



POWER ECONOMY COMMITTEE

REPORT OF STUDY GROUP—I



VOL. I

GOVERNMENT OF INDIA
MINISTRY OF IRRIGATION AND POWER
POWER ECONOMY COMMITTEE

POWER GENERATING STATIONS

REPORT OF STUDY GROUP—I

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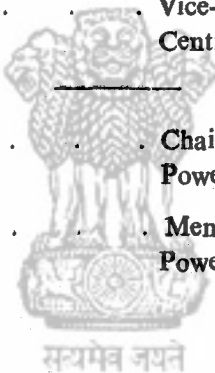
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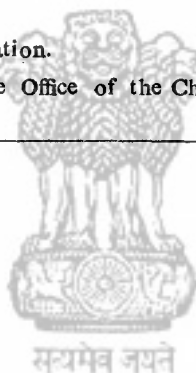
GOVERNMENT OF INDIA
POWER ECONOMY COMMITTEE
REPORT OF STUDY GROUP—I

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SCOPE

1. The resolution setting up the Power Economy Committee states that the cost of electricity supply in the country has been rising despite large scale technological development and points to the need for detailed review of the measures for better utilisation of existing generating facilities as an urgent need for utilising the limited resources of the country efficiently. The Study Group I has been set up by the Power Economy Committee for the purpose of carrying out this review. The very first Term of Reference of the Power Economy Committee sets out the task as follows:—

“To review the pattern of utilisation of available plant capacity during the past 5 years and their operational efficiency and fuel consumption, to consider the scope of improving economy in power generation together with specific measures for attaining them.”

2. The total installed capacity of electric power generating plant in the country is now (1969-70) 15.5 GW (GW=Gigawatt=million kW).

This is composed of the following:—

	<i>GW</i>	<i>Percentage</i>
Water Power	6.1	39.2
Steam Power	8.5	55.2
Diesel Power/Gasturbine	0.5	3.2
Nuclear Power	0.4	2.6

The water power plants include a number of micro hydel stations with generating units rated at fractions of MW. The thermal power stations are mostly steam power stations although a couple of gas turbine installations are also included. A few steam and diesel power stations are captive industrial plants, the former often supplying process steam also. Only one nuclear power station (Tarapore) is in operation and has an installed effective capacity of 400 MW. The make-up of power generation facilities in the near future is also not likely to depart much from this pattern, although nuclear power and hydro-electric power may come into somewhat more prominence. The Study Group has, therefore, proceeded to examine closely the performance and problems of hydro-electric power plants and steam power plants. This is followed by examination of some problems common to the different power systems including problems of management, etc.

CHAPTER 2

**POWER PLANT AVAILABILITY AND
UTILISATION**

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SECTION 1

**POWER PLANT AVAILABILITY
AND UTILISATION**

1. The basic function of electric power station plant and equipment is to generate electrical energy. Evidently, for best utilisation and profitability, the power generating plant should generate electrical energy to the maximum extent possible. Ideally, full 8,760 kWhr of electrical energy should be produced in a year for every kW. of plant capacity installed. Since the electrical energy cannot be stored as such and must be generated at the time it is needed for use, there are two factors limiting the generation of electrical energy from a plant to a lower value.

1.1 Firstly, the load demand fluctuates and would be less than the aggregate power generation capability during a number of intervals every day. The load then constrains the generation.

1.2 Secondly, at times, the power generating plant in a given installation may not be available for generating the requisite electric power. The plant may be out of service for repairs or maintenance or the plant may not be able to give full output owing to some mal-functioning or defects. In such cases, of scheduled or unscheduled outage generally some less efficient plant may have to be pressed into service wherever possible. The system will also require to have idle reserve capacity sufficient to cover such shortages. In either case, the cost of power generation will increase.

2. The second factor above, contributes substantially to increase in the cost of power and must be watched very carefully. Studies regarding equipment availability have, therefore, become an important activity in the manage-

ment of power generation facilities. Due to the different inherent characteristics of the different sources and methods of power generation, the question of plant availability has also to be viewed in different light in different cases.

3. In thermal power stations, the chemical energy in fuels is converted into electrical energy. The power station may be considered as a "kWhr factory" where raw-material in the form of fossil fuel is processed to yield electrical energy. Technically, steam power plants are best suited for constant production level throughout the year except for periods of maintenance outages. Operation at partial or widely varying loads is less efficient and also accelerates the depreciation of the equipment. The equipment availability, therefore, bears a direct relation to economic operation of the plant and the highest availability must be aimed at and achieved. This applies with even greater force to the nuclear power plants of the type installed or proposed to be installed in the country, presently.

4. In the case of hydro-electric power stations, the position is more complex. The energy potential at each site is limited although it may vary from year to year, depending on the availability of water. The energy that is available at each site is thus fixed for every year irrespective of the installed capacity of the power plant. The utilisation of this can, however, be scheduled to suit the requirements of the electric power system, depending upon the storage capacity available for water. This puts the plant availability of hydro stations in a different class. The criteria for the most economic operation would be that (i) the hydro-electric plant exploit

the full energy potential of a site every year and (ii) fully meet the needs of the system in respect of high priced peak energy requirements by use of the hydro-electric installations in the combined system. Since the plant capacity installed is well in excess of the minimum needed for exploiting the designed energy potential of any site, and the secondary energy available varies seasonally, there is ample scope for scheduling the preventive maintenance and often even the overhauls in the off peak periods or periods of the year when plant requirements may be less due to restricted water availability or restricted system requirements so far as hydro generation is concerned. This, coupled with the inherent simplicity and robustness of hydro-electric equipment have made the question of plant availability less critical for hydro-electric power plants in contrast to the importance of availability for thermal power stations. The experience in the country in recent years is reviewed below:—

5. Figure 2-1 gives the energy generated in kilowatt hours per kilowatt of installed generating capacity in the country, over the past 31 years, i.e., from 1939 to date. The two main sources of energy generation have been the fossil fuel burning thermal power plant and the hydro-electric power plant. The effect of the various factors discussed in the foregoing can clearly be seen in Fig. 2-1. In the early years, most of the power stations operated practically independently. There were few inter-connections and the power generation in individual power stations had generally to meet the load requirements from time to time independently. Naturally, the spare generating capacity had also to be kept available separately in each power station. This resulted in very low figure for kWhr per kW. in the early years. Further, some of the power stations took long to build up the load to their full capacity and this kept the utilisation at a low figure for a considerable time. The data regarding thermal power generation plotted here includes the diesel power stations as well as the steam ones. The diesel sets are usually run for electric power supply only for a few hours in the day. This has also contributed to the low plant utilisation.

6. The apparent erratic nature of individual points of Figure 2-1 is partly due to the fact that when new power plant is installed in a year, it

does not contribute substantially to the energy generation in the same year. This results in the utilisation showing a dip in that year before rising higher in subsequent years. It is seen that the utilisation of thermal plant has been continually on the increase and has improved rapidly over the years after about 1954. This is partly due to the improvement in the load conditions and partly due to increasing degree of inter-connected operations of different power stations. This has naturally led to increasingly better utilisation figures for thermal power plants and decreasing figures of utilisation (in terms of kWh/kW) for the hydro power plants for the reasons already discussed above. The utilisation of hydro power plant has also shown ups and downs accordingly to the water availability in the respective years.

7. Generally, the overall plant utilisation has risen continuously till about 1964-65, showing the trend towards net overall improvement. This is the result of the inter-play of a number of factors such as inter-connected/integrated operation, enabling higher system demand to be met from the same installed capacity; reduction in the need for standby plant, the effect of the preventive maintenance practices yielding better plant availability etc. Table 2-1 shows the experience in regard to plant utilisation in a number of leading countries in the recent years. Under the conditions in India in regard to the hydro and thermal energy resources it would appear that we should strive to achieve the degree of plant utilisation achieved in the U.S.A. or U.S.S.R. if not that in Japan or Canada.

8. In planning of larger inter-connected power generation facilities the knowledge of outage data for generating equipment has become of increasing importance. This is especially true now when probability methods are being increasingly used in deciding upon the extent of reserve capacity, optimum size of generating units etc. The question of plant availability and outage data require detail consideration for each mode of power generation and these are therefore examined further in the chapters on performance and problems of thermal power plants and hydro power plants respectively. The data on the brief period of commercial operation of the Tarapur Atomic Power Plant is also presented here in Table 2.2.

9. It is evident that a uniform basis of reporting plant availability and plant outage records is essential for scientific analysis. There has been considerable confusion in this in the past and a number of different sets of definitions have been adopted by different bodies in the leading countries. It is proposed to adopt for our purpose the definitions evolved by the Edison Electric Institute after considerable work and experience over the last ten years. A set of these definitions is enclosed as Annexure 2-1.

10. The performance and problems of operation of the thermal as well as hydro-electric power plants have been studied and presented in a comprehensive manner in the subsequent chapter. The various elements affecting power plant availability and utilisation are also discussed. All the studies support the following con-

clusions for the generating plants in India.

10.1 There is an urgent need to improve power plant availability and utilisation. For this, integrated operation of the power systems in every region as well as improvement in availability of thermal power plants are necessary.

10.2 Modern methods of scientific management, particularly operation analysis should be introduced immediately and utilised increasingly for improving the quality of preventive maintenance and reducing the plant outage time for maintenance.

10.3 Separate technical cells for quality control in operation and maintenance, improving fuel efficiency etc., should be set up in each organisation directly under the Chief Engineer and in the case of Electricity Boards directly under Technical Members.

TABLE 2-1
ENERGY GENERATION IN DIFFERENT COUNTRIES FROM VARIOUS RESOURCES

Country	Total Energy Generation (Million kwh)			Energy Generation/kw installed		
	1960	1965	1968	1960	1965	1968
1	2(a)	2(b)	2(c)	3(a)	3(b)	3(c)
U.S.A.						
Hydro	149515	196984	225870	4500	4500	4355
Thermal	694155	956942	1197114	4600	4750	4700
Nuclear	518	3657	12528	1800	4000	4450
TOTAL	844188	1157583	1435512	4500	4700	4635
U. S. S. R.						
Hydro	50913	81434	104040	3600	3750	3855
Thermal	241361	425238	534621	4650	4850	4700
Nuclear	..	..	..	..	..	..
TOTAL	292274	506672	638661	4400	4650	4500
U. K.						
Hydro	3133	4625	4446	2670	2630	2060
Thermal	131758	175532	191660	3740	4070	3625
Nuclear	2079	15836	27196	6800	6580	5845
TOTAL	136970	195993	223302	3740	4150	3745
FRANCE						
Hydro	40344	46429	50342	3930	3700	3475
Thermal	31644	54116	64424	2750	3700	3515
Nuclear	130	897	3159	1340	3090	2485
TOTAL	72118	101442	117925	3330	3700	3465

Power Economy Committee

TABLE 2-1—(Contd.)

1	2(a)	2(b)	2(c)	3(a)	3(b)	3(c)
JAPAN						
Hydro	58471	76420	74570	4200	4800	4180
Thermal	57001	115672	195014	5200	4930	5635
Nuclear	..	36	1027	..	3000	5740
TOTAL	115472	192128	270611	4880	4850	5140
CANADA						
Hydro	105883	117064	134600	5670	5600	5400
Thermal	8574	27090	39968	1960	3800	3720
Nuclear	..	120	858	..	6000	3900
TOTAL	114457	144274	175426	4980	5110	4870
SWEDEN						
Hydro	31066	46428	48771	4430	5130	4700
Thermal	3652	2648	7443	1870	980	2260
Nuclear	..	18	23	..	1800	2300
TOTAL	34718	49094	56237	3850	4170	4110
ITALY						
Hydro	46106	43008	43477	3650	3030	2945
Thermal	5030	33874	50264	1680	3860	3500
Nuclear	..	3510	2576	..	1500	4010
Others	2104	2576	2694	7330	7700	7260
TOTAL	56240	62968	104011	3200	3390	3450
INDIA						
Hydro	7847	15233	20320	4250	3700	3425
Thermal	12276	21592	92200	3300	3570	3470
Nuclear	..	..	..	..	..	..
TOTAL	20123	36825	49520	3590	3650	3460

Note.—Energy generation per KW installed have been worked out on the basis of average installed capacity during the year.

Source : U. N. Statistical Year Book—1968.

TABLE 2-2
PLANT AVAILABILITY & UTILISATION AT TARAPUR ATOMIC POWER STATION
Two Generating Sets Rated 210 MW EACH

Period	Total Energy Generated (Million Units)		Net energy sent out (Million Unit)		One hr. peak gross generation MW	Service hours %		Capacity Factor %	Output Factor %		
	MSEB	GSEB	Total	Total		Unit 1	Unit 2				
										Combined for unit 1 & 2	
1	2	3	4	5	6	7	8	9	10		11
November, 1969	.	.	.	.	.	.	.	.	.	.	.
December, 1969	.	.	.	.	.	.	.	.	.	.	.
January, 1970	.	.	.	.	.	.	.	.	.	.	.
February, 1970	.	.	.	.	.	.	.	.	.	.	.
March, 1970	.	.	.	.	.	.	.	.	.	.	.
April, 1970	.	.	.	.	.	.	.	.	.	.	.
May, 1970	.	.	.	.	.	.	.	.	.	.	.
June, 1970	.	.	.	.	.	.	.	.	.	.	.
July, 1970	.	.	.	.	.	.	.	.	.	.	.
August, 1970	.	.	.	.	.	.	.	.	.	.	.
September, 1970	.	.	.	.	.	.	.	.	.	.	.
October, 1970	.	.	.	.	.	.	.	.	.	.	.
November, 1970	.	.	.	.	.	.	.	.	.	.	.
December, 1970	.	.	.	.	.	.	.	.	.	.	.

NOTE : (1) Unit No. 1 was on annual inspection/maintenance from July 14 to August 29, 1970.

(2) Unit No.2 was on annual maintenance/inspection from September 2 to October 21, 1970.

OUTAGE REPORTING PROFORMA OF EDISON ELECTRIC INSTITUTE

[illegible]

SECTION 2

STUDY OF PLANT AVAILABILITY ON A NATIONWIDE BASIS

1. The question of availability of equipment has been discussed in great detail in the Studies in this Report. In the past, the power stations have been constructed and operated in an isolated manner. Even within the organisation of a single State Electricity Board, there has not been adequate pooling of information and experience regarding working of the power stations and other electrical installations. This has resulted in inaccurate as well as inadequate appreciation of the problems involved and of the significance of the various factors contributing to the unsatisfactory working of the power system components. In fact, in many cases, it has not been possible to even establish any norms for the operation, with the result that it has not been possible to say, in a scientific manner whether the operation has been satisfactory. Now with the large number of generating units of each category already in operation, a very powerful tool can be forged in the shape of statistical and engineering analysis of the data regarding plant availability.

2. Introduction of statistical and engineering analysis will enable a number of very useful studies leading to:—

- (i) Establishment of norms of availability (including partial availability) for each type of equipment;
- (ii) Continuous monitoring of the performance of the operation and usage of equipment in different power stations;
- (iii) Evaluation of new technological innovations or procedures, apparatus, etc. in regard to their effectiveness in improving the performance of power installations;

- (iv) Identification of problems faced by the various units of power supply industry on a broad national base, leading to formulation of the most economical and reliable solution;
- (v) Evaluation of the efficacy of integrated operation and system load despatch procedures in use;
- (vi) Provision of basic data for formulating the policies regarding spares inventories, technical manpower requirements, special T. & P. etc.; and
- (vii) Provision of basic data for planning of future programme of power development.

3. It is quite clear from our Studies that any analysis of equipment availability will have to be comprehensive. The availability is normally measured in terms of hours (or proportion of time) for which the equipment is available for use in a year. It is seen that, in the working of many power systems in the country, this is inadequate; for considerable periods, the power plant may be "available" but its capability may be severely limited. Such occurrence may be much more serious than what the loss in generating capacity would indicate. If a 60 MW thermal unit is capable of generating only half the power for one reason or the other, then under certain conditions, its efficiency and heat rate may be much worse than that of a generating set rated at 30 MW. This means that the economy of installation of a larger generating set is not only wiped out but, in fact, the set with a reduced capability may be subject to much faster wear and tear and also

be much more costly to operate for production of energy. It is, therefore, necessary that such partial availability should be taken note of.

4. The information required for studies in this connection may be divided into two parts. Firstly, all the relevant information regarding each item of equipment must be collected together and properly organised. This information can, in fact, be made into a "Data Bank" which can be drawn upon throughout the life of the plant. Any modifications to the plant and equipment or changes in its parameters on account of its age or any improvements, renovations etc. will have to be taken note of as and when these occur. Secondly, information regarding the operation of the plant will have to be reported periodically. Yearly returns may serve the purpose but it would appear highly desirable to have six-monthly returns in this respect. Timely submission of full information is highly important. Failure in this regard on the part of even a few organisations would delay the processing, analysis and study of the information and would greatly mar the value of these studies and the benefit to be derived by other organisations also.

5. A few points that would deserve particular attention in setting up such a system of data collection and processing may be mentioned here.

5.1 The format for data collection should be very stable. Frequent changes in the format create a lot of confusion and make it extremely difficult to carry out any statistical analysis. The format should, therefore, not be changed for periods of at least 5-7 years at a time. This also indicates the great deal of care and thought that would be required in formulating the questionnaires, proformae etc. for data collection. It may be worthwhile to prepare trial drafts in the first instance and try these out on two or three power systems covering the whole range of expected data for some short periods. Trial studies can also be made on the basis of such data and thereafter the questionnaires proformae etc. can be finalised.

5.2 The various questions should be unambiguous and preferably should be capable of being answered in terms of "yes/no" or by giving a number. For this purpose, the questions and the form of answers can be coded, taking into ac-

count the various possible answers. This procedure will, in fact, have to be carried to a great deal of refinement if use is to be made of computers for the purpose of analysis and studies.

5.3 One great hurdle in all such data collection is an inadequate appreciation or understanding of the questions by persons responsible for furnishing the answers. It is, therefore, necessary to have clear cut definitions for all the terms to be used and detailed instructions must be drawn up regarding the manner in which the data is to be furnished.

6. One important factor in success of such work is the feeling of purposefulness. The Central organisation which may be in-charge of the work of analysis studies etc. must carry out its part of the work with utmost speed, diligence and thoroughness and make the results of the studies available to the organisations contributing the data. Such feed-back of the results to the Electricity organisations throughout the country will help in creating an awareness of the use and purpose of this work and will greatly assist timely collection of the requisite data.

7. In this connection, it would be worthwhile to profit by the experience gained by the Edison Electric Institute and its vast network of constituent companies in the U.S.A. Under a Research Project of the Institute (Project No. 76), the data collection and analysis system for availability information has been under study for expanding the analysis and dissemination capability of the EEI Equipment Availability system. The past few years have been a tremendous growth in demand for availability information for the various purposes already recounted before. This led to the development of numerous data collection and analysis system by different groups in the electrical industry. Many power companies were faced with the burden of reporting the same outage data to support many of these systems. This led to wasteful duplication of effort and, moreover, the wide variety of defects in reporting instructions made comparison of results often meaningless. As a result of the above Research Project, new reporting instructions have now been devised to accommodate all the modern types of generating plant and equipment and to reduce ambiguity as well as preparation time for the data wherever possible. All the data to be utilised have

been organised into a single historical data base instead of annual summaries kept previously. In this way, each outage can always be related to the design information and other outages for a particular generating unit. This is the same basic approach as has already been followed in the foregoing studies of the Power Economy Committee, taking note of the individual generating units, as identifiable units. The EEI have found that this greatly expands the analysis capability of the system. In the past, the equipment availability information has been published by EEI, in the shape of an annual report. It is now felt that this report utilises only a small fraction of the information potential available. In order to meet the different needs of the different industry groups, the matters have been so arranged that besides the one published report, several sets of computer reports geared to the needs of specific industry groups are now feasible. The Figure 2-2 shows the flow of information in this new system. It may be noted that input of data into the data base, the retrieval of selected data and analysis of selected data are completely independent functions. This permits retrieval and analysis of data at any time with whatever data that may be currently available in the data base.

8. While the procedures for annual reporting to main industry groups are yet being established, it has been ensured that each organisation submitting data to the Institute for these studies will receive a report on each of the units. Any errors detected by the system will be indicated in these reports and this automatic error detection and feed-back will continually improve the integrity of the data base.

9. As a result of the experience of the last nine years, the data collection system has been further revised and streamlined recently (January 1970). The data reporting is now in three parts:

9.1 Part-I is a tabular statement in respect of each generating unit giving the data and period of each outage, its cause, any time lost in waiting, man-hours worked on primary cause, man-hours worked on major equipment and reduction of capacity due to partial outage. All the data regarding the types of outages and causes therefore are digitalised by assigning standard code numbers to these. All the other information is

also expressed in a uniform manner in numerical form. The prescribed proforma is given in Table 2-3.

9.2 Part-II gives a yearly summary of operating data. This includes the maximum dependable capacity of the units. The type of loading (Base, peak, etc.), hours of running, number of starts of unit, total energy generation and auxiliary consumption, fuel particulars etc.

9.3 Part-III is the basic design data for each generating unit and this is to be submitted only once during the life of each generating unit. Subsequently, this data is to be resubmitted only if major changes are made, altering the characteristics significantly. Separate proformae are prescribed in respect of data for fossil fuel burning units, hydro electric units, nuclear units etc. and distinction is also made between gas turbines, diesel or steam units. These data are required to be given in a fairly detailed manner and form the basis of the data bank for the computerised system of analysis.

10. A study of this system indicates that it would be very well suited for adoption in India with a few modification in some of the proformae.

11. Exchange of Operating Experience

11.1 One more step in the scope of improving economy in power generation is promoting exchange of operating experience of various stations. At present, there is in general a hesitancy and reserved outlook on the part of all power plant personnel about the occurrence and failures or accidents at their station.

11.2 Every accident or occurrence has a natural cause, which when determined gives recourse to remedial measures. Generally, the causes can be classified under "incontestably clear" or "seemingly clear" or "temporary not sustained". In case of "incontestably clear" cases solution can easily be determined. In case of "temporary but not sustained", the operating staff can be advised expedient solutions to prevent the temporary condition recurring. But in case of "seemingly clear" cases, there is a definite chance of recurrence of the accident probably with heavier damages. Particularly in such cases "exchange of operating experience" would be of great help.

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11.3 Generally, "exchange of operating experience" will help in:

- (a) reduction of occurrences or accidents
- (b) reliability of operation
- (c) economy
- (d) development of power plant technology
- (e) and most important of all, improvement in the understanding of operating personnel.

11.4 These can be achieved by convening conference of senior staff of various power stations to discuss their operating experience with an open mind. Further, each of them can put forth problems which may be hampering their plant operation and may find from one of the other participants a suitable solution. Such

a Conference should be conducted by an agency such as CWPC. All participants should earlier give details of problems solved and problems for which they seek an answer. These should be circulated to all the participants so that suitable solutions can be obtained.

It is felt exchange of operating experience can to a large extent improve the standards of operating staff, reduce outages and occurrences which will add to the fuel economy.

Such meetings or conferences of power plant authorities are regularly held in United States and Germany.

12. If the above system of voluntary reporting of problems does not work satisfactorily, statutory regulations making compilation and supply of such information obligatory should be made.



HYDRO ELECTRIC POWER STATIONS

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SECTION 1

GENERAL

1. Hydro-electric power stations constituted about 42% of the installed capacity in the country in 1968-69 and provided about 40% of the energy. Hydro-electric generation is thus responsible for providing a far greater proportion of country's energy supply than is the case in many advanced countries. This position is likely to be maintained for a considerable time on account of the many attractions it offers in regard to initial cost, foreign exchange cost, operation cost etc., and the fact that a large number of favourable sites still remain to be exploited.

2.1 Utilisation of water power started very early, the first significant stations having been constructed in the first decade of the 20th century. The initial development of power grids in the country also centred round hydro-electric schemes as in Mysore, Maharashtra, Kerala, Madras, Punjab and U.P. This trend continued and intensified in the post Independence era through such schemes as Hirakud, Bhakra, Chambal Valley Development, Koyna, Rihand, Barapani, Jaldhaka, Sharavathy, Sabarigiri and Kunda. Evolution of composite hydro-thermal grids also began to be noticeable by this time as in the case of Damodar Valley Corporation, the Madras system, the Bombay-Poona area in Maharashtra etc. With the taking up of Multipurpose River Valley Projects, flood control projects, etc., greater attention also came to be given to a variety of hydro-electric schemes and their planning for co-ordinated operation in the interests of better utilisation of resources. Very significant contributions have been made in this latter field by the Central Water and Power Commission and its

predecessor bodies. This includes the nationwide hydro-electric survey which has provided the basis for all further work.

3. Presently, a great deal of attention is being devoted to the design of water power stations. With the emergence of vast interconnected and integrated power systems covering the whole length and breadth of the country, the different modes of power generation will also assume rather specialised functions. The large nuclear and thermal power stations will be increasingly considered as "kilowatt-hour factories" endeavouring to generate as much energy as possible at the lowest possible cost. The hydro-electric power stations on the other hand, will have a dual role. Firstly, they will endeavour to extract all the energy potential that may be available in the waterways of the country year to year and season to season. Secondly, the exploitation of this energy potential will also be re-regulated to meet the highly variable requirements of the system loads at various times and various places. The re-regulation will result in a manifold enhancement of the value of the energy available from water and system peak loads will be met. The flexibility, ease of control and simplicity of hydro-electric developments will be utilised for optimisation of the power system performance and provision of peak loads, frequency regulation etc. This makes it important to design, construct and operate the hydro-electric installations in a highly reliable manner obtaining a full measure of the flexibility and economy of operation.

SECTION 2

REVIEW OF HYDRO ELECTRIC DEVELOPMENT

1. Although India had an early start in the field of Hydro-electric development, the tempo of development was very slow indeed upto the time of independence. By that time, the total installed capacity came to about 500 MW distributed over 11 power stations and about 49 generating units. Since then about 195 generating units totalling a capacity of about 5728 MW have been installed and commissioned (July 1970).

2. Figure 3-1.1 shows the number of generating units added each year since independence. An integral curve on 1/10 scale has also been plotted to show the total number of generating units commissioned since independence by the end of each calendar year. Another cumulative (integral) curve shows the total number of generating units in commission in the country by the end of each year, taking into account the generating units commissioned before independence also.

3. Figure 3-1.2 shows the same data as figure 3-1.1 but expressed in terms of MW as installed capacity instead of number of generating units. The bar chart in this figure shows the MW capacity added in each calendar year and the two integral curves show respectively the total generating capacity added since independence and the total generating capacity taking into account the pre-independence installations have been plotted against the year 1947 for reference. In these two curves, on the time scale of the year, the periods of the successive 5-year plans have also been marked. It would be noticed that although the 'number of units added every year' has shown distinct improvement in each successive plan period, the position in this respect is somewhat erratic. This would seem to bring out the need of proper perspective planning for the country as

a whole and that too on a continuing basis instead of from plan to plan.

4. The range of hydro-electric installations covers practically the entire spectrum of hydro-electric development and there are with us power plants of almost every well-known manufacture in the world. The range of head utilised extends from 4 m. (at Kosi, recently commissioned) to 867 m (at Pykara). The maximum rated flow handled by a single turbine is 170 m per sec. (at Hirakud) and the flow through the 75 MW Ukai turbines to be commissioned shortly will be 180m³/s per machine. Figure 3-1.3 shows the rating of the largest generating unit in operation in the country from year to year. In keeping with the general trend in the world, the unit size in India has also grown from about 20 MW in 1947 to 120 MW in 1966. Units of 130 MW (Iddiki) and 165 MW (Beas Stage I) have now been planned for new power stations under construction and bigger units are being considered for some of the schemes under planning. Although much bigger units have already been planned and installed elsewhere in the world. It is to be remembered that in the field of hydro-electric generation the general trend does not necessarily indicate the most economic solution which appropriately have to be matched to the environmental conditions of the scheme and the sites of development.

5. Figure 3-1.4 shows the number of generating stations added each year. This has been drawn up on the same lines as figure 3-1.1 and figure 3-1.2. It is seen that the tempo of development had increased, till in 1966 and 68, 17 and 14 new units were respectively added contributing 918 MW and 715 MW of new capacity. This tempo has, however, fallen off and is not

likely to be reached in the current five-year plan. This is a serious set-back.

6. A curve showing the total number of hydro power stations in operation from year to year has also been added. In 1947, at the time of independence, India had only 11 hydro-electric power stations in operation. During the first five years, the additions to the installed capacity were in the shape of additional units in the existing

power stations. The first three new power stations (after independence) were the power stations commissioned in the year 1951-52 (in Tamil Nadu, Uttar Pradesh and Maharashtra). The total number of hydroelectric power stations now stands at 65. (It may here be stated that hydro-electric units of less than 1000 kW or micro hydel installations are not included in the above review. Also, here the power station is taken to mean a hydro-electric installation in a single building.)



SECTION 3

GEOGRAPHICAL CONSIDERATIONS

1. Hydro-electric installations in the country, as mentioned above, cover a comprehensive range of heads, ratings and site conditions. When giving consideration to the economy, operating problems and reliability of hydro-electric generation, it is necessary to take account of the entire work of the project, including the hydraulic works for storage and conveyance of water, the regulation features as well as the power station installation. The initial cost as well as operational features and problems are greatly influenced by factors of topography, geology and hydrology of a particular site. Hydro-electric installations thus have a close relationship with the geographical factors. These can be employed as a basis for a rational classification.

2. The hydro-electric installations in India may be broadly classified as (i) Himalayan and (ii) Peninsular.

3. The category of Himalayan schemes would cover those located in the Himalayan mass itself as well as in the associated young-fold mountains such as in NEFA, Nagaland, and the Shiwaliks. The low head developments in the sub-Himalayan plains can also be included in this class. The topographical and geological peculiarities of this region are well-known and, in turn, determine the main features of the Hydro-electric schemes. The main river channels in this area are characterised by deep gorges and narrow valleys. The valleys of tributary streams are also steep and narrow, offering very little storage facilities. The geological formations are relatively recent, giving rise to problems of construction as well as those arising from silting and erosion. Significant storage possibilities occur only in the lower portion of the course of the rivers, just ahead of

their exit through the mountains. The rainfall is on the average less than for some other main mountains in the country. The pattern also ranges from a purely monsoon type in the east to purely cyclonic at the western end. A very significant respect in which the Himalayan hydrology differs from that in the rest of the country is in regard to glacier and snow storage which give rise to significant discharges in the streams in summer and a slightly different pattern of flow than is the case with purely monsoon fed rivers.

4. The Peninsular topography which covers most of the country ranges from mature to senile. At two or three locations such as in Western Ghats and Assam steep escarpments are available, presenting very favourable conditions for hydro-electric development. Concentrated falls are also presented by local features such as the Nilgiris, which essentially forms a very elevated plateau. The mature valleys generally offer good storage sites and some possibility of very large storage at economic cost are known. Almost everywhere, the geology is more stable than in the Himalayas. The hydrology over this entire area is purely monsoon, although many gradations of this are to be found. The escarpment features such as Western Himalayas or the Southern face of Khasi-Jaintia hills which face the monsoon, receive extra-ordinarily heavy rainfall which goes on decreasing sharply inland. Areas in the Southern peninsular facing the Bay of Bengal receive significant winter rainfall from the return monsoon.

5. These factors affect the character of the hydro-electric plant in the different areas. The Himalayan schemes are characterised usually by meagre and costly storages. Very often, at least

up to the present these have to be made as run-of-the-river schemes. Heavy silt and boulders and bed-loads in the waters have to be taken into account. Development of larger heads usually require construction of fairly long tunnels, channels etc., in usually difficult geological and topographical conditions. These factors also play a part in the operation and maintenance of the scheme where problems of erosion, breach of channels, blocking by boulders and other similar factors have to be taken care of. The high summer-flows resulting from glaciers and snow-storage, however, compensate for many of the other problems and help to yield greater dependable power in spite of smaller storages. Schemes particularly in the upper-reaches can be utilised purely for power purposes as the demand of irrigation etc. Influence only the lowest reservoir just before the debouch of the river into plains. In view of the inadequacy of storage, the need for co-ordinated operation would be evident for improving energy utilisation at the site.

6. The Peninsular schemes in general are provided with reasonable amount of storage. Schemes already completed or under construction have storages up to 12,000 million cu.m. (Nagarjun Sagar). Some reservoirs such as at Gandhisagar (gross storage 9,000 million cu.m.) are capable of storing almost twice the average annual flow of the rivers and can help to provide regulation over a number of years. By a combination with the escarpment features mentioned above, it has been possible to develop many high-head schemes with adequate storage such as at Koyna, Sharavathi and Idikki. Over most of the country, however, in the mature valleys the development have to be of the low or medium head type with power stations located at the dam or occasionally with power channels. The cost of storage is also usually low as compared to the Himalayan schemes, although, due to concentrated monsoon rainfall, the cost level is higher all

over the country as compared to countries having more distributed rainfall. Due to monsoon hydrology, it is practically impossible to consider schemes purely of the run-of-the-river projects without storage in the Peninsular region. The constituent therefore helps to secure a balance in the economy of Peninsular and the Himalayans Schemes. The stable geology lends usually to simpler and unhindered construction. The construction and operation problems are simple and are relatively easier.

7. The Himalayan areas have throughout been considered highly seismic. The construction of major works in this region is therefore further constrained by these factors. However, after the major earthquakes which have recently occurred over the Peninsular areas (such as the Koyna earthquake of 1967) it is necessary to consider the entire country as susceptible to seismic activity. The entire area in Assam including that belonging to Peninsular topography is also amongst the most seismic in the world. Provisions for safety against earthquakes have therefore now to be incorporated in almost all the schemes in the country. Another problem, which affects the cost of hydro-electric schemes in this country is the prevalence of heavy flood flows due to monsoon nature of rainfall. These tend to increase the cost of storage and regulation works, cross drainages etc. as well as the power stations. The rise in water level during floods at some of the water power installations amounts to 20 or 25 metres.

8. In the face of the above considerations it is necessary to devote attention to better designs for improving both economy and efficiency of hydro power generation. Particular thought needs to be given to the problem of the 'Himalayan' type of schemes, as a very large proportion of water power potential to be developed in future lies in this area.

SECTION 4

ECONOMIC CONSIDERATIONS

1. It is a peculiarity of hydro electric power developments that the cost of working these installations is practically independent of the amount of energy produced. Only in rare cases, the water used for power generation is required to be paid for (This would correspond to the cost of fuel in the thermal power stations). In almost all the water power developments however, the cost of water is included in the capital cost of the project, even where the water resource is developed for multiple purposes. The cost of power generation is, therefore, made up of simply the interest, depreciation and operation and maintenance charges. Typically, the interest charge amounts to about 60%, the depreciation about 22% and the operation and maintenance about 18% of the annual cost of a hydro electric installation. It is, therefore, quite clear that the lowest cost of energy production will be achieved when (i) the maximum possible amount of energy is generated at any given site and when the annual charges are reduced to a minimum. (ii) When working in an inter-connected system a hydro electric development can further (iii) contribute to optimising the working of a system by contributing the high priced peak energy, thus enabling better utilisation of the thermal power plants.

2. From these basic considerations, the main factors that can contribute to maximum degree of economic working are as indicated below:—

2.1 Adequate and competent planning and design: This influences all the three factors stated above and is, therefore, of the highest importance. The planning has to fit a scheme in the overall plea for a region. A scheme has to fit

in the electrical system of the region in respect of its energy as well as power potential, secondary power, inter-connections, reactive power contribution etc. On the water side, the scheme has to fit into the overall plan for development of the water resources for a number of competitive uses including irrigation, flood control etc. Effect of other developments on the same stream, their coordinated operation and optimisation of the benefits all enter into the picture.

2.2 Consideration is next required to minimise the capital cost of the given scheme. This is also a complex matter and detailed and thorough field investigations, thorough knowledge of the construction methods and capabilities, geology, hydraulics, communications, and other considerations come into the picture. The detailed design work greatly influences speed and ease of construction of the project as well as its reliability and ease of operation and maintenance. All these point to the great importance of adequate design capability and detailed and thorough field investigations. These matters are considered further elsewhere in this report.

2.3 As already mentioned, the speed of project execution is a very peculiar factor affecting its capital cost. Delay in construction delays the benefits from the project and also increases its capital cost. This matter is considered in greater detail elsewhere.

2.4 The cost of the plant and equipment form a relatively small proportion of the total capital cost. However, it affects the cost of energy to a greater extent than the civil works' cost, because of the relatively higher depreciation and its greater share of the cost of operation and

maintenance. Since the new water power developments will have to depend exclusively on the plant and equipment to be supplied by the indigenous manufacturers, this factor has recently assumed a new dimension. For various reasons, the cost of plant and equipment supplied by M/s H.E. and B.H.E. are disproportionately high compared to the costs experienced in the past.

Table 3-1 gives the prices given by M/s. Heavy Electricals or M/s. Bharat Heavy Electricals as the case may be for the generating sets planned on them. The prices range from 127 to 665 Rs/KW with Rs. 268 per KW as the median value. Some more recent prices are understood to be

even higher. Table 3-2 gives the prices of hydro-electric generating sets imported in the last decade (since 1961). The ratings of the sets cover a similar range but the prices vary only between Rs. 76.2 and 249 Rs./KW. The median value is also low at Rs. 129.2 per KW. The high prices of indigenous manufacture is an important factor in increasing costs of water power.

Inadequate design capability in the newly set up manufacturing units also contributes substantially in increasing the cost as well as time of construction of the projects. This factor, therefore, presents a great deal of scope for improvements.

TABLE 3—1
PRICES QUOTED BY INDIGENOUS MANUFACTURERS FOR HYDRO-ELECTRIC GENERATING SETS

S. No.	Name of Project	Installed capacity MW	Prices Quoted (Rs. lakhs)		Price Rs./kW		Price Rs. kW	Remarks
			Turbines	Generators	Turbines	Generators	Generator Set	
1	2	3	4	5	6	7	8	9
1	Chibro	4×60	240.48	287.44	100	120	220	
2	Obra	3×33	126.60	114.60	161	146	307	Prices are pre-devaluation.
3	Ramganga	3×60	149.70	230.13	83	128	211	
4	Dehar	4×165	345.36	495.24	52	75	127	
5	U.B.D.C.	3×15	99.96	119.79	222	267	489	
6	Upper Sindh	2×11	38.40	59.84	170	265	435	
7	Bassi	3×15	38.67	41.22	108	115	223	Prices are pre-devaluation.
8	Sharavati III	2×89	138.68	195.04	78	110	188	
9	Ukai	4×75	308.40	301.60	103	100	203	
10	Koyna III	4×80	213.92	262.24	67	82	149	
11	Gumti	2×5	31.28	35.20	313	352	665	
12	Giri	2×30	80.28	95.42	133	159	292	
13	Chenani	2×4.6	36.00	for two sets.	..	..	391	
14	Kunda IV	1×50	133.96	for the set.	..	..	268	
		2218.2						

TABLE 3—2
PRICES QUOTED FOR IMPORTED HYDRO-ELECTRIC GENERATING SETS

Sl. No.	Name of Project	Installed capacity (MW)	Year of order	Prices quoted (Rs. lakhs)		Price Rs/kW on F.O.R. basis*		Price Rs/kw Generator set on F.O.R. basis*	Remarks
				Turbines	Generators	Turbines	Generators		
1	2	3	4	5	6	7	8	9	10
1	Upper Sileru (Andhra)	2×60	1961	43.35 f.o.b.	62.18 f.o.b.	53.0	76.2	129.2	
2	Mettur Tunnel (Madras)	2×50	1961	73.88 c.i.f.	70.23 c.i.f.	101.6	96.4	198.0	
3	Periyar IV Unit (Madras)	1×35	1961	6.93 c.i.f.	15.82 c.i.f.	27.25	62.25	89.5	
4	Yamuna I Stage (Uttar Pradesh)	2×11.25	1962	21.49 f.o.b.	14.42 f.o.b.	140.2	94.2	234.4	
5	Barapani	3×9	1961	9.81 f.o.b.	12.09 f.o.b.	53.4	66.0	119.4	
6	Matatila U.P.	3×10	1961	17.03 f.o.b.	15.06 f.o.b.	83.5	73.7	157.2	
7	Sholayar (Kerala)	3×18	1961	12.29 f.o.b.	22.41 f.o.b.	33.5	61.1	94.6	
8	Pamba (Kerala)	6×50	1962	141.5 f.a.s.	123.81 f.a.s.	69.5	60.6	130.1	
9	Koyna II Stage (Maharashtra)	4×75	1962	79.6 c.i.f.	86.77 c.i.f.	36.4	39.8	76.2	
10	Sarkarpaty	1×30	1962	10.61 f.o.b.	12.15 f.o.b.	52.0	59.5	111.5	
11	Purna	3×7.5	1963	16.60 f.o.b.	21.22 f.o.b.	110.0	139.0	249.0	
12	Bhakra Right Bank	4×120	1963	179.6 c.i.f.	197.5 c.i.f.	51.4	56.6	108.0	
13	Balimela	6×60	1964	94.8 c.i.f.	139.0 c.i.f.	36.3	53.1	89.4	
14	Sholayar (Madras)	1×25	1965	8.94 f.o.b.	14.98 f.o.b.	52.6	88.4	141.0	
15	Jaldhaka	1×9	1965	5.02 f.o.b.	8.02 f.o.b.	82.2	131.0	213.0	

*F.O.R. prices have been calculated on the following basis :

F.O.B. Price = 1.005 F.A.S. Price.

C.I.F. Price = 1.07 F.O.B. Price.

F.O.R. Price = 1.375 C.I.F. Price.

SECTION 5

MODERNISATION

1. One interesting facet of modern technological development is that the economic benefits of some of the very old hydro electric plants can be improved very considerably by modernisation. The scope for this occurs for several reasons. Hydro electric installations, made long time back often employed rough and ready methods. With the modern technological refinements in hydraulics there is often very considerable scope for improving the performance or even the energy potential of such sites. Remodelling of water diversion, conveyance and control systems can yield substantial improvements by reduction of losses and increasing reliability as well as ease of operation & maintenance.

2. The normal life of the hydro electric plant is generally taken as 35 years but there are instances where the power plant and equipment have been in operation much longer. The old machines are prone to frequent outages and give low efficiencies. By replacement of these machines by modern ones, considerable improvements can be achieved. Modern turbines have substantially better efficiencies and the range of application of the reaction turbines has extended so much that, in many cases, it is possible to replace the existing impulse turbine installations by reaction once thus gaining improved efficiencies and increased output due to better efficiencies as well as higher utilisation of the head.

3. Generators with improved insulation and closed-air-circuit ventilation give a much improved performance.

4. Renovation and augmentation of excitation system upgrading of the switchgear capacities, installation of improved protection control and communication facilities are in any case required for fitting the very old stations in the working of the modern inter-connected power system.

5. It is felt that such modernisation of existing power plants deserve more attention than what it has received in the past in this country. In the older hydro electric installations, the work and the cost involved in such projects for modernisation would often be found to be more paying than construction of new power projects. For comparable capacity there is hardly any expenditure involved for development of the working facilities at the site as the colonies, roads etc., are already existing. The design and planning of the work can also be done with greater certitude as the hydrology as well as geology of the area is already known definitely. The above considerations have already been found valid or the modernisation projects already under construction or execution such as Jogindernagar, Tata Electric Power Companies, Mohora, Sivasamudran etc. Other older installations are also likely to present considerable scope in this direction.

