eff.
TES 501	2	9	304 L	Ø 2.0 m H 4.3 m	1.77	1.2	50	Two 250 µ mesh strainers
	1	0.11	316 L	--	--	4	140	
	1	5	316 L	Ø 1.6 m H 4.2 m	1.4	3	140	Electrical heating 5.5 KW + stirrer 2.2 KW - 140rd/mn heat insulation

TABLE II

PUMPS

ORIGIN	FLOWRATE (m3/hr)	NUMBER	MATERIAL	TOTAL MANOMETRIC HEAD (m)	ROTATION SPEED OF PUMP (rd/mn)	POWER CAPACITY (KW)	DESIGN PRESSURE (bar eff)	DESIGN TEMPERATURE (°C)	OTHER CHARACTE-RISTICS*
TEU 501	10	1	304 L	95	3,000	18.5	15	70	C
TEU 503	10	1	316 L	40	3,000	4	15	70	C
	0.15	2	316 L			0.75		20	V 20 kg
	5	1	316 L	50	3,000	4	15	70	C
TEU 504	27	1	316 L	60	3,000	4	15	50	C 300 kg
TEU 505	10	1	A414 grE	40	3,000	4	15	70	C
TEU 506	600	1	316 L	20	1,480	75	17.5		C
	4	1	304 L	65		5,5	17.5		C
TEU 507	10	2	304 L	40	3,000	4	15	70	C
TEU 501	27	2	304 L	95		24	15	50	C 425 kg

* C : centrifugal pump - V : metering pump

TABLE II (continued)

ORIGIN	FLOWRATE (m3/hr)	NUMBER	MATERIAL	TOTAL MANOMETRIC HEAD (m)	ROTATION SPEED OF PUMP (rd/mn)	POWER CAPACITY (KW)	DESIGN PRESSURE (bar eff)	DESIGN TEMPERATURE (°C)	OTHER CHARACTERISTICS*
TEU 503	27	2	304 L	55		7.9	17.5	113	245 kg submerged rotor
	100	1	304 L	50		24	15		C 450 kg
	5	2	304 L	50		4	15		160 kg mechanical seal + tight braid
	4	2	304 L	65		30	17.5		C 205 kg
	115	2	304 L	8.3		5.2	17.5	102	C 155 kg
TEP 504	27	2	304 L	60		15	15		C 300 kg
	10	1	304 L	30		4	15		Mechanical seal + tight braid 160 kg
TEG 501	38Nm3/hr for 7 bar eff.	2	304 L		400	18.5	9		1.3 t positive displacement pump (metallic membrane) service pressure : 7 bar eff.

TABLE III - OTHER EQUIPMENT

EQUIPMENT	REF.	NUMBER	CHARACTERISTICS
TEU 501			
Filter	FI	2	- 5 µm (cartridges) - Efficiency : 98% - Tank : V = 0.24 m3 Ø = 500 mm H = 1300 mm - Weight when empty : 410 kg - Material : 304 L - Design pressure : 15 bar eff. - Design temperature : 80°C - Flowrate : 10 m3/h
TEU 502			
Demineralizer	DE	2	- Tank : Ø = 985 mm H = 3425 mm - Weight when empty : 870 kg - Material : 304 L - Design pressure : 12 bar eff. - Capacity : 1.5 m3 of IERS
Filter	FI	1	- 25 µm - Efficiency : 98% - Tank : V = 32 l Ø = 210 mm H = 950 mm - Weight when empty : 118 kg - Material : 304 L - Design pressure : 12 bar eff. - Flowrate : 10 m3/h
TEU 503			
Filter	FI	1	- 5 µm - Efficiency : 98% - Tank : V = 157 l Ø = 406 mm H = 1300 mm - Weight when empty : 330 kg - Material : 316 L - Design pressure : 13.5 bar eff. - Design temperature : 70°C - Flowrate : 10 m3/h

