SGHWR
And
DIMPLE

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DIMPLE AND ITS CURRENT EXPERIMENTAL PROGRAMME

G INGRAM

1. INTRODUCTION

DIMPLE is a multi-purpose, zero power, water moderated reactor owned by the UKAEA and located at AEE Winfrith in Dorset. Originally it was built at AERE Harwell and from 1954 was used for nuclear data measurements, using the pile-oscillator technique. Twenty years ago it was transferred to Winfrith, a fast-dump system was incorporated, and it was then used to validate water reactor calculational methods, in particular, to support the design of the prototype power reactor at Winfrith, SGHWR. The plant has now been refurbished to continue this role, concentrating on the criticality field, and pursuing an experimental programme relevant to the manufacture, transport, storage and re-processing of reactor fuel. Operation of the reactor began in September this year.

Descriptions of the plant, its potentialities and the first series of experiments related to the transport and storage of low enrichment fuel are outlined below.

2. DESCRIPTION

2.1 Plant Layout

The layout of DIMPLE is illustrated in Figure 1. The reactor consists essentially of a large aluminium tank, 2.6m diameter and 4m high, enclosed in a steel-lined concrete block shield. This provides a secondary containment, which is vented to atmosphere through absolute filters. Stainless-steel pipes link the reactor tank, through dump-valves, to dump tanks located in a pit. These accommodate the moderator when the reactor is shut-down and are also enclosed in a steel-lined secondary containment, again vented to atmosphere through absolute filters.

Additional circuits allow heating, cooling and clean-up of the moderator. Heating is at a rate of 5°C/hour up to a maximum of 80°C. The cooling rate is 10°C/hour down to ambient.

2.2 Reactor Control

Although, in principle, the reactor may be operated with banks of control rods, to maintain clean core geometries, the current series of experiments is controlled by moderator level. When taking the reactor critical, water is added initially to the reactor tank by means of a coarse pump. This is automatically inhibited at a predetermined level, and a fine pump is then used to raise or lower the level by small, precisely determined amounts. A weir, external to the reactor tank, dictates the maximum water level that can be achieved. Depth probes monitor the level of water for safety and experimental purposes, the most accurate of these giving readings to ± 0.1mm.

The reactor power is measured by a series of boron detectors located in submersible pods adjacent to the core. These cover a range of seven decades from shut-down up to the maximum operating power, which corresponds to a peak fuel flux of 3 x $10^8 n/cm^2$-sec. If the reactor power exceeds this maximum value, or the rate of change of reactor power exceeds a pre-set level, the reactor is automatically shut-down.

Reactor shut-down is by means of a fast-dump system. This lowers the water level in the reactor tank by at least 10cm in 0.6 sec and by 30cm in about 1 sec, which is sufficient to compensate the most extreme transients which could be induced by mal-operation of the plant. The principle features of the fast dump system are illustrated in Figure 2. It consists essentially of a bubble of air trapped in a 2m diameter stainless-steel bell jar located under the core. When the reactor is tripped the bubble is vented to the air space at the top of the reactor tank.

Draining of the reactor tank is achieved at a slower rate using a partial dump - valve, which lowers the moderator below the level of the fuel, or by a main dump-valve, which completely drains the reactor tank, or by a combination of the two.

2.3 Core Layout

Figure 3 shows a typical arrangement of a pin lattice assembly within the reactor tank. It also shows the fast-dump system and the submersible pods housing the boron detectors.

The fuel pins are supported rigidly and with a high degree of accuracy on aluminium lattice plates located on U-shaped aluminium beams, which span the reactor tank and which in turn are supported by a chassis secured to the tank. These lattice beams are usually pre-assembled and loaded with fuel in an adjacent building and transported to the reactor using a mono-rail system.

Although, in principle, there are other means of accommodating fuel in DIMPLE, this arrangement with its high degree of reproducibility and its ability to accommodate lattices up to 1.5m in diameter, is being used in the first series of experiments.

2.4 Fuel

Approximately 4 tonnes of uranium oxide fuel, in the form of 10mm diameter sintered pellets, is available for use in DIMPLE. The enrichments range from 2% to 7%, with most of the fuel being at 3% enrichment. Mixed-oxide fuel is also available to provide a better simulation of irradiated conditions.

To facilitate handling, the uranium oxide pellets are wrapped in thin aluminium foil, while the mixed-oxide pellets are sealed in thin-walled aluminium capsules. Both types of pellet are then sealed in cans which may be of aluminium or stainless-steel.

3. EXPERIMENTAL PROGRAMME

3.1 Aims

The main aims of the experimental programme are to:

(a) validate the methods under development for criticality predictions and to establish realistic estimates of the associated uncertainties;

(b) define benchmarks in areas where experimental data are sparse and where the need for data is likely to become of increasing importance to designers;

(c) undertake close simulation of particular designs, under normal and accident conditions, to minimise uncertainties in the assessments for these items.

