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RURAL ELECTRIFICATION

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Letter of transmittal

Bangkok, Thailand,
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Sir,

The report which I have the honour to submit, incorporates, with certain modifications, two studies (E/CN.11/EP/13 and E/CN.11/EP/23) undertaken by the secretariat of the Economic Commission for Asia and the Far East and originally submitted to the Sub-Committee on Electric Power. The Sub-Committee considered these at its second and third *sessions respectively and recommended that they be widely disseminated.*

The present report analyses the problem of rural electrification in the countries of the region. Various technical and economic questions relating to electric power development in rural areas are discussed and suitable methods and practices are suggested. The financial considerations relating to rural electrification projects are dealt with in some detail, as finance is the greatest single obstacle faced by all the countries. The report points out that, for a number of reasons, the economics of rural electrification schemes cannot be judged on the same basis as those of ordinary commercial enterprises, and that it accordingly appears necessary for the governments concerned to accept the main responsibility for promoting rural electrification and for bearing the financial burden involved through one or other of the various methods described in the report.

The report was prepared by the Industry and Trade Development Division of the secretariat of the Economic Commission for Asia and the Far East. Acknowledgments are due to the governments, government officials and experts of the various countries for their valuable assistance and co-operation, without which the preparation of the report would not have been possible.

(*Signed*) P. S. LOKANATHAN,

Executive Secretary

Economic Commission for Asia and the Far East

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SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The importance of electric power in the economic uplift of a country is stressed in the introduction to this report, which reviews the present power position in the region. More than 80 per cent of the population of the region lives in rural areas. If the objective of raising the standard of living of the common man is to be achieved, the problem to be solved is how to produce more wealth in agriculture and industry and to provide greater opportunities for gainful employment. It is necessary to provide mechanical aid for intensive cultivation, and increase industrial production. The need for resuscitating the cottage industries to provide remunerative employment for the agriculturist during the off-season is stressed. The desirability of dispersing industries for security reasons and of providing employment for unemployed is pointed out. Further, the benefits to be derived from the prevention of the population's exodus from the villages to urban areas are stressed.

Electricity can provide one of the most effective means of solving this problem. The realization of industrial potentialities and agricultural development are closely related to the success of rural electrification programmes in the region. The rural loads are scattered. The demand per consumer is small, owing to the low standard of living, and it is difficult to supply power at economic rates for such small scattered loads. The problem, in fact, offers a challenge and an opportunity to the engineers and administrators of the power-suppply industry; a satisfactory solution will depend upon the ingenuity and professional skill they will bring to bear upon it, and also on the co-operation they secure from research institutions, manufacturers and distributors of agricultural equipment and domestic appliances and from the consumers.

Chapter I briefly details the present position of rural electrification in the countries of the region. The progress so far achieved is insignificant except in the case of Japan and China: Taiwan. Some details on the progress of rural electrification in some of the countries outside the region are given for comparison.

Chapter II deals with the technical aspects of the problem, namely, production, transmission and distribution. The various factors influencing the decision as to whether the suppply of power to a particular village or group of villages should come from an existing power network or from a local generating station to be established are discussed. The supply from a large network would provide an area with cheap power if the distance of the load-centre from the available point of supply on the grid is commensurate with the extent of the load to be catered for. This necessitates a scientific appraisal of the probable demand for power in the area over short-term and long-term periods.

The usual types of power plant for the establishment of local generating stations are described. In cases where supply from a large hydro and thermal grid becomes uneconomical, it may be possible to build small hydro-power stations at dam sites or small drops in irrigation channels or on perennial mountain streams; the latter can be developed on stream-flow with very little storage. With regard to local thermal stations, the capacity of the station to be established influences the decision as to whether the station is to be equipped with steam or diesel generating sets. So long as the capacity of each unit required is smaller than about 250 kW, diesel-engine generating sets may generally prove more economical.

For a steam station, the merits of various types of fuel are discussed. Concerted efforts should be made to utilize the low-grade coals available in large quantities in almost all the countries of the region. These could be mined, and partly or wholly processed on the basis of experience gained in Australia, Germany and Czechoslovakia.

For diesel stations, the scope for using alternative fuels is limited. In view of the fact that rural diesel installations are mostly small high-speed diesel engines, the use of processed bunker fuel in place of diesel oil is not considered possible at the present stage of technical development. With regard to the use of vegetable or animal oils, the experience of the Directorate of Agriculture of the State of Viet-Nam during the second world war is referred to.

Standardization of sizes of generating sets, of voltages and frequencies is of utmost importance to secure maximum economy in the long run. To stimulate thoughts on this question, the pros and cons are discussed and certain standards of sizes and voltages are suggested.

On the subject of transmission, stress is laid on the need for economy in construction. The advantages of standardizing voltages for transmission are detailed. The extent of load and the distances to be covered are important considerations. The requisite qualifications for an ideal rural line may be summarized as follows:

1. Adaptability for isolated supply en route
2. Margin for development of load
3. Low initial cost
4. Reasonable reliability of supply and low maintenance
5. Simplicity of construction with minimum number of parts.

The object to be kept in view in the design of a transmission line is the efficient transmission of power to the consumer over as long a distance as possible and at as high a voltage as is practicable and economical, and reduction of the number of voltage transformations to a minimum. Sound engineering development consists in meeting the immediate and foreseeable needs at the minimum cost consistent with technical suitability and reliability of service; risks have to be balanced, and a satisfactory solution is one which combines immediate suitability with reasonable flexibility to meet increased demands in the future.

In order to assess the effect of the cost of each component of a transmission line on the cost of the completed line, a brief study of each component is made. The high factors of safety and large ground-clearances stipulated in the various government enactments and the rules framed thereunder in the past, were mainly intended for use in urban areas and require suitable revision in order that the costs of rural electrification may be reduced.

As the countries of the region possess rich forests, wooden supports should be used as far as possible for transmission and distribution lines. In order to lengthen the life of wooden supports and cross-arms, vacuum-cum-pressure treatment with preservatives is recommended. Two of the treatments usually employed are detailed in appendix 1.

In the construction of transmission lines, the omission of overhead ground wire and a reduction of ground clearances are calculated to reduce the cost of construction considerably, without in any way adversely affecting the efficiency or reliability of service. Furthermore, the graded porcelain-enclosed fuses in the case of voltages of 11 kV and below, and the open expulsion-type fuses combined with group-operated isolators up to 33 kV at appropriate points in a system, are inexpensive, but effective substitutes for automatic oil circuit breakers to secure protection against overloads and ground faults.

The economics of single-phase supply are detailed. As a result of concerted efforts on the part of various research institutions and manufacturers of agricultural equipment, the maximum demand of each type of farm equipment has been reduced to 5 hp. This demand can be satisfactorily met by single-phase supply, with considerable savings in the costs of rural electrification.

Satisfactory power supply to consumers necessitates the maintenance of voltage at the consumers' end within permissible limits. The various means of achieving the objective are discussed. Ring mains and the use of shunt and series capacitors are detailed.

In the planning of a distribution system, the immediate as well as the prospective loads should be taken into consideration. In order to reduce the cost of the distribution systems, the following deviations from conventional practices may be considered for rural areas in the light of practice in and outside the region:

1. Use of No. 10 SWG or No. 8 B&S hard drawn bare copper for short-span consumers' secondaries;

2. Omission of guarding between high-tension and low-tension conductors when run on the same pole; wherever necessary, a simple flat iron clamp may serve the purpose of a continuous guarding;

3. Installation of inexpensive types of fuses, either on the high-tension side or on the low-tension side of the distribution transformer, combined with individual fuses provided at the point of tapping for consumer supply so as to secure protection against overloads and ground faults.

4. Installation of small-capacity transformers on single poles and larger ones on platforms supported by more than one pole;

5. Installation of lightning arrestors at strategic points in a system rather than at each transformer centre to secure effective protection against lightning;

6. Use of low-core-loss transformers to lower the losses in the distribution system.

Chapter III deals with the utilization of electricity. Knowledge, food and health are three of the basic factors for human progress affecting the ability of both rural and urban populations to live satisfying lives and dwell harmoniously with each other. The real objective of rural electrification is to improve the economic status of rural populations by increasing production and to improve human welfare by providing an environment equal in comfort and convenience to that enjoyed by urban centres.

Amongst the specific uses of electricity, its use in agriculture as an aid to intensive cultivation of land is described. Examples of increased production secured by irrigation of the land are given. Another important field for the application of electricity, the reclamation of marshy land, is mentioned.

The use of electricity in small and medium-size industries is indicated. The extent of the power requirements of cottage industries is detailed. Mention is made of the success of Japan's industrializtion, which is attributed to the availability of cheap electricity throughout the country.

For the present, the demand for electricity in the rural areas of the region will be limited to a few purposes: lighting, lifting water for irrigation and operating small machinery for the processing of agricultural products. The use of electricity on the pattern of western farms is not expected in the near future owing to the different methods of farming and to the fact that the holdings are small and the standard of living low. In order to indicate the potentialities, some of the most common uses of electricity on the farm and the benefits to be derived therefrom are illustrated. Even though individual farms cannot afford to own large agricultural equipment, electricity will provide the means for the farmer to combine with his neighbour in the collective ownership and economical utilization of equipment, thus increasing the quality and quantity of production and reducing drudgery. Special stress is laid on the advisability of establishing a chain of refrigeration plants to preserve food, sea products, vegetables and fruit and so avoid the colossal losses due to the perishable nature of these articles. Initially, the provision of co-operative cold storage facilities at least for a group of villages is urged.

Chapter IV deals with propaganda and load-building methods. It is necessary to educate the farmer and give him convincing proof of the advantages that will accrue to him from the use of electricity. It is pointed out that even in some western countries where holdings are large, literacy and the standard of living high, it took considerable time and effort on the part of the power-supply organizations to introduce electricity on the farm. It is considered that the time and money spent on propaganda and publicity will be amply repaid in due course by an increasing use of energy in rural areas, which will raise the standard of living of the rural population.

Chapter V assesses the problem of tariffs. The two basic considerations that govern the formulation of tariffs which will satisfy both the producer and the consumer are what the service costs to produce and what it is worth to the consumer. Electricity has special features which require consideration in the formulation of tariffs. It is not possible economically to store electricity in significant quantities, at least at the present stage of technical development; the demand in a power-supply system fluctuates sharply over different periods of time; it reaches a maximum at a particular time of the day and this maximum varies with the seasons of the year; the capacity of each part of the equipment, such as generating plant, transmission lines, transformers, etc., should be adequate to meet that highest demand even though it may occur only once a year and may last for a short time. Furthermore, the electric-supply industry enjoys a limited monopoly, therefore the ordinary laws of supply and demand are not applicable to the determination of prices.

On the production side, the cost will be influenced either by the encouragement given and subsidies paid by the government or by municipalities in order to secure the incidental benefits to the health of the community and the establishment of industries, or by their attempts to secure high profit to be used for the benefit of other services. On the consumption, side, habits, prejudices, initial investment and competition from alternative services influence the value of the service to the consumer.

Tariffs for rural areas present a special problem. The main problem in rural electrification is the economical supply of power to small loads scattered over wide areas. On the one hand, the cost of energy supply is higher than for urban areas, and on the other hand the value of service to the consumer is lower. Although cost considerations demand higher tariffs, a uniform tariff for urban and rural supply for a particular class of service is the cry of the day. Therefore, tariffs which are broadly based on the laws of economics and duly modified to take into account all factors influencing production (such as maximum demand, time and place of supply) as well as the value of service to the consumer, may be considered satisfactory.

A strict application of the marginal cost theory in the *formulation of tariffs brings about unrealistic results.* For instance, a substantial portion of the cost of electricity consists of depreciation and interest charges on the capital invested. Taking the price trend during the last decade, the cost of additional plant installed from time to time, either for replacement of or for increase in capacity of old plant, has been higher. If the tariffs are to be based on the marginal-cost principle, the charges for electricity consumed by new consumers will have to be higher than those being paid for by existing consumers, even though the purpose for which the electricity is used is the same in both cases. Furthermore, even existing consumers will be required to pay a higher rate for additional electricity consumed. Such a method of charging consumers is not only impracticable but perhaps illegal as undue discrimination.

The two major items on which the cost of electricity depends are the quantity of energy (kWh) consumed, and the power (kW) at which the energy is consumed. Broadly speaking, the former determines the amount of fuel consumed and the latter the size of the plant required to meet the demand. On an average, 25 per cent of the total cost of electricity is represented by items proportional to energy (kWh) "variable cost", and 75 per cent by items proportional to power (kW) "fixed cost". In the case of hydro plants, however, the variable cost is practically nil, whereas in thermal plants it represents 85-90 per cent of fuel cost plus a small part of the wage bill. A detailed examination of various aspects shows that the fixed charges can best be related *to power (kW) supply, and the variable charges* to energy (kWh) supply. As the consumer cost can be related to the number of consumers, a charge per consumer would be most appropriate. Therefore, from the cost point of view, the best structure of tariffs which reflects the *incidence of cost in a practical way is that* which contains (*a*) kW charge, (*b*) kWh charge, and (*c*) consumer charge.

Electricity being the essential factor in developing the resources of a country, the growth of the electricity industry has to find its due place in the general plan of industrial development of the country. Chapter VI of the report deals with the financial aspect of the industry, with special reference to the financing of rural electrification.

Amongst various external factors affecting the electric-supply industry, two primary ones are detailed, namely, continuous rise in cost and government intervention. The former has resulted in the principle of amortization's losing its objective value, and the latter, which varies from complete nationalization to control *of the development and financial activities* of private electricity undertakings, has changed the very basis on which the industry operated in earlier times. The cumulative effect has been that sufficient capital has not been forthcoming for the required expansion of the industry.

The electric-supply industry in countries of the region had been financed in the past mostly by public limited companies, one of whose primary objectives was to secure immediate returns on the capital invested. Therefore their operations were confined to urban areas; the rural areas, where 80 per cent of the population lives, were neglected.

Financing of rural electrification cannot be subjected to the normal tests of satisfactory returns on investments. Experience has shown that even in some of the western countries, where the standard of living is higher and farm holdings are large, the return on investments for rural electrification is not adequate, at least initially. In the case of the rural areas in countries of the region, the problem is more difficult as the concentration of load per unit area is much less and the growth of load will be slow owing to the very low standard of living.

It is *recognized that every effort should be made* towards reducing the costs of installing and operating rural electric-supply facilities. Also, it will be justifiable to insist that the consumer should be called upon to pay for electricity at rates which would adequately cover all charges. However, in the interests of encouraging rural electrification, at least in the initial stages, it is essential to provide suitable inducements to the rural consumer in the form of reduced rates, etc. This naturally leads to some kind of subsidy for rural electrification by the government or by other public authority.

Among the possible methods of governmental assistance are the following:

(*a*) The government advances the entire amount of capital required for rural electrification and recovers the amount in easy instalments as the schemes begin to yield a return, a low rate of interest being charged for the outstanding loan during the initial stages of operation. This may be done in two ways:

(*i*) The money may be advanced to electric supply undertakings which are directed to extend electricity to rural areas;

(*ii*) Co-operatives may be formed in the areas to be served and the money advanced to them, the necessary technical and administrative assistance being rendered by a government organization exclusively set up for the purpose.

(*b*) Outright payment is made to an electric supply undertaking to cover a portion of the capital cost of rural electrification, the proportion payable by government being determined in each case depending upon the prospective load conditions of the area to be served.

(*c*) The government guarantees the undertaking entrusted with the work of rural electrification to make good the losses that may be incurred.

(*d*) A suitable taxation policy is adopted to enable undertakings to build up reserves to be utilized for extension of electricity to rural areas.

INTRODUCTION

Two reports on rural electrification with particular reference to the countries of the ECAFE region[1] were prepared by the Secretariat under the approved work programme of the Commission. These two reports were discussed at the second and third sessions of the Sub-Committee on Electric Power held in Bangkok in 1952 and 1953 respectively. In accordance with the recommendations of the sub-committee, duly approved by the Committee on Industry and Trade and by the Commission, these two reports have now been integrated.

The basic material for the preparation of the report was derived from the replies sent by some of the countries of the region to the questionnaire issued by the secretariat. In some cases, members of the secretariat visited the countries of the region and obtained information through discussions with the competent officials. A considerable amount of material was also obtained from the documents published by the World Power Conference, the Rural Electrification Administration of the United States Department of Agriculture, the Edison Electric Institute, the Tennessee Valley Authority, the Central Water and Power Commission, India, and from administration reports of various government and private power-supply organizations in and outside the region.

It is generally admitted that the extent of power development in a country provides one of the principal means of estimating its economic prosperity and the standard of living of the people. Table 1 gives a picture of the existing power supply conditions in the ECAFE region as compared with some of the western countries.

1. E/CN.11/EP/13 and E/CN.11/EP/23

TABLE 1

POWER PLANT INSTALLED AND ENERGY GENERATION

Country	Area ('000 km²)	Population (millions)	Installed capacity			Generation	
			Total ('000 kW)	Per km² (kW)	Per 1,000 population (kW)	Total (million kWh)	Per capita (kWh)
Canada	9558.0	12.6	7857	0.7	620	45048	3580.0
Sweden	449.0	6.7	2853	6.4	425	10581	1580.0
United Kingdom	244.0	49.8	14486	59.4	291	50624	1020.0
United States	7828.0	146.5	63090	8.1	436	291100	1990.0
Burma	677.0	18.1	36	0.06	2.2	182	6.8
Ceylon	66.0	7.1	54	0.82	7.6	81	11.4
China: Taiwan	35.9	6.4	304	8.5	47	—	—
Federation of Malaya	135.3	5.0	131	0.97	26.2	600.0	120.0
Hong Kong	1.0	1.8	110	110	68.0	293	163.0
India	3161.0	342.1	1537	4.85	4.5	5103	15.0
Cambodia, Laos and Viet-Nam	740.0	27.0	79	0.07	1.7	182	6.8
Indonesia	1904	76.4	140	0.07	1.8	362	4.8
Japan	382	80.7	8701	23.6	108	36007	446.0
Pakistan	935	73.3	82	0.88	1.12	164	2.2
Philippines	296	19.2	132	0.45	6.9	459	23.9
Singapore	0.7	1.0	37.0	5.3	37.0	158.3	158.3
Thailand	518	17.7	28	0.05	1.58	53.8	3.0

Source: United Nations Statistical Yearbook, 1949-50; *Economic Survey of Asia and the Far East*, 1949; Replies to secretariat questionnaire.

Before the second world war, the governments of the countries of the region, with very few exceptions, took little interest in the development of power production. The power-supply industry was mostly in the hands of private enterprise. The immediate profit motive inherent in private enterprise discouraged extension of their activities to rural areas where the financial returns are not as good as in urban areas. During the second world war, many of the power installations in some of the countries of the region were wholly or partially destroyed, which made an already bad position worse.

However, in the post-war period, the countries of the ECAFE region have evinced a strong desire to strengthen their economy. They have laid adequate emphasis on power development. Furthermore, it is stressed that raising the standard of living of the common man, which is the principal aim, cannot be accomplished unless electricity is extended to rural areas as expeditiously as possible, particularly in view of the fact that more than 80 per cent of the population of the region lives in rural areas. When allocating funds, the Government of India has made a liberal provision for power development and has stressed that the extension of electricity to rural areas should be one of the principal preoccupations of the organizations entrusted with power supply.

The chief sources for large-scale generation of power are water, coal and mineral oil. The hydro-power potential as compared with the total installed capacity in 1949 and the capacity of projects under execution and active consideration for implementation during the period 1951-56 are given in table 2; it will be seen that the proportion of the total hydro resources of the region so far utilized is comparatively very small. With regard to solid fuels, the region's resources of high-grade coals are limited, but large reserves of inferior coals are known to exist. As low-grade coals have been successfully used in many countries, like Germany, Czechoslovakia and Australia, there is reason to believe that solid fuels consisting of inferior coals are adequate to meet the demand of the region for thermal power production. Thus the potential resources of the region for power production are ample. The expansion of electricity generation, transmission and distribution can be expedited provided the necessary capital, heavy electrical equipment and essential materials like steel, copper and aluminium are made available.

Many countries of the region have programmes of tube-well construction and electricity will be a useful means for their successful working. Although the tube-wells can be powered by oil engines or steam engines, the utilization of electricity for this purpose has practical and economic advantages.

With the availability of electric power, industries may be dispersed. Industries may be established wherever raw materials are available and the concentration in industrial centres, with all the consequent social, sanitary and labour problems, which yet remain unsolved in large industrial towns, can be avoided.

TABLE 2

POTENTIAL HYDRO CAPACITY AS COMPARED WITH INSTALLED CAPACITY IN 1949 AND CAPACITY OF PROJECTS UNDER EXECUTION AND ACTIVE CONSIDERATION FOR IMPLEMENTATION DURING 1951—1956 IN THE ECAFE REGION

('000 kW)

	Estimated potential hydro capacity	Installed capacity in 1949		Programme 1951-56			
		Hydro	Total	Hydro	Thermal	Diesel	Total
Burma	9,000	13	36	20	10	1	31
Cambodia, Laos and Viet-Nam	4,500	26.3	79[a]	95	15	14	29
Ceylon	500	249.2	54[b]	42	—	—	95
China: Taiwan	3,358	559	304	996	35	—	77
India	40,000	—	1,537	—	627	—	1,623
Indonesia	3,309	73.4	140	12	—	24	36
Korea (South)	2,240	62.2	—	—	—	—	—
Malaya	1,000	29.3	168[b]	—	180	—	180
Pakistan	6,000	9.6	82[b]	183	48	40	271
Philippines	1,500	50.4	132	271	—	—	271
Thailand	3,000	—	28[b]	14	13	2	29

a. 1948
b. 1950

Source: Economic Survey of Asia and the Far East, 1950

The figures of consumption in the United States furnished by the Edison Electric Institute show that until recently, rural consumption was very low:

TABLE 3

TOTAL YEARLY CONSUMPTION IN THE UNITED STATES FOR ALL SUBSCRIBERS

Year	Total output (million kWh)	Rural (million kWh)
1926	56,089	723
1929	76,294	1,602
1934	71,082	1,858
1939	105,768	1,881
1944	198,161	3,373
1949	248,750	7,425

In recent years most European countries and Japan made special efforts to promote rural electrification, despite financial and technical difficulties, and have achieved a good measure of success. The problem of rural electrification is likely to prove very difficult in the countries of the region and it will take all the skill and ingenuity of technicians and engineers engaged in the profession and skilful management on the part of organizations handling power generation and distribution to solve it even partially. In fact, rural electrification offers an opportunity and a challenge to the electrical engineers and administrations of the region. An attempt is made in this report to assess the problem from the technical and economic points of view; solutions to some of the problem from the technical and economic points of view; solutions to some of the problems are indicated on the basis of the experience of countries in and outside the region.

CHAPTER I

PRESENT STATUS OF RURAL ELECTRIFICATION

A. COUNTRIES OF THE REGION

North Borneo

Strictly speaking, there is no rural electrification in North Borneo. Electric-power supply is confined to urban areas.

Burma

In 1939, there were 74 public supply undertakings operating under licences and 24 under sanctions. Of the total of 98, only one undertaking, the Rangoon Electric Tramway and Supply Co., serving Rangoon and Insein, had a maximum demand of 7,420 kW. The Burma Electric Supply Co., in Mandalay, had a maximum demand of 797 kW. Six others had a demand of between 100 and 300 kW, and 90 had a demand of less than 100 kW with an average of 10 kW. Most of them supplied electricity between sunset and sunrise and the current in most places was DC.

Since the second world war, 34 towns have been electrified under the national plan and more towns are being electrified each year. In the absence of a high-tension network, local generation and distribution has been adopted for the electrification of towns. This has been accomplished by the installation of diesel-engine sets of 22 kW and 54 kW. It may be stated that, owing to various difficulties encountered during the post-war period, no comprehensive scheme of rural electrification has been evolved. The development plans for the electric-supply industry are expected to give rural electrification its due place.

Ceylon

Very little, if any, rural electrification, in the true sense of the term, has taken place in Ceylon. On the other hand, small village communities in rural districts with sufficient built-up areas have developed small electricity schemes of their own. At present, electricity is available only in municipal, urban and council towns. With the commencement of the hydro-electric scheme at Norton Bridge in the central part of the island, several transmission lines have been built to serve the country. Future plans for electricity supply will include rural areas along with municipal and urban towns.

China: Taiwan

Extensive rural electrification has been accomplished in China: Taiwan. The progress achieved by the end of 1951, the rural use of power as on March 1953 and the proposed five-year plan of rural electrification are shown in the following tables.

TABLE 4

RURAL ELECTRIFICATION IN CHINA: TAIWAN (1951)

	Total number of areas	Already electrified	Not yet electrified	
			To be electrified in near future	To be electrified at a later period
Cities and towns each having more than 1,000 families)	88	88 (100%)		
Sub-divisions of above cities and towns, (designated as *li* (each having about 200 families) ..	3,470	3,289 (94.8%)	141 (4.1%)	40 (1.1%)
Hsien (villages) (each having less than 1,000 families)	235	219 (93.2%)	4 (1.7%)	12 (5.1%)
Sub-divisions of above *hsien* designated as *chung* (hamlets) (each having about 150 families) ..	3,056	2,573 (84.2%)	184 (6.0%)	299 (9.8%)

Table 5

Rural use of power in China: Taiwan (March 1953)

District	Lighting: Number of farming consumers	Lighting: As % of total consumers in each district	Lighting: Contract capacity in (metered consumer) (amperes)	Lighting: Number of lamps (non-metered consumer)	Power[a]: Number of consumers	Power[a]: Contract capacity (kW)	Irrigation power[b]: Number of consumers	Irrigation power[b]: Contract capacity (kW)
Taipei	16,071	17.5	36,838	24,988	377	2,348.00	35	925
Keelung	5,685	20.7	7,990	9,495	82	591.50	1	20
I-Lan	14,879	51.0	10,610	13,715	432	2,110.00	53	83
Hsin-chu	8,934	43.9	18,205	12,833	408	2,893.70	6	84
Tai-chung	41,389	58.9	47,745	56,976	852	4,024.00	59	361
Chang-hua	23,542	32.8	14,517	34,382	146	4,018.00	40	549
Chia-i	17,313	23.4	16,951	21,416	357	3,410.25	79	2,242
Tai-nan	31,081	22.6	18,720	40,443	492	1,834.35	42	903
Kao-hsiung	33,136	49.1	15,222	50,752	340	13,768.75	759	4,093
P'ing-tung	19,728	55.6	11,152	43,911	298	3,866.43	393	4,148
Tung-ch'u	4,496	28.0	4,429	6,990	74	563.00	—	—
Total	216,254	40.6	202,379	315,901	3,858	39,427.98	1,467	13,408

a. Small power for farm use other than irrigation power.
b. Both of high-tension and low-tension services.

Table 6

Proposed five-year plan of rural electrification in China: Taiwan

		First year	Second year	Third year	Fourth year	Fifth year	Total
	Number of non-supplied villages to be supplied ..	52	98	120	50	37	357
	Number of families to be served	12,195	25,936	23,600	6,200	1,811	69,742
	Population	67,616	132,332	139,614	12,519	10,900	362,981
For farm-lighting	Increase in number of farm consumers	6,097	14,797	19,269	14,182	7,828	62,173
	Increase in number of lamps . .	7,438	17,039	23,989	14,802	8,009	71,277
	Increase in capacity (kW)	446.28	1,022.34	1,439.34	888.12	480.54	4,276.62
	Increase in consumption (1,000 kWh)	446.28	1,022.34	1,439.34	888.12	480.54	4,276.62
For irrigation	New irrigated area (100 ares)[a] .. .	5,000	10,000	10,000	10,000	5,000	40,000
	Increase in capacity (kW)	1,650	3,300	3,300	3,300	1,650	13,200
	Increase in consumption (1,000 kWh)	9,600	19,200	19,200	19,200	9,600	76,800
For grain-threshing	Increase in capacity (kW)	180	360	360	360	180	1,440
	Increase in consumption (1,000 kWh)	788.4	1,576.8	1,576.8	1,576.8	788.4	6,307.2
For rice-hulling	Increase in capacity (kW)	90	180	180	180	90	720
	Increase in consumption (1,000 kWh)	394.2	788.4	788.4	788.4	394.2	3,153.6
For miscellaneous farm work	Increase in capacity (kW)	180	400	550	600	300	2,030
	Increase in consumption (1,000 kWh)	788.4	1,752	2,409	2,628	1,314	8,891.4

a. 1 are = 100 m^2

Federation of Malaya

Very little rural electrification has taken place. Approximately 100 villages are supplied with electricity, about 50 per cent of them by high-tension lines from neighbouring towns, and about 50 per cent by small diesel generating stations. The demand in rural areas and farms at present is poor and the enormous cost of compensation for the transmission way-leaves makes rural electrification ordinarily uneconomical.

The future programme includes the installation of several more diesel power stations in villages. Some of these will be installed by the Central Electricity Board and the others by private persons or companies under licences from the Central Electricity Board.

The board is investigating means of avoiding the necessity of paying compensation and one of the methods suggested is the use of underground cables. These investigations are still in their early stages.

Hong Kong

The China Light and Power Co., Ltd., which supplies electricity on the mainland, serves the urban area of Kowloon and the rural areas in the New Territories. Most of the places in the area are provided with electricity from the central generating stations owned and operated by the above company.

India

The need for extension of electricity to rural areas has been realized in an increasing measure during recent years. In the Electricity (Supply) Act of 1948, the creation of State electricity boards in the various States in India has been envisaged. These boards are charged with the special responsibility of promoting the development of rural electrification and rationalizing the electricity-supply industry with a view to achieving over-all national economy.

A number of State governments which have already undertaken the development of large hydro-electric resources and the construction of extensive grid systems are paying considerable atttention to the electrification of rural areas. Mysors, Madras, Uttar Pradesh and Travancore-Cochin have done considerable work in this field. The number of towns and villages supplied with electricity in 1952 is given in table 7.

TABLE 7

NUMBER OF TOWNS AND VILLAGES ELECTRIFIED, INDIA (1952)

Population range	Total number of towns or villages in India	Towns or villages with public electricity supply: Number	Towns or villages with public electricity supply: As % of total
Over 100,000 . . .	73	73	100.00
50,000-100,000	111	109	98.2
20,000- 50,000	401	308	76.81
10,000- 20,000	856	4,028	0.72
5,000- 10,000	3,101		
Below 5,000	556,565		
Total	561,107	4,518	0.81

The future programme of various States lays special stress on rural electrification. In the Five-Year Plan under execution, the States are charged with the responsibility of expediting rural electrification.