EQUIPMENT	REF.	NUMBER	CHARACTERISTICS
TEU 504			
Filter	FI	2	- 5 µm - Efficiency : 98% - Tank : H = 1395 mm Ø = 634 mm - Weight when empty : 690 kg - Material : 316 L - Design pressure : 15 bar eff. - Flowrate : 27 m3/h
TEU 505			
Filter	FI	2	- 5 µm - Efficiency : 98 % - Tank : H = 1300 mm Ø = 406 mm - Material : 304 L - Flowrate : 10 m3/h - Design pressure : 9 bar eff. - Weight when empty : 300 kg - Design temperature : 80°C
TEU 506			
Evaporator	EV	1	- Material : 316 L - Design pressure : 8.45 bar eff. - Design temperature : 110°C - Dimensions : Ø = 1700 mm H = 950 mm - Weight : 2.6 t - 3 trays
Evaporator Heat exchanger	HT	1	- Shell and tube type heat exchanger - P = 2.81×10^3 kW - Weight : 4.1 t - Exch. surface : 103 m2 - Steam : 4.7 t/h - 139°C - 4.5 bar eff. - 316 L (tubes) - Concentrate : 600 t/h - 104°C - 109°C - 8.5 bar eff. - 304 L
Condenser	CS	1	- P = 2.43×10^3 kW - Weight : 1.55 t - Exch. surface : 40 m2 - Distillate : 3.5 t/h - 98°C - 8.5 bar eff. - 304 L - RRI (chilling water) : 125 t/h - 35°C - 55°C 8.5 bar eff. -A414 grE

EQUIPMENT	REF.	NUMBER	CHARACTERISTICS
TEU 506			
Distillate chiller	RF	1	- P = 2.43 x 10^3 kW - Exch. surface : 5 m2 - Distillate : 3.5 t/h - 98°C - 50°C - 15.7 bar eff. - 304 L - RRI (chilling water) : 14 t/h - 35°C - 47°C 8.7 bar eff. -A414 grE
TEP 502			
Demineralizer	DE	4	- 4 demineralizer broken down as follows : 2 x 1.5 m3 cation IERs 2 x 1.5 m3 mixed bed (66%C - 33%A) - 27 m3/hr water - Design pressure : 13.6 bar eff. - Design temperature : 60°C - Tank : 2.2 m3 H : 2.5 m - Ø : 1 m - Weight when empty : 0.95 t - Material : 304 L
Filters	FI	1	- 5 µm - Efficiency : 98% - Flowrate : 27 m3/h - Design pressure : 15 bar eff. - Design temperature : 80°C - Material : 304 L - Tank : V = 157 l H = 1.3 m Ø = 0.4 m - Weight when empty : 300 kg
	FI	1	- 25 µm - Efficiency : 98% - Flowrate : 27 m3/h - Design pressure : 13.5 bar eff. - Design temperature : 80°C - Material : 304 L - Tank : V = 46 l H = 0.85 m Ø = 0.27 m - Weight when empty : 132 kg
TEP 503			
Gas stripper	ZE	2	- 25 m3/h - H = 7.77 m - L = 2.23 m - Width = 1.7 m - Material : 304 L - Weight when empty : 3.2 t

EQUIPMENT	REF.	NUMBER	CHARACTERISTICS
TEP 503			
Gas stripper heating	HT	2	- P = 1.22 x 10^3 kW - Exch. surface : 34.5 m2 - Weight : 900 kg - Primary effluents : 27 m3/hr 113.3°C - 113°C 4.5 bar eff. - 304 L (tubes) - Steam : 1.97 t/h 136°C 9 bar eff. A414 grE - Sizing : 0.95 m x 0.65 m x 2.14 m
Condenser	CS	2	- P = 55.3 kW - Exch. surface = 4.5 m2 - Weight when empty : 330 kg - Hot fluid : 80 kg/h - 111°C - 50°C 4.5 bar eff. - 304 L - RRI : 5 t/h - 35°C - 44.5°C 8.1 bar eff. - A414 grE
Regenerative heat exchanger	EX	2	- P = 1,128 kW - Exch. surface = 24.6 m2 - Weight when empty : 770 kg - Hot fluid : 27 m3 - 113°C - 75.6°C 11 bar eff. - 304 L - Cold fluid : 27 m3/h - 50°C - 88°C 8.5 bar eff. - 304 L
Effluent chiller	RF	2	- P = 810 kW - Exch. surface = 25.8 m2 - Weight when empty : 1020 kg - Hot fluid : 27 m3 - 75.6°C 11 bar eff. - 304 L - RRI : 34 m3/h - 35°C 8.8 bar eff. - A414 grE
Evaporator	EV	2	- Flowrate : 3.85 t/h - Counter flow : 0.35 t/h - H = 3.692 m - Width = 2.039 m - L = 3.692 m - Material : 304 L - Weight : 2.554 t - 3 trays
Evaporator heating	HT	2	- P = 2.62 x 10^3 kW - Exch. surface = 61 m2 - Concentrate : 115 m3/h - 101°C - 106°C 8.5 bar eff. - 304 L - SVA : 4.4 t/h - 138.9°C 4.5 bar eff. - 304 L

