Manpower Requirements for Future Nuclear Power Programmes

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The scarcity of engineers and technicians trained in nuclear power technology may inhibit the growth of nuclear power if steps are not taken to insure an adequate supply of well-trained technical manpower. This paper examines the projected growth of nuclear power to the year 2000. Estimates of technical manpower needed to satisfy this growth are made to 1990, and estimates of the number of engineers being graduated are compared. Finally, criteria are chosen to establish those geographical areas which will probably experience technical manpower stress because of nuclear power programmes.

FORECASTS OF NUCLEAR POWER GROWTH

An early 1973 forecast of nuclear power programmes in OECD countries up to 1990 is given in the joint report by the OECD Nuclear Energy Agency and the IAEA[1]. These data were extrapolated to the year 2000 using the "most likely" growth rates given in a USAEC forecast[2], and are shown in Table 1.

The forecast growth of nuclear power in fourteen selected developing countries throughout the world (Argentina, Bangladesh, Chile, Egypt, Greece, Jamaica, Korea, Mexico, Pakistan, Philippines, Singapore, Thailand, Turkey and Yugoslavia) was developed by the IAEA for the 1973 Market Survey for Nuclear Power in Developing Countries[3]. Using the Market Survey results and methodology as a basis, a preliminary evaluation has been made of the potential market for nuclear plants in all of the developing countries of the world. These results provided a basis in early 1973 for estimating the installed nuclear capacities of the non-OECD regions shown in Table 1.

As a consequence of the large world oil price increases which occurred in late 1973 and early 1974, the national nuclear programmes in many countries heavily dependent on oil for power production were revised upward. The more recent forecasts were based on the

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1 OECD – NEA/IAEA Joint Report, Uranium Resources, Production and Demand, August 1973
2 USAEC, Nuclear Power 1973–2000, WASH-1139, 1972
3 International Atomic Energy Agency, Market Survey for Nuclear Power in Developing Countries: General Report, STI/PUB/357, August 1973

The OECD Dragon Reactor at A.E.E. Winfrith, England, being developed for possible commercial exploitation, is an example of the many areas for which trained manpower will be required in the near future. Photo: UKAEA ▶

