Study on the Lower Support in "MONJU" Core Fuel Pins

August, 1972

SUMITOMO ELECTRIC IND., LTD.

〒319-1184　茨城県那珂郡東海村村松4番地49
核燃料サイクル開発機構
技術展開部 技術協力課

電話:029-282-1122(代表)
ファックス　:029-282-7980
電子メール:jserv@jnc.go.jp

—— CONTENTS ——

1. Results of the Test on Trial Construction of Large-sized Casting Type Grid (Lower Support) for Fuel Elements

The Process of the Trial Construction:

1-1 Castings Trial

The grid for the present test was constructed on the basis of experiences of 1971, when a casting type grid was made for the JOYO core fuel assembly. Although the size was large, good castings with smooth surface were produced.

1-2 Machining

The castings made in the manner above-mentioned were machined into a grid. Followings are descriptions about the machining process, the machines used and major problems that arose in the process.

Fig. 1 illustrates the machining process and lists the machines used therein, of which explanation is given in order.

i) Roll Grinding of the Upper and Lower Sides:
The roll grinding of the upper and lower sides was made by a vertical milling machine, and these sides were machined by 0.5mm each. This way the castings were cleaned of their peculiar surface swells and rid completely of casting surface. In this case, attention was paid to obtain right angularity between the casting boss and the upper and lower surfaces.

ii) Grinding of the Upper and Lower Sides:
Then a surface grinder was used to grind the upper and lower sides, thereby raising the accuracy of flatness and at the same time grinding the casting to a finishing thickness. There were no problems in this part of the process.

iii) Marking-Off:
After the machining of the upper and lower sides, marking-off was made for drilling.

Since the pitch of the casting boss is deviated from the one at the time of metal mold owing to strains by the cooling of the casting, care was exercised. Although this casting type grid is made in a symmetrical form, direction of strains differed according to castings.

Accordingly, the determination of pitch was made by the following method. First, the position of grid center was assumed, then the total assumption of the distance from this assumed center to the outermost peripheral hole was made, and the determination of a center in which the outermost peripheral hole would not deviate from the casting boss was made on a trial and error basis. The pitch of the grid was determined by following the pitch of every hole from this center. In regard to outermost peripheries, they were marked off by measuring from the grid center in the same method.

In this process, it must be borne in mind that if the casting boss fails to maintain a good right angularity with the upper and lower sides as warned against in connection with the roll grinding of these two sides in the first process, it would cause a great shift in the central position on the upper and lower sides, a thinning in the thickness of the boss, and in an extreme case, a thinning out or a break. Bad parallelism is sometimes observed between bosses, and these bosses, even though they are excellently at right angles to the upper and lower sides, are sometimes different in their thickness more or less.

iv) Roll Grinding of Six Sides:

In line with the marking-off made in the preceding process, outermost peripheries were machined by a universal milling machine. In this process, no R was taken, leaving 7R to be machined in a final finishing.

v) Drilling:

Drilling was done by a NC boring machine. The drilling process began with the drilling of an initial hole by a center drill.

followed by its machining by a drill, and ended with a finishing by a reamer. Prior to machining, investigation was made into effects of temperatures at the time of machining. Since there are many holes and temperatures of castings rise during machining, causing strains to occur, this prompts pitch to deviate due to cooling after machinework. It is for this reason that thermometry was made during drilling, by the use of a contact surface-thermometer. The temperature was taken right after the machining, which started with No. 1 in the first row, proceeded to hole No. 2 and then to No. 3 on the second row and so forth and finished at No. 9 in the seventh row. The results of the thermometry are given in Graph 1. The temperature rise was in a range of 34°C ~ 40°C.

Next, a check was made to see if pitches varied with the progress of the machining from the first row to the second and to a final row.

The method used in this checking involved a drilling of holes in No. 1 and No. 2 in the first row and then in No. 7 and No. 9 in the seventh row, measuring of pitches thereof, then the drilling of holes in the remaining No. 8 in the first row and up, and rechecking of pitches at each stage of the process to see if variations developed.

The results are plotted in Graph 2.

The above results revealed that deformations through machining thermal strain and internal stress-induced strains were unexpectedly so small that they pose no drilling problems. Consequently, casting work was made all on the same conditions.

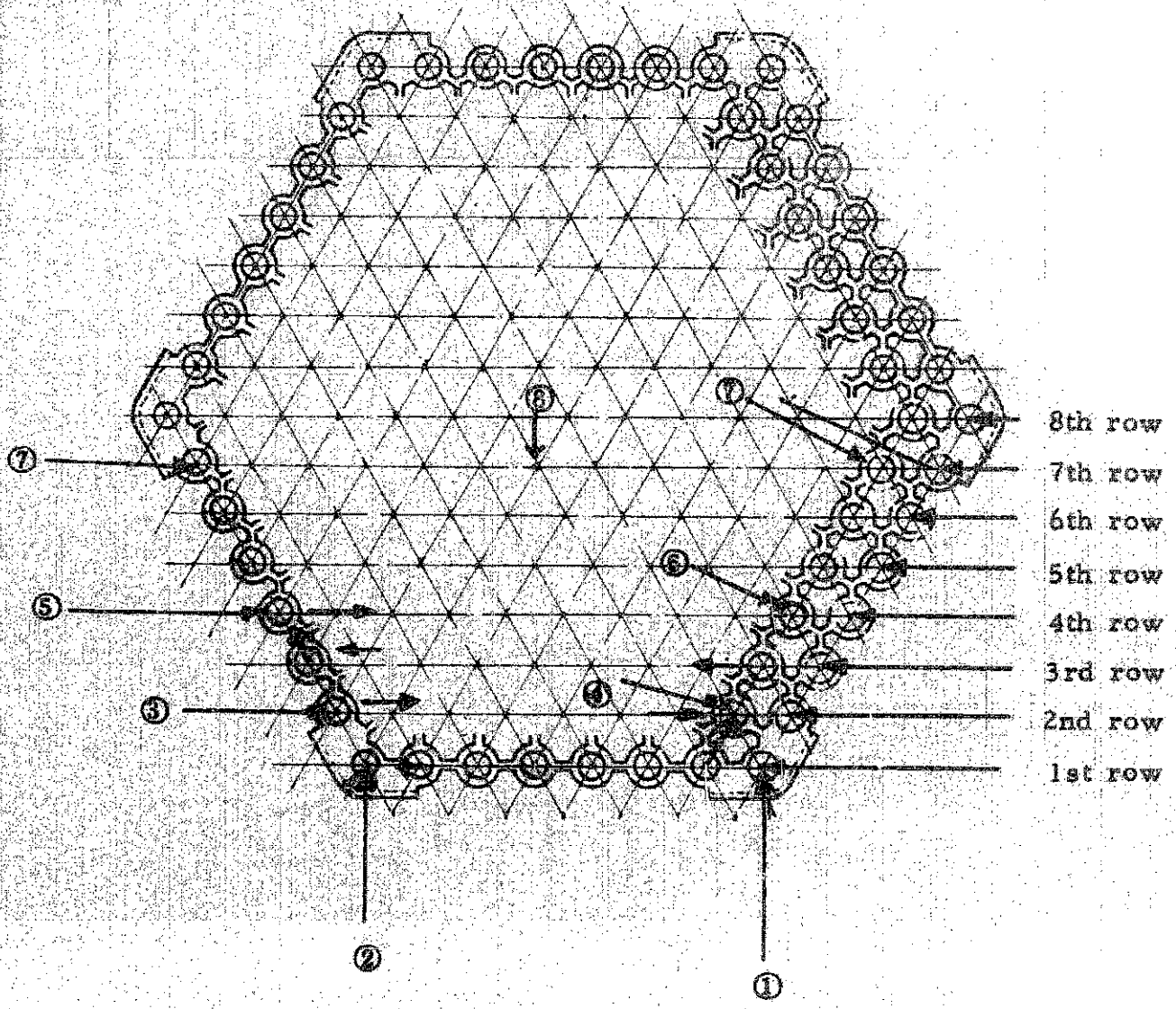
vi) Finishing:

Using a diamond file, etc., fins and furrs were removed and 7R on hexagonal periphery finished.

Fig. 1 Machining Process and Machines Used.

Roll grinding of the upper and lower sides	Vertical milling machine
Grinding of the upper and lower sides	Surface grinder
Marking-off	Surface table & Height gauge
Roll grinding of six sides	Universal milling machine
Drilling	NC boring machine
Finishing	

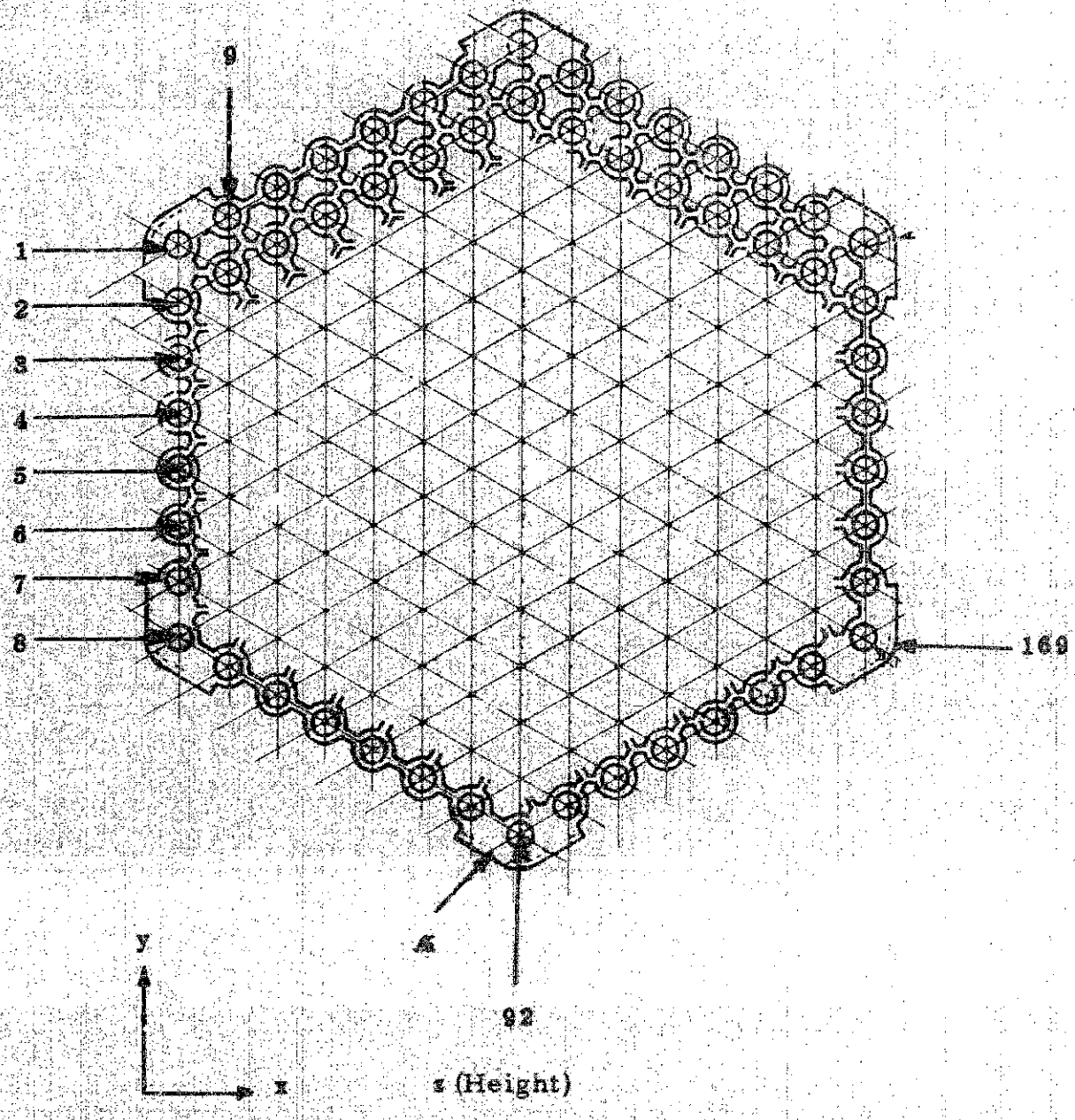
Fig. 2


⑧
⑦
⑦
⑤
⑤
④
③
②
①
8th row
7th row
6th row
5th row
4th row
3rd row
2nd row
1st row

