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OBSERVATIONS ON ATOMIC POWER IN LATIN AMERICA

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NOTE: This text is subject to editorial revision.

1. Introduction

In assessing the technical and economic feasibility of atomic power in Latin America, it is essential to recognize that common characteristics of culture, language and tradition do not overshadow the variety of local economic and technical factors upon which a sound power development programme has to be predicated.

In most of the Latin American republics (a) the per capita consumption figure is low. Progress made during the last decade was varied (see table 2); (b) the percentage of capital expenditure for power in government plans is high 1/ , but emphasis and implementation varies; (c) the shortage of development capital is perhaps the most common handicap; it precludes simultaneous investment in many directions and implies the need for priorities. What would be spent on atomic power to relieve the power shortage in the cities, would come at the expense of the needs for irrigation, resettlement, land reclamation and land reform. All of these needs are going to compete for the allocation of scarce financial resources available for economic development.

Most of Latin America is heavily dependent on exports of raw materials, which have been affected by the persistent weakening of the demand, as reflected in the fall of world prices. In spite of the pace of industrial development, the countries have not achieved sufficient levels of domestic production of consumer goods to offset imports. The Gross National Product and consumption, computed on a per capita basis and at constant prices are at a standstill. Short-term worries with stabilization and balance of payment difficulties have become so harassing that not much has been done to plan aggressively for long-term economic development. The structural weaknesses of the Latin American economy (lack of money or capital market, system of land tenure, dependence on a few raw materials, the chronic balance of payment desequilibria) have in themselves precluded a broad power development programme.

There is reason to believe that, at this time, a great deal more attention will be given to economic development of Latin America. Any attempt to expedite the development of the Latin American economy must place first priority on a sound, well-balanced and well-dispersed power programme, planned with emphasis on the priorities of social usefulness in an effort to stimulate an accelerated tempo of economic development throughout Latin America.

2. The sui-generis of power planning in Latin America

In the past, the demand for electric energy has grown faster in Latin America than in North America. It is likely that, because of the difference in absolute levels of GNP, and the anticipated rise in the rate of increase

1/ A rough percentage breakdown of public investment in power of government plants in the past few years would give the following objectives: Nicaragua 6 per cent, Guatemala 20 per cent, Colombia 16 per cent and Brazil 33 per cent.

/ of GNP

of GNP in Latin American countries that the demand for power will increase even more rapidly in the years to come. Table 1 shows that production of electrical energy has grown in the last decade at the annual compounded rate of 9.5 - 11 percent against 8.5 per cent in North America (and for a population growth of some 2.6 per cent per annum in Latin America instead of 1.75 per cent in the United States).

The need for some additional power capacity is, therefore, pressing. It is concomitant with the ever-increasing clamour for economic development. In Latin America, the consumption of power will grow faster than the national income because of the needs for communications, irrigation, housing, etc., but the two greatest shortages - lack of dollar exchange and of large, interconnected power systems - will not be relieved by nuclear power.

Throughout Latin America the lack of local coal is still endemic. But the world petroleum outlook in this decade indicates that numerous new discoverires and very high production levels everywhere are creating an oversupply, and the price of fuel oil has decreased instead of the shortages and spiraling of prices anticipated in 1955.

For many of the Latin American nations, a decision to enter the nuclear power field may be to the detriment of a few more immediately needed economic development projects.

The problem of financing a vast Latin American power programme is aggravated by the endemic shortage of capital. The fact that present knowledge of the capital investment required for small nuclear power plants is fragmentary is quite discouraging. The notion that "cheap power is the best stimulant to accelerated industrialization" so prevalent abroad is incompatible with estimated unit costs for large and well-sponsored atomic plants: 12 mills/KWH at Indian Point(compared with Consolidated Edison's best and latest conventional power at Astoria: 7.5 mills)10.5 mills in the most economical atomic project on the European continent (compared with conventional unit cost 2/3 of that). Even for power plants of New York and Detroit size, this would lead, with conditions now prevailing in Latin America, to a probable unit cost of 19 mills, which is certainly no "catalyst to prompt industrialization". For plants of smaller size, this would lead to a cost of nearly 30 mills.