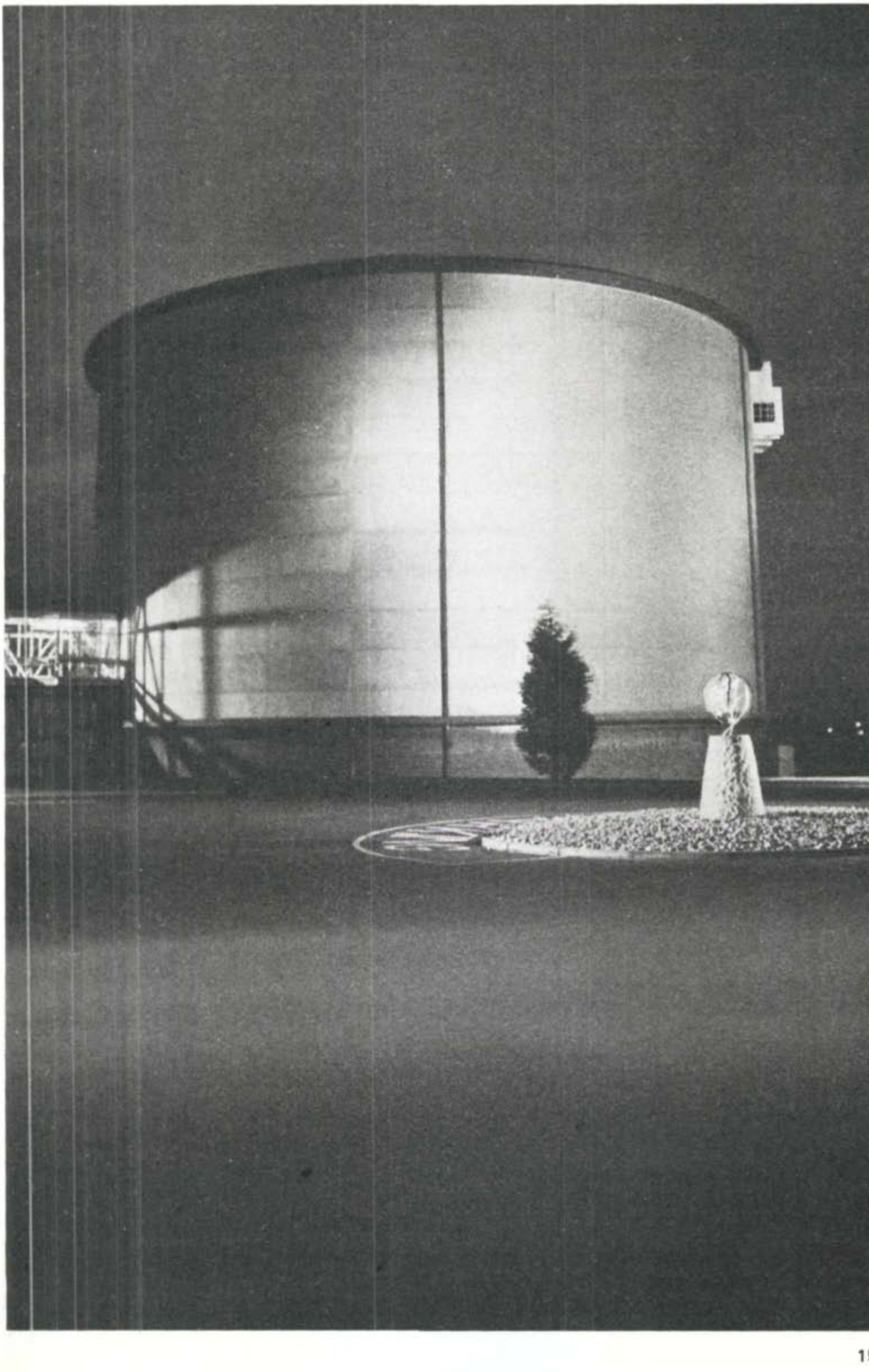

Table 1: Early 1973 Projections of Installed Nuclear Capacity by Region (GWe, end of year)

REGION	1975	1980	1990	2000
OECD Europe	26.5	81.3	373	1000
OECD North America	56.7	138.5	539	1300
OECD Pacific	8.6	33.0	106	250
Latin America	0.3	3.4	49	140
Asia and Far East	1.7	5.9	56	150
Africa and Middle East	–	1.2	21	45
Centrally Planned Economies	9.5	38.4	246	670
World Total[a]	104	302	1390	3580

[a] Excluding China

Table 2: Summary of Engineering Manpower Estimates of Future Requirements for Nuclear Power Programmes

REGION	1975	1980	1985	1990
OECD Europe	16 300	30 000	49 000	71 000
OECD North America	23 000	41 000	62 000	88 000
OECD Pacific	6 300	8 800	12 900	18 100
Centrally Planned Economies	11 100	22 000	40 000	57 000
Asia and Far East Min. Domestic	900	2 000	3 800	5 800
Poss. Foreign	1 680	3 600	5 500	7 000
Latin America Min. Domestic	580	1 580	3 200	5 300
Poss. Foreign	1 440	3 200	5 100	6 400
Africa and Middle East Min. Domestic	360	1 100	2 400	3 800
Poss. Foreign	860	2 300	4 500	5 300

assumption that the future growth in total electricity demand would not decline appreciably as the result of high oil prices. The more recent forecasts also assume that the nuclear share of future capacity additions would not be influenced by opposing factors such as the increased use of indigenous energy sources, environmental consideration, the scarcity of investment funds, and the unwillingness of the public sector in many countries to accept a rapid proliferation of nuclear plants. Recognizing that such factors may tend to ameliorate the growth of nuclear power, it was decided for the purpose of this paper to adopt the more conservative forecasts of early 1973 shown in Table 1, rather than the more recent forecasts of accelerated demand.

