DRAWINGS

FIG 1

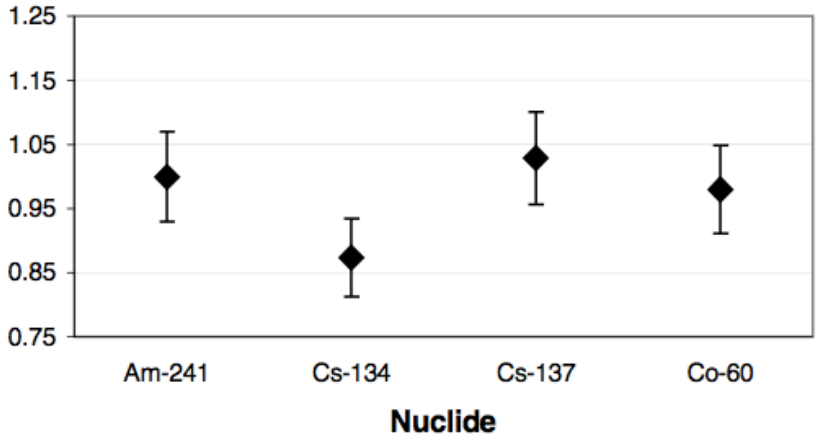


FIG 2

PRIMARY COOLANT SYSTEM

Type	Internal recirculation pump system
Operating pressure	73.1 kg/cm^2
Feedwater inlet temperature	215.5 Degrees Celcius
Steam outlet temperature	287.4 C
Number of recirculation pumps	10
Recirculation mass flow (100% rated)	52,200 t/hr

REACTOR PRESSURE VESSEL

Internal height	21 m
Internal diameter	7.1 m
Wall thickness minimum	174 mm
Materials	Low alloy steel/stainless steel cladding

FIG 3

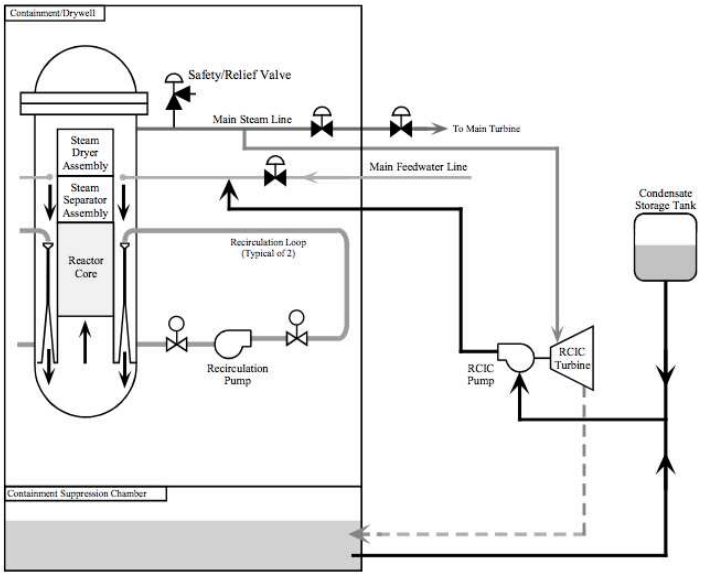

Containment/Drywell
Safety/Relief Valve
Main Steam Line
To Main Turbine
Steam Dryer Assembly
Steam Separator Assembly
Main Feedwater Line
Condensate Storage Tank
Reactor Core
Recirculation Loop (Typical of 2)
Recirculation Pump
RCIC Pump
RCIC Turbine
Containment Suppression Chamber

