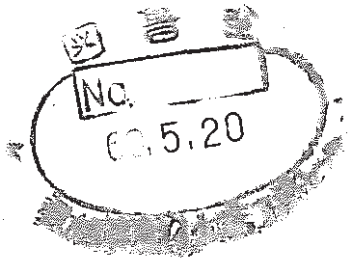
「常陽」MK-I ブランケット燃料(NFJI11,NFJO 4K, NFJO64及びNFJO 5L) の照射後試験

—燃料要素の破壊試験—



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大洗工学センター

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

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—燃料要素の破壊試験—

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要 旨

高速実験炉「常陽」MK－I炉心の4体のブランケット燃料集合体の照射後試験を実施した。NFJI11は，炉心位置5D1で50MW第1サイクルから75MW第6サイクルまで照射された。NFJO4K，NFJO64及びNFJO5Lは，それぞれ6D1，7D1及び8D1の炉心位置で臨界から75MW第6サイクルまで照射された。これらの4体は炉心中心に向けて直列に並んでいる集合体であり，MK－I炉心のブランケット燃料領域での照射挙動，とりわけ径方向の挙動を把握する為に各集合体から1～2本の燃料ピンを選択して破壊試験を実施した。実施した試験は，金相試験（燃料組織観察）及び燃焼率測定試験である。

(1) NFJI11，NFJO4K，NFJO64及びNFJO5Lの4体とも燃料組織変化は認められない。またFCCIも観察されずに健全に燃焼している。

(2) 燃焼率測定結果から，実測値とJYHISTコード計算値を比較したところ，軸方向の相対的な分布はよく一致しているが，径方向の分布については実測値の変化が計算値より小さな傾きをもって変化していることがわかった。

(3) 燃料中の生成プルトニウムの含有率は，燃焼率の増大とともに含有率も増大するが，変化率は燃焼率より小さい。

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Post Irradiation Examination of JOYO MK-I Blanket Fuel (NFJI11, NFJO4K, NFJO64, and NFJO5L)

- Destructive Examination of Fuel Elements -

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Abstract

The JOYO MK-I blanket fuel subassemblies; NFJI11, NFJO4K, NFJO64, and NFJO5L were irradiated in the core location of 5D1, 6D1, 7D1, and 8D1 respectively. One of four subassemblies NFJI11 was irradiated from the 50MW 1st cycle to the end cycle of MK-I core, and the others from the 50MW low power test to the end cycle.

One or two fuel pins were selected from each subassembly and the destructive post irradiation examinations that were metallographic examination and burnup measurement, were performed in AGF.

The following results were obtained;

(1) Fuel restructurings were not found for all subassemblies under microstructure observation.

(2) FCCI was not observed for all subassemblies.

(3) Axial distribution of normalized measured burnups had a good agreement with calculated profile by JYHIST code for all subassemblies.

(4) Radial distribution curve of measured burnups toward the core center had more gentle slope than the calculated one.

(5) Plutonium content which was generated by the neutron capture of U-238, varied with burnup, and the distribution curve had more gentle slope than the burnup curve.

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1. まえがき

「常陽」MK－Iブランケット燃料集合体NFJI11，NFJO4K，NFJO64及びNFJO5Lの4体は，同じ炉心半径方向のD方向において，それぞれ第5，第6，第7及び第8列で50MW及び75MW出力で照射された集合体である。照射期間は，NFJI11を除く3体が「常陽」MK－I炉心の臨界から最終サイクル（75MW第6サイクル）までの全サイクルを経験しており，NFJI11は50MWの第1サイクルから最終サイクルまでの照射を経験している。

これらのブランケット燃料の照射挙動を把握するため各集合体より1～2本の燃料ピンを選び照射後試験を行った。

試験項目は，(1)燃焼率測定及び(2)金相試験である。

2. ブランケット燃料ピンの仕様

試験対象となった各集合体を構成しているブランケット燃料ピンの仕様をTable 1－1に示す。

3. 照 射 条 件

NFJI11，NFJO4K，NFJO64 及びNFJO5L集合体の炉心装荷位置をFig.1－1に示す。また各集合体において破壊試験を実施したブランケット燃料ピンの各集合体内装荷位置をFig.1−2に示す。各集合体の照射条件をTable 2－1に示す。

試験に供した各ブランケット燃料ピンの軸方向照射及び試料切断位置をFig.2−1〜Fig.2−4−2に示す。

4. 試験の方法及び結果

4.1 金相試験

(1) 試料調整方法

必要長さに切断された金相試料切断片（約１０㎜）は，エポキシ樹脂にて埋込んだ後１２０番から順次６００番までの耐水研磨紙にて粗研磨を行い（この工程は水を使用），６μmから順次１／４μmまでダイヤモンドペーストを用いて仕上研磨を実施し（この工程はラッピング・オイル使用），最後に0.０５μmアルミナにてバフ研磨を実施した。

研磨後の光顕観察としては，燃料／被覆管のギップ部の観察及び高倍率によるブランケット燃料ボイド率測定用の写真撮影を行った。その後燃料部分に関しては，Ａｒガスによるイオン腐食を行った後，燃料部の詳細組織観察を実施した。

(2) 結　果

照射後試験を実施したブランケット集合体NFJI11，NFJO4K，NFJO64，及びNFJO5Lは，それぞれの照射位置が5D1，6D1，7D1及び8D1と炉心中央から順次遠くなるため，それらの線出力はTable 2－1に示すごとく照射末期の最も線出力の高い時期においても，１０８Ｗ／cmから１０Ｗ／cmと炉心燃料と比較して著じるしく小さい。この様な条件で照射されたブランケット燃料の中心ピンのイオンエッチング後の金相組織写真をPhoto.1～4に示す。これらの写真よりブランケット燃料はＦＣＣＩなども発生しておらず，きわめて健全といえるが，燃料組織上特徴的なことが，1，2あるのでそれに関して述べる。

① ブランケット燃料は先に述べた様にきわめて線出力が低いため，燃料の温度もそれに従って低く，組織変化もほとんど起っておらず，ペレット製造時の造粒組織がそのまま残っている。又，その造粒した粒の境界には多数のボイドが見られる。

② 燃料内のクラックは出力変動時に生ずる熱応力に依存するため，高出力のピンではその数が多い。今回照射後試験を行ったブランケット燃料においても，線出力の比較的高いNFJI11及びNFJO4Kにおいては，燃料外表面に到達するクラックが認められるが，他の２つの燃料ピンには認められない。JYHISTによる最高線出力から判断すると，クラックが入るか否かの境界は２０～４０Ｗ／cm程度と思われる。Olanderによると簡単な熱応力計算より，燃料中にクラックの入る線出力は約50W／cmと報告されているが[1]，この結果と若干異っている。ブランケット燃料の線出力の計算結果は当室で実施した燃焼率の測定結果とほぼ一致していることから，燃料のクラッキングは燃料への応力集中などの別の機構も考慮する必要があることを示唆しているものと思われる。

4.2 燃焼率測定

(1) 燃料調製方法

試料調製の方法と手順をFig.3－1に示す。

(2) 結　果

NFJI11，NFJO4K，NFJO64及びNFJO5L集合体試料の燃焼率測定結果を，Table 3－1にまとめて示す。表中の「Bunup （Measured）」は，^{148}Ndを指標核種として測定した結果である。比較対象として予想計算値を「Bunup （Calculated）」欄に示す。この値は，JYHISTコードから得られた値から中性子捕獲反応及びγ線発熱等を除外補正したものである。また「Pu content」は，各試料中のPu含有率の測定結果を示したものであり，生成－消滅過程を経て試料中に残留したPu量を示している。Table 3－2に，今回の測定で使用した^{148}Nd，^{146}Nd，^{145}Ndの実効核分裂収率の計算例を示した。各fissileからの核分裂収率は全集合体とも同じ数値を使用している。Table 3－3に，今回の測定に使用したスパイク液の濃度，組成等のデータを示す。質量分析結果から得られたU，Pu，Ndの同位体組成及びPu含有量並びに燃焼率計算結果をTable 3－4－1～3－4－3（NFJI11），Table 3－5－1～3－5－6（NFJO4K），Table 3－6－1～3－6－4（NFJO64），及びTable 3－7－1～3－7－4（NFJO5L）に示した。

これらの測定結果を基にして相互比較した結果を次に示す。Fig.4－1－1～4－1－4は，それぞれNFJI11，NFJO4K，NFJO64及びNFJO5L集合体の中央ピン（１０ピン）の軸方向の燃焼率分布について，実測値と計算値を比較したものである。Fig.4－2－1～Fig.4－2－4は，上記の燃焼率軸方向分布を最大測定値で規格化して示したものであり，合わせてγスキャン結果とPu含有量の分布を示したものである。同様に炉心半径方向に各集合体を並べて実測値と計算値の比較をしたものをFig.4－3に示す。更にFig.4－4－1～4－4－3に各集合体ごとに径方向について燃焼率，γ線強度及びPu含有率の分布を中央ピンで規格化して比較した図を示す。

以上の結果以下のことを確認した。

① 各集合体の中央ピン軸方向中央位置での燃焼率測定結果は，0.174（NFJI11），0.077（NFJO4K），0.033（NFJO64）及び0.016atom%（NFJO5L）であり，第5列及び第8列のNFJI11とNFJO5Lについては実測値の方が計算値より大きな値を示した。反対に，第6列及び第7列のNFJO4KとNFJO64については実測値の方が計算値より小さな値を示した。

② 燃料ピンの軸方向に於ける規格化した燃焼率分布は，各集合体とも実測値と計算値がほぼ一致している。

③ 集合体内径方向に於ける規格化した燃焼率分布は，NFJO5Lについては，実測値と計算予想値はほぼ一致するが，その他のNFJO4K及びNFJO5Lについては，実測値の方が計

算値より緩い傾斜で変化した。

④ Ｐｕ含有率の分布は，軸方向及び径方向とも燃焼分布に比例して変化するが，その変化率は燃焼度より小さな値を示した。

(3) 考　察

① Ｆｉｇ.４－３からわかるように，ブランケット燃料集合体内の径方向の燃焼率分布については実測値と計算値で大きな差が見られる。ここで第５列のＮＦＪＩ１１については中心ピン１点のみの測定点しか得られていないが，既に照射後試験を終了したＮＦＪＩＯＱ（５Ａ１）及びＮＦＪＩＯＲ（５Ｃ２）の測定結果を合わせて検討すると，実測値と計算値の分布の差は炉心に近ずくほど大きくなることが認められる。この原因として「常陽」運転監視コード（ＳＭＡＲＴ）からＪＹＨＩＳコードへ提供される径方向出力ピーキング係数が，炉心に近い領域で過大にとられている可能性がある。しかしながら，ＳＭＡＲＴコードから得られる燃焼データが核分裂反応以外の反応を含む全核反応による発熱量（ＭＷＤ／ＭＴＭ）であるのに対し，ＡＧＦで得られるデータが核分裂による原子数変化率（ａｔｏｍ％）であることから，両者を比較する為に幾つかの補正を行っており，これらの補正に含まれる誤差も考慮する必要がある。これらの点を含めて，「常陽」ＭＫ－Ｉ炉心全体の燃焼特性についての評価検討作業を現在進めている。

② ブランケット中のＰｕの生成量については，「常陽」データバンキングシステムから照射後集合体１体当たりのPuO_2量として情報が得られる。一方ＡＧＦの実測データは各測定ポイントのＰｕ量の情報であるので，両者を比較する場合にはポイントデータから集合体１体当たりのＰｕ量を求める必要がある。今回のＮＦＪＯ４Ｋ集合体の測定では，ピン軸方向について上下端一杯に採取点を広げているので，得られた結果をもとに各集合体１体中のＰｕ量を次のような方法で試算してみた。

1) 集合体の軸方向の分布を，正規分布曲線式の$f(z)=b\cdot\exp(-a\cdot z^2)$〔ｚは，最大点からの軸方向距離〕で近似した。ＮＦＪＯ４Ｋの例をＦｉｇ.４－５－１に示すが，よくフィットしている。Ｆｉｇ.４－４－２のＰｕ含有率の一点鎖線は，得られたフィッティング式による曲線である。残りの３体（ＮＦＪＩ１１，ＮＦＪＯ６４，ＮＦＪＯ５Ｌ）については軸方向の測定点が最小限度の３点であるが，同様の方法でフィッティング式を求めた。

2) 集合体の径方向の分布を，$f(r)=b'\exp(-a'\cdot r)$〔ｒは炉心中心から各ピンまでの距離〕の式で近似した。Ｆｉｇ.４－５－２は，このフィッティング結果を示した。ここでＮＦＪＩ１１は，他の３体より照射期間が短いので実測点に平行移動している。Ｆｉｇ.４－３のＰｕ含有率の一点鎖線は，得られたフィッティング式による曲線である。

3) 上記の軸方向，径方向分布の近似式を基に，集合体１体中の平均Ｐｕ含有率を求め，Ｐｕの全量を求める。

得られた結果と予想計算値を比較した結果をTable ３－８に示した。計算値との差は最大

で＋6.3％と良い一致を示している。この結果から，「常陽」データバンキングから得られる情報の信頼性はかなり高いものと思われる。

5. 謝　　辞

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6. 参 考 文 献

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2) PNC SN941 84-01
「常陽」MK-Iブランケット燃料集合体(NFJI0Q)の燃焼率試験

3) PNC SN941 83-17
「常陽」MK-Iブランケット燃料(NFJI0R)の照射後試験(3)
-燃料要素の破壊試験-

【データ集】

1. 製造仕様及び照射条件

Table 1-1 Fabrication parameters of NFJI11, NFJO4K, NFJO64, and NFJO5L blanket pin

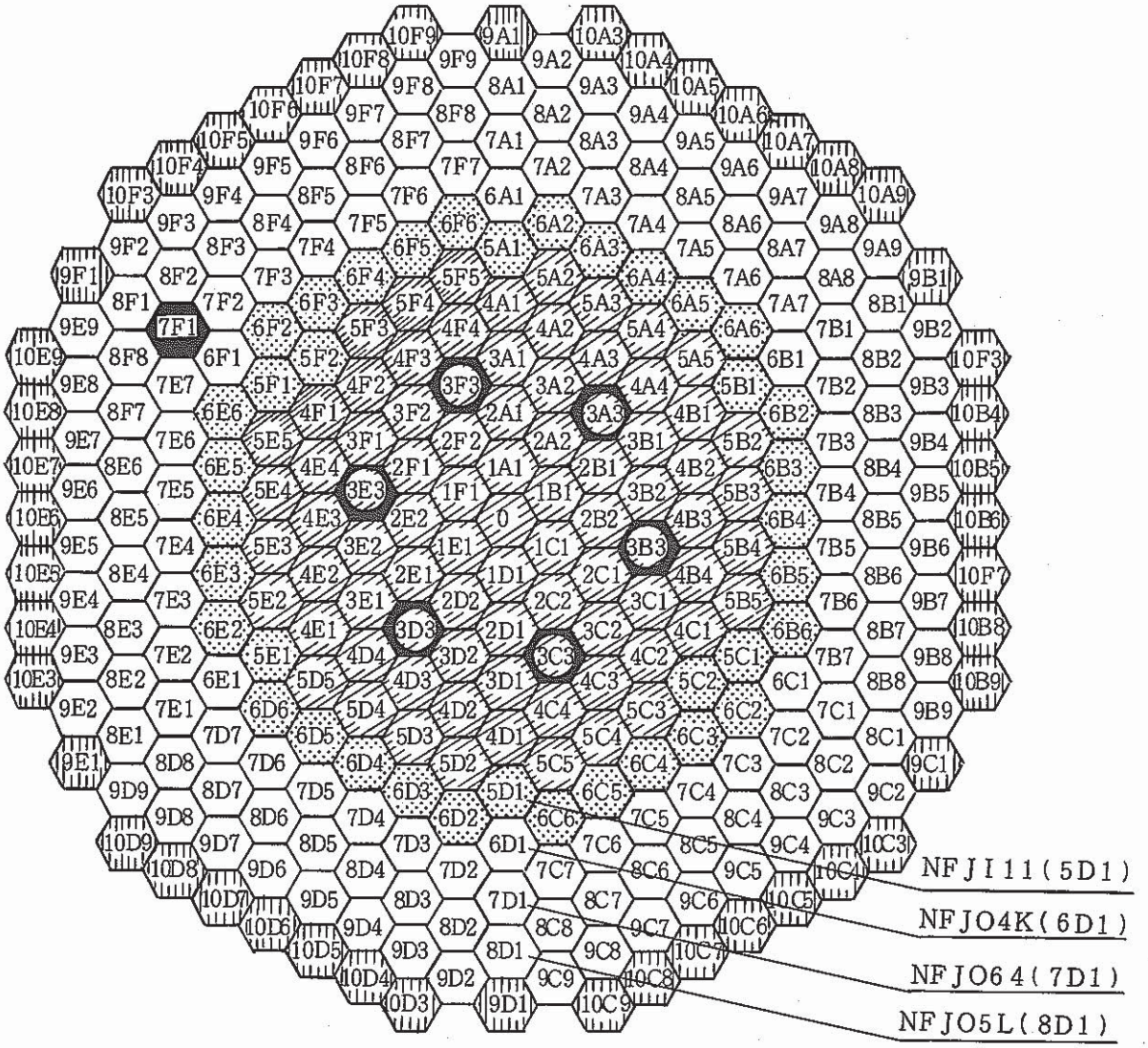
Blanket fuel	
Pellet diameter (mm)	13.6
Pellet length (mm)	20
Composition	Depleted UO_2
O/U ratio	2.00～2.02
Pellet density (% T.D)	94.0
Cladding	
Material	SUS316
Outer/inner diameter (mm)	15.0/13.8
Lot identification	NFJI11:K000 NFJO4K:S001 NFJO64:S000 NFJO5L:S002
Blanket fuel pin	
Pin length (mm)	1915
Pin outer diameter (mm)	15.0
Blanket fuel stack length (mm)	1400
Fuel/Cladding dia. gap (mm)	0.1

Table 2-1 Irradiation condition of NFJI11, NFJO4K, NFJO64, and NFJO5L subassembly