The programme will pursue a diagnostic approach. Thus the experiments will not only establish the critical size or k-value, but will also examine other physics properties of the assemblies, to probe for possible compensating errors in the methods and data applied in the predictions. This is important if the conclusions from the relatively idealised geometry of the experiments are to be applied with a high level of confidence to the more complex geometries normally encountered in plant and flask designs. These additional experiments will include measurements of the reaction rates of prime importance to the neutron balance, fine structure measurements and reaction-rate distributions through the assemblies.

The programme will include both critical and sub-critical experiments, to extend the range of lattice parameters and to allow mock-ups of practical configurations. This sub-critical work will provide an ideal opportunity to pursue a further aim, to investigate the feasibility of developing a reliable plant instrument for monitoring sub-criticality.

The present reactor hardware is geared to work with pin lattices in light water. In principle the programme could be developed to explore other configurations. Thus, by the use of tanks driven by pin fuel, a technique which has already been applied in DIMPLE to study steam-cooled fast reactor lattices (1), it would be possible to look at a range of solutions. This approach could equally well be used with uranium oxide powders, to extend the range of enrichments and H/U ratios available for validation. However, as the enrichment increases, it could well be worth considering the use of Zebra at Winfrith (2) for this work and for comparable mixed-oxide studies, since this zero power reactor has already demonstrated its potential for k-infinity studies with a benchmark for uranium metal (3).

3.2 Experiments

The first series of DIMPLE experiments is based on the use of steel-clad 3% enriched uranium oxide pins in an existing CAGR flask design. This incorporates a boron-steel walled skip insert and is used to transport irradiated CAGR fuel clusters. The skip insert provides a realistic environment for generic studies and for the development of sub-critical monitoring techniques and also offers the opportunity for validating its proposed use for the storage of dismantled CAGR fuel.

As a necessary preliminary to this work, measurements are being made with the fuel in a simple cylindrical array on a 13.2mm pitch, which is a re-build of an earlier DIMPLE benchmark lattice. This serves the dual purpose of providing a clean geometry reference assembly, while at the same time allowing the properties of the earlier lattice to be re-assessed using up-to-date experimental techniques. In addition, precise modelling of the current lattice in the MONK Monte Carlo Code will provide a rigorous validation for 3% enriched fuel in a relatively high neutron leakage environment.

The loading chosen for the preliminary studies is R1/100H (4), which is shown diagramatically in Figure 4. It comprises 1565 steel-clad 3% enriched oxide pins with a nominal fuel length of 700mm. The experimental programme includes measurements of the fission and capture rates in U238 and the fission rate in Pu239 relative to fission in U235 at the centre of the lattice, fine structure measurements of the U235 fission rate in the moderator relative to that in the fuel and U235, U238 and Pu239 fission rate scans axially and radially through the assembly using foils and fission chambers. In addition, several sub-critical versions of the lattice are being assembled, to commission the reactor noise and modified source multiplication techniques (5) that will be used for sub-critical monitoring in the CAGR skip experiments later this year.

The arrangement of the CAGR skip insert in DIMPLE is shown in Figure 5. Multi-purpose lattice-plates within the skip allow a detailed study of a range of arrays. Typical examples are shown in Figures 6 to 9. That in Figure 6 is a simple square array, which provides a critical reference assembly. Figure 7 is a second critical configuration, where the additional fuel at the boundary increases the interaction between the compartments. A more realistic sub-critical arrangement, typical of a fuel cluster, is shown in Figure 8, and Figure 9 represents a potential accident situation, with the cluster slumping towards the wall of the skip insert. Other accident simulations, where, for example, additional fuel is dropped into the spaces between the cluster arrays will also be included in the programme.

The present range of CAGR skip insert experiments will occupy a large part of next year. The next stage of the programme awaits an assessment of priorities, with the possibilities of introducing fuel at a higher enrichment, introducing mixed-oxide fuel, increasing the level of boron absorption or simulating damage to the skip insert all being under active consideration.

4. CONCLUSION

The DIMPLE plant, its potentialities and its experimental programme over the next year, related to the storage and transport of low enriched uranium oxide fuel, have been outlined above. It is envisaged that the future programme will be developed to include other fuel types and will lead eventually to other absorber configurations.

