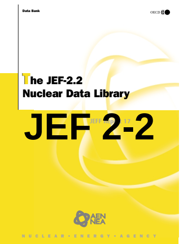

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AEA Technology
Technical Services Division

Specification of the DIMPLE S01 Benchmark Assemblies

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Summary

The report provides a detailed specification of the geometry and composition of the DIMPLE S01 assemblies. The descriptions are provided in a benchmark format suitable for independent analyses using calculation models in two or three dimensions and are recommended for inclusion in the international integral benchmark testing programme of the Joint Evaluated File (JEF) of basic nuclear data.

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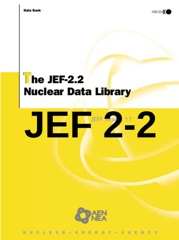

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1. INTRODUCTION

Assembly S01A was first built in 1983 following a refurbishment of the DIMPLE reactor. It was a rebuild of an earlier benchmark, R1/100H/20, originally studied in DIMPLE in 1967[1] and in the JUNO reactor in 1966[2]. It comprised 1565 3% enriched uranium dioxide fuel pins arranged on a square pitch of 1.32cm to provide a cylindrical, light water moderated core 59cm in diameter and just under 50cm high. A second version, S01B, with 1441 pins on the same pitch was built to study the worth of edge fuel pins and changes in the core parameters.

The high leakage S01 assemblies, with over 20% of the neutrons leaking from the core, served a dual purpose. Firstly, they allowed the earlier benchmark data to be re-assessed using modern experimental techniques. Secondly, they provided clean-geometry reference assemblies for the subsequent DIMPLE S02 programme, where nearly 20% of the neutrons were absorbed in a boron-steel walled transport/storage skip[3].

A range of core physics parameters, such as the critical moderator level and water height reactivity coefficient, was measured in each assembly. Extensive reaction-rate distribution measurements and ^{235}U fission fine structure measurements were performed to provide diagnostic data.

As a result of a detailed analysis of the DIMPLE S06 benchmark series[4] a number of improvements to the previous description of the S01 assemblies[5] were identified. These included the definition of assembly temperature, revision of the critical moderator levels, corrections to the fuel cladding and wrapper/gap densities and a revised uncertainty analysis. This report provides a definitive detailed specification of the geometry and composition of the DIMPLE S01 assemblies in a benchmark format suitable for independent analyses using calculation models in two or three dimensions.

2. BRIEF DESCRIPTION OF DIMPLE

DIMPLE is one of two low power reactors owned and managed by AEA Technology at its Winfrith site in the South of England. The reactors offer a comprehensive research capability[6].

DIMPLE is a versatile, water moderated reactor used to investigate performance, safety and safeguards issues relevant to the entire nuclear fuel cycle. Thus, in addition to the lattice studies described in this report, the current DIMPLE programme includes reactivity and neutron source measurements with samples of irradiated fuel discharged from power reactors[7], criticality experiments relevant to fuel manufacturing, transport, storage and reprocessing issues[8], and the development of sub-critical monitoring techniques[9].

A general view of DIMPLE is given in Figure 1. The reactor can accommodate a wide range of experimental configurations. Conventional assemblies consist of fuel pins supported, and precisely located, between upper and lower lattice plates inside a large aluminium primary vessel (2.6m diameter and 4m high). Both simple geometry fuel pin benchmarks and more complex configurations, representative of operational or accident conditions, can be built. Flexibility is accomplished by varying the lattice plate design, fuel type and the inclusion of non-fuel components such as structural or absorber materials. Designs have been investigated for other fuel geometries (eg plate fuel and solutions) and systems with neutron spectra ranging from fast to well thermalised. The ability to control the reactor by means of moderator level alone permits sub-critical and critical assemblies to be studied without the complicating perturbation of control rods. Shut-down is achieved by means of a fast-dump system. When the reactor is operating, a 2m diameter stainless steel bell-jar situated approximately 25cm below the core sustains an air cavity. By venting the cavity through a pair of large valves, the water level can be dropped by 30cm in about one second.

e reactor's low power operation of less than 200W and ease of access (Figure 2) provides for icient configuration modifications or complete assembly changes.

3. DESCRIPTION OF THE ASSEMBLIES

To check predictions of critical moderator level and the water height reactivity coefficient ($d\rho/dH$) at various fuel loadings five S01 configurations were studied. These covered the S01A reference loading of 1565 pins (Figure 3), the removal of 16 edge pins and the addition of 20 and 32 edge pins, (Figure 4) and the removal of 124 edge pins for S01B (Figure 5).

The fuel pins employed to construct the S01 assemblies comprised 3% enriched uranium dioxide pellets, 1.013cm diameter, wrapped in adhesive aluminium foil and stacked within stainless steel cans, 1.094cm outer diameter, to a fuel height of approximately 69cm. The 72cm cans were sealed at each end using aluminium end plugs, with aluminium shims making up any space between the top of the fuel and upper end plug. Plan and elevation views of the fuel pins are given in Figures 6 and 7, respectively.

The pins were supported, and precisely located, between aluminium lattice plates. A stainless steel dowel, fitted into the bottom end plug, retained each pin in the lower lattice plate. The top end of each pin located in a hole in the upper lattice plate (Figure 7). As illustrated in Figure 2, the lattice plates in DIMPLE are secured to aluminium fuel support beams, which in turn are supported by a tubular stainless steel chassis. The S01 assemblies required a total of six fuel support beams and associated pairs of lattice plates. Simplified models of the lattice plates and lower fuel support assembly that maintain volume, mass and composition are provided in Figures 8 and 9, respectively.

A sectional elevation of the S01 assembly within the primary vessel is provided in Figure 10. A series of neutron detectors was located in submersible pods in the water reflector around the S01 assemblies for reactor control and monitoring. These pods, and the surrounding support structures, were distant enough from the core so as not to influence the core physics measurements.

3.1 Composition Data

Composition data for the 3% enriched fuel pins are provided in Table 1, the moderator in Table 2 and the pin dowels, lattice plates and lower support assembly in Table 3. The composition data for each material sum to 100% and, as will be noted from the uncertainties, the number of significant figures quoted does not imply the accuracy.

3.2 Geometric and Density Data

Geometric and density data for the 3% enriched fuel pins are provided in Table 4, and the pin dowels, lattice plates, lower support assembly and moderator in Table 5. Recommended geometric and density values are given to the number of significant figures necessary for consistency of data and do not imply the accuracy, as will be noted from the uncertainties assigned to certain values. Pin diameter uncertainties are not included in the uncertainties associated with the density, allowing the values to be combined independently in sensitivity calculations.

3.3 Temperature

The data quoted in the previous sections are appropriate to a reference ambient temperature condition of 20°C. Measurements were made of assembly temperature during the experiments using a series of platinum resistance bulbs, with mean assembly values ranging from about 15°C to 19°C. The uncertainty on the temperature measurements themselves amounted to ±0.1°C, where the corresponding moderator density change is given in Table 5. The effect of deviations from the reference temperature of 20°C on the measured critical moderator level and bucklings is outlined in the next section.

4. CHARACTERISATION OF THE ASSEMBLIES

In addition to the detailed definition of geometry and composition, the characterisation of the S01 assemblies involved the measurement of a range of core physics parameters. For each assembly, the critical moderator level and the water height reactivity coefficient (dρ/dH) were determined experimentally. The results of the measurements are summarised in Table 6, together with the values corrected to 20°C.

Comprehensive axial and radial reaction-rate distributions were measured in S01A to provide detailed data for comparison with calculated values. Included were three reactions of major significance to the overall neutron balance, namely fission in ^{235}U and ^{238}U and capture in ^{238}U, as well as fission in ^{239}Pu. Relative radial reaction-rate scans were performed with activation foils located at the plane of the peak axial flux. Axial measurements were carried out with foils at a central core location and with a miniature fission chamber. The measured reaction-rate distributions are given in Reference 5 together with derived buckling values. Recommended mean axial and radial buckling values, and their associated uncertainties, are provided in Table 6.

An important feature of the S01A experimental programme was the measurement of the ^{235}U fission fine structure through a fuel pin and into the moderator region. The experiments were designed to provide detailed diagnostic data to supplement the results of the whole assembly reaction-rate distribution measurements. The experimental procedures and the results of the fine structure measurements are given in Reference 5.

To relate the distributions measured for each reaction, experiments were performed at a central core location to determine the ^{238}U to ^{235}U Fast Fission Ratio (FFR), the ^{239}Pu to ^{235}U fission ratio and the Relative Conversion Ratio (RCR). In the context of this work the RCR is defined as the ratio of the capture-rate per atom of ^{238}U to the fission-rate per atom of ^{235}U in the DIMPLE core, relative to the corresponding ratio measured in the well-defined thermal column spectrum of the NESTOR neutron source reactor[6]. The definitive results of these measurements, taken from Reference 10, are provided in Table 7.