S/A No	Location	Irradiation cycle	Max. Linear* Heat Rate(EOL) W/cm	Burnup* MWD/MTM
NFJI11	5 D 1	5 0(1)~ 7 5(6)	1 0 8	1 8 9 0
NFJO4K	6 D 1	5 0(0)~ 7 5(6)	4 5	9 8 1
NFJO64	7 D 1	5 0(0)~ 7 5(6)	2 2	4 8 6
NFJO5L	8 D 1	5 0(0)~ 7 5(6)	1 0	2 2 5

* Calculated by JYHIST code (at a axial cente point of a center pin)

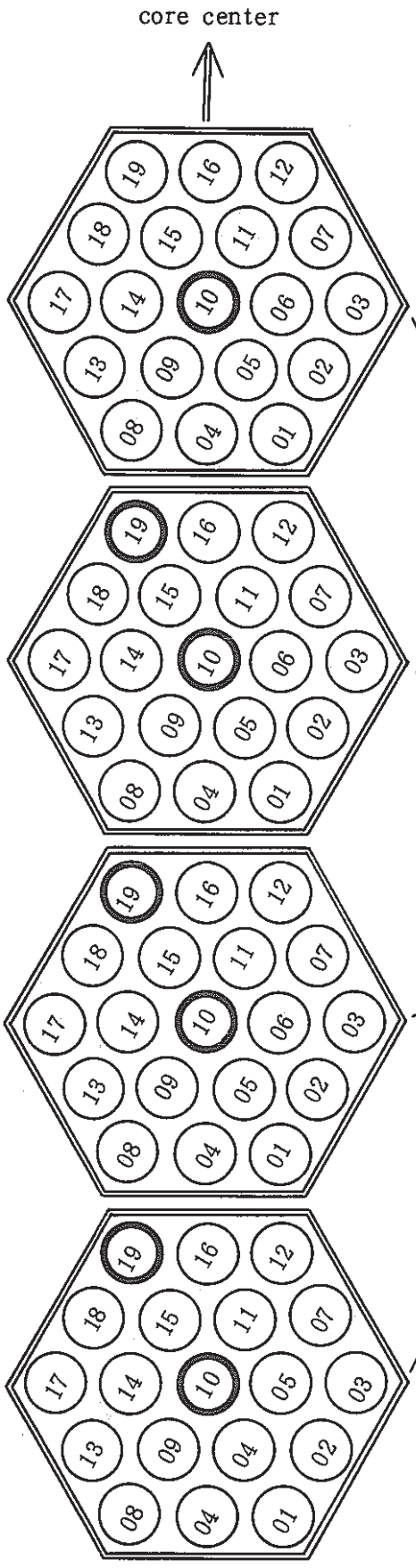
炉内照射位置



構成要素種類	装荷位置	
炉心燃料集合体	73本	
制御棒	6本（3A3*, 3B3*, 3C3°, 3D3*, 3E3°, 3F3°）*：調整棒 °：安全棒	
半径方向プランケット集合体	185本（内側 42本，外側 143本）	
中性子源	1本（7F1）	
反射体	48本	

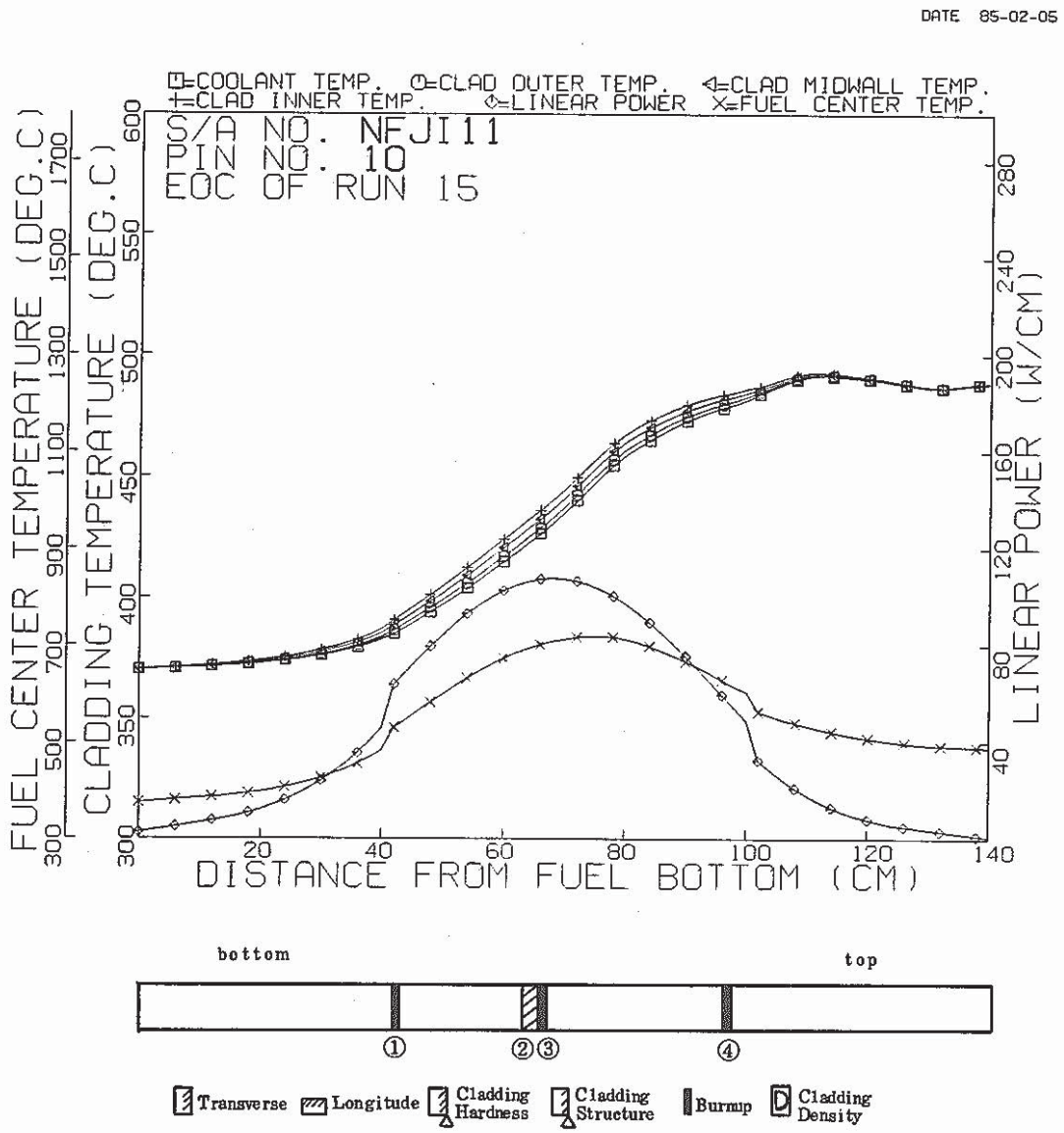
高速実験炉炉心マトリックス

Fig. 1-1 Irradiation position of NFII11, NFJO4K, NFJO64, and NFJO5L subassembly in JOYO MK-I core



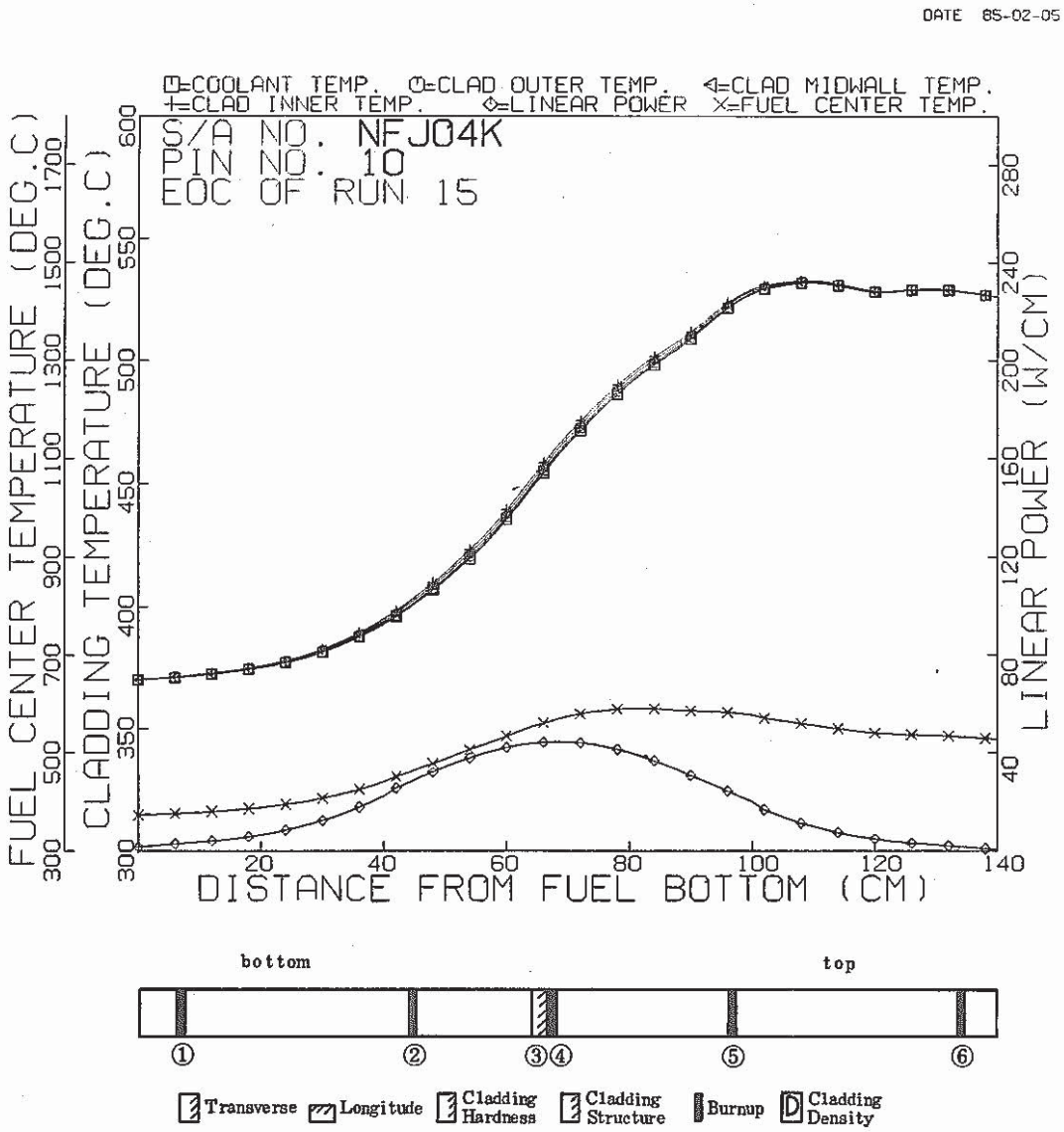
Location	S/A	Examinated pin No.
5D1	NFJI11	5710
6D1	NFJO4K	5810 5819
7D1	NFJO64	5610 5619
8D1	NFJO5L	5410 5419

Fig. 1-2 Examinated pins of NFJI11, NFJO4K, NFJO64, and NFJO5L subassembly



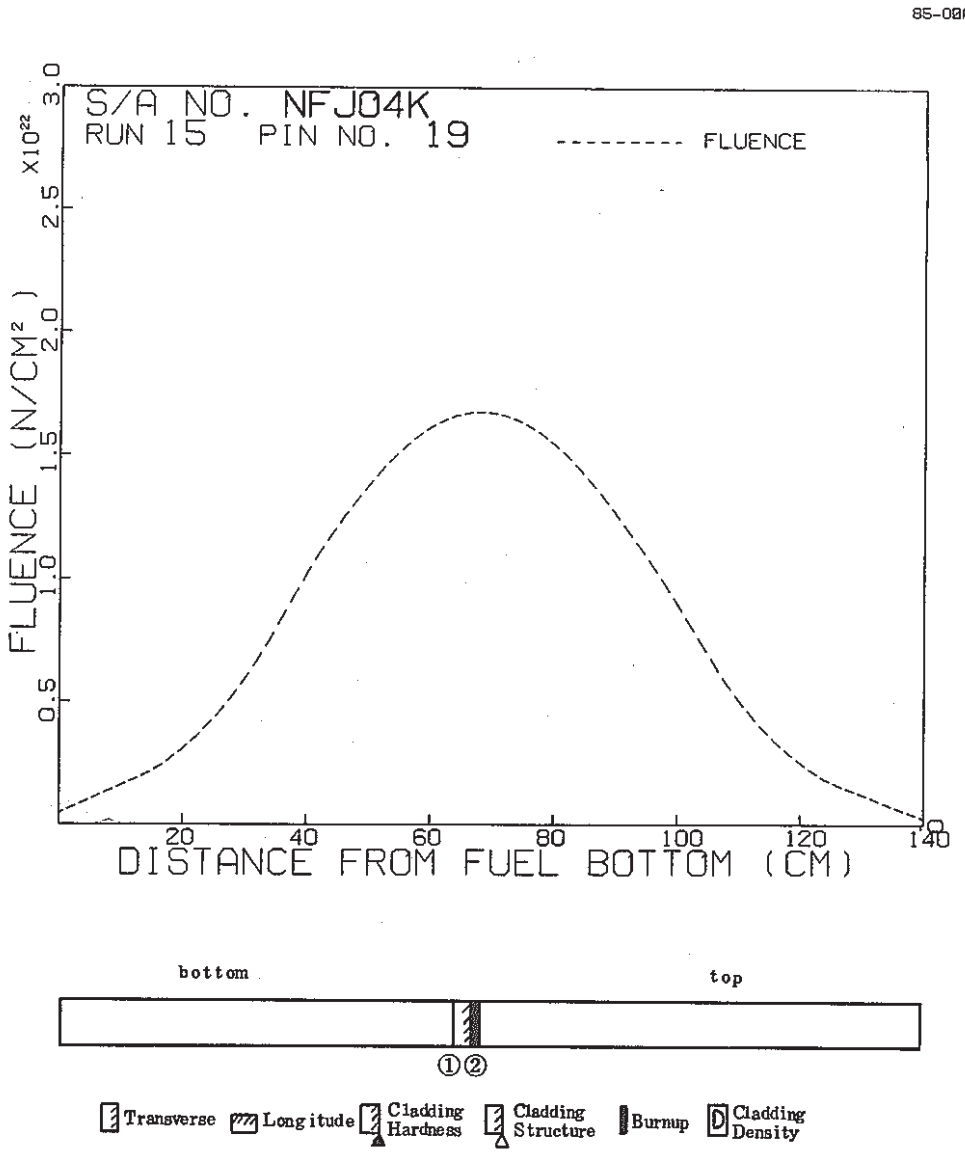
No.	Section No.	Distance from bottom of fuel column (mm)
①	571022	407.0~412.0
②	571042	656.0
③	571043	656.5~661.5
④	571062	968.0~973.0

Fig. 2-1 Irradiation condition and sectioning diagram of NFJI11 5710 pin



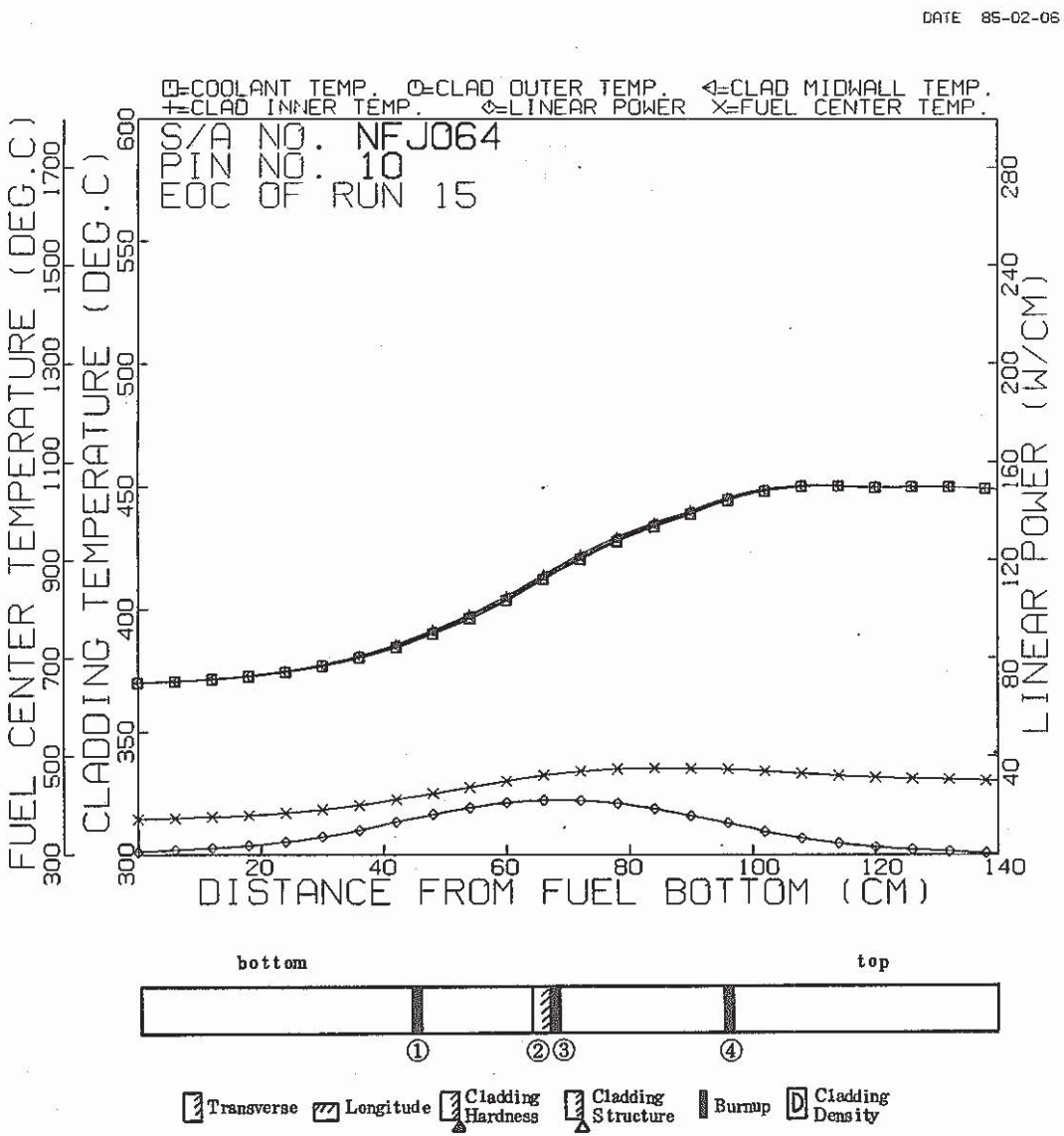
No.	Section No.	Distance from bottom of fuel column(mm)
①	581022	50.0~55.0
②	581042	20.5~25.0
③	581062	669.5
④	581063	670.0~675.0
⑤	581082	980.5~985.0
⑥	5810A2	1345.5~1350.0