MANPOWER ESTIMATION, MODEL AND RESULTS

To make estimates of the future manpower needs for the forecast nuclear power programmes, it was necessary to assume a simplified model fuel cycle consisting of plants for conversion of yellow cake or nitrate to UF_6, plants for enrichment, plants for conversion of UF_6 to UO_2 and fuel fabrication, nuclear power plants, reprocessing plants and plants for production of mixed oxide recycle fuel. Light water reactors have been assumed to dominate up to 1990, but case studies have been made with a significant part heavy water reactors. Uranium mining has been left out as it would have to be estimated based on future resource locations rather than fuel cycle requirements in other locations but experience would indicate that the additional manpower requirements would be marginal even though they may be important locally. Manpower requirements for research and development programmes have to be estimated separately.

The manpower requirements have been estimated for model facilities based on experience from existing industrial plants. For the fuel cycle plants, it was assumed that one would be introduced when needs would justify a plant of minimum commercial size. It was also assumed that the same trained staff as for operation would be needed for project work and commissioning during a reasonable lead time before plant production. For nuclear power plants, which will pose the major manpower requirements, it was necessary to make a more detailed estimate due to both the large qualified staff needed during the preparatory stages and the long time schedule of ten years from initiation of a project until commercial operation (two years preparation, site selection and early design; two years bidding and preparation and review of safety report and six years construction time). The project time was divided in two periods of four years preparation and six years construction, and manpower requirements[4] were averaged over these periods for both the owner organization and the supplier organization. For regions without reactor plant suppliers this also gives a possibility to estimate separately domestic and foreign manpower requirements.

With these models it is possible to project approximately the basic requirements for trained manpower to support the forecast nuclear power programmes up to 1990. Part of the results are given in **Table 2** for engineering manpower. There are, however, several fundamental difficulties in making these estimates. The first is that different countries have different educational systems, and there would be differences in allotting a specific task to an engineer or a technician. Furthermore, the model plants include some which have not yet been realized, e.g. 1500 t/y reprocessing plants or 25 t Pu/y recycle fabrication plants.

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[4] R.W. Deutsch, J.W. Whitney; Nuclear News, June 1974, p. 71, and WASH-1130 (Revised).

Table 3: Approximate Distribution of Engineering Manpower to Occupational Discipline for four Major Nuclear Power Industry Segments in the U.S.A., 1972 (percentage)

SEGMENT	Discipline					
	N.E.	Ch.E.	M.E.	E.E.	C.E.	Others[a)]
Nuclear Utilities	9	3	29	38	16	5
Nuclear Steam Supply System Manufacturing	17	13	41	15	5	9
Nuclear Architect-Engineer	21	8	23	5	22	21
Fuel Processing, AEC, and Small Reactor Component Manufacturing	16	20	34	20	7	3

a) Includes quality control engineer, reactor licensing engineer, and environmental specialist.

Table 4: Percentage of all Engineering Graduates of Preceding 5 Years Required by the Nuclear Power Industry

REGION	1975	1980	1985	1990
OECD Europe	4.3%	6.1%	8.4%	10.4%
OECD North America	6.0%	8.8%	11.4%	14.1%
OECD Pacific	1.4%	1.4%	1.6%	1.9%
Centrally Planned Economies	0.6%	0.8%	1.2%	1.4%
Asia and Far East (Domestic)	0.5%	0.8%	1.1%	1.4%
Latin America (Domestic)	0.5%	1.0%	1.6%	2.1%
Africa and Middle East (Domestic)	0.4%	0.9%	1.5%	2.0%

For these it has been necessary to estimate staff requirements using scaling factors from the chemical industry. A third difficulty is that, while it is reasonable now to state what the minimum economical plant sizes are, it is not possible to assess the size of plants which may be in operation in the late 1980's. Finally, it should be possible to achieve considerable manpower savings through integrated planning and management of several plants, particularly if the industrial structure in a country permits this. These savings cannot be estimated for whole regions but attempts have been made to estimate them from individual countries with resulting savings of engineers of up to about 25% of the forecast requirements.

AVAILABILITY OF ENGINEERS

Statistics reporting the number of engineers and technicians being trained each year have been tabulated annually for each of its Member States by UNESCO[5] and several other agencies and foundations. For a number of reasons, these data are not without discrepancies, especially with respect to the training of technicians. This is partly due to the fact that there is such a diverse system of training programmes and schools for the training of technicians, and such a broad definition of the term "technician" used internationally. If craftsmen are at one end of the technician scale and engineers at the other, the dividing lines are not clearly understood or agreed to from one country to another, or even from one industry to another. Engineers are somewhat easier to identify, being graduated from universities, technical colleges, or equivalents. The data on engineers seems to be more consistent and more reliable than for technicians, and for this paper only the engineering data are used.