5. EXPERIMENTAL UNCERTAINTIES

Included in the tables specifying the geometry and composition data for the S01 assemblies are the associated uncertainties (1σ). Table 8 provides a summary of the uncertainties on the key calculation model parameters in order that their effect on k-effective and the measured reaction-rates can be evaluated. In assessing the impact of compositional variations it is recommended that, as in previous studies, changes in mass are compensated by aluminium. Experience has shown that experimental uncertainties such as those in Table 8 result in an overall uncertainty on a measured k-effective value of typically ± 0.001 to ± 0.002 Δ(-1/k).

f assembly definition uncertainties are assessed using a three-dimensional calculation method the ncertainty in the axial dimensions, and in particular the measured critical height, would replace that for the measured buckling in Table 8. However, as the reactivity change associated with these uncertainties is very similar, the overall uncertainty on k-effective would remain about the same.

The uncertainty associated with the reproducibility with which identical assemblies can be rebuilt from the same components is largely covered by the uncertainty in the pin pitch. The pin pitch deviations across the gap between lattice plates identified in Table 5 should be included in any rigorous whole core analysis and is significant enough to be treated explicitly rather than including in any estimate of the experimental uncertainties. Previous analysis[5] has indicated that representation of the gaps in a reference S01A calculation model reduces k-effective by 0.0017 $\Delta(-1/k)$.

Reactor physics codes generally assume that all neutrons are born at energies in the prompt neutron fission spectrum. In reality, a small fraction (~0.7%) are born in the delayed neutron spectrum at slightly lower energies and this should be taken into account in any rigorous analysis. Calculations to assess the importance of this effect on the k-effective values calculated for small benchmark assemblies show the correction is of similar magnitude to the experimental uncertainties[11]. The correction has been calculated to be 0.0004 $\Delta(-1/k)$ for the S01 assemblies.

6. CONCLUSIONS

This report has provided a detailed specification of the geometry and composition of the DIMPLE S01 assemblies. The descriptions are provided in a benchmark format suitable for independent analyses using calculation models in two or three dimensions and are recommended for inclusion in the international integral benchmark testing programme of the Joint Evaluated File (JEF) of basic nuclear data.

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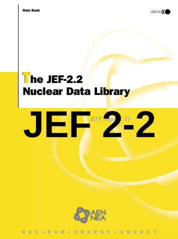


Table 1

Composition Data for 3% Enriched Fuel Pins

Element/ Isotope	Composition (weight %)				
	3% Enriched Fuel(1)	Fuel Wrapper(2)	Outer Clad(3)	Upper End Plug and Shims(4)	Lower End Plug(5)
^{234}U	0.0169±0.0003				
^{235}U	2.6465±0.003				
^{236}U	0.0363±0.0003				
^{238}U	85.3603±0.003				
Al	0.0285	84.7439	0.246	98.1891	97.5006
C		12.76			
Cl		0.005			
Co			0.102		
Cr		0.0025	18.0		
Cu		0.015	0.152	0.0047	0.0072
Fe	0.0080	0.3	67.552	0.2719	0.22
H		2.13			
Mg		0.0015		1.2032	1.84
Mn		0.006	1.66	0.1733	0.265
Mo			0.34		
Ni		0.002	11.18	0.0056	0.0085
O	11.8919				
Si	0.0116	0.025		0.1465	0.15
Sn		0.009			
Sr		0.0001			
Ti			0.666	0.0057	0.0087
V			0.05		
Zn			0.052		

Notes:

(1) Data source Reference 12. The uncertainties on the uranium isotopes are a quadratic combination of the absolute measurement uncertainties and the standard error on the mean composition values given in Reference 13. For all cases, the measurement uncertainties dominate. In addition to the isotopic uncertainties, an uncertainty associated with the total uranium content of 88.06±0.03% must be included in any error analysis. The absolute measurement uncertainty on the remaining elements is ±10%.

(2) Data source Reference 12. The fuel wrapper comprised adhesive (CH_2) aluminium foil. Absolute uncertainties of ±1% for Al, ±2% for C, ±5% for Fe, ±20% for Cl, ±100% for Sr and ±10% for remaining elements.

(3) Data source Reference 12. Absolute uncertainties of ±1% for Fe, ±2% for Cr, Mn, Ni and ±10% for remaining elements.

Notes to Table 1 (cont'd):

(4) Composition data for end plug and shims from Reference 14 combined in proportion to their masses of 1.300g and 0.688g, respectively.

(5) Data source Reference 14.

Table 2

Composition Data for Moderator

Element	Composition[1] (weight %)
Al	
C	
Co	
Cr	
Cu	
Fe	
H	11.19
Mn	
Mo	
Ni	
O	88.81
P	
S	
Si	
Ti	
V	
Zn	

Note:

(1) Data source Reference 12. Calculations using detailed chemical analyses of the moderator have shown that trace elements have a negligible effect on the neutron balance.

Table 3

Composition Data for Pin Dowels, Lattice Plates and Lower Support Assembly

Element	Composition (weight %)				
	Pin Dowels(1)	Upper Lattice Plate(2)	Lower Lattice Plate(3)	Fuel Support Plate(4)	Fuel Beam Base(5)
Al		97.00	97.07	71.360	87.405
C				0.010	0.001
Co	0.125				0.003
Cr	16.85			4.729	1.371
Cu	0.28	0.01	0.03	0.015	0.016
Fe	70.515	0.35	0.30	18.508	5.500
Mg		2.08	2.12	1.498	0.508
Mn	1.17	0.34	0.36	0.659	0.156
Mo	0.425				0.006
Nb				0.105	0.018
Ni	9.65			2.836	0.774
P				0.006	0.001
S	0.07			0.003	0.001
Si	0.425	0.20	0.12	0.215	4.071
Sn					0.042
Ti	0.44	0.01		0.049	0.126
Zn	0.05	0.01		0.007	0.001

Notes:

(1) Data source Reference 14.

(2) Winfrith bond number AEW1078. Data taken from manufacturer's test certificate.

(3) Winfrith bond number AEW908. Data taken from manufacturer's test certificate.

(4) Included in the data for the aluminium fuel support plate are a number of associated stainless steel components. The composition data for the support plate and these components have been taken from Reference 14 (data for support plate distance pieces considered applicable for dowels and fixings) and combined in proportion to their measured weights:

Notes to Table 3 (cont'd):

Component	Number of Components per Beam	Total Mass per Beam (g)
Fuel support plates	2	2208.80
Dowels and fixings	2	17.44
Support plate distance pieces and fixings	6	298.26
Location blocks and fixings	8	483.84
Total Assembly	8	3008.34

(5) Included in the data for the fuel beam base are a number of associated stainless steel components. The composition data for the fuel beam base and these components have been taken from Reference 14 and combined in proportion to their weights. The stainless steel components were weighed and the mass of the fuel beam bottom derived from the geometry described in the footnotes to Table 5:

Component	Number of Components per Beam	Total Mass per Beam (g)
Fuel beam base	1	13194.76
Hook bolt and fixings	12	295.80
Clamp plate	6	790.56
Total Assembly		14281.12

Table 4

Geometric and Density Data for 3% Enriched Fuel Pins

Region	Parameter[1]	Value
Fuel[2]	Diameter, a_1, (cm) Length, l_3, (cm) Density (g/cm^3)	1.013 ±0.002 69.285±0.001 10.42 ±0.001
Wrapper/Gap[3]	Inner diameter, a_1, (cm) Outer diameter, a_2, (cm) Density (g/cm^3)	1.013 ±0.002 1.0398±0.003 0.868 ±0.003
Clad[4]	Inner diameter, a_2, (cm) Outer diameter, a_3, (cm) Length, l_2, (cm) Density (g/cm^3)	1.0398±0.003 1.0937 ±0.0003 71.730±0.001 7.806 ±0.003
Upper End Plug and Shims[5]	Diameter, a_2, (cm) Length, j_2, (cm) Length external to clad, j_1, (cm) Density (g/cm^3)	1.0398 1.463 0.048 1.600
Lower End Plug[6]	Diameter, a_2, (cm) Length, i_2, (cm) Length external to clad, i_1, (cm) Density (g/cm^3)	1.0398 1.078 0.048 1.644

Notes:

(1) Radial dimensions 'a' identified in Figure 6. Axial dimensions 'i', 'j' and 'l' identified in Figure 7.

(2) Data source Reference 13. The uncertainty in the fuel diameter is not included in the density uncertainty.

(3) Data source Reference 15. The aluminium wrapper has been smeared over the whole gap between the fuel and stainless steel clad. The density is calculated on the basis of the total aluminium mass of 2.60±0.01g (Reference 13), the fuel length, l_3, and the diameters, a_1 and a_2, given above. The uncertainties in the diameters are not included in the density uncertainty.

(4) Data source Reference 16. The inner diameter was not measured directly and the uncertainty covers the range of the engineering drawing specification. The fact that this is not strictly a 1σ uncertainty is unimportant as the impact of a variation in this parameter is small. The uncertainty associated with the clad diameter is dominated by the absolute systematic calibration accuracy. The mean clad outer diameter for the fuel pins employed in the S01 assemblies, calculated using the correlation given in Reference 16, is well within the uncertainty associated with the mean value for the whole stock of 4330 pins given in the table. The density is calculated on the basis of the can mass of 50.57±0.02g, the length, l_2, and the diameters, a_2 and a_3, given above. The uncertainties in the diameters are not included in the density uncertainty.