SECTION 6

WATER MANAGEMENT

1. Optimum utilisation of energy potential is intimately linked with proper water management. This fact is often overlooked. The actual operation of the power plant and the associated scheduling of water flows have to be guided mainly by the designer's operating criteria. Some of the power systems in India have suffered badly when this basic point has been ignored.

2. As mentioned previously, no significant development of hydro power is possible in most parts of the country without adequate storages. The stored water or the storage space in the larger, low or medium head installations is also needed for irrigation and flood control. The gross inflows are mostly subject to large variations from year to year in addition to seasonal fluctuations. This multiplicity of complex factors requires most careful attention to be paid to the water management not only at the planning stage but in the stage of operation also.

3. It is not generally appreciated that the constraints on generation at a particular hydro electric plant are normally set by availability of water and not by the capacity of the plant as is the case with fuel burning plant. A particular hydro site with a given regulation facility and a specified method of operation in the system has a limited quantum of energy than can be generated. This has to be carefully anticipated and programmed. Any transgressing of this limit can only lead to non-availability of energy at a later stage, upsetting the generation and capability not only of the plant but of the grid as a whole, overdrawal particularly in a reservoir operating over more than one year will also result in reduction of plant capacity and also lead to

operating difficulties for the plant. It is, therefore, to be emphasised that operating schedules for hydro electric power plant should be made considerably in advance by a competent planning and designs group taking the water availability, system energy availability, capacity requirements etc. into account. These should then be strictly adhered to.

4. Requirements like irrigation have an entirely different pattern of water requirements. Conflicting requirements for use of water for such purposes pose a challenging problem for improving utilisation of hydro electric energy. The CW & PC have been striving hard to ensure proper attention to this aspect and to introduce the concept of coordinated operation of hydro-electric power schemes. Hirakud was first such case with two power stations in series hydraulically. Another notable example is the Chambal cascade where, by provision of a series of three reservoirs—a large primary regulating reservoir at Gandhi Sagar, a re-regulating reservoir at Ranapratap Sagar and a pondage facility at Jawahar Sagar with power stations at the three dams it has been possible to utilise almost the entire river flow for the conflicting purposes of power generation as well as irrigation. By proper planning operations the total plant installed has also been kept down to minimum. Similar studies made by CWPC have enabled vast improvements in the utilisation of energy from hydro electric schemes in Tamil Nadu by a complementary operation of high head, purely hydro electric schemes and low head irrigation controlled scheme. With this consideration it has been economical to add 200 MW at Mettur to utilise the energy available seasonally in the irrigation period. Major improvements

have been made in the utilisation of energy from Bhakra reservoir by coordination of irrigation and power use and this will be still further improved with the advent of high head Dehar scheme designed for complementary seasonal operation. Another seasonal scheme planned recently is the Ram Ganga which will help to firm up the run-of-the-river energy of the numerous low head plants in Uttar Pradesh. Other seasonal storage schemes are under consideration in Jammu & Kashmir and elsewhere. Some of the instances quoted above illustrate the scope that exists for further improvement in utilisation of energy potential at a given hydro site in further stages of development.

5. There are many instances of serious seasonal impairment of plant capability for long periods arising from injudicious water management. Capacity of the Gandhi Sagar power station was seriously impaired over a period of three or four years of successive drought. This reservoir of gross storage capacity of over 9000 million cubic metres is designed to provide regulation of the river flows over a number of years so that utilisation of water approaches closely the average of the annual flow of the river. In the initial years of its working when years of good rainfall occurred, energy far exceeding the plant average output was drawn from the power plant situated at this dam resulting in over depletion of the "carry over" storage provided. As a consequence, when the first drought year occurred, the reservoir storage was grossly inadequate. As alternative arrangements could not immediately be made, further depletion had to be made ultimately going even below the dead storage level. Fortunately the generating plant is of excellent design and construction and was able to operate under these arduous conditions with capacity reduced to nearly 60 per cent. Further, due to insufficiency of water, it had to be operated for even

much lower outputs. For considerable period, the plant had to be run merely as synchronous condenser. This is an extreme example which illustrates difficulties which may arise from faulty water management. Similar problems though of a smaller magnitude, are a common occurrence on many reservoirs. In the present situation of general power shortage, there are short sighted influences pressing for early overdrawal of water after storage, resulting in short falls later on in the same year or in the succeeding year depending on the operation planning of reservoirs. These have come to notice all over the country. Recent examples are Tungabhadra, Rihand, etc. Presently (July 1970) the Bhakra reservoir is known to be suffering from a serious problem of this nature due to overdrawal of last year and early in the season.

6. Considerable benefits can be secured even at the present time by close coordinated operation of fuel burning and hydro electric plants and the problem should be given close attention. The problem of finding adequate storages for the Himalayan schemes has already been mentioned. Vast majority of these schemes will have considerably higher power outputs available for many months in the year compared to the minimum 'dependable' value which will occur for a short period, and on the basis of which the scheme might be originally planned. Such schemes will require a periodical review for improving their energy utilisation whenever any new schemes offering any diversity are taken up. It hardly needs to be mentioned that improvement of energy potential utilisation at a given scheme will result in more economic power generation. Close attention to water management especially in the context of integrated operation of all available plant in the grid for hydro electric schemes will lead to better utilisation of other plants as well as a lower cost of energy on the whole.

SECTION 7

PLANT AVAILABILITY AND UTILISATION IN HYDRO-ELECTRIC POWER STATIONS

1. The general basis on which the utilisation and availability of energy from hydro electric power stations have to be judged, has been discussed earlier in the report. Basically, the availability of any plant should be considered "Satisfactory", if it is available for operation whenever required. In the case of hydro stations, the energy potential at a site is the primary constraint and the generation is limited by the water available and the degree of regulation possible. The energy generation has no direct relation to the installed capacity of the plant, as the plant capacity is designed to programme the energy at a load factor suiting the system requirements. The installed capacity is usually much in excess of the capacity required to exploit the planned power potential at 100% load factor. Further, the nominal plant capacity provided at a hydro-electric site has often to be fixed taking into consideration the variations in the turbine output on account of variation of head. Consideration has therefore to be given for criteria appropriate for judging the utilisation and availability of hydro-electric plants. Mere comparison with installed capacity of the plant is not adequate.

2. Each hydro-electric plant is projected to provide a certain capacity value and to exploit a definite amount of energy potential at a given site. The storage type of development forms a great majority of hydro-electric installation in India. In these cases, there is a wide scope for scheduling the energy generation to match the requirements of the power system throughout the year. For isolated installations, the design annual load factor is usually 60%. Most of the modern plant installations are being designed with a much lower annual load factor of the order of

25% or even less to improve utilisation of fuel burning plants and thereby the overall economics of power generation. This entails an installed capacity well in excess of what would be required merely for utilising the energy potential of the site.

2.1 The plant availability and utilisation can be considered deficient only to the extent that it was not available for power generation when required for its capacity was short of planned requirements at that time or the total utilisation of energy in the period of study fell short of the planned utilisation. The plant availability also needs to be examined to see if the plant was actually available for generation of high priced energy at the time of the peak loads. Collection and compilation of data for consideration against such a framework presents a number of complications, as a large number of variables including the state of and degree of interconnections, power interchanges, etc., enter the picture.

3. In run-of-the-river projects, storage for water is usually very small and enables scheduling of the energy generation only over periods of a day or a week. The energy potential of the site is dependent on the expected flows. The energy that cannot be availed of due to lack of load or inadequacy of generating plant are lost. The run-of-the-river plants form only a small proportion of the hydro-electric installations in the country. Canal-drop power stations on irrigation canals would form a bulk of such developments in future also. Generally, there is little difficulty in absorbing the full energy generation of these plants in the respective power systems. In these cases, the plant availability has to match

the energy availability from time to time. Within the limit of energy availability, the plant utilisation and availability have the same significance as that for thermal power plants.

4. Table 3-3 gives data regarding availability of hydro-electric plants from the view point of exploitation of the energy potential. For each power station in the country, the design firm energy potential is given. The actual energy generation is also then tabulated for the years 1966-67, 1967-68 and 1968-69. The first of these years was particularly a bad year on account of the drought conditions. The energy potential actually available at each site naturally varied from year to year. A review of the table shows that the hydro-electric stations have, by and large, been quite successful in exploiting practically the entire energy potential at each place. In many cases, the actual energy generation has exceeded the design firm energy potential quite substantially. This is understandable on account of the variable nature of water availability. Energy generation in excess of the design firm potential also indicates that the availability of the plant has been well above that required for exploiting the design firm potential. This is a satisfactory state of affairs.

5. The available data, also indicates that there have been no significant cases of hydro capacity not being available when required for use except when there was also a simultaneous shortage of energy. If a reservoir is overdrawn, shortage of energy as well as reduction in plant capacity due to reduced head results. This condition has occurred, but only very rarely and was due to faulty water management. Generally, even with shortage of energy, the kW capacity is available so long as the reservoir is not drawn down below the planned minimum drawn down level. The plant availability therefore remains important.

6. Provision of reactive power to the system is often an important function of hydro-electric generating units in this country, particularly where the generating capacity is small compared to the transmission system. The Umiam Barapani Power Station in Assam is a case in point. The four 9 MW sets in this station have to be kept running for keeping the transmission system charged even when the kW load is too low to

require their operation. It is interesting that in recent instances such as at Gandhi Sagar, even when energy availability was reduced to insignificant values and the plant capacity also drastically reduced, the hydro generating plant continued to render valuable service to the system by operation as synchronous condensers. In other places also, the performance of hydro plants in such circumstances has been satisfactory.

7. Further studies have also been made of the plant availability and utilisation for some major hydro-electric power stations over a period of three years. It is considered that it will meet the present purpose if the study extends over a select number of power stations depending on the availability of data in this regard.

7.1 The plant utilisation and availability have been studied in respect of the generating sets separately in each case, unit by unit. The period of study is from 1967-68 to 1969-70. The data regarding operation and maintenance of each individual unit for this period has been studied and analysed to bring out the following:

- (1) *Service Hours (SH).*—These are the total number of hours that the unit was actually operated with breakers closed to the station busbars. These represent actual hours of operation of the generating units during the year.
- (2) *Available Hours (AH).*—This is the time in hours during which a unit or major equipment is available. This is the sum of the service hours and the hours during which the unit was available for service but was not utilised on account of load conditions or due to other reasons like water availability etc.
- (3) *Plant Maintenance Hours (MOH).*—The time in hours for which the unit was not available for service due to outage for purposes of routine, preventive or statutory maintenance and inspection.
- (4) *Forced Outage Hours (FOH).*—The hours during which a unit or major equipment was not available due to forced outage, a generally unforeseeable event.

The sum of the time intervals 2, 3 & 4 above is the total number of hours in the year.

(5) *Availability Factor*.—This is the ratio of the number of hours (AH) in a year to the total number of hours.

7.2 The results of the above study are tabulated in Tables 3-4 and 3-5. This study covers a total of 350 unit-years in 119 units with an aggregate rated capacity of 3928 MW. The turbines of all the principal types, viz., impulse, reactive and fixed as well as movable blade propeller, have been covered. The power stations include both storage and run-of-the-river types. It will be seen from Table 3-4 that some of the installations considered are over 50 years old, while some others are very recent ones and include the largest size of generating sets in the country.

7.3 As in the case of steam power stations, this study has been very seriously handicapped for want of accurate and complete data on a uniform basis. The data available have been recast to bring these on a uniform basis and enable a comparative study of the performance of the different installations. The results of the study have also been presented graphically in Figure 3.2. The different time intervals have been expressed as percentage of the total time in a year. These percentages have been plotted in the form of bars, one for each unit-year.

7.4 In the bar, the left-hand side depicts the service hours (SH) and availability hours (AH). In the case of the three power stations of Tata Electric Companies, the service hours are not known separately. The power stations are, however, known to have been operating (during the years in question) at load factors as low as 20-25% in the non-monsoon period and at base load when the lakes are spilling. Thus, by and large, the actual hours of operation (SH) are much less compared to AH. This applies to all storage plants. At Mohora (J&K) and in the canal drop power stations at Ganguwal and Kotla, SH equal AH. This is the correct manner of operation for run-of-the-river working.

7.5 The right end of each bar depicts the MOH i.e. hours taken, for planned maintenance outages. It is seen that the MOH has differed very widely even for the same set in different years. As well as for different sets in a given station in the same year. In forty unit-years, zero MOH has been reported. Out of these, some pertain to the first year of operation of newly installed units. In six unit-years the MOH ap-

pear to have been masked by FOH. MOH as high as 3320 hours for horizontal impulse units and 6,900 hours for Francis turbines have also been reported. These are clearly abnormal occurrences. The most common value of MOH appears to lie under 500 hours. In fact, in 233 units-years (out of 350), MOH has been 5% or less, i.e. under about 18 days or 440 hours. The MOH for horizontal impulse machines is understandably lower compared to that for vertical Francis or propeller machines.

7.5.1 In a large number of cases, the MOH appears to be considerably more than what should actually be required for a hydro-electric plant. This has perhaps been because there was no particular reason for hurrying up with the maintenance work. With the increasing inter-connections of power sources, this position would change. It will be in the larger interests to complete the maintenance and overhaul work in the shortest possible time, so that the generating plant in question is available to the system as spare, particularly in the event of forced outage on some other generating unit. This will enable reduction of the spare capacity required to be installed in the integrated power system. It is already the experience on some integrated power systems that it is difficult to take out generating units for long maintenance outages. This is because of the requirement of peak load generation, so that most of the hydro units are required to work at least for a short time every day.

7.6 Next to the MOH, is plotted the FOH (forced outage hours). It is interesting to note that out of 350 unit-years in the study, 92 have reported nil FOH and 151 further have reported FOH under two days. In other words, in about 70% of the cases the forced outages have amounted to less than 2 days ($\frac{1}{2}\%$) in the year. This speaks for the high degree of reliability of operation of hydro-electric power plants. The highest FOH reported has been 152 hours for horizontal impulse machine and 2567 hours for vertical propeller machine. These are, again, abnormal cases. Mostly the FOH have been very small—quite in contrast with the experience on steam power stations. The small FOH experienced are also mostly due to causes not pertaining to the power plant but mostly arising from mal-tripping of electrical protective relays and such like occurrences. It is felt that careful attention to the protective devices as well as instrumentation and

alarm systems and proper co-ordination of the protective systems could enable almost complete elimination of forced outages on hydro power stations. It has to be remembered that the protective systems need to be reviewed and reset again and again as a system grows so that these can work satisfactorily with changing system parameters, including action of similar protective systems in other parts of the power system.

7.7 The above study of actual working of a number of generating units, as well as the

nation-wide review of utilisation of energy potential of hydro-electric plants clearly show that the performance of hydro-electric installations in respect of plant availability has generally been satisfactory though there is still some scope for further improvement by scientific management. With greater attention to design details of the individual installations as well as system interconnections, the position will be even better in the case of both the present as well as future installations.



TABLE 3-3
FIRM ENERGY POTENTIAL OF HYDRO-ELECTRIC PROJECTS AND ACTUAL ENERGY PRODUCTION

Sl. No.	State Hydro Power Station	Installed Capacity in 1969 (MW)	Designed Firm Energy Potential	Actual Energy Production			Actual Energy Production as percentage of designed firm energy potential.			Reasons for Low Energy Production compared to Col. (4).
				1966-67	1967-68	1968-69	1966-67	1967-68	1968-69	
1	2	3	4	5	6	7	8	9	10	11
Andhra Pradesh :										
1	Tungabhadra R.B. }	66	236	326	309	304	138.13	131	129	
2	Hampi .	15				28				
3	Nizamsagar .	114	735	459	577	535	62.45*	78.5*	72.8*	*Rainfall sub-normal.
4	Machkund .									
5	Upper Sileru .	120	386		166	481		43*	124.6	*Late commissioning of Unit—Oct. '67
Assam :										
1	Umtru }	47	1357	785	1052	1348				
2	Umiam (Stage I) }									
Jammu & Kashmir :										
1	Mohora .	9	79							
2	Ganderbal .	15	92			67				
Kerala :										
1	Palli vasal .	38	285	186	207	208	62.5	75	75.2	*Low load demand on grid.
2	Sengulam .	48	182	118	119	128	65.4	65.5	70	
3	Panniar .	30	148	49	61	73	33	41	49	
4	Neriamangalam L.B. .	45	239	235	223	218	99.1	94.1	92	
5	Poringalkuthu .	32	171	147	172	176	85.4	100	102	
6	Sholayar .	54	233	76	104	214	32.5	44.44	91	
7	Sbatigiri .		1160	271	521	608	23.4	45	52.4	
TOTAL			2418	1082	1407	1625				

Madhya Pradesh/Rajast/ or. :

1	Gandhi Sagar	.	.	.	.	.	.	.	116	366	98	143	281	26.85	39.2	77
2	Ranapratap Sagar	.	.	.	.	.	.	.	172	500		34	262	6.8	6.8	52.4
	TOTAL	.	.	.	.	.	.	.		866		177	543			*Low water availability.

Maharashtra :

1	Bhira	.	.	.	.	.	.	.	236	1350	1036	1148	1090	86.33	95.67	91
2	Bhivpuri	.	.	.	.	.	.	.								
3	Khopoli	.	.	.	.	.	.	.	540	2150	2724	2841	2990	123.8	129.1	136
4	Koyna	.	.	.	.	.	.	.	23	39		10	25	26*	26*	64.1
5	Purna	.	.	.	.	.	.	.								*Subnormal rainfall.
	TOTAL	.	.	.	.	.	.	.		3500	3760	3999	4105			

Mysore :

1	Sivasamudram	.	.	.	.	.	.	.	42	272	243	240	254	82	81	86
2	Shimsha	.	.	.	.	.	.	.	120	788	834	755	813	105.8	95.70	105.2
3	Jog	.	.	.	.	.	.	.	27	70	69	67	84	98.57	95.70	120
4	Munirabad	.	.	.	.	.	.	.	33	120	54	55	81	45*	45.83*	67.5*
5	Bhadra	.	.	.	.	.	.	.		2230**	1255	1115	1252	54*	48*	53.8*
6	Sharavathi	.	.	.	.	.	.	.								
	TOTAL	.	.	.	.	.	.	.		3480	2455	2232	2484			

** Potential corresponding to the present stage of development i.e. 6 units.

The designed firm energy potential corresponding to ultimate development is 4680 GWh.

Orissa :

1	Hirakud I	.	.	.	.	.	.	.	270	1055	646	801	849	61.2	75.9	80
	Hirakud II	.	.	.	.	.	.	.								

Punjab/Haryana :

1	Bhakra L.B.	.	.	.	.	.	.	.	450	3554	3533	3939	4543	99	110.5	121.8
2	Bhakra R.B.	.	.	.	.	.	.	.	600							
3	Ganguwal	.	.	.	.	.	.	.	77							
4	Kotla	.	.	.	.	.	.	.	77							
5	Joginder Nagar	.	.	.	.	.	.	.	48	158	207	222	232	130	142	147
	TOTAL	.	.	.	.	.	.	.		3722	3740	4161	4775			

Tamil Nadu :

1	Pykara	.	.	.	.	.	.	.	70	451	316	407	415	77	99.3	101.2
2	Moyar	.	.	.	.	.	.	.	36							
3	Mettur	.	.	.	.	.	.	.	240	613	578	510	561	94.3	84.8	91.5
4	Mettur Tunnel	.	.	.	.	.	.	.								

TABLE 3-3—(Contd.)
FIRM ENERGY POTENTIAL OF HYDRO-ELECTRIC PROJECTS AND ACTUAL ENERGY PRODUCTION—(Contd.)

Sl. No.	State Hydro Power Station	Actual Energy Production as percentage of designed firm energy potential											Reason for Low Energy Production Compared to Col. (4)
		Installed Capacity in 1969 (MW)	Designed Firm energy Potential	Actual Energy Production					Actual Energy Production as percentage of designed firm energy potential				
				1966-67	1967-68	1968-69	1966-67	1967-68	1968-69	1966-67	1967-68	1968-69	
1	2	3	4	5	6	7	8	9	10	11			
5	Papanasam	.	.	.	.	.	.	.	.	.	.		
6	Periyar	28	111	101	109	132	190.1	98.2	118.9				
7	Kundah I	140	500	454	393	449	20.8	78.6	89.8				
8	Kundah II	.	.	.	.	.	.	.	.				
9	Kundah III	.	.	.	.	.	.	.	.				
10	Kundah IV	.	.	.	.	.	.	.	.				
11	Kundah V	.	.	.	.	.	.	.	.				
12	Sarkarpathi	.	.	.	.	.	.	.	.				
	TOTAL	30	157**	18	50	63	11.47	31.9	40.13				
			3577	2098	2729	3044							
Uttar Pradesh :													
1	Rihand	300	900	883	593	587	97.92*	65*	64.36*	*Subnormal rainfall.			
2	Matatila	30	124	83	130	130	67.4	105.7	105.7*				
3	Yamuna Stage I	85	525	248	190	190	47.2*	38.1*	38.1*	*Installation not completed.			
	TOTAL		1549	1214	723	907							
West Bengal :													
	Jaldhaka Stage I	18	79		14	22*		18*	28.2*	*Power station closed down in Oct. '68 for a considerable period due to flood disaster.			
D.V.C. :													
1.	Tilaya	.	.	.	.	.	.	.	.				
2.	Matthon	.	.	.	.	.	.	.	.				
3.	Panchet Hill	.	.	.	.	.	.	.	.				
	ALL INMIA (55 Power Stations)	104	246	120	203	275	114.3	193.3	262	(b) Non-completion of distribution network.			
			22180	16046	17560	20193							

**The diversion of flows from Paniar and Sholayar are yet to be completed and therefore, the potential at present will be lower than the designed potential of 157 GWh.

(b) Non-completion of distribution network.

TABLE 3-4
EQUIPMENT AVAILABILITY AND UTILISATION
Power Stations taken for Sample Survey

Sl. No.	Name of Power Station	No. of Units	Year of commissioning	Rated Output (MW)	Head (m)	Speed (rpm)	Type of Turbine	Remarks
1	2	3	4	5	6	7	8	9
1	Bhakra L. B. (Punjab)	1	1960	90	122	166.7	VF	
		2	1961	90	122	166.7	VF	
		3	1961	90	122	166.7	VF	
		4	1961	90	122	166.7	VF	
		5	1961	90	122	166.7	VF	
2	Bhakra R. B. (Punjab)	1	1966	120	122	187.5	VF	
		2	1966	120	122	187.5	VF	
		3	1967	120	122	187.5	VF	
		4	1968	120	122	187.5	VF	
		5	1968	120	122	187.5	VF	
3	Ganguwal (Punjab)	1	1961	29.25	30	166.7	VP	
		2	1955	24	30	166.7	VK	
		3	1955	24	30	166.7	VK	
4	Kotla (Punjab)	1	1961	29.25	30	166.7	VP	
		2	1956	24	30	166.7	VK	
		3	1956	24	30	166.7	VK	
5	Bhira (Maharashtra)	1	1927	22	457	375	HI	
		2	1927	22	457	375	HI	
		3	1927	22	457	375	HI	
		4	1927	22	457	375	HI	
		5	1940	22	457	375	HI	
		6	1952	22	457	375	HI	
6	Bhivpuri (Maharashtra)	1	1920	12	463	300	HI	Progressively under renovation.
		2	1920	12	463	300	HI	
		3	1920	12	463	300	HI	
		4	1920	12	463	300	HI	
		5	1948	12	463	300	HI	
		6	1948	12	463	300	HI	
7	Khopoli (Maharashtra)	1	1915	12	463	300	HI	
		2	1915	12	463	300	HI	
		3	1915	12	463	300	HI	
		4	1915	12	463	300	HI	
		5	1915	12	463	300	HI	
		6	1923	10	463	300	HI	
8	Sharavathi (Mysore)	1	1964	89.1	465	300	VI	
		2	1965	89.1	465	300	VI	
		3	1967	89.1	465	300	VI	
		4	1967	89.1	465	300	VI	
		5	1969	89.1	465	300	VI	
		6	1968	89.1	465	300	VI	
		7	1967	89.1	465	300	VI	
9	Bhadra (Mysore)	1	1963	12	43	250	VK	
		2	1964	12	43	250	VK	
		3	1962	2	35	500	VK	
		4	1964	7.2	18	214	VK	
10	Munirabad (Mysore)	1	1962	8.5	23	214	VK	
		2	1962	8.5	23	214	VK	
		3	1964	10.5	23	214	VK	
11	Shimsha (Mysore)	1	1940	8.6	182	500	VF	
		2	1940	8.6	182	500	VF	

TABLE 3-4—(Contd.)

Sl. No.	Name of Power Station	No. of Units	Year of commissioning	Rated output (MW)	Head (m)	Speed (rpm)	Type of Turbine	Remarks
1	2	3	4	5	6	7	8	9
12	Mahatma Gandhi (Mysore)	1	1948	12	365	428	HI	
		2	1948	12	365	428	HI	
		3	1950	12	365	428	HI	
		4	1950	12	365	428	HI	
		5	1952	18	365	428	HI	
		6	1952	18	365	428	HI	
		7	1953	18	365	428	HI	
		8	1953	18	365	428	HI	
13	Sivasumdrum (Mysore)	2	1904	3	121.5	500	HF	
		3	1924	6	121.5	375	HF	
		4	1904	3	121.5	500	HF	
		5	1904	3	121.5	500	HF	
		6	1907	3	121.5	500	HF	
		7	1914	3	121.5	500	HF	
		8	1924	6	121.5	375	HF	
		9	1918	3	121.5	500	HF	
		10	1928	6	121.5	375	HF	
		11	1928	6	121.5	375	HF	
14	Koyna I & II (Maharashtra)	1	1962	63	475	300	VI	
		2	1962	63	475	300	VI	
		3	1963	63	475	300	VI	
		4	1963	63	475	300	VI	
		5	1966	75	475	375	VI	
		6	1966	75	475	375	VI	
		7	1966	75	475	375	VI	
		8	1967	75	475	375	VI	
15	Pykara (Tamil Nadu)	1	1931	6.25	857	600	HI	
		2	1931	6.25	857	600	HI	
		3	1931	6.25	857	600	HI	
		4	1939	10	857	600	HI	
		5	1939	10	857	600	HI	
		6	1954	13.6	867	600	HI	
		7	1954	13.6	867	600	HI	
16	Moyar (Tamil Nadu)	1	1952	12	372	428	VI	
		2	1952	12	372	428	VI	
		3	1953	12	372	428	VI	
17	Kundah I (Tamil Nadu)	1	1960	20	428	317	VI	
		2	1960	20	428	317	VI	
		3	1964	20	428	317	VI	
18	Kundah II (Tamil Nadu)	1	1960	35	428	714	VI	
		2	1960	35	428	714	VI	
		3	1961	35	428	714	VI	
		4	1961	35	428	714	VI	
		5	1964	35	428	714	VI	
19	Kundah III (Tamil Nadu)	1	1965	60	600	412	VF	
		2	1965	60	600	412	VF	
20	Kundah IV (Tamil Nadu)	1	1966	50	150	64	VF	
21	Kundah V (Tamil Nadu)	1	1964	20	268	428	VF	
22	Mettur Dam (Tamil Nadu)	1	1937	10	46	250	DF	
		2	1937	10	46	250	DF	
		3	1937	10	46	250	DF	
		4	1940	10	46	250	DF	

TABLE 3-4—(Contd.)

Sl. No.	Name of Power Station	No. of Units	Year of commissioning	Rated output (MW)	Head (m)	Speed (rpm)	Type of turbine	Remarks
1	2	3	4	5	6	7	8	9
23	Mettur Tunnel (Tamil Nadu)	1	1966	50	40	136.3	VK	
		2	1966	50	40	136.3	VK	
		3	1966	50	40	136.3	VK	
		4	1968	50	40	136.3	VK	
24	Periyar (Tamil Nadu)	1	1958	35	386	750	VF	
		2	1959	35	386	750	VF	
		3	1959	35	386	750	VF	
		4	1965	35	386	750	VF	
25	Papasanam (Tamil Nadu)	1	1945	7	71	600	VF	
		2	1945	7	71	600	VF	
		3	1945	7	71	600	VF	
		4	1951	7	71	600	VF	
26	Sarkarpathy (Tamil Nadu)	1	1966	30	89	250	VF	
27	Aliyar (Tamil Nadu)	1	1970	60	412		VF	
28	Mohora (Jammu & Kashmir)	1	1962	4.56	120	600	HF	
		2	1962	4.56	120	600	HF	
28 Stations		119	3928.17 installed					

KEY:

V—Vertical
H—Horizontal
D—Double

F—Francis
K—Kaplan

I—Impulse
P—Propeller

Thus VF—Vertical Shaft Francis Turbine.

SECTION 8

RELIABILITY OF HYDRO-ELECTRIC INSTALLATIONS

1. The primary sources of electric power in the country are rapidly getting inter-connected. In the coming years, there will be hardly any hydro-electric installations which will be operating in isolation (except, of course, micro hydel installations in remote areas, which are not being considered here). The reliability and availability of the hydro-electric installations have, therefore to be ensured in the context of their interconnected and, progressively, integrated operation with other sources of power such as conventional thermal as well as nuclear-power plants. Under these conditions, more and more need will be felt for operation of the hydropower plants in the top portion of the load curve, deriving important contribution to the kW-capacity of the system while, of course, yielding in full measure the energy available in the water resources. The hydro-electric plants are usually closely associated with long transmission lines on account of compulsions of geography and they have often to be utilised for providing reactive capacity to the system. Thus, certain hydro-electric generating units may have to be kept spinning even when the energy potential available at these sites in a particular year has already been utilised to the full extent.

2. It is clear that reliability and plant availability of hydro-power plant is important to the system out of all proportion with energy contribution of such plant to the system, and is mainly dictated by its capacity contribution. These requirements can be met easily if the preventive maintenance can be accommodated in the periods of low demand for the plant. It will be seen that the daily operating requirements for hydro-electric plant will normally provide intermittent short

spells of low load or even no load when one or more units in the installation can be shut down. Similarly, periods permitting fairly long shut-downs extending over weeks may also occur at installations at storage dams during conditions of high head or where the waters are to be regulated to meet fixed irrigation schedules.

3. Considerable experience in the operation and maintenance of hydro-electric installations over practically the entire spectrum of ratings, heads and operating conditions for the power plants of many different designs and makes is already available in the country. It is recognised that the requirements of different installations will not be stereotyped. Each installation will have its own peculiarities and these must be taken into consideration very carefully in formulating the operation as well as maintenance practices for that installation. The main broad features common to most of the hydro-electric installations are discussed here. (The question of water management has already been discussed earlier).

4. Hydro-electric installations commonly involve construction of dams, weirs or other structure for storage and diversion of water as well as tunnels, channels and pressure pipelines for conveyance of water. Any failure of these, particularly that of a water storage structure is fraught with serious consequences, involving extensive damage to property and even loss of life, over and above the loss of power and energy generation. Repairs and replacements require extensive financing and time. Therefore, it is of utmost importance that every care must be taken during the construction to avoid defects and eliminate the possibility of failure, either partial or

complete, of any of the structures. For this thorough inspection of the works during the construction stage and systematic observation during the maintenance stage are essential.

4.1 In many of the foreign countries, like the U.S.A., U. K., France, Germany, Italy and Switzerland, the safety of dams is ensured through special organisations. Similarly, it is felt that assistance by way of expert advice must be given at the time of construction of dams in India also. This can best be done by having a small compact body of experts in specialised subjects like grouting, concrete and masonry control, foundation

treatments, instrumentation etc. The function of this body should be advisory to enable avoidance of any defects in construction. The Ministry of Irrigation and Power have already proposed to organise a "Dams Safety Service".

4.2 The functions of the proposed service are given in Annexure 3-1. It is strongly recommended that such a service should be set up without any further delay and made use of in all the Hydro-electric works. Further, scope of such service should be extended to cover the works such as tunnels, penstocks etc. for conveyance of water for hydro-electric projects.



SECTION 9

ADEQUATE AND PROPER DESIGN

1. This is one of the most important factors for safe and reliable working of hydro-electric installations over long years. Very often, these installations involve major civil engineering works such as dams, tunnels, canals and pressure pipelines. The technology of design and construction of these has progressed to great refinements. However, in the case of hydro-electric installations, special attention is required to be given to an integrated approach to the design of the entire water storage, conveyance and control systems. The project areas are often quite spread out over considerable distances and are also in isolated and remote parts of country. The normal complement of personnel for operation and maintenance of the project may be quite small. At the same time, any damage or failure in the hydraulic works or power installations in the project can do serious damage not only to the supply of power from the project, but even by way of flooding of downstream areas, discontinuity of water supply for irrigation, industries or for cities. Because of this, the question of safety under all normal and abnormal conditions of operation has to be kept in view throughout.

2. An important factor in ensuring safe and efficient operation is the provision of adequate and reliable communication facilities. This includes both telecommunications facilities as well as roads, ropeways, trolleys etc. It should be conveniently possible to patrol all parts of the project areas and also communicate with the power station and, through that, with the rest of the power system under emergency conditions.

3. Special mention may be made of measures for ensuring safety from rupture of the pressure pipelines. This could occur due to variety of

causes such as falling rocks, earthquakes, pressure surges, etc. These can be disastrous unless the designs provide special measures.

4. Seasonal changes which are a feature of many projects must be taken note of and adequately provided for. These may affect the safety as well as operation of the plant. Examples of these are heavy charge of silt and suspended matter in the water during monsoon, icing conditions at the intakes of tunnels or pressure pipelines in some parts of the country, floating of timber down the rivers at certain times of the year etc.

5. The design of the power stations should take into account operating conditions likely to prevail over a long period, as well as emergency conditions. Thus, the system power factor experienced at the generators may undergo a considerable change over years. In certain power stations, limited excitation capacity has imposed severe restrictions on the usefulness and even the load carrying capacity of the generating units. Similarly, the arrangements for emergency operation of auxiliaries, flexibility in switching facilities, busbar arrangements etc., can be provided at a very nominal cost at the time of making the original installations. Provision of these arrangements at a later date is a very costly proposition. Moreover, this may also involve outages, restrictions in operation etc., when the system requires these facilities. Planned outages will also be necessary for making modifications for providing these facilities at a later date.

6. One peculiarity of the hydro-electric plants is that the auxiliary power requirements

as well as the number of auxiliaries are very small but all of these are absolutely essential for the operation of the generating sets. These auxiliaries cannot be taken out of operation even for short time for maintenance purposes without risking outage of the main generating units. This must also be kept in view at the design stage.

7. Troubles due to cavitation and erosion have been found to be a very common feature on the hydro-electric stations in India. This requires careful consideration in the design of the turbine and the power station as well as in deciding operation criteria for generating units. Damage due to cavitation to a moderate extent is usually to be expected on most installations, particularly because of the need to optimise the capital investment in the power installations instead of incurring heavy capital expenditure for making a cavitation-free installation. The conditions of working often demand operation over wide range of head variation as well as long operation at part loads. It is therefore, highly desirable to make it a practice to optimise the

installation designs by undertaking a thorough investigation of cavitation possibilities by means of model testing. Fortunately a water tunnel capable of taking runner models of even upto 500 mm diameter has been commissioned recently at the CWPRS Poona and some further facilities are being planned for BHEL at Hardwar. Some technical institutions have also certain facilities. It is in the interests of the manufacturers as well as the users of hydroelectric equipment to make full use of these facilities in evolving the optimum designs for determining the most desired installation parameters. The time and cost involved in this would be re-paid several times over by the benefits to be gained.

8. Attention should be given similarly to minimising damage due to erosion etc. to the optimum extent. The remedies principally lie in the field of design of civil works, but considerable improvements can also be made by choice of suitable materials for affected components of equipment as well as design features of the equipment.



SECTION 10

OPERATION AND MAINTENANCE

1. The hydro-electric equipment is by and large very robust and reliable. However it is also important to operate it carefully and within its designed range of operation. Confidence in the inherent robustness has sometimes led to neglect with consequent costly damage and plant outages. Careful operation and timely maintenance on hydro-electric equipment yield long years of trouble-free and economic operation. In keeping with the requirements of the system, these units had to be started and stopped and operated at variable loads quite often.

2. It is a characteristic of the reaction type of hydraulic turbines that instability and vibrations are experienced under certain load conditions. This may vary widely at different heads and will be influenced by venting or introduction of compressed air. The region of such operation must be carefully noted and avoided in the operating schedules.

3. The bearings and turbine seals have particularly been the vulnerable spots subject to random failure. This is a very complicated matter as the design of the seals materials used in the construction of the seals, shaft and runners, the silt content in the water and other factors, all play a part. In some extreme cases, design of the sealing arrangements has been found missing. In most cases, however, safe and reliable operation can be ensured by suitably designed instrumentation to watch (i) the build up of pressure under the turbine covers; and (ii) whether the turbine seals are lubricated and cooled adequately during working of the turbine under the various conditions of operation at different loads and heads. This is also important if the machine works at times as a synchronous condenser.

4. The importance of clean and ample supply of auxiliary water cannot be over-emphasised. Sometimes large quantities of cooling and sealing water are required for the turbine seals, shaft glands etc. In addition, large quantities of cooling water are required for the generator air coolers, transformers etc. It is highly important to ensure that the water is free from suspended matter to the degree specified. In some instances in the Himalayan Region very serious erosion damage has been caused even when particle size of suspended material in the water was within the prescribed limits. Petrographic analysis of the suspended matter showed that water carried highly abrasive angular particles of silica instead of rounded clay particles assumed. This points to the importance of a proper understanding of the nature of silt load carried by water.

5. Cavitation phenomena have been much discussed in technical literature. The plant sigma cannot much be changed economically in an existing installation. The important thing therefore is to operate the turbines scrupulously within limits prescribed for the range of loads permissible under different heads and tail water conditions. Transgression of these limits leads to very rapid deterioration and heavy damage. If an extension of operating range is absolutely necessary, measures such as introduction of compressed air, or even modifications to the turbine runner have to be explored.

6. One important aspect of operation often neglected is the continuous monitoring of performance. It is highly important that all the indications, including temperatures, pressures and

flows at various points, are correctly read and recorded in the prescribed manner. Periodic review of this data is essential for reliable and economic operation of the plant. The performance of governors should also be checked over as wide a range (of the different parameters) as readily possible, periodically.

7. The importance of annual inspection of the insides of turbine etc., cannot be over-emphasised. It is only under grave national emergency that these plants should be worked continuously without such a break. These inspections must be carried out by persons having enough experience and expert knowledge regarding the equipment to be inspected. There are serious cases of damage to equipment where, due to inexpert inspection initial incipient damage on account of cavitation or erosion remained unnoticed and unattended. These damages grow to serious proportions and then very costly and long outages become unavoidable. This is particularly true of the damage to turbine, valves, etc., due to cavitation and erosion. Under a system of periodic inspection and repairs, the repairs can be kept down to very small proportions. Such "cosmetic" repairs can be usually done without any major dismantling of the turbine equipment as only a light degree of grinding, welding or metal deposition by spraying etc., are involved. If however, heavy repairs have to be undertaken, then it becomes necessary to arrange for heat treatment and stress relieving on the runner or other major components. This means a long outage of the generating set as well as increased spending on repairs, spare parts, expert personnel and so on.

8. It would be worthwhile in this regard to build up expert repair crews for attending to a number of hydraulic turbine installations in a system or region. This is because considerable expertise is involved in carrying out these repairs particularly welding. Techniques such as metal spraying have also to be adopted in some cases. Welding repairs to turbines done without proper attention to correct hydro dynamic profiles deteriorate rapidly and sometimes cause further damage.

9. Erosion damage is also rather common in this country. The highly variable flows of our rivers due to monsoon conditions yield highly

variable quality of water and the silt charge. During certain periods, these can be very heavy, particularly, in the Himalayan regions. This silt is also found to be highly abrasive. Such damage has been experienced not only on run-of-the-river plants but also on storage type installations. The erosion affects the turbine units, guide vanes, nozzles, needles, seals etc. Such damage has been noticed on all types of turbines. A careful design of the hydraulic works with special features for silt elimination can go a long way in reducing the damage to a minimum. Complete elimination, however, does not appear to be feasible. In fact, on certain installations, it has been suggested that the power station may be closed down during certain short periods, when a high charge of suspended matter is known to occur.

10. It may be mentioned that one of the common failings leading to substantial erosion damage has been initial start-up of the power plant without proper cleaning up of the water conductor system to remove all debris collected during construction.

11. Among the various components of water conductor system, the gates have perhaps given the greatest amount of trouble at various installations. The occasions for operation of the gates are few and far between. This leads to disuse of the operating facilities and is the main cause of troubles. Accumulation of silt deposits or other material have often made opening and closing of the gates stop logs etc., very difficult. Periodic inspection and maintenance of gate seals, hoisting arrangements etc., is very necessary.

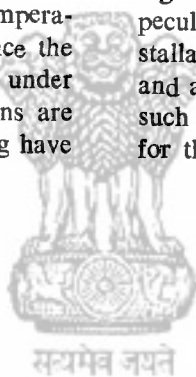
12. Another feature that needs attention is that many times under emergency conditions or under some interim arrangements such as partly constructed operations, certain measure of expediency have to be taken, which can often get overlooked later on, leading to difficulties. The need for proper logging of these measures cannot be over-emphasized. Grave situations affecting the reliability of the plant and leading to serious accidents can occur when the arrangements made as a matter of expediency in an emergency are later forgotten. In one case, some steel rods were welded at the gate seats and seals for ensuring proper sealing. These were forgotten by the time the need to open these gates arose, several months later. The efforts to open the

gates resulted in an accident due to failure of hoisting mechanism. Such like expedient measures are perhaps unavoidable in case of long tunnels, pipe lines, surge tanks etc. Proper logging of these will obviate future complications and troubles.

13. Another class of avoidable troubles arises due to various automatic control and supervision device features falling into disuse. Many of these checks are required at long intervals and cannot usually be taken care of as a part of the normal routine operation and maintenance. Special programmes, have, therefore, to be drawn up for effecting these checks etc., as an annual or a biennial programme in a manner similar to that already recommended in respect of cavitation. Very often, a number of devices provided for continuous supervision of certain pressures, temperatures, clearances, etc., fall into disuse. Since the plant can be operated quite conveniently under these conditions, necessary corrective actions are not taken. Certain failures of thrust bearing have

been traced to failure of the bearing insulation leading to corrosive shaft currents. In at least a couple of places, it was noticed that the carbon dioxide lines for automatic fire protection of generators or the devices for initiation carbon dioxide discharge, had been disconnected at the time of some maintenance operation and had remained like that for several months thereafter. The damage to the generator in case some fire had occurred in this period, could have been disastrous. Similarly, there have been cases where bypass valves draft tube and even intake gates have become inoperable due to silt deposits, or the load on the thrust-bearing has progressively increased to dangerous proportions due to increasing runner clearances on account of wear.

14. The behaviour of hydro-electric generating sets under earthquake conditions is rather peculiar. It is, therefore, desirable that the installation should be studied from this view point and a proper guide for emergency measures under such abnormal and unusual conditions drawn up for the guidance of the operating staff.