Fig. 2-2-1 Irradiation condition and sectioning diagram of NFJO4K 5810 pin



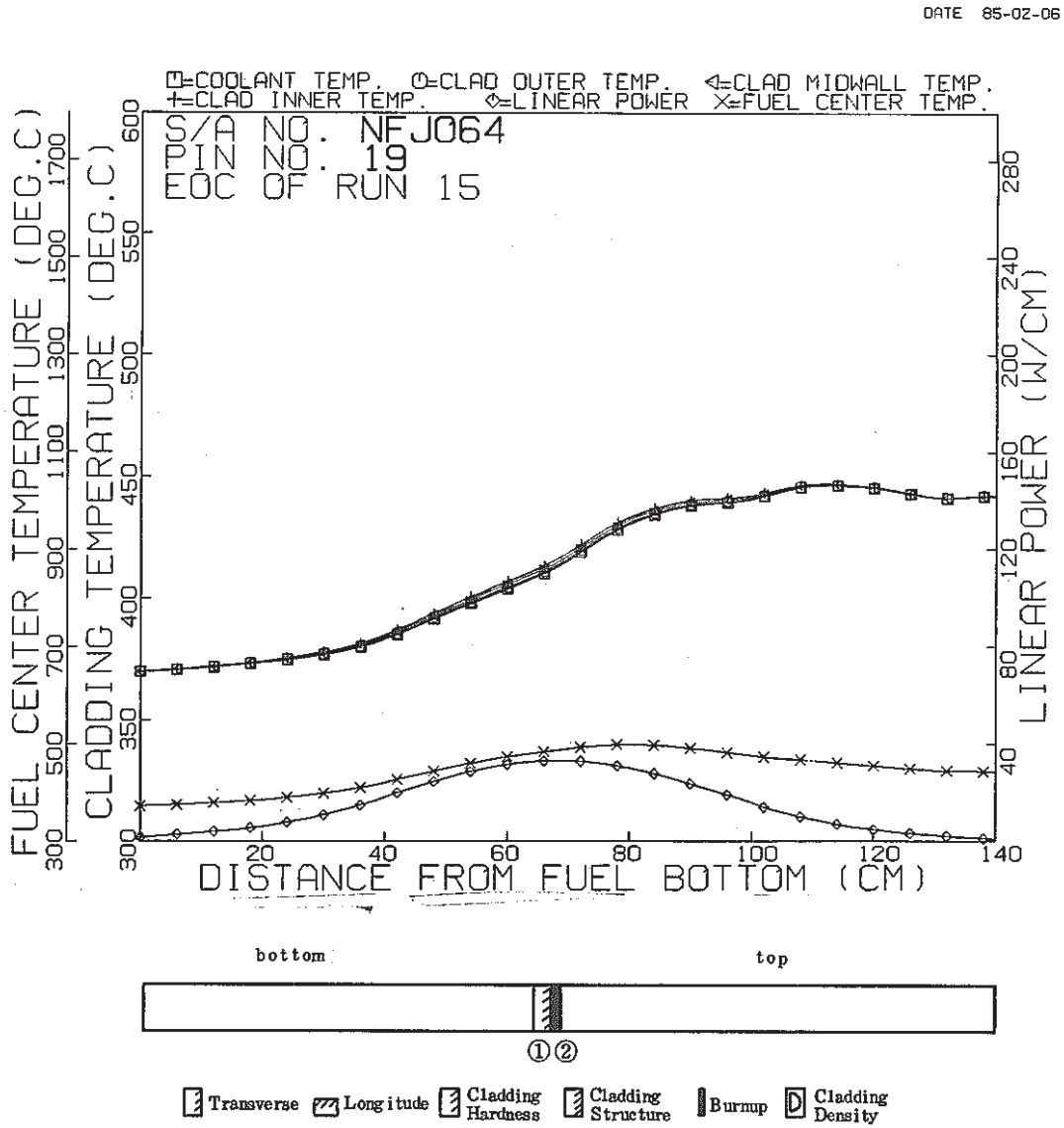
No.	Section No.	Distance from bottom of fuel column (mm)
①	581922	669.5
②	581923	670.0~675.0

Fig. 2-2-2 Irradiation condition and sectioning diagram of NFJO4K 5819 pin



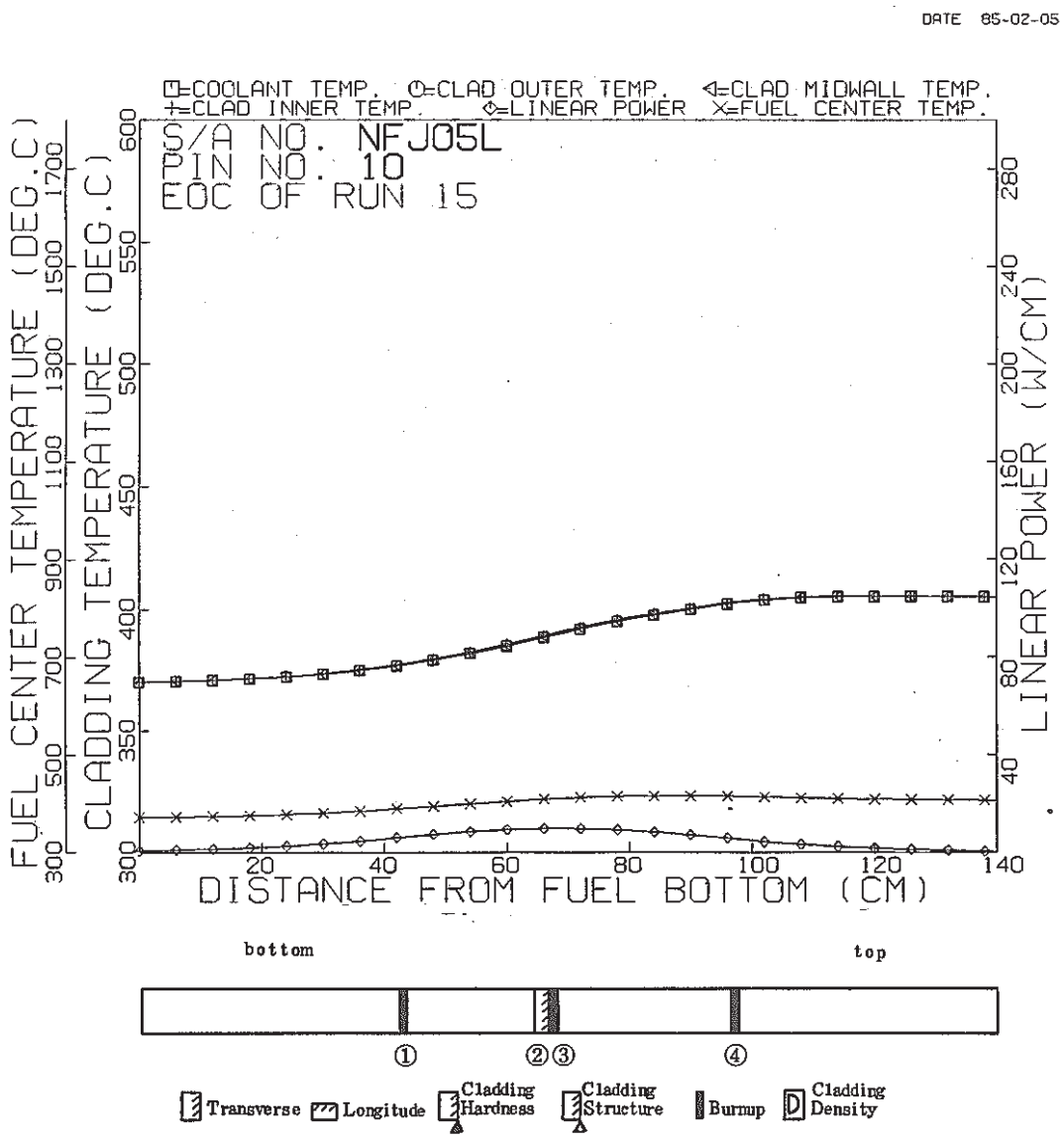
No.	Section No.	Distance from bottom of fuel column (mm)
①	561022	407.5~412.5
②	561042	656.5
③	561043	657.0~662.0
④	561062	967.0~972.0

Fig. 2-3-1 Irradiation condition and sectioning diagram of NFJO64 5610 pin



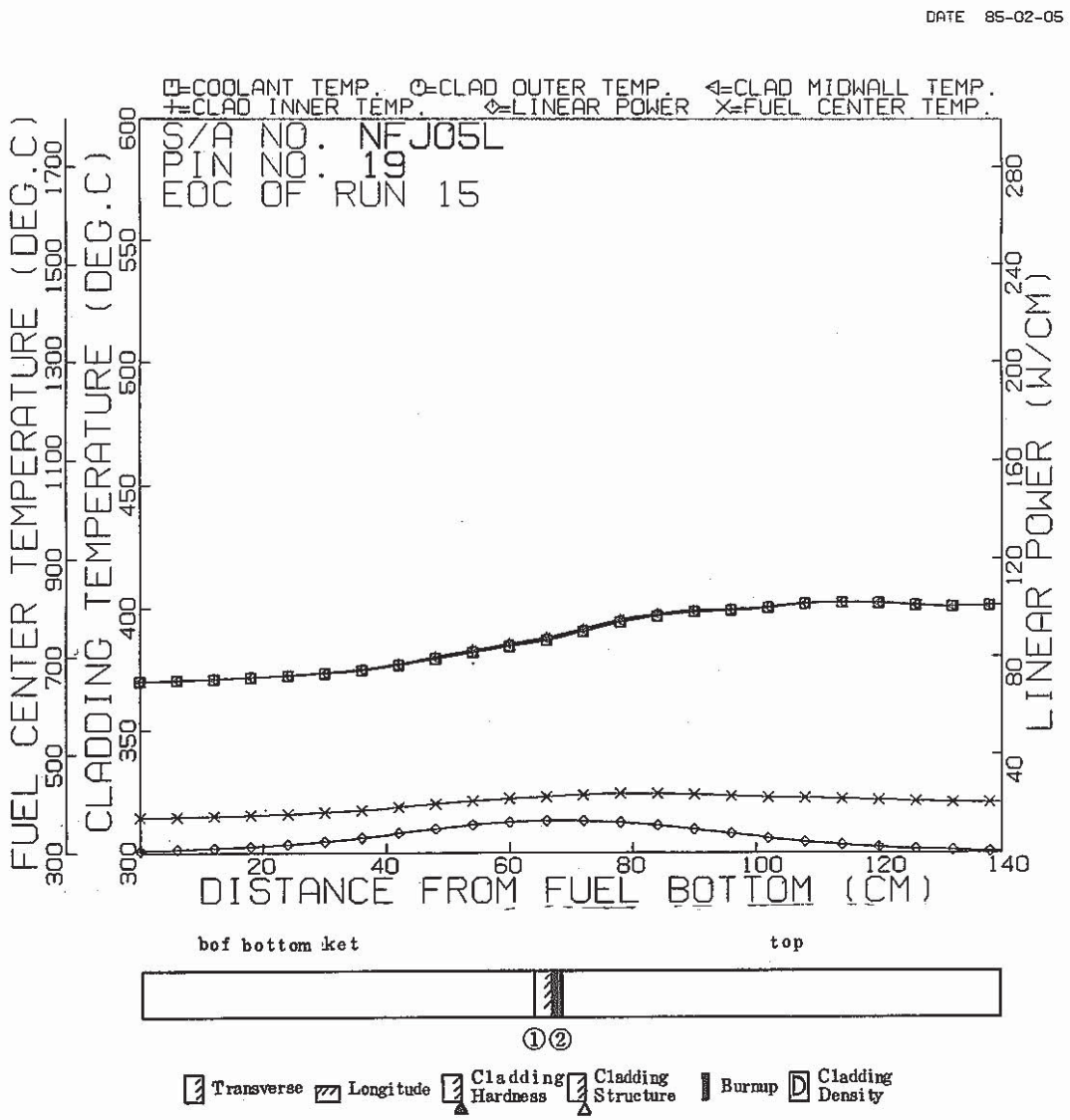
No.	Section No.	Distance from bottom of fuel column (mm)
①	561922	656.5
②	561923	657.0~662.0

Fig. 2-3-2 Irradiation condition and sectioning diagram of NFJO64 5619 pin



No.	Section No.	Distance from bottom of fuel column (mm)
①	541022	407.0~412.0
②	541042	656.0
③	541043	656.5~661.5
④	541062	968.0~973.0

Fig. 2-4-1 Irradiation condition and sectioning diagram of NFJO5L 5410 pin

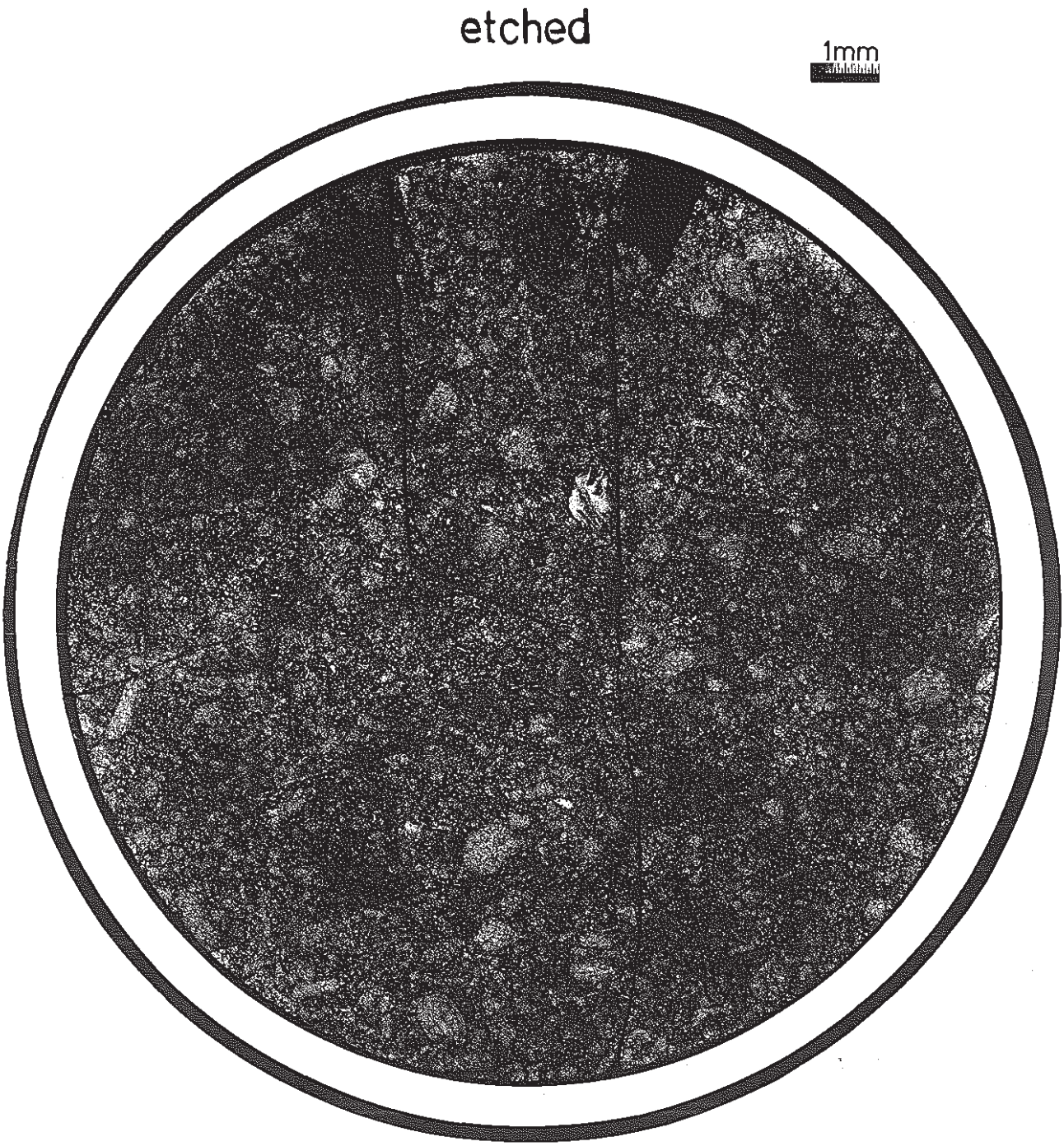


No.	Section No.	Distance from bottom of fuel column (mm)
①	541922	656.5
②	541923	657.0~662.0