Projections of energy requirements and load forecasting for the various countries are sketchy, and they require competent review and co-ordination with the development programmes of the areas. Both the Geneva Conference and the World Power Meeting in Vienna reveal that objective load data are lacking, and it is gratifying that ECLA and OAS intend to study the broader administrative problems inherent to the prosecution of an aggresive power programme. Direct technical assistance in the field of nuclear energy for engineering and for integration into the existing systems is necessary before sound economic planning allows us to dismiss as impracticable the "reactor vogue".

/ However urgent

However urgent is our concern with power development in Latin America we cannot ignore the local engineering facts, which are today somewhat different from those expected in 1955. There is a chronic overproduction of fuel oil, particularly in Venezuela, and more discoveries are likely in that hemisphere. The four recessions in North America have lowered considerably the price of power generating equipment, and new simplification in design of conventional power plants has accentuated the disparity of cost with that of atomic power.

It should be borne in mind that per capita reserves of hydro power are larger in Latin America than in North America; while fixed capital cost per hydro-KW is larger than for thermal power, the major portion of the former is spent on local labour and local construction materials, with no "balance of payments problems" **afterwards**.

The foreign exchange required by six recent Latin American hydroelectric projects varied from 40 to 70 per cent of the plant cost. For atomic power this is likely to be close to 90 per cent. Canada has estimated that fixed charges per KWH will be 2.5 times higher for atomic electric stations as for hydroelectric stations (3 to 7.5 mills as against 1.2 - 3.4 mills).

Where there is local surplus of oil or natural gas, considerable saving of capital can be realized by generating thermal power. But in countries where there are balance of payments difficulties and fuel has to be imported and paid for in dollars, all feasible and competitive hydroelectric sites have to be utilized first before any consideration is given to atomic energy.

Because of the non-quantifiable problems associated with atomic energy (danger of accidents, disposal of wastes, etc.), the basic principle has to be as follows: All conventional means of power utilization should be exploited until the more efficient (lowest cost) sources are expended and nuclear power becomes economically competitive with the then remaining marginal sources of hydroelectric and thermal power. Because of the extreme importance of economic development of Latin America we cannot allow the glamour of atomic power to affect the planning of power programmes in underdeveloped countries.

3. The outlook for atomic power

The technical feasibility of large atomic power plants is now proven, even though it is considerably more expensive than conventional power. For areas devoid of potential hydroelectric sites, or without conventional fuel, satisfactory large-scale atomic projects are already under way. The largest cities in the United States, the British Grid, India and Japan will have atomic power that is fully warranted and logically integrated in their power systems. In those few areas where there are no mineral fuels and no hydroelectric power, but where foreign exchange or loans are likely, atomic power might provide the answer but is unlikely to be in as large

/ sizes of

sizes of plant as are planned for large industrial cities.

The continued high level of industrial activity anticipated in 1955 for the industrially developed countries, at a time when fuel prices were spiralling upwards, induced some experts to forecast an eventual shortage of conventional fuels and prompt acceptance of atomic power. Even if the first quotations by the manufacturers of large reactors were not entirely satisfactory as to cost, the large power systems felt that atomic plant costs would drop materially, and they decided to use some atomic power, even before it became competitive, and absorb the difference in the costs of the balance of the system, or through accelerated tax amortization. Today's comparative costs are quite different - and less encouraging - than those anticipated in 1955.

The most likely hydro sites in Latin America require a capital investment between 275 and 400 dollars per KW of installed capacity. While these costs vary from one site to another (in India, for instance, the presently considered sites are estimated to cost from 320 to 480 dollars per KW, or twice the cost of thermal KW), it can be said in general that about 60 per cent of this capital investment would consist of local currency for large local employment of unskilled labour in popular public works. The net dollar outlays required,therefore, are about 110 to 160 dollars per kilowatt of hydro, and first priority will have to go to the equipment of the still available hydro sites, which do not entail expensive and cumbersome maintenance or other problems inherent to a new form of energy.

The engineering development of small nuclear power stations, suitable for use in countries where the demand for electricity occurs in relatively small units, is lagging far behind the development of larger central station units. Although there is no doubt today as to the technical feasibility of small-size atomic power plants, many engineering difficulties (shielding, investment in critical mass, design and life of fuel elements, problems of waste, etc.) are likely to be obstacles that are as costly to surmount for a 20 000 -40 000 KW reactor as for a super power plant.