Indonesia

Although a fairly large number of towns have been supplied with electricity from various thermal and hydro-electric stations throughout the country, no attempt at supplying power to rural areas has been made so far. The future plans of the country contemplate extensive generation and transmission systems throughout the country and due regard is expected to be paid to the subject of rural electrification.

Japan

In Japan, about 97.5 per cent of all the villages and towns have been electrified. The electricity-supply industry has made special efforts to popularize the use of electricity in rural areas. As a result, there were 646,000 motors in use in 1950, against 12,000 in 1927.

The country is experiencing a great power shortage and the extension of electricity to the remaining rural towns and villages is not being undertaken. However, a few additions are being made from time to time by supplying power to communities which are near the existing supply feeders.

Korea

A considerable amount of rural electrification had been accomplished in the past but owing to the recent war, many of the power plants, transmission and distribution systems have been destroyed.

Laos

There is no rural electrification in Laos. Six urban areas are electrified. The plants, which vary from 556.25 kVA to 15 kVA, consist of gas and diesel engines varying in size from 11.25 kVA to 125 kVA.

Pakistan

Owing to a severe shortage of power, very little has been done in the way of rural electrification, except in the North-West Frontier Province. About 15 small towns, ranging in population from 9,000 to 15,000, are connected to the grid of Malakand hydro-electric station and the supplpy is being extended to other small towns and villages. The Punjab Government has a scheme of lift-irrigation and drainage of water-logged areas. The programme provides for the sinking of 5,000 wells with an aggregate power demand of 50,000 kW. The Sind Government has at present a scheme for the electrification of 19 small towns and villages which will be supplied from the central steam-generating station at Hyderabad (Sind). The East Bengal Government has undertaken the electrification of small towns by the installation of transportable diesel generating sets. As the demand grows, the towns will be connected to a central station network within economic reach and it is proposed from time to time to shift the diesel sets to new unelectrified localities.

TABLE 8

RURAL ELECTRIFICATION IN PAKISTAN

Population range	Number of electrified towns
Over 100,000	13
50,000-100,000	8
20,000- 50,000	31
10,000- 20,000	25
5,000- 10,000	22
Below 5,000	4

Philippines

At the end of 1951, 357 towns were supplied with electricity, including Manila; 44 towns, including Manila, are served from the integrated system of the Manila Electric Co. which has an installed capacity of 119,200 kW; 6 of the other places are served by hydro-power, and the remainder by diesel. The capacity of the plants varies from 3,500 kW to 8 kW. There are 9 plants of over 1,000 kW capacity each; 11 plants have a capacity between 500 and 1,000 kW each; 83 plants have a capacity between 100 and 500 kW each, the balance of the plants have a capacity below 100 kW each.

The future plans of electric-power development involve the establishment of many new hydro generating stations and a network of transmission lines. Due consideration is expected to be given to the subject of rural electrification as soon as the high-tension transmission system is completed.

Sarawak

There is no rural electrification in the strict sense of the term. There are, however, small stations serving small towns. There are at present 10 plants, varying in size from 18 kW to 1,463 kW, run by diesel engines and serving 10 towns.

Singapore

The electric supply in Singapore is limited to the municipal area and a few adjoining places. The extension of electricity to rural areas is considered very uneconomical as the demand for power is very small, owing to the low standard of living of the population in these areas.

Thailand

There are 98 towns, besides Bangkok, that are electrified either by the government or by private licensed plants. The government installations selling power to the public have a total capacity of 9,211.2 kW.

The Government of Thailand, through the Division of Rural Electrification in the Department of Public Works, Ministry of Interior, is making strenuous efforts to provide electricity expeditiously to as many towns as possible. In the absence of a transmission grid, local generation by diesel-engine sets and local distribution is adopted wherever possible. Municipalities are encouraged, and technical assistance is rendered to them, to own and operate an electric-supply industry. In some cases, the government itself establishes and operates the industry. Public limited companies are also permitted to own and operate the undertakings, subject to government control through the Division of Rural Electrification. In the course of the last seventeen months, 30 towns have been electrified and 15 more schemes are under implementation. It is proposed to extend the operation as conditions permit. Additional capacity to the extent of 8,489 kW will be made available when the plans are completed. Private installations selling power to the public have a capacity of 3,556 kW. Thus, the total capacity installed for selling power to the public amounts to 12,767.2 kW and an addition of 8,489 kW is proposed. When the additions are completed, a population of 16 million will have a supply of 21,256.2 kW.

The rural installations vary in capacity from 10 kW to 1,144 kW. There are only two installations of more than 1,000 kW, one in Chiengmai and the other in Kanchanaburi. The next largest capacity is 425 kW. There are 11 installations generating at 110 V and 220 V DC. The rest are 50-cycle plants generating at 110 V and 220 V. All the additions proposed are to be 220 V and 50-cycle units. The capacity of the proposed plants varies widely. The new installations will be of 24, 27, 30, 50, 85 and 100 kW.

B. Countries outside the region

Australia

The State Electricity Commission of Victoria supplies power to 743 towns apart from the major cities. The following table for 1950 operations indicates the importance attached to the electrification of places outside metropolitan areas:

TABLE 9

ELECTRIFICATION IN VICTORIA, AUSTRALIA

	Outside metropolitan area	Metropolitan area
Poles erected	10,171	1,741
High-voltage lines erected (miles)	351.5	12.4
Low-voltage lines erected (miles)	306.8	446
Sub-stations erected	331	35
Capital expenditure (£A)	1,177,881	390,064

It is interesting to note that out of 743 places electrified, there are only 14 with a population of more than 5,000 and 87 with a population of over 1,000. Also there are 122 places with a population of 50 and less. One electrified place has a population of 6, with 4 consumers. At the end of 1950, 15,741 farms were supplied with electricity from a central station system.

The State Electricity Commission has prepared in 1951 a comprehensive rural electrificatiton plan to be completed in ten years, which provides for:

(*a*) 178,000 consumers in areas outside the capital to be connected; only 22,000 of them are at present receiving supply from local undertakings;

(*b*) 48 local undertakings in the rural areas to be acquired by the commission and the supply to be extended to 650 centres and other small settlements not yet electrified.

Canada

In 1920, the Power Commission Act was amended to authorize the supply of rural service on a new basis known as the Rural Power District Plan. Each rural power district contained about 100 square miles and was operated as an individual unit with its own rates based on the cost of supplying the service. This plan was very successful in developing and promoting rural service throughout the province. Grants-in-aid were paid by various provincial governments to the extent of 50 per cent of the cost of all the installations of rural transmission lines and equipment necessary to extend power to rural consumers and to reduce the charge of power to a minimum.

In 1943, the rural electric service was so wide-spread that all rural power districts were amalgamated into one provincial rural power district and the rates were also reduced. This was made possible by the increase in rural consumption. It is reported that in 1941 Canada had 732,862 farms, of which 148,272, or approximately 20 per cent, had electric service. It is estimated that by 1950 this percentage had doubled.

Denmark

According to a census made by the government in the spring of 1950, 93 per cent of all farms were supplied with electricity; 0.6 per cent had electricity supplied from their own power units, and the balance, that is 92.4 per cent, were connected to public power systems. The bulk of the 7 per cent of farm properties which have no electricity are so situated that they cannot, at reasonable cost, be connected to the power systems for public supply.

France

Rural electrification started about 1919. At that time electrical distribution was well developed in towns, industrial centres and the most favourably situated small areas. There remained 40 per cent of the population to be reached by the rural electrification programme. Most of the rural population has now been provided with the amenities of electricity supply.

Ireland

The position of rural electrification in Ireland at the end of 1943, as reported by the Electricity Supply Board was as follows:

Table 10

Electricity supply in Ireland, 1943

	Supplied from national network		Supplied by local enterprise		Without supply		Total	
	Number	Total population	Number	Total population	Number	Total population	Number	Population
Cities and towns of over 500 population	193	1,121,813	26	30,303	2	1,077	221	1,153,193
Villages of 200-500 population[a]	104	34,304	28	9,076	83	23,690	215	67,070
Villages of under 200 population	80	11,175	13	1,727	293	34,718	386	47,620
Scattered population		18,290				1,682,247		1,700,537
Total	377	1,185,582	67	41,106	378	1,741,732	822	2,968,420

a. A village is defined as a cluster of 20 houses or more.

The Electricity Supply Board is pursuing steadily a ten-year programme of rural electrification under which it hopes to cover 400,000 rural homes and isolated farms at an average density of 17 houses per square mile. Table 11 gives an idea of the progress achieved between 1947 and 1950.

Table 11

Rural electrification of one area in Ireland, 1947-1950

Year ending 31 March	Number of poles erected	Kilometres of line strung	Consumers connected
1947	1,300	62	Nil
1948	15,986	1,156	2,203
1949	32,002	2,762	9,262
1950	40,972	3,330	13,688
Total	90,260	7,310	25,153

Sweden

It is claimed that 50 per cent of the farms of 5 acres and above in size are supplied with electricity. Originally, rural supply was from small hydro-electric plants. This gave place to supply from large grids from 1913 onwards. Rural electrification extended rapidly towards the end of the first world war, owing to lack of kerosene and petroleum.

Switzerland

No detailed statistics are available. Thorough investigations in a rural district of Switzerland (Canton of Lucerne) over a productive area of 1,260 km² containing about 9,600 farms have shown that the number of transportable electric motors used increased from 44 in 1940 to 7,677 in 1950. The increase in consumption in a typical area of 1,309 hectares, containing 122 farms with 760 agricultural workers, shown in table 12.

Table 12

Increase in power consumption in one area of Switzerland

	Light	Power	Heat	Total
1940	28,316	40,255	33,438	102,009
1950	43,219	62,067	122,218	227,504
Increase (%)	53	54	265	122

United States of America

The annual survey at the end of June 1950 indicated that 5,053,676, or 86.3 per cent, of all United States farms were receiving central-station electric service. In sharp contrast to this, only 10.9 per cent of the farms were served 15 years before, when the Rural Electrification Administration was established.

The Rural Electrification Administration (REA) was created by an Executive Order in May 1935 as a temporary agency under the authority given the President in the Emergency Relief Appropriation Act of 1935. The Rural Electrification Act of 1936 established a permanent agency of the same name, and it functioned as an independent government agency until July 1939, when REA became a part of the United States Department of Agriculture. It has functioned as an agency of the department since that date.

The Rural Electrification Administration makes loans for a period of 35 years to persons, corporations, States, Territories, municipalities, people's utility districts and co-operatives, for the construction and improvement of electric generation, transmission and distribution facilities. Of the total loans made up to 30 June 1953, 81 per cent of the dollar amount was for electric distribution facilities, slightly more than 18 per cent was for generation and transmission facilities, and 0.7 per cent was for consumption facilities. The classification of REA electric borrowers is as follows:

Co-operatives	984
Public power districts	44
Other public bodies	26
Power companies	25
Total	1,079

In the early years of its lending programme, REA found it necessary to give considerable assistance to its borrowers. This assistance included organizational, legal, engineering, accounting, management, member education and other related assistance. However, as the borrowers grew in size and gained experience, REA decreased its assistance. At the present time, the agency's assistance is limited primarily to those borrowers who request advice and help which they cannot, for various reasons, provide themselves, and to those borrowers who constitute a real or potential loan security risk.

As on 30 June 1953, REA had loaned $2,730 million to 1,079 electric borrowers. These loans provided 1,351,000 miles of distribution lines, 33,800 miles of transmission lines, and 1,153,000 kW of generating capacity. By 30 June 1953, REA borrowers were serving 3,952,000 rural consumers.

CHAPTER II

TECHNICAL ASPECTS OF RURAL ELECTRIFICATION

Technical aspects of rural electrification can be conveniently studied under the following headings: A. Production; B. Transmission; C. Distribution.

A. Production

1. TYPES OF PLANT

The usual types of power-producing plants are:

(*a*) Hydro-power plants
(*b*) Thermal-power plants
  (*i*) Steam
  (*ii*) Diesel
(*c*) Wind-power plants.

The chief hindrance to rapid progress in rural electrification is the scattered nature and small size of loads. In the countries of the ECAFE region, the demand per installation and the *per capita* consumption are very low as compared with those of rural populations in western countries. The loads, wherever electricity has so far been made available, are mostly for lighting, irrigation pumping sets and small machinery for processing agriculture products. This pattern of electricity consumption is likely to continue for some time to come.

The question whether a place should obtain its power supply from a large high-tension grid or should have its own generating station, individually or by groups, should be studied on the basis of existing power facilities. While it is admitted that supply from a large grid has many advantages, the distance from the centre of the rural distribution to the point of suppply on the grid is a factor of considerable influence. If the delivery of power from the point of supply on the grid involves the construction of a very long length of high-tension transmission line, it would be more advantageous to have separate generating stations, at least temporarily until the grid supply becomes available at a nearer point or until the loads in the area grow to such an extent as to warrant the expenditure on the construction of long transmission lines. It may also be that the existing grid is unable to meet the additional demand, in which case the decision in favour of local generation is inevitable. The following paragraphs from the 1950 Report of Administration of the Rural Electrification Administration (REA) of the United States are appropriate:

"The need for additional generating and transmission capacity to meet the unprecedented growth in the demand for power by rural consumers, and relatively inadequate supplies in many localities, have necessitated expansion of this aspect of the loan programme since the close of World War II.

"In areas where large Federal hydro-electric installations have been built or planned, REA borrowers are concerned with meeting the problem of obtaining power from such installations when they are completed. In the meantime, however, they are faced with the problem of obtaining power from other sources until the large multi-purpose dams are completed. In several instances, it has been necessary to make generation and transmission loans for the provision of adequate power capacity on an interim basis. When low-cost hydro-electric power becomes available, the generating facilities financed by REA will become stand-by or firming-up capacity, in the event that they are not needed on a full-time basis.

"Although it is expected that the loan funds required for generation and transmission facilities will decrease during the next five years, the ability of REA to finance this type of facility is one of the most important factors in safeguarding the security of nearly two billions of dollars that already have been loaned for distribution facilities.

"The distribution borrowers must be able to continue to obtain adequate power at a cost within the range of economically feasible operation. If they cannot obtain power from commercial sources at costs within this range, they must have the ability to finance their own generation and transmission capacity. Moreover, as long as REA financing for this purpose is available, distribution borrowers are able to negotiate with commercial sources on more equitable terms, and in many cases it is possible to obtain more reasonable wholesale rates without the necessity of providing their own facilities."

It is well known that the United States have very extensive hydro and thermal high-tension grids and many multiple-purpose river valley schemes are contemplated or are under construction. These are expected to add several million kilowatts to the generating capacity and thousands of miles of high-tension transmission lines. If interim establishment of generating stations is necessary in the United States, as evidenced from the above quotation, it is perhaps much more so in the countries of the ECAFE region. In these countries very few such large grids exist and most of them are at present unable to meet the demand in the areas covered by their distribution system. Many power-supply companies are imposing severe cuts in consumption and in many countries, parts of towns are blacked out periodically for long hours. Thus, it is unlikely that they will be able to meet additional demands from rural areas until the large multiple-purpose river valley schemes, some under execution and others in contemplation, are developed and serviced. However, there are some areas where rural supply from central stations is possible.

If an examination of the existing conditions shows the necessity of establishing a local generating station, the next problem is the type of plant to be installed—whether it should be steam or diesel; if the former, what is the fuel to be used. Even in the case of diesel plant, the economic advantages of using bunker fuel or vegetable oils in place of mineral oils require examination.

(*a*) *Hydro-power plants*

It is recognized that the establishment of small hydro plants in the neighbourhood of load centres in rural areas would meet the needs of those areas, but their scope seems to be limited. The dam sites and small drops in the channels built primarily for other essential purposes such as irrigation are potential sources of power. The development of power at these canal sites sometimes helps further to increase the acreage commanded by the irrigation system by the installation of large and small pumping units for irrigating outlying areas. Wherever a large quantity of underground water is available within a reasonable distance from potential sources of power, the power generated at the above places can be economically utilized to lift underground water for irrigation purposes. The adoption of the above system has brought under irrigation large tracts in the Gangetic plains of India and large tracts in the United States and other countries which otherwise would have remained unproductive in spite fo the richness of the soil.

Similarly, small perennial mountain streams are potential sources of power. The utilization of their continuous flow of water with very small storages for power production is economical provided the stream can be used within a reasonable radius from its source. Usually these streams are in mountainous areas, far away from load centres. Nevertheless, wherever such a potential source exists, it should be thoroughly investigated and harnessed, even at the risk of the scheme's being temporarily uneconomical, so long as it is ascertained by reasonably accurate estimates that it will be economical in the long run. The reduction of recurring costs due to the absence of fuel and non-dependency on imports in some cases should be appropriately assessed in working out the economics of these power resources.

(*b*) *Thermal-power plants*

The primary consideration that will influence the decision between steam and diesel plants is the size of the plant required. It is recognized that the availability of cheap coal or furnace oil or wood has considerable bearing on the choice of plant. Nevertheless, it is felt that for plants having a capacity of less than about 250 kW, the factors in favour of diesel plant seem to be overwhelming.

Before a decision is taken regarding the type of plant, a fairly accurate estimate of the probable demand of the area to be served is essential.[1] Initially, the demand for power in rural areas is bound to be small. However, a reasonable forecast of the load demand over a period of say ten years, could be made and on the basis of such forecast, proper decisions can be taken as to the size and type of plant to be installed.

Another factor influencing a decision is the type of service required. From the nature of the loads anticipated, a graph showing the hourly demand over 24 hours may be drawn. If the load is such as to concentrate itself during a few hours of the day and at other times to be practically nil, obviously a steam plant would be very uneconomical. It is recognized that intermittent supply is not to be recommended, but if economic considerations demand such a step, it may have to be adopted initially and such a decision will have a considerable bearing on the selection of the type of generating plant.

1. For a detailed discussion of the subject, see "Techniques of estimating future power demands". (E/CN.11/EP/14).

(i) Steam plant

If the considerations referred to above lead to the decision to establish a steam plant, the question to be examined is the type of fuel to be used. The decision will naturally be influenced by the availability and price of each type of fuel. However, the following detailed consideration will, it is believed, be useful.

The types of fuel ordinarily used are wood, coal and furnace oil.

a. ***Wood.*** Many countries of the ECAFE region possess very rich forests, but very few of them can afford to utilize wood for burning in boilers for steam-raising. Even though some countries have in the past established such plants and some of the plants are still in operation, the tendency is gradually to abandon the use of wood fuel. No country can affford to deplete its valuable forest wealth for such purposes over long periods.

b. *Coal.* The high quality coal resources of the region are limited. Some countries of the region do not possess this valuable material; therefore they have to depend entirely on imports. In the case of countries which possess this material, it is presumed that there is an urge to conserve this asset and to utilize it only for purposes for which other types of fuel cannot be used, such as metallurgy. On the other hand, low-grade coals are stated to be available in large quantities in almost every country of the region. If power production is to be made stable and is to be entirely based on the indigenous source of fuel, the utilization of low-grade coals assumes great importance. The question involved is to find a solution for the economic processing of these low-grade coals and to design boilers for utilizing them as mined, or partially or wholly processed. It is understood that this has been successfully tackled in some of the countries; therefore it is a question of investigating the possibility of utilizing the methods employed in those countries with modifications, if necessary, to suit the local requirements.[1]

c. *Furnace oil.* Very few countries of the region possess furnace oil resources, but Brunei, Burma, Indonesia and Pakistan are stated to possess indigenous supplies of fuel oil. The other countries have to depend entirely upon imports. However, it may be mentioned that if a country has to depend on imported fuels, for various reasons, it may be advantageous to decide in favour of the use of fuel oil owing to the ease of transport and handling and the smaller number of plant accessories required, provided it is also reasonably cheap.

(ii) Diesel plant

The very small size of the units generally required for rural electrification in countries of the region often leads to the establishment of diesel-engine-driven generating stations. Generally speaking, these stations serve as pilot power-development schemes helping to build up loads in the rural areas in the initial stages; when a sizeable load-development has been achieved in one area, it would be found economical to extend the transmission networks from an existing neighbouring power system to that area and close down the diesel station. Alternatively, with adequate load-growth it may be possible to build a new steam station in place of the diesel unit and arrange for power supply to a larger area than that commanded by the diesel plant. When alternative supply arrangements have been made in any area developed by diesel plants, the diesel sets could be shifted to other areas for similar development. The diesel plants are well suited for pilot schemes on account of the comparative ease with which they can be transported, installed and commissioned.

Diesel oil has to be imported by the countries of the region with the exception of Brunei, Burma, Indonesia and Pakistan. To reduce this dependence, efforts have been made in the past to replace diesel oil by other fuels and vegetable oils and fish oils available in the country. It is reported that in Viet Nam, various types of vegetable oils were used during the second world war. Their experience in the use of vegetable oils as fuel and their studies lead to the following conclusions:

a. Vegetable oils are substitute products of inferior quality to the various diesel oils;

b. There is considerable risk of rapid deterioration of the equipment;

c. The cost per kWh produced is comparatively higher.

It appears therefore that the use of vegetable or animal oils as fuels in diesel or semi-diesel engines is not justifiable except perhaps in very exceptional circumstances. Furthermore, in view of the relative world scarcity of edible oils, the use of these oils as fuel is not to be recommended.

In Laos, the National Electricity Department has sometimes used wood oil (which is oleo-resin, a fluid exuded by the trunks of several species of dipterocarps

1. The subject is treated at length in "Lignite resources of the region and their exploitation and utilization" (E/CN.11/EP/16).

such as the *may nhang, tabeng, may koung* and *may sat*) in the 75 hp six-cylinder Renault diesel motors with which the barges of the Savannakhet-Vientiane service on the Mekong river were equipped and also in 50 hp semi-diesel Bollinder motors. Before wood oil was adopted as a fuel, the engines had been operated with fuel oil and the consumption of wood oil was found to be about the same as that of fuel oil. The use of wood oil necessitated cleaning the injection pump and the piston head about every 300 hours. No unusul wear was noticed. The cost of wood oil was lower than the cost of fuel oil at the time.

Bunker fuel, duly processed, has been successfully used in low— and medium-speed diesel engines. Wherever fairly large diesel engines are required for rural electrification, the economics of using bunker fuel should be examined. According to reports, in favourably situated installations, a saving of 30 to 35 per cent may be realized. However, it may be mentioned that bunker fuel cannot be used in small high-speed diesel engines; this economy measure is threfore of limited application in the case of rural electrification.

(*c*) *Wind-power plants*

Wind has been a source of motive power for centuries. In many countries agricultural operations, mainly the pumping of water, are carried out by various types of wind motors. There are many small wind-driven electricity-generating units in operation in isolated areas in most countries. The theoretical wind-power passing through a circle of 10 ft in diameter is reckoned as 3.1 hp at 20 mph and 10.4 hp at 30 mph.

The average wind velocity varies widely from country to country and area to area. It is estimated that an ordinary wind motor requires a minimum wind velocity of 7 to 10 mph for the effective working of a generator. If the wind velocity varies widely with the time of the day and the season, a continuous supply of power from wind-motor-driven generators cannot be guaranteed. Therefore such installations require storage batteries as a necessary complement. This calls for the installation of automatic devices for connecting the battery to the generator when the proper charging voltage is developed and to disconnect it when the voltage is low, that is when the wind velocity is below the minimum.

The size of the generator varies with the size of the wheels and the height of the tower. It varies from 0.5 kW for an 8 ft diameter wheel to 10 kW for a 30 ft wheel. Mention may be made of a large wheel-turbine installation having a capacity of 1,000 kW, serviced in 1941 on Grandpa's Knob (Hubbardton, Vermont, USA). This was in service until 26 March 1945, when a blade failed. It had 80 ft long blades and was mounted on a 200 ft tower.

Wind is a valuable source of power in isolated areas where the requirements are small. The economics of large installations are still under study. A group of experts under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) are making a special study of this problem.

2. Standardization of sizes, voltages and frequencies

In countries of the region, a variety of voltages and frequencies is used. The main reason for this diversity of voltages and frequencies has been that, as the undertakings were promoted independently by several private companies, each determined the size of the plant and voltage to be adopted, depending upon the availability of equipment and the prospective demand at the time the undertaking was established. Lack of over-all supervision and co-ordination has resulted in the establishment of these units of varied character.

Whatever may have been the reason in the past, it is essential to ensure that such haphazard development is avoided in the future. The benefits to be derived from standardization are numerous. To mention a few:

(*i*) Low cost of manufacture of equipment on account of large-scale production;

(*ii*) Low maintenance cost due to a plentiful supply of cheap spare parts as a consequence of mass production;

(*iii*) Feasibility of interchange of units and spare parts;

(*iv*) Possibility of interconnection of transmission and distribution due to uniformity in voltage and frequencies.

Furthermore, when the countries of the region start manufacturing heavy electrical plant the standardization of various types of equipment will make large-scale production economical and reduce to a minimum the capital outlay to be incurred by the factory for machine-tools, jigs and dies.

(*a*) *Size of generating plant*

It is recognized that the size of the plant to be established in a particular area is determined by the prospective load. It is also true that a station consisting of a very large number of small-size units is less economical than a station having a small number of units of equivalent total capacity. Very often the demand is likely to be under-estimated, the result being the establishment of a station with one or two small units; as the loads grow the addition of small-size units eventually results in a station's consisting of a large number of small units after a few years. This can be partially avoided by moving small units to new areas and installing larger-size units in their place where the load has grown. In any case, standardization seems to be very necessary.

The standard sizes to be specified must be in conformity with the standard size of the diesel engines manufactured by well-known manufacturers, so that equipment may be secured expeditiously and at the minimum cost. The following are suggested as possible standard sizes:

50 kW, 100 kW, 200 kW, 500 kW

The reason for suggesting 50 kW as the smallest size unit is that however small the community to be served may be, at least one or two irrigation pumps and a few motors to run machinery for processing agricultural products will be installed. Therefore, generating equipment of less than 50 kW may soon prove to be too small. Where the daily-load curve indicates that the load during several hours is comparatively small. the economies to be realized by installing a smaller-size unit to be run during the low-load period must be examined and this installation should receive favourable consideration when the light load is of the order of 20 to 30 per cent of the peak and lasts several hours of the day. It is recognized that this involves additional capital, but over-all economy may dictate such a course of action.

(*b*) *Voltage of generation*

The voltages that can be considered for rural purpose are:

DC 110V 220V

AC 3-phase 400V 4-wire; 3-phase 3,300V 6,600V 11,000V.

It is presumed that generation voltages above 11,000V are not required for the time being in the rural areas of countries of the region. The factors that influence the decision with regard to the voltage are:

(*i*) Size of the generating unit

(*ii*) Area of the distribution system, i.e. the distance between the generating station and the tail-end consumer

(*iii*) How soon the grid supply is expected

(*iv*) Comparative cost of high-tension generation and a combination of low-tension generator and transformer.

In the past DC supply has been adopted for urban as well as rural areas. With the growing advantages of AC over DC (*e.g.* simplicity and cheapness of consumer equipment and ability to transmit power over long distances economically), AC is now being universally adopted. Almost all countries are making special efforts to convert the existing DC distribution systems to AC; therefore, for the purpose of this report, it may be assumed that DC generation is of no interest to rural electrification schemes in the region.

With regard to the selection of an appropriate voltage, if the size of the plant is 100 kW and less, economic considerations lead to the adoption of a 400V 3-phase 4-wire system. The advantage of this system over a 220V 3-phase 3-wire system is the higher capacity of the system for the same weight of copper. Furthermore, the presence of a grounded neutral provides safety against broken conductors and grounding in the interior wiring of consumers installation. With the generating voltage of 3-phase 400 V, step-up and step-down stations may be established at suitable locations to meet load demands at comparatively long distance. This may be more economical than adopting increased generation voltage so long as the proportion of the load to be transmitted over long distances is small.

Where the capacity of the plant is large (about 500 kW) and the area to be covered is wide, high-tension generation is recommended. This eliminates costly transformation at the generating end. For intermediate capacity stations, the decision will have to based on individual merit after the cost of high-voltage generation, switch gear, cables, etc. has been compared with that of a combination of low-tension generating equipment, transformers and auxiliary equipment.

In the case of a high-tension generating station, the choice of an appropriate voltage is important. The higher the voltage, the larger is the block of power that can be transmitted for the same size of conductor. In an overhead distribution system, for mechanical reasons, the minimum size of conductor that can safely be used is No. 8 SWG or No. 6 B & S copper. If the load is comparatively small and can be distributed within the limits of permissible loss and regulation with a No. 8 SWG copper conductor at 3,300V, no advantage can be gained by adopting a higher voltage. On the other hand, the advantages of the potential capacity of a higher-voltage distribution system may outweigh the initial increased cost of higher-voltage generation equipment. Also, there is not much difference in cost between 3.3 kV and 11 kV transmission and distribution systems. Each problem of voltage selection will have to be examined on its merits. In any case, the choice of voltage may advantageously be limited to 3.3 kV and 11 kV.

The selection of an appropriate voltage in the case of supplies to be made available from a hydro grid, has been the subject of considerable discussion and study. Careful consideration is also necessary in the case of a distribution system initially established for supply from a central generating station with the definite understanding that it will have to be fed from a hydro grid in the near future. As the problem is one of transmission, it is dealt with under section B hereinafter.

(*c*) *Frequency*

There are three frequencies at present in existence in the region: 25, 50 and 60 cycles per second. Some of the 25-cycle installation are being converted into 50-cycle. While 25-cycle supply was the outcome of early electrification projects, 50- and 60-cycle frequencies have come to stay. For various reasons, the United States have adopted the 60-cycle frequency in preference to the 50-cycle. Continental Europe, the United Kingdom and many of the countries of the ECAFE region have adopted 50-cycles per second. Therefore, for future electrification, there does not seem to be much choice before the engineers of the countries of the region. The adoption of the 50-cycle frequency seems to be universal and desirable.

B. Transmission

The main obstacle to the rapid expansion of rural electrification has been the problem of making electricity available economically to small units scattered over long distances. The manufacturers of farm equipment, agricultural colleges, research institutes and engineers in the field have been working hard on the connected technical and financial problems. With the combined efforts of all the above organizations and with the co-operation of consumers, it has been possible considerably to reduce the cost of transmission and distribution. Concessions granted by Post and Telegraph Departments and Electricity Commissions in various countries have also helped. It cannot be said however that here are no more problems. It will perhaps take several years of persistent efforts on the part of everybody concerned to overcome the difficulties that still exist.