Graph 1

Hole No.	Temperature (°C)
1	38
2	40
3	36
4	34
5	35
6	38
7	38
8	36
9	38

Fig. 3



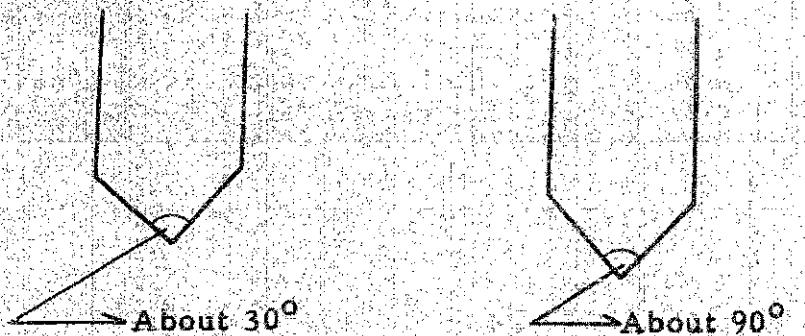
Graph 2

	Pitch between No. 1 and No. 2	Pitch between No. 5 and No. 6	Petch between No. 7 and No. 9
Standard (Target tolerances)	55.30	79.00	102.70
Initial pitch	55.27	–	102.68
After the 1st row was worked	55.27	–	102.68
After the 2nd row was worked	55.27	–	102.68
After the 3rd row was worked	55.26	–	102.68
After the 4th row was worked	55.26	78.97	102.68
After the 5th row was worked	55.26	78.96	102.67
After the 6th row was worked	55.26	78.96	102.67
After the 7th row was worked	55.26	78.95	102.67
After the 8th row was worked	55.26	78.95	102.67

2. Size Examination Results

Measurement of pitches was made using the coordinates measuring device borrowed from Power Reactor & Nuclear Fuel Development Corporation.

2-1 Probes Used



2-2 Measured Positions

Positions were set as illustrated in Fig. 3 and the numbers of holes were decided.

2-3 Measuring Method

(1) In setting, keep the difference in x coordinate of holes 1 and 8 within 2 μ.

(2) Insert the probe into the 92 holes and set the y and Z coordinates at zero.

(3) Measure from 1 to 169.

(4) After measurement, recheck the coordinates of 1, 8 and 92 (to see deviations occurring during measurement).

2-4 Results of Examination

Grids Nos. 3, 5, 8, 9 and 12 were examined. The results are given in Tables 3 ~ 7.

Graph-3-1
Grid No.3

001	X 000.002	Y-082.996	Z 000.032
002	X-000.002	Y-075.096	Z-000.028
003	X-000.002	Y-067.208	Z 000.118
004	X-000.014	Y-059.312	Z 000.304
005	X 000.006	Y-051.412	Z 000.114
006	X 000.004	Y-043.508	Z 000.174
007	X 000.004	Y-035.608	Z 000.188
008	X-000.004	Y-027.698	Z 000.112
009	X 006.844	Y-086.940	Z 000.094
010	X 006.844	Y-079.044	Z 000.112
011	X 006.838	Y-071.156	Z 000.172
012	X 006.838	Y-063.268	Z 000.236
013	X 006.838	Y-055.362	Z 000.196
014	X 006.836	Y-047.458	Z 000.232
015	X 006.842	Y-039.558	Z 000.172
016	X 006.842	Y-031.648	Z 000.118
017	X 006.842	Y-023.750	Z 000.096
018	X 013.684	Y-090.888	Z 000.114
019	X 013.688	Y-082.990	Z 000.128
020	X 013.672	Y-075.100	Z 000.204
021	X 013.684	Y-067.220	Z 000.224
022	X 013.692	Y-059.308	Z 000.160
023	X 013.684	Y-051.406	Z 000.172
024	X 013.692	Y-043.508	Z 000.190
025	X 013.686	Y-035.606	Z 000.126
026	X 013.684	Y-027.698	Z 000.134
027	X 013.690	Y-019.800	Z 000.056
028	X 020.532	Y-094.840	Z 000.070
029	X 020.536	Y-086.946	Z 000.136
030	X 020.520	Y-079.050	Z 000.160
031	X 020.526	Y-071.166	Z 000.216
032	X 020.528	Y-063.248	Z 000.172
033	X 020.536	Y-055.356	Z 000.146
034	X 020.536	Y-047.450	Z 000.246
035	X 020.534	Y-039.550	Z 000.182
036	X 020.536	Y-031.648	Z 000.108
037	X 020.526	Y-023.746	Z 000.104
038	X 020.534	Y-015.830	Z-000.006
039	X 027.378	Y-098.788	Z-000.028
040	X 027.370	Y-090.890	Z 000.136
041	X 027.360	Y-083.004	Z 000.184
042	X 027.364	Y-075.116	Z 000.250
043	X 027.378	Y-067.208	Z 000.160
044	X 027.374	Y-059.306	Z 000.160
045	X 027.372	Y-051.404	Z 000.186
046	X 027.366	Y-043.504	Z 000.242
047	X 027.372	Y-035.598	Z 000.206
048	X 027.374	Y-027.686	Z 000.128
049	X 027.378	Y-019.788	Z 000.020
050	X 027.374	Y-011.870	Z 000.016
051	X 034.224	Y-102.742	Z 000.112
052	X 034.216	Y-094.842	Z 000.124
053	X 034.208	Y-086.956	Z 000.204
054	X 034.218	Y-079.072	Z 000.220
055	X 034.220	Y-071.160	Z 000.186
056	X 034.224	Y-063.258	Z 000.178
057	X 034.224	Y-055.362	Z 000.190
058	X 034.220	Y-047.442	Z 000.206
059	X 034.224	Y-039.564	Z 000.208
060	X 034.226	Y-031.660	Z 000.132

061	X 034.226	Y-023.720	Z 000.026
062	X 034.230	Y-015.832	Z 000.000
063	X 034.224	Y-007.892	Z-000.118
064	X 041.066	Y-106.680	Z 000.102
065	X 041.066	Y-098.788	Z 000.146
066	X 041.046	Y-090.902	Z 000.194
067	X 041.060	Y-083.020	Z 000.214
068	X 041.062	Y-075.104	Z 000.196
069	X 041.066	Y-067.212	Z 000.182
070	X 041.064	Y-059.310	Z 000.190
071	X 041.062	Y-051.392	Z 000.238
072	X 041.068	Y-043.482	Z 000.158
073	X 041.066	Y-035.574	Z 000.106
074	X 041.066	Y-027.662	Z 000.056
075	X 041.064	Y-019.760	Z-000.008
076	X 041.060	Y-011.840	Z-000.142
077	X 041.068	Y-003.966	Z-000.002
078	X 047.916	Y-110.624	Z 000.126
079	X 047.914	Y-102.732	Z 000.108
080	X 047.902	Y-094.844	Z 000.186
081	X 047.904	Y-086.964	Z 000.228
082	X 047.906	Y-079.050	Z 000.210
083	X 047.896	Y-071.152	Z 000.192
084	X 047.906	Y-063.250	Z 000.196
085	X 047.910	Y-055.362	Z 000.220
086	X 047.914	Y-047.442	Z 000.146
087	X 047.906	Y-039.556	Z 000.118
088	X 047.912	Y-031.616	Z 000.062
089	X 047.912	Y-023.722	Z 000.046
090	X 047.904	Y-015.808	Z-000.008
091	X 047.908	Y-007.902	Z-000.020
092	X 047.904	Y 000.020	Z-000.032
093	X 054.750	Y-106.682	Z 000.078
094	X 054.744	Y-098.802	Z 000.176
095	X 054.744	Y-090.920	Z 000.214
096	X 054.750	Y-083.002	Z 000.152
097	X 054.750	Y-075.114	Z 000.184
098	X 054.748	Y-067.210	Z 000.196
099	X 054.750	Y-059.306	Z 000.084
100	X 054.758	Y-051.390	Z 000.188
101	X 054.756	Y-043.478	Z 000.106
102	X 054.754	Y-035.578	Z 000.066
103	X 054.758	Y-027.660	Z 000.012
104	X 054.750	Y-019.762	Z-000.002
105	X 054.754	Y-011.852	Z-000.020
106	X 054.744	Y-003.960	Z-000.016
107	X 061.584	Y-102.752	Z 000.188
108	X 061.592	Y-094.852	Z 000.184
109	X 061.592	Y-086.952	Z 000.258
110	X 061.588	Y-079.054	Z 000.180
111	X 061.592	Y-071.144	Z 000.192
112	X 061.596	Y-063.244	Z 000.196
113	X 061.600	Y-055.328	Z 000.250
114	X 061.592	Y-047.436	Z 000.124
115	X 061.598	Y-039.514	Z 000.072
116	X 061.598	Y-031.590	Z 000.060
117	X 061.590	Y-023.684	Z 000.030
118	X 061.600	Y-015.802	Z-000.020
119	X 061.596	Y-007.884	Z-000.026
120	X 068.420	Y-098.814	Z 000.180