The role of the small to medium-size plant. Small reactors will meet the important need in central station generation for small electric systems, especially municipal and rural co-operative systems, and also in auto-generation of power by mines and other dispersed industries. Except for the large centres of population in Latin America, the main opportunity will be for small reactors in areas where the markets for power are yet to be developed, and are too sparse markets to be met by water power, and where transport of conventional fuel requirements for developing such new electric power markets is difficult and expensive.

The apparent need in South America for small reactors under 75 000 KW emphasizes the importance of greatly intensifying work in this field. But the low capital and financing costs are a prerequisite of their use. The

/co-operative

co-operative movement in Latin America should join forces and establish joint study teams to do something about it.

These opportunities for service by smaller atomic reactors to meet the fast-growing power requirements for large segments of Latin America present a challenge that cannot be neglected or ignored. Finding the method or means for expanding the electric needs not only for the smaller population units of Latin America can bring rapid advancement in standards of living.

Last, but not least, the industries that are of utmost urgency in the economic development programme of some Latin American countries are industries which do not require enormous concentration or large consumption of power per unit of production. There is not much likelihood of electrolytic aluminum, magnesium, titanium or manganese industries in most Latin American countries. Those that aspire to first priority in industrial development of the area are likely to be industries that have for example, the following characteristics:(a) high employment per unit of value added; (b) a high dispersion factor; (c) a rapid turnover; and (d) that provide a high degree of import substitution. Food industries, textile finishing, housing, miscellaneous manufactures, etc. are industries that are likely to extend beyond the capital cities and, therefore, will require small to medium power plants. Naturally, in those areas where there are vast natural resources to equip specific power projects, some very large plants may be necessary to meet the needs of various Latin American governments, and the author hopes that these will soon come into being. The only point made here is that a comprehensive, well-balanced power programme for Latin America requires first some small and medium dispersed conventional power units.

4. <u>Latest data on atomic power costs</u>

The most frequently encountered nuclear power cost formula $C = 2400\ MW^{-4}$ leads to a capital investment of 560 dollars/KW for a 40 000 KW atomic power reactor and to 165 dollars/KW for a 30 000 unit (as against 240 dollars for hydro and 140 for thermal KW). Fig.1 illustrates the application of this latest A.E.C. formula to various reactor costs. 2/ Table 4 shows that for a load factor of 80 per cent, financial charges of 14 per cent and proportionate generating costs of 7.2 mills/KW, the total generating cost for nuclear energy is now in the vicinity of 19.7 mills/KWH. Few Latin American power systems of medium size can face such a cost, except in areas devoid of other power sources.

Those who wish to analyse the detailed cost structure for various power sources and various load characteristics may refer to the 1960

2/ This formula was derived from the cost of larger power units (100 000 to 300 000 KW) and is considered by the author to be a minimum investment curve

/ volume of

Table 1

GROWTH OF ELECTRIC ENERGY IN THE MAIN AREAS OF THE WORLD

Area	1950	1959	Percentage increase
	Net production of electric energy (millions of KWH)		
North America	448 289	910 977	103.2
South America	19 251	43 315	125.0
Central America a/	3 358	8 408	150.4
Europe b/	379 528	840 851	121.5
Africa	15 883	34 961	120.1
Asia	64 263	184 732	187.5
Oceania	15 339	31 106	102.8
World total	945 961	2 054 350	117.2
	Installed capacity (thousands of KW)		
North America	94 575	200 991	112.5
South America	5 779	10 500	81.7
Central America	1 025	2 384	132.6
Europe	105 925	224 050	111.5
Africa	4 015	9 384	133.7
Asia	16 545	44 494	168.9
Oceania	4 191	7 662	82.8
World total	232 059	499 465	115.2

Source: U.S. Federal Power Commission, World Power Data 1960.

a/ Including West Indies.
b/ Including the USSR and the countries of Eastern Europe.

