

SUS制御棒半挿入実験

局所出力変動および熱中性子束分布データ集

1983年5月

動力炉・核燃料開発事業団

大洗工学センター

複製又はこの資料の入手については、下記にお問い合わせください。

〒311-13 茨城県東茨城郡大洗町成田町4002

動力炉・核燃料開発事業団

大洗工学センター システム開発推進部・技術管理室

Enquires about copyright and reproduction should be addressed to: Technology Management Section O-arai Engineering Center, Power Reactor and Nuclear Fuel Development Corporation 4002 Narita-cho, O-arai-machi, Higashi-Ibaraki, Ibaraki-ken, 311-13, Japan

動力炉・核燃料開発事業団 (Power Reactor and Nuclear Fuel Development Corporation)

SUS制御棒半挿入実験

局所出力変動および熱中性子束分布データ集

竹村守雄^{*}，小綿泰樹^{**}
安保昌憲^{***}，柴田邦広^{***}，北山一宏^{****}

要 旨

圧力管型重水炉の実証炉においては、出力調整用制御棒（SUS制御棒）を用いて負荷追従運転を行うことになっている。このためSUS制御棒（以下単に制御棒とよぶ）引抜に伴う制御棒近傍の局所的出力変動に関し、核設計コードの精度評価を行ない燃料設計および負荷追従運転に反映させる必要がある。この精度評価に必要な実験データとして燃料ピンの局所的出力変動および熱中性子束分布を測定した。

0.54wt%プルトニウム燃料を部分装荷した25cmピッチ格子のDCA炉心のほぼ中央部に、実証炉に用いる制御棒と同一寸法の74mmφのSUS制御棒を炉心下端から505mmの高さに半挿入し、その位置から制御棒を100mm引抜いた場合（反応度で約40¢印加）について実験を行った。また、局所出力変動に関してはWIMS-CITATIONコードを用いた3次元拡散計算結果との比較も行った。

この結果以下の事項が明らかとなった。

- (1) 燃料集合体内第3リング燃料ピンの局所的出力変動は、制御棒に最も近い燃料ピンで最大となり、その最大出力変動は、制御棒先端の引抜部分のほぼ中間の位置で発生する。ただし、局所出力変動が第3リング燃料ピンで最大となるかどうかはこの実験では明らかではない。
- (2) 制御棒を100mm引抜いた場合、引抜かない場合に比較し、第3リング燃料ピンの最大出力変動比は (1.12 ± 0.03) である。

* 川崎重工業株式会社

** 大洗工学センター重水臨界実験室

*** 三菱重工業株式会社

**** 新型転換炉ふげん発電所

- (3) 燃料ピンの局所出力変動が顕著に起る燃料集合体は、制御棒に隣接した集合体およびそれから更に1ピッチ離れた位置の集合体とであるが、隣接燃料集合体でも制御棒からみて裏側の位置にある燃料ピンでの出力変動は2%以下で極めて小さい。
- (4) 第3リング燃料ピンにおける最大出力変動比の計算値は1.168となり、実験値と比べて約4%過大評価する。

May. 1983

Critical Experiment on Half-Inserted SUS Control-rod
Measurement of change in power distribution
in fuel pin close to control-rod

M. Takemura^{*}, Y. Kowata^{**}, M. Abo^{***}
K. Shibata^{****} and K. Kitayama^{****}

Abstract

Pressure tube type heavy water reactor has an advantage of load following operation compared with light water reactor. It is planned to prove the possibility of load following operation in the Fugen type demonstration reactor using stainless control-rod (SUS control-rod).

Changes in local power distribution and thermal flux distribution due to a small withdrawal of SUS control-rod have been measured for the purpose of confirming the soundness of fuel pin from the viewpoint of the load following operation and fuel design.

SUS control-rod (74mm ϕ) with the same dimension as those of the demonstration reactor was inserted into the D₂O moderator of the central region of 0.54wt% plutonium mixed-oxide fuel lattice in 25-cm pitch DCA core. The lower end height of the control-rod inserted was changed from 505mm to 605mm (about 40 $\%$ change in reactivity).

Experimental results for the local power change were compared with calculations obtained from WIMS-D and CITATION codes.

The following were concluded from the present study.

- (1) The maximum power change in outer layer pins of fuel cluster due to a small withdrawal of the control-rod occurs in the nearest fuel pin at the middle position of the axial displacement of the control-rod.

* Kawasaki heavy industry Co. Ltd.

** Heavy water critical experimental section, Oarai engineering center, PNC.

*** Mitsubishi heavy industry Co. Ltd.

**** Fugen power station, PNC.

(2) Outer layer fuel pin power after 100mm withdrawal of control-rod is (1.12 ± 0.03) times in maximum as large as that before withdrawal.

(3) Local pin power change due to withdrawal of the control-rod occurs mainly in the fuel pins of the nearest and the second nearest fuel clusters to the control-rod. Even in the nearest fuel cluster to the control-rod, power change in the back side fuel pin to the control-rod is very small below 2%.

(4) Calculated value of maximum ratio for the outer layer fuel pin power due to 100mm withdrawal of the control-rod overestimate experimental one about 4%.

Contents

| | |
|---|----|
| 1. Core configuration | 1 |
| 2. Measurement condition | 9 |
| 3. Results of criticality, control-rod worth and power level | 19 |
| 4. Results of power distribution | 27 |
| 5. Neutron flux distribution near the control-rod | 53 |
| 6. Radial neutron flux distribution in the core | 63 |
| 7. Axial neutron flux distribution near the control-rod | 75 |
| 8. Result of lattice cell and reactor core calculation | 93 |

1. Core configuration

- Fig. 1.1 Configuration of DCA core having 25-cm pitch lattice.
- Fig. 1.2 Cross-sectional view of a fuel assembly.
- Fig. 1.3 Cross-section of stainless-steel control-rod.
- Fig. 1.4 Vertical arrangement of control-rod in DCA core.

Table 1.1 Specification of fuel assembly and composed materials.

Table 1.2 Composition of fuel pellet, sheath and control-rod.

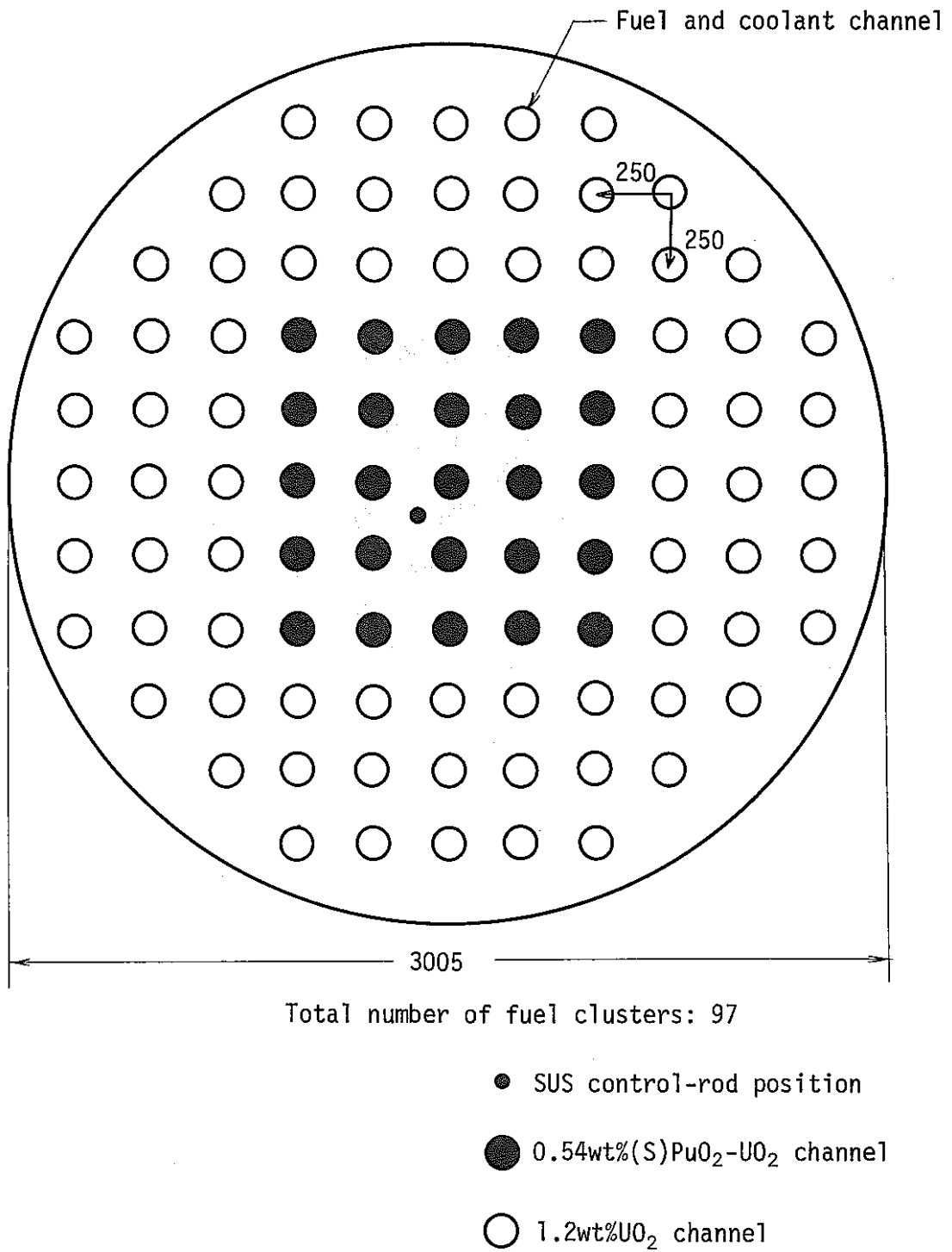


Fig. 1.1 Configuration of DCA core having 25-cm pitch lattice

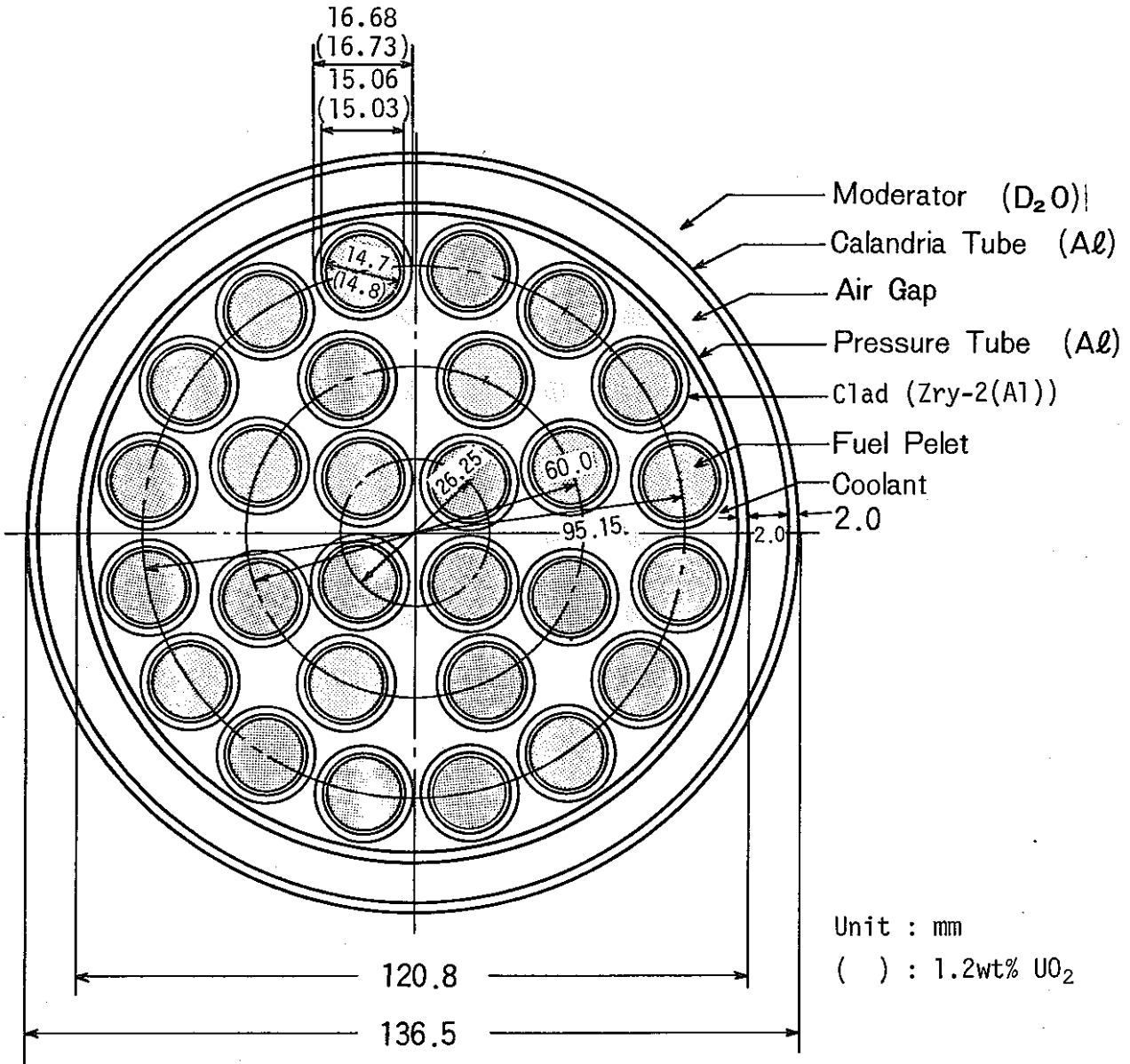
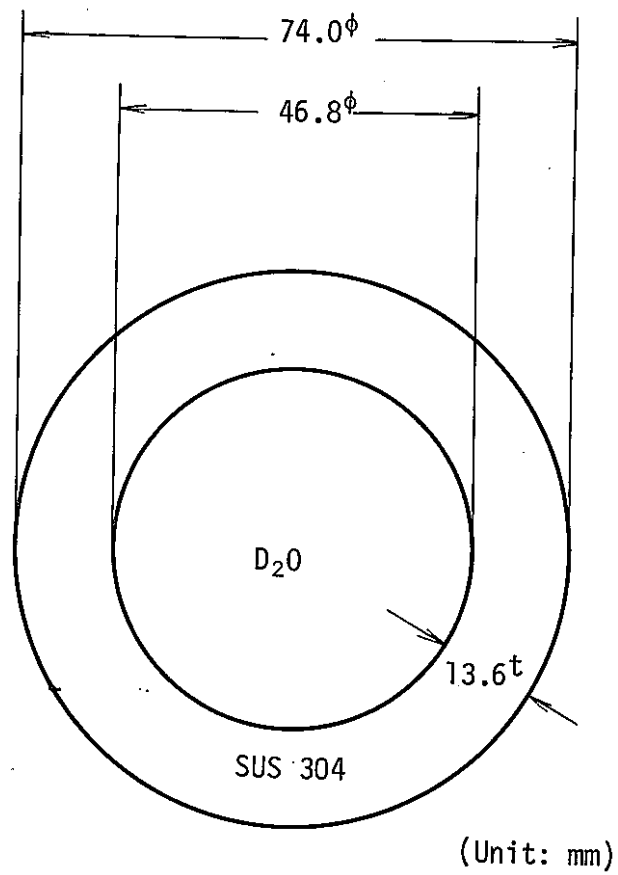


Fig. 1.2 Cross-sectional view of a fuel assembly



| | |
|----------|------------------------|
| Absorber | SUS 304 |
| Length | 1500 mm |
| Density | 7.93 g/cm ³ |

Fig. 1.3 Cross-section of stainless steel control-rod

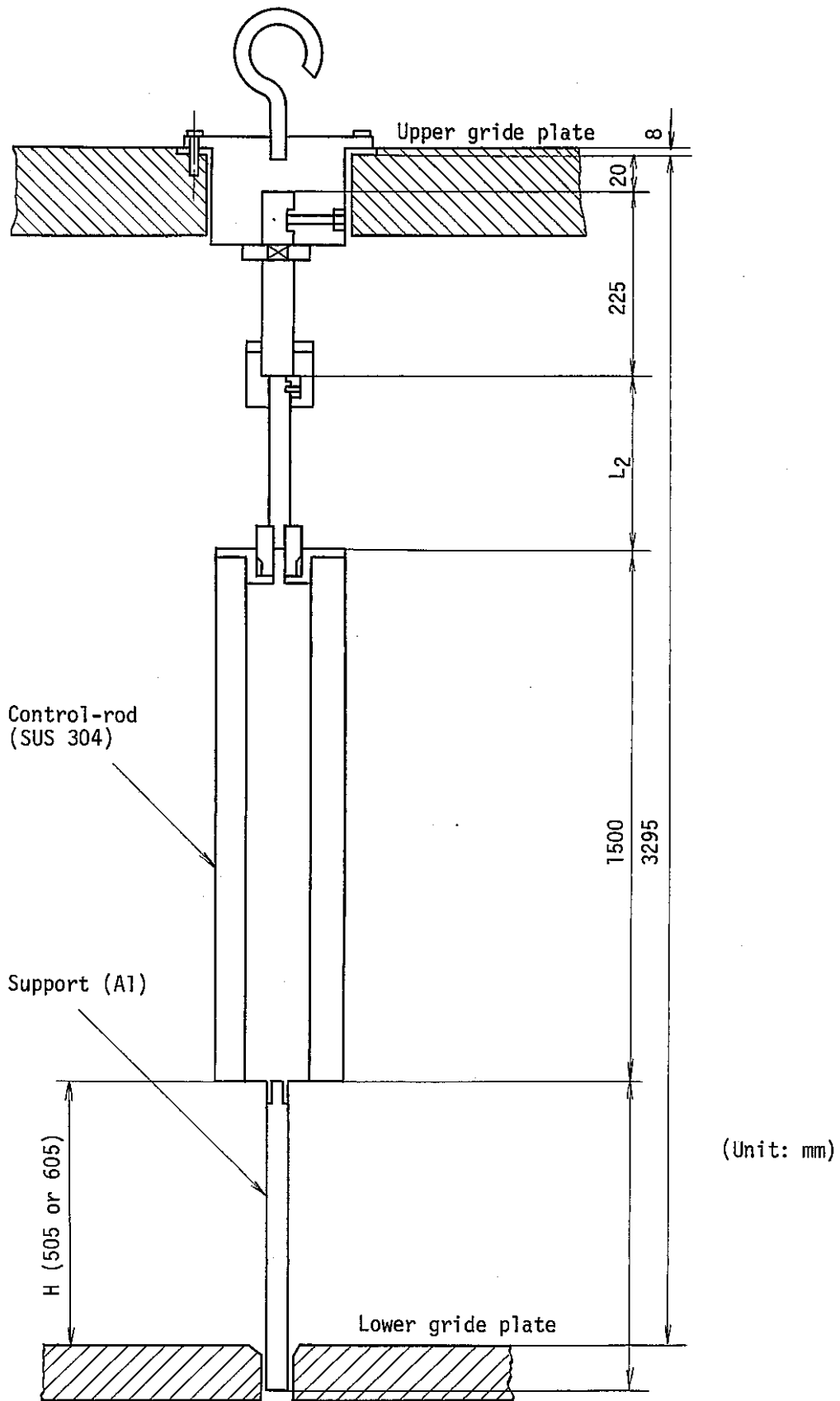


Fig. 1.4 Vertical arrangement of control-rod in DCA core

Table 1.1 Specification of fuel assembly and composed materials

(a) Fuel rod

| Fuel rod | Name | Outer dia. (mm) | Material | Density (g/cm ³) |
|--|--------|--------------------|---|---------------------------------|
| 0.54wt% PuO ₂ -UO ₂ | Pellet | 14.80 | Pu enriched PuO ₂ -UO ₂ * | 10.17 |
| | Gap | 15.03 | Helium | — |
| | Sheath | 16.73 | Zry-2 | 6.523 |
| 1.2wt% UO ₂ | Pellet | 14.80 | 1.2wt% UO ₂ | 10.36 |
| | Gap | 15.03 | Helium | — |
| | Sheath | 16.73 | Al-Mg alloy | 2.674 |

$$* \text{ Enrichment} = \frac{\text{PuO}_2}{\text{PuO}_2 + \text{UO}_2}$$

(b) Composed material

| Name | Inner dia. (mm) | Outer dia. (mm) | Material | Density (g/cm ³) |
|----------------|--------------------|--------------------|-----------------------------|---------------------------------|
| Pressure tube | 116.8 | 120.8 | Al-Mg alloy | 2.674 |
| Gap | 120.8 | 132.5 | Air | 0.001 |
| Calandria tube | 132.5 | 136.5 | Al-Mg alloy | 2.674 |
| Moderator | 136.5 | — | 99.45 mol% D ₂ O | 1.1045 |
| Coolant | — | — | H ₂ O | 0.9978 |
| Control-rod | 46.8 | 74.0 | SUS 304 | 7.93 |

Table 1.2 Composition of fuel pellet, sheath and control-rod

(a) Pellet

| Pellet | Nuclide | Ingredient (wt%) | | Atomic number density ($\times 10^{24}/\text{cm}^3$) |
|--|---------|------------------|---------|---|
| | | Pu | whole | |
| 0.54wt% PuO ₂ -UO ₂ (36-rod fuel) | U -235 | | 0.6214 | 1.620×10^{-4} |
| | U -238 | | 86.782 | 2.233×10^{-2} |
| | Pu-238 | 0.021 | 0.00010 | $< 10^{-7}$ |
| | Pu-239 | 90.360 | 0.4304 | 1.103×10^{-4} |
| | Pu-240 | 8.640 | 0.04115 | 1.050×10^{-5} |
| | Pu-241 | 0.915 | 0.00436 | 1.108×10^{-6} |
| | Pu-242 | 0.064 | 0.00030 | $< 10^{-7}$ |
| | O -16 | | 12.12 | 4.640×10^{-2} |
| 1.2wt% UO ₂ (28-rod fuel) | U -235 | | 1.057 | 0.00028 |
| | U -238 | | 86.793 | 0.02275 |
| | O -16 | | 12.150 | 0.04738 |

(b) Sheath and control-rod

| Fuel rod or control-rod | Material | Nuclide | Ingredient (wt%) |
|---|-------------|----------|------------------|
| 0.54wt% PuO ₂ -UO ₂ | Zry-2 | Zr | 98.22 |
| | | Sn | 1.48 |
| | | Fe | 0.14 |
| | | Cr | 0.10 |
| | | Ni | 0.06 |
| 1.2wt% UO ₂ | Al-Mg alloy | Al | 96.98 |
| | | Ag | 2.60 |
| | | Inpurity | 0.42 |
| Control-rod | SUS 304 | Fe | 70.363 |
| | | Cr | 18.36 |
| | | Ni | 9.00 |
| | | Mn | 1.80 |
| | | Si | 0.39 |
| | | Ca | 0.046 |
| | | P | 0.03 |
| S | 0.009 | | |

2. Measurement condition

Table 2.1 List of experiment for various parameters.

- Fig. 2.1 Identification number of fuel channel and vertical experimental hole.
- Fig. 2.2 Transversal arrangement of fuel clusters contiguous to control-rod for measurement of power distribution.
- Fig. 2.3 Configuration of measurement system of gamma-ray emitted from ^{140}La in fuel.
- Fig. 2.4 Result of collimeter resolution for ^{140}La gamma-ray measurement system.
- Fig. 2.5 Arrangement of Dy samples for measurement of axial flux distribution in the face of fuel pin near the control-rod.
- Fig. 2.6 Measurement position of radial flux distribution in the core by Cu samples.

Table 2.1 List of experiment for various parameters

| Withdrawal height of control-rod (mm) | Axial power distribution of fuel pin | Thermal neutron flux distribution near the control-rod | | Thermal neutron flux distribution in the core | |
|---------------------------------------|--------------------------------------|--|---|---|--------------------------|
| | | Axial distribution of the face of fuel pin (Dy) | Radial distribution in the moderator (Dy) | Axial distribution (OD1, 2B2) (Cu) | Radial distribution (Cu) |
| (Full 0 insertion) | | | ○ | | ○ |
| 505 | ○ | ○ | ○ | ○ | ○ |
| 605 | ○ | ○ | ○ | ○ | ○ |

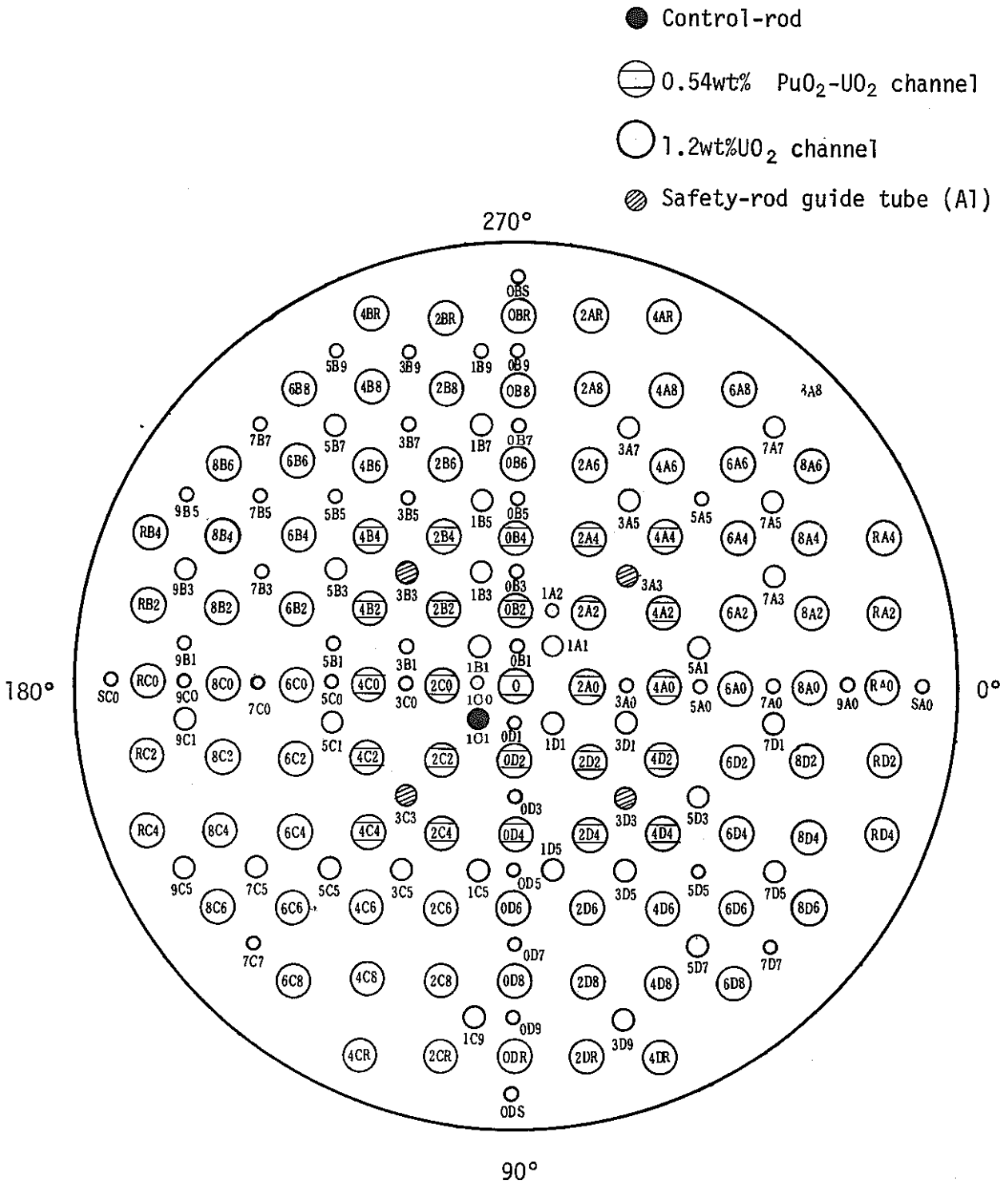


Fig. 2.1 Identification number of fuel channel and vertical experimental hole

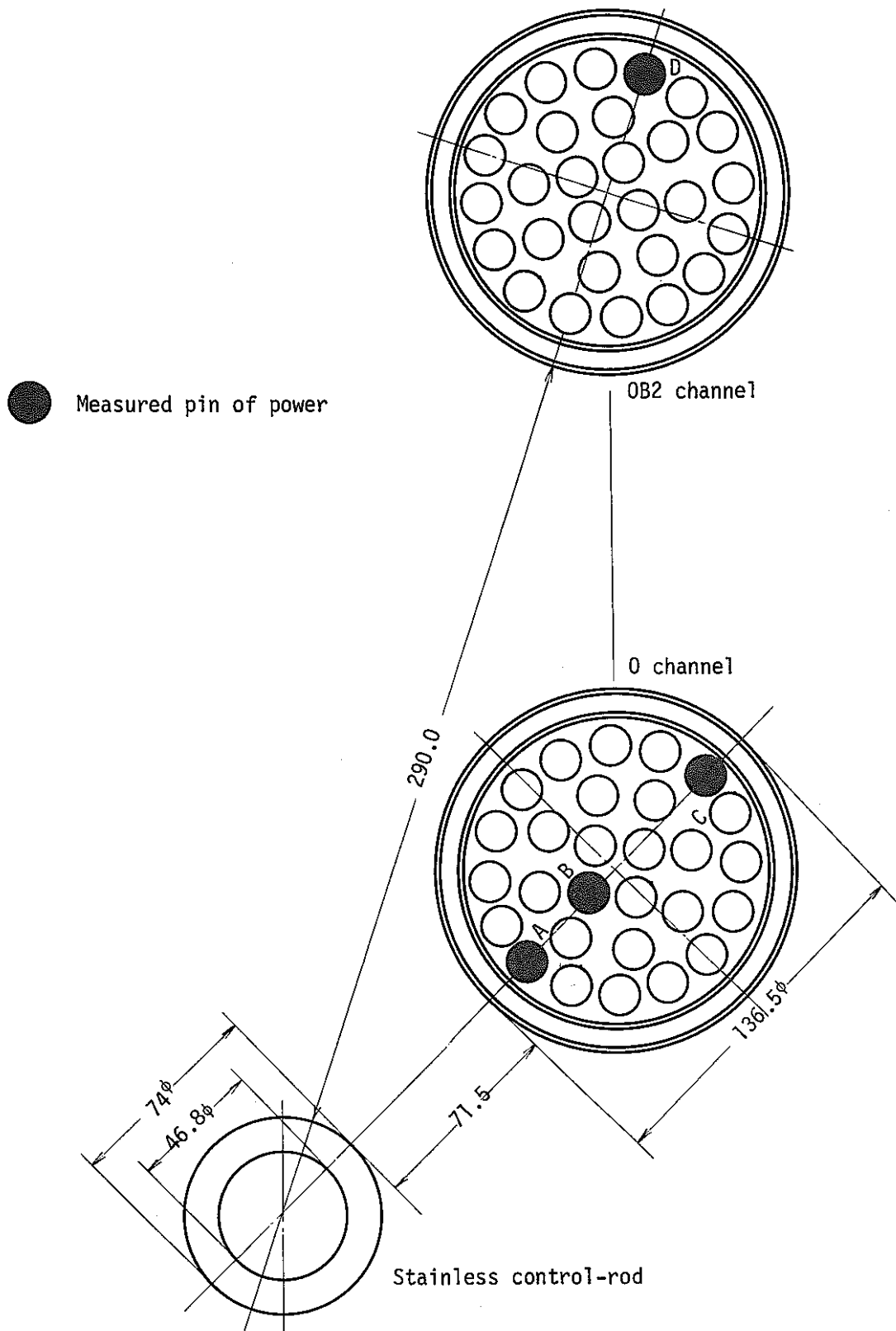


Fig. 2.2 Transversal arrangement of fuel clusters contiguous to control-rod for measurement of power distribution

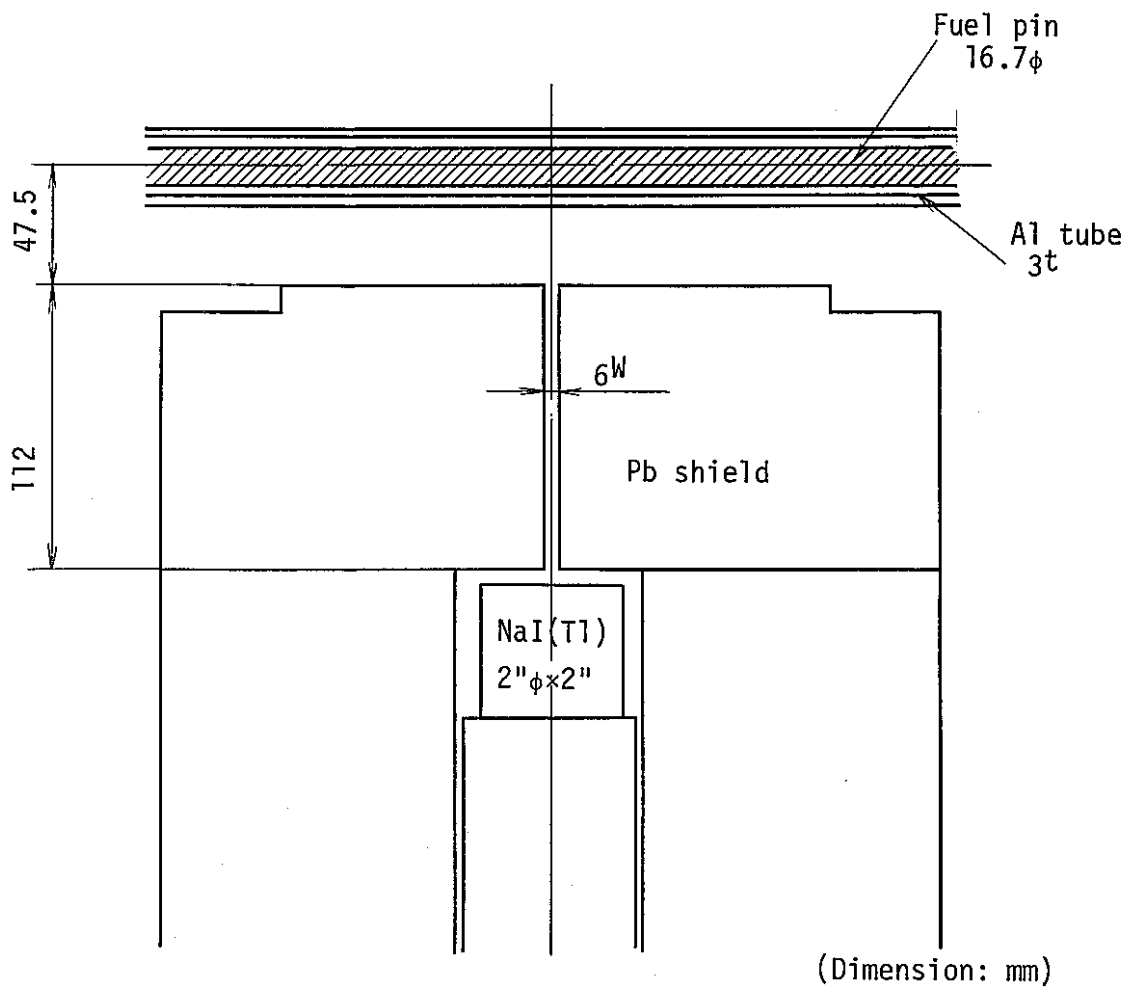


Fig. 2.3 Configuration of measurement system of gamma-ray emitted from ^{140}La in fuel