Fig. 2-4-2 Irradiation condition and sectioning diagram of NFJO5L 5419 pin

2. 測定方法及び結果

－金相試験－



Photo。－1　Postirradiation ceramography of JOYO MK－1 blanket fuel, NFJI11

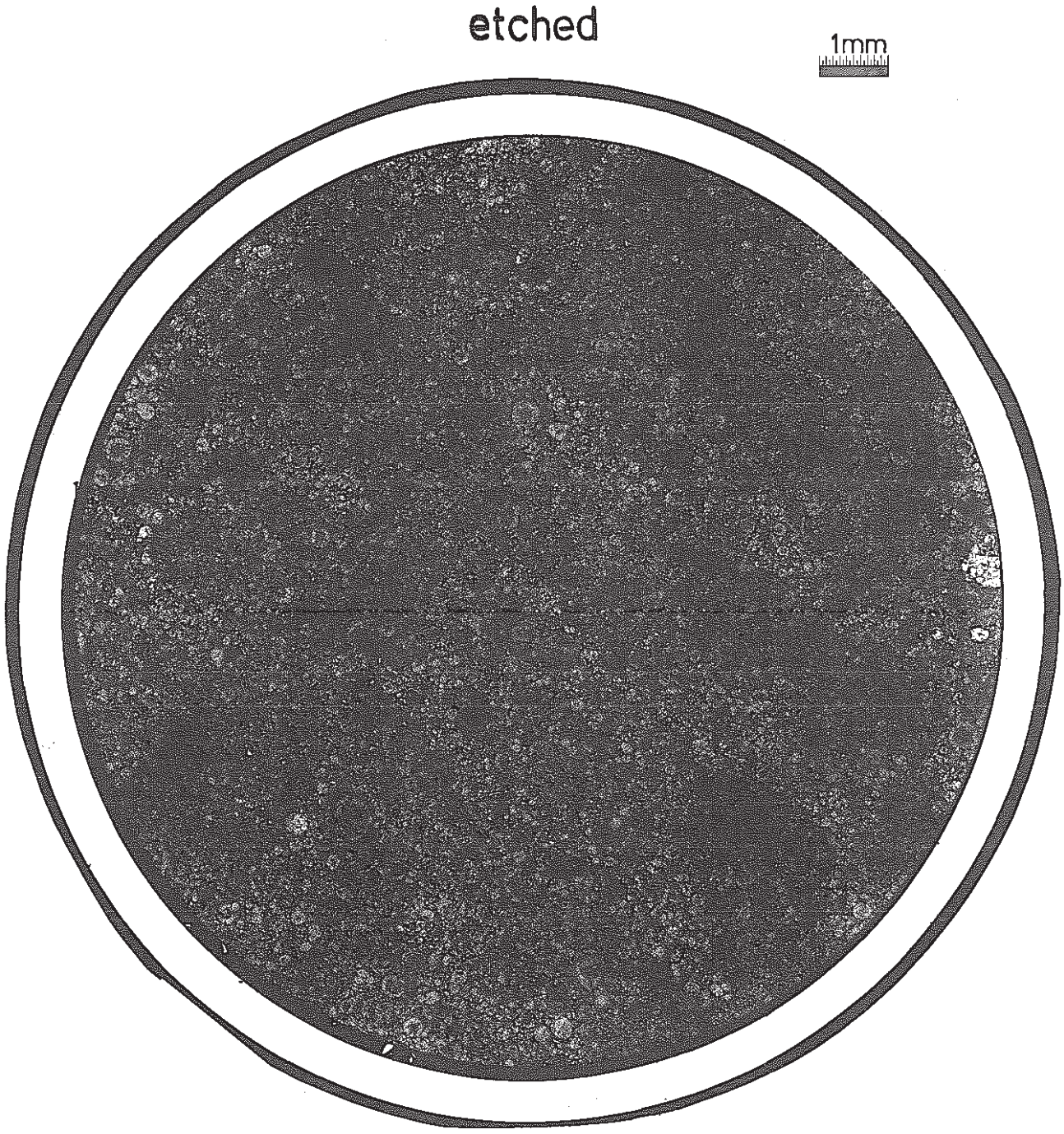


Photo. −2 Postirradiation ceramography of JOYO MK−1 blanket fuel, NFJO4K

Photo. −3 Postirradiation ceramography of JOYO MK−1 blanket fuel, NFJO64

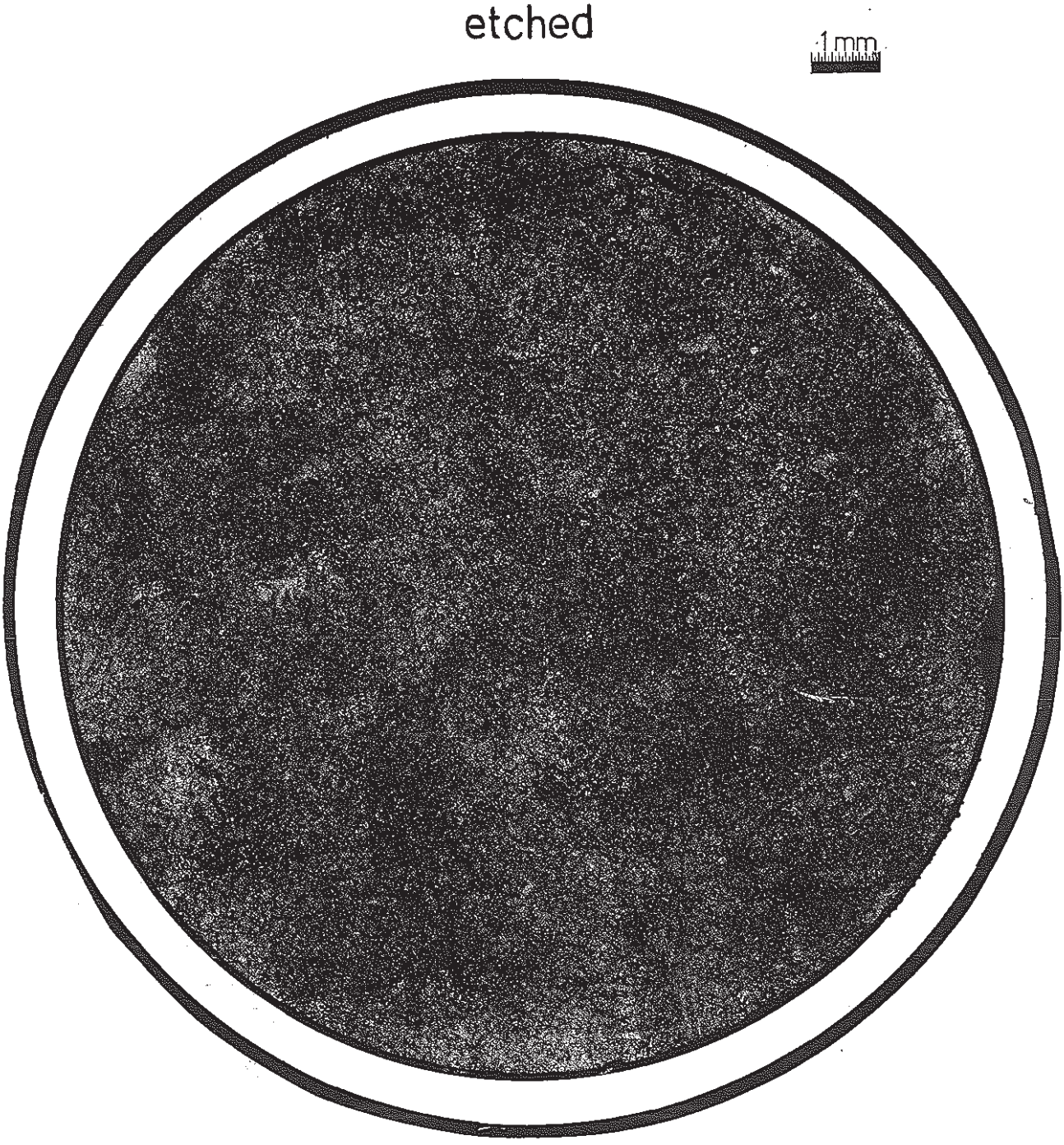


Photo. -4 Postirradiation ceramography of JOYO MK-1 blanket fuel, NFJO5L

3. 測定方法及び結果

― 燃焼率測定 ―

Table. 3-1 Summary of burnup measurement of NFJI11, NFJO4K, NFJO64, and NFJO5L

S/A No.	Pin No.	Sample No.	Sampling *1 Position (mm)	Pu content (atom%)*2	Burnup(atom%)	
					Calculated *3	Measured *4
NFJI11	5710	571022	407.0~412.0	0.566	0.074	0.086
		571043	656.5~661.5	0.808	0.138	0.174
		571062	968.0~973.0	0.551	0.072	0.091
NFJO4K	5810	581022	50.0~ 55.0	0.114	0.004	0.005
		581042	420.5~425.0	0.463	0.049	0.045
		581063	670.0~675.0	0.611	0.081	0.077
		581082	980.5~985.0	0.426	0.041	0.040
		5810A2	1345.5~1350.0	0.090	0.002	0.004
	5819	581923	670.0~675.0	0.724	0.136	0.106
NFJO64	5610	561022	407.5~412.5	0.298	0.021	0.019
		561043	657.0~662.0	0.431	0.036	0.033
		561062	967.0~972.0	0.306	0.021	0.021
	5619	561923	657.0~662.0	0.527	0.055	0.046
NFJO5L	5410	541022	407.0~412.0	0.195	0.009	0.010
		541043	656.5~661.5	0.279	0.015	0.016
		541062	968.0~973.0	0.192	0.009	0.010
	5419	541923	657.0~662.0	0.338	0.020	0.022

*1 Distance from fuel bottom

*2 Pu/(Pu+U)×100

*3 Measured by Nd-148 monitor method

*4 Calculated by JYHIST code (corrected)

Table. 3-2 Calculation of effective fission yield for blanket fuel(example)

Nuclide	Composition (Atom Fraction) (AF)	Fission Cross Section (CS) b	Nd-148		Nd-146		Nd-145	
			Fission Yield (FY) %	Fractional Fission Yield	Fission Yield (FY) %	Fractional Fission Yield	Fission Yield (FY) %	Fractional Fission Yield
U -233	0.000000	- [1]	1.14 [2]	-	3.20 [2]	-	4.10 [2]	-
U -234	0.000007	- [1]	1.44 [2]	-	3.08 [2]	-	4.00 [2]	-
U -235	0.001852	2.171 [1]	1.68 [3]	0.109	2.94 [3]	0.191	3.76 [4]	0.244
U -236	0.000061	0.096 [1]	1.81 [2]	0.000	3.06 [2]	0.000	3.77 [2]	0.000
U -238	0.989987	0.042 [1]	2.08 [3]	1.399	3.40 [3]	2.287	3.50 [2]	2.354
Pu-238	0.000001	- [1]	1.76 [2]	-	2.79 [2]	-	3.24 [2]	-
Pu-239	0.008010	2.027 [1]	1.65 [3]	0.432	2.46 [3]	0.644	3.01 [3]	0.788
Pu-240	0.000071	0.382 [1]	1.84 [2]	0.001	2.83 [2]	0.001	3.34 [2]	0.001
Pu-241	0.000000	2.961 [1]	1.94 [2]	0.000	3.01 [2]	0.000	3.52 [2]	0.000
Pu-242	0.000000	0.279 [1]	2.04 [2]	0.000	3.18 [2]	0.000	3.70 [2]	0.000
Effective Fission Yield %			1.94		3.12		3.38	

Note;Fractional FY=(AF)(CS)(FY)/Σ(AF)(CS)
Effective FY=Σ(Fractional FY)
1)SMART code
2)TRG-2143-R
3)ICP-1050-1
4)AERE-R-8753

Table. 3-3 Input data to burnup calculation code (common)

```
   S3 ;   4.3914E+18   U233 in spike (atoms/ml)
 A242 ;   7.9674E+17   Pu242 in spike (atoms/ml)
  A50 ;   7.1740E+15   Nd150 in spike (atoms/ml)

C42/50 ;   4.824980     Nd142/Nd150 of natural Nd
C45/50 ;   1.472180     Nd145/Nd150
C46/50 ;   3.050830     Nd146/Nd150
C48/50 ;   1.021325     Nd148/Nd150

S42/50 ;   0.008937     Nd142/Nd150 of spike
S45/50 ;   0.004336     Nd145/Nd150
S46/50 ;   0.009122     Nd146/ND150
S48/50 ;   0.007046     Nd148/Nd150

  S43 ;   0.014108     U234/U233 of spike
  S53 ;   0.000401     U235/U233
  S83 ;   0.006410     U238/U233

  S92 ;   0.001309     Pu239/Pu242 of spike
  S02 ;   0.013696     Pu240/Pu242
  S12 ;   0.000859     Pu241/Pu242
```

Table. 3-4-1 Result of isotope analysis and burnup calculation for NFJI11 571022 sample

S/A NO.(FAB) ; NFJI11	PIN NO.(PIE) ; 5710
SAMPLE NO. ; 571022	SAMPLE POSITION ; 407.0~412.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000008	0.001915	0.000061	-(a)
0.007515	0.000096	0.001931	0.000058	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000054	0.007316	0.000034	0.000000	-(a)
0.000054	0.010640	0.000202	0.240901	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	3.877763	3.788874	3.086780	2.778275	1.694389	-(a)
0.000000	1.741940	1.640350	1.381227	1.240595	0.766974	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0008	0.1911	0.0061	99.8020

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0054	99.2650	0.7262	0.0034	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	23.8983	23.3505	19.0236	17.1223	10.4424	6.1629

Pu CONTENT (atom%)/(weight%) ; 0.566 / 0.568

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.4720E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	2.4916E+17	4.0014E+17	4.4699E+17
EFFECTIVE FISSION YIELD	;	1.97E-02	3.18E-02	3.42E-02
NUMBER OF FISSIONS (fissions/sample)**	;	1.2648E+19	1.2583E+19	1.3070E+19
BURNUP (atom%)#	;	0.086	0.085	0.089
SPECIFIC BURNUP (MWD/MTM)##	;	766	763	792

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-4-2 Result of isotope analysis and burnup calculation for NFJI11 571043 sample

S/A NO.(FAB)	; NFJI11	PIN NO.(PIE)	; 5710
SAMPLE NO.	; 571043	SAMPLE POSITION	; 656.5~661.5 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000007	0.001871	0.000062	-(a)
0.006997	0.000090	0.001888	0.000066	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000110	0.008895	0.000037	0.000000	-(a)
0.000110	0.011088	0.000159	0.156881	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	3.779080	4.818524	3.023932	2.719522	1.678767	-(a)
0.000000	2.437598	2.402394	1.928861	1.743757	1.077334	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0007	0.1867	0.0062	99.8064

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0109	99.1039	0.8815	0.0037	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	22.2040	28.3112	17.7671	15.9786	9.8636	5.8755

Pu CONTENT (atom%)/(weight%) ; 0.808 / 0.812

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.5848E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	5.3575E+17	8.6829E+17	9.5272E+17
EFFECTIVE FISSION YIELD	;	1.94E-02	3.12E-02	3.39E-02
NUMBER OF FISSIONS (fissions/sample)**	;	2.7616E+19	2.7830E+19	2.8104E+19
BURNUP (atom%)#	;	0.174	0.175	0.177
SPECIFIC BURNUP (MWD/MTM)##	;	1550	1570	1580

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-4-3 Result of isotope analysis and burnup calculation for NFJI11 571062 sample

S/A NO.(FAB)	; NFJI11	PIN NO.(PIE)	; 5710
SAMPLE NO.	; 571062	SAMPLE POSITION	; 968.0~973.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000019	0.001927	0.000055	-(a)
0.005905	0.000074	0.001926	0.000054	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000077	0.006720	0.000024	0.000000	-(a)
0.000077	0.009355	0.000162	0.194148	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	3.832906	3.690475	3.056697	2.748761	1.688955	-(a)
0.000000	2.027519	1.966730	1.611569	1.447616	0.890335	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0019	0.1923	0.0055	99.8003

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0076	99.3225	0.6674	0.0024	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	23.9291	23.0398	19.0831	17.1607	10.5442	6.2431

Pu CONTENT (atom%)/(weight%) ; 0.551 / 0.554

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.8732E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	3.3512E+17	5.4616E+17	6.0962E+17
EFFECTIVE FISSION YIELD	;	1.97E-02	3.18E-02	3.42E-02
NUMBER OF FISSIONS (fissions/sample)**	;	1.7011E+19	1.7175E+19	1.7825E+19
BURNUP (atom%)#	;	0.091	0.092	0.095
SPECIFIC BURNUP (MWD/MTM)##	;	810	818	849

NOTE ; * Distance from fuel bottom(BFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-5-1 Result of isotope analysis and burnup calculation for NFJO4K 581022 sample

S/A NO.(FAB)	; NFJO4K	PIN NO.(PIE)	; 5810
SAMPLE NO.	; 581022	SAMPLE POSITION	; 50.0~55.0 (mm)#

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000017	0.002021	0.000047	-(a)
0.007014	0.000089	0.001999	0.000042	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000007	0.007049	0.000039	0.000016	-(a)
0.000007	0.018432	0.001409	1.116410	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	5.434022	4.753931	3.927850	3.274705	1.940362	-(a)
0.000000	0.198662	0.247518	0.142718	0.128622	0.076300	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0017	0.2017	0.0047	99.7919

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0007	99.2939	0.6999	0.0039	0.0016

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	26.7279	23.3828	19.3196	16.1071	9.5439	4.9186

Pu CONTENT (atom%)/(weight%) ; 0.114 / 0.115

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.5702E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	1.3256E+16	2.3319E+16	2.6213E+16
EFFECTIVE FISSION YIELD	;	1.78E-02	2.94E-02	3.50E-02
NUMBER OF FISSIONS (fissions/sample)**	;	7.4471E+17	7.9316E+17	7.4894E+17
BURNUP (atom%)#	;	0.005	0.005	0.005
SPECIFIC BURNUP (MWD/MTM)##	;	42	45	43

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-5-2 Result of isotope analysis and burnup calculation for NFJO4K 581042 sample

S/A NO.(FAB)	; NFJO4K	PIN NO.(PIE)	; 5810
SAMPLE NO.	; 581042	SAMPLE POSITION	; 420.5~425.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000012	0.001954	0.000060	-(a)
0.007152	0.000087	0.001944	0.000056	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000020	0.007049	0.000033	0.000004	-(a)
0.000020	0.010885	0.000265	0.280331	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.004812	4.127680	3.672868	3.203957	2.834774	1.728030	-(a)
0.000000	1.215295	1.248189	0.946884	0.843188	0.518124	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0012	0.1950	0.0060	99.7978

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0020	99.2944	0.6999	0.0033	0.0004

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0290	24.9074	22.1629	19.3334	17.1057	10.4273	6.0342

Pu CONTENT (atom%)/(weight%) ; 0.463 / 0.465

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.5452E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	1.3113E+17	2.1397E+17	2.4016E+17
EFFECTIVE FISSION YIELD	;	1.89E-02	3.04E-02	3.38E-02
NUMBER OF FISSIONS (fissions/sample)**	;	6.9381E+18	7.0386E+18	7.1052E+18
BURNUP (atom%)#	;	0.045	0.046	0.046
SPECIFIC BURNUP (MWD/MTM)##	;	401	407	410

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-5-3 Result of isotope analysis and burnup calculation for NFJO4K 581063 sample