FIG 4

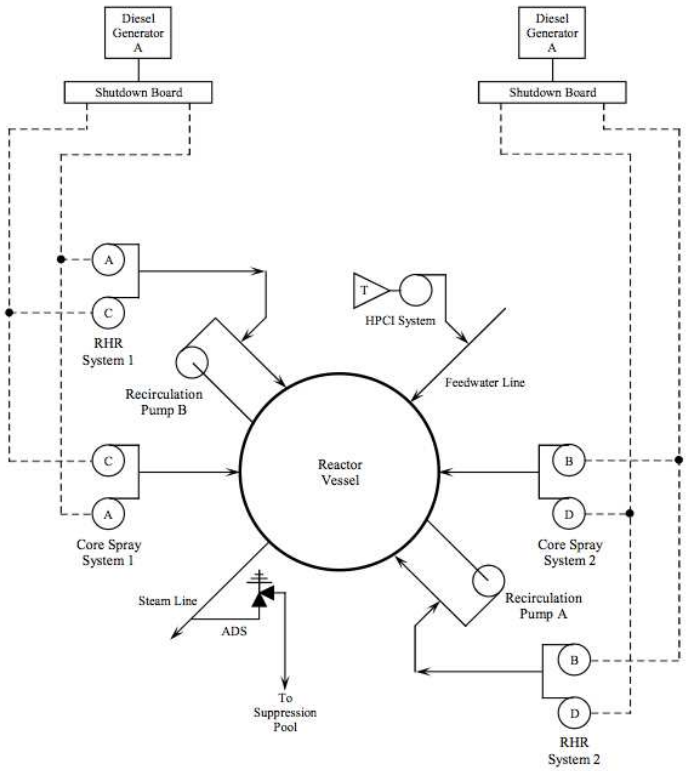

Diesel Generator A
Shutdown Board
Diesel Generator A
Shutdown Board
A
C
RHR System 1
T
HPCI System
Recirculation Pump B
Feedwater Line
C
A
Core Spray System 1
Reactor Vessel
B
D
Core Spray System 2
Steam Line
ADS
Recirculation Pump A
To Suppression Pool
B
D
RHR System 2

FIG 5

Radioactive Cesium				
Mammalian cells:				
Human peripheral blood lymphocytes	Micronuclei	No data	+	Balasem and Ali 1991
Human peripheral blood lymphocytes	Chromosomal aberrations	No data	+	Doggett and McKenzie 1983
Human peripheral blood lymphocytes	Chromosomal aberrations	No data	+	Hintenlang 1993
Human peripheral blood lymphocytes	Chromosomal aberrations	No data	+	Iijima and Morimoto 1991
Human peripheral blood lymphocytes	Sister chromatid exchange	No data	–	Iijima and Morimoto 1991
Human spermatozoa	Chromosomal aberrations	No data	+	Mikamo et al. 1990, 1991
Human spermatozoa and zona-free hamster oocytes fertilization system	Micronuclei	No data	+	Kamiguchi et al. 1991
Mouse (BALB/c, SC3T3/W, Scid/St cells)	DNA double-strand breaks	No data	+	Biedermann et al. 1991
Chinese hamster ovary cells	Chromosomal aberrations, sister chromatid exchange	No data	+	Arslan et al. 1986

FIG 6

Table 1
Naturally Occurring Radionuclides in Seawater

Radionuclide	*Activity Concentration, mBq/l*
Tritium	0.6 (1)
Carbon-14	4.3 (1)
Potassium-40	11 000 (2)
Lead-210	5.0 (1)
Polonium-210	3.7 (1)
Bismuth-214	0.7 (1)
Radon-222	0.7 (1)
Uranium-234	47 (3)
Uranium-238	41 (3)
Radium-226	3.6 (1)

FIG 7

Radionuclide Symbols, Principal Emissions and Half-lives[1]

Radionuclide	*Symbol*	*Principal Emission[2]*	*Half-life*
Tritium	H-3	β	12.35 years
Carbon-14	C-14	β	5730 years
Potassium-40	K-40	β	1.28×10^9 years
Cobalt-60	Co-60	β	5.27 years
Strontium-90	Sr-90	β	29.12 years
Niobium-95	Nb-95	β	35.15 days
Zirconium-95	Zr-95	β	63.98 days
Technetium-99	Tc-99	β	213 000 years
Ruthenium-106	Ru-106	β	368.2 days
Iodine-131	I-131	β	8.04 days
Caesium-134	Cs-134	β	2.06 years
Caesium-137	Cs-137	β	30 years
Cerium-144	Ce-144	β	284.3 days
Polonium-210	Po-210	α	138.38 days
Plutonium-238	Pu-238	α	87.74 years
Plutonium-239	Pu-239	α	24 065 years
Plutonium-240	Pu-240	α	6537 years
Plutonium-241	Pu-241	β	14.4 years
Americium-241	Am-241	α	432.2 years