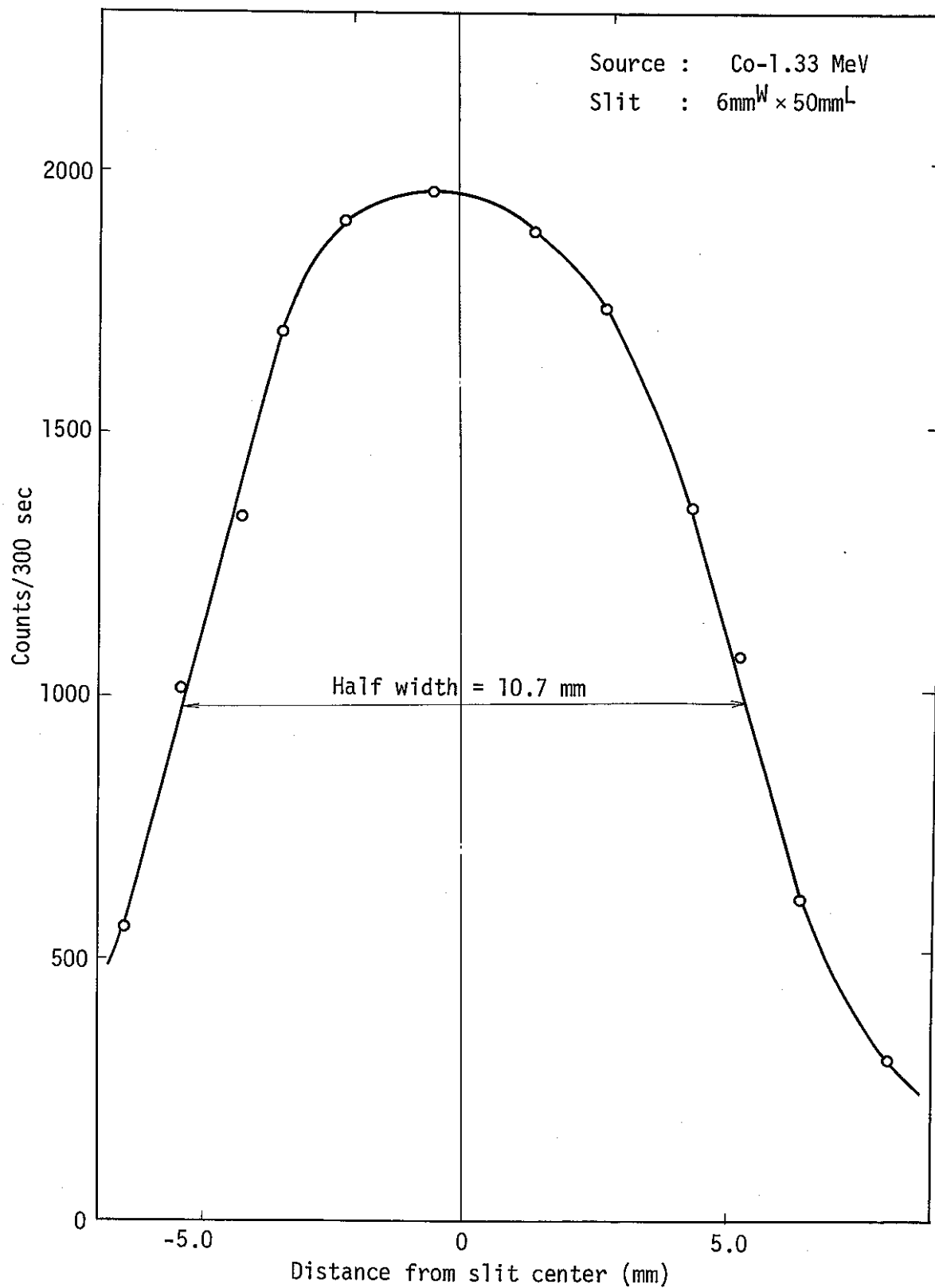


Fig. 2.4 Result of collimator resolution for ¹⁴⁰La gamma-ray measurement system

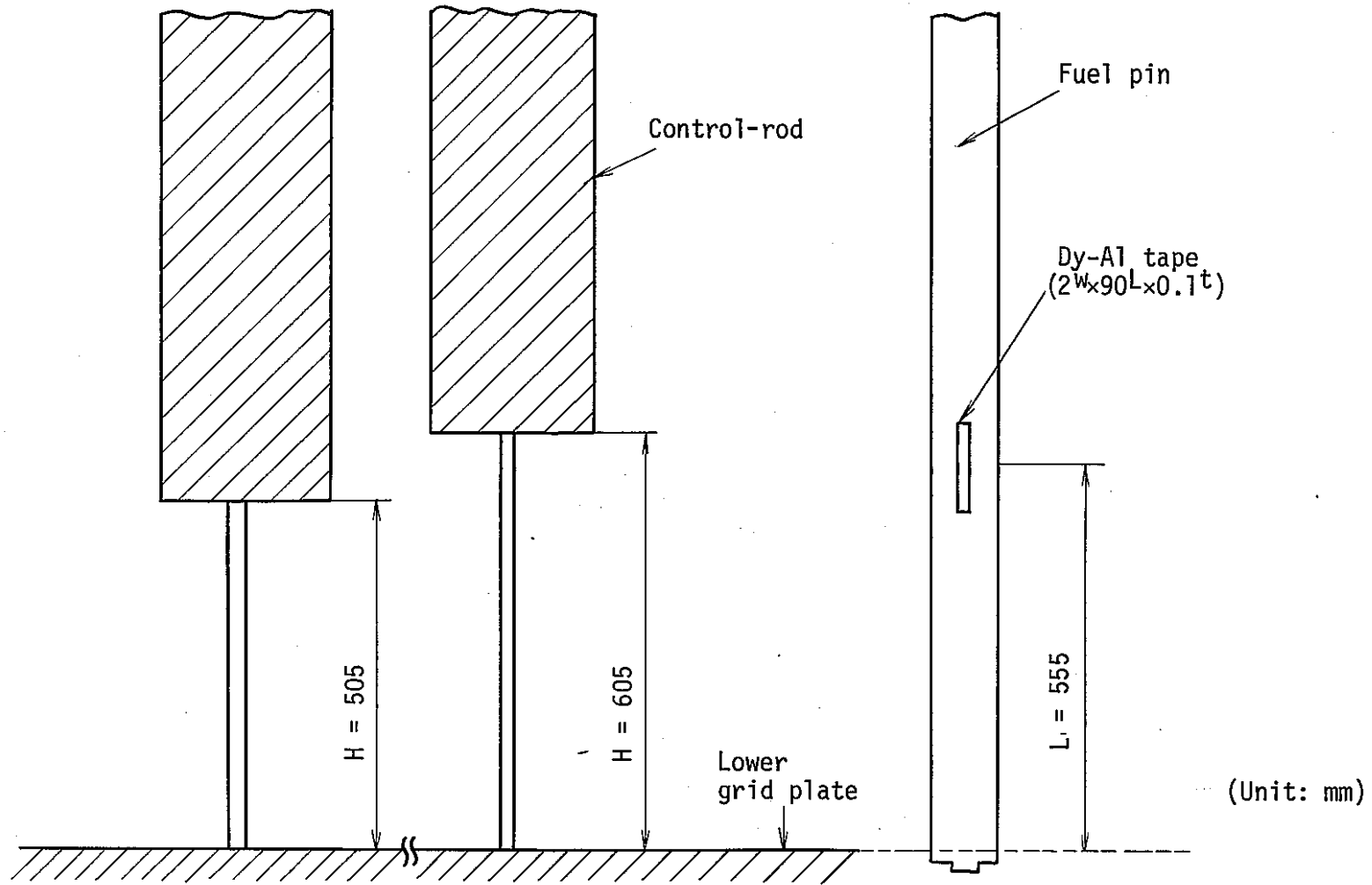


Fig. 2.5 Arrangement of Dy samples for measurement of axial flux distribution in the face of fuel pin near the control-rod

Radial position of $3\phi \times 10^L$ Cu
(Axial height: middle of core height)

\bigcirc In the center of cluster

\odot In D_2O moderator

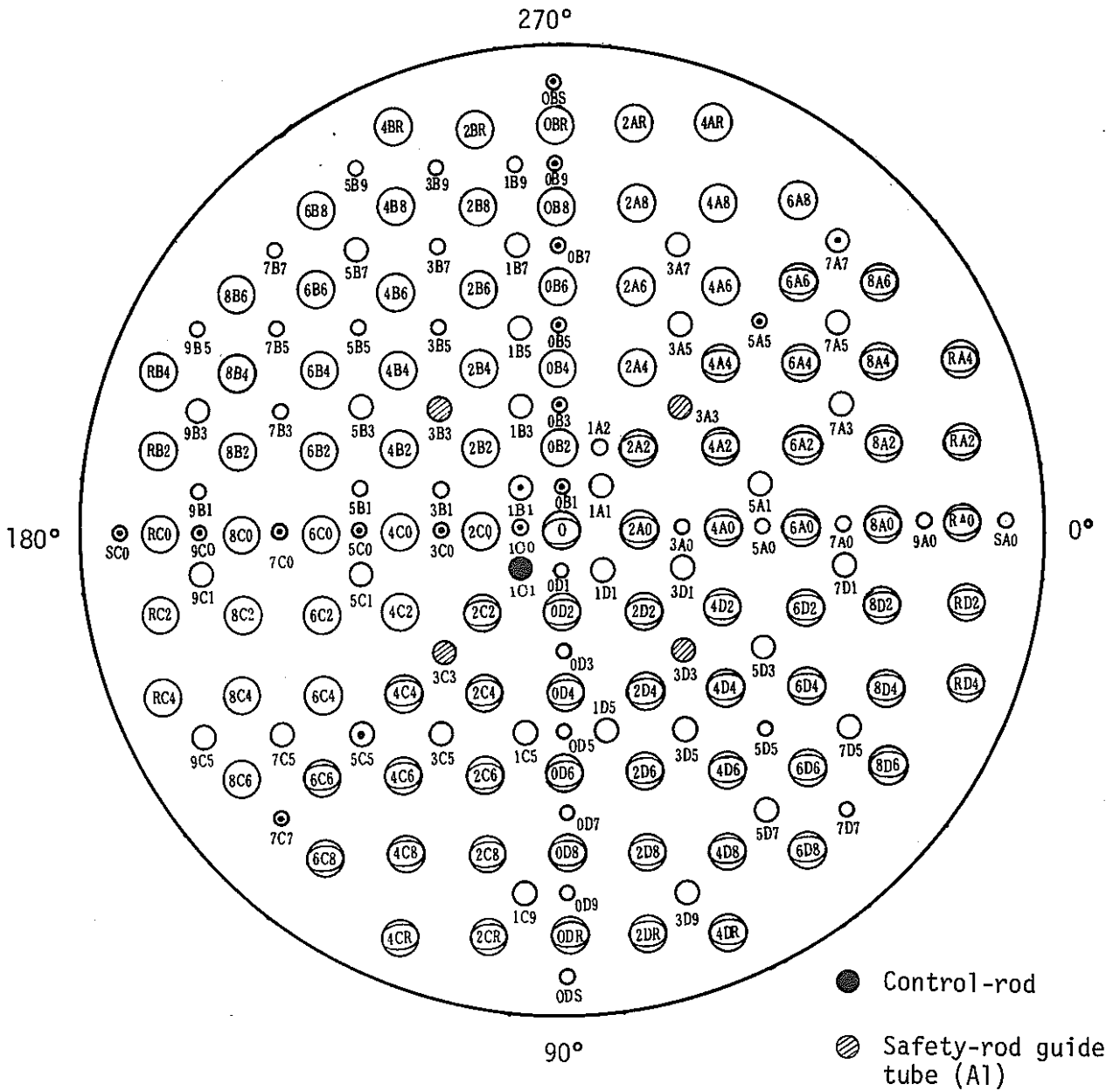


Fig. 2.6 Measurement position of radial flux distribution in the core by Cu samples

3. Results of criticality control rod worth and power level

- Table 3.1 Experimental result of critical moderator level and stainless control-rod reactivity worth.
- Table 3.2 Relative Au foil's activity at the face of reactor tank for power normalization in various measurement cases.
- Table 3.3 Maximum ratio of fuel pin power due to 100mm (505 → 605mm) withdrawal of control-rod.
- Table 3.4 Results for power conversion ratio obtained by three dimensional diffusion analysis.
- Table 3.5 Relation between relative power and Cu activity at 555mm height.

Table 3.1 Experimental result of critical moderator level and stainless control-rod reactivity worth.

Void fraction : 0%

Control-rod position : 1C1 (0.54wt%PuO₂-UO₂ lattice region)

| Control-rod | | Coolant H ₂ O level (mm) | Critical D ₂ O level (mm) | Difference of critical levels (mm) | Control-rod worth (\$) |
|---------------------------|-------------------------|---|--|--|------------------------------|
| Withdrawal height (mm) | Insertion length (%) | | | | |
| Withdrawal | 0 | 920 | 920.2 | 0.0 | — |
| 605 | 35 | 930 | 930.8 | 10.6 | -0.55 ± 0.07 |
| 505 | 46 | 935 | 938.4 | 18.2 | -0.94 ± 0.07 |
| 0 | 100 | 960 | 956.4 | 36.2 | -1.82 ± 0.07 |

Table 3.2 Relative Au foil's activity at the face of reactor tank for power normalization in various measurement cases

Axial position of foils : 555mm

(Unit : cps/mg)

| Withdrawal height of control-rod (mm) | Axial power distribution of fuel pins near the control-rod (1KW × 2hr irradiation) | Thermal neutron flux distribution (Cu) | |
|---------------------------------------|--|---|--|
| | | Axial distribution (300W × 30min irradiation) | Radial distribution (300W × 30min irradiation) |
| Full insertion | ————— | ————— | 6.252 ± 0.060 |
| 505 | 19.58 ± 0.03 | 6.333 ± 0.038 | 6.306 ± 0.009 |
| 605 | 19.48 ± 0.11 | 6.608 ± 0.063 | 6.474 ± 0.011 |

Table 3.3 Maximum ratio of fuel pin power due to 100mm (505 → 605mm) withdrawal of control-rod

| Channel No. | Fuel pin No.* | Distance from control-rod surface (mm) | Maximum pin power ratio (P_{605}/P_{505}) | Core height of occurring max. power ratio (cm) |
|-------------|---------------|--|---|--|
| 0 | A | 92.2 | 1.12 ± 0.03 | 57 ~ 58 |
| | B | 126.6 | 1.10 ± 0.03 | 47 ~ 50 |
| | C | 187.3 | 1.02 ± 0.02 | 42 ~ 60 |
| 0B2 | D | 443 | 0.93 ± 0.03 | 45 ~ 53 |

* See Fig. 22.

Table 3.4 Results for power conversion ratio obtained by three dimensional diffusion analysis

| Fuel channel | | Withdrawal height of control-rod | |
|---|-------------------------|----------------------------------|----------|
| | | 505 | 605 |
| 0 | ϕ_{thermal} | 30.69 | 33.68 |
| | ϕ_{epi} | 150.17 | 158.35 |
| | ϕ_{ave} | 41.83 | 45.30 |
| | Power(P) | 2.431E+4 | 2.549E+4 |
| | P/ϕ_{av} | 581.16 | 562.69 |
| OB2 | ϕ_{thermal} | 32.56 | 33.02 |
| | ϕ_{epi} | 153.70 | 155.75 |
| | ϕ_{ave} | 43.86 | 44.46 |
| | Power(P) | 2.546E+4 | 2.492E+4 |
| | P/ϕ_{av} | 580.48 | 560.50 |
| $\gamma \left[= \frac{(P/\phi_{\text{av}})_{0\text{ch}}}{(P/\phi_{\text{av}})_{\text{OB2ch}}} \right]$ | | 1.0012 | 1.0039 |

Table 3.5 Relation between relative power and Cu activity at 555mm height

| Withdrawal height of control-rod H | Fuel region | Total Cu activity in core, B | Relative power P' | Au foil activity on core tank, A |
|---------------------------------------|--|---------------------------------|----------------------|-------------------------------------|
| 505 | 0.54wt%PuO ₂ -UO ₂ | 37.68 | 48.23* | |
| | PuO ₂ -UO ₂ around rod | 7.92 | 10.15** | |
| | 1.2wt%UO ₂ | 63.57 | 63.57 | |
| | Total | | 121.95 | 6.474 |
| 605 | 0.54wt%PuO ₂ -UO ₂ | 37.99 | 48.63* | |
| | PuO ₂ -UO ₂ around rod | 8.34 | 10.72** | |
| | 1.2wt%UO ₂ | 63.51 | 63.51 | |
| | Total | | 122.85 | 6.306 |

* $B \cdot \beta$ } γ : See Table 3.4

** $B \cdot \beta \cdot \gamma$ } $\beta = \frac{C_p(0.54\text{wt}\%\text{PuO}_2\text{-UO}_2)}{C_p(1.2\text{wt}\%\text{UO}_2)} = 1.28$ (C_p : Conversion ratio of power to Cu activity)

Power correction factor at the measurement of axial pin power distribution

$$\frac{P_{605}}{P_{505}} = \frac{6.306}{6.474} \cdot \frac{122.85}{121.95} \cdot \frac{A_{605}}{A_{505}} = 0.986 \left(\frac{A_{605}}{A_{505}} = \frac{19.58}{19.48} \text{ from Table 3.2} \right)$$

4. Results of power distribution

- Table 4.1 Axial relative power distribution of fuel pin in the case of 505mm withdrawal height of control-rod.
- Table 4.2 Axial relative power distribution of fuel pin in the case of 605mm withdrawal height of control-rod.
- Table 4.3 Axial buckling evaluated from least squares fitting of ^{140}La activity's distribution in fuel pin.
- Table 4.4 Axial distribution of ^{140}La activity in fuel pin in the case of 505mm withdrawal height of control-rod (1)~(4).
- Table 4.5 Axial distribution of ^{140}La activity in fuel pin in the case of 605mm withdrawal height of control-rod (1)~(4).
- Fig. 4.1 Axial pin power distribution in O channel cluster (1)~(6).
- Fig. 4.2 Axial pin power distribution in OB2 channel cluster (1)~(2).
- Fig. 4.3 Change in axial pin power distribution due to 100mm withdrawal of control-rod (1)~(4).

Table 4.1 Axial relative power distribution of fuel pin in the case of 505mm withdrawal height of control-rod

| Channel No. | | 0 | | | | | | OB2 | |
|--------------|-------------|--------|---------|--------|---------|--------|---------|--------|---------|
| Fuel pin No. | | A | | B | | C | | D | |
| No. | Height (mm) | Power | Error | Power | Error | Power | Error | Power | Error |
| 1 | 0.0 | 0.3753 | 0.02466 | 0.3768 | 0.02393 | 0.5583 | 0.02749 | 0.5543 | 0.02788 |
| 2 | 5.0 | 1.523 | 0.04225 | 0.9046 | 0.03403 | 1.504 | 0.04216 | 1.637 | 0.04458 |
| 3 | 10.0 | 2.125 | 0.04932 | 1.260 | 0.03940 | 2.320 | 0.05158 | 2.379 | 0.05309 |
| 4 | 15.0 | 2.796 | 0.05615 | 1.523 | 0.04295 | 2.890 | 0.05725 | 2.999 | 0.05926 |
| 5 | 20.0 | 3.360 | 0.06132 | 1.751 | 0.04580 | 3.583 | 0.06346 | 3.527 | 0.06406 |
| 6 | 25.0 | 3.845 | 0.06543 | 2.057 | 0.04938 | 4.014 | 0.06704 | 4.098 | 0.06887 |
| 7 | 27.5 | 4.056 | 0.06725 | 2.241 | 0.05151 | 4.121 | 0.06802 | 4.361 | 0.07113 |
| 8 | 30.0 | 4.267 | 0.06881 | 2.238 | 0.05137 | 4.455 | 0.07051 | 4.480 | 0.07192 |
| 9 | 32.5 | 4.262 | 0.06890 | 2.393 | 0.05314 | 4.488 | 0.07089 | 4.776 | 0.07436 |
| 10 | 35.0 | 4.468 | 0.07037 | 2.439 | 0.05351 | 4.763 | 0.07284 | 4.785 | 0.07426 |
| 11 | 37.5 | 4.672 | 0.07203 | 2.413 | 0.05336 | 4.749 | 0.07288 | 4.835 | 0.07481 |
| 12 | 40.0 | 4.597 | 0.07135 | 2.613 | 0.05620 | 4.909 | 0.07393 | 4.970 | 0.07565 |
| 13 | 42.5 | 4.473 | 0.07054 | 2.456 | 0.05381 | 4.931 | 0.07422 | 5.071 | 0.07657 |
| 14 | 45.0 | 4.562 | 0.07110 | 2.450 | 0.05364 | 5.025 | 0.07476 | 5.121 | 0.07677 |
| 15 | 47.5 | 4.466 | 0.07050 | 2.447 | 0.05372 | 4.889 | 0.07393 | 5.240 | 0.07781 |
| 16 | 50.0 | 4.376 | 0.06968 | 2.452 | 0.05367 | 4.900 | 0.07388 | 5.037 | 0.07617 |
| 17 | 52.5 | 4.147 | 0.06801 | 2.327 | 0.05247 | 4.795 | 0.07324 | 5.021 | 0.07615 |
| 18 | 55.0 | 4.096 | 0.06750 | 2.445 | 0.05360 | 4.833 | 0.07339 | 4.877 | 0.07499 |
| 19 | 57.5 | 3.902 | 0.06605 | 2.195 | 0.05105 | 4.586 | 0.07168 | 4.763 | 0.07430 |
| 20 | 60.0 | 3.801 | 0.06511 | 2.154 | 0.05050 | 4.461 | 0.07060 | 4.805 | 0.07446 |
| 21 | 62.5 | 3.440 | 0.06217 | 2.074 | 0.04971 | 4.281 | 0.06934 | 4.467 | 0.07203 |
| 22 | 65.0 | 3.341 | 0.06120 | 1.981 | 0.04857 | 4.249 | 0.06896 | 4.347 | 0.07094 |
| 23 | 67.5 | 3.053 | 0.05871 | 1.837 | 0.04699 | 3.804 | 0.06550 | 4.111 | 0.06921 |
| 24 | 70.0 | 2.936 | 0.05754 | 1.712 | 0.04539 | 3.670 | 0.06426 | 3.938 | 0.06764 |
| 25 | 72.5 | 2.628 | 0.05467 | 1.679 | 0.04508 | 3.346 | 0.06158 | 3.401 | 0.06318 |
| 26 | 75.0 | 2.475 | 0.05306 | 1.514 | 0.04289 | 3.168 | 0.05989 | 3.261 | 0.06178 |
| 27 | 77.5 | 2.278 | 0.05111 | 1.351 | 0.04082 | 2.827 | 0.05682 | 2.940 | 0.05893 |
| 28 | 80.0 | 2.189 | 0.05008 | 1.331 | 0.04045 | 2.508 | 0.05359 | 2.725 | 0.05671 |
| 29 | 85.0 | 1.619 | 0.04352 | 0.9558 | 0.03493 | 1.735 | 0.04511 | 2.017 | 0.04921 |
| 30 | 90.0 | 0.9839 | 0.03480 | 0.6154 | 0.02901 | 1.062 | 0.03613 | 1.118 | 0.03760 |
| 31 | 95.0 | 0.4510 | 0.02524 | 0.2749 | 0.02151 | 0.5008 | 0.02639 | 0.5815 | 0.02849 |
| 32 | 100.0 | 0.3466 | 0.02291 | 0.2460 | 0.02075 | 0.4087 | 0.02443 | 0.4469 | 0.02571 |
| 33 | 105.0 | 0.3003 | 0.02180 | 0.1904 | 0.01920 | 0.3328 | 0.02269 | 0.3886 | 0.02441 |

Table 4.2 Axial relative power distribution of fuel pin in the case of 605mm withdrawal height of control-rod

| Channel No. | | 0 | | | | | | OB2 | |
|--------------|-------------|--------|---------|--------|---------|--------|---------|--------|---------|
| Fuel pin No. | | A | | B | | C | | C | |
| No. | Height (mm) | Power | Error | Power | Error | Power | Error | Power | Error |
| 1 | 0.0 | 0.5281 | 0.02730 | 0.3886 | 0.02432 | 0.5699 | 0.02749 | 0.5103 | 0.02645 |
| 2 | 5.0 | 1.503 | 0.04273 | 0.8837 | 0.03383 | 1.562 | 0.04265 | 1.408 | 0.04087 |
| 3 | 10.0 | 2.312 | 0.05218 | 1.239 | 0.03927 | 2.317 | 0.05127 | 2.139 | 0.04961 |
| 4 | 15.0 | 2.911 | 0.05820 | 1.570 | 0.04374 | 2.973 | 0.05772 | 2.698 | 0.05539 |
| 5 | 20.0 | 3.711 | 0.06538 | 1.827 | 0.04691 | 3.577 | 0.06309 | 3.220 | 0.06027 |
| 6 | 25.0 | 4.010 | 0.06788 | 2.161 | 0.05073 | 4.067 | 0.06713 | 3.787 | 0.06517 |
| 7 | 27.5 | 4.276 | 0.07019 | 2.262 | 0.05197 | 4.113 | 0.06771 | 3.915 | 0.06635 |
| 8 | 30.5 | 4.376 | 0.07082 | 2.337 | 0.05265 | 4.322 | 0.06914 | 4.124 | 0.06792 |
| 9 | 32.5 | 4.564 | 0.07242 | 2.362 | 0.05304 | 4.456 | 0.07039 | 4.196 | 0.06862 |
| 10 | 35.0 | 4.696 | 0.07329 | 2.529 | 0.05465 | 4.743 | 0.07235 | 4.349 | 0.06969 |
| 11 | 37.5 | 4.810 | 0.07430 | 2.597 | 0.05548 | 4.829 | 0.07320 | 4.366 | 0.06996 |
| 12 | 40.0 | 4.759 | 0.07377 | 2.596 | 0.05535 | 4.894 | 0.07346 | 4.506 | 0.07091 |
| 13 | 42.5 | 4.895 | 0.07494 | 2.623 | 0.05575 | 4.894 | 0.07369 | 4.603 | 0.07178 |
| 14 | 45.0 | 4.871 | 0.07462 | 2.654 | 0.05594 | 4.886 | 0.07342 | 4.628 | 0.07184 |
| 15 | 47.5 | 4.849 | 0.07461 | 2.732 | 0.05685 | 4.940 | 0.07403 | 4.618 | 0.07190 |
| 16 | 50.0 | 4.831 | 0.07433 | 2.634 | 0.05575 | 4.903 | 0.07355 | 4.610 | 0.07172 |
| 17 | 52.5 | 4.672 | 0.07329 | 2.611 | 0.05565 | 4.843 | 0.07333 | 4.538 | 0.07131 |
| 18 | 55.0 | 4.459 | 0.07150 | 2.405 | 0.05341 | 4.747 | 0.07240 | 4.478 | 0.07072 |
| 19 | 57.5 | 4.306 | 0.07046 | 2.385 | 0.05331 | 4.608 | 0.07159 | 4.313 | 0.06957 |
| 20 | 60.0 | 4.048 | 0.06824 | 2.228 | 0.05152 | 4.469 | 0.07032 | 4.201 | 0.06857 |
| 21 | 62.5 | 3.800 | 0.06634 | 2.169 | 0.05100 | 4.375 | 0.06981 | 4.025 | 0.06730 |
| 22 | 65.0 | 3.575 | 0.06429 | 2.023 | 0.04925 | 4.128 | 0.06776 | 3.852 | 0.06576 |
| 23 | 67.5 | 3.368 | 0.06261 | 1.953 | 0.04855 | 3.928 | 0.06627 | 3.599 | 0.06376 |
| 24 | 70.0 | 3.074 | 0.05981 | 1.781 | 0.04641 | 3.695 | 0.06423 | 3.346 | 0.06146 |
| 25 | 72.5 | 2.878 | 0.05808 | 1.692 | 0.04544 | 3.351 | 0.06139 | 3.141 | 0.05974 |
| 26 | 75.0 | 2.554 | 0.05468 | 1.546 | 0.04349 | 3.020 | 0.05831 | 2.965 | 0.05801 |
| 27 | 77.5 | 2.465 | 0.05398 | 1.411 | 0.04182 | 2.771 | 0.05606 | 2.575 | 0.05431 |
| 28 | 80.0 | 2.167 | 0.05070 | 1.335 | 0.04069 | 2.485 | 0.05314 | 2.397 | 0.05243 |
| 29 | 85.0 | 1.539 | 0.04328 | 0.9173 | 0.03446 | 1.799 | 0.04567 | 1.636 | 0.04386 |
| 30 | 90.0 | 0.8985 | 0.03407 | 0.5720 | 0.02829 | 1.049 | 0.03573 | 0.9061 | 0.03365 |
| 31 | 95.0 | 0.4659 | 0.02608 | 0.2692 | 0.02147 | 0.5033 | 0.02625 | 0.4515 | 0.02527 |
| 32 | 100.0 | 0.3202 | 0.02276 | 0.2659 | 0.02139 | 0.3385 | 0.02262 | 0.3918 | 0.02396 |
| 33 | 105.0 | 0.3403 | 0.02325 | 0.2076 | 0.01980 | 0.3622 | 0.02318 | 0.2855 | 0.02142 |

Table 4.3 Axial buckling evaluated from least squares fitting of ^{140}La activity's distribution in fuel pin

| Withdrawal height of control-rod (mm) | Fitting range (mm) | Axial buckling B_z^2 (m^{-2}) | |
|---------------------------------------|--------------------|--|--|
| | | Pin No. : C (3rd ring pin of 0ch) | Pin No. : D (3rd ring pin of 0B2ch) |
| 505 | 50 - 850 | 9.37 ± 0.07 | 9.13 ± 0.08 |
| | 100 - 800 | 9.23 ± 0.09 | 9.16 ± 0.10 |
| | 150 - 750 | 9.26 ± 0.12 | 9.30 ± 0.14 |
| | 200 - 700 | 9.21 ± 0.20 | 9.33 ± 0.21 |
| | Average | 9.23 ± 0.10 | 9.26 ± 0.10 |
| 605 | 50 - 850 | 9.29 ± 0.06 | 9.39 ± 0.05 |
| | 100 - 800 | 9.23 ± 0.07 | 9.29 ± 0.07 |
| | 150 - 750 | 9.20 ± 0.11 | 9.40 ± 0.09 |
| | 200 - 700 | 9.15 ± 0.26 | 9.48 ± 0.12 |
| | Average | 9.24 ± 0.10 | 9.36 ± 0.10 |

Table 4.4 Axial distribution of ^{140}La activity in fuel pin in the case of 505mm withdrawal height of control-rod

(1) Channel number : 0

Fuel pin number : A

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------|---------------------------|-----------------------|--------------------------------|----------------------------|
| 1 | 0.0 | 668277 | 525 | 4.584E 03 | 2.679E 02 |
| 2 | 5.0 | 668804 | 1787 | 1.813E 04 | 4.660E 02 |
| 3 | 10.0 | 669330 | 2466 | 2.542E 04 | 5.436E 02 |
| 4 | 15.0 | 669857 | 3221 | 3.354E 04 | 6.186E 02 |
| 5 | 20.0 | 670383 | 3852 | 4.032E 04 | 6.750E 02 |
| 6 | 25.0 | 670909 | 3913 | 4.098E 04 | 6.803E 02 |
| 7 | 30.0 | 671436 | 4323 | 4.539E 04 | 7.144E 02 |
| 8 | 35.0 | 671962 | 4521 | 4.753E 04 | 7.303E 02 |
| 9 | 40.0 | 672489 | 4750 | 5.000E 04 | 7.484E 02 |
| 10 | 45.0 | 673015 | 4747 | 4.998E 04 | 7.483E 02 |
| 11 | 50.0 | 673541 | 4509 | 4.743E 04 | 7.298E 02 |
| 12 | 55.0 | 674067 | 4295 | 4.514E 04 | 7.128E 02 |
| 13 | 60.0 | 674594 | 3949 | 4.142E 04 | 6.843E 02 |
| 14 | 65.0 | 675120 | 3651 | 3.822E 04 | 6.587E 02 |
| 15 | 70.0 | 675646 | 3232 | 3.372E 04 | 6.209E 02 |
| 16 | 75.0 | 676173 | 2759 | 2.864E 04 | 5.752E 02 |
| 17 | 80.0 | 676699 | 2438 | 2.519E 04 | 5.421E 02 |
| 18 | 85.0 | 677226 | 1834 | 1.869E 04 | 4.732E 02 |
| 19 | 90.0 | 677752 | 1124 | 1.105E 04 | 3.764E 02 |
| 20 | 95.0 | 678278 | 589 | 5.289E 03 | 2.823E 02 |
| 21 | 100.0 | 678804 | 446 | 3.750E 03 | 2.512E 02 |
| 22 | 105.0 | 679331 | 411 | 3.374E 03 | 2.431E 02 |
| 23 | 27.5 | 680268 | 4898 | 5.174E 04 | 7.618E 02 |
| 24 | 32.5 | 680795 | 5204 | 5.505E 04 | 7.850E 02 |
| 25 | 37.5 | 681321 | 5541 | 5.869E 04 | 8.097E 02 |
| 26 | 42.5 | 681847 | 5401 | 5.719E 04 | 7.997E 02 |
| 27 | 47.5 | 682374 | 5219 | 5.524E 04 | 7.865E 02 |
| 28 | 52.5 | 682900 | 4914 | 5.196E 04 | 7.638E 02 |
| 29 | 57.5 | 683426 | 4611 | 4.870E 04 | 7.405E 02 |
| 30 | 62.5 | 683953 | 4028 | 4.242E 04 | 6.933E 02 |
| 31 | 67.5 | 684479 | 3591 | 3.771E 04 | 6.556E 02 |
| 32 | 72.5 | 685006 | 3167 | 3.314E 04 | 6.169E 02 |
| 33 | 77.5 | 685532 | 2704 | 2.814E 04 | 5.716E 02 |

(2) Channel number : 0

Fuel pin number : B

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------------|---------------------------------|-----------------------------|--------------------------------------|----------------------------------|
| 1 | 0.0 | 750179 | 527 | 4.757E 03 | 2.771E 02 |
| 2 | 5.0 | 750706 | 1140 | 1.155E 04 | 3.901E 02 |
| 3 | 10.0 | 751232 | 1544 | 1.604E 04 | 4.494E 02 |
| 4 | 15.0 | 751758 | 1869 | 1.965E 04 | 4.920E 02 |
| 5 | 20.0 | 752285 | 2181 | 2.311E 04 | 5.297E 02 |
| 6 | 25.0 | 752811 | 2530 | 2.699E 04 | 5.689E 02 |
| 7 | 30.0 | 753337 | 2732 | 2.924E 04 | 5.905E 02 |
| 8 | 35.0 | 753864 | 2987 | 3.208E 04 | 6.167E 02 |
| 9 | 40.0 | 820947 | 3078 | 3.413E 04 | 6.454E 02 |
| 10 | 45.0 | 754916 | 2940 | 3.157E 04 | 6.122E 02 |
| 11 | 50.0 | 755443 | 2947 | 3.165E 04 | 6.131E 02 |
| 12 | 55.0 | 755969 | 2959 | 3.180E 04 | 6.144E 02 |
| 13 | 60.0 | 756495 | 2567 | 2.745E 04 | 5.738E 02 |
| 14 | 65.0 | 757021 | 2332 | 2.484E 04 | 5.481E 02 |
| 15 | 70.0 | 757548 | 2062 | 2.184E 04 | 5.168E 02 |
| 16 | 75.0 | 758074 | 1858 | 1.958E 04 | 4.919E 02 |
| 17 | 80.0 | 758600 | 1598 | 1.669E 04 | 4.582E 02 |
| 18 | 85.0 | 759126 | 1209 | 1.236E 04 | 4.023E 02 |
| 19 | 90.0 | 759653 | 809 | 7.915E 03 | 3.352E 02 |
| 20 | 95.0 | 760179 | 428 | 3.675E 03 | 2.553E 02 |
| 21 | 100.0 | 760705 | 400 | 3.364E 03 | 2.485E 02 |
| 22 | 105.0 | 761232 | 320 | 2.474E 03 | 2.277E 02 |
| 23 | 27.5 | 762006 | 2559 | 2.742E 04 | 5.743E 02 |
| 24 | 32.5 | 762532 | 2779 | 2.988E 04 | 5.978E 02 |
| 25 | 37.5 | 763058 | 2784 | 2.994E 04 | 5.985E 02 |
| 26 | 42.5 | 763585 | 2945 | 3.175E 04 | 6.151E 02 |
| 27 | 47.5 | 764111 | 2842 | 3.061E 04 | 6.047E 02 |
| 28 | 52.5 | 764637 | 2650 | 2.847E 04 | 5.848E 02 |
| 29 | 57.5 | 765163 | 2636 | 2.832E 04 | 5.834E 02 |
| 30 | 62.5 | 765690 | 2401 | 2.570E 04 | 5.579E 02 |
| 31 | 67.5 | 766216 | 2211 | 2.359E 04 | 5.364E 02 |
| 32 | 72.5 | 766743 | 1956 | 2.075E 04 | 5.061E 02 |
| 33 | 77.5 | 767269 | 1603 | 1.681E 04 | 4.606E 02 |

(3) Channel number : 0

Fuel pin number : C

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------------|---------------------------------|-----------------------------|--------------------------------------|----------------------------------|
| 1 | 0.0 | 686777 | 761 | 7.164E 03 | 3.166E 02 |
| 2 | 5.0 | 687303 | 1859 | 1.903E 04 | 4.780E 02 |
| 3 | 10.0 | 687830 | 2843 | 2.967E 04 | 5.861E 02 |
| 4 | 15.0 | 688356 | 3503 | 3.681E 04 | 6.487E 02 |
| 5 | 20.0 | 688883 | 4265 | 4.506E 04 | 7.142E 02 |
| 6 | 25.0 | 689409 | 4878 | 5.170E 04 | 7.629E 02 |
| 7 | 30.0 | 689935 | 5370 | 5.703E 04 | 7.999E 02 |
| 8 | 35.0 | 690462 | 5776 | 6.143E 04 | 8.292E 02 |
| 9 | 40.0 | 690988 | 5970 | 6.354E 04 | 8.429E 02 |
| 10 | 45.0 | 691515 | 6014 | 6.403E 04 | 8.462E 02 |
| 11 | 50.0 | 692041 | 5908 | 6.290E 04 | 8.390E 02 |
| 12 | 55.0 | 692568 | 5795 | 6.169E 04 | 8.312E 02 |
| 13 | 60.0 | 693094 | 5359 | 5.698E 04 | 8.000E 02 |
| 14 | 65.0 | 693620 | 5079 | 5.396E 04 | 7.794E 02 |
| 15 | 70.0 | 694147 | 4412 | 4.674E 04 | 7.276E 02 |
| 16 | 75.0 | 694673 | 3782 | 3.992E 04 | 6.750E 02 |
| 17 | 80.0 | 695199 | 3053 | 3.203E 04 | 6.084E 02 |
| 18 | 85.0 | 695726 | 2132 | 2.205E 04 | 5.119E 02 |
| 19 | 90.0 | 696252 | 1379 | 1.389E 04 | 4.167E 02 |
| 20 | 95.0 | 696779 | 677 | 6.280E 03 | 3.019E 02 |
| 21 | 100.0 | 697305 | 599 | 5.436E 03 | 2.864E 02 |
| 22 | 105.0 | 697831 | 509 | 4.460E 03 | 2.673E 02 |
| 23 | 27.5 | 698998 | 4982 | 5.301E 04 | 7.736E 02 |
| 24 | 32.5 | 699524 | 5357 | 5.710E 04 | 8.018E 02 |
| 25 | 37.5 | 700050 | 5763 | 6.152E 04 | 8.313E 02 |
| 26 | 42.5 | 700577 | 5986 | 6.395E 04 | 8.471E 02 |
| 27 | 47.5 | 701103 | 5876 | 6.277E 04 | 8.396E 02 |
| 28 | 52.5 | 701629 | 5838 | 6.237E 04 | 8.371E 02 |
| 29 | 57.5 | 702155 | 5488 | 5.858E 04 | 8.122E 02 |
| 30 | 62.5 | 702682 | 5149 | 5.490E 04 | 7.874E 02 |
| 31 | 67.5 | 703208 | 4557 | 4.848E 04 | 7.418E 02 |
| 32 | 72.5 | 703734 | 4057 | 4.305E 04 | 7.009E 02 |
| 33 | 77.5 | 704261 | 3408 | 3.600E 04 | 6.440E 02 |

(4) Channel number : OB2

Fuel pin number : D

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------------|---------------------------------|-----------------------------|--------------------------------------|----------------------------------|
| 1 | 0.0 | 768892 | 720 | 6.953E 03 | 3.196E 02 |
| 2 | 5.0 | 769418 | 1889 | 2.002E 04 | 4.983E 02 |
| 3 | 10.0 | 769945 | 2750 | 2.966E 04 | 5.967E 02 |
| 4 | 15.0 | 770471 | 3493 | 3.797E 04 | 6.702E 02 |
| 5 | 20.0 | 770997 | 4122 | 4.502E 04 | 7.267E 02 |
| 6 | 25.0 | 771524 | 4737 | 5.191E 04 | 7.781E 02 |
| 7 | 30.0 | 772050 | 5153 | 5.658E 04 | 8.111E 02 |
| 8 | 35.0 | 772576 | 5520 | 6.070E 04 | 8.391E 02 |
| 9 | 40.0 | 773103 | 5767 | 6.348E 04 | 8.576E 02 |
| 10 | 45.0 | 773629 | 5972 | 6.579E 04 | 8.727E 02 |
| 11 | 50.0 | 774156 | 5845 | 6.439E 04 | 8.637E 02 |
| 12 | 55.0 | 774682 | 5707 | 6.286E 04 | 8.538E 02 |
| 13 | 60.0 | 775208 | 5546 | 6.107E 04 | 8.421E 02 |
| 14 | 65.0 | 775735 | 4918 | 5.404E 04 | 7.940E 02 |
| 15 | 70.0 | 776261 | 4475 | 4.909E 04 | 7.583E 02 |
| 16 | 75.0 | 776787 | 3740 | 4.085E 04 | 6.949E 02 |
| 17 | 80.0 | 777314 | 3127 | 3.399E 04 | 6.371E 02 |
| 18 | 85.0 | 777840 | 2254 | 2.420E 04 | 5.442E 02 |
| 19 | 90.0 | 778366 | 1301 | 1.350E 04 | 4.198E 02 |
| 20 | 95.0 | 778893 | 741 | 7.221E 03 | 3.252E 02 |
| 21 | 100.0 | 779419 | 598 | 5.616E 03 | 2.963E 02 |
| 22 | 105.0 | 779945 | 522 | 4.764E 03 | 2.797E 02 |
| 23 | 27.5 | 781073 | 4907 | 5.405E 04 | 7.951E 02 |
| 24 | 32.5 | 781600 | 5333 | 5.885E 04 | 8.284E 02 |
| 25 | 37.5 | 782126 | 5473 | 6.044E 04 | 8.393E 02 |
| 26 | 42.5 | 782652 | 5712 | 6.314E 04 | 8.573E 02 |
| 27 | 47.5 | 783178 | 5842 | 6.462E 04 | 8.670E 02 |
| 28 | 52.5 | 783705 | 5670 | 6.270E 04 | 8.546E 02 |
| 29 | 57.5 | 784231 | 5374 | 5.938E 04 | 8.326E 02 |
| 30 | 62.5 | 784757 | 4999 | 5.518E 04 | 8.037E 02 |
| 31 | 67.5 | 785284 | 4615 | 5.087E 04 | 7.730E 02 |
| 32 | 72.5 | 785810 | 3859 | 4.236E 04 | 7.085E 02 |
| 33 | 77.5 | 786336 | 3335 | 3.647E 04 | 6.601E 02 |