S/A NO.(FAB)	; NFJ04K	PIN NO.(PIE)	; 5810
SAMPLE NO.	; 581063	SAMPLE POSITION	; 670.0~675.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000010	0.001903	0.000057	-(a)
0.005004	0.000063	0.001911	0.000063	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000045	0.008851	0.000043	0.000000	-(a)
0.000045	0.010888	0.000155	0.148669	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	3.948228	4.284033	3.085375	2.756381	1.692000	-(a)
0.009433	2.010081	1.855222	1.567770	1.394119	0.869290	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0010	0.1899	0.0057	99.8034

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0045	99.1140	0.8773	0.0043	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	23.5490	25.5519	18.4026	16.4403	10.0918	5.9644

Pu CONTENT (atom%)/(weight%) ; 0.611 / 0.614

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 2.2117E+22

	[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample) ;	3.1792E+17	5.0135E+17	5.7015E+17
EFFECTIVE FISSION YIELD ;	1.87E-02	2.98E-02	3.35E-02
NUMBER OF FISSIONS (fissions/sample)**;	1.7001E+19	1.6824E+19	1.7019E+19
BURNUP (atom%)# ;	0.077	0.076	0.077
SPECIFIC BURNUP (MWD/MTM)## ;	686	679	687

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-5-4 Result of isotope analysis and burnup calculation for NFJO4K 581082 sample

S/A NO.(FAB)	; NFJO4K	PIN NO.(PIE)	; 5810
SAMPLE NO.	; 581082	SAMPLE POSITION	; 980.5~985.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000018	0.001961	0.000054	-(a)
0.005224	0.000055	0.001940	0.000042	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000032	0.006384	0.000019	0.000000	-(a)
0.000032	0.009409	0.000189	0.222373	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.044983	3.855160	3.152502	2.801913	1.716541	-(a)
0.000000	1.404390	1.504095	1.091655	0.971669	0.593673	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0018	0.1957	0.0054	99.7971

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0032	99.3606	0.6343	0.0019	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	24.4099	23.2644	19.0241	16.9084	10.3586	6.0346

Pu CONTENT (atom%)/(weight%) ; 0.426 / 0.428

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 2.1148E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	1.6106E+17	2.6534E+17	2.9850E+17
EFFECTIVE FISSION YIELD	;	1.89E-02	3.05E-02	3.39E-02
NUMBER OF FISSIONS (fissions/sample)**	;	8.5214E+18	8.6997E+18	8.8054E+18
BURNUP (atom%)#	;	0.040	0.041	0.042
SPECIFIC BURNUP (MWD/MTM)##	;	360	367	372

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-5-5 Result of isotope analysis and burnup calculation for NFJO4K 5810A2 sample

S/A NO.(FAB)	; NFJ04K	PIN NO.(PIE)	; 5810
SAMPLE NO.	; 5810A2	SAMPLE POSITION	; 1345.5~1350.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000011	0.001994	0.000029	-(a)
0.007809	0.000101	0.002018	0.000035	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000035	0.002285	0.000035	0.000000	-(a)
0.000035	0.023946	0.002378	1.568858	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.011942	5.320194	4.714099	3.858598	3.268510	1.923685	-(a)
0.000307	0.134655	0.131028	0.098661	0.089240	0.055280	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0011	0.1990	0.0029	99.7970

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0035	99.7651	0.2280	0.0035	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0594	26.4725	23.4567	19.1998	16.2636	9.5720	4.9759

Pu CONTENT (atom%)/(weight%) ; 0.090 / 0.090

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.4099E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	9.2252E+15	1.5748E+16	1.7812E+16
EFFECTIVE FISSION YIELD	;	1.81E-02	3.01E-02	3.53E-02
NUMBER OF FISSIONS (fissions/sample)**	;	5.0968E+17	5.2320E+17	5.0459E+17
BURNUP (atom%)#	;	0.004	0.004	0.004
SPECIFIC BURNUP (MWD/MTM)##	;	32	33	32

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-5-6 Result of isotope analysis and burnup calculation for NFJO4K 581923 sample

S/A NO.(FAB)	; NFJ04K	PIN NO.(PIE)	; 5819
SAMPLE NO.	; 581923	SAMPLE POSITION	; 670.0~675.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000023	0.001931	0.000071	-(a)
0.005922	0.000075	0.001906	0.000067	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000050	0.009520	0.000063	0.000003	-(a)
0.000050	0.011524	0.000162	0.148405	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	3.752516	3.592651	2.951711	2.735072	1.690768	-(a)
0.013669	2.096146	2.020437	1.645675	1.517417	0.928615	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0023	0.1927	0.0071	99.7979

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0050	99.0456	0.9429	0.0062	0.0003

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	23.8668	22.8501	18.7735	17.3957	10.7537	6.3602

Pu CONTENT (atom%)/(weight%) ; 0.724 / 0.727

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.8711E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	3.6650E+17	6.0485E+17	6.6562E+17
EFFECTIVE FISSION YIELD	;	1.85E-02	2.95E-02	3.33E-02
NUMBER OF FISSIONS (fissions/sample)**	;	1.9811E+19	2.0503E+19	1.9989E+19
BURNUP (atom%)#	;	0.106	0.109	0.107
SPECIFIC BURNUP (MWD/MTM)##	;	944	977	953

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-6-1 Result of isotope analysis and burnup calculation for NFJO64 561022 sample

S/A NO.(FAB)	; NFJ064	PIN NO.(PIE)	; 5610
SAMPLE NO.	; 561022	SAMPLE POSITION	; 407.5~412.5 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000001	0.001987	0.000037	-(a)
0.006070	0.000075	0.001981	0.000052	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000037	0.005472	0.000023	0.000000	-(a)
0.000037	0.010516	0.000281	0.369694	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.487664	4.263592	3.399282	2.956851	1.789914	-(a)
0.000000	0.754327	0.701017	0.572326	0.501166	0.304483	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0001	0.1983	0.0037	99.7979

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0037	99.4498	0.5442	0.0023	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	25.0745	23.8225	18.9933	16.5212	10.0010	5.5874

Pu CONTENT (atom%)/(weight%) ; 0.298 / 0.299

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.8177E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	6.4567E+16	1.0728E+17	1.2285E+17
EFFECTIVE FISSION YIELD	;	1.87E-02	3.04E-02	3.41E-02
NUMBER OF FISSIONS (fissions/sample)**	;	3.4528E+18	3.5289E+18	3.6027E+18
BURNUP (atom%)#	;	0.019	0.019	0.020
SPECIFIC BURNUP (MWD/MTM)##	;	170	173	177

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-6-2 Result of isotope analysis and burnup calculation for NFJO64 561043 sample

S/A NO.(FAB)	; NFJ064	PIN NO.(PIE)	; 5610
SAMPLE NO.	; 561043	SAMPLE POSITION	; 657.0~662.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000012	0.001952	0.000049	-(a)
0.008617	0.000113	0.001964	0.000055	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000044	0.007101	0.000040	0.000000	-(a)
0.000044	0.012089	0.000286	0.363230	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.341512	4.352317	3.318197	2.900492	1.767258	-(a)
0.000000	0.870334	0.804846	0.664271	0.585569	0.357348	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0012	0.1948	0.0049	99.7991

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0044	99.2866	0.7050	0.0040	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	24.5564	24.6175	18.7683	16.4057	9.9959	5.6562

Pu CONTENT (atom%)/(weight%) ; 0.431 / 0.432

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.2821E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	7.9027E+16	1.3056E+17	1.4832E+17
EFFECTIVE FISSION YIELD	;	1.85E-02	2.97E-02	3.37E-02
NUMBER OF FISSIONS (fissions/sample)**	;	4.2717E+18	4.3961E+18	4.4012E+18
BURNUP (atom%)#	;	0.033	0.034	0.034
SPECIFIC BURNUP (MWD/MTM)##	;	297	306	306

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-6-3 Result of isotope analysis and burnup calculation for NFJO64 561062 sample

S/A NO.(FAB) ; NFJ064	PIN NO.(PIE) ; 5610
SAMPLE NO. ; 561062	SAMPLE POSITION ; 967.0~972.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000012	0.002379	0.000044	-(a)
0.006974	0.000087	0.002384	0.000044	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000009	0.005248	0.000015	0.000000	-(a)
0.000009	0.010923	0.000319	0.412775	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.575801	4.322441	3.448592	2.997334	1.803485	-(a)
0.000000	0.728576	0.681710	0.548393	0.479286	0.291595	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0012	0.2373	0.0044	99.7571

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0009	99.4756	0.5220	0.0015	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	25.2143	23.8182	19.0030	16.5164	9.9378	5.5104

Pu CONTENT (atom%)/(weight%) ; 0.306 / 0.308

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.5828E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	6.1166E+16	1.0139E+17	1.1639E+17
EFFECTIVE FISSION YIELD	;	1.87E-02	3.03E-02	3.42E-02
NUMBER OF FISSIONS (fissions/sample)**	;	3.2709E+18	3.3462E+18	3.4033E+18
BURNUP (atom%)#	;	0.021	0.021	0.022
SPECIFIC BURNUP (MWD/MTM)##	;	184	189	192

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-6-4 Result of isotope analysis and burnup calculation for NFJO64 561923 sample

S/A NO.(FAB)	; NFJO64	PIN NO.(PIE)	; 5619
SAMPLE NO.	; 561923	SAMPLE POSITION	; 657.0~662.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000020	0.001964	0.000066	-(a)
0.006620	0.000089	0.001961	0.000072	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000026	0.007847	0.000039	0.000000	-(a)
0.000026	0.010970	0.000212	0.228076	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.237267	3.952541	3.254466	2.862574	1.745966	-(a)
0.000000	1.316880	1.226595	1.010733	0.893310	0.546897	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0020	0.1960	0.0066	99.7954

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0026	99.2150	0.7785	0.0039	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	24.8479	23.1782	19.0846	16.7865	10.2386	5.8641

Pu CONTENT (atom%)/(weight%) ; 0.527 / 0.529

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 1.6705E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	1.4121E+17	2.3156E+17	2.6203E+17
EFFECTIVE FISSION YIELD	;	1.83E-02	2.93E-02	3.34E-02
NUMBER OF FISSIONS (fissions/sample)**	;	7.7165E+18	7.9030E+18	7.8452E+18
BURNUP (atom%)#	;	0.046	0.047	0.047
SPECIFIC BURNUP (MWD/MTM)##	;	412	422	419

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-7-1 Result of isotope analysis and burnup calculation for NFJO5L 541022 sample

S/A NO.(FAB) ; NFJO5L	PIN NO.(PIE) ; 5410
SAMPLE NO. ; 541022	SAMPLE POSITION ; 407.0~412.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000005	0.002012	0.000041	-(a)
0.005448	0.000063	0.002010	0.000033	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000004	0.004580	0.000022	0.000000	-(a)
0.000004	0.011465	0.000329	0.505644	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.638065	4.839586	3.428998	3.004665	1.792325	-(a)
0.012063	0.485980	0.448339	0.358854	0.311994	0.188073	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0005	0.2008	0.0041	99.7946

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0004	99.5415	0.4559	0.0022	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	24.7977	25.8751	18.3333	16.0646	9.5828	5.3466

Pu CONTENT (atom%)/(weight%) ; 0.195 / 0.196

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 2.0232E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	3.6118E+16	6.0105E+16	7.0805E+16
EFFECTIVE FISSION YIELD	;	1.79E-02	2.92E-02	3.43E-02
NUMBER OF FISSIONS (fissions/sample)**	;	2.0178E+18	2.0584E+18	2.0643E+18
BURNUP (atom%)#	;	0.010	0.010	0.010
SPECIFIC BURNUP (MWD/MTM)##	;	89	91	91

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-7-2 Result of isotope analysis and burnup calculation for NFJO5L 541043 sample

S/A NO.(FAB)	; NFJO5L	PIN NO.(PIE)	; 5410
SAMPLE NO.	; 541043	SAMPLE POSITION	; 656.5~661.5 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000011	0.001985	0.000041	-(a)
0.005126	0.000081	0.002054	0.000049	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000011	0.005913	0.000041	0.000000	-(a)
0.000011	0.010526	0.000281	0.333145	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.488620	4.332828	3.339154	2.985583	1.769391	-(a)
0.010974	0.754020	0.691390	0.561452	0.487849	0.294721	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0011	0.1981	0.0041	99.7967

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0011	99.4070	0.5878	0.0041	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	25.0543	24.1847	18.6383	16.6647	9.8763	5.5817

Pu CONTENT (atom%)/(weight%) ; 0.279 / 0.281

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 2.1520E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	6.1770E+16	1.0216E+17	1.1994E+17
EFFECTIVE FISSION YIELD	;	1.77E-02	2.86E-02	3.38E-02
NUMBER OF FISSIONS (fissions/sample)**	;	3.4899E+18	3.5720E+18	3.5486E+18
BURNUP (atom%)#	;	0.016	0.017	0.017
SPECIFIC BURNUP (MWD/MTM)##	;	145	148	147

NOTE ; * Distance from fuel bottom(BFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-7-3 Result of isotope analysis and burnup calculation for NFJO5L 541062 sample

S/A NO.(FAB)	; NFJO5L	PIN NO.(PIE)	; 5410
SAMPLE NO.	; 541062	SAMPLE POSITION	; 968.0~973.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000013	0.002003	0.000035	-(a)
0.004973	0.000050	0.001967	0.000033	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000007	0.004485	0.000037	0.000000	-(a)
0.000007	0.010869	0.000341	0.469317	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.000000	4.719651	5.274688	3.494340	3.077042	1.824909	-(a)
0.005660	0.523767	0.492716	0.388903	0.337486	0.202936	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0013	0.1999	0.0035	99.7953

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0007	99.5491	0.4465	0.0037	0.0000

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0000	24.3399	27.2023	18.0208	15.8687	9.4113	5.1571

Pu CONTENT (atom%)/(weight%) ; 0.192 / 0.193

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 2.2163E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	3.9617E+16	6.6441E+16	7.7726E+16
EFFECTIVE FISSION YIELD	;	1.79E-02	2.92E-02	3.43E-02
NUMBER OF FISSIONS (fissions/sample)**	;	2.2133E+18	2.2754E+18	2.2661E+18
BURNUP (atom%)#	;	0.010	0.010	0.010
SPECIFIC BURNUP (MWD/MTM)##	;	89	92	91

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table. 3-7-4 Result of isotope analysis and burnup calculation for NFJO5L 541923 sample

S/A NO.(FAB)	; NFJO5L	PIN NO.(PIE)	; 5419
SAMPLE NO.	; 541923	SAMPLE POSITION	; 657.0~662.0 (mm)*

VOLUME RATIO OF SPIKE SOLUTION TO SAMPLE SOLUTION ; 0.250

ISOTOPIC RATIO OF U,Pu,Nd IN (a)SAMPLE AND (b)SAMPLE-SPIKE MIXTURE ;

[U233/238]	[U234/238]	[U235/238]	[U236/238]	
0.000000	0.000006	0.001983	0.000044	-(a)
0.005250	0.000062	0.001990	0.000036	-(b)

[Pu238/239]	[Pu240/239]	[Pu241/239]	[Pu242/239]	
0.000010	0.006323	0.000055	0.000009	-(a)
0.000010	0.010145	0.000249	0.281654	-(b)

[Nd142/150]	[Nd143/150]	[Nd144/150]	[Nd145/150]	[Nd146/150]	[Nd148/150]	
0.005349	4.558650	4.169385	3.442292	2.971674	1.797471	-(a)
0.011908	0.906984	0.372832	0.697773	0.611774	0.366174	-(b)

ISOTOPIC COMPOSITION OF U,Pu,Nd IN SAMPLE (atom%) ;

[U233]	[U234]	[U235]	[U236]	[U238]
0.0000	0.0006	0.1979	0.0044	99.7971

[Pu238]	[Pu239]	[Pu240]	[Pu241]	[Pu242]
0.0010	99.3644	0.6283	0.0055	0.0009

[Nd142]	[Nd143]	[Nd144]	[Nd145]	[Nd146]	[Nd148]	[Nd150]
0.0298	25.4037	23.2345	19.1826	16.5601	10.0167	5.5726

Pu CONTENT (atom%)/(weight%) ; 0.338 / 0.340

NUMBER OF TOTAL HEAVY ELEMENT (atoms/sample) ; 2.1024E+22

		[Nd148]	[Nd146]	[Nd145]
NUMBER OF Nd NUCLIDE (atoms/sample)	;	8.0695E+16	1.3542E+17	1.5575E+17
EFFECTIVE FISSION YIELD	;	1.76E-02	2.83E-02	3.35E-02
NUMBER OF FISSIONS (fissions/sample)**	;	4.5850E+18	4.7852E+18	4.6491E+18
BURNUP (atom%)#	;	0.022	0.023	0.022
SPECIFIC BURNUP (MWD/MTM)##	;	195	203	197

NOTE ; * Distance from fuel bottom(DFFB)
** FISSIONS=NUMBER OF Nd/EFFECTIVE FISSION YIELD
# BURNUP=100*FISSIONS/(TOTAL HEAVY ELEMENT+FISSIONS)
1.12 atom% B.U=10000 MWD/MTM B.U

Table 3－8 Comparison between measured and calculated amounts of PuO_2 in blanket fuel subassemblies

S/A No.	Location	Amount of PuO_2 (g)		Error(%) Meas. vs calc.
		Calculated	Measured	
NFJI11	5D1	164	159	－3.0
NFJO4K	6D1	135	132	－2.2
NFJO64	7D1	92.3	90.1	－2.4
NFJO5L	8D1	56.8	60.4	＋6.3