FIG 8

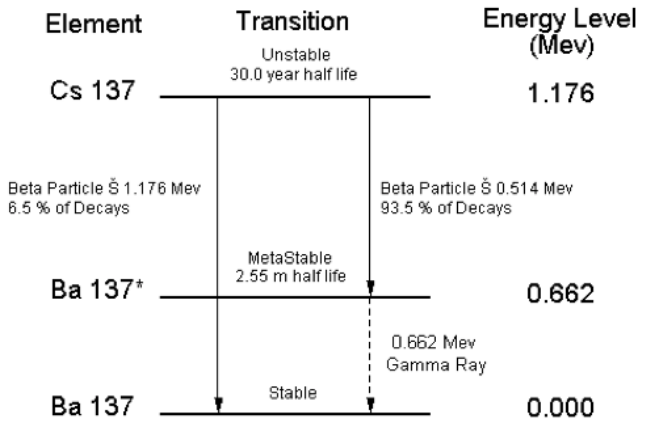


FIG 9

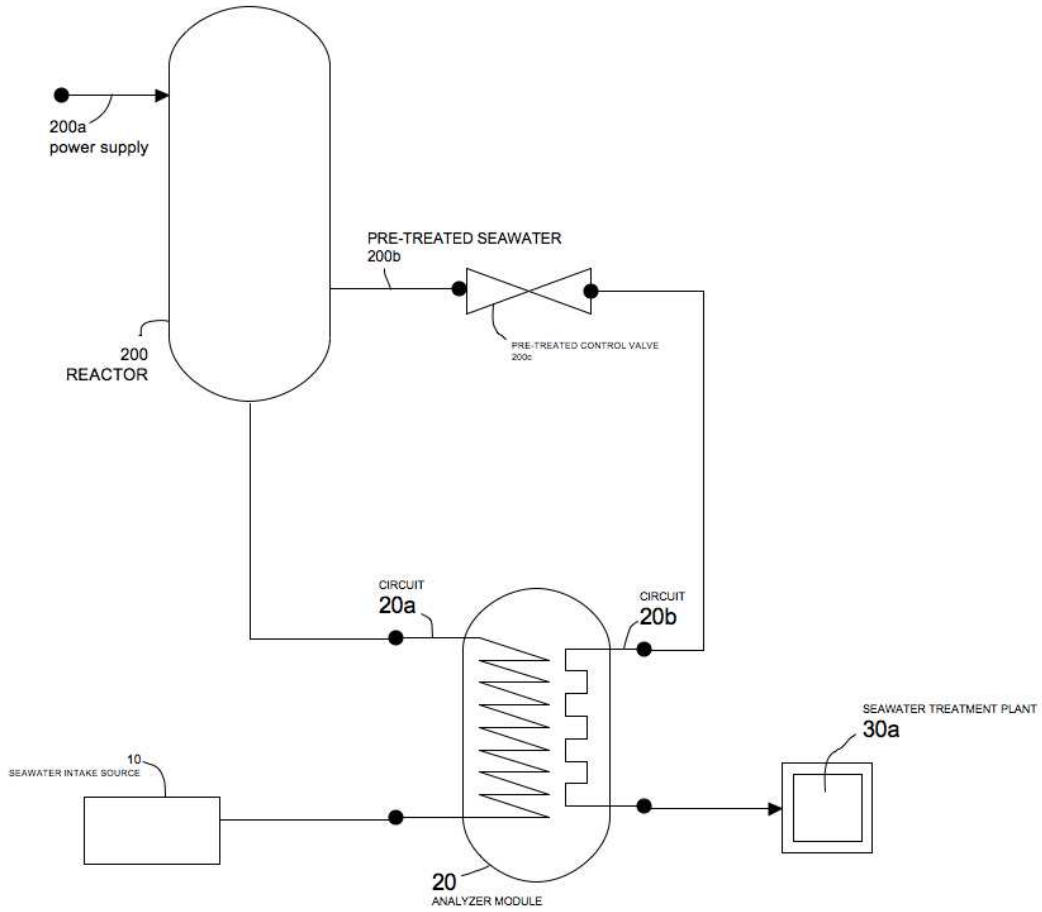

200a
power supply
PRE-TREATED SEAWATER
200b
PRE-TREATED CONTROL VALVE
200c
200
REACTOR
CIRCUIT
20a
CIRCUIT
20b
SEAWATER TREATMENT PLANT
30a
10
SEAWATER INTAKE SOURCE
20
ANALYZER MODULE

FIG 10

Major radiation accidents (1945–97) and early fatalities in nuclear and non-nuclear industries

Year	Place	Source	Dose (or activity intake)	No. of persons with significant exposure[a]	No. of deaths
1945–46	Los Alamos, USA	Criticality	≤ 13 Gy	10	2
1958	Vinča, Yugoslavia	Experimental reactor	2.1–4.4 Gy	8	1
1958	Los Alamos, USA	Criticality	0.35–45 Gy	3	1
1960	USSR	^{137}Cs (suicide)	~15 Gy	1	1
1960	USSR	Radium bromide (ingestion)	74 mBq	1	1 (after 4 years)
1961	USSR	Submarine accident	10–50 Gy	> 30	8
1961	Switzerland	^{3}H	3 Gy	3	1
1961	Idaho Falls, USA	Explosion in reactor	≤ 3.5 Gy	7	3
1962	Mexico City, Mexico	^{60}Co capsule	9.9–52 Sv	5	4
1963	China	^{60}Co	0.2–80 Gy	6	2
1964	Federal Republic of Germany	^{3}H	10 Gy	4	1
1964	Rhode Island, USA	Criticality	0.3–46 Gy	4	1
1966	Pennsylvania, USA	^{198}Au	Unknown	1	1