Graph-3-3

```
121  X 068.424 Y-090.902 Z 000.246
122  X 068.426 Y-083.020 Z 000.166
123  X 068.424 Y-075.100 Z 000.160
124  X 068.428 Y-067.210 Z 000.204
125  X 068.440 Y-059.282 Z 000.152
126  X 068.434 Y-051.376 Z 000.128
127  X 068.400 Y-043.400 Z 000.774
128  X 068.438 Y-035.570 Z 000.030
129  X 068.432 Y-027.640 Z 000.006
130  X 068.436 Y-019.742 Z 000.024
131  X 068.422 Y-011.824 Z-000.004
132  X 075.268 Y-094.860 Z 000.278
133  X 075.274 Y-086.960 Z 000.152
134  X 075.268 Y-079.044 Z 000.164
135  X 075.274 Y-071.162 Z 000.162
136  X 075.284 Y-063.232 Z 000.160
137  X 075.280 Y-055.342 Z 000.138
138  X 075.284 Y-047.438 Z 000.034
139  X 075.282 Y-039.504 Z 000.044
140  X 075.282 Y-031.624 Z 000.014
141  X 075.282 Y-023.704 Z 000.004
142  X 075.272 Y-015.802 Z 000.004
143  X 082.104 Y-090.918 Z 000.178
144  X 082.110 Y-083.012 Z 000.130
145  X 082.114 Y-075.120 Z 000.152
146  X 082.122 Y-067.182 Z 000.136
147  X 082.122 Y-059.274 Z 000.126
148  X 082.118 Y-051.378 Z 000.024
149  X 082.122 Y-043.444 Z-000.122
150  X 082.122 Y-035.542 Z 000.004
151  X 082.122 Y-027.630 Z 000.008
152  X 082.108 Y-019.742 Z 000.004
153  X 088.962 Y-086.966 Z 000.174
154  X 088.962 Y-079.068 Z 000.156
155  X 089.014 Y-071.126 Z 000.194
156  X 088.974 Y-063.220 Z 000.182
157  X 088.972 Y-055.330 Z 000.026
158  X 088.976 Y-047.404 Z-000.006
159  X 088.966 Y-039.496 Z 000.032
160  X 088.972 Y-031.582 Z 000.012
161  X 088.962 Y-023.688 Z-000.014
162  X 095.794 Y-083.012 Z 000.154
163  X 095.806 Y-075.074 Z 000.246
164  X 095.804 Y-067.188 Z 000.196
165  X 095.806 Y-059.276 Z 000.076
166  X 095.814 Y-051.368 Z-000.030
167  X 095.806 Y-043.442 Z 000.014
168  X 095.808 Y-035.545 Z 000.010
169  X 095.800 Y-027.624 Z-000.010
```

Graph-4-1

Grid No.5

000	X-000.000	Y-082.910	Z 000.196
001	X-000.000	Y-082.910	Z 000.196
002	X 000.054	Y-075.042	Z 000.026
003	X 000.006	Y-067.184	Z 000.024
004	X-000.010	Y-059.278	Z 000.034
005	X 000.026	Y-051.358	Z 000.016
006	X-000.018	Y-043.484	Z 000.030
007	X-000.000	Y-035.590	Z 000.010
008	X 000.006	Y-027.700	Z 000.000
009	X 006.864	Y-086.842	Z 000.184
010	X 006.810	Y-078.962	Z 000.238
011	X 006.836	Y-071.132	Z 000.016
012	X 006.802	Y-063.242	Z 000.016
013	X 006.844	Y-055.326	Z-000.032
014	X 006.860	Y-047.432	Z 000.028
015	X 006.804	Y-039.550	Z 000.042
016	X 006.788	Y-031.630	Z 000.010
017	X 006.806	Y-023.756	Z 000.006
018	X 013.698	Y-090.798	Z 000.268
019	X 013.642	Y-082.880	Z 000.218
020	X 013.664	Y-074.996	Z 000.226
021	X 013.674	Y-067.160	Z 000.028
022	X 013.682	Y-059.282	Z 000.006
023	X 013.646	Y-051.348	Z 000.006
024	X 013.660	Y-043.504	Z 000.316
025	X 013.680	Y-035.590	Z 000.114
026	X 013.648	Y-027.704	Z-000.008
027	X 013.656	Y-019.798	Z 000.026
028	X 020.504	Y-094.672	Z 000.208
029	X 020.514	Y 086.794	Z 000.244
030	X 020.506	Y-078.964	Z 000.226
031	X 020.520	Y-071.042	Z 000.216
032	X 020.496	Y-063.204	Z 000.016
033	X 020.516	Y-055.310	Z-000.024
034	X 020.498	Y-047.404	Z-000.006
035	X 020.552	Y-039.512	Z 000.270
036	X 020.510	Y-031.618	Z 000.008
037	X 020.498	Y-023.736	Z 000.026
038	X 020.482	Y-015.850	Z-000.020
039	X 027.354	Y-098.638	Z 000.242
040	X 027.350	Y-090.722	Z 000.306
041	X 027.340	Y-082.862	Z 000.170
042	X 027.346	Y-074.974	Z 000.216
043	X 027.326	Y-067.0 6	Z 000.210
044	X 027.342	Y-059.268	Z-000.002
045	X 027.336	Y-051.350	Z-000.014
046	X 027.344	Y-043.470	Z 000.062
047	X 027.334	Y-035.544	Z 000.170
048	X 027.304	Y-027.660	Z 000.038
049	X 027.326	Y-019.770	Z-000.024
050	X 027.326	Y-011.900	Z 000.020
051	X 034.212	Y-102.544	Z 000.218
052	X 034.180	Y-094.690	Z 000.262
053	X 034.19'	Y-086.804	Z 000.228
054	X 034.182	Y-078.896	Z 000.254
055	X 034.156	Y-071.064	Z 000.212
056	X 034.136	Y-063.126	Z 000.236
057	X 034.166	Y-055.290	Z-000.034
058	X 034.166	Y-047.398	Z-000.042
059	X 034.182	Y-039.534	Z 000.082
060	X 034.160	Y-031.620	Z-000.004

061 X 034.158 Y-023.712 Z-000.012
062 X 034.168 Y-015.794 Z 000.010
063 X 034.156 Y-007.962 Z 000.020
064 X 041.054 Y-106.516 Z 000.258
065 X 041.022 Y-098.624 Z 000.258
066 X 041.024 Y-090.748 Z 000.200
067 X 041.012 Y-082.862 Z 000.254
068 X 041.004 Y-074.986 Z 000.202
069 X 041.004 Y-067.044 Z 000.190
070 X 040.990 Y-059.146 Z 000.176
071 X 041.000 Y-051.362 Z-000.018
072 X 041.016 Y-043.476 Z 000.078
073 X 040.992 Y-035.542 Z-000.012
074 X 040.984 Y-027.678 Z-000.034
075 X 040.984 Y-019.778 Z 000.078
076 X 040.990 Y-011.896 Z 000.022
077 X 040.984 Y-003.994 Z-000.018
078 X 047.856 Y-110.490 Z 000.216
079 X 047.882 Y-102.572 Z 000.256
080 X 047.854 Y-094.696 Z 000.228
081 X 047.860 Y-086.758 Z 000.194
082 X 047.836 Y-078.900 Z 000.194
083 X 047.876 Y-070.972 Z 000.180
084 X 047.848 Y-063.114 Z 000.178
085 X 047.862 Y-055.214 Z 000.146
086 X 047.850 Y-047.390 Z-000.050
087 X 047.854 Y-039.502 Z 000.018
088 X 047.834 Y-031.596 Z-000.036
089 X 047.816 Y-023.708 Z 000.076
090 X 047.804 Y-015.792 Z 000.036
091 X 047.798 Y-007.900 Z 000.022
092 X 047.790 Y-000.014 Z-000.014
093 X 054.726 Y-106.504 Z 000.270
094 X 054.668 Y-098.562 Z 000.276
095 X 054.672 Y-090.726 Z 000.270
096 X 054.670 Y-082.820 Z 000.250
097 X 054.658 Y-074.960 Z 000.250
098 X 054.702 Y-067.022 Z 000.240
099 X 054.648 Y-059.128 Z 000.198
100 X 054.656 Y-051.258 Z 000.184
101 X 054.678 Y-043.452 Z-000.028
102 X 054.678 Y-035.554 Z-000.022
103 X 054.658 Y-027.644 Z-000.060
104 X 054.652 Y-019.762 Z 000.006
105 X 054.652 Y-011.866 Z 000.028
106 X 054.670 Y-003.936 Z-000.020
107 X 061.564 Y-102.570 Z 000.266
108 X 061.480 Y-094.668 Z 000.228
109 X 061.534 Y-086.782 Z 000.286
110 X 061.512 Y-078.884 Z 000.200
111 X 061.538 Y-070.950 Z 000.266
112 X 061.486 Y-063.100 Z 000.206
113 X 061.486 Y-055.152 Z 000.188
114 X 061.456 Y-047.284 Z 000.190
115 X 061.478 Y-039.482 Z 000.102
116 X 061.510 Y-031.588 Z 000.042
117 X 061.506 Y-023.682 Z-000.044
118 X 061.496 Y-015.802 Z-000.020
119 X 061.486 Y-007.920 Z 000.016
120 X 068.334 Y-008.582 Z 000.244

Graph-4-3

121	X 068.374	Y-090.702	Z 000.156
122	X 068.396	Y-082.840	Z 000.216
123	X 068.354	Y-074.896	Z 000.268
124	X 068.346	Y-067.062	Z 000.180
125	X 068.346	Y-059.108	Z 000.224
126	X 068.336	Y-051.230	Z 000.202
127	X 068.320	Y-043.330	Z 000.146
128	X 068.332	Y-035.518	Z-000.032
129	X 068.336	Y-027.634	Z-000.070
130	X 068.314	Y-019.722	Z 000.032
131	X 068.340	Y-011.864	Z 000.032
132	X 075.190	Y-094.610	Z 000.188
133	X 075.168	Y-086.754	Z 000.234
134	X 075.142	Y-078.882	Z 000.230
135	X 075.174	Y-070.966	Z 000.224
136	X 075.178	Y-063.084	Z 000.238
137	X 075.188	Y-055.188	Z 000.196
138	X 075.138	Y-047.282	Z 000.178
139	X 075.166	Y-039.380	Z 000.204
140	X 075.162	Y-031.586	Z-000.068
141	X 075.162	Y-023.662	Z-000.028
142	X 075.136	Y-015.774	Z-000.052
143	X 082.036	Y-090.716	Z 000.224
144	X 082.030	Y-082.780	Z 000.194
145	X 082.038	Y-074.918	Z 000.206
146	X 082.010	Y-067.034	Z 000.256
147	X 082.024	Y-059.092	Z 000.278
148	X 082.046	Y-051.222	Z 000.192
149	X 082.000	Y-043.302	Z 000.200
150	X 082.000	Y-035.454	Z 000.186
151	X 082.004	Y-027.610	Z-000.088
152	X 082.002	Y-019.748	Z-000.038
153	X 088.882	Y-086.772	Z 000.200
154	X 088.796	Y-078.882	Z 000.212
155	X 088.830	Y-070.958	Z 000.224
156	X 088.840	Y-063.062	Z 000.238
157	X 088.860	Y-055.158	Z 000.206
158	X 088.838	Y-047.260	Z 000.298
159	X 088.842	Y-039.368	Z 000.170
160	X 088.826	Y-031.488	Z 000.156
161	X 088.842	Y-023.680	Z-000.076
162	X 095.706	Y-082.814	Z 000.118
163	X 095.684	Y-074.856	Z 000.200
164	X 095.648	Y-067.008	Z 000.252
165	X 095.724	Y-059.094	Z 000.288
166	X 095.658	Y-051.232	Z 000.204
167	X 095.664	Y-043.328	Z 000.204
168	X 095.678	Y-035.490	Z 000.204
169	X 095.680	Y-027.482	Z 000.076

