INTERNATIONAL CONFERENCE
ON NUCLEAR POWER AND ITS FUEL CYCLE
SALZBURG, AUSTRIA • 2–13 MAY 1977

INTERNATIONAL ATOMIC ENERGY AGENCY

IAEA-CN-36/EG (574)

PROJECTED ROLE OF NUCLEAR POWER IN EGYPT AND PROBLEMS ENCOUNTERED IN IMPLEMENTING THE FIRST NUCLEAR PLANT

K.E.A. Effat, H. Sirry, M.F. El-Fouly,
E. El-Sharkawy, A.F. El-Saiedi

Atomic Energy Establishment and Nuclear Power
Plants Authority, EGYPT.

1. INTRODUCTION

One of the essential needs for maintaining and promoting growth of economy of any country is securing adequate and assured supply of energy. This applies to both developed and developing countries; Egypt is no exception. Egypt with its rapid increasing population, and in trying to improve the living standards of its population, is making plans to ensure a maximum supply of energy consistent with the viable national economy and within the desirable socio-economic development. Different alternatives of energy sources are continuously considered and evaluated following the dynamic changes in the international energy market and the development of local energy sources and demands.

Earlier studies of the role of Nuclear Power in Egypt has been carried out since 1963; and the possibilities of introducing and integrating nuclear power into the Power

System in Egypt, were discussed in a paper presented to the fourth International Conference on peaceful uses of Atomic Energy, held in Geneva, in 1971 (1).

In the present paper the energy situation in Egypt will be reviewed in the light of recent studies of the projected role of nuclear power. The present and future energy programs and the power system and economic considerations which led to the conclusion to use nuclear power plants for the fulfilment of a major portion of the electric energy demand in the coming few decades, will be discussed. Since Egypt is now involved in the realization of its first nuclear power plant, a brief discussion of problems encountered and foreseen in implementing the project is presented.

2. ELECTRIC ENERGY DEMAND

2.1 Background

Electric power was introduced in Egypt as early as 1895. Prior to 1964, the generation, transmission, and distribution of electric energy was handled by a number of independent governmental organizations and some private companies. In 1964, the entire electricity supply industry was placed under unified national control by the formation of the "Ministry of Electric Power". A restructuring of the Ministry was carried out in 1976 naming it as the "Ministry of Electricity and Energy", and creating two other new additional authorities namely:- "The Nuclear Power Plants Authority" (NPPA) and "The Qattara Depression Authority" (QDA).

The other two authorities namely, The Egyptian Electricity Autority (EEA) is the operating body of the Ministry responsible for generation, transmission, and distribution of electric energy; while the Rural Electrification Authority (REA) is the responsible body for the promotion and development of sub-transmission and distribution systems in rural areas, small provincial towns and villages, while their operation remains the responsibility of the EEA.

2.2. Load Growth & Energy Demand

The present Unified Power System (UPS) in Egypt comprises a hydro-electric cascade of 2445 MW installed capacity in upper Egypt, connected by two 500 K.V. transmission lines with a thermal generating block of about 1557 MW installed capacity to the Cairo area and lower Egypt. Detailed description of this system has been given in various published papers and reports (1,2).

Table (I) and Figure (1) show the anticipated development of the installed generating capacity, the maximum demand, and the annual generated energy over the next 25 years.

In 1975 the installed generating capacity reached about 4000 MW, and the annual generated energy was 9.7 billion Kwhs, 3.0 billion Kwhs from thermal units and 6.7 billion Kwhs from hydro. The maximum demand of the UPS was 1775 MW and it occurred at 18.00 hours in December of 1975.

It is to be noted that the maximum demand for that year increased by 21% while the annual generated energy increased by 14.7%.

The monthly generated energy for July 1976 has increased by 21%; when compared with the 1975 figures. This is due mainly to the operation of some of the major electricity consuming industrial loads such as the Aluminium and Iron & Steel complexes.

Also earlier in the same year, the fertilizer factory in Talkha and the Oil Refinery in Alexandria have been commissioned and are now in full production. As a result of all these large new loads coming into the picture the generated energy in 1976 has reached 13.5 billion Kwhs as compared to 9.7 billion Kwhs in 1975, as mentioned earlier.

Furthermore, during 1977 many of the delayed Industrial projects are being completed, e.g. the Aluminium Complex at Nag-Hammadi will reach its full production (2 billion Kwhs/annum); the Helwan Iron & Steel Complex will also be in full production about the same time and the SUMED oil pipeline between the Suez Gulf and the Mediterranean Sea will be in the commissioning stage.

Inspite of those rather high rates of growth in 1975 and 1976, over the last 10 years, the average annual rate of growth was 10% for the maximum demand and 11% for annual energy generation. Based on the policy of utilizing to a maximum the cheap available hydro-electric energy from the Aswan Cascade, in order to save on fuel oil, it is expected that this additional energy consumption will be supplied by the hydro cascade thus about 96 % of the available hydro energy will be utilized as compared to 74 % in 1975. Consequently after 1976 any further increase in the energy consumption demands will have to be met by additional thermal generating capacity.

3. LOAD DEMAND FORECASTS

3.1 General

Generally, long range forecasts apply to the way society is expected to develop without investigating the specific details of individual components of load. Usually this philosophy is permissible because details are not known about the individual loads on a long range basis. For this reason, long range forecasts are usually based on the GNP and the anticipated growth of per capita energy consumption.

However, short range forecasting, on the other hand, is needed to firm up generation requirements in order to be able to supply known scheduled loads.