The model for estimating the future supply of new engineers available to the nuclear power industry in the various regions of the world is based on the following assumptions:

(1) Engineers from all of the basic specializations will be employed by the nuclear industry, and

(2) A linear extrapolation of the data on new engineering graduates for the years 1960 to 1970 can be used to estimate the number of new engineers being made available in 1975, 1980, 1985, and 1990.

The history of technology has shown that when a major new technology has been developed and begins to become well-established and widely used, engineers from many disciplines participate in the growth of the new industry. Eventually there may be developed specialized curricula for training engineers especially for the new industry, but initially there are no such specialized curricula available. This evolution appears to be at least in part true also for the nuclear industry. At present, only a small fraction of the engineers needed by the nuclear industry are being trained in the nuclear engineering curricula, and the major portion are produced by the basic curricula of electrical, mechanical, chemical, and civil engineering. An example of this is demonstrated in **Table 3** showing the background for the nuclear industry in the United States in 1972. Also, because of the complex nature of the nuclear industry, many of its technical problems are specialized, and can best be handled by engineers trained in the basic engineering disciplines. For these reasons, the estimates of the future technical manpower supply for the nuclear industry are based on the estimates of the future supply of new engineers of all disciplines.

Projections of the number of engineers being graduated each year can be compared with the number of engineers required each year by the growing nuclear power industry. These projections have been made for several regions and for several typical countries. **Table 4** shows the percentage of engineers being graduated that are likely to be required by the nuclear power industry for the years 1975, 1980, 1985 and 1990. For OECD Europe and OECD North America, the average annual increases in the number of engineers being graduated is based on the average annual increases of the decade 1960—1970, a rate of increase that may not be sustained in the future. For other regions of the world, a projected growth rate

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[5] UNESCO Statistical Yearbook, Paris, 1972 and preceding years.

of 10% in the supply of new engineers has been used as a model. Growth rates for the decade 1960–1970 were much higher than 10%, but there is reason to believe that in many countries the high rates of increase will not be maintained.

In order to determine which regions or countries are likely to experience technical manpower stresses because of the requirements of the nuclear power industry, one can estimate a threshold above which manpower stresses will occur. For example, it is likely that 5% of all new engineering graduates can be taken up by the nuclear power industry without undue technical manpower stress being placed on other competing industries, at least in most countries and regions of the world. On the other hand, if more than 10% of all new engineers will be required by the nuclear power industry, probably significant manpower stress would be felt in most countries. Thus, Table 4 predicts some interesting consequences in the form of shortages of engineers in North America by 1985, and in Europe by 1990. Using the above criteria, the other regions of the world probably will not experience serious engineering manpower problems. Projections of the number of technicians needed are approximately the same as the number of engineers.

It is obvious that for each country which anticipates construction of nuclear power plants, universities, colleges, and institutes for training engineers, scientists, and technicians are needed. In addition, specialized training facilities will be necessary to provide intensive training in specialized areas of nuclear power technology. Although some of this specialized training will be realized at colleges and universities, it will be necessary for the electric utilities, the atomic energy commissions and other branches of the nuclear power industries to establish and maintain training facilities to upgrade their own personnel. Comprehensive in-service training by the industry will be necessary to provide specialized technicians and engineers needed by the industry. Probably most of the engineers will be trained primarily in the basic engineering disciplines, with specialized training and experience provided by the nuclear power industry.

CONCLUSIONS

It appears probable that manpower stresses will develop in North America and in Western Europe as large numbers of engineers are required to build, operate and maintain the various plants of the nuclear power industry. Table 4 indicates that more engineers are required in the advanced, or supplier, countries than in the developing countries when a power plant is built in a developing country, and this will tend to accentuate the problems of stress in the advanced countries. Research and development will utilize comparatively few engineers compared to the numbers required in construction, operation, and maintenance, and this emphasis represents a change from the normal emphasis on research and development now being fostered in the engineering schools.