1967	USSR	X-radiation medical diagnostic facility	50 Gy	1	1 (after 7 years)
1968	Wisconsin, USA	^{198}Au	Unknown	1	1
1968	Chicago, USA	^{198}Au	4–5 Gy (bone marrow)	1	1
1972	Bulgaria	^{137}Cs (suicide)	> 200 Gy (local, chest)	1	1
1975	Brescia, Italy	^{60}Co	10 Gy	1	1
1978	Algeria	^{192}Ir	≤ 13 Gy	7	1
1982	Norway	^{60}Co	22 Gy	1	1
1983	Constitu, Argentina	Criticality	43 Gy	1	1
1984	Morocco	^{192}Ir	Unknown	11	8
1985	China	^{198}Au (mistake in treatment)	Unknown, internal	2	1
1985–86	USA	Accelerator	Unknown	3	2
1986	Chernobyl, USSR	Nuclear power plant	1–16 Gy	134	28
1987	Goiânia, Brazil	^{137}Cs	≤ 7 Gy	50[b]	4
1989	El Salvador	^{60}Co irradiation facility	3–8 Gy	3	1
1990	Israel	^{60}Co irradiation facility	> 12 Gy	1	1
1990	Spain	Radiotherapy accelerator	Unknown	27	≤ 11
1991	Nesvizh, Belarus	^{60}Co irradiation facility	10 Gy	1	1
1992	China	^{60}Co	> 0.25–10 Gy	8	3
1992	USA	^{192}Ir brachytherapy	> 1000 Gy (local)	1	1
1994	Tammiku, Estonia	^{137}Cs	1830 Gy (thigh) + 4 Gy (whole body)	3	1
1996	Costa Rica	Radiotherapy	Unknown	110	≤ 40
1997	Kremlev, Sarov, Russian Federation	Criticality experiment	5–10 Gy	1	1

