

DRAWINGS

FIG 1

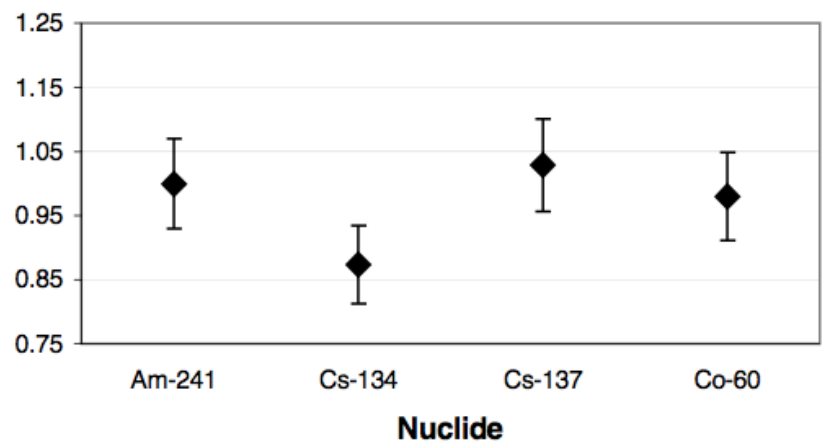


FIG 2

**PRIMARY COOLANT SYSTEM**

|                                      |                                    |
|--------------------------------------|------------------------------------|
| Type                                 | Internal recirculation pump system |
| Operating pressure                   | 73.1 kg/cm <sup>2</sup>            |
| 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