Sound engineering development consists in supplying the immediate and foreseeable needs at the minimum cost consistent with technical suitability and reliability. There is no virtue in making excessive provision for future development or in providing plant which is unduly heavy or costly for the work. Risks must be balanced and the best solution of any engineering problem is usually one which combines immediate suitability with reasonable flexibility to meet increasing demands.

It is recognized that solutions have been found to many problems facing organizations in charge of rural electrification in western countries. Though many of the solutions are useful to the engineers of the ECAFE region, many special problems peculiar to the region still call for a solution. To mention one, the rural population of the region, which is more than 80 per cent of the total population, lives in small hamlets with a very low standard of living. Therefore, the power demand per installation and the *per capita* consumption will be very low, at least for some time to come. The main load for the present will consist of domestic lighting, irrigation pumping installations and machinery for processing agricultural products. As many cultivators have small holdings and are unable to invest large sums of money in the installation of pumping sets, the number of pumps to be serviced per mile, or the load in hp per mile of the feeder will necessarily be small. This aspect will have considerable bearing on the design of the transmission and distribution systems.

The problem of the central station service centres principally on its main objective, that of producing electrical energy in comparatively large blocks at suitable points and distributing this energy to a multitude of consumers scattered over a relatively large area. Some authors compare this to the distribution of merchandise. In the distribution of merchandise, it is usually sound policy to transport in large-capacity units from a source of supply as far as possible towards the ultimate consumers, sub-dividing the branching out where necessary into smaller and more practical units, attempting to reach the consumers with a minimum number of transfer or transformation points. The principle underlying the distribution of electrical energy is that it should be conveyed to the consumers over as long a distance as practicable with as high a capacity and voltage as practicable and economical, and that the number of transformations should be reduced to a minimum.

The upper limits of circuit voltage are governed by various factors, some inherent in the construction of the electrical equipment and some arising from external causes. However, these conditions are constantly changing and developments in the art of electric-power transmission are making it possible to accomplish results which in the past may have been regarded as impracticable. In the setting up of any electrical transmission and distribution system, various limitations to operating voltage must be kept clearly in mind and provision made for taking advantage of any development and changes which may reasonably be expected.

In the selection of circuit voltages, the following points must be given due consideration:

(*i*) Minimum number of transformations
(*ii*) Use of standard voltages
(*iii*) Future system requirements
(*iv*) Maximum voltage limitations
(*v*) Economy of construction and operation.

1. General design of rural transmission lines

The electricity regulations enforced in various countries impose certain restrictions on the design of transmission lines and distribution systems; in the past, owing to the fact that transmission and distribution were limited to urban areas, the ground clearances and safety factors have been over-emphasized. These are not equally important in respect of rural lines in unfrequented parts.

2. Standard voltages

Many advantages accrue from the use of recognized standard voltages. To mention only two, thanks to bulk purchases of equipment, the manufacturing cost of such equipment can be reduced; inter-connection between various systems would be economical if voltages were identical. The requisite qualifications for the ideal rural lines can be briefly summarized as follows:

(*i*) Adaptability for isolated supplies en route
(*ii*) Margin for development of load
(*iii*) Low initial cost
(*iv*) Reliability of supply and low maintenance cost
(*v*) Simplicity of construction with minimum number of parts.

The proper selection of a circuit voltage may eliminate the necessity of unduly complicating the system in the future by the addition of another voltage class for reinforcement. Conversely, uneconomically high voltages should not be adopted unless they can be justified by increased loads anticipated within a few years. Experience has shown that compromising on an intermediate voltage for the present in order to lower the cost will ultimately result in more voltage levels and transformations than may be considered economical. It is recognized that factors other than economy and operating desirability may enter into the final determination of the circuit voltages, owing to peculiar circumstances of the locality, such as space, terrain, local laws and regulations, etc.

At present, various voltages are adopted in the region, *e.g.*:

3-phase AC 220V 380V 400V 2,200V 3,300V 4,400V 6,600V 11,000V 13,200V and 22,000V.

Although in western countries like the United States of America, transmission voltages of 132 and 220 kV have been used for rural transmission systems, the loads expected in the countries of the ECAFE region are comparatively small and therefore voltages higher than 22,000V may not be required, at least for some time to come.

The selection of an appropriate voltage is dependent upon the extent of load to be carried and area to be covered. However, the mechanical strength of conductors limits the size of the conductors to be used and pole heights are regulated by the requirements of minimum ground clearances. Furthermore, whether the supply is from a general grid or from local generating stations has considerable influence on the selection of an appropriate voltage.

It is certainly advantageous to select a voltage which will allow transmission of the required power to meet the present demand and have a potential capacity to meet anticipated future demand, but it must admit of a high-tension supply's being taken to the various centres of low-tension distribution, thus eliminating a second transformation. While the total load to be transmitted and area to be covered are a guide, further details are necessary. Load statistics (kVA demand per square mile) can provide valuable guidance, but they do not present the exact requirement for selection of an appropriate voltage. For instance, a load of 1,000 kVA per square mile may mean 2,000 consumers scattered over an area of one square mile or three or four consumers scattered over the same area. Obviously, the transmission and distribution problems must be quite different in each case.

To assist the engineers in quickly designing comparatively small transmission and distribution systems, which are ordinarily required in the case of rural electrification, a voltage-drop chart and a power-loss chart using ACSR cable (aluminium cable, steel reinforced) and bare, hard-drawn copper conductors have been prepared. Some of the charts prepared and published by the Tennessee Valley Authority of the United States are comprehensive and simple to apply and hence have been reproduced (see chart I). Thse charts are suitable for application in the case of supply voltages of 230V, 440V, 2,300V, 4,400V, 6,600V, 11,000V, 13,200V and 22,000V. The size of conductors for transmission over various distances can be selected for different loads, with allowable voltage drops up to 14 per cent and power loss in per cent of kW delivered up to 14 per cent, both for ACSR cables and copper conductors.

In order to effect economies in the construction of transmission and distribution systems for rural electrification, agriculture colleges, research institutes, manufacturers of equipment and distributors of electrical appliances have made a detailed study of the various operations on a farm. This revealed that by suitably modifying the designs of various kinds of machinery ordinarily required on a farm, the power requirement of the machines could be reduced to 5 hp or less. Single-phase motors of 5 hp and less have been successfully designed, with the result that it was established that all operations on an average-size farm could be accomplished with a single-phase motor. Therefore, electricity-distribution engineers took advantage of this fact and decided to make single-phase power supply available to farms, thus reducing the cost considerably.

Another method that can be adopted to make a rural power supply economical is to construct the transmission and distribution system suitable for a higher voltage, such as 11 or 22 kV, and in order to reduce the capital outlay on transformers, make a lower voltage supply available initially. This provides for a potential capacity for future growth of load. In some cases, this will avoid reconstruction of the transmission and distribution system when grid supply is made available.

Comparative figures for two projects in the United States are given below:

TABLE 13

CORPARISON OF TWO ELECTRIFICATION PROJECTS IN COLORADO, USA

	Project A	Project B
Primary miles	387	208
Consumers	434	238
Cost using 12.47/7.2 kV including sub-stations and transmission ($)	559,756	625,000
Cost using 23.9/13.8 kV including sub-stations and transmission ($)	475,565	415,000
Saving 23.9/13.8 over 12.47/7.2 (%)	15	34

In order to make rural electrification as cheap as practicable, the British Post Office Authorities have granted certain concessions, which are summarized below:

(*i*) Reduced operating distances between the high-voltage (not exceeding 6.6 kV) lines and post-office lines.

(*ii*) Attachment of post-office subscribers' lines to power-line poles.

(*iii*) Attachment of low-voltage service lines to post-office poles.

(*iv*) Reciprocal use of post-office and power-line poles for flying-stay purposes.

(*v*) Concessions as to the details of cradle guarding.

The concessions granted by the Electricity Commission of the United Kingdom can be summarized as follows:

(*i*) Reduction in radial thickness of ice loading to be allowed on high-voltage conductors from 3/8" to 3/16".

(*ii*) Modification of certain restrictions regarding special protection where high-voltage conductors are erected along or across roadways.

(*iii*) Relaxation of requirements where high-voltage and low-voltage lines are carried by the same post.

3. MATERIALS

It is felt that a study of the construction of an economical transmission line cannot be complete without mention of the various materials required. The principal materials that are used for the construction of transmission lines are:

(*a*) Supports
(*b*) Cross arms
(*c*) Insulators
(*d*) Conductors
(*e*) Overhead ground wires
(*f*) Isolating devices and protective equipment

It is generally accepted that aerial lines are more economical feeders than underground cables. It is recognized that special circumstances may necessitate the use of cables. To quote an instance, the supply of power to rubber, tea and coffee estates may require special consideration. In some cases, the construction of aerial lines involves the cutting down of a number of trees and the estate owners may object to such a procedure because the removal of shade trees, for instance, may have adverse effects on the yield of the estate. Even the laying of underground cables in these cases may be difficult and may damage a number of plants, making the proposition uneconomical. It must be recognized that most of the estate owners have at present other forms of motive power such as steam, diesel, etc., for carrying out the manufacturing processes on their estates. The central-station supply will have to be made attractive to them: the cost of installation should not be prohibitive nor should it affect the yield of the estate. Therefore, it is suggested that in the study of various systems of construction of feeders for power supply to such estates, consideration should be given to the cost of feeding estates with lead-covered, weather-proof, un-armoured cables suspended from an appropriate-size steel messenger-cable strung either on specially erected supports or fixed to the branches of reliable trees.

(a) Supports for transmission lines

The usual types of supports used for transmission lines are:

(*i*) Wooden posts
(*ii*) Steel rails
(*iii*) Rolled steel sections
(*iv*) Reinforced cement concrete posts
(*v*) Lattice poles
(*vi*) Tubular steel poles.

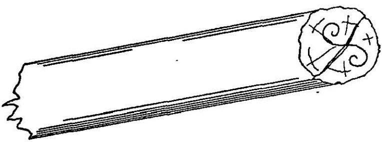
(*i*) *Wooden posts*

Among the countries of the ECAFE region, only India and Japan are producing steel at present. Even India's production of steel is totally inadequate to meet its own requirements. There is an over-all shortage of steel in the region. Fortunately, almost all the countries possess rich forests and these are in many cases capable of yielding straight poles of sufficient height to meet the requirements of transmission lines up to 22 kV, which is the maximum voltage that can be considered economical at present for rural electrification in the region. It may here be mentioned that wooden poles have been used in India for transmission lines up to 110 kV. Canada, the United States and many western countries have used wooden poles up to 132 kV.

The main disadvantage of wooden poles is their comparatively short life due to inherent defects such as the setting-in of dry rots, etc., and damage caused by insect pests. To prolong the life of these poles a considerable amount of money, time and labour has been spent by forest research institutions and chemical-compound manufacturers in order to produce chemicals and processes which would ensure longer life to the wood. It may be mentioned that two chemicals commonly used at present are creosote and ASCU. There are several processes of treatment, for instance the Bethell process and the Rueping process (see appendix 1).

Particular attention may be drawn to the fact that the cutting of notches and drilling of holes before the poles are treated has lengthened their life, as it prevents the exposure of untreated parts of the wood to weather and destructive insect pests.

Furthermore, it has been observed that after being fixed in the ground treated poles often crack at the bottom and thus expose the untreated portion to attack by white ants. The tendency to splitting can be noted when the poles are stacked, after treatment, for a short time. In order to avoid splitting, hoop-iron about 2″-2½″ wide, 1/16″ thick and about 12″ long is driven in the wood edgewise in the shape of an elongated "S" (see fig). However, although it has been claimed that the difficulty had been successfully overcome by this method, the problem has been only partially solved.



The tops of poles are protected by a sheet metal cover forming a roof to prevent rain water, etc., from penetrating into the cracks in the top of the pole. This also has somewhat extended the life of the poles.

In some parts of America, the poles that deteriorate in service are specially treated with pentachlorophenol to prevent further decay (see appendix 2). Treatment with creosote or ASCU gives an average life of over 15 years. Experience shows that the deterioration of wooden poles due to dry rot occurs about 6″ below the surface of the ground. In order to lengthen the life of wooden poles, some distribution companies have adopted a procedure of clamping wooden poles to reinforced cement concrete butts fixed in the earth. This prevents access of white ants to the wood. The choice of such a system depends upon the extent of the damage that can be anticipated from the underground insect pests. The method is naturally costlier than the use of wooden poles buried in the ground and therefore the economics of the problem are dependent upon local conditions. Chart II shows the method of fixing the poles as noted above.

The types of wood used for supports in the States of Mysore and Madras, India, are compared in table 14.

TABLE 14

COMPARATIVE STRENGTH OF SOME IMPORTANT WOOD POLES IN INDIA
(Teak = 100)

Species	Botanical name	Hardness (%)	Weight (%)	Strength as a beam (%)	Stiffness (%)	Shock resisting ability (%)	Retention of shape (%)	Shear (%)
1. Teak	Tectona grandis	100	100	100	100	100	100	100
2. Irul	Xylia xylocarpa	195	125	100	105	90	65	155
3. Pine	Pinus insignis	85	90	80	90	90	85	155
4. Mesus	Mesus ferrea	215	140.1	145.1	150.1	160.1	55.1	145.1
5. Mathi	Terminalia tomerloza	150	125	105	110.1	130.1	65.1	115
6. Honnai	Pterocarpus marsupium	135	115	105	95.1	135.1	75.1	115.1
7. Irumbogam	Hopea parviflora	200	135	120	120	130	65.1	155.1
8. Casuarina	Casurina exquisitefolea	125	115	85	100	135	50.1	150.1

Source: Proceedings of the World Power Conference, New Delhi, 1951

It is well known that many countries of the region use wooden poles from their own forests for electrical distribution, some after treatment and some without treatment, but no details of the processes of treatment or the types of wood are available. For countries which possess rich forests, the use of wooden poles, treated or untreated, for rural electrification is to be recommended in order to reduce the cost of electrification to a minimum. Even though the life of treated wooden poles is short, from the national point of view, their replacement once in 15 years is more economical than the import of steel supports lasting over longer periods. Some of the varieties of wood referred to above are not useful for other works and therefore their use permits a regulated exploitation of the forest resources of the country. The cost incurred in cutting the trees in the forest, transporting them to the site of treatment (if treatment plants exist) and from treatment plants to the place of utilization and the payment of a royalty to the government for extraction from the forest should not be prohibitive if the whole thing is properly organized.

A reference to table 15 giving the comparative costs per mile of transmission lines using various types of supports will show that the cost of transmission lines using wooden poles involves the minimum of expenditure, although the maintenance and replacement costs may be slightly higher.

TABLE 15

COMPARATIVE COSTS OF TRANSMISSION LINES, MYSORE STATE, INDIA

(Indian rupees)

Size of wire (copper)	Wooden supports				Steel rails			Fabricated steel structures 33 kV
	2.3/4.6 kV	11/13.2 kV	22 kV	33 kV	2.3/4.6 kV	11/13.2 kV	22 kV	
6 B & S	6,600	7,270	8,420	11,300	7,200	7,450	9,220	12,220
4 B & S	8,630	9,270	10,400	13,200	9,100	9,500	11,200	14,200
2 B & S	9,520	9,520	13,500	16,400	12,300	12,750	14,500	17,000

Re 1 = US$0.21
Copper price: Rs 2.5 per lb
Steel rails: Rs 325 per long ton.

With regard to the number of supports to be used per mile and the height of each support, the size and tensile strength of the conductor as well as the regulations on the subject of minimum clearances from the ground have to be considered. If communication conductors are carried on the same supports as power conductors, a slightly greater height may be required. Where low-tension conductors are carried on the same supports as high-tension conductors, the height of the poles will have to be appropriately determined, on the basis of the minimum ground-to-conductor clearance that is required.

Table 16 shows the number of poles per mile required and the approximate relative cost of pole, hardware and labour, exclusive of conductors, for the various lengths of spans.

TABLE 16

POLES AND SPANS PER MILE: RELATIVE COST

Spans (ft)	Poles per mile	Relative cost (%)
150	36	100.0
200	27	77.5
250	22	65.4
300	18	55.5
350	15	48.5
450	12	45.1

Source: Ley Hearn and Jeffery: "Use of Electricity in Agriculture" (World Power Conference, New Delhi, 1951).

The electricity-supply rules in force in many countries of the region specify a ground clearance of 18 ft. Many States in India, particularly Mysore and Madras, have successfully reduced the ground clearance for rural lines to 15 ft. This reduction of ground clearance by 3 ft has helped to reduce the cost of transmission by about 3 per cent. The Tennessee Valley Authority (USA) has also effected certain reductions in the requirements of ground clearance in order to cheapen rural electrification (see chart III).

(*ii*) *Steel rails*

In a country where long lengths of transmission lines and large distribution systems are to be constructed in order to expedite rural electrification. a sufficient number of wooden poles may not be procurable. Even in cases where the resources are rich, the area of exploitation may be inaccessible. Furthermore, the transport problem may create a botttleneck, over-all treatment plants may not be available and the capacity may not be adequate to meet the requirements. In such cases steel rails may be the next cheapest support. The steel rails released from railways as well as steel rails which are rejected by the railways at the rolling mills because of minor defects form a good source of supply of supports for rural electrification. The sizes generally used are 41¼ lb, 50 lb, 60 lb and 75 lb per yard depending on the number of supports used per mile and the size and tensile strength of the conductor.

(*iii*) *Rolled sections*

It has been found that rolled sections of equivalent strength to rails of a particular size are cheaper than rails owing to their lower steel content. Rolled sections are popular where second-hand cheap rails are not available. Where steel rolled sections of appropriate size are available, it will be advantageous to use them in preference to the more expensive tubular posts.

(*iv*) *Reinforced cement concrete poles*

Owing to the general shortage of steel in the region and the increased production of cement in some of the ECAFE countries, reinforced cement concrete poles are being used for transmission and distribution systems in order to minimize dependency on imported materials. The chief disadvantage of such forms of construction is the difficulty of transport to the site of erection from the manufacturing site. Attempts are being made to cast the poles at site, but the absence of water for curing the poles at the site where the poles are to be erected is often a serious handicap. Some designs prepared by the Cement Marketing Co. of India are given in Chart IV. These designs are simple and are easily manufactured. Such poles have been made as light as practicable due consideration being given to the requirements of strength and facility of transport. Where sufficient numbers of wooden poles are not procurable and second-hand steel rails and rolled sections are not available, the choice of minimum-cost supports falls on the reinforced cement concrete poles. The advantage of this type of poles is that maintenance is practically nil, as they do not require periodical painting as steel posts do, nor are they likely to deteriorate from the effects of weather, acidity in the soil or insect pests. They are almost everlasting.

(*v*) *Lattice poles*

With this type of construction light rolled sections of steel, such as angles and flats, can be used. Although none of the countries of the ECAFE region at present possesses equipment for manufacturing tubular poles, some of the countries do have rolling and re-rolling mills producing light structurals which could be conveniently used for the fabrication of lattice poles of the required sizes and heights. If wooden poles or second-hand rails are not available and there are difficulties in the use of reinforced cement concrete poles, the choice falls on lattice poles wherever light steel structurals can be procured. In this form of construction the support can be manufactured either in sections or in individual parts and galvanizing can be done in small galvanizing plants, the maintenance cost being thus reduced to a minimum; the sections can be transported easily and assembled at site.

(*vi*) *Tubular steel poles*

As already stated, none of the countries of the ECAFE region possesses plants for the manufacture of tubular poles. Owing to the general shortage of steel and the increased cost of production, not only is the price of these poles, imported from western countries, comparatively very high, but considerable difficulties are being experienced by the countries of the region in securing supplies. Therefore, this type of poles for support for rural electrification would probably be adopted only as a last resort.

(*b*) *Cross-arms*

The materials that are generally used for the manufacture of cross-arms are wood and angle iron.

Wooden cross-arms are extensively used for rural electrification in western countries. In the countries of the ECAFE region, wooden cross-arms will have to be treated in the same way as the wooden poles described above if reasonable life is to be expected. Inasmuch as sawn scatlings have to be used, unless they are well seasoned and appropriately dimensioned, warping occurs. Experience has shown that the difference in cost between wooden cross-arms and angle-iron cross-arms is very little and the latter are therefore recommended. However, if work is delayed for want of the necessary steel for making cross-arms, the use of wooden cross-arms is advisable.

The length of cross-arms is governed by the distance between supports and the spacing between conductors, the main criterion being that the conductors should not come within arcing distance of one another when swinging. The economy that can be effected by reduction in length is small, but even small savings on every item will result in a considerable over-all economy.

(*c*) *Insulators*

The standardization of insulator sizes helps to effect economies. As a general practice, three sizes of insulators are being adopted:

(*i*) For voltages up to and including 6.6 kV
(*ii*) For voltages up to and including 13.2 kV
(*iii*) For voltages up to 22 kV

Except in India and Japan, no facilities at present exist for the manufacture of electro-porcelain. Even in India, the electro-porcelain manufactured is for use on 22 kV and below. Although raw materials needed for electro-porcelain manufacture exist in almost everp country of the region, very few factories have been established so far. This is probably due to the fact that the demand for this material has been very small, owing to the limited activities of electrical undertakings. At present, most of the countries of this region, except India, depend for low-tension insulators on imports from western countries and Japan. If extensive rural electrification is to be accomplished, the price of every article to be used in the project must be reduced to a minimum. Furthermore, as almost every government is contemplating extensive expansion in generation, transmission and distribution of electricity, with particular reference to rural electrification, the demand for these insulators will increase and will justify the establishment of more than one appropriately equipped electro-porcelain making factory in the countries of the region. With the establishment of these factories, the price of the insulators is expected to come down and thus contribute to the reduction in cost of rural electrification. Hence it is strongly urged that some countries of the region should make an effort to establish electro-porcelain factories to meet all their own requirements and those of the neighbouring countries. In the case of transmission lines up to 22 kV, pin-type insulators could be used, but the use of even suspension insulators in the case of 22 kV lines has been in vogue. The design of strain-insulators should be such as to eliminate as far as possible hardware requirements. Such types of insulators are being made by standard manufacturers and should be selected as they are bound to be cheaper than those which involve hardware as an integral part of the anchor-insulator equipment.

(*d*) *Conductors*

As already mentioned, the number of supports per mile in a transmission line is determined by the tensile strength of the conductor that is available for use. Although copper has been a common material for overhead conductors, its increased cost and the current shortage have led to the adoption of ACSR cables. It is recognized that high-tensile-strength copper alloys are being manufactured but, compared with ACSR cable, they are uneconomical. Furthermore, copper is not found in the countries of the region and these have to depend upon imports. The manufacture of aluminium, until very recently, was not undertaken in any of the countries of the region. Recently, however, some countries have established their own plants and more are likely to be established in the future. While deposits of copper ore have not been found in such large quantities, the deposits of bauxite are certainly extensive[1] and therefore, with the production of cheap electricity under the multiple-purpose projects under execution and under contemplation, aluminium manufacture will gain impetus and this may replace copper gradually.

In the design of transmission lines, the conventional methods provide for large factors of safety. Recently, in order to cheapen the construction cost, the safety factors have been curtailed and experince has shown that this curtailment has had no adverse effects on the efficiency and safety of the lines. For determining the length of span and the strength of supports, the permissible tension of the conductors is taken as one-half of the value of the yield point. Wind pressure is assumed to be between 15 and 18 lb/sq in. The extra load on conductors due to ice formation at low temperature is also taken into account. But, as already mentioned, these requirements are slackened to some extent, depending upon the conditions prevailing in the locality, and the reduction of safety factors has helped to reduce the cost.

(*e*) *Overhead ground wires*

The conventional practice in the past was that for all high-tension lines above 2,200V, overhead ground wires were to be run along the whole length of the transmission line. Recently, this question has received considerable attention with a view to reducing the cost of rural lines. Except for a few areas which are subject to very heavy lightning discharges, the overhead ground wire has been completely omitted for voltages up to and including 22 kV. This has not only saved the cost of the overhead ground wire, but has also reduced the height of the poles to be used for each type of transmission line, since the power conductors are shifted to the top of the pole and the required minimum ground clearances are secured with lower supports.

(*f*) *Isolating devices and protective equipment*

The conventional method of providing appropriate isolating equipment at the sub-station end of a feeder line has been to have an oil circuit-breaker with the necessary relays for the operation of the circuit breaker on overloads, earth faults, etc., and an isolating single-pole-operated or group-operated switch. In the case of rural lines designed to supply small loads, the use of such costly equipment may not be justified. Therefore, the practice has been to provide the line with one of the following simple devices. In the case of voltages up to 13.2 kV, porcelain-housed fuse cartridges are used, so long as the load is not in excess of 100 amperes. Several companies manufacture expulsion fuse cut-outs of different types and these are certainly cheaper than oil circuit-breakers. The above types of fuses serve as a protection against overloads and also as a simple means of isolating the line. In the case of 22 kV lines, expulsion types of fuse cut-outs are available possessing enough rupturing capacity for small-capacity transmission and distribution systems. Another practice is a combination of a group-operated disconnecting switch and bare fuse wire mounted on horn gaps. Experience has shown that the above forms of simple protective and isolating equipment have served the purpose without affecting the efficiency or the continuity of service. It is to be understood that this does not give the same standard of service as can be expected from an installation having oil circuit-breakers with protective relays and sometimes with automatic re-closing facilities, but to achieve the objective of making the service as cheap as practicable, this luxury can be dispensed with.

In order that the interruptions to the service may be confined to as small a part of the system as possible, fuse switches have been used at strategic locations and fused in accordance with a co-ordinated plan based on the calculated short circuit currents obtainable at various points on the system. This ensures that the fuse nearest the fault operates. It has been found, however, that 70 to 80 per cent of these interruptions are due to temporary fault conditions. This has led to the development of repeater switches of the two- or three-shot types. These switches have the ability of clearing temporary faults and automatically restoring service but they stay open after a pre-determined number of shots, if the fault persists.

4. Voltage regulation

Service continuity and voltage regulation are problems to be dealt with right from the start. They raise more problems initially than later, because customers may have been given an exaggerated idea of the service to be obtained, while the service may actually be dependent upon single-source transmission and distribution-line supplies, and the operating and maintenance forces may be not too well organized.

The usual measures that can be adopted for improving the voltage regulation are as follows:

1. "Possibility of expanding the aluminium industry in the ECAFE region" (E/CN.11/I&T/29)

(*a*) Increase the size of conductor or duplicate the lines.

(*b*) Make the supply systems into ring mains.

(*c*) Install voltage regulators such as induction voltage-regulators or static condensers.

Obviously the first remedy, increasing the copper section of the transmission lines, is expensive. It may also be difficult to duplicate the line on supports which already carry live conductors without prolonged interruption. Therefore, if two neighbouring circuits could be formed into a loop, some advantage could be gained, but this cannot be stated to be a universal remedy. The installation either of voltage regulators of the induction type or of stepped regulators has been a fairly common practice. These voltage regulators can be installed economically by using pole-mounted types that can be mounted at distribution centres at a low cost. These are very efficient and maintain the voltage fairly constant at the end of the lines, boosting or bucking to the extent of 10 per cent.

The use of capacitors for voltage regulation. Series capacitors can also be used for the regulation of voltage. These are current-operated devices which responds only to the current flowing through them and can be used as voltage regulators which respond automatically and instantaneously to variations of load current. They have the additional advantage of producing voltage correction without the necessity of mechanically driven controls and therefore provide a simple and practically maintenance-free method of voltage regulation. Another advantage of this equipment is that it checks the voltage rise due to the leading power factor which may arise in long transmission and distribution lines. The one serious disadvantage of this type of voltage regulation is that in some cases it may cause "hunting" in synchronous machines, as it changes the line constants. Therefore, careful examination of the system is necessary before capacitors are used for voltage regulation.[1]

In making a decision on the voltage to be selected for the transmission system of a rural electrification project, all the above factors must be taken into consideration. As mentioned earlier, the selection should be made among the prefererd voltages in order to limit the number of voltages that may be used. In the case of low-tension supplies of small capacity for concentrated areas, 400V 3-phase 4-wire is sufficient; in the case of rural electrification schemes involving long transmission and distribution systems, with local generation, 11 kV can be used. It must be mentioned that some countries, particularly the United States, have adopted 13,200V in preference to 11 kV. There can be no doubt that 13,200V, being higher voltage than 11 kV, makes it possible to transmit larger blocks of power over the same distance or to transmit the same blocks of power over a longer distance, but the practice in most of the countries of the ECAFE region has been to adopt 11 kV.

In the case of supplies to be obtained from the high-tension grid of a large hydro system, the existing medium voltages have to be examined. For instance, if a 33 kV system already exists, no object will be served by stepping it down to 22 kV for the purpose of a rural electrification scheme, even though the 33 kV is slightly costlier than the 22 kV. If a step-down is absolutely necessary and extension of the 33 kV system is uneconomical on account of the very small load, stepping it down to 11 kV would be preferable, but where the high-tension transmission system is of 66 kV and above, stepping it down from the higher voltage to 22kV and conveying the power to the low-tension distribution centre at 22 kV appears to be more economical. Though initially this is a little more expensive than 11 kV, the main advantage of selecting a voltage of 22 kV is that the potential capacity of the system is large and under the present conditions of difficulty in determining accurately the anticipated future demand a larger potential capacity in a system to be established is of great advantage.

C. Distribution

When the primary voltage of transmission has been selected, load centres (i.e. suitable locations for power-source points) can be determined by careful analysis of load density and distances within the area. In this phase of study, all loads that it is intended to serve should be taken into account rather than only those which may be immediately realized. As mentioned in the section on transmission-line conductors, the voltage selected should be such as to involve minimum transformation, i.e. the installation of transformers for stepping down the voltage from the selected high-tension voltage to a 400V 3-phase 4-wire system, if the supply decided upon is a 3-phase supply. The usual types of loads that can be anticipated in rural areas are:

(*i*) Medium-size electric motors up to 15 hp to drive irrigation pumping sets and machinery for processing agricultural products;

(*ii*) Domestic needs, such as lighting, fans, refrigerators, etc.;

(*iii*) Street lighting.

1. The Rural Electrification Administration of the United States Department of Agriculture has made an extensive study of the system and has given full details of its theory and operation, the determination of the location of the capacitors and the calculation of the required capacitor ratings in its bulletin: "Use of Series Capacitors for Voltage Regulation".