Table 4.5 Axial distribution of ^{140}La activity in fuel pin in the case of 605mm withdrawal height of control-rod

(1) Channel number : 0

Fuel pin number : A

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------|---------------------------|-----------------------|--------------------------------|----------------------------|
| 1 | 0.0 | 748723 | 695 | 6.615E 03 | 3.119E 02 |
| 2 | 5.0 | 749249 | 1781 | 1.865E 04 | 4.803E 02 |
| 3 | 10.0 | 749776 | 2618 | 2.793E 04 | 5.776E 02 |
| 4 | 15.0 | 750302 | 3312 | 3.563E 04 | 6.473E 02 |
| 5 | 20.0 | 750828 | 4106 | 4.444E 04 | 7.189E 02 |
| 6 | 25.0 | 751355 | 4491 | 4.872E 04 | 7.513E 02 |
| 7 | 30.0 | 751881 | 4978 | 5.414E 04 | 7.903E 02 |
| 8 | 35.0 | 752407 | 5398 | 5.881E 04 | 8.226E 02 |
| 9 | 40.0 | 752934 | 5415 | 5.901E 04 | 8.240E 02 |
| 10 | 45.0 | 753460 | 5559 | 6.062E 04 | 8.349E 02 |
| 11 | 50.0 | 753986 | 5492 | 5.989E 04 | 8.301E 02 |
| 12 | 55.0 | 754513 | 5108 | 5.564E 04 | 8.013E 02 |
| 13 | 60.0 | 755039 | 4526 | 4.919E 04 | 7.554E 02 |
| 14 | 65.0 | 755566 | 4009 | 4.346E 04 | 7.121E 02 |
| 15 | 70.0 | 756092 | 3474 | 3.752E 04 | 6.642E 02 |
| 16 | 75.0 | 756618 | 2910 | 3.126E 04 | 6.097E 02 |
| 17 | 80.0 | 757145 | 2421 | 2.583E 04 | 5.580E 02 |
| 18 | 85.0 | 757671 | 1695 | 1.776E 04 | 4.709E 02 |
| 19 | 90.0 | 758197 | 1060 | 1.070E 04 | 3.785E 02 |
| 20 | 95.0 | 758724 | 592 | 5.498E 03 | 2.922E 02 |
| 21 | 100.0 | 759250 | 443 | 3.841E 03 | 2.588E 02 |
| 22 | 105.0 | 759776 | 438 | 3.786E 03 | 2.577E 02 |
| 23 | 27.5 | 760537 | 4744 | 5.174E 04 | 7.748E 02 |
| 24 | 32.5 | 761063 | 5076 | 5.545E 04 | 8.012E 02 |
| 25 | 37.5 | 761590 | 5311 | 5.808E 04 | 8.193E 02 |
| 26 | 42.5 | 762116 | 5413 | 5.923E 04 | 8.272E 02 |
| 27 | 47.5 | 762642 | 5394 | 5.903E 04 | 8.260E 02 |
| 28 | 52.5 | 763169 | 5154 | 5.637E 04 | 8.079E 02 |
| 29 | 57.5 | 763695 | 4704 | 5.136E 04 | 7.727E 02 |
| 30 | 62.5 | 764221 | 4233 | 4.612E 04 | 7.340E 02 |
| 31 | 67.5 | 764748 | 3799 | 4.129E 04 | 6.964E 02 |
| 32 | 72.5 | 765274 | 3214 | 3.477E 04 | 6.422E 02 |
| 33 | 77.5 | 765801 | 2746 | 2.956E 04 | 5.952E 02 |

(2) Channel number : 0

Fuel pin number : B

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------------|---------------------------------|-----------------------------|--------------------------------------|----------------------------------|
| 1 | 0.0 | 767528 | 516 | 4.670E 03 | 2.768E 02 |
| 2 | 5.0 | 768055 | 1061 | 1.076E 04 | 3.803E 02 |
| 3 | 10.0 | 768581 | 1411 | 1.467E 04 | 4.341E 02 |
| 4 | 15.0 | 769107 | 1834 | 1.941E 04 | 4.913E 02 |
| 5 | 20.0 | 769633 | 2119 | 2.260E 04 | 5.264E 02 |
| 6 | 25.0 | 770160 | 2423 | 2.600E 04 | 5.615E 02 |
| 7 | 30.0 | 770686 | 2650 | 2.855E 04 | 5.864E 02 |
| 8 | 35.0 | 771213 | 2877 | 3.109E 04 | 6.103E 02 |
| 9 | 40.0 | 771739 | 2980 | 3.225E 04 | 6.209E 02 |
| 10 | 45.0 | 772265 | 2954 | 3.197E 04 | 6.184E 02 |
| 11 | 50.0 | 772792 | 2894 | 3.131E 04 | 6.124E 02 |
| 12 | 55.0 | 773318 | 2745 | 2.965E 04 | 5.971E 02 |
| 13 | 60.0 | 773844 | 2507 | 2.699E 04 | 5.717E 02 |
| 14 | 65.0 | 774371 | 2280 | 2.445E 04 | 5.464E 02 |
| 15 | 70.0 | 774897 | 2025 | 2.160E 04 | 5.164E 02 |
| 16 | 75.0 | 775423 | 1761 | 1.864E 04 | 4.833E 02 |
| 17 | 80.0 | 775949 | 1517 | 1.591E 04 | 4.506E 02 |
| 18 | 85.0 | 776476 | 1096 | 1.119E 04 | 3.875E 02 |
| 19 | 90.0 | 777002 | 716 | 6.934E 03 | 3.200E 02 |
| 20 | 95.0 | 777528 | 397 | 3.356E 03 | 2.496E 02 |
| 21 | 100.0 | 778055 | 378 | 3.144E 03 | 2.448E 02 |
| 22 | 105.0 | 778581 | 337 | 2.684E 03 | 2.341E 02 |
| 23 | 27.5 | 779987 | 2507 | 2.706E 04 | 5.733E 02 |
| 24 | 32.5 | 780514 | 2584 | 2.793E 04 | 5.819E 02 |
| 25 | 37.5 | 781040 | 2858 | 3.102E 04 | 6.110E 02 |
| 26 | 42.5 | 781567 | 2869 | 3.115E 04 | 6.123E 02 |
| 27 | 47.5 | 782093 | 2960 | 3.218E 04 | 6.218E 02 |
| 28 | 52.5 | 782619 | 2857 | 3.103E 04 | 6.114E 02 |
| 29 | 57.5 | 783145 | 2602 | 2.817E 04 | 5.845E 02 |
| 30 | 62.5 | 783672 | 2448 | 2.644E 04 | 5.678E 02 |
| 31 | 67.5 | 784198 | 2134 | 2.292E 04 | 5.317E 02 |
| 32 | 72.5 | 784725 | 1869 | 1.994E 04 | 4.993E 02 |
| 33 | 77.5 | 785251 | 1540 | 1.624E 04 | 4.557E 02 |

(4) Channel number : OB2

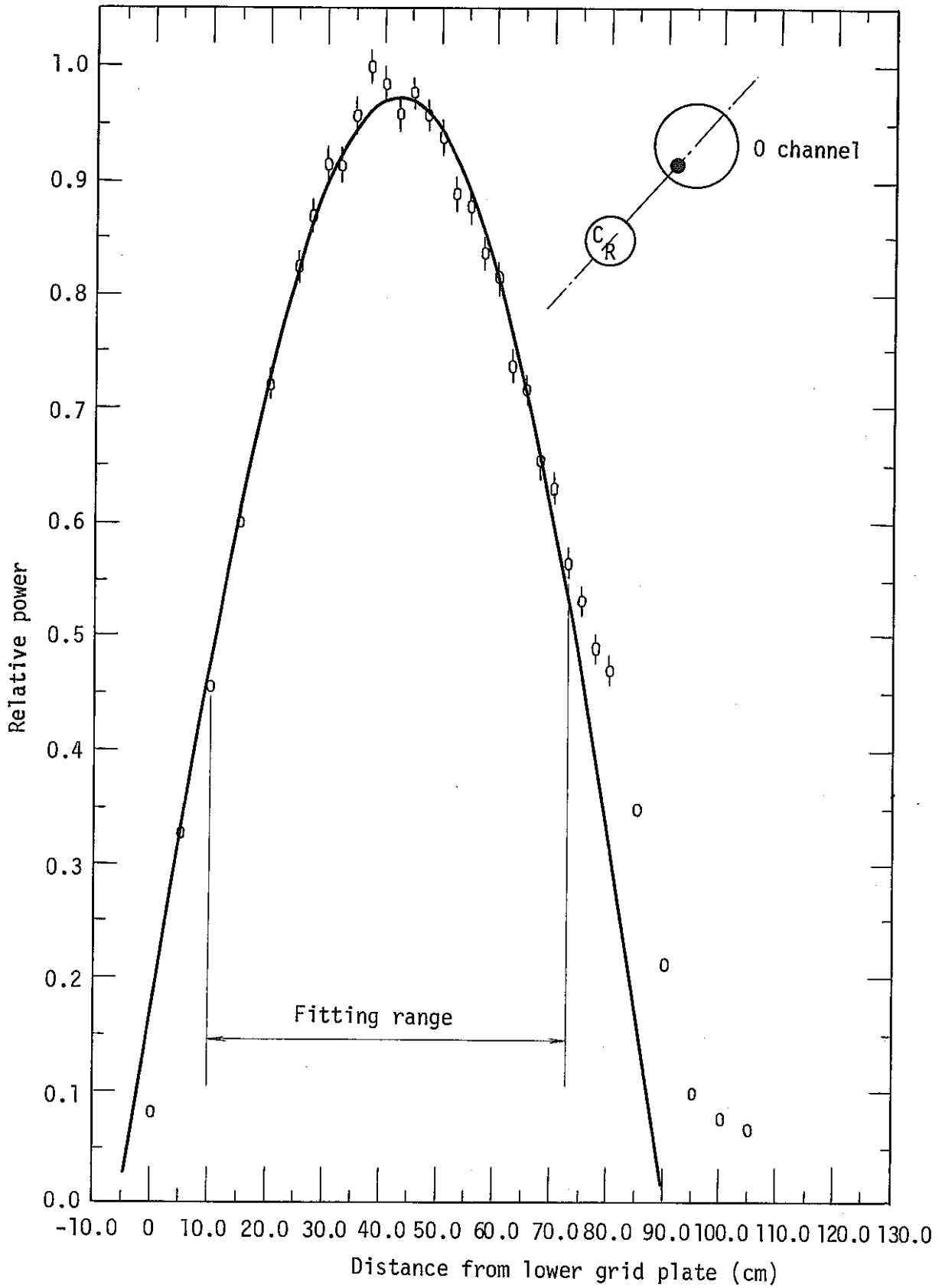
Fuel pin number : D

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------------|---------------------------------|-----------------------------|--------------------------------------|----------------------------------|
| 1 | 0.0 | 689163 | 675 | 6.241E 03 | 3.006E 02 |
| 2 | 5.0 | 689689 | 1682 | 1.713E 04 | 4.563E 02 |
| 3 | 10.0 | 690215 | 2494 | 2.592E 04 | 5.508E 02 |
| 4 | 15.0 | 690741 | 3130 | 3.281E 04 | 6.147E 02 |
| 5 | 20.0 | 691268 | 3728 | 3.929E 04 | 6.694E 02 |
| 6 | 25.0 | 691794 | 4358 | 4.611E 04 | 7.226E 02 |
| 7 | 30.0 | 692320 | 4707 | 4.990E 04 | 7.505E 02 |
| 8 | 35.0 | 692847 | 5023 | 5.333E 04 | 7.749E 02 |
| 9 | 40.0 | 693373 | 5233 | 5.562E 04 | 7.908E 02 |
| 10 | 45.0 | 693899 | 5455 | 5.803E 04 | 8.073E 02 |
| 11 | 50.0 | 694426 | 5465 | 5.815E 04 | 8.082E 02 |
| 12 | 55.0 | 694952 | 5228 | 5.560E 04 | 7.909E 02 |
| 13 | 60.0 | 695478 | 4956 | 5.266E 04 | 7.706E 02 |
| 14 | 65.0 | 696005 | 4567 | 4.845E 04 | 7.405E 02 |
| 15 | 70.0 | 696531 | 3863 | 4.083E 04 | 6.825E 02 |
| 16 | 75.0 | 697057 | 3427 | 3.611E 04 | 6.439E 02 |
| 17 | 80.0 | 697584 | 2745 | 2.872E 04 | 5.784E 02 |
| 18 | 85.0 | 698110 | 1873 | 1.926E 04 | 4.817E 02 |
| 19 | 90.0 | 698636 | 1107 | 1.095E 04 | 3.767E 02 |
| 20 | 95.0 | 699163 | 613 | 5.591E 03 | 2.894E 02 |
| 21 | 100.0 | 699689 | 519 | 4.572E 03 | 2.697E 02 |
| 22 | 105.0 | 700215 | 424 | 3.541E 03 | 2.481E 02 |
| 23 | 27.5 | 701322 | 4619 | 4.912E 04 | 7.461E 02 |
| 24 | 32.5 | 701848 | 4929 | 5.250E 04 | 7.704E 02 |
| 25 | 37.5 | 702375 | 5195 | 5.540E 04 | 7.907E 02 |
| 26 | 42.5 | 702901 | 5453 | 5.821E 04 | 8.099E 02 |
| 27 | 47.5 | 703428 | 5476 | 5.848E 04 | 8.118E 02 |
| 28 | 52.5 | 703954 | 5329 | 5.689E 04 | 8.012E 02 |
| 29 | 57.5 | 704480 | 5071 | 5.409E 04 | 7.820E 02 |
| 30 | 62.5 | 705007 | 4757 | 5.069E 04 | 7.581E 02 |
| 31 | 67.5 | 705533 | 4296 | 4.568E 04 | 7.213E 02 |
| 32 | 72.5 | 706059 | 3739 | 3.963E 04 | 6.742E 02 |
| 33 | 77.5 | 706586 | 3038 | 3.201E 04 | 6.096E 02 |

(3) Channel number : 0

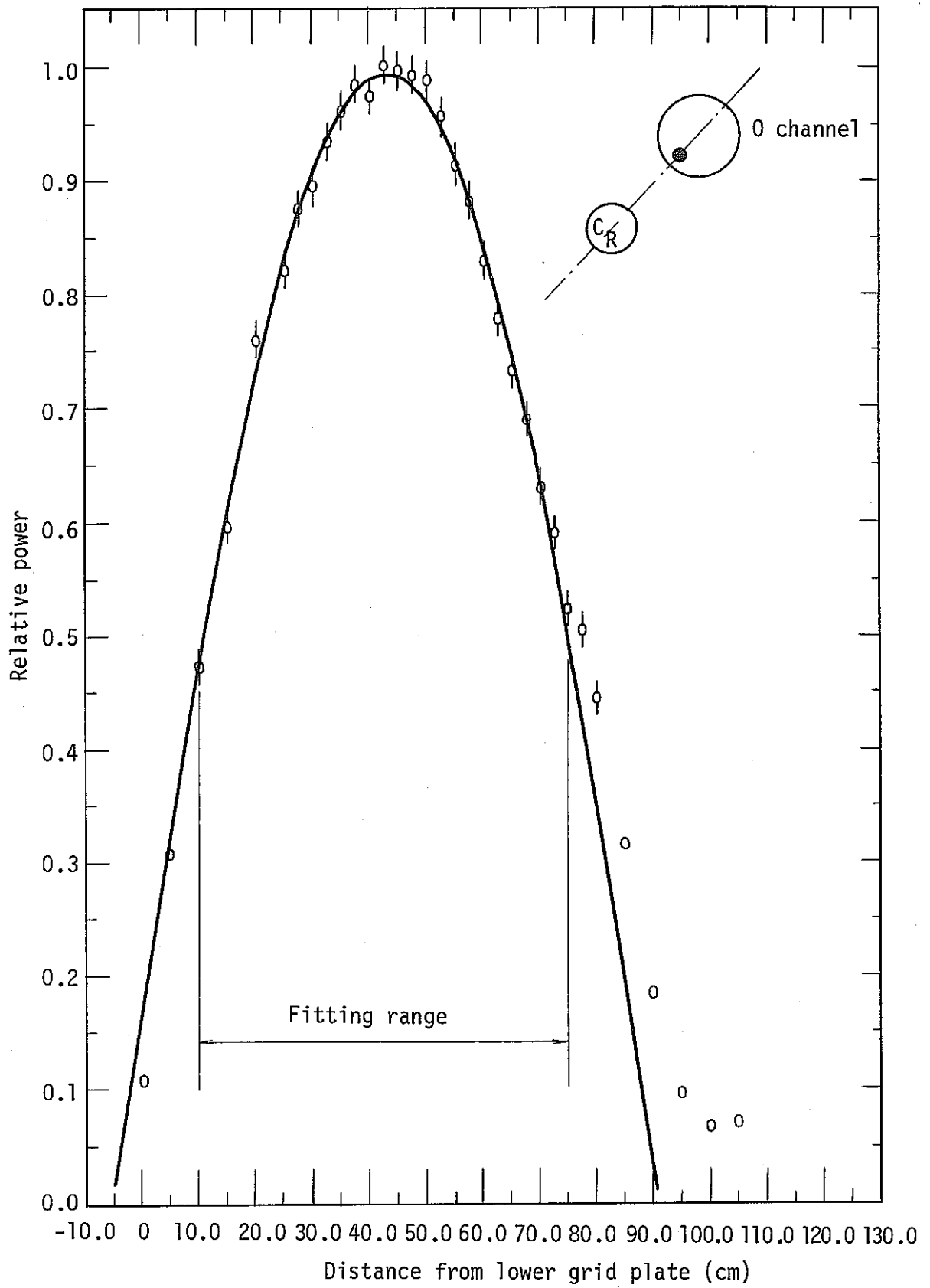
Fuel pin number : C

| No. | Height from grid plate (mm) | Time after shutdown (sec) | Counts per 500 sec Co | Counts after time correction C | Error of counts δC |
|-----|-----------------------------------|---------------------------------|-----------------------------|--------------------------------------|----------------------------------|
| 1 | 0.0 | 663686 | 813 | 7.662E 03 | 3.234E 02 |
| 2 | 5.0 | 664212 | 2065 | 2.108E 04 | 4.984E 02 |
| 3 | 10.0 | 664739 | 2991 | 3.101E 04 | 5.957E 02 |
| 4 | 15.0 | 665265 | 3851 | 4.024E 04 | 6.737E 02 |
| 5 | 20.0 | 665792 | 4605 | 4.833E 04 | 7.353E 02 |
| 6 | 25.0 | 666318 | 5352 | 5.635E 04 | 7.917E 02 |
| 7 | 30.0 | 666844 | 5795 | 6.111E 04 | 8.234E 02 |
| 8 | 35.0 | 667371 | 6234 | 6.583E 04 | 8.537E 02 |
| 9 | 40.0 | 667897 | 6301 | 6.656E 04 | 8.584E 02 |
| 10 | 45.0 | 668423 | 6269 | 6.623E 04 | 8.564E 02 |
| 11 | 50.0 | 668950 | 6282 | 6.638E 04 | 8.574E 02 |
| 12 | 55.0 | 669476 | 5992 | 6.328E 04 | 8.379E 02 |
| 13 | 60.0 | 670002 | 5695 | 6.011E 04 | 8.173E 02 |
| 14 | 65.0 | 677523 | 5113 | 5.400E 04 | 7.773E 02 |
| 15 | 70.0 | 678050 | 4537 | 4.781E 04 | 7.332E 02 |
| 16 | 75.0 | 678576 | 3772 | 3.958E 04 | 6.701E 02 |
| 17 | 80.0 | 679102 | 3005 | 3.132E 04 | 6.001E 02 |
| 18 | 85.0 | 679629 | 2173 | 2.236E 04 | 5.135E 02 |
| 19 | 90.0 | 680155 | 1305 | 1.301E 04 | 4.037E 02 |
| 20 | 95.0 | 680681 | 703 | 6.523E 03 | 3.051E 02 |
| 21 | 100.0 | 681208 | 492 | 4.249E 03 | 2.619E 02 |
| 22 | 105.0 | 681734 | 526 | 4.617E 03 | 2.694E 02 |
| 23 | 27.5 | 682709 | 5142 | 5.442E 04 | 7.809E 02 |
| 24 | 32.5 | 683236 | 5613 | 5.951E 04 | 8.154E 02 |
| 25 | 37.5 | 683762 | 5996 | 6.365E 04 | 8.425E 02 |
| 26 | 42.5 | 684289 | 6103 | 6.482E 04 | 8.500E 02 |
| 27 | 47.5 | 684815 | 6197 | 6.585E 04 | 8.566E 02 |
| 28 | 52.5 | 685341 | 6090 | 6.471E 04 | 8.494E 02 |
| 29 | 57.5 | 685867 | 5840 | 6.202E 04 | 8.323E 02 |
| 30 | 62.5 | 686394 | 5466 | 5.799E 04 | 8.058E 02 |
| 31 | 67.5 | 686920 | 4950 | 5.243E 04 | 7.677E 02 |
| 32 | 72.5 | 687446 | 4181 | 4.413E 04 | 7.069E 02 |
| 33 | 77.5 | 687973 | 3466 | 3.641E 04 | 6.453E 02 |

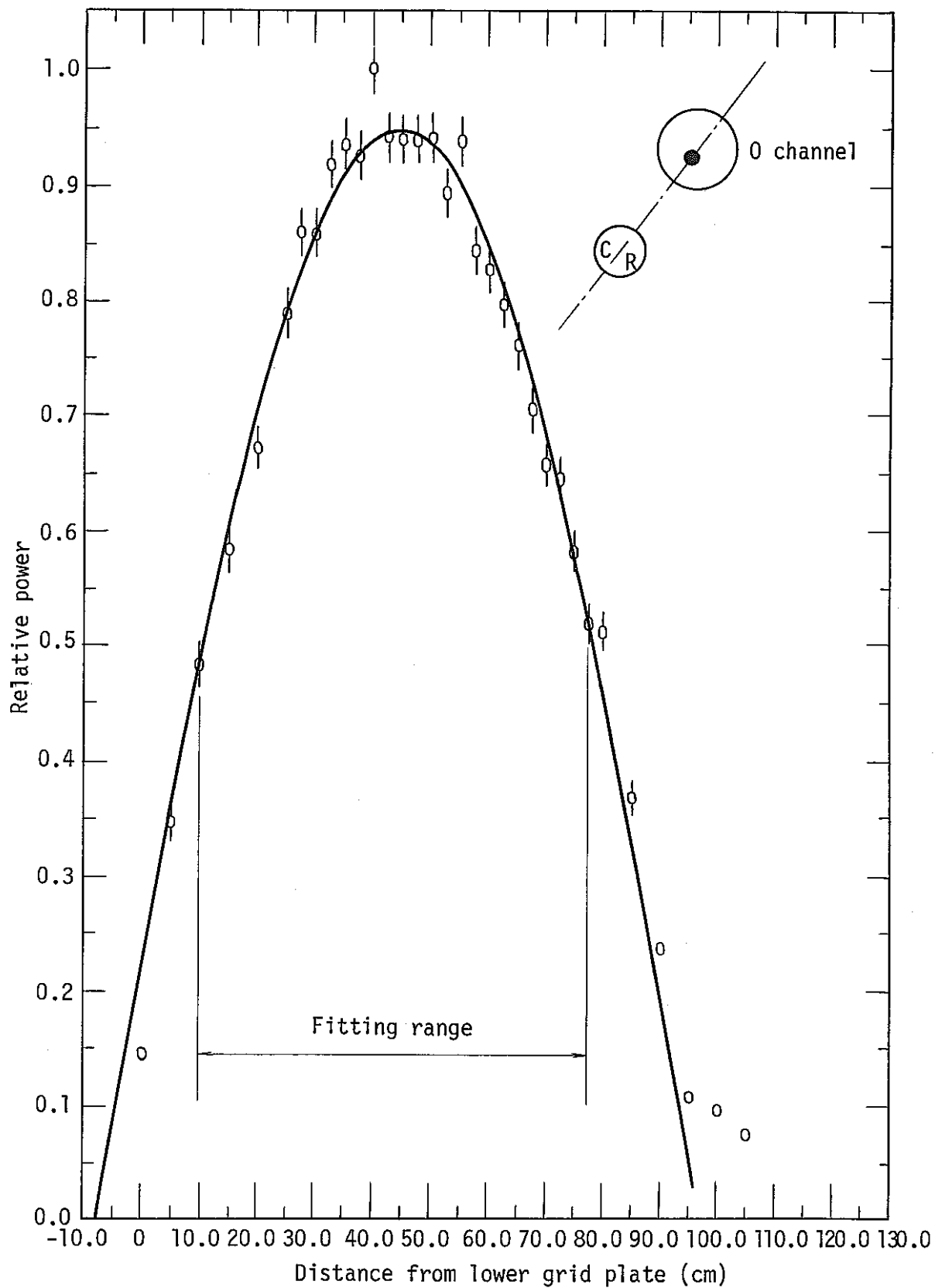


(1) Control-rod: 505 mm withdrawal Pin No.: A (3rd ring)

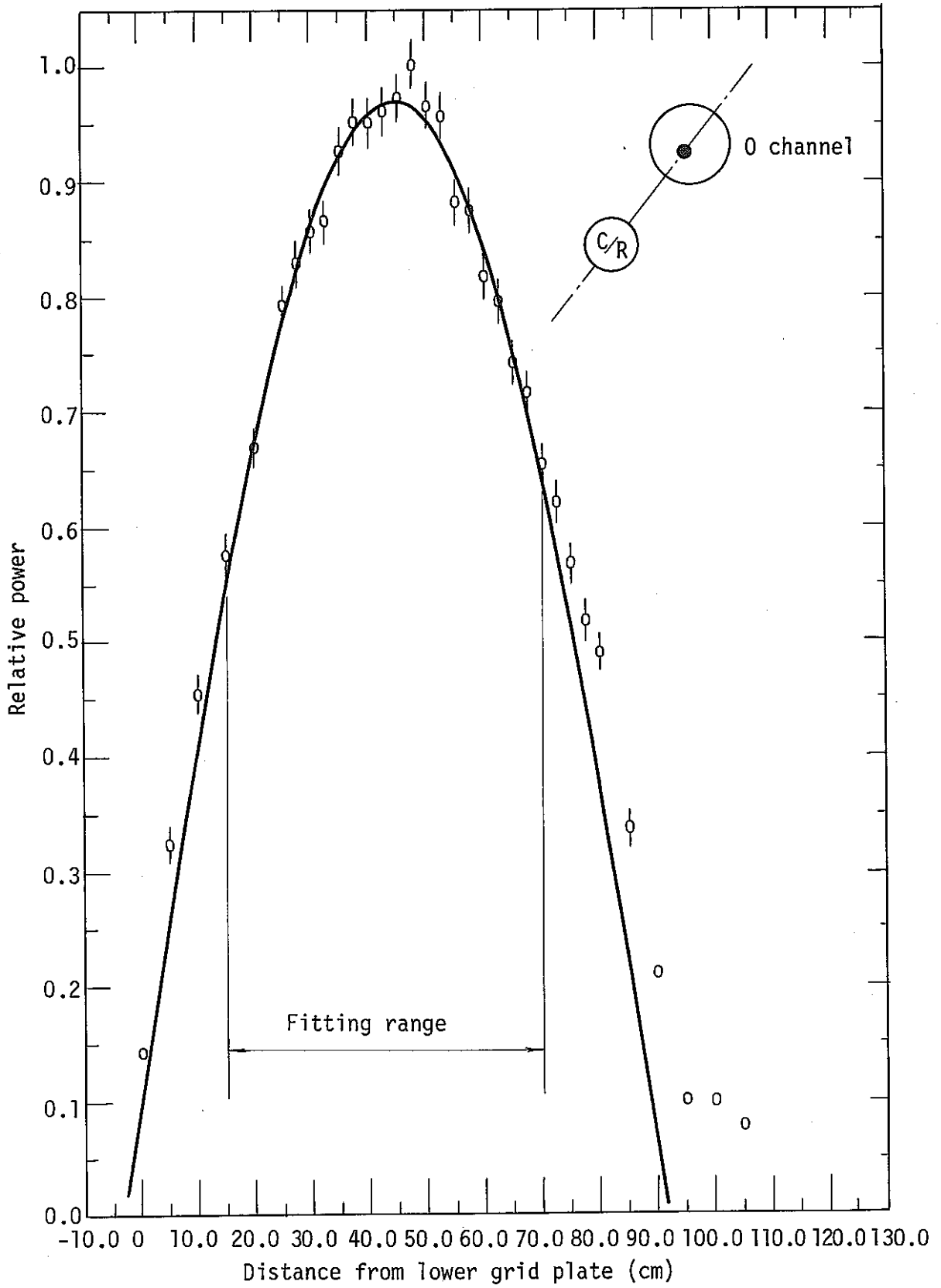
Fig. 4.1 Axial pin power distribution in 0 channel cluster



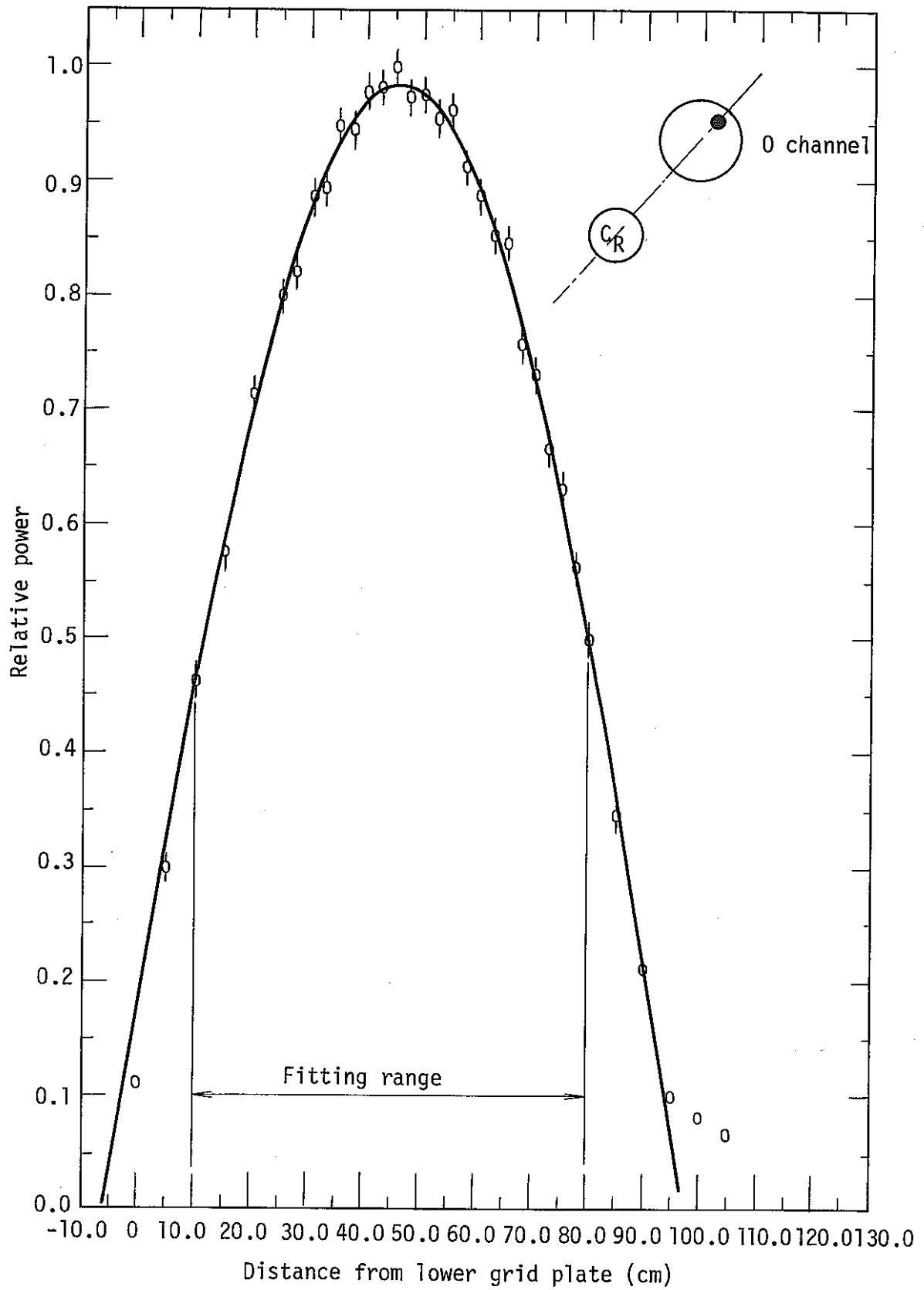
(2) Control rod: 605 mm withdrawal Pin No.: A (3rd ring)



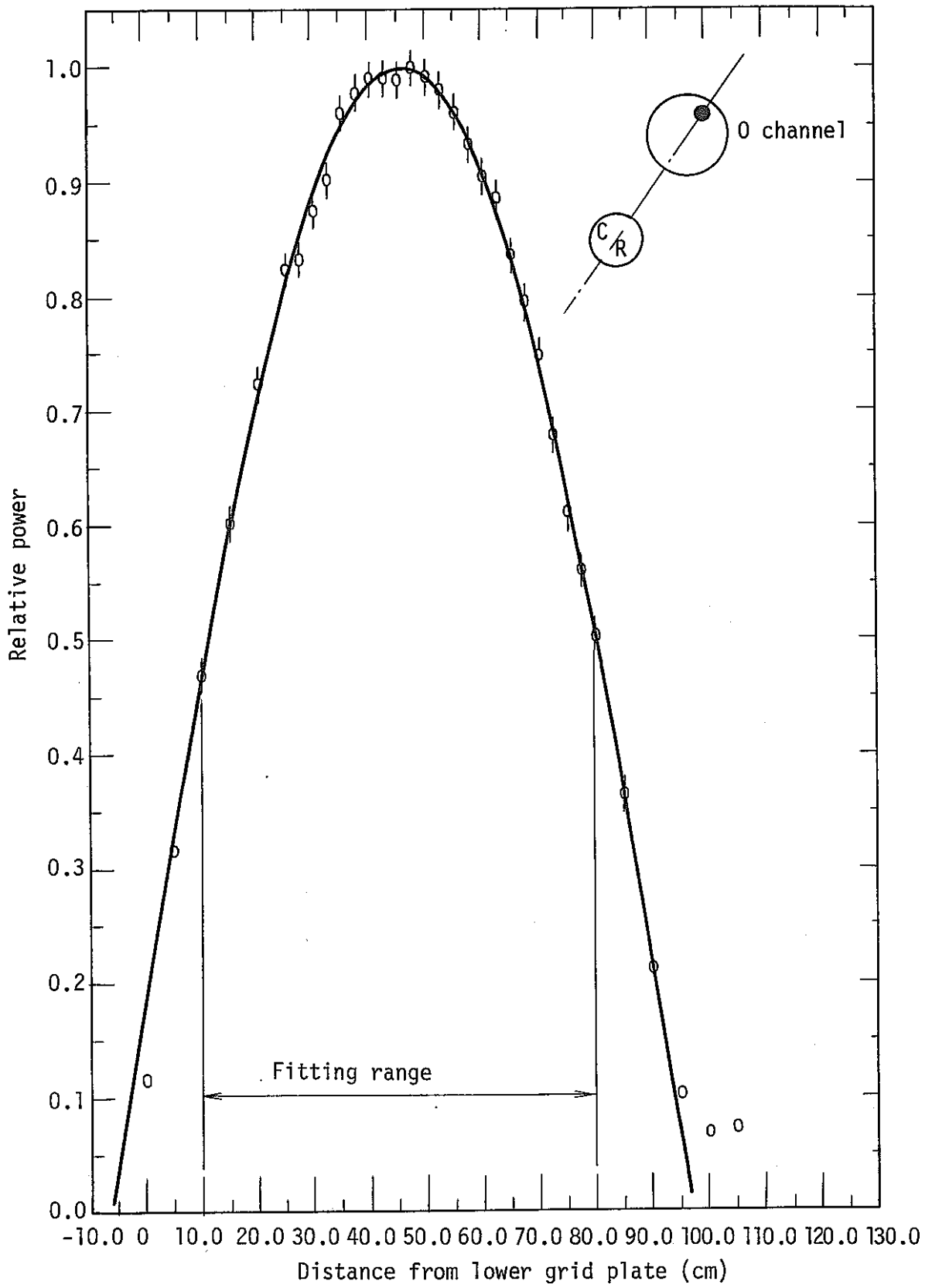
(3) Control-rod: 505 mm withdrawal Pin No.: B (1st ring)