Notes to Table 4 (cont'd):

(5) A cylindrical geometry has been assumed, with the diameter equal to the internal diameter of the clad and the length equal to the distance between the top of the fuel and top of the plug. The density is calculated on the basis of this geometry and the combined mass of the upper end plug of 1.300±0.005g and average shim loading of 0.688±0.002g (Reference 13). The rubber seal washer is not included.

(6) A cylindrical geometry has been assumed, with the diameter equal to the internal diameter of the clad and the length equal to the average lower end plug height. A cylindrical hole, 0.63cm in diameter and 0.4cm deep, has been assumed for the dowel (see Table 5). The density is calculated on the basis of this geometry and the lower end plug mass of 1.300±0.005g (Reference 13). The rubber seal washer is not included.

Table 5

Geometric and Density Data for Pin Dowels, Lattice Plates, Lower Support Assembly and Moderator

Region	Parameter[(1)]	Value
Pin Dowel[(2)]	Diameter, e, (cm)	0.63
	Length, i_3, (cm)	1.4
	Length external to bottom plug, i_4, (cm)	1.0
	Density (g/cm^3)	6.072
Upper Lattice Plate[(3)]	Distance between top of lower lattice plate and top of upper lattice plate, h_1, (cm)	60.34
	Thickness, t_1, (cm)	0.64
	Length, w_1, (cm)	121.920
	Width, w_2, (cm)	71.172
	Distance of first pin hole centre from edge along length, w_3, (cm)	25.979
	Distance of first pin hole centre from edge along width, w_4, (cm)	0.606
	Pin hole diameter, r_1, (cm)	1.111
	Pin hole pitch, p, (cm)[(4)]	1.3200±0.0005
	Interstitial drainage hole diameter, r_2, (cm)	0.4
	Density (g/cm^3)	2.669
Lower Lattice Plate[(3)]	Thickness, t_2, (cm)	1.27
	Length, w_5, (cm)	86.360
	Width, w_2, (cm)	71.172
	Distance of first pin dowel hole from edge along length, w_6, (cm)	8.199
	Distance of first pin dowel hole from edge along width, w_4, (cm)	0.606
	Pin dowel hole diameter, r_3, (cm)	0.64
	Pin dowel hole pitch, p, (cm)[(4)]	1.3200±0.0005
	Interstitial drainage hole diameter, r_4, (cm)	0.64
	Density (g/cm^3)	2.681

Table 5 (cont'd):

Region	Parameter[1]	Value
Fuel Support Plate[5]	Thickness, m_1, (cm) Height, n_1, (cm) Length, w_7, (cm) Centre of assembly to outer edge, m_3, (cm) Density (g/cm^3)	2.0155 1.778 128 4.5085 3.279
Fuel Beam Base[6]	Thickness, m_2, (cm) Height, n_2, (cm) Length, w_7, (cm) Centre of assembly to outer edge, m_3, (cm) Density (g/cm^3)	1.5446 12.7 128 4.5085 2.844
Moderator[7]	Moderator density (g/cm^3)	0.9982041±0.00002

Notes:

(1) Pin dowel dimensions identified in Figure 7, lattice plate dimensions in Figure 8 and fuel support plate and fuel beam dimensions in Figure 9.

(2) A simplified geometric specification is provided of the pin dowels that is common to several DIMPLE pin components (see Reference 4). The density is based on the measured dowel mass of 2.65±0.09g for the 3% enriched fuel pins (Reference 13).

(3) The S01 assemblies were constructed using six pairs of upper and lower lattice plates as shown in Figures 3 to 5. These are represented as a single upper lattice plate and single lower lattice plate in Figure 8, both covering 53 x 53 pin locations. The geometric values have been taken from the engineering drawings. The densities have been calculated for the simplified geometry using the measured total masses of 9390g for the six upper lattice plates and 14658g for the six lower lattice plates.

(4) The quoted uncertainty for the pin pitch is based on a series of measurements reported in Reference 4 and in the case of the S01 assemblies is only applied to the pin holes within a lattice plate. In the S01 study measurements were made of the pin pitch across the gaps at the extreme ends of the six top lattice plates and the six bottom lattice plates. The mean deviation from the specified pitch of 1.3200cm for each top and bottom pair of lattice plates is given in the following table.

Beam Numbers	3/4	4/5	5/6	6/7	7/8
Deviation (cm)	-0.069	-0.015	-0.025	-0.023	-0.061

Notes to Table 5 (cont'd):

(5) Associated with the two fuel support plates on which each lower lattice plate was located were a number of stainless steel components. These items were weighed and their volumes derived using a density of 8.05g/cm^3 (Reference 17). Due to the number and complexity of their geometry these items have been smeared into the two fuel support plates. The length and height of the plates have been maintained as specified in the engineering drawings. However, their thicknesses have been increased from the actual value of 1.9177cm to 2.0155cm to ensure the correct amount of moderator is displaced by inclusion of the stainless steel components. The density has been derived for the simplified geometry and the total mass of the assembly.

(6) Due to the complexity of the cast aluminium fuel beam base geometry and associated stainless steel components, a simplified model has been derived maintaining both total volume and mass. The simplified model represents the fuel beam base side-members over a length equivalent to the fuel support plates and height as specified in the engineering drawings. The volume of seven cross-members in the beam base and the stainless steel components has been included in this geometry by increasing the actual thickness of each side member from 1.3335cm to 1.5446cm. The volume of the fuel beam base was derived from the engineering drawings and a mass calculated using a density of 2.7g/cm^3 (Reference 17). The volume of the stainless steel components was calculated from their measured weights and a density of 8.05g/cm^3 (Reference 17). The final density of the fuel beam base was derived from the simplified geometry and total mass of the assembly.

(7) Density data from Reference 18. The moderator density uncertainty is equivalent to the ±0.1°C uncertainty on the moderator temperature.

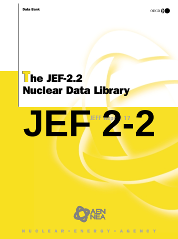


Table 6

Summary of the S01 Assemblies Critical Moderator Level, dρ/dH and Buckling Measurements

Configuration (No of Pins)	Measurement Date	Moderator Height[1] (cm)		dρ/dH (mN/cm)	Mean Assembly Temperature (°C)	Temperature Corrected to 20°C[2]		Buckling (m^{-2})[3]	
		PLG (spin)	Above Fuel Base			Mod Height (cm)	dρ/dH (mN/cm)	Axial	Radial
S01B (1441)	17/11/83	187.36	53.31	206.2	16.8	53.47	199.7	21.5±0.2	
+20 (1585)	2/12/83	182.53	48.49	255.9	17.0	48.64	249.6		
+32 (1597)	8/12/83	182.21	48.17	267.1	15.2	48.41	257.3		
-16 (1549)	9/12/83	183.56	49.52	234.9	16.3	49.70	227.4		
S01A (1565)	12/12/83	183.07	49.03	242.8	15.4	49.26	233.4	24.1±0.2	41.5±0.3

Notes:

(1) The measured Precise Level Gauge "Spot-In" (PLG (spin)) values have been converted using the measured calibration data provided in Reference 13, where the moderator height above the fuel base in cm, H_c, is given by:

$$H_c = [0.99909 \times PLG(spin) - 0.19384] - [132.61 + 1.078]$$

where PLG(spin) is the measured value in cm and 132.61 is the distance in cm between the nominal tank bottom and the top of the lower lattice plate and 1.078 is the distance in cm between the top of the lower lattice plate and the fuel base (see Table 4 and Figure 7)

; to Table 6 (cont'd):

(2) The recommended 20°C values are based on a least squares fit to measurements made in S02A (Reference 3). An uncertainty of ±0.03cm(1σ) has been assigned to the recommended critical moderator level on the basis of large numbers of repeat measurements (eg Reference 4). In addition to the accuracy associated with the fits to the experimental data is a systematic uncertainty of ± 0.3cm due to the meniscus effect between the pins. An uncertainty on the water height reactivity coefficient of ±5mN/cm(1σ) has been assigned, which mainly represents the error on the weighted straight line fit to the experimental points. There is also a systematic contribution of ±5% arising from uncertainties in the delayed neutron parameters used to calibrate the reactivity scale.

(3) The axial buckling values are the mean of the ^{235}U data provided in Tables 13 and 14 of Reference 5. The uncertainty assigned to the measured axial buckling values is a quadratic combination of the uncertainties associated with the spread of the individual buckling measurements, the temperature deviation from the reference temperature of 20°C and the effect of replacing a fuel pin by the scanning guide tube and chamber. The uncertainty contributions to the axial buckling values were assessed as follows:

(i) In the case of S01A the spread of the individual buckling measurements was represented by the standard error on the mean and amounted to $0.1m^{-2}$. For S01B, where only two scans were performed, the spread was represented by the deviation from the mean value, which again amounted to $0.1m^{-2}$.