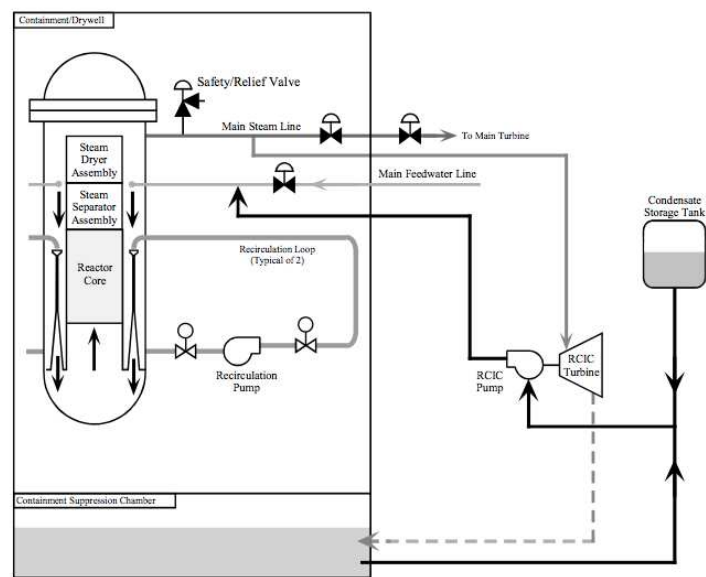


FIG 4

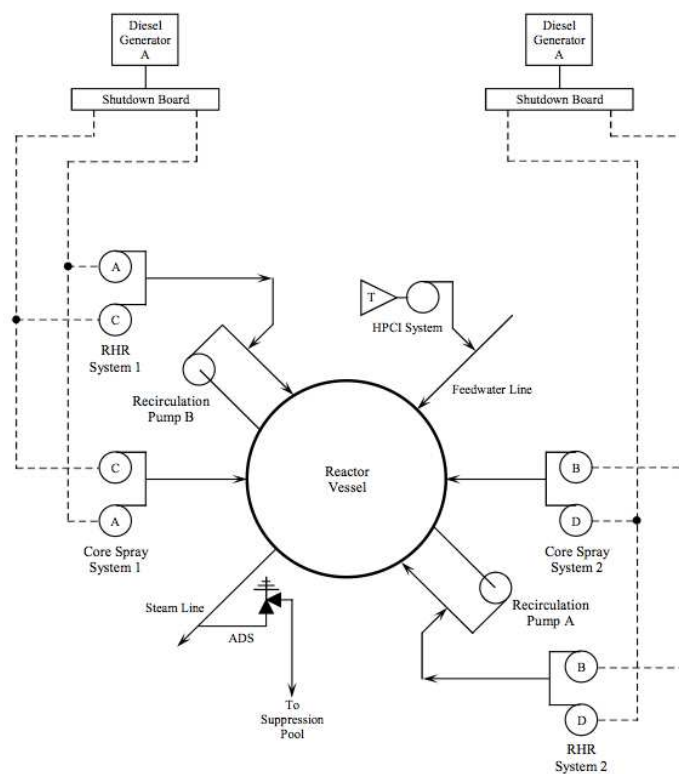


FIG 5

**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**

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

FIG 7

**Radionuclide Symbols, Principal Emissions and Half-lives<sup>(1)</sup>**

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

FIG 8

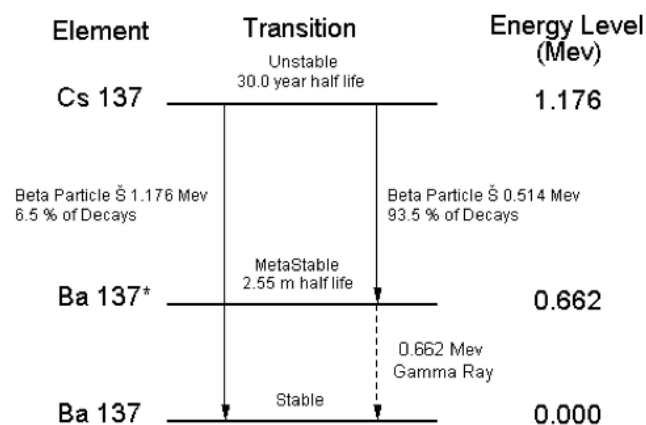


FIG 9

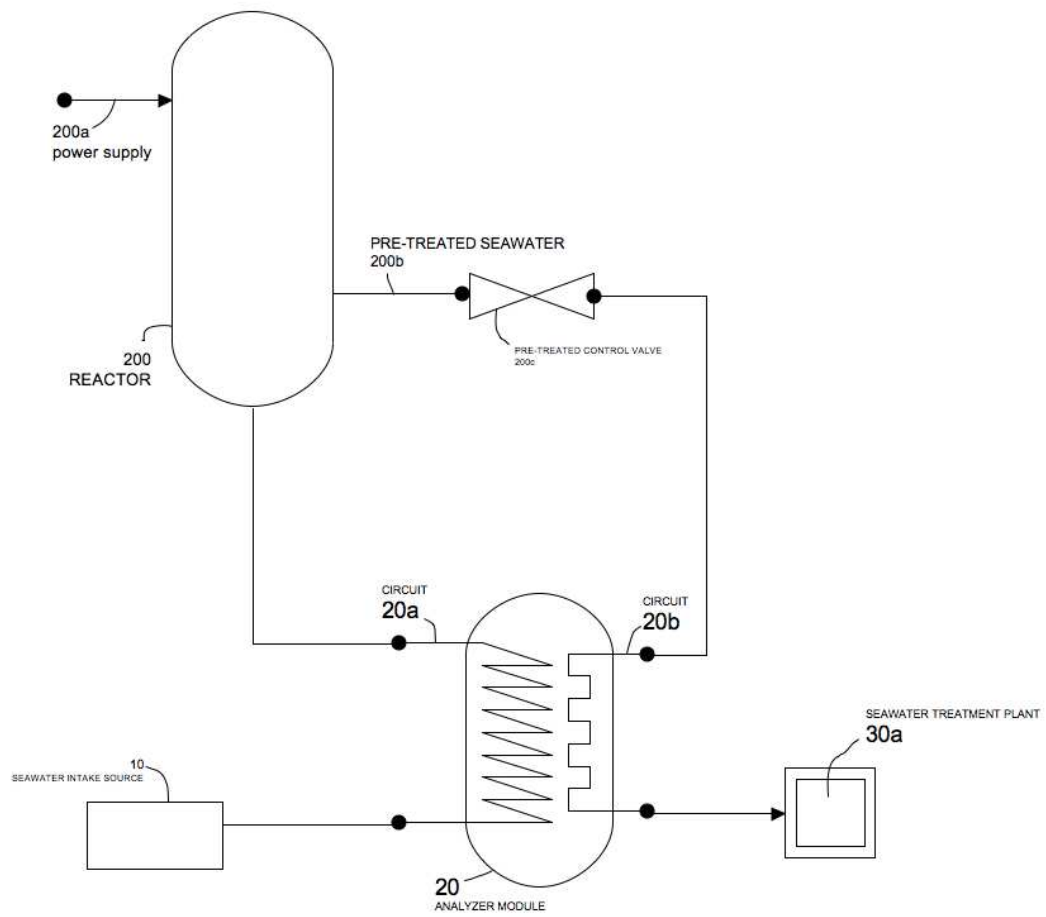


FIG 10

**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 <sup>a</sup> | 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                               | <sup>137</sup> 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                        | <sup>3</sup> H                           | 3 Gy                                | 3                                                     | 1                 |
| 1961    | Idaho Falls, USA                   | Explosion in reactor                     | ≤ 3.5 Gy                            | 7                                                     | 3                 |
| 1962    | Mexico City, Mexico                | <sup>60</sup> Co capsule                 | 9.9–52 Sv                           | 5                                                     | 4                 |
| 1963    | China                              | <sup>60</sup> Co                         | 0.2–80 Gy                           | 6                                                     | 2                 |
| 1964    | Federal Republic of Germany        | <sup>3</sup> H                           | 10 Gy                               | 4                                                     | 1                 |
| 1964    | Rhode Island, USA                  | Criticality                              | 0.3–46 Gy                           | 4                                                     | 1                 |
| 1966    | Pennsylvania, USA                  | <sup>198</sup> Au                        | Unknown                             | 1                                                     | 1                 |
| 1967    | USSR                               | X-radiation medical diagnostic facility  | 50 Gy                               | 1                                                     | 1 (after 7 years) |
| 1968    | Wisconsin, USA                     | <sup>198</sup> Au                        | Unknown                             | 1                                                     | 1                 |
| 1968    | Chicago, USA                       | <sup>198</sup> Au                        | 4–5 Gy (bone marrow)                | 1                                                     | 1                 |
| 1972    | Bulgaria                           | <sup>137</sup> Cs (suicide)              | > 200 Gy (local, chest)             | 1                                                     | 1                 |
| 1975    | Brescia, Italy                     | <sup>60</sup> Co                         | 10 Gy                               | 1                                                     | 1                 |