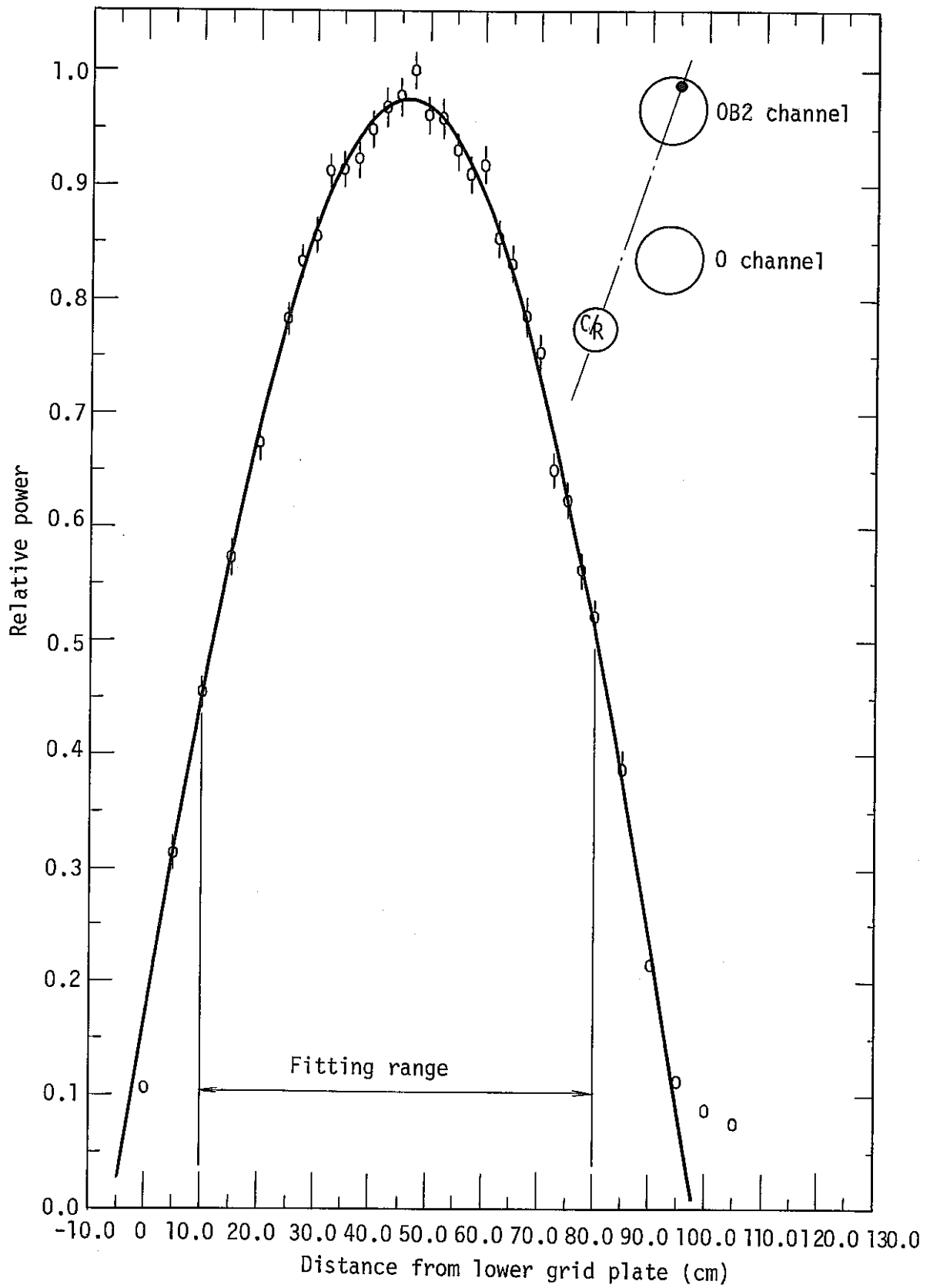
(4) Control-rod: 605 mm withdrawal Pin No.: B (1st ring)



(5) Control-rod: 505 mm withdrawal Pin No.: C (3rd ring)

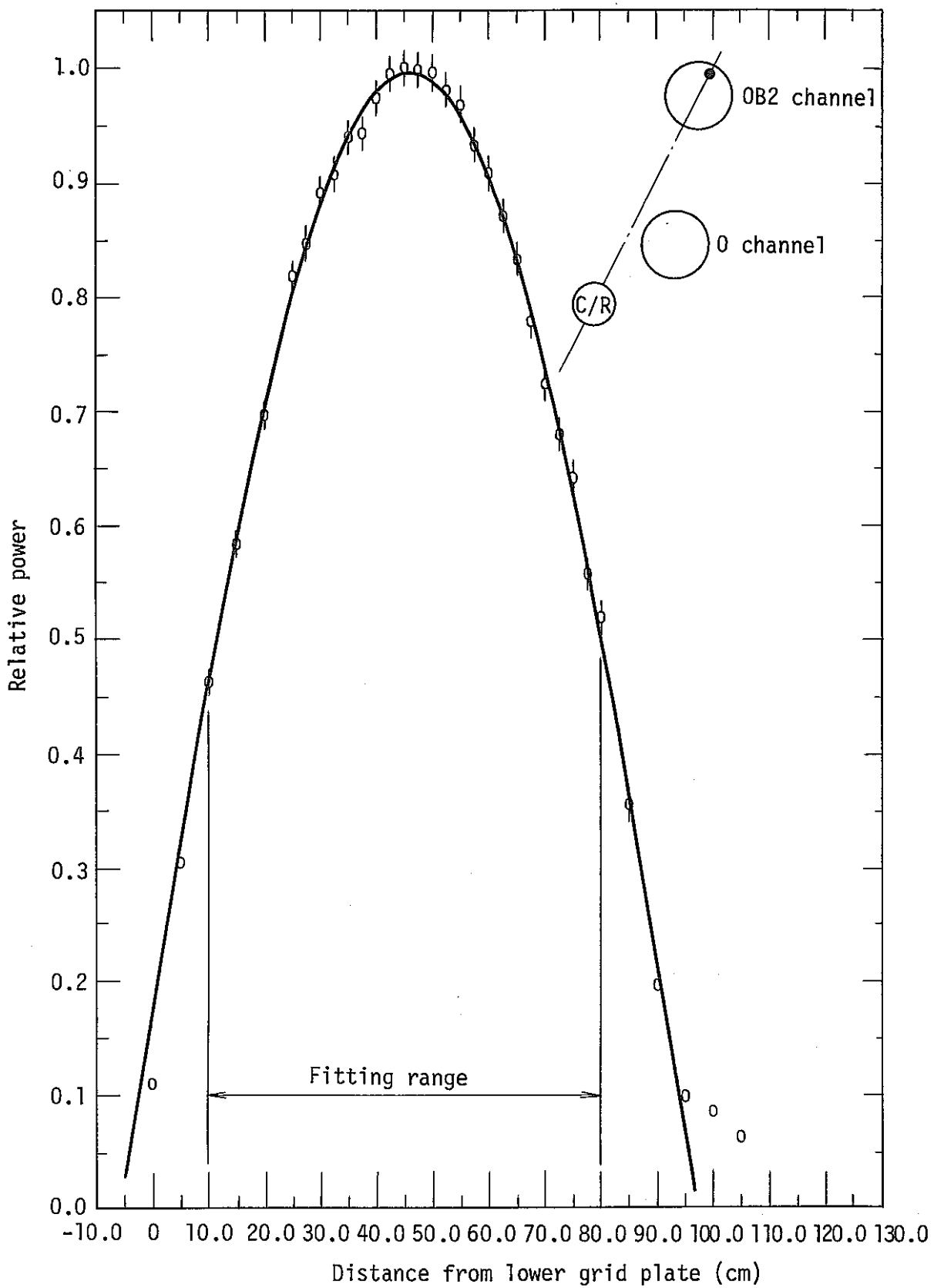


(6) Control-rod: 605 mm withdrawal Pin No.: C (3rd ring)

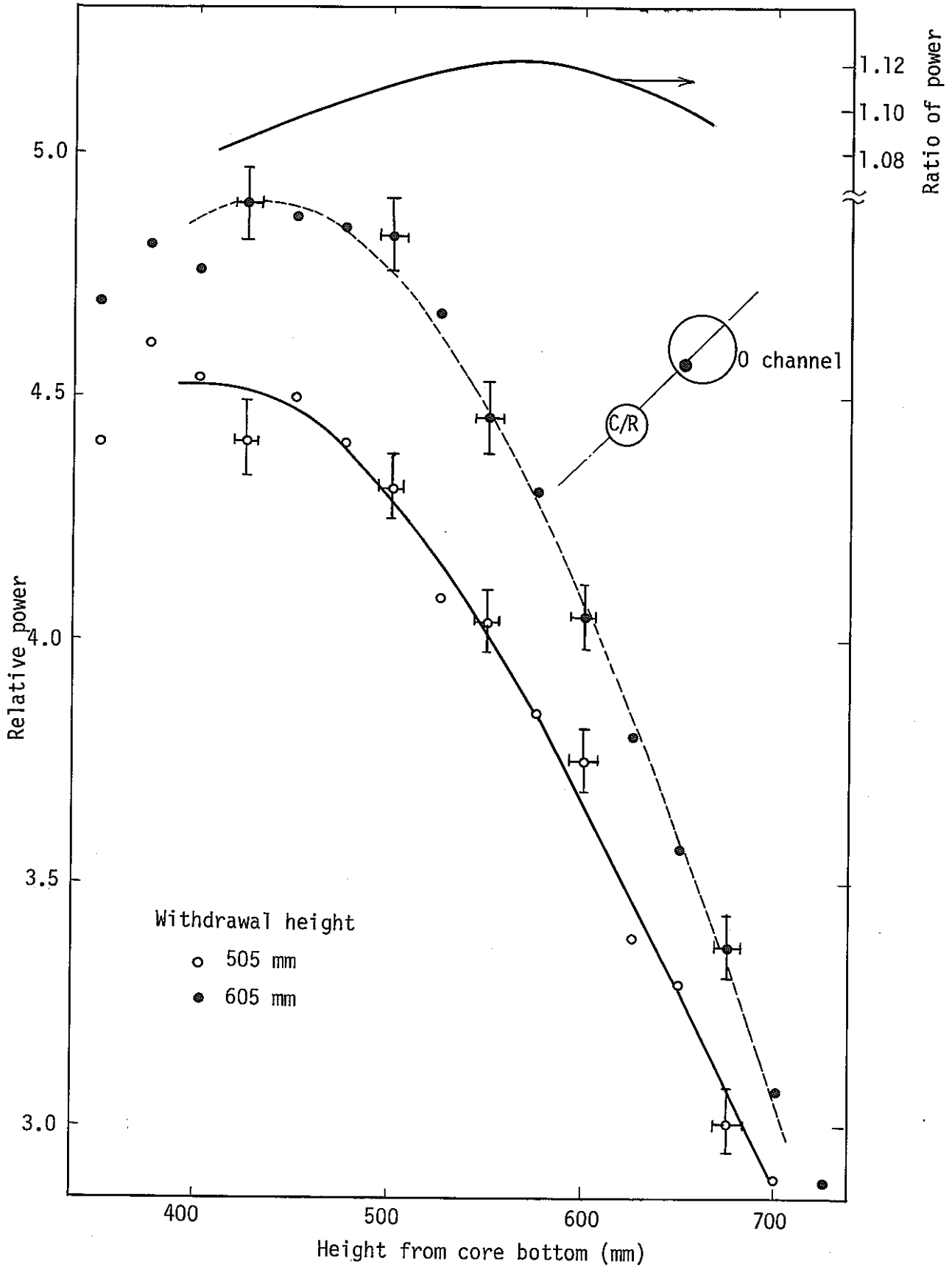


(1) Control-rod: 505 mm withdrawal Pin No.: D (3rd ring)

Fig. 4.2 Axial pin power distribution in OB2 channel cluster

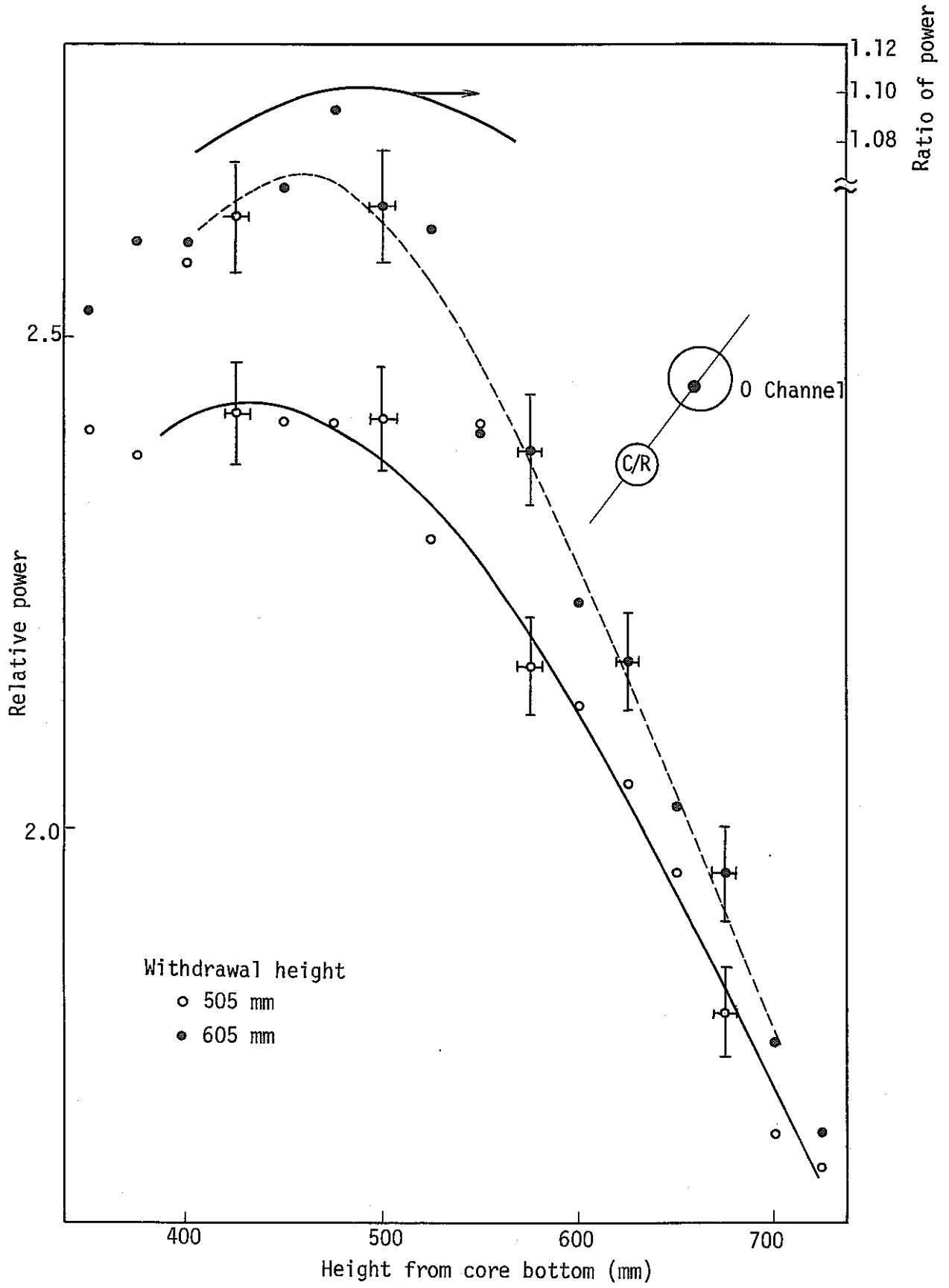


(2) Control-rod: 605 mm withdrawal Pin No.: D (3rd ring)

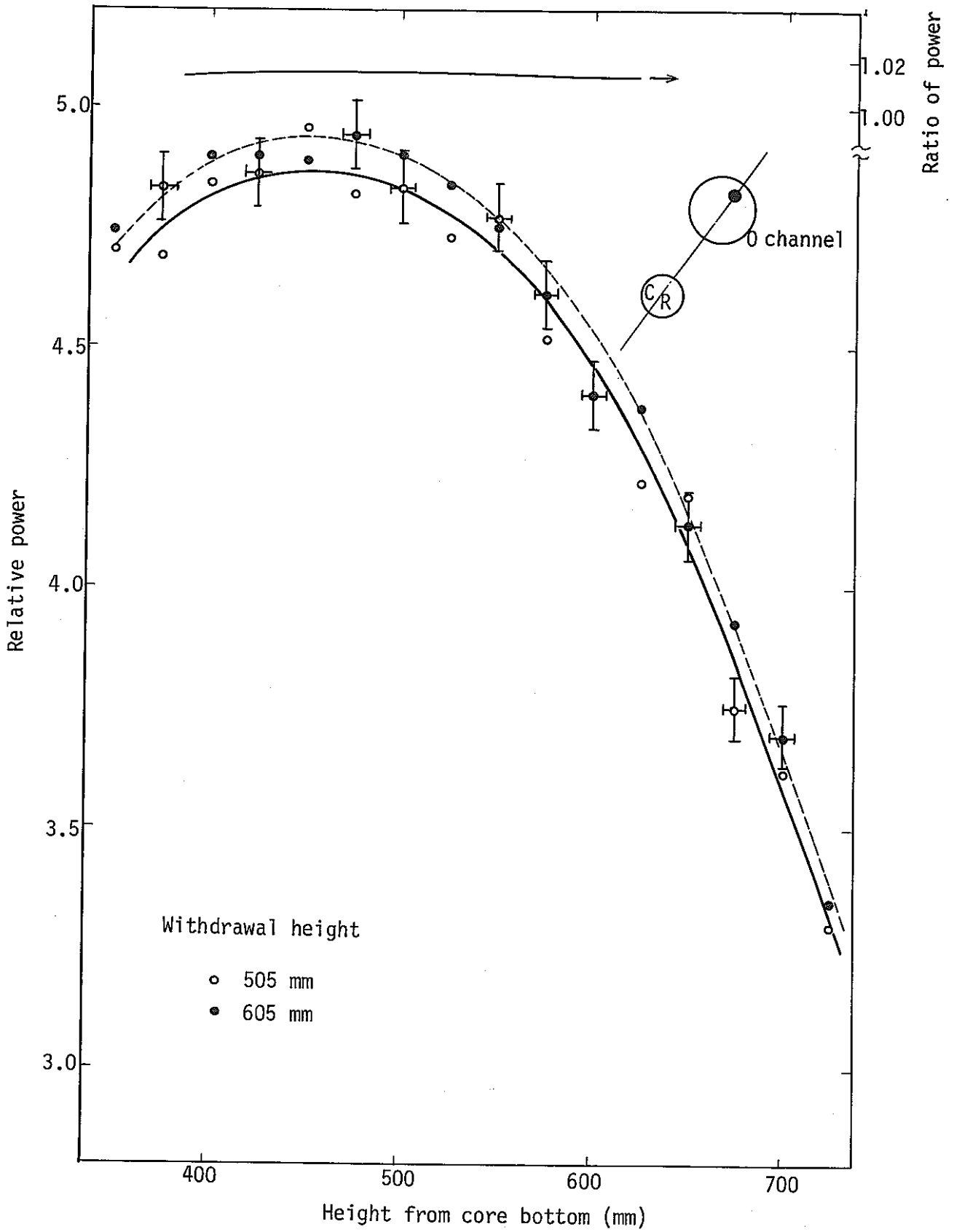


(1) Pin faced on the control-rod in 0 channel
(3rd ring pin)

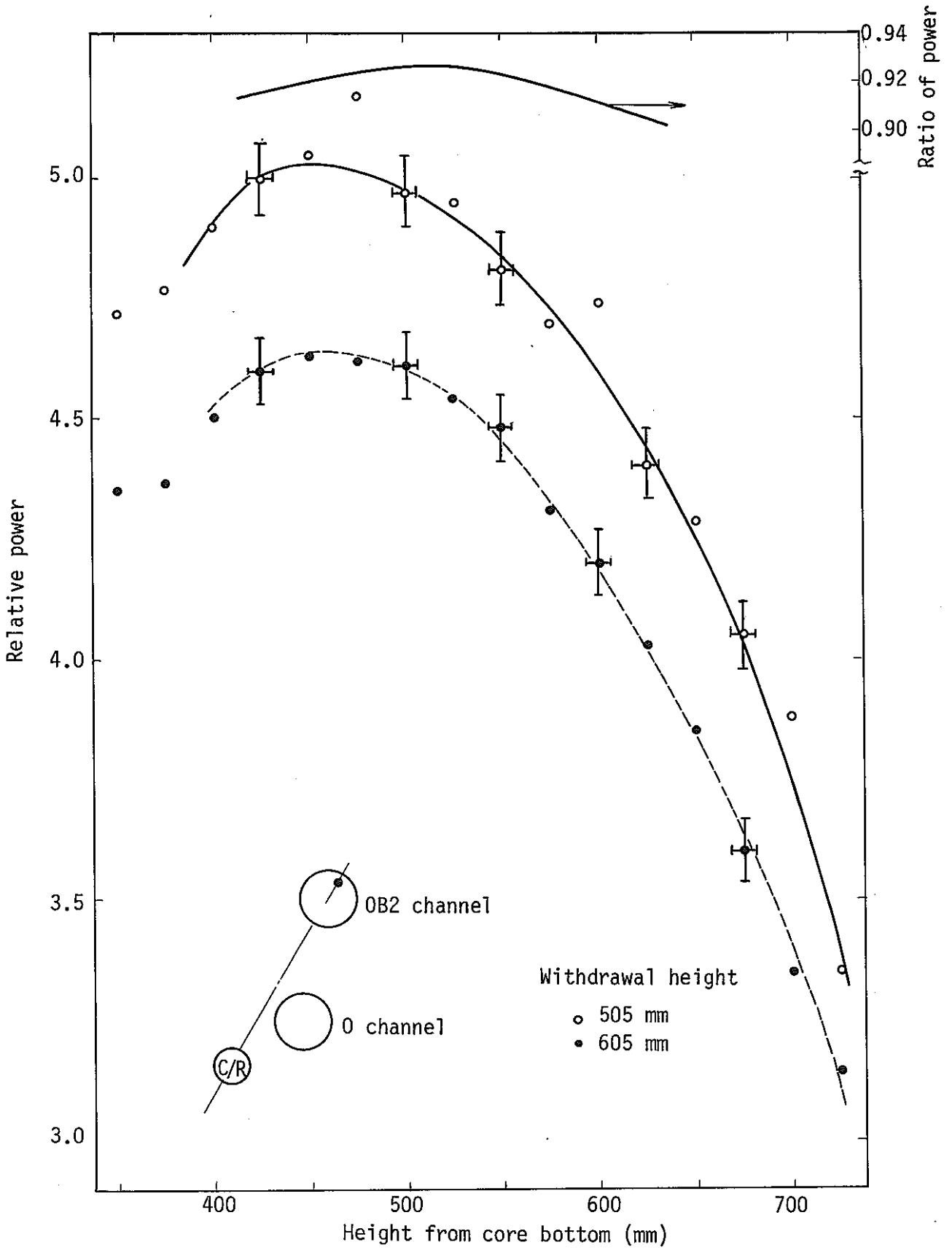
Fig. 4.3 Change in axial pin power distribution due to 100 mm withdrawal of control-rod



(2) Inside pin of 0 channel (1st ring pin)



(3) Backward pin into the control-rod in 0 channel
(3rd ring pin)



(4) Backward pin into the control-rod in OB2 channel (3rd ring pin)

5. Neutron flux distribution near the control-rod

- Table 5.1 Radial Dy reaction rate distribution in D₂O near the control-rod (1)~(3).
- Table 5.2 Axial Dy reaction rate distribution round fuel pins in 0 channel cluster (1)~(2).
- Fig. 5.1 Change in thermal neutron flux distribution in moderator to various withdrawal height of control-rod.
- Fig. 5.2 Magnitude of thermal neutron flux at inner and outer surface of 0 channel fuel pin near the control-rod of 505mm withdrawal.
- Fig. 5.3 Magnitude of thermal neutron flux at inner and outer surface of 0 channel fuel pin near the control-rod of 605mm withdrawal.

Table 5.1 Radial Dy reaction rate distribution in D₂O near the control-rod

(1) Control-rod : Fully inserted

| No. | Measurement region | Distance from core center (mm) | Weight of Dy foil (mg) | Reaction rate C (20 sec ⁻¹) | Error of C (20 sec ⁻¹) | Normalized reaction rate | Remarks | |
|-----|------------------------------|--------------------------------|------------------------|---|------------------------------------|--------------------------|---|--|
| 1 | Control-rod ~ Och fuel | - 68.25 | 10.80 | 1.892E 04 | 1.136E 02 | 0.648 | Calandria tube surface D ₂ O Control-rod surface | |
| 2 | | - 74.0 | 11.08 | 1.904E 04 | 9.555E 01 | 0.671 | | |
| 3 | | - 84.0 | 11.06 | 1.905E 04 | 9.977E 01 | 0.699 | | |
| 4 | | - 94.0 | 10.86 | 1.807E 04 | 9.245E 01 | 0.707 | | |
| 5 | | -104.0 | 10.96 | 1.807E 04 | 1.581E 02 | 0.683 | | |
| 6 | | -114.0 | 10.93 | 1.685E 04 | 1.548E 02 | 0.650 | | |
| 7 | | -124.0 | 11.28 | 1.548E 04 | 8.497E 01 | 0.591 | | |
| 8 | | -134.0 | 11.30 | 1.342E 04 | 1.110E 02 | 0.515 | | |
| 9 | | -139.8 | 11.09 | 1.211E 04 | 4.673E 01 | 0.444 | | |
| 10 | | -139.8 | 11.34 | 1.179E 04 | 7.649E 01 | 0.454 | | |
| 11 | | -139.8 | 11.03 | 1.155E 04 | 1.847E 02 | 0.444 | | |
| 12 | Och fuel ~ 2A2ch fuel | 68.25 | 10.96 | 2.325E 04 | 2.604E 02 | 0.894 | Calandria tube surface D ₂ O | |
| 13 | | 74.0 | 10.96 | 2.539E 04 | 1.050E 02 | 0.967 | | |
| 14 | | 84.0 | 11.15 | 2.753E 04 | 8.835E 01 | 1.041 | | |
| 15 | | 94.0 | 10.91 | 2.841E 04 | 7.993E 01 | 1.107 | | |
| 16 | | 104.0 | 10.87 | 3.004E 04 | 7.636E 01 | 1.158 | | |
| 17 | | 114.0 | 11.33 | 3.045E 04 | 1.175E 02 | 1.181 | | |
| 18 | | 124.0 | 11.21 | 3.212E 04 | 3.274E 02 | 1.216 | | |
| 19 | | 134.0 | 10.96 | 3.333E 04 | 5.781E 01 | 1.248 | | |
| 20 | | 144.0 | 11.14 | 3.329E 04 | 1.956E 02 | 1.262 | | |
| 21 | | 154.0 | 10.94 | 3.329E 04 | 2.123E 02 | 1.275 | | |
| 22 | | 164.0 | 11.14 | 3.354E 04 | 1.674E 02 | 1.284 | | |
| 23 | | 174.0 | 10.74 | 3.663E 04 | 7.928E 01 | 1.278 | | |
| 24 | | 184.0 | 10.83 | 3.662E 04 | 2.263E 02 | 1.270 | | |
| 25 | | 194.0 | 10.71 | 3.498E 04 | 1.314E 02 | 1.281 | | |
| 26 | | 204.0 | 10.68 | 3.437E 04 | 2.027E 02 | 1.287 | | |
| 27 | | 214.0 | 10.90 | 3.101E 04 | 1.580E 02 | 1.269 | | |
| 28 | | 224.0 | 10.88 | 3.074E 04 | 1.121E 02 | 1.227 | | |
| 29 | | 234.0 | 10.71 | 3.243E 04 | 1.362E 02 | 1.218 | | |
| 30 | | 244.0 | 10.53 | 3.159E 04 | 5.417E 01 | 1.187 | | |
| 31 | | 254.0 | 10.80 | 2.961E 04 | 6.542E 01 | 1.139 | | |
| 32 | | 264.0 | 10.51 | 2.981E 04 | 1.546E 02 | 1.076 | | |
| 33 | | 274.0 | 10.39 | 2.897E 04 | 1.479E 02 | 1.000 | | |
| 34 | | B.G | — | — | 1.050E 01 | 3.775E 00 | | |
| 35 | | B.G | — | — | -1.069E 01 | 1.208E 01 | | |

(2) Control-rod : 505mm withdrawal

| No. | Measurement region | Distance from core center (mm) | Weight of Dy foil (mg) | Reaction rate C (20 sec ⁻¹) | Error of C (20 sec ⁻¹) | Normalized reaction rate | Remarks | |
|-----|------------------------------|--------------------------------|------------------------|---|------------------------------------|--------------------------|---|--|
| 1 | Control-rod ~ Och fuel | - 68.25 | 10.71 | 2.264E 04 | 8.749E 01 | 0.736 | Calandria tube surface D ₂ O Control-rod surface | |
| 2 | | - 74.0 | 10.59 | 2.384E 04 | 1.748E 02 | 0.763 | | |
| 3 | | - 84.0 | 10.71 | 2.398E 04 | 2.216E 04 | 0.810 | | |
| 4 | | - 94.0 | 10.86 | 2.276E 04 | 1.442E 02 | 0.820 | | |
| 5 | | -104.0 | 11.04 | 2.514E 04 | 6.700E 01 | 0.811 | | |
| 6 | | -114.0 | 10.65 | 2.335E 04 | 1.337E 02 | 0.794 | | |
| 7 | | -124.0 | 10.99 | 2.230E 04 | 9.356E 01 | 0.712 | | |
| 8 | | -134.0 | 10.72 | 1.776E 04 | 2.969E 02 | 0.612 | | |
| 9 | | -139.8 | 10.97 | 1.534E 04 | 1.277E 02 | 0.546 | | |
| 10 | | -139.8 | 10.58 | 1.638E 04 | 1.098E 02 | 0.532 | | |
| 11 | | -139.8 | 10.90 | 1.663E 04 | 7.953E 01 | 0.556 | | |
| 12 | Och fuel ~ 2A2ch fuel | 68.25 | 10.59 | 2.796E 04 | 1.682E 02 | 0.921 | Calandria tube surface D ₂ O | |
| 13 | | 74.0 | 10.76 | 3.152E 04 | 2.628E 02 | 0.979 | | |
| 14 | | 84.0 | 10.60 | 3.423E 04 | 1.689E 02 | 1.044 | | |
| 15 | | 94.0 | 10.74 | 3.384E 04 | 8.734E 04 | 1.119 | | |
| 16 | | 104.0 | 10.88 | 3.350E 04 | 2.395E 02 | 1.182 | | |
| 17 | | 114.0 | 11.01 | 3.666E 04 | 6.486E 01 | 1.200 | | |
| 18 | | 124.0 | 10.83 | 3.796E 04 | 1.063E 02 | 1.247 | | |
| 19 | | 134.0 | 10.69 | 3.760E 04 | 1.919E 02 | 1.260 | | |
| 20 | | 144.0 | 11.02 | 3.935E 04 | 2.382E 02 | 1.286 | | |
| 21 | | 154.0 | 10.76 | 4.171E 04 | 2.459E 02 | 1.281 | | |
| 22 | | 164.0 | 10.84 | 4.022E 04 | 1.805E 02 | 1.288 | | |
| 23 | | 174.0 | 10.67 | 3.874E 04 | 1.638E 02 | 1.321 | | |
| 24 | | 184.0 | 10.76 | 3.774E 04 | 9.541E 01 | 1.305 | | |
| 25 | | 194.0 | 10.83 | 3.719E 04 | 8.602E 01 | 1.296 | | |
| 26 | | 204.0 | 10.76 | 3.790E 04 | 9.623E 01 | 1.290 | | |
| 27 | | 214.0 | 10.87 | 3.530E 04 | 1.312E 02 | 1.273 | | |
| 28 | | 224.0 | 10.85 | 3.976E 04 | 1.294E 02 | 1.261 | | |
| 29 | | 234.0 | 10.53 | 3.701E 04 | 1.772E 02 | 1.215 | | |
| 30 | | 244.0 | 10.67 | 3.539E 04 | 5.254E 01 | 1.181 | | |
| 31 | | 254.0 | 10.89 | 3.274E 04 | 7.436E 01 | 1.112 | | |
| 32 | | 264.0 | 11.01 | 2.978E 04 | 1.375E 02 | 1.082 | | |
| 33 | | 274.0 | 10.72 | 3.079E 04 | 5.996E 01 | 1.000 | | |
| 34 | | B.G | — | — | -7.616E 00 | 2.645E 01 | | |
| 35 | | B.G | — | — | 6.917E 00 | 2.778E 01 | | |

(3) Control-rod : 605mm withdrawal

| No. | Measurement region | Distance from core center (mm) | Weight of Dy foil (mg) | Reaction rate C (20 sec ⁻¹) | Error of C (20 sec ⁻¹) | Normalized reaction rate | Remarks | |
|-----|------------------------------|--------------------------------|------------------------|---|------------------------------------|--------------------------|---|--|
| 1 | Control-rod ~ Och fuel | - 68.25 | 10.80 | 2.785E 04 | 1.343E 02 | 0.828 | Calandria tube surface D ₂ O Control-rod surface | |
| 2 | | - 74.0 | 11.08 | 2.870E 04 | 1.716E 02 | 0.878 | | |
| 3 | | - 84.0 | 11.06 | 2.967E 04 | 1.779E 02 | 0.946 | | |
| 4 | | - 94.0 | 10.86 | 2.897E 04 | 1.033E 02 | 0.984 | | |
| 5 | | -104.0 | 10.96 | 3.036E 04 | 1.220E 02 | 0.989 | | |
| 6 | | -114.0 | 10.93 | 3.011E 04 | 1.918E 02 | 1.008 | | |
| 7 | | -124.0 | 11.28 | 3.050E 04 | 3.257E 02 | 1.011 | | |
| 8 | | -134.0 | 11.30 | 3.012E 04 | 4.686E 01 | 1.004 | | |
| 9 | | -139.8 | 11.09 | 3.138E 04 | 1.450E 02 | 0.993 | | |
| 10 | | -139.8 | 11.34 | 2.914E 04 | 3.660E 01 | 0.975 | | |
| 11 | | -139.8 | 11.03 | 2.842E 04 | 5.695E 01 | 0.950 | | |
| 12 | Och fuel ~ 2A2ch fuel | 68.25 | 10.96 | 2.777E 04 | 7.793E 01 | 0.927 | Calandria tube surface D ₂ O | |
| 13 | | 74.0 | 10.96 | 3.019E 04 | 1.366E 02 | 0.999 | | |
| 14 | | 84.0 | 11.15 | 3.305E 04 | 2.122E 02 | 1.085 | | |
| 15 | | 94.0 | 10.91 | 3.417E 04 | 2.241E 02 | 1.156 | | |
| 16 | | 104.0 | 10.87 | 3.583E 04 | 2.518E 02 | 1.200 | | |
| 17 | | 114.0 | 11.33 | 3.633E 04 | 1.307E 02 | 1.223 | | |
| 18 | | 124.0 | 11.21 | 3.817E 04 | 1.751E 02 | 1.255 | | |
| 19 | | 134.0 | 10.96 | 3.953E 04 | 1.329E 02 | 1.286 | | |
| 20 | | 144.0 | 11.14 | 3.914E 04 | 3.025E 02 | 1.288 | | |
| 21 | | 154.0 | 10.94 | 3.930E 04 | 2.743E 02 | 1.307 | | |
| 22 | | 164.0 | 11.14 | 3.957E 04 | 1.904E 02 | 1.318 | | |
| 23 | | 174.0 | 10.74 | 4.274E 04 | 3.082E 02 | 1.295 | | |
| 24 | | 184.0 | 10.83 | 4.298E 04 | 2.600E 02 | 1.294 | | |
| 25 | | 194.0 | 10.71 | 4.099E 04 | 1.240E 02 | 1.303 | | |
| 26 | | 204.0 | 10.68 | 3.984E 04 | 2.254E 02 | 1.296 | | |
| 27 | | 214.0 | 10.90 | 3.605E 04 | 1.365E 02 | 1.282 | | |
| 28 | | 224.0 | 10.88 | 3.573E 04 | 2.705E 02 | 1.239 | | |
| 29 | | 234.0 | 10.71 | 3.776E 04 | 9.081E 01 | 1.231 | | |
| 30 | | 244.0 | 10.53 | 3.679E 04 | 2.602E 02 | 1.200 | | |
| 31 | | 254.0 | 10.80 | 3.423E 04 | 1.309E 02 | 1.141 | | |
| 32 | | 264.0 | 10.51 | 3.435E 04 | 2.123E 02 | 1.077 | | |
| 33 | | 274.0 | 10.39 | 3.336E 04 | 2.795E 02 | 1.000 | | |
| 34 | | B.G | — | — | 1.551E 01 | 2.210E 01 | | |
| 35 | | B.G | — | — | -1.378E 01 | 2.240E 01 | | |

Table 5.2 Axial Dy reaction rate distribution round fuel pins in 0 channel cluster

(1) Withdrawal height of control-rod : 505mm

| No. | Height from grid plate (cm) | Pin faced on the control-rod | | | | Opposit side pin toward the control-rod | | | |
|-----|-----------------------------|------------------------------|-----------|------------|-----------|---|-----------|------------|-----------|
| | | Outer side | | Inner side | | Outer side | | Inner side | |
| | | activity | error | activity | error | activity | error | activity | error |
| 1 | 60.0 | 2.247E 04 | 1.965E 02 | 1.495E 04 | 2.190E 02 | 2.903E 04 | 5.341E 02 | 1.849E 04 | 9.432E 01 |
| 2 | 59.5 | 2.314E 04 | 2.047E 02 | 1.484E 04 | 1.630E 02 | 2.917E 04 | 2.839E 02 | 1.846E 04 | 2.277E 02 |
| 3 | 59.0 | 2.361E 04 | 1.760E 02 | 1.481E 04 | 1.778E 02 | 2.954E 04 | 4.969E 02 | 1.868E 04 | 2.521E 02 |
| 4 | 58.5 | 2.389E 04 | 5.540E 01 | 1.548E 04 | 2.518E 02 | 2.990E 02 | 2.982E 02 | 1.920E 04 | 4.943E 02 |
| 5 | 58.0 | 2.355E 04 | 1.218E 02 | 1.524E 04 | 1.547E 02 | 3.058E 04 | 2.088E 02 | 1.938E 04 | 2.216E 02 |
| 6 | 57.5 | 2.356E 04 | 2.179E 02 | 1.552E 04 | 1.608E 02 | 3.046E 04 | 2.123E 02 | 1.895E 04 | 1.519E 02 |
| 7 | 57.0 | 2.373E 04 | 2.525E 02 | 1.549E 04 | 1.372E 02 | 2.996E 04 | 4.048E 02 | 1.919E 04 | 1.053E 02 |
| 8 | 56.5 | 2.359E 04 | 1.830E 02 | 1.551E 04 | 4.163E 01 | 2.982E 04 | 1.658E 02 | 1.923E 04 | 1.459E 02 |
| 9 | 56.0 | 2.381E 04 | 2.765E 02 | 1.564E 04 | 2.010E 02 | 2.952E 04 | 2.961E 02 | 1.892E 04 | 1.304E 02 |
| 10 | 55.5 | 2.440E 04 | 3.124E 02 | 1.605E 04 | 2.714E 02 | 3.007E 04 | 2.760E 02 | 1.951E 04 | 1.421E 02 |
| 11 | 55.0 | 2.531E 04 | 1.846E 02 | 1.637E 04 | 2.718E 02 | 3.112E 04 | 1.427E 02 | 2.003E 04 | 1.313E 02 |
| 12 | 54.5 | 2.575E 04 | 2.369E 02 | 1.670E 04 | 1.014E 02 | 3.093E 04 | 3.141E 02 | 1.987E 04 | 9.144E 01 |
| 13 | 54.0 | 2.566E 04 | 3.827E 02 | 1.693E 04 | 2.890E 02 | 3.109E 04 | 1.638E 02 | 2.035E 04 | 3.095E 02 |
| 14 | 53.5 | 2.599E 04 | 1.079E 02 | 1.695E 04 | 1.101E 02 | 3.154E 04 | 2.080E 02 | 2.036E 04 | 2.030E 02 |
| 15 | 53.0 | 2.648E 04 | 1.786E 02 | 1.730E 04 | 2.335E 02 | 3.266E 04 | 1.598E 02 | 2.048E 04 | 1.342E 02 |
| 16 | 52.5 | 2.654E 04 | 1.099E 02 | 1.706E 04 | 1.740E 02 | 3.222E 04 | 2.003E 02 | 2.043E 04 | 1.677E 02 |
| 17 | 52.0 | 2.706E 04 | 2.871E 02 | 1.695E 04 | 2.427E 02 | 3.210E 04 | 1.279E 02 | 2.023E 04 | 1.617E 02 |
| 18 | 51.5 | 2.773E 04 | 3.976E 02 | 1.724E 04 | 9.726E 01 | 3.193E 04 | 3.594E 02 | 2.063E 04 | 2.053E 02 |
| 19 | 51.0 | 2.738E 04 | 2.169E 02 | 1.763E 04 | 9.905E 01 | 3.167E 04 | 2.699E 02 | 2.075E 04 | 9.965E 01 |