3.2 Short and Long Term Forecasts

Future Energy demand & load forecasts in Egypt have been carried out in a number of previous studies which are published in various papers and reports (1,2). The load demand forecasts, taken as a basis for the present study are those undertaken recently by the Egyptian Electricity Authority and given in table (II), together with previous forecasts for comparison. These forecasts are directed to the determination of the short term needs till 1985 as well as the general trend long range requirements until the year 2000.

The forecasted daily annual energy consumption, peak load, and daily and annual load factors for the years 1975 to 2000, are shown in table (I). It can be seen that these forecasts while different in some details from previous forecasts are consistent and in general agreement with the results obtained by independent international studies carried out by the IAEA (2) and the World Bank (IBRD) (3).

It is worthy to mention here that in view of the new changes of the political and economic policies of Egypt, by encouraging foreign investment and joint ventures, a large number of heavy industries are now under consideration. These new industries were not included in the forecasts for the first five years, (1976 - 1981) of the short term plan, and it is expected that they will reflect an additional demand of about 800 MW by 1985 over and above the official forecasted 10 years plan.

However, allowance is made for them in table (I) in order to reflect as accurately as possible the maximum anticipated demand with available data up to date. Higher growth rates of peak load and energy demand should be expected at first to compensate for the low rates of growth that prevailed because of the war conditions.

4. SYSTEM EXPANSION PROGRAMS

Table (I) show that the annual energy consumption is expected to go from about 10,000 million Kwhs in 1975 to 32,000 in 1985, and finally to 100,300 million Kwhs in the year 2000, while the peak load is expected to increase from about 1770 MW in 1975, to 4850 MW in 1985, and finally to 15390 MW in the year 2000. For the years 1995 - 2000 and into the twenty first century the annual rate of increase for ordinary loads is taken as 6.5 % and for heavy industries as 7.0%. Statistically it is established that the rate of growth of power demand in well-developed countries such as

U.S., Canada, and Western Europe is about 7½ / year. This is of course the combined result of poulation growth and increased rate of power consumption per capita.

Accordingly, systematic programs of planned generating capacity expansion are prepared. When planning the additional thermal (oil-fired and gas) generating capacity needed to meet future power demand, the winter period of minimum available hydro-electric power from the Aswan Cascade is considered. This critical period of the year is that of maximum demand on thermal generation to meet the peak load of the country. Also as a guide to the possible loss of load probability or generation failure, it was assumed that hydro units were taken off down for scheduled maintenance at the same time the largest thermal unit was lost to forced outage. Together with these assumptions a retirement plan for the old oil-fired and gas turbine units has been worked out as shown in table (III).

The remaining or the excess of the available firm capacity, based on the previously mentioned assumption, above the estimated daily peak load are the system reserve capacity. On the above basis, scheduled system additions were worked out, they include gas turbine plants to be constructed in a very short crash program for the years (1977 - 1979), and small oil-fired units to meet the system near-term demand, and larger oil-fired units and nuclear units to meet the system long term demand. Also, the development of the first and second phase of the Qattara hydro-solar project are foreseen before the year 2000.

4.1 Type and Size of Plants for the System Expansion Plans

Based on the power system considerations given above as well as the economics of various alternative energy sources, the type and size of plants for new system additions of generating capacity was established both for the short term plans to meet the requirements up-to the year 1984 and for the long range programme up to the year 2000.

Considering alternative energy sources; geothermal resources in Egypt are essentially non-existent on any suitable scale to be considered for power generation. There are coal deposits in Sinai, but they are too small to be considered for power production. Importation of coal for this purpose is not economically feasible. Natural gas deposits do exist in the country, however, the present and projected production of natural gas does not warrant further consideration with respect to the requirements for the large generating units required, in addition to those committed already for gas. The two remaining indigenous energy sources, hydro and thermal, are the only significant alternatives to be considered further.

Potential hydro-electric power resources are the Qattara Depression Project and the Nile Barrages. Although the Qattara Depression project is planned to have an installed capacity of about 600 MWe in its first stage and could replace a thermal generating unit of comparable size, it is not considered a timely viable alternative. This is because of present indications of very high capital costs beside many uncertainties of using clean nuclear explosions with such large amounts for excavations of the intake channel, and the requirements of an extended schedule for completion. It could become an economically feasible alternative for some later thermal stations, after completion of the feasibility as well as the technical, and economical studies associated with clean nuclear explosions.

Another source of hydro-electric power is the River Nile barrages. There are 10 of those scattered along the river. If all the ten were utilized for hydro-electric power generation, a maximum total installed capacity of 600 MW could be realized, however, the usable capacity would drop to 300 MW during the low-water winter season. The fact that the first of these generating units would not be available until 1985, coupled with the variation in generating capacity due to seasonal water level variations, indicates that this source of energy is not a comparable alternative for thermal generation. The two alternative energy sources requiring further close economic comparison are thermal units either oil-fired or nuclear plants.

4.1.1. Economic Comparison of oil-fired and nuclear plants

On the basis of the above analysis a closer comparison between oil-fired and nuclear plants was undertaken to assess and evaluate the economic merits of each type for their use in the system expansion plan.

Although such economic comparison has been the subject of many and diversified studies published in conferences, symposia and IAEA reports (4-9) such data cannot be readily applied for any specific situation due to the differences in the local conditions, economic assumptions and the continuous changes in the cost data and the parameters used in such studies. A striking example is the increase in oil prices at the end of 1973, from about 3 U.S. dollars per barrel to 11.65 dollars per barrel, which resulted in a tremendous change in the economics of Nuclear Power Plants and made it possible for sizes of Nuclear Plants in the small and medium range to be competitive with oil fired plants even at sizes as low as 150 MW(e) (10).