A practice that can be conveniently followed is to bring the high-tension line to the centre of the village to be supplied with power, and to extend the low-tension lines in all directions from the centre. Aerial lines, being least expensive, should be adopted for the secondary distribution system. Street lights may be on a parallel system and an additional wire may be provided with a time-switch to turn them on and off in the evening and in the morning. Particular mention must be made of the fact that inasmuch as the irrigation pumping loads are likely to be scattered it may not be possible for a single transformer centre to cater for the needs of a large number of installations. Wherever the demand for irrigation pumping sets is concentrated in a small area. a central point of supply must be established, even though it may involve a slightly large size of conductors for secondaries in some cases. In other cases separate transformer centres will inevitably have to be installed for each.

In order to illustrate the above, a sketch showing the servicing of four irrigation pumping installations, two power installations, twelve street lights and forty lighting installations is attached (see chart V). In this connexion, it may be mentioned that the extension of high-tension lines to the centre of a town and of low-tension lines therefrom for distribution to individual installations may sometimes involve the running of high-tension and low-tension conductors on the some pole. The conventional regulations require that wherever high- and low-tension conductors are carried on the same supports, proper guarding should be provided between the two throughout their entire length. This provides 100 per cent safety against the high-tension conductors' coming in contact with low-tension conductors (thus causing damage to the equipment to be connected to the low-tension supply system) and safety to persons handling the equipment, but it is considered a costly safeguard. Simple devices have been found to serve the same purpose. A loop of flat iron surrounding the high-tension conductors on either side of each support, properly grounded, will provide the necessary safety. Any conductor that snaps, before falling to the ground or making contact with a low-tension conductor, will come in contact with the iron guard provided and the fuse will blow, thus de-energizing the conductor. Chart VI shows a very simple form of this construction. In many cases even such protection has not been provided, but no serious effects have been noted in years of operation.

Distribution transformers

It is desirable to standardize the sizes of the distribution transformer to ensure maximum economy. In cases where the supply is to be made available from locally established low-tension generating stations, the question does not arise. Transformers are required when supplies are to be made available from high-tension local generating stations or when supplies are taken from large grids. Where single-phase supply meets the requirements, single-phase transformers will be required. Where 3-phase supplies are called for, it will be more economical to use one 3-phase transformer than three single-phase transformers. Experience suggests the use of 10 kVA and 15 kVA for single-phase supplies. If the supply is at 11 kV- 3-phase, the transformer sizes that would be most useful are 25 kVA, 50 kVA and 75 kVA. If the supplies are being utilized direct from 22 and 33 kV, the sizes of transformers that would be most useful would be 75 kVA and 100 kVA respectively.

Owing to the large number of transformers connected to a rural supply and the inherent low-load factor, it is preferable to use transformers having low iron losses.

Inasmuch as a large number of transformers are required at various load centres on a high-tension distribution system, simple and inexpensive designs for the installations should be adopted. Amongst the various methods that are used for the erection of transformers of 25 kVA and less, single-pole mounting is considered the best (see chart VIIa). The same procedure can conveniently be adopted even in the case of 3-phase transformers. When larger-size transformers are to be used, or three single-phase transformers of large capacity are required for making a 3-phase supply available, a 2-pole structure with a platform in between may be the most economical (see chart VIIb). In the case of small-size transformers below 25 kVA, three single-phase transformers can be mounted on a single pole, two on one side and one on the other, but this depends upon the strength of the pole used for the purpose.

Overload protection

For small transformers, porcelain-housed self-contained fuse cartridges are used. These, properly graded, form a safe and economical means of securing the necessary protection against overloads and also serve as isolating links for disconnecting the transformers from service. In the case of large-size transformers which are either mounted on a platform in the ground or on a platform supported by more than one pole (see chart VIIb), the cheapest way of providing the necessary overload protection is to have a group-operated disconnecting switch and a bare fuse wire stretched across horn gaps, the location of the horn gaps being such as to permit the safe replacement of the fuse when the group-operated disconnecting switch is in an open position.

Some organizations adpot fuse protection on the low-tension side of transformers also, but many believe that the fuse protection provided at the point where each consumer installation is connected to the low-tension system, combined with the fuse protection provided on the high-tension side of the transformer, is adequate. Some organizations do not provide any fuse protection on the high-tension side of the transformer but rely for protection entirely on the fuse cut-outs provided on the low-tension side. In any case, protection on both high-tension and low-tension sides seems to be a costly safeguard which can be dispensed with in favour of protection either on the high-tension side or on the low-tension side, co-ordinated with fuse protection at individual consumer-supply points.

Over-voltage protection

Over-voltages may occur as a result of:

(*i*) Defects in the extra high-tension system imposing high tension over the medium-voltage transmission and distribution system.

(*ii*) Lightning discharges bringing about over-voltages on aerial systems.

Over-voltages due to the first cause are very few and therefore ordinarily not provided for. As stated in section B 3 (*e*), overhead ground wires used to be provided for protection against over-voltages due to lightning; however, for purposes of economy in the rural electrification network, these may be eliminated up to and inclusive of 22 kV.

In order to protect the transformers, conventional practice has been to install a set of lightning-arresters nearest to the transformer on the high-tension side. When the transformers to be installed are small, the cost of lightning-arresters forms a substantial portion of the cost of the installation. Furthermore, except in areas that are subject to very heavy lightning storms, it seems unnecessary to provide lightning-arresters near each transformer installation in a system. In a system consisting of several miles of distribution covering an area of about one-half to one square mile the installation of lightning-arresters at strategic points to protect a number of transformers connected to the system seems most economical. This practice has been adopted by some of the undertakings and the reduction of the number of lightning-arresters installed has not resulted in any marked increase in the damage to the transformers.

Where single-phase supplies are available, single-phase transformers with a single bushing have been designed the cost being reduced proportionately.

"A point of interest for the trend of future design of small pole-mounted transformers is the development of the all-insulated type where the tank is of porcelain or stoneware. Such transformers have given every satisfaction in operation for over two years. The advantages of this method of construction are:

"(*a*) No high-voltage or low-voltage insulator bushihgs are necessary;

"(*b*) The over-all size and weight is reduced by not having an earthed metal tank;

"(*c*) No tap changing switch is required as the various tappings can be brought out to separate high-voltage terminals consisting only of studs fitted through the tank;

"(*d*) The tendency to oil acidity is reduced and the non-metallic tank is corrosion-proof;

"(*e*) Painting is not required and as there are no insulator bushings, maintenance is practically nil".[1]

However, although many advantages are claimed, as above, this form of transformer construction does not seem to have thrived; it is only mentioned to give an idea of the efforts that are being brought to bear on the problem of making rural electrification less expensive.

As mentioned above, the aerial lines are the cheapest form of construction. The conventional method has been that each consumer's overhead aerial line is brought to the nearest pole of the low-tension distribution system and at this point an enclosed fuse-box is fixed to provide the necessary protection against overloads or earth faults, and facility for disconnecting the service as and when required. This involves the installation of a weather-proof box of wood or metal in which the fuse-holding equipment is to be installed, which naturally makes it costly. Several types of aerial fuses have been developed. Some are intended to be installed at one of the poles to which the consumer's aerial line is attached. In some cases, it is attached in the middle of the span of the secondary by means of a wooden piece fixed across the wires. These, being weather-proof, do not require any separate wooden or metallic housing. Some undertakings have adopted a box for the combined installation of the meter and the fuse-disconnecting device. In some cases, rural consumers are supplied with electricity on a flat-rate basis, eliminating the use

1. Picles, J.S. and Wills, W.H.: "Rural Electrification: the Use of the Single-Phase System of Supply", in *Journal of the Institution of Electrical Engineers*, vol. 93, part II, December 1946

of meters entirely, particularly in the case of small lighting installations, where the cost of the meter forms a disproportionately high part of the cost of arranging a supply; therefore the elimination of meters will effect a substantial saving.

Cases may arise where, in spite of the application of all the economics suggested above, the scheme will still be uneconomical because the prospects of load growth are poor. As a last resort, a scheme with restricted supply may be considered, in which the capacity is reduced and different category loads are served at different times of the day—*e.g.* irrigation, 6 a.m. to 12 noon, medium industries between 12 noon and 6 p.m. and domestic from 6 p.m. to midnight or on any other schedule to suit local conditions. This may prove less costly in the case of local generation and distribution using diesel generating sets than in the case of supply from a grid, when the saving may not be worth the trouble. Nevertheless, the adoption of this method in cases where the supply of essential materials such as distribution transformers is limited may help in pushing forward rural electrification, unrestricted supply being resumed as soon as equipment becomes available. It must be recognized however that some additional expenditure is necessary to enforce the restrictions, which undoubtedly will also make the supply unpopular with the consumers.

CHAPTER III

UTILIZATION

Rural electrification has two primary objectives. First, to improve the economic status of the rural population by increasing the productivity of human and animal labour, and secondly, to promote rural welfare by providing an environment equal in comfort and convenience to that enjoyed in urban centres. Thus electrification can be a powerful factor in preventing the drifting of the rural population to urban centres, where higher wages and more of the comforts of life are available.

A. General agriculture

It is recognized that the demand for electricity in rural areas in the countries of the ECAFE region is limited at present to uses such as domestic lighting and fans, pumping (lifting water to irrigate the land), and driving small simple machines for processing agricultural products. The use of power on the same scale as in the farms of the western countries may not be realized in the near future. As economic conditions improve, electrically-driven machines may gradually be installed, probably not on an individual basis, as holdings are small, but on a co-operative basis. It is not difficult to visualize that all the people of a village or a group of villages within easy reach of one another may have a centre where these facilities can be made available for their use. The establishment of a community refrigerated-storage plant may serve an area and preserve vegetables, fruit and meat, thus avoiding the enormous waste that is now occurring.

Water

In large multiple-purpose river valley projects, it has been established that irrigation and power production should go hand in hand to make the schemes economical and to increase the area to be commanded. There are many areas where large irrigation schemes are not practicable but where rich resources of underground water exist. Wherever electricity has been introduced, electrically-driven pumping sets, large and small, have brought a copious supply of water to the surface, improved the yield of the land and brought larger areas under irrigation. This has ensured a greater return for the cultivators, with considerable reduction in drudgery. In fact, this method of using electricity is so popular that a very heavy demand exists in several States in India. Limited generation capacity and a dearth of the essential materials like steel, copper, etc. required for the extension of transmission and distribution systems is holding up the progress. Chart VIII shows a typical small-pumping installation. The interesting feature of this installation is that, as the water level in the well varies at different seasons of the year, arrangements have been made to locate the pumping set at three different levels in order to maintain the suction heights appropriate for the centrifugal pump.

The financial results of five years of operation and the annual working expenses of the Ganga hydro-electric grid, India, which serves thousands of tube wells, are shown in table 17.

TABLE 17

GANGA HYDRO-ELECTRIC GRID, UTTAR PRADESH, INDIA

(1) *Irrigation pumping by tube-wells*

Year	1949-50
Number of wells	2,200
Area irrigated	898,000 acres
Total revenue assessment	Rs9,840,000 (Re 1 = US$0.21)
Area irrigated per tube-well	408 acres
Revenue per well	Rs4,473
Revenue assessment per acre	Rs11

(2) *Tube-wells—working expenses and return on capital*

(*a*) Annual working expenses of one tube-well under the 300-well project

		(Rs)
(i)	Maintenance and repairs, etc.	385
(ii)	Energy charges at Rs 80 per bhp per year	1,000
(iii)	Depreciation	989
(iv)	Establishment	1,715
(v)	Miscellaneous	11
	Total	4,100

(*b*) Financial forecast for the 300-well project

		(Rs)
(i)	Capital outlay	10,700,000
(ii)	Gross revenue	1,442,000
(iii)	Working expenses (300 x Rs4,100)	1,230,000
(iv)	Net revenue	212,000
(v)	Return of capital	1.92%

The Central Water and Power Commission, India, has estimated the cost of lift irrigation by different methods as follows:

TABLE 18

COST OF LIFT IRRIGATION IN INDIA

	Per acre per crop of paddy
	(Rs)
By animal power	300
By oil-engine driven pumps	83
By electric motor and pump	50
(Cost of power being 0.75 anna per kWh).	

Source: Proceedings of the World Power Conference, New Delhi, 1951.

Another important use to which electricity is being put to at present wherever it has been introduced is the reclamation of marshy lands. In many places where marshes had existed for centuries, rich tracts have been freed of water and malaria, making room for prosperous farms yielding food and fruit in plenty.

The next important use to which electricity is and can be put is the processing of agricultural products. To mention a few:

- Rice-hulling and polishing
- Cotton-ginning
- Groundnut-decorticating
- Flour-milling
- Oil-extraction
- Timber-sawing
- Tea, coffee and rubber processing.

Rice-hulling and polishing, corn-milling, and timber-sawing have traditionally been done by hand and such work imposes a severe physical strain on the workers. A number of applications for power supply are being received for the above purposes in newly-electrified areas in India.

Traditionally, oil-extraction in rural parts has been done by animal labour. There are large-scale oil mills in various centres using other forms of motive power. Apart from the limited capacity, oil-extraction by animal power is not economical, as much oil is left in the seeds. The availability of efficient small-size expellers, electrically driven, enables the grower of oil seeds to extract the oil and market it, retaining the cake for use as manure. The flexibility and economy afforded by electricity is leading to its replacing other forms of motive power even in the case of large centrally situated oil-extraction mills.

The power requirements and output of some of the electrically driven small processing plants in rural areas of India are shown in table 19.

TABLE 19

POWER REQUIREMENTS AND OUTPUT OF SMALL PROCESSING PLANTS IN INDIA

	Power (hp)	Output (lb/h)
Rice-huller and polisher (large)	25	2,400
Cotton-ginning (double-roller type) ..	4 to 5	78
Groundnut-decorticator	25	7,500 (shelled groundnuts)
Flour mill (for rice, wheat, cholam and ragi)	5 to 7.5	180
Oil-extraction (pinto oil press) for gini-gili, cocoanut, castor and groundnut	3	15

Tea, coffee and rubber are agricultural products which require processing before marketing. The estates producing these commodities have at present some types of motive power for processing; they are conscious of the benefits to be derived from the introduction of electricity, but they have not been electrified on a large scale owing to inaccessibility and the distances involved. With the cheapening of line construction, it has been possible to reach some of them and attempts are being made to reach others. The nature of loads of a tea estate and the development of the tea-industry load in Madras State, India, are outlined in appendix 3.

B. Cottage industries

The rural populations of the countries of the region who earn their living by agriculture are busy only during a certain portion of the year. It is particularly so where only one crop per year is grown. It is roughly estimated that for more than one-third of the year the cultivators are idle. Furthermore, if improved methods of agriculture are introduced, other occupations will have to be found for a large number of cultivators who may become surplus manpower on the farm. If the standard of living is to be raised, facilities will have to be provided for their alternative employment during their idle period. Therefore, all countries of the region are stressing the need for a rapid expansion of cottage industries. Amongst many forms of cottage industries that can be established with the help of electricity, mention may be made of the following:

- Silk-throwing (reeling)
- Weaving on individual powerlooms
- Machine-knitting

Cording for the woollen-drugget industry
Tape-weaving
Button-making
Coir industry
Wooden-toy making
Small machine shops

Artisans in the countries of the region depend on these industries for livelihood; but in many cases, the equipment used is crude, the production is small and, unless it is produced by a master craftsman, it is not generally saleable at good prices in the competitive market. Owing to the inadequate income derived from some of these industries, even the artisan classes who traditionally live on such trades have been abandoning them. Therefore the cottage industries must be revived on modern lines and the quality and quantity of their production improved to make them a worthwhile occupation. Electricity can do much in this direction. In this connexion, it may be mentioned that Japan's industrial system is not centred in some urban areas. Japan's success in industrialization may be stated to be due to decentralization and the availability of power at reasonable rates throughout the country, including rural areas. The rural areas thus contribute their full share to industrial progress. Thanks to electricity, machine-tools can be used, ensuring uniformity of quality and increased production. The introduction of electricity into rural areas, and the introduction of the improved tools required for the cottage indusrtries with financial and technical assistance, will provide employment for the population all the year round, which will be a real step forward in the economic uplift of the country. The sizes of the motors required for various cottage industries are small, as can be seen from these few examples:

Silk throwing—½ hp
Single-unit power loom—½ hj
Knitting machine—1/3 hp
Carding of wool—3 hp
Tape-weaving—¾ hp
Wooden-toy making—½ hp
Small machine shops—3 hp

The experience of a village in the State of Mysore, India, will serve to illustrate the benefit that the introduction of electricity will confer to rural areas. In this village there are a number of cloth weavers. Each possessed one or two handlooms and earned an uncertain livelihood depending on market fluctuations. Ever since the introduction of electricity, every one of them uses powerlooms and now runs more than one, taking power ranging from ½ to 1 hp. The village has a population of about 18,000 and there are at present 448 powerloom installations with a connected hp of 1,140. Thus every weaver has increased his production several fold and is able to hold his place in the competitive market and assure himself of a decent living with reduced drudgery. The following comparative costs bring out the overwhelming advantages of the powerloom over the handloom.

TABLE 20

COMPARATIVE COSTS OF HANDLOOM AND POWERLOOM, INDIA

	Handloom (Rs)	Powerloom (Rs)
Capital cost per loom	400	6,000[a]
Interest and depreciation per annum	20	600
Repairs and maintenance per annum	30	200
Wages for the operator (Rs3 per day for the handloom worker and Rs4-8 per day for the powerloom worker, who, however, handles 2 looms for 250 working days)	750	563
Energy charges for powerloom working 250 days of 8 hours each at 1 anna per unit		63
Overhead charges, rents, etc.	50	150
Total expenses	850	1,576
Number of sarees of 9 yd x 45 in produced per annum (per loom)	125	400
Cost of production per saree (excluding raw materials)	6.8	3.9

a. Estimated cost of a new installation. Second-hand looms are also in common use, in which case the initial cost will be substantially lower.

Source: Proceedings of the World Power Conference, New Delhi, 1951.

Electricity has several useful applications in sericulture, which is an important rural industry in some countries of the region. The eggs can be stored in refrigerators to delay hatching. The hatchery can be air-conditioned so that the rearing and nursing of the worms may be carried out under controlled conditions of temperature and humidity. Electricity is useful in cocoon conditioning plants, in which hot air is blown over mature cocoons to kill the worms, after which the cocoons may be safely preserved indefinitely until they are required for reeling. Hand-reeling has been said to be responsible for the low quality of silk. Electricity can be used and is being used successfully to secure a high standard of finish, uniformity and smoothness of filature silk by using fractional horse-power motors for machine-reeling in cottages.

C. Farms

Although, as already stated, a demand for electricity on the scale of the western farms is not likely to materialize in the region in the near future, the following paragraphs briefly describe the various uses to which electricity can be put and the benefits to be derived therefrom in order to bring out the potential of loads.

Farm power-supply has engaged the attention of engineers, agricultural experts and farm-machinery producers and their sustained efforts have made farm electrification an economic proposition. Intensive studies have been made of the application of electricity to various types of farm work. It is claimed that electricity is used for about 400 purposes. This does not mean that every farm uses electricity for 400 purposes. However, there is scarcely a step in the growing, processing and distribution of farm products that electricity cannot aid in some way or other. The increased use of electricity will depend upon the ingenuity of the designers of farm equipment.

Water

Apart from the use of water for irrigation, which has given the farmer a positive control over the vagaries of rainfall, the availability of water under pressure on a farm is a great asset. An increase in water consumption results wherever such supply is made available. The need of water in a farm estimated as follows:

Table 21

Water consumption

	(gal/day)
For each person	85
cow	25
horse	15
pig	5
sheep	1.5
For 100 chickens	2.5

Obviously, much work at present done by human labour on the farm can be saved by the installation of an automatic pressure-water system. Among the many benefits a pressure-water system confers, mention may be made of the following: cows, which are usually watered two or three times per day, drink ten to fourteen times a day when running water is made available for drinking, and it is estimated that milking cows provided with a plentiful supply of fresh water produce 10 to 20 per cent more milk, with a 6 to 12 per cent higher butter fat content. In a hennery, laying fowl will produce 8 to 10 per cent more eggs when a supply of fresh water is always available. The increase of automatic water supply in the pigsty has been found to increase production by 17 per cent. In addition, water under pressure affords fire-protection and sanitary convenience throughout the house and barns.

Farm power

The electric motor is one of the most useful contrivances to the farmer. There is on the market farm equipment with built-in motors. In some cases a portable motor is used for running various machines situated in different parts of the farm. A fully electrified farm of 23 hectares in Switzerland is reported to be equipped with over 13 built-in and portable motors with a total capacity of approximately 30 kW and a total connected load of 75.7 kW. The details of the machinery and the consumption of energy on such a farm are contained in appendix 4.

Electricity can be used for ploughing, but this use has not yet become general. The use of electric motors in thrashing machines is very common. Various sizes are recommended—7.5 to 50 hp—depending upon the size of the farm, 30 acres to 250 acres.

Grain-drying

Uncertain weather conditions often necessitate the installation of artificial grain-drying equipment. Various types are in use. The basic process is the blowing of heated air and cold air through a layer of grain; a cleaner and an elevator for loading can usefully be added. For a 6 per cent extraction of moisture, the power requirement is 5 hp and the consumption 6 to 10 kWh/ton.

Grass-drying

The repeated cutting of grass and other herbage and its rapid drying is now an accepted method of securing high-protein feed for livestock. The reduction of the moisture content from about 85 per cent to 5 per cent makes electrical drying an uneconomic proposition. Therefore, a simple conveyor-type machine for processing grass is used. This involves the use of motors for compressors, fans, elevators, mills, cubers, etc. up to 100 hp. The electric-power consumption varies with the conditions of drying from 80 to 230 kWh per ton dried.

Lighting

The primary use of electricity on the farm is for lighting the farm house and other buildings. It is estimated that the installation of adequate lighting, besides eliminating the fire hazards due to the use of oil lanterns, reduces the time spent on farm chores by 30 per cent. In poultry farming, the installation of electric light, by lengthening the day, is estimated to increase the yield of laying hens by 11 per cent; moreover, it makes it possible to alter the laying periods to make them coincide with the maximum-price season.

Heating

Many farms have enough fuel of their own. However, the electric range is becoming very popular. Its success has been the result of the convenience it affords, particularly during the busy season when the housewife welcomes its installation. The availability of hot water on farms is an invaluable asset. It is required for the cleaning of milk pails and for washing udders before milking. Steam is required on the farm for sterilization purposes; it is now being made available by storage-steam producers or by the heated steel-block method; in both cases electricity is the heating agent. Water from mountain springs is very cold; if this water is heated to 12-14°C and given to cattle for drinking, it increases milk production by 1 kg per head of cattle per day. Warming the water prevents the extraction of heat from the animal reserves, eliminates chills and promotes the normal functioning of the digestive organs.

Dairy farming

As already stated, electricity can provide hot water for various purposes and steam for sterilization. There is no substitute for clean, safe and wholesome milk. Many countries have laws insisting upon the appropriate treatment of milk before it is made available for public consumption. Cleanliness at every stage of milk production is insisted upon and dairymen have found that an efficient electrically-equipped milk house on the farm is a necessity. The primary equipment is the milking machine. Modern milking machines are designed to extract milk in the most natural way by a combination of vacuum and pulsating air pressure, simulating the action of the calf when feeding direct from the cow. The soothing uniform action of the mechanical milkers prevents injury, which often results from too vigorous hand-milking. The cost of owning and operating a single milking machine for 15 cows is estimated at $4.48 per month.

Pasteurization is the only known method of making milk safe for human consumption. It is a complicated process involving costly equipment, which is carried out at a central point where the milk is collected from various farms. It has been found that the milk taken from the cow contains bacteria, which multiply rapidly if time lapses between milking and pasteurization. When a central agency collects from different farms, delay in some cases is inevitable. However, if the milk is stored at a low temperature, about 50°F, bacteria-multiplication is negligible; therefore the dairymen have found it profitable to install electric milk-coolers for the storage of milk during the interval, thus eliminating losses due to rejects.

Feed-processing

It is recognized that the processing of feed increases its nutritive value. Ground grain is more easily digested than whole grain, since it is more thoroughly penetrated by the digestive juices. There is less waste of processed feed as a result of better mixing, and balanced rations can be given to the animal as it will be unable to discriminate between different feeds. Daily grinding ensures the freshness of the feed, thereby preserving the vitamin content of grain. All this helps increase the quality and quantity of the yield. Furthermore, chaff-cutting and root-slicing are laborious tasks; the installation of small motors, in some cases portable ones, has reduced the time taken for the job and also the drudgery on the part of the farm-hand.

Poultry farming

Farmers are of the opinion that, owing to keen competition, poultry-raising is uneconomical unless electricity is available. Electricity holds the field exclusively for the incubation and brooding of chicks. It is claimed that the best results are achieved by using electric incubators, which facilitate close control of temperature, humidity and air circulation.

Fruit-growing

High-pressure spraying of orchards with chemicals to protect the trees and the crop has become essential in the fruit-growing industry. Electric pumping is certainly handy and economical. Fruit-sorting and grading machines are increasingly being used in well-lighted farm buildings. A very significant contribution has been made by electricity in preserving and transporting fruit. Orchards are often located far away from potential markets. It is not unusual to find that fruit grown in one part of a large country is not obtainable in another part of the same country. The transport of fruit, even over short distances, by road, rail or water, involves a very high percentage of loss. This not only results in a national loss of food, but makes it costlier to the consumer. Some fruits, for proper storage, require not only the maintenance of low temperature but the control of carbon-dioxide concentration. Electrical refrigeration has provided the required means at minimum cost for the storage of fruit at orchards, transport over long distances and storage at potential market centres until it is delivered to the consumer. Domestic refrigerators add to the above series for preservation until consumption. Thus the fruits grown in far-away orchards are available for consumption by people living thousands of miles away with practically no loss in the process and without much alteration in flavour or nutritive value. Indeed, fruit grown in any part of the world can be made available to the population everywhere. Vegetables, meat and sea products may similarly be distributed throughout a country.

Horticulture

Electricity in horticulture has been extensively used for commercial market gardening and nursery work. Its normal use has been for pumping, compost mixing and the heating of glass houses. The recent trend in the United Kingdom has been to use electricity increasingly for soil-warming for various purposes. This has been the result of the combined efforts of the electrical research associations of the United Kingdom and the keen interest taken by the power-supply undertakings. Soil-warming is accomplished at low voltage from the secondary side of a transformer, the voltage range used being 4-6 V for small sets and for small-scale commercial use, under certain conditions, up to 30 V. Hot beds are provided by installing soil-warming wire in the frames and under light. The specific loading is normally 4-6 W/sq ft (45-65 W/m^2). Propagating beds are provided with heating facilities by placing the soil-warming wires in sand under light. Specific loading of 5-7 W/sq ft (54-75 W/m^2) is recommended; the control is effected either through thermostats in the sand or by hand through observation of temperature. Soil-sterilizing is being generally carried out by the electrode method, but recent investigations indicate that immersion heaters may prove successful.

Pig-breeding

Electric pig-breeders have paid large dividends by preventing losses during the farrowing season.

Electric fencing

Electric fencing is being increasingly used for controlling the grazing of pastures and preventing cattle from straying.

CHAPTER IV

PROPAGANDA AND LOAD-BUILDING METHODS

Even in western countries, where holdings are large, literacy and the standard of living higher, the farmer needs to be convinced of the desirability of abandoning age-old traditional methods, for new methods of production, preservation and processing of agricultural products before he will make any change. Intensive propaganda has to be undertaken, particularly in areas to be served from large multiple-purpose projects. A few of the methods adopted are described hereinafter.

A. Demonstration farms and convoys and sound films

It is stated that the best results are achieved by establishing demonstration farms within easy reach of the farmers of an area to be served. Farmers readily adopt changes when they see the results of changes made on other farms and when the means for making the desired improvement are within their reach. The demonstration should be such as to indicate correctly the capital cost and the running cost of each appliance and the correct assessment of the burden of these on the cost of the end-product. To mention an instance, the Central Swiss Power Co. at Lucerne has, for over a decade, run its own farm on electricity, undertaking research on all the applications of electricity to farm operations. The results are based on figures obtained in practical operation and nothing is recommended that has not been studied and found successful at the research farm. Electrical appliances were fitted with measuring devices and control apparatus to make an exact and reliable recording of power consumption. The result has been very successful and the rural consumption of electricity has increased by leaps and bounds.

In large countries it may not be possible to establish in every area demonstration farms that are within easy reach of all farmers; therefore spoken words and pictures have to be used. The Rural Electrification Administration of the United States has adopted a unique method. It produced a motion picture entitled "Power and Land". This documentary film was concerned with how farmers could obtain electric service and how they could use it on the farm. For over a decade this picture was shown all over the country and it is claimed that this has contributed most to making electricity popular in rural areas.

Another educational device used was a caravan fitted with a variety of electrical devices for farm home use and farm production. The caravan was accompanied by experts in farm machinery and appliances and also electrical experts who were in a position to given convincing answers to questions from visitors. The caravan moved from place to place among the rural and agricultural population. Each apparatus and appliance was equipped with such measuring devices as are required to give proof of the capacity and consumption of electrical energy so as to determine on the spot the incidence of the electricity charge on the end-product. Many organizations have published a large number of illustrated pamphlets explaining the specific applications of electricity in homes and farms and the benefits that accrue therefrom. These are being widely circulated.

Amongst the many experiments in load-building designed to show farmers the advantages of electrification, which are carried out by various organizations, the procedure adopted in the electrified rural commune of Magnet (Allier), France, needs special mention. The experiment consisted of placing at the disposal of a large number of subscribers all the apparatus to modernize their farms, free of charge, for a period of one year, at the end of which time they were free to buy the equipment finally or to return it. The current used was charged to the consumer. The experiment was started in 1939 and was carried on for ten years, during part of that time under unfavourable conditions due to the war. Nevertheless it was found that over this ten-year period, the consumption of electricity in the commune of Magnet increased in the ratio of 1:5 against a rate of increase elsewhere of 1:2. The commune of Magnet, numbering 649 inhabitants, had 183 subscribers before the experiment. The number of subscribers increased to 211 over the period under consideration and the average consumption per subscriber from 112 to 486 kWh.