(2) Withdrawal height of control-rod : 605mm

| No. | Height from grid plate (cm) | Pin faced on the control-rod | | | | Opposit side pin toward control-rod | | | |
|-----|-----------------------------|------------------------------|-----------|------------|-----------|-------------------------------------|-----------|------------|-----------|
| | | Outer side | | Inner side | | Outer side | | Inner side | |
| | | activity | error | activity | error | activity | error | activity | error |
| 1 | 60.0 | 2.593E 04 | 1.986E 02 | 1.739E 04 | 2.094E 02 | 2.949E 04 | 3.791E 02 | 1.826E 04 | 1.663E 02 |
| 2 | 59.5 | 2.561E 04 | 3.313E 01 | 1.715E 04 | 2.166E 02 | 2.921E 04 | 4.348E 02 | 1.859E 04 | 3.843E 02 |
| 3 | 59.0 | 2.586E 04 | 7.238E 01 | 1.760E 04 | 2.211E 02 | 2.951E 04 | 3.439E 02 | 1.872E 04 | 1.272E 02 |
| 4 | 58.5 | 2.626E 04 | 1.337E 02 | 1.753E 04 | 2.101E 02 | 2.987E 04 | 3.381E 02 | 1.880E 04 | 1.610E 02 |
| 5 | 58.0 | 2.664E 04 | 1.574E 02 | 1.806E 04 | 1.582E 02 | 2.978E 04 | 1.653E 02 | 2.820E 04 | 3.475E 02 |
| 6 | 57.5 | 2.663E 04 | 3.875E 02 | 1.805E 04 | 1.975E 02 | 3.011E 04 | 3.263E 02 | 1.926E 04 | 1.693E 02 |
| 7 | 57.0 | 2.693E 04 | 2.871E 02 | 1.770E 04 | 2.679E 02 | 2.930E 04 | 9.229E 01 | 1.968E 04 | 2.582E 02 |
| 8 | 56.5 | 2.676E 04 | 2.169E 02 | 1.794E 04 | 1.043E 02 | 2.891E 04 | 1.004E 02 | 1.955E 04 | 3.418E 02 |
| 9 | 56.0 | 2.707E 04 | 3.873E 02 | 1.789E 04 | 1.500E 02 | 2.893E 04 | 1.617E 02 | 1.959E 04 | 1.360E 02 |
| 10 | 55.5 | 2.767E 04 | 1.407E 02 | 1.779E 04 | 9.494E 01 | 2.904E 04 | 1.986E 02 | 1.924E 04 | 2.007E 02 |
| 11 | 55.0 | 2.811E 04 | 3.331E 02 | 1.750E 04 | 1.341E 02 | 3.012E 04 | 1.123E 02 | 1.897E 04 | 1.193E 02 |
| 12 | 54.5 | 2.864E 04 | 1.934E 02 | 1.817E 04 | 1.335E 02 | 2.985E 04 | 2.226E 02 | 1.927E 04 | 2.604E 02 |
| 13 | 54.0 | 2.907E 04 | 2.084E 02 | 1.842E 04 | 1.415E 02 | 3.012E 04 | 1.886E 02 | 1.938E 04 | 1.097E 02 |
| 14 | 53.5 | 2.954E 04 | 1.843E 02 | 1.849E 04 | 2.257E 02 | 3.101E 04 | 2.482E 02 | 1.972E 04 | 2.103E 02 |
| 15 | 53.0 | 2.939E 04 | 1.217E 02 | 1.892E 04 | 3.423E 02 | 3.122E 04 | 8.981E 01 | 1.997E 04 | 1.506E 02 |
| 16 | 52.5 | 2.964E 04 | 2.093E 02 | 1.889E 04 | 1.480E 02 | 3.083E 04 | 2.788E 02 | 1.991E 04 | 2.800E 02 |
| 17 | 52.0 | 3.032E 04 | 2.626E 02 | 1.906E 04 | 2.651E 02 | 3.157E 04 | 4.255E 02 | 1.951E 04 | 2.630E 02 |
| 18 | 51.5 | 3.028E 04 | 7.486E 01 | 1.922E 04 | 2.442E 02 | 3.196E 04 | 3.150E 02 | 2.001E 04 | 7.580E 01 |
| 19 | 51.0 | 3.076E 04 | 3.168E 02 | 1.922E 04 | 1.006E 02 | 3.221E 04 | 1.337E 02 | 1.999E 04 | 2.016E 02 |

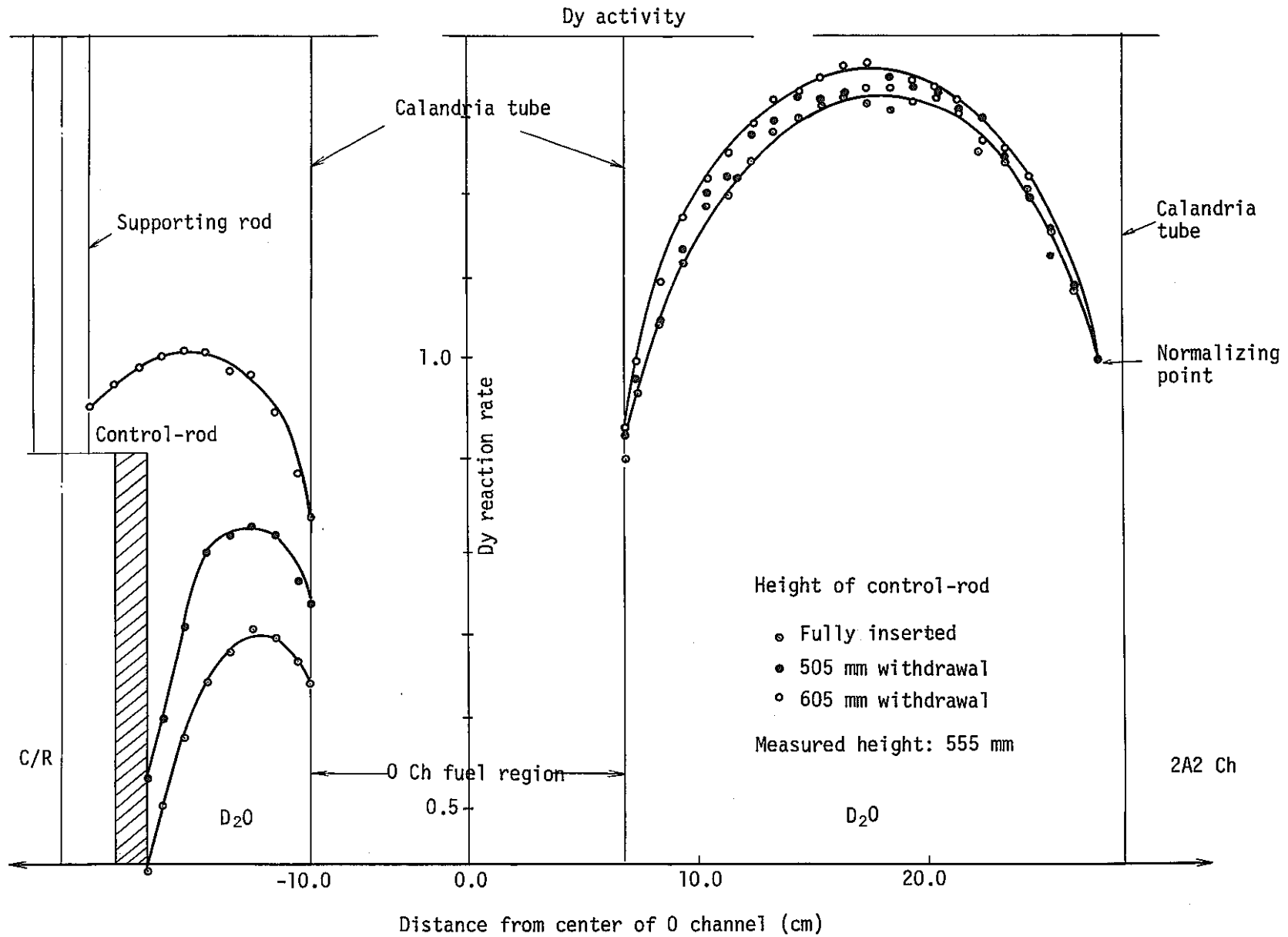
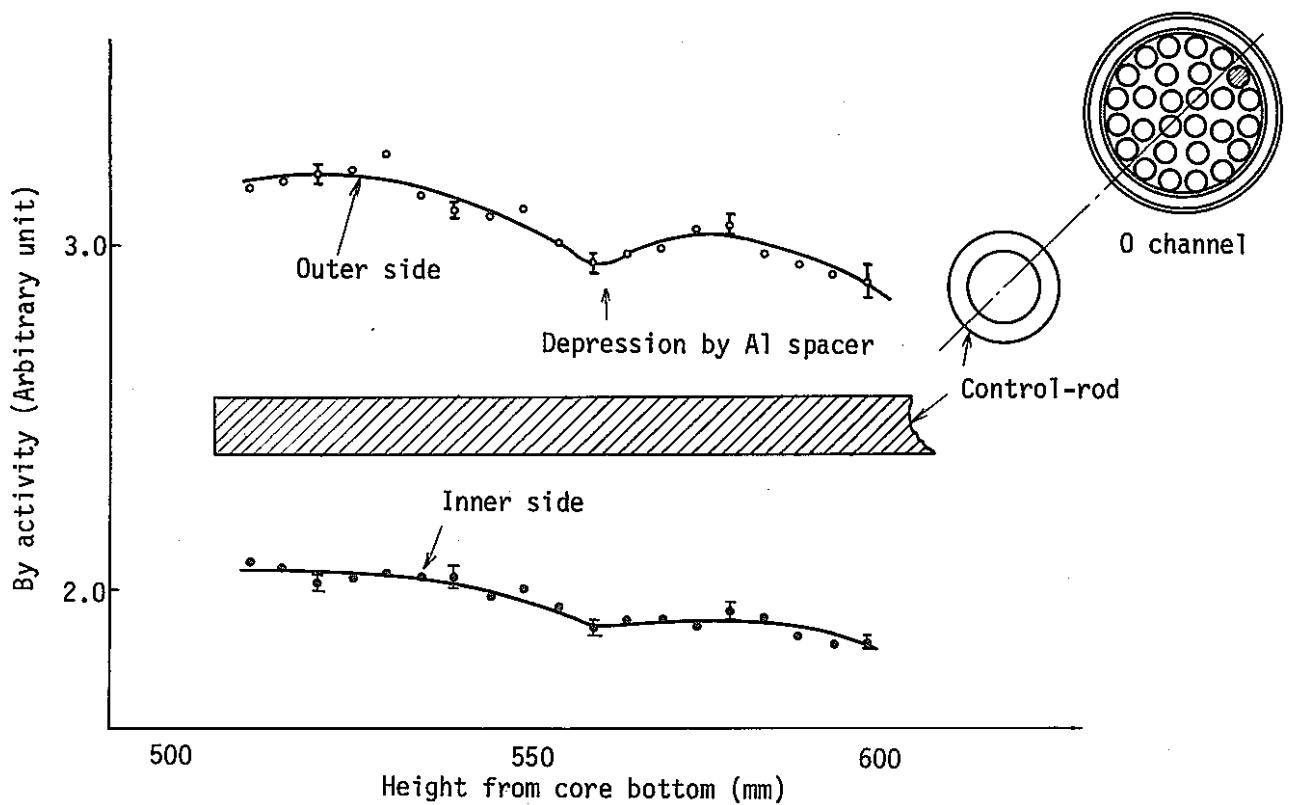
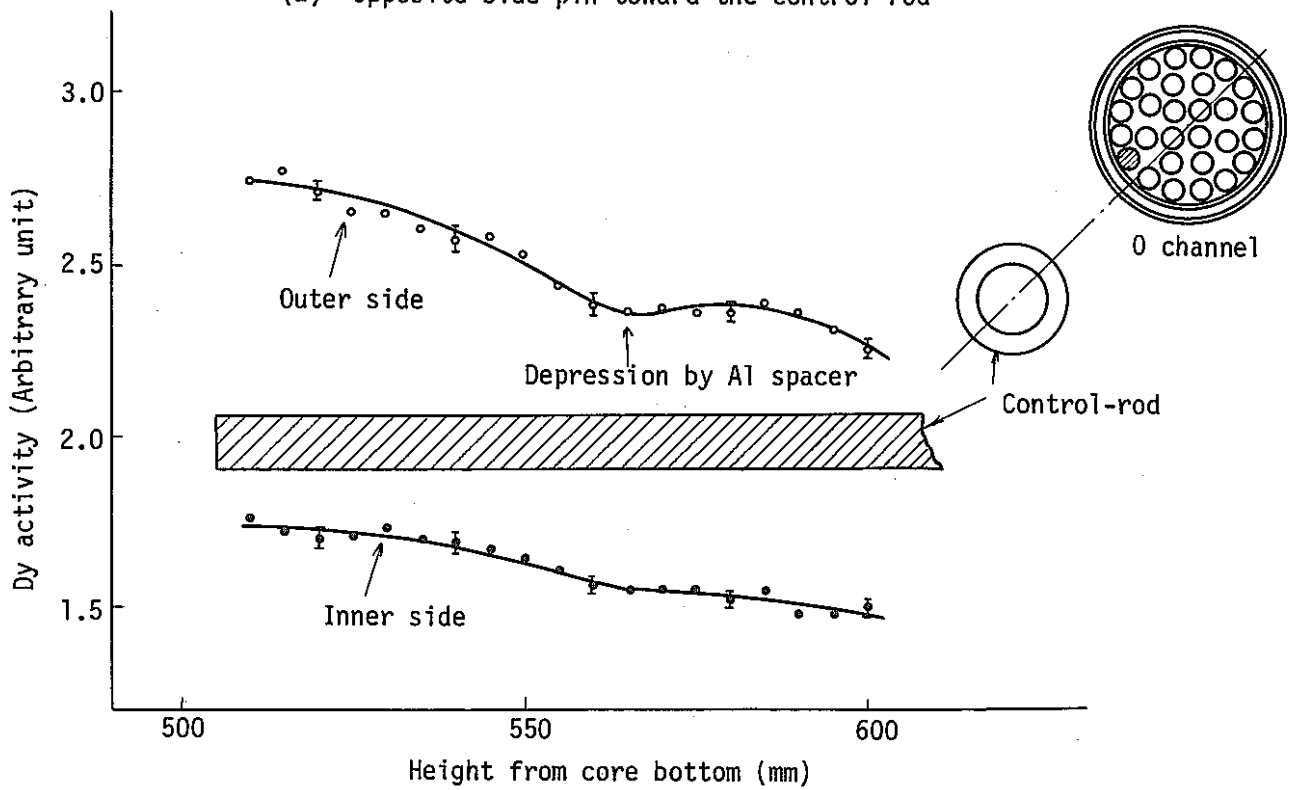


Fig. 5.1 Change in thermal neutron flux distribution in moderator due to various withdrawal height of control-rod.

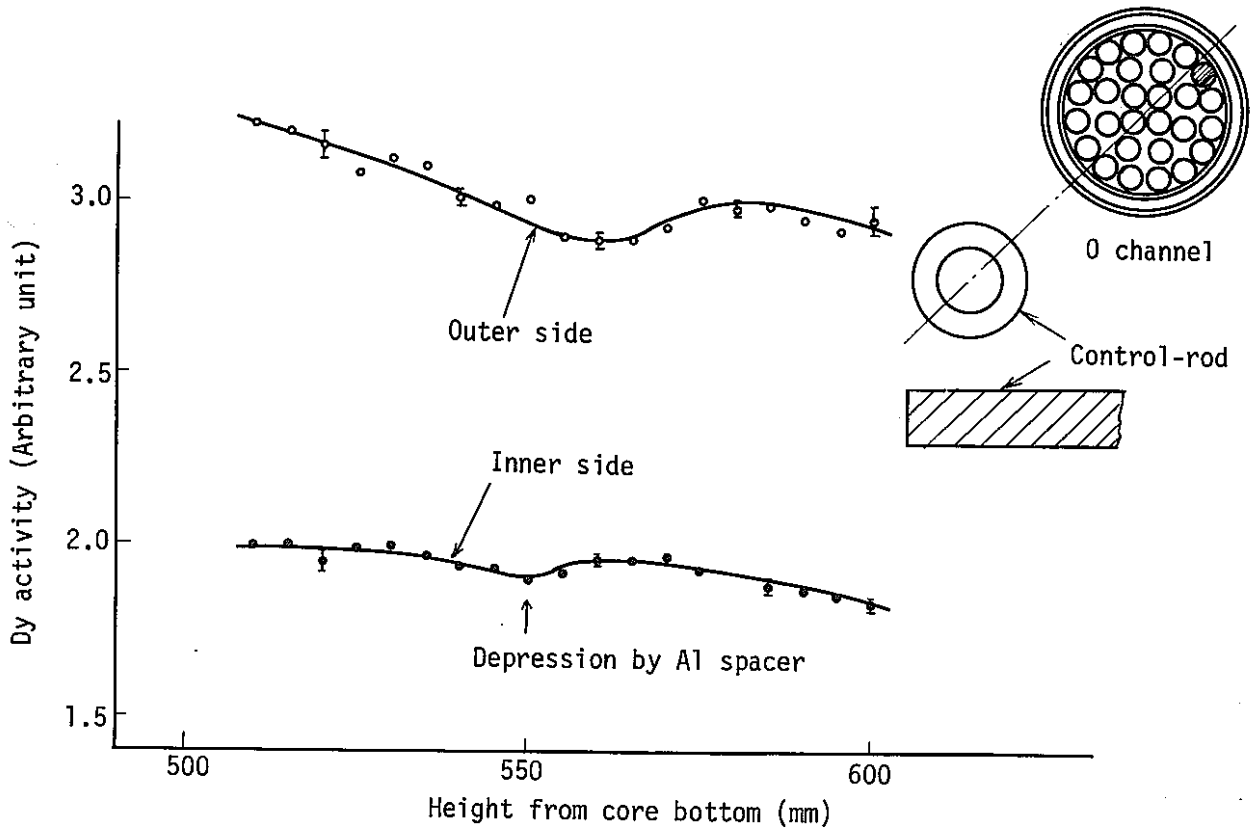


(2) Opposite side pin toward the control-rod

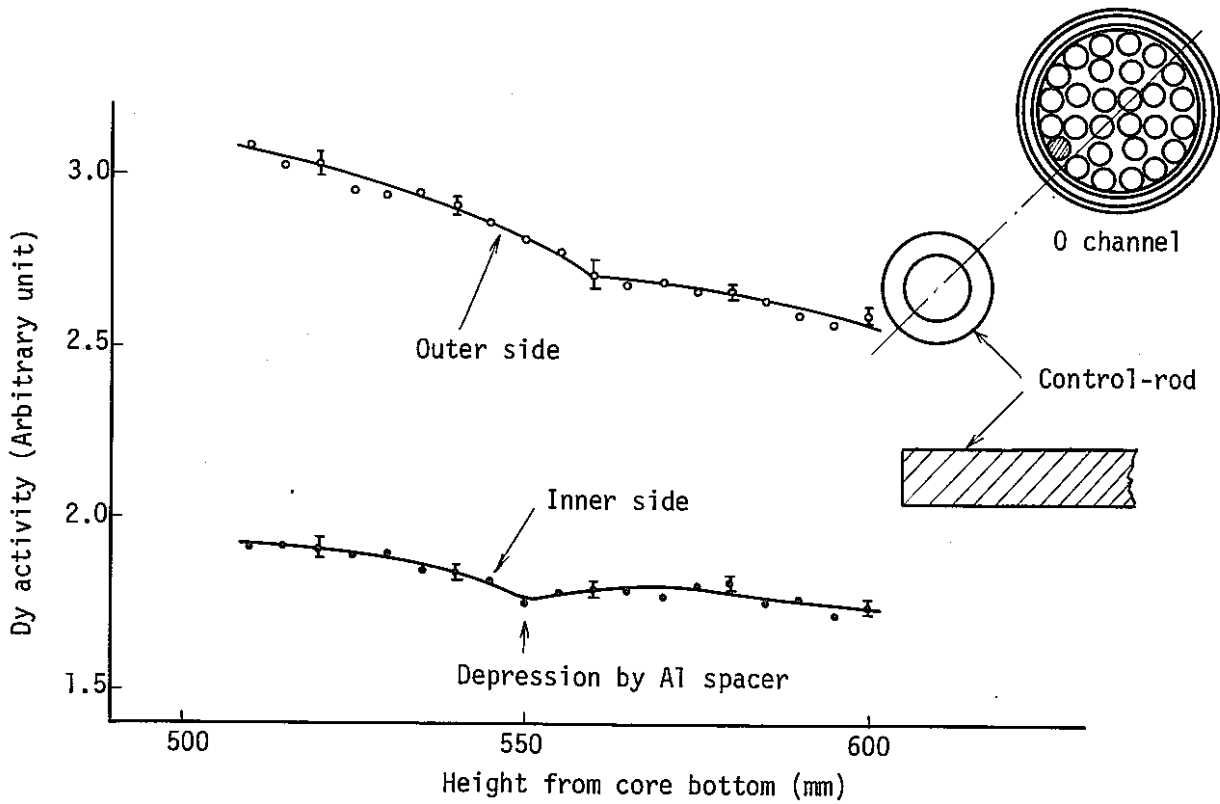


(1) Pin faced on the control-rod

Fig. 5.2 Magnitude of thermal neutron flux at inner and outer surface of 0 channel fuel pin near the control-rod of 505 mm withdrawal



(2) Opposit side pin toward the control-rod



(1) Pn faced on the control-rod

Fig. 5.3 Magnitude of thermal neutron flux at inner and outer surface of 0 channel fuel pin near the control-rod of 605 mm withdrawal

6. Radial neutron flux distribution in the core

Table 6.1 Radial reaction rate distribution of Cu pieces at 555mm core height (1)~(3).

Fig. 6.1 Radial reaction rate distribution of Cu pieces at 555mm core height (1)~(3).

Fig. 6.2 The rate of radial flux distribution at 555mm height due to change in control-rod withdrawal from 505mm to 605mm.

Fig. 6.3 Radial thermal flux distribution at 555mm core height (1)~(3).

Table 6.1 Radial reaction rate distribution of Cu pieces at 555mm core height

(1) Full insertion of control-rod

(Unit : cps/mg)

| In the center of Cluster | | | | | | | | In D ₂ O | | | |
|--------------------------|-------------|----------|-----------|-----|-------------|----------|-----------|---------------------|-------------|----------|-----------|
| No. | Channel No. | Activity | Error (%) | No. | Channel No. | Activity | Error (%) | No. | Channel No. | Activity | Error (%) |
| 1 | 6A6 | 854 | 0.876 | 27 | 0D4 | 1449 | 0.399 | 53 | OBS | 929 | 0.739 |
| 2 | 8A6 | 478 | 1.101 | 28 | 2D4 | 1462 | 0.550 | 54 | OB9 | 2600 | 0.487 |
| 3 | 4A4 | 1351 | 0.274 | 29 | 4D4 | 1275 | 0.344 | 55 | OB7 | 4246 | 0.379 |
| 4 | 6A4 | 1215 | 0.438 | 30 | 6D4 | 1163 | 1.235 | 56 | OB5 | 6293 | 0.693 |
| 5 | 8A4 | 740 | 0.903 | 31 | 8D4 | 722 | 1.474 | 57 | OB3 | 7397 | 0.260 |
| 6 | RA4 | 309 | 0.936 | 32 | RD4 | 293 | 1.239 | 58 | OB1 | 7829 | 0.392 |
| 7 | 2A2 | 1851 | 0.169 | 33 | 6C6 | 742 | 0.376 | 59 | SC0 | 835 | 0.987 |
| 8 | 4A2 | 1606 | 0.585 | 34 | 4C6 | 1040 | 1.059 | 60 | 9C0 | 2286 | 0.746 |
| 9 | 6A2 | 1459 | 1.001 | 35 | 2C6 | 1251 | 0.645 | 61 | 7C0 | 3985 | 0.545 |
| 10 | 8A2 | 923 | 0.891 | 36 | 0D6 | 1330 | 0.669 | 62 | 5C0 | 5465 | 0.162 |
| 11 | RA2 | 432 | 0.749 | 37 | 2D6 | 1314 | 0.941 | 63 | 3C0 | 6530 | 0.524 |
| 12 | 0 | 1672 | 0.213 | 38 | 4D6 | 1156 | 0.640 | 64 | 1C0 | 6218 | 0.288 |
| 13 | 2A0 | 1824 | 0.378 | 39 | 6D6 | 819 | 0.899 | 65 | 1B1 | 8247 | 0.346 |
| 14 | 4A0 | 1665 | 0.439 | 40 | 8D6 | 454 | 1.489 | 66 | 7C7 | 1790 | 0.565 |
| 15 | 6A0 | 1514 | 1.140 | 41 | 6C8 | 412 | 1.034 | 67 | 5C5 | 4249 | 0.211 |
| 16 | 8A0 | 960 | 0.641 | 42 | 4C8 | 634 | 1.009 | 68 | 7A7 | 2110 | 0.459 |
| 17 | RA0 | 475 | 1.878 | 43 | 2C8 | 800 | 0.446 | 69 | 5A5 | 4926 | 0.189 |
| 18 | 2C2 | 1418 | 0.322 | 44 | 0D8 | 857 | 0.674 | | | | |
| 19 | 0D2 | 1556 | 0.781 | 45 | 2D8 | 840 | 0.898 | | | | |
| 20 | 2D2 | 1734 | 0.476 | 46 | 4D8 | 699 | 0.773 | | | | |
| 21 | 4D2 | 1528 | 0.270 | 47 | 6D8 | 449 | 1.069 | | | | |
| 22 | 6D2 | 1437 | 0.561 | 48 | 4CR | 265 | 1.715 | | | | |
| 23 | 8D2 | 912 | 1.284 | 49 | 2CR | 374 | 0.778 | | | | |
| 24 | RD2 | 435 | 1.484 | 50 | 0DR | 432 | 1.242 | | | | |
| 25 | 4C4 | 1157 | 0.377 | 51 | 2DR | 400 | 1.028 | | | | |
| 26 | 2C4 | 1301 | 0.617 | 52 | 4DR | 287 | 0.403 | | | | |

(2) Withdrawal height of control-rod : 505mm

(Unit : cps/mg)

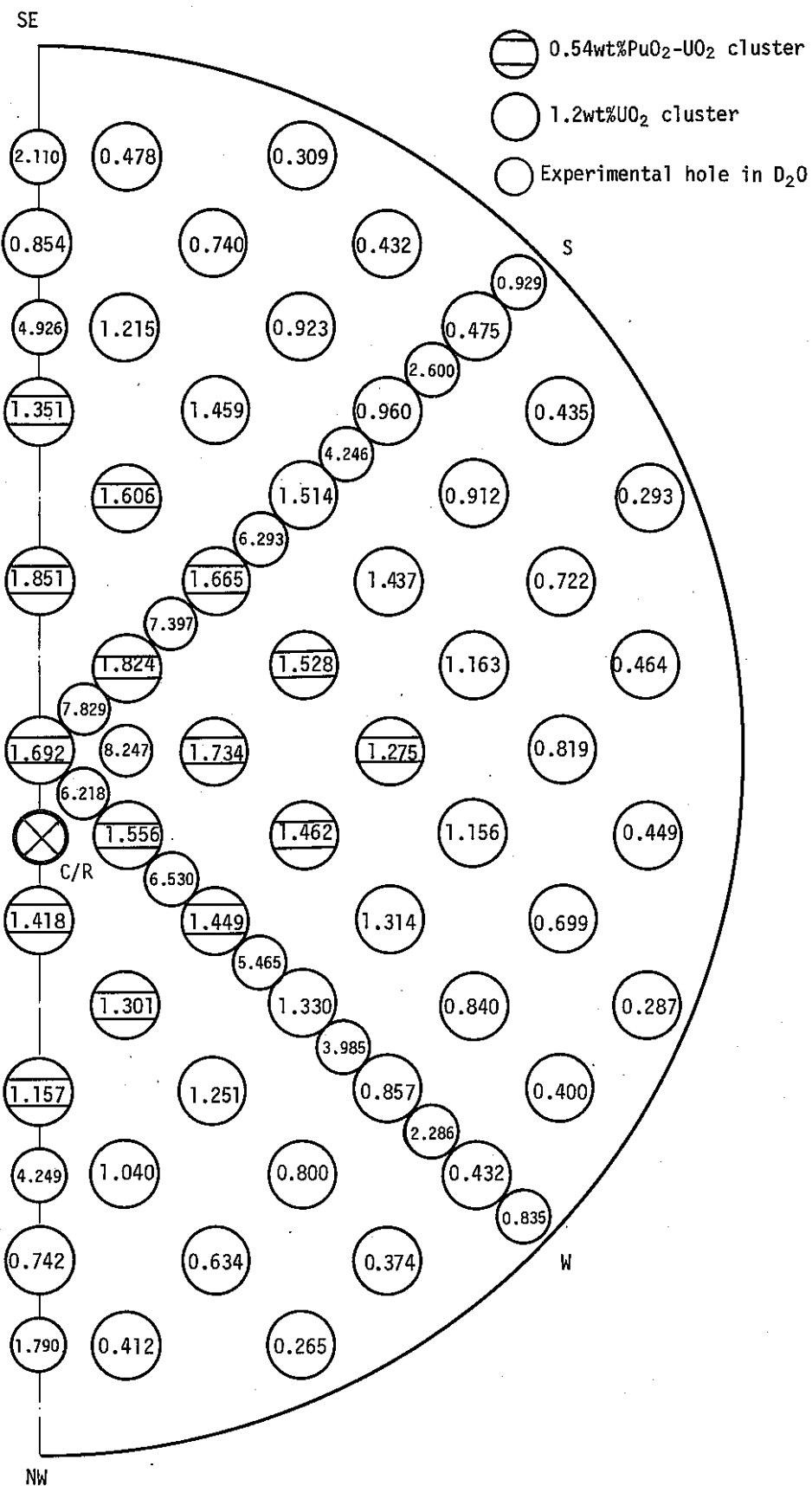
| No. | In the center of Cluster | | | | In D ₂ O | | | | | | |
|-----|--------------------------|----------|-----------|-----|---------------------|----------|-----------|-----|-------------|----------|-----------|
| | Channel No. | Activity | Error (%) | No. | Channel No. | Activity | Error (%) | No. | Channel No. | Activity | Error (%) |
| 1 | 6A6 | 877 | 1.225 | 27 | 0D4 | 1651 | 1.013 | 53 | 0B5 | 951 | 0.744 |
| 2 | 8A6 | 491 | 2.451 | 28 | 2D4 | 1630 | 0.550 | 54 | 0B9 | 2669 | 0.537 |
| 3 | 4A4 | 1413 | 1.227 | 29 | 4D4 | 1382 | 0.756 | 55 | 0B7 | 4455 | 0.196 |
| 4 | 6A4 | 1259 | 0.362 | 30 | 6D4 | 1231 | 1.054 | 56 | 0B5 | 6676 | 0.434 |
| 5 | 8A4 | 756 | 0.527 | 31 | 8D4 | 754 | 0.419 | 57 | 0B3 | 8333 | 0.524 |
| 6 | RA4 | 312 | 2.093 | 32 | RD4 | 310 | 1.594 | 58 | 0B1 | 8837 | 0.248 |
| 7 | 2A2 | 1994 | 0.533 | 33 | 6C6 | 835 | 0.934 | 59 | SC0 | 898 | 1.118 |
| 8 | 4A2 | 1688 | 0.771 | 34 | 4C6 | 1165 | 0.608 | 60 | 9C0 | 2495 | 0.180 |
| 9 | 6A2 | 1520 | 0.853 | 35 | 2C6 | 1422 | 1.274 | 61 | 7C0 | 4458 | 0.452 |
| 10 | 8A2 | 950 | 0.626 | 36 | 0D6 | 1482 | 0.485 | 62 | 5C0 | 6174 | 0.289 |
| 11 | RA2 | 449 | 1.199 | 37 | 2D6 | 1429 | 0.641 | 63 | 3C0 | 7627 | 0.186 |
| 12 | 0 | 1974 | 0.549 | 38 | 4D6 | 1228 | 0.657 | 64 | 1C0 | 7650 | 0.156 |
| 13 | 2A0 | 2066 | 1.091 | 39 | 6D6 | 872 | 0.494 | 65 | 1B1 | 9518 | 0.293 |
| 14 | 4A0 | 1803 | 0.459 | 40 | 8D6 | 472 | 1.855 | 66 | 7C7 | 1990 | 0.288 |
| 15 | 6A0 | 1579 | 0.250 | 41 | 6C8 | 448 | 0.925 | 67 | 5C5 | 4774 | 0.428 |
| 16 | 8A0 | 999 | 0.476 | 42 | 4C8 | 696 | 1.109 | 68 | 7A7 | 2141 | 0.435 |
| 17 | RA0 | 489 | 1.326 | 43 | 2C8 | 890 | 0.726 | 69 | 5A5 | 5107 | 0.233 |
| 18 | 2C2 | 1741 | 1.059 | 44 | 0D8 | 934 | 0.400 | | | | |
| 19 | 0D2 | 1864 | 0.759 | 45 | 2D8 | 893 | 0.182 | | | | |
| 20 | 2D2 | 1942 | 0.841 | 46 | 4D8 | 742 | 1.179 | | | | |
| 21 | 4D2 | 1656 | 0.633 | 47 | 6D8 | 492 | 0.869 | 56* | 0B5 | 7115 | 0.373 |
| 22 | 6D2 | 1504 | 0.408 | 48 | 4CR | 294 | 1.674 | 57* | 0B3 | 8918 | 0.643 |
| 23 | 8D2 | 992 | 1.177 | 49 | 2CR | 420 | 1.398 | 58* | 0B1 | 9377 | 0.782 |
| 24 | RD2 | 458 | 0.683 | 50 | 0DR | 462 | 1.470 | 62* | 5C0 | 6549 | 0.334 |
| 25 | 4C4 | 1308 | 0.666 | 51 | 2DR | 429 | 0.930 | 63* | 3C0 | 8121 | 0.442 |
| 26 | 2C4 | 1538 | 0.462 | 52 | 4DR | 296 | 2.038 | 64* | 1C0 | 8096 | 0.735 |

* Measurement of Cu pieces activated in core having control-rod of 605mm height for the correction of change in amplifier's gain