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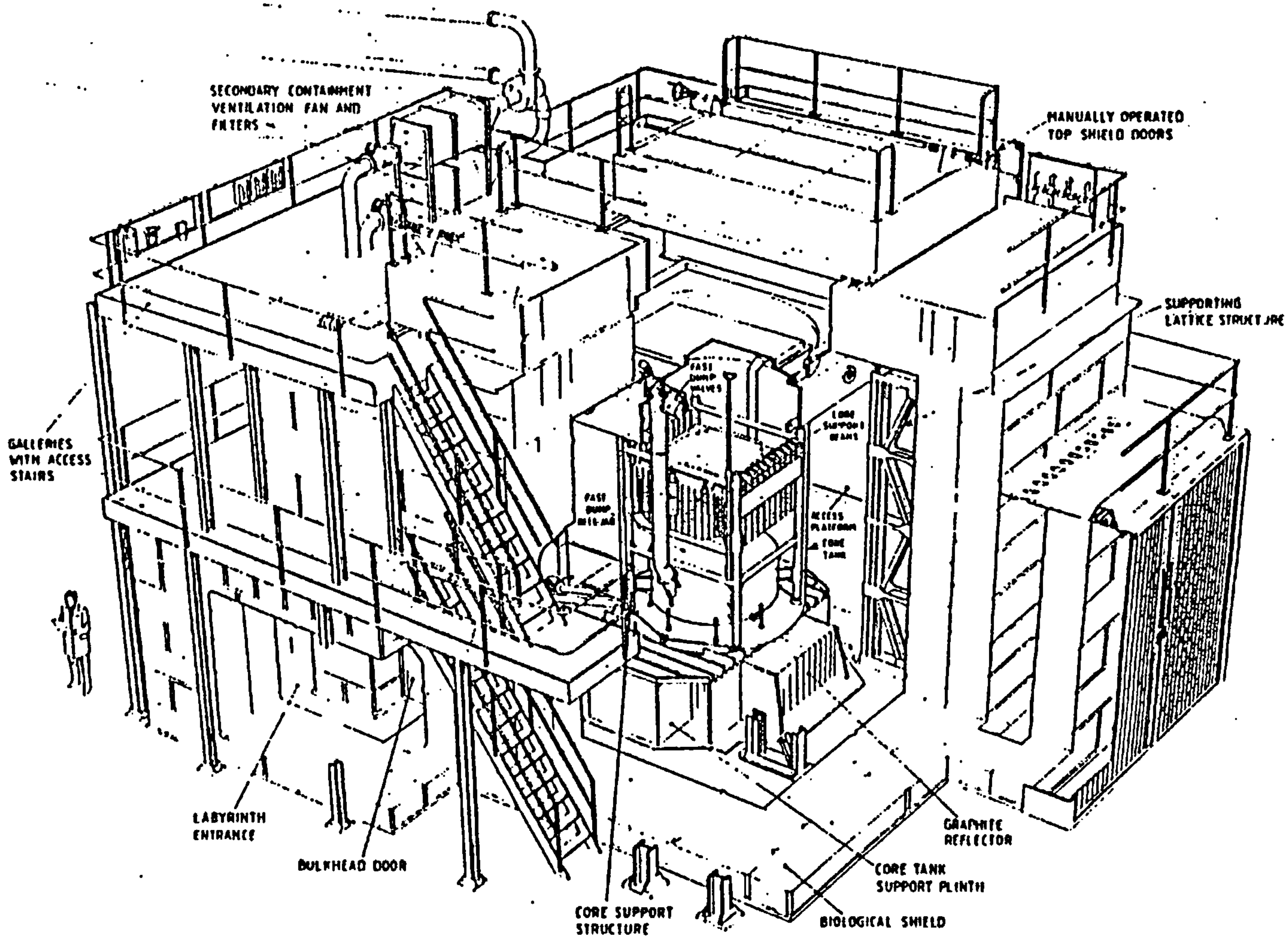