Graph-5-1
Grid No.8

001	X 000.000	Y-082.872	Z-000.072
002	X 000.014	Y-074.986	Z-000.072
003	X-000.028	Y-067.092	Z-000.080
004	X-000.022	Y-059.188	Z-000.082
005	X-000.002	Y-051.286	Z-000.064
006	X-000.016	Y-043.424	Z-000.074
007	X-000.030	Y-035.508	Z-000.052
008	X-000.002	Y-027.612	Z-000.048
009	X 006.830	Y-086.824	Z-000.066
010	X 006.836	Y-078.926	Z-000.074
011	X 006.820	Y-070.994	Z-000.076
012	X 006.812	Y-063.136	Z-000.068
013	X 006.820	Y-055.258	Z-000.050
014	X 006.816	Y-047.356	Z-000.046
015	X 006.804	Y-039.468	Z-000.044
016	X 006.830	Y-031.550	Z-000.058
017	X 006.838	Y-023.680	Z-000.028
018	X 013.686	Y-090.752	Z-000.064
019	X 013.658	Y-082.838	Z-000.046
020	X 013.650	Y-074.982	Z-000.052
021	X 013.674	Y-067.072	Z-000.050
022	X 013.656	Y-059.192	Z-000.044
023	X 013.656	Y-051.288	Z-000.040
024	X 013.620	Y-043.396	Z-000.036
025	X 013.666	Y-035.506	Z-000.032
026	X 013.628	Y-027.612	Z-000.026
027	X 013.652	Y-019.692	Z-000.028
028	X 020.534	Y-094.710	Z-000.048
029	X 020.508	Y-086.820	Z-000.044
030	X 020.500	Y-078.908	Z-000.046
031	X 020.492	Y-071.008	Z-000.044
032	X 020.514	Y-063.112	Z-000.044
033	X 020.502	Y-055.246	Z-000.044
034	X 020.488	Y-047.328	Z-000.034
035	X 020.466	Y-039.424	Z-000.030
036	X 020.496	Y-031.530	Z-000.026
037	X 020.476	Y-023.664	Z-000.024
038	X 020.484	Y-015.722	Z-000.026
039	X 027.358	Y-098.610	Z-000.050
040	X 027.356	Y-090.756	Z-000.050
041	X 027.316	Y-082.846	Z-000.044
042	X 027.340	Y-074.932	Z-000.042
043	X 027.332	Y-067.050	Z-000.042
044	X 027.336	Y-059.160	Z-000.058
045	X 027.324	Y-051.250	Z-000.042
046	X 027.340	Y-043.386	Z-000.038
047	X 027.328	Y-035.508	Z-000.040
048	X 027.300	Y-027.570	Z-000.030
049	X 027.304	Y-019.708	Z-000.042
050	X 027.326	Y-011.772	Z-000.040
051	X 034.148	Y-102.614	Z-000.050
052	X 034.182	Y-094.680	Z-000.050
053	X 034.176	Y-086.806	Z-000.044
054	X 034.170	Y-078.892	Z-000.046
055	X 034.170	Y-070.990	Z-000.040
056	X 034.170	Y-063.096	Z-000.040
057	X 034.176	Y-055.230	Z-000.038
058	X 034.176	Y-047.308	Z-000.028
059	X 034.148	Y-039.414	Z-000.038
060	X 034.148	Y-031.530	Z-000.030

061 X 034.166 Y-023.610 Z-000.028
062 X 034.138 Y-015.716 Z-000.028
063 X 034.156 Y-007.848 Z 000.036
064 X 041.002 Y-106.524 Z-000.056
065 X 041.026 Y-098.642 Z-000.052
066 X 041.014 Y-090.728 Z-000.048
067 X 041.008 Y-082.828 Z-000.044
068 X 041.012 Y-074.938 Z-000.046
069 X 040.996 Y-067.038 Z-000.042
070 X 040.984 Y-059.152 Z-000.050
071 X 041.026 Y-051.268 Z-000.038
072 X 040.998 Y-043.356 Z-000.024
073 X 040.994 Y-035.468 Z-000.022
074 X 041.000 Y-027.566 Z-000.020
075 X 040.974 Y-019.690 Z-000.026
076 X 040.978 Y-011.772 Z-000.020
077 X 041.000 Y-003.896 Z-000.020
078 X 047.856 Y-110.504 Z-000.052
079 X 047.848 Y-102.598 Z-000.060
080 X 047.840 Y-094.698 Z-000.054
081 X 047.826 Y-086.808 Z-000.056
082 X 047.838 Y-078.908 Z-000.050
083 X 047.832 Y-071.012 Z-000.042
084 X 047.842 Y-063.112 Z-000.038
085 X 047.842 Y-055.202 Z-000.028
086 X 047.844 Y-047.316 Z-000.030
087 X 047.844 Y-039.418 Z-000.020
088 X 047.836 Y-031.512 Z-000.008
089 X 047.824 Y-023.630 Z-000.008
090 X 047.836 Y-015.728 Z-000.012
091 X 047.834 Y-007.828 Z-000.006
092 X 047.854 Y 000.006 Z-000.008
093 X 054.700 Y-106.536 Z-000.044
094 X 054.672 Y-098.628 Z-000.048
095 X 054.678 Y-090.736 Z-000.044
096 X 054.640 Y-082.830 Z-000.064
097 X 054.644 Y-074.918 Z-000.040
098 X 054.648 Y-067.050 Z-000.032
099 X 054.650 Y-059.170 Z-000.046
100 X 054.694 Y-051.270 Z-000.022
101 X 054.704 Y-043.352 Z-000.020
102 X 054.680 Y-035.470 Z-000.002
103 X 054.700 Y-027.566 Z-000.008
104 X 054.696 Y-019.670 Z 000.002
105 X 054.686 Y-011.754 Z-000.000
106 X 054.688 Y-003.878 Z-000.000
107 X 061.490 Y-102.588 Z-000.064
108 X 061.504 Y-094.672 Z-000.050
109 X 061.478 Y-086.768 Z-000.056
110 X 061.474 Y-078.890 Z-000.054
111 X 061.484 Y-070.990 Z-000.046
112 X 061.490 Y-063.088 Z-000.036
113 X 061.496 Y-055.234 Z-000.028
114 X 061.508 Y-047.308 Z-000.038
115 X 061.526 Y-039.400 Z-000.038
116 X 061.530 Y-031.510 Z-000.018
117 X 061.518 Y-023.610 Z-000.010
118 X 061.498 Y-015.708 Z-000.004
119 X 061.518 Y-007.836 Z-000.010
120 X 068.358 Y-098.590 Z-000.060

Graph-5-3

121	X 068.342	Y-090.728	Z-000.046
122	X 068.352	Y-082.842	Z-000.050
123	X 068.356	Y-074.930	Z-000.044
124	X 068.346	Y-067.010	Z-000.040
125	X 068.328	Y-059.154	Z-000.030
126	X 068.344	Y-051.260	Z-000.042
127	X 068.366	Y-043.358	Z-000.030
128	X 068.354	Y-035.466	Z-000.024
129	X 068.338	Y-027.570	Z-000.016
130	X 068.352	Y-019.676	Z-000.020
131	X 068.366	Y-011.778	Z-000.000
132	X 075.194	Y-094.702	Z-000.080
133	X 075.192	Y-086.770	Z-000.070
134	X 075.224	Y-078.890	Z-000.054
135	X 075.190	Y-070.984	Z-000.044
136	X 075.180	Y-063.104	Z-000.040
137	X 075.214	Y-055.212	Z-000.038
138	X 075.188	Y-047.306	Z-000.020
139	X 075.196	Y-039.404	Z-000.018
140	X 075.186	Y-031.508	Z-000.004
141	X 075.182	Y-023.624	Z 000.002
142	X 075.206	Y-015.710	Z 000.004
143	X 082.062	Y-090.704	Z-000.070
144	X 082.042	Y-082.830	Z-000.064
145	X 082.056	Y-074.910	Z-000.066
146	X 082.014	Y-067.052	Z-000.042
147	X 082.038	Y-059.164	Z-000.028
148	X 082.034	Y-051.238	Z-000.022
149	X 082.050	Y-043.358	Z-000.012
150	X 082.032	Y-035.464	Z-000.006
151	X 082.044	Y-027.560	Z 000.000
152	X 082.024	Y-019.696	Z 000.010
153	X 088.858	Y-086.780	Z-000.068
154	X 088.872	Y-078.890	Z-000.060
155	X 088.872	Y-070.978	Z-000.052
156	X 088.838	Y-063.080	Z-000.036
157	X 088.872	Y-055.222	Z-000.026
158	X 088.878	Y-047.300	Z-000.022
159	X 088.860	Y-039.390	Z-000.024
160	X 088.874	Y-031.506	Z-000.006
161	X 088.866	Y-023.624	Z-000.020
162	X 095.674	Y-082.812	Z-000.060
163	X 095.694	Y-074.912	Z-000.052
164	X 095.674	Y-067.016	Z-000.050
165	X 095.692	Y-059.172	Z-000.038
166	X 095.708	Y-051.258	Z-000.032
167	X 095.718	Y-043.364	Z-000.028
168	X 095.694	Y-035.452	Z-000.030
169	X 095.554	Y-027.572	Z-000.032