| 1978    | Algeria                            | <sup>192</sup> Ir                        | ≤ 13 Gy                             | 7                                                     | 1                 |
| 1982    | Norway                             | <sup>60</sup> Co                         | 22 Gy                               | 1                                                     | 1                 |
| 1983    | Constita, Argentina                | Criticality                              | 43 Gy                               | 1                                                     | 1                 |
| 1984    | Morocco                            | <sup>192</sup> Ir                        | Unknown                             | 11                                                    | 8                 |
| 1985    | China                              | <sup>198</sup> 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    | Goiania, Brazil                    | <sup>137</sup> Cs                        | ≤ 7 Gy                              | 50 <sup>b</sup>                                       | 4                 |
| 1989    | El Salvador                        | <sup>60</sup> Co irradiation facility    | 3–8 Gy                              | 3                                                     | 1                 |
| 1990    | Israel                             | <sup>60</sup> Co irradiation facility    | > 12 Gy                             | 1                                                     | 1                 |
| 1990    | Spain                              | Radiotherapy accelerator                 | Unknown                             | 27                                                    | ≤ 11              |
| 1991    | Nesvizh, Belarus                   | <sup>60</sup> Co irradiation facility    | 10 Gy                               | 1                                                     | 1                 |
| 1992    | China                              | <sup>60</sup> Co                         | > 0.25–10 Gy                        | 8                                                     | 3                 |
| 1992    | USA                                | <sup>192</sup> Ir brachytherapy          | > 1000 Gy (local)                   | 1                                                     | 1                 |
| 1994    | Tammiku, Estonia                   | <sup>137</sup> 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<sub>1</sub> (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 <i>et al.</i> (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                | Sasaki <i>et al.</i> (1978b) |
|                     | Female |           | 77          | 65              | 17          | 7            | 1              | 1                |                              |
| 17                  | Male   | 3         | 22          | —               | —           | 46**         | —              | —                |                              |
|                     | 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<sub>1</sub> mice after irradiation *in utero* and postnatal treatment with TPA**