FIG 11

Incidences of tumours in B6WF$_1$ (C57BL/6 × WHT/Ht) mice after prenatal exposure to X-radiation

Treated stage (dpc)	Sex	Dose (Gy)	No. of mice	Incidence (%)					Reference
				Total incidence	Lung tumour	Liver tumour	Ovarian tumour	Pituitary tumour	
12	Male	2	44	11**	5*	0	–	0	Sasaki *et al.* (1978a)
	Female		53	15**	4	0	0	0	
16–18	Male	2	126	73**	56**	17	–	1	
	Female		140	77	39**	10	14*	9*	
Control	Male	0	55	46	24	7	–	0	
	Female		77	65	17	7	1	1	
17	Male	3	22	–	–	46**	–	–	Sasaki *et al.* (1978b)
	Female		53	–	–	13*	–	–	
17	Male	1.5	39	–	–	28**	–	–	
	Female		53	–	–	8	–	–	
Control	Male		84	–	–	7	–	–	
	Female		129	–	–	1	–	–	

dpc, days *post coitum*. Significantly different from controls at *$p < 0.05$ and **$p < 0.01$

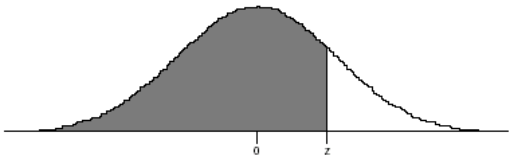
FIG 12

Induction of tumours in PTHTF$_1$ mice after irradiation *in utero* and postnatal treatment with TPA

Dose (Gy)	TPA	Tumour-bearing mice		Skin tumour[a]		Hepatoma in males		
		Incidence	%	Incidence	%	Incidence	%	Tumours per liver
1.03	+	14/47	29.8**	5/47	10.6*	8/23	34.8*	0.57
	–	3/49	6.1	0/49	0.0	1/25	4.0	0.04
0.3	+	6/38	15.8	1/38	2.6	4/20	20.0	0.20
	–	2/51	3.9	0/51	0.0	1/26	3.8	0.04
0	+	4/54	7.4	0/54	0.0	1/29	3.4	0.03
	–	3/50	6.0	0/50	0.0	1/22	4.5	0.05

From Nomura *et al.* (1990). TPA, 12-*O*-tetradecanoylphorbol 13-acetate
[a] Four squamous-cell carcinomas and two pigmented basal-cell carcinomas
*$p < 0.05$, **$p < 0.01$ when compared with untreated controls

FIG 13



Normal Deviate z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-4.0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
-3.9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
-3.8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
-3.7	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
-3.6	.0002	.0002	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
-3.5	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
-3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
-3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
-3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
-3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
-3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
-2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
-2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
-2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
-2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
-2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
-2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
-2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
-2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
-2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
-2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
-1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
-1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
-1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
-1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
-1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
-1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
-1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
-1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
-1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
-1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
-.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
-.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
-.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
-.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
-.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
-.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
-.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483

FIG 14

$$z = \frac{deviation\ from\ mean}{std.\ deviation} = \frac{x - \mu}{\sigma}$$

FIG 15

$$\mathbf{Z}_i = \lambda_1 + \lambda_2 f_i + \lambda_3 f_i^2 + \lambda_4 f_i^3 + \boldsymbol{\epsilon}_i$$