Graph-6-1
Grid No.9

001	X-000.002	Y-082.896	Z 000.222
002	X 000.060	Y-075.040	Z 000.100
003	X 000.034	Y-067.136	Z 000.206
004	X 000.062	Y-059.272	Z 000.124
005	X 000.018	Y-051.338	Z 000.158
006	X 000.026	Y-043.484	Z 000.156
007	X 000.010	Y-035.582	Z 000.156
008	X 000.002	Y-027.670	Z 000.210
009	X 006.912	Y-086.870	Z 000.088
010	X 006.908	Y-079.004	Z 000.108
011	X 006.890	Y-071.098	Z 000.096
012	X 006.874	Y-063.188	Z 000.128
013	X 006.892	Y-055.334	Z 000.120
014	X 006.860	Y-047.380	Z 000.156
015	X 006.866	Y-039.528	Z 000.190
016	X 006.858	Y-031.644	Z 000.182
017	X 006.838	Y-023.728	Z 000.190
018	X 013.758	Y-090.806	Z 000.148
019	X 013.748	Y-082.912	Z 000.098
020	X 013.754	Y-075.014	Z 000.110
021	X 013.742	Y-067.126	Z 000.086
022	X 013.726	Y-059.238	Z 000.094
023	X 013.748	Y-051.362	Z 000.124
024	X 013.698	Y-043.440	Z 000.088
025	X 013.708	Y-035.566	Z 000.096
026	X 013.698	Y-027.690	Z 000.102
027	X 013.682	Y-019.766	Z 000.194
028	X 020.596	Y-094.746	Z 000.140
029	X 020.594	Y-086.834	Z 000.128
030	X 020.586	Y-078.940	Z 000.068
031	X 020.594	Y-071.026	Z 000.064
032	X 020.570	Y-063.158	Z 000.018
033	X 020.564	Y-055.266	Z 000.096
034	X 020.572	Y-047.404	Z 000.210
035	X 020.526	Y-039.484	Z 000.124
036	X 020.542	Y-031.588	Z 000.108
037	X 020.542	Y-023.732	Z 000.090
038	X 020.508	Y-015.824	Z 000.256
039	X 027.454	Y-098.686	Z 000.090
040	X 027.444	Y-090.786	Z 000.070
041	X 027.424	Y-082.878	Z 000.060
042	X 027.424	Y-074.992	Z 000.078
043	X 027.422	Y-067.088	Z 000.058
044	X 027.390	Y-059.208	Z 000.076
045	X 027.406	Y-051.312	Z 000.088
046	X 027.422	Y-043.446	Z 000.084
047	X 027.368	Y-035.518	Z 000.086
048	X 027.398	Y-027.646	Z 000.102
049	X 027.406	Y-019.768	Z 000.138
050	X 027.346	Y-011.866	Z 000.208
051	X 034.272	Y-102.640	Z 000.156
052	X 034.288	Y-094.718	Z 000.064
053	X 034.282	Y-086.844	Z 000.060
054	X 034.258	Y-078.942	Z 000.052
055	X 034.266	Y-071.024	Z 000.068
056	X 034.246	Y-063.138	Z 000.036
057	X 034.230	Y-055.238	Z 000.160
058	X 034.222	Y-047.354	Z 000.044
059	X 034.246	Y-039.484	Z 000.080
060	X 034.242	Y-031.546	Z 000.322

061 X 034.214 Y-023.698 Z-000.036
062 X 034.218 Y-015.802 Z 000.100
063 X 034.166 Y-007.904 Z 000.306
064 X 041.108 Y-106.546 Z 000.190
065 X 041.106 Y-098.644 Z 000.138
066 X 041.110 Y-090.770 Z 000.068
067 X 041.112 Y-082.874 Z 000.068
068 X 041.108 Y-074.966 Z 000.090
069 X 041.096 Y-067.066 Z 000.050
070 X 041.092 Y-059.172 Z 000.116
071 X 041.068 Y-051.285 Z 000.064
072 X 041.056 Y-043.376 Z 000.142
073 X 041.056 Y-035.528 Z 000.036
074 X 041.036 Y-027.604 Z 000.100
075 X 041.032 Y-019.728 Z 000.304
076 X 041.026 Y-011.846 Z 000.124
077 X 041.002 Y-003.964 Z 000.274
078 X 047.932 Y-110.458 Z 000.234
079 X 047.934 Y-102.564 Z 000.206
080 X 047.936 Y-094.686 Z 000.030
081 X 047.942 Y-086.808 Z 000.028
082 X 047.944 Y-078.906 Z 000.048
083 X 047.934 Y-071.006 Z 000.104
084 X 047.924 Y-063.115 Z 000.106
085 X 047.878 Y-055.186 Z 000.198
086 X 047.896 Y-047.334 Z 000.094
087 X 047.902 Y-039.434 Z 000.068
088 X 047.902 Y-031.566 Z 000.124
089 X 047.884 Y-023.626 Z 000.122
090 X 047.856 Y-015.780 Z 000.118
091 X 047.856 Y-007.920 Z 000.138
092 X 047.816 Y 000.004 Z 000.216
093 X 054.778 Y-106.520 Z 000.160
094 X 054.800 Y-098.618 Z 000.104
095 X 054.800 Y-090.728 Z 000.080
096 X 054.792 Y-082.854 Z 000.084
097 X 054.786 Y-074.948 Z 000.070
098 X 054.768 Y-067.048 Z 000.072
099 X 054.750 Y-059.146 Z 000.054
100 X 054.754 Y-051.248 Z 000.128
101 X 054.738 Y-043.348 Z 000.046
102 X 054.736 Y-035.468 Z 000.086
103 X 054.762 Y-027.620 Z 000.154
104 X 054.712 Y-019.686 Z 000.116
105 X 054.718 Y-011.830 Z 000.146
106 X 054.680 Y-003.906 Z 000.114
107 X 061.604 Y-102.542 Z 000.134
108 X 061.624 Y-094.646 Z 000.060
109 X 061.630 Y-086.756 Z 000.050
110 X 061.626 Y-078.888 Z 000.048
111 X 061.616 Y-070.986 Z 000.110
112 X 061.610 Y-063.090 Z 000.052
113 X 061.608 Y-055.194 Z 000.126
114 X 061.588 Y-047.286 Z 000.162
115 X 061.538 Y-039.382 Z 000.382
116 X 061.542 Y-031.514 Z 000.144
117 X 061.570 Y-023.618 Z 000.086
118 X 061.508 Y-015.750 Z 000.106
119 X 061.532 Y-007.820 Z 000.106
120 X 068.454 Y-098.576 Z 000.190

Graph-6-3

121	X	068.458	Y	-090.704	Z	000.054
122	X	068.448	Y	-082.830	Z	000.048
123	X	068.442	Y	-074.946	Z	000.126
124	X	068.452	Y	-067.034	Z	000.060
125	X	068.442	Y	-059.130	Z	000.100
126	X	068.434	Y	-051.216	Z	000.126
127	X	068.418	Y	-043.326	Z	000.106
128	X	068.398	Y	-035.418	Z	000.106
129	X	068.386	Y	-027.568	Z	000.106
130	X	068.402	Y	-019.680	Z	000.110
131	X	068.388	Y	-011.758	Z	000.124
132	X	075.288	Y	-094.638	Z	000.152
133	X	075.282	Y	-086.746	Z	000.064
134	X	075.302	Y	-078.866	Z	000.114
135	X	075.292	Y	-070.984	Z	000.078
136	X	075.282	Y	-063.080	Z	000.124
137	X	075.280	Y	-055.164	Z	000.112
138	X	075.282	Y	-047.286	Z	000.106
139	X	075.266	Y	-039.390	Z	000.104
140	X	075.218	Y	-031.442	Z	000.066
141	X	075.224	Y	-023.622	Z	000.102
142	X	075.228	Y	-015.720	Z	000.172
143	X	082.118	Y	-090.682	Z	000.136
144	X	082.110	Y	-082.794	Z	000.108
145	X	082.114	Y	-074.904	Z	000.102
146	X	082.114	Y	-067.028	Z	000.076
147	X	082.104	Y	-059.118	Z	000.182
148	X	082.130	Y	-051.206	Z	000.084
149	X	082.094	Y	-043.308	Z	000.140
150	X	082.084	Y	-035.388	Z	000.210
151	X	082.086	Y	-027.524	Z	000.056
152	X	082.058	Y	-019.624	Z	000.142
153	X	088.940	Y	-086.740	Z	000.216
154	X	088.968	Y	-078.836	Z	000.054
155	X	088.958	Y	-070.930	Z	000.090
156	X	088.922	Y	-063.095	Z	000.110
157	X	088.934	Y	-055.160	Z	000.244
158	X	088.930	Y	-047.246	Z	000.112
159	X	088.934	Y	-039.324	Z	000.116
160	X	088.906	Y	-031.450	Z	000.086
161	X	088.906	Y	-023.566	Z	000.078
162	X	095.800	Y	-082.786	Z	000.206
163	X	095.800	Y	-074.874	Z	000.070
164	X	095.808	Y	-066.990	Z	000.114
165	X	095.816	Y	-059.114	Z	000.116
166	X	095.798	Y	-051.182	Z	000.210
167	X	095.794	Y	-043.272	Z	000.250
168	X	095.762	Y	-035.386	Z	000.098
169	X	095.714	Y	-027.504	Z	000.226

Graph-7-1
Grid No.12.

001	X	000.000	Y-082.882	Z	000.026
002	X	000.002	Y-075.022	Z	000.054
003	X	000.014	Y-067.102	Z	000.062
004	X	000.038	Y-059.202	Z	000.078
005	X	000.010	Y-051.332	Z	000.060
006	X	000.028	Y-043.422	Z	000.080
007	X	000.024	Y-035.528	Z	000.084
008	X	000.004	Y-027.618	Z	000.140
009	X	006.842	Y-086.846	Z	000.058
010	X	006.860	Y-078.942	Z	000.040
011	X	006.852	Y-071.080	Z	000.062
012	X	006.856	Y-063.156	Z	000.090
013	X	006.852	Y-055.270	Z	000.108
014	X	006.854	Y-047.358	Z	000.090
015	X	006.874	Y-039.478	Z	000.096
016	X	006.838	Y-031.590	Z	000.116
017	X	006.826	Y-023.682	Z	000.080
018	X	013.666	Y-090.802	Z	000.066
019	X	013.684	Y-082.924	Z	000.036
020	X	013.684	Y-075.026	Z	000.070
021	X	013.680	Y-067.124	Z	000.082
022	X	013.690	Y-059.232	Z	000.060
023	X	013.680	Y-051.340	Z	000.070
024	X	013.680	Y-043.430	Z	000.100
025	X	013.674	Y-035.520	Z	000.088
026	X	013.660	Y-027.652	Z	000.050
027	X	013.662	Y-019.760	Z	000.060
028	X	020.522	Y-094.742	Z	000.050
029	X	020.520	Y-086.856	Z	000.058
030	X	020.522	Y-078.964	Z	000.054
031	X	020.578	Y-071.122	Z	-000.096
032	X	020.568	Y-063.242	Z	-000.066
033	X	020.572	Y-055.342	Z	-000.052
034	X	020.582	Y-047.422	Z	-000.142
035	X	020.536	Y-039.502	Z	000.052
036	X	020.512	Y-031.582	Z	000.074
037	X	020.500	Y-023.702	Z	000.064
038	X	020.504	Y-015.800	Z	000.024
039	X	027.342	Y-098.702	Z	000.048
040	X	027.350	Y-090.816	Z	000.040
041	X	027.356	Y-082.934	Z	000.024
042	X	027.362	Y-075.014	Z	000.040
043	X	027.348	Y-067.140	Z	000.052
044	X	027.360	Y-059.228	Z	000.024
045	X	027.330	Y-051.324	Z	000.082
046	X	027.342	Y-043.436	Z	000.048
047	X	027.338	Y-035.524	Z	000.062
048	X	027.320	Y-027.642	Z	000.038
049	X	027.316	Y-019.746	Z	000.052
050	X	027.312	Y-011.844	Z	000.008
051	X	034.194	Y-102.660	Z	000.002
052	X	034.202	Y-094.768	Z	000.014
053	X	034.204	Y-086.868	Z	000.030
054	X	034.210	Y-078.982	Z	000.004
055	X	034.202	Y-071.075	Z	000.002
056	X	034.198	Y-063.180	Z	000.024
057	X	034.188	Y-055.282	Z	-000.008
058	X	034.194	Y-047.382	Z	000.006
059	X	034.180	Y-039.482	Z	000.102
060	X	034.180	Y-031.584	Z	000.042