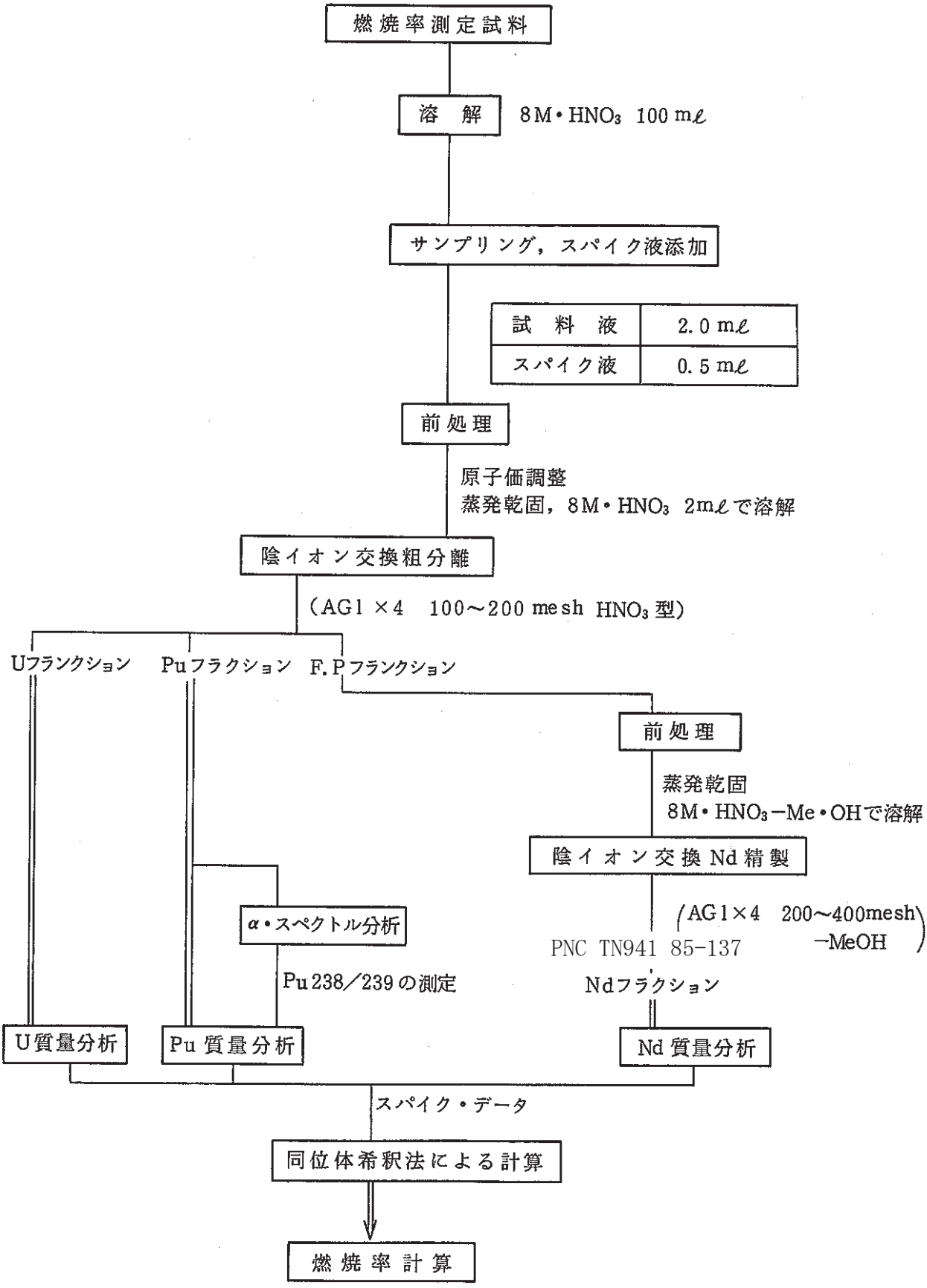


Fig. 3－1　Process for burnup measurement in AGS

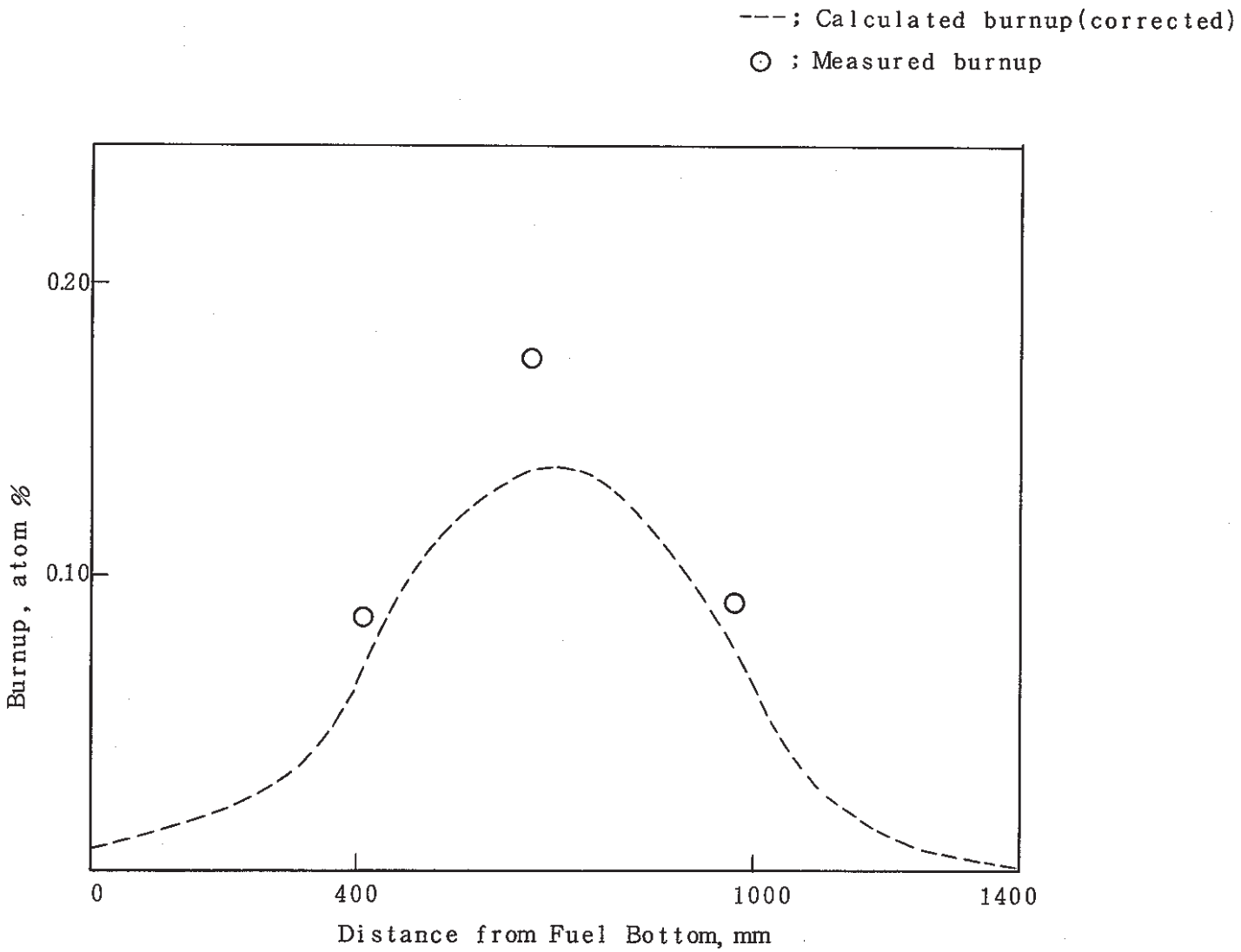


Fig. 4-1-1 Axial distribution of burnup on NFJI11 5710 pin (absolute value comparing)

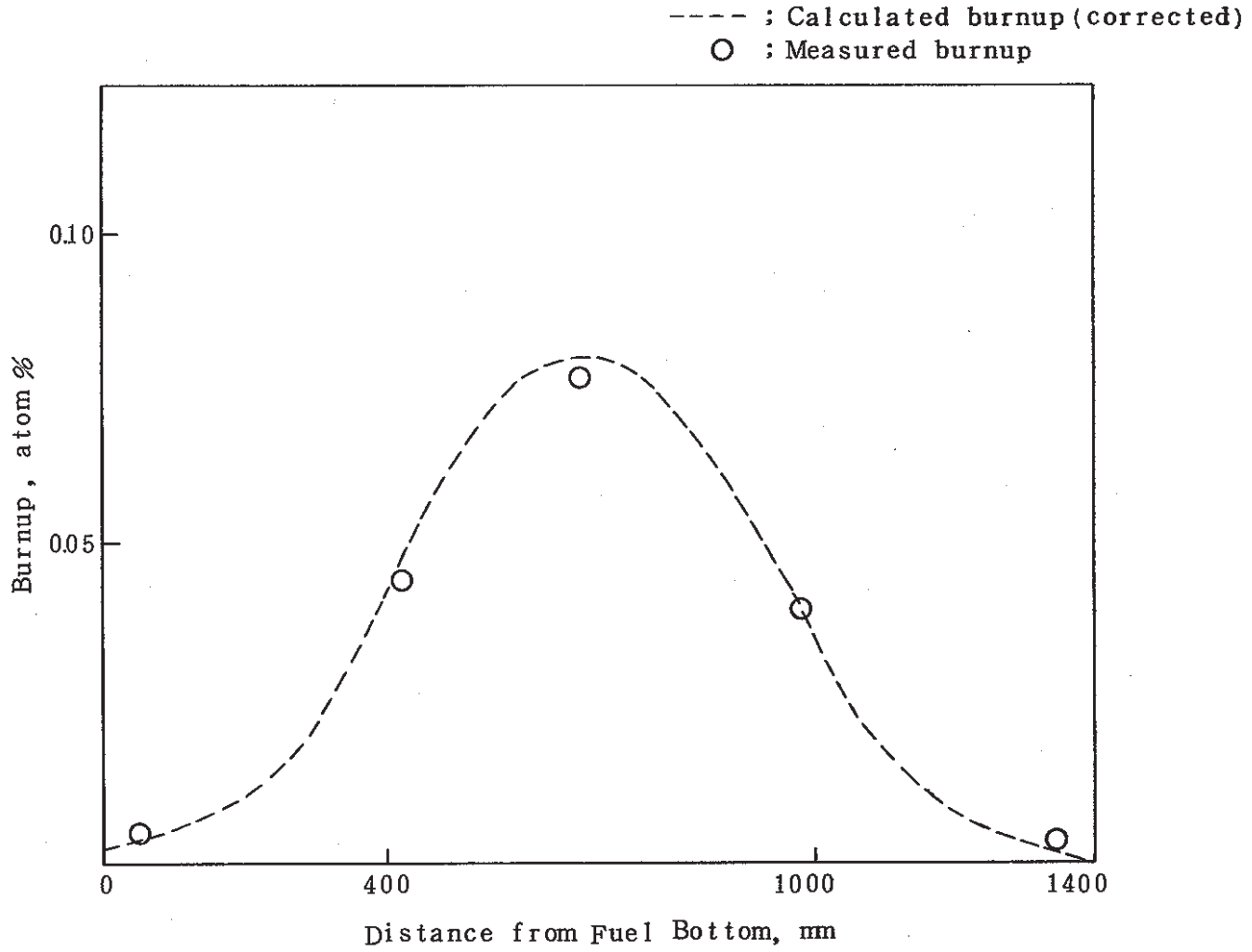


Fig. 4-1-2 Axial distribution of burnup on NFJO4K 5810 pin (absolute value comparing)

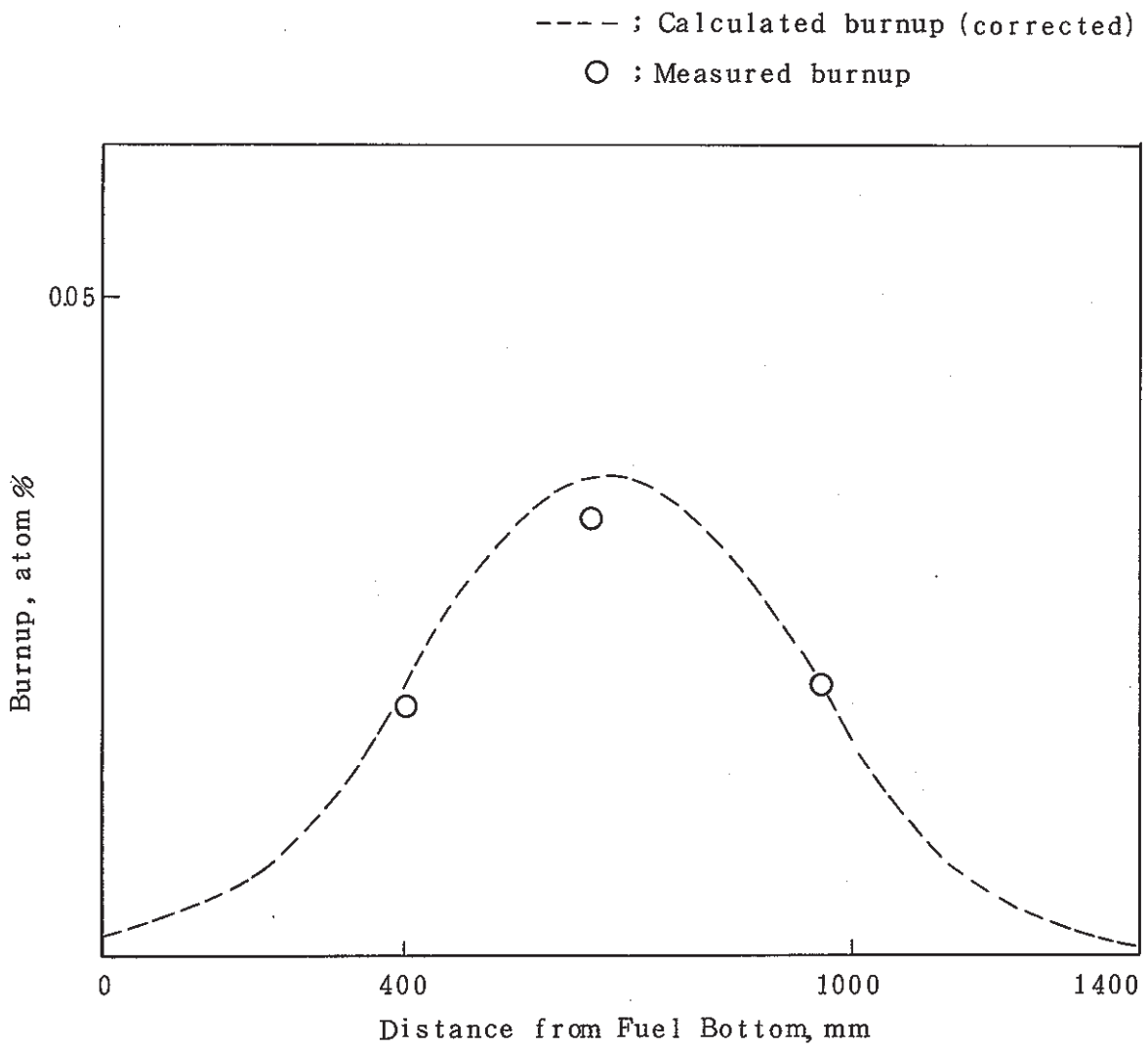


Fig. 4-1-3 Axial distribution of burnup on NFJO64 5610 pin (absolute value comparing)

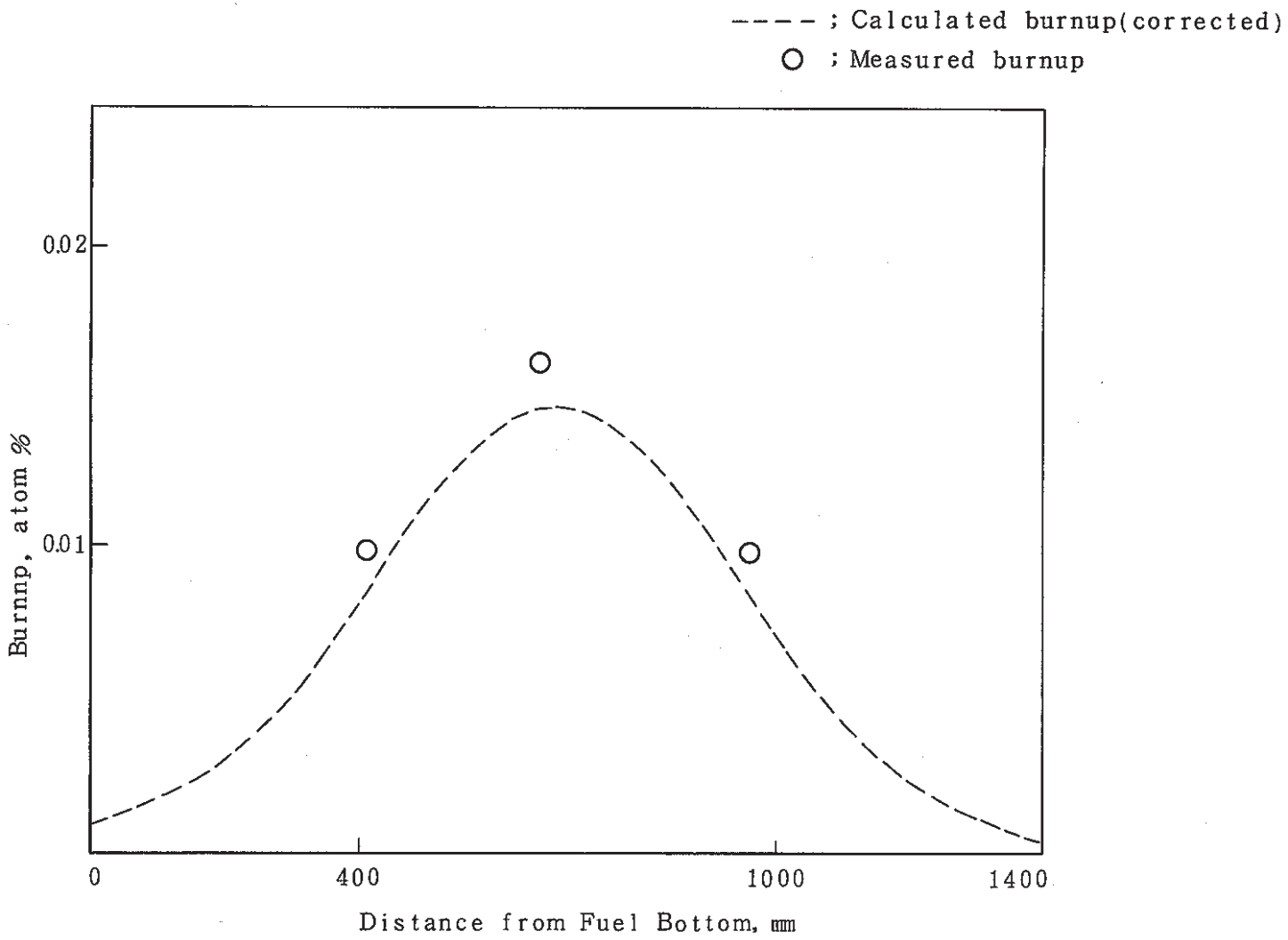


Fig. 4-1-4 Axial distribution of burnup on NFJO5L 5410 pin(absolute value comparing)