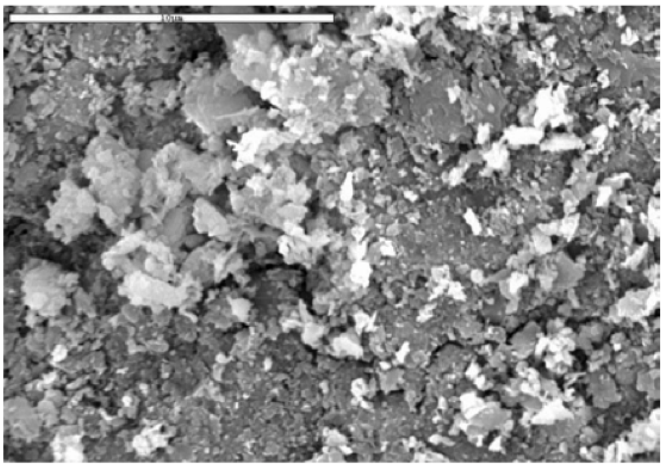
1000

$$\begin{pmatrix} Z_{1i} \\ Z_{2i} \\ Z_{3i} \\ Z_{4i} \\ Z_{5i} \\ Z_{2i}Z_{4i} \\ Z_{2i}Z_{5i} \\ Z_{3i}Z_{4i} \\ Z_{3i}Z_{5i} \end{pmatrix} = \begin{pmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \lambda_{42} & 0 \\ 0 & 1 & 0 \\ 0 & 0 & \lambda_{21}\lambda_{42} \\ 0 & 0 & \lambda_{21} \\ 0 & 0 & \lambda_{42} \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} f_{1i} \\ f_{2i} \\ f_{1i}f_{2i} \end{pmatrix} + \begin{pmatrix} \epsilon_{1i} \\ \epsilon_{2i} \\ \epsilon_{3i} \\ \epsilon_{4i} \\ \epsilon_{5i} \\ u_{1i} \\ u_{2i} \\ u_{3i} \\ u_{4i} \end{pmatrix}$$

2000

$$\begin{aligned} u_{1i} &= \lambda_{21} f_{1i}\epsilon_{4i} + \lambda_{42} f_{2i}\epsilon_{2i} + \epsilon_{2i}\epsilon_{4i} \\ u_{2i} &= \lambda_{21} f_{1i}\epsilon_{5i} + f_{2i}\epsilon_{2i} + \epsilon_{2i}\epsilon_{5i} \\ u_{3i} &= f_{1i}\epsilon_{4i} + \lambda_{42} f_{2i}\epsilon_{3i} + \epsilon_{3i}\epsilon_{4i} \\ u_{4i} &= f_{1i}\epsilon_{5i} + f_{2i}\epsilon_{3i} + \epsilon_{3i}\epsilon_{5i} \end{aligned}$$