Table 2

ENERGY CONSUMPTION IN LATIN AMERICA, 1949-59
(KWH per capita)

Country	1949	1959	Percentage increase
Colombia	62	218	251
Cuba	142	391	175
Dominican Republic	37	130	251
Guatemala	20	90	350
Jamaica	63	134	112
Mexico	175	293	67
Panama	100	236	136
Venezuela	105	502	378
Argentina	255	445	74
Bolivia	43	140	225
Brazil	55	282	412
Chile	260	590	126
Paraguay	20	70	250
Peru	28	284	914
Uruguay	165	477	189

Table 2 gives the increase in consumption of electric energy, on a *per capita* basis, over the last decade. The international energy statistics of the United Nations express the country figures in kilogrammes of coal equivalent *per capita*; because of possible discrepancies in the conversion factors adopted for various types of fuel and watersheds, it was felt that the traditional KWH/capita figure might be more illustrative when comparative costs were considered.

Table 3

LATIN AMERICA: PER CAPITA GROSS NATIONAL PRODUCT
(Dollars)

Country	1952-54 a/	1959 b/	Percentage increase
Argentina	460	372	- 19.1
Bolivia		55	
Brazil	230	210	- 8.7
Chile	360	521	44.7
Colombia	250	243	- 2.8
Costa Rica		412	
Cuba	310	389	25.5
Dominican Republic	160	232	45.0
Ecuador	150	201	34.0
El Salvador		200	
Guatemala	160	172	7.5
Haití		67	
Honduras	150	197	31.3
Mexico	220	293	33.2
Nicaragua		211	
Panama	250	381	52.4
Paraguay	140	132	- 5.7
Perú	120	150	25.0
Uruguay		198	
Venezuela	540	1 062	96.7

Sources:

a/ Per capita national products of 55 countries, 1952-54 (United Nations Publication, Sales No. 1957.XVII.2)

b/ International Cooperation Administration, Office of Statistics and Reports, Estimates of gross national product, April 10,1961.

Table 4

CAPITAL AND GENERATING COSTS FOR NUCLEAR POWER
(Mills/KWH)

Capital cost	Financial charges At 14%	80% load factor	Generating costs	Total cost
Dollars	Mills/KWH		Mills/KWH	Mills
100	14 000	2.00	7.2	9.20
133	18 600	2.65	7.2	9.85
140	19 600	2.80	7.2	10.00
150	21 000	3.00	7.2	10.20
200	28 000	4.00	7.2	11.20
300	42 000	6.00	7.2	13.20
400	56 000	8.00	7.2	15.20
500	70 000	10.00	7.2	17.20
600	84 000	12.00	7.2	19.20
700	98 000	14.00	7.2	21.20
800	112 000	16.00	7.2	23.20
900	126 000	18.00	7.2	25.20
1 000	140 000	20.00	7.2	27.20

Average cost of U.S. incremental thermal power capacity: 140 dollars per KW, which for a load factor of 80 per cent, is equivalent to:

$$\frac{19\ 600 \times 100}{8\ 760 \times 80} \quad \frac{19\ 600}{7\ 008} = 2.8 \text{ mills, which plus } 7.2 \text{ mills} = 10 \text{ mills}$$

Source: Latest formula for nuclear reactor capital costs of the AEC: $C = 2\ 400\ R^{-4}$ where C is the capital investment in dollars per kilowatt and R is the rating in Megawatts per generating unit. For foreign construction costs this formula should be increased, in our opinion, by 15 per cent.