Consequently the break-even size criterea generally used for comparison between Nuclear and Oil-fired plants is no longer an important factor in the introduction of Nuclear Plants in the power systems of developing countries. The size selection is however made on various other considerations rather than on pure economic grounds (11) and is mainly governed by the power system considerations such as system reliability and stability as well as the commercial availability of unit sizes from manufacturers Based on various considerations and on the minimum size available for light water reactors of about 600 MW studies were made for plants of 600 MW capacity. The situation in Egypt, in 1971, has been that nuclear plants are competitive with oil plants in the range of 300-400 MW (1) at the currently subsidised price by the Government of 7.5 L.E/ ton of crude oil equivalent to (18.25 U.S. Dollars) however, for a valid economic analysis, the international price of approximately ($ 75/tonne) is going to be considered here.

Figure (2) shows a comparison by year after the plant start of commercial operation of the cumulative differential operating cost savings, for a nuclear plant versus an oil-fired plant in the 600 MW capacity size. This figure has been prepared using capital and operating costs estimated from actual bids recieved in 1975 for the Sidi-Kreir nuclear project, and cost data on operating oil-fired plants of the same size under comparable economic conditions. This evaluation was performed for a 12-year period of plant operation, using current International prices for fuel costs of $ 75/tonne for fuel oil, nuclear fuel prices as given in table(V) and using present worth methods to the date of commercial operation. As shown from Figure (2), the cumulative savings in operating costs of the nuclear plant with respect to an oil-fired plant will equal the difference in capital cost of the nuclear plant over the oil-fired plant after approximately 4.5 years of operation. Furthermore, the cumulative savings will equal the total capital cost of the nuclear plant after approximately 10 years of operation.

The sensitivity of power generating cost to fuel price variations has been evaluated under the same conditions described for Figure (2) and the results are shown in Figure (3). Power generating costs are considerably less sensitive to fuel price variations for a nuclear plant than for a conventional oil-fired plant. For example, a 50% increase in fuel price would increase generating costs by 5 mills/Kwhs for a 600 MW nuclear power plant while a corresponding effect for an oil-fired plant would be an increase of 18 mills/kwhs in generating costs. Consideration of the above analysis and based on the conclusions reached by the Market Survey Study carried out by the IAEA in 1973, as well as the availability of unit sizes for light water reactors revealed the important role that nuclear plants are to play in meeting further load growth with unit sizes starting initially at 600 MW and ultimately reaching unit sizes of 1000 MW. Based on that fact that a 600 MW block is required by the year 1984, a decision was reached in 1974 to include in the first 10 year program. Egypt's First Nuclear Power Plant at Sidi-Kreir with a nominal capacity of 600 MWe.

4.1.2 Short Term Generation Program

The present planned additions of new power generation capacity to meet the power demand until 1984 consist of the addition of thermal generating units and the first nuclear power plant. The total added generation capacity for this short term program, as can be seen from table (IV) will be 2707 MW.

Accordingly, the total installed thermal (name plate) capacity connected to the Unified Power System in the year 1984 shall be:-

Installed thermal capacity in 1984.	1517 MW
New additional capacity.	2707 MW
Total thermal capacity.	4224 MW
Usable thermal capacity was 75 % availability.	3168 MW

The participation of the hydro cascade at Aswan in the peak load demand, during the minimum water period and including all emergency hydro-electric generation, can reach 1470 MW in the year 1984. Therefore, the total usable generation of the UPS will be for that particular year 4638 MW. However, table (I) shows that the expected maximum system load for 1984 is 4600 MW. This shows that this short term programme will only cover the needs up till 1984 with a very small margin, Further additions to the system to cover long term needs up to the year 2000 will be provided mainly by nuclear plants, thermal plants and hydro projects.

4.1.3 Long Range Prospects of Nuclear Power

Figure (1) and Table (IV) present the proposed generating units as scheduled for installation before the year 2000, and table (III) lists the retirement plan for the existing thermal and gas turbine units to the year 2000. The proposed plan is based on the full utilization of available hydro and thermal plants. Nuclear energy will be first introduced to the system in 1983 with the installation of Sidi-Kreir Unit 1. In the years following 1983 systematic installetion of 600 MW and 1000 MW nuclear units is planned.

A consideration of the expected load growth and the retirement plant of existing generation capacity shows that there is a need for about 14700 MW of generating capacity until the year 2000.

According to the plans for expansion of the generating capacity a portion of this deficit shall be covered by hydro-electric power generation from the Qattara Project, the remaining part shall be basically covered by nuclear plants ranging in unit size from 600 MWe to 1000 MWe as the system load increases, in addition to some oil and gas fired thermal plants whenever indicated by favourable local conditions to carry with the hydro generation the system load variations and emergency reserve.

It is estimated that by the year 2000 about 40% of the total generating capacity shall be composed of 9-10 nuclear plants totalling about 6600 MWe.

It is interesting to note that these conclusions for the nuclear installations up to the year 2000 are consistent with the results of the IAEA Market Survey for Nuclear Power in Egypt carried out in 1973.

5. OPERATION OF THE FUTURE SYSTEM

The plants are considered on their merit order of operating economy. Hydro-electric and nuclear units are expected in 1983-1990 to carry s much of the base load as possible with oil-fired units carrying the balance of the base load. Oil-fired and gas turbine units are expected to carry the peak demand. Furthermore, within each category of plan (nuclear, oil-fired, etc..) the units are considered in the order of age, to represent the newer units as being "preferred" over the older units.