B. Sale of equipment on the hire-purchase system

Among the other load-building methods adopted is financial assistance in several forms. The financing of rural electrification schemes by governments and in some cases the granting of subsidies to power-supply undertakings for the extension of transmission and distribution to rural areas are some of the types of assistance rendered. The establishment of a Rural Electrification Administration by the United States Department of Agriculture is one striking example of government help. Many western countries have established separate organizations to deal with the question of rural electrification in order to secure optimum results as expeditiously as possible.

In India, agricultural loans are granted for digging irrigation wells and for the purchase and installation of pumping sets, the amount advanced being recovered in easy annual instalments. In Mysore, half the cost of digging irrigation wells is met by the government and the other half is treated as a loan. The electricity departments of the Governments of Madras and Mysore hold large stocks of electrically driven pumping sets of reputed makes which are made available to cultivators on hire-purchase terms.

There is a serious power-shortage in the countries of the region. In some areas, the electric pumping set is so popular that there is a large unsatisfied demand. However, all the countries of the region are contemplating a large expansion of power-generation, almost doubling the capacity by 1956. Every government is anxious to see that a substantial portion of the benefits reach the rural population; therefore it is necessary not only to extend the transmission and distribution system to rural areas, but to educate the farmers in the beneficial use of electricity. With this end in view the following is suggested.

Demonstration farms should be established on the lines of what is being done by Central Swiss Power Co. in Lucerne. Documentary films should be prepared showing the various uses of electricity in the context of the living conditions and agricultural operations of the rural population of the countries of the region and exhibited throughout the countries. Convoys demonstrating the simple labour-saving appliances within easy reach of the population, should move about the country. Owing to the general inability of farmers to own individually all the labour-saving devices, the co-operative movement should be encouraged. It might be most helpful if governments were to establish a centre within easy reach of the population of a village, or within reach of a number of villages, fitted with farm machinery and appliances which would be made available free of charge in the first instance or on a nominal hire basis. Such centres should be staffed with experts who can render the necessary technical assistance to the rural population with a view to beneficial use of the equipment and appliances. In some cases, if individual farmers wish to own and operate some of the appliances, these should be made available on the hire-purchase system, the rate of interest levied being what the government usually pays on public loans.

To quote an example, the success achieved by the Electricity Board of Northern Ireland may be mentioned. Within a period of about eight years, it was able to supply on hire the following appliances:

TABLE 22

NUMBER OF ELECTRICAL APPLIANCES ON HIRE TO CONSUMERS IN NORTHERN IRELAND, 1939

Total number of consumers	41,358
Cookers	5,871
Breakfast-cookers	1,483
Boiling plates	1,258
Irons	17,860
4-pint kettles	7,693
Wash boilers	1,431
1 kW fires	1,900
2 kW fires	6,300
Water-heaters	522
Immersion heaters	507

The percentage of literacy among the rural population of the ECAFE region is of course extremely low. Nevertheless, a few illustrated pamphlets published in the local languages would help towards reaching the objective.

C. Maintenance service and expert advice

When a large number of appliances are individually owned by farmers and the rural population, a mobile workshop, adequately staffed to effect minor repairs at site, should be maintained as part of the organization which is established to render assistance to farmers. Knowledge about machines among the rural population is extremely low and small appliances and gadgets, though robustly built and ordinarily trouble-free, develop minor defects. If these are attended to immediately, heavy expenditure later will be avoided. Everything possible should be done to convince the agriculturist that mechanization and electrification have brought progress, increased production and saving of drudgery in their wake and to ensure that the machines and equipment are not a source of trouble to him. The mobile workshop should be manned by a staff of well qualified technicians and mechanics who can carry out the job required of them promtply and willingly.

At each centre covering a certain area, expert advice should be available to every farmer regarding the use of electricity and of electrically driven appliances. The establishment of a separate organization with the specific objective of extending rural electrification would expedite the achievement of results.

Chapter V

TARIFFS

A. Supply and demand

Electricity supply has essentially a limited monopolistic character inasmuch as, generally, a single undertaking is permitted to distribute electricity in a certain area. Furthermore, in the domestic field, electricity can be considered as essential for certain uses and optional for others; for instance lighting, and in some cases the use of vacuum cleaners, can be considered as essential in the sense that a consumer would pay a higher rate to obtain the service, even though a similar service might be obtainable at a cheaper rate by alternative means, because electricity offers more convenience and cleanliness. Heating and cooking are two examples of the optional use of electricity.

Special features of electricity—such as impractibility of storing electricity in significant quantities and sharp fluctuations of demand in a supply system reaching a maximum during a short interval of time during the day —play an important role in the formulation of tariffs. This necessitates the provision in each equipment in generation, transmission and distribution systems of a capacity sufficient to meet the maximum demand on the system. Obviously, when the demand is less, some equipment is idle or partially used, the result being that the cost of production is higher than what it would have been had the equipment been fully utilized all the time. In the case of thermal plants, the varying demand prevents utilization of equipment at maximum efficiency level and in some cases involves banking of boilers with the same result.

While various remedies have been employed to reduce the ill effects of the inherent characteristics referred to above, it has not been possible to eliminate them completely. The development of integrated power systems is one of the best remedies so far found. Another remedy is attractive tariffs for off-peak load consumption. Although it may be stated that the tariffs in force have a bearing on the over-all cost of supply, the use-value to the consumer has ruled the market rather than the actual cost of supply in each case.

B. Marginal cost

The concept of marginal cost was the starting point for a comparatively recent school of thought according to which the assessment of marginal costs should be used as the basis for a tariff-rate policy. In the following paragraphs, an attempt is made to assess the extent to which this theory can be applied to the formulation of tariffs in the context of the special features of the electricity-supply industry.

The special features which should receive consideration for the study of the marginal cost principle may be stated to be the following:

(*a*) Electricity at present enjoys only a limited monopoly as it is subject to competition from coal and gas in certain aspects of its utilization;

(*b*) Electricity is made available to a consumer and is not re-saleable by him;

(*c*) The electric-supply industry is a dynamic field requiring replacement of and additions to the plant from time to time;

(*d*) The life of electric power plant is 25 to 30 years and therefore market fluctuations in the price of plants bring to bear various factors in the costing of electricity;

(*e*) Electricity undertakings are public limited companies and are subject to keen public criticism; increases in tariffs based on anticipated increases in prices would not be acceptable;

(*f*) While discriminative tariffs between classes of consumption may be acceptable, discrimination between consumers for use of electricity for the same purpose would not be tolerated;

(*g*) The fixed costs form a major portion of the cost of production of electricity;

(*h*) An accurate determination of the contribution of individual consumers to system peaks is extremely difficult.

The basis of the marginal cost theory is to compare the value of output with the value of resources used up. When an expense is incurred, certain of the resources are converted to the particular purpose of the enterprise. If the product has a greater value than the resources used up, the enterprise should continue and even expand, whereas if it has a lesser value, the enterprise should curtail its activity or close down. In the case of electricity, a major portion of the costs are non-recurring and cannot be recovered by shutting down a plant but can be made to yield the value if used over a long period, that is, over the whole life of the plant.

Marginal cost, in the case of electricity, is defined as the increase in the annual cost which results from supplying one more unit per annum. Mathematically, it is represented by $\delta y/\delta x$, that is the rate of change in cost with output where y is total annual cost and x total annual output. The mean cost is y/x. The marginal cost is the change resulting from a change in output and hence only the costs which vary with output will appear therein. The mean cost, on the other hand, is made up of all items, including those unrelated to output. Therefore, in a steady price condition, the marginal cost is lower than the mean cost. The difference between the two will depend upon the difference between output-related costs and the total costs. In the case of electricity, assuming that a portion of even fixed costs may be treated as output-related as certain kilowatts will have to be allocated to every additional consumer for him to consume kilowatt-hours, in respect of additional consumers the difference between marginal cost and mean cost is small as compared with the difference in the case of additional kilowatt-hour consumption by an existing consumer without increase in his kilowatt demand.

An ideal tariff, in the economic sense, is one that reflects all the services rendered to the consumer and the various parts of the tariffs would exactly correspond to the various operations of the undertakings. Each consumer should be made to pay for the kilowatt-hour supplied the exact cost involved in the production of *that* kilowatt-hour, that is, each consumer should be billed on the basis of marginal cost. This is obviously unrealistic in the electric-supply industry, no matter how perfect it may appear to be.

In order to indicate how tariffs established on a purely marginal-cost basis can be impracticable, the following may be mentioned. The electric industry is a dynamic field, additions to plant have to be made from time to time as the demand increases. In the world of changing prices, the cost of machinery and of its installation varies from time to time. The price trend during the last decade has been on the increase. It is a well-known fact that a substantial portion of the production cost of electricity consists of depreciation and interest charges. When the cost of additional plant to be installed is higher and tariffs are to be based on marginal cost. it is obvious that the charges to be borne by the existing consumers for electricity supplied will be less than those to be paid for by the new consumers, even though the purpose for which energy is used is the same in both cases. This is not only impracticable but perhaps illegal as undue discrimination. In fact, this argument can be extended further to show that any existing consumer, when he wants additional supply, may be required to pay more per unit than what he is paying for his present consumption.

The value of service to the consumer is an important factor which canot be ignored. A tariff based entirely on cost is likely to bring about a result quite contrary to what it is desired to accomplish. Let us presume that a tariff provides for heating and cooking the same rate as for lighting, which in turn is based on cost of production. Such a rate would obviously be above the value of service for heating and cooking and below the value of service for lighting. The result would be, in a very few years, a complete change in the pattern of consumption. The lighting consumers would increase as the would be able to obtain the service at a very low rate and the heating consumers would dwindle in number inasmuch as they could get the same service by alternative means. Much of the capital equipment, particularly of the distribution system, would be badly under-employed owing to low load-factor of the lighting load and the cost of supply would rise and it might even make the electricity supply for lighting uneconomical if charges were increased by the undertaking to cope with the increase in cost.

As stated earlier, tariffs should satisfy both parties, the producer and the consumer. The undertaking as a whole should pay its way and should not exploit its position as a monopolistic industry. It does not mean that each separate rate in a tariff should attempt to recover all direct and indirect charges incurred in the production of energy regardless of the value of the service rendered to the consumer. Electricity supply, in spite of its peculiarities, has to fulfil two conditions: the buyer should be satisfied with the value received for the money he spends and the seller should recover, on the whole, all expenses plus a reasonable profit.

All the above varied influences have been summarized by D. J. Bolton in his book on *Electrical Engineering Economics* as follows:

"The rules governing electricity pricing are the same in principle as for any other service and commodity. Cost, which can be numerically related to a consumption variable, should as far as practicable be covered by a corresponding variable in the tariff. Other expenses can be loaded as and where they can best be met, which, in practice, will usually mean spreading them according to what the market will bear. Electricity supply differs from other industries only in respect of the *proportions* in which these two principles operate.

"The outstanding features of electricity supply economics from the pricing aspects are as follows:

"(*a*) The very high ratio of overheads to running cost;

"(*b*) The fact that many of the former are indivisable, that is they cannot be rigidly related to any practicable output variable (kWh, kW or consumers);

"(*c*) The difficulty that even of the divisible portion, those which are demand-related cannot be precisely allocated to consumers through ignorance of their effective demands on the supply system (which is a very different matter from their individual maximum demands);

"(*d*) The very high use-value of certain portions of the consumption which encourages 'market-bearing' methods of allocation.

"The hard core of cost-relating has therefore a soft and woolly exterior; it casts an extensive penumbra, and over this dark and dubious area the tariff-framers have ample scope for their operations and a correspondingly large margin of error."

C. Cost of electricity

The cost of electricity is dependent on two major factors, namely, the quantity of energy (kWh) consumed and the rate (kW) at which it is consumed. Broadly speaking, the former determines the amount of fuel consumed and the latter the size of the plant required to meet th demand. While the energy can be added up throughout the day and the year and the total sum represents approximately the fuel utilized for the consumer, the power demand fluctuates and it is the largest power demand at any one time that determines the size of the plant required to meet the demand of the consumer. The latter is known as the "maximum demand".

Furthermore, the cost varies with the type of supply and the point of supply. High-tension supply costs less than low-tension supply. In the case of consumers who are situated far away from the supply mains, the cost involved in arranging for the supply is greater than in the cse of nearer consumers. Within certain limits, the cost is not related to any of the electrical quantities. namely kilowatt or kilowatt-hour.

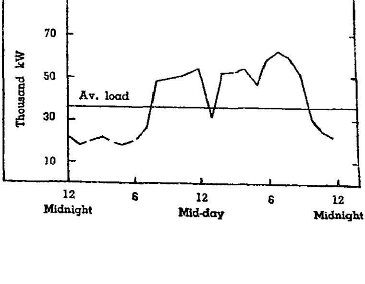
The kilowatt and kilowatt-hour costs are affected by various factors. A few important ones are:

Load factor
Diversity factor
Power factor
Integration
Losses

1. Load factor

The load factor is the ratio of the number of kilowatt-hours supplied during a given period to the number that would have been supplied had the maximum demand been maintained throughout the period. The following diagram indicates the typical load curve. From the diagram, it can be seen that the load factor on the day was about 62.9 per cent.

DAILY LOAD CHART



The weekly load factor of such a system would be lower in view of the fact that during the week-end holidays, the industries being shut down, the load demand would be less. The annual load factor would be further reduced owing to other holidays as well as to variations that occur in the pattern of the daily load curve during the different seasons of the years. The ideal load would be that having unity load factor. Unfortunately, not only the power-consuming apparatus is not connected to the supply system all the time, but when connected, it does not take the full load continuously during the period it is connected.

In the case of lighting, even though a residential building may have 30 lights installed, only three or four of them will be in use at a time except on very special occasions. Furthermore, lights are normally used in a residential building between sundown and 10 p.m. Thus, lighting forms one of the poorest load-factor loads. Since electricity cannot be economically stored in large quantities, the supply undertaking will have to have equipment ready to meet the full demand of 30 lights at the instant it is required once the installation is connected to the system.

In the case of industry also, all electrical motors in a factory do not work at their full load all the time. Moreover, some industries work only a single shift during the day. Week-end holidays and annual holidays reduce the load factor considerably. The undertaking should have a plant ready to meet the daily maximum demand the moment it is required. The result is that while the plant and organization are set up to meet the maximum demand of a consumer and are in a position to meet the demand at any moment throughout the period the installation is connected to the supply system, it is utilized only to the extent of the load factor of the demand. While daily load fators of 60 to 80 per cent have been realized in many undertakings, annual load factors of 50 to 60 per cent are considered very satisfactory. Inasmuch as 75 per cent of the cost of electricity are due to fixed charges which have no bearing on the actual quantity of energy (kWh) generated, such idle time adds to the cost of energy, hence improvement of the load factor is always the concern of a supply enginer.

Experience has shown that, generally, different loads have different load factors. A few are mentioned below:

Type of load	Load factor (%)
Domestic and commercial lighting	15–18
Public lighting	40–45
Municipal water-supply	25–50
Irrigation pumps	15–20
Deep mines	70–75
Surface mines	25–30
Electro-chemical and electro-metallurgical industries	
Electric furnace or cell	97–99
Auxiliaries	35–45
Industrial load	
Factories working single shift	20–25
Factories working double shifts	35–40
Factories working three shifts	55–60

In order to improve the load factor of a system over and above that which is secured by the inherent diversity of various demands (see tables 23 and 24), several methods are adopted. Mention may be made of the special tariffs that are offered for supplies during off-peak hours. Storage-type water-heaters are recommended in place of instantaneous water-heaters and arrangements are made to bring the storage-type hetaers into service during off-peak hours. Propaganda is carried on, requesting housewives to connect as few domestic appliances as possible at any one time and avoid their use as far as practicable during peak hours. A higher rate is charged for energy consumed above a certain maximum during peak hours at certain seasons of the year. In short, every possible effort is made to reduce the peak load on a supply system as far as possible and higher consumption (kWh) per kilowatt connected is encouraged.

2. Diversity factor

The diversity factor is defined as the ratio of the sum of maximum demands of several consumers or loads to their maximum simultaneous demand. The factor as defined above is greater than unity. In effect, diversity operates in exactly opposite direction to that of load factor. Despite the low load factors of the individual consumers, a high diversity between the various loads would enable the supply system as a whole to maintain a high load factor. The load factors of certain types of loads are inherent and cannot be improved individually, but the system load factor can be improved by utilizing the diversity (the diversity being purposely introduced where possible).

The coincident demand of a group of users, even of the same category, is usually not as great as the sum of the indivdual demands. The demand factors of a group of residential users as observed in the United States are shown in table 23.

Table 23

Transformer demands of residential groups in (Chicago, Ill., USA)

Watts connected per user	Number of groups	Number of users	kW connected	kW demand	% demand
Under 550	2	267	132	60	45.5
550 – 750	15	1.505	1,021	367	35.9
750 – 850	13	1,109	917	330	36.0
850 – 950	8	650	589	218	37.0
950 – 1,050	8	848	841	292	34.7
1,050 – 1,250	18	1,606	1,764	566	32.1
1,250 – 1,450	13	1,077	1,375	397	28.8
1,450 – 1,650	9	745	1,113	339	30.4
1,650 – 1,950	2	267	479	101	21.2
Over 1,950	2	163	362	64	17.7
Total	90	8,237	8,593	2,734	31.8

The daily load diagram of a power-supply system serving a large city is the composite demand made by the various classes of consumers. Industrial demand is heaviest during daylight hours and a considerable part of it disappears before the demand for lighting nears its peak in the evening. Table 24 gives the average figures of diversity factor:

Inasmuch as the diversity factor helps reduce the peak demand on the system, it contributes to the lowering of cost.

3. Power factor

The power factor is defined as the ratio of the average power to the volt-ampere product or the product of the RMS value of the AC voltage and the RMS value of the current in a circuit. The power factor is always less than unity and arises from the fact the ordinarily the voltage and current in an AC circuit are never in phase. The larger the phase difference between them the lower the power factor. The effect of a low power factor in a circuit is to reduce the available effective power capacity and it is therefore essential to keep the power factor as near unity as possible.

Of the many methods employed to bring up the factor are the installation of synchronous condensers of appropriate capacity at appropriate locations in a power system, the use of static condensers, etc. Consumers are encouraged to install suitable corrective devices in their factories—such as commutator-type motors, static condensers, etc.—by the introduction of suitable penalty clauses against low power factors in the tariff agreements.

It is however too expensive to install corrective equipment to reach unity power factor and therefore, in an extensive power-supply system designed to meet a composite demand of industrial and domestic loads, a power factor of approximately 0.85 is accepted as satisfactory.

Table 24

Diversity factors

Elements of system between which dviersity factors are stated	Diversity factors for			
	Residence lighting	Commercial lighting	General power	Large users
Between individual users	2.0	1.46	1.45	—
Between transformers	1.3	1.3	1.35	1.05
Between feeders	1.15	1.15	1.15	1.05
Between sub-stations	1.1	1.10	1.1	1.1
From users to transformer	2.0	1.46	1.44	
From users to feeder	2.6	1.90	1.95	1.15
From user to sub-station	3.0	2.18	2.24	1.32
From users to generating station	3.29	2.40	2.46	1.45

4. Integration

Even though the electric-supply industry started as isolated systems in the past, the recent trend has been to connect these isolated systems as far as practicable into an integrated grid. Some of the grids are very large, involving millions of kilowatts of power. In some cases, these large grids are inter-connected for interchange of power. Such large grids have not yet developed in the electric-supply industry in the countries of the region, except in the case of Japan and China: Taiwan. The reasons for this trend and the benefits that can be derived from an integrated power system have been dealt with in a separate ECAFE document.[1]

Load factor, power factor and the time of the day when peak load occurs vary with the undertakings, depending upon the nature of loads connected and the seasonal differences. The diversity that exists in patterns of consumption in the different systems gets integrated when the power-supply systems are integrated, the result being an improvement in load factor and power factor with consequential reduction in cost. Furthermore, facility of maximum exploitation of all generating sites, utilization of large-size economical units and reduction of cold and spinning reserves to a minimum help reduce both kilowatt and kilowatt-hour costs in a supply system.

5. Losses

Another factor which affects the cost is losses in generation, transmission and distribution. Inherently, every apparatus and circuit used in the power-supply industry involves some loss. These losses arise from the dissipation of heat in the circuit. Tariffs should take into consideration losses involved in making power and energy available at the point of supply. This increases the cost proportionately to the losses involved. Moreover, its ill effects are maximum during the peak-load time, which makes the position worse.

Energy losses in equipment can be divided into two parts, iron loss and copper loss. Iron loss is almost constant, as a constant voltage (subject to small variations) is maintained throughout the period the equipment is in service, irrespective of the load it carries. On the other hand, copper loss is in direct proportion to the square of the current carried, which in turn depends on the load carried or energy supplied. Some authorities consider that in determining the cost of energy, due consideration should be given to both aspects—in other words, cost due to iron loss must form part of fixed charges and copper loss should form part of running charges. However, it is a mattetr for the decision of the undertaking, depending upon the extent of the error involved if such a division is not made. It may be mentioned that the iron losses in distribution transformers in extensive low-tension distribution systems form a recognizable portion of the energy sent out of the sub-station.

6. Elements of cost

The various factors that enter into the cost of electric energy can be briefly stated as follows:

(*a*) Fuel
(*b*) Salaries and wages
(*c*) Repairs and maintenance
(*d*) Depreciation and interest charges
(*e*) Cost of servicing individual consumers
Miscellaneous (rent, taxes, etc.).

From the very nature of the charges involved, some of these are related to the plant capacity and are entirely independent of the energy (kWh) sold. Therefore it becomes necessary to allocate these charges in such a way as to make the incidence of charge appropriate as far as a practicable.

Broadly speaking, on an average, a quarter of the total costs of electricity supply is represented by fuel or items proportional to energy (kWh) and three quarters by fixed-cost items proportional to power (kW). It is recognized that variable costs for hydro-electric plant are approximately nil, whereas for thermal plants they represent 85 to 90 per cent of fuel costs plus a proportion of the wage bill. Furthermore, the ratio, in the case of thermal plants, varies with the variation in cost of fuel. For instance, at the present time, in respect of plants that have been in service since before the second world war, the proportion of variable cost to fixed cost is very high as the cost of fuel has increased two to three times over pre-war prices.

This disparity is very noticeable in the case of Japan. Most of the plants in service are pre-war plants. Since these plants were installed, there has been a precipitous fall in the value of the yen due to inflation. This is borne out by the fact that while the yen was equal to half a US dollar in the pre-war period, it is today equal to only 1/360 of a US dollar. The capital value of plants incidentally determines the fixed cost of power. However, it remains very low if it is expressed at its original book value. Capital assets have been revalued recently, but the revised values do not fully reflect the inflationary element in price. The rise in the

1. "Co-ordinated development of hydro and thermal power and integrated power development" (E/CN.11/EP/22).

price of fuel, on the other hand, is fully reflected in higher fuel cost and the result has been an abnormal rise in the proportion of variable cost to fixed cost.

The fixed cost forms a very high proportion of the total cost. If a single rate is to be levied, it would be logical to charge on power basis. But there are two difficulties: firstly, it is difficult accurately to determine the consumer's demand as a proportion of the over-all system demand; secondly, it would lead to waste of energy to a greater extent than a purely energy tariff would lead to waste of power. Therefore it becomes necessary to allocate these charges in such a way as to make the incidence of the charges as reasonable as practicable.

As mentioned earlier, electricity costs are divided into three categories: fixed costs; variable costs; and consumer costs.

Fixed costs include every item which is a function of time and which goes on from year to year, independently of output. It comprises all capital charges on the plant and buildings, such as interest, depreciation, insurance, etc., maintenance (except insofar as affected by output), rents and rates. It includes a majority of the management and operating expenses, wages and salaries, since these are very little affected by the energy output. It also should include such charges as cannot be allocated to any other items.

Variable costs include such items as are proportional to the actual units sold. Chiefly, the fuel cost and losses in the system form part of these costs.

Consumer costs consist of the cost of metering, invoicing and collection and other miscellaneous expenditure directly relating to servicing of the consumers, which are related neither to the kilowatt supplied nor to the energy (kWh) consumed but are roughly proportional to the number of consumers served.

The annual expenditure incurred by an electricity undertaking falls under the following heads: Generating system, Transmission system, and Distribution system. In the case of an integrated system, the transmission can be grouped with generation as the generating stations and the main transmission lines form and operate as one unit. The transmissio lines serve as a station bus. The sub-transmission and the distribution can be classed as one distribution system.

The average cost per unit varies according to whether it is calculated at the terminals of generating plant or at some point in the supply system. Generally speaking, the average cost per unit decreases as production increases since the fixed costs are distributed over the number of kilowatt-hours sent out. This relationship would remain valid up to the point where the installed capacity in a purely hydro system would reach the maximum output. But in the case of a purely thermal and a combined hydro and thermal system, the cost of fuel consumed is reflected in a characteristic curve. In present days, when old and new plants, both thermal and hydro, with different efficiencies and thermal plants using different fuels are linked together into an integrated systems, a linear relationship in the average cost of unit cannot be expected.

(a) Fuel

There is a general impression that all the expenditure incurred on fuel can be regarded as running cost. While the major portion of fuel consumed is for energy (kWh) produced, it is to be recognized that when a battery of boilers are in use, some of them will have to be banked when the load is light. Though fuel is consumed, when the boilers are banked, no energy is produced, therefore the cost of fuel so consumed will have to be allocated to the fixed charges. The extent of the fuel used in banking is dependent upon the load factor of the load on the supply system. Some authorities estimate that this unproductive utilization of coal or fuel can be limited to about 5 per cen of the total annual consumption by proper planning in the case of isolated stations. This can be further reduced by the station engineer and the load despatchers by proper pre-determination of the daily load curve of the system well in advance in the case of an integrated system.

(b) Salaries and wages

Salaries and wages of an establishment can be considered as a fixed charge as they are not directly dependent upon the amount of energy produced. However, as more energy is sold and a larger number of consumers are connected to the system, additional staff for the maintenance of the service and for work in the billing department would be necessary, but such additions are not made when existing consumers increase their consumption. Therefore, it has been found extremely difficult to correlate the expenditure with the quantity of energy (kWh) sold.

(c) Repairs and maintenance

As the charges under this heading are a function of the size of the undertaking, they form part of the fixed charge, so also are taxes, rents etc., except in the case where taxes are payable on the amount of energy sold.

(*d*) *Depreciation and interest charges*

The abdve charges are dependent upon the capital, both fixed and working, invested in the undertaking, and do not depend upon the amount of energy sold.

Mention should be made of the difference of opinion that exists between the cost accountant and the economist as to the correctness of the provision to be made on both these accounts. The usual view of the cost accountant is that technically, depreciation means expired capital outlay and the requirement of depreciation provision will have been met if, at the end of plant life, there is a sufficient amount to amortize the initial loan or to purchase new plant of equal cost. On the other hand, the economist contends that provision to be made should be such as to make it possible to purchase and install a plant of equal capacity at the end of the life of the existing plant.

Electric-supply undertakings are by no means static. Additions to the plant have to be made from time to time. The price of electric machinery has been constantly varying with the result that the installation cost for the production, transmission and distribution of electricity is increasing—or, sometimes, decreasing, but the general trend in recent years has been that the price is continually on the increase. When replacement is to be effected on the above basis, the cost of a plant of equal capacity is likely to be higher, even though the normal life of the electric equipment is of the order of 25 years.

According to the procedure favoured by the cost accountant, the price of electricity will be low throughout the whole period of life of the existing plant, even though the price of eelctricity in the neighbouring area where new plants of higher cost have been installed is higher. At the end of the life of the existing plant, a new plant will have to be installed at higher cost and tariffs will have to be revised accordingly. This would involve a sharp sudden rise in tariffs at the time. Normally, additional plant is installed from time to time, owing to the dynamic nature of the industry, either to add to the capacity or to effect replacement as parts of plant become worn out or obsolescent. During this process, it is not possible to distinguish between the kilowatts and the kilowatt-hours supplied from old and new plant, therefore tariffs are revised at regular intervals, the average cost of new and old plant being taken into consideration. Thus the objection referred to above is overcome to some extent.

With regard to the adoption of the economist's suggestion, even though no extra cost is incurred by the electric supply undertaking, the tariffs will have to be stepped up to meet the rise in price of machinery. However, electric-supply equipment has a long life of 25 to 30 years and during this period, the price may rise or fall and the variations may possibly smoothen out and may not require the adoption of such a precautionary measure.

With regard to the interest charges, the procedure adopted in accounting for the expenditure incurred does not allow any charge other than the payment actually made, therefore the question of making a provision anticipating an increase in the price of equipment would not be acceptable.

(*e*) *Consumer costs*

The consumer costs will have to be based on the actual capital expenditure incurred in supplying energy to the particular consumer. This generally takes the form of an annual minimum, a certain percentage of the capital expended.

Last, but not least, is the recognition of the fact that no tariff can be in excess of the use-value of the energy to the consumer. If, on the basis of the above calculation, a rate is worked out which is far in excess of the use-value to the consumer for the particular purpose for which the energy is to be used, it becomes necessary to reduce the tariff and to transfer the losses so incurred to other categories of supply which can bear the losses. Therefore not only detailed scientific calculations have to be made for determining the tariffs but the undertaking has to manipulate them on the basis of what the market can bear.

From the description of the nature of the charges, it is apparent that the fixed charges can best be related to power (kW) supplied and the variable charges to the energy (kWh) supplied. As the consumer costs can be related to the number of consumers, a charge per consumer would be most appropriate. Therefore, from the cost point of view, the best structure of tariff, which reflects the incidence of cost in a practical way, is that which contains (*i*) kW charge, (*ii*) kWh charge, and (*iii*) consumer charge.

While kWh cost and consumer cost are susceptible of easy and fairly accurate determination, the kW cost presents many difficulties. The main difficulty is determination of the contribution of a consumer to the peak load of the system which is the basis of calculation of kW cost in a supply system. Under the headings "Load factor" and "Diversity factor", it has been shown that the system peak is not the sum of the individual consumer maximum demands. It may be that a particular consumer is using power at a time other than the system peak hour. For instance, a newspaper printing press, using power during the early hours of the morning, would not be contributing to the system peak. Furthermore, as the pattern of consumption changes with the seasons of the year and if some electro-metallurgical or electro-chemical industry is connected to the system, the hour of peak load may shift from morning to afternoon, and what was considered once as a peak load time may become off-peak load time.

In order to overcome this difficulty, several methods have been suggested for determining the contribution of a consumer to the system's maximum demand (MD) for levying the kW charge.