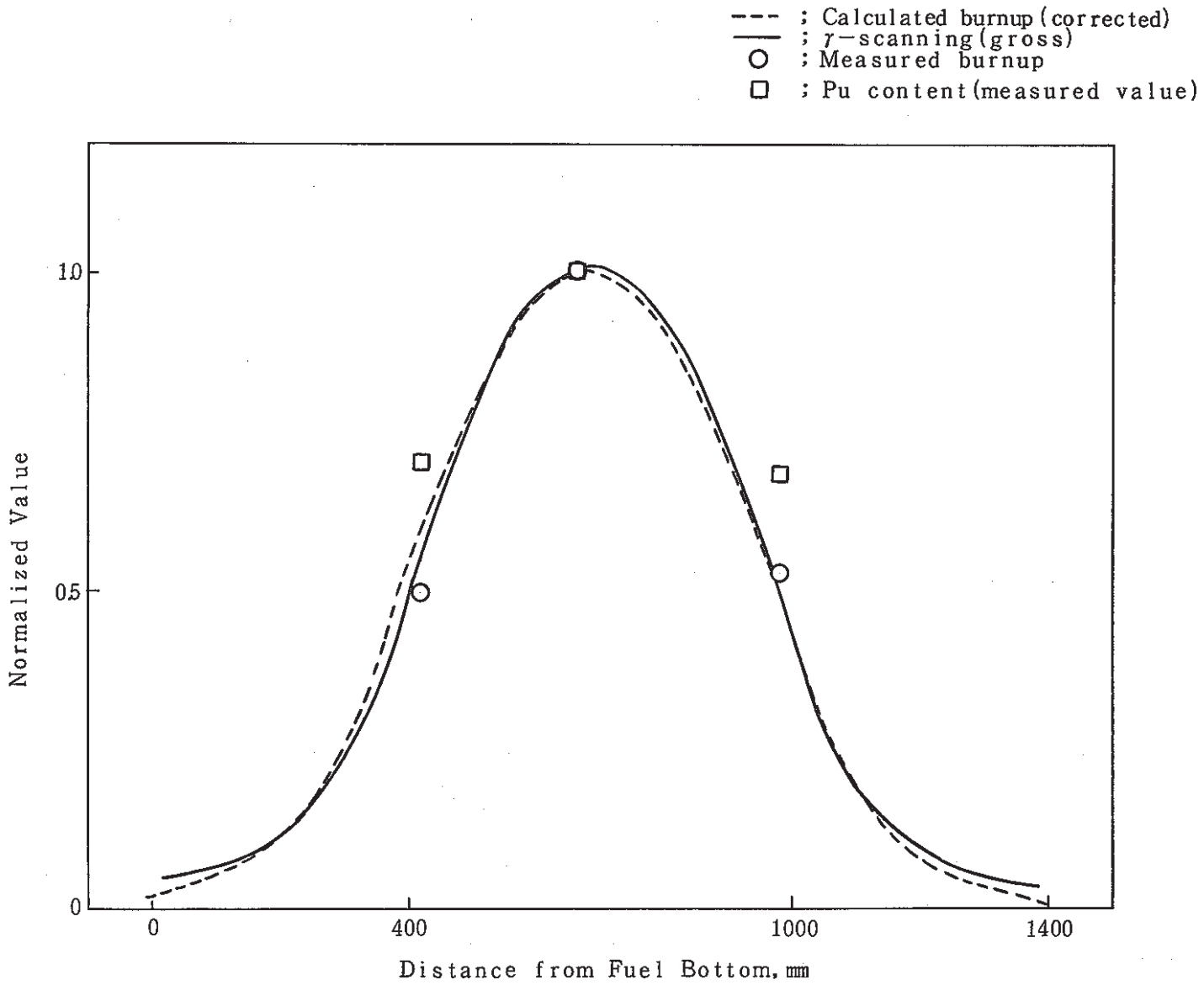


Fig.4-2-1 Axial distribution of burnup, Pu content and γ-scanning on NFJI11 5710 pin (normalized value comparing)

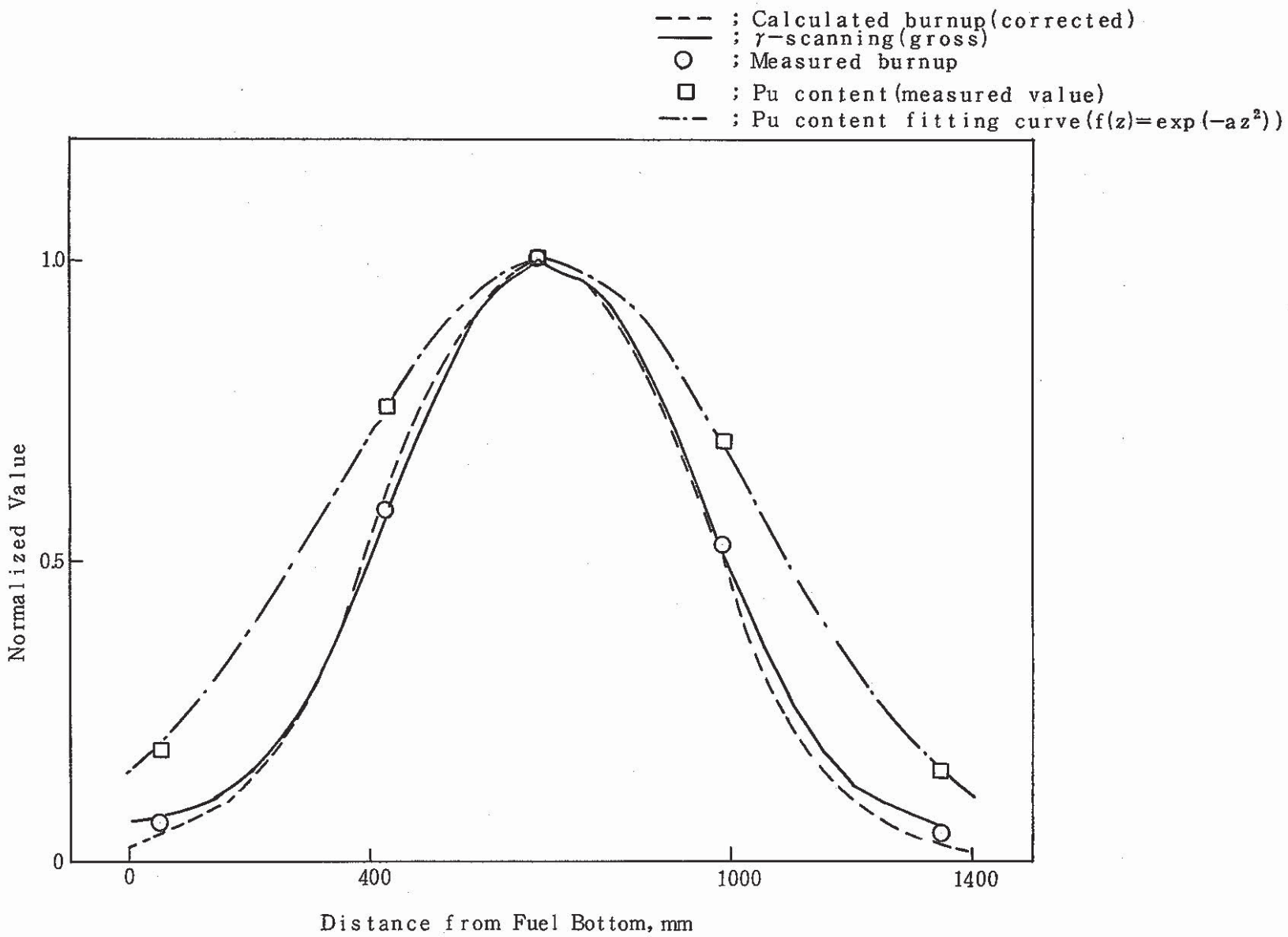


Fig. 4-2-2 Axial distribution of burnup, Pu content and γ-scanning on NFJO4K 5810 pin (normalized value comparing)

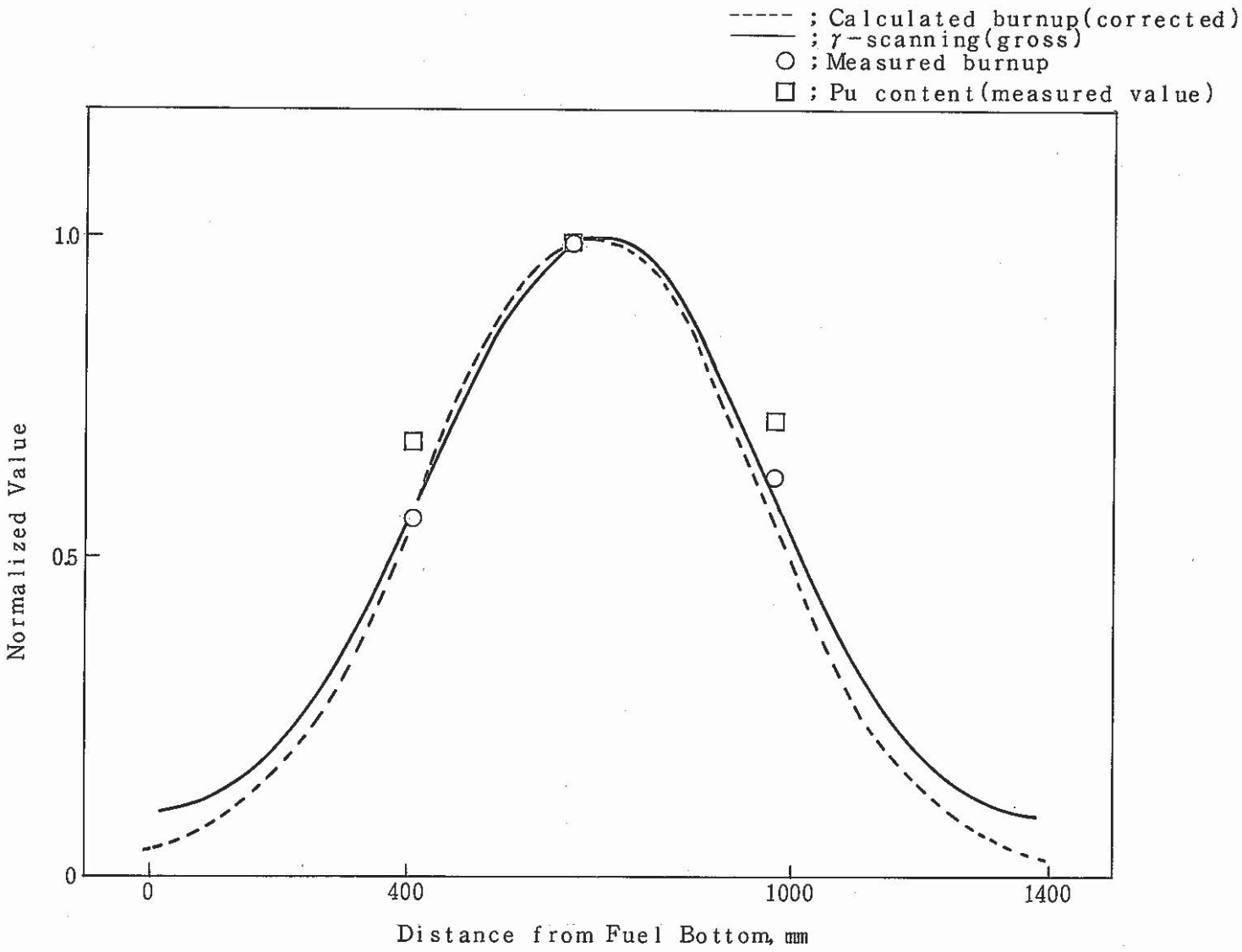


Fig.4-2-3 Axial distribution of burnup, Pu content and γ-scanning on NFJO64 5610 pin (normalized value comparing)

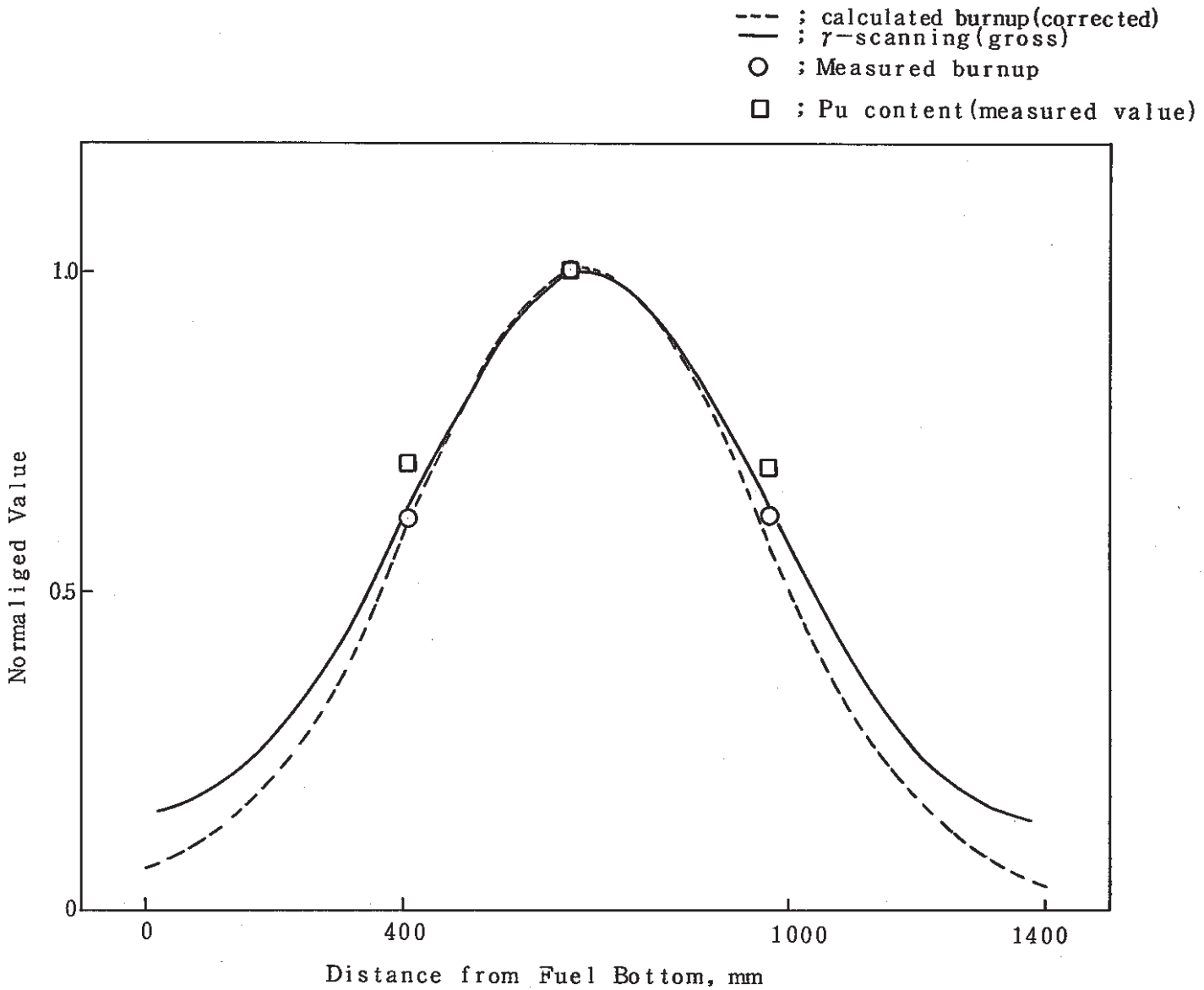


Fig. 4-2-4 Axial distribution of burnup, Pu content and γ-scanning on NFJO5L 5410 pin (normaliged value comparing)

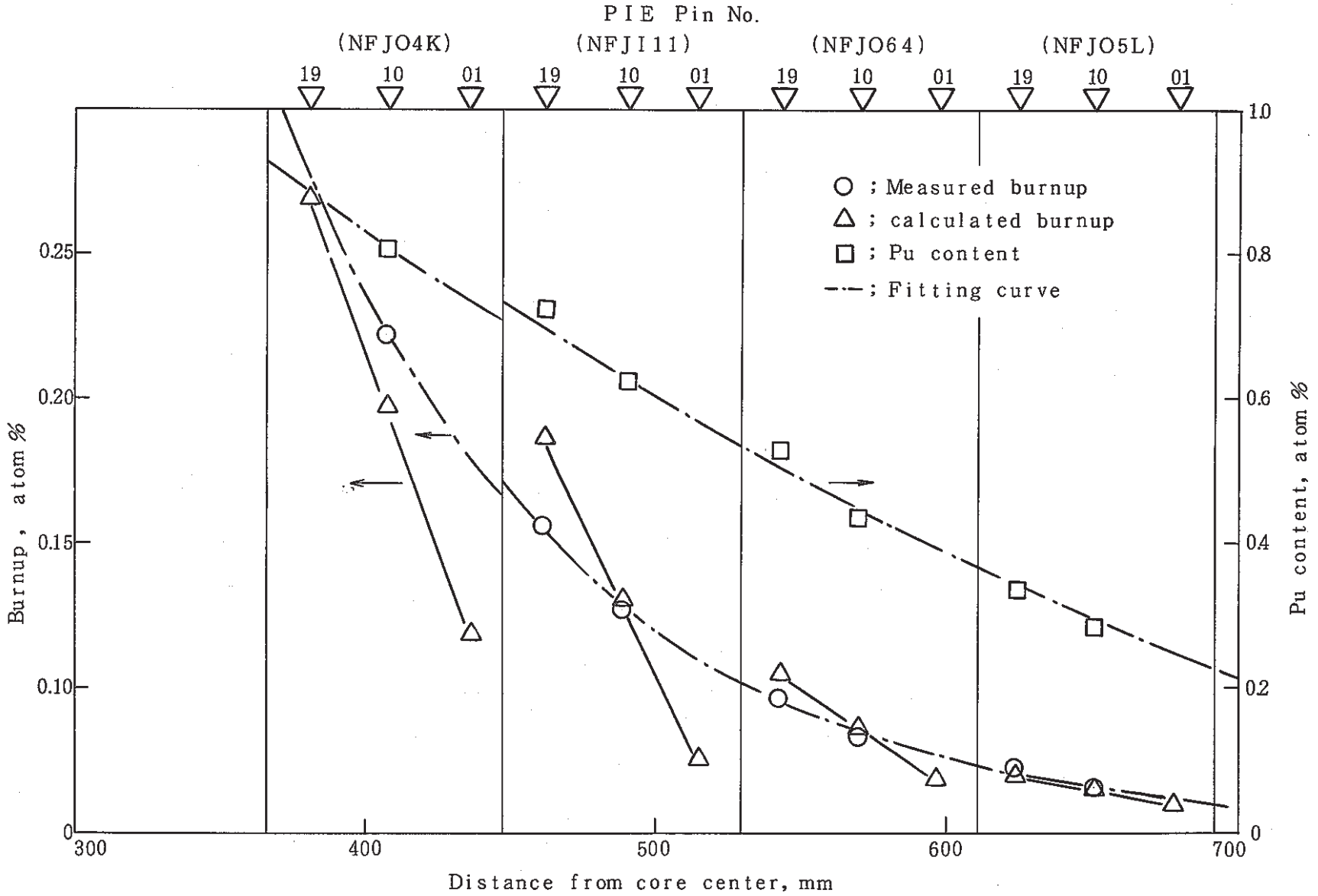


Fig. 4-3 Radial distribution of burnup and Pu content in NFJI11, NFJO4K, NFJO64, and NFJO5L subassembly(absolute value comparing)

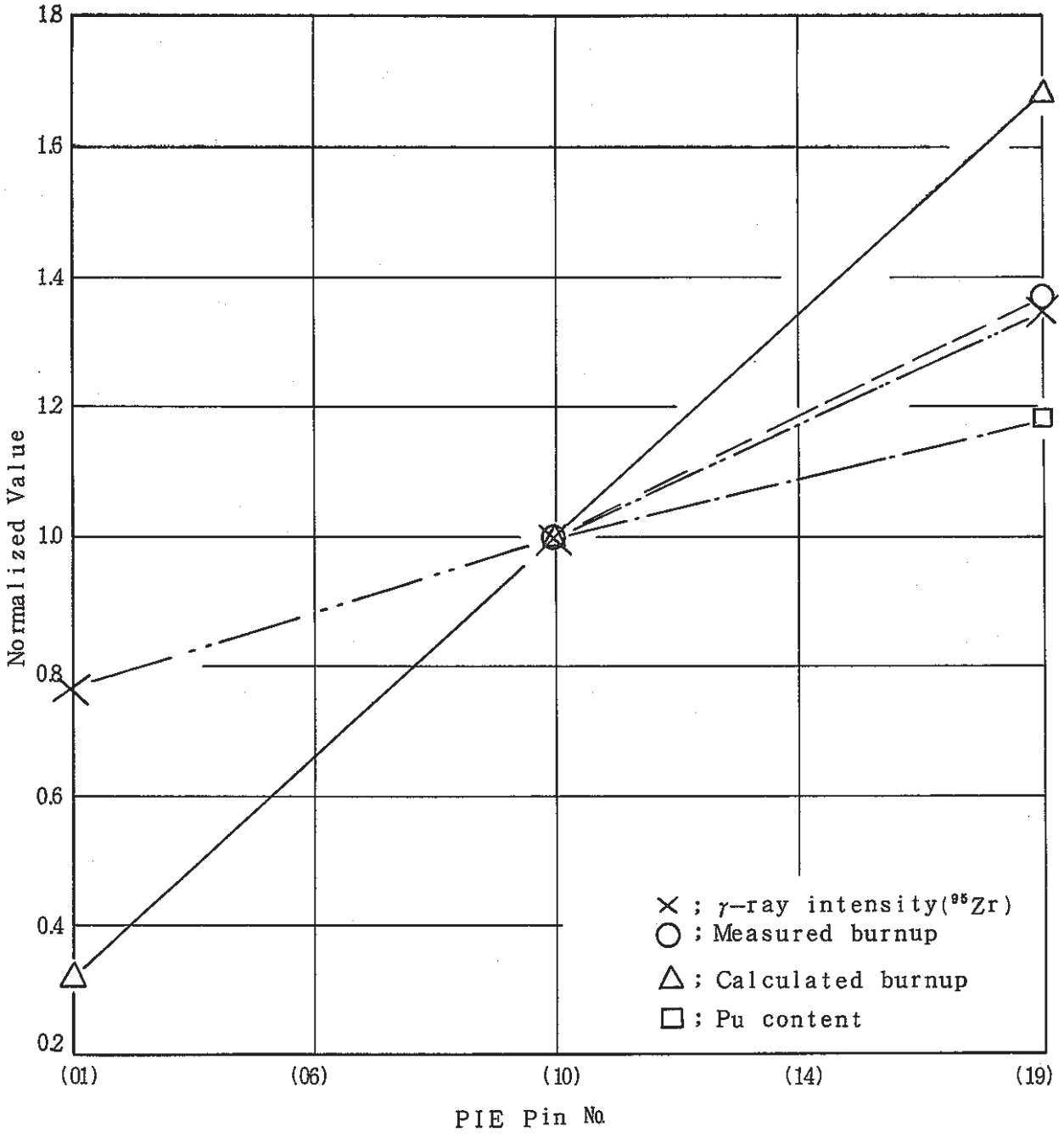


Fig. 4-4-1 Radial distribution of burnup, Pu content and γ-ray intensity in NFJO4K subassembly (normalized value comparing)

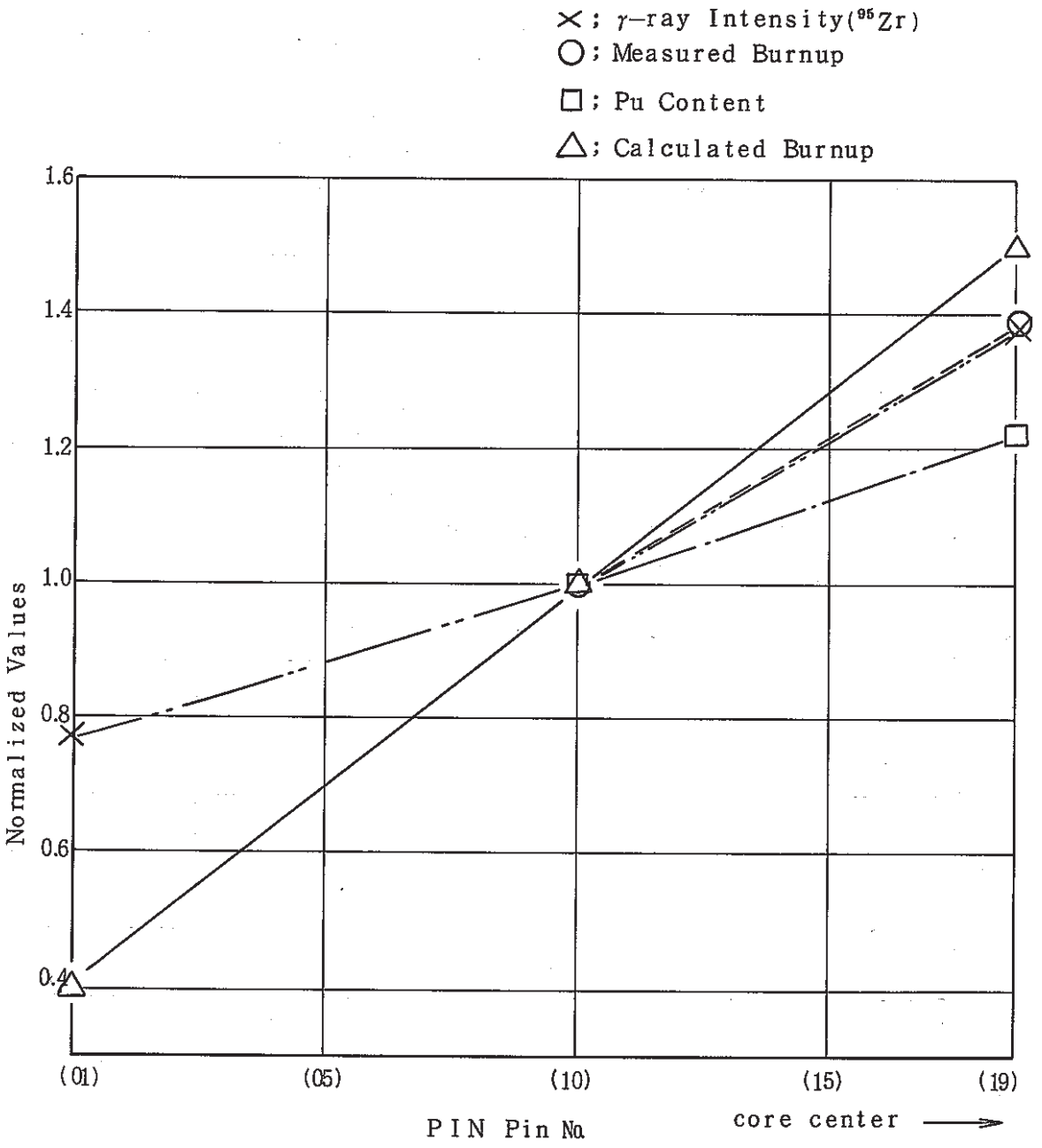


Fig. 4-4-2 Radial distribution of burnup and, Pu content and γ-ray intensity in NFJO64 Subassembly

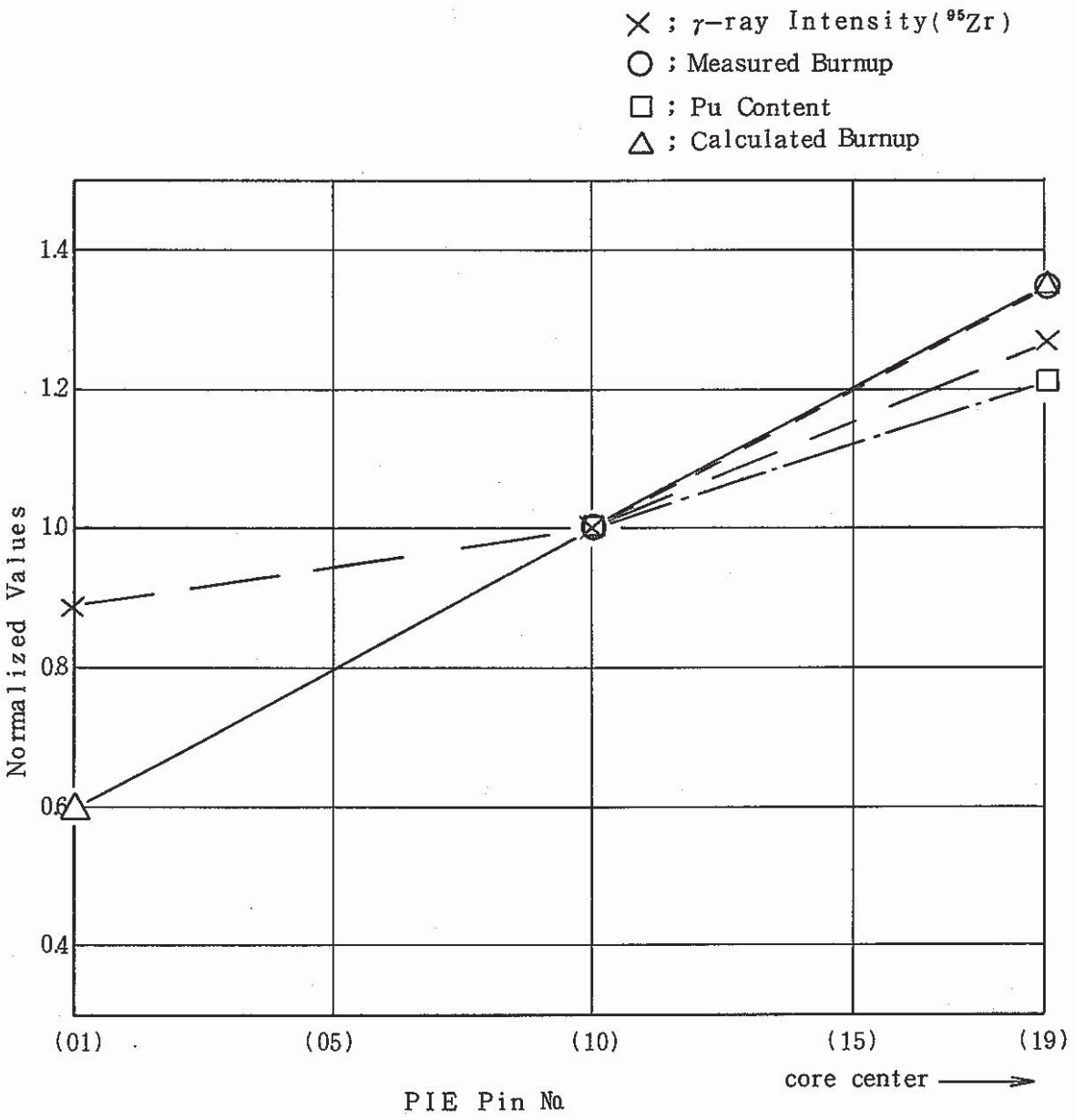


Fig. 4−4−3 Radial distribution of burnup, Pu content and γ−ray intensity in NFJO5L subassembly (normalized value comparing)

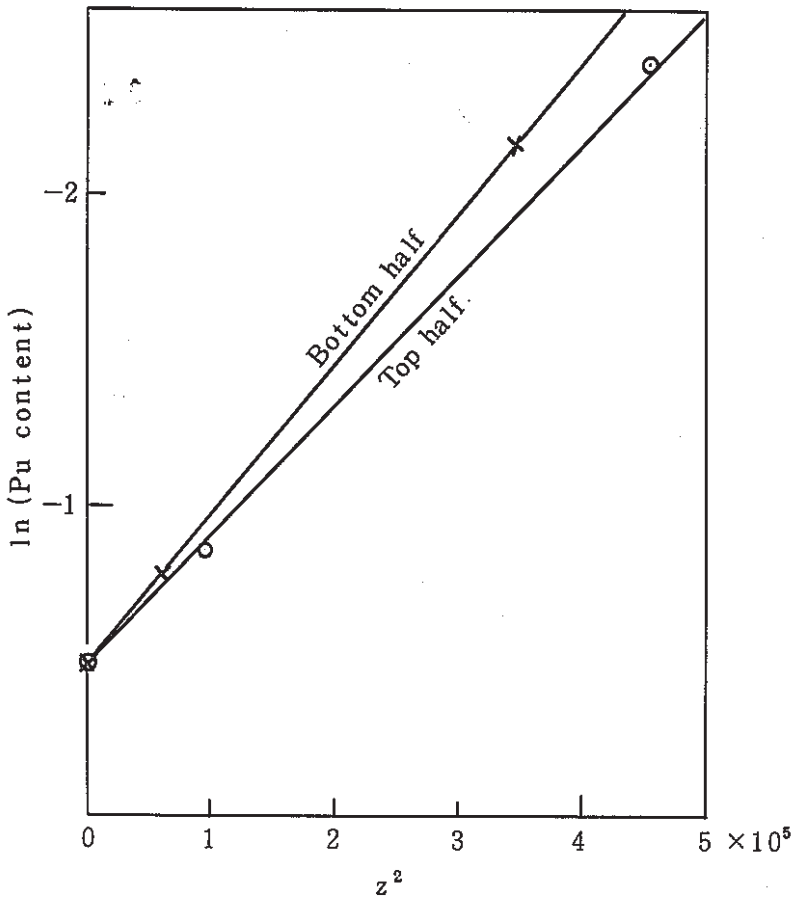


Fig. 4−5−1 Axial distribution of Pu content of NFJO4K 5810 pin represented by the function $\exp(-az^2)$

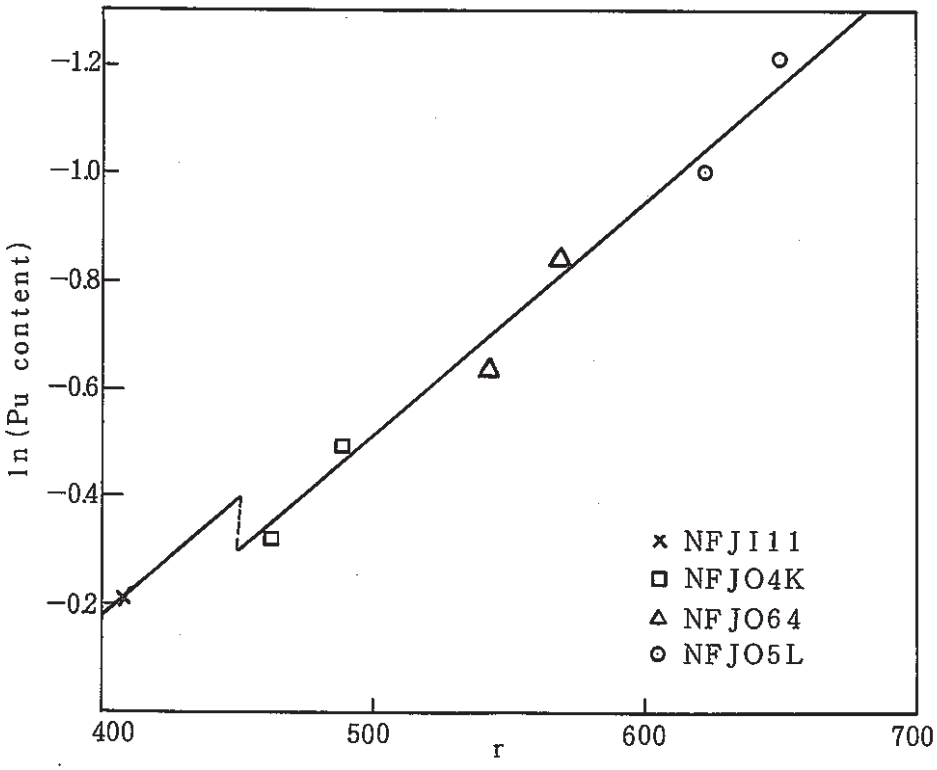


Fig. 4−5−2 Radial distribution of Pu content represented by the function $\exp(-a'r)$