Figure (1), which shows peak, average and minimum demand as compared to the output of all hydro-electric and nuclear units combined shows that, under any operating condition, this combined capacity will be less than the minimum demand. For this reason, the output of all nuclear and hydro-electric units should be utilized as often as possible.

Oil-fired units will provide that portion of the base load not provided for by nuclear and hydro-electric units and will also provide most of the reserve and peak power required. Gas turbine units will provide the balance of the peak power not provided for by the oil-fired units and will constitute a portion of the system's reserve.

5.1 Operation of Egypt's First Nuclear Plant

Although Sidi-Kreir will be Egypt's first atomic power plant and will be succeeded by newer and larger atomic plants in the immediate future, Figure (1) shows that the demand growth of the system will necessitate the use of the unit as often as possible. For this reason, the use of the unit will be limited strictly by availability, and not by economics.

Historical data and statistics for nuclear power plants of the type expected indicates that typical unit availabilities are approximately 77%. Combining this availability with a typical plant output factor of 90%, past units have yielded capacity factors in the range of 70%.

It also shows that these figures to be relatively independent of plant maturity.

However, newer nuclear units reaching commercial operation within the past few years have shown significantly better performance records than these which are reflected by historical data. This variation in statistical data can be attributed to the continuing refinement of nuclear power plant design based on operating experience and the inclusion of early, less sophisticated nuclear power plants in the historical data.

Based on the performance of late nuclear power plants in the U.S. and Europe and the expected improvements in reliability in future designs, it is estimated that Sidi-Kreir, Unit I can be expected to yield about 85% unit availability combined with a 95% output factor. This combination would yield a plant capacity factor of approximately 80 %. Considering the fact that many newer nuclear plants reaching commercial operation are meeting or exceeding this capacity factor, it can be considered to be a conservative estimate.

6. IMPLEMENTATION OF THE FIRST NUCLEAR POWER PROJECT

Following the decision taken in 1974 to start the nuclear programme by the implementation of the first atomic power plant, at Sidi-Kreir about 30 Kms west of Alexandria, with a nominal capacity of 600 MWe, steps were undertaken for the initiation and organisation of the various tasks necessary for the realisation of such major undertaking. The first of these tasks was the selection of the reactor system to be used. After careful studies, and comparative cost analysis, the light water reactor system using slightly enriched uranium as fuel was chosen, leaving competition between the pressurised and boiling water reactor systems only. Accordingly a fuel enrichment Service Agreement was concluded with the USAEC (Presently ERDA) in June 1974. An invitation of Bids was prepared in August 1974 by the Ministry of Electricity and the Atomic Energy Establishment including general coverage to technical and commercial requirements, but did not include detailed specifications of the plant. The invitation was sent to the four U.S.A. reactor manufactures and only two firms, the General Electric, and the Westinghouse Electric Corporation submitted Bids in response to this invitation in February 1975.

After technical and economic evaluation of the two bids received, the Westinghouse Electric Corporation was selected for the negotiation of a contract for the design and construction of the plant and a letter of intent was issued in March 1976. Contract negotiations are now taking place with Westinghouse with the objective of attaining an effective contract covering the technical, commercial, contractural and legal aspects and the precise definition of the suppliers scope for the realisation of the project with appropriate warranties and guarantees and a well defined schedule. For the evaluation of Bids, and contract negotiations as well as other tasks in the pre contractual stage, a U.S. Consulting engineering firm (Burns & Roe Inc.) has been selected to provide engineering services during the various stages of the development of the project. It is hoped that a successful contract with Westinghouse, will be concluded early 1977, which will be followed by the initiation of site construction work during the same year.

Reviewing, the experience gained in Egypt during the implementation of the tasks undertaken in the precontractual stage for the nuclear project, some of the important considerations related to each of the various tasks are briefly discussed, and may be summarised in the following main points:-

1. One of the important early decisions to be taken; once the feasibility of a nuclear plant has been established; is the choice of the reactor system to be utilised for the nuclear plant. Among the proven available systems, the first selection has to be made between either a system using natural uranium or enriched uranium as fuel. Various technical, political and economic arguments in support of the selection of either system are too well known to be repeated here. However, the important message to be brought in this connection that the preselection of whichever system to be used prior to bid invitations are issued could save a great deal of effort, time, and expenses which are wastefully spent in evaluation of different systems using different reactor types, and quite often, of different sizes.

It would be even more desirable, in case of the choice of the enriched fuel system, to make a pre-choice between pressurised and boiling systems before bid invitations. Experience in Egypt both in 1964, and 1974 has strongly supported these views, and has shown that the results of the evaluation of Bids of these two reactor systems are usually not conclusive due to marginal differences in economics. In addition scopes for supplies and services from different manufactures are not easily equalised, particularly that different sizes are usually submitted by the Bidders as their standard readily available designs regardless of whatever scope or size is specified in the bid invitation.

2. Regarding the task of preparation for bid invitations the type of contract required should be established whether a turn-key, limited scope of supply, or only NSSS Supply,... etc. The bid invitation documents to be prepared should precisely, and in as much detail as possible, specify general and contractual conditions on which a contract with the successful Bidder will be based; sensitive site parameters, and conditions particularly those with cost impacts on design should be well defined. The type, and size of the plant should be set together with acceptable limits of deviations, which should be clearly stated and strictly adhered to in the evaluation of Bids. Preparation of detailed technical specifications can be useful, but can be time consuming, cumbersome and expensive, and of limited value. Bidders, especially for proven reactor systems, are usually submitting, their own designs with their standard specifications. However what is important to specify in the bid invitation documents are the codes, standards and regulations to be used and the cut off date for their application, as well as the major design criteria to be followed by the supplier.