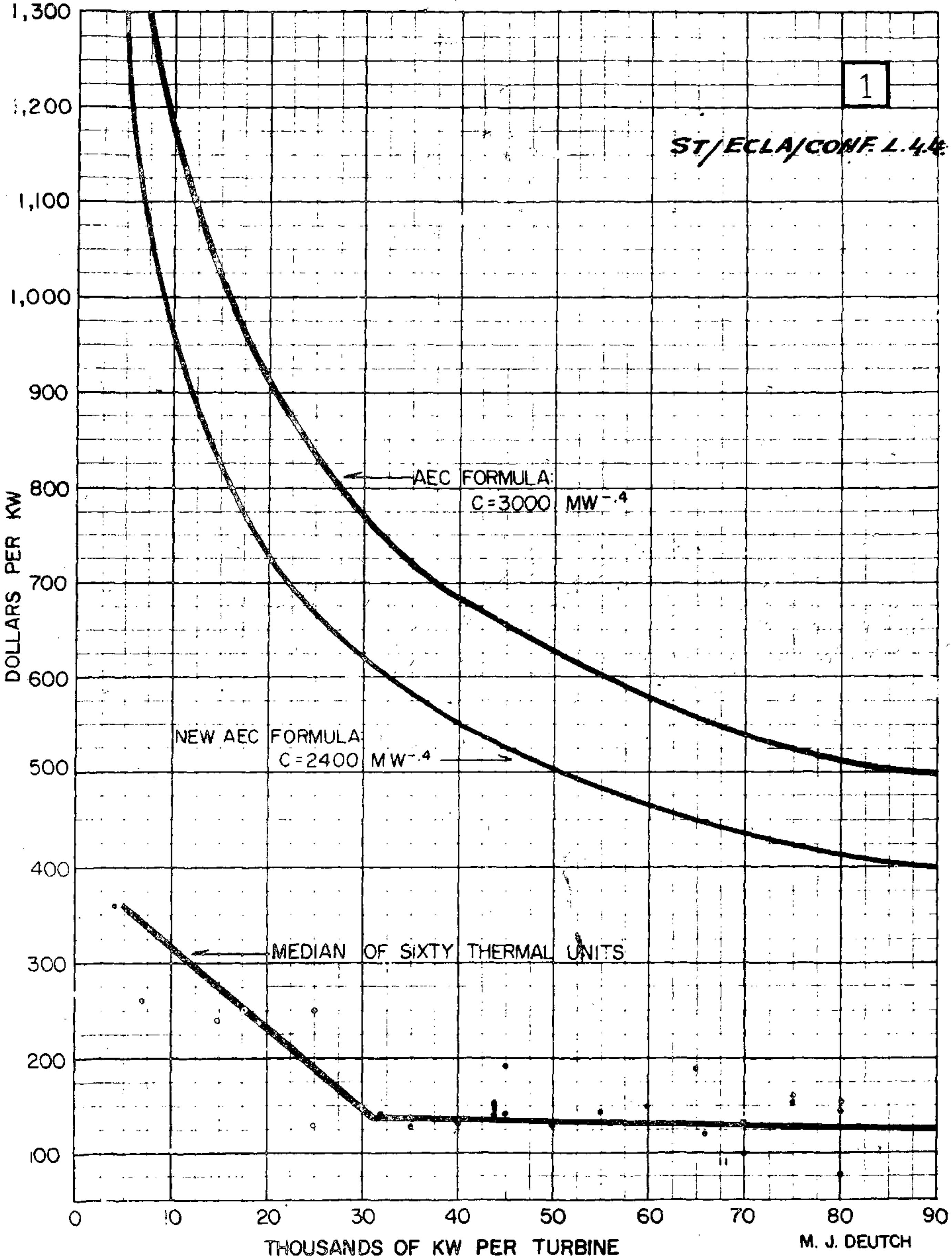
Table 5

ATOMIC POWER REQUIREMENTS FOR IRRIGATION BY DESALTING AND SELECTED BASIC CHEMICAL INDUSTRIES

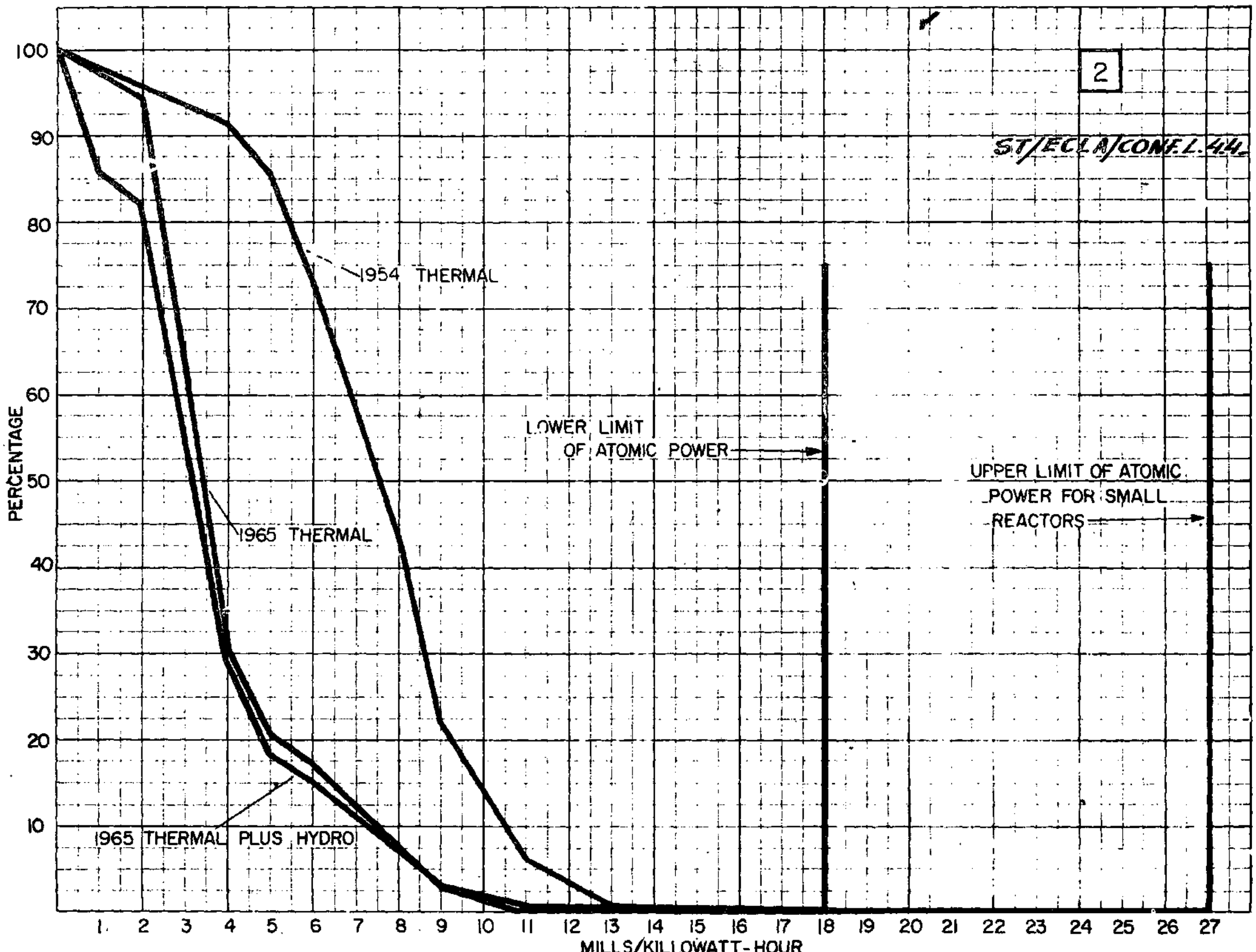
Industry	Minimum Economic Size	Power Re-requirements KWH/AF	Power cost a 5¢/KWH	Total Product Cost	Additional cost with Atomic power a. 25 mills/KWH	Sales value c/	Total cost with Atomic power a 25 mills
						Dollars per acre-foot	
a/	210,000	3 800	19	212	66		$ 278
Irrigation water b/	350,000/AF	2 250	11	127	44		171
	Tons/Annum	KWH/T	$/T	$/T	$/T	$/T	$/T
Ammonia d/	30,000	12 000	60	135	240	170	375
Phosphoric Acid e/	33,000	4 100	20	113	80	204	193
Magnesium	10,000	16 000	80	368	320	585	688
Caustic Soda	20,000	2 800	14	81.5	56	85	147.50
Chlorine f/	17,500	---					
Vinyl Resins	8,000	3 600	18	283	64	600	347

Notes:
a/ High salinity brackish waters (4 300 ppm).
b/ Low salinity brackish waters.
c/ Estimated at 1958 prices *cif* Europe. Will recompute in April 1960.
d/ By the Electrolytic process.
e/ By the electrothermal process.
f/ Produced jointly with caustic soda.

CAPITAL COST OF ATOMIC POWER COMPARED WITH THE 60 LATEST THERMAL PLANTS IN THE U. S. A.



CUMULATIVE DISTRIBUTION OF ELECTRIC GENERATING COSTS IN THE U. S. A. 1954 (ACTUAL FIGURE) AND 1965 (FORECAST)



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