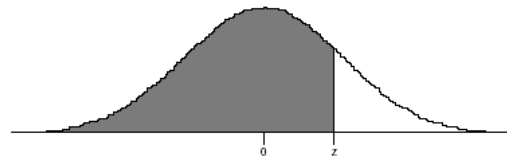
| Dose (Gy) | TPA | Tumour-bearing mice |        | Skin tumour <sup>a</sup> |       | Hepatoma in males |       |                   |
|-----------|-----|---------------------|--------|--------------------------|-------|-------------------|-------|-------------------|
|           |     | Incidence           | %      | 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

<sup>a</sup> 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<br>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

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

FIG 15

$$\begin{aligned}
 & \boxed{Z_i = \lambda_1 + \lambda_2 f_i + \lambda_3 f_i^2 + \lambda_4 f_i^3 + \epsilon_i} \quad 1000 \\
 & \left( \begin{array}{c} Z_{1i} \\ Z_{2i} \\ Z_{3i} \\ Z_{4i} \\ Z_{5i} \\ Z_{2i}Z_{4i} \\ Z_{2i}Z_{5i} \\ Z_{3i}Z_{4i} \\ Z_{3i}Z_{5i} \end{array} \right) = \left( \begin{array}{ccc} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \lambda_{42} & 0 \\ 0 & 1 & 0 \\ 0 & 0 & \lambda_{21}\lambda_{42} \\ 0 & 0 & \lambda_{21} \\ 0 & 0 & \lambda_{42} \\ 0 & 0 & 1 \end{array} \right) \left( \begin{array}{c} f_{1i} \\ f_{2i} \\ f_{1i}f_{2i} \end{array} \right) + \left( \begin{array}{c} \epsilon_{1i} \\ \epsilon_{2i} \\ \epsilon_{3i} \\ \epsilon_{4i} \\ \epsilon_{5i} \\ u_{1i} \\ u_{2i} \\ u_{3i} \\ u_{4i} \end{array} \right) \quad 2000 \\
 & \begin{aligned} u_{1i} &= \lambda_{21}f_{1i}\epsilon_{4i} + \lambda_{42}f_{2i}\epsilon_{2i} + \epsilon_{2i}\epsilon_{4i} \\ u_{2i} &= \lambda_{21}f_{1i}\epsilon_{5i} + f_{2i}\epsilon_{2i} + \epsilon_{2i}\epsilon_{5i} \\ u_{3i} &= f_{1i}\epsilon_{4i} + \lambda_{42}f_{2i}\epsilon_{3i} + \epsilon_{3i}\epsilon_{4i} \\ u_{4i} &= f_{1i}\epsilon_{5i} + f_{2i}\epsilon_{3i} + \epsilon_{3i}\epsilon_{5i} \end{aligned}
 \end{aligned}$$

FIG 16

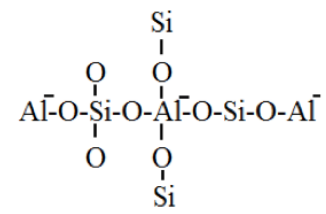
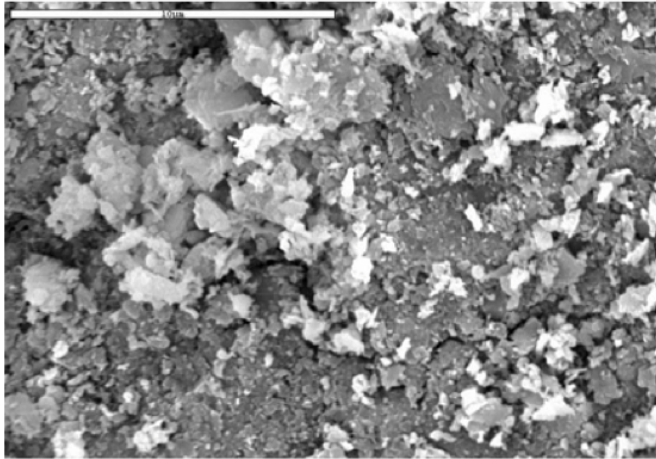