3. The use of a foreign experienced consultant to provide services and assistance with the various tasks for implementation of the project, while is usually essential in any developing country embarking on its first nuclear project, it is

necessary that the work of the consultant should be assigned for specific and well defined objectives. A well qualified group of local counterparts should be available to follow up and evaluate any results or recommendations prepared by the consultant. The ultimate decisions to be taken by the responsible authorities should always be based on the presentation of the local body in charge of the project and should not be left entirely to the consultant.

4. Regarding the task of making bid evaluations, as stated earlier, this task can be greatly facilitated if a preselection of one type only is made beforehand e.g. BWR or PWR or PHWR, etc.. Competition should however be maintained between several bidders for the same plant size, and for a well defined scope and general conditions of Contract. Bid evaluation of two or three different reactor systems of PWR, BWR, PHWR designs is not practical and would only lead to confusing results. Technical and economic evaluation of several bids is carried out to ascertain conformity with bid specifications, regulatory requirements and scope of services and supply.

This task involves pricing of components and services . In this respect, the consultant experience is needed and hence his impartiality is quite important.

5. Site investigations is one of the important tasks to be carefully and timely undertaken. The early availability of accurate site data and parameters could save great deal of efforts and considerable savings in schedule time. Certain sensitive parameters could greatly influence the plant design. These parameters should be identified and clearly specified in the bid invitation documents. Bidders designs based on assumed parameters could contain many items which form major changes during or after the negotiations of a contract, and may result in conflicts between the Suppliers and Owners.

The above considerations clearly indicate that during the precontractual stage for the implementation of a nuclear project, it is important to direct the efforts to shorten the time for the accomplishment of the various tasks, and to reduce as far as possible unnecessary sources of delay in reaching a final contract with the supplier. This is not only important in reducing the overall project schedule, but also to avoid unnecessary additional costs due to escalation of prices and cost of services.

During the precontractual stage other forseen tasks in the following stages of implementation of the Project, such as, site preperation and development services, project management, training of key personnel should be initiated.

It is hoped that this brief discussion of some of the problems encountered in the implementation of nuclear projects may be of help to other developing countries embarking on the realisation of a nuclear programme.

REFERENCES

(1) EL KOSHAIRY, M.A., ELGUEBEILY M.A., .. et al. On The Possibilities of introducing and integrating nuclear power in the United Arab Republic power system. Peaceful Uses of Atomic Energy, 4th Int. Conference, Geneva (1971).

(2) Market Survey For Nuclear Power in Developing Countries, Egypt, Arab Republic Report, IAEA, Vienna (1973).

(3) Power Sector Survey in Egypt, EEA Internal report, Sanderson & Porter Inc., November (1976).

(4) LANE, J.A. Current and Projected Economics of Light Water Reactors, International Survey Course of Economic and Technical Aspects of Nuclear Power Technical report, IAEA, 114 Vienna, (1969).

(5) KHAN, M.A., Prospects of Intermediate Power Reactors, International Survey Course of Economic and Technical Aspects of Nuclear Power, Technical Report IAEA-114, Vienna (1969).

(6) BRIGGS, D.S., KHAN, M.A., Small and Medium Power Reactors, Present Status and Prospects, Atomic Energy Review Vol. VII, Nº. 3 (1969).

(7) Power Reactors of Interest to Developing Countries, Tecnical Report, IAEA - 140 Vienna (1971).

(8) Steps to Nuclear Power Guidebook, Technical Document, IAEA - 164, Vienna (1974).

(9) Extrapolation of Capital Cost Experience in Developing Countries,
Technical Report, IAEA, Vienna (1976).

(10) Market Survey For Nuclear Power in Developing Countries, Report, 1974 edition, IAEA, Vienna (1974).

(11) EFFAT, K.E.A., Size Selection Considerations for nuclear power plants in developing countries; Small and Medium. Size power Reactors, PL-297/25 IAEA, Vienna (1969).

TABLE (I)

PROJECTED DAILY AND ANNUAL ENERGY CONSUMPTION PEAK LOAD FACTORS FOR THE YEARS 1975 - 2000

	1975	1976	1977	1978	1979	1980	1982	1984	1985	1990	1995	2000
1. Daily consumption, 10^6 Kwhrs												
1.1. Ordinary loads	18.5	21.4	23.5	25.8	28.4	31.2	37.8	45.6	30.2	79.0	108.2	148.2
1.2. Canal Area loads		0.5	1.0	1.5	2.0	2.5	3.5	4.5	4.8	7.6	10.4	14.2
1.3. Heavy Industrial loads, existing, under construction or contracted for:												
1.3.1. Fertilizer (KIMA)	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
1.3.2. Aluminium	2.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
1.3.3. Iron & Steel	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
1.3.4. Oil Pipelines (SUMED)		3.6	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
1.4 Heavy Industrial loads, beyond 1977				4.3	8.6	8.6	17.2	17.2	17.2	49.4	73.9	104.8
Total daily consumption	30.9	40.3	43.5	52.4	59.8	63.1	79.3	88.1	93.0	156.8	213.3	288.0
2. Annual consumption, 10^9 Kwhs	9.8	13.8	15.2	81.1	20.8	21.9	27.3	30.3	32.0	54.6	74.3	100.3
3. Daily Load Factor	0.733	0.819	0.806	0.824	0.817	0.809	0.806	0.798	0.799	0.780	0.780	0.780
4. Annual Load Factor	0.631	0.768	0.771	0.780	0.774	0.769	0.760	0.752	0.753	0.744	0.744	0.744
5. Maximum System Load, MW	1770	2050	2250	2650	3050	3250	4100	4600	4850	8380	11400	15390