061 X 034.180 Y-023.700 Z 000.042
062 X 034.158 Y-015.794 Z 000.034
063 X 034.144 Y-007.910 Z 000.018
064 X 041.032 Y-106.602 Z-000.036
065 X 041.042 Y-098.744 Z 000.022
066 X 041.036 Y-090.828 Z-000.004
067 X 041.038 Y-082.938 Z-000.014
068 X 041.024 Y-075.024 Z-000.018
069 X 041.026 Y-067.120 Z 000.014
070 X 041.020 Y-059.236 Z-000.010
071 X 041.018 Y-051.328 Z 000.004
072 X 041.012 Y-043.444 Z-000.020
073 X 040.992 Y-035.542 Z 000.010
074 X 041.000 Y-027.648 Z 000.008
075 X 040.984 Y-019.744 Z 000.028
076 X 040.984 Y-011.854 Z 000.068
077 X 040.980 Y-003.960 Z-000.020
078 X 047.860 Y-110.538 Z-000.068
079 X 047.896 Y-102.642 Z-000.046
080 X 047.872 Y-094.744 Z-000.030
081 X 047.862 Y-086.872 Z-000.028
082 X 047.858 Y-078.966 Z-000.008
083 X 047.838 Y-071.064 Z 000.000
084 X 047.830 Y-063.202 Z-000.012
085 X 047.842 Y-055.278 Z-000.018
086 X 047.822 Y-047.400 Z 000.002
087 X 047.818 Y-039.482 Z 000.050
088 X 047.830 Y-031.594 Z 000.016
089 X 047.826 Y-023.690 Z 000.070
090 X 047.826 Y-015.794 Z 000.086
091 X 047.816 Y-007.920 Z 000.052
092 X 047.832 Y 000.008 Z-000.040
093 X 054.732 Y-106.564 Z-000.022
094 X 054.738 Y-098.700 Z-000.058
095 X 054.728 Y-090.804 Z-000.030
096 X 054.682 Y-082.922 Z 000.008
097 X 054.706 Y-075.024 Z 000.014
098 X 054.582 Y-067.140 Z-000.000
099 X 054.692 Y-059.252 Z-000.004
100 X 054.666 Y-051.338 Z 000.024
101 X 054.688 Y-043.458 Z 000.030
102 X 054.666 Y-035.560 Z 000.034
103 X 054.678 Y-027.658 Z-000.016
104 X 054.566 Y-019.780 Z 000.072
105 X 054.560 Y-011.860 Z 000.086
106 X 054.672 Y-003.980 Z 000.026
107 X 061.560 Y-102.640 Z-000.044
108 X 061.556 Y-094.728 Z-000.030
109 X 061.518 Y-086.852 Z-000.018
110 X 061.510 Y-078.962 Z-000.020
111 X 061.530 Y-071.080 Z-000.004
112 X 061.520 Y-063.190 Z 000.012
113 X 061.494 Y-055.270 Z 000.002
114 X 061.502 Y-047.402 Z 000.012
115 X 061.502 Y-039.500 Z 000.018
116 X 061.518 Y-031.604 Z 000.034
117 X 061.486 Y-023.712 Z 000.084
118 X 061.500 Y-015.840 Z 000.114
119 X 061.500 Y-007.922 Z 000.060
120 X 068.364 Y-098.692 Z 000.012

Graph-7-3

121	X 068.344	Y-090.798	Z-000.004
122	X 068.362	Y-082.924	Z 000.042
123	X 068.346	Y-075.024	Z-000.010
124	X 068.356	Y-067.148	Z 000.024
125	X 068.334	Y-059.244	Z 000.052
126	X 068.344	Y-051.340	Z-000.008
127	X 068.342	Y-043.454	Z-000.008
128	X 068.340	Y-035.568	Z 000.038
129	X 068.324	Y-027.664	Z 000.030
130	X 068.320	Y-019.762	Z 000.054
131	X 068.338	Y-011.862	Z 000.050
132	X 075.222	Y-094.760	Z-000.046
133	X 075.202	Y-086.842	Z-000.048
134	X 075.204	Y-078.970	Z-000.006
135	X 075.180	Y-071.056	Z 000.012
136	X 075.206	Y-063.196	Z-000.048
137	X 075.186	Y-055.284	Z 000.010
138	X 075.202	Y-047.390	Z 000.000
139	X 075.200	Y-039.482	Z 000.064
140	X 075.192	Y-031.590	Z-000.032
141	X 075.214	Y-023.706	Z 000.008
142	X 075.186	Y-015.822	Z 000.068
143	X 082.048	Y-090.790	Z-000.052
144	X 082.046	Y-082.920	Z-000.016
145	X 082.020	Y-075.028	Z-000.000
146	X 082.038	Y-067.160	Z-000.022
147	X 082.014	Y-059.242	Z-000.014
148	X 082.044	Y-051.324	Z 000.070
149	X 082.024	Y-043.432	Z-000.010
150	X 082.034	Y-035.564	Z 000.024
151	X 082.016	Y-027.670	Z 000.046
152	X 082.004	Y-019.778	Z 000.080
153	X 088.868	Y-086.850	Z-000.048
154	X 088.872	Y-078.962	Z-000.010
155	X 088.882	Y-071.070	Z 000.028
156	X 088.898	Y-063.190	Z 000.028
157	X 088.864	Y-055.284	Z-000.038
158	X 088.862	Y-047.378	Z 000.010
159	X 088.860	Y-039.486	Z 000.028
160	X 088.814	Y-031.610	Z 000.014
161	X 088.834	Y-023.704	Z 000.020
162	X 095.724	Y-082.904	Z-000.056
163	X 095.714	Y-075.002	Z-000.020
164	X 095.678	Y-067.098	Z-000.046
165	X 095.700	Y-059.210	Z-000.006
166	X 095.684	Y-051.346	Z-000.038
167	X 095.712	Y-043.442	Z 000.004
168	X 095.698	Y-035.526	Z-000.032
169	X 095.674	Y-027.640	Z-000.028

3. Results of Test by Compression at Right Angles to the Spindle

A test by compression at right angles to the spindle was conducted on unmachined castings, on the basis of Item 4 "Tests and Checks" in the "Specifications concerning the Support Structure for Fuel Elements of MONJU Core Fuel Assembly."

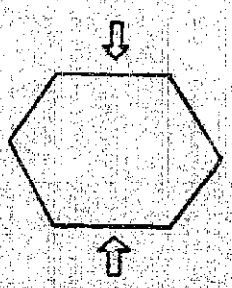
Castings and testing machines used were as follows.

Castings: Two pieces of castings, 12mm thick, whose X-ray inspection showed no blowholes, or other internal or external defects.

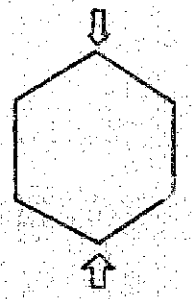
Testing Machines: 10-ton Amsler universal testing machine

3-1 Test Method

Measurement was made of strength in two different directions.



A



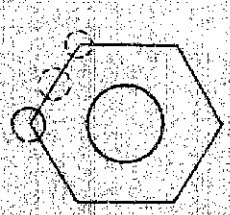
B

3-2 Results

A. Load-displacement curve is given in Graph 8.

The limit switch actuated at 9.2 ton, so no further measurement could be made by the testing machine.

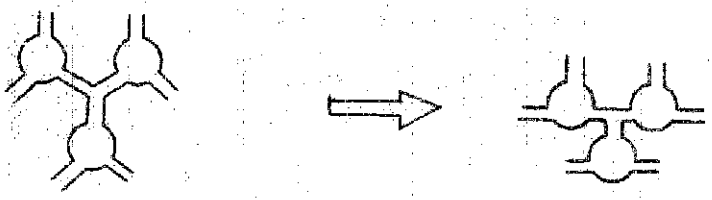
Process of displacement



Deformation displacement is found occurring in some parts of the ribs. It is particularly notable in ribs of center a.

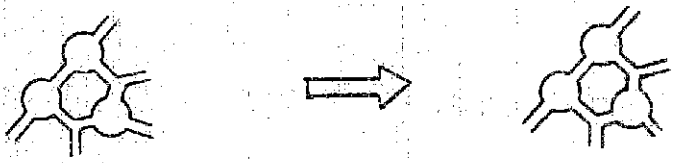
The ribs in the center deformed as follows.

Compression

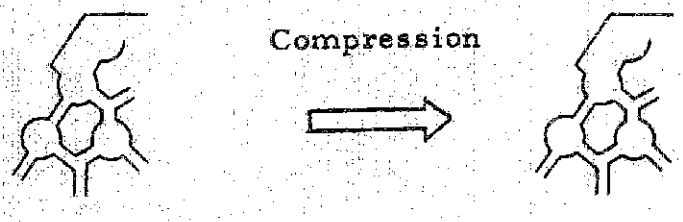


Peripheral b ribs

Compression

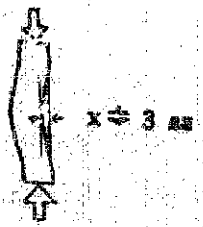


Corner C ribs



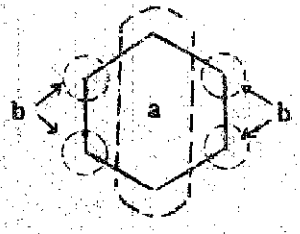
Corner d ribs scarcely deformed.

Becuase of the load, the castings buckled by about 3 mm as illustrated in the following figure.

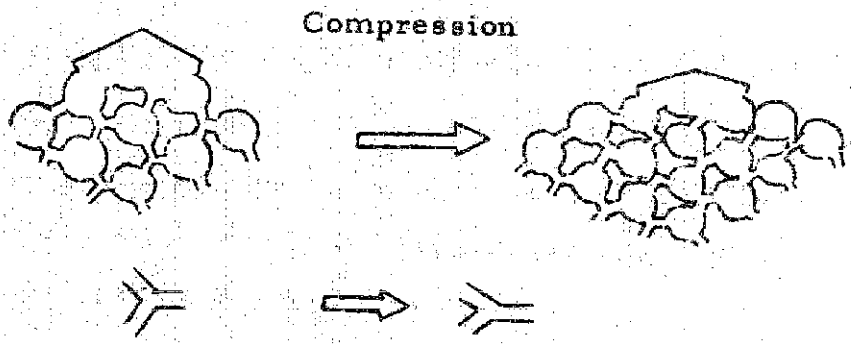


B. Load-displacement curve is given in Graph 9.

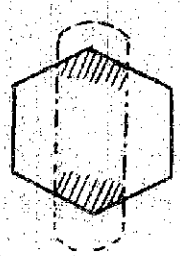
Process of deformation



Deformation is noticed in every rib of the casting, excepting corner b. It was particularly significant in part a.