SECTION 11

MONITORING OF PERFORMANCE

1. In the foregoing Sections, the importance of reliability and plant availability of water power plants for the power system has already been discussed. The importance to the system is much more than the proportion of energy contribution from hydro source would indicate, as the hydro-electric plants have other functions to perform in the system operation for improving and optimising the working of the system. Moreover, the energy contribution of the hydro-electric plants is also very substantial. In fact, in the past years, power stations like Koyna, Bhakra and Sharavathi have constituted some of the largest single sources of electrical energy in the country. For example, the energy generation at Koyna has been 2841 and 2990 GWh. in the years 1967-68 and 1968-69 respectively whereas the largest single thermal source of electrical energy has been Neyveli Power Station contributing 2071 and 2128 GWh of energy in these years. In contrast with the thermal power stations, however, the hydro-electric power plants are extremely simple, easy to operate and trouble free. This simplicity, dependability and robustness of the plant, however, lead to neglect of such power stations and it is, therefore, necessary to create an awareness of the need to monitor the performance of hydro-electric power stations. The effects of forced outages or reduced capability or reduced efficiency in the case of the major power stations like Sharavathi, Koyna or Bhakra can indeed be very costly for the respective regions.

2. Deterioration of performance of hydro-electric installations can be due to several causes. It can take place in the different elements of an installation. In the water conductor system, deterioration of the surface conditions in tunnels,

power channels or penstocks can be quite serious. All these reduce the net head available and sometimes also the maximum possible flow. In and around a turbine, blockage or breakage of some vanes in the guide apparatus, cavitation damages in the water passages (particularly the runner), formation of large pits in the concrete draft tube surfaces, enlargement of the sealing gaps in the turbine, deterioration of shaft seals are some of the most common forms of deterioration. These lead to increased friction or reduced volumetric efficiency and can, therefore, be detected by detecting reduction efficiency.

2.1 Deterioration of the conditions of seals can also be detected by installation of pressure gauges on the turbine covers, spiral casings etc. It is rather unusual to provide such facilities for pressure measurements at the turbine covers etc. but the information obtained from these is so valuable that it is recommended that strategically located pressure gauges may be provided in all reaction turbine installations for monitoring the turbine seals.

3. Broadly speaking, the efficiency of the plant can serve as a good overall indicator for the purpose. There are, of course, other methods of detecting deterioration in the power stations; however, efficiency remains the best indicator for watching the performance without stoppage. Some further indications can also be provided by installation of appropriate instruments in various places. Measurement of turbine efficiency, particularly the measurement of water flow through the turbine, have always presented some very difficult problems. Precise field measurements of the turbine efficiency can be very costly in the case of

certain installations, depending on the length of penstocks, layout of the installation, head, output etc. Because of this, there is a tendency of waiving such tests for acceptance purposes even when these are prescribed in the contract for the plant. One reason for this is also the urgency of commissioning the plant. It is not realised that forgoing of these tests is a loss to the project as this makes subsequent monitoring of its performance very difficult. It is, therefore recommended that as extensive a programme of testing as possible should be carried out on every new generating unit so as to get as much scientific information about its performance as possible.

4. One of the commonest methods of monitoring performance during operation is the use of Index methods. Piezometer taps are provided at appropriate places on the spiral casing, speed ring etc. and the pressure differentials between these various points are calibrated against the water flows through the turbine at the time of the field acceptance test. Once this calibration is done, it is very simple to assess the efficiency of the generating unit in operation quickly and fairly accurately. A comprehensive Test Code for Index Testing of Hydraulic Turbines is being brought out by the International Electro-technical Commission (IEC). A Test Code prepared by the American Society of Mechanical Engineers (ASME) has already been adopted in U.S.A.

5. Recently, other methods have also come to the fore. These include the thermo-dynamic method of efficiency measurement and ultrasonic method of flow measurement. Ultrasonic method involves installation of appropriate probes and sources of ultrasonic signals in appropriate places such as penstock, draft tube etc. With the help of these, the flow of water can be measured at any time.

5.1 The thermo-dynamic method eliminates the need for flow measurements altogether. In this method, a water sample from the penstock is expanded adiabatically till its temperature is exactly equal to that of the water in the tailrace. This enables a direct measurement of the losses in the turbine and hence of efficiency. This method is applicable only at heads higher than 100 or 150 metres. However, where it is applicable, it provides a very simple and economical method for monitoring of the turbine efficiency.

6. It is strongly recommended that each new generating unit to be installed in the country should be provided with adequate means for continuous monitoring of its performance. Measures should also be introduced in existing power stations to ensure monitoring of the performance continuously or at least at short intervals.

CHAPTER 4

STEAM POWER STATIONS

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SECTION 1

BRIEF HISTORY OF DEVELOPMENT

1. Initially, coal based steam power stations comprised small load centre installations supplying urban requirements of power at Calcutta, Bombay, Madras, Kanpur and other cities and towns. The first station was commissioned at Calcutta in 1899 followed by Madras and Kanpur (1906) and Delhi (1908). Development up to World War I was, however, extremely slow, the pace increasing somewhat there after. The installed thermal capacity prior to World War II was 540 MW, all of which was established and operated by private licensees.

2. The first major step in development of economic thermal power through advantageously located large mine-mouth installations was taken when the Damodar Valley Corporation inaugurated the work on the installation of the Bokaro Thermal Station with 3 generating units of 57.5 MW each in 1948-49. The total installed capacity of thermal plant in the country was increased from 1.004 GW in 1951 to 1.547 GW in 1956 and 2.436 GW at the end of 2nd Plan (GW=Gigawatt=million kW.).

3. There have been some important major changes in thermal power development in recent years. Firstly, although the larger urban centres of power generation have continued to

grow, there has been a decided trend of setting up large thermal power stations at pit heads utilising directly the output of the collieries or of the coal washeries. The latter had been set up for supplying coking coal to the large steel plants and the large quantities of washery by products are being utilised as fuel in the thermal power plants. Notable examples of such installations have been Patratu, Chandrapura, Durgapur, Satpura and Kothagudam. Unlike their predecessors, these large mine-mouth power stations also involve development of large inter-connected transmission systems.

4. While the older developments were almost entirely in the private sector, these recent developments which require very sizable investments in developing the sites, arranging for necessary water supply and other facilities etc. are being carried out in the public sector either by the State Electricity Boards or by organisations like D.V.C., Neyveli Lignite Corporation etc. The question of construction of some of the large power stations directly by the Central Government is under consideration in view of the huge outlays required and the benefits extending beyond the boundaries of individual States.

SECTION 2

PRESENT INSTALLATIONS

1. The Thermal Power plants are playing an increasingly important role in the electric power generation in the country. By 1969-70, the installed plant capacity in steam power stations account for 8.5 Gigawatts out of 15.5 GW total installed capacity in the country. In 1969-70, the energy generated by the Steam

Power Stations amounted to 31535 million kW hours out of the national total of 56190 million kW hours of electrical energy from all sources. In other words, the Steam Power Stations accounted for about 55% of the total installed capacity and contributed about 56.1% of the total energy.



SECTION 3

MAJOR GROUPS OF POWER PLANTS

1. In any analysis of the performance of Thermal Power Stations in the country, the progressive changes in the type of power plants used must be taken into account appropriately. Figures 4-1.1, 4-1.2, 4-1.3 & 4-1.4 give an analysis of the make-up of the thermal installations. The analysis has been given for the period from 1956 onwards as the development prior to that is not of great significance for the present purposes. The year by year installation of all the generating units rated at 15 MW and above each, have been analysed in accordance with the date of installation and principal parameters. In 1955, there were only 19 generating sets of ratings of 15 MW and above in the country (500 MW total). This number has now (early 1970) grown to 122 sets accounting for 6050 MW of installed capacity. These have been classified into three groups for purposes of analysis of their performance and suggesting ways and means for improvement. The principal parameters of the generating sets in these groups are given in Table 4-1.

2. The first group is composed of generating units in the range of 15 to 36 MW. These operate under the steam conditions of 55 to 61 atmosphere pressure and about 485°C temperature. The boilers of these units are equipped with stoker firing. There are 22 such units in operation in the country presently and these account for about 0.55 GW installed capacity. It will be seen from the Figures 4-1.1, 4-1.2, 4-1.3 & 4-1.4 that this group was important in the earlier years and that further additions in this group have practically come to a stop.

3. The second group is composed of generating units with ratings of 15 to 100 MW of

non-reheat type. These have the steam parameters of 85 to 103 atmospheres pressures and 510 to 538°C temperature. The boilers of all these units are fired with pulverised fuel and in some cases, also by oil or gas. There are 80 such sets in operation in the country presently accounting for about 3.83 GW. This is the most predominant group in the present operation of thermal generation in terms of both the MW capacity as well as the number of units. Installation of these units has dominated the scene in the '60s'. It is expected that more generating sets in this group will also be added in the 70s although this group may lose its predominating position in the coming years.

4. The third group is comprised of generating units of ratings ranging from 82.5 MW to 150 MW. These operate with steam parameter of 103 to 170 atmosphere pressures and 538 to 565°C temperature. These are all reheat units. The boilers of all these units are fired with pulverised fuel and in some cases also by oil or gas. The first such unit was installed in 1964 and by now there are 9 units in operation. They account for about 1.04 GW installed capacity. The indigenous manufacture (both HEL and BHEL) are equipped to manufacture these units. With expansion of the transmission networks and system inter-connection, there will be no difficulty in absorbing future additions of capacity in units of this size or even bigger on most of the systems. This, coupled with the better efficiency and economies of scale, make it obvious that it is the units of this group that will predominate the future installation.

5. In the course of the current Five-Year Plan, installation of 45 generating sets is already

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in hand and these are expected to be commissioned by 1973-74. This will increase the installed capacity (in units of 15 MW and above) from 5.4 GW to 9.8 GW. It is interesting to note that no generating unit in Group I above is under installation presently. In Group II, 20 generating units aggregating 1.5 GW will be added and in Group III 24 generating units aggregating 2.96 GW will be added. Thus the total installed capacity in Group II will become 5.3 GW by 1973-74 and that in Group III will become 4 GW.

TABLE 4—1
PARAMETERS OF STEAM-ELECTRIC GENERATING
UNITS IN OPERATION IN INDIA

Group	Unit Capacity in MW	Steam conditions at stop valve	
		Pressure in Kg/Cm ²	Temperature in °C
1	2	3	4
I . .	15	55	485
	15	57	482
	30	59.7	482
	30	61	482

contd.

	1	2	3	4
II . .	15	55	485	
	15	41.8	450	
	30	60.8	482	
	36.6	60.8	482	
	50	60.8	482	
	50	90	535	
	60	89	510	
	60	90	525	
	62.5	89	510	
	62.5	89	510	
	63.5	89	510	
	75	71	496	
	75	103	538	
	100	90	535	
III . .	87.5	103	538/538	
	110	130	565/535*	
	110	130	535/535*	
	120	127.6	538/538*	
	140	127.6	538/538	
	140	141.7	538/538*	
	150	169.8	565/538	

*Not yet commissioned.



SECTION 4

ELEMENTS OF COST OF ENERGY GENERATION

1. The cost of energy generation from the steam power stations is dependent on a large number of factors. These need to be analysed with a view to identifying the areas in which substantial economies and improvements can be achieved.

2. The main factors making up the total cost of generation in a steam power station can be broadly classified as fuel cost, fixed cost and operation and maintenance cost. The overall costs of energy per kWh at bus-bar together with the constituents, viz. fuel cost, fixed cost, operation and maintenance cost have been worked out for some representative steam power stations under the three different groups. Tables 4-2.1 to 4-2.4 show the overall costs, fuel costs, fixed costs, operation and maintenance costs in paise per kWh of energy sent out for some of the years from 1955 to 1969 for the three groups of steam power stations. Table 4-2.5 shows the percentage ratio of cost of fuel per kWh. to overall cost per kWh. of energy sent out.

3. The overall costs at the Table 4-2.1 include (a) cost of fuel (b) fixed costs (c) operation and maintenance costs and (d) other minor costs. The fuel cost covers the costs of transportation of fuel, supporting fuel oil and coal handling cost. The fixed charges include (a) interest (b) depreciation (c) proportionate share of general overheads, direction, other offices etc. The operation charges include (a) salaries, wages and allowances (b) lubricants and consumable stores (c) cooling water (d) loose tools and (e) other chargeable expenses. The maintenance charges include the repairs and maintenance for

(a) boiler plant and equipment (b) turbine and generator (c) switchgear and switchboard (d) water cooling system (e) miscellaneous power plant and (f) power house building and civil works.

4. It would be seen from Table 4-2.1 that the total cost of energy per kWh is much less for the power stations having large unit sizes near the coal mines than for those which are located at distant places and having smaller size units. Bokaro Thermal Power Station under Group-2 for which the data are available for all the years upto 1969 shows that the cost of generation has gradually risen from 3.34 paise per kWh to 5.64 paise per kWh during the period from 1955 to 1969. Similarly, for Ahmedabad Thermal Power Station under Group I, the cost has gradually risen from 7.08 paise in 1966 to 7.81 paise in 1968. This is true even for the power stations where there has not been any increase in the installed capacity on account of the new larger unit sizes. The overall cost of generation for other power stations does not show this trend mainly because there have been additions in between of larger units which have caused a reduction in the cost of generation.

5. It would be seen from Table 4-2.5 that the fuel cost generally constitutes from 35% to 65% of the total cost of energy. The wide range is partly attributable to the different annual load factors experienced. The percentage of fuel cost is higher for steam power stations under Group 1 as compared to the steam power stations under Groups 2 and 3. This is because the thermal overall efficiency of the power stations under Groups 2 & 3 is much higher than

that of power stations under Group 1. It would therefore be desirable that, in future, the power stations should, as far as possible, be of higher capacity so that the cost of fuel per kWh generated is minimised. Table 5 also indicates the extent to which the power houses nearer to the coal mines have less fuel cost than those located at distant places. The cost of transportation of coal from coal mines to the power stations is thus a major element of cost.

6. Table 4-2·3 shows that the fixed charges constitute about 20 to 40% of the total cost of energy generated. As this constitutes a large part of the total cost, it will be more profitable to reduce the fixed charges as much as possible. These can be reduced by (a) minimising the investment in the capital cost and (b) utilising to the maximum extent possible the rated capacity

of installed plant so that the high fixed charges get distributed over a large number of units generated. *Higher plant utilisation is therefore very important.*

7. Table 4-2·4 indicates that the cost of operation and maintenance is showing a gradual increase over years generally for almost all the power stations under the 3 groups. But the overall effect of this increase on the total cost of the energy sent out is not appreciable as these constitute about 5 to 10 per cent of the total cost of energy sent out. Nevertheless, the importance of proper operation and maintenance in running the power station cannot be over-emphasized. The operation and utilisation of available plant capacity in the most economical manner technologically depends entirely on competent O. & M.

TABLE 4-2.1
ANALYSIS OF COST OF ENERGY GENERATION AT CERTAIN STEAM POWER STATIONS
4-2.1 Cost of Energy per KWh at Bus Bar

(Figures in Paise)

Sl. No.	Name of Power Station	Y E A R S						
		1955-56	1962-63	1964-65	1965-66	1966-67	1967-68	1968-69
<i>GROUP—I</i>								
1	Nellore	..	..	..	..	7.97	11.82	8.46
2	Khaparkheda	..	..	..	4.96	5.30	5.66	6.73
3	Ahmedabad	..	..	..	..	7.08	7.13	7.81
<i>GROUP—II</i>								
1	Kothagudem	..	..	..	..	7.43	8.03	7.74
2	Bokaro*	3.34	2.67	2.98	3.68	3.79	5.01	5.64
3	Patratu	..	..	..	..	7.78	7.73	11.55
4	Neyveli	..	..	5.13	..	6.07	5.69	5.26
5	I. P. Station	..	..	..	..	8.83	..	11.02
6	I. P. Stn. Extn.	..	..	..	..	..	..	10.2
<i>GROUP—III</i>								
1	Chandrapura*	..	..	..	2.91 (3.20)	2.77 (3.04)	3.32 (3.65)	..
2	Bandel	..	..	..	..	5.76	6.14	6.03
3	Durgapur*	..	..	..	5.45	3.769	4.54	4.76
4	Trombay	..	..	5.98	6.51	7.41	7.50	6.89

*Represents cost per kWh generated.

Figures in bracket represent the cost per kWh sent out taking into consideration losses and consumption by auxiliaries etc. @10%.

TABLE 4-2.2

ANALYSIS OF COST OF ENERGY GENERATION AT CERTAIN STEAM POWER STATIONS

4-2.2 Cost of fuel per KWH of Energy Sent out

(Figures in Paise)

Sl. No.	Name of Power Station	Y E A R S						
		1955-56	1961-62	1964-65	1965-66	1966-67	1967-68	1968-69
GROUP—I								
1	Nellore (1×30 MW)	..	..	..	3.73	4.36	6.05	4.64
2	Khaperkheda (3×30)	..	..	..	3.59	3.72	3.88	3.95
3	Ahmedabad (8×15+2×30)	..	..	..	..	4.36	4.81	5.02
GROUP—II								
1	Kothagundem (4×60)	..	..	..	..	3.73	3.82	3.62
2	Bokaro (3×50+1×75)	0.88	1.18	1.37	1.67	1.72	2.13	2.45
3	Patratu (4×50)	..	..	..	..	3.22	2.97	3.55
4	Neyveli (6×50+1×100)	..	..	3.37	2.93	3.61	3.09	2.89
5	Paras (1×30+1×62.5)	..	सत्यमेव जयते	..	3.85	4.41	4.02	4.30
6	I. P. Station (1×36)	..	..	3.18	3.65	3.98	4.55	5.20
7	I. P. Stn. Extn. (2×62.5)	..	..	..	..	..	5.26	5.08
GROUP—III								
1	Chandrapura (3×140)	..	..	..	1.47	1.53	1.81	1.83
2	Bandel (4×87.5)	..	..	..	..	2.17	2.23	2.31
3	Durgapur (2×75/82.5+1×140)	..	..	..	2.28	1.81	2.00	2.42
4	Trombay (3×62.5+1×150)	..	..	2.92	3.45	3.77	3.93	3.90

TABLE 4-2.3

ANALYSIS OF COST OF ENERGY GENERATION AT CERTAIN POWER STATIONS

4-2.3 Fixed Charges Per KWH of Energy Sent out

(Figures in Paise)

Sl. No.	Name of Power Station	Y E A R S						
		1955-56	1962-63	1964-65	1965-66	1966-67	1967-68	1968-69
GROUP—I								
1	Nellore	..	..	..	1.88	2.57	3.81	2.53
2	Khaparkheda	..	..	..	0.61	0.77	0.78	1.45
3	Ahmedabad	..	..	..	..	1.63	1.40	1.69
GROUP—II								
1	Kothagudem	..	..	..	..	3.47	3.63	3.46
2	Bokaro	1.38	0.91	1.01	1.40	1.40	1.97	2.21
3	Patratu	..	..	..	..	3.84	4.13	6.44
4	Neyveli	..	..	1.20	..	1.50	1.88	1.50
5	Paras	..	..	..	..	..	..	..
6	I. P. Station	..	..	..	..	3.99	..	5.07
7	I. P. Stn. Exten.	..	..	..	..	..	..	4.58
GROUP—III								
1	Chandrapura	..	..	..	1.27	1.20	1.40	..
2	Bandel	..	..	..	..	3.19	3.36	3.19
3	Durgapur	..	..	..	1.85	1.19	1.79	1.77
4	Trombay	..	..	2.50	2.41	2.79	2.56	2.12

TABLE 4-2.4

ANALYSIS OF COST OF ENERGY GENERATION AT CERTAIN STEAM POWER STATIONS

4-2.4 Operation and Maintenance Charges per KWH of Energy sent out

(Figures in Paise)

Sl. No.	Name of Power Station	Y E A R S						
		1955-56	1962-63	1964-65	1965-66	1966-67	1967-68	1968-69
GROUP—I								
1	Nellore	..	..	..	0.74	1.0	1.95	1.29
2	Khaparkheda	..	..	..	0.75	0.81	1.00	1.20
3	Ahmedabad	..	..	..	..	1.09	0.93	1.09
GROUP—II								
1	Kothagudem	..	..	..	..	0.23	0.58	0.65
2	Bokaro	0.85	0.41	0.41	0.59	0.49	0.61	0.61
3	Patratu	..	..	..	..	0.72	0.62	1.56
4	Neyveli	..	..	0.77	..	..	0.67	0.60
5	Paras	..	..	..	1.10	1.30	2.80	1.10
6	I. P. Station	..	..	..	..	0.86	..	0.75
7	I. P. Stn. Extn.	..	..	..	..	..	..	0.53
GROUP—III								
1	Chandrapura	..	..	..	0.31	0.18	0.28	0.24
2	Bandel	..	..	..	..	0.40	0.55	0.53
3	Durgapur	..	..	..	1.04	0.56	0.53	0.34
4	Trombay	..	..	0.56	0.65	0.85	1.01	0.87

TABLE 4-2.5
ANALYSIS OF COST OF ENERGY GENERATION AT CERTAIN STEAM POWER STATIONS
4-2.5 Percentage Ratio of Cost of Fuel to Overall Cost of Energy sent out

Sl. No.	Name of Power Station	Y E A R S						
		1955-56	1962-63	1964-65	1965-66	1966-67	1967-68	1968-69
GROUP—I								
1	Nellore	..	..	..	58.5	54.8	51.1	55.0
2	Khaperkheda	..	..	..	72.38	70.19	52.57	58.69
3	Ahmedabad	..	..	..	..	61.56	67.40	64.24
GROUP—II								
1	Kothagudem	..	..	..	..	50.20	47.57	46.77
2	Bokaro	25.66	43.07	44.63	45.4	45.4	42.5	43.4
3	Patratu	..	..	..	..	41.39	38.43	30.72
4	Neyveli	..	..	65.69	..	59.47	52.20	54.94
5	Paras	..	..	..	..	..	..	..
6	I. P. Station	..	..	..	..	45.07	..	47.18
7	I. P. Station Extn.	..	..	..	..	..	..	49.80
GROUP—III								
1	Chandrapura	..	..	..	45.9	50.0	49.5	43.9
2	Bandel	..	..	..	..	37.70	36.32	38.32
3	Durgapur	..	..	..	37.48	43.24	39.30	50.85
4	Trombay	..	..	48.83	52.99	50.88	52.40	57.1

TABLE 4-2·6
ANALYSIS OF COST OF ENERGY GENERATION AT CERTAIN POWER STATIONS
4-2·6 Fixed Charges per KWH Installed

(Figures in rupees)

Sl. No.	Name of Power Station	YEARS						
		1955-56	1962-63	1964-65	1965-66	1966-67	1967-68	1968-69
GROUP—I								
1	Nellore	..	..	..	115·70 (30)	134·50 (30)	124·70 (30)	138·50 (30)
2	Khaparkheda	..	..	..	31·50 (90)	44·40 (90)	45·30 (90)	75·60 (90)
3	Ahmedabad	..	..	..	..	84·20 (180)	88·45 (180)	98·25 (180)
GROUP—II								
1	Kothagudem	..	..	..	..	163·31 (120)	126·00 (240)	132·05 (240)
2	Bokaro	29·80 (150)	59·54 (225)	69·72 (225)	78·12 (225)	79·10 (225)	97·02 (225)	79·52 (225)
3	Patratu	..	..	..	..	129·09 (50)	105·59 (200)	114·53 (200)
4	Neyveli	..	..	55·60 (250)	..	77·30 (300)	87·28 (400)	96·70 (400)
5	I. P. Station	..	..	..	..	254·70 (36)	321·60 (36)	225·50 (36)
6	I. P. Stn. Extn.	..	..	..	..	..	..	..
GROUP—III								
1	Chandrapura	..	..	..	69·35 (280)	78·10 (280)	76·84 (280)	64·82 (280)
2	Bandel	..	..	..	..	76·32 (350)	80·47 (350)	88·00 (350)
3	Durgapur	..	..	..	70·19 (150)	73·31 (150)	82·48 (290)	77·59 (290)
4	Trombay	..	..	131·00 (187·5)	81·50 (337·5)	96·90 (337·5)	121·00 (337·5)	111·00 (337·5)

Note.—Figures in brackets indicate installed capacity in MW.

TABLE 4-2.7

ANALYSIS OF COST OF ENERGY GENERATION AT CERTAIN STEAM POWER STATIONS

4—2.7 Operation and Maintenance charges Per KW Installed.

(Figures in rupees)

Sl. No.	Name of Power Station	YEARS						
		1955-56	1962-63	1964-65	1965-66	1966-67	1967-68	1968-69
GROUP—I								
1	Nellore	..	..	..	44.4 (30MW)	52.70 (30MW)	63.80 (30MW)	70.70 (30MW)
2	Khaparkheda	..	..	..	38.70 (90)	46.90 (90)	58.80 (90)	57.90 (90)
3	Ahmedabad	..	..	..	..	56.21 (180)	58.50 (180)	63.83 (180)
GROUP—II								
1	Kothagudem	..	..	..	..	10.73 (120)	19.26 (240)	24.90 (240)
2	Bokaro	18.44 (150)	27.00 (225)	28.64 (225)	32.60 (225)	27.55 (225)	30.18 (225)	21.37 (225)
3	Patratu	..	..	..	..	24.20 (50)	15.90 (200)	27.78 (200)
4	Neyveli	..	..	35.60 (250)	..	35.40 (300)	31.76 (400)	37.10 (400)
5	Paras	..	..	..	56.10 (30)	60.60 (30)	34.60 (92.5)	44.90 (92.5)
6	I, P. Stn. Extn.	..	..	..	..	54.31 (36)	..	33.48 (36)
GROUP—III								
1	Chandrapura	..	..	..	16.07 (280)	11.95 (2.80)	15.48 (280)	..
2	Bandel	..	..	..	..	9.63 (350)	13.13 (350)	14.79 (350)
3	Durgapur	..	..	..	39.45 (1.05)	34.70 (10.5)	24.50 (290)	15.33 (290)
4	Trombay	..	..	29.30 (187.5)	21.90 (337.5)	29.50 (337.5)	43.60 (337.5)	45.80 (337.5)

Note.—Figures in brackets indicate installed capacity in MW.

SECTION 5

FACTORS AFFECTING COST OF ENERGY AND POWER

1. As is seen from the foregoing when viewed on the long-term basis, economy in power-generation in steam power plants is a complex matter, dependent on a large number of factors.

2. As already pointed out, the cost and availability of fuel is one of the most important factors. This is naturally so, as the fuel may be considered as the raw material which the power plant processes to yield electrical energy. The cost of the product naturally depends on the raw-material. The nature of the fuel has also a great influence on the cost of operation and maintenance of the power plant. In fact, the fuel influences the fixed cost also. The capital outlay required is influenced by the fuel for which the power plant is to be designed and the transportation, storage and handling facilities as well as any problems of by-products posed by the types of fuels used. The power plants utilising coal have costlier installations and they have more problems in the operation and maintenance than power plants using petroleum fuels, as in the latter case, problems of ash disposal, railway yard, storage, fuel pulverisation etc. get eliminated.

3. Once the planning and construction of the power plant is over, the main problems are really those of operation and maintenance. Good performance of power plants may be considered to have three main facets, viz., efficiency, availability and economy. These are obviously inter-related. Efficiency of the power plant depends, first and foremost, on the parameters chosen for the power plant and equipment, the rating of the plant, type of fuel etc. The effect of increasingly large power plant sizes on im-

provement in efficiency has been brought out in Table 4-3 given. The efficiency also depends on the power consumption of auxiliaries and competence of operation and maintenance. In a large measure, efficiency and economy also depend on the manner in which a power plant is operated. A large steam power plant can give its optimum efficiency when operated continuously under optimum conditions. If the level of power output fluctuates, the efficiency is brought down. Moreover, at lower levels of power output, costly oil support is required to maintain stability of combustion in the boiler furnace and this pushes up the fuel costs. Taking the system as a whole, use of large high efficiency units to the maximum extent for generating the energy requirements of the system leads to a maximum degree of efficiency and economy.

4. Tables 4-2.6 & 4-2.7 show the fixed charges and operation and maintenance charges in rupees per kW installed for some representative power stations for some of the years from 1955 to 1969 under three different groups. While these charges do not give any idea of the plant utilisation etc., they give valuable information about the fixed charges. It would be seen from these tables that there is a gradual increase in these charges over the past years. The capital investment per kW of the installed capacity appears to be steadily rising since 1955. This has to be watched carefully in view of increasing costs of raising capital. The rising O. & M. charges in spite of large (and fewer) generating units show the effect of rising wage bills and higher costs of spares. These can be compensated only by better plant utilisation.

5. The above tables have been worked out on the basis of the data supplied by the concerned authorities in reply to the questionnaire circulated by the Power Economy Committee. It has been very difficult to calculate the exact cost of fuel, O & M charges, fixed charges etc. because the data supplied by them was not on a uniform basis. Some of the data looked very abnormal and could not be utilised. It has been experienced that some of the costs calculated on the basis of the data received are often inexplicably inconsistent. Similar difficulties have been experienced while working on other analysis. This clearly demonstrates the urgent need to introduce a uniform system of accounting on a rational basis. This will prove very useful in from the different power stations.

6. For identical reasons several years back, the Federal Power Commission in the U.S.A. has made it obligatory for every American utility to present its accounts in a standardised way known as the Uniform System of Accounting. This enables studies and cost comparisons in a precise manner. The relative importance of the various components of the total cost of energy generated and transmitted can be judged accurately by analysing the costs on a rational basis.

7. The above tables have been worked out only for those steam power stations for which the data supplied by the authorities were nearly complete. Although a few figures may appear to be inconsistent, they amply define the trends obtaining at present in the country.



SECTION 6

EFFICIENCY OF ENERGY GENERATION

1. Table 4-3 gives the distribution of the steam power stations in the country in terms of their overall thermal efficiency for the years 1962-63 and 1967-68. Complete data for more recent periods are not yet available. The thermal efficiencies shown here are the actual overall efficiencies achieved in the power station operations. These are based on the actual consumption* of coal of different grades, fuel oil etc., the respective calorific values of the fuels and the gross electrical energy generated. It may be noted that the number of generating stations in the lower efficiency brackets has progressively reduced while that in the higher efficiency brackets has increased. In many cases, this is due to addition of larger high efficiency generating units in existing power stations resulting in the higher overall efficiency in the operation of the power station and its consequent migration to a higher efficiency bracket. It will be seen that there were only 11 power stations in the country, operating at efficiencies better than 20% in the year 1962-63. This number has gone up to 32 in 1967-68. About 65% of the electrical energy generation from steam power stations during 1967-68 has been at an efficiency of 25% or better. The national overall efficiency works out to 23.13% for 1967-68 against 27.99% in U.K. (CEGB). It is noteworthy that the highest efficiency achieved in any one station during 1967-68 was at Chandrapura (DVC) 34.2% as against the highest of 34.6% reported in U.K. at Ferrybridge 'C' Station.

2. With the steam power stations contributing nearly 60% of the total production of

electrical energy in the country, it is obvious that improvement of the overall efficiency of these power stations is of vital importance in reducing the cost of electrical energy. With an estimated coal consumption of nearly 22 million tonnes, improvement in power station efficiency has obviously an important role in conservation of the natural resources of primary energy of the country. Figures 4-2 and 4-3 give an analysis of 91 power stations (out of 94) in operation during 1967-68.

3. Figure 4-2 shows the installed capacity operating at an overall efficiency of at least the given efficiency at any point. This shows that the median point (3,000 MW capacity) efficiency is about 28%. In other words, an installed capacity of 3000 MW operated at an efficiency of 28% or better while an equal installed capacity operated at efficiencies lower than 28%. The curve is practically flat up about 12% efficiency showing that the installed capacity involved in efficiencies under 12% is very small—of the order of 200 MW. The operation and maintenance costs on a number of power stations is bound to be relatively very large, compared to the larger high efficiency stations. Shutting down these plants and giving power supply at those points from the grid fed from high efficiency power stations would obviously yield very considerable savings. Even after allowing for transmission losses, such a step would give worthwhile savings in fuel as well as energy costs. The question of taking similar action for power stations operating at efficiencies below 20% which cover less than 1/4th of the present installed capacity can be considered later

*Note : This is the total coal intake of the power station. coal fired in the boiler plus the coalmill rejects.

In case of pulverised fuel fired boilers this equals the

4. Figure 4-3 shows the energy generation of each of the 91 plants in 1967-68 against the efficiency at which the energy was generated.

4.1 The distribution of the points is generally what would be expected from theoretical considerations. For improvement in the overall efficiency of energy production, the peak of the curve has to be shifted to the right, towards the high efficiency region and the envelope of the curve on the left side should descend to the level of abscissa as steeply as possible. This criterion gives a clear indication of the stations where improvements would be most rewarding. The increased steepness of the envelope can be achieved in two distinct ways. Firstly, the efficiency of operation of the power stations lying on the envelope could be improved by close control of the power station operation and providing adequate maintenance or improvements on auxiliary apparatus, leakages, heat losses etc. This will move these points to the right—to the higher efficiency region. Secondly, the energy generation at these stations could be reduced (in favour of that from more efficient stations in the same grid) thus lowering these points. Similar data in regard to the year 1968-69 and 1969-70, has also been plotted to observe the trend of some major power stations. These are also marked.

4.2 It will be seen that the Bokaro Power Station has been brought more inside the envelope by reducing the energy generation at that station. This reduction is compensated by higher energy generation on the more efficient stations of the DVC system at Chandrapura and Durgapur.

The energy generation at Ahmedabad and New Cossipore has been reduced but this does not improve the matter as the efficiency has also been correspondingly reduced and these points stay on the envelope.

Energy generation from the older 100 MW installation at Korba has been reduced and that at the higher efficiency 4×50 MW units has been raised. This has improved the overall efficiency substantially.

4.3 It is seen that the energy generation at practically all the large high efficiency stations, viz., Trombay, Neyveli, Chandrapura, Durgapur and Bandel has increased substantially in the

year 1968-69. In this process, however, the efficiency of some of these power stations has been reduced. Such reduction in efficiency with increased energy production is not what would normally be expected and it would be worthwhile to investigate these happenings. In the case of Chandrapura, it is understood that the coal mill rejects had increased in 1968-69 owing to poorer quality of washery by-products being supplied.

4.4 As already pointed out, it appears worthwhile to examine the working of the following power stations on the envelope in the first instance (with a view to improving their efficiency or reducing the energy production) for yielding substantial benefits:—

- (1) Ahmedabad.
- (2) Panki (Kanpur).
- (3) Chola (Maharashtra).
- (4) C.E.S.C. (New Cossipore).
- (5) C.E.S.C. Southern.
- (6) C.E.S.C. Mulajore.
- (7) Khaperkheda.
- (8) Korba.

4.5 In the following power stations which are relatively small and also rather old, scope for improvement in working may be limited but the gain by eliminating these in due course may be worthwhile from the viewpoint of economy and resources conservation:—

- (1) DESU, Rajghat.
- (2) Kandla.
- (3) Porbandar.
- (4) Nepa Nagar.
- (5) Gouripur.
- (6) Ramagundam (Old plant).
- (7) Sijua-Jherriah.
- (8) Benares.
- (9) Gorakhpur.
- (10) Dishergarh.

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(11) Old Cossipore.

(12) Mau.

(13) Mainpuri.

(14) Indore.

(15) Sikka.

5. It is interesting to note that in 1967-68 and 1968-69, the largest single sources of electrical energy in the country were:—

(Thermal only. Some hydro sources. exceeded these)

	1967-68	1968-69
Neyveli	2071 GWh.	2319 GWh.
Trombay	1572 „	1900 „
Chandrapura	1539 „	1913 „

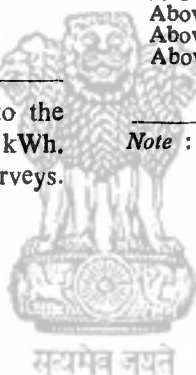
Even these stations could not be utilised to the full energy potential which is taken as 6,000 kWh. per installed kW. in the Annual Power Surveys.

TABLE 4-3

DISTRIBUTION OF STEAM POWER STATIONS IN TERMS OF OVERALL THERMAL EFFICIENCY

Overall Thermal Efficiency	Number of generating Stations	Aggregate installed capacity (MW)	Energy generated by the group (GWh)
1	2	3	4
Year 1962-63 :			
Under 10%	24	115.51	172.00
Above 10% but below 15%	34	719.29	2076.71
Above 15% but below 20%	14	533.95	1726.65
Above 20%	11	1167.50	6201.50
GRAND TOTAL	83	2536.35	10176.86
Year 1967-68 :			
Under 10%	18	114.29	205.23
Above 10% but below 15%	31	640.06	1765.48
Above 15% but below 20%	10	547.71	2205.63
Above 20% but below 25%	7	767.50	3394.60
Above 25% but below 30%	17	1989.60	6877.93
Above 30%	7	1901.50	7783.88
GRAND TOTAL	91	596.	22232.75

Note : 3 Power Stations with aggregate capacity of 14.75 MW not taken in the analysis for 1967-68 due to no generation or want of data.



SECTION 7

PLANT AVAILABILITY AND UTILISATION
IN STEAM POWER STATIONS

The power plant availability is another aspect of efficient and economic operation. The factors that affect outages and availability are:—

- (a) Mode of Operation.
- (b) Quality and Reliability of Maintenance.
- (c) Efficiency of Maintenance.
- (d) Causes external to Plant.
- (e) System Requirements.

(a) *Mode of Operation.*—Mode of operation has a considerable effect on the availability and outage of a unit. Correct operation includes correct lubrication and cleanliness in addition to proper handling of the plant, loading and unloading at specified rates, control of rate of change of temperature etc. These factors have a marked effect on the operating life of the plant and duration of outage for repair. Often a damage caused by negligence in operation may not become apparent immediately, but serious damage may result from faulty operation necessitating prolonged outage for repairs.

(b) *Quality and Reliability of Maintenance.*—In order to keep the plant fit for service, the quality of maintenance must be the highest possible order. Thus the use of correct materials and spare parts, proper tools and tackles, and trained and conscientious personnel to carry out the work accurately and properly can never be over-emphasized. A well maintained plant can be depended upon to give trouble-free service when in operation and thereby help to reduce outages and the requirement of standby plant.

(c) *Efficiency of Maintenance.*—Time spent on maintenance may be a good investment to

prevent further breakdowns. However, maximum economy of time is necessary. This can be achieved through adequate supply of spares, tools and tackles and number of trained personnel and proper scheduling of maintenance work. Three shift working and other techniques may also be introduced during the shut-down to reduce the period of outage.

(d) *Causes external to Plant.*—External causes often affect the availability of the plant and there are instances where a failure of the system has resulted in major break-down of the plant due to failure of the auxiliary power causing loss of oil pumps, feed water, etc. Proper understanding of the problem and establishment of an operating drill together with preventive measures may reduce the ill effect of external causes and reduce outage due to this cause.

(e) *System requirements.*—It has to be remembered that in spite of all efforts, the output from the unit may be reduced because of insufficient demand. Some variation of the output of the unit also takes place with system frequency etc., and thus, there is an inevitable shortfall in the output even when the plant is available and in spite of the operating staff keeping a close watch.

Shortfall may also occur due to temporary reduction in the plant capacity mainly on account of temporary fault in the auxiliaries although the unit as a whole is available and is operating on load. This can be minimised by efficient maintenance and proper operation.

An analysis of the availability of some major Indian power plants in recent years follows:—

SECTION 8

CASE STUDY OF PLANT AVAILABILITY AND UTILISATION

1. A study has been made of the plant availability and utilisation for different steam power stations over a period of five years. It is considered that it will meet the present purpose if the study extends over a select number of power stations in each of the three groups. The principal details of the equipment studied are given in Table 4-4.

2. The plant utilisation and availability have been studied in respect of the boiler plant and turbo-generator sets separately in each case, unit by unit. The period of study is from 1964-65 to 1968-69. The data regarding operation and maintenance of each individual unit for this period has been studied and analysed to bring out the following:—

- (1) *Service Hours (SH)*.—These are the total number of hour that the unit was actually operated with breakers closed to the station busbars. These represent the utilisation of the units during the year.
- (2) *Plant Maintenance Hours (MOH)*.—The time in hours for which the unit was not available for service due to outage for purposes of routine, preventive or statutory maintenance and inspection.
- (3) *The Forced Outage Hours (FOH)*.—The hours during which a unit or major equipment was not available due to forced outage, a generally unforceable event.
- (4) *Available Hours (AH)*.—This is the time in hours during which a unit or major equipment is available. This is sum of the service hours and the hours during which the unit was available for

service but was not utilised on account of load conditions or due to other complementary equipment being under repair or maintenance (e.g. T.G. set not being utilised due to boiler outage).

The sum of the time intervals 2, 3 & 4 above is the total number of hours in the year.

- (5) *Capacity Factor*.—This is the ratio of the number of units actually generated in a year to the number of units that would have been generated if the plant were to work at rated capacity throughout.

3. The results of the above study are given group-wise in Tables 4-5, 4-6 and 4-7. This covers a total of 161 unit years in 38 units and 47 boilers with an aggregate rated capacity of 2389 MW.

4. The study has been seriously handicapped for want of accurate data on uniform bases. It is found that there is growing awareness among the power station authorities of the need to maintain proper records and to analyse these records from time to time to assess the performance in respect of plant utilisation and availability. There is, however, considerable confusion about the precise definitions of the various terms. The data collected and compiled at different power stations are also not on a uniform basis. This makes it difficult to compare the performance of different power stations accurately. However, it is felt that the data collected and presented here are representative and enable a fairly correct appreciation of the performance.

5. The records show that the performance of different generating units varies widely from

year to year, often even in the same power station. This makes it difficult to identify the trends of the different factors over the years. The data has, therefore, been processed further graphically. The different time intervals have been expressed as percentages of the total time in a year and have been plotted in the form of histograms for different generating units, separately for the boiler and the turbo-generator sets figures 4-4.1, 4-4.2 & 4-4.3. These graphs show the relative variation of these factors from year to year.

6. The following general observations are made:—

6.1 Every year, there has been some outage for maintenance etc. In some years, no MOH (plant maintenance hours) are shown and only FOH (forced outages) are shown. This is because when the forced outage is long enough, it has been possible to carry out the normal maintenance also during that period. In other words, the FOH includes the MOH in these years.

6.2 The data and information available are not detailed enough to bring out the extent of waiting hours for want of spares or special equipment etc., in the period of forced outage for maintenance.

6.3 The data often shows the SH (Service Hours) for boiler to be higher than that for the T.G. set. In such cases, the definition of SH has not been strictly followed and the starting up time of the boiler is included in SH. This does not, however, detract much from the studies.

6.4 The service hours (SH) show the time for which the unit has been run. This does not indicate whether the unit ran at the full load or only at partial load. In many cases, while SH may be high, the capability of the unit has been severely restricted, due to outage of some vital components like one of the I.D. fans or pulverising mill units or plugged condenser tubes, etc. This can, however, be estimated from the value of the output factor, i.e., capacity factor divided by SH in percentage.

7. Group 1

These are stocker fired non-reheat units, Ratings of only 15 MW and above are considered.

The data has been studied for 3 power stations covering 7 units, 11 boilers and 145 MW of installed capacity. 34 unit-years are covered.

7.1 MOH (Maintenance Hours) for boilers at Khaparkheda have been of the order of 10-15% for units 1 and 2 but have extended upto 50% in unit 3. In the case of Paras, the MOH has extended upto 25% on one boiler only while very little MOH has been reported on the other boiler. The long forced outage in one year is the prominent feature at Paras. The boiler maintenance time at Barauni, which burns petroleum fuels, is understandably short. Here also, the forced outages are a prominent feature.

7.2 At Khaparkheda and Paras, the units have been run during most of the availability period (SH=AH). The capacity factors are, however, of the order of 60% only. In the case of Barauni, the forced outages are a prominent feature on all the three units and there are substantial gaps between AH and SH, indicating that the units have not been run for a substantial portion of the available period. The capacity factors are even lower; of the order of about 35% for all the 3 units. It is, therefore, clear that, for all the units studied particularly for Barauni, there is considerable scope for obtaining substantially larger energy production. Presumably this has not been possible because of the peculiarities of the loads in the respective power systems and the limitations of inter-connections etc. With integrated operation of power stations, this position would be considerably improved.