TABLE (II)

COMPARISON OF FORECASTS FOR ENERGY AND MAXIMUM DEMAND

Year	1973 Forecast by E E A			Market Survey Study Forecast used for WASP program			1976 Forecast by EEA		
	Energy 10^9 Kwhs	Load factor (%)	Max demand (MW)	Energy 10^9 Kwhs	Load factor (%)	Max.demand (MW)	Energy 10^9 Kwhs	Load factor (%)	Max demand (MW)
1978	18.5	71.6	2950	18.4802	71.9	2923	18.1	78	2650
1980	20.7	72.8	3246	20.6690	71.9	3282	21.9	76.9	3250
1985	29.2	68.8	4845	29.1248	67.9	4831	32	75.3	4850
1990	47.0	64.0	8383	47.0019	64.0	8383	54.6	74.4	8380
1995	72.0	63.8	12883	63.9065	64.0	11398	74.3	74.4	11400
2000	110.0	63.8	19662	86.3057	64.0	15393	100.3	74.4	15390

TABLE (III)

PLANNED RETIREMENT OF GENERATING UNITS

EGYPTIAN ELECTRICITY AUTHORITY

Year of retirement	Site Location	Type	No. of Units and MW Rating	Total MW
1983	Cairo North	T	1 x 20	—
1984			2 x 10	40
1985	Cairo North	T	2 x 30	60
1986	Talkha	T	3 x 12.5	37.5
1989	Tebbin	T	3 x 15	45
1990	Damanhour	T	2 x 15	30
1991	Siouf	T	2 x 26.5	53
1994	Suez	T	4 x 25	100
1995	Cairo South	T	4 x 60	240
1996	Max	GT	2 x 14	28
1997	Talkha	T	3 x 30	90
1998	Cairo West	T	3 x 87.5	262.5
1998	Damanhour	T	3 x 65	195.0
1999	Siouf	T	2 x 30	60

TABLE IV

PROPOSED GENERATING INSTALLATIONS SHOWING PROJECTED NUCLEAR PROGRAMME

Year	Site Location	Type	Nº. of Units and MW Ratings	Total MW Nuclear	Total MW Thermal
1977	Helwan	G.T.	6 x 20		120
1977	Kafr El Dawar	T.	2 x 110		220
1978	Talkha	G.T.	9 x 20		180
1979	Cairo West, Unit No. 4	T.	1 x 87		87
1980	Abu Kir	T.	4 x 150		600
1981	Ismailia	T.	2 x 150		300
1981	Suez (I)	T.	2 x 150		300
1982	Suez (II)	T.	2 x 150		300
1983	Sidi-Kreir, Unit No. 1	N.	1 x 600	600	
	Total added Generation for Short and Long Term Plans			2707	
1985	Sidi-Krier, Unit No. 2	N.	1 x 600	600	
1986	Cairo, North, Unit No. 6	T.	1 x 600		600
1987	Cairo Zone / Qattara I	N/H	1 x 600		600
1988	Lower Egypt Zone	T.	1 x 800		800
1989	Upper Egypt Zone	N.	1 x 600	600	
1990	El Arish No. 1	N.	1 x 600	600	
1991	El Arish No. 2	N.	1 x 600	600	
1992	Cairo Zone	T.	1 x 600		600
1993	Cairo Zone / Qattara II	N/H	1 x 600	600	
1994	Upper Egypt Zonz	T.	1 x 800		800
1995	Cairo Zone	N.	1 x 1000	1000	
1996	Cairo Zone	T.	1 x 1000		1000
1997	Upper Egypt Zone	N.	1 x 1000	1000	
1998	Upper Egypt / Lower Egypt Zones	T.	2 x 800		1600
1999	Cairo Zone	N.	1 x 1000	1000	
	Total added Generation for Short and Long Term Plans			14707	

G.T. = Gas Turnine   H = Hydro
N = Nuclear   T = Oil or Gas-fired conventional steam plant.

Table(V). COSTS OF NUCLEAR FUEL MATERIAL AND SERVICES

Item	Unit	Unit Price Jan. 1978.	Escalation Rate % year
Uranuim as U_3O_8	\$/16 U_3O_8	40	6
Conversion U_3O_8 UF_6	\$/Kg U	2.7	6
Enrichment	\$/SWU	65	4.04
Spent Fuel Shipping.	\$/Kg U	50	6
Reprocessing	\$/Kg U	150	6
Pu-Credit (0.6 parity).	\$/gm Pu	23.88	-

N.B. Fuel Fabrication costs were obtained from Bids received for the Sidi-Kreir nuclear plant.