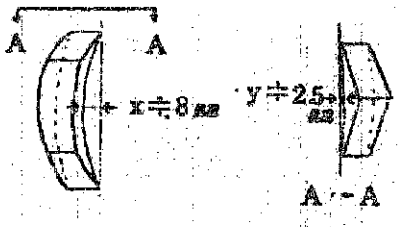
Unlike the test results in A, deformation is particularly noticeable in the shadowed portion of ribs in part a. Some of the ribs were found to have broken.



Out of the two concaves in Graph 9, the one with smaller load resulted at the time when the ribs in the shadowed portion of the above figure collapsed. With the collapse of ribs, the rigidity of specimens increases more than before the collapse, thus creating a rightward upturn in the load-displacement curve once again. The other concave occurred when all ribs in part broke.

When the curve reaches a maximum it begins downward trend,

since the buckling of speciments becomes larger in this neighborhood. The degree of buckling is as illustrated below.



4. Rib Strength Test Results

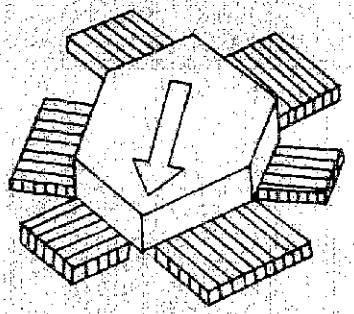
Rib strength test was conducted by application of axial compression with regard to unmachined castings, on the basis of Item 4 "Tests and Checks" in the "Specifications concerning the Support Structure for Fuel Elements of MONJU Core Fuel Assembly."

4-1 Castings and Testing Machines Used

Castings: One piece of casting, 12 mm thick, whose X-ray inspection showed fine blowhole in its outermost periphery.

Testing Machine: 10-ton Amsler universal test machine

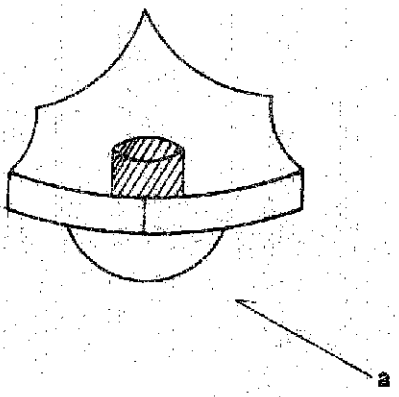
4-2 Test Method



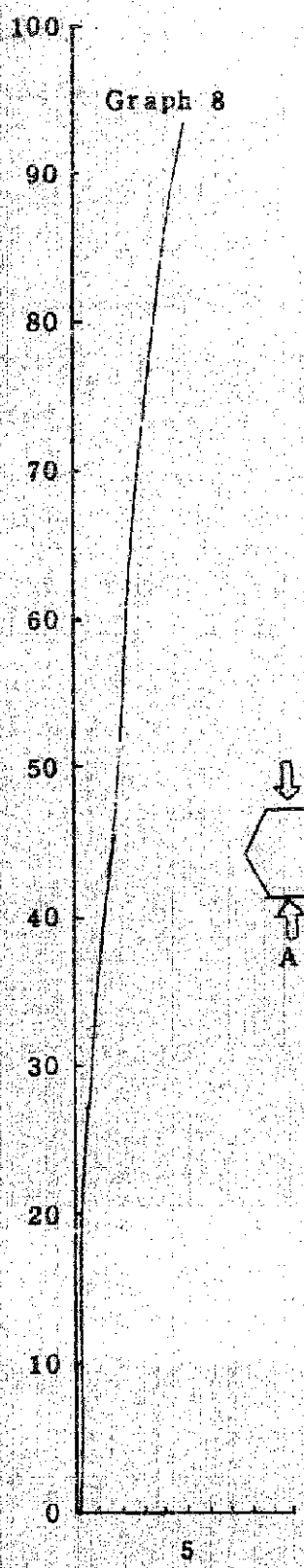
As illustrated in the left figure, steel plates were inserted under specimen periphery and load was applied on seven bosses in the upper center.

4-3 Results

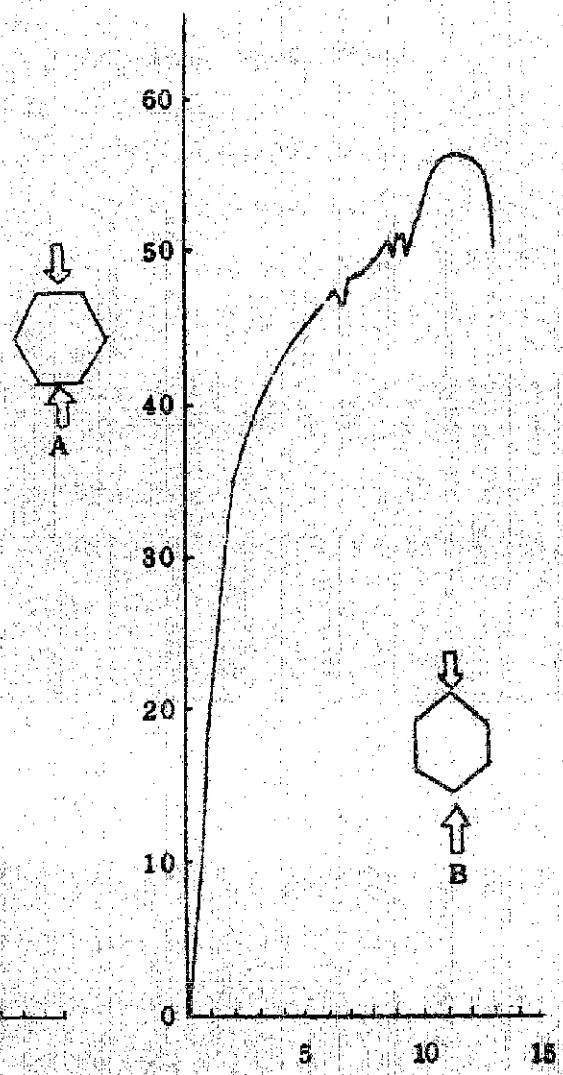
Load-displacement curve is given in Graph 10. Under a load of about 5.6 ton, a crack occurred in a rib of part a as illustrated below, and because of its deterioration, the curve begins to take a downward trend.



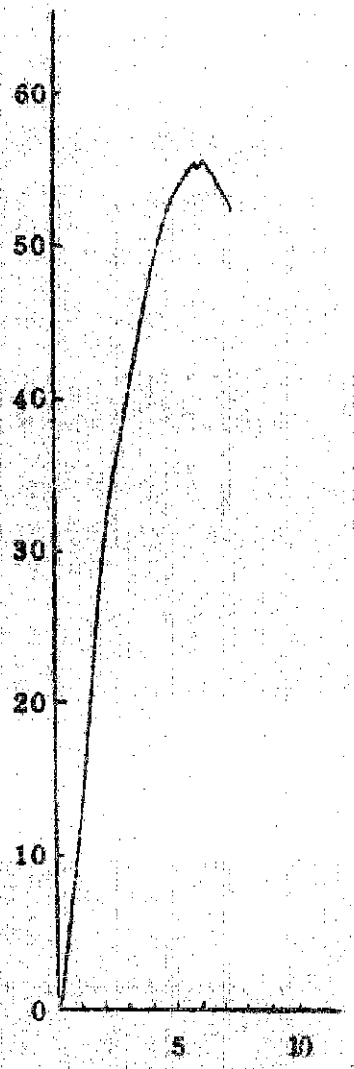
Graph 8



Graph 9



Graph 10



5. Blowhole Inspection

Castings were immersed in a X-ray shielding solution, whose density was the same with that of the castings, and were subjected to X-ray inspection.

Out of all castings X-rayed for inspection, the following eight castings were found to have blowholes.

Nos. 1, 5, 7, 10, 11, 15, 16, 18. These represent the positions where troubles of some form or other might develop when they are machined. These castings can be described as being worse than the castings used in JOYO core. This is attributed to insufficient dead head at the time of castings production resulting from their large size.

6. Degree-of-Cavity Test on Castings

Specific gravity was measured in regard to unmachined castings on the basis of Item 4 "Tests and Checks" in the "Specifications concerning the Support Structure for Fuel Elements of MONJU Core Fuel Assembly."

6-1 Castings Used

No. 6 Casting in which no blowholes were detected by X-ray inspection

No. 10 Casting in which blowholes were detected by X-ray inspection

No. 14 "

No. 15 "

No. 18 "

6-2 Test Method

1. Weight measurement in the air W [g]
2. Castings were immersed in water and pressure reduced for thirty minutes
3. Weight measurement in water W_1 [g]

4. Calculation of specific gravity

$$D = \frac{W}{W - W_1} \cdot \rho$$

ρ : Specific gravity of water at test water temperature

Here no correction is made by air buoyancy.

6-3 Results

No. 6	7.934	Specific gravity of SUS32	7.98 ~ 8.03
No. 10	7.862		
No. 14	7.917		
No. 15	7.925		
No. 18	7.931		

7. Review

The results of the series of tests and checks revealed that except for some blowholes, there were no problems with regard to strength and dimensional accuracy and that casting surface has improved enough to describe the castings as passable and available. In regard to blowholes, their solution can be found through further study on methods of casting.

With MONJU, casting-type grid can be usable instead of knock bar type. For MONJU, it is far beneficial to use the grid type, since the increase in the use of fuel pins makes the assembly of knock bar system difficult.

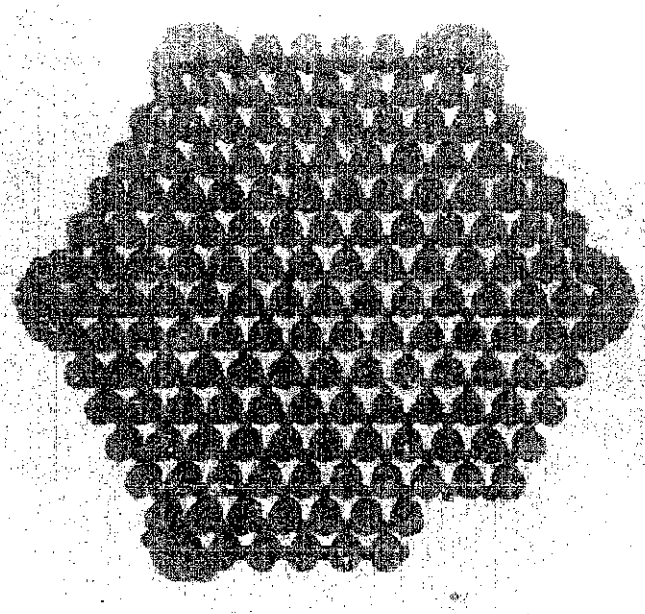


Photo.1. Castings: Upperleft corner is missing, due to its submission to a destruction test following a discovery of blowholes in it.