One method is the "peak-responsibility method." This method allocates demand-related cost in proportion to the demand of each class of consumers at the time of the annual collective maximum demand on the supply system concerned, that is to a load which makes no demand whatsoever at the critical time when no demand-related cost is levied. If the maximum demand of a load coincides with the maximum demand of the system, the allocation is in direct proportion to the extent of the maximum demand. In the case of constant loads, the charges wil lbe proportional to the maximum demand. As already stated, the time of system peak may shift from season to season, completely changing the characteristic of a load from peak load maximum demand to off-peak maximum demand, in which case the method fails.

The second method is what is called "demand method". The allocation is based on the maximum demand of the individual consumer, irrespective of whether or not the maximum demand occurs at system peak load time. This method does not recognize off-peak load but allows a constant load the benefit of average diversity though the load by itself is incapable of any diversity.

The most recent method suggested is the "consumption-and-demand method". The question a tariff formulator has to answer is what it costs to supply a particular class of consumers. According to propounders of the consumption-and-demand method, this question can be accurately answered. It is claimed that this method translates as much as possible the economic cost theory into a workable formula.

The basic assumption made is that a period of potential peak-load can be fairly accurately determined. It is presumed that during non-potential-peak period, there is no possibility of a system peak occuring, no matter how attractive the rates are during the period. This is assumed to be between 11 p.m. and 7 a.m. The second assumption is that MD of a particular class of consumers and their total consumption during the period of potential demand can be determined either by the installation of appropriate MD meters or by a calculation based on the knowledge of the load factor of the load and of the total consumption. The total consumption during the potential-peak period has to be determined on the basis of total consumption of the class of consumers and the characteristic of such loads. The formula suggested is as follows:

Allocation to a component load $= kx + dy$
x and y being determined as follows:

$$C = (\Sigma K)\ x + (\Sigma d)\ y$$

$$\frac{C}{P} = Tx + y$$

C — Total annual demand-related cost in respect of a system

P — Annual collective MD on the system

d — Highest demand of a component load during during the potential-peak period

K — Annual consumption of a component load during the potential-peak period.

T — Aggregate annual duration of the potential-peak period.

An example is given to illustrate the method:[1]

"The potential peak period is taken at 7 h to 23 h of the two winter quarters, giving a value for T of 2,910 hours. The total system load is made up of five component loads, namely, domestic, commercial, public-lighting, industrial low-voltage and industrial high-voltage, for each of which is known the consumption quarter by quarter and the annual MD. Separate demand-related costs would be required for the high-voltage system (including the generation or bulk-supply cost) and for the low-voltage system, since the industrial high-voltage component does not participate in the low-voltage costs. For simplicity of illustration the two sets of costs are aggregated in the following summary. Figures for the complete system are as follows (in order to simplify the equations, the consumption is expressed in megawatt-hours and the time in 1,000 hours):

1. Bolton, D.J.: *Electrical Engineering Economics*, vol. II, 1951, pp 148-149.

Annual consumption in potential-peak period[2]	8,340,000 kWh (Σk)
Sum of annual MD's of component loads	8,500 kVA (Σd)
Annual system MD	6,650 kVA (P)
Annual demand-related costs .. .	£ 42,800 (C)

Applying the two formulae, namely—

$$C = (\Sigma k)\ x + (\Sigma d)\ y \text{ and } \frac{C}{P} = Tx + y$$

gives $y = 4.33$ and $x = 0.726$, *i.e.,* £4.33 per kVA and £0.726 per 1,000 kWh consumed during the potential-peak period.

"The application of these two coefficients will give the allocation of demand-related costs to each of the component loads. For example, the data for the domestic load is as follows:

Annual units sold in potential-peak period	2,760,000 kWh (K)
Annual MD	2,200 kVA (D)

"The component load allocation is given by $C = Kx \times 0.726 + 2{,}200 \times 4.33 = £2{,}000 + £9{,}530 = £11{,}530$.

"The above calculation must be regarded as a whole, namely, as a mechanism for allocating the expenses proportional to system demand amongst the component loads responsible for it. Although the mechanism operates on a dual basis, the two costs when calculated must be added together again to form the total demand-related cost of the component load. Moreover, whatever is done with the two components, they are only a device for conveying in conjunction the demand-related cost. They are not a tariff, or even part of one."

The next problem is the determination of the maximum demand of individual consumers during the potential-peak period. In the case of large consumers, the expenditure involved in the installation of 30-minute integrated-maximum-demand meters is justified. But in the case of small installations, it is felt that the cost of installation of such meters would be disproportionately high. Therefore, various methods have been developed.

The simplest method is the determination of maximum demand on the basis of ratable value, floor area or number of rooms served. In some cases, the installed capacity is treated as a basis for determining MD. Some undertakings rate the installations before servicing, that is, actually measure the MD at the time all the outlets in the consumer installation are in service. This is, of course, more expensive as the undertaking has to have an organization to rate the installation not only at the time of servicing, but also periodically.

In order to determine which of the above would bear a relation to the maximum demand and the energy consumption of an installation, a sample survey of domestic two-part tariff consumers was conducted by the British Electrical and Allied Industries Research Association[1], with the following result:

The survey covered an analysis of data in respect of about 300 two-part tariff consumers selected from certain areas in the former London and Home Counties electricity district. On the premises thus selected, demand indicators were installed and were read with the house service meters at four weekly intervals throughout the year 1947. Though the period may be considered as abnormal, owing to the severe winter of 1947 as well as to the restriction imposed on domestic consumption and account of coal shortage, it was felt that almost every year of the post-war period had something special which made the period abnormal and, therefore, the year selected was considered a sample period of the post-war period. A study of the data collected led to the conclusion that under conditions of heterogeneous development as to appliances installed, neither ratable value nor floor area nor number of rooms of a dwelling appear to be substantially related to the consumers' actual demand on the supply system. However, a substantial association seems to exist between the installed load and the corresponding maximum demand.

This investigation indicates that any one of the inexpensive samples refererd to earlier for determining the fixed charge component of the two-part tariff is as good as the other and there is nothing much to permit choosing between them. Individual cases will have to be dealt with on their merits. The method to be adopted will depend upon the accuracy required and the cost involved in determining it.

As already stated, the best tariff structure is the one that reflects kW cost, kWh cost and consumer cost. The determination of consumer cost is simple. In order to illustrate in as a detailed manner as possible the determination of fixed cost and variable cost, D. J. Bolton has worked out an example and prepared a chart which are reproduced here (table 25 and chart)). The costs mentioned are only illustrative. While the calculations referred to in the example pertain to a single station, it may be stated that the problem becomes more complicated in a modern integrated system. Nevertheless it is felt that cost calculations can be made on the basis indicated.

1. Estimated as follows: By taking six typical daily load curves, curves, one for each month of the two winter quarters, the proportion of kWh sent out between 23 h and 7 h averaged 10 per cent, and this figure was used for the complete system. Within this total an adjustment was made on account of the public-lighting load (in which the proportion was known and higher) and a figure of 8 per cent was assumed for each of the other component loads.

2. Technical Report Ref. K/T 127.

D. Types of tariff

In order to see that the tariffs have the necessary economic background and practicable applicability, various types of tariffs have been devised. Broadly speaking, the effect of almost every tariff, except the flat-rate energy charge, is to reduce the price per unit of electricity as the annual consumption increases, other things remaining the same. These other things may be for instance, the size of the consumer's installation or his maximum demand. While, generally, under certain conditions of supply, the over-all cost per unit of energy consumed is practically the same in all cases, the various structures are so formulated as to have a favourable psychological effect. Maximum effort is directed towards securing a high load factor by lowering the price within certain limits for increased consumption per kW connected to make the cost of supply as low as practicable.

Every undertaking, except very small ones, has a large number of tariff items indicating different rates for electricity consumed for different purposes. The rates, furthermore, vary on the basis of load factor, power factor and, in some cases, time of day. Besides, consumers have alternative tariffs to choose from. In general, it may be stated that the attempt on the part of the undertakings has been to increase the load factor by lowering the rates within certain limits. Even though the over-all cost of energy (kWh) sold by the undertaking is practically the same, the rates charged vary with the purpose for which it is used, that is, the use-value of the consumer has played a prominent part in the formulation of tariffs. Moreover, the attempt on the part of the formulators of tariffs to secure favourable psychological effect is evident from the perusal of tariffs of large undertakings such as the Calcutta Electric Supply Corporation, India, and the Tata Hydro Power Co., Bombay, India.

The various types of tariffs are the following:

(*a*) Flat-rate tariff
(*b*) Multiple-purpose tariff
(*c*) Two-part tariff
(*d*) All-in tariff
(*e*) Block tariff
(*f*) Step tariff.

The above are some of the usual types of tariffs and there are many others which can be classed as minor modifications of the above. Apart from the above, special tariffs are in use in some of the undertakings. To mention a few:

(*a*) Power-factor tariff
(*b*) Equated-rate tariff
(*c*) Off-peak tariff
(*d*) Restricted-hour tariff.

1. Usual types of tariff

(*a*) *Flat-rate tariff*

This is the simplest type of tariff. It comprises a single charge in proportion to the number of units (kWh) supplied. This type of tariff is generally adopted by very small undertakings where elaborate calculations are not called for. Some of these undertakings provide supply during certain periods of the day—for instance, sunset to midnight—and power is supplied for lights and fans only. The rate is fixed on the basis of an over-all cost, inclusive of a reasonable return on the capital invested. In order to protect the interests of consumers, governments of countries concerned have enacted legislation as to what the reasonable return should be.

(*b*) *Multiple-purpose tariff*

Undertakings supplying power for various purposes adopt a simple modification of flat-rate tariff inasmuch as different flat rates are charged for consumption for different purposes. While the basis of the tariff is an over-all cost inclusive of a reasonable return on capital invested, the variation seems to be based on the principle of what the market can bear. A serious objection to this type of tariff is that it involves the installation of separate meters and separate wiring for various purposes; this entails extra cost which, as far as practicable, should be avoided both on the part of the undertaking and on the part of the consumer.

(*c*) *Two-part tariff*

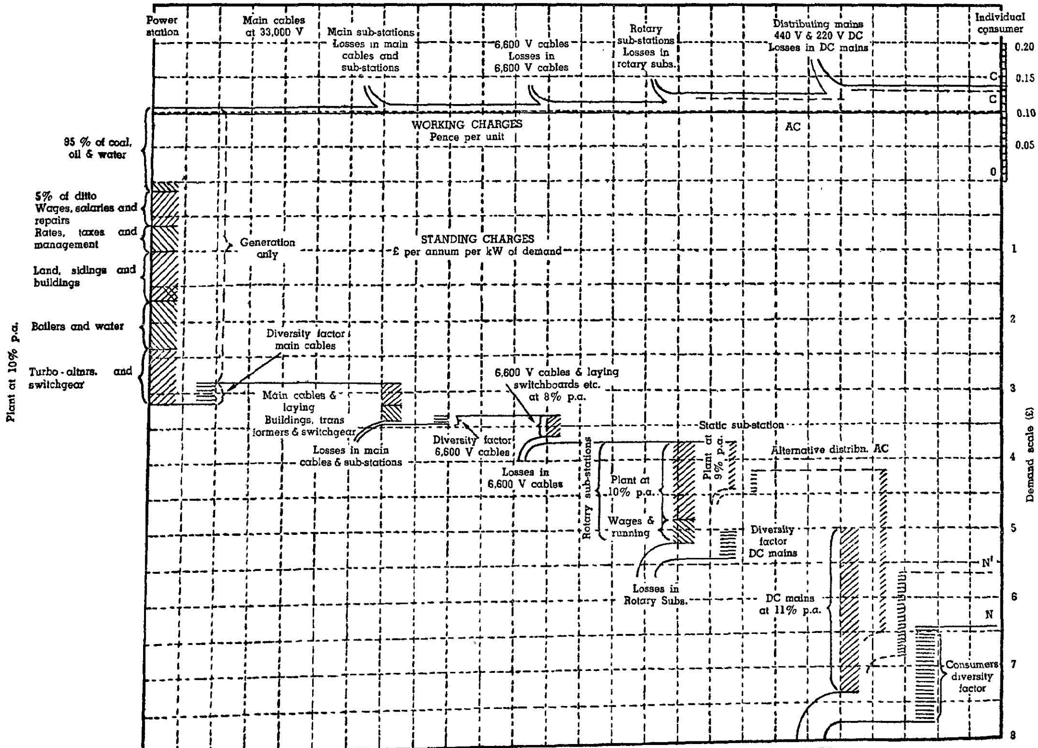
Large undertakings supplying power for composite loads, domestic and industrial, found that a flat-rate tariff, or a multiple-purpose tariff, was unsatisfactory both from consumer's and supplier's point of view. The flat rate does not reflect the incidence of different types of costs in a complex supply system, therefore a two-part tariff was developed. This consists of a standing charge—which comprises capacity cost, consumer cost, all indivisible charges—and a running charge, which is the charge per unit of energy (kWh) consumed, based on cost of fuel and losses in the system.

The standing charge varies with the purpose for which electricity is used. In the case of domestic supply, the standing charge is based on ratable value, floor area, number of rooms, and some undertakings base this

Table 25

Minimum station load, 70,000 kW. Station load factor, 40 per cent (the total installed is 100,000 kW)

	Fixed			Running	
	Annual cost (£1,000)	kW available (1,000)	Annual cost per kW of demand	Annual units delivered (10^6)	Cost per units (pence)
Fuel, etc.—95 per cent of £134,000		—		245	0.125
5 per cent of £134,000	7				
Wages, rates, etc.	64				
Station first cost (at 10 per cent per annum)	150	70	£3. 3. 0.		
	221				
Diversity factor main cables of 1.10		77	£2.17. 3.		Point A
Cost of main cables and sub-stations (at 9 per cent per annum)	40.5				
	261.5				
Losses in main cables and sub-stations (kW reduced 2½ per cent, units 3½ per cent) ..		75	—	236.4	0.129
Diversity factor 6,600 V cables of 1.05		79	£3. 6. 2.		Point B
Cost of cables, etc. (at 8 per cent per annum) ..	32			234	0.1307
	293.5				
Losses (1 per cent reduction in kW and units) ..		78	£3.15. 0.		Point C
Cost of rotary subs. (at 10 per cent per annum)	80				
Running expenses of ditto	24				
	397.5				
Losses (kW reduced 7 per cent, units 11 per cent)		72.6	—	208	0.147
Diversity factor DC mains of 1.10		79.8	£4.19. 5.		Point D
Cost of DC mains £20 x 79.8 (at 11 per cent per annum)	175.6				
	573.1				
Losses (7½ per cent reduction in kW and units) ..		73.8	—	192.2	0.159
Diversity factor individual consumers of 1.20 ..		88.6	£6. 9. 2.		Point E



Complete supply system

charge on the capacity of the installation or the maximum demand. The object is to see that it covers all charges which are not related to energy supply. None of the methods is free from error. Sample survey has revealed that the maximum demand of a consumer is not related to ratable value, floor area or number of rooms. However, a substantial relationship has been proved to exist between the connected load and the maximum demand. To this extent, this method is less inaccurate. However, the fact remains that the consumer's maximum demand and time of occurrence are dffierent from the system's maximum demand. Any charge calculated on the basis of the system's maximum demand is inaccurate if made applicable to consumers on the basis of their individual maximum demand.

In the case of industrial tariffs, the standing charge is based on maximum demand on each installation at an agreed period. Each of the three main classes of cost is taken into account separately. The standing charge includes the consumer cost, apart from capacity cost. The running charge is based entirely on energy cost, and in the case of thermal plant, the "fuel clause" ensures that the relationship is maintained when the cost of fuel varies. The maximum demand is determined by the installation of a special meter which records the maximum demand in addition to registering the energy (kWh) consumed. Owing to the high cost of such meters, the supply cost is disproportionately high in the case of small installations. In order to overcome this difficulty, some undertakings determine the maximum demand by actual measurements at the time of starting service to installation. Even in this case, the objection that it is not correct to charge a consumer on the basis of individual maximum demand at the rate calculated on the basis of system maximum demand still stands. It may be stated that inasmuch as the time at which the maximum demand is to be determined can be fixed to be the time at which the peak demand on the system occurs, to some extent, the maximum demand of the individual consumer can be considered as being that part which contributes to the system peak load; but none the less it is not theoretically correct.

An important defect of this type of tariff is that it does not help to reduce the peak on the system. Some authorities express the opinion that even though the two-part tariff has contributed to the expansion of domestic consumption, which was one of the objectives of its promoters, it has caused increase in power demand in the supply system. The increase in power demand on the British Electricity Authority grid is stated to be due to the fact that a large number of space-heating appliances have been connected by the domestic consumers because of favourable rates offered by BEA. Owing to the inability of the British Electricity Authority to increase the generating capacity to meet the increased peak-load, load-shedding had to be adopted with its consequential inconvenience to consumers and dislocation in industrial production.

Since the two-part tariff reflects to the extent practicable the incidence of charge, it has been largely adopted.

(*d*) *All-in tariff*

In the case of domestic supply, the practice of charging different rates for use of electricity for different purposes involves the installation of different meters and separate wiring in each installation. In the case of small consumers, the capital cost to be incurred both by the undertaking and by the consumer is disproportionately high, therefore the all-in tariff has been evolved. It is either flat or two-part tariff and makes no distincttion regarding the purposes for which electricity is used in homes and farms. The purpose was two-fold, one being to save the additional cost involved and the other, to prevent the use by consumers of electricity from lower tariff meter for higher tariff purposes.

(*e*) *Block tariff*

An increase in flexibility over the two-part tariff is provided by the block tariff. Here, consumption is divided into layers (blocks) in each of which a different running charge applies, the charge being lower as the consumption increases. Under a fixed-block tariff, the size of the block is the same for all consumers. Under a variable-block tariff, it is determined in the same way as the fixed component of the two-part tariff. Block tariffs are attractive to people who do not want to be committed to periodical payment without relation to actual consumption and want to secure quantity discount.

(*f*) *Step tariff*

This is a slight modification of block tariff. In this case, when each block is exceeded, all the energy (kWh), not merely the additional one, is charged at a lower rate. This secures better psychological attraction on the part of the consumer.

2. Special types of tariff

(*a*) *Power-factor tariff*

It has been shown earlier that the maintenance of high power factor as near unity as practicable in the supply system makes the cost of energy supply lower. In order to ensure that the power factor of the demand of a particular consumer is not below a certain minimum fixed, say 0.8 or 0.85, the tariff provides for extra charge if the power factor is less than the one fixed. In some cases, a consuming apparatus having a power factor less than .7 is denied power supply. The consumers owning such apparatus are required to install power factor corrective equipment to bring up the power factor to the required minimum before the apparatus is connected to the system.

Some undertakings have tariffs on a kVA basis which penalize connexion of low-power factor equipment to the system.

(*b*) *Equated-rate tariff*

Some power supply organizations undertake the interior wiring of installations and supply of domestic appliances. In such cases, the rates charged for electricity consumed, usually a flat rate, comprise all costs of energy and hire or hire-purchase instalment and maintenance of equipment.

(*c*) *Off-peak tariff*

This is a tariff in which lower price is charged for electricity consumed outside prescribed peak-load hours. Some undertakings have tariffs in which electricity consumed between the hours of 10 p.m. and 7 a.m. is charged at a lower rate. For instance, cotton-spinning and weaving mills in the State of Mysore, India, are supplied with electricity from the State's hydro network at 0.45 anna per kWh for day power, and 0.35 anna for night power. In order to avoid the shifting of day load to night, certain restrictions are imposed. In each case the intention is that the off-peak loads should increase and the load factor of the system be raised to as high a figure as practicable.

(*d*) *Restricted-hour tariff*

This is a tariff which is generally comparatively low and the supply is available for a limited time during the day. This is intended to encourage the use of electricity for special equipment, such as storage-type water-heaters. The water is heated during the time the power is available and the hot water is available to consumer throughout the day. In some industrial undertakings, storage-type steam-raisers are used.

Domestic consumers need electricity from 6 a.m. to about 10 p.m. During this period, unrestricted supply is required. Therefore, any restrictioon imposed in the form of either reduction in supply or the application of different rates at different times during the above period will, to say the least, impose an unnecessary burden on the housewives and it is likely to prevent some middle-class families from using electricity for certain purposes. Furthermore, inasmuch as the differentiation can be made only in the case of large installations, it is doubtful whether the increase in rates of supply would dissuade the consumers from using electricity as they have been doing hitherto.

In the above circumstances, the two-part tariff, which has come to be accepted as a tariff which reflects incidence of charge more accurately than any other so far evolved and in which due consideration is given to the use-value to the consumer, can be considered as the best form of tariff at present.

CHAPTER VI

FINANCE

The continuous rise in costs in most of the countries has seriously affected the power-supply industry. The result has been that the principle of amortization has lost its objective value. This has been largely responsible for the declining supply of private capital for long-term investment. Furthermore, the increase in the price of equipment has necessitated considerably more capital for the establishment of new plants.

Government intervention has varied from complete nationalization to legislation controlling the development and the financial activities of private electricity undertakings. Nationalization has changed the very basis on which the industry operated earlier. To mention a few factors, revenue surpluses are claimed by the treasury, and adequate provision is not always made for development plans commensurate with the importance of the industry, apart from the delays in sanctions and allotments of funds, etc. that occur in government routine.

In the case of government control of private undertakings, some authorities hold that the "reasonable returns" fixed in many cases are too low to attract the required capital. The taxation policy adopted by governments does not always admit of sufficient reserves being built up for re-investment in the industry as has been done in the past.

The electric-supply industry in countries of the ECAFE region has been managed in the past mostly by public limited companies. The primary objective of their activities has been to secure immediate returns on the capital invested. Therefore, the operations were confined to the more profitable urban areas, while the rural areas were neglected, with the result that more than 80 per cent of the population in the region have been denied the benefits of electricity. Recently, the governments of the countries of the region have shown a considerable desire to extend the benefits of electricity to rural areas. The main obstacle in the way of rapid expansion in this direction is stated to be lack of finance.

At present, the demand for electricity in every country of the region is far in excess of the existing capacity. While plans have been made by various countries for increasing the capacity during the five-year period 1951-1956, conservative load estimates have indicated that the plans fall far short of the need of the countries. Furthermore, many of these plans are not being implemented with the speed originally contemplated; this is due to various reasons, one of them being lack of finance. Even urban areas, where electricity has already been made available, have been suffering from shortages. Partial black-outs and curtailment of supply under low-stream-flow conditions and during maximum demand periods are the order of the day rather than the exception.

In view of the fact that a large portion of the region's population lives in rural areas, it is imperative that rural electrification should form an integral part of the development of the electric-supply industry of a country.

A. Special features of investment in rural electrification

The financing of rural electrification cannot be subjected to the normal test of return on investment. Even in some of the western countries where the standard of living is high and farm holdings are large, and where the cost of electrification has been made as low as possible, it has been found that the return on the investment is not adequate, at least initially. Various methods for the financing of rural electrification have therefore been adopted in order to lessen the burden on the consumers in the initial stages.

In this region, and particularly in the rural areas, the problem is more difficult, as the concentration of load per unit area is much less than in western countries and the growth of load is also slow because of the very low standards of living. Yet it is felt that unless electricity is extended to rural areas, the standard of living of the common man cannot be raised and, if the *conventional test for financial investment is applied*, rural electrification cannot be accomplished. It can be confidently stated that provided sufficinet time is allowed, electricity will find its way into farms and cottages, and consumption will increase. As incomes rise over a *period of time, many investments in the power-supply* industry that are unprofitable to begin with can be expected eventually to yield a reasonable return. Moreover, if a public viewpoint is taken, allowance will be made for the fact that the supply of power to areas as yet not reached by electricity will provide the economic environment—the external economics—needed to make investment in other fields more attractive. The charges and profits of electricity undertakings are not fully commensurate with these widely diffused benefits of which at least a part will be recoverable through other agencies.

Two primary considerations arise in connexion with plans for rural electrification. Firstly, how can costs be minimized? Secondly, how can the direct financial losses be made good in the initial stages?

The extent of use of electricity by the rural population will depend upon whether the price of electricity is sufficiently low to be within their reach. Furthermore, the use of electricity in agricultural operations and processing of agricultural productts is closely related to its incidence on the cost of the produce. Given the need for rural electrification, it is essential that everything possible be done to make electricity available to rural areas at the lowest price practicable. The possibility of doing this will depend on the extent to which the cost of producing and distributing electricity can be reduced.

As a major portion of the cost of electricity is the fixed charge, it is necessary to make the capital cost as low as practicable. Mention may be made of the trend towards adoption of large-size units to reduce the cost per kilowatt installed. The technique of development of integrated power systems has permitted the optimum exploitation of hydro sites, the reduction of spinning and cold reserves and the reduction of coal consumption to the barest minimum in the thermal stations. These have reduced the cost per kilowatt of firm capacity and the cost per kilowatt-hour generated. The adption of high temperature and pressure in thermal plants, made possible by the ues of special alloys, has secured considerably higher efficiency in the conversion of fuel into electric power, thus substantially reducing the cost per kilowatt-hour generated. The adoption of high voltages for transmission has made it possible to transmit large blocks of power from point of generation to point of consumption with minimum loss, thus contributing its share towards the reduction of cost per kilowatt-hour supplied. With regard to the distribution system, special techniques have been developed to make the rural lines as little expensive as practicable. Many expensive gadgets, usually included in urban distribution systems, have been dispensed with without any serious sacrifice of continuity of supply or efficiency of service.

Despite all the efforts to bring down the cost of rural electrification schemes, it is generally found that if the consumers are to be supplied with electricity at rates which they would be able to bear, losses are inevitable, at least in the initial stages.

There are two ways of meeting the deficit. The consumers concerned may be made to pay or rural suppliers may be subsidized in part or in full.

The first method is possible where there are consumers in rural areas who will be willing to contribute in one form or the other to the cost of the plant rather than doing without this service. Some of the electricity undertakings have been successful in securing such contributions from consumers' surpluses, but cases of this kind are few and it is extremely doubtful whether this procedure could yield substantial results in countries of the ECAFE region.

The following are some of the methods adopted in securing consumers' contribution:

(*a*) Demanding from consumers individually or collectively a non-refundable contribution to cover a portion of the capital cost involved in electrification;

(*b*) Demanding a loan from prospective consumers, either free of interest or at a low rate of interest, the amount so loaned to be adjusted against charges for current consumed payable by the consumers over a period of years.

If the consumers canônt be made to pay, the only alternative is a subsidy. Subsidies can take different forms. There is, first, the possibility of shifting the burden to the *urban* consumers. One way of doing this would be for the electricity undertaking to raise the urban tariffs and to charge more in both rural and urban areas. As a result, electricity would be sold above cost in urban areas and there would be surpluses that could be used for subsidizing the rural part of the enterprise. The prerequisite for the adoption of such a procedure is that the existing tariffs be low enough to stand the required increase. Naturally, the greater the required increase in tariffs, the greater the proportion of the capital to be devoted to rural electrification.

• The merit of the method lies in the fact that the burden is imposed upon all the consumers who are expected to derive benefits from the prosperity of the undertaking in the future. Rural electrification is expected to pay its way after a few years of operation and in some cases may even become remunerative in the course of time. The direct benefit of such a development would accrue to the consumers of electricity in the form of reduction of tariffs.

If the conditions are such as to rule out an increase in tariffs, the government—i.e. the general tax-payer—has to foot the bill, if there is to be rural electrification. The question whether the burden should be passed on to the urban consumer or to the general tax-payer is debatable. This is a question of fairness and equity regarding which opinions will differ.

Government subsidies may take various forms. The object is that the burden on the general tax-payer should be as low as practicable and it should be imposed only when it is absolutely necessary. In this connexion it should also be borne in mind that rural electrification schemes will have to compete with other requests for government subsidy. Before agreeing to subsidize rural electricity projects, governments should make sure that there is an immediate demand or quick potential demand for electricity from the rural community for uses other than mere lighting. Multiple uses of electricity, in other words, should be the essential basis on which a government should agree to subsidize rural electrification projects.

One of the ways open to the government is nationalization. In this case, the government will set the pace of rural electrification and any loss that may be incurred is made good from general revenues.

In cases where the power-supply industry is owned and operated by public limited companies and the development and financial policy is controlled by the government, the subsidy may take any of the following forms:

(*a*) The government advances the entire amount of capital required for rural electrification and recovers the amount in easy instalments as the scheme begins to yield a return, a low rate of interest being charged for the outstanding loan during the initial stages of operation. This may be done in two ways:

(*i*) The money may be advanced to electric-supply undertakings which are directed to extend electricity to rural areas;

(*ii*) Co-operatives may be formed in the areas to be served and the money advanced to them, the necessary technical and administrative assistance being rendered by a government organization exclusively set up for the purpose.

(*b*) Outright payment is made to an electric supply undertaking to cover a portion of the capital cost of rural electrification, the proportion payable by government being determined in each case depending upon the prospective load conditions of the area to be served.

(*c*) The government guarantees the undertaking entrusted with the work of rural electrification to make good the losses that may be incurred.

(*d*) A suitable taxation policy is adopted to enable undertakings to build up reserves to be utilized for extension of electricity to rural areas.

(*a*) *Government advance*

The government's advancing all capital required for rural electrification at a low rate of interest means that the difference between the interest payable by the government on public loans and the rate of interest levied for the amount advanced to the undertaking will have to be made good from general revenues.

The advantage to be gained by advancing the money to an existing undertaking is that the technical and administrative experience of the undertaking would be harnessed and expeditious action could be expected. The necessity of organizing an administrative and technical set-up for running the industry would not arise.

With regard to the setting-up of co-operatives with capital advanced by the government, many advantages are claimed. Apart from self-help being encouraged, a feeling among the consumers that they are active partners in a public utility serving them has many desirable effects towards securing efficient operation of the undertaking. In this case, it is absolutely necessary that the government set up a special organization with technical and administrative experts to form co-operatives and direct operation to a successful conclusion.

(*b*) *Outright payment by the government*

The second method is outright payment by the government to cover a portion of the capital cost of rural electrification. The electric-supply undertakings can estimate on the basis of experience the probable revenue that can be realized from prospective consumers. Any difference between the actual cost of providing the supply and the capitalized value of the anticipated revenue has to be made good by the government. This method of capital contribution has the merit of committing the government to payment of a fixed sum at one time. The risk is known and is undertaken after examination of all aspects of the case, but the defect attributed to the method is that when the rural electrification carried out by the money so advanced becomes remunerative, the beneficiaries will be the consumers of electricity and/or shareholders of the company and the government will not derive any direct benefit that may accrue.