8. Group 2

This is the largest group, covering 23 generating units and 28 boilers, aggregating to 1324.1 MW of installed capacity. 95 unit-years have been covered. As already shown elsewhere, this is the most prominent group in the installations made in the Sixties. These are all non-reheat units with pulverised fuel fired boilers.

8.1 The experience of the DVC power stations as well as Trombay and Indraprastha have shown quite a high proportion of SH (service hours). These particular power stations are working in large integrated systems, and this has no doubt helped in permitting the units to be run over practically the entire period of availability (AH).

8.2 The performance record of the DVC Power Stations indicates that while SH is quite high the capacity factor is low in case of some units. In the case of one unit at Bokaro it was as low as 11% in 1968-69. This has been due to bending of the turbine shaft caused by failure of the auxiliary oil pump to develop sufficient oil discharge pressure even though started immediately on total power failure of the power station. There has also been drop in output factor, i.e., the ratio of the units actually generated to the units that could have been generated during the service hours if operating at full capacity, particularly at Bokaro (in case of one unit it was as low as 27 per cent.) The reasons are twofold—one as explained earlier, is that in DVC the ash content of fuels, which are mainly or totally washery bye products, fed to the power stations has progressively deteriorated with commissioning of Kargali 2nd stage, Dugda 2nd Stage and Patherdih. Earlier with Kargali and Dugda 1st stages (Patherdih washery not being there) fresh raw coal was used to tamper the bad effects of the relatively better quality middlings. With new washeries, the quality of washery by-products is worse and, moreover, no fresh coal is required to supplement the requirements of fuel any more. The second reason for drop of the output factor in Bokaro is commissioning of more efficient 140 MW reheat units, changing the pattern of energy production in the DVC system. While the latter reason is a corollary of an expanding system and not an undesirable thing, the former clearly indicates a colossal loss.

8.3 At Neyveli, there have been special problems due to lignite fuel. It is understood that special efforts have been made to reduce the maintenance outage hours systematically by introduction of operation Research methods. The capacity factor has varied from year to year but the output factor is uniformly high.

8.4 In the case of Patratu, the availability has been rather poor on Unit 2, due to various difficulties. The utilisation and output factor of the units are, however, good.

9. Group 3

These are the largest generating units in the country and the study covers 8 generating units and 8 boilers total 920 MW of installed capacity,

32 unit-years have been covered. These are Reheat type units with pulverised fuel boilers.

9.1 It is seen from the records that SH has been quite high compared to other groups. This is important for economy, especially in view of the large unit size and large investments.

9.2 The plants in the Eastern Region have, however, shown a preponderance of forced outages over the normal maintenance outages and the capacity factors as well as output factors have been rather low. Both these features are undesirable from the view-point of economic power generation. Those are, however, mainly due to the troubles already mentioned regarding the power stations in this region.

9.3 In Trombay the output factor has progressively increased from 75% to 90%.

10. From the data supplied by some of the older power stations it is seen that the availability in the Indian power stations is very much below the U.S. standards. It is true that in USA, fuel used is either oil, gas or coal of very much lower ash content, but even taking these advantages in the US power stations into account, *it is clear that there is much scope for improvement in availability of our stations.*

11. Boilers

11.1 Boiler outages have varied widely. Much of the loss of availability may be accounted for by unusually long time taken for boiler statutory overhauls which have varied from 716 hours to as many as 5492 hours. It is observed from the figures available that some of the systems have taken 1700 hours on an average for overhaul of the boilers. This by itself accounts for 19.5% loss of availability. It is, therefore, obvious that there is a great scope of reduction in outage while doing statutory boiler overhaul work. It is felt that the overhaul should be done within weeks from the day the boiler is taken off to the time it steams to run a turbo-generator—in other words 4 weeks inclusive of inspection of the Boiler Inspector. If this can be done, then the outage due to overhauls would come down to 7.6% even if the same is carried out every year regularly and by doing so, it would be possible to reduce other forced outages. The gain in availability would be 11.9%.

11.2 It is not essential technically that the boiler overhaul should necessarily be done every

year. It should be left to each system to decide the interval it wants to put between the consecutive overhauls. The deciding factor should be that the total outage due to overhauls and other causes should be minimum. The total outage can then be kept as low as 12% or even lower, despite use of inferior fuels.

11.3 It is felt that constant monitoring of the working of the boiler equipment to ensure that the plant operates within the recommended range of levels, temperatures, pressures etc., at the different points in the system would help considerably in improving the plant availability and reducing the forced outages and maintenance.

11.4 Whenever abnormal conditions are noticed, a rectification of these should be fitted into the preventive maintenance schedule. A build-up of abnormal conditions becomes consolidated and difficult to rectify if the requisite maintenance is postponed. A short shut down of a week or so at intervals of, say six months, enables timely preventive maintenance and inspection and reduces possibilities of long forced outages or difficulties in annual maintenance.

11.5 It is necessary to equip the plant with all the requisite scaffolding and special tools and

tackles etc., so that the inspection and maintenance can be carried out very quickly. Metal scaffolding that can be quickly erected is advantageous. The maintenance, tools and equipment should also be kept in good repair.

12. A survey of the boiler forced outage records of the above power plants shows that the following have been the principal causes accounting for most of the forced outage hours (FOH) roughly in their order of importance :—

1. Boiler Tubes Leakages (Water Wall tubes)
2. Super heater and economiser tubes leakages (due to erosion).
3. I. D. Fan Erosion.
4. Clinker formation (especially in stoker fired boilers)
5. Mill troubles (wearing of parts, fouling of lubrication system)
6. Raw coal feeder jamming.
7. Flame failure.
8. Leakages in valves.
9. Bearing troubles in I.D. & F. D. Fans.

These are discussed further under "Problems of Operation of Steam Power Station".

TABLE 4-4

SAMPLE SURVEY OF EQUIPMENT AVAILABILITY AND UTILISATION DETAILS OF POWER STATIONS

Sl. No.	Name of Power Station	No. of Units	Year of commissioning	Rated output (MW)	Steam conditions at stop valve		No. of Boilers per unit	Fuel used (Ash and Moisture %)	Remarks
					Pressure ata	Temp o.c.			
1	2	3	4	5	6	7	8	9	10
Group I : Stoker-fired Boilers, Non-Reheat Units (7 Units, 11 Boilers, 145 MW, 34 Unit Years)									
1	Khaparkheda (Maharashtra)	1	1960	30	59.7	482	2	Grade III (32.5%)	
		2	1964	30	59.7	482	2	Do.	
		3	1964	30	59.7	482	2	Do.	
2	Paras (Maharashtra)	1	1960	30	.	.	2	Grade II (32.5%)	
3	Barauni (Bihar)	1	1963	15	55	485	1	Oil	
		2	1963	15	55	485	1	„	
		3	1966	15	55	485	1	„	

TABLE 4-4—(Contd.)

1	2	3	4	5	6	7	8	9	10
Group 2 : Pulverised Fuel Boiler, Non-reheat Units (23 Units, 28 Boilers, 1324 Mw, 95 Units Years)									
1	Indraprastha (Delhi)	1	1963	36.6	61	482	2	Grade III	
		2	1967	62.5	89	510	1	Do.	
		3	1967	62.5	89	510	1	Do.	
2	Neyveli(Tamil Nadu)	1	1962	50	90	535	1	Lignite (54.60%)	
		2	1963	50	90	535	1	Do.	
		3	1963	50	90	535	1	Do.	
		4	1963	50	90	535	1	Do.	
		5	1964	50	90	535	1	Do.	
		6	1965	50	90	535	1	Do.	
		7	1967	100	90	535	2	Do.	
3	Korba (M.P.)	1	1967	50	90	535	1	(45.31)	
		2	1968	50	90	535	1	(45.31)	
4	Trombay (Maharashtra)	1	1956	62.5	85	510	1	Grade I slack (21.5%)	
		2	1957	62.5	85	510	1	Do.	
		3	1968	62.5	85	510	1	Do.	
5	Bokaro (D. V. C.)	1	1963	57.5	61	482	2	Middlings (31.5-35%)	
		2	1953	57.5	61	482	2	Do.	
		3	1953	57.5	61	482	2	Do.	
		4	1960	75	103	538	1	Do.	
6	Durgapur (D. V. C.)	1	1961	75	103	538	1	Middlings (38%)	
		2	1962	75	103	538	1	Do.	
7	Patratu (Bihar)	1	1966	50	90	535	1	Non-grade (32%)	
		2	1967	50	90	535	1	Do.	
Group 3 : Pulverised fuel, reheat units (8 units, 8 Boilers, 920 Mw, 32 unit years)									
1	Trombay (Maharashtra)	1	1965	150	170	565	1	Grade II slack (27%)	
2	Chandrapura (D. V. C.)	1	1964	140	127.6	538	1	Washery By- products (41-44%)	
		2	1965	140	127.6	538	1	Do.	
3	Durgapur (D. V. C.)	1	1967	140	127.6	538	1	Middlings (38%)	
4	Bandel (W. Bengal)	1	1966	87.5	103	538	1	Grade II (22-38%)	
		2	1966	87.5	103	538	1	Grade III B (29-36%)	
		3	1966	87.5	103	538	1	Middlings (34%)	
		4	1966	87.5	103	538	1		

TABLE 4-5
EQUIPMENT AVAILABILITY AND UTILISATION GROUP I

Year	Parti- culars	Khaparkheda (Maharashtra)						Paras (Maharashtra)						Barauni (Bihar)					
		Unit No. 1			2			Unit No. 1			Unit No. 1			2			3		
		B-1	B-2	TG	B-1	B-2	TG	B-1	B-2	TG	B-1	B-2	TG	B	TG	B	B	TG	B
1964-65	SH	6144	6870	7315	3613	3735	5124	3414	895	1983	7500	7775	8396	..	..	3329	3275	5411	5310
	MOH	1506	1022	926	..	855	..	883	1152	..	967	733	..	..	..	744	..	854	..
	FOH	206	325	328	336	264	83	452	..	64	202	251	363	..	..	3202	4000	118	1095
	AH	7084	7413	7506	8424	7641	8677	7425	7608	8696	7591	7776	8397	..	..	4814	4760	7888	7665
	%CF	..	..	55.40	..	..	59.80	..	..	40.20	..	..	62.2	..	..	..	22.3	..	38.3
1965-66	SH	7352	6542	7361	6570	6353	7281	6453	6865	..	8331	8034	8603	3495	3144	4873	4198	4322	3862
	MOH	1152	1152	..	1320	1032	..	1392	192	..	330	648	..	648	..	744	..	720	..
	FOH	177	157	..	104	86	..	221	460	..	98	77	156	744	3500	2363	3782	162	1342
	AH	7433	7473	8760	7330	7642	8760	7147	8108	8760	8332	8035	8604	7468	5260	5753	4978	7878	7418
	%CF	..	..	56.20	..	..	53.20	..	..	62.60	..	..	66.2	..	21.8	..	29.2	..	35.9
1966-67	SH	5250	5088	6919	6139	5684	7011	5341	6085	6868	8741	5560	8179	6562	6399	5872	5397	5652	1545
	MOH	1362	646	..	840	936	..	1128	867	..	..	2199	512	..	..	..	..	464	..
	FOH	175	742	336	..	115	48	747	248	144	19	..	67	2018	2181	128	603	370	1341
	AH	7225	7372	8424	7920	7709	8712	6885	7645	8616	8741	6561	8181	6742	6579	8632	8157	7926	7419
	%CF	..	..	61.20	..	..	62.00	..	..	67.20	..	..	59.8	..	45.9	..	40.5	..	35.5
1967-68	SH	6387	6257	8526	7423	7138	8539	7084	6616	8444	1200	1376	1376	5939	5749	4808	4678	7214	7086
	MOH	942	1032	..	607	1118	..	980	956	..	..	..	..	994	1994	704	1704	744	744
	FOH	461	1139	257	200	186	344	178	864	339	7583	7408	7408	1180	1170	531	660	457	213
	AH	7381	6613	8527	7977	7580	8540	7626	6964	8445	1201	1376	1376	6586	6594	6525	6396	7559	7803
	%CF	..	..	64.80	..	..	66.05	..	..	65.65	..	..	9	..	..	..	..	..	..
1968-69	SH	4815	5504	7045	6887	6556	8302	6465	7043	7123	8619	7210	8260	5733	5365	6335	6293	5580	5422
	MOH	1416	1944	1414	1104	1200	..	744	744	1315	..	1201	..	..	..	..	..	..	..
	FOH	1033	295	300	270	168	457	336	389	320	140	348	499	859	1227	412	655	2243	2400
	AH	6335	6545	7070	7410	7416	8327	7704	7651	7125	8620	7211	8261	7901	7533	8348	8105	6517	6360
	%CF	..	..	5.345	..	..	62.30	..	..	52.20	..	..	55.7	..	35.9	..	33.8	..	38.63

TABLE 4—6
EQUIPMENT AVAILABILITY AND UTILISATION GROUP 2

Year	Parti- culars	Indraprastha Station (Delhi)						Korba (M. P.)						Trombay (Maharashtra)					
		Unit No. 1			2			Unit No. 1			2			Unit No. 1			2		
		B-1	B-2	TG	B	TG	B	TG	B	TG	B	TG	B	TG	B	TG	B	TG	B
1964-65	SH	8136	8136	7962	..	..	..	..	..	..	..	..	..	6819	6819	7439	7439	6210	6210
	MOH	380	498	..	..	..	..	..	..	..	..	..	..	1860	1860	882	..	2218	2218
	FOH	244	126	797	..	..	..	..	..	..	..	..	..	..	..	81	22	417	107
	AH	8136	8136	7962	..	..	..	..	..	..	..	..	..	6900	6819	7856	8343	6434	6317
	%CF	..	..	59.15	..	..	..	..	..	..	..	..	..	..	..	65.5	..	67.7	..
1965-66	SH	8591	8606	8443	..	..	..	..	..	..	..	..	..	1568	1568	8698	8698	310	310
	MOH	..	..	..	..	..	..	..	..	..	..	..	..	..	..	7192	..	..	8187
	FOH	163	..	316	..	..	..	..	..	..	..	..	..	..	..	..	62	263	..
	AH	8597	8760	8443	..	..	..	..	..	..	..	..	..	8760	1568	8760	8698	573	573
	%CF	..	..	72.9	..	..	..	..	..	..	..	..	..	..	..	15.5	..	86	..
1966-67	SH	8473	8482	8259	..	..	..	..	..	..	..	..	..	..	..	..	5796	5796	8398
	MOH	168	168	..	..	..	..	..	..	..	..	..	..	..	..	..	2892	..	..
	FOH	96	110	501	..	..	..	..	..	..	..	..	..	..	..	..	..	72	328
	AH	8596	8482	8259	..	..	..	..	..	..	..	..	..	8760	..	..	5868	8698	8432
	%CF	..	..	70.8	..	..	..	..	..	..	..	..	..	..	..	..	..	52	..

TABLE 4-6—(Contd.)

1967-68	SH	8741	7856	8736	1678	1638	484	431	6444	6444	4900	4900	4470	4470	8512	8512	4288	4288
	MOH	..	886	..	..	..	..	..	140	..	468	..	..	4193	85	..	..	4354
	FOH	19	..	24	505	546	260	312	2175	23	2067	254	36	61	42	121	..	118
	AH	8765	7898	8760	1678	1638	484	432	6445	8737	5157	7338	8724	4506	8633	8639	8760	4288
	%CF	..	..	67.7	..	31.05	..	17.05	..	50.8	..	50.2	..	27.4	..	68.2	..	36.2
1968-69	SH	5488	7725	8518	8222	7812	7260	6937	3574	3574	7821	7821	8326	8326	1478	1478	7076	7076
	MOH	2242	757	..	..	168	..	..	4368	4368	..	..	252	..	..	7264	187	1234
	FOH	1030	277	241	538	179	1500	1722	810	7	920	18	60	122	..	18	94	169
	AH	5488	7726	8519	8222	7813	7260	7038	3582	4385	7840	8742	8448	8638	8760	1478	8479	7357
	%CF	..	..	50	..	45	..	43.25	..	29.7	..	64.6	..	74	..	13.3	..	64.7



TABLE 4-6—(Contd.)

Year	Particulars	Bokaro (D.V.C.)						Durgapur (D.V.C.)						Patratu (Bihar)					
		Unit No. 1			2			3			4			Unit No. 1			2		
		B-1	B-2	TG	B-1	B-2	TG	B-1	B-2	TG	B	TG	B	TG	B	TG	B	TG	B
1964-65	SH	8604	8600	8755	..	8580	8675	8736	7578	8740	6585	6572	5607	5502	7326	7259	..	..	..
	MOH	..	..	..	..	..	..	..	1103	..	2175	..	2692	..	..	..	..	..	..
	FOH	156	152	5	..	90	85	24	79	20	..	2183	461	3258	1434	1501	..	..	..
	AH	8604	8608	8755	..	8690	8675	8736	7578	8740	6585	6572	5607	3258	7326	7259	..	..	..
	%CF	..	..	81.7	..	..	78	..	..	71.8	..	51.88	..	41.9	..	54.1	..	..	..
1965-66	SH	5285	5528	6323	6706	6801	6858	8359	8678	8704	8273	8265	3584	3540	6631	6544	3071	2968	..
	MOH	1053	3199	2344	1902	1959	..	..	..	..	..	..	..	3636	1474	..	1554	228	..
	FOH	2422	33	93	152	..	1902	401	82	56	487	495	5176	1584	655	2216	1810	3220	..
	AH	5285	5528	6323	6706	6801	6858	8359	8678	8704	8273	8265	3584	3540	6631	6544	3076	2992	..
	%CF	..	..	51.8	..	..	62.2	..	..	78	..	55.85	..	27.9	..	50.9	..	38.7	..
1966-67	SH	7040	8095	8585	8534	8246	8667	6959	6688	8565	4393	4360	7805	7732	7326	7296	6690	6623	3095
	MOH	797	..	..	215	..	..	..	..	..	4133	3133	..	..	..	..	862	126	1016
	FOH	923	665	175	11	514	93	1801	2072	195	234	1267	955	1028	1434	1464	1207	2010	1013
	AH	7040	8095	8585	8534	8246	8667	6959	6688	8565	4393	4360	7805	7732	7326	7296	6691	6624	3095
	%CF	..	..	72.4	..	..	79.2	..	..	62.8	..	26.4	..	58.8	..	54.7	..	66.8	..

TABLE 4-6—(Contd.)

1967-68	SH	8044	7206	8662	6972	6973	8484	8368	7903	8690	2525	2473	5190	5157	3637	3513	6510	6060	13521	830
	MOH	296	1486	..	1213	1310	..	..	..	..	..	6027	286	86	4363	387	1254	1263	449	586
	FOH	420	68	98	575	477	276	392	857	70	6235	260	2284	3517	760	4860	746	768	..	5896
	AH	8044	7206	8662	6972	6973	8484	8368	7903	8690	2525	2473	5190	5157	3637	3513	6784	6753	8335	2302
	%CF	..	..	69.7	..	..	66.2	..	..	67.9	..	10.6	..	37.05	..	21.4	..	65.1	..	17.9
1968-69	SH	6651	8365	8510	6371	8659	8680	6479	7039	8103	1647	1577	6566	6451	7645	7658	..	..	..	..
	MOH	1827	..	..	1975	..	..	2158	1520	657	..	6025	..	1170	..	..	..	..	..	..
	FOH	282	395	250	414	101	80	123	201	..	7113	1158	2194	1139	1115	1102	..	..	..	..
	AH	6651	8365	8510	6371	8659	8680	6479	7039	8103	1647	1577	6566	6451	7645	7658	..	..	..	..
	%CF	..	..	61	..	..	56	..	..	34.4	..	11	..	37.1	..	45	..	..	..	..

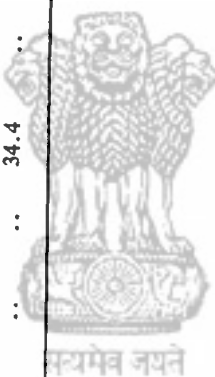


TABLE 4-6—(Contd.)

Neyveli (Tamil Nadu)													
Year	Particulars	Unit No. 1		2		3		4		5		6	
		B	TG	B	TG	B	TG	B	TG	B	TG	B	TG
1964-65	SH	4885	4885	5911	5911	4872	4872	6811	6811	6259	6259	..	..
	MOH	3570	3570	1942	1942	3373	3373	408	408	..	..	..	..
	FOH	28	275	..	906	442	72	1110	430	1768	51	..	..
	AH	5162	4925	6818	5912	4945	5315	7242	7922	6992	8709	..	..
	%CF	..	51.9	..	58.3	..	50.2	..	74.0	..	65.4	..	..
1965-66	SH	7533	7533	7195	7195	7227	7227	5866	5866	6099	6099	4264	4264
	MOH	..	..	..	1039	1039	..	..	2528	2528	2493	..	..
	FOH	118	1107	529	4	1212	320	165	199	167	..	352	641
	AH	8642	7653	7192	7717	7548	8440	6067	6033	7000	7167	8408	8119
	%CF	..	78.1	..	76.4	..	77.3	..	62.4	..	65.8	..	43.8
1966-67	SH	4633	4633	4782	4782	2813	2813	7185	7185	6420	6420	6560	6560
	MOH	3679	3679	2617	2617	5492	5492	..	..	1318	1318	..	..
	FOH	377	70	1311	47	453	..	1574	..	894	126	1318	881
	AH	4704	5011	4832	6096	2815	3268	7186	8760	6548	7316	7442	7879
	%CF	..	45.5	..	46.6	..	28.7	..	72.6	..	65.2	..	68.6

TABLE 4-6—(Contd.)

1967-68	SH	7337	7337	6783	6783	6388	6388	5042	5042	5148	5148	5540	5539	3665	3353	5200
	MOH	1200	1200	..	..	1042	1042	2366	2366	3276	3276	2514	2514	1990	1990	1990
	FOH	221	..	1374	601	933	395	711	639	48	286	453	252	1468	1468	101
	AH	7363	7584	7410	8183	6809	7347	5707	5079	5460	5222	5817	6018	5326	5326	6693
	%CF	..	76.7	..	72.8	..	65.5	..	53.4	..	52.8	..	59.8	..	..	45.8
1968-69	SH	7222	7222	5338	5338	6132	6132	6950	6950	7559	7559	6713	6713	4612	5099	4967
	MOH	761	761	2171	2171	1939	1939	982	982	278	278	1804	1804	3055	3055	3055
	FOH	406	369	657	592	357	331	694	132	922	..	242	..	606	606	131
	AH	7592	7639	5932	5989	6464	6490	7084	7646	7560	8482	6714	6956	5099	5099	557
	%CF	..	76.9	..	56.8	..	66.1	..	74.3	..	80.7	..	74.3	..	..	49.0

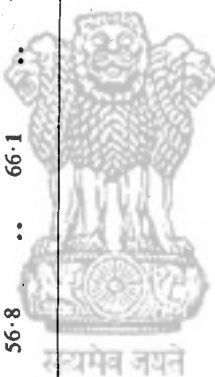


TABLE 4-7
EQUIPMENT AVAILABILITY AND UTILISATION GROUP 3

Year	Parti- culars	Trombay (Maharashtra)			Chandrapura (D.V.C.)			Durgapur (D.V.C.)			Bandel (W. B.)					
		Unit No. 1		B	Unit No. 1		B	Unit No. 3		B	Unit No. 1		B	Unit No. 1		B
		TG	B		TG	B		TG	B		TG	B		TG	B	
1964-65	SH	..	..	3676	3600	..	..	..	..	..	..	..	..	..	..	..
	MOH	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	FOH	..	..	693	769	..	..	..	..	..	..	..	..	..	..	..
	AH	..	..	3676	3600	..	..	..	..	..	..	..	..	..	..	..
	%CF	..	..	..	66.9	..	..	..	..	..	..	..	..	..	..	..
1965-66	SH	5854	5854	7580	7559	7150	7095	..	..	984	984	7472	7472	1398	1678	1678
	MOH	165	..	789	..	..	..	..	..	..	..	360	..	624	..	..
	FOH	154	330	391	1201	6110	1665	..	..	4776	..	..	..	72	..	..
	AH	6184	6173	7580	7559	7150	7095	..	..	3192	7986	8400	8760	1734	2430	2194
	%CF	..	66.2	..	66.4	..	59.7	..	..	..	7	..	33.3	23.7	..	45.3
1966-67	SH	5641	5641	7909	7850	7628	7601	1100	1056	2199	2199	6687	6687	2987	5785	5785
	MOH	3050	3050	..	..	1036	..	..	..	672	..	384	..	4056	768	..
	FOH	35	34	851	910	96	1159	1804	1848	3216	..	..	96	216	672	..
	AH	5675	5676	7909	7850	7628	7601	1100	1056	4872	8760	8376	8664	8544	4704	8760
	%CF	..	47.5	..	75.6	..	72.9	..	24.1	..	13.3	..	39.8	17.2	..	34.9

TABLE 4-7—(Contd.)

1967-68	.	.	.	.	SH	7767	7767	6142	6100	7533	7420	8262	8040	5828	5828	6058	6058	..	..	5645	5645
					MOH	..	..	2242	..	..	..	..	..	528	528	..	..	..	8784	938	..
					FOH	172	821	376	2660	1227	1340	498	720	..	..	216	..	..	..	384	..
					AH	8588	7939	6142	6100	7533	7420	8262	8040	8256	8784	8040	8784	8784	..	7462	8784
					%CF	..	64.5	..	57.2	..	68.3	..	74.2	..	50.2	..	44	..	..	..	40.5
1968-69	.	.	.	.	SH	8093	8093	7904	7840	5082	5038	8061	8004	7280	7280	4947	4947	5440	5446	6146	6146
					MOH	458	..	..	..	2482	491	..	..	1480	..	2376	..	209	1248	600	..
					FOH	82	127	856	920	1196	3231	699	756	..	..	1344	..	96	1752	1680	528
					AH	8220	8633	7904	..	5082	5038	8061	8004	7280	8760	8760	8455	8455	5660	6480	8332
					%CF	..	81	..	64.7	..	41.4	..	64.3	..	49.2	..	34	..	31.8	..	41



SECTION 9

PRICING OF COAL AND WASHERY BY-PRODUCT FUELS

1. The cost of fuel constitutes 30 to 65% of the cost of each kilo-watt-hour generated and is, therefore, by far the most important element of energy cost.

2. The cost of the fuel for a power station is composed of the cost of coal or washery by-products at the source and the cost of transportation and handling. The latter are discussed separately in this Report. In considering the pricing policy, it must be borne in mind that the power supply industry is given very little freedom in choosing the fuels for the different power stations. In the colliery areas, the large power stations are mostly linked to specific collieries or washeries and even the power stations situated far away from the collieries are usually tied to certain sources of coal, the choice in this being further narrowed down by the transport policy in regard to routing of coal traffic decided by the Railways from time to time. In consonance with the national policy of conserving better coal for metallurgical and other purposes, the power supply industry is obliged to use the inferior coals and the washery by-products. The low calorific value of these as well as the highly abrasive ash-content necessitates costlier installations of boiler plant and auxiliary equipment as well as very heavy charges of operation and maintenance and replacement of parts. These factors have to be kept in view in formulations for coal prices.

3. It is of interest in this connection to take note of the fuel policy formulated in the United Kingdom (UK) where the fossil fuels are now inadequate. In the Fuel Policy—White Paper (November, 1967), Her Majesty's Government has accepted the Power Industry's argument that the cost of special measures to support the use of

uneconomic fuels in power stations should be borne by the Exchequer and not by the Electricity Consumers. In terms of the coal industry Act, 1967, the cost reimbursable to the CEGB towards supporting the protection of Coal Industry amounted to £3.4 million for the period 1-8-67 to 31-3-68.

4. In the past, when the coal prices were controlled, the price of different grades of coal was not related directly to its heat-content (k Cal/kg.) Thus the cost of the low grade fuels (in terms of their heat content) worked out higher than that of high grade coals which were not permitted for burning in power stations. The lower calorific value also meant more cost on transportation due to the higher tonnage for the same heat value. The pricing was based on the argument by the mining organisations that the cost of mining for both the inferior as well as the superior coals was about the same and that, therefore, the prices could not be fixed proportionate to the heat content. Such system of pricing amounts to a hidden levy on the power supply industry, subsidising other uses of coal. This will have to be borne in mind if coal prices were to be controlled once more. Presently, the basic price levels for fuels for each power station are supposed to be fixed by free inter-play of supply and demand.

5. In our present conditions, the power supply industry, which is the largest consumer of coal and also practically the only consumer for inferior coals and washery by-products, should be entitled to get these fuels at an attractive price. The trade is still following the old gradation of coal which are not based on the heat value. The coal trade is not used to selling coal

on the basis of heat value and, therefore, some indirect formula has to be negotiated for achieving this objective. The following suggestions are based on recent experience in this regard:—

5.1 Firstly, the maximum permissible ash content should be specified (say 30%) so that inferior coals are eliminated. Then the price to be paid for this coal can be fixed on the basis of the tendered rates with a price adjustment clause for a short-fall in heat value. Thus, if the basic (tendered) rate is Rs. 28 per metric tonne and the calorific value is 6,000 kCal/kg, then a penalty of 25 paise per short-fall of 50 kCal/kg. will compensate for any changes in heat value. The actual price paid for the coal will thus be on the basis of its heat value, and would then work out to about Rs. 5 per million kilo Calories at the pit head.

5.2 In the case of washery by-products, the position is different because the price does not depend on tendered rate and free play of competition, as the washeries are almost entirely under the NCDC and HSL. In the past, the prices were subject to bilateral agreements which were based on the controlled rates for coal. One of the largest consumers of middlings/by-products paid for these on the equivalent in terms of coal of Grade III-B containing up to 35% ash less Rs. 2.50 per tonne. The equivalent in terms of middlings was calculated in the following manner:—

The ash content of the rejects and middlings was taken as 55 and 35 per cent respectively. Then the formula used was:

Middling Content:—

$$= \frac{(\text{Total tonnages of the mixture}) \times \{55 - (\text{Ash per cent in the mixture})\}}{20}$$

The denominator 20 represents the difference between the percentage ash content of rejects and middlings.

5.3 Thus it would be seen that the price of middlings/by-products was being fixed in terms of Grade III-B coal without making any allow-

ance for the extra cost to the Power station on account of deleterious effect of the high ash fuels and the higher cost of transport and ash disposal. As already discussed in the foregoing, these factors must be taken into account. The Energy Survey Committee of India which submitted its report in 1965 had considered the washery by-products as zero cost fuels. Even if this is not found acceptable by NCDC and HSL in actual practice, there is a clear case for a lower price for these. This can be worked out taking into account the loss of efficiency, plant availability and plant capability in power stations using such fuels. For middlings having ash content less than 32%, it may be reasonable to fix the price at a rate equivalent to that for coal of the same heat value less Rs. 2.5 per tonne. Recently, the Government has further exempted cesses on middlings/by-products in line with the recommendation made by the Tariff Commission. These are the minimum incentives that the Power Industry must insist on to maintain its viability and to compensate for the lack of freedom to choose its fuel according to its best interests.

6. The sizes of power stations are increasing continuously and the requirements of coal are growing. There would, therefore, be an increasing trend to tie certain collieries to specific power stations on a long term basis. Under these circumstances, it would be economical to have long-term coal contracts between the power stations and coal suppliers. The guarantee of a large steady market for the coal raisings will enable higher degree of mechanisation and rationalisation in coal production. While earmarking the collieries for power stations, planning of alternative sources will also have to be kept in view, particularly in view of possibilities of colliery shut-downs due to labour troubles or breakdown of rail transport facilities. These coal contracts should ensure that the prices as well as the quality of fuel (chemical composition as well as size) are stable. The stability of the price and quality of fuel will greatly facilitate progressive increase in the efficiency, dependability and working of the power stations.

SECTION 10

QUALITY OF COAL

The Table 4-8 gives the results of a survey of the quality of coal made available to the different power stations in the country vis-a-vis the quality of coal for which the respective boiler installations have been designed. Data of 52 coal-based steam power stations with installed capacity of 15 MW and above in operation for the year 1969-70 have been presented. These aggregate to an installed capacity of over 6.24 GW. Generally speaking the quality of coal is seen to meet the design requirements.

In a few cases (e.g. Bhusaval) the coal actually supplied was of better quality than that for which the boiler was designed (Higher calorific value, lower ash content). Such a condition also creates difficulties in operation and maintenance of the boilers and reduces equipment availability. The problem of utilisation of inferior grades of coal and washery by-products are in a class by itself and are discussed in a separate section.

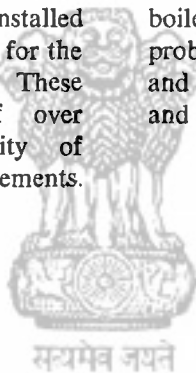


TABLE 4-8

QUALITY OF COAL—COMPREHENSIVE SURVEY OF QUALITY REQUIRED AND QUALITY AVAILABLE

(Data for the year 1969-70)

				Proximate Analysis of coal used					Quality of coal for which Boilers are designed							
Sl. No.	Name of the power Station	Installed capacity (MW)	Quality of coal available for burning in boilers	Ash %	Moisture %	Volatile matter %	Fixed Carbon %	Calorific value (kCal kg.)	Grade	Ash %	Moisture %	Volatile matter %	Fixed Carbon %	Calorific value (kCal kg.)	Remarks	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1	Ahmedabad	217.5	Selected	11-19	4-13	..	..	6110								
			Gd. I Slack	19.0	2.5	30.0	..	5833								
			Gd. II Slack	23.4	3.5	28.0	..	5550								
2	Agra	30.0	Selected A Slack	11.76	2.75	35.17	50.32	6878								
			Selected B Slack	14.04	4.85	33.43	47.68	6210								
3	Amarkantak	60.0	Gd. II Slack	21.10	6.22	27.66	845.00	5433		30-35	8-10	18-22	38-39	4900-5050		
4	Bhavnagar	16.6	Selected B Steam	19.68	3.93	32.31	44.08	6833	Gd. I Steam							
			Gd. I Steam	17.60	3.20	32.40	46.8	6400								
	Ballarshah	22.5	Gd. I Slack	12-16	6-10	30-25	..	5500-6000								
			Gd. II Slack	16.20	6.10	28-32	..	5400-5600								
	Bokaro	225.0	Washery middlings	29.31	2.85-4.5	23-25	..	5490-5795								
7	Bandel	330.0	Gd. II Middlings	25-28 29.8-34.8	..	30-32 20-22	..	5400-5595 5130-5510		35	10	22-24	..	4600		
8	Bhusaval	62.5	Gd. I & II	20-25	2.3	25.30	..	5500-5800								
			Pench Slack Chanda	22-30	4.5	25.28	..	5300-5600		28.35	10 max.	30	..	3600		
9	Barauni	45.0	Gd. III B Non-gd.	32.4	0.2-0.5	20-21.3	..	5233-5630		42	10	20	..	4000		
10	Chandausi	15.6	Rubble	8.02	1.54	35.44	..	6827							Earlier to 1969-70 %age of ash content in rubble was higher, for 1967-68, it was 16.26 fixed. In 1963-66 selected A steam was used.	
11	Chandni	17.0	Gd. I Slack	19.0	2.5	30.0	..	5833		23.2	12.2	23.3	38.9	5010		
			Gd. II Slack	23.4	3.5	28.0	..	5550								
			Gd. III Slack	24.0	2.0	28.0	..	5580								

TABLE 4-8—(Contd.)
 QUALITY OF COAL—COMPREHENSIVE SURVEY OF QUALITY REQUIRED AND QUALITY AVAILABLE
 (Data for the year 1969-70)

Proximate Analysis of coal used										Quality of coal for which Boilers are designed						
Sl. No	Name of the power Station	Installed capacity (MW)	Quality of coal available for burning in boilers	Ash %	Moisture %	Volatile matter %	Fixed Carbon %	Calorific value (kCal kg.)	Grade	Ash %	Moisture %	Volatile matter %	Fixed Carbon	Calorific value (kCal kg.)	Remarks	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
12	Chandrapura	420.0	Middling	37-38	4.1-5.8	19-20	..	4770-4930								
13	Calcutta	499.5	Selected A	10-14.5	4-7	30-34	..	6200-6600		12-15	8-10	30-34	..	..		
			Selected B	10-15	10-14	30-33	..	5900-6100								
			Gd. I	13-17	11-16	29-32	..	5700-6000								
14	Delhi (15MW)	15.0	Gd. II	23.00	5.0	23-28	..	4722-5444								
			Gd. III	32.35	2-6	19-24	..	4222-6110								
15	Delhi (Indraprastha)	36.6	Gd. II	23.00	5.0	23-28	47	4722-5444	Gd. III	32.25	2-6	19-24	5220-6110	..	On account of variation in moisture content, the Cal. value varies from 4722 to 5444 KCal/kg.	
			Gd. III	32.35	2-6	19-24	..	5220-6110								
16	Delhi (I.P. Sn. Extn.)	187.5	Gd. III													
17	Durgapur (W. Bengal)	285.0	ROM Gd. I & II Washery Sinks	20.00 34.60	6 1.3	30 18.7		5572 5190	No. 1 & 2 Boilers No. 3 & 4 Boilers Bo. 5 Boiler	31.5 38.0 40.0	10 8-10 6 (free) 2 (inherent)	28.8 19.2 18.0		4445 .. 4500		
18	Durgapur (DVC)	290.0	Middlings	32-34	3-4.8	18.5-19.8	..	5300-5525								
19	Ennore	60.0	Singareni Slack	24.08	6.42	23.82	45.68	5070	Pulverised coal							
20	Faridabad	15.0	Gd. I Slack	16-21	5-8	32.40	..	6555-6400	Gd. I Slack	6-21	5-8	32-40	..	5555-6400		
21	Gorakhpur	15.0	Gd. I Slack	13.86	5.29	33.14	..	6330	Gd. I Slack	16-21	5-8	32-40	..	5555-6400		
22	Gourepore (W.B.)	29.25	Selected A	14.10	2.80	37.10	46.0	6680	Selected A & B							
			Selected B	14.60	4.40	34.50	46.5	6422								
23	Harduaganj 'A' (New)	90.0	Gd. I Slack	19.00	4.00	31.00	46.0	..	(i) Gd. I slack (ii) Gd. II slack						(i) For John Thompson Boiler. (ii) For Hitachi Boilers.	
	Harduaganj 'A' (Old)	20.0	Gd. I	17.60	3.20	32.40	46.8	64000								
			Selected A	14.10	2.80	37.10	46.0	6422								
24	Harduaganj 'B'	100.0	Gd. II slack	20-25	1-6	30-34	43-47	5550-6000	Gd. II slack	20-25	1-6	30-34	43-47	5550-6000		
25	Hyderabad	22-25		28-30	5-6	20	50	4281-45567	Slack coal	..	..	..	..	4356		
26	Jaipur	15.5	Gd. I slack	115.5-17.80	5.6-6.0	21.4-26.5	52.3-56.8	5125-5611	Selected A	10.4	10	31	48.6	6160		
			{ Gd. I Steam	17.60	3.2	32.4	46.8	6400								

	27	Jabalpur .	.	15.	5	Gd. I	slack	19.0	2.5	30.0	5833						
28	Khaparkhedra .	.	120.00			Gd. II & } Kamptee II Gd. III } Kamptee III } West		18.0 20.0 23.0	10 10 4		5300 5100 5200 540 5200	*	25.0	7.50	28.5	39.0	5289
	Barkuhi					Ranwata		21									
	Verna					silewara		20.0	9								

[illegible]

TABLE 4-8—(Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
43	Patratu	• • • 200.0	Non-grade	22.25— 32.80	1.00— 7.10	26.2— 30.99	• •	4520—5400		39—45	12—6.0	40.0	• •	3080—3500	
44	Ranagudam	• • • 37.5	ingrauti coal	19.98	6.78	27.05	• •	4835	Slack coal]						
45	Renusagar	• • • 135.0	R.O.M. (Bingurda top ream)	30.13	14.23	25.10	30.54	3820		29.6	6.7	29.6	34.1	4650	Earlier Singarani coal was being used.
46	Sohwal	• • • 19.56	Gd. I slack	17.5	6.65	31.25	• •	5695	Gd. I slack]	17.5	6.65	31.25	• •	5695	
47	Ikka	• • • 16.0	Gd. I slack	18.70	3.70	22.30	55.30	6096							
			Gd. II	25.50	2.36	27.90	24.24	5687	Gd. I slack Select- ed slack.						
48	Shahpur	• • • 16.0	Gd. II slack	23.7	3.6	28.1	44.6	5545	Gd. II slack						
49	Satpura	• • • 250.0	Gd. III slack	32.5	3.98	26.02	38.5	5100 (Gross)	• •	40	10]	20	30	3811	
50	Talcher	• • • 250.00	Quality I	13.2—20	9.1—10	29.4— 38.4	• •	5150—5534		30—40	6—20	25.32	• •	7020—8840	
51	Trombay	• • • 337.5	Gd. I steam]												
			Gd. II slack	22.16	4.82	26.56	46.46	5555—5833							
			Gd. I slack	19.0	2.5	30.6	• •	5833							
52	Uttaran	• • • 67.5	Gd. I slack	14.76— 19.94	3.13— 7.78	• •	• •	5597—5874							

*For unit No. 4
only.Now converted to gas
firing since 1965.

SECTION 11

UTILISATION OF BY-PRODUCTS FROM COAL WASHERIES IN THERMAL POWER STATIONS

1. The Government of India, on the recommendations of the Middlings Utilisation Committee and the Energy Survey Committee, have laid down a policy that the boilers of the Public Utilities should use inferior coals and those tied to the coal washeries should use middlings or by-products having an ash content of upto 45%. This policy was adopted firstly to conserve good metallurgical coal and secondly to use by-products left over after washing medium quality metallurgical coal for use in the steel plants. Accordingly, 14 coal washeries have already been established in the country and are in operation. One or two additional washeries are also in operation but these are captive washeries and are not contributing any fuel for the power supply industry. Presently two-product washeries are predominant so far as their output of by-product fuels (floats etc.) is concerned. The availability of these by-product fuels will also increase quite substantially in the current plan both from the two-product and three-product washeries.

This position is quite in accordance with the recommendations of the Energy Survey Committee of India. This was based on the presumption that boilers when suitably designed would be quite capable of burning inferior coals and, therefore, can be employed to utilise the left-overs of the washeries. The Energy Survey Committee of India thus concluded that the balance of advantages lies with the two-product system of washeries so long as markets are available for the use of the by-products for electricity generation and other uses. The Authorities of the Power Stations, who have been using middlings and by-products from the washeries over the past few years, have, however, found from actual experience that under the conditions obtaining here,

the operation of their thermal power stations has been suffering very badly on account of the quality of fuel. The availability of the boiler plant and equipment has gone down and the capability is also seriously affected, leading to reduced output from the large power stations. The working has been made even more uneconomical by the high rate of wear and tear on the plant and now there are grave doubts as to whether utilisation of washery by-products as *practised presently* serves the interest of overall national economy. Table 4-9 gives the relative proportion of usage of the by-product fuels by different organisations. It is seen that by far the biggest user of the by-product fuels is the D.V.C. group of power stations. Experience regarding fuels from different sources and operation of equipment of different makes under the same management is available in the D.V.C. This is a valuable base for study.