(3) Withdrawal height of control-rod : 605mm

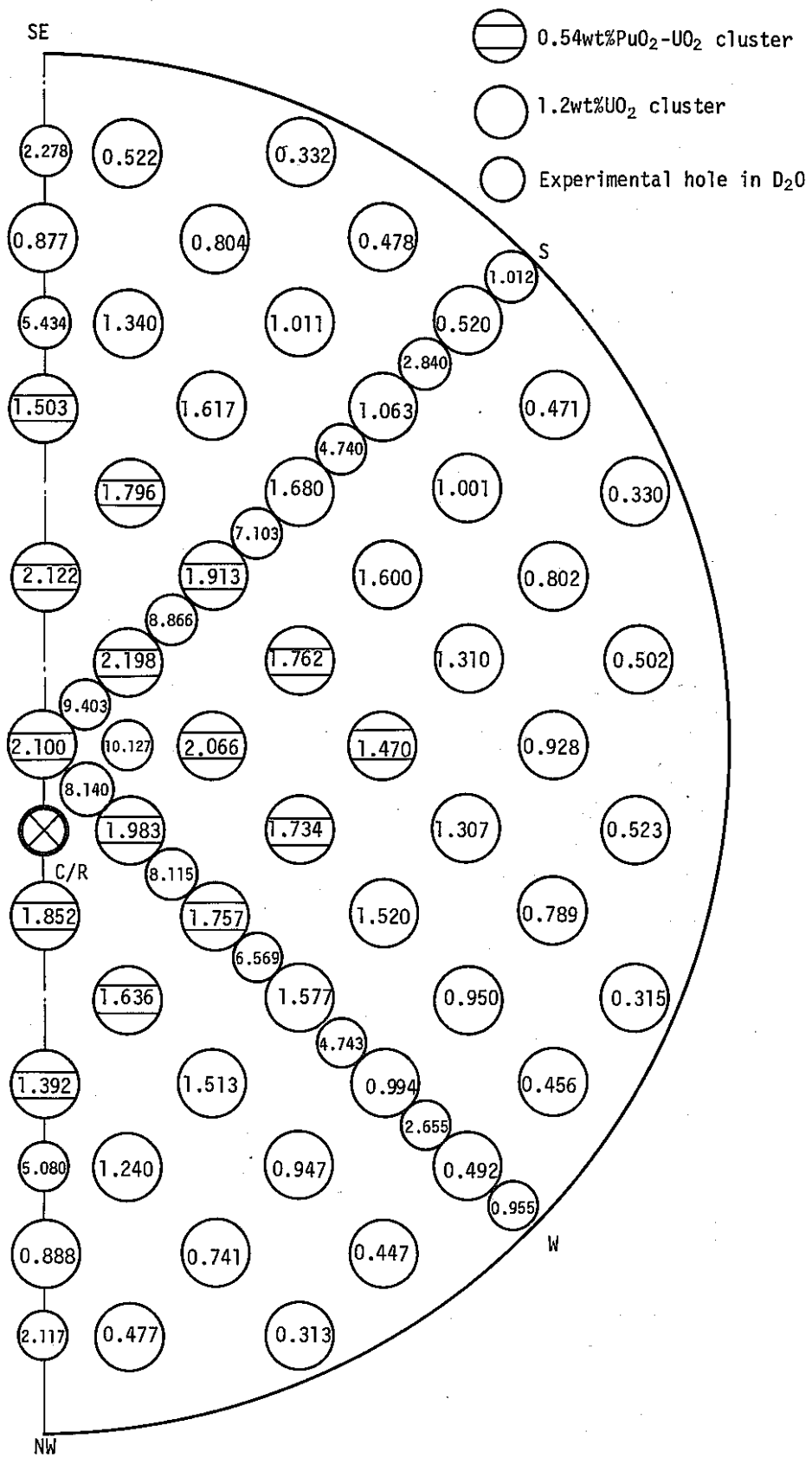
(Unit : cps/mg)

| In the center of Cluster | | | | | | | | In D ₂ O | | | |
|--------------------------|-------------|----------|-----------|-----|-------------|----------|-----------|---------------------|-------------|----------|-----------|
| No. | Channel No. | Activity | Error (%) | No. | Channel No. | Activity | Error (%) | No. | Channel No. | Activity | Error (%) |
| 1 | 6A6 | 907 | 1.023 | 27 | OD4 | 1792 | 0.601 | 53 | OBS | 986 | 0.607 |
| 2 | 8A6 | 519 | 1.076 | 28 | 2D4 | 1752 | 0.403 | 54 | OB9 | 2780 | 0.654 |
| 3 | 4A4 | 1494 | 0.520 | 29 | 4D4 | 1462 | 0.694 | 55 | OB7 | 4661 | 0.487 |
| 4 | 6A4 | 1302 | 0.570 | 30 | 6D4 | 1301 | 0.851 | 56 | OB5 | 7011 | 0.256 |
| 5 | 8A4 | 793 | 0.843 | 31 | 8D4 | 782 | 0.492 | 57 | OB3 | 8614 | 0.563 |
| 6 | RA4 | 335 | 0.945 | 32 | RD4 | 325 | 0.944 | 58 | OB1 | 9610 | 0.193 |
| 7 | 2A2 | 2140 | 0.542 | 33 | 6C6 | 882 | 0.624 | 59 | SC0 | 977 | 0.708 |
| 8 | 4A2 | 1812 | 1.053 | 34 | 4C6 | 1263 | 0.598 | 60 | 9C0 | 2648 | 1.082 |
| 9 | 6A2 | 1601 | 0.741 | 35 | 2C6 | 1532 | 0.851 | 61 | 7C0 | 4767 | 0.706 |
| 10 | 8A2 | 981 | 1.045 | 36 | OD6 | 1610 | 0.331 | 62 | 5C0 | 6647 | 0.446 |
| 11 | RA2 | 476 | 0.561 | 37 | 2D6 | 1544 | 0.678 | 63 | 3C0 | 8354 | 0.118 |
| 12 | 0 | 2174 | 0.408 | 38 | 4D6 | 1310 | 0.501 | 64 | 1C0 | 9041 | 0.137 |
| 13 | 2A0 | 2204 | 0.500 | 39 | 6D6 | 927 | 1.067 | 65 | 1B1 | 10442 | 0.449 |
| 14 | 4A0 | 1904 | 0.795 | 40 | 8D6 | 506 | 1.323 | 66 | 7C7 | 2128 | 0.269 |
| 15 | 6A0 | 1642 | 0.619 | 41 | 6C8 | 479 | 1.301 | 67 | 5C5 | 5148 | 0.161 |
| 16 | 8A0 | 1053 | 0.794 | 42 | 4C8 | 734 | 1.571 | 68 | 7A7 | 2242 | 0.928 |
| 17 | RA0 | 509 | 1.227 | 43 | 2C8 | 942 | 0.635 | 69 | 5A5 | 5349 | 0.627 |
| 18 | 2C2 | 1953 | 0.246 | 44 | OD8 | 1005 | 0.764 | | | | |
| 19 | OD2 | 2109 | 0.385 | 45 | 2D8 | 955 | 2.396 | | | | |
| 20 | 2D2 | 2097 | 0.556 | 46 | 4D8 | 790 | 0.586 | | | | |
| 21 | 4D2 | 1758 | 0.273 | 47 | 6D8 | 517 | 1.408 | | | | |
| 22 | 6D2 | 1603 | 0.376 | 48 | 4CR | 313 | 1.021 | | | | |
| 23 | 8D2 | 994 | 0.869 | 49 | 2CR | 449 | 1.087 | | | | |
| 24 | RD2 | 475 | 1.790 | 50 | ODR | 499 | 0.451 | | | | |
| 25 | 4C4 | 1420 | 0.417 | 51 | 2DR | 466 | 0.975 | | | | |
| 26 | 2C4 | 1687 | 0.525 | 52 | 4DR | 326 | 2.544 | | | | |

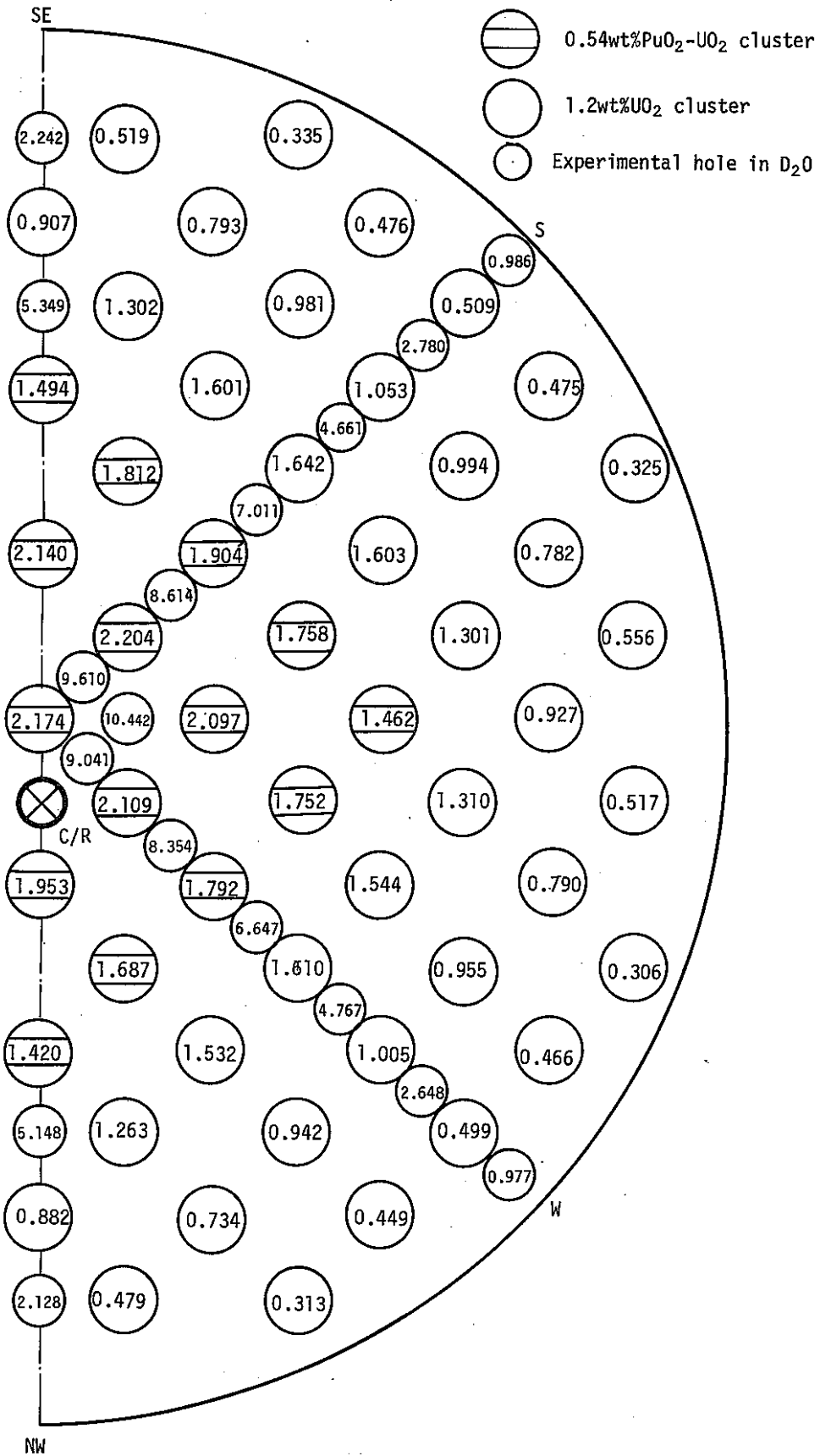


(1) Full insertion of control-rod

Fig. 6.1 Radial reaction rate distribution of Cu pieces at 555 mm core height



(2) Withdrawal height of control-rod: 505 mm



(3) Withdrawal height of control-rod: 605 mm

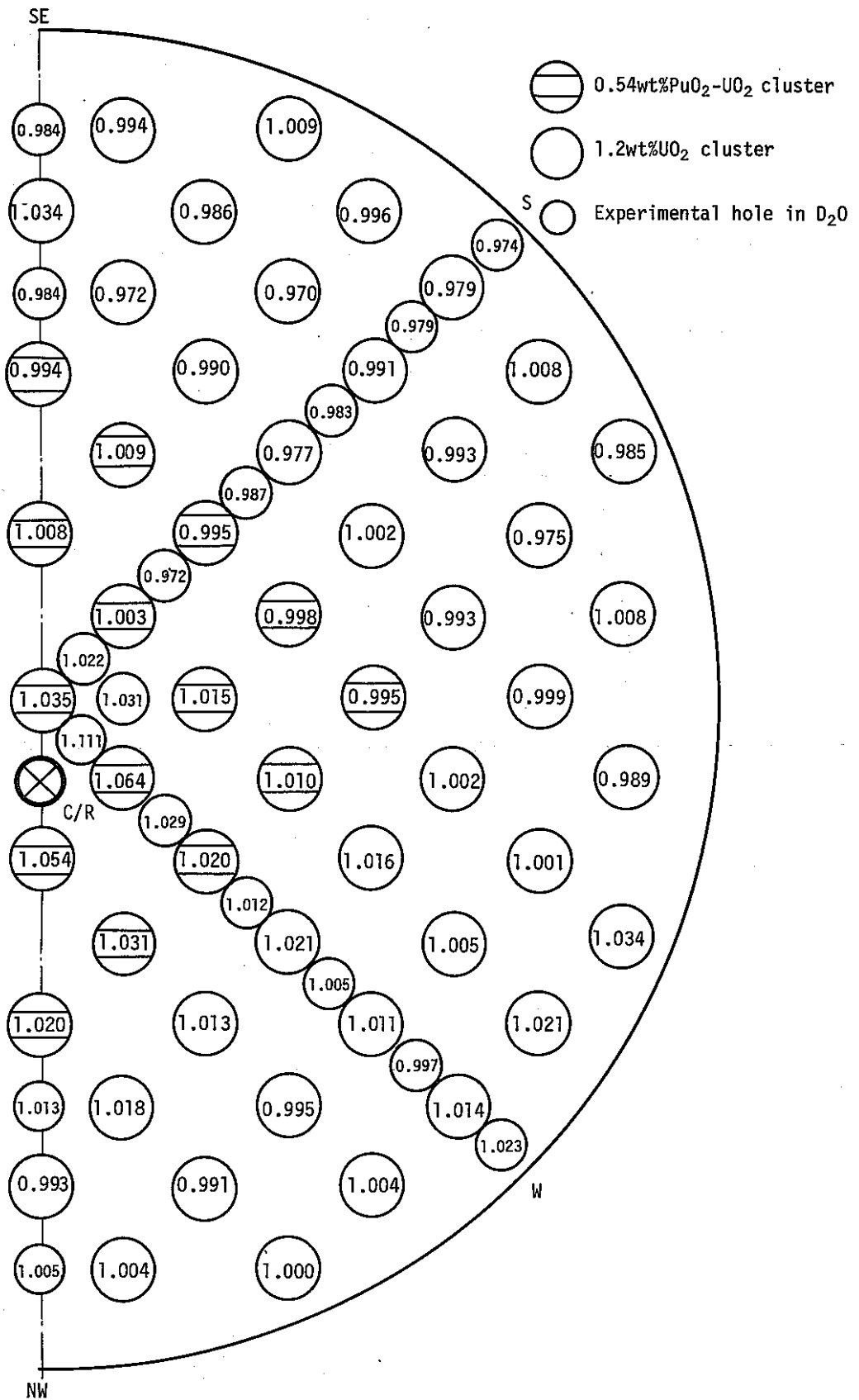


Fig. 6.2 The ratio of radial flux distribution at 555 mm height due to change in control-rod withdrawal from 505 mm to 605 mm

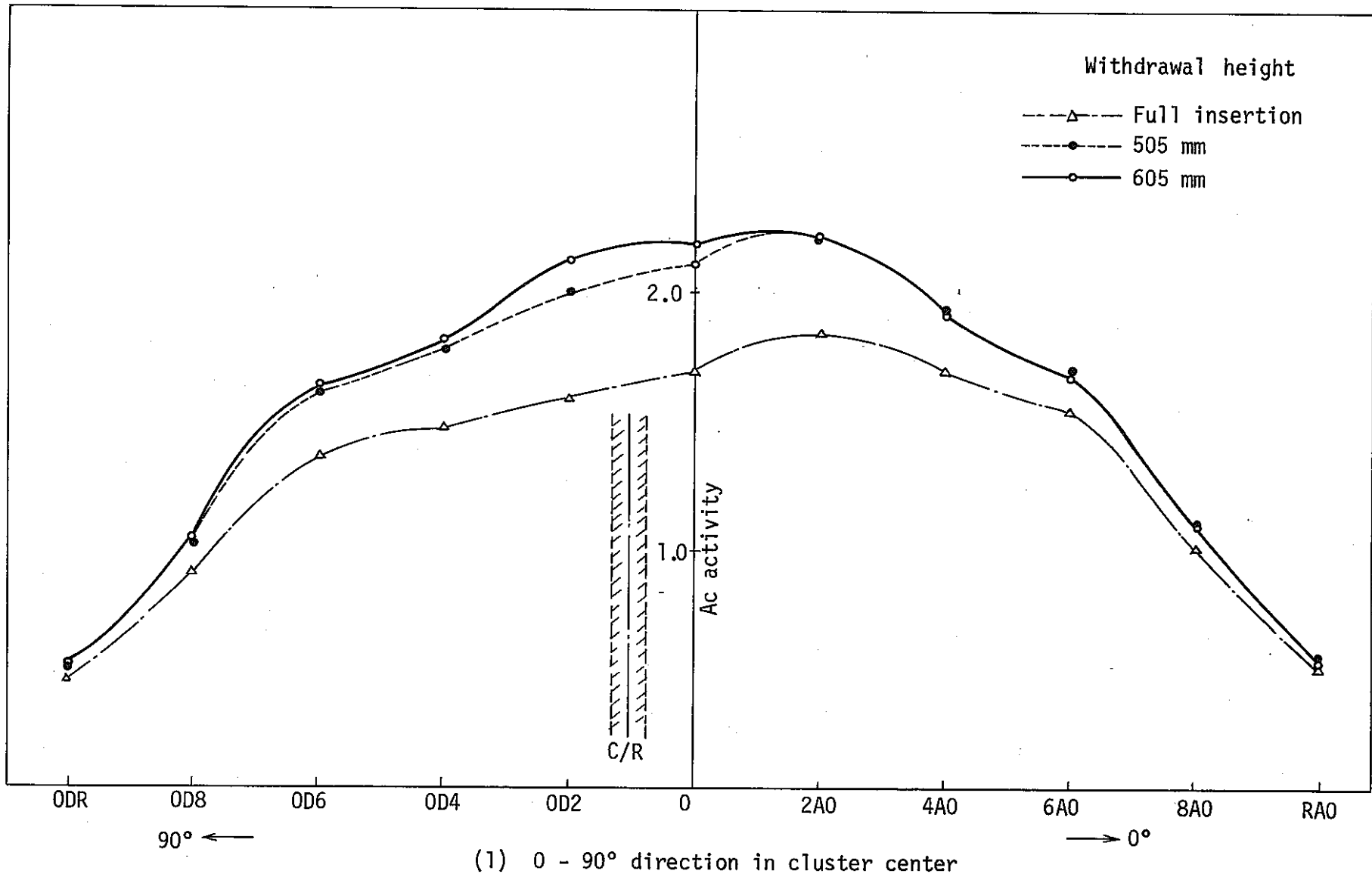
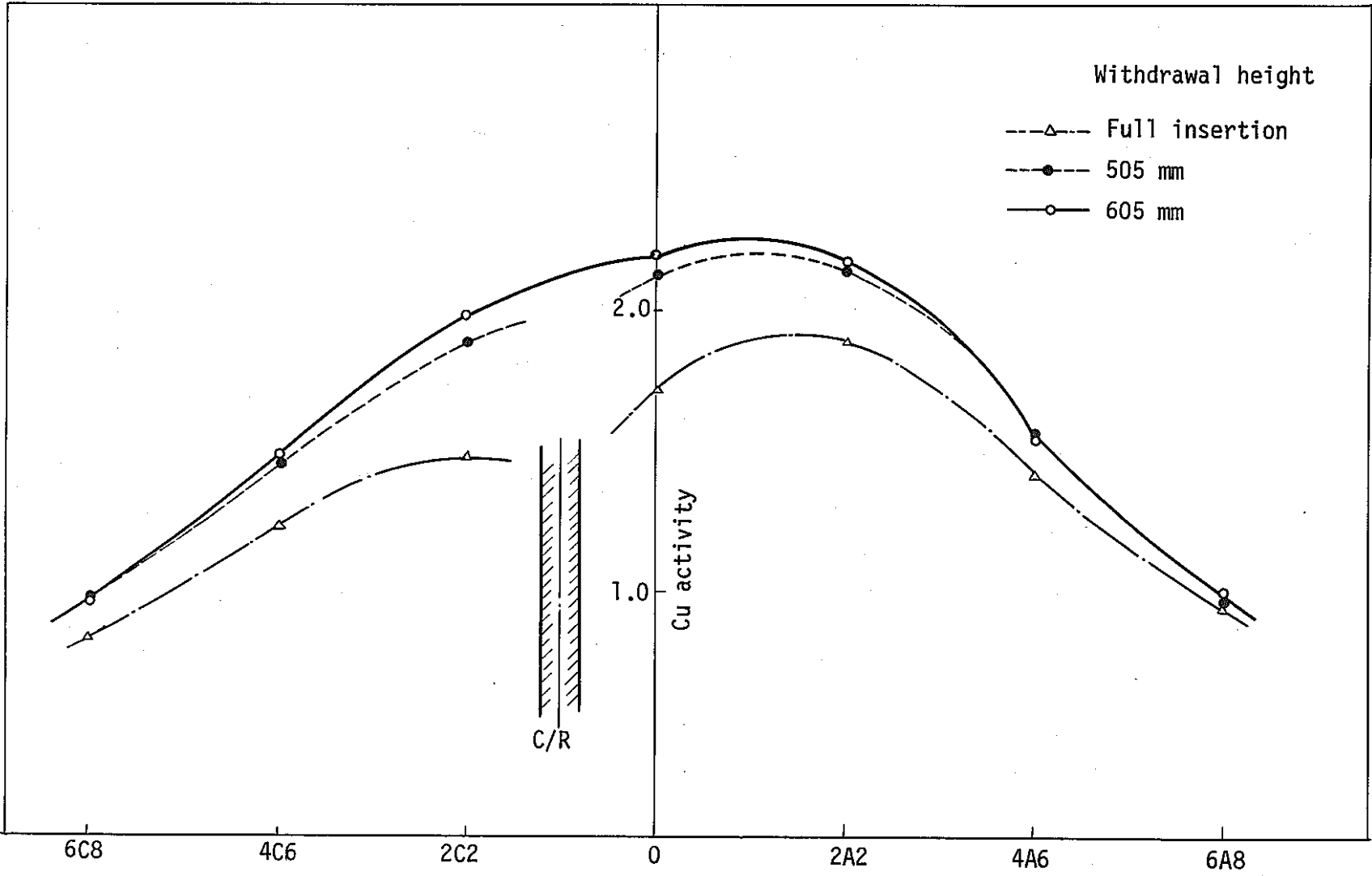
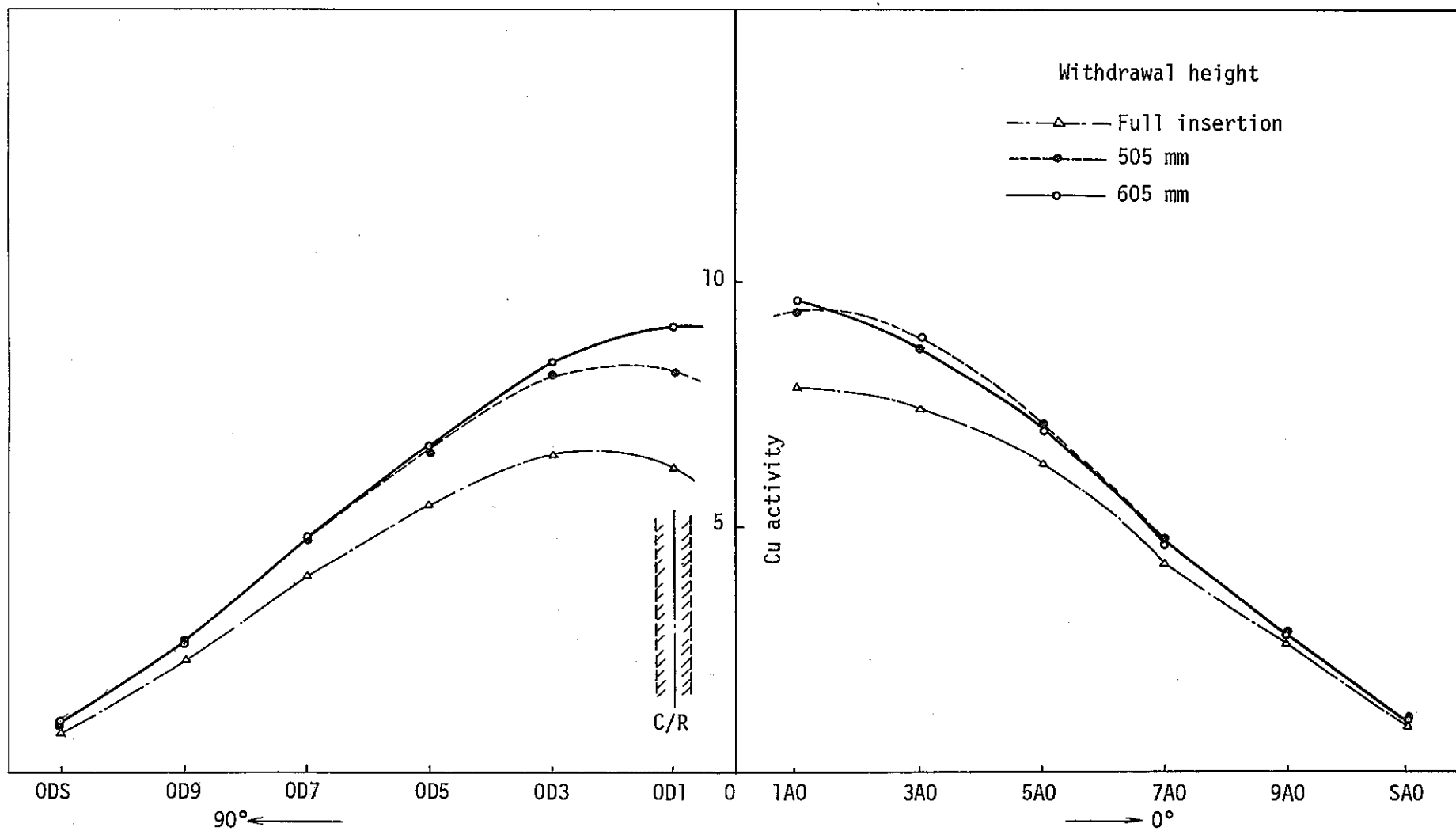


Fig. 6.3 Radial thermal flux distribution at 555 mm core height



(2) 45° direction in cluster center



(3) 0 - 90° direction in D₂O moderator

7. Axial neutron flux distribution near the control-rod

- Table 7.1 Least squares fitting result for axial buckling obtained from Cu activity.
- Table 7.2 Measurement of axial flux distribution by Cu wire near the control-rod of 505mm withdrawal (1)[~](2).
- Table 7.3 Measurement of axial flux distribution by Cu wire near the control-rod of 605mm withdrawal (1)[~](2).
- Fig. 7.1 Axial neutron flux distribution near the control-rod of 505mm withdrawal (1)[~](2).
- Fig. 7.2 Axial neutron flux distribution near the control-rod of 605mm withdrawal (1)[~](2).
- Fig. 7.3 Dependence of axial buckling of fitting range in the core with control-rod (1)[~](2).

Table 7.1 Least squares fitting result for axial buckling obtained from Cu activity

| Withdrawal height of control-rod (mm) | Critical level (mm) | Measured position | Axial buckling B_z^2 (m^{-2}) | |
|---------------------------------------|---------------------|-------------------|-------------------------------------|-----------------|
| | | | Measured | Averaged |
| 505 | 938.9 | 2B2 | 9.10 ± 0.07 | 9.13 ± 0.06 |
| | | OD1 | 9.15 ± 0.06 | |
| 605 | 931.7 | 2B2 | 8.82 ± 0.08 | 9.21 ± 0.08 |
| | | OD1 | 9.61 ± 0.08 | |

Table 7.2 Measurement of axial flux distribution by Cu wire near the control-rod of 505mm withdrawal

(1) Position : 2B2 (Center of fuel cluster) Critical level : 938.9 mm
Coolant level : 935 mm

| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 1 | 20 | 322.0 | 909 | 1783.8 | 0.232 |
| 2 | 40 | 322.7 | 988 | 1943.6 | 0.254 |
| 3 | 60 | 323.5 | 1160 | 2290.6 | 0.299 |
| 4 | 80 | 324.2 | 1380 | 2734.5 | 0.357 |
| 5 | 100 | 325.0 | 1543 | 3064.4 | 0.400 |
| 6 | 120 | 325.7 | 1787 | 3557.7 | 0.464 |
| 7 | 140 | 326.5 | 1905 | 3797.9 | 0.496 |
| 8 | 160 | 327.2 | 2069 | 4131.1 | 0.540 |
| 9 | 180 | 328.0 | 2322 | 4644.5 | 0.607 |
| 10 | 200 | 328.7 | 2408 | 4821.2 | 0.630 |
| 11 | 220 | 329.5 | 2625 | 5263.0 | 0.687 |
| 12 | 240 | 330.2 | 2764 | 5547.6 | 0.725 |
| 13 | 260 | 331.0 | 2824 | 5672.8 | 0.739 |
| 14 | 280 | 331.7 | 3104 | 6243.5 | 0.813 |
| 15 | 300 | 332.5 | 3144 | 6328.9 | 0.827 |
| 16 | 320 | 333.2 | 3265 | 6578.4 | 0.859 |
| 17 | 340 | 334.0 | 3402 | 6860.9 | 0.896 |
| 18 | 360 | 334.7 | 3467 | 6997.5 | 0.912 |
| 19 | 380 | 335.5 | 3601 | 7274.8 | 0.948 |
| 20 | 400 | 336.3 | 3706 | 7493.4 | 0.979 |
| 21 | 420 | 337.0 | 3784 | 7657.0 | 1.000 |
| 22 | 440 | 337.8 | 3649 | 7387.5 | 0.965 |
| 23 | 460 | 338.5 | 3725 | 7547.2 | 0.986 |

(continued)

| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 24 | 480 | 339.3 | 3729 | 7560.6 | 0.987 |
| 25 | 500 | 340.0 | 3760 | 7628.8 | 0.996 |
| 26 | 520 | 340.8 | 3667 | 7636.1 | 0.995 |
| 27 | 540 | 341.6 | 3647 | 7406.4 | 0.967 |
| 28 | 560 | 342.3 | 3561 | 7237.5 | 0.945 |
| 29 | 580 | 343.1 | 3487 | 7091.2 | 0.926 |
| 30 | 600 | 343.8 | 3507 | 7136.8 | 0.932 |
| 31 | 620 | 344.6 | 3285 | 6687.0 | 0.873 |
| 32 | 640 | 345.3 | 3222 | 6562.3 | 0.857 |
| 33 | 660 | 346.1 | 3065 | 6244.8 | 0.814 |
| 34 | 680 | 346.8 | 3008 | 6131.9 | 0.801 |
| 35 | 700 | 347.6 | 2864 | 5840.4 | 0.763 |
| 36 | 720 | 348.3 | 2668 | 5441.5 | 0.711 |
| 37 | 740 | 349.1 | 2484 | 5066.8 | 0.662 |
| 38 | 760 | 349.8 | 2408 | 4913.8 | 0.642 |
| 39 | 780 | 350.6 | 2208 | 4505.3 | 0.588 |
| 40 | 800 | 351.3 | 1889 | 3850.9 | 0.503 |
| 41 | 820 | 352.1 | 1783 | 3635.0 | 0.475 |
| 42 | 840 | 352.8 | 1605 | 3270.1 | 0.427 |
| 43 | 860 | 354.3 | 1364 | 2776.7 | 0.363 |
| 44 | 880 | 358.6 | 1143 | 2329.0 | 0.304 |
| 45 | 900 | 359.3 | 980 | 1992.3 | 0.260 |
| 46 | 920 | 360.1 | 669 | 1347.8 | 0.176 |

(2) Position : OD1 (D₂O moderator)

Critical level : 938.9 mm

Coolant level : 935 mm

| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 1 | 20 | 1374.8 | 3007 | 15502 | 0.310 |
| 2 | 40 | 1375.6 | 3787 | 19565 | 0.391 |
| 3 | 60 | 1376.3 | 4148 | 21454 | 0.429 |
| 4 | 80 | 1377.1 | 4727 | 24481 | 0.490 |
| 5 | 100 | 1377.9 | 5281 | 27382 | 0.548 |
| 6 | 120 | 1378.6 | 5903 | 30640 | 0.613 |
| 7 | 140 | 1379.4 | 6247 | 32455 | 0.649 |
| 8 | 160 | 1380.1 | 6664 | 34652 | 0.693 |
| 9 | 180 | 1380.9 | 6923 | 36028 | 0.721 |
| 10 | 200 | 1381.6 | 7446 | 38785 | 0.776 |
| 11 | 220 | 1382.4 | 7767 | 40490 | 0.810 |
| 12 | 240 | 1383.1 | 8121 | 42369 | 0.845 |
| 13 | 260 | 1383.9 | 8223 | 42932 | 0.859 |
| 14 | 280 | 1384.6 | 8747 | 45706 | 0.914 |
| 15 | 300 | 1385.4 | 8844 | 46246 | 0.925 |
| 16 | 320 | 1386.1 | 8980 | 46991 | 0.940 |
| 17 | 340 | 1386.9 | 9124 | 47779 | 0.956 |
| 18 | 360 | 1387.6 | 9249 | 48468 | 0.969 |
| 19 | 380 | 1388.4 | 9401 | 49300 | 0.986 |
| 20 | 420 | 1389.2 | 9528 | 50004 | 1.000 |
| 21 | 440 | 1389.9 | 9406 | 49395 | 0.988 |
| 22 | 460 | 1391.9 | 9209 | 48445 | 0.969 |
| 23 | 480 | 1392.7 | 9009 | 47426 | 0.948 |
| 24 | 500 | 1393.6 | 8787 | 46290 | 0.926 |
| 25 | 520 | 1394.4 | 8709 | 45912 | 0.918 |

(continued)

| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 26 | 540 | 1395.2 | 8685 | 45819 | 0.916 |
| 27 | 560 | 1396.1 | 8345 | 44055 | 0.881 |
| 28 | 580 | 1396.9 | 8188 | 43255 | 0.865 |
| 29 | 600 | 1397.7 | 7888 | 41697 | 0.834 |
| 30 | 620 | 1398.5 | 7542 | 39892 | 0.798 |
| 31 | 640 | 1399.4 | 7302 | 38647 | 0.773 |
| 32 | 660 | 1411.9 | 6960 | 37249 | 0.745 |
| 33 | 680 | 1412.6 | 6502 | 34814 | 0.696 |
| 34 | 700 | 1413.4 | 6122 | 32794 | 0.656 |
| 35 | 720 | 1414.1 | 5528 | 29621 | 0.592 |
| 36 | 740 | 1418.2 | 5189 | 27900 | 0.558 |
| 37 | 760 | 1419.0 | 4700 | 25279 | 0.506 |
| 38 | 780 | 1419.8 | 4109 | 22102 | 0.442 |
| 39 | 800 | 1420.8 | 3628 | 19518 | 0.389 |
| 40 | 820 | 1421.7 | 3043 | 16366 | 0.327 |
| 41 | 840 | 1422.5 | 2546 | 13686 | 0.273 |
| 42 | 860 | 1423.3 | 1880 | 10084 | 0.202 |
| 43 | 880 | 1424.2 | 1246 | 6651.9 | 0.133 |
| 44 | 900 | 1425.0 | 708 | 3735.6 | 0.075 |
| 45 | 920 | 1425.8 | 547 | 2863.5 | 0.057 |

Table 7.3 Measurement of axial flux distribution by Cu wire near the control-rod of 605mm withdrawal

(1) Position : 2B2 (Center of fuel cluster) Critical level : 931.7 mm
Coolant level : 930 mm

| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 1 | 20 | 116.5 | 1769 | 2915.5 | 0.288 |
| 2 | 40 | 117.3 | 1745 | 2877.5 | 0.286 |
| 3 | 60 | 118.0 | 1884 | 3111.4 | 0.309 |
| 4 | 80 | 118.8 | 2368 | 3922.2 | 0.389 |
| 5 | 100 | 119.5 | 2502 | 4148.8 | 0.412 |
| 6 | 120 | 120.3 | 2843 | 4722.1 | 0.469 |
| 7 | 140 | 121.0 | 3204 | 5329.6 | 0.529 |
| 8 | 160 | 121.8 | 3564 | 5936.4 | 0.589 |
| 9 | 180 | 122.5 | 3626 | 6044.3 | 0.600 |
| 10 | 200 | 123.3 | 4064 | 6783.3 | 0.671 |
| 11 | 220 | 124.0 | 4241 | 7085.0 | 0.703 |
| 12 | 240 | 124.8 | 4567 | 7637.6 | 0.758 |
| 13 | 260 | 125.5 | 4766 | 7977.3 | 0.791 |
| 14 | 280 | 126.3 | 4949 | 8290.5 | 0.823 |
| 15 | 300 | 127.0 | 5041 | 8451.1 | 0.838 |
| 16 | 320 | 127.8 | 5307 | 8904.8 | 0.883 |
| 17 | 340 | 128.5 | 5540 | 9303.8 | 0.923 |
| 18 | 360 | 129.3 | 5524 | 9283.0 | 0.919 |
| 19 | 380 | 130.0 | 5687 | 9564.6 | 0.949 |
| 20 | 400 | 130.8 | 5803 | 9766.9 | 0.969 |
| 21 | 420 | 131.5 | 5904 | 9944.5 | 0.987 |
| 22 | 440 | 132.3 | 5864 | 9883.4 | 0.981 |
| 23 | 460 | 133.0 | 5880 | 9917.3 | 0.984 |
| 24 | 480 | 133.8 | 5927 | 10004 | 0.992 |

(continued)

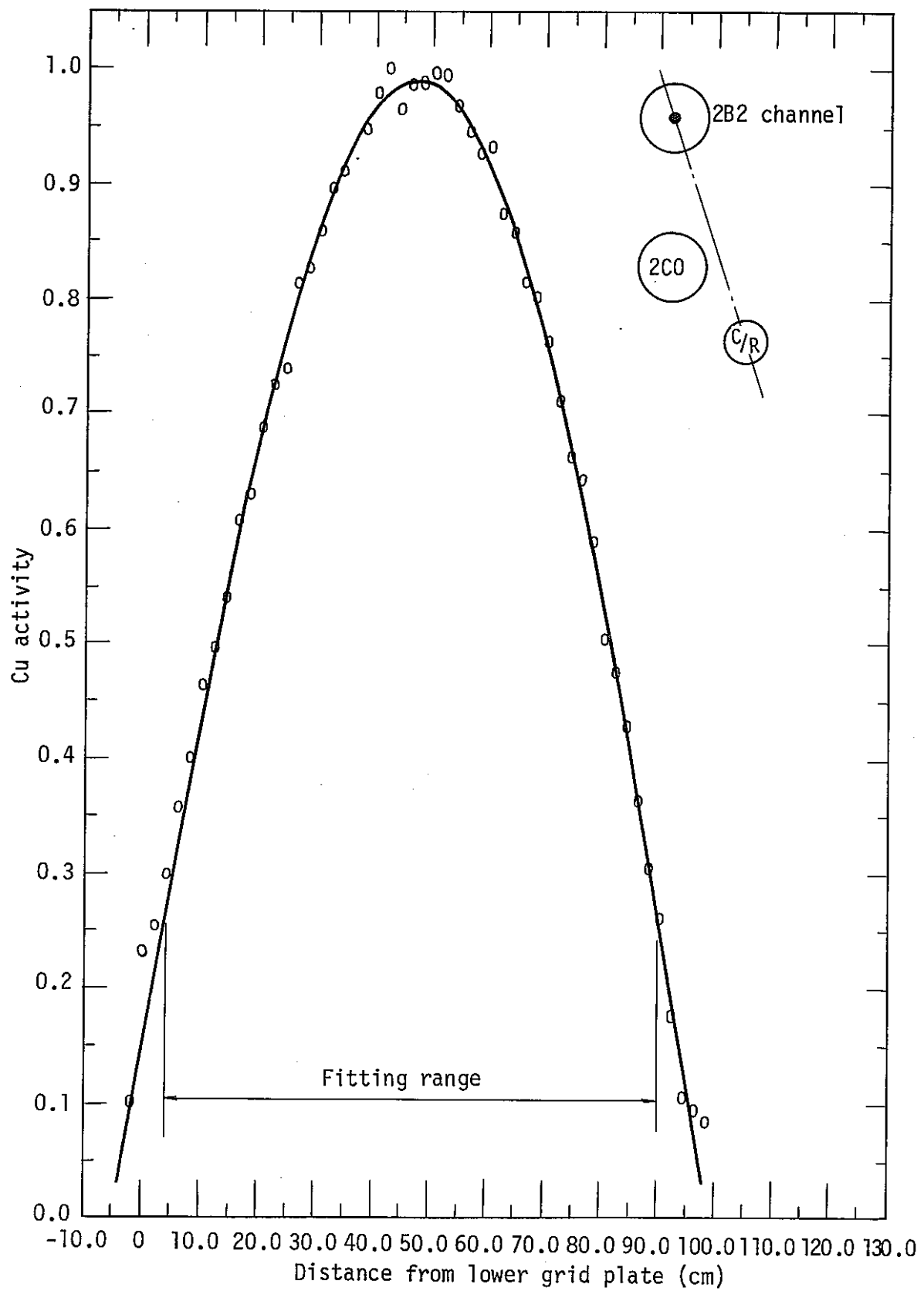
| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 25 | 500 | 134.5 | 5944 | 10039 | 0.996 |
| 26 | 520 | 135.3 | 5964 | 10080 | 1.000 |
| 27 | 540 | 136.0 | 5825 | 9850.8 | 0.975 |
| 28 | 560 | 136.8 | 5748 | 9726.8 | 0.965 |
| 29 | 580 | 137.5 | 5809 | 9836.9 | 0.976 |
| 30 | 600 | 138.3 | 5627 | 9534.2 | 0.946 |
| 31 | 620 | 139.0 | 5405 | 9162.7 | 0.909 |
| 32 | 640 | 139.8 | 5202 | 8823.3 | 0.875 |
| 33 | 660 | 140.5 | 5080 | 8621.2 | 0.855 |
| 34 | 680 | 141.3 | 4942 | 8391.8 | 0.833 |
| 35 | 700 | 142.0 | 4802 | 8158.5 | 0.809 |
| 36 | 720 | 142.8 | 4364 | 7416.2 | 0.736 |
| 37 | 740 | 143.5 | 4249 | 7224.6 | 0.717 |
| 38 | 760 | 144.3 | 4041 | 6874.0 | 0.682 |
| 39 | 780 | 145.0 | 3763 | 6402.9 | 0.634 |
| 40 | 800 | 145.8 | 3480 | 5922.8 | 0.588 |
| 41 | 820 | 146.6 | 3161 | 5380.3 | 0.534 |
| 42 | 840 | 147.3 | 2807 | 4777.0 | 0.474 |
| 43 | 860 | 148.1 | 2529 | 4303.4 | 0.427 |
| 44 | 880 | 148.8 | 2185 | 3715.8 | 0.369 |
| 45 | 900 | 149.6 | 1841 | 3127.5 | 0.310 |