FIG 16



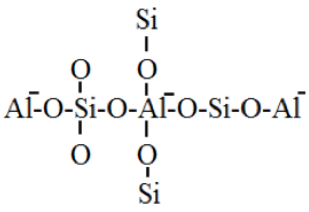


FIG 17

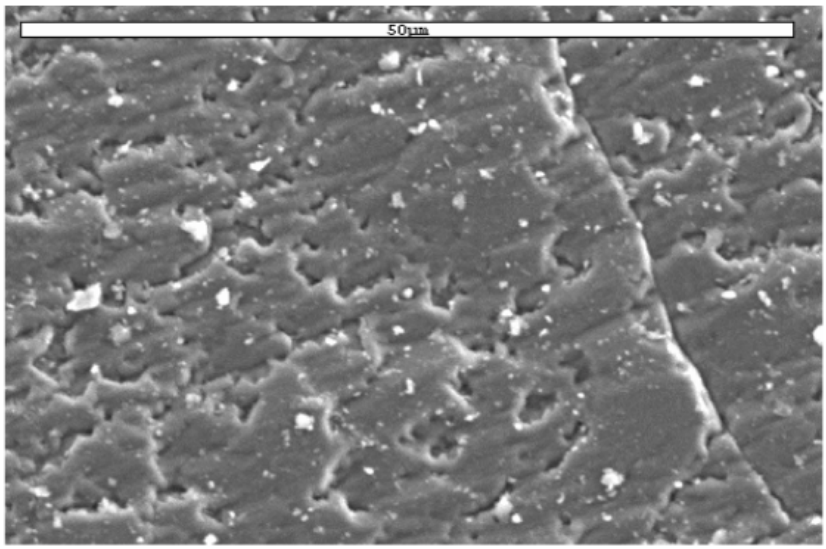


FIG 18

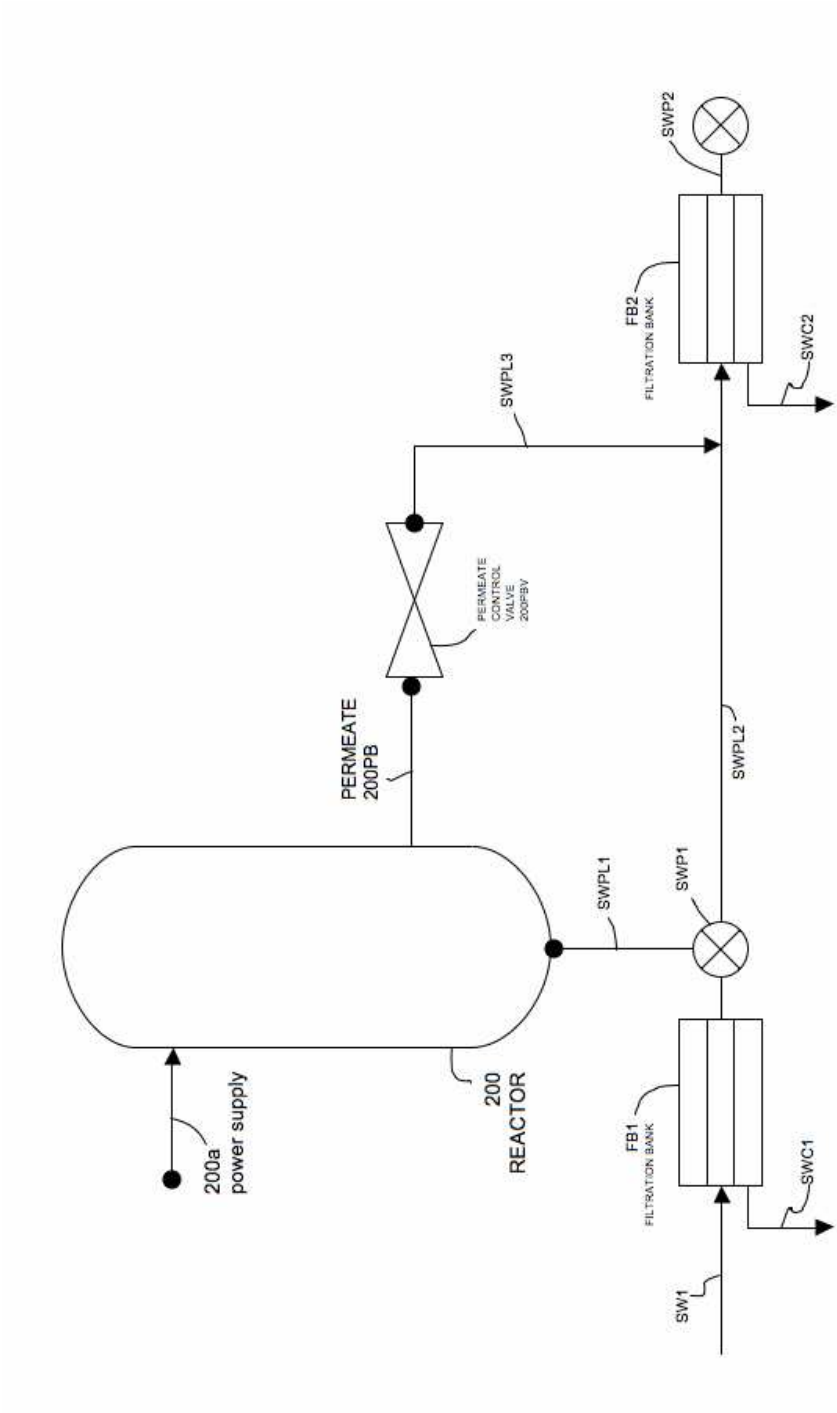

SWP2
FB2
FILTRATION BANK
SWC2
SWPL3
PERMEATE CONTROL VALVE 200PBV
PERMEATE 200PB
SWPL2
SWPL1
SWP1
200 REACTOR
200a power supply
FB1
FILTRATION BANK
SWC1
SW1

FIG 19