(ii) A contribution to the uncertainty identified in (i) above is the variation of assembly temperature from one scan to another. In principle, corrections to the buckling measurements to account for deviations from the reference temperature of 20°C could be deduced. However, for simplicity the uncertainty has been appropriately increased to cover the maximum deviation of 5°C, where such a temperature deviation is equivalent to a variation in the critical height of about 0.25cm and an error in the buckling of about $\pm 0.15m^{-2}$.

(iii) In the case of the fission chamber scans the replacement of a fuel pin by the scanning tube and chamber introduces a variable radial and axial uncertainty. On the basis of an analysis performed in Reference 4 this uncertainty amounts to $\pm 0.1m^{-2}$.

In the case of the S01A radial buckling value derived from the Jo-Bessel fit to the radial ^{235}U foil measurements provided in Table 16 of Reference 5 the uncertainty is taken as the deviation from the mean value.

Table 7

S01A Reaction-Rate Ratio Measurements

Fast Fission Ratio (FFR)[1]		
(f8/f5)[2]	P(t)[3]	(F8/F5) DIMPLE
0.00227±1.0%	1.33±3.3%	0.00302±3.4%

F9/F5[1]		
(F9/F5) DIMPLE / (F9/F5) NESTOR	(F9/F5) NESTOR[4]	(F9/F5) DIMPLE
1.614±0.9%	1.3543	2.189±0.9%

Relative Conversion Ratio (RCR)[1]		
(C8/F5) DIMPLE / (C8/F5) NESTOR	(C8/F5) NESTOR[4]	(C8/F5) DIMPLE
4.284±0.5%	0.004744	0.0203±0.5%

Notes:

(1) Data taken from Reference 10. F5 = ^{235}U fission, F8 = ^{238}U fission, F9 = ^{239}Pu fission and C8 = ^{238}U capture.

(2) f8/f5 is the measured fission product gamma-ray activity as described in Reference 19.

(3) P(t) is a function of time that relates the ratio of fission product gamma-ray activity to the ratio of actual fission-rates (F8/F5), as described in Reference 19.

(4) The NESTOR ratios have been derived from the '1986' WIMS Nuclear Data Library using the Maxwellian Averaged Thermal Cross-Sections given in Reference 20.

Table 8

Key Assembly Definition Experimental Uncertainties

Parameter	Uncertainty
Buckling	$0.2m^{-2}$
UO_2 Density	$0.001 g/cm^3$
UO_2 Diameter	0.002cm
^{235}U Enrichment	0.003%
^{238}U Enrichment	0.003%
Fuel Pin Clad OD	0.0003cm
Fuel Pin Clad ID	0.003cm
Fuel Pin Clad Density	$0.003 g/cm^3$
Foil Wrapper Hydrogen	0.213%
Foil Wrapper Density	$0.003 g/cm^3$
Moderator Density	$0.00002 g/cm^3$
Pin Pitch Within Lattice Plate[(1)]	0.0005cm

Note:

(1) The deviation in the pin pitch between lattice plates identified in Note 4 of Table 5 should be included in any rigorous whole core analysis. It is significant enough to be treated explicitly by dividing the total width of the upper and lower lattice plates into six equal sections and representing the gaps.

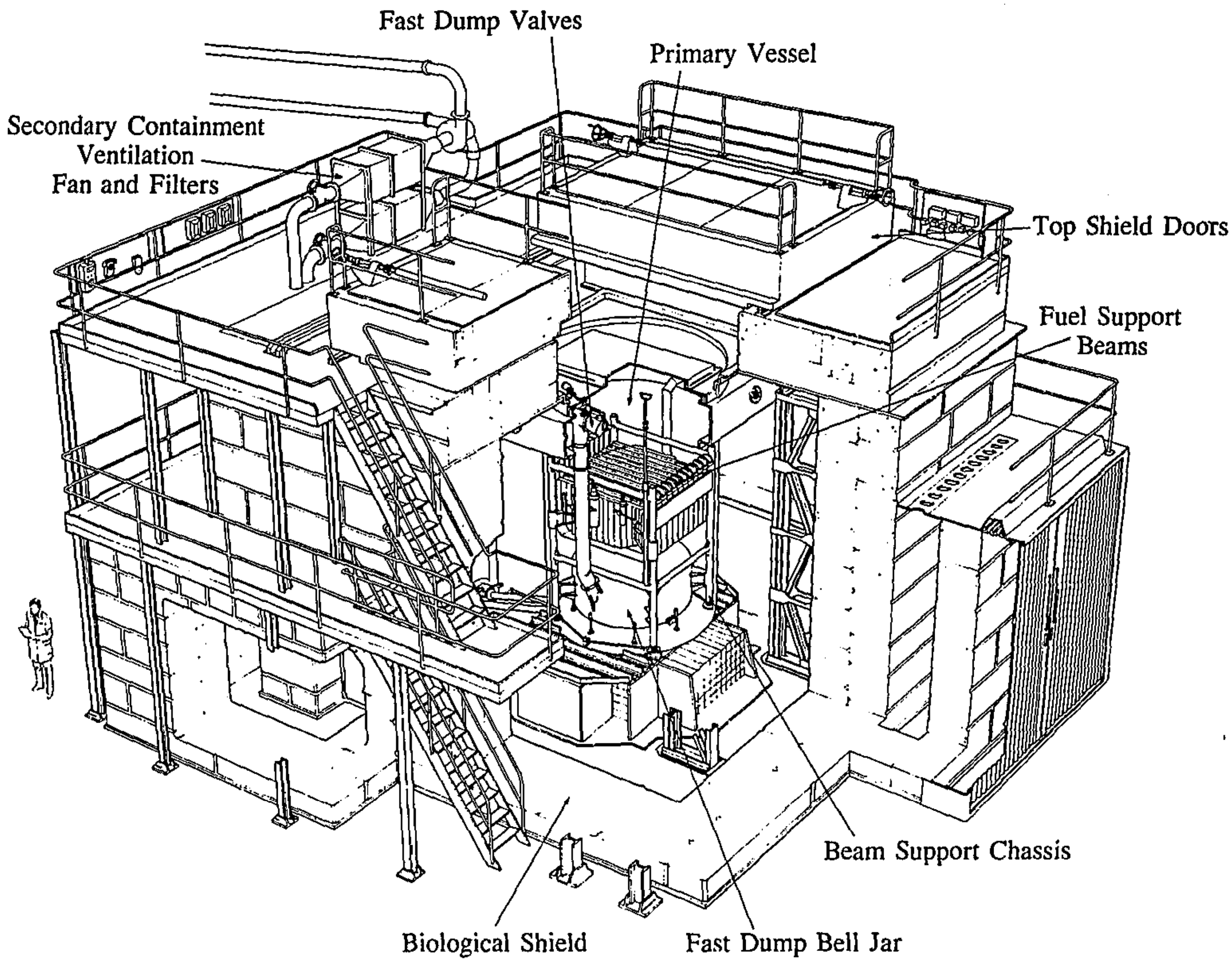


Figure 1 General View of DIMPLE

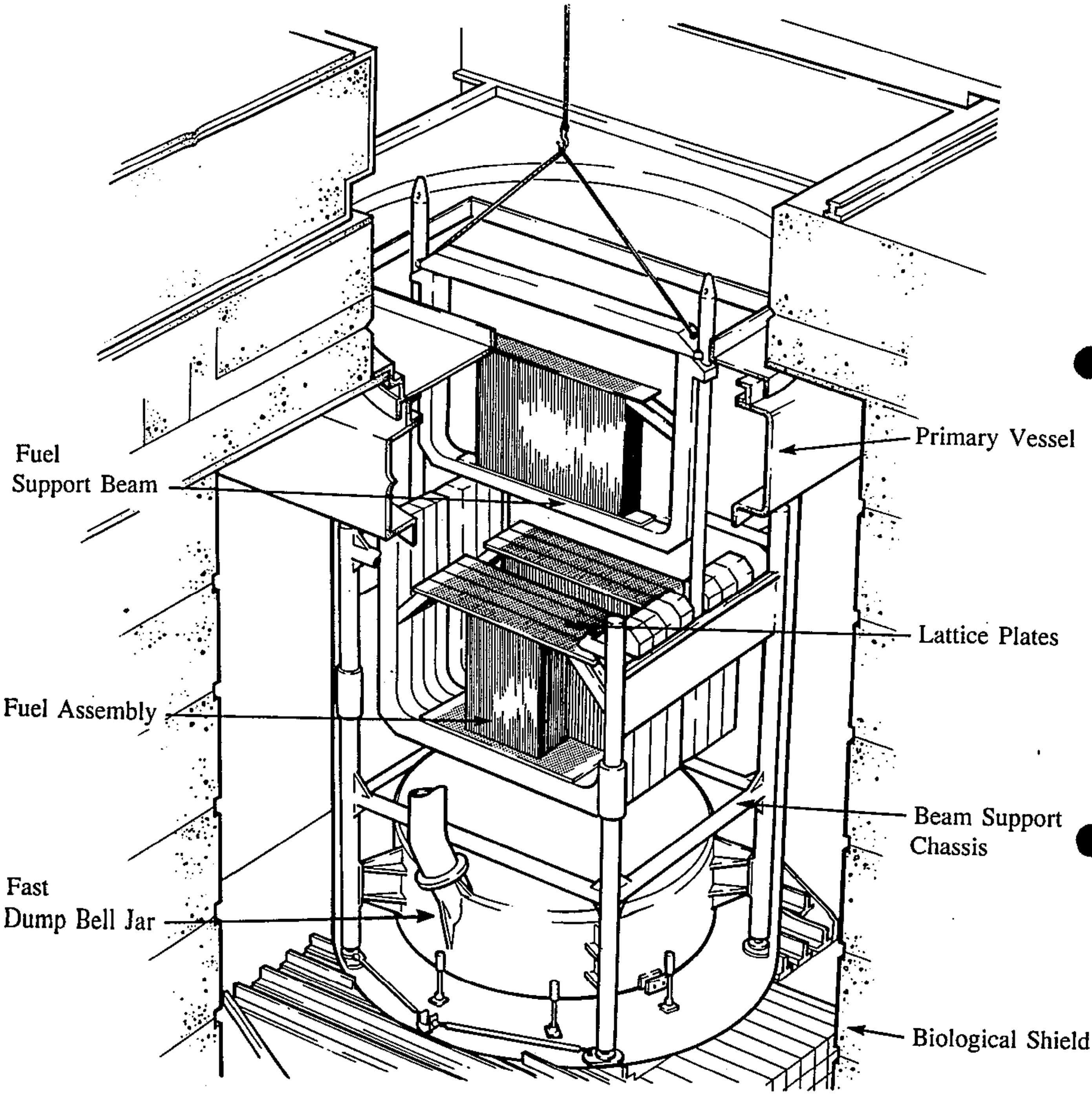
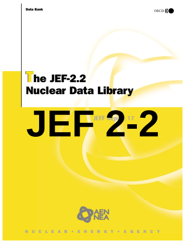