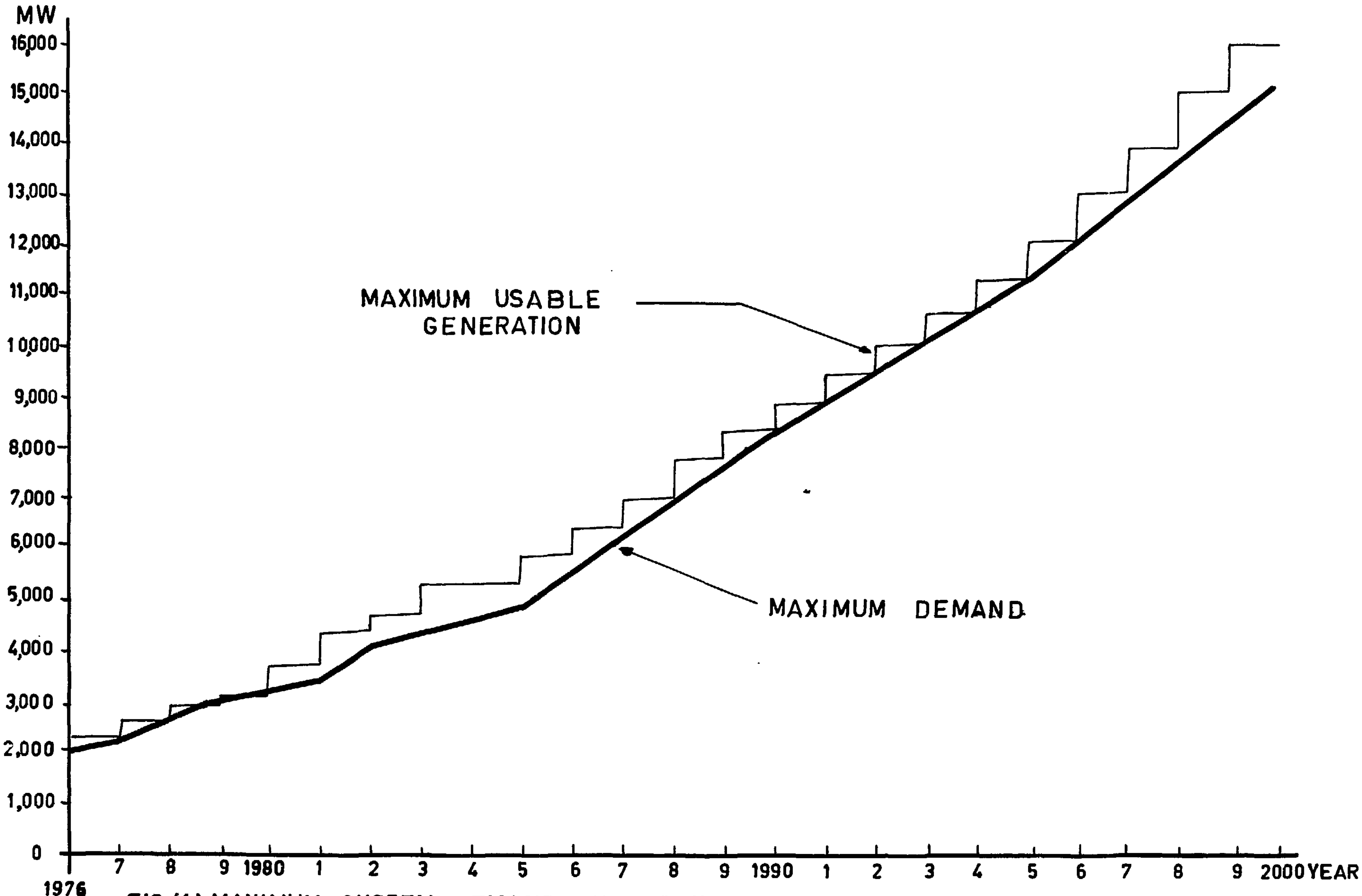

FIG.(1) MAXIMUM SYSTEM DEMAND AND GROWTH OF GENERATING CAPACITY.