EQUIPMENT	REF.	NUMBER	CHARACTERISTICS
TEU 503			
Regenerative heat exchanger	EX	2	- P = 96.5 kW - Exch. surface : 3.5 m2 - Weight when empty : 281 kg - Hot fluid : 3.5 t/h - 98.5°C 15.7 bar eff. - 304 L - Cold fluid : 3.5 t/h - 50°C - 73.7°C 8.7 bar eff. - 304 L
Distillate condenser	CS	2	- P = 2.43 x 10^3 kW - Exch. surface = 40.2 m2 - Weight when empty : 1.6 t - Hot fluid : 3.85 t/h - 98.5°C 8.5 bar eff. - 304 L - RRI : 125 t/h - 35°C - 51.8°C 8.5 bar eff. - A414 grE
Distillate chiller	RF	2	- P = 101.8 KW - Exch. surface = 3.37 m2 - Weight when empty : 478 kg - Distillate : 3.5 t/h - 75°C - 50°C 15.7 bar eff. - 304 L - RRI : 14 t/h - 35°C - 41.25°C 8.7 bar eff. - A414 grE
Concentrate chiller	RF	2	- P = 98.8 kW - Exch. surface = 2.12 m2 - Weight when empty : 355 kg - Concentrate : 2.1 t/h - 102.6°C - 60°C 8.7 bar eff. - 304 L - RRI : 9 t/h - 35°C - 44.5°C 8.7 bar eff. - A414 grE
TEP 504			
Filter	FI	1	- 5 µm - Efficiency : 98% - Flowrate : 10 m3/h - Material : 304 L - Design pressure : 13.5 bar eff. - Design temperature : 80°C - Tank : Volume = 46 l H = 0.85 m Ø = 0.27 m - Weight : 132 kg

EQUIPMENT	NUMBER	CHARACTERISTICS
TES : Concentrates drumming station		
Drumming station conveyor	1	Capacity : 1 concrete drum Maximum load : 6000 daN Type : Wall mounted Hoist motor power : 1.85 kW Travel motor power : 0.8 kW Travel speed : 3 m/min Hoist speed : 1 m/min
Air lock trolley	1	Capacity : 1 concrete container Maximum load : 6000 daN Type : Rail mounted Gear motor power : 0.9 kW Travel speed : 3 m/min
Disposable blade mixer	1	Plunger motor power : 1.5 kW Max. rotation motor power : 15 kW Rotation speeds : 24 rpm - 36 rpm Capacity : 420 l Equipped with : - disposable mixing blade, - TV camera, - dust extraction system
Dry mix screw	1	1.5 kW 1.2 m3/h
TES : Mix batching plant + final sealing station		
Buffer storage	4	Type of storage : hoppers Hopper capacity - gravel : 4 m3 - sand : 4 m3 - lime : 2 m3 - cement : 4 m3
Mix batching storage	7* + 7	Type of storage : mobile standard containers Container capacity : 3 m3 Storage capacity - gravel : 6 m3 - sand : 6 m3 - lime : 3 m3 - cement : 6 m3 * 7 in upper part of concrete batching plant + 7 in ground storage area

EQUIPMENT	NUMBER	CHARACTERISTICS
Mixer	1	Capacity : 420 litres Motor power : 11 kW Production capacity : 250 litres per concrete batch
Feed screws	3	Flowrate : 15 m3/h L : 5 m ø : 150 mm
Conveyor belt between batching plant and final sealing station	1	Width : 650 mm Length : 5 m Capacity : 80 t/h
Skips	2	Dry mix : capacity 1600 l Concrete : capacity 800 l
Weighing devices	2	Concrete (associated with mixer) : 1,000 kg dry mix (gauging hopper) : 500 kg
Final sealing area trolley	1	Capacity : 1 concrete container Maximum load : 6000 daN Type : Rail mounted Motor power : 0.9 kW Travel speed : 3 m/min
TES : Miscellaneous waste		
Compactor	1	Capacity : 25 t Motor power : 15 kW
TES : Filter		
Filter transfer lead cask	1	Weight : 7 t Thickness of lead : 10 cm Gripper motor power : 0.2 kW
Vibration table	1	Number of vibrators : 2 Unit power : 4.4 kW
TES : Handling devices		
Cranes	3	Mix batching plant overhead crane : 6,300 daN Travelling crane : 8,000 daN Loading-unloading travelling crane : 5,000 daN
Concrete drum automatic gripper	1	Capacity : 6,000 daN

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(Volume 2)
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This study is part of an overall theoretical exercise aimed at evaluating a selection of management routes for LWR waste based on economical and radiological criteria.

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