2. A case study of the Chandrapura Power Station of the D.V.C. has been made. This power station, designed to utilise Dugda Washery middlings, was the first one to be planned to use middlings with high percentage of ash and every care was taken to see that the boilers were suitably designed.

2.1 Firstly, the quality of middlings to be expected was assessed with the help of Central Fuel Research Institute who worked on a pilot plant for the purpose. This indicated that the composition of the middlings and combination of middlings and rejects may be expected to include the following respectively:—

Ash	30.1%	35.5%
Moisture	1.2%	1.3%
Volatile material	20.5%	21.9%
Calorific value Kcal/kg.	5645	5022

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As against this, the DVC, after discussions with boiler manufacturers and other authorities, specified a fuel having the following analysis :—

Ash	38 to 43%
Moisture	4 to 6%
Volatile material	15 to 13%

2.2 While ordering the boilers, the DVC also specified the following :—

Location	Max. Gas Temperature Degree °C.	Max. Gas Velocity Meters per second	Min. clear space between Tubes (mm)
Superheater Platen	1100	8.23	250
Reheater Platen	980	9.45	125
Reheater Inlet	870	13.41	75
Horizontal Superheater	815	17.68	50
Economizer	Lower	11.38	50

2.3 It was hoped that this specification and the provision of combination mechanical-cum-electrostatic dust collector would mitigate the erosion due to fly ash. In the contract for fuel with the HSL and NCDC, it was stipulated that in case the ash content exceeds the ceiling of 42%, no payment would be made.

2.4 The first 140 MW reheat unit with steam at 123.5 atm., 537°C and 537°C reheat was commissioned in November, 1964. Further identical units were commissioned in May, 1965 and July 1967 respectively.

2.5 Dugda-I Washery (3 stage) owned by M/s. Hindustan Steel has been supplying Chandrapura about 0.36 million tons of middlings and rejects with an ash content of about 35 per cent. Dugda-II Washery which is only a 2 Stage Washery was commissioned in September, 1968 and the supply being received is about 0.7 million tons of by products with an ash content of 40 per cent. The quality of the by-product fuel received from Dugda Washeries and used at the station was as given below. (Upto September, 1968, when Dugda-II was commissioned, the washery products were insufficient. The station

fuel was a blend of raw coal and had a somewhat lower ash content).

	Dugda By-products-Ash	Station Coal-Ash
1964-65	34.94%	34.92%
1965-66	35.63%	33.70%
1966-67	35.06%	33.39%
1967-68	36.23%	33.86%
1968 (upto end of Aug., 1968)	34.86%	34.28%
1968-69 (Sept., 1968-March, 1969)	37.20%	36.80%
1969-70 (April-Dec., 1969)	37.75%	37.75%

The above figures are averages for these periods. Monthly averages have been upto 41.6 per cent and daily averages have been even higher. The quality of fuel has thus progressively deteriorated.

2.6 The effects of use of by-products having such high ash content have been as follows :—

(1) Inability of the generating units to carry full load due to sharp fall in the capacity of pulverising mills. The unit output has been reduced from 75 MW to 55 MW at Durgapur (DVC).

(2) Increase in the coal mill outage for maintenance of mill parts like bullring, rolls and exhausters fans.

(3) Appreciable burner erosion resulting in instability of fire. Unit No. 3 was put on commercial operation on August 1, 1968 but by July, 1969, it showed appreciable burner erosion. On the other hand, Units 1 and 2, with station coal having around 33 per cent ash could carry on without comparable erosion on burners for two years. The instability of fire has resulted in unit outage with considerable system disturbances despite use of expensive oil support during low load periods. There were 36 outages due to fire-out on units 2 and 3 during 1969.

(4) Increase in the quantity of ash handled. The abrasion on ash handling plant has created problems of ash disposal resulting in ash build-up in the dust collector and consequent poor performance.

(5) Increase of wear on I.D. fan. This has reduced the capacity of the units from time to time. Unit No. 2 has had shut down at I.D.

fan on 8 occasions from April, 1969 to October, 1969 and Unit No. 3 on 3 occasions. (Unit No. 1 was out for some other reason).

(6) Serious progressive deterioration in over-all plant efficiency. The annual efficiency figures are given below:—

1965-66		35.18 per cent
1966-67		35.15 „
1968-69		34.55 „
1969-70		31.81 „
(8 months)		

Drop in efficiency of about 3.34 per cent means increase in fuel consumption by about 10 per cent.

(7) The statutory overhaul of Boiler No. 1 in 1965-66 was done in 789 hours and of Boiler No. 2 in 1966-67 in 1036 hours but overhaul of Boiler No. 1 in 1967-68 took 2241 hours and of Boiler No. 2 in 1968-69 as much as 2482 hours. Thus the overhaul period has increased by one month i.e. about 8 per cent. In other words, 8 per cent more generating capacity has to be provided (on account of lower plant availability) in order to be able to meet the same load demand. In a system with 4 million kW installed capacity, this would mean about 300 MW, the cost of which would be about Rs. 54 crores.

(8) The additional installations and lower efficiencies also mean additional costs on fuel raising, transport and ash disposal. Huge additional investments will thus be necessary if we are not able to operate our thermal stations in a better manner.

3. The West Bengal State Electricity Board has also had similar experience in the operation of their Bandel Thermal Power Station. The monthly average ash content of the station coal has varied from 28% to 33% in 1967, 29.4% to 34.6% in 1968 and 27.2% to 31.1% in 1969. The station coal includes washery by-products, the proportion of which has recently been reduced with a view to improving the plant performance. The Annexure 4-2 gives the troubles encountered and the remedial measures taken.

4. The experience at other plants of D.V.C., Bihar etc. also fully supports the findings of the above study. We are thus now in a position to arrive at rational scientific conclusions, based on

the experience in Indian power plants, of utilisation of washery middlings such as become available from the Indian coal washeries. The earlier views on the subject a few years back had, in the absence of experience under Indian conditions, been based on expectations in the light of experience elsewhere. It would now be in the fitness of things to modify these earlier views and policies to suit the Indian conditions, so that the maximum conservation of natural resources as well as the best possible utilisation of financial and other resources can be achieved. It is only in this manner that economic and technically satisfactory working of washery based power stations can be achieved. Taking into account the studies embodied in the report of the Energy Survey of India Committee and other bodies as well as the experiences related above, the following conclusions are arrived at:—

(i) Utilisation of coal washery by-products is a necessity from the larger national view-point for conserving the supplies of coking coal, improving the economics of coal supplied for different uses and for disposal of large volume of washery by-product.

(ii) It is the abrasive content of the ash that plays havoc in the boiler plant and equipment. The deleterious effects of ash itself are relatively less. It is, therefore, necessary to equip each washery with adequate equipment for removal of stones and other abrasive material. The ash content should also be reduced preferably to 28-32%.

(iii) To achieve the above, it is necessary that steps should be taken immediately in the existing coal washeries to reduce the abrasive material and to ensure that ash content does not exceed 28-32%. Further, it must be laid down that the future washeries should be on 3 State ones and equipped with adequate arrangements for removal of stones and other abrasive material.

(iv) Detailed studies and tests would be necessary on the present inputs and products of the two-stage washeries to establish the extent to which lower ash middlings can be produced and the additional washing machinery required. Studies for this should be instituted, possibly at Central Fuel Research Institute immediately.

(v) It is recommended that a practical timetable for taking the above corrective actions must

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be established immediately jointly by all concerned. We feel that the corrective actions in respect of the existing washeries should not take more than two years for becoming fully operative.

(vi) The factors responsible for erosion damage to the boiler plant and equipment have so far eluded scientific identification. Research work for this should be initiated immediately.

(vii) Design, construction and material in the boiler plant, appurtenant plant and equipment require considerable further attention for devising ways and means of living with washery by-

product fuels. The existing power plant installations should be fully utilised making field trials of different new innovations or designs of equipment for this purpose. The equipment requiring attention is the coal mills, I.D. fans, layout and arrangement of super-heater and economiser tubes, ash handling disposal systems, design and arrangement of burners. It is strongly recommended that our nascent boiler plant manufacturers and manufacturers of appurtenant equipment approach this problem earnestly in collaboration with the organisations owning and operating the existing power stations, so as to evolve the necessary Indian technology.



TABLE 4-9
PRODUCTION OF WASHERY BY-PRODUCTS AND THEIR DESPATCHES TO POWER STATIONS, STEEL PLANTS AND OTHERS DURING 1969-70.
 (Figures in thousand tonnes)

Sl. No.	Name of Washery	Stock as on 1-4-69	Production 1969-70	Supply to Thermal Power Stations										Supply to Steel Plants				Stock as on 1-4-70	Plant consumption Power & domestic	Remarks															
				Total	D.V.C.					Bandel T.P.S. Trombay D.P.L.					TISCO	Rourkela	Bhilai																		
					Bokaro	Durgapur	Chandrapur	Tata T.P.S.	Durgapur	Trombay D.P.L.																									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19																	
TWO PRODUCT																																			
1	Lodha	11.8	110.2	122.0	..	..	..	90.7	..	..	..	..	..	..	2.9	93.6	23.4	5.0																	
2	Dugda II	..	676.4	676.4	..	..	671.0	..	..	..	..	..	..	..	..	671.0	0.2	5.2																	
3	Durgapur (D.P.L.)	..	136.0	136.0	..	..	..	..	..	136.0	..	..	..	..	..	136.0	..	..																	
4	Bhojudih	127.5	312.2	439.7	..	..	..	..	..	..	..	..	..	..	..	..	439.7	..	In the absence of outlet the by-products are being dumped.																
5	Kathara*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	*Under trial run.																
6	Swang*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	**Under construction.																
7	Gidi** (Blendable)	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..																	
TOTAL																			139.3	1234.8	1374.1	..	..	671.0	90.7	..	136.0	..	..	..	2.9	900.6	463.3	10.2	
THREE PRODUCT																																			
1	West Bokaro	10.2	121.8	132.0	..	..	..	191.0	9.0	..	104.6	..	..	..	24.3	104.6	14.2	13.2																	
2	Jamadoha	0.4	282.9	283.3	34.3	..	..	..	..	..	15.5	..	..	..	..	274.1	0.1	9.1																	
3	Kargali	..	378.7	378.7	378.7	..	..	..	..	..	..	0.9	2.1	..	..	378.7	..	..																	
4	Dugda-I	20.1	274.4	294.5	..	..	270.8	..	..	..	..	..	..	..	..	273.8	15.8	4.0																	
5	Patherdih	14.6	489.6	504.2	..	424.8	7.7	62.2	..	..	..	..	..	..	..	494.7	9.5	0.5																	
6	Durgapur (HSL)	28.5	268.3	296.7	..	258.5	..	..	..	..	..	..	..	..	15.2	273.7	22.5	0.5	This washery was completed by the end of 1969.																
7	Chasnalla	..	22.0	22.0	..	..	..	..	..	..	..	..	..	..	5.0	5.0	17.0	..																	
TOTAL																			73.8	1837.6	1911.4	413.0	683.3	278.5	253.2	9.0	..	120.1	0.9	2.1	44.5	1804.6	79.1	27.7	
GRAND TOTAL																			213.1	3072.4	3285.5	413.0	683.3	949.5	343.9	9.0	136.0	120.1	0.9	2.1	47.4	2705.2	542.4	37.9	

Source : Deptt. of Mines and Metals.

TABLE 4—10
BROAD PATTERN OF THE LINKAGE OF POWER
HOUSES WITH COAL WASHERIES

<i>Power House</i>	<i>Washery</i>
1. Bokaro	Kargali
2. Durgapur (DVC)	Durgapur (HSL) Patherdih
3. Durgapur (PPS)	Durgapur (WB)
4. Bandel	Londa (1)
5. Chanderpura	Dugda I Dugda II
6. Patratu	Kothara Gidi Sawang
7. Santaldih	Bhojudih

(1) Only a small quantity of middlings from Lodna is taken by Bandel. If this Power House could make blending arrangements, it would provide an outlet for Bhojudih middlings till such time as Santaldih comes up.

(2) Middlings from Kathara and Swang may be partially diverted to the new Power House which the Bokaro Steel propose to set up at their works.

(3) Durgapur (DVC) is supplied from Jama-doba also though not formally linked.



SECTION 12

**TRANSPORT OF COAL TO THERMAL
POWER STATIONS—UNIT TRAIN****1. Introduction :**

1.1 At the end of the Second Plan, there were very few large thermal power stations in the country. The coal consumption of most of these stations was less than half-a-million tons per year. The coal supply to these stations was also not linked to any particular colliery. Most of the coal for these stations was being obtained after calling yearly tenders. The transport of this coal was, therefore, being done from the various collieries in wagon loads as per the requirements of the various collieries. During the course of the Third Plan, construction of a number of Thermal power stations with unit sizes of 50 and 100 MW was taken up and by the end of 1969, a number of these had been completed. The coal consumption of some of these stations will be of the order of a million tons per year. Most of these stations have been linked with particular mines and long-term coal contracts are being drawn between the power station authorities and the mines. This will, therefore, involve constant movement of coal between two points. Such large quantities are best transported by means of unit train instead of wagon loads. The Power Stations are now in a position to take continuously a rake load of coal and the railways will not have to marshall wagons to form rakes every time at the junction stations. The basic change in the unit train concept is in handling coal by train load instead of wagon load lots.

1.2 In the unit train concept, normally the train uses bottom discharge type of wagons so that after coming to the station, it moves very slowly over the hoppers and the bottom dump wagons are discharged one by one without stopping the train. At the mine end also, the train

does not stop, but is continuously loaded by chutes while the train is moving at a slow speed. No tippler is required at the power station for unloading purposes and there is no waiting time at the station, the reduction in time, therefore, at the power station and the mine considerably increases the turn around of the wagons and hence reduces the capital investment on the rolling stock. On unloading at the destination, the train would immediately proceed back to the mine, load and return. No time is to be lost between loading, unloading and running. In such a service, the railway operation stimulates a conveyor belt. By adoption of unit train, it would be possible to increase the speed of the trains and thus to save time in the running time of the trains. Moreover, the inspection of the wagons, which is normally done after about 400 KM, can be planned in a proper manner. The stoppages of the unit train could be arranged at such stations where inspection facilities are available. There need be no other stoppages of the unit train.

1.3 Various devices are used to open the doors of the wagons for unloading. They vary from simple mechanical type to electronic devices, with the help of the latter, it is possible to unload full train loads of 10,000 tons from 6½ to 15 minutes.

1.4 In addition to the doing away of wagon tipplers, the space requirement for marshalling yard at the station and the length of railway track are considerably reduced. It is also no longer necessary to employ shunting locomotives at the station.

2. Use of Unit Train in advanced countries :

2.1 This concept was first introduced in U.S.A. where the thermal power stations were

utilising gas and oil in addition to coal for power generation. The various types of fuels had to compete each other and this led to reduction in the cost of the various types of fuels. In the face of this competition, the unit train concept came into being there. The railways had to recognize that if the coal industry, which was one of their best customers, was to compete successfully against the growing popularity of the other fuels, coal had to be delivered to power plants at a much lower cost than was possible under the existing high freight structure. The serious consideration given by the coal industry and the utilities since 1960 to pipeline transportation of coal further led rail roads to re-shape their thinking and in 1962, the concept of unit train was born.

2.2 In U.S.A., it has been estimated that unloading by wagon load lots costs about $4\frac{1}{2}$ cents per ton, whereas unit train unloading by hopper gates costs about one cent per ton, the handling time being reduced by a factor of 10. In spite of rising cost of labour and materials, the average cost of transport has come down. Factors, which reduce the cost per ton, are higher wagon utilisation (in spite of an empty return) and higher load per wagon. These can be seen from the comparative estimates for conventional and unit train operations to transport 1.5 million tons of coal a year, on the basis of study made in U.S.A., as per the data given in the Table below:—

Conventional Vs. Unit Trains—Comparative cost of Transport (1.5 million Tons of coal)

	Conventional	Unit train
Wagon Capacity (Tons) .	63	100
Loads per wagon per year	2,175	150
Tons per wagon per year	1,370	15,000
Wagons required	1,095	100
Costs per wagon (\$)	10,600	13,300
Total investment on wagons (\$)	11,607,000	1,330,000
A mortization per year (\$)	1,145,000	131,000
Cost per ton (\$)	0.763	0.087
Extra capital investment over unit train operation (\$)	10,267,000	..

Sources : Snoffer, R. D. and Hanson, V. D.—The Unit Train —Planning Operating and Financing, Coal Age, March, 1964, p. 54.

2.3 In the U.S.A., a train rake comprises of 100 to 200 wagons constituting a train load of 6000 to 15000 tons of coal per rake. The train haulage loads even range from 35,000 to 40,000 tons.

2.4 In United Kingdom also, all movement of coal at present to the various stations is being done by bottom discharge type wagons and merry-go-round unit train. The CEGB are using a 32 ton capacity wagon whenever feasible, unit train having a pay load of 1000 tons. On the introduction of unit train there, the retention of the wagons at power station was reduced from 24 hours to one hour. Storage sidings at the station were practically eliminated and the total lengths of track at the station reduced from an average of 26 KM to an average of 7 KM.

Significant benefit accrued to British Railways from this development, wagon building programme was cut to half and the utilisation of locomotives and train crew was intensified. This resulted in new tariffs in 1962 reflecting the reduction in costs achieved with the new system. In India at present, rakes of 45 wagons containing about 2500 tons of coal or train loads of 3600 tons are being hauled. Such trains as unit trains can, therefore, meet the complete annual requirements of a power station.

3. Prospects for use of unit train in India :

3.1 The Energy Survey Committee (1965), in its report, had suggested that closed circuit unit train movement of coal should be investigated for certain large power plants, which were contemplated for location away from the coal fields. The World Bank Mission, which was investigating methods of improving the capacity of the Indian Railways, had gone into this question in detail and it had found that in circumstances, where a minimum quantity of 400,000 tons of coal per year had to be transported, the unit train movement offered a considerable advantage. The World Bank Mission had calculated the tariff for such closed circuit movement based on the cost figures supplied to them for such operations.

These are given below:—

Distance in Km.	Tariff rate per tonne in wagon loads (Oct., 1963)	Calculated rate for closed circuit operation by unit trains
	Rs.	Rs.
50	6.16	1.37
100	7.33	2.20
200	9.90	3.87
300	13.28	5.54
400	15.33	7.21
500	17.13	8.88
600	18.82	10.55
700	20.33	12.22
800	21.66	13.89
1000	24.58	17.23
2000	34.73	33.93

Source : Energy Survey Committee Report (1965)—Page 134.

3.2 The Energy Survey Committee had calculated the cost of movement of coal by unit trains at Rs. $(0.53 + 0.0167 \times \text{KM})$ as against Rs. $(3.94 + 0.343 \times \text{KM})$ for car load lots, based on a 10% return on capital. The present day tariff per metric ton for transportation of coal is based on the formulae i.e. Rs. $5.52 + 0.032 \times D$ in Km for distances upto 240 KM and Rs. $7.50 + 0.027 \times D$ in Km for distances upto 1,000 Km. The effect of reduced cost on coal transport by this method is considerable on the cost of energy per KWH. The Energy Survey Committee has indicated rail cost per KWH of 1.47 paise for a distance of 600 Km. for car load lots against 0.63 paise for coal movement in closed circuit unit trains.

3.3 The comparative cost for transport of fuel in wagon load lots by closed circuit unit trains and transport of energy by EHV transmission lines is also indicated below:—

Distance in Km.	Cost per kwh (paise)		
	By wagon lots	By unit train	Transmission of Energy by EHV Transmission lines 300 MW at 70% L.F.
1	2	3	4
50	0.43	0.12	0.26
100	0.52	0.20	0.39
200	0.72	0.35	0.56
300	0.90	0.50	0.75
600	1.44	0.94	1.31

(Based on the data presented by the Energy Survey Committee which is given in Table 4-13, the above data has been brought up to present price levels).

On the perusal of the above Table, it will be seen that EHV transmission of energy is cheaper than transport by rail by conventional method i.e. by wagon load lots for all distances, whereas transportation of energy by rail by unit train is even cheaper as compared to EHV transmission of energy. The transportation of energy by rail by unit train is the cheapest. Keeping in view overall national interest we must adopt ways and means which would bring down the overall cost to the nation. Savings in this regard can be shared by the Railways and Power Supply industry to mutual benefit.

3.4 We have plentiful natural resources of non-coking low grade coal. In addition, an economic outlet has to be found for the surplus by-product coal (middlings) obtained by the beneficiation of low grade metallurgical coal. Large thermal power stations are being generally set up near the source of these fuel resources. However, in certain cases, it may be more advantageous to locate such stations at the load centre and these may also be required to be established in regions away from coal fields for firming up hydro-power. In some cases, it may be essential to establish thermal stations of sizable capacity at points remote from coal pits from the point of view of grid stabilisation and also to make zones of supply self-supporting in the case of unforeseen extensive damage to interconnecting transmission lines.

3.5 Further, these have to be located both from the consideration of availability of fuel as also availability of water. The latter is also a major consideration and even the mine-mouth stations may have to be located at places where plentiful supplies of water are readily available. In other cases, coal may have to be moved to the power stations from central washeries. Rail transport is, therefore, mostly involved in the transport of coal from the source to its ultimate use.

In the absence of closed circuit rail movement, with the present coal freight structure, even a short haul of middlings has become uneconomical. In order, therefore, that these resources are able to compete with other sources of energy, it is necessary that the freight rates of transport of coal to various power stations are based on

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the unit train concept of coal movement, if power has to be generated economically using these re-trains is adopted.

3.6 The cost of fuel constitutes about 80% of the running cost or about 50% of the overall cost of generation of electrical energy in thermal power stations. The cost of transport by rail at places further from collieries may constitute anywhere upto about 55% of the cost of fuel delivered to the station. Thus, the cost of rail transport is a major item forming 15 to 25% of the cost of energy generation, depending on the distance of power station from the fuel source. The freight structure at present applicable to fuel transport needs early review.

3.7 With a view to working out the relative economics of the various modes of transportation of energy, a study has been made in respect of the principal thermal power stations. The volume of transportation of coal is indicated in Table 4-11 & 4-12. The Table 4-11 contains data in respect of the volume of coal consumptions and railway freights etc. for the year 1968-69. Table 4-12 contains data in respect of the volume of coal consumptions and freights in respect of the year 1973-74 (by end of Fourth Plan). The estimated freights for the transportation of coal for the year 1973-74 have been worked out on the basis of transportation of coal by (i) conventional methods i.e. by wagon load lots and (ii) by unit trains. From Table 4-12 it will be seen that an annual saving upto Rs. 10.82 crores would be

possible in case transportation of coal by unit trains is adopted.

3.8 In the concept of unit train for movement of coal, the fact of return of empty wagons to the coal mines after unloading of coal at the power stations may seem to be a disadvantage. But it has been proved in advanced countries like U.S.A., U.K. etc. that the cost of transportation of coal works out to be far less in respect of unit trains as compared to the cost of transportation by wagon loads, in spite of 100% return of empty wagons. In the case of Indian Railways, it is understood that the average proportion of 'empties' is 50 to 60 per cent. There are, however, areas where there are 100% 'empties' after transport of coal. It is, therefore, suggested to initiate the transportation of coal by unit train in those areas where the percentage of empties is 100% or so.

3.9 The above data are being furnished as a ready basis for further study. It is suggested that the matter may be examined in depth by the Railway Board in consultation with the C.W. & P.C. so as to evolve better methods of transportation which would bring down the overall cost to the nation.

4. The concept of transportation of coal by unit train has been adopted by Madhya Pradesh Electricity Board for transportation of coal for Korba-II (200 MW) Thermal Power Station from Manikpur Colliery located at a distance of 10 km. from the power station. Their experiences are given in Annexure 4-3.

TABLE 4-11

REGIONWISE REQUIREMENTS OF RAIL TRANSPORT FOR COAL FOR POWER STATIONS—1968-69

Sl. No.	Zone	Name of Station	Capacity (MW)	Estimate annual coal consumption mil. tonnes	Quantity Trans-ported by Rail Mil. Tonnes	Quantity Colliery/Washery from which transported	Approximate distance in Km.	Price of Coal Rs. per tonne	Transport cost Rs. per tonne	Annual Freight Rs. Million	Annual Coal Traffic in Million Tonnes Km.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Eastern Region	Chandrapura	420	0.97	..	Dugda Middlings	2.75 to 24	20.67 to 28.43	1.94 to 4.25	..	..	By belt conveyor and by road.
2		C. E. S. C.	499.5	1.28	1.28	West Bengal Coal Fields	200	35.23	14.50	18.560	256	
3		Bandel	330	0.53	0.53	Patherdih, Jama-doba	200	27	13.50	7.155	106	
4		Durgapur (D. V. C.)	290	0.79	0.30	Patherdih & D.S. P. Washeries	50	28	11.50	3.45	15.0	By road, by Belt Conveyor and Rail.
5		Durgapur (West Bengal).	285	0.55	0.43	Middlings & W. B. Coal	30-115 (av-50)	28	6 to 11 (avg. 8.50)	3.655	21.50	
6		Bokaro	255	0.55	..	Kargali/Bermo Mines Washery	15	29	3.50	..	..	By Aerial Rope-way.
7		Patratu	150	0.25	0.25	Kathara Giridih and Sawang	35	29.86 to 32.53	11.00	2.75	8.75	
8		Barauni	45	0.05	0.05	Raniganj, Giridih	200	27.19 to 31.53	16.50	0.825	10.00	
9		Talcher	187.5	0.75	..	Talcher	9	31.0	0.54 to 1.00	..	..	Belt Conveyor.
TOTAL			2462.0	5.72	2.84					36.395	417.25	

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TABLE 4-11—(Contd.)
REGIONWISE REQUIREMENT OF RAILS TRANSPORT FOR COAL FOR POWER STATIONS—1968-69

Sl. No.	Zone	Name of Station	Capacity (MW)	Estimate annual coal consumption mil. tonnes	Quantity transported by Rail Mil. Tonnes	Quantity Colliery/Washery from which transported	Approximate distance in Km.	Price of Coal Rs. per tonne	Transport cost Rs. per tonne	Annual Freight Rs. Millions	Annual Coal Traffic in Million Tonnes Km.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
10	Western Region	Satpura	250	0.37	..	Patherkheda	3	30.20	..	..	..	Belt Conveyor.
11		Korba	300	0.55	..	Mainikpur Ghordera	10	16.73 33.29 (under arbitration)	1.52	..	..	
12		Khaper-Kheda	120	0.40	0.40	Silwara C. I. Coal pits (Pench Valley Kampta).	9 to 69 164 (av. 50)	31.0	5 to 10.30 (Rs. 8 av)	3.2	20.0	By road, By Rail
13		Paras	92.5	0.30	0.30	Ditto	276 to 364	31.17	13.90 to 4.425 15.60 (av 14.75)	..	96.0	
14		Bhusaval	62.5	0.10	0.10	C. I. Coal pits (Pench Valley Kampta)	400 to 511 (av 450)	31.17	13 to 21.60 (av 17.30)	1.730	45.0	
15		Amarkantak	60.0	0.21	..	Ditto.	..	..	..	..	..	Pit mouth.
16		Chola	136.0	0.30	0.30	Ditto.	9.50	..	33.64	10.092	285.0	
17		Trombay	337.5	0.25	0.25	Ditto.	955.00	39.17	33.64	8.410	238.75	Only 30% Coal and Oil.
18		Dhuvaran	254.0	..	..	..	..	..	..	..	..	
19		Ahmedabad	217.5	0.52	0.52	..	1200	33.0	30.20 to 37.35 (av. 33.25)	17.290	624.0	Coal and Oil.
20		Utran	67.5	0.36	0.36	..	1000	33.0	34	12.24	380.00	Coal 50% rest Oil and Gas.
TOTAL			1897.5	3.36	2.23					573.87	1668.75	
21	Northern Region	Delhi	290	0.57	0.57	Bihar	1250	31.67 (Grade II)	37.50	21.375	712.50	

TABLE 4-11—(Contd.)

REGIONWISE REQUIREMENTS OF RAILS TRANSPORT FOR COAL FOR POWER STATIONS—1968-69

Sl. No.	Zone	Name of Station	Capacity (MW)	Estimate annual coal consumption mil. tonnes	Quantity transported by Rail mil. tonnes	Colliery/Washery from which transported	Approximate distance in. Km.	Price of Coal Rs. per tonnes	Transport cost Rs. per tonne	Annual Freight Millions	Annual Coal Traffic in Million Tonnes Km.	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
22		Kanpur	152	0.62	0.62	Bihar	800	35.0	33.00	20.46	496.00	
23		Harduaganj	210	0.36	0.36	Ditto.	1100	36.0	39.00	14.04	396.00	
24		Obra	150	0.44	0.44	Suigruli	300	30.00 (Grade II)	19.00	8.36	132.00	
25		Renusagar	135	0.45	..	Ditto.	..	30.90 (Grade II)	..	..	..	Aerial Ropeway.
TOTAL			937	2.44	1.99					64.235	1736.50	
26	Southern Region	Kothagudem	240	0.62	0.62	Singaraeni	30	35.92	11.00	6.82	18.60	
27		Ramgundam	37.5	0.05	0.05	Ditto.	30	35.92	11.00	0.55	1.50	
28		Nellore	30	0.12	0.12	Ditto.	300	30.00	20.00	2.40	36.00	
29		Basin Bridge	87.5	0.24	0.24	Singareni C.F. and Bihar.	1000	32.00	36.00	8.64	240.00	
30		Neyveli	400	2.60	..	South Arcot	..	18.00	..	..	..	Belt Conveyor (Demand restricted to about 2.6 million ton.
TOTAL			795.0	1.03	1.03					18.41	296.10	
GRAND TOTAL			6091.5	12.51+2.60 Lignite	8.63					176.427	4118.60	

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TABLE 4—12

[REGIONWISE REQUIREMENTS OF RAIL TRANSPORT FOR COAL POWER STATIONS—1973-74]

NOTE.—Power Station Units below 10 MW capacity have not been taken in to account (Assumption coal consumption at 2.8 tonnes/KW of installed capacity)

Sl. No.	Zone	Name of Station	Capacity MW	Estimated annual coal consumption million tonnes	Quantity transported by million tonnes	Approximate distance in KM	Annual coal traffic in million tonnes	Freight Rate Rs./tonne	Annual freight in Rs. (Mill.)	Freight charges per prevalent rate	Freight rate Rs./tonne	Annual freight in Rs. (Mill.)	Freight charges based on unit train concept	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13		
1	Eastern Region	Chandrapura	660	1.85	..	..	..	..	..	..	..	..	..	
2		C. E. S. C.	443	1.24	1.24	200	228	11.92	14.780	6.00	7.44			
3		Bandel	330	0.92	0.92	200	184	11.92	10.966	6.00	5.52			
4		Santalidih	240	0.67	0.67	30	20.1	6.80	4.556	3.00	2.01			
5		Durgapur (DVC)	290	0.81	0.40	50	20.0	7.12	2.848	3.00	1.20			
6		Durgapur (W. B.)	285	0.80	0.40	50	20.0	7.12	2.848	3.00	1.20			
7		Bokaro	255	0.715	..	..	..	..	..	..	..	..	..	
8		Patratu	620	1.74	1.74	35	60.90	6.80	11.832	3.00	5.22			
9		Barauni	145	0.14	0.14	200	28.00*	11.92	1.668	6.00	0.84	*1/3 coal, rest oil		
10		Talcher	250	0.70	..	..	..	..	..	..	..	..	..	
TOTAL			351.8	9.585	5.51		561.00		49.498		23.43			

TABLE 4-12—(Contd.)

REGIONWISE REQUIREMENT OF RAIL TRANSPORT FOR COAL POWER STATIONS—1973-74

NOTE.—Power Station Units below 10MW capacity have not been taken in to account) (Assumption coal consumption at 2.8 tonnes/KW of installed capacity)

Sl. No.	Zone	Name of Station	Capacity MW	Estimated annual coal consumption million tonnes	Quantity transported by million tonnes	Approximate distance in KM	Annual Coal traffic in million tonnes	Freight charges as per prevalent rate		Freight charges based on unit train concept		Remarks
								Freight Rate Rs./tonne	Annual freight in Rs. (Mill)	Freight Rate Rs. tonne	Annual freight in Rs. (Mills.)	
1	2	3	4	5	6	7	8	9	10	11	12	13
Western Region												
11		Satpura	312.5	0.88	0.400	50	20.00	7.12	2.848	3.00	1.20	
12		Korba	300.0	0.84	0.336	60	10.16	7.44	2.499	4.00	0.44	
13		Khaperkheda	120.0	0.336	0.26	200	52.00	11.92	3.099	6.00	0.56	
14		Paras	92.5	0.26	0.175	400	70.00	18.00	3.150	11.00	1.925	
15		Bhusawal	52.5	0.175	0.168	950	361.00	33.4	12.692	24.00	9.12	*Rest oil
16		Amarkantak	60.00	0.168	0.38	955	191.0*	34.00	8.50	24.00	6.00	
17		Chola	136.00	0.38	0.25	900	360.0*	32.3	12.920	24.00	9.60	*1/3 coal & rest oil
18		Trombay	337.50	0.25	0.40	1000	170.0*	34.5	5.865	24.00	4.08	
19	Western Region	Dhuvaran	534.0	0.40	0.17	1000	126.0	34.5	4.347	24.00	3.024	
20		Ahmedabad	180.0	0.17	0.126	30	20.1	6.8	4.556	3.00	2.01	
21		Uttaran	45.0	0.126	0.67	400	312.0	18.0	14.040	11.00	8.58	
22		Koradi	240.0	0.67	0.78	400	67.2	18.0	3.024	11.00	1.85	
23		Nasik	280.0	0.78	0.168	400	67.2	18.0	3.024	11.00	1.85	
24		Parli	60.0	0.168								
TOTAL			2760.0	5.603	4.115	1769.46		77.540		50.293		
Northern Region												
25		Delhi	314	0.88	0.88	917	806.960	32.80	28.864	24.00	21.12	
26		Kanpur	152	0.428	0.428	483	206.724	20.70	8.859	13.50	5.778	
27		Hurduaganj	300	0.84	0.84	804	675.36	30.60	25.704	20.00	16.80	
28		Obra	550	1.55	1.55	60	93.00	7.44	11.532	4.00	6.20	
29		Renusagar	125	0.35	0.35	950	186.00	33.40	6.546	24.00	4.704	
30		Faridabad	70	0.196	0.196	950	796.00	33.40	28.056	24.00	20.16	
31		Badarpur	300	0.84	0.84	1215	747.225	39.50	24.292	28.00	17.220	
32		Bhatinda	220	0.615	0.615							
TOTAL			2031	5.699	5.349	3511.269		133.853		91.9820		

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TABLE 4-12—(Contd.)

REGIONWISE REQUIREMENT OF RAIL TRANSPORT FOR COAL POWER STATIONS—1973-74

NOTE.—Power Station Units below 10MW capacity have not been taken in to account) (Assumption coal consumption at 2.8 tonnes/KW of installed capacity)

Sl. No.	Zone	Name of Station	Capacity MW	Estimated annual coal consumption million tonnes	Quantity transported by million tonnes	Approximate distance in KM	Annual coal traffic in million tonnes KM	Freight charges as per prevalent rate		Freight charges based on unit train concept		Remarks
								Freight Rate Rs./tonne	Annual freight in Rs. (Mill)	Freight Rate Rs./tonne	Annual freight in Rs. (Mills)	
1	2	3	4	5	6	7	8	9	10	11	12	13
33	Southern Region .	Kothagudam .	460	1.29	1.29	2.0	2.58	6.80	8.772	3.03	3.87	
34		Ramagundam .	100	0.28	0.28	30.0	8.40	6.80	1.904	3.00	0.84	
35		Nellore .	30	0.084	0.084	450.0	37.800	19.50	16.38	28.00	2.352	
36		Basin Bridge .	118	0.505	0.505	650.0	328.250	25.50	12.877	18.00	9.09	
37		Neyveli .	600	4.2 (Lignite)	4.2 (Lignite)	..	..	..	..	..	..	
38		Ennore .	330	0.60	0.60	650.0	390.00*	25.50	15.300	18.00	10.80	*Partly Oil
TOTAL			1638	2.759+ 4.2 (mill. ton lignite)	2.759	767.030		40.491			26.952	
GRAND TOTAL			9947	23.646+ 4.2 (Lignite)	17.733	6608.759		301.382			192.657	

NOTE.—Freight rates in Col. 10 have been assumed as those calculated by Energy Survey Committee for closed circuit Operations by unit trains increased by about 50% to account for general/freight increase during the period 1963-70. The rates have been assumed as under :—

Distance in km.	50	100	200	300	400	500	600	700	800	1000	1200
Freight rate	3.00	4.00	6.00	8.50	11.00	13.50	16.00	18.00	20.00	24.00	28.00

TABLE 4—13
COMPARATIVE COSTS FOR TRANSPORT FUEL
AND ELECTRICAL ENERGY

Distance (Km)	Cost per kWh (Paise)		
	By wagon load lots	By unit train	Transmission of Energy by EHV Transmission lines 300 MW at 70 % L.F.
50 . .	0.34	0.08	0.20
100 . .	0.44	0.13	0.30
200 . .	0.65	0.23	0.43
300 . .	0.85	0.33	0.58
600 . .	1.47	0.63	1.01

Source : "Energy Survey Committee Report (1965)"—
—pages 133-135.



SECTION 13

RATIONALISATION OF FREIGHT STRUCTURE FOR TRANSPORT OF COAL OVER SHORT DISTANCES

The Railways, at present, have a fixed tariff for transportation of coal for short distances upto 40 Km. The various power stations, viz., Chandrapura, Talcher, Satpura have adopted transportation of coal by belt conveyors, whereas power stations like Bokaro have adopted transportation by aerial ropeways. For Durgapur (DVC) power station, transportation of coal is being done by belt conveyor as well as by rail. The amount of freight being paid by various power stations located within 50 Km. from the source of coal is tabulated as under:—

Coal Traffic for Thermal Power Stations Year 1968-69			
Name of Station	Coal transported in million ton	Coal traffic in million ton Kilo-tre	Annual freight paid in Rs. mill.
Durgapur (DVC)	0.30	15.0	3.45
Durgapur WB)	0.43	21.50	3.655
Patratu	0.25	8.75	2.75
Khaperkheda	0.40	20	3.2
Kothagudam	0.62	18.6	6.82
Ramagundam	0.05	1.5	0.55
TOTAL	2.05	85.35	20.425

It will be seen that for transportation of 2.05 million tonnes, the freight charges upto Rs. 2.04 crores are being paid annually i.e. at an average rate of Rs. 10.00 per tonne. Usually, it has been seen that it does not cost more than Rs. 5.00 per tonne for such short distance haulage by other means like belt conveyors, aerial ropeways etc. Obviously, the freight being paid by the various power stations is very high and the Power Supply Industry is carrying an unnecessary burden. In the absence of a rationalised freight structure, it is not possible to determine as to what is the most economical method of transportation for coal for power stations which are located close to the source of coal as such comparison gets distorted. It is, therefore, essential that the Railways should rationalise the tariff structure for short distances so that the most economical alternatives, out of the three available alternatives, viz. (i) belt conveyors; (ii) aerial ropeways; (iii) by railways, could be adopted in the interests of the minimum economic cost to the Nation. There is also perhaps room for reduction of the rates.

SECTION 14

POLICY OF PRICING FOR PETROLEUM FUELS

1. The petroleum fuels used for large thermal stations in the country are variously named as residual fuel oil (RFO) or hot heavy stock (HHS). The former term is used in the case of Koyali Refinery in Gujarat supplying Dhuvaran and Ahmedabad, while the latter term is used in case of supplies from Indian Oil Corporation (IOC) to Barauni Power Station and supplies from ESSO and Burmah Shell Refineries to the Trombay Power Station in Bombay. Both these products are substantially the same. They are by-products of the refineries, and unless these are utilised as they are produced, the output of the refineries will be seriously affected for want of adequate storage facilities for these.

2. Policy of Pricing :

2.1 Power stations like Dhuvaran and Barauni have been designed and constructed for utilising these by-product fuels. However, it is found that the prices charged for these by-product fuels are substantially higher than those for coal per unit of heat content. The price is generally around Rs. 100 per metric tonne for the hot heavy stock or residual fuel oil. The only exception is Dhuvaran Power Station of the Gujarat State Electricity Board. They are presently receiving RFO to the extent of 1050 tonnes per day at Rs. 45 per tonne and natural gas from Cambay Gas Field to the extent of 130,000 m³/day at Rs. 62.86 per 1000m³. It is, however, understood that these prices are valid only for a limited period of time. It is understood that prices of these by-product petroleum fuels are generally being decided on the basis of cost of alternative fuels (providing the same heat value) in that area. Alternatively, the price of

fuel oil is being fixed by IOC on the import parity basis. When the crude oil production was in its infancy, the import parity pricing was probably the only solution possible and in view of the small quantities of indigenous crude, it was rational to fix the price on the basis of crude prices in the Persian Gulf area which supplied major portion of the crudes. Continuance of this practice now, however, does not appear to be rational and perhaps gives a substantial margin of profit to the IOC at the cost of the power supply industry.

2.2 For most of the other products which are used by a large number of consumers, ceiling prices are being fixed. Prices have been prescribed even for furnace oil as it is used as fuel by many industries. No price has, however, been prescribed in this manner for HHS or RFO. It is understood that this has been done in view of the fact that HHS and RFO are being sold by the producers directly to the actual users who are very few and, at the same time, big and strong enough to be able to negotiate reasonable prices. In practice, however, this is not found to be the case and the power supply industry is obliged to pay very high prices. It may be noted here that the price ceilings fixed for other petroleum products from the refineries do not depend on the prices arrived at mutually by the suppliers and consumers for HHS or RFO. The price of these consumer items will not, therefore, go up even if lower prices are negotiated for the power station fuels.

2.3 One of the main impediments in proper pricing of these fuels is that no proper costing

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has apparently been done so far for the production cost of oil crudes obtained in India. The need for such costing has already been pointed out by the Oil Pricing Committee (Ministry of

Petroleum etc.) and others. It is, therefore, necessary to expedite an appropriate study in this regard for the different oil and gas fuels in the country.



SECTION 15

AVAILABILITY OF PETROLEUM FUELS

1. Presently, the main use of HHS and RFO is as fuels in large thermal power stations. There are other proposals of using these, as well as the gas, materials for petro-chemical industries. If these possibilities materialise, future availability of these products as fuels may be restricted or even stopped.

2. It is understood that there are already proposals for withdrawing the fuel gas and perhaps also HHS from Dhuvaran, for use as raw materials by the fertiliser factories. This will seriously upset the working of Dhuvaran power station which has been designed for these fuels. If coal is now to be used as a major fuel, substantial initial investments may have to be made for adequate coal storage and handling facilities and other auxiliaries.

3. Barauni Power Station in Bihar is another case in point. The site of the Thermal Power Station was located at Barauni due to its proximity to the Oil Refinery and the possibility of getting full requirement of furnace oil for the power plant. In the year 1963, in a discussion held with the Ministry of Mines and Fuels, the Bihar State Electricity Board was assured the supply of 2,20,000 tons of furnace oil annually with effect from 1966. A direct pipe line from the Refinery to the Power Station had also been proposed for delivery of oil and the Bihar State Electricity Board paid over Rs. 6 lakhs to the Refinery for installation of this pipe line. Following this agreement, Electricity Board made certain changes in the coal receiving, storing and handling arrangements in the power station and concentrated on proper arrangement for receiving furnace oil, storing it in the premises and for

burning the furnace oil in all the 5 boilers of 145 MW power plant. Nearly a crore of rupees have been spent on making these arrangements for the above purposes. The modified coal handling arrangement is limited to burning of coal as a stand-by fuel only.