(*c*) *Government guarantee*

Subsidizing the electric-supply undertaking by making good the loss from general revenues at the end of each year of operation is a method less acceptable than the preceding one. The reason is that the government will be committing itself to payment of an indefinite amount for an indefinite period. The only point in favour of this form of subsidizing is that the burden to be borne by the government is spread over and that there is a possibility of its not becoming due.

In order to overcome the objection raised against this method of subsidizing, to reduce the burden on government to as little as practicable and also to have the incidence of charge as and when absolutely necessary, the following modification of the above method is suggested. The undertaking entrusted with the work of extending electricity to rural areas would be asked to treat the losses to be incurred at the initial stages as deferred expenditure to be adjusted against the profits to be earned in later years. The result of operation over a pre-determined numbr of years would be examined and if it is found that at the end of the period the undertaking has been unable to secure a reasonable return on the capital invested, the deficit may be made good by the government. The merit of the method lies in the fact that every effort would have been made to avoid as far as practicable burdening the general tax-payer and the levy would be made only if it was impossible to avoid it. Furthermore, experience has shown that in many cases it may confidently be hoped that the levy will not be necessary. The load development in the areas served may be such as to make operations remunerative. For instance, the establishment of a large new industry in the area may result in the re-allocation of capital expenditure between the industry and rural electrification so as to make the burden on the rural consumer equal to or lower than that on the urban consumer, in which case the question of payment of subsidy would not arise.

(*d*) *Taxation*

The adoption of a suitable taxation policy is a procedure which amounts to remission of taxes in one form or other. A certain percentage of the profits, if invested in rural electrification, may be exempted from taxation.

The methods suggested above are expected to infuse confidence in the investing public and with the safeguard provided, investment in rural electrification will not in any way be different from investment in other industries. In fact, the assurance given should make investment in rural electrification an attractive proposition.

Subsidy payment is objected to on various grounds. The primary objection is that it encourages inefficient operation. It is also argued that the imposition of an additional burden on the general tax-payer for the benefit of rural consumers of electricity is inequitable. It is contended that inasmuch as it is the consumers of electricity who will eventually benefit by the prosperity of the electric-supply undertaking, the burden due to loss, if any, at the initial stages should be passed on to the urban consumers.

On the other hand, in support of the policy of subsidizing the industry at the expense of the general tax-payer, the following arguments may be advanced. It has been made very clear that rural electrification involves losses at the initial stages of operation. But it is agreed that rural electrification is essential for raising the standard of living of the people of the region and increasing production. As the burden of the loss cannot be borne by the rural consumers of electricity alone, there is no other choice but to transfer the burden on to the general tax-payer. Indirect economic benefits created by the extension of electricity to rural areas accrue to the community at large; therefore, subsidy payment from general revenues, which in turn is a burden on the general tax-payer, is justifiable. In any case if rural electrification is to be carried out, subsidies will have to be paid in one form or another, as otherwise the required capital will not be forthcoming. If the industry is nationalized, the loss sustained is met from general revenues. The payment of subsidies by government to an electricity undertaking entrusted with rural electrification is nothing different; one is payment to self by government and the other is payment to another organization from general revenues. Economically, there is no difference between the two. As to the fear of inefficient operation the control the government has on the undertakings makes it easy to prevent such inefficiency.

B. Methods of financing adopted by countries of the region

Ceylon

The capital for the development of the electrical industry in the island is loaned by the Central Government. The period allowed for the payment of the loan is as follows:

		(years)
(a)	Complete electric lighting scheme	20
(b)	Building (power house, etc.) and cranes	30
(c)	Distribution mains and switchgear	25
(d)	Engines and auxiliaries	15
(e)	Meters, services and street lights	10

Loans in respect of lighting schemes are payable on the equated-payment basis starting on the third anniversary of their issue, interest at 4 per cent being payable for the first two years. The equated annual payments for each of the above categories are:

(a) 0.07899333 of the loan
(b) 0.06001298 of the loan
(c) 0.06730906 of the loan
(d) 0.10014373 of the loan
(e) 0.14852783 of the loan

India

No definite financial policy has been laid down in respect of rural electrification. However, the need for extending electricity to rural areas has been incrasing felt in recent years. In the Electricity Supply Act of 1948, the creation of State Electricity Boards in the various States in India has been envisaged. Although the act does not contain any specific provision for special measures designed to give impetus to rural electrification, it enables State governments to grant subventions for such other purposes beneficial to electrical development in the State. In almost all cases, the rates offered to rural areas are maintained at the same level as in the adjoining areas falling within the same grid system. The Planning Commission, in its First Five-year Plan, has attached considerable importance to the use of electricity in rural areas and has suggested that the States should set up a special machinery on the lines followed by the Rural Electrification Administration in the United States of America.

It is also held in some quarters that in order to augment the financial resources required for the expansion of rural electrification, certain portions of the proceeds of taxation on the sale of electricity and of the betterment levy (which is in the nature of capital levy) on properties which are supplied with electricity could be credited to the electricity development fund.

Japan

Owing to great shortage of electricity, no special effort is being made to extend electricity to rural areas. As stated in chapter I, section A, nearly 97.5 per cent of the towns and villages have already been electrified and therefore there are very few places which are beyond the reach of the present electricity grid. However, applications for supply of electricity to communities which are at present not served by electricity are entertained, subject to the following conditions. The electricity supply company is prepared to invest Y7,060 ($19.61) per consumer to be connected. Any cost over and above the amount mentioned, required for extending electricity to the area, will have to be paid for by the consumers individually or collectively. In order to reduce the burden on the consumers, the Ministry of Agriculture and Forestry extends aid to the consumers from a subsidizing fund at its disposal. The aid, consisting of one third of the consumer's share payable to the undertaking, is met by the Ministry of Agriculture and Forestry, provided the consumer intends to introduce electricity into his place for purposes of increasing rural production. In the case of a rural community intending to construct a small-scale power plant for its own use because of the prohibitive cost involved in obtaining electricity from existing grids, the Ministry of Agriculture and Forestry will loan the entire amount required for the establishment of the plant at a low rate of interest.

In cases where electricity supply to rural communities is arranged from an existing general grid, the tariffs levied are the same as those in force in urban areas. Only for definite periods during the year and under certain conditions deemed deserving of special consideration from the agricultural policy viewpoint, is a discount system of one sort or another applied to the authorized power rates. The discount system is applied to such uses of electricity as are indispensable to agricultural production, especially production of rice and barley which constitute the nation's staple food. Such uses as insect-enticing lamps, irrigation, drainage, husking, etc. are limited to certain seasons of the year.

APPENDIX 1

Wood-preservation processes

A. *The Bethell Process*[1]

This process was patented by John Bethell (British Pat. 7731—11 July 1838) and covered, among other features, the injection of tar and "dead oil of tar" into wood by applying pressure in closed cylinders. As practised today, the general procedure outlined in the original patent is still followed, although there have been marked improvements in the mechanical phases of the treatment. Seasoned wood is placed in the treating cylinder; the cylinder doors are sealed and a preliminary vacuum is drawn on the charge. This vacuum, which is usually carried to a maximum of at least 22", is maintained for from 16 minutes to an hour. Then, without admitting air, the cylinder is completely filled with hot preservative oil, after which additional oil is forced into the retort to build up the required pressure. The pressure generally reaches a maximum of from 125 to 200 lb/sq in and is maintained until the desired absorption is attained, or to virtual refusal. The temperature of the preservative is usually required to average at least 180°F and not to exceed 210°F. When the required amount of preservative has been injected into the wood, the pressure is releasd, and the oil drained from the cylinder. A short final vacuum is usually applied to dry the surface of the timber, although this step was not provided for in the original Bethell patent. The distinguishing characteristic of this, and also every other full-cell treatment is the preliminary vacuum, the purpose of which is to exhaust part of the air from the outer layers of the wood. This not only facilitates the entrance of preservative into the wood but also largely eliminates any cushioning effect of the air, which would otherwise force out part of the injected preservative when pressure is released.

Some operators attach great importance to the intensity and duration of the preliminary vacuum, and take pains to obtain as high a vacuum as practicable and to hold it for more than 30 minute. They also keep the vacuum pump running while the cylinder is being filled with preservative, in order to remove any air that may be forced out of the wood when it is first contacted by the hot oil. There can be no question that these special precautions tend to reduce the amount of air remaining in the wood, and they may prove important in special treatments, where the highest possible absorption is required. It is very doubtful, however, that they have such significance in commercial treatments.

1. Hunt, George M. and Garret, George A.: *Wood Preservation.*

B. *The Rueping Process*[2]

The Rueping (or Ruping) process was patented in the United States of America in 1902 by Max Ruping of Germany (US Pat. 709,799). Its chief characteristic is the application of preliminary air pressure to the wood prior to the injection of the preservative oil. The timber to be treated should be air-dry for best results, but green material may be used, provided it is first conditioned by the steaming-and-vacuum or the boiling-under-vacuum method. Air is injected into the treating cylinder until the desired pressure is obtained, with the result that a certain amount is forced into the wood. The cylinder is then filled with preservative in such a way that the injected air is trapped in the wood. The filling may be accomplished by forcing the preservative into the bottom of the retort and allowing air to escape from the top just rapidly enough to maintain a constant pressure. Another way of carrying out the operation is to have the preservative in an overhead tank under the same pressure as the compressed air in the cylinder and, by means of a suitable arrangement of pipes, to allow the oil to flow into the retort by gravity while the air passes up into the space vacated by the preservative. After the filling is completed, the preservative is forced into the timber by the application of a higher pressure until the desired absorption is obtained, thus further compressing the air imprisoned in the wood. The pressure is then released, the preservative drained from the cylinder, the charge subjected to a high final vacuum for a period of 30 minutes or more. As soon as the pressure is released, the compressed air in the wood expands and forces out a considerable amount of the preservative that was injected. The final vacuum hastens the recovery[3] of oil and also shortens the period during which the preservative will continue to drip from the timber.

2. *Ibid.*

3. The maximum amount of preservative contained in the wood at the end of the pressure period is called the gross absorption; the absorption; the amount expelled after the release of the pressure but without the application of vacuum is termed the kickback; the amount recovered from the wood during the final vacuum is sometimes called the drip or drain; the kickback plus the drip constitute the total recovery; and the net amount left in the wood is known as the net absorption or net retention. In commercial practice, kickback and drain are not determined separately.

As a result of this recovery, the net retention of preservative associated with a given penetration is definitely less than would be required to saturate the wood with oil to the same depth. It follows that, with a limited net retention, deeper penetration is obtained by the Rueping Process than by the full-cell (Bethell) treatment.

The intensity of the preliminary air pressure is governed by the character of the wood being treated and the net absorption of preservative desired. When low absorptions are specified in wood that is very receptive to treatment, such as the air-dry sapwood of southern pine, air pressures as high as 100 lb/sq in may be used. When more refractory woods or higher net retentions are involved, lower pressures are employed; in any given case, the precise intensity will depend largely upon the judgment of the operator, but pressures of 50 to 75 lb/sq in are most common. In some plants, the practice is to start filling the cylinder with preservative as soon as the air pressure is built up to the desired amount; while in others, the maximum pressure is maintained for 15 to 30 minutes before filling. The advantage of holding the pressure on the wood for such a period has not been established and is probably slight, at best.

The pressures employed in injecting preservatives into the wood are commonly about 100 lb higher than the preliminary air pressures, but it is frequently inadvisable to increase them to such an extent. The preservative pressures seldom exceed 200 lb/sq in, the maximum permitted under the specifications of the American Wood-Preservers' Association, and it is usually unnecessary to raise them above 150 lb. With woods of low compressive strength, or green timber that has been softened by steaming, it is often desirable to set the limit at 115 to 125 lb, since greater pressures may tend to cause collapse and checking of such material. With creosote, the temperature is usually required to average not less than 180°F and not to exceed 210°F.

The proportion of the gross absorption of preservative recovered from the wood upon release of preservative pressure and application of final vacuum varies widely. It is influenced by the character and condition of the wood, the relation between the preliminary-air and preservative pressures, the temperature of the preservative, and, no doubt, various other factors. Recoveries as high as 50 to 60 per cent of the gros sabsorption are sometimes obtained, but those of 20 to 40 per cent are more common. The amount of oil recovered cannot be controlled at will by the plant operator, but he learns by experience what to except under different cotnditions and controls the gross absorption accordingly. It is probable that, in many cases, the wood itself is compressed appreciably during the preservative pressure period, thus permitting extra oil to enter the cylinder and indicating higher gross absorptions than are actually obtained in the wood. The subsequent expansion of the wood, upon release of pressure, increases the recovery of oil. This effect is greater when high preservative pressures are used, especially with wood that has been softened by preliminary steaming.

The Rueping process has proved to be very practical and effective and, since its introduction in 1905, has been extensively employed in the United States. It is now the principal creosoting process in use in this country.

Another patent obtained by Rueping (US 1,008,864, No. 14, 1911) covers the use of repeated applications of air pressure and vacuum, after the injection of the oil, for the purpose of recovering additional quantities of oil and of forcing the preservative deeper into the wood. This process appears to have found little, if any, commercial use.

Treatment of wooden line-supports in Mysore, India

Equipment

1 boiler capacity 20 hp
maximum pressure used 100 lb
1 pressure pump } worked by steam engines
1 vacuum pump }
1 treating cylinder length 45 ft dia 5 ft
2 low service tanks for preservative solution
22′6″ × 6′ × 5′ each
Quantity of wood that can be treated per charge
400 cu ft

Treating mixture

50% coal tar creosote
50% diesel oil
or
ASCU treatment
1 part arsenic pentoxide
2 parts copper sulphate
3 parts potassium (or sodium) dichromate

Process

(1) The timber is loaded into the treating chamber and the end-doors closed.

(2) A vacuum is created inside the cylinder to a maximum of 22″ depending on the condition of the wood. This takes about 20 minutes or even more in the case of green timber.

(3) The hot creosote solution is let into the chamber till it is full and the inlet valve closed.

(4) Steam is admitted into the pipes inside the treating cylinder to keep the solution hot.

(5) The preservative is pumped into the cylinder by the pressure pump and the pressure built up to 125 lb/sq in. With this arrangement, the required quantity of preservative will be absorbed by the timber. The absorption allowed in the plant is 6 lb/cu ft of timber and this may be varied as desired.

(6) The drain valve is opened, the solution is let back into the tank and the drain valve is closed.

(7) A vacuum is again created in the treating cylinder (15 to 20 lb/sq in) and maintained for about 15 to 20 minutes. During this process the outer surface of the timber is dried and the extra solution is eliminated.

(8) The solution collected in the treating cylinder is let back into the service tanks.

The charge is taken out and stacked in the sheds where it is left to cure for about 15 days.

The above processing takes about 2 to 2½ hours.

The total time taken per charge, including loading and unloading, is 4 to 4½ hours.

On an average, 600 cu ft of timber are treated every day, *i.e.* two charges of 300 cu ft.

The process for ASCU treatment is the same as above, except that while the creosote solution is heated for treatment, the ASCU solution is injected cold.

The above process is known as the Bethell Process and is the one adopted at the Wood-preservation Plant at Bhadravati.

APPENDIX 2

Treatment of wooden poles in service in the United States of America[1]

Development in the field of wood pole treatment in other parts of the world is of special interest to the region. Therefore an interesting article from *Electrical World* indicating what one utility in the United States (Commonwealth Edison Co., Chicago, Ill.) is doing in this respect is reproduced hereinafter.

Investigations begun in 1942 disclosed hundreds of standing western red cedar poles on the Commonwealth Edison Co.'s system had heart rot in their tops. Most of these poles were 11 to 18 years old. It was apparent that the 90-degree method of roofing poles did not prevent decay and that enough water was retained in the untreated pole tops to promote the development of fungus growth.

In brief, the method of treating partially rotted pole tops consists of cutting off the top of the pole about one inch below the 90-degree roof and removing the decayed wood from thhe hole to expose sound wood. The next operation is to sterilize the exposed cavity by pouring into it a pint or quart, or more, of the 5% pentachlorophenol-petroleum oil solution such as is generally used for pole treatment. Then a paste, prepared of fly ash and pentachlorophenol solution, is poured into the cavity. This paste is made sufficiently thick to set properly but still thin enough to allow pouring. Usually, the checks in the pole are not wide enough to permit the paste to run out, if it is not too thin.

Finally, the "filling" is protected from the elements by tacking a piece of slate-surfaced roofing paper to the top of the pole. Precautions are taken to prevent contact between the paper and the paste.

Cost of material is very small compared to labour costs involved. In 1944, these costs were estimated to be $0.20 for material and $8.80 for labour, transportation and supervision. In 1950, these costs were somewhat higher, but in view of the higher cost of new poles and labour for replacement of poles and equipment, this method is still very economical. To date about 2,000 poles have been treated in this manner.

About one year after the first pole top was treated, borings were taken about 6″ from top of pole. The inner ½″ of the borings contained as much as 0.36 lb of dry pentachlorophenol per cubic foot of heartwood.

Examination of a number of pole tops, after the cavity was cleaned of the decayed wood insofar as practicable, showed that the decay along the pith of the pole may extend down for several inches or perhaps several feet. Therefore, a generous amount of liquid pentachlorophenol is poured into the opening in order to sterilize not only the bottom of the cavity, but also the decay along the centre portion of the pole.

To determine the residual pentachlorophenol, sections were cut, approximately 2″ in thickness, from each of the pole tops. Drilling were taken for analysis from the inner surface of each section ¼″ deep and in some instances between ¼″ and ½″ deep.

Results of the determination of pentachlorophenol by the sodium-peroxide-fusion method given in the following table tend to show that a greater amount of pentachlorophenol is absorbed by the upper section of the pole than at the lower levels. It is also indicated that pentachlorophenol is absorbed and remains in the wood for a long period of time after this treatment. It should, therefore, have a lasting effect by arresting the decay of wood at the point of application.

1. Circular letter of the Federation of Electricity Undertakings of India, December 1951.

Pentachlorophenol content (lb/cu ft of wood)	Transverse sections				
Pole No.	Section 1	Section 2		Section 3	
	Top 2″ of pole	About 7″ below section 1		Just below bottom of cavity	
	(a)	(a)	(b)	(a)	(c)
1	0.27	0.23	...	0.16	...
2	0.23	0.15	0.12	...	0.03
3	0.24	0.19	0.02	...	0.02

(a) Drilling taken up to ¼″ from the inner surface of the hole (except where no hole was present in the section).
(b) Drilling taken between ¼″ and ½″ from the inner surface of the cavity or hole.
(c) Drilling taken from the centre of the section because there was no hole present.

APPENDIX 3

Electricity in the tea industry in India[1]

Several tea factories in South India use electricity for the processing of tea leaves. Electricity is used for withering, rolling and drying the tea leaf. The average handling capacity of a factory in South India is 8,000 lb of wet leaf in 24 hours and the average connected load per factory 110 kW.

POWER REQUIREMENTS OF A TEA FACTORY

Type of machine	Total power required (hp)
Withering fans	14 (a pair)
Rollers	40 (a bank of five)
Roll breakers	2
Tea driers	7
Cutters, sifters, packers and exhaust fans	5 to 7

GROWTH OF TEA INDUSTRY LOAD IN MADRAS STATE

Year	Connected load (kW)
1933—1934	950
1938—1939	3,561
1943—1944	3,869
1948—1949	4,749
1949—1950	5,205

1. "Rural Electrification in Madras State (India)" (Proceedings of the World Power Conference 1951).

APPENDIX 4

The entirely electrified farm[2]

The research farm of the Central Swiss Power Co. (CKW) at Rothenburg near Lucerne, may serve as an example of a fully electrified farm.

1. *Power*

There are two classes of electric apparatus: those with a built-in motor and those used only temporarily which are driven by a motor on wheels or a portable motor.

(*a*) Devices with built-in motor

	(kW)
Threshing mill	15.00
Lift for goods	2.06
Milk-cooler	1.47
Drying machine	0.99
Milker	0.74
Stable ventilator	0.60
Cream-separator	0.37
Cleaning apparatus for animals	0.24
Laundry centrifuge	0.20
Refrigerator	0.12
Total	21.79

(*b*) By means of a 4 kW motor on wheels and 2 portable motors (each for 2.2 kW), the following operations can be carried out:

Operations	
Threshing Mincing of fodder Rough grinding of corn Manure-pumping Manure-stirring Milling Potato-sorting Water-pumping Turnip-topping Grinding Hay-baling Fruit-pressing	Total 8.20 kW

2. Ringwald, F.: "Electricity in Farming and Gardening" (Proceedings of the World Power Conference, New Delhi, 1951).

Consequently the fully electrified farm is equipped with over 13 built-in and rolling and portable motors with a total output of approximately 30 kW.

2. *Light*

Devices for general lighting and those for specific purposes are summarized as follows:

	(W)	
Dwelling house	990	
Farm building	1,340	
Poultry pen	200	
Pigsty	480	
Barn		
General lighting	2,895	
Stable lighting	280	
Total	6,185	(6.2 kW)

3. *Heat*

The numerous heating apparatuses are sub-divided as follows:

	(W)	
Dwelling house		
Kitchen water heater	600	
Bath water heater	1,200	
Kitchen range	12,900	
Space heating	2,000	16.7 kW
Farm building		
Washing machine	7,500	
Bottle sterilizing apparatus	3,000	
Drying machine	1,250	
Various additional heating apparatus	1,500	13.25 kW
Poultry pen		
Heating of perches	720	
Drink water heating	50	
Space heater	1,000	1.77 kW
Pigsty		
Pig food stove	4,500	
Water heater	300	
Radiator	250	5.05 kW
Baarn and stable		
Stable water heater	300	
Space heating of calves' stable	1,200	
Water heater for cattle drinking water	1,200	2.7 kW
Total		39.47 kW

Thus the fully electrified farm of 23 hectares contains the following installations:

	(kW)
Power	30.0
Light	6.2
Heat	39.5
Total	75.7

The annual consumption of power is:

	Power (kWh)	Light (kWh)	Heat (kWh)	Total (kWh)
Refrigerator	1,000			
Milk-cooler	700			
Washing centrifuge	10			
Machine for cleaning cattle	70			
Milking machine	630			
Stable ventilator	240			
Dehydrator, mechanical part	200			
Lift for goods	30			
Cream-separator	100			
Threshing mill	1,500			
Dwelling house		850		
Farm building		375		
Pigsty		185		
Barn, general lighting		420		
Stable lighting		1,000		
Poultry pen, lighting to increase breeding		100		
Kitchen range			3,800	
Washing machine			2,300	
Dehydrator (heat)			650	
Food stoves (2)			4,000	
Drinking water tank for animals (6 winter months)			3,200	
Stable water-heater			2,650	
Kitchen water-heater			5,000	
Sterilizing apparatus			4,000	
Heating for perches } during 5 to 6 winter months			1,020	
Heating for drinking water } during 5 to 6 winter months			70	
Space heating } during 5 to 6 winter months			940	
Total	4,480	2,930	27,630	35,040
%	14	8	78	
per ha	195	129	1,210	1,534

Annual costs based on an average price of Rp[a] 8.284 per kWh: Swiss Fr.2,901.71.

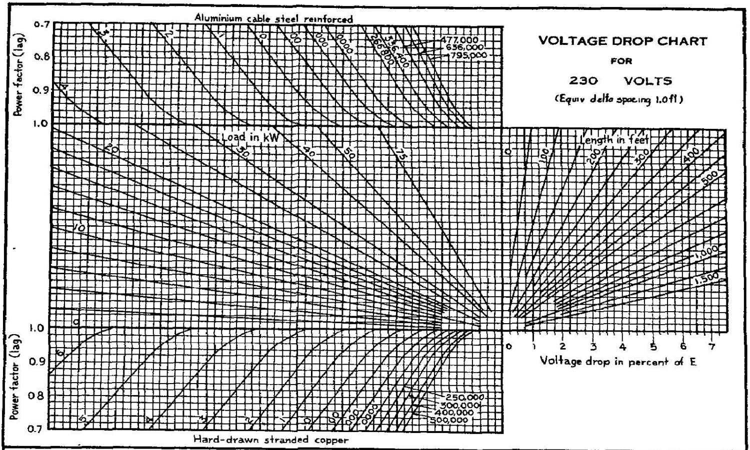
a. 1 Swiss franc=100 rappen (or centimes).

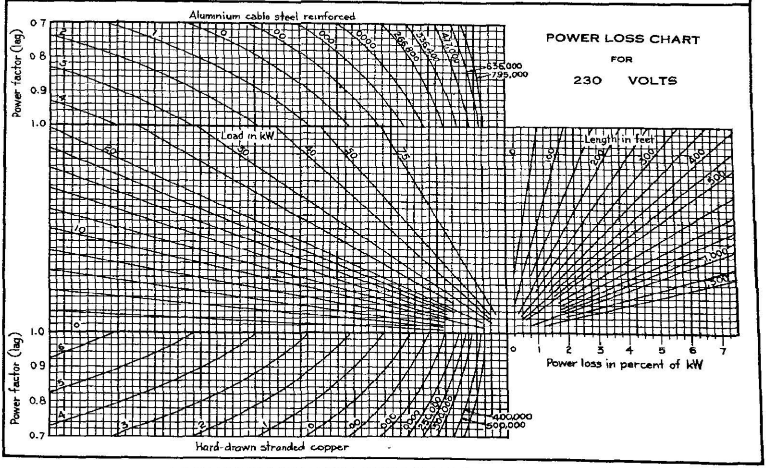
This shows the immediate possibilities of power utilization in a fully electrified farm. Needless to say, the full electrification will not be realized in a day. In most cases, electrification will start where it seems to be most important and will then go on. The fact that electricity consumption is concentrated mainly upon heat points the way to the present needs: to cover these, electricity is mainly used at night, and very favourable tariffs can be granted. This explains the surprising fact that a rate of 8.284 Rp per kWh can be taken as the annual average price for electric power. Further savings on the power bill can be obtained by automatic control and temperature-regulators with cut-off devices. In this way no kWh will be wasted. Another advantage of such an arrangement is to relieve the farmer of supervision and control.

Instructions for using the voltage drop and power loss charts

[Chart I (8 sheets)]

In using the following charts, enter them from one of the two sets of material and size-of-conductor curves. If the conductor is copper, use the lower left hand curves. If the conductor is aluminium, use the top left hand curves. Select and follow along size-of-conductor curve to where it intersects the horizontal line representing the receiving-end power factor. From this point, proceed vertically up or down depending on the conductor material to where the line representing the receiving-end load in kilowatts is intersected, then continue horizontally to the right until the line representing the length of the line in feet or miles is reached. Drop vertically and read the voltage drop or the power loss as the case may be.





LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240
kW multiplier	1.297	1.271	1.247	1.225	1.200	1.177	1.155	1.134	1.113	1.093	1.073	1.054	1.035	1.017	1.000	0.983	0.966	0.350	0.934	0.918

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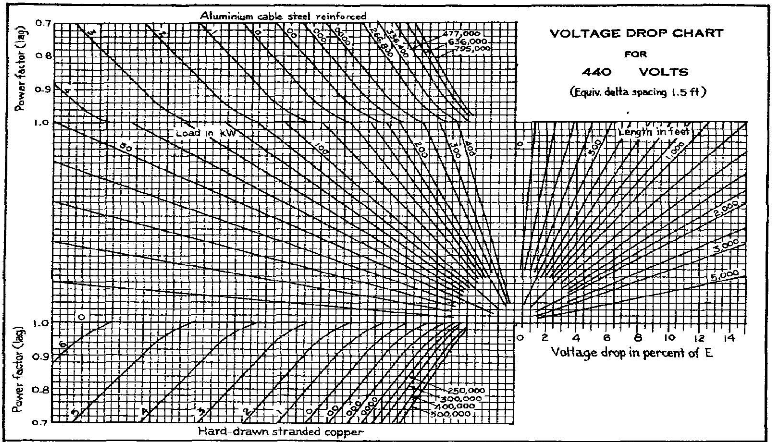
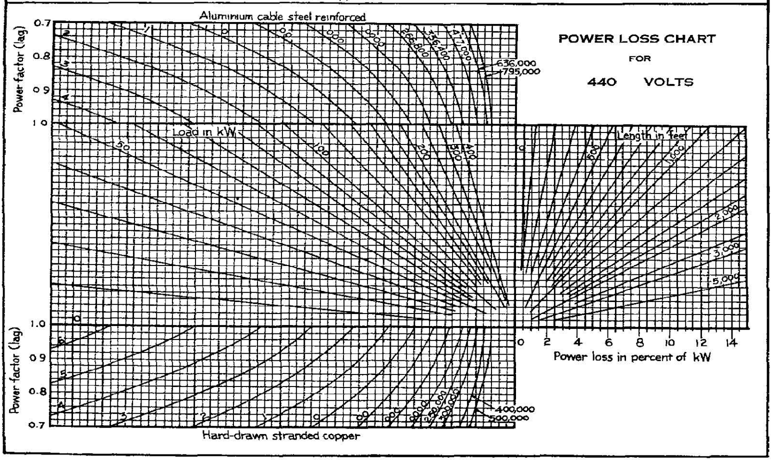
CHART I (Sheet 2)





LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage	404	408	412	416	420	424	428	432	436	440	444	448	452	456	460	464	468	472	476	480
kW multiplier	1.186	1.163	1.141	1.119	1.097	1.077	1.057	1.037	1.018	1.000	0.982	0.965	0.948	0.931	0.915	0.899	0.884	0.869	0.853	0.840

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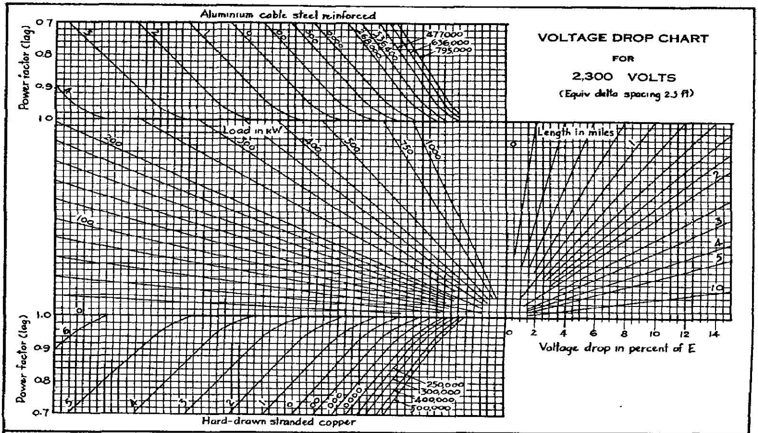

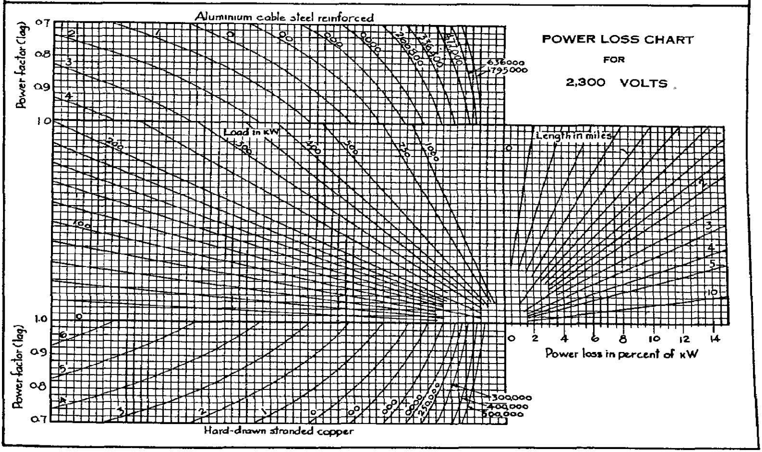

LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage	2020	2040	2060	2080	2100	2120	2140	2160	2180	2200	2220	2240	2260	2280	2300	2320	2340	2360	2380	2400
kW multiplier	1.297	1.271	1.247	1.223	1.200	1.177	1.155	1.134	1.113	1.093	1.073	1.054	1.035	1.017	1.000	0.983	0.966	0.950	0.934	0.918

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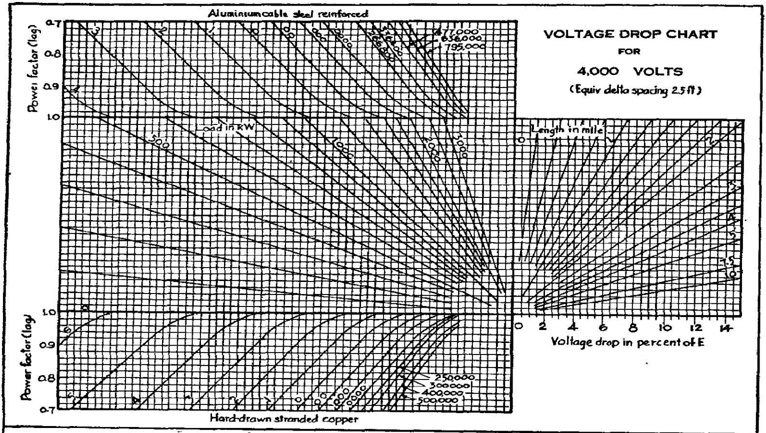

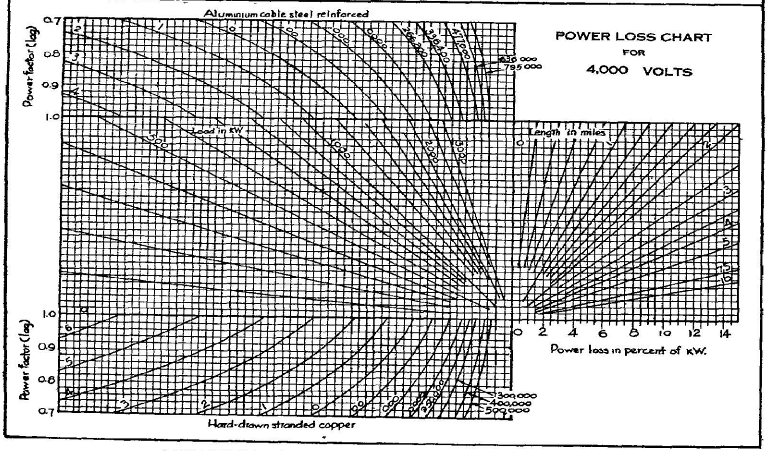

LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage	3850	3900	3950	4000	4050	4100	4150	4200	4250	4300	4350	4400	4450	4500	4550	4600	4650	4700	4750	4800
kW multiplier	1.079	1.052	1.026	1.000	0.975	0.952	0.929	0.907	0.886	0.865	0.846	0.827	0.808	0.790	0.773	0.756	0.740	0.724	0.709	0.694

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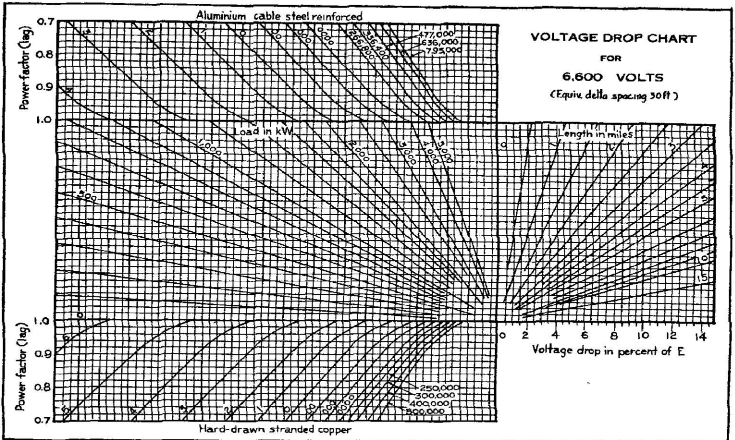

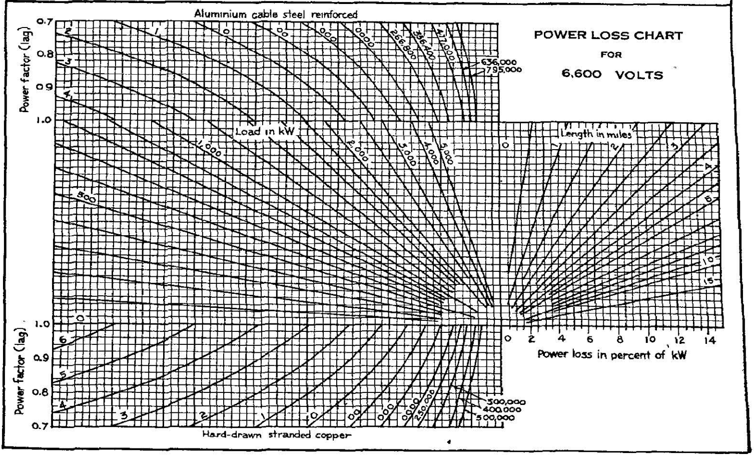

LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage	5950	6000	6050	6100	6150	6200	6250	6300	6350	6400	6450	6500	6550	6600	6650	6700	6750	6800	6850	6900
kW multiplier	1.230	1.210	1.190	1.171	1.152	1.133	1.115	1.097	1.080	1.063	1.047	1.031	1.015	1.000	0.985	0.970	0.956	0.942	0.928	0.915

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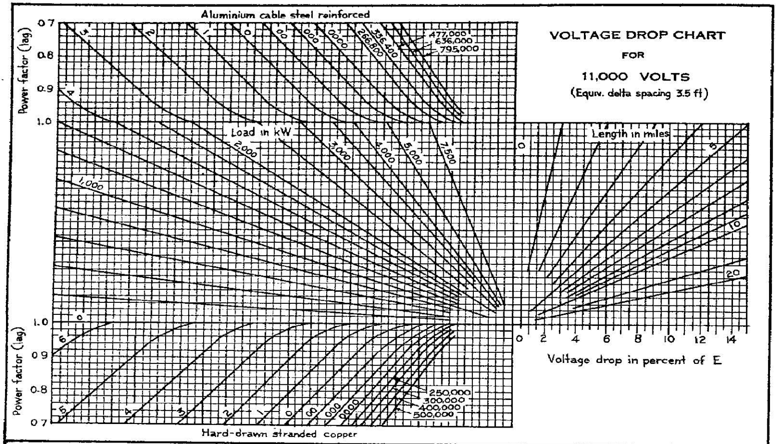
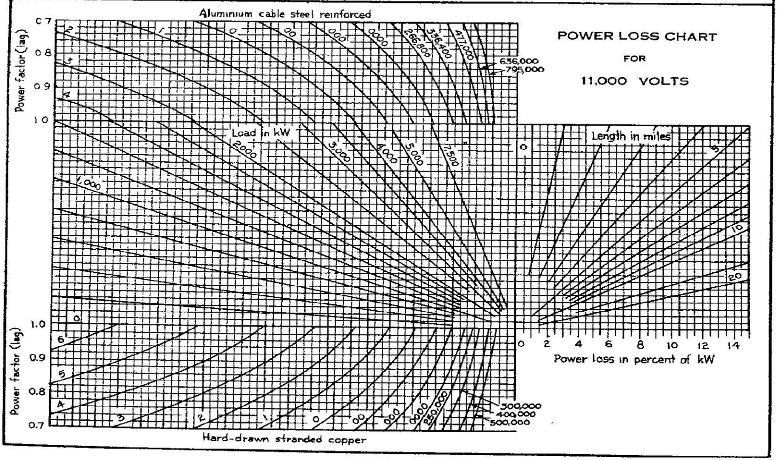
CHART I (Sheet 6)





LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage (kV)	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8
kW multiplier	1.234	1.210	1.186	1.163	1.141	1.119	1.097	1.077	1.057	1.037	1.018	1.000	0.982	0.965	0.948	0.931	0.915	0.899	0.884	0.869

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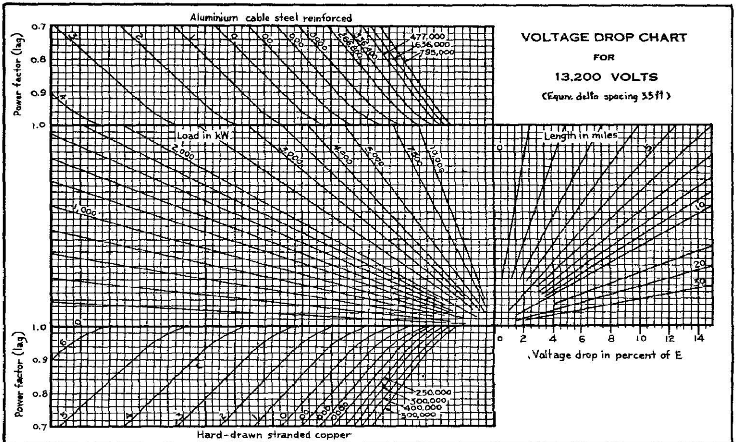

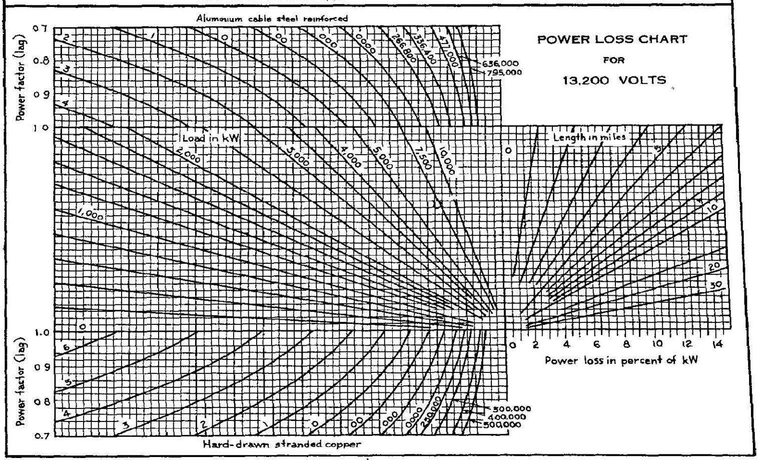

LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage (kV)	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.5	12.9	13.0	13.1	13.2	13.3	13.4	15.5	13.6	13.7	13.8
kW multiplier	1.230	1.210	1.190	1.171	1.152	1.133	1.115	1.097	1.080	1.063	1.047	1.031	1.015	1.000	0.985	0.970	0.956	0.942	0.928	0.915

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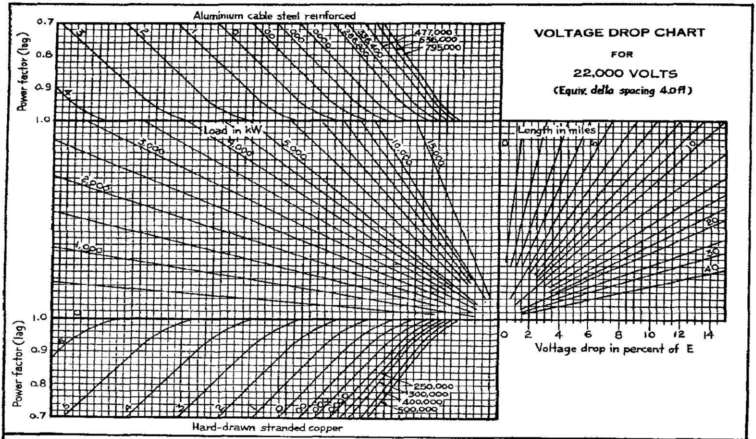

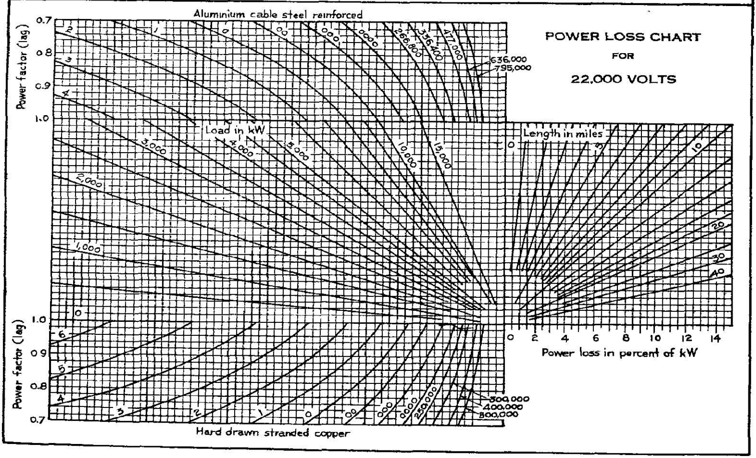

LOAD MULTIPLIERS FOR DIFFERENT RECEIVER VOLTAGES

Receiver voltage (kv)	19.2	19.4	19.6	19.8	20.0	20.2	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0
kW multiplier	1.313	1.286	1.260	1.234	1.210	1.186	1.163	1.141	1.119	1.097	1.077	1.057	1.037	1.018	1.000	0.982	0.965	0.948	0.931	0.915

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Method of fixing wooden poles to reinforced cement concrete butts

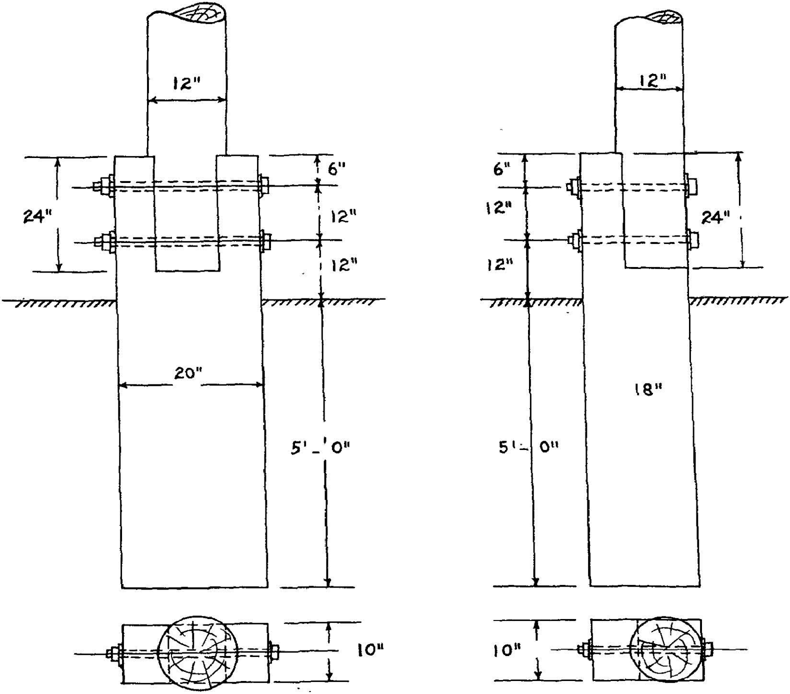

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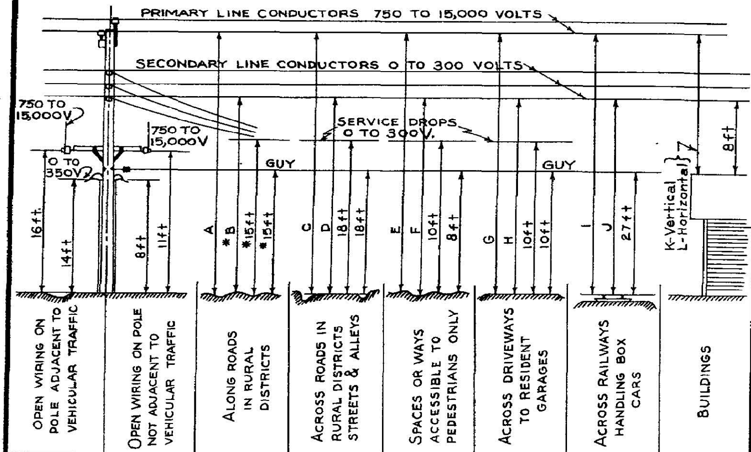
CHART III



SPAN LENGTH	A	B	C	D	E	F	G	H	I	J	K	L
0 TO 150 ft	18'-0"	15'-0"	20'-0"	18'-0"	15'-0"	12'-0"	20'-0"	10'-0"	28'-0"	27'-0"	8'-0"	8'-0"
150 TO 200 ft	18'-6"	15'-6"	20'-6"	18'-6"	15'-6"	12'-6"	20'-6	10'-6"	28'-0"	27'-6"	8'-6"	8'-6"
200 TO 250 ft	19'-0"	16'-0"	21'-0"	19'-0"	16'-0"	13'-0"	21'-0"	11'-0"	29'-0"	28'-0"	9'-0"	9'-0"
250 TO 300 ft	19'-6"	16'-6"	21'-6"	19'-6"	16'-6"	13'-6"	21'-6"	11'-6"	29'-6"	28'-6"	9'-6"	9'-6"
300 TO 350 ft	20'-0"	17'-0"	22'-0"	20'-0"	17'-0"	14'-0"	22'-0"	12'-0"	30'-0"	29'-0"	10'-0"	10'-0"
350 TO 400 ft	20'-6"	17'-6"	22'-6"	20'-6"	17'-6"	14'-6"	22'-6"	12'-6"	30'-6"	29'-6"	10'-6"	10'-6"
400 TO 450 ft	21'-0"	18'-0"	23'-0"	21'-0"	18'-0"	15'-0"	23'-0"	13'-0"	31'-0"	30'-0"	11'-0"	11'-0"

NOTE:

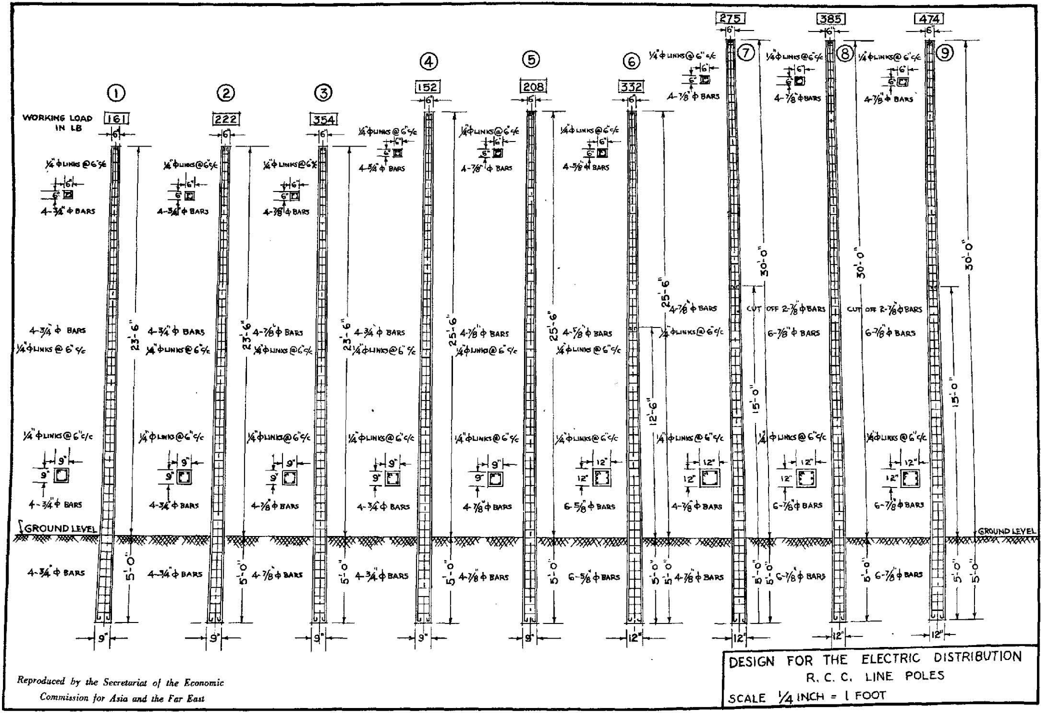
* Where line is located relative to fences, ditches, or embankments such that the ground under the line cannot be traveled except by pedestrians, these dimensions may be reduced to that required for "Spaces accessible to pedestrians only."

(EXTRACT) TENNESSEE VALLEY AUTHORITY

RURAL LINE STANDARDS

MINIMUM CLEARANCE OF WIRES ABOVE GROUND

CHART IV



WORKING LOAD IN LB
1 2 3 4 5 6 7 8 9
161 222 354 152 208 332 275 385 474
6"
1/4" φ LINKS @ 6" c/c
4-3/4" φ BARS
4-7/8" φ BARS
4-5/8" φ BARS
23'-6"
25'-6"
30'-0"
15'-0"
12'-6"
5'-0"
CUT OFF 2-7/8" φ BARS
6-7/8" φ BARS
6-5/8" φ BARS
9"
12"
GROUND LEVEL
DESIGN FOR THE ELECTRIC DISTRIBUTION
R. C. C. LINE POLES
SCALE 1/4 INCH = 1 FOOT

A TYPICAL RURAL DISTRIBUTION LAY-OUT

The Department of Electricity, Govnt. of Madras — INDIA

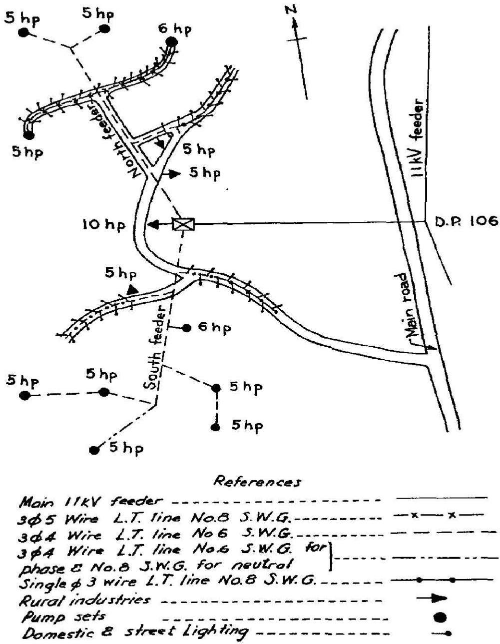


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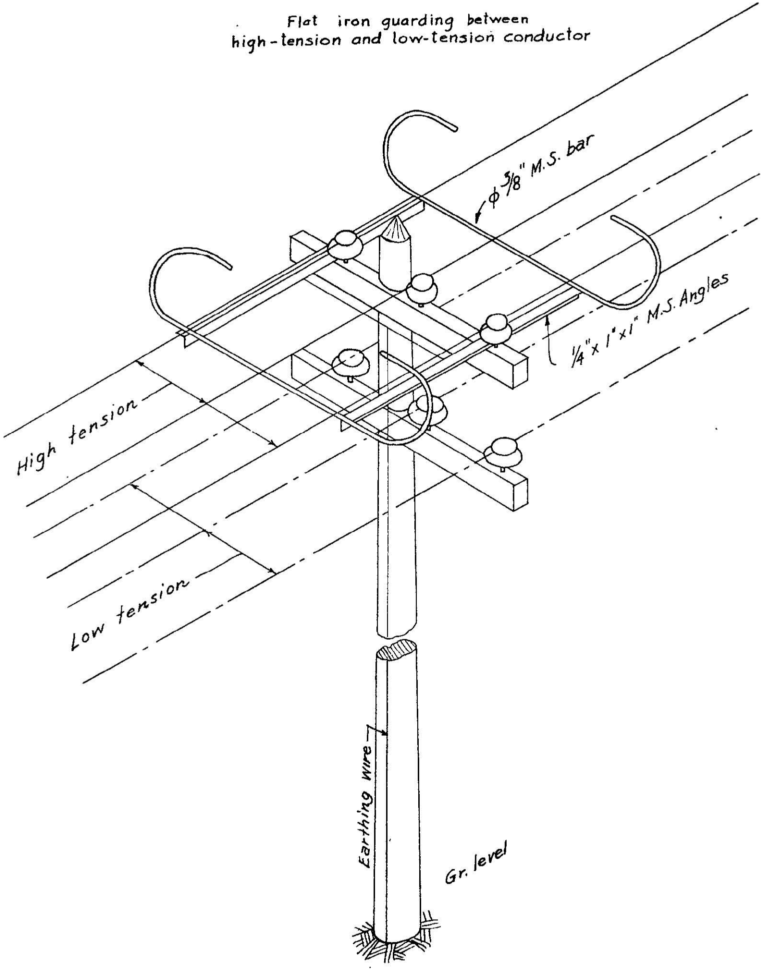
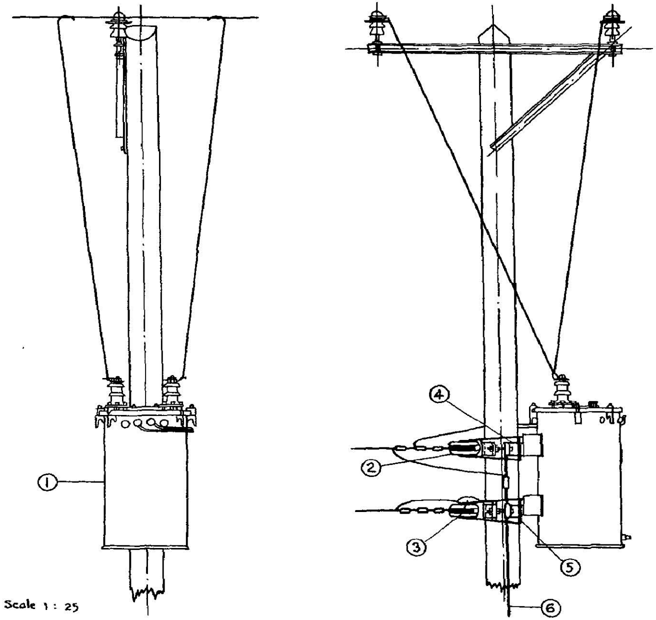
CHART VI


Flat iron guarding between
high-tension and low-tension conductor
φ 3/8" M.S. bar
1/4" x 1" x 1" M.S. Angles
High tension
Low tension
Earthing Wire
Gr. level

11 KV single-phase transformer mounting on rural lines



Item.	Description	No. Reqd.
1	11,000 V/230 V single-phase transformer	1
2	Strain insulator	2
3	L.T pole fuse base assembly	1
4	Pole straps	4
5	Mounting for transformer	2
6	Bare copper stranded earth wire	1

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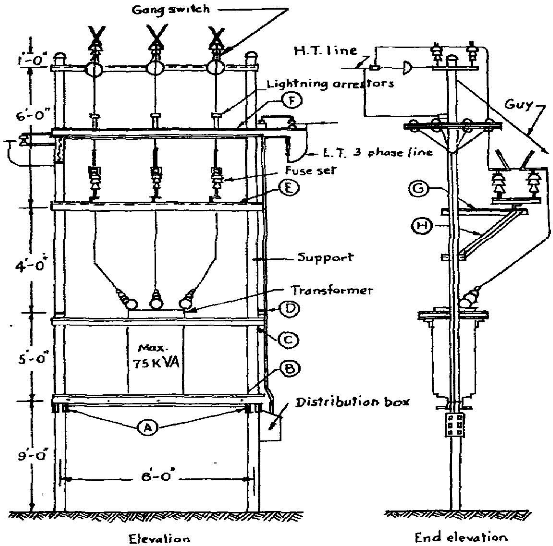
CHART VIIb



S.No	Name of member	Number required	Size of member	Remarks
1	A	2	—	Guy clamps
2	B	2	9'-0"	3"x1½" channel
3	C	2	9'-0"	2½"x2½"x¼" angle
4	D	2	3'-0"	3"x1½" channel
5	E	1	8'-11"	2"x2"x¼" angle
6	F	1	8'-10"	2"x2"x¼" angle
7	G	2	3'-0"	2"x2"x¼" angle
8	H	2	3'-6"	2"x2"x¼" angle

A TYPICAL DOUBLE POLE TRANSFORMER STRUCTURE

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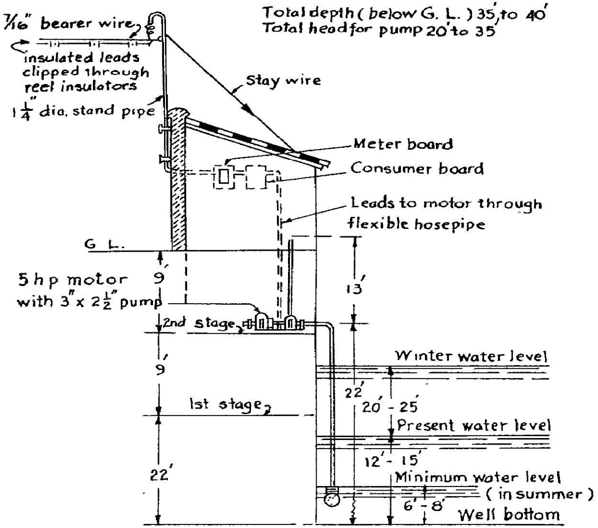

AN IRRIGATION PUMP SET INSTALLATION IN MADRAS (INDIA)

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