Figure 2 Typical Arrangement of Assembly Within DIMPLE Primary Vessel



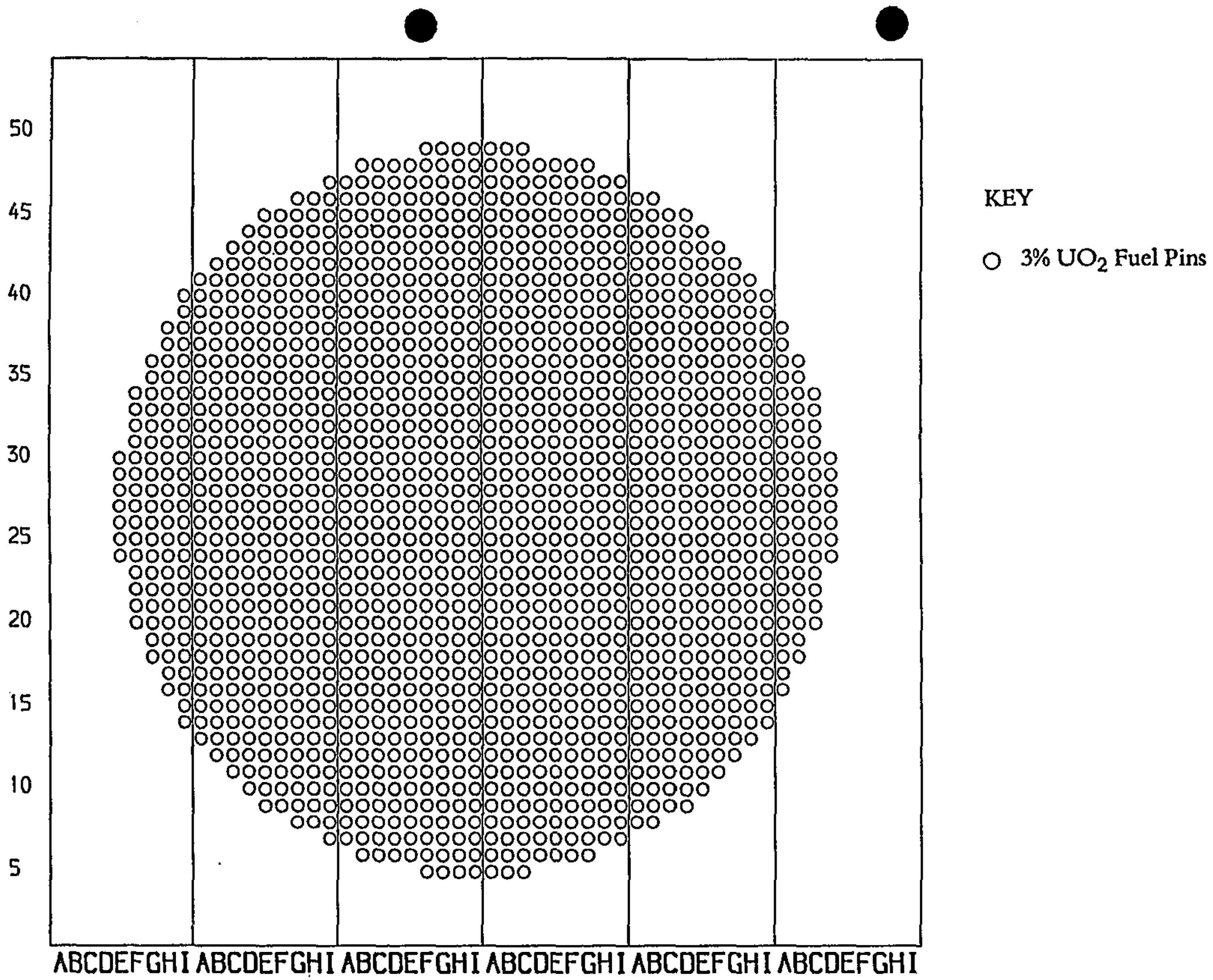
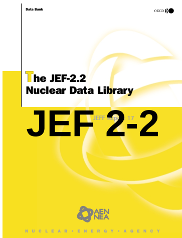


Figure 3 DIMPLE Assembly S01A



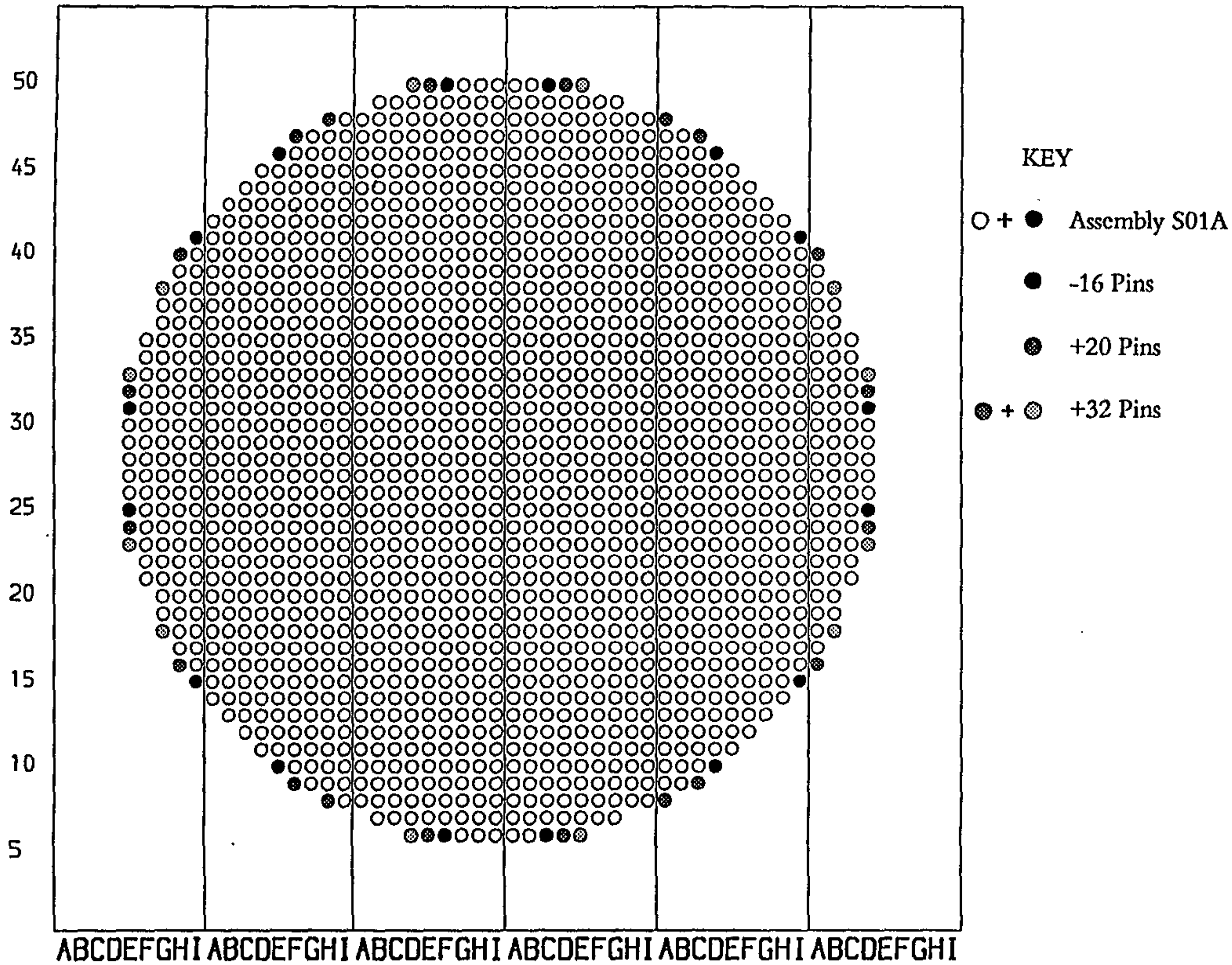


Figure 4 DIMPLE Assembly S01A Showing Positions of Removed and Added Pins

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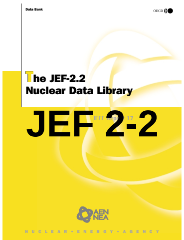