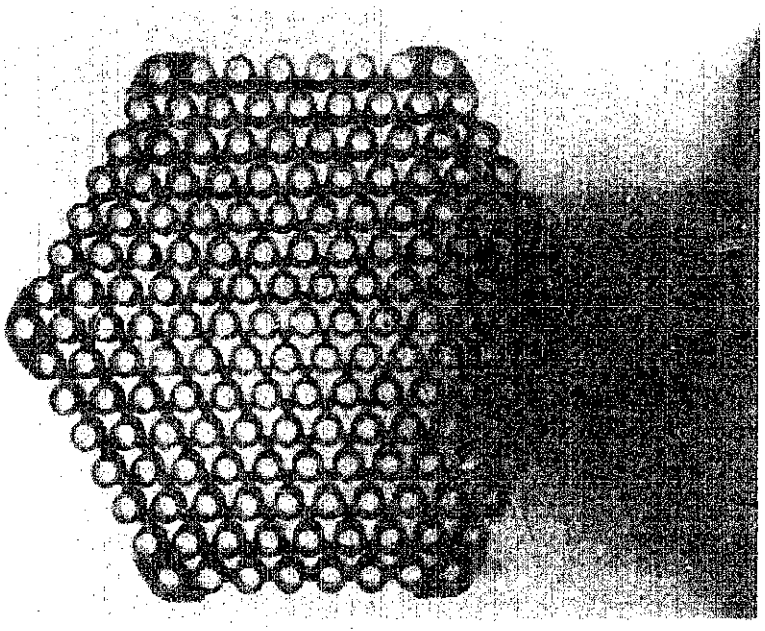


Photo.2. After machining

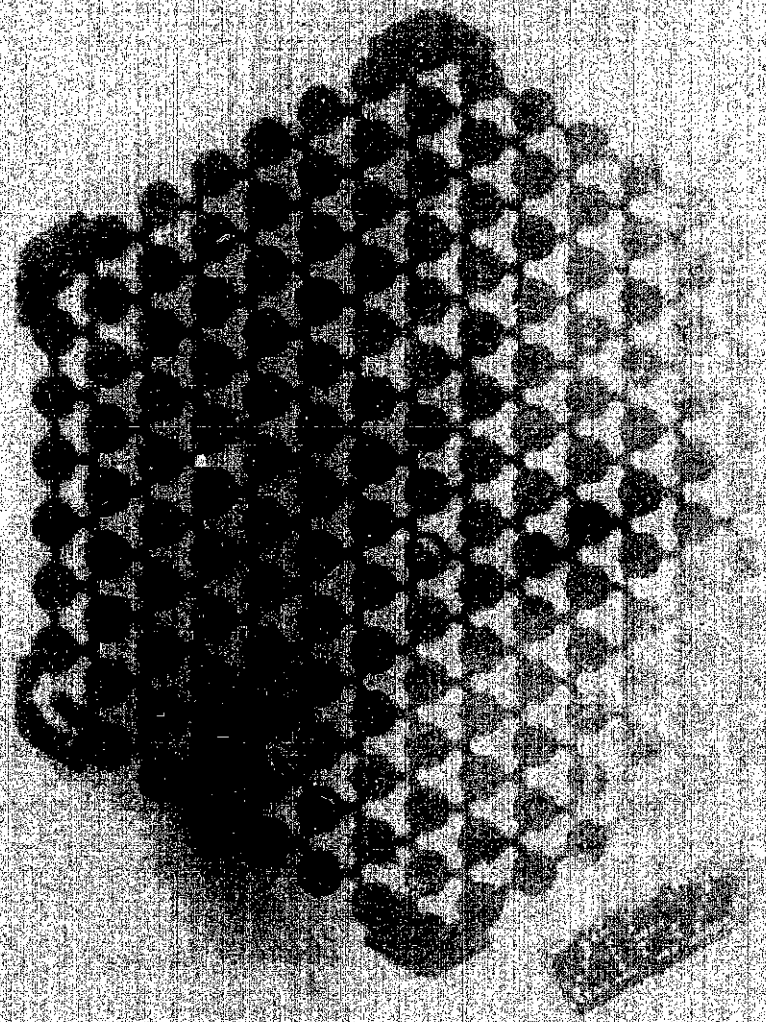


Photo. 3. X-ray photograph of blowholes: Blowholes are found in the lowerleft end.

Photo.4. Destruction test on the blowholes in Photo 3.

Photo. 5. Compression test: load 9.2 ton.

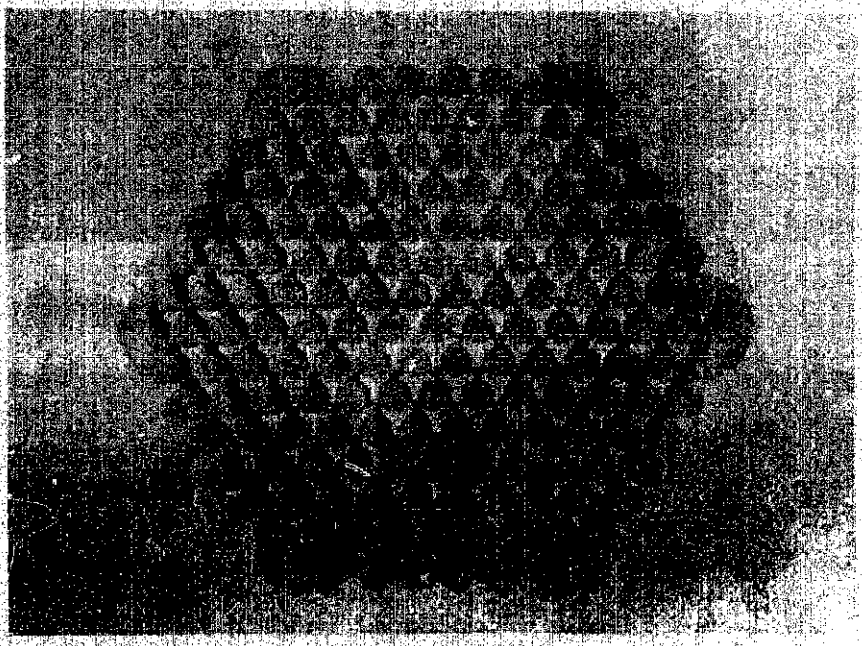


Photo. 6. After test.

Photo. 7.
Compression test:
load 4.6 ton.

Photo. 8.
Compression test:
load 5.3 ton.

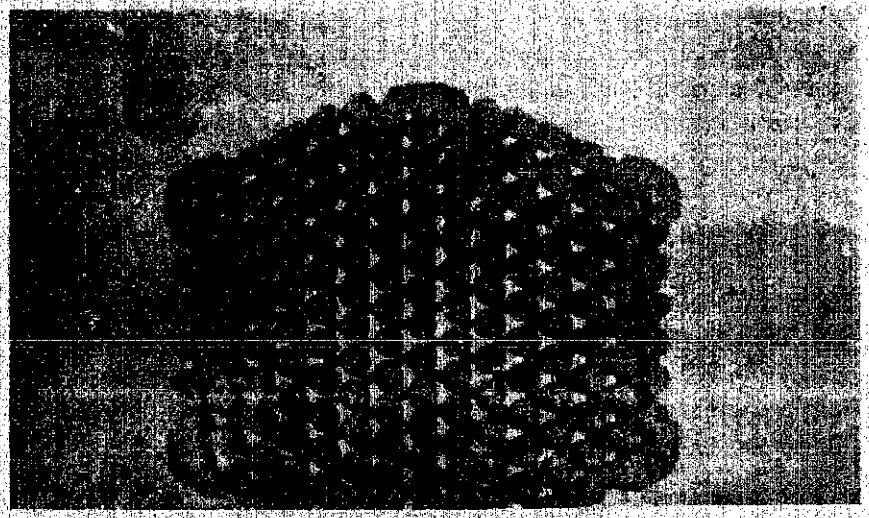


Photo. 9.
After test.

Photo. 10.
Compression test:
load 5.6 ton.

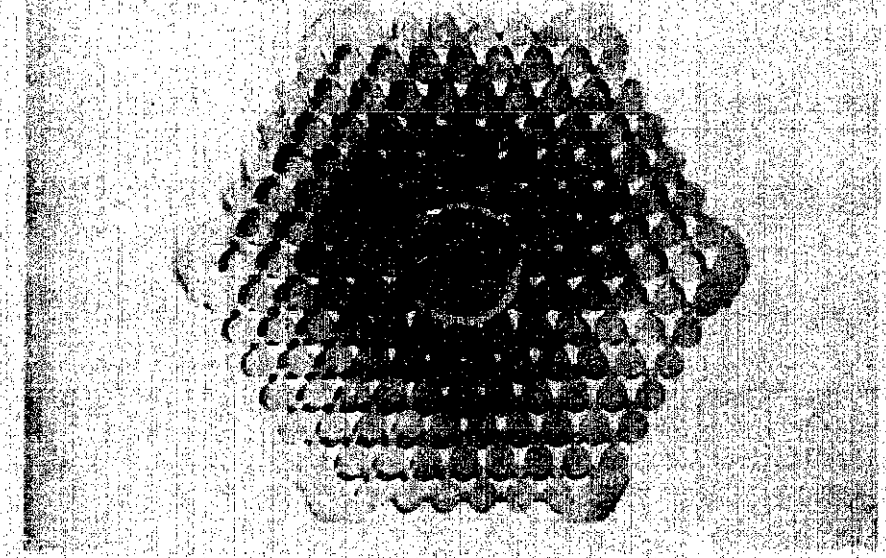


Photo. 11.
After test:
The circle in the center is the upper side of the compressed end.

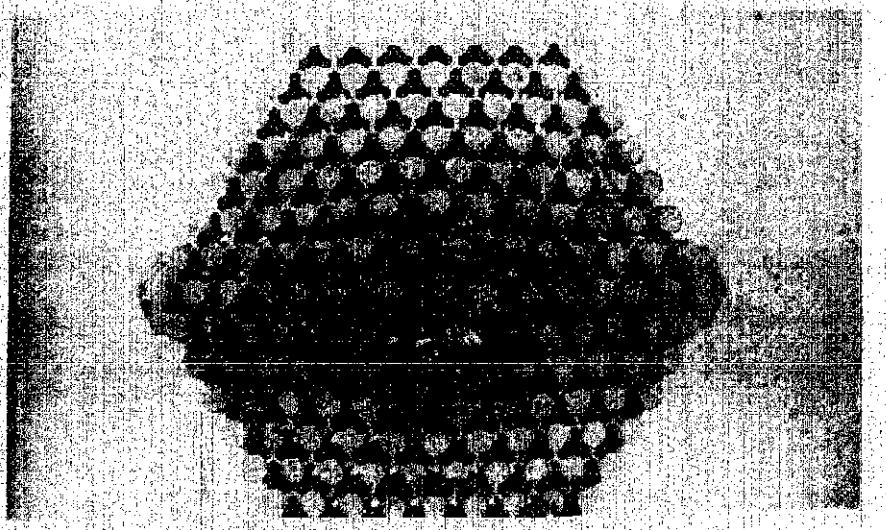


Photo. 12.
After test:
The circle in the center is the rear side