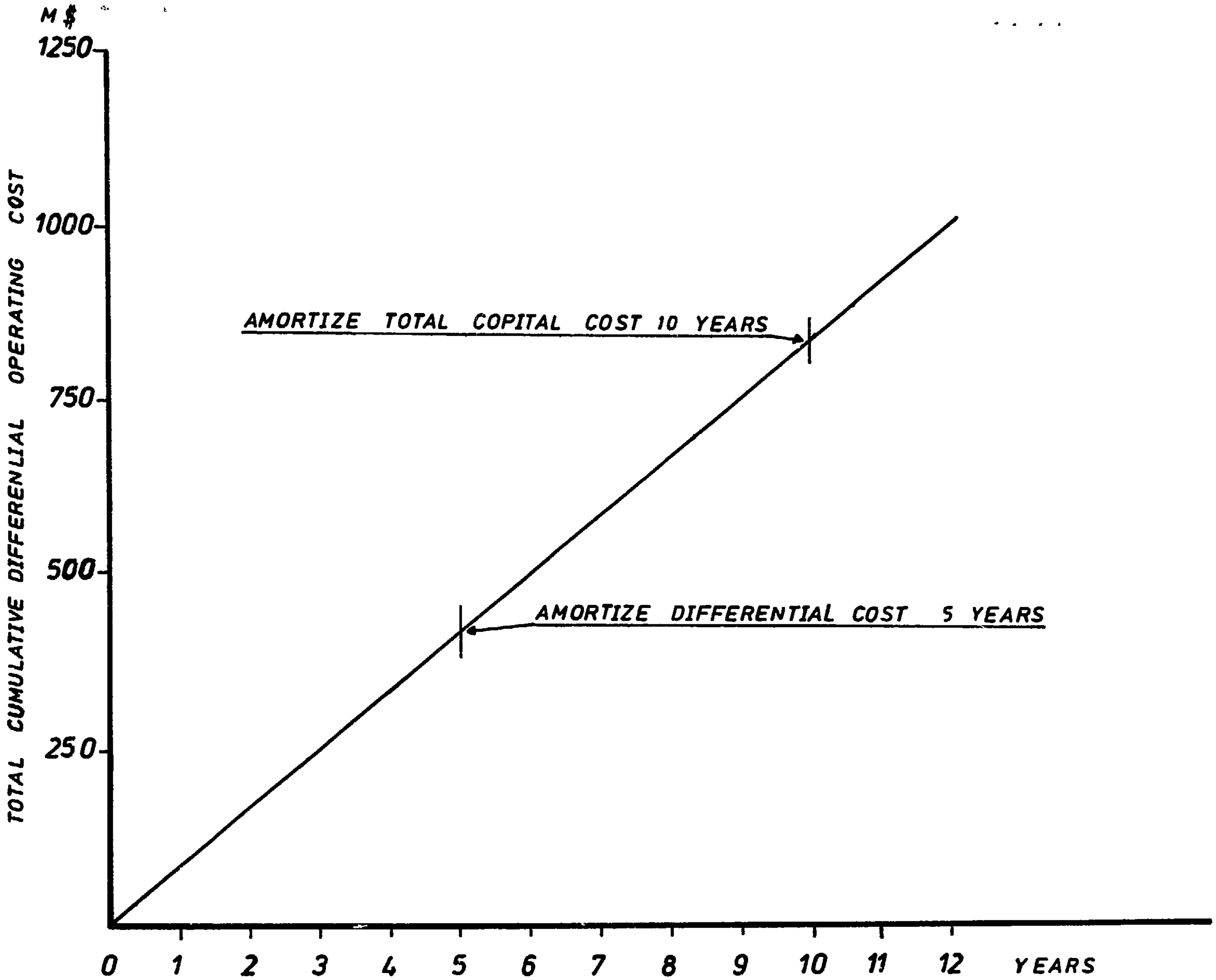

FIG.(2). CUMULATIVE DIFFERENTIAL FUEL COST SAVINGS NUCLEAR FUEL VERSUS OIL.

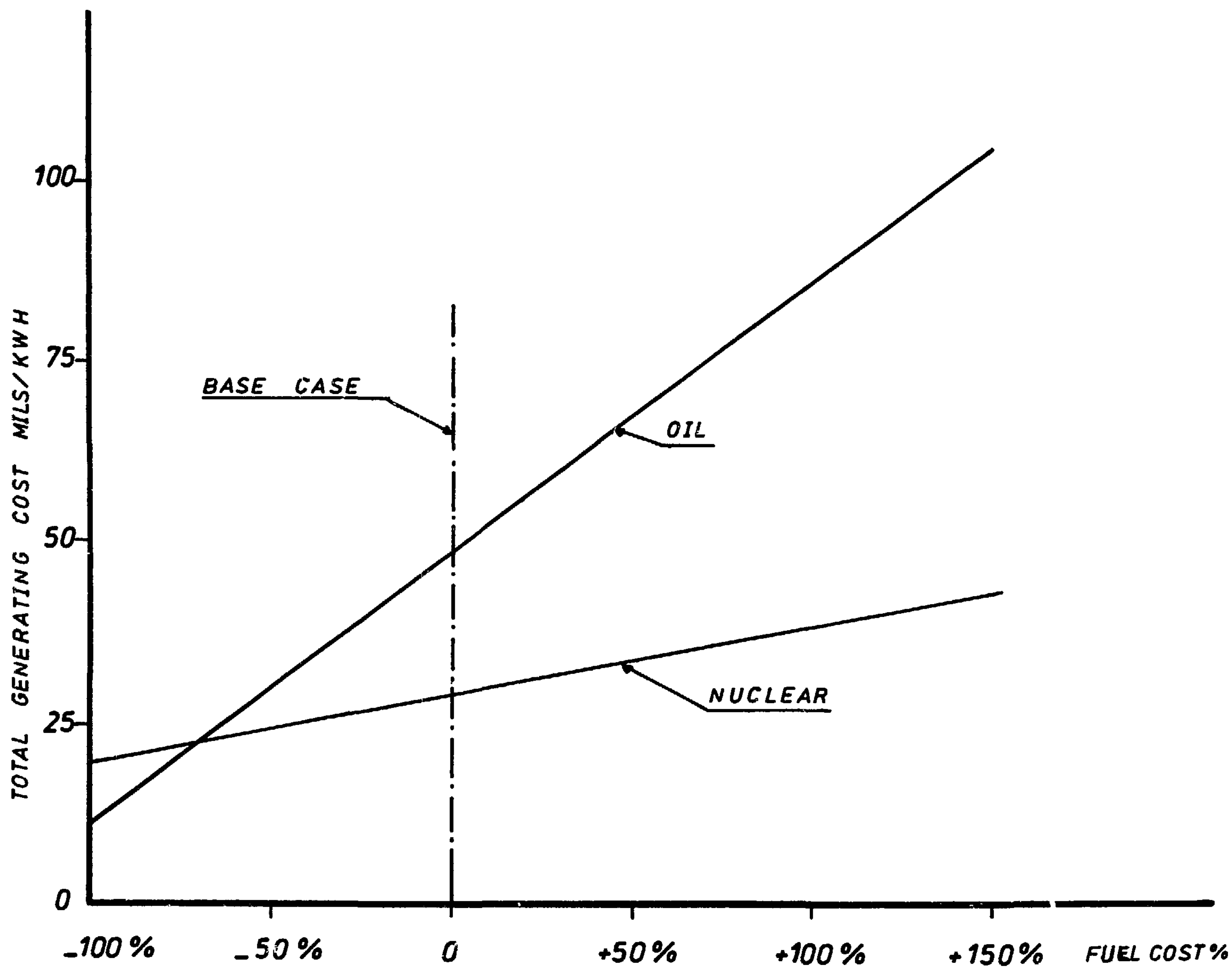

FIG.(3). SENSITIVITY OF POWER GENERATING COSTS TO FUEL PRICE VARIATION NUCLEAR FUEL VERSUS OIL.