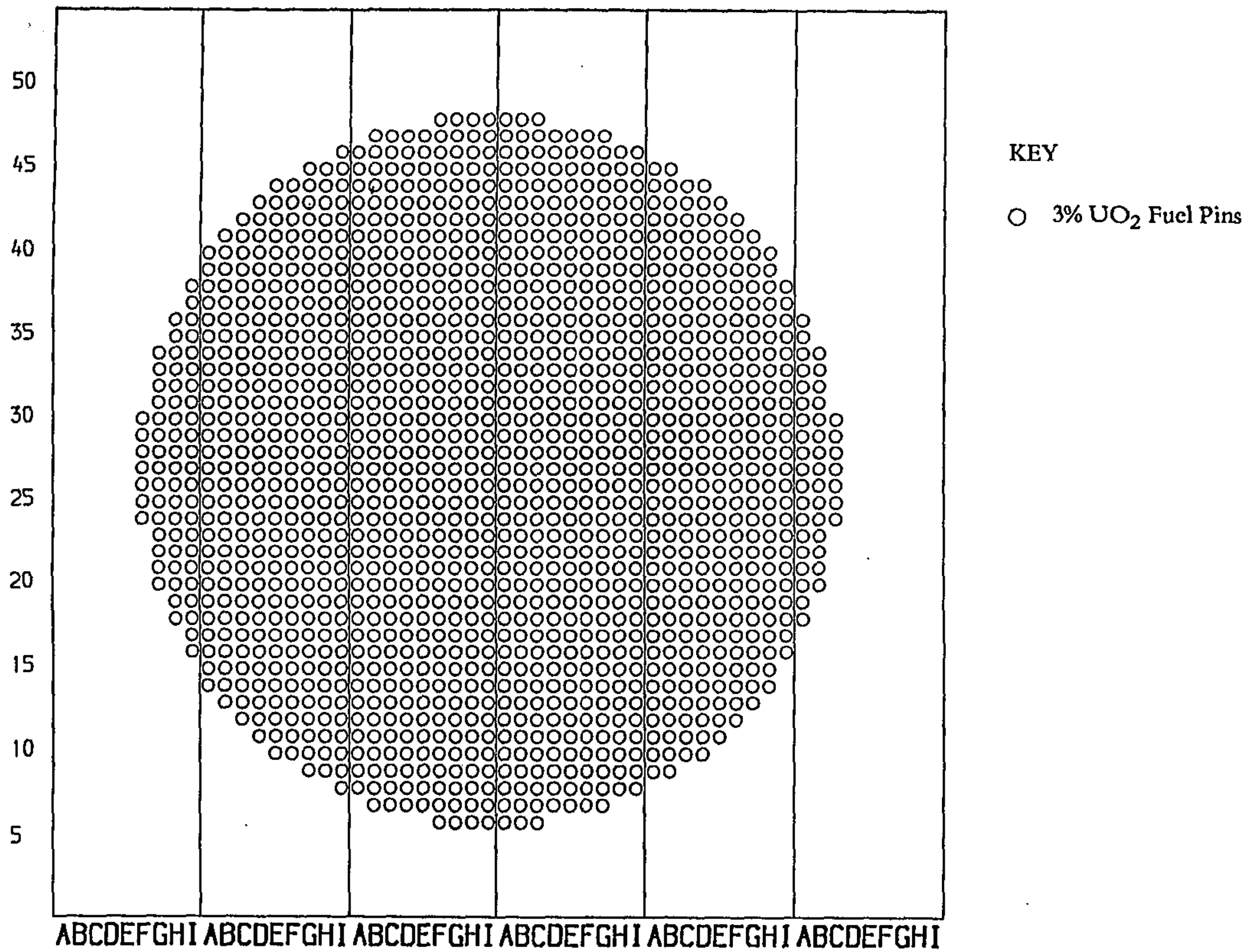
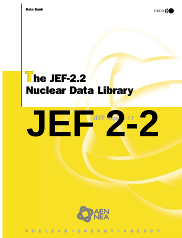


Figure 5 DIMPLE Assembly S01B



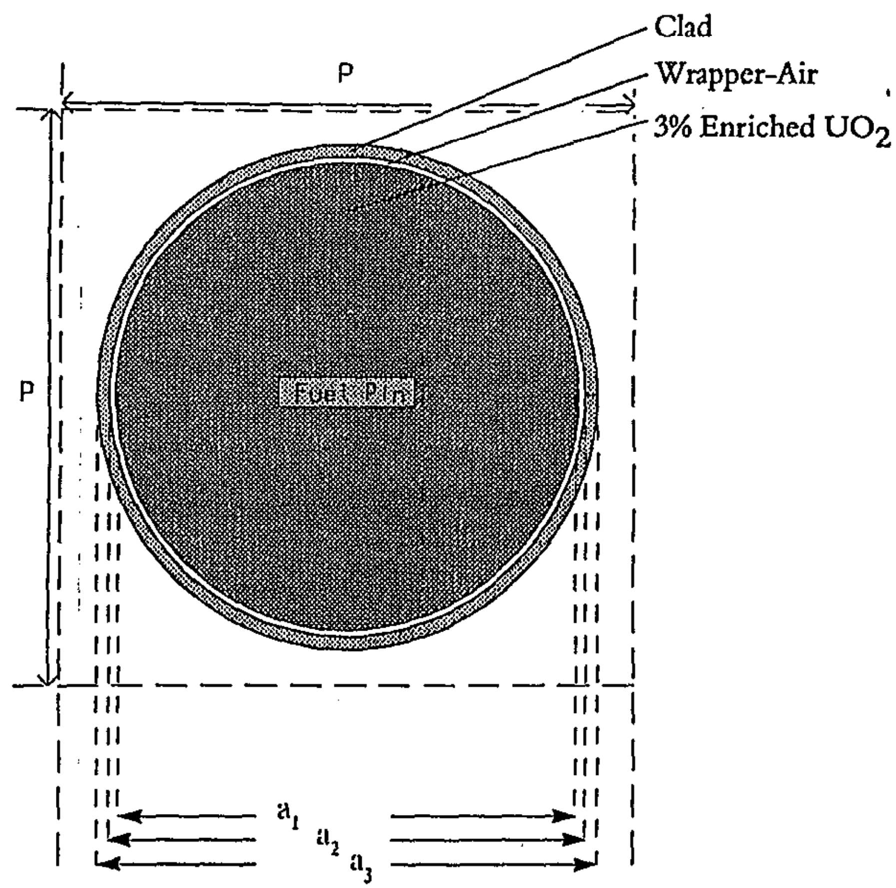


Figure 6 Sectional Plan View of 3% Enriched Fuel Pin

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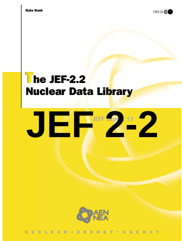