3.1 L.S.H.S. and furnace oil, which are by-products are now being supplied to the Barauni Thermal Power Station by the Refinery. The supply is being made by truck and railway wagons because the pipe line has not yet been made ready by the Refinery. The maximum off-take per month has reached a figure of nearly 7,000 tons for operation of 3 units only. (1×50 MW and 2×15MW). When another unit of 50 MW is commissioned shortly, the requirement of furnace oil will increase to 15,000 tons per month. In addition, there is a proposal to extend the Barauni Thermal Power Station by installation of one more 110 MW unit in the 4th Plan with boiler having only oil firing arrangement. Then the requirement of oil per month will go up by another 10,000 tons. As a matter of fact, there is a scheme for installing a second 110 MW unit at Barauni in the Five-year Plan. Thus the total requirement of fuel by Barauni Thermal Power Station during 4th Plan period will go up from 15,000 tons to 25,000 tons per month.

3.2 It is now suddenly learnt from the Fuel Adviser of the IOC that the production pattern of the Barauni Refinery is being altered and the Bihar State Electricity Board will now receive only 9,000 tons of residual oil for burning in the boilers. This means that the power production in the North Bihar region will have to be considerably curtailed in the near future. This will naturally result in idle capacity which will

ruin the economic working of the Electricity Board besides involving heavy national loss. Coal firing can be re-introduced in some of the units but for this purpose several modifications in the coal storing and handling arrangements will have to be made for which nearly half a crore of rupees may have to be invested by the Electricity Board. Besides, there is shortage of space for coal storage. Also, there is no adequate reserves of coal in the Giridih mines and, therefore, arrangements may have to be made for supply of coal to Barauni from the distant Jharia coal-fields which will increase the cost of power further.

4. It is evident from the above that there are certain serious lacunae in the matter of forward planning in regard to petroleum fuels in large thermal power stations. In response to an enquiry from the P.E.C., the Ministry of Petroleum has replied as follows:—

“It has been observed from our end studies done in this Division for 1968, that about 22.6% of fuel oils consumed during that year were used for power generation. It will be difficult for us to give any assessment for the share of Fuel Oil to be used for Power Generation in future years. However, as per our latest estimates, the total consumption of Fuel Oils during 1970 to 1979 will be as under:—

Year	Million tons
1970	4.777
1971	5.118
1972	5.656
1973	6.452
1974	6.756
1975	7.083
1979	8.662

It is not possible for us to give the estimate for availability of Fuel Oils during these years, as some proposals for putting

up secondary processing units in certain refineries are under consideration of this ministry and the availability of Fuel Oils will significant vary with the acceptance or rejections of these proposals.”

4.1. As already stated in the case of Barauni Power Station, non-availability of these fuels coming up without warning can prove disastrous to the programme of power generation and hence to the programme of industrial and agricultural growth in the areas depending on petroleum fuels. This is a very serious matter and action must be initiated immediately to ensure that advance planning of at least five years or so is available at all times. It is further essential that representatives of the appropriate power station authorities/ Electricity Boards be associated with this planning work from the beginning. In the interest of power generation programme, it is also necessary that firm long-term contracts are entered into with the Suppliers of petroleum fuels so as to ensure stability of prices as well as quality of these fuels. This is necessary in the interest of reliable and economic power generation.

5. In the light of the forgoing, it is strongly recommended that commitments already made regarding supply of petroleum fuels to power stations should be honoured fully in future also. Owing to the shortcomings of the planning in this respect mentioned in the foregoing, it is possible that certain compulsions may arise in this regard. In case of power stations based entirely on petroleum fuels, if it turns out that the petroleum fuels are not likely to be available in future, these power stations should be taken into confidence and given a warning sufficiently in advance to enable their making alternative arrangements. The power stations should be compensated for the additional costs involved in changing over to other fuels.

PROBLEMS IN OPERATION OF STEAM POWER STATIONS

Operation of the Steam Power Stations in India has been studied with a view to identifying the important causes of forced outages or reduction of capability of the generating plant. In a number of cases, valuable lessons can be drawn for improving the design and performance in future. These studies are primarily based on the larger thermal power plants which contribute the greater part of thermal energy generation in India. These include the power stations of the D.V.C., nine large State Electricity Boards as well as some other important stations like Renu Sagar, Neyveli etc. Care has been taken to cover power stations belonging to all the 3 groups of equipment parameters mentioned in the review of installations earlier. The causes as well as the possible remedies are given briefly in the following. These are arranged according to the different sub-systems of the Thermal Power Stations. Only the Thermo-Mechanical Systems are covered here and the Electrical Systems will be covered jointly with Hydro Power Stations and Electrical Grid Systems.

1. Coal Handling :

1.1 Pilferage :

With the introduction of 8-wheeler open BOX wagons for coal movements, the pilferage is on the increase. The railways must take effective measures to prevent pilferage of coal from the wagons on the way from the Collieries to the Power Station.

1.2 Ingress of iron along with coal :

Selection of the mode of coal transportation is done considering the distance of the Power Station from the coal mines. On Power Stations

near the coal mines and washeries belt conveyor system is often used for transport of fuel. If adequate provision is not made to separate tramp iron at the source, it is carried with the fuel on the conveyor. Sometimes the tramp iron with sharp edges may cut the belt conveyors resulting in interruption in fuel supply to the units and heavy maintenance expenditure. Unless the magnetic Separators are efficient, ingress of iron causes feeder jams, and if it finds passages to the pulverisers, forced outage of the affected pulveriser mill as well. In a direct system of pulverised fuel (PF) firing, such intrusion results either in erosion of generating capacity or, in some cases, loss of ignition leading to tripping of the unit, particularly in case of reheat installations.

In so far as the Bin System of firing is concerned, any interruption in the milling plant may or may not result in loss of generating capacity, but a ferrous intrusion foreign to the pulveriser is fraught with the danger of the equipment suffering damage and prolonged outage.

Tramp iron does not form part of coal bands in the mines, but finds its place at the time of coal mining or stacking before loading coal in wagons. This is an avoidable trouble provided collieries take care to see that loose pieces of iron are not left at the place where coal is stacked at the mine. This sort of trouble cannot be entirely eliminated, but much improvement can be effected by annexing the co-operation of the colliery authorities.

1.3 Bunker arching :

Arching in coal bunkers, either due to cessation of mass flow of coal, or formation of rat holes, is a common phenomenon. In the first

case, the bunker inclination has a positive role to play. It should be such as to facilitate easy flow, about 55 degree valley angle with the horizontal being considered ideal. Proper choice of crushed coal particle size also has important bearing on flow. If the coal is too fine and wet, chances of arching are enhanced. Power Stations installed in areas having high rainfall should therefore have covered conveyors while ensuring that coal is crushed to proper size.

The collieries should supply the contracted size coal so that crushing at the station can be regulated; otherwise, if supplied with too much fines, station will not be in a position to avoid arching in the bunkers. Co-operation of colliery authorities is essential, and preferably, fines below 1/16" should not be supplied.

1.4 Bunker fires :

There is an attempt on the part of utility concerns to procure increasingly better quality of coal, sometimes even Gr. I or even selected Gr. for pulverised fuel (PF) installations designed to burn inferior coal in the hope of achieving higher combustion stability. This invariably means high volatile matter (VM)—low ash coals at least in the Eastern Region. Such coals are susceptible to spontaneous combustion in the yard as well as in the bunkers. This trend of using higher grades of coal for pulverised fuel (PF) installations designed for low grade coal should be discouraged. Utility concerns should be won over to using the right type of coal for which the particular installation may have been designed.

1.5 Coal Handling :

Special attention is to be paid and proper equipments are to be installed in the coal handling plant for dust suppression as the dust nuisance poses a problem for good housekeeping and also the dust hinders the smooth operation of the equipment.

2. Coal Mills :

Type of mill system for different coals suitable in the country needs investigation.

2.1 In direct-fired installations outage of coal mill means either erosion of generating capacity or standby availability, as the case may be. Hence particular attention must be paid to the choice of equipment for given service conditions.

However, it has been the experience of D.V.C. that, irrespective of the type of mill used—whether suction type or pressure type—some control over the quality of coal, in respect, especially, of alpha-quartz is necessary. It has been established that erosion of the milling plant, burner, boiler pressure parts and fans, is very much associated with the amount of alphaquartz present in coal. Choice of coal, should therefore be such as to ensure nominal alphaquartz in the coal received by the station.

2.2 The D.V.C. has recently entered into an agreement with the Central Fuel Research Institute to develop means of economically and effectively isolating alpha-quartz from coal. Research in respect of the same has already been initiated by C.F.R.I.

2.3 If a comparison is drawn regarding the performance of the two types of coal mills installed in D.V.C. Power Stations, namely, Raymond type suction and Ball type pressure mills, it will be seen that pressure mills have an edge over the suction type mills. This is mainly because of the fact that the primary air (PA) fans for the pressure mills handle clean air, while exhausters for the suction mills have to handle pulverized coal and suffer heavy erosion in the process.

2.4 However, for pressure mill installations, where primary air fans are used, generative type of air preheaters seem to offer hindrance as they tend to pass appreciable amounts to fly ash with the forced draft air. As a result, the PA fans suffer erosion and get unbalanced during operation. Recuperative type air preheaters would appear to be more suitable for such installations.

2.5 The indigenous manufacture is so far confined to only the tubular air preheaters.

3. Boilers :

3.1 Mode of firing :

D.V.C. has had the experience of using for many years all types of firing in pulverised fuel (PF) boilers. It has been operating front-fired boilers at Bokaro (Boilers 1, through 6), corner-fired boilers at CTPS (reheat Boilers 1, 2 and 3), downshot-fired boilers at Durgapur (Boilers 1 & 2) and at Bokaro (Boiler 7) and downshot-fired boiler with double arch at Durgapur (reheat Boiler 3). The quality of coal generally specified for pulverised fuel (PF). Installations in this

country, including that of middlings, closely approximates Gr. III B or Gr. III A coal. Hence there cannot be much of variation in coal characteristics particularly in the Eastern Region so far as the proximate analysis goes. It is our considered opinion that, based on operating statistics, downshot-fired boilers with double arch are ideally suited for PF installations in our country, since the boiler installed at Durgapur Unit 3 has returned maximum operating stability over a period of 3 years of operation and, consequently, the availability factor has also been very high. Chances of loss of ignition and consequent explosion in such installations are remote, if operated with due care and caution. Efficiency-wise, this boiler is well comparable with any of the other installations. The burner design is simple and rugged, and the rate of erosion has been negligible during the period of study.

3.2 Initial Firing

This depends on the quality of oil/gas employed. Some power stations have reported that light oil or kerosene would not give satisfactory results with high tension electrical spark. Natural gas has given satisfactory results in these cases.

3.3 Flame Failure :

This can occur due to choking of burners or insufficient supply of coal or due to feeding of inert matter with coal; and may even lead to furnace explosion. In addition, during low load operation, too sudden changes in loading, consequently in firing rates can cause flame failures.

3.4 Furnace explosions :

3.4.1 This trouble has been experienced in some pulverized fuel fired boilers. The resultant damage to water walls, refractories and structural can be very extensive, leading to prolonged shut-downs for repairs at heavy costs. The boiler outage due to this in one case, for example, has been 4,700 hours.

3.4.2 The physics of furnace explosion is rather intricate. Normally, the fuel injected into the boiler furnace does not reach beyond the space occupied by the flame. The fuel is burnt up almost completely within the flame. In case of flame failure, a large volume of boiler furnace gets charged with fuel dust in suspension. This burns explosively when ignited spontaneously or

otherwise. The question of flame going out arises only at low loads. Under these circumstances, a supporting oil flame is usually provided. Sometimes, however, the trouble with the flame going out has been experienced at loads as high as 70% when the fuel got mixed up with inert material in coal-yard, and no oil support is present.

3.4.3. One solution has been to use oil support at all loads. But this is a costly proposition. The operation of the power system in a manner such that the thermal generating units are not required to operate at low loads or fluctuating loads can completely eliminate the danger of furnace explosions and also minimise the need for costly oil support.

3.4.4 In case of oil and gas fired stations, furnace explosions may result from inadvertent admission of fuel before starting or after shut-down of the boiler and by spontaneous combustion or normal light off. Positive shut off valves for fuel control and thorough purging of furnace before and after shutting down the boiler are essential.

3.5 Slag formation :

This is a serious problem which may cause curtailment of generating capacity or even complete forced shut-down. Usual reasons for this are:—

- (i) Change in the quality of coal from that specified;
- (ii) Defective design of burners;
- (iii) High furnace heat release leading to very high temperature. This is often due to use of a higher grade coal than specified. In one case, the furnace temperature reached 1600°C, whereas the ash melting point was about 1400°C.

Apart from proper care in operation and maintenance, the following remedial measures may be useful:—

- (i) Increase in the fineness of the pulverised fuel.
- (ii) Adjustment of burner velocity and direction;
- (iii) Effective soot blowing-use of water blowers in the furnace;

(iv) Use of excess air (This should not, however, be so much as to affect the efficiency of the boiler).

(v) Reducing the output of the boiler.

3.6 Fly ash erosion :

3.6.1 Tube failures due to fly ash erosion are not infrequent in pulverised fuel (PF) boilers. But these could be minimised to a large extent by judicious selection of gas velocities on the one hand, and by incorporating baffle plates or shields on the other at suitable locations in the boiler second pass, especially on the rear side, with a view to protecting tubes from the erosive effects of fly ash. However, location of shields would depend on actual observation of erosion.

3.6.2 In order to protect the induced draft fans, installation of electrostatic precipitators in all pulverised coal fired units is imperative. The dust collecting plant should be such as to operate at an efficiency of no less than 96 to 97%. In one of the DVC installations, where such a high efficiency could be achieved, none of the two ID fans installed needed any attention in 3 years, whereas in another installation, where no electrostatic precipitator has been provided and the efficiency of which is comparatively much lower, each of the 2 ID fans needed maintenance and balancing once every two months for the first 8000 hours of operation, once every month for the next 4000 hours of operation and once every 15 days for the next 6000 hours of operation. Ultimately, the ID fan impellers lost their aerofoil design characteristics due to constant rebuilding and were severely derated.

3.6.3 The aerofoil design ID fan impellers lose capacity rapidly due to wear. As such, for Indian coals the backward vane type or the axial fans are better suited. One problem that may occur with axial fans is that at very low loads (30%) it may be necessary to run only one set of fans as the fan characteristics are such that the two fans cannot be made to share the load equally.

3.6.4 In case of dual fired boilers (oil and coal) mechanical and electrostatic precipitators should be oversized by 15 to 20% as otherwise there will be frequent load restriction resulting from clogging and for subsequent cleaning.

3.7 Internal conditioning :

The importance of close control of internal conditioning of steam—condensate—feed—water—boiler water cycle, for high pressure—high temperature installations can hardly be over-emphasised. If proper conditioning is ensured, internal corrosion and consequent failure can almost be totally eliminated. Acid cleaning of boilers once every 3 to 4 years of operation might also be additionally helpful, depending upon the mode of treatment being followed. Qualified experts in the line should be entrusted with the task of maintaining a vigilant eye on internal conditioning of the entire cycle. Plant operatives should also be trained to realise and appreciate the importance of the same so that they may follow recommendations in earnest in respect of feeding conditioning chemicals and sampling.

3.8 Gland and flange leakages :

In high pressure installations gland and flange leakages account for several outages. Unfortunately, indigenous development of suitable quality of packing materials and flange gaskets for high pressure-high temperature application has not yet been very encouraging. Manufacturers should endeavour to develop suitable materials in collaboration with Scientific Research Institutes. This is not a very difficult problem, but is of vital importance to the thermal stations for reduction in outage period.

3.9. Leakage of boiler pressure parts :

Leakage of tubes is one of the most common occurrences. A serious case of leakage was reported on the convection tubes where the fitting had been done by rolling the end of the tube. This type of failure is due to inadequate rolling of the tubes and thermal stresses during frequent trippings from full load. Improved rolling of the tubes seems to be the only solution and some electronic apparatus is also now available for this purpose.

Leakages may also result from overheating due to the insufficient heating surface or insufficient flow at low loads (startups). Provision of additional heating surface or proper operating instructions to maintain a minimum flow to ensure adequate flow or modifications to the configuration may become necessary.

3.10. Problems in Stoker Fired Boilers :

Majority of installations below 30 MW (*i.e.* Group 1) have been provided with stoker fired boilers. A number of installations of 30 MW also are equipped with a stoker; examples are 3×30 MW at Khaperkheda, 1×30 MW at Paras and 2×30 MW at Harduaganj which are provided with spreader stoker fired boilers. The most important feature of stoker-fired units is their sensitiveness to the size (sieve analysis) of the coal being used, the air distribution in the bed getting affected if the fines exceed stipulated percentage. With the run of mine coals supplied to such boilers, difficulty is generally experienced in fulfilling the combustion requirement. The proper admission of air at various zones of combustion in a stoker-fired boiler is of vital importance to minimise losses. The burn-out may be hampered by a molten mass in a reduction zone in the bed.

With ordinary stokers, maintenance of a heated arch is essential to effect satisfactory ignition. With spreader stokers such fine arches are not needed. It is usual to have about 35% suspension burning in spreader stoker and that rest on the coal bed. Stationary grates for small boilers are adopted (1 MW units), the large ones having stokers in continuous movement from front to back or vice-versa. In one particular installation, the design of the stoker proved highly inadequate to complete the combustion of the coal presumably the length of travel being insufficient to effect the complete burn-out of the coal. In another installation, trouble was experienced with the coal feeder coupling.

Other features of the plant which usually cause embarrassment in operation with spreader stockers are jamming of feeders and improper distribution of coal, leading to increased unburnt carbon loss. The boilers with spreader stockers tend to suffer from high loss as in most cases a grit re-firing system is introduced. This leads to erosion of tubes.

4. Deterioration of the Efficiency of Electrostatic Precipitator (Dust Collector) :

This causes serious damage to the ID fans and also creates problems of air pollution. The causes may be (i) inadequate "treatment" time;

(ii) ash of higher resistivity; (iii) insufficient sparking voltage; (iv) insufficient cleaning of the electrodes; and (v) inadequate area of electrodes.

The remedy for the existing installations is to add on a further section of precipitator. As a temporary measure, steam or water injection can be tried at the inlet of precipitator for decreasing the resistivity of the ash.

For new installations, it is important to match the precipitator design to the correct specifications of the fuel to be used.

5. Turbine-generator :

5.1 Once tuned and run in, this piece of equipment should not cause trouble in a power plant provided its operation is safe in the hands of trained and experienced personnel. However, oil leakages from turbine oil lines have accounted for several outages, and in two particular instances, the leakage oil started huge conflagration and caused heavy damage to the plant and equipment in a D.V.C. power station. In order to guard against this, it is essential that all turbine generator oil lines run through guard pipes. Indigenous manufacturers should incorporate such piping system as a standard design feature, as has been done by a wellknown US Manufacturer. Alternatively, the station designer must ensure meticulously that the oil lines do not run near the hot steam lines anywhere. Research should also be directed to find fire proof lubricating oil for turbo-generators.

5.2 Failure of the governing system and/or turbine stop and control valves is also reported by several power stations. Heavy wear of the exciter commutator has also been reported, leading to the necessity of regrinding. These are mostly caused by dust infiltration. Here again the importance of maintaining the milling plant in a condition that permits no coal dust leakages assumes particular significance. However, the turbine room should preferably be isolated from the boiler room so that no dust nuisance can take place in the turbine room.

5.3 Malfunctioning of the governing system due to seizure of cam shaft bearings has also been reported from some stations, offering the reason as failure of the lubricant to withstand high temperature conditions and drying up in the process.

Molykote grease might be used in such cases with adequate precaution to ensure that no dust nuisance takes place in the turbine area.

5.4 Chattering of control valves is also reported to have been causing disruption in operating turbogenerator units to capacity or schedule. This is a matter that needs to be referred to the manufacturers for their advice as the constructional features can only dictate how best the problem could be resolved.

5.5 Turbine Blade Deposits :

These are caused by a number of factors such as inadequate treatment of the boiler make-up water and progressive concentration of the dissolved contents in the water. However, well run power stations with control of quality of water should not have such difficulties. The presence of deposits is indicated by an increase of stage pressures.

Most of the power stations remove these deposits by fly ash blasting, using indigenously manufactured equipment. During operation, many power stations employ 'washing' of the turbine at few days intervals and avoid outages. This is done by bringing the steam temperature down to within 20°C of the saturation temperature by hand control and then reverting to the normal superheat temperature in a matter of 4 hours each way.

6. Condenser and Circulating Water System :

6.1 Whether or not the circulating water flow is once through or recirculating through cooling towers, shock chlorination for about 30 minutes in every 8 to 24 hours, according to necessity, is imperative so that no slimy deposition in condenser tubes may take place. Once algae is allowed to grow, the condenser tubes get fouled and cooling efficiency decreases proportionately with the result that turbine back pressure goes up and the thermal efficiency drops rapidly. The machine may not even be able to take full load after a certain period. Moreover, with every shut-down, the algae present in tubes gives rise to a phenomenon commonly known as differential aeration, and tubes suffer corrosion. Unless, therefore, one is reasonably certain that the circulating water is free from algae and that no slimy deposit exists in the condenser tubes, at least one circulating water pump should be kept

running even in a standby or shutdown unit. In cooling tower installations, where the water might contain excessive mineral salts, prevention of scaling in tubes is another aspect that needs proper attention. Dosing of lime and phosphate assumes special significance in this context.

6.2 In order to keep condenser tubes clean and to keep the tube inlets free from barnacles etc., suitable back wash arrangements should be provided so that the tubes can be kept clean while in operation without resorting to isolating one section thereby restricting the availability of the unit.

6.3 The air cooler section of condensers should preferably be made of stainless steel tubes so as to guard against ammonia corrosion, the source of ammonia being such conditioning chemicals as hydrazine, morpholine, monocyclohexylamine, etc. For the same reason, the ejector after condenser drain should be run continuously to waste rather than back to the condenser. Stainless steel tubes may not sometimes be satisfactory in salt water operation.

7. Boiler Feed Pumps :

Failure of boiler feed pumps on account of substandard materials used in construction has been reported from several power stations. The pump impeller and volute chambers have to be of stainless steel in difficult cases although this is rather expensive. Pumps should also have mechanical bearings in addition to balancing drums. They should also have shaft mounted oil pumps to take over the lubrication from standby motor-operated pump during operation so that no damage to bearings can take place in the event of total power failure. Alternatively, emergency pumps driven from DC supply are also sometimes employed.

8. Feed Water Heaters :

Persistent leakage of high pressure feed water heater tubes has caused erosion of generating capacity in some installations due to problems of high superheat temperatures in the boiler. Metallurgy of heater tubes merit special consideration in such cases. Moreover, under hot start-up conditions, high pressure heaters should only be commissioned into service after

matching inlet water temperature with shell temperature obtaining at any instant.

9. Compressed air :

Compressed air is used in many Power Stations to work the control system in some cases and provide the motivating force for diaphragm—operated valves and instrument control drives. This air has to be necessarily free from oil, dirt and moisture. Dependable oil-less compressors are, therefore, needed to be developed in the country. Dust nuisance in pulverised fuel (PF) installations is a common feature. With a view to prevent ingress of dust, all compressors should be installed separately in a room away from the power station proper, so that they are enabled to draw clean air. Suitable air driers in the circuit should be provided to remove moisture from the air. M/s. Ingersoll Rand and M/s. Kirloskar Pneumatic Co. are already making compressors, suitable for this purpose (Teflon or Graphite ring) in the country.

10. Ash handling system :

Dependability and efficiency of the ash handling system should be such as to effect proper removal of fly ash and bottom ash from the boilers at suitable intervals. Without constant care and attention, this system can develop into a bottleneck.

11. Water Treatment and Demineralisation :

11.1 Malfunctioning of the clarifier, getting choked with precipitated Ca Co₃ and unreacted lime, has caused total outage of generating units as the clarifier cannot otherwise be cleared of the precipitates. Such problems might best be referred to water conditioning experts to advise on proper dosage of pre-treatment chemicals and the mode of getting rid of the heavy sludge without having to take recourse to total shut-down.

11.2 Fouling of ion-exchange resin and its degradation is another aspect that requires special safeguard. Wherever ion-exchangers are installed to process raw water, aeration towers should be set up with a view to facilitate removal of as much iron from raw water as possible so that the ion-exchanger zeolites do not get coated with oxides of iron.

12. General cleanliness :

It is apparent from the foregoing that dust nuisance and a polluted atmosphere in a Power

Station could spell ruin for the equipment and the instrumentation system as a whole. Hence special vigilance in all power stations is required in order to prevent atmospheric pollution by coal dust and fly ash.

13. Quality of coal :

With the objective of conserving metallurgical coal, the national policy has been to induce the utility concerns, having pulverised fuel (PF) installations, to use inferior coals. Power stations tied to washeries have perforce to use the washery by-products with an ash content of as high as 45%. This policy has led to very heavy wear and tear of the boiler installations, leading to frequent outages, particularly in the absence of any effective means of regulating the abrasive characteristics of coal and ash. This is considered at length in a separate section.

14. Power stations required to operate at a low load factor often experience reduced plant availability due to operation at low loads. This position will of course improve when interconnections of power stations are more effective. However, stations that are expected to remain isolated and obliged to run on very low load factor might consider going in for interconnected boilers to facilitate shutting down one or two boilers in the night without having to take turbo-generator units out of service.

15. Adequate capacity diesel set (or other source of standby power) with provisions to cut in the set automatically in case of a total power failure in the station must be provided. This is required for running the essential auxiliaries like turning gear motor, oil pump for the turbine etc.

16. Adequate D.C. power should be made available by the battery set for running some essential auxiliaries like emergency bearing oil pump for turbine and seal oil pumps and emergency lighting.

17. The thermal power station handles high combustion materials—fuel, lubricants etc. Adequate suitable fire fighting equipment should be installed at various locations in the plant and the personnel should be well trained in handling different fire fighting equipment. In addition, well equipped and well trained fire fighting squads should be maintained.

SECTION 17

MAINTENANCE AND REPAIR FACILITIES IN STEAM POWER STATIONS

1. Considerations in layout :

1.1 In developing a layout of a power station, adequate thought has to be given to the maintenance of plant and equipment installed therein. The layout itself can incorporate features which facilitate use of minimum number of lifting facilities and reduction of man-hours required for lifting plant and equipment and transporting the same if necessary to repair shops which are to be located within the power station area. For example, it is general practice to provide an electrically operated overhead crane in the turbine house to facilitate maintenance of the turbo generator sets. The same crane can be used for maintenance of number of items of equipment located below the turbo generator operating floor level as for instance oil pumps, oil coolers condensate pumps etc. This can be achieved by having openings in the operating floor level and locating the relevant equipment at basement so as to be within easy reach of the E.O.T. crane. From the above point of view a layout which provides for installation of vertical feed heaters in the turbine room area and boiler feed pumps also in the turbine room basement appears to be the simplest so far as the maintenance of these equipment is concerned as the E.O.T. crane of the turbine house can be used.

1.2 It is good practice to have a railway siding into the power plant premises to facilitate receipt and handling of the equipment parts. Usually a railway siding is extended into the turbine house so that the E.O.T. crane in the turbine house can be used to unload equipment from railway wagons.

1.3 In laying out the plant in the turbine house and other areas particular attention is given

to space required for placing bulky and heavy components such as cover of the high pressure cylinders, cover of the low pressure cylinder, high pressure rotor, low pressure rotor, rotor balancing machine, bearing covers, generator rotor etc. Some of the parts of the turbine could be laid directly on the foundation of the turbine. These are generator end covers, barring gear, high pressure cylinder diaphragms, etc.

For maintenance of transformers one or two bays are provided at one end of the turbine house.

1.4 Platforms are provided at regions which are not easily accessible to give access for pipeline maintenance and repair.

1.5 For maintenance of various other equipment, most convenient facility is to provide mono-rails of adequate capacity located at various points. The layout has to take care of any latches required for lowering of equipment from higher floors and in case lift is provided the layout will have to facilitate transporting of equipment to the lift.

2. General guidelines in regard to provision of usual maintenance facilities for various regions in a thermal power plant are given below :

2.1 Turbine house :

(1) The turbine house should be equipped with an electric overhead travelling crane for handling the equipment for unloading incoming heavy packages during construction.

(2) For equipment falling outside the reach of the E.O.T. crane local lifting devices should be provided.

(3) If the turbine house is having a basement, provision is made for latches in the operating floor level to facilitate access to the E.O.T. crane or other local lifting devices to the equipment situated in the basement.

(4) Provision for railway siding entry into the turbine house of one or both ends should be made. The length of the siding being such as to facilitate unloading by the E.O.T. crane.

2.2 (1) Service platforms around and between the boilers should be provided.

(2) Railway siding should be extended to facilitate handling of heavy equipment assemblies.

(3) Access should be provided for the mobile crane to handle assemblies of equipment such as gas heater, economisers etc.

(4) Monorails with pulley-blocks of adequate capacity should be provided for handling of other equipment such as primary air fans, mill fans, mills, etc.

(5) A passenger-cum-goods lift should be provided in the boiler house.

2.3 Coal handling Plant :

(1) Monorails with hand-operated pulley-blocks should be provided for the maintenance of equipment in crusher house, any transfer points where drive heads of conveyors are installed.

(2) Conveyor galleries and trestles are provided with equipment with openings and devices used for repair required for replacing and unwinding belts.

2.4 Fuel Oil facilities :

(1) In the fuel oil pump house provision is made for monorails with hand operated pulley-blocks.

(2) Plant and equipment located outdoor should be maintained using mobile cranes.

2.5 Pump House :

(1) Electric overhead cranes are provided for repair of CW pumps installed in separate pump house.

(2) Lifting tackles are provided for repairing drain pumps and other minor pumps.

(3) For maintenance of screens and gates in intake structures, crane girders are provided.

2.6 Instruments and Controls :

(1) For repair of instruments and control devices laboratories equipped with the following sections should be constructed :

- (a) Pyrometry and gas analysers.
- (b) Instruments for measuring pressures.
- (c) Electronic devices.
- (d) Devices for automation and safety.
- (e) Precision shop.
- (f) Mechanical Lab.
- (g) Electrical Lab.

(2) All the above laboratories should be located in a building known as auxiliary building situated close to the main building and provided with easy access from the main building.

(3) Transportation of instruments between the laboratory and the places of installation of instruments should be by special trolleys.

(4) Minor repairs to instruments should be provided at specific service points in the main building.

2.7 Electrical Equipment :

(1) Step up transformers, unit transformers and station transformers should be repaired in the service bay provided in the turbine house, in case the outdoor yard is located in the immediate vicinity of the main building.

(2) In case the outdoor yard is located at a greater distance from the main building then the transformers are repaired in the transformer repair shop.

(3) To facilitate handling of transformer oils, oil pipes should be laid up to the transformer and to the points where they are to be repaired.

(4) For inspection and repair of busbars, string and post insulators and various assemblies of transformer equipment, a provision should be made for telescopic ladder or for collapsible scaffolds.

2.8 Outdoor Yard :

(1) Provision is made for access to outdoor yard by mobile cranes, fork lift tractors, telescopic towers, mobile ladder tractors, etc.

(2) RC cable channels or pipelines in the switchyard should be laid out in such a way as not to hinder passage of mobile cranes etc. mentioned above.

3. Repair Shops :

3.1 In order to carry out repair work in power station provision should be made for a central repair shop which should be located in the combined auxiliaries building.

3.2 Provision should be made for the following shops:—

- (a) M/C Shop: equipped with lathes, boring and drilling machines, shaping machines, slotting machine, grinders, milling machines, etc., for carrying out various machining operations.
- (b) Electrical repair shop: equipped with lathes, drilling machine, electrical furnace, M/C for static balancing of motors and heavy duty filters vice.
- (c) Fitting shop: equipped with fitters vice, drilling M/cs, grinders, lapping machines hydraulic presses etc., for carrying out various fitting jobs.

(d) Carpentry shop: equipped with planing machine, circular saw, wood turning lathes etc.

(e) Welding shop: for carrying out various welding operations, electric welding equipment, grinders and drilling machines etc. are provided.

(f) Smithy shop: equipped with smith's furnace, electric furnace for heat treatment, pneumatic hammer, blower, etc.

4.1 A central layout of acetylene, oxygen, compressed air, electric welding current lines should be provided for the main building, chemical water treatment plant, receiving bunker device.

4.2 Electric welding distribution centres to connect electric welding machines should be located in the turbine room for welding works for the turbine and its accessories. Socket outlets for low voltage lighting should be provided on the operation platforms.

4.3 Compressed air line in the turbine room should be laid to the turbine generator, feed pumps and other equipment.

4.4 Laying of power lines is required for all the operation levels of each unit in the boiler house and in the bunker-deaerator bay considering maintenance of equipment and for the most remote places during repairs of equipment.

SECTION 18

INSTRUMENTATION IN POWER PLANTS

1. In a thermal power plant, instrumentation plays a most important and vital role, on which depends the efficiency, availability, security and safety of a power plant. With the growth of power demand, bigger units are being installed and it is very essential that these units must run very efficiently and economically. The outage of a large unit will upset the system and the indirect losses, due to interruption of power, to the industries may be heavy. It is, therefore, essential that the generating units must run smoothly and uninterruptedly. To achieve this, it is very essential that the controls and instruments must be very well planned, efficient and reliable. Currently, when we are having grids and super-grids, where many power stations are tied up, it is necessary that the controls and instruments should not only be efficient and reliable, but should also be fast operating. This subject, therefore, needs adequate attention.

2. There has been phenomenal development in the field of instrumentation technology both for boiler control and operation, turbo-generator control and operation and for electrical instrumentation and metering. For safe operation, the boilers are provided with feed water controls, indications of chemical concentrations and conductivity of water and coal mill temperature apart from various boiler safety and interlock devices. The turbines are provided with supervisory controls consisting of records of vibration, eccentricity, differential expansion speed and temperature indications of turbine, casing and Turbo Generator bearings. Also, there are various level controls installed in the feed heaters, deaerator, condensate hot-well and other tanks supplying make-up and cooling water. For efficiency, the

boiler is provided with combustion control which regulates feed of coal, forced and induced drafts according to the load requirements and also maintains steam and air ratio to give the best boiler efficiency. They are also provided with steam pressure and temperature regulation to enable the plant run at the designed steam parameters which condition is very essential to get the most economical generation. There are also indications and records of steam pressure temperatures at the inlet and outlet of heat exchangers and gas and air temperature at various points of gas passage in boiler to air preheater and economiser. All these indications are utilised for calculation of heat balance and at the same time monitoring the internal conditions of the apparatus. Some of the power stations are also provided with multipoint bearing, temperature recorders for monitoring the bearing temperatures. Annunciations are provided to warn the operators in the control room when the limits of temperatures and levels in heaters and tanks have been exceeded to enable them to take timely action to save the machines from undergoing outage or from the damage.

3. To maintain the instruments, controls and relays in satisfactory working condition, it is very essential to have a well equipped laboratory with different substandard equipments so that the instruments, relays, etc., could be tested to maintain the proper accuracy. The instruments have to be thoroughly tested before installation and also have to be checked from time to time during operation so that chances of mal-operation of instruments and relays are minimised. In the laboratory, there should also be spare tested relays and some important instruments so that in

case of necessity the tested equipment could be installed without any loss of time. In a modern power station, all the operations are controlled by the instruments and it is very essential to have good and well experienced laboratory staff and technicians for preventive maintenance as well as special repairs. It is essential that substantial efforts are made to have properly trained instrument engineers, as a very slight extra expenditure on this account pays very rich dividends by way of safety of expensive equipment and economy in running expenses as a result of efficient operation of the plant. Since there are quite a large number of control instruments and relays in a power station, a small good workshop is also essentially needed for taking up the repair of the instruments and relays.

4. It has often been observed that sophisticated instrumentation is provided in the station designs but that this is either not fully installed due to various reasons of expediency or not fully utilised for want of proper maintenance. *It has been the experience that most of the power station troubles and failures can be traced to parts of the instrumentation system being out of commission.* It is, therefore, important that power stations should not work without properly functioning instruments in all the sub-systems. Special instrumentation cells and well-equipped instrument laboratories should be put up in each large power station as well as for the power system as such. The instrumentation cell should be manned with the specially trained and experienced staff and *no obstracle should be placed in the procurement of spare parts for the instrumentation and controls already working in the power station.*



SECTION 19

**MODIFICATION OF INDIAN BOILER
REGULATIONS AND INDIAN BOILERS
ACT**

1. According to the Boilers Act, the boilers are required to be shut down for overhaul and inspection at least once in a year. This is a factor unnecessarily limiting the availability of large and costly modern boiler installations. Necessary modification of this will improve the availability of boiler plant leading to more economical operation. The boiler regulations were originally designed to deal with smaller boilers, specially of the Lancashire type used in small process industries and vertical type in the coal mines. The operation of these boilers was invariably manual and left to staff without the technical background which is possessed by those in charge of the modern power stations. The boilers used to be fed with water which was available and without regard to its quality such waters could leave sufficient scales on the boiler surfaces to cause accident due to overheating of plants. Maintenance of water level was neither automatic nor fool proof, which under certain conditions could and did result in explosion of pressure parts and danger to human life. Therefore, the statutory laws were promulgated for the safety of the fire attendants and people working in the near premises. The modern boilers cannot work under such conditions. Before there is even a remotest chance of pressure part explosion, there will be a tube failure. The tube failure acts as a built-in safeguard and a compulsive factor to keep the boiler in a tip-top condition. Therefore, so far as the statutory requirement to ensure the safety aspect by subjecting a modern boiler to annual overhaul and inspection is concerned, it is a hang over of the past. Earlier it is modified to suit the modern conditions, better it would be for the economy of the Electricity Undertakings. It is our suggestion that the period for inspection

is extended to 2 years. Besides, it is also statutorily required to subject a boiler to a hydrostatic test before the inspector in case of failure of a tube or work on any pressure part. Since due to limitation on the time of the inspectors who have a very wide jurisdiction, it is not easy to get them on a short notice as a result of which unplanned outage time gets prolonged. Also as a result of this difficulty, hydrostatic test is carried out twice, once to make sure that the boiler stands the hydrostatic pressure before the inspector comes and the other time after the inspector comes. With big units, any prolongation of outage means a lot of financial loss to the Electricity Boards and inconvenience to the consumers due to resulting power shortage. It is suggested that statutory provisions should be waived for between the annual or the suggested biennial inspections. The Power Station Engineers are of sufficiently high calibre to be left with the responsibility of care of the boilers and their safe operation. Boiler Inspector has to play an important role during the construction stages and for initial certification of boilers before commencement of operation.

2. There is further a feeling among leading technologists that the hydrostatic test of boilers during the annual or the suggested biennial inspection need only be at the operating pressure and only once in four years need the boiler be subjected to 1.25 times the working pressure. This needs consideration of the Central Boilers Board. In this connection, it may be mentioned that the test pressure to which fusion welded boilers have to be subjected has been reduced from 1.5 times the working pressure to 1.25 times the working pressure. Therefore, in any

case, subjecting the boiler to 1.25 times the working pressure during biennial inspection should be quite in order. The question of further relaxation, however, needs serious consideration.

3. Modifications in Indian Boiler Regulations in the light of modern technological advances :

The Central Boilers Board reviews the Indian Boiler Regulations from time to time and has been making a number of relaxations in specific cases so that the Indian Boiler Regulations (IBR) do not come in the way of adoption of modern technological advances. The census of installations of large steam power plants in recent years, presented in Section 3, shows that a definite trend has been established in installations of large pulverised fuel fired reheat generating units. The manufacturing technology to be adopted in this country for such units is also fairly well defined by now. It is, therefore, recommended that the Central Boilers Board may incorporate suitable amendments in the IBR to take into account the modern technological advances which are already being adopted as a standard practice. The main points of this nature are given below. It may be mentioned that these have already been approved by the Central Boilers Board in specific cases.

3.1 Use of Alloy Steels and Austenitic Materials for high pressure, high temperature plants :

The IBR provisions should cover the chemical composition, allowable working stresses, heat treatment, extent of radiography etc. for the use of alloy steels and austenitic materials. The material specifications of ASME/ASTM may be helpful in this connection.

3.2 Feed Regulating Valve :

The IBR (Regulation 336) requires that the feed regulating valve shall be so arranged as to enable it to be satisfactorily operated from the boiler floor. With the advent of hydraulic couplings (the controls for which are located in the Central Control Room for automatic or remote manual control of feed supply) there is no more any functional necessity for the feed regulating valves where such hydraulic couplings are provided.

3.3 Boiler Feed Discharge Piping :

The IBR (Regulation 520) states that the feed piping shall be designed for the maximum

pressure which can be generated by the boiler feed pumps unless special provision is made to prevent the pressure being communicated to the pipe line.

3.3.1. In certain cases, Technical Adviser, Central Boilers Board has agreed that use of hydraulic couplings for the pump may be treated as "a special provision to limit the pressure on boiler feed discharge piping to the design pressure at maximum flow". This enables economies in piping designs. This could be made the recognized practice.

3.3.2 It may further be pointed out that the boiler feed pump working against shut off cannot be expected to occur in normal operation. In other countries, the standard codes have a special provision for occasional increases of short duration in both pressures and temperatures beyond the nominal design values. The ASME (American Society of Mechanical Engineers) Boiler Code for example provides in Para P-23 (f):

"Either pressure or temperature, or both, may exceed the design values if the stress in the pipe wall calculated by the formulae using the maximum expected pressure during the variation does not exceed the S-value allowable for the maximum expected temperature during the variation by more than the following allowances for the periods of duration indicated:

- (1) Upto 15 per cent increase above the S-value during 10 per cent of the operating period;
- (2) Upto 20 per cent of the S-value during 1 per cent of the operating period."

Such a provision in the IBR would lead to considerable economies in the boiler feed discharge piping.

3.4 Annual Hydraulic test of steam lines :

The IBR (Regulation 377) requires that every boiler shall be hydraulically tested annually. This provision would require an annual hydraulic test for the cold and hot reheat lines also in the case of modern reheat units. The boiler outage overhaul time can be substantially reduced if such test is not required on the steam lines as reheater belongs to an entirely separate hydraulic circuit. In certain cases, ruling has already been given that no steam pipes, hot or

cold, reheat or main steam, need be subjected to any annual hydraulic test.

3.5 Boiler Headers :

The IBR (Regulation 245) states that all headers and similar pressure parts shall be of forged steel, seamless steel pipes or of cast steel. The standard practice of some leading manufacturers is, however, to use fabricated headers and it is, therefore, necessary to permit headers fabricated from plates by welding to be used. They should, of course, be required to comply with the provisions of IBR for cylindrical shells.

4. List of Recognised Inspectors :

The IBR (Appendix C) gives list of recognised Inspectors who can inspect and certify manufacture of equipment falling under IBR as complying with its regulation. This list includes certain Chief Inspectors of Boilers of various States who can inspect and certify boilers during manufacture but it has not been clarified whether it is mandatory that such inspection be carried

out by the Boiler Inspectorate of the State where the manufacturers' works are located. This is likely to create confusion, particularly, since it is not clear as to who will inspect and certify compliance with IBR of pressure piping, valves, turbine casing, etc.

5. List of Recognised Steel Makers :

The IBR has included some of the Indian manufacturers in the list of recognised steel makers but this list has to be amended to include all major steel manufacturers in India. In addition, standardisation of stress values of steel being produced indigenously is called for.