FIG.1. GENERAL VIEW OF DIMPLE REACTOR

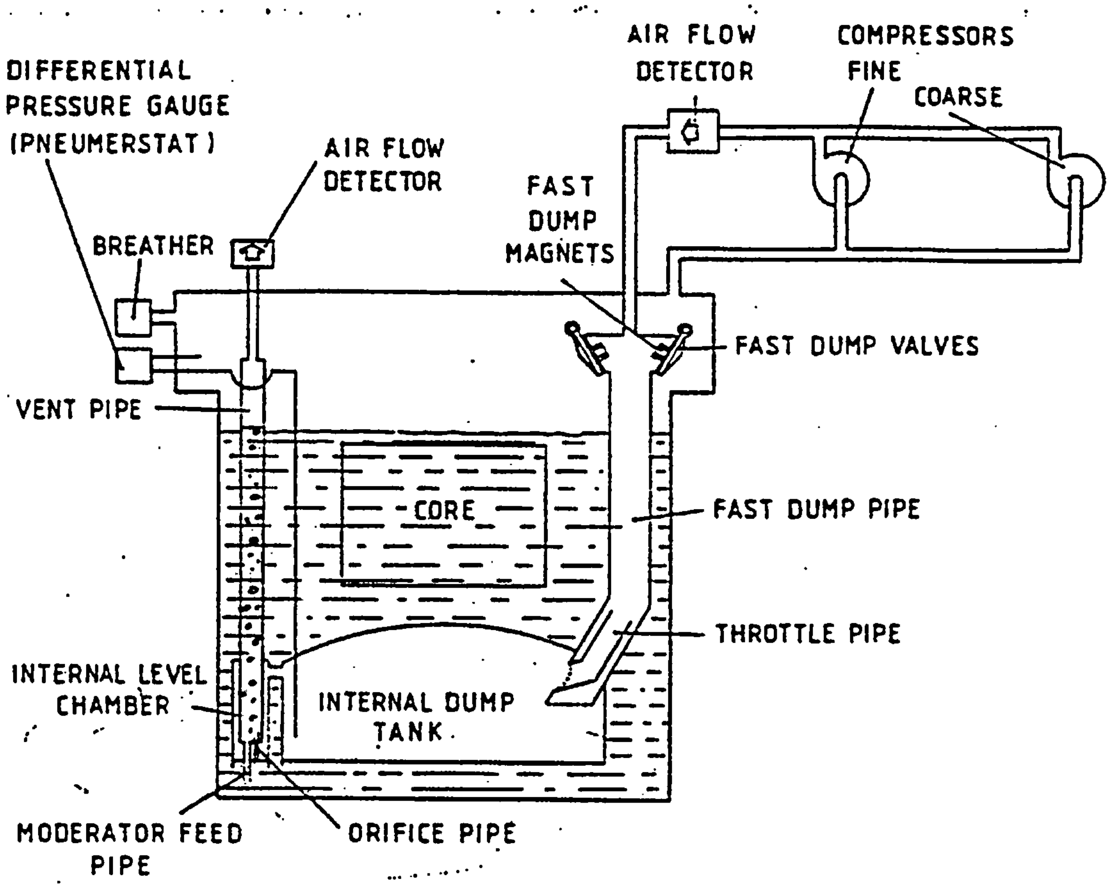


FIG. 2 . DIAGRAM OF FAST DUMP SYSTEM

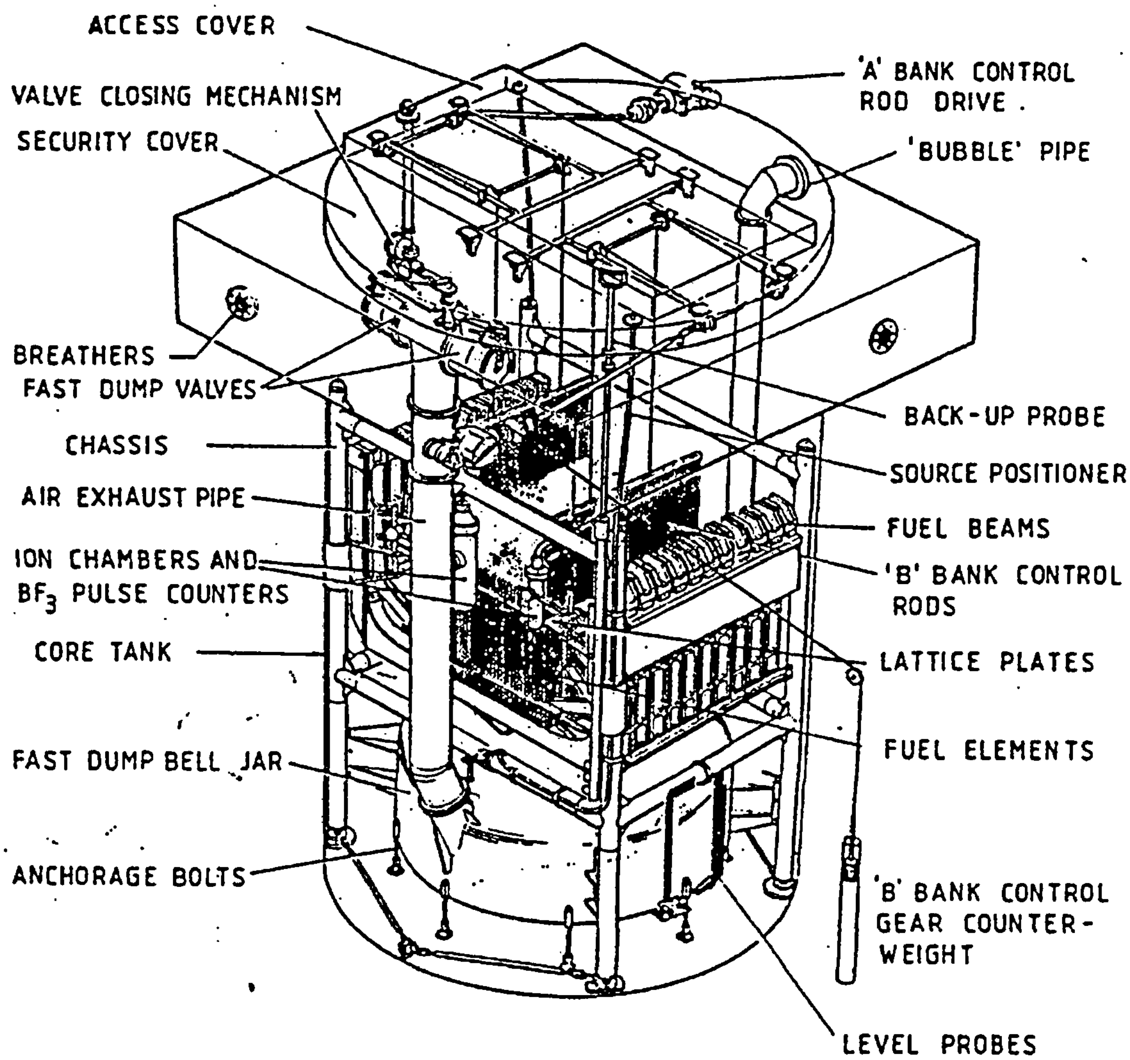


FIG. 3. GENERAL ARRANGEMENT OF CORE

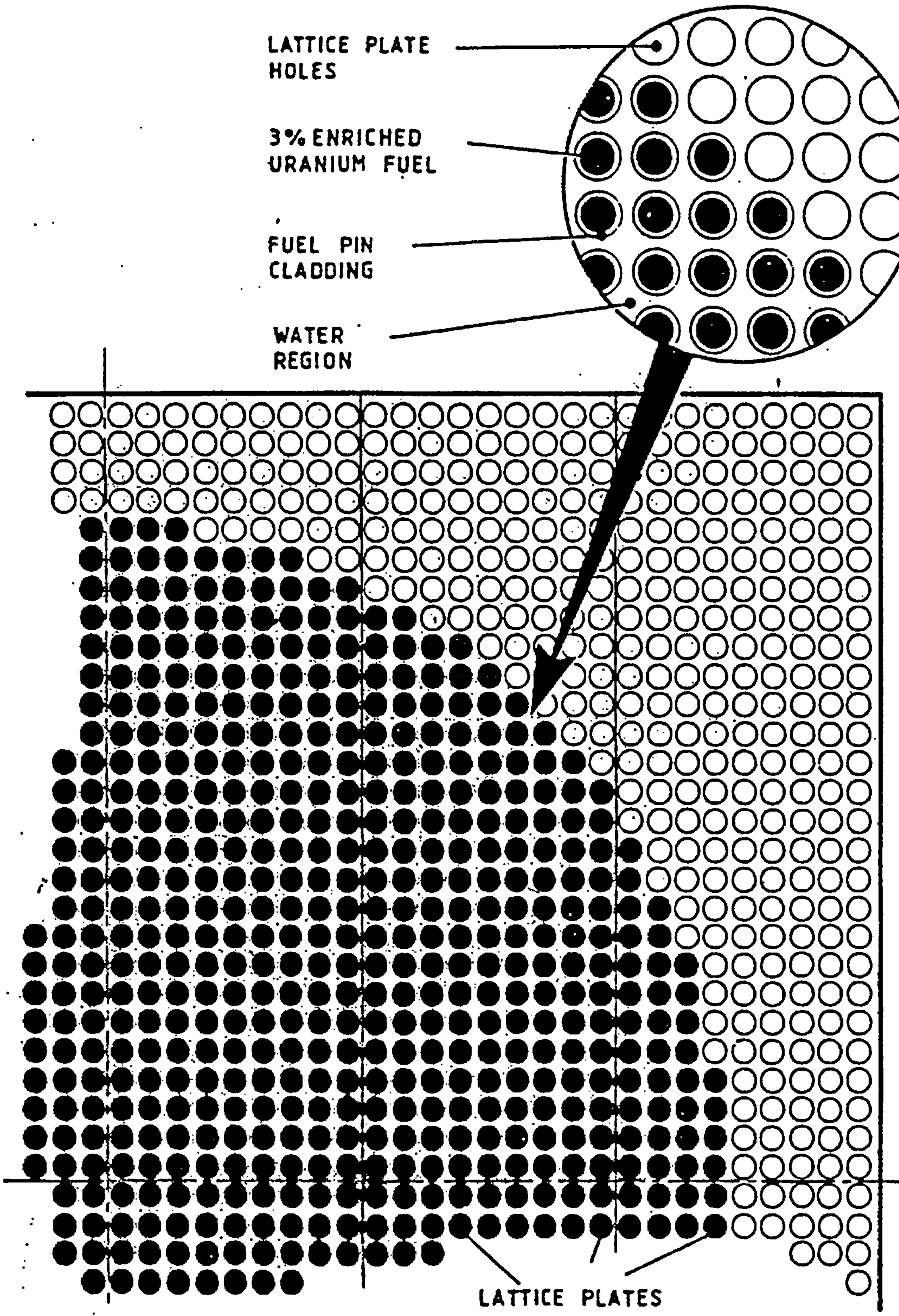
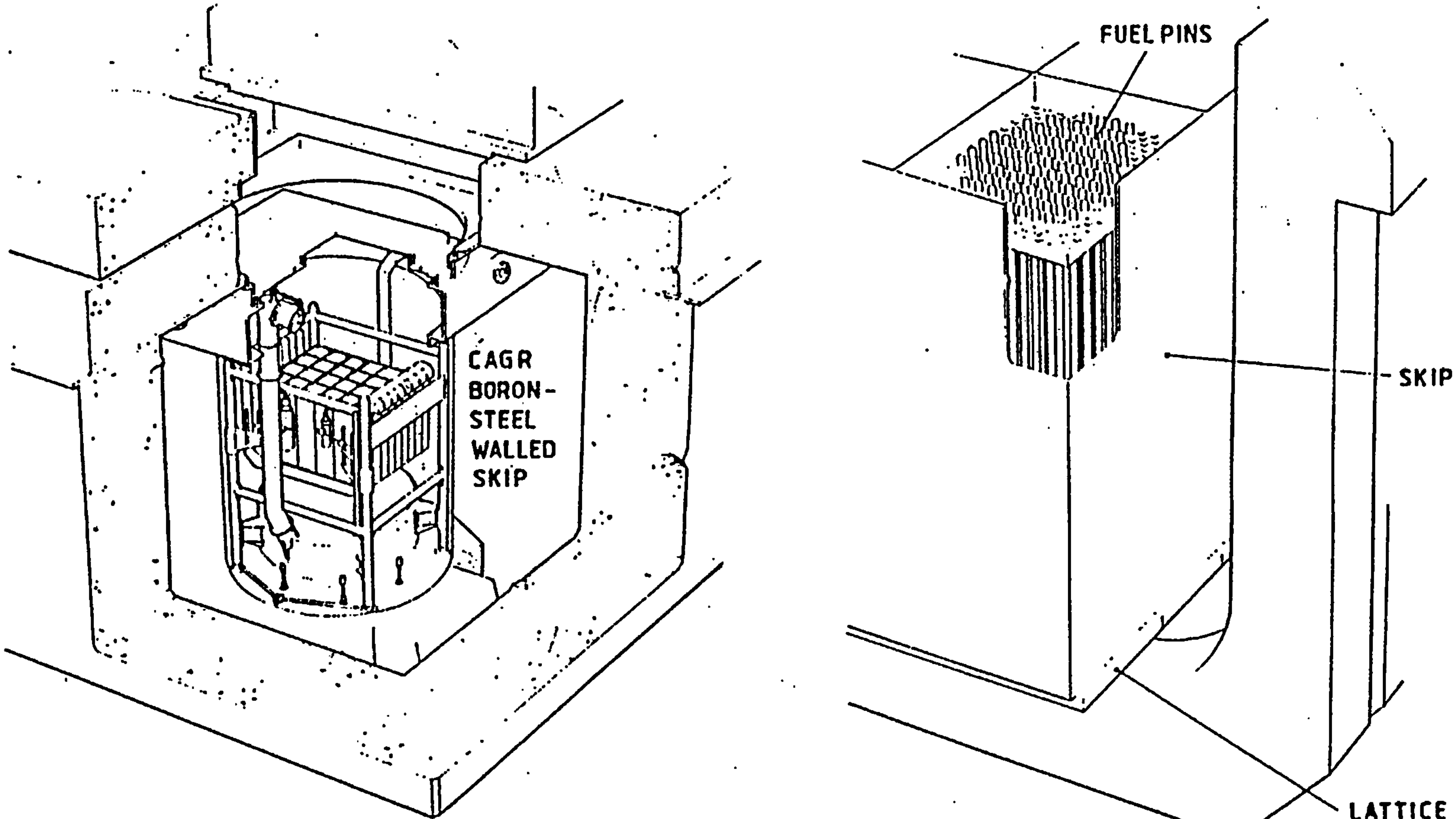


FIG. 4. QUARTER PLAN OF CYLINDRICAL GEOMETRY
3% ENRICHED URANIUM PIN LATTICE, 13·2 mm PITCH



LOCATION OF SKIP ON DIMPLE BEAM

PART VIEW OF SKIP WITH 3% ENRICHED URANIUM

FIG. 5. LAYOUT OF CAGR SKIP INSERT IN DIMPLE

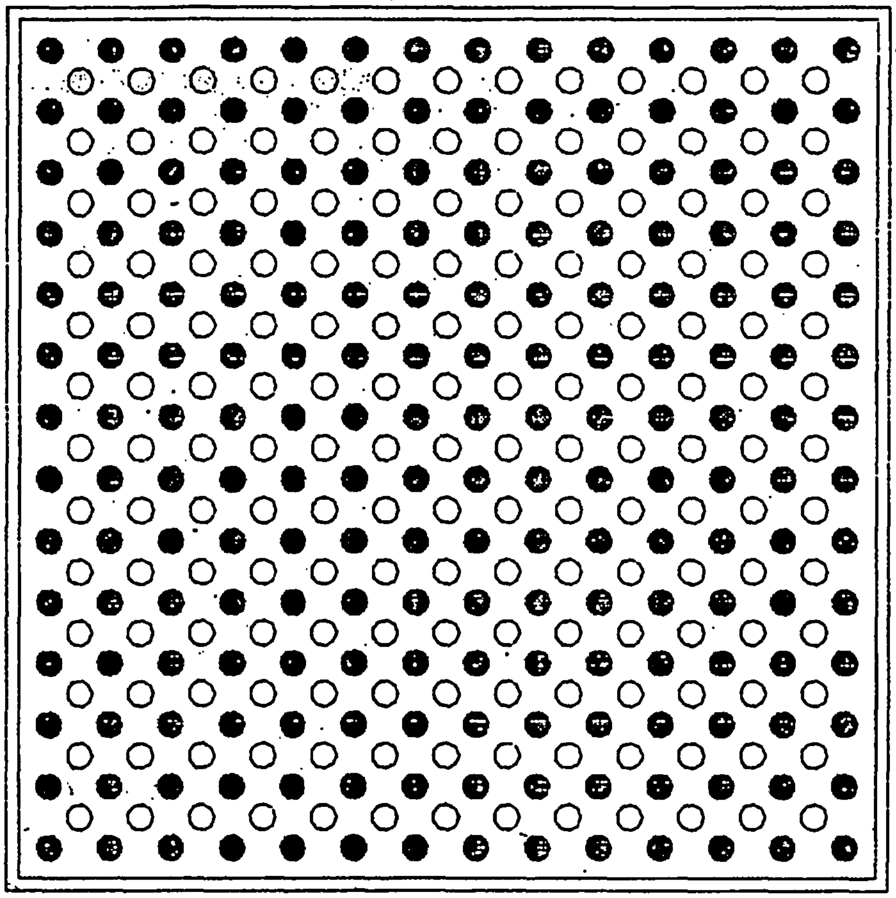


FIG.6. CRITICAL ARRAY

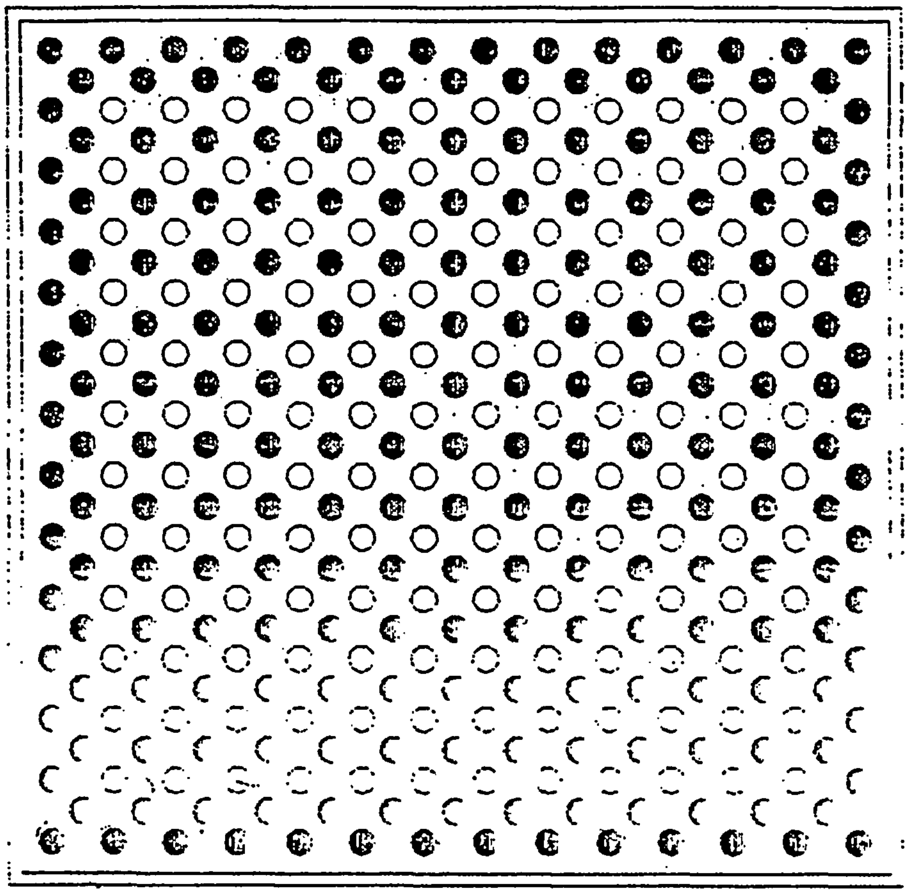


FIG.7. CRITICAL ARRAY, INCREASED FUEL LOADING

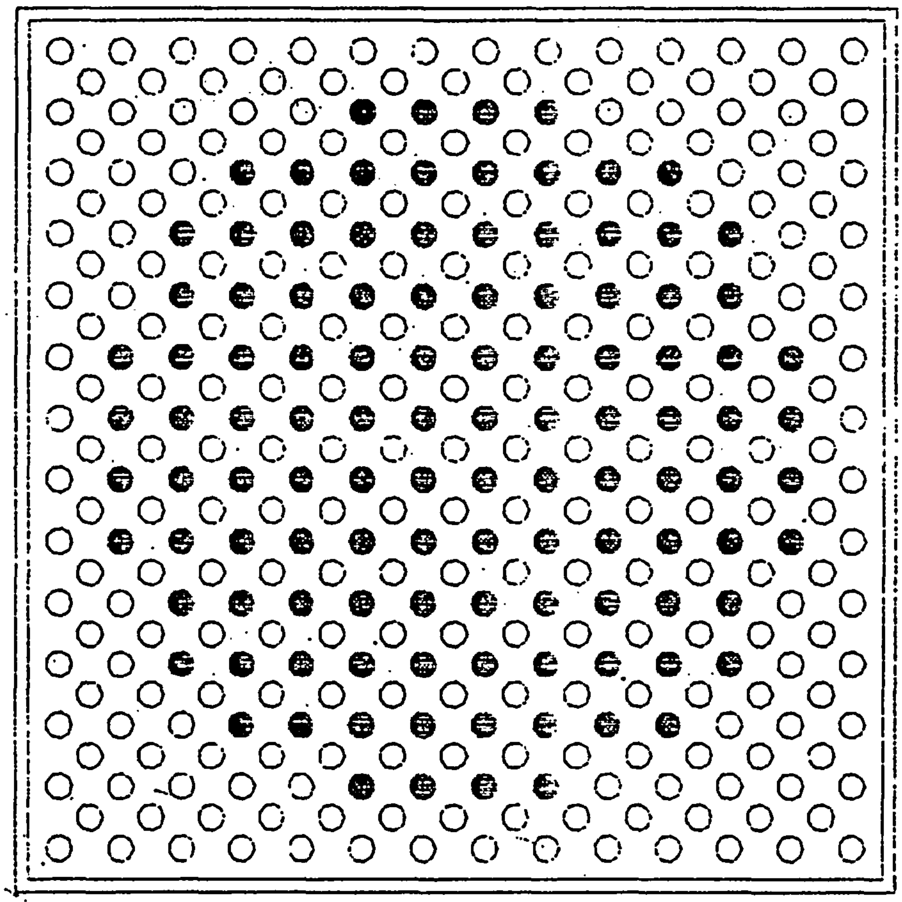


FIG.8. SUB-CRITICAL CLUSTER ARRAY

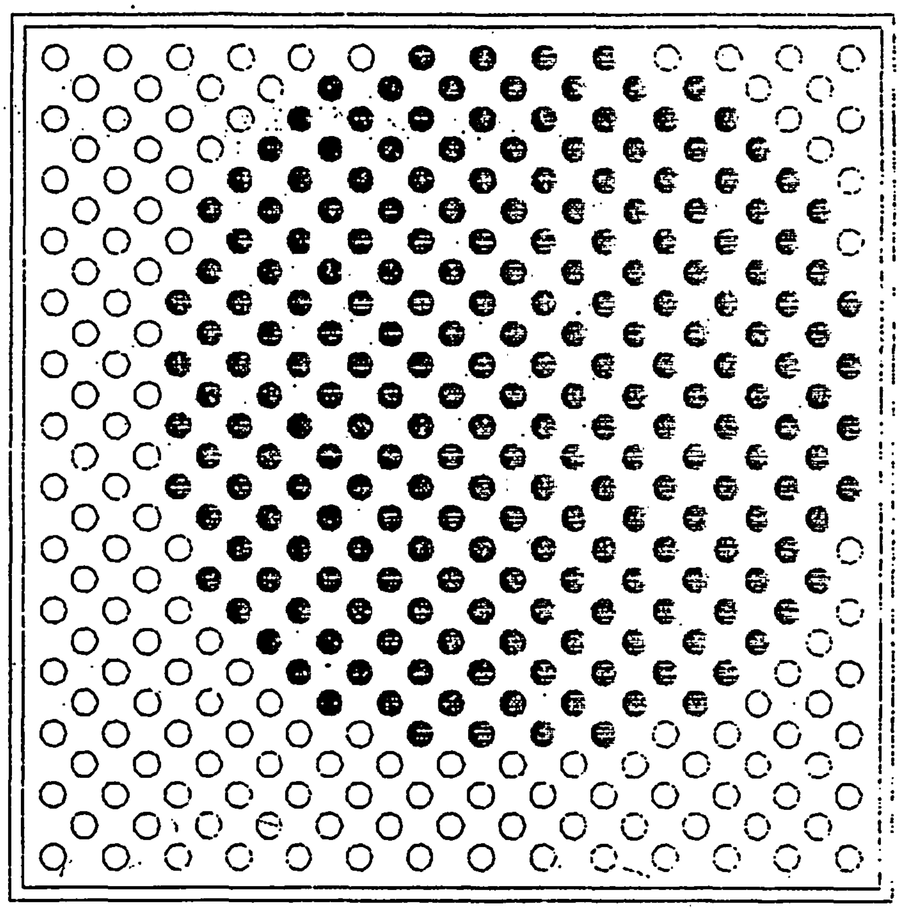


FIG.9. SLUMPED SUB-CRITICAL CLUSTER ARRAY