FIG 17

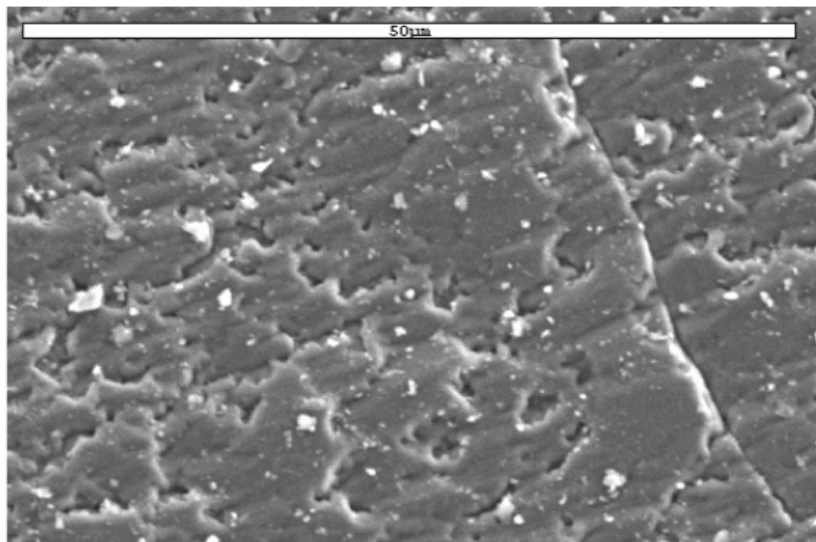


FIG 18

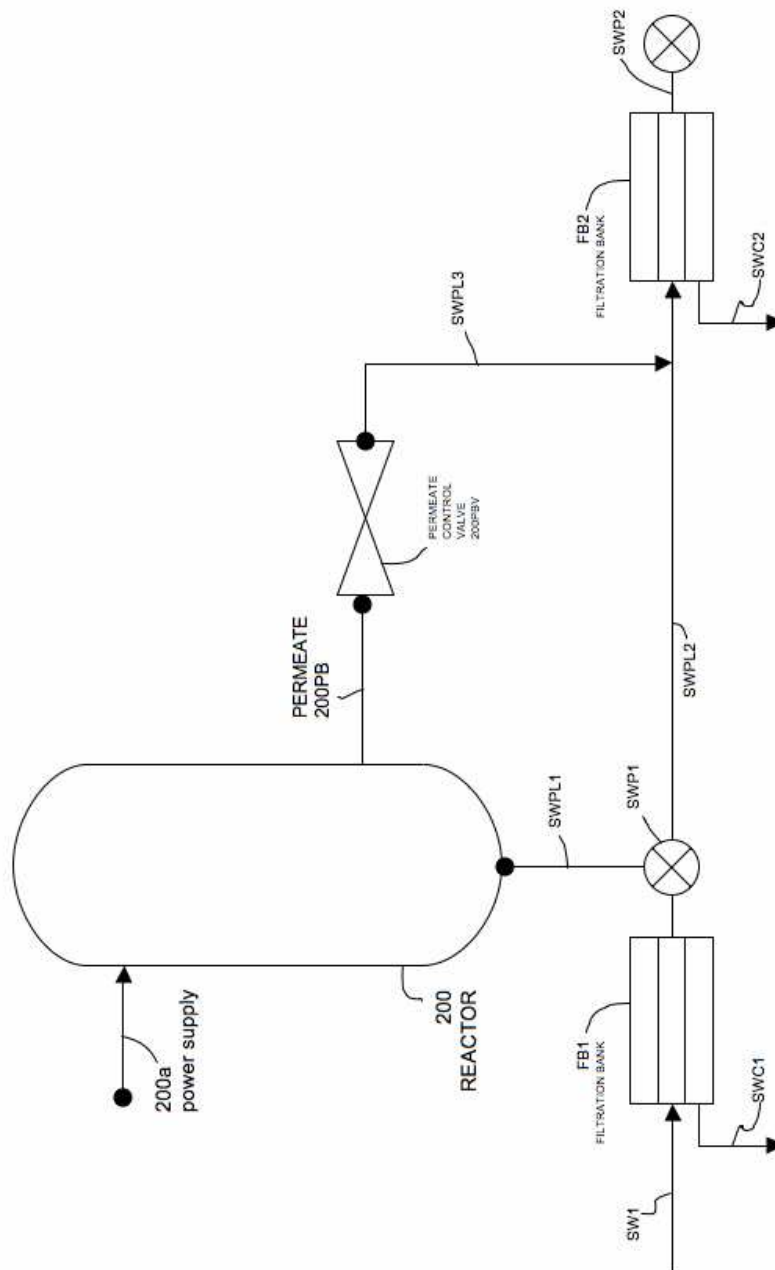


FIG 19