6. Code for Unfired Pressure Vessels :

The Indian Standard Code for unfired pressure vessels is already being formulated in the Indian Standards Institution. From the safety viewpoint, it appears desirable to make some statutory provisions for inspection at various stages in manufacture and use of equipment coming under the category of unfired pressure vessels.



SECTION 20

ASH DISPOSAL

1. Introduction :

1.1 The rapid increase in the installed capacity in thermal power plants all over the country is certain to bring to a head the problems of ash disposal. The national policy of making maximum use of low grade coal and washery by-products will aggravate conditions in this regard very rapidly. The total annual consumption of fuels presently (1968-69) is 12.45 million tons of coal and 2.6 million tons of lignite. This is expected to rise to 23.6 million tons of coal and 4.2 million tons of lignite by 1973-74. This indicates that at present about 4 million tons of fly ash and one million tons of bottom ash is already produced in the country annually and that this quantity is likely to be doubled in the next few years. The disposal of such huge quantities of ash is a formidable problem. The dumping of ash will gradually choke the available spaces around the power stations. The dumping of ash without return on account of non-utilisation of ash imposes heavy burden on the economics of power station. This is a serious matter that will affect the economy of power plants in a number of ways and various aspects of the problem must be considered rationally without loss of time.

1.2 Major considerations in the design and setting up of large steam power stations include the behaviour of the ash during combustion and its handling and disposal. The problems regarding design of boiler furnace etc. will have to be tackled in consultation with the manufacturers of equipment. Apart from these, however, the ash disposal itself presents two-fold problems— (i) pollution and (ii) ash disposal.

2. Pollution :

There is already growing consciousness in the country about the pollution and it is to be expected that, along with laws and regulations controlling disposal of industrial wastes, regulations prohibiting or regulating dumping of ash will be promulgated in the coming years. These regulations, along with the cost of ash disposal, would make it an urgent necessity for the power plant authorities to explore ways and means of finding uses for the ash. The fly ash in power stations also poses serious threat of air pollution. The various aspects of air pollution are discussed below :—

2.1 Control of Air Pollution :

At present, we do not have any organisation which has the overall responsibility at the national level for control of air pollution etc. However, in a few localities such as Bombay, Ahmedabad, the Chief Inspector of Boilers has been authorised by local regulations to check the Ringleman chart number for the smoke emanating from thermal power station chimneys and impose restriction if smoke with Ringleman Chart number exceeding 4 is emitted. Emission, which exceeds Ringleman Chart No. 6 is prohibited. The same authority is empowered to scrutinize all proposals for construction of furnaces etc. which are likely to cause smoke emissions. So far the requisite legislation has not been enacted at the national level, only a few local legislations have been enacted. In the cities of Calcutta, Kanpur, Ahmedabad and Bombay, local legislations like Smoke Nuisance Commission Act, 1905, Bombay Smoke Nuisance Act, 1912, Gujarat Smoke Nuisance Act, 1963 have been enacted. But these Acts have jurisdiction confined to the respective

cities only and not to other areas. These local legislations stipulate minimum stack height, and permissible smoke levels which impinge on operation. No limits to the rate of deposition/concentration of sulphur compounds of fly ash are prescribed.

2.2 Air Pollution Levels :

The table 4-14.1 gives an idea of the air pollution levels/deposition rate. These values were calculated by CW&PC based on the fuel consumption, ash content, dust collection plant efficiency, exist gas velocity, height of chimney, etc. Procedure for measurement of pollution are under consideration of the Indian Standards Institution. If pollution levels due to a power station are established to be objectionable, measures to remedy the same can be thought of. In selection of sites for thermal power stations, air pollution does not figure as a major criterion. However, in developing the layout of a power station, due consideration is given to topography and meteorological conditions. The design provides for adequate amount of air to be supplied to ensure as complete a combustion as possible. In the case of pulverised fuel fired boilers, the mills are designed to give an optimum fineness of pulverised coal and turbulent mixing of coal and air takes place in the furnace which promotes complete combustion.

2.3 Ash extraction from fuel gases :

Table 4-14:1 gives the type and design collection efficiency of the dust collecting plants. It will be seen that 74% of the boilers for which data were collected are provided with mechanical collectors with design efficiency ranging from 70 to 90% and 22% of the boilers are provided with combined mechanical and electrostatic precipitators of collection efficiency ranging from 95 to 98%. No attempt has been made to remove sulphur compounds from flue gases in view of the fact that most of the coals, with the exception of some Assam coals, are having low sulphur content and the pollution level of SO_2 is small compared to concentration of fly ash. In general, the Indian coals, (with the exception of Assam coal whose sulphur content varies from 2 to 10%) are of low sulphur content. Table 4-14.1 indicates the sulphur content of coals fired in thermal power stations considered. The fuel oils, in general, have a maximum sulphur content of 3 to 4%.

No attempt has been made so far to remove sulphur from fuel before combustion. Removal of sulphur before combustion is considered uneconomical. Except a few power stations, using fuel oil and gas, all other power stations use coal. The ash and sulphur contents of coals fired in various major thermal power stations are given at table 4-14.1.

2.4 Measurement of pollution :

There appear to be no attempts made to systematically measure the pollution of sulphur dioxide or fly ash in the vicinity of thermal power stations. Studies have been made in and around Calcutta by All India Institute of Hygiene and Public Health. Calcutta, with a view to estimating the dust fall, airborne dust, concentration of sulphur dioxide, aldehydes, ammonia and oxides of nitrogen. The summary of the results of these studies made from 1955 to 1958 are given below:—

Soot fall . . .	39.38 — 90.98 tons/sq. mile/ month
Sulphur dioxide . .	0.021— 0.058 ppm.
Oxides of nitrogen . .	0.043— 0.122 ppm.
Ammonia . . .	0.160— 0.266 ppm.
Aldehydes . . .	0.04 — 0.12 ppm.
Respirable dust . .	0.071— 0.600 ppm.

2.5 Analysis of prevalent practice in India :

Recently, the Specialised Engineering Organisation of CW&PC have carried out a study on air pollution from thermal power stations in India covering 20 major thermal power stations (total installed capacity of 5.614 million kW.). Table 4-14.2 presents an analysis of the data in respect of stack heights and exit gas velocities. The data covers a total of 104 boilers served by 58 stacks in the 20 power stations.

2.5.1 It is seen that 52.9% of the boilers under study covering an installed capacity of 52.5% of the total capacity under study were provided with stacks with design exit velocities in the range 10 to 15 m/sec. 31.7% of the boilers serving 33% of the installed capacity under consideration were provided with design stack exit velocities in the range 20 to 30 m/sec.

2.5.2 Stack height :

There are 5 stacks of 120 m. height out of a total of 58, and these 5 stacks serve 21 boilers covering 18.9% of the installed capacity under

consideration. The majority of the installations have stack of 60 m height (36 stacks serving 44 boilers for an installed capacity of 2.25 million kW).

2.5.3 Out of 104 boilers under study, 77 boilers are provided with mechanical dust collectors with design efficiency ranging from 70 to 90%. 24 boilers are provided with mechanical-cum-electro-static precipitators with design efficiency ranging from 95 to 98%. No dust collector has been installed for three boilers as these are oil/gas fired ones. Special efforts are required to maintain the efficiency of electrostatic precipitators.

2.5.4 There is no uniform legislation regarding pollution control and in the case of power stations located near pit mouths where the regions are not very much urbanised, the practice has been to go in only for mechanical dust collectors whose efficiency is less than 90%. In the other cases, electrostatic precipitators combined with mechanical collectors have been installed with efficiencies as high as 98%. It is generally seen that in the case of such power stations, the pollution level of fly ash is much lower than that in the other power stations. The exact constants in various regions in India will have to be determined by research. Various organisations concerned such as the ISI, the Health Institute, Central Water and Power Commission will have to get together to study the prevailing levels of pollution and devise measures to minimise pollution. The calculations here, however, give an indication of the broad trends of contamination level in the atmosphere where power stations are situated.

2.6 Recently, the Indian Standards Institution has set up a Committee (CDC 18.5) to study the whole problem of air pollution.

The following measures may be required: --

- (a) Minimise source of emission, in other words to provide common stack for a number of boilers.
- (b) Design stack for an optimum exit velocity of effluent gases near about 25 m/sec.
- (c) Increase stack height so that the pollution levels in the area are reduced.

2.7 In addition, high efficiency precipitation plants must be installed. The problem in the case of thermal power stations is that the more efficient electrostatic precipitators are quite costly; being as high as about 10 per cent of the boiler plant cost. As the installation of the highly efficient dust precipitators does not improve the power station economy, the general tendency is to avoid going in for costly electrostatic precipitating plants. Further, some parts of the electrostatic precipitators require imported materials such as discharge electrode wires and rectifier units. Mechanical dust collectors of conventional design involve large draft drops and corresponding high power consumption. This limits the efficiency achieved. It is quite clear that any regulations that may be prescribed in the near future will affect the capital as well as operating costs of the steam power stations. It is, therefore, recommended that the representatives of the Electric Supply Industry and CWPC should be invited to participate in the formulation of these regulations. Adequate attention should also be given to this aspect in the design and construction of new power plants as any corrective measures required to be added subsequently are bound to be more costly.

3. Ash Disposal:

Considerable studies have already been carried out on this subject. Even in countries like Germany where the production of fly ash is of the same order as in India presently, a great deal of research is being carried out to find uses of fly ash. Presently, the recommendations for utilisation of fly ash are generally centred around its properties as pozzolana.

3.1. In U.S.A. quite a few tall buildings have been constructed with fly ash concrete. The high strength concrete required for such structures can be prepared by use of fly ash, mixed with the cement. It has been observed that upto 30% saving in the use of cement can be made by substituting cement with fly ash as pozzolana material. With this substitution, the 3-day and 7-day strength of concrete is reduced but there is no difference in the 20-day strength. The substitution has, therefore, enabled considerable economies in the cost of mass concrete in dams, marine works, road building etc. and this has helped in achieving at least partially

an economic disposal of fly ash. It has been reported that fly ash utilisation of as much as 27.40 and 50% of the total ash production has been achieved respectively in Germany, U.K. and France. The Edison Electric Institute in USA has reported that the production of ash in U.S.A. in 1967-68 was 27.5 and 29.6 million tonnes respectively and that with the intense applied research and promotional activities, it was possible to achieve an ash utilisation of 13.8 and 17.5% respectively, in these years. Their summary regarding ash collection and utilisation in the year 1968 is given in Table 4-15. This indicates the relative importance of the major areas of use for the ash. This can assist the applied research work in this country for finding solution to the problem of huge quantities of ash,

3.1.1. In their annual report for the year 1967-68, the Central Electricity Generating Board, U.K., have stated as follows :

"Pulverised-fuel ash

Sales of pulverised-fuel ash increased to 3.7 million tons, representing 42 per cent of the total output. The increase indicates the widespread acceptance of PFA as a building and civil engineering material. The first purpose-built plant for the production of ready-mixed cement-stabilised PFA was established at Brighton during the year and others are expected to follow. Some 2,000 tons of PFA were exported to the Continent during the year in the form of hollow cenospheres (floaters) collected from ash lagoons. This material is in demand for the manufacture of lightweight thermally insulating blocks and refractories. A large market is known to exist for floaters and the Board are developing a new design of collecting plant."

3.2 In India, various research organisations, notably the Central Building Research Institute (CBRI), the Central Road Research Institute (CRRI) and Cement Research Institute (CRI) have done considerable work in developing ways for the utilisation of fly ash. A number of uses have been developed; of these, the following are important:—

- (i) In road construction using lime-fly ash-soil mixtures;
- (ii) In the manufacture of Portland pozzolana cement;
- (iii) In making sintered light-weight aggregate for use in light-weight concrete, blocks or slabs, etc.
- (iv) As a fine aggregate in mortars, concrete, concrete blocks, cinder concrete bricks, sandlime bricks, etc.;
- (v) In the manufacture of cement;
- (vi) In the manufacture of aerated concrete;
- (vii) In making bricks from clays soils;
- (viii) As a filler in rubber, paint, bituminous concrete and bituminous products;
- (ix) As a raw material for glass;
- (x) In soil stabilisation;
- (xi) In sand blasting in place of sand for cleaning turbine blades;
- (xii) As a filter layer under pavements;
- (xiii) In oil well sealing.

3.3 A number of large power stations in India are located near big cities like Calcutta, Bombay, Madras, Delhi, Nagpur, Nasik, Ahmedabad, etc., where huge house building projects and development of new colonies and Industrial Estates are under way. The use of fly ash for bricks wall panels and admixtures in cement will not only go a long way in providing essential building materials and relieving cement shortage but will also save considerable expenditure to power station authorities in the disposal of fly ash. It is reported that the efforts of some of the power stations in Tamil Nadu in this direction have been very successful. Road building and reclamation of low areas can also utilise large quantities of bottom ash as well as fly ash. Much further efforts are, however, required in this direction in order to assist in bringing down the costs of power generation effectively. In the use of ash in the building activities, the Indian Standards Institution and Institutes like Central Building Research Institute, Central Road Research Institute, National Building Organisation etc. will have to give a lead by carrying out necessary research and testing work and establishing national standards of quality. It has to be remembered that even for a given power station, the quality of coal varies so much from time to time that the ash produced also varies considerably in its chemical composition. This factor will have to be taken into account.

3.4 Current position :

Fortunately, there is an increasing awareness regarding the need for the use of fly ash in the power supply industry as well as among other authorities in the country. The Neyveli Lignite Corporation Ltd. have, for example, been able to sell some of their fly ash to building industry to earn revenue as follows :—

Year	1964-65	1965-66	1966-67	1967-68	1968-69
Rs. (Lakhs)	2.33	4.72	2.51	3.13	0.56

On behalf of the Delhi Development Authority and 'C' Power Station, the National Building Organisation, New Delhi, has made some field trials in the use of fly ash in building constructions. During the course of construction of Rihand Dam in U.P., fly ash was utilised to a substantial extent in the mass concrete with attendant economies.

4. The Central Water and Power Commission and construction authorities are generally well seized of the problem and the possibilities of use of fly ash in large mass concrete or masonry structures as pozzolana are usually explored. Difficulties however, do occur due to inadequate appreciation of the problem of fly ash by certain local authorities. In the case of one Dam prospects of use of 2-3 lakh tones of fly ash as pozzolana were explored. The proposal for use of fly ash had to be given up as the power station authorities insisted on a price of Rs. 40 per tonne for the fly ash and this price together with the rail transport charges made use of fly ash uneconomical. Disposal of ash costs money at each power station. It will therefore be reasonable to expect that the power station authorities should make ash available freely for any civil engineering uses at a normal price. This should in no case exceed the cost of coal at the power station multiplied by the proportion of ash content. Considerable amount of further research and development work may be useful. The Central Building Research Institute, Roorkee, have intimated the Power Economy Committee that they could undertake investigations on the uses of fly ash in making bricks from expansive soils such as black cotton soil and for silicate bonded high strength building bricks, if such a project is sponsored. It is also understood that Cement Research Institute, New Delhi, would be prepared to undertake work regarding analysis and assessment of fly ash of different power stations and participate

in any applied research and development work in this regard.

Apart from these developments, it is now necessary to take practical measures for ash utilisation even on the basis of the presently known possibilities. The power station authorities are normally fully engaged with planning, construction and operation of the power generating stations and transmission and distribution works. It is, therefore, very difficult for them to carry out any effective research and development work or promotional activities on their own. Such efforts would also mean wasteful duplication in the different power systems. It is, therefore, strongly recommended that in each region, the Regional Electricity Board or the State Electricity Boards co-operatively should set up a non-profit Corporation for this purpose. The power stations should make all the ash available to the Corporation free of charge and the Corporation should take all possible actions for marketing and utilising all the ash. The Corporation will promote further research and development on necessary capital equipment, preparation of national standards and specifications for ash disposal and actively pursue the use of ash in the large number of areas in civil engineering.

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SURVEY OF POWER STATIONS DESIGNS IN REGARD TO AIR POLLUTION AND STACK DESIGN

4-14.1 DETAILS OF POWER STATIONS

Sl. No.	Name of Thermal Power Stations	Boiler		Fuel Characteristics		Fly ash ex-traction Plant		Stack	Velocity of fine ash at stack exit		Concentration at stack exit		Maximum ground level concentration				
		Number of Units & Capacity (MW)	Number & capacity Tonnes/hr	Pressure Kg/Cm ² (abs)	Temperature °C	Ash %	Sulphur %		Type of Firing	Type	Collecting efficiency	Num-ber	Height m.	Fly ash gm/m ²	SO gm ² /m ³	Fly ash mg/m ³	SO mg ² /m ³
								exit									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Kothagudem]	• 4 × 60	4 × 254	90.8	516	39.51	0.38	P. F. Fired	Mechanical Collector	80	4	77	14.4	7.05	0.80	12.80	0.578
2	Nellore .	• 1 × 30	1 × 90.3	63.3	496	35.00	0.50	P. F. Fired	Do.	85	2	48.4	9.30	4.32	0.997	4.80	0.432
3	Gauhati •	• 1 × 30	1 × 150	64.4	487	..	1.00	Oil Fired	..	..	1	36.50	9.10	..	0.832	..	0.412
4	Patratu .	• 4 × 50	8 × 220	101	540	45.00	0.21	P. F. Fired	Mechanical Collector	85	2	120.0	21.80	6.22	0.456	3.88	0.115
5	Bokaro .	• 3 × 57.5	6 × 136.1	63.9	488	30.00	0.70	P. F. Fired	Do.	85	3	62.20	7.00	3.35	1.225	2.435	0.615
		• 1 × 75	1 × 331.6	106.5	541	30.00	0.70	P. F. Fired	Do.	90	1	62.20	11.60	1.915	1.05		
6	Durgapur (D.V.C.)	• 2 × 82.5	2 × 331.1	106.5	541	40.00	0.70	P. F. Fired	Do.	90	2	53.30	11.60	3.19	1.310	3.897	0.95
		• 1 × 140	1 × 154	138.4	541/541	40.00	0.60	P. F. Fired	Mechanical-cum-Electrostatic	98	1	68.70	8.66	0.66	1.16		
7	Chandrapura]	• 2 × 140	2 × 435	131.5	540.6	40.00	0.60	P. F. Fired	Do.	98	1	80.00	30.50	0.66	1.163	0.753	0.666
		• 1 × 140	1 × 435	131.5	540.6	40.00	0.60	P. F. Fired	Do.	98	1	80.00	15.25	0.66	1.163		
					540.6												
					540.6												
8	Dhuvaran •	• 4 × 63.5	9 × 136.1 (One stand-by)	95.9	516	..	1.20	Oil gas Fired]	Mechanical Collector	90	4	61.00	10.10	..	0.845	..	1.075
9	Neyveli •	• 6 × 50	6 × 220	101	540	5.5	0.30	P. F. Fired	Do.	80	2	60.00	20.20	1.22	0.785	4.22	1.352
		• 1 × 100	2 × 220	101	540	5.5	0.30	Do.	Do.	80	1	60.00	13.5	1.22	0.785		
10	Amarkantak •	• 2 × 30	4 × 83	72.06	496	30.00	0.60	P. F. Fired	Mechanical Collector	80	2	35.00	13.40	4.043	0.95	13.4	1.26
11	Korba •	• 3 × 30	6 × 81.7	61.25	496	25.0	0.60	Stoker	Mechanical Collector	70	3	53.4	10.10	1.68	0.898		
		• 1 × 10	2 × 36.3	36.2	404	25.0	0.60	Stoker	Do.	70	2	20.55	10.07	1.51	0.805	5.78	1.23
		• 4 × 50	4 × 220	101.0	540	38.81	0.60	P. F. Fired	Do.	80	1	120.00	21.20	7.11	1.30		

SURVEY OF POWER STATIONS DESIGNS IN REGARD TO AIR POLLUTION STACK DESIGN
4-14.1 DETAILS OF POWER STATIONS (Contd.)

Sl. No.	Name of Thermal Power Stations	Boiler	Fuel Characteristics					Fly ash ex-traction Plant	Stack	Velocity of flue ash at stack exit M/c	Concentration stack exit		Maximum ground level concentration						
			Number of Units & Capacity (MW)	Pressure Kg/Com- (abs)	Temperature °C	Ash %	Sulphur %				Type of Firing	Type	Collecting efficiency	Num- ber	Height m.	Fly ash gm/m ²	SO gm ² /m ³	Fly ash mg/m ³	SO mg ² /m ³
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
12	Satpura	• 4 × 66.9	4 × 272.2	92.4	516	40.0	0.40	P. F. Fired	Mechanical Collector	77.50	5	61.00	15.00	6.74	0.674	25.6	1.075		
13	Trombay	• 2 × 62.5	2 × 272.9	93.8	512.6	..	3.75	Oil Fired	..	..	1	76.2	7.32	..	3.32	..	..		
		• 1 × 62.5	1 × 272	93.8	512.6	40.0	0.50	P. F. Fired	Do.	82.7	1	76.2	13.3	3.81	0.645	2.312	2.413		
		• 1 × 150	1 × 477	180.5	571.1	10.0	0.20	P. F. Fired	Mechanical-cum-Electrostatic	98	1	76.2	10.70	0.74	3.32	The maximum concentration of SO referred is with Oil Firing.	..		
					540.6		3.75	for Oil Fired					12.2	..	3.53				
14	Talcher	• 4 × 62.5	4 × 272	95.0	512.8	34.0	0.60	P. F. Fired	Do.	95	2	60.05	10.03	1.31	1.15	2.30	1.054		
15	Indraprastha (Delhi)	• 1 × 56.6	2 × 64.7	64.3	489	28.50	0.60	P. F. Fired	Mechanical Collector	82.2	1	61.60	12.20	3.55	0.975	..	..		
		• 2 × 62.5	2 × 272	92.4	516	28.50	0.60	P. F. Fired	Mechanical-cum-Electrostatic	97.6	1	61.00	11.20	0.637	1.11	2.905	1.174		
		• 1 × 62.5	1 × 272	92.4	516	28.50	0.60	P. F. Fired	Do.	97	1	61.00	11.80	0.564	1.03	..	..		
16	Hardanganj	• 2 × 50	2 × 220	101.0	540	30.00	0.60	P. F. Fired	Mechanical Collector	85	1	100.00	24.60	2.81	0.88	1.715	0.216		
		• 2 × 60	2 × 260	96.0	540														
17	Obra	• 5 × 50	5 × 220	101.0	540	38.90	0.27	P. F. Fired	Do.	80	1	120.00	28.70	8.06	0.603	3.88	0.101		
18	Bandel.	• 4 × 82.5	4 × 283.5	106.5	543	35.00	0.40	P. F. Fired	Mechanical-cum-Electrostatic	98	4	61.0	9.10	0.506	0.68	1.144	0.768		
19	Durgapur Project	• 2 × 77	2 × 317.6	74.8	500	40.00	0.60	P. F. Fired	Do.	97	2	50.5	12.80	1.045	1.230	..	..		
		(Unit 3 & 4)	1 × 77																
		(Unit 5)	1 × 317.6	74.8	500	40.00	0.60	P. F. Fired	Do.	97.5	1	50.3	13.80	0.868	1.225	..	..		
20	Santalidih	• 4 × 120	4 × 393	134.6	541/541	40.00	0.40	P. F. Fired	Do.	97	2	100.0	10.70	1.01	0.70	0.483	0.189		
21	Renusagar	• 2 × 67.5	2 × 268	88.2	515	30.5	0.50	P. F. Fired	Mechanical Collector	64	1	60.96	10.30	..	0.758	..	..		

*The value of maximum ground levels concentration has not been calculated since data pertaining to Units 1 & 2 are not available.

TABLE 4—14·2

SURVEY OF POWER STATIONS DESIGNS IN REGARD
TO AIR POLLUTION AND STACK DESIGN

4-14·2 ANALYSIS OF DATA

1. Stack Exit Velocity

Velocity m/sec.	No. of stacks	No. of boilers	Installed capacity MW
5-10	12	16	839·6
10-15	37	55	2933·6
20-30	9	33	1850·0
TOTAL	58	104	5614·2

2. Stack Height

Height of stack	No. of stacks	No. of boilers	Installed capacity MW
50	5	7	100
50	10	13	516
60	26	44	2250·7

2. Stack Height—(contd)

Height of stack	No. of stacks	No. of boilers	Installed capacity MW
75-80	9	11	997·5
100	3	8	700·0
120	5	21	1050·0
TOTAL	58	104	5614·2

3. Dust Collecting Plant

Type of dust collectors	No. of boilers	Installed capacity MW
Mechanical Collector	77	3185·1
Mechanical cum electrostatic pre- cipitators	24	2274·1
None	3	155·0
TOTAL	104	5614·2

TABLE 4—15

ASH COLLECTION AND UTILISATION IN U. S. A. (1968)

	Fly Ash Tons	Bottom Ash Tons	Boiler Slag (If separated from Bottom Ash) Tons
	1	2	3
1. Total Ash Collected	19,813,747	7,259,212	2,554,56
2. Ash Utilized (Ash utilized to include ash sold as well as used by company for its own use in concrete, road base stabilisation, etc. Does not include ash hauled or pumped by company to disposal or fill area)			
(a) Mixed with cement clinker or mixed with cement (pozzolan cement)	23,458	..	..
(b) Mixed with raw material before forming cement clinker	107,666	17,510	230,256
(c) Stabilizer for road bases, parking area etc.	141,142	17,009	69,04
(d) Partial replacement of cement in—			
1. Concrete products (blocks bricks, pipe etc.)	113,790	..	17
2. Structural concrete	106,244	..	..
3. Dams and other mass concrete	92,411	..	..
(e) Lightweight aggregate	190,192	32,387	..
(f) Fill material for roads, construction sites, etc.	205,757	583,094	964,220
(g) Filler in asphalt mix	103,827	13,820	63,604
(h) Miscellaneous (Due to the interest shown in this category, Please itemize these uses on the back of this Questionnaire or on a separate sheet of paper including the approximate tonnage of fly ash, bottom ash or boiler slag utilized for each miscellaneous item.	132,582	448,445	256,136
TOTAL ITEM 2-	1,216,745	1,112,265	1,376,048
3. Ash removed from plant sites at no cost to utility but not covered in cate- gories listed under "Ash Utilization".	686,738	705,788	96,432
TOTAL UTILIZED ITEMS 2 AND 3	1,903,483	1,818,053	1,472,480

TABLE 4-15—(Contd.)

	1	2	3
(h) Miscellaneous—Itemized			
Sold for Vanadium	81,216	200	81
Street Ice Control		23,277	9,136
Anti-skid Material		311,150	
Mine Subsidence	16,540		
Extinguishing Mine Fires	3,162		
Filler Mortar	2,300		
Grouting	2,025		
Abrasive Cleaning	226		
Test caps for compressive tests	55,000		
On concrete cylinders	6		
Refractory Ad-Mix	40		
Home concrete dry mix	34		
Experimental—Ready-Mix Supplier	66		
Subsurface-Heavy Construction	2,819		
Foundries Manufacturing Prod. & Fillers	2,700		
Poz-O-Pac.	475		
Asphalt Shingles		67,696	4,989
Sandblasting Grit		22,565	123,842
Land Fill	1,400	20,607	
Spontaneous Combustion Control	15,500		
Seal for Fire			15,500
Drain Base Aggregate			160
Water Filler Media			270
Pottery Company for Research, ...	280		
Aggregate for Asphalt Paving			46,428
Filler in Foundry Sand	1,550		
Power House Insulating Cement	445		
Chemical Products	210		
Unclassified	1,264	3,000	

SECTION 21

STAFFING FOR STEAM POWER PLANTS

1. In order to ensure that the power stations are run only by well experience staff, certain standards of recruitment at lowest level and promotion to higher levels have to be maintained. The boiler statutory regulations specify passing of examinations, conducted by the various State Boiler Boards, but these examinations are not comprehensive enough to embrace entire power stations nor are they statutorily enforceable to all the employees working in a power station. The boiler statutory regulations expect at least one operator incharge of the boiler to possess necessary boiler certificates and since very many more than one person work in a power station whose lack of knowledge and experience may adversely affect or even damage an equipment, it is necessary to evolve methods and procedures for recruitment and promotion to ensure that no inexperienced or partially experienced operator is allowed to handle the expansive equipment in a modern thermal power station. The staffing requirements of each power station and important receiving station should be specified by the designers of that particular installation, so as to effect the coordinated and optimum operation of the system. There should be a requirement, preferably statutory, that the O & M staff be trained adequately through some training institute before being given full charge of the costly and intricate modern power equipment. Some system of certification of competence also need be introduced so that only the duly certified staff is posted in the power plants.

2. The staff required for operation and maintenance must be sanctioned and positioned at least one and half years before the expected day of commissioning of all the different units. The

whole of the O & M staff should be given initial training of six months in some institute then the staff should be posted at the power plant during and commissioning in the installation, test-staff can get training on the specified plant by watching of participating in the installation, testing and commissioing work. Association of the regular operating staff with the operational plant during the construction phase will prove to be a valuable source of training as the manufacturers' expert personnel is available during the construction phase at site. During this period it is important that the personnel recruited for O & M should be assigned definite responsibility and task.

3. The pattern of staffing of the large power stations and their appurtenant works such as stores etc. should be standardised. In the case of power stations the standardisation can be on the basis of parameter system generating sets, number of generating sets, type of fuel etc.

These standardised patterns for manning all power stations and sub-stations etc., should be approved by the Government and accepted by the trade unions as well as management. Standard pattern will have the virtue of elimination of complaints from the unions of personal bias, of power station Engineers from fear of being questioned in case of break-down on an equipment due to lack of adequate supervision. The management too would feel assured of providing maximum possible checks and security at minimum cost.

The standard pattern would not only apply to placement of staff but on office, accounts and stores procedures on which depend numbers in each office.

Staff in stores depends on inventories carried in the power station. In India Power Stations carry very large inventories. One of the main reasons for this is excessive difficulty in getting spares for machines which so far have been of foreign make. As this is an important matter affecting availability and economy of generation a separate chapter is being devoted to this.

Standard organisation for two, four and six unit station giving one T.G. one boiler unit system has been given in the Table 4-16. This is based on the assumption that each operator takes full responsibility of the duties assigned to him.

4. It is understood that the various power supply systems are experiencing difficulty in staffing of personnel in the thermal power stations. On the transmission and distribution side the personnel enjoy various facilities like city comforts, public contacts etc., whereas the personnel engaged on the thermal power plant cannot enjoy the facilities on account of location of power plants away from the cities. Accordingly it is suggested that proper incentives should be given to the personnel to be engaged on the operation

and maintenance of thermal power stations so as to invite sufficiently good talent to handle the various sophisticated and expensive equipment installed at the power stations. In this connection the practice being followed by Maharashtra State Electricity Board will be of interest. A new generation cadre has been created in which all the categories of staff are given some generation allowance and some categories of staff are also given an advance increment in their scale of pay in addition to generation allowance. The incentives being given to the various categories of staff in the Generation Cadre are detailed in Table 4-17. It is felt that in case such practice is followed by other Electricity Boards, this may solve the problem of staffing in the thermal plants. Proper staffing means better operation of the thermal plants and lessening of outages which would mean greater revenues and greater output. The incentives offered to the personnel would be over-compensated by the benefits derived. It is, therefore, recommended that a Generation Cadre should be created in the State Electricity Boards /Undertakings with adequate monetary incentives.

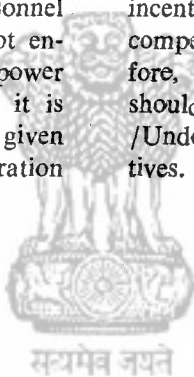


TABLE 4-16

RECOMMENDED OPTIMUM PATTERN FOR STAFFING OF STEAM POWER STATIONS

Name of the post	No. of Posts		
	For 2 Units	For 4 Units	For 6 Units
1	2	3	4
1. General Superintendent	1	1	1
2. Stenographer	1	1	1
3. M/Peon	1	1	1
II. Fuel Combustion and Efficiency			
1. Fuel Combustion and Efficiency Engineer	1	1	1
2. Asstt. Engineer (Fuel)	1	1	1
3. Chargehand	1	1	1
4. Operator	3	3	3
5. Asstt. Gr. II.	1	1	1
6. Asstt. Gr. III-cum-Typist	1	1	1
7. Sampling Supervisor	1	1	1
8. Fuel Sample Collector	2	2	2
9. Messenger/Peon	1	1	1
10. Sr. Chemist	1	1	1
11. Chemist	2	2	2
12. Chemical Asstt.	4	4	4
13. Asstt. Gr. III-Cum-Storekeeper	1	1	1
14. Sample Preparer	2	2	2
<i>Engineer (Technical)</i>			
1. Executive Engineer	1	1	1
2. Asstt. Engineer (Mech./Elec.)	2	2	2
<i>Office</i>			
1. Asstt. Gr. I.	1	1	1
2. Asstt. Gr. II	1	1	1
3. Jr. Steno	1	1	1
4. Asstt. Gr. III-cum-Typist.	1	1	1
5. Messenger/Peon	1	1	1
<i>Costing</i>			
1. Sr. Cost Accountant	1	1	1
2. Asstt. Gr. I (Costing)	1	1	1
3. Asstt. Gr. II (Costing)	1	1	1
4. Asstt. Gr. III-cum-Typist.	1	1	1
<i>Power House and Civil Maint</i>			
1. Tech. Gr. I (Carpenter)	1	1	1
2. Tech. Gr. I (Mason)	1	1	1
3. Rigger (Sr.)	1	1	1
4. Sk. Khalasi	2	2	2
5. Khalasi	1	1	1
6. Overseer/Estimator	1	1	1
<i>Drawing Office</i>			
1. Sr. Draftsman	1	1	1
2. Jr. Draftsman	1	1	1
3. Tracer-cum-Printer	1	1	1
4. Duftry	1	1	1

TABLE 4-16—(Contd.)

1	2	3	4
Stores			
1. Stores Officer	1	1	1
2. Sr. Store Keeper	1	1	1
3. Store Keeper Gr. II	3	3	3
4. Asstt. Gr. II	1	1	1
5. Asstt. Gr. III cum-Typist	1	1	1
6. Technician Gr. II (Carpenter)	1	1	1
7. Tech. Gr. III (Painter-cum-Carpenter)	1	1	1
8. Sk. Khalasi	6	6	6
9. Messenger/Peon	1	1	1
10. Sweeper	1	1	1
IV. Operation (Mechanical)			
1. Superintendent (O & M)	1	1	1
2. Stenographer	1	1	1
3. Messenger/Peon	1	1	1
A. Power Units (Operation)			
1. Shift Superintendents	..	..	5
2. Shift Charge Engineer	5	5	5
3. Asstt. Engineer (Mech.)	9	17	25
4. Controller (Mech.)	8	17	26
5. Controller (Elec.)	4	9	14
6. Asstt. Controller (Mech.)	32	48	64
7. Operator (Mech.)	27	42	57
8. Asstt. Operator (Mech.)	14	28	42
9. Errand Boy	4	4	4
B. Instrumentation			
1. Instrument Engineer	1	1	1
2. Asstt. Gr. II-cum-Store Keeper	1	1	1
3. Asstt. Engineer (Mech./Elec.)	2	2	2
4. Stenographer	1	1	1
5. Messenger/Peon	1	1	1
6. Foreman Gr. I	1	1	1
7. Sr. Instrument Mechanic	2	2	2
8. Instrument Mech. Gr. I	4	4	4
9. Instrument Mech. Gr. II	3	3	3
10. Sk. Khalasi	3	3	3
C. Power House Clearing			
1. Labour Supervisor	1	1	1
2. Sk. Khalasi	4	4	4
3. Khalasi	6	6	6
4. Sweeper	4	9	14
V. Operation and Maintenance (Electrical)			
1. Superintendent (O & M) Elec.	1	1	1
2. Executive Engineer (Elec.)	1	1	1
3. Asstt. Gr. II	1	1	1
4. Jr. Stenographer	1	1	1
5. Asstt. Gr.-III cum-Store Keeper	1	1	1
6. Messenger/Peon	1	1	1

TABLE 4-16—(Contd.)

1	2	3	4
VI. Operation			
1. Asstt. Engineer (Elec.)	5	5	5
2. Asstt. Controller (Elec.)	5	9	13
3. Operator (Elec.)	4	8	12
4. Technician Gr. II (Elec.)	5	9	13
A. Maintenance Inside the Power House			
1. Asstt. Engineer (Elec.)	2	2	2
2. Foreman Gr. I.	1	1	1
3. Technician Gr. I (Elec.)	1	1	1
4. Chargehand	1	1	1
5. Technician Gr. II (Elec.)	4	4	6
6. Technician Gr. III (Elec.)	4	4	5
7. Technician Gr. I (Telephone)	1	1	1
8. Tech. Gr. I (Crane/Tech. Gr. I Crane/Elevator Driver)	1	1	1
9. Sk. Khalasi	8	9	9
Maintenance outside the Power House			
1. Asstt. Engineer (Elec.)	1	1	1
2. Foreman Gr. I (Elec.)	1	1	1
3. Technician Gr. I.	6	6	6
4. Tech. Gr. II (Elec. / Lineman)	6	6	6
5. Tech. Gr. III (Elec.)	8	8	8
Power House			
1. Telephone Operator	2	2	2
2. Sk. Khalasi	10	10	10
Maintenance (Mechanical)			
1. Supdt. maintenance (Mech.)	1	1	1
2. Executive Engineer (Mech.)	1	1	1
3. Asstt. Gr. II.	1	1	1
4. Jr. Stenographer	1	1	1
5. Asstt. S/K-cum-Gr. III.	1	1	1
6. Messenger/Peon	1	1	1
7. Asstt. Engineer (Mech.)	1	1	1
Inside the Power House			
1. Serang Gr. I.	1	1	1
2. Rigger	6	6	6
3. Sk. Khalasi	14	18	18
Outside The Power House			
1. Yard Supervisor	1	1	1
2. Sk. Khalasi	1	1	1
3. Mali	1	1	1
4. Khalasi	3	3	3
5. Sweeper	3	3	2
6. Weigh Bridge Attendant	2	2	2
Turbine Auxiliaries			
1. Foreman	1	1	1
2. Chargehand	1	1	1
3. Technician Gr. I.	3	3	3
4. Technician Gr. II.	3	3	3
5. Technician Gr. III.	3	3	3

TABLE 4-16—(Contd.)

1	2	3	4
Boiler and Auxiliaries			
1. Foreman Gr. I.	1	1	1
2. Foreman Gr. II.	1	1	1
3. Chargehand	1	1	1
4. Technician Gr. I.	6	6	6
5. Technician Gr. I. (Mason)	1	1	1
6. Technician Gr. II. (Mason)	2	2	2
7. Technician Gr. II.	8	8	8
8. Technician Gr. III.	2	2	2
Welding			
1. Foreman Gr. I. (Welding)	2	2	2
2. Tech. Gr. I. (Welder)	2	2	2
3. Tech. Gr. II (Welder)	2	2	2
4. Tech. Gr. III (Welder)	3	3	3
B, Outside the Power House			
1. Asstt. Engineer	1	1	1
2. Foreman Gr. I.	1	1	1
3. Asstt. Gr. II-cum-Store Keeper (Tools Clerk)	1	1	1
4. Tech. Gr. I. Turner (Machinist)	5	5	5
5. Tech. Gr. II. (Bench Fitter/Tinsmith etc.)	5	5	5
6. Hammer Man	1	1	1
7. Khalasi	2	2	2
Coal Handling wagon Tippler Railway Truck and Power House Yards (O & M)			
1. Foreman Gr. I.	1	1	1
2. Chargehand	2	2	2
3. Technician Gr. I.	4	4	4
4. Technician Gr. II.	8	10	10
5. Skilled Khalasi	5	5	5
6. Khalasi	2	2	2
CMT Bull Dozer, Crane Loco 2 Shift (O & M)			
1. Foreman Gr. I	1	1	1
2. Chargehand	1	1	1
3. Technician Gr. I	5	5	5
4. Technician Gr. II	4	4	4
5. Technician Gr. III	1	1	1
6. Asstt. Gr. III-cum-S/K.	1	1	1
7. Driver	8	8	8
8. Diesel Truck-Driver	1	1	1
9. Bus Driver	1	1	1
10. Technician Gr. I (Dozer Scraper etc.)	6	6	6
11. Skilled Khalasi	4	4	4
12. Cleaner for M. T. Vehicles	2	2	2
Administration			
1. Administrative Officer	1	1	1
2. Asstt. Gr. I	1	1	1
3. D/Accountant	1	1	1
4. Asstt. Gr. II	3	3	3
5. Jr. Stenographer	1	1	1

TABLE 4-16—(Contd.)

1	2	3	4
6. Asstt. Gr. III-cum-Typist	1	1	1
7. Asstt. Gr. III.	3	3	1
8. Asstt. Gr. III (Time Keeper)	4	4	3
9. Duplicating Machine Operator-cum-Duplicating and Record Keepera	1	1	4
10. Messenger/Peon	1	1	1
11. Sweeper	1	1	1
<i>Welfare</i>			
1. Welfare Officer	1	1	1
2. Asstt.-cum-Typist (Welfare Centre)	1	1	1
3. Caretaker (Welfare Centre)	1	1	1
4. General Servant	1	1	1
5. Sweeper (Welfare Centre)	1	1	1
<i>Leave Reserve</i>			
1. Asstt. Gr. III-cum-Typist	2	2	2
2. Asstt. Gr. III (S/K)	1	1	1
<i>Security</i>			
1. Security Officer	1	1	1
2. Security staff	40	40	40

NOTE.—The above does not include staff for Accounts, medical, School and Colony Services and is based on cooling towers for cooling water requirements and coal conveyor for transport of the coal supplies.

Total for 2 Units comes to 508

Total for 4 Units comes to 599

Total for 6 Units comes to 690

For a station having 120 MW units, number of personnel per MW would be 2.21, 1.34 and 1.06 in case of 2, 4 and 6 units respectively.

TABLE 4-17
INCENTIVES OFFERED IN TYPICAL GENERATION CADRES
(MAHARASHTRA)

Sl. No.	Category of posts	Generation Allowance granted to the recognised degree/diploma holding engineers posted in the P.S.S Rs./P.M.	Method of filling in the post	Remarks
1	2	3	4	5
<i>I. Pay Group I</i>				
1.	Sr. Power Station Superintendent	75.00	By departmental promotion or by direct recruitment.	
2.	Power Station Superintendent	75.00	Do.	
3.	Asstt. Power Station Superintendent	75.00	By departmental promotion and by direct recruitment provided that every fourth vacancy shall be filled by direct recruitment.	
4.	S. Thermal Engineer	75.00	Do.	
<i>II Pay Group II-A</i>				
5.	Shift Engineer	50.00	By departmental promotion or by direct recruitment.	One advance increment in addition to the generation allowance is also given.
6.	Maintenance Engineers (Boiler)	50.00	Do.	Do.
7.	Maintenance Engineers (Turbine)	50.00	Do.	Do.
8.	Dy. Executive Engineer (Instrumental Control)	50.00	..	..
9.	Chief Chemist	..	..	..
10.	Sr. Control Engineer (Boiler & Turbine Operation).	50.00	By departmental promotion or by direct recruitment.	One advance increment in addition to generation allowance is also given.
11.	Control Engineer	50.00	Do.	Do.
12.	Asstt. Shift Engineer	50.00	..	Do.
13.	Senior Chemist	..	By departmental promotion or by direct recruitment.	
14.	Chargeman Gr. I	40.00	75% of the vacancies are to be filled from Chargeman Gr. II by departmental promotion, preference being given to diploma holders. Remaining 25% to be filled by direct recruitment.	The Engineering Graduates are given three advance increments in addition to generation allowance.
<i>III. Pay Group II-B</i>				
15.	Chief Foreman	..	By departmental promotion or by direct recruitment.	
16.	Head Foreman	..	Do.	