(2) Position : OD1 (D₂O moderator)Critical level : 931.7 mm
Coolant level : 930 mm

| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 1 | 20 | 1259.3 | 3040 | 14122 | 0.306 |
| 2 | 40 | 1260.1 | 3704 | 17239 | 0.373 |
| 3 | 60 | 1260.8 | 4447 | 20731 | 0.449 |
| 4 | 80 | 1261.6 | 5000 | 23337 | 0.504 |
| 5 | 100 | 1262.3 | 5408 | 25266 | 0.545 |
| 6 | 120 | 1263.1 | 5881 | 27504 | 0.594 |
| 7 | 140 | 1263.8 | 6461 | 30247 | 0.653 |
| 8 | 160 | 1264.4 | 6920 | 32425 | 0.700 |
| 9 | 180 | 1265.3 | 7247 | 33985 | 0.734 |
| 10 | 200 | 1266.1 | 7825 | 36730 | 0.793 |
| 11 | 220 | 1266.8 | 8189 | 38469 | 0.830 |
| 12 | 240 | 1267.6 | 8266 | 38858 | 0.841 |
| 13 | 260 | 1268.3 | 8747 | 41153 | 0.888 |
| 14 | 280 | 1269.1 | 9086 | 42782 | 0.924 |
| 15 | 300 | 1269.8 | 9262 | 43642 | 0.944 |
| 16 | 320 | 1270.6 | 9367 | 44169 | 0.956 |
| 17 | 340 | 1271.3 | 9583 | 45220 | 0.979 |
| 18 | 360 | 1272.1 | 9465 | 44692 | 0.967 |
| 19 | 380 | 1272.8 | 9623 | 45471 | 0.984 |
| 20 | 400 | 1273.6 | 9549 | 45151 | 0.977 |
| 21 | 420 | 1274.3 | 9766 | 46211 | 1.000 |
| 22 | 440 | 1275.1 | 9521 | 45080 | 0.976 |
| 23 | 460 | 1275.8 | 9662 | 45779 | 0.991 |
| 24 | 480 | 1276.6 | 9388 | 44508 | 0.961 |
| 25 | 500 | 1277.3 | 9426 | 44719 | 0.965 |

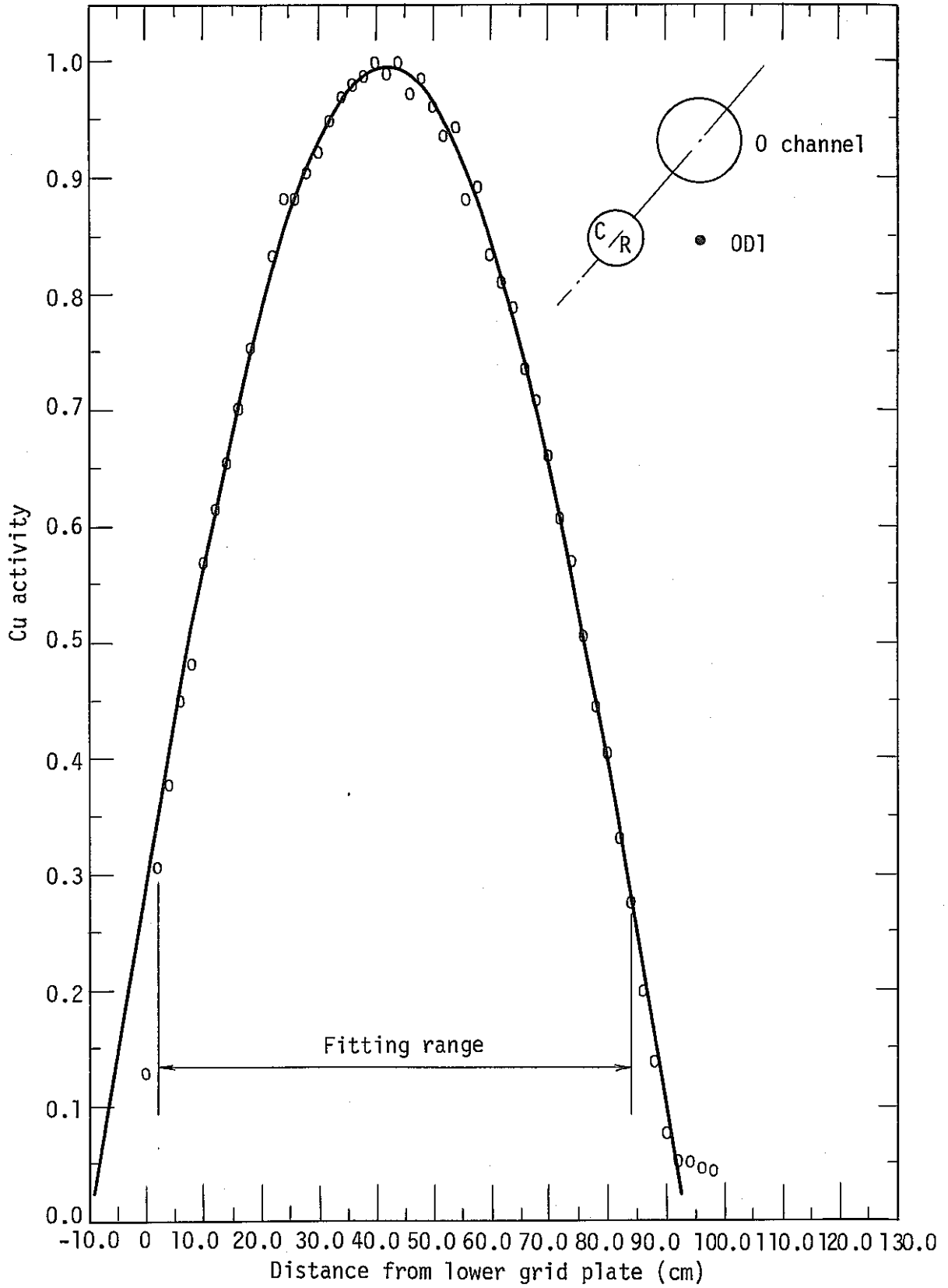
(continued)

| Position No. | Height from core bottom Z (mm) | Time after shutdown (min) | Measured counts Co (per 40 sec) | Counts after time correction C (per 40 sec) | Normalized value (max=1.0) |
|--------------|--------------------------------|---------------------------|---------------------------------|---|----------------------------|
| 26 | 520 | 1278.1 | 9105 | 43222 | 0.935 |
| 27 | 540 | 1278.8 | 8845 | 42012 | 0.907 |
| 28 | 560 | 1279.6 | 8647 | 41097 | 0.887 |
| 29 | 580 | 1280.3 | 8368 | 39794 | 0.861 |
| 30 | 600 | 1281.1 | 8029 | 38204 | 0.827 |
| 31 | 620 | 1281.8 | 7629 | 36319 | 0.786 |
| 32 | 640 | 1282.6 | 7405 | 35274 | 0.763 |
| 33 | 660 | 1283.3 | 6980 | 33265 | 0.720 |
| 34 | 680 | 1284.1 | 6443 | 30719 | 0.665 |
| 35 | 700 | 1284.8 | 6124 | 29212 | 0.632 |
| 36 | 720 | 1285.6 | 5586 | 26655 | 0.577 |
| 37 | 740 | 1286.3 | 5205 | 24847 | 0.538 |
| 38 | 760 | 1287.1 | 4604 | 21981 | 0.476 |
| 39 | 780 | 1287.8 | 4161 | 19870 | 0.430 |
| 40 | 800 | 1288.6 | 3569 | 17040 | 0.368 |
| 41 | 820 | 1289.3 | 2924 | 13952 | 0.302 |
| 42 | 840 | 1290.1 | 2468 | 11769 | 0.255 |
| 43 | 860 | 1290.8 | 1802 | 8572.7 | 0.185 |
| 44 | 880 | 1291.6 | 1089 | 5146.0 | 0.111 |
| 45 | 900 | 1293.7 | 644 | 3009.5 | 0.065 |
| 46 | 920 | 1298.8 | 521 | 2427.3 | 0.053 |

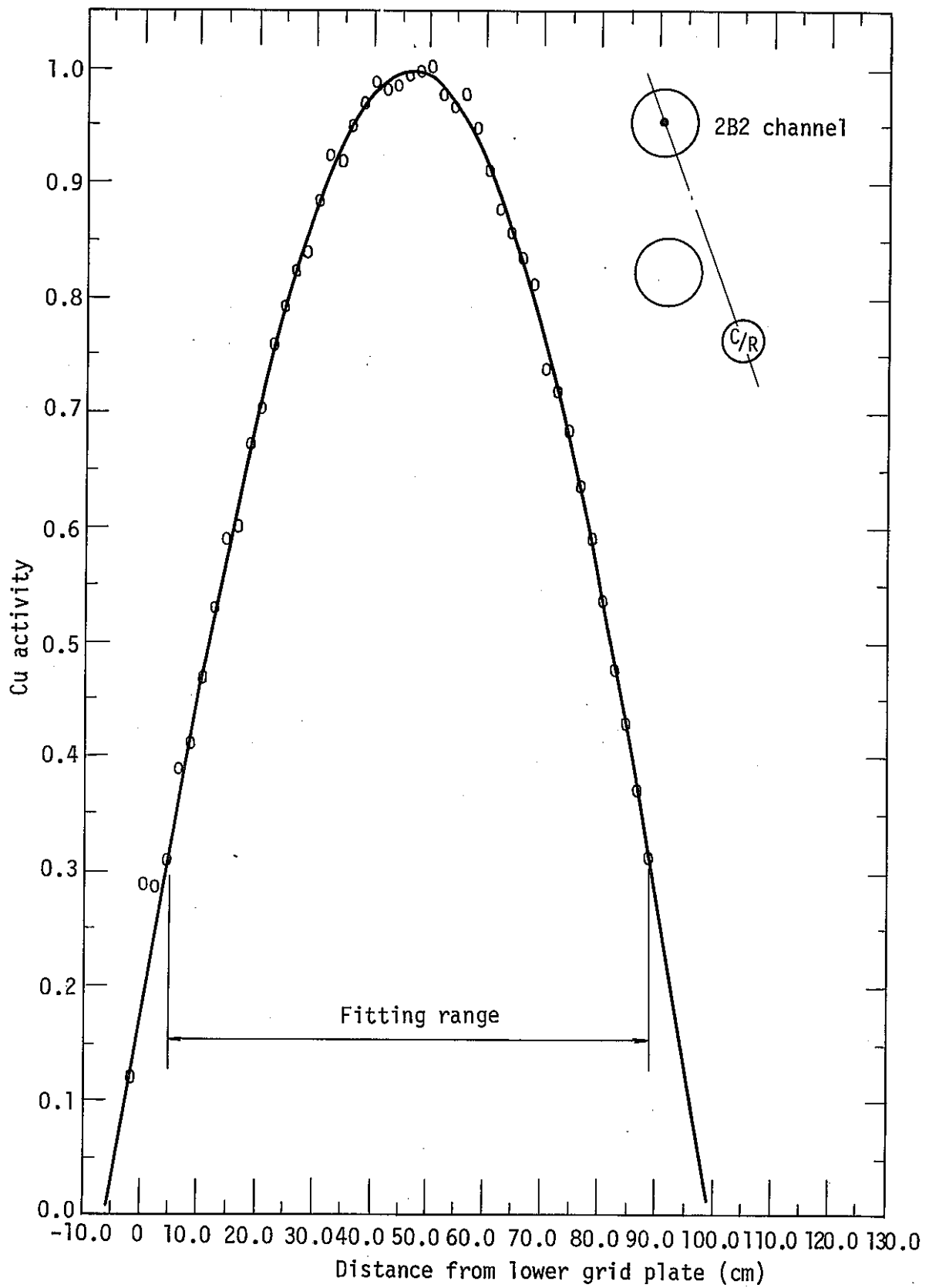


(1) Center of 0.54wt% PuO₂-UO₂ cluster in 2B2 channel

Fig. 7.1 Axial neutron flux distribution near the control-rod of 505 mm withdrawal

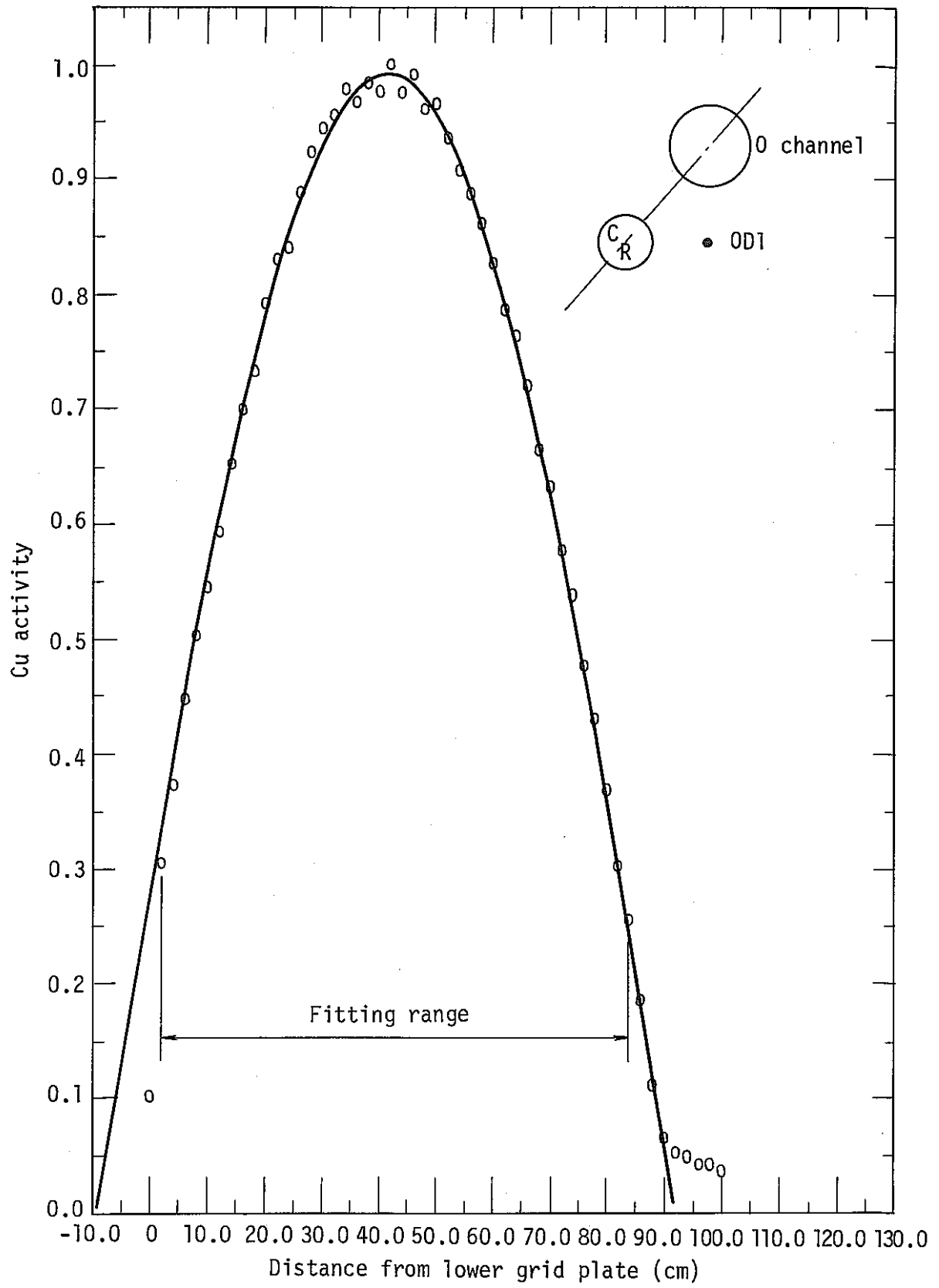


(2) D₂O moderator in OD1 position

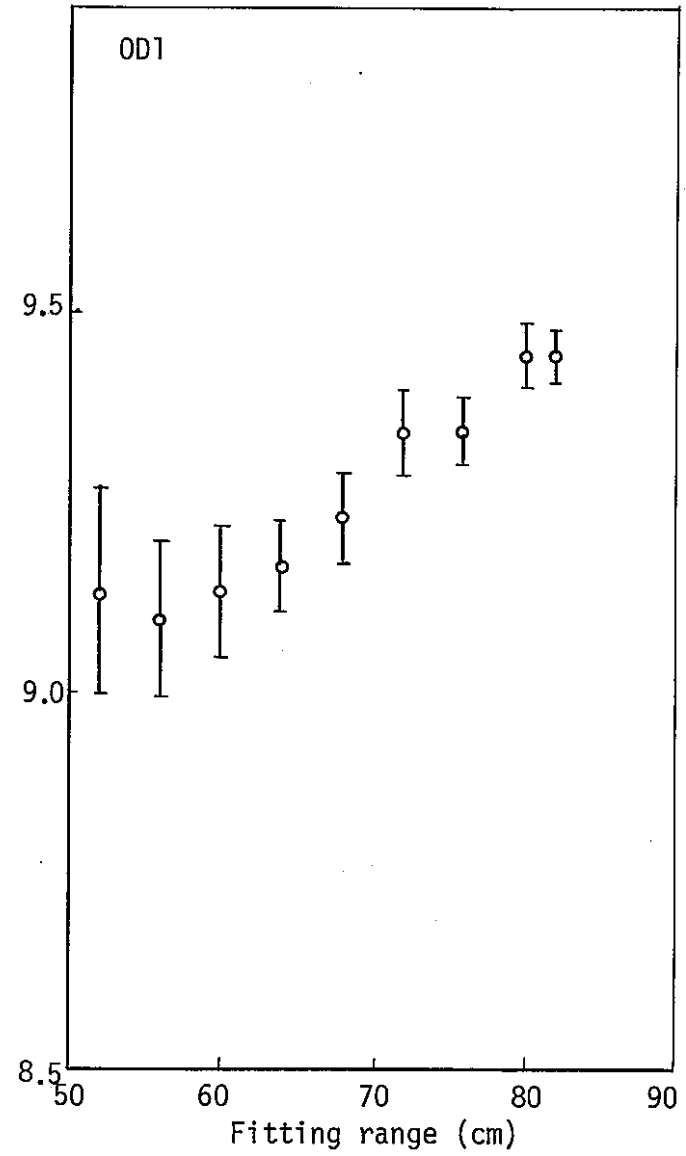
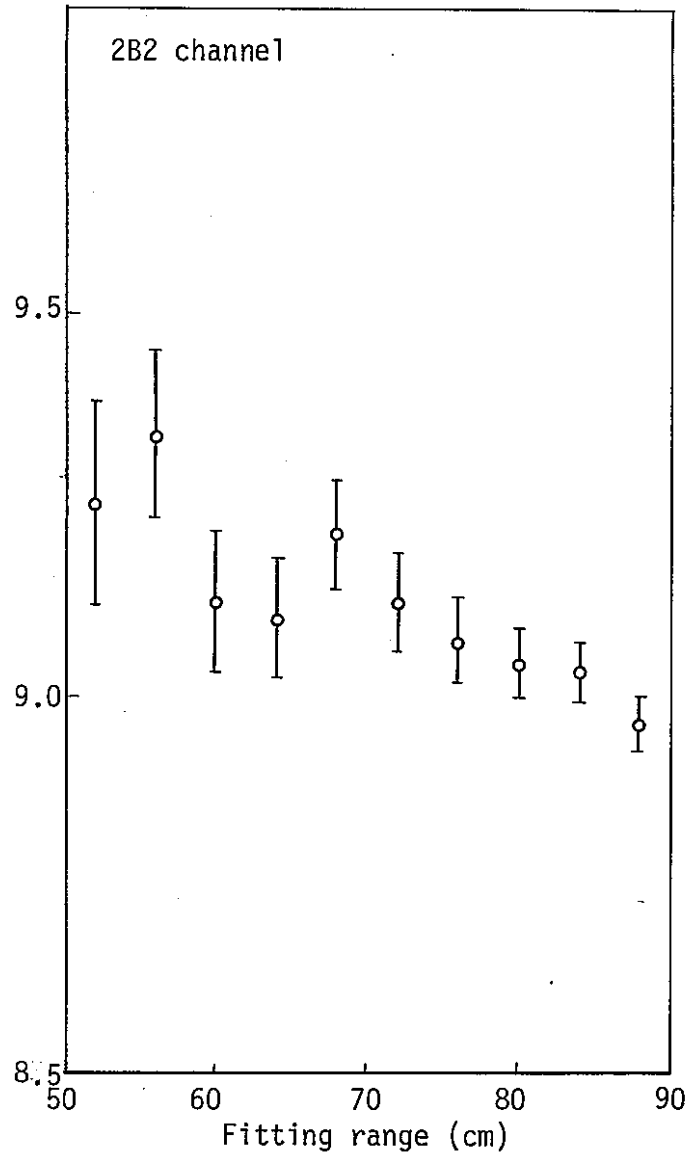


(1) Center of 0.54wt% PuO₂-UO₂ cluster in 2B2 channel

Fig. 7.2 Axial neutron flux distribution near the control-rod of 605 mm withdrawal

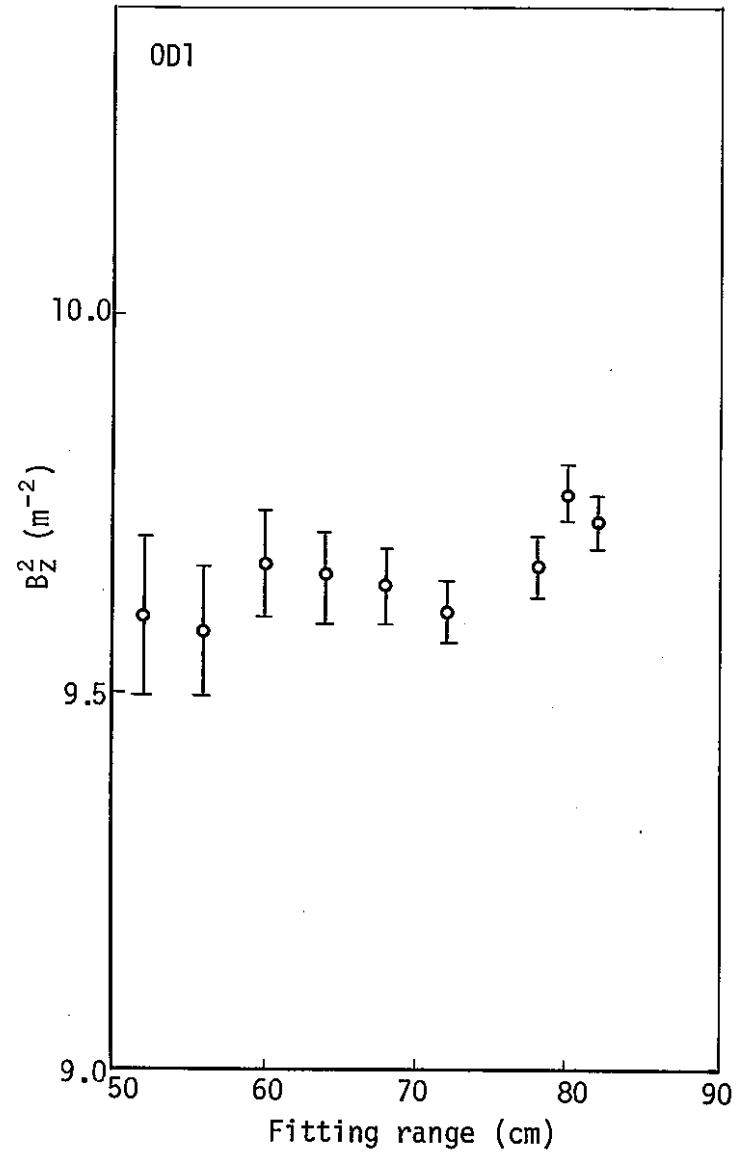
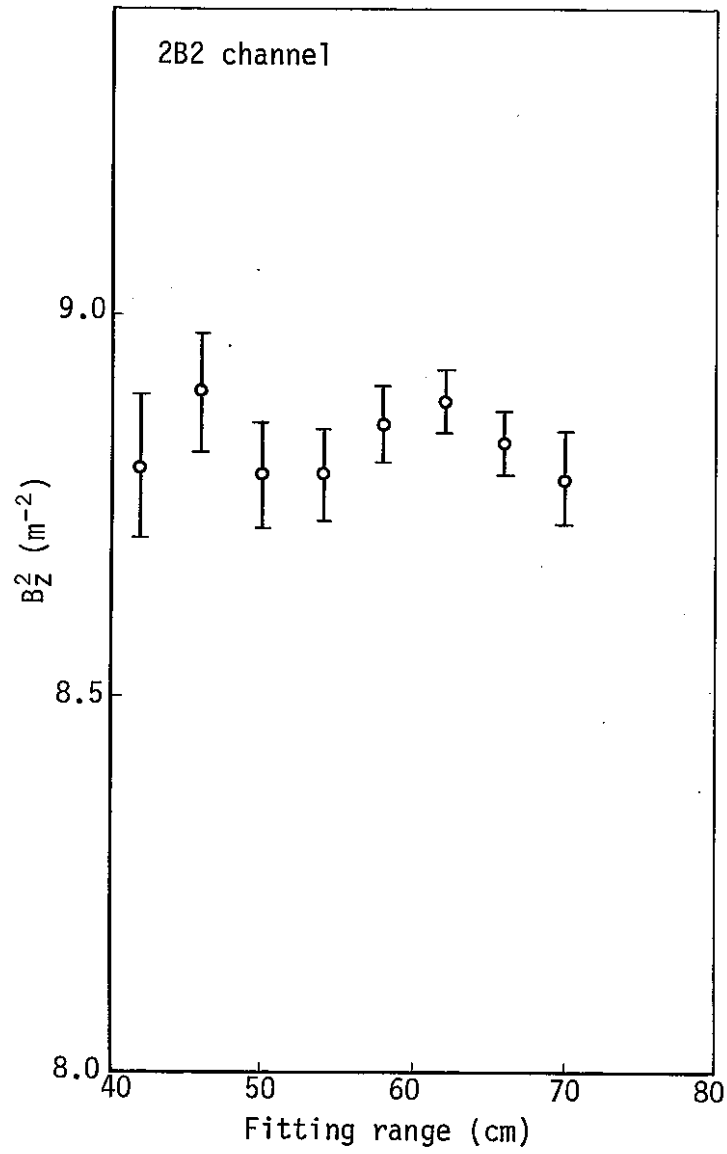


(2) D₂O moderator in ODI position



(1) Control-rod withdrawal height: 505 mm

Fig. 7.3 Dependence of axial buckling on fitting range in the core with control-rod



(2) Control-rod withdrawal height: 605 mm

8. Result of lattice cell and reactor core calculation

- Table 8.1 Zone macroscopic cross sections used in the diffusion calculation.
- Table 8.2 Boundary condition for neutron flux and result of multiplication factor.
- Table 8.3 Axial power distribution obtained from three dimensional diffusion calculation.
- Table 8.4 Comparison between experiment and calculation for maximum ratio of fuel pin power due to 100mm withdrawal of control-rod.
- Fig. 8.1 WIMS multi-cell model for control-rod and surrounding plutonium cells.
- Fig. 8.2 X-Y plane model of three dimensional diffusion calculation (1)~(2).
- Fig. 8.3 Axial plane model for three dimensional diffusion calculation.
- Fig. 8.4 Fine mesh structure of the nearest fuel channel to the control-rod at the height of inserted control-rod.
- Fig. 8.5 Ratio of fuel pin power in 0 channel cluster due to 100mm withdrawal from 505mm height (P_{605}/P_{505}) (1)~(6).

Table 8-1 Zone macroscopic cross sections used in the diffusion calculation

| ZONE | NAME | GRP | D | Σ_r | Σ_a | $\nu\Sigma_f$ |
|------|---|-----|-----------|------------|------------|---------------|
| 1 | D ₂ O Reflector | 1 | 1.3765E+0 | 1.0462E-2 | 0.0 | 0.0 |
| | | 2 | 8.4994E-1 | 0.0 | 1.2439E-4 | 0.0 |
| 2 | 1.2wt% UO ₂ Cell | 1 | 1.3453E+0 | 1.1638E-2 | 2.3157E-3 | 1.4379E-3 |
| | | 2 | 8.4968E-1 | 0.0 | 7.7596E-3 | 1.0147E-2 |
| 3 | 0.54wt% PuO ₂ Cell | 1 | 1.3425E+0 | 1.1392E-2 | 2.4504E-3 | 1.4310E-3 |
| | | 2 | 8.5337E-1 | 0.0 | 8.4659E-3 | 1.1902E-2 |
| 4 | OB2 channel 1st Ring | 1 | 8.8336E-1 | 1.6235E-2 | 1.0670E-2 | 6.4013E-3 |
| | | 2 | 2.7120E-1 | 0.0 | 1.0705E-1 | 1.6004E-1 |
| 5 | 2nd Ring | 1 | 8.7385E-1 | 1.8993E-2 | 1.0002E-2 | 5.9805E-3 |
| | | 2 | 2.4853E-1 | 0.0 | 9.9618E-2 | 1.4643E-1 |
| 6 | 3rd Ring | 1 | 8.7143E-1 | 1.5151E-2 | 1.2946E-2 | 7.4441E-3 |
| | | 2 | 2.9446E-1 | 0.0 | 1.2329E-1 | 1.8774E-1 |
| 7 | C/T+Air+ P/T+H ₂ O | 1 | 2.6416E+0 | 1.0552E-2 | 2.7925E-4 | 0.0 |
| | | 2 | 7.8920E-1 | 0.0 | 6.7460E-3 | 0.0 |
| 8 | D ₂ O | 1 | 1.3125E+0 | 1.0017E-2 | 0.0 | 0.0 |
| | | 2 | 8.2750E-1 | 0.0 | 1.2312E-4 | 0.0 |
| 9 | 2B2 channel C/T+Fuel | 1 | 1.0842E+0 | 1.4826E-2 | 8.3496E-3 | 4.8364E-3 |
| | | 2 | 4.1231E-1 | 0.0 | 6.0792E-2 | 8.6563E-2 |
| 10 | D ₂ O | 1 | 1.3125E+0 | 1.0017E-2 | 0.0 | 0.0 |
| | | 2 | 8.2750E-1 | 0.0 | 1.2312E-4 | 0.0 |
| 11 | 0 channel 1st Ring | 1 | 8.9477E-1 | 1.5388E-2 | 1.0377E-2 | 6.4029E-3 |
| | | 2 | 2.7260E-1 | 0.0 | 1.0659E-1 | 1.5937E-1 |
| 12 | 2nd Ring | 1 | 8.8228E-1 | 1.8128E-2 | 9.7813E-3 | 6.0036E-3 |
| | | 2 | 2.4974E-1 | 0.0 | 9.9567E-2 | 1.4645E-1 |
| 13 | 3rd Ring | 1 | 8.8183E-1 | 1.4333E-2 | 1.2589E-2 | 7.4059E-3 |
| | | 2 | 2.9511E-1 | 0.0 | 1.2319E-1 | 1.8762E-1 |
| 14 | C/T+Air+ P/T+H ₂ O | 1 | 2.6499E+0 | 1.0003E-2 | 2.7116E-4 | 0.0 |
| | | 2 | 7.8549E-1 | 0.0 | 6.7463E-3 | 0.0 |
| 15 | D ₂ O | 1 | 1.3188E+0 | 9.2667E-3 | 0.0 | 0.0 |
| | | 2 | 8.2889E-1 | 0.0 | 1.2260E-4 | 0.0 |
| 16 | 2CO, 2C ₂ , OD ₂ ch. C/T+Fuel | 1 | 1.0944E+0 | 1.4077E-2 | 8.1455E-3 | 4.8357E-3 |
| | | 2 | 4.1093E-1 | 0.0 | 6.1210E-2 | 8.7258E-2 |
| 17 | D ₂ O | 1 | 1.3188E+0 | 9.2667E-3 | 0.0 | 0.0 |
| | | 2 | 8.2889E-1 | 0.0 | 1.2260E-4 | 0.0 |
| 18 | Control-Rod | 1 | 6.5600E-1 | 5.5885E-3 | 4.9684E-3 | 0.0 |
| | | 2 | 4.1378E-1 | 0.0 | 1.1532E-1 | 0.0 |
| 19 | D ₂ O around control-rod | 1 | 1.2889E+0 | 1.0980E-2 | 0.0 | 0.0 |
| | | 2 | 8.3584E-1 | 0.0 | 1.2004E-4 | 0.0 |

Table 8.2 Boundary condition for neutron flux and result of multiplication factor

(1) Boundary condition

| Direction | | Boundary condition or extrapolation distance (cm) |
|-----------|-------|---|
| X-Y | | $-\frac{D}{\phi} \cdot \frac{d\phi}{dX}$ |
| Z | Upper | 5 |
| | Lower | 6 |

(2) Multiplication factor

| Withdrawal height of control-rod (mm) | Core height (mm) | K_{eff} |
|---------------------------------------|------------------|-----------|
| 505 | 938.6 | 0.99724 |
| 605 | 930.9 | 0.99779 |

Table 8.3 Axial power distribution obtained from three dimensional diffusion calculation

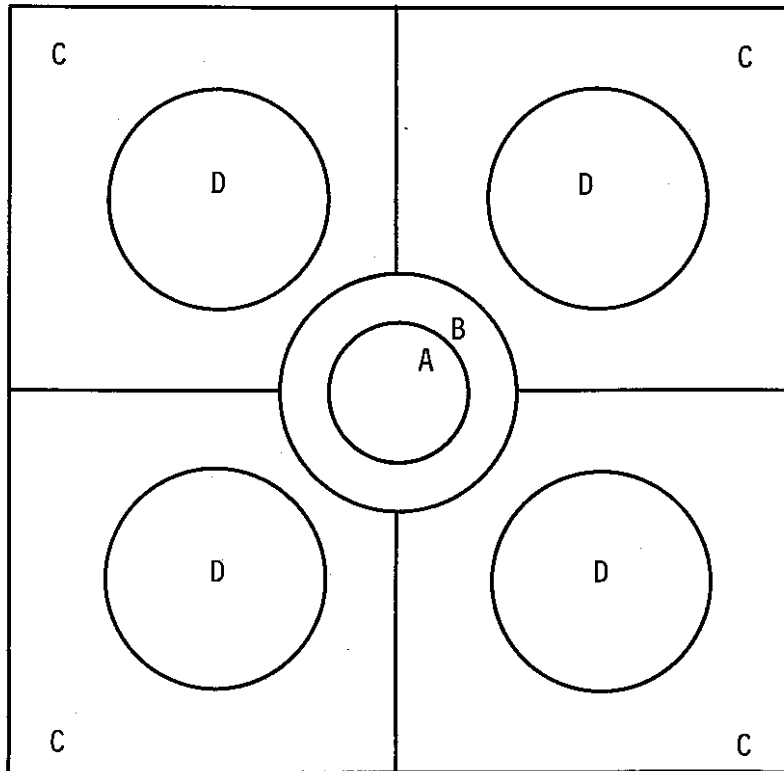
Reactor power : 10^6 watt (watt/cm)

| Control-rod withdrawal (mm) | Height from core bottom (mm) | 0 channel | | | OB2 channel |
|-----------------------------|------------------------------|-----------|-------|-------|-------------|
| | | Pin A | Pin B | Pin C | Pin D |
| 505 | 6.0 | 5.59 | 2.84 | 5.47 | 4.52 |
| | 18.1 | 11.62 | 6.00 | 11.39 | 9.46 |
| | 28.5 | 15.25 | 7.91 | 15.09 | 12.61 |
| | 37.3 | 16.91 | 8.85 | 17.04 | 14.34 |
| | 43.9 | 16.79 | 8.98 | 16.26 | 14.85 |
| | 48.3 | 16.20 | 8.84 | 17.44 | 14.93 |
| | 52.2 | 14.75 | 8.40 | 16.95 | 14.76 |
| | 55.5 | 14.40 | 8.09 | 16.49 | 14.46 |
| | 58.8 | 13.61 | 7.75 | 15.90 | 14.02 |
| | 62.7 | 12.67 | 7.29 | 15.06 | 13.34 |
| | 69.3 | 10.97 | 6.38 | 13.27 | 11.83 |
| | 79.7 | 7.72 | 4.50 | 9.46 | 8.48 |
| 90.4 | 3.88 | 2.21 | 4.80 | 4.30 | |
| 605 | 6.0 | 5.80 | 2.93 | 5.12 | 4.59 |
| | 18.1 | 12.08 | 6.20 | 11.69 | 9.58 |
| | 28.5 | 15.99 | 8.22 | 15.52 | 12.75 |
| | 37.3 | 18.01 | 9.28 | 17.57 | 14.49 |
| | 43.9 | 18.36 | 9.52 | 18.11 | 15.00 |
| | 48.3 | 18.17 | 9.48 | 18.12 | 15.06 |
| | 52.2 | 17.60 | 9.26 | 17.82 | 14.88 |
| | 55.5 | 16.83 | 8.96 | 17.36 | 14.56 |
| | 58.8 | 15.78 | 8.54 | 16.69 | 14.10 |
| | 62.7 | 14.23 | 7.79 | 15.59 | 13.39 |
| | 69.3 | 11.78 | 6.67 | 13.59 | 11.82 |
| | 79.7 | 7.96 | 4.60 | 9.51 | 8.36 |
| 90.4 | 3.95 | 2.24 | 4.78 | 4.20 | |

Table 8.4 Comparison between experiment and calculation for maximum ratio of fuel pin power due to 100mm withdrawal of control-rod