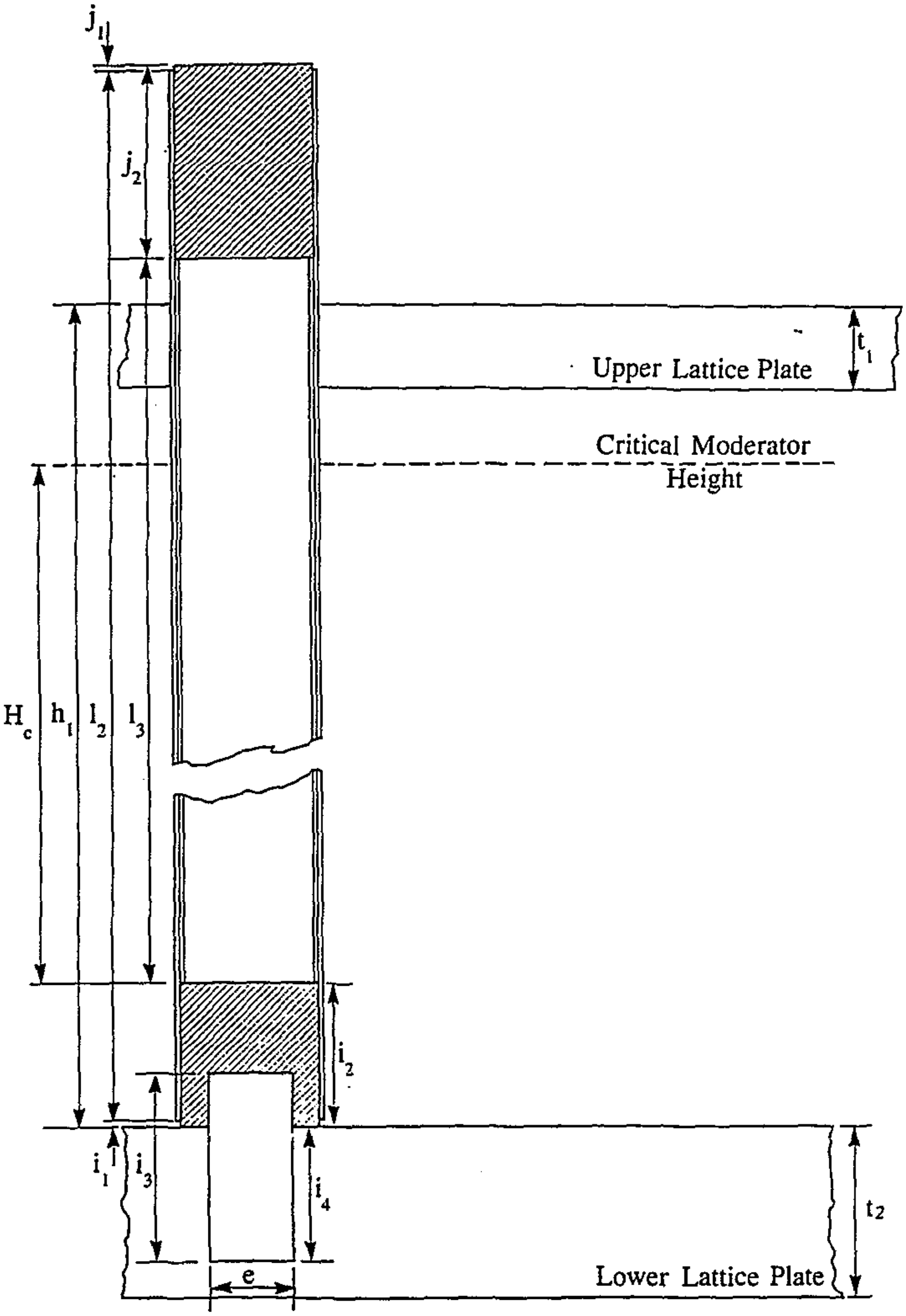

Figure 7 Sectional Elevation View of 3% Enriched Fuel Pin and Lattice Plates

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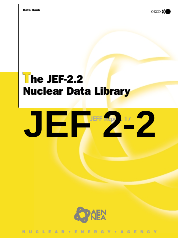
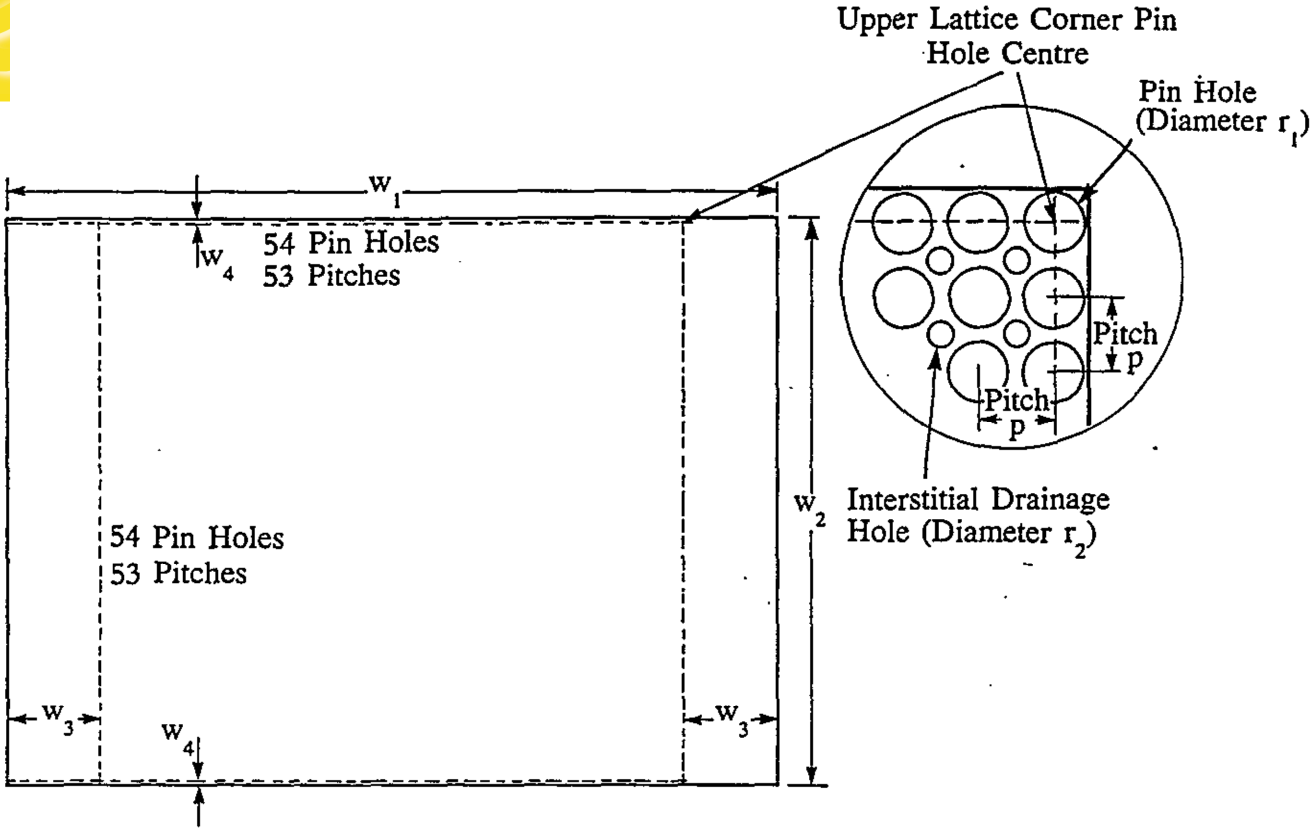
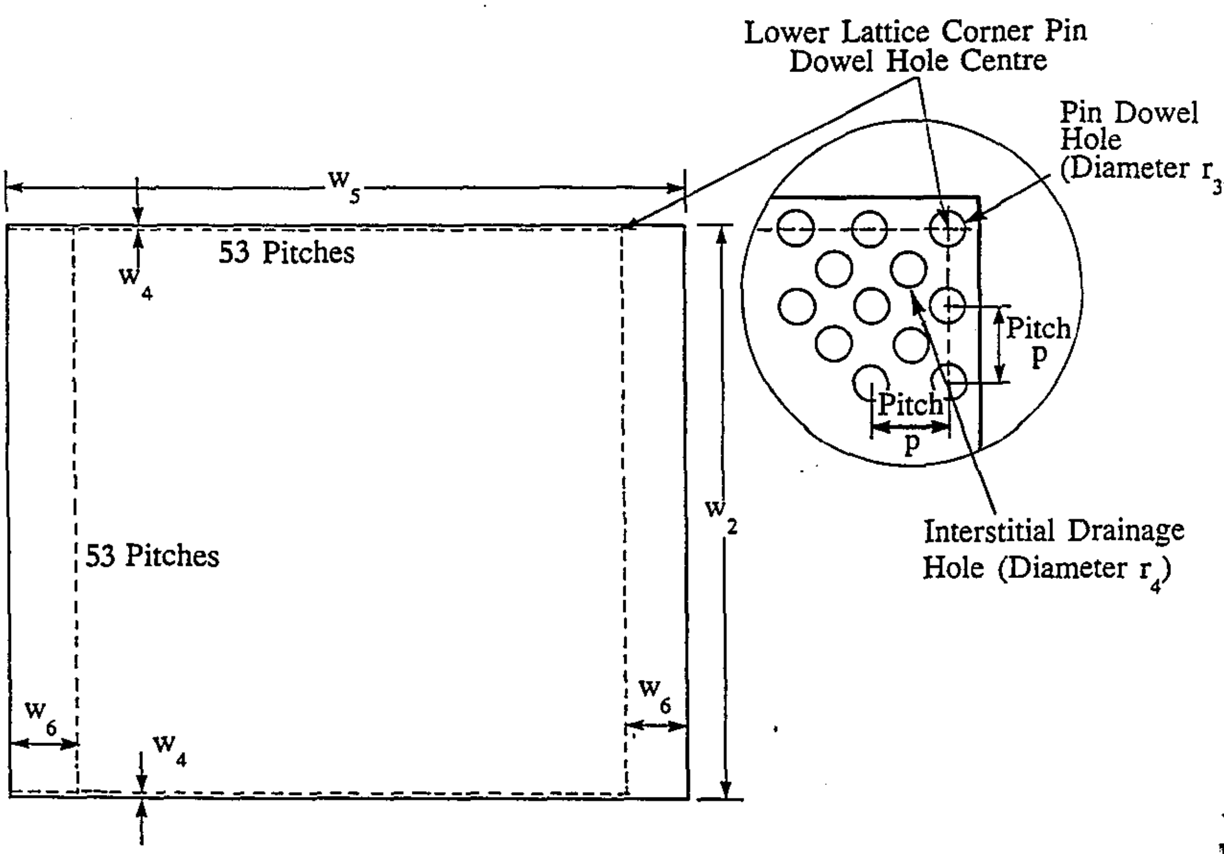