SECTION 22

TRAINING OF PERSONNEL FOR OPERATION AND MAINTENANCE OF STEAM POWER STATIONS

1. The thermal power plants are playing an increasingly important role in the electric power generation in the country. Under the provision of Fourth Five Year Plan installation of additional 4.53 GW of thermal power has been envisaged. Consistent with the above increase in generating capacity, it has been estimated that about 1500 engineers and diploma holders and 4500 technicians would be needed to cater to the requirements of operation and maintenance of new thermal power plants to be installed. Besides, availability of trained personnel for the existing installation is also not satisfactory, as a result of which it has not been possible to operate the various plants under the optimum conditions.

2. Training facilities presently available in India

2.1 Only a beginning in the matter of providing training facilities has been made in recent years by the Central Water & Power Commission. The following pilot schemes have been started in Neyveli, Durgapur and Delhi.

2.2 Neyveli :

This institute offers training facilities for senior personnel and the annual intake is 30 to 40 candidates. The institute offers training to the operation and maintenance engineers, who possess either an engineering degree or diploma. The training programme is for a period of one year. During the first six months, lecture classes are arranged in the afternoon and study of the layout of the plant in the morning. The latter six months are spent by the trainees undergoing intensive inplant training at the Neyveli Thermal Power Station including participation in the operation and maintenance of the same. The inplant training includes the trainees taking parallel

shifts with the operating personnel of power stations. During this period, the trainees are also sent on extensive tours so that they get well acquainted with the working of other major steam power stations as well as the manufacturing process in the large factories like Heavy Electricals (BHOPAL). The lecture classes are held by well experienced engineers of the Neyveli Thermal Power Station and the officers of the institute. This is the oldest training institute and the sixth batch has started in March, 1970. The following courses are offered: (i) Thermal Engineering, (ii) Electrical Engineering, (iii) Automatic Control and Instrumentation. The training equips the trainees to fill the positions of Assistant Engineers and Shift Engineers in-charge in the case of graduates and Controllers and Assistant Controllers in the case of diploma holders, in large thermal power stations.

2.3 Durgapur :

This institute offers training to junior personnel in the categories of operators, mechanics and electricians who possess either a diploma in electrical or mechanical engineering or degree in science from a recognised university. The training programme is for a period of one year from April, to March. The programme is so arranged as to lay greater stress on in-plant training. During the first half of the course, lectures are arranged in the morning and inplant study of the layout etc. of the power station in the afternoon. In between, the trainees are attached to shifts for one month in order to acquaint themselves better with the equipment to be handled. During the remaining five months trainees are attached to regular shift duties sharing the responsibility with

the regular operating staff under the supervision of the officer-in-charge of power station. During the training programme written tests are held to assess the progress made by the trainees. Following course are available: (i) Electrical operation; (ii) Electrical maintenance; (iii) Mechanical operation; (iv) Mechanical maintenance. The training equips the trainees to fill the positions of Mechanical and Electrical Operators and in-charge of maintenance crews for electrical and mechanical works in large thermal power stations.

2.4 Delhi :

A third pilot training institute has been started in Delhi in April, 1970. This is on the same lines as Neyveli Institution and offers identical courses. This institute has training facilities for 30 trainees.

2.5 Apart from the above institutions some of the electric supply undertakings like D.V.C. Tatas, U.P.S.E.B., W.B.S.E.B., G.S.E.B. and M.S.E.B. are having the training facilities to a moderate extent.

2.6 It will be seen that at present training facilities for junior as well as senior personnel are quite meagre. With the existing facilities, it will not be possible to cope with the requirement of trained personnel needed for the proposed power plants and the existing power plants. The present intake of 70 senior personnel and about 75 junior personnel in the various training institutions is grossly inadequate. It is argued in some quarters that there is difficulty in getting the requisite number of trainees for the existing institutions and that, therefore, there is no need of planning their further expansion. This position is not acceptable. It is the duty of the CEA to see that the necessary training facilities are created in the country and, at the same time, to create an awareness among the power supply authorities regarding the need for training. It is possible that some of the power supply undertakings may not yet be fully aware of the available training facilities. Some power supply undertakings will even have to be awakened to the need of having properly trained personnel in the interest of safety, improved plant life and continuity of supply. By the end of the 4th Plan, the capital investment in the thermal power plants alone would be of the order of Rs. 2,000 crores on the basis of present-day cost.

It is absolutely necessary that properly trained personnel are available for the operation and maintenance of such costly and highly complex plant and equipment. The expense of imparting proper training to the O. & M. personnel is really indispensable input for economical and reliable generation of electrical energy. Partly, it also in the nature of insurance premium for the costly plant and equipment. Better operation of the power plants mean better conditions of power supply to the industry and agriculture which in turn would mean better production and prosperity.

3. The C.W. & P.C. and the Union Ministry of Irrigation and Power have shown commendable initiative in setting up the above training institutes. These facilities are, however, grossly inadequate, particularly on account of the institutes being not properly equipped with staff as well as equipment and other training facilities. Since the main beneficiaries are the State Electricity Boards and other major electricity undertakings in each region, it appears desirable that the Regional Electricity Boards themselves should be responsible for organising and operating adequate training facilities in the respective regions. The Regional Electricity Boards should work out the necessary programme for training of about 100 trainees per year in each of the four major regions. The existing Training Institutes can be taken over by the Regional Electricity Boards and new ones started wherever necessary. The Regional Electricity Boards can finance and equip these Institutes to suit the requirements of the power installations in their respective areas and special training may be imparted for dealing with problems peculiar to the respective regions.

3.1 As the institutes grow up they should install sophisticated simulators for training control room operators/engineers and shift engineers who are vital for safe operation of large units. Simulators are dynamic and can be used for training personnel to handle all plant emergencies. Any length of in-plant training will not substitute the above training as emergencies cannot be created on running units.

3.2 When adequate training facilities are set, it is strongly recommended that it should be obligatory for all technical personnel to be employed for operation and maintenance to have proper

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competency certificates issued by the training institutes or by the respective Governments, before they can be posted for these duties. If, necessary, adequate legislation may be passed for the purpose. It should also be necessary for the personnel already employed to undergo some prescribed formal training before obtaining further promotions. It is suggested that the training institutes should admit candidates only on the basis of their being sponsored by the Electricity Boards/Under-takings in that region. The institute should, however, be outside the scope of say union activities. It is necessary to run these institutes in a well

organised, well equipped and efficient manner in order to inculcate a proper sense of discipline and technical know-how which are both very necessary for safe and efficient working of the power systems.

4. The middle level engineers should also be sent for a few weeks at a stretch to the large manufacturing units such as Heavy Electricals, Bharat Heavy Electricals or Instrumentation Factory at Kota for proper understanding of the plant and equipment.



CHAPTER 5

COMMON PROBLEMS

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SECTION I

**MANUFACTURING AND DESIGNING
CAPABILITY OF INDIGENOUS
MANUFACTURERS**

1. The manufacture of power plant and equipment for all new power stations is now being planned in the manufacturing units under Heavy Electricals (India) Ltd. (HEL) and Bharat Heavy Electricals (India) Ltd. (BHEL). Needs in regard to the instrumentation are expected to be met by Instrumentation Ltd., Kota. The programme and scope of manufacture of these manufacturing units is based on technologies purchased from their foreign collaborators. Although the collaborators have a very wide experience in the respective lines, the experience of the indigenous manufacturing units has shown that the design details and range of technological innovations available to the indigenous manufacturers are rather restricted and generally it has not been possible to carry out adaptations of the imported technology to suit the needs of power stations etc. under the Indian conditions. The hydro-electric power station has, in each case, to be designed anew to make the best use of local conditions. Even in the steam power stations, the design of the condensers, for example, has to be related to the temperature and quality of the cooling water, the type and design of the coal mills have to be chosen appropriately for the type of coal available and so on. All these point to the need for developing adequate design capability of the indigenous manufacturers. For want of these, very substantial economies possible in the initial cost of plant and equipment as well as in the operation and maintenance of the plant are being lost to the power supply industry. Apart from the monetary costs, additional costs are involved in the case of inadequate or inappropriate designs on account of difficulties of operation, increased requirement of maintenance outages etc.

2. There is, therefore, an urgent need to develop the design capability in the manufacturing units so that the technology acquired for plant and equipment is fully utilised in a manner suited to the Indian conditions. A survey of the present position shows that this matter has already been receiving some attention in the past few years. Very considerable ground is yet to be covered before concrete results can be achieved.

3. The Central Board of Irrigation and Power (CBI&P) formed Working Groups for Hydro-electric Power Plants, Thermal Power Plants, Switchgears, Transformers and Industrial Motors with a view to standardising the specifications for these, after taking into account the details of the technology available to the manufacturing units. These Working Groups did commendable work in exploring areas where the technology purchased by the manufacturers could be utilised to the maximum possible extent in the Indian Power Stations. They also sorted out areas where modifications and adaptations were desirable. It is highly desirable that the reports of these working Groups be gone into and their recommendations put into practice. Some of the Working Groups like the one on "Hydro-electric plant" have also given thought to the manner in which future technological developments could be absorbed. This is a very important matter requiring as early an implementation as possible.

4. In 1967, the Ministry of Irrigation and Power formed a committee for standardisation of layouts and designs for thermal power plants. The synopsis of its Sub-committee on "Standardisation of Mechanical and Electrical Equipment"

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is attached as Annexure 5-1. The position currently obtaining in regard to the boiler plant is summarised in a D.O. letter of the General Manager of M/s. BHE, Tiruchirapalli, a copy of which is attached as Annexure 5-2. It is necessary for the Power Economy Committee to take a view on these matters after discussions with the respective manufacturers.

5. One difficulty in the development of designs for new plant and equipment is that the indigenous manufacturers have not yet gained experience with their full present range of manufacture before embarking on a programme of extension of their range of manufacture. A case in point would be development of designs for large thermal generating units of capacities 300 MW and higher. The power systems would understandably be reluctant to accept units of higher capacities which may be newly developed by each manufacturer, as the financial stakes in their proper, safe and economical working are very high indeed. On the other hand, the indigenous manufacturers must get an opportunity to extend their range of manufacture on their own without being tied up to foreign collaboration for every change or extension of the purchased designs. This matter has been considered at great length by the Study Group. It appears that one practical way of dealing with the situation would be as follows:—

6. Supposing on the basis of the future needs of the country, the indigenous manufacturers decide to develop a 300 MW generating set on

their own, the Electricity Supply Industry should make available to the manufacturers their thinking in respect of the requirements of such sets in regard to their specifications etc. from the purchaser's viewpoint. Through the good offices of the CWPC/CEA, it should also be possible to decide some site where an experimental set could be installed in the first instance. With close collaboration of the manufacturing units and the Electricity Supply Industry, a proto-type should be designed, manufactured and installed at the selected site. The manufacturing unit should undertake to do this work as a part of the product design work (as is required of any manufacturer) on his own expense and initiative. The power system should make every facility available for installation and subsequent testing and commercial operation of the set as a part of the power system. After gaining experience with the working of the set and carrying out any requisite further developments in the designs and various sub-systems, it should be possible to have the newly developed set working in a satisfactory manner. Depending on its performance in regard to reliability, efficiency, etc., the power system should then agree to purchase the set at a mutually negotiated price. Such an arrangement would prove beneficial to both the manufacturer as well as the Power Supply Industry and it is believed that it is in this manner that further technological advance can be achieved. This is only an illustrative example, needless to say similar process would apply for the development of other equipment also.

SECTION 2

**IMPORT OF SPARES FOR OPERATION
AND MAINTENANCE OF POWER
SYSTEMS—PROCEDURAL DELAYS
AND DIFFICULTIES**

1. Non-availability of adequate spare parts in time has figured as an important element in reduced availability of power plant and equipment as well as operation in an inefficient and at times unsafe manner. Almost all the plant and equipment presently in commission is imported. The spare/replacement parts for these are mostly of a proprietary nature and have to be imported. The indigenous manufacturers have tight delivery position for the supply of main generating plant and equipment. They, therefore, show little interest in producing odd bits of spare parts. As a result of this, even a number of minor and fast moving spares are not being procured indigenously. It is, therefore, certain that at least some imports of spares will have to continue over the life of the presently installed plant. With the difficult position regarding foreign exchange, these imports involve certain procedures for sanction and release for foreign exchange and issue of import licences. These procedures at times involve delays and difficulties which may be frustrating and costly.

1.1 An analysis has been made of the cases received by CW&PC, during 1969 for import of spares for power systems. A total number of 427 cases were received during the year. Of these, 338 cases were given control numbers (in other words these cases were considered as complete) and in the remaining cases, correspondence was in progress with the State Electricity Boards/Project Authorities. Foreign exchange was released (out of 338 cases) for 257 cases. For the remaining cases, references were pending in DGTD Office/Project authorities for clarification and partly in CW & PC. The total value of cases received was over Rs. 2.8 crores. The foreign

exchange which was released accounted for Rs. 2.0 crores of which release under free resources was about Rs. 0.5 crore. Balance releases were under various available credits. Out of the cases, both complete and incomplete, for which foreign exchange totalling to about Rs. 0.8 crore was not released, it was noticed that free resources releases agreed to in all cases would account for 0.5 crore (the balance of about Rs. 0.3 crore would have had to be covered under the available credits etc.) It is also interesting to note that total number of emergent cases received during 1969 calendar year were only five which involved foreign exchange to the extent of Rs. 10.8 lakhs —of which Rs. 8.5 lakhs were released against available credits and releases under free resources for Rs. 2.3 lakhs only.

2. Project authorities invite tenders or obtain quotations from the original suppliers wherever the spares to be procured are of a proprietary nature. On the basis of these quotations, they forward their request for the release of foreign exchange to the Central Water & Power Commission together with a list of goods. On scrutiny, if the C.W. & P.C. finds that the listed spares are covered under general clearance issued by the Director General of Technical Development (which is an annual feature) no reference is made to the D.G.T.D. However, where it is found that the general clearance given by the D.G.T.D. does not cover all the items included in the list of goods, specific references are made to the DGTD for obtaining indigenous clearance. The list of spares together with the values is also referred by the Foreign Exchange Directorates to the Specialised Thermal and Hydro-Electric Directorates and their comments obtained regarding essentiality or

otherwise of allowing the import of the spares in question.

3. The DGTD have given general clearance from indigenous angle for procurement of spares of the following categories:—

- (a) Spares for boilers, turbines, diesel generating sets and all types of mechanical equipment;
- (b) Spare parts for electrical machinery and switchgear/equipment in operation which form proprietary items and have to be obtained only from the Suppliers of the original equipment and without which the equipment cannot be kept in working condition, excluding restrictive sizes of ball bearings.

4. As stated above, for items which do not come under the general clearance, individual references are made to the D.G.T.D. References have also to be made, irrespective of general clearance, to DGTD, if the value of spares involved is substantial and items like pumps, bearings instruments etc. are included in the list of goods. The Project Authorities are also required to furnish a certificate when sending their proposals stating that no banned items are included in the list of goods to be imported. Generally, the time taken by the DGTD for clearing the list of goods from indigenous angle varies from 2 to 6 weeks, depending upon the items involved. In certain cases, time taken may be even more. A few sample cases are given in Annexure 5-3. It would be seen that in some cases, the delays have been as much as nearly two years. Another point of interest is that in almost all these cases, the whole list of goods was cleared by the D.G.T.D ultimately but a lot of delay had already occurred. The non-availability of spares in time seriously affects the operation and maintenance of the power stations. Most of the areas in the country are today suffering from shortage of power and if they are not able to run even the installed sets properly, supply of power further suffers greatly, causing substantial loss of revenue, loss of industrial production and inconvenience to the consumers. In this connection, a note recorded by the Chief Electrical Engineer, D.V.C., is attached as Annexure 5-4. Similarly, experience of U.P. State Electricity Board in specific cases is cited at Annexure 5-5. It would be seen from

the list of goods cited by him that for want of spares which have still not been procured, instruments and controls for which the spares are intended, are not working satisfactorily. Without proper maintenance of the relevant controls, it would be unsafe to operate the boilers at their rated full load capacity. For want of spares for ash water and raw-water pumps, the pumps cannot be maintained properly and their failure affects power generation.

5. Sometimes, the D.G.T.D. suggests that the project Authorities should approach some indigenous manufacturers and then the CW & PC have to write back to them for doing the needful. Experience has shown that the indigenous manufacturers referred to by the D.G.T.D. are generally unable to quote for the supplies and then after considerable delay, reference is again made to the D.G.T.D.

5.1 During these clearances from D.G.T.D. and issue of import licence, it has been noticed that in a large number of cases the validity of the offer had expired. In obtaining an extension of validity of the offer, the project authorities found that the suppliers have increased their prices anywhere from 10% to 30%. Unfortunately, if the spares are of proprietary nature, this extra incidence due to delays has to be borne by the project authorities and additional foreign exchange has to be released by the Government of India by again making references to the Ministry of Irrigation and Power/Finance etc.

5.2 In the case of U.S. Aid Non-Project Loan, after the release of foreign exchange, the Project Authorities have to follow the U.S. Aid procedure. Where the cases are of a proprietary nature, the C.W. & P.C. obtains a waiver from the local U.S. Aid Authorities for not following the Small Business Notification procedure. However, where the supplies cannot be termed as proprietary, the Project Authorities have to invite tenders by giving notice to the Office of Small Business either directly or through ISM, Washington. To that extent, the foreign exchange released earlier is to be treated as only initial release. In case, on the basis of actual tenders after following Small Business Notification, the foreign exchange required is higher, a fresh reference has to be made to the Ministry of

Irrigation and Power, who in turn refer the case to the Ministry of Finance before the revised foreign exchange is issued.

6. As already stated, it is most important that the power plants in the country are run at the highest availability and efficiency when we are suffering from shortage of power. It has, therefore, to be seen as to what steps should be taken to avoid delays in procurement of spares.

6.1 In 1965, the Mathur Committee appointed by the Government of India gave certain recommendations for streamlining the procedures and delegating powers to the various State Electricity Boards/Project Authorities. These recommendations, in so far as they relate to the procurement of spares for maintenance and operation of power systems, were as follows:—

- (a) The State Electricity Boards/Project Authorities should be placed at par with public sector projects and separate unit-wise allocation of foreign exchange should be made to them by the Ministry of Irrigation and Power.
- (b) CWPC should act exactly as the DG TD do in the case of actual users in the private sector.

6.2 The procedure for issue of import licence in the case of public sector projects was that they should approach CCI&E direct in so far as their requirement for spares were concerned and the Mathur Committee accordingly had suggested that in the case of State Electricity Boards also, this procedure should be followed. The Government while accepting these recommendations stated that the CW & PC should undertake ex-post-facto check on a selected basis in regard to the items actually imported by the State Electricity Boards/Project Authorities. It was further specified by the Mathur Committee that even if the objective of delegating effective powers to the projects through the various measures is not considered immediately feasible in view of the present extreme scarcity of foreign exchange, it should be accepted as the desirable goal and the aim should be to reach this goal as soon as it is feasible to do so. In that event, the whole question should be reviewed periodically—say once in six months—at the time of allocating foreign exchange to see whether any or all the recom-

mendations not considered feasible at the present moment should be accepted and implemented at that time.

7. Previously, the State Electricity Boards etc. could make applications direct to CCIE for spares for a value of Rs. 4,000 per year for import of emergent requirements of spares. At the time of the last Conference of the Chairmen of the State Electricity Boards held in 1970, this limit was raised to Rs. 10,000 per year for each unit of the State Electricity Board. Even though this is a considerable improvement on the earlier procedure, it is not likely to go a long way in solving the problem of procurement of major spare parts in time. It is appreciated that it may be difficult to give all the powers to the State Electricity Boards for import of spares as, in a majority of cases, the foreign exchange has to be released under various loans/credits.

8. The CW&PC is authorised to release free foreign exchange for spares upto Rs. 3 lakhs in individual cases without any reference to the Ministry of Irrigation and Power, if allocated foreign exchange is available. However, where the spares are to be procured from the available credits, for example, U.S. Non-Project Loan, West Germany Credit, U.K. Credit etc., a reference has to be made by the CW & PC to the Ministry of Irrigation and Power who in turn forward the papers to the Ministry of Finance for their specific approval for release under the various credits. Where the value of spares is higher than Rs. 3 lakhs, the case is referred by the CW & PC to the Ministry of Irrigation and Power, who have got powers to release foreign exchange in individual cases upto Rs. 10 lakhs from free resources (However, such requests are few).

9. The following steps are suggested for expediting procurement of spares in so far as D.G.T.D. and CW&PC are concerned:—

9.1 It is seen that generally where a reference to D.G.T.D. is not involved, release of foreign exchange by CW&PC/Ministry of Irrigation and Power is done with a reasonable time. Abnormal delays occur in most of the cases referred to D.G.T.D. The Mathur Committee had recommended that the procedure should be reviewed periodically. Experience has also shown that after protracted

correspondence and delays, ultimately the list of goods proposed by the Project Authorities was cleared by the D.G.T.D. from the indigenous angle. It is, therefore, suggested that the CW & PC should keep with them all the information about indigenous manufacture of spares and release foreign exchange on their own without any reference to the D.G.T.D. Where in particular cases, the CW & PC may have some doubts, one of their officers should discuss the matter with the concerned officers in the D.G.T.D. instead of entering into long correspondence and then the CW&PC should take action about the release of foreign exchange. For this purpose, a special liaison cell should be created in the CWPC and the concerned officer should be provided with proper facilities for conveyance etc.

9.2 The State Electricity Boards/Project Authorities should be advised to review the position regarding spares every quarter and take anticipatory action so that proposals regarding release of foreign exchange and issue of import licence are processed well in time. It is seen that emergency spare cases are few and the majority of the cases are in regard to normal wear and tear of various components. The Project Authorities should prepare detailed list of such spares periodically on the basis of their past experience and indicate their projected requirements year by year. These lists should be scrutinised and co-ordinated by the C.W.&P.C. Public Sector Heavy Electrical Manufacturing Factories of Bhopal Tiruchi, Hyderabad and Hardwar should be requested to take steps for their manufacture. We must organise ourselves for the manufacture of spares in the country itself so that before long import is not to be resorted to. It may also be mentioned that manufacturers have a good margin of profit in the supply of spares and this will be to the advantage of the indigenous electric supply manufacturing undertakings. Till the manufacture is organised in the country, the Heavy Electrical Factories should give the clearance to import without delay.

9.3 The Government of India has taken a policy decision that in future the generating plant and equipment would be manufactured in the country by the above public sector undertakings and no import would be allowed. In this connection, it has to be mentioned that for the manu-

facture of the generating plant, these undertakings have to import various components of a large value. If these factories are not able to manufacture these components, it is clear that all the spares in regard to the same would also continue to be imported till such time as these can be made in the country. The responsibility for import of such components should be assigned to these public sector undertakings and they should be asked to assure in future supply of spares for the generating plants supplied by them.

10. Issue of Import Licences by the Chief Controller of Imports and Exports):

10.1 The import licence applications are forwarded by the CW & PC/Ministry of Irrigation and Power, depending upon the authority who has released the foreign exchange; to the Chief Controller of Imports and Exports. It is noticed that normally CCI&E takes between 4 to 8 weeks for issue of an import licence. However, abnormal delays occur in some cases and a few examples are given in Annexure 5-6. CW&PC is also not able to assist the Electricity Boards etc. in the matter as before. Formerly, the CW&PC had a special officer known as Liaison Officer for this purpose. He used to expedite the cases in the Office of the CCI & E etc. by personal contact, furnished any clarifications required at various levels on the spot and greatly helped in getting the import licence issued quickly. The above arrangement is however, no longer possible as the Liaison Officer is now permitted to contact only the Deputy Chief Controller in the office of CCI&E. In this set up, the D.C.C. verifies the position of the case and intimates the same to the Liaison Officer after a few days. Thus a delay of several days is introduced. Further any clarifications required by the Office of the CCI&E cannot be furnished in the course of these interviews and this means further loss of time, leading to undue delays in the issue of import licences.

10.2 Another difficulty which is being felt is that while revalidating the import licence, the CCI&E sometimes raises the issue that the old D.G.T.D. clearance should be got revised in respect of the fact that the orders have already been placed by the Project Authorities after due release of foreign exchange. In certain cases, these licences are in respect of generating plant and

equipment, the import of which has now been banned by the Government of India. The DGTD do not give any clearance in such cases and a reference has to be made to the Committee of Economic Secretaries for getting such cases cleared and for which revalidation has been asked for from the CCI&E. There are instances where an equipment has already been received but the CCI&E refuses to revalidate the import licence and insists on the formalities, viz., reference to the Committee of Economic Secretaries being completed. Sometimes when a fresh reference is made, the DGTD suggest deleting some items which were originally cleared by them and for which orders had already been placed, special efforts then have to be made by the CW&PC to get these items recleared from the DGTD. This is time consuming and irritating as it does not seem to serve any purpose.

10.3 During this clearance from the DGTD for issue of import licence, it has been found that in a number of cases, the validity of the offer had expired and when asked by the Project Authorities to extend the validity, the Suppliers increase the prices considerably, sometimes varying from 10% to 30%. If the equipment or spares are of a proprietary nature, this extra expense due to delays has to be borne by the Project Authorities and additional foreign exchange then has to be released by the Government of India thus causing unnecessary burden on the scanty foreign exchange resources.

11. In its recommendations, the Mathur Committee had suggested that CCI&E should normally issue the import licence within 2 weeks of its receipt of the complete papers including treasury challan. In regard to the revalidation of the import licence, the Mathur Committee had recommended that if the applicant had made commitments during the initial validity period of the import licence, CCI&E should dispose of the application on merits without reference to the CW&PC, but if the applicant had not made any commitments, the application should be referred to CW&PC for advice and then dealt with further. The Mathur Committee had also stated that where the amendments in the import licence application form sent for revalidation are of a minor nature the application should be made direct to CCI&E by the Project Authorities but where the

charge in value or description of goods was involved, the application should be routed through CW & PC.

12. To avoid delays in the issue of import licences which in turn result in delay in work and increase in prices, as well as increased period of outages of the generating plant and equipment, the following suggestions are made:—

12.1 An Officer of the Ministry of I&P/ CW&PC should be attached to the Office of the CCI&E and authorised to deal with the import licence application forms relating to Irrigation and Power Sector. It would be recalled that some years back, a lot of difficulties were experienced in allocation of steel for the various projects by the Iron and Steel Controller and to overcome the same, an officer of the CW&PC was attached to the Office of the Iron and Steel Controller in the rank of Deputy Director and the undue difficulties about the allocation of steel then disappeared. The same procedure is now suggested for expediting the issue of import licences which should be issued within two weeks.

12.2 In cases where firm commitments have been made by the Project Authorities after indigenous clearance of the D.G.T.D. and release of Foreign Exchange, and issue of import licence, no objection should be raised at the time of revalidation of import licence. This should be done as a matter of routine by the CCI&E within a week. The Project Authorities may record a certificate to the effect that firm commitments on the basis earlier approved by the Government of India have already been made by them and such applications may be sent direct by them to the CCI & E under advice to CW&PC. As our policy is to manufacture more and more equipment and spares in these in the country the number of such cases will keep on decreasing with time. Any back reference should be addressed by the CCI&E to the C.W.&P.C. whose recommendations should be accepted.

13. It will be seen from the foregoing that the various procedures which have been devised with the intention to minimise costly imports and to conserve Foreign Exchange have, in the case of power supply industry, become very cumbersome, unwieldy and time consuming. This is defeating the very purpose of their existence and as a result the foreign exchange expenditure often

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increases. Moreover, there is considerable economic loss to the Nation by way of reduced power and energy availability for the industries and agriculture. It is, therefore, strongly recommend-

ed that at least the above suggestions may be adopted and implemented immediately. A further basic review of these procedures may be attempted as a part of the administrative reforms.



SECTION 3

METHODS OF MEETING PEAKING LOADS

1. In all power systems there is a percentage of time during the day when the maximum demands in various spheres of utilisation are simultaneous, thus giving rise to what is called peaking in a daily load curve. The duration, frequency of occurrence and intensity of peaks vary with different power systems, due to types of utilisations. The peaking demands can be met by one or more of the following :

- (1) Hydro-electric units in the system.
- (2) Pumped-storage hydro-electric units.
- (3) Gas turbines.
- (4) Package diesel units.
- (5) Two shift operation of thermal units.
- (6) Integrated regional grid operation.
- (7) Specially designed thermal units to operate under incremental loads.
- (8) High pressure heater by-passing in thermal units.
- (9) Operation of thermal units under variable pressures.
- (10) Low frequency operation during peak periods.
- (11) Mill control in thermal units.

2. Each of these is discussed below in so far as application limitations are concerned :

- (1) Hydro-electric units are essentially suitable for peaking duty in as much as it can be started and fully loaded in a few minutes. But its application is limited in systems mainly or preponderantly thermal in regions where hydro-electric power potential is limited.

- (2) Pump-storage hydro-electric units are ideal as these can not only meet substantially the peaking demands but also even out to a large extent the low loads during nights by operating these units as pumps drawing about 1.5 times of the generating capacity. The sizing of the units can be determined from peaking requirements and economical storage facilities on the downstream of the power house. However, its application is also limited in as much as economical installation of pumped-storage units depends, mainly on topography and other feature like discharge for other purposes than power generation. In high heads installations this tends to be economical but in run of river schemes utilising medium and low heads the cost of downstream storage facilities may become prohibitive.

In respect of both (1) and (2) above, another limitation is imposed on their application in the sense that where seasonal rivers are concerned hydro-electric units can operate as peaking plants during non-monsoon months only as during monsoon most of those rivers carry so much flow that it would be uneconomical to run these units at other than base load.

- (3) Gas turbines constitute a popular method of supplying peaks and in recent years have undergone extensive development. Its usage in India has so far been restricted to areas where natural gas is available. It can however be used at other places also with oil as fuel. It can pick up rated load in about 2 minutes from spinning and 20

minutes from standstill. It is a compact unit and can be installed in crowded localities. This feature is utilised by locating a few gas turbine sets at important load centres which leads to economy in transmission facilities and advantage in meeting individual peaks at these centres all of which may not occur at the same timing.

- (4) Package units run with diesel are also used for peaking demand, which has to be small due to limitation in size of available package units. These also are compact units and can be located at various load centres for advantages mentioned under gas turbines.
- (5) As load during the night is considerably less than the load during peak and other day time, a preponderantly thermal system finds it difficult to maintain operation of the units during night hours. This thermal units on basis of two-shift operation, in the U.K. and other places. This no doubt imposes frequent starting and stopping operations having adverse effect by way of wear and tear and overall life of the plant.
- (6) Assuming that dry period flow pattern for hydro-electric stations in a system is favourable (its energy content equivalent to the energy content in the top portion of the load curve for the capacity of hydro units) there is no difficulty in meeting peak demands during dry months from the hydro-electric units. That assumption is not always correct nor there may be enough hydro-electric capacity to meet the substantial part of peaking demands. In these circumstances, other units in the system, i.e., thermal have to meet the peaking demands. Not all power systems in India have proper combination of thermal and hydro units, as nature has not provided such possibilities. But the situation can substantially change if integrated regional grid operation is resorted to whereby the hydro-thermal generation could serve more than one system in the region or even hydro generation of one region helps systems of another region.

(7) to (9) Thermal units with built-in-incremental capacity are a new trend. Peaking capacity is obtained by modifying the conventional unit and steam cycles to varying degrees and encroaching upon normal design margins. The modifications involve (1) running the units at higher throttle pressures thus increasing inlet and exhaust flows, (2) operating the units with two top heaters out while maintaining the same throttle flow, (3) designing the exhaust for maximum flow under higher throttle pressures and with two top heaters out of service. These can achieve an incremental capacity upto about 30%. No doubt the cost of turbine becomes higher, but this also involves additional cost for larger boiler capacity, additional capacity in the cycle equipment, generator and its step-up transformer, etc. Nevertheless, there will be a substantial saving in such installations over conventional thermal units of similar capacity from the viewpoint of equipment cost and cost of civil and structural works.

- (10) A power system can be operated at reduced frequency, subject to any limitations imposed on its thermal units whereby the loads at the consumer ends are reduced marginally. This was done in the U.K. immediately after World War II when the increased load demand could not be matched by generation capacities available. Such operation over continuous duration has some deleterious effects on the generation capacities. Such operation could be utilized to meet peaking capacity for short duration. This is possible if a power system is run independently where frequency control can be effected as necessary.
- (11) Most of the present day thermal units are equipped with pulverised fuel fired boilers and each boiler is generally provided with three or more pulverisers. Without changing the basic steam parameters, if possible to bring in or cut out one or more mills and increase or decrease load of the unit over a substan-

tial range—the lowest-limit being that load at which the furnace stability can be maintained without secondary fuel support. For example, provided all the mills for full load are available in service, a 140 MW can be operated without oil support at loads 65 MW to 140 MW. This feature when backed up by proper instrumentation and control can substantially meet the peaking demand—no doubt at low load operation, its efficiency will have to be partly sacrificed. This does not involve any additional cost but calls for more operating duties on the part of operators of such thermal units meeting peak demands. In order that over-all generation efficiency is kept high, it is imperative that smaller and older thermal units are given peaking duties while

high efficiency newer plants are run at base loads. This type of control is practised in preponderantly thermal systems where separate peaking capacity is not installed.

3. Apart from these means of meeting system peak demands, methods have to be employed for diversification of load to even out the load curve by introduction of restriction on users and of preference tariff for off-peak hours loads.

4. In a developing country like, India, where limited capital requires diversification into many fields of activities to promote country's overall welfare, installation of separate peaking units or creating incremental peaking capacity in conventional thermal units by investing additional capital should be considered only after exhausting all other means as stated above for meeting peak demands.



SECTION 4

TROUBLES IN ELECTRICAL EQUIPMENT IN POWER STATIONS

Faults in electrical equipment have resulted in loss of plant availability and power generation. It is, therefore, necessary that electrical equipment is carefully selected, installed and operated. This aspect is discussed briefly as follows.

1. Large motors :

In modern thermal power stations, auxiliary motors are of high capacity with heavy starting current. This is particularly significant in case of boiler feed pump motors which generally are the largest amongst all the motors in a Station.

1.1. The starting current of these motors can be anywhere from 5 to 8 times the full load current. Therefore, every start puts quite a strain on the winding insulation. The accepted practice now is to delay the restart of motor till it comes to rest after the motor trips. Such restarts should be limited to one only and there should be a time gap of at least 2 hours for the motor to cool down after the first hot restart.

1.2. In view of this, great care needs to be taken while specifying these motors and suitable instructions are required to be given to the operating personnel. Any failure to take precaution in the manufacture or during operation is likely to lead to insulation failure of the motor windings. Industry or humid atmosphere, completely enclosed motors should be specified so as to effectively prevent ingress of moisture or coal dust. Quite a few motor insulation failures have been reported on account of these two factors.

1.3. In our country, repair of such large motors takes a long time due to lack of availability of replacement coils which have to be

specially made in each case. It is, therefore, prudent to have a spare motor, for each set of motors to enable the repair to the damaged motor to be carried out without impairing the capacity of the generating unit. This is even more true of motors which, during operation, require hot restarts as in case of boiler feed pumps and coal mills.

2. Generators:

Electrical faults on generators have been rare. Due attention should be given to surge protection of the generator and earthing of the neutral to minimise possibilities of damage. Only one instance has come to notice recently where a very old hydro generator was possibly damaged by lightning, otherwise, performance of generators electrically has been quite satisfactory. Close attention should, however, be paid to proper maintenance practices such as cleaning of the winding, keeping it heated during non-operating periods etc.

3. Transformers :

Proper selection of transformers for power stations is very important. The number, vector group of the windings and the capacity of each type of transformer should be carefully evaluated consistent with economy and the reliability and flexibility of the electrical system in a power station. Transformers of proven design over a number of years should be chosen. Proper attention to the handling and laying of various high voltage and low voltage cables connected to the transformers is very important, as there is every likelihood of faults developing in these cables from time to time, thereby jeopardising the generating capacity of a station.

3.1. For hydro power stations the transformers are mostly of water-cooled type, this is due to the fact that water cooled transformers are compact in size, hence more suitable for transportation to remote locations. Moreover, the availability of water is also a determining factor in case of transformers for hydro power stations. The instances of failures of transformer windings even of very large transformers have been relatively high. These have been due to a variety of causes such as over voltages of atmospheric or system origin, inadequacies or defects in cooling systems, ingress of water from the cooling system. Damage to cooler tubes of both transformers and generators have come to notice very often and points to the necessity of manufacturers giving greater attention to choosing materials suited to quality of cooling water actually available. Failure of coolers has quite often been responsible for fairly long forced outages. It should be ascertained that the cooling water used is free from suspended matter thereby avoiding erosion of the cooler tubes. Further it should be ascertained that inadvertent high pressure is not allowed to impinge on the cooler tubes. Suitable surge tanks should be installed to absorb the effects of water hammer.

3.2. In a number of cases, faults originating from the transformers taps have taken place. It is important that the design and quality of manufacture of transformers installed at power stations and major substations be of the highest order. The maintenance personnel should strictly follow the procedures for checking and maintenance of oil and keep careful watch over temperatures etc. so that defects could possibly be noted before growing to proportions of major damage. Buchholz or similar relays, in fact, form the most important safeguard for the transformer, the same should be kept in proper working order and its performance carefully logged.

4. Protection against lightning and transient over voltages :

For purposes of protection from lightning and transient over voltages it is essential that the lightning arrester ratings should be carefully selected keeping in view the duty involved, and these are installed as close to the transformer terminals as practicable.

A few instances of failure of lightning arrester have come to notice. In the general case, failures arise from wrong application. However

all cases cannot be fully explained by this and may be due to inherent vagaries of lightning phenomenon. It is necessary that performance of lightning arrestors be properly monitored to discover any defective pieces and the insulators kept clean especially in areas subject to pollution, particularly just before the onset of monsoon.

5. Circuit Breakers :

Special care is required to be taken in the selection of high voltage circuit breakers for the generating units. It is wise to select a breaker of proven design over a number of years in similar local conditions. Particularly in the case of air blast circuit breakers, it is quite possible that serious trouble may be encountered in the operating mechanism of the breaker or in the breaker itself due to leakage of compressed air. Reliable central compressor for these breakers should be provided for the compressed air supply, and adequate attention should be paid to the maintenance and operation of the air compressor. The porcelain insulators of the circuit breakers should also be kept clean.

5.1. Failures of high voltage circuit breakers have been rare and generally due to extraordinary causes such as, earthquakes. With the rapid expansion of power systems and integrated operation that are now taking place, it is however, important that the adequacy of circuit breakers at various points be kept under review and timely action taken to replace breakers wherever necessary or to augment its rupturing capacity or to make provisions in the system to protect the circuit breakers from being subject to excessive duty. The importance of stringent maintenance of the auxiliary and ancillary apparatus of this most important item of equipment can hardly be over-emphasised.

6. Outdoor Switchyard :

Care must be taken in the design of the bus bars and its connectors and type of conductor used for the same. Adequate care is also required during erection of the bus bar connectors as otherwise serious trouble may be faced from time to time jeopardising generating output from the station for several hours. Similarly, careful selection of the high voltage isolators are required to be made either with local control or remote control as considered necessary for a particular station. The isolators should have fool-proof electrical and mechanical interlocks with the corresponding circuit breakers.

7. Protection and Control :

7.1. The selection of the ratings of current transformers/potential transformers require specialized knowledge. The ratings and characteristics of the current transformers require to be matched properly with the VA burden and characteristics of the relays. The current transformers for the high voltage circuit breakers should be of reliable make and preferably have double secondary windings so that the primary and back up protective relays can be connected separately to the two windings. This is desirable since, for a single secondary winding current transformer, any fault in this winding puts both the primary and back up protective relays out of commission. This is extremely dangerous in a power station.

7.2. It is necessary that correct operations of the protective relays are tested annually by primary injection tests at site so that the relays, along with their associated circuits, are tested and any abnormality promptly attended to. It is also necessary to pay special attention to relay settings. These have to be co-ordinated properly with the line protective relays as otherwise either the generator circuit breakers and/or reserve transformer circuit breakers are liable to trip even for a fault on the transmission lines and thereby put one or more generating units out of commission.

7.3. In a large capacity power station, it is desirable to have one or more bus section circuit breakers with the bus zone differential relay protection so that, for a fault in any one section of the bus, the entire station is not put out of commission.

7.4. It has been found advantageous to have D.C. operated contactor starters for all important 400 volts motors in a station so that these contactors do not trip out on under voltage for

any voltage dip caused by a transient fault in the high voltage systems either in the switchyard or in the outgoing high voltage lines.

7.5. The reliability of auxiliary power supplies particularly D.C. supply is of the highest importance in ensuring proper operation of the station as well as reliable functioning of the protective gear. In some cases it has been found that a modification of the grouping of circuits can lead to greater reliability. Close attention should be paid to this feature at the time of initial designs and further review should be taken whenever any instance of difficulty or malfunctioning comes to notice. Power supply for initial starting of power station must be fully secured. It is of great importance to ensure that all the annunciation and alarm systems in a power station or substation are maintained to be fully operational at all times. Deficiencies in this regard have been noticed many times which arise from failure of one link or the other of the system having remained neglected. It should be ensured that annunciation and alarm systems are adequate for the needs at any particular time and it should be kept in full working order.

7.6. Close attention should also be given to proper placing of cables so that these will not be subjected to deterioration due to weather or some other local causes and can be easily identified for maintenance purposes. In laying of cables it should be ensured that damage to some type of cable will not result in injury to other cables. Attention should also be given to avoiding inadvertent effects by one type of cables on another. Power cables and control cables should be laid in separate cable trenches. The cable runs should be carefully planned and these should be kept away from oil tanks and other inflammable material

CHAPTER 6

RECOMMENDATIONS AND CONCLUSIONS

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**CONCLUSIONS AND
RECOMMENDATIONS**

Plant Availability and Utilisation

1. There is an urgent need to improve power plant availability and utilisation. For this integrated operation of the power systems in every region as well as improvement in availability of thermal power plants are necessary.
2. Modern methods of scientific management, particularly operation analysis should be introduced immediately and utilised increasingly for improving the quality of preventive maintenance and reducing the plant outage time for maintenance.
3. Separate technical cells for quality control in operation and maintenance, improving fuel efficiency etc., should be set up in each organisation directly under the Chief Engineer and in the case of Electricity Boards directly under Technical Members.
4. Continuous monitoring of the plant availability (including partial availability) should be introduced immediately.
5. There should be a system of studying the plant availability, causes of outages and statistical analysis of availability outages on a nationwide basis. This may be done through Central Board of Irrigation & Power. The system evolved by Edison Electric Institute of U.S.A. may be adopted for the purpose with certain modifications.
6. A system of voluntary reporting in respect of technical problems of equipment

failures and operating difficulties should be instituted immediately. The systems already developed in India as well as in U.K. and U.S.A. should be studied and common modern system of reporting and analysis should be evolved, for All-India application. The data collection may be at the level of individual systems or regions, but the analysis of incidence and sharing of this valuable technical experience should be on an All-India basis. This should be organised through the Central Water & Power Commission.

If the above system of voluntary reporting of problems does not work satisfactorily, statutory regulