Power Reactors of Interest to Developing Countries

The increase of oil prices has heightened further the interest of developing countries in nuclear power. The updated IAEA market survey encompassed 55 developing countries and indicated a potential market for 150,000 to 200,000 MW(e) of nuclear capacity in these countries before the end of the 1980's. Some 20% of this capacity was in units of 500 MW(e) or smaller. At the Panel a number of designs for small units was presented in detail and their provenness discussed. Other problems such as financing, contracting, and training were considered. Recommendations on the Agency role in implementing nuclear power growth in developing countries were formulated. Although the definitive time schedule is uncertain, it now seems generally recognized that nuclear power will play an increasingly important role in the electricity production of developing countries.

The Potential Market and Need for SMPRs*)

In 1974 the Agency up-dated and extended its market survey to additional developing countries. The latest data as presented in **Table 1**, indicates the very much increased market for small plants compared with the 1973 market survey reports. As this table indicates, of the total market or 220,000 MW(e) some 20% or 45,000 MW(e) would be in approximately plants of 500 MW(e) or less, with a majority of these plants being in the size ranges 150 – 200 MW(e) [about 60] or 400 MW(e) [about 45].

TABLE 1:
Market for Nuclear Plants in 55 Developing Countries by Size of Unit (1981-1990)

Capacity (MWe)	150	200	250	300	400	500	600	800	1000	1200	1500	Total
Number of units	34	29	13	18	46	14	72	43	42	38	7	356
Total Capacity (GWe) (GWe)	5.1	5.8	3.3	5.4	18.4	7.0	43.2	34.4	42.0	45.6	10.5	220.7

It should be stressed that the Market Survey cannot be considered a firm forecast of installed nuclear power capacity in any specific country studied. There are several reasons for this:

(a) The oil price increase has introduced a discontinuity in the energy demand growth in many countries. The drop in growth or even in the energy consumption level itself may be of a transitory nature but it is extremely difficult to forecast what the new growth rates will be when the situation stabilizes again. They are likely to be lower than past growth rates.

*) Small and Medium Power Reactors

(b) While it is clear that the alternatives to oil fired plants in most of the countries in the market survey now include hydro as well as nuclear plants, data have not been available for a detailed estimation of hydro potential in each country. In several cases hydro projects may now exist which would give cheaper power than nuclear plants. The analytical approach used in the Market Survey is not accurate enough for individual countries when considering hydro and therefore more detailed country studies are needed.

(c) The availability of funds for financing plants will be a deciding factor for the expansion programmes and it is not at all clear that enough funds would be available, or on which terms. Since fossil plants require less initial funding than nuclear ones, they may be chosen despite being less economical in the long term.

(d) The ground rules and cost parameters of the Market Survey, especially the capital costs assumed, may not be realistic but the fact remains that there is little, if any, practical experience on which one could base better estimates.

(e) While the larger plants [600 MW(e) and greater] are commercially available, the availability of smaller power plants has been very uncertain.

Availability of SMPRs

While virtually all the reactor manufacturing States, namely Canada, France, Germany Fed. Rep., Japan, Sweden, the United Kingdom, the USA and the USSR have units operating in the range of SMPR, most manufacturers have standardized for economic reasons on units 600 MW(e) and larger. In Sweden, there have been preliminary studies on small underground units, while the USSR has recently placed in service 24 MW(e) units at Bilibinsk on the Bering Strait.

Heavy water reactors of either the CANDU or SGHWR type (manufactured by AECL, Canada, and the Nuclear Power Group, UK, respectively) have been proposed for the size range of about 300 MW(e). These units would become available through either scaling down from 500 MW(e) units (Pickering CANDU) or scaling up from the 100 MW(e) (Winfrith Heath SGHWR) unit, which are currently in operation. The British programme has chosen the 600 MW(e) size SGHWR so the scale-up to this size will be available. In the case of both these reactors there is hardly any domestic interest in SMPRs. It would therefore be necessary to have joint action by several potential customers before a SMPR design would be initiated.

Both CANDU and SGHWR are of a basically modular design, which should be considered when evaluating the problems of size variation. With the SGHWR designs, up to 1300 MW(e) can be achieved by increasing the number of identical channel units using the same operating parameters as the Winfrith plant. Other components such as steam drums, pumps and valves do not require special design or deviation from the range of proven manufacture.

Another category of units for small and medium size reactors proposed at the Panel was the pressurized light water type. In general these designs are based on experience with ship propulsion. The Interatom (F. R. Germany) design is for integral PWRs in the size range 35-310 MW(e) based on the Otto Hahn plant as shown in **Table 2.** A PSAR (preliminary safety analysis report) has been submitted to national licensing authorities for a ship reactor of this type which would correspond to a 220 MW(e) plant and conceptual safety clearance is expected in 1975. **Figure 1** is a photograph of the steam generator of the N. S. Otto Hahn whose components are similar to the design for land-based units.

Table 3 presents some technical data presented at the Panel for Technicatome's (France) PWRs which are also based on experience with naval propulsion units. The size ranges encompassed are from 35 – 95 MW(e) and a 310 MW(e) unit. The primary circuit of the large unit is shown in **Figure 2.** These units represent studies of the advanced conceptual design stage for which detailed cost estimates have been made and found promising.

A 35 MW(e) plant may be installed in the future in Polynesia. In the context of these design studies different direct heat applications have also been investigated and industrial process heat uses in France may call for the first installations of plants of this type.

Another integral PWR type plant discussed at the Panel is being developed by Babcock and Wilcox (USA) for ship propulsion. This unit could produce over 90 MW(e) in a land-based version (**Figure 3**). A preliminary safety analysis report for the ship reactor has been submitted to US regulatory authorities but licensing is not yet complete. The first

TABLE 2: Technical Data for Interatom Integral PWRs

Electrical Power Output, MWe	35	58	89	120	182	245	310
On Site Power Demand, MWe	2	3.5	5.5	7	11	14.5	18.5
Gross Power Output, MWe	37	61.5	94.5	127	193	259.5	328.5
Thermal Power Capacity, MWth	120	200	300	400	600	800	1000
Reactor Power Density, MWth/m^3	←			70			→
Number of Fuel Elements	32	45	57	69	89	101	121
Fuel Rod Configuration	←			15 X 15			→
Fuel Rod Outer Diameter, mm	←			10.75			→
Primary System Pressure, kg/cm^2	←			98.4			→
Steam Generation rate, kg/s	62	103	155	206	309	412	515
Steam Pressure, Kg/cm^2	←			48			→
Steam Temperature, °C	←			270			→

TABLE 3: Technical Data for Technicatome PWRs

Net Electrical Power Output, MWe	35	60	95	340
Thermal Power Capacity, MWth	135	220	330	1100
Number of Fuel Elements	56	72	112	112
Enrichment of Fuel, Wt % U-235	5	5	5	3.5
Number of Control Rods	12	16	20	33
Primary System Pressure, kg/cm^2	143	143	143	160
Steam Pressure, kg/cm^2	48	48	48	59
Steam Temperature, °C	261	261	254	298
Number of loops	1	2	3	2

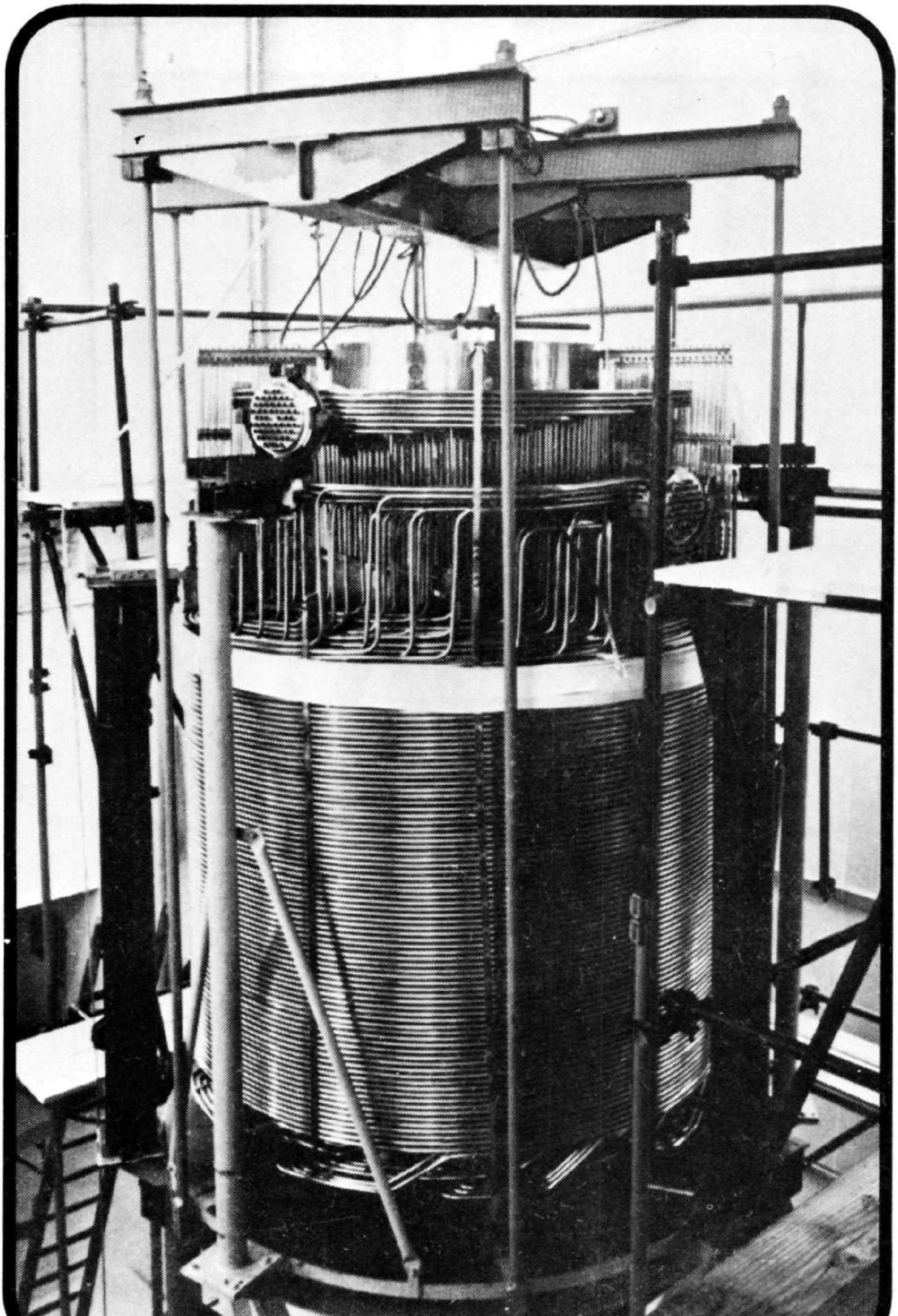

Fig. 1. Steam generator of N.S. Otto Hahn. Credit: Interatom

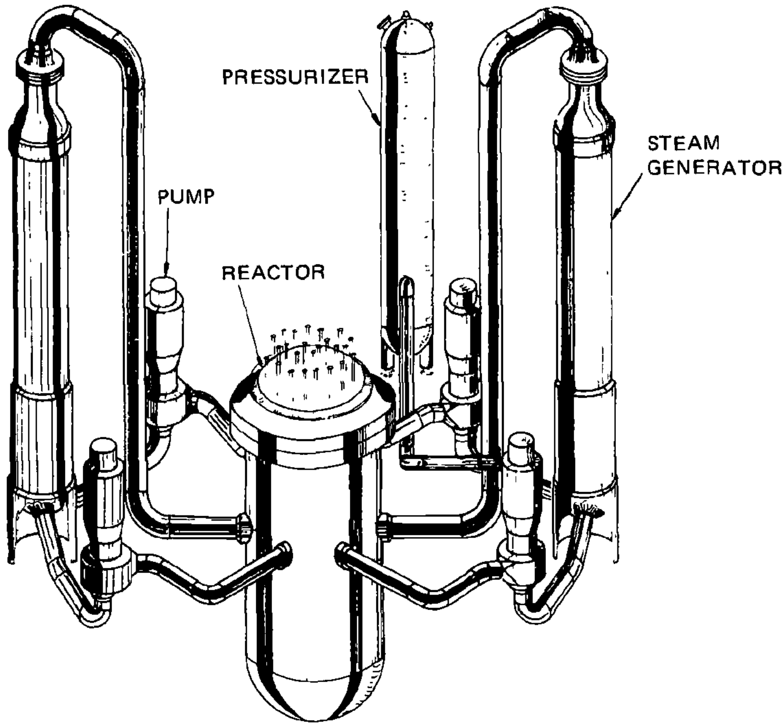

Fig.2. Primary Circuit of Technicatome 340 MWe Unit
Credit: Technicatome

commercial unit may be in operation in the early 1980's in a ship. Although a ship plant is more difficult to design than a land-based unit, the transformation into a land-based plant will require considerable and costly engineering work. Thus, this type of plant may eventually be offered commercially in land-based units but it will be many years before it can be done.

Contract Types and Financing

As expected, the possible contract types would vary greatly between different suppliers, from a pure turnkey contract for the whole plant from the reactor vendor to a separate contract for the nuclear steam supply system, turbine, and balance of plant. Some financing institutions have indicated a preference for a package type of contract in which competitive bidding for the various plant systems is assured. Such a package which would involve a nuclear steam supply system of nuclear island for which an engineering-construction firm could take on the overall project responsibility.

Financing institutions criteria would normally require that the potentially available units for sale to developing countries could be considered proven and licensable. The former criterion is quite difficult to apply in general, and would have to be judged in particular

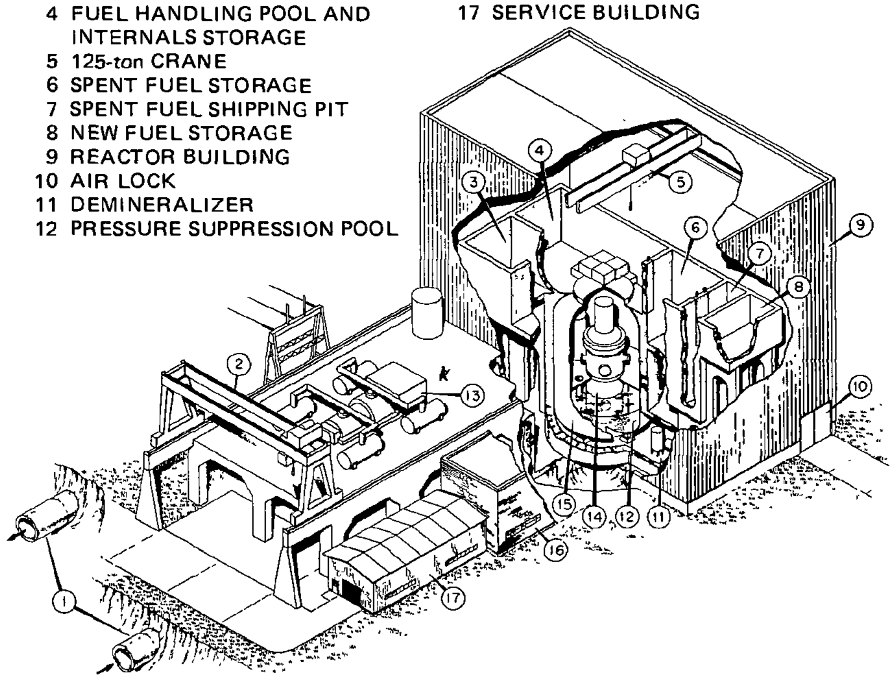

Fig.3. 313 MW(t) Nuclear Steam Supply with 90-MW(e) Turbine Generator
Credit: Holifield Nat. Lab.

applications. The IAEA's efforts in developing a set of internationally acceptable safety criteria and standards will aid the foreseen needs of the developing countries relative to the second criterion. The domestic operation in the manufacturer's country of a similar unit or reference plant to the one being sold the developing country appears to be an ideal way of meeting these criteria.

Another important aspect is the scale of financing required through 1990. This level was estimated for regions of the 55 developing countries covered by the Market Survey as follows:

	Billions of Dollars*
Europe, Middle East and Africa	24.5
Asia and Far East	35.3
Centrally Planned Economies	13.9
Central and South America	24.3
Total	98.0

* 1974 Constant US Dollars

The level of those capital requirements is formidable and can very well be one of the limits to the growth of nuclear power in these countries. The outlook for funding may not be very encouraging and concessionary terms which have been given on some nuclear reactors in the past are less likely to be available.

In the context of these financing difficulties it does not seem too likely that larger-than-needed commercially available units will be purchased and operated at low capacity as an alternative to small units. This approach can be economical over the long term and is an immediate way to purchase a commercially available reactor. It does not seem likely, however, since it would exacerbate the problems of initial capital requirements. In addition, once a large nuclear unit is connected to a grid there would be a tendency to operate it at full capacity because of its low operating costs. If the nuclear unit's capacity is a significant fraction of the total grid, the system's reliability can be severely reduced.

IAEA's Future Plans

Evolving from the recommendations of the November 1974 Panel, the Agency is convening a technical group from reactor manufacturing countries on June 30, 1975 to prepare a catalogue of small and medium power reactor design characteristics. This catalogue will contain up-to-date technical data, and to the extent possible, realistic cost estimates.

This catalogue could be used as an input for further discussions by Member States as they plan their electrical power programmes. During the General Conference (September, 1975) there will be the opportunity also to discuss the possibility suggested by the Panel regarding future concerted action by several potential buyers interested in SMPRs.

The possibility of an interest by buyers in six to ten essentially identical units could help to make more designs available. Such co-operation by the potential buyers would probably also help to assure that capital costs could be held within a reasonable range.

INTERNATIONAL SYMPOSIUM ON
ADVANCES IN BIOMEDICAL DOSIMETRY, VIENNA, 10-14 MARCH

Thirty-one countries and 5 international organizations were represented by 139 participants and 15 observers at the symposium, during which 49 papers were presented in 10 sessions.

Dosimetry in Life Sciences

The uses of radiation in medicine and biology have grown in scope and diversity to make the Radiological Sciences a significant factor in both research and medical practice. Of critical importance in the applications and development of biomedical and radiological techniques is the precision with which the dose may be determined at all points of interest in the absorbing medium. This has developed as a result of efficacy of investigations in clinical radiation therapy, concern for patient safety and diagnostic accuracy in diagnostic radiology and the advent of clinical trials and research into the use of heavily ionizing radiations in biology and medicine.