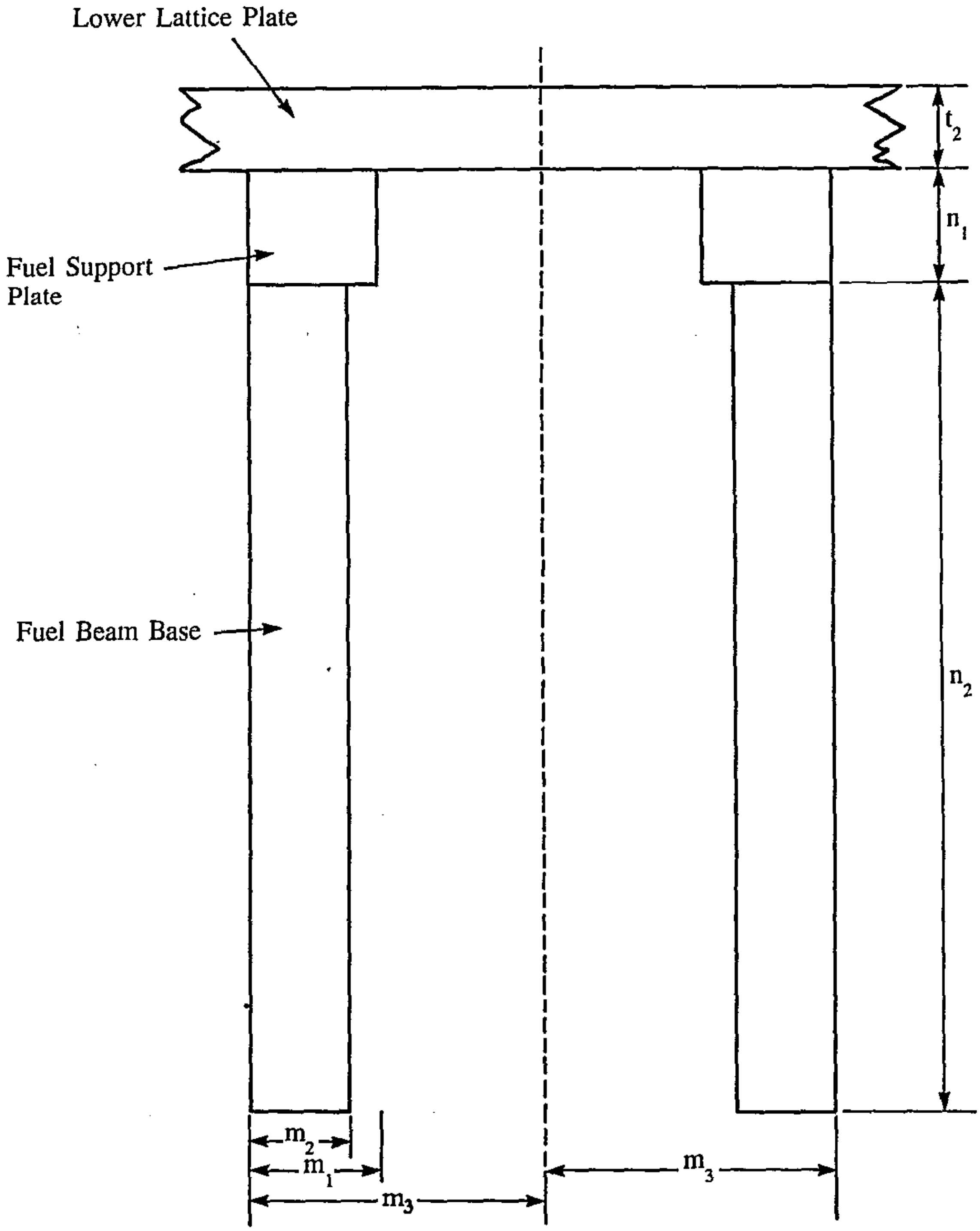


Upper Lattice (Thickness t_1)



Lower Lattice (Thickness t_2)

Figure 8 Simplified Plan Views of Upper and Lower Lattices

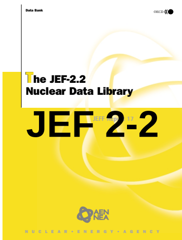


Length of Lower Lattice Plate w_5

Length of Fuel Support Plate w_7

Length of Fuel Beam Base w_7

Figure 9 Simplified View of Lower Fuel Support Assembly



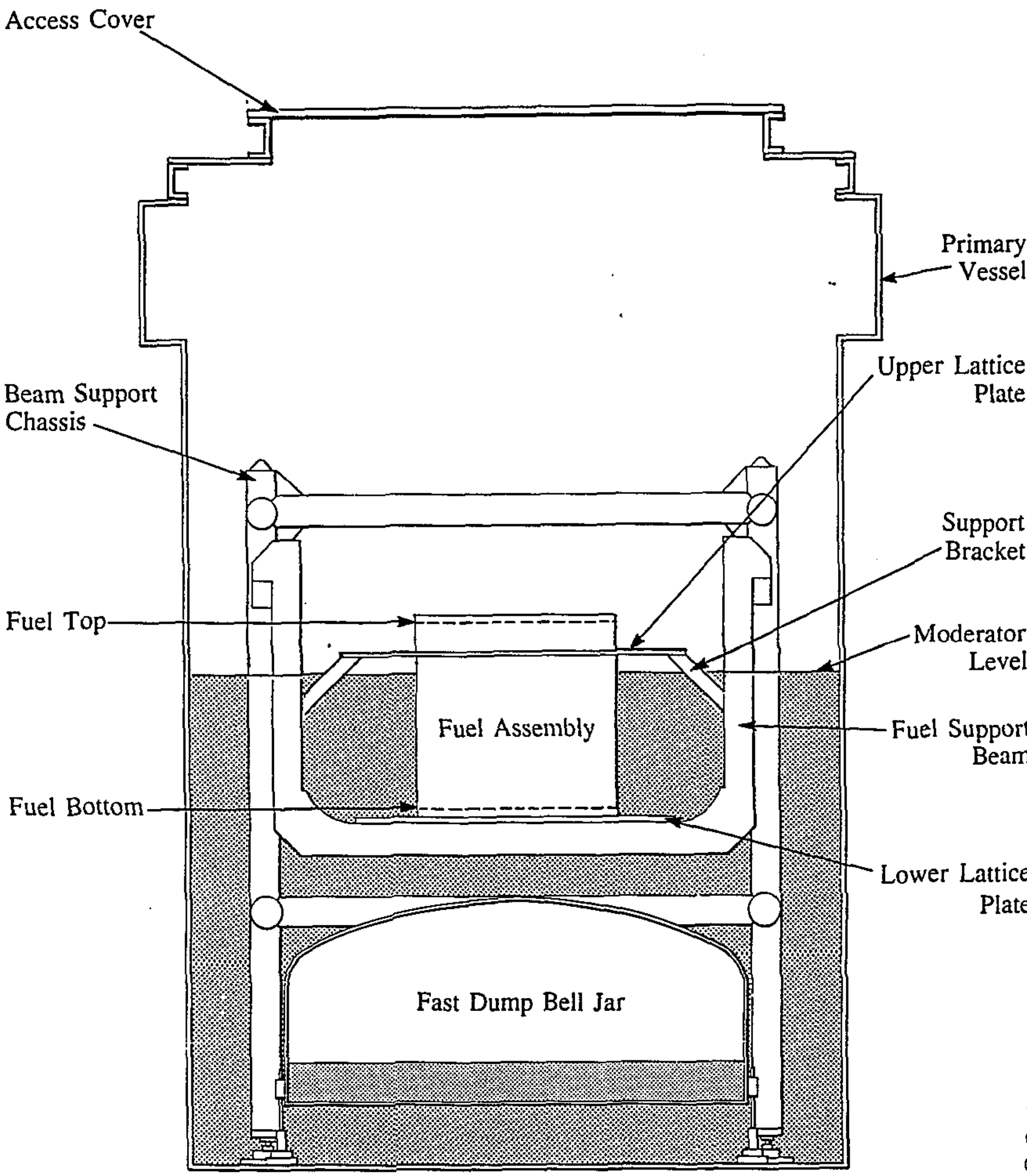


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Figure 10 General Sectional Elevation View

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