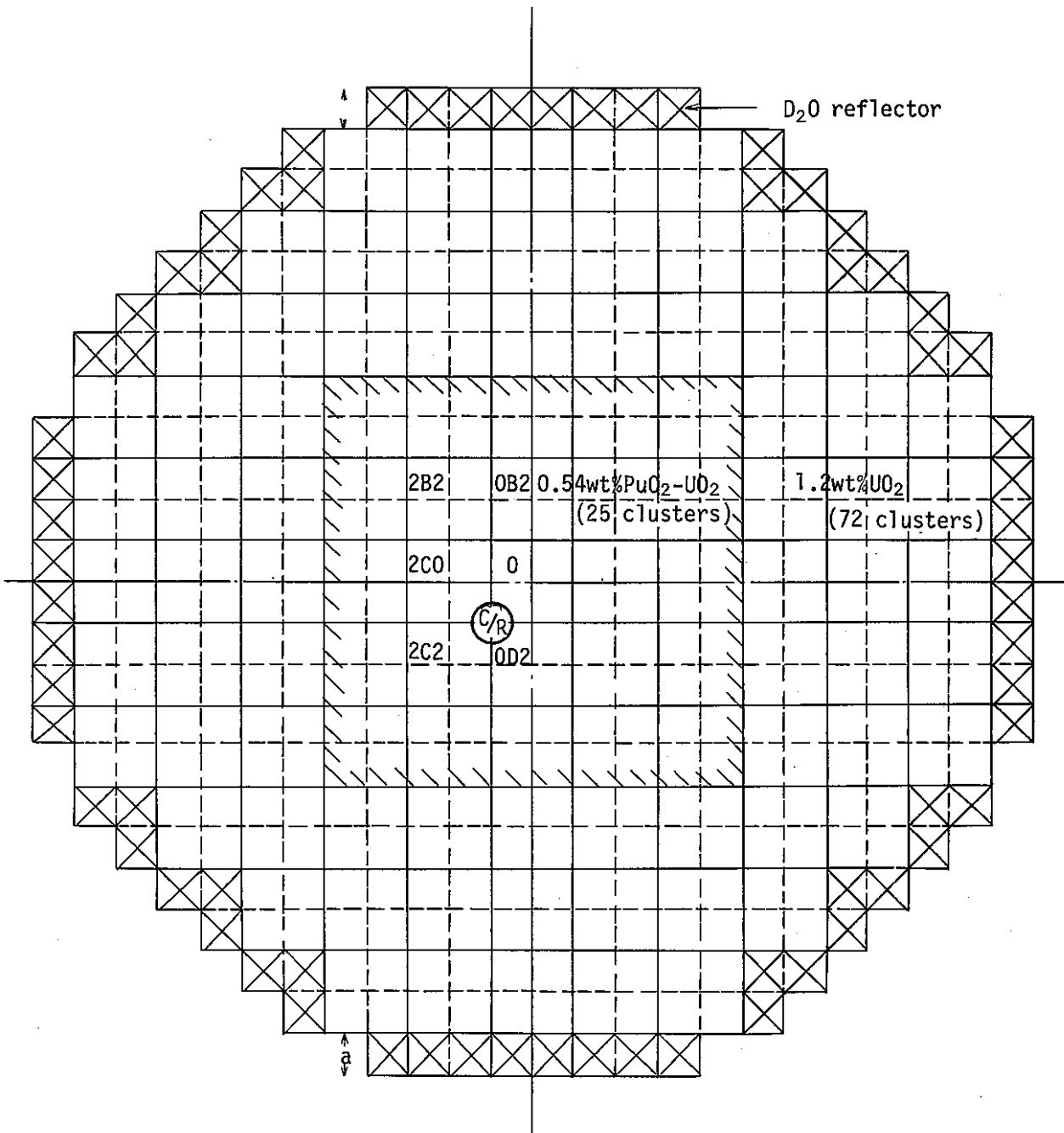
| Channel No. | Fuel pin No. | Distance from control-rod surface (mm) | Pin power ratio due to 100mm withdrawal (P_{605}/P_{505}) | | Error* |
|-------------|--------------|--|---|-------|--------|
| | | | Exp. | Cal. | |
| 0 | A | 92.2 | 1.12 ± 0.03 | 1.168 | 4.3 |
| | B | 126.6 | 1.10 ± 0.03 | 1.108 | 0.7 |
| | C | 187.3 | 1.02 ± 0.02 | 1.053 | 3.2 |
| 0B2 | D | 443 | 0.93 ± 0.03 | 1.007 | 8.3 |

$$* \text{ Error} = \frac{\text{Cal.} - \text{Exp.}}{\text{Exp.}}$$



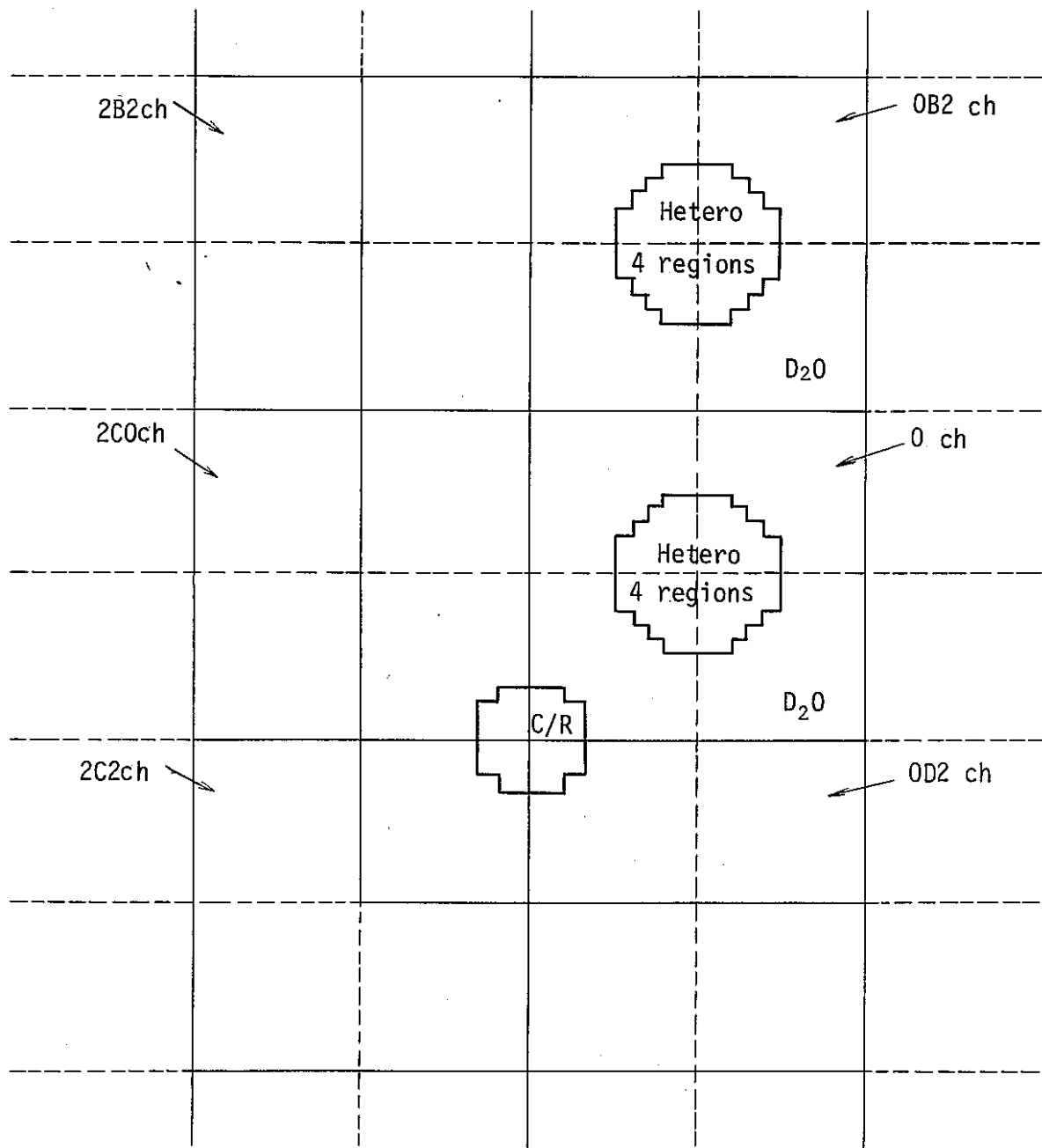
- A: Control rod (74 ϕ)
 - B: D₂O around control-rod (82 ϕ)
 - C: D₂O
 - D: Fuel region
- } Control rod cell

Fig. 8.1 WIMS multi-cell model for control-rod and surrounding plutonium cells



Plane mesh points: 2 mesh points/unit cell (= 12.5 cm)

Fig. 8.2 (1) X-Y plane model of three dimensional diffusion calculation



(2) X-Y plane model of three dimensional diffusion calculation

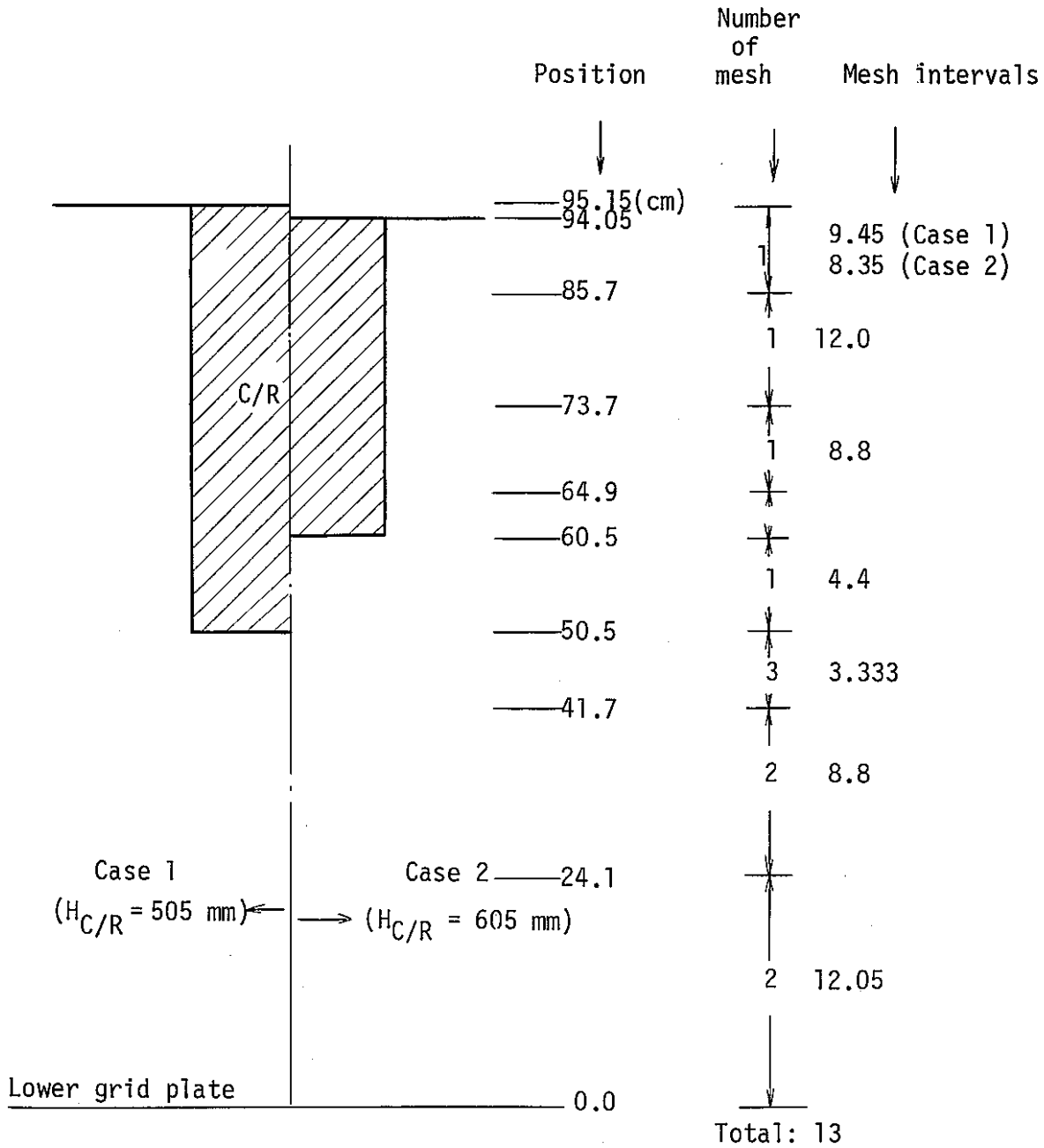


Fig. 8.3 Axial plane model for three dimensional diffusion calculation

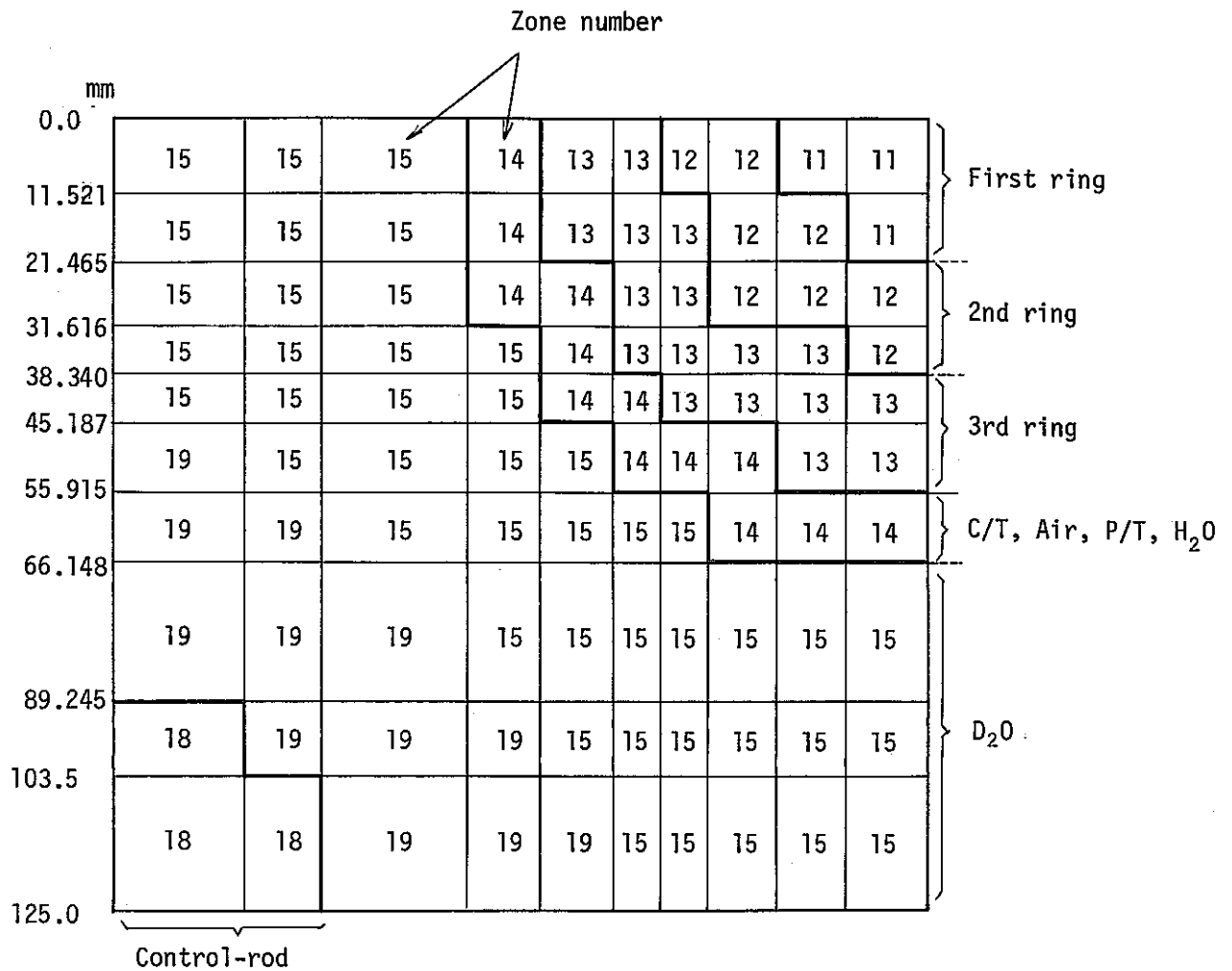
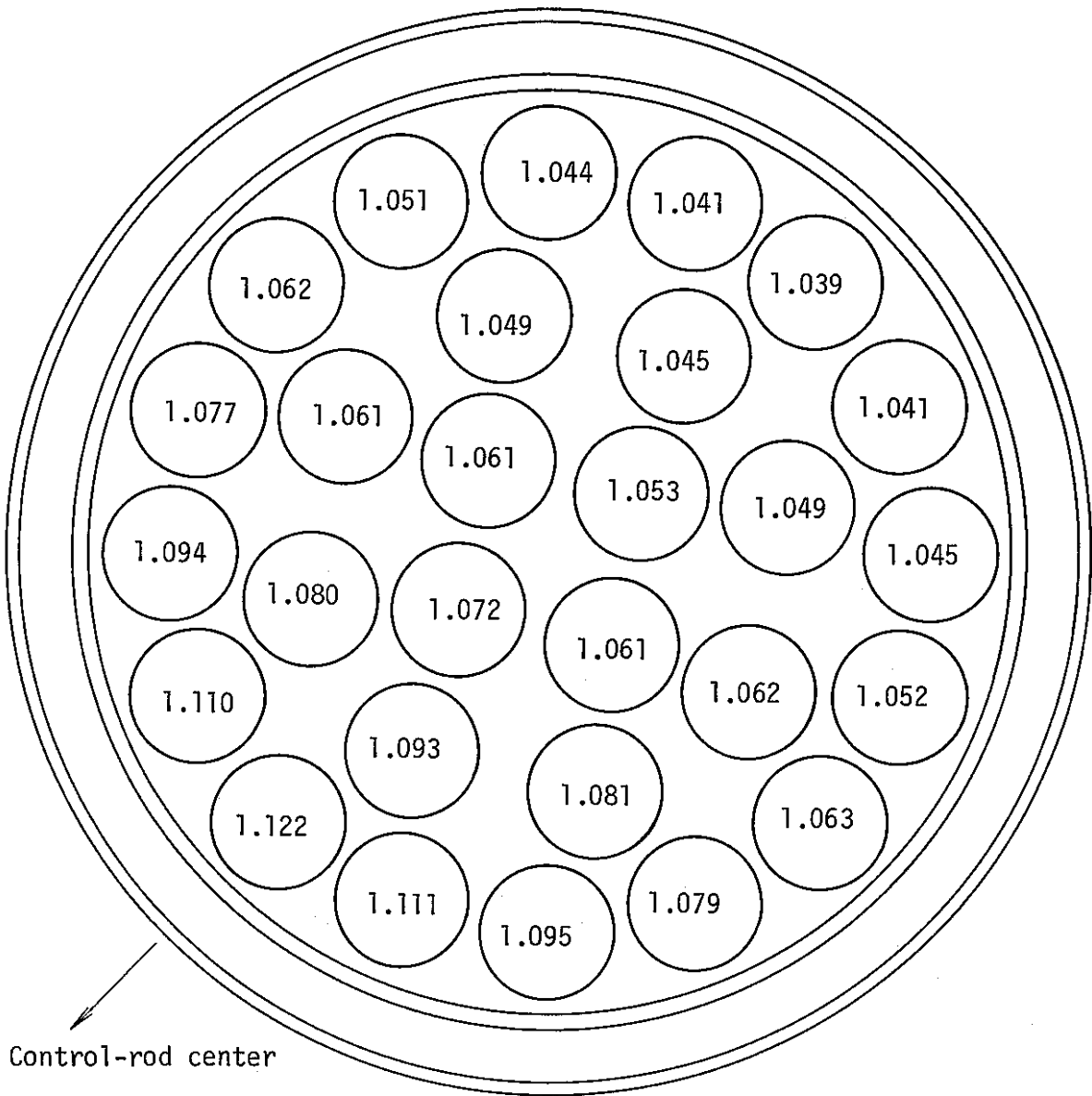
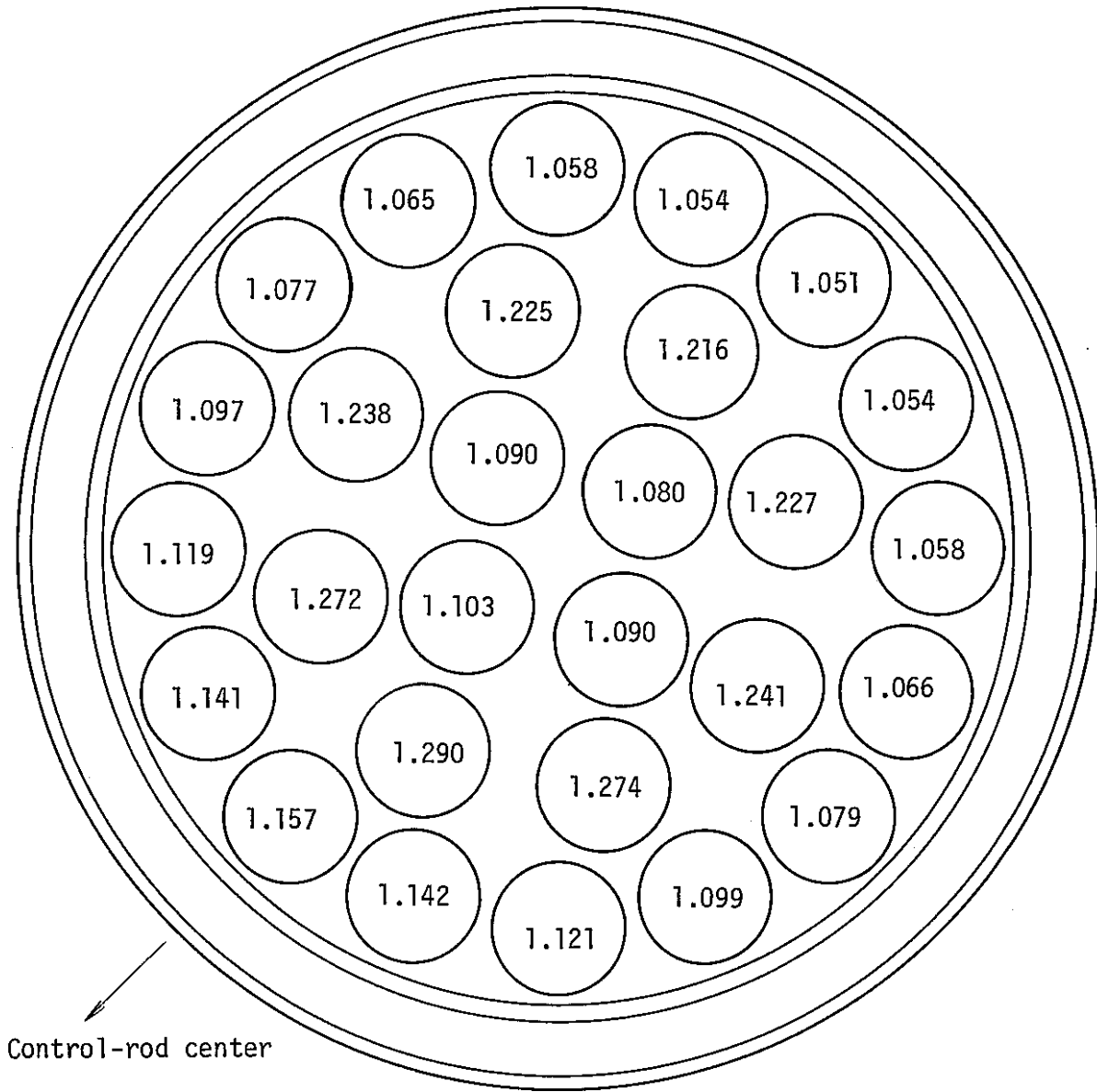


Fig. 8.4 Fine mesh structure of the nearest fuel channel to the control-rod at the height of inserted control-rod

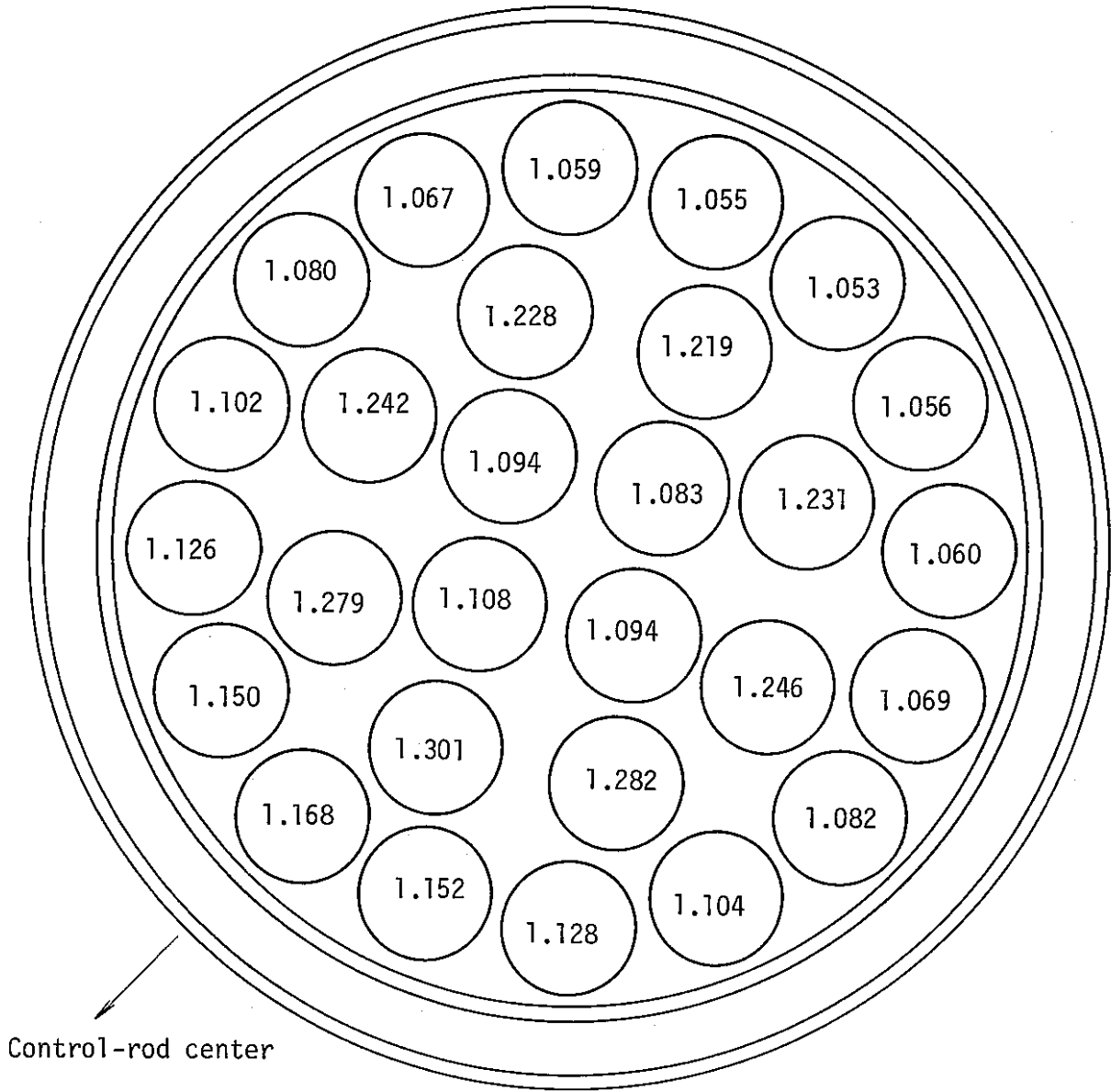


(1) Height from core bottom: 483 mm (layer 6)

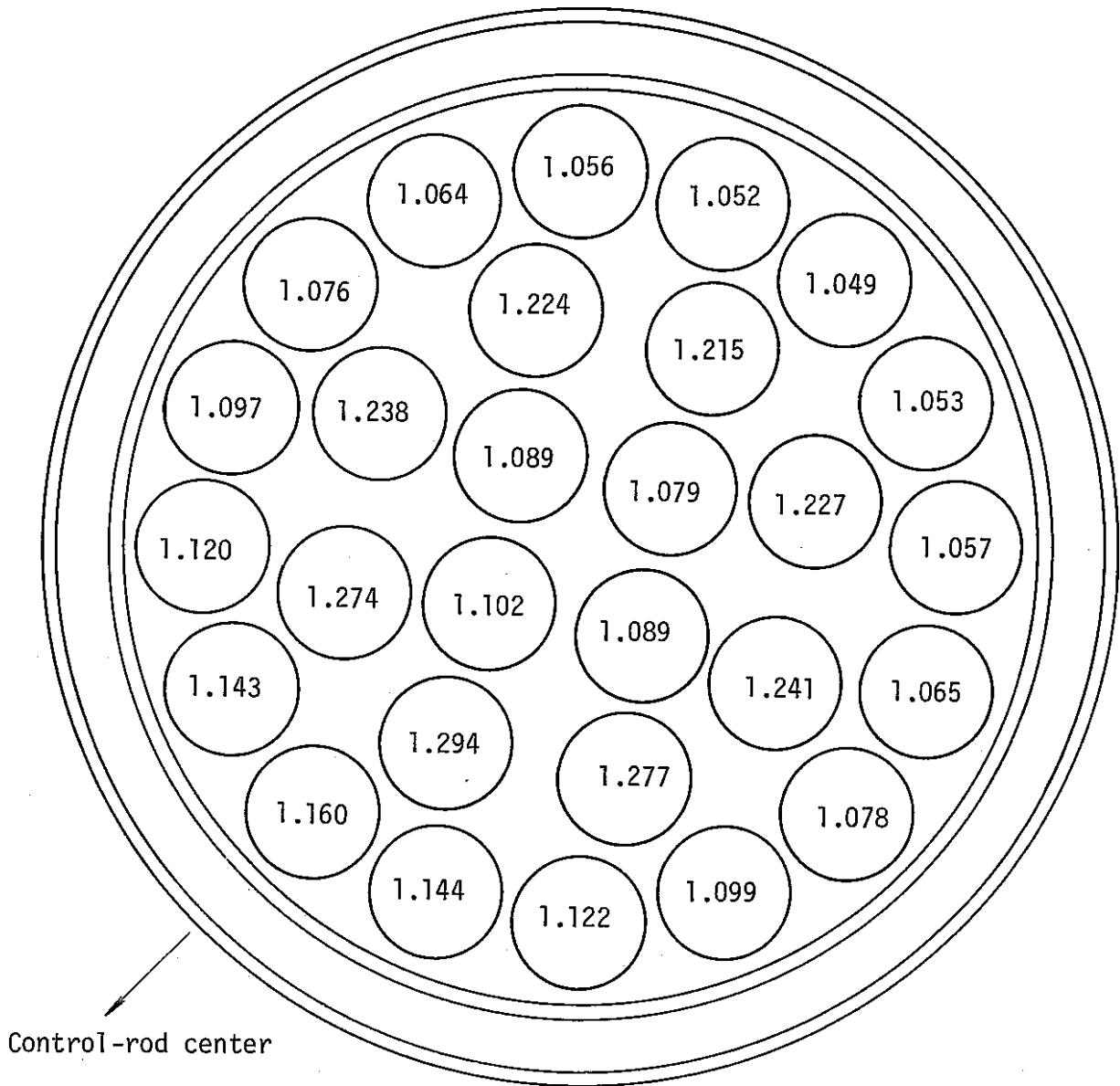
Fig. 8.5 Ratio of fuel pin power in 0 channel cluster due to 100 mm withdrawal from 505 mm height (P_{605}/P_{505}).



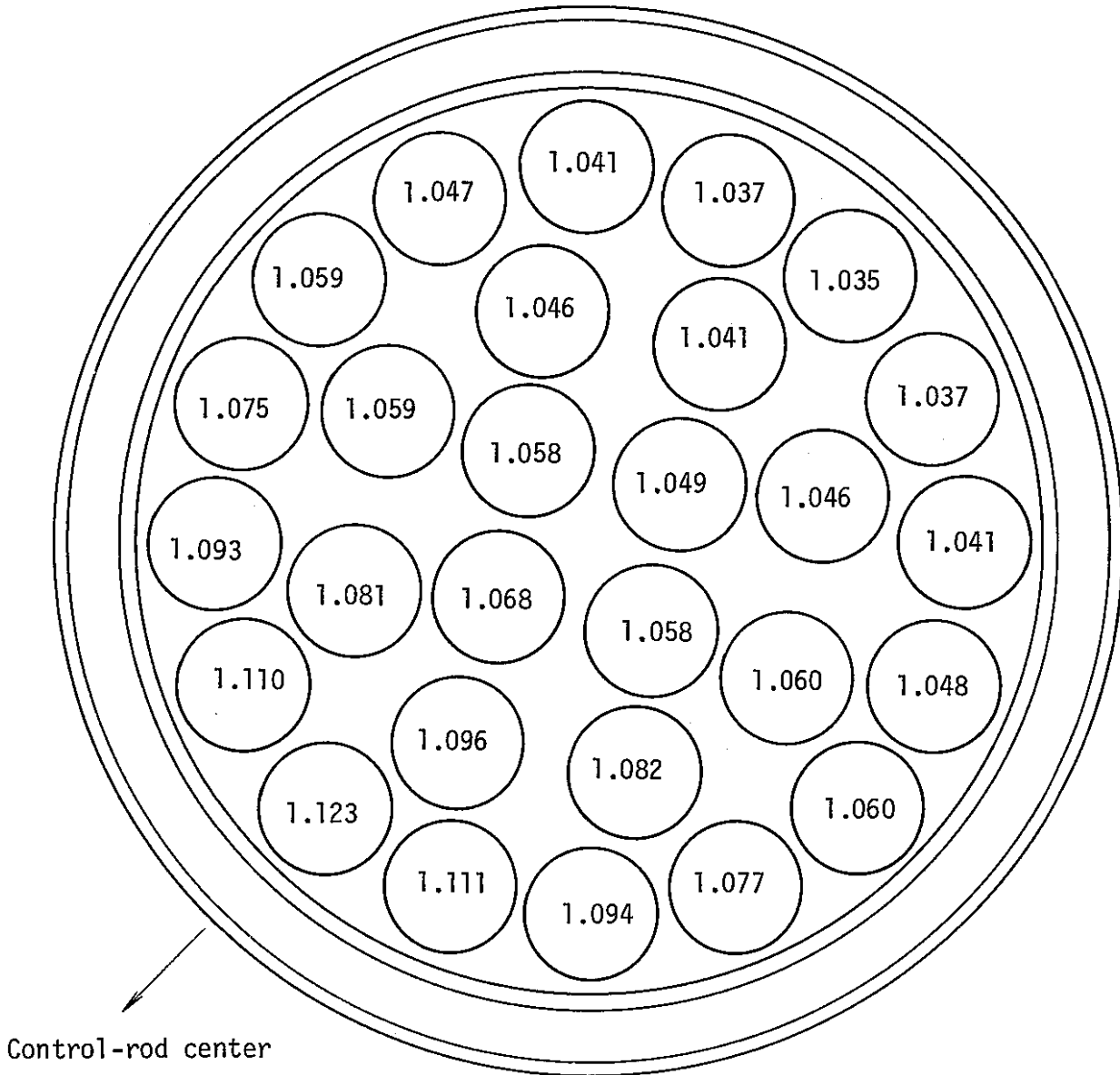
(2) Height from core bottom: 522 mm (layer 7)



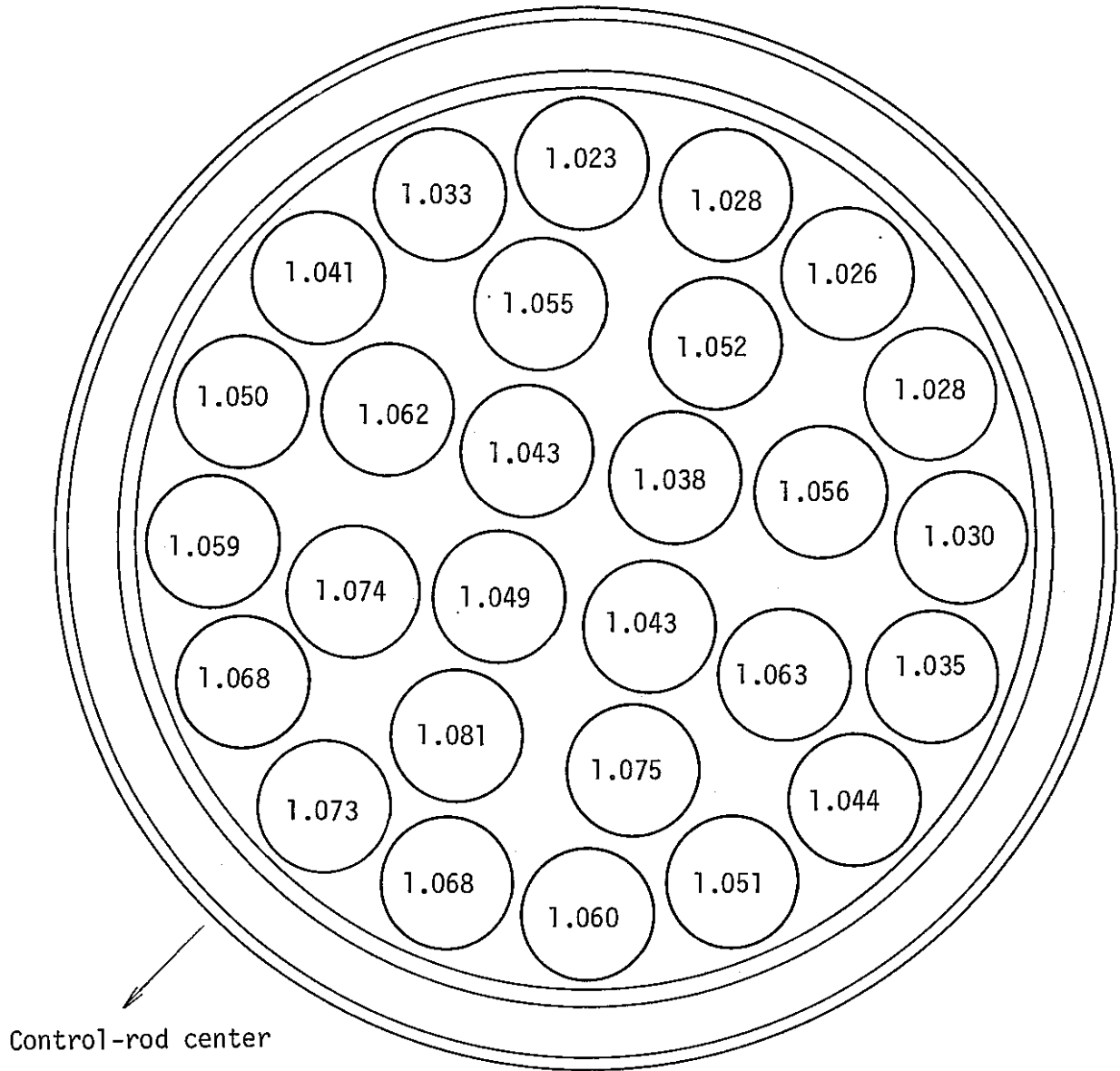
(3) Height from core bottom: 555 mm (layer 8)



(4) Height from core bottom: 588 mm (layer 9)



(5) Height from core bottom: 627 mm (layer 10)



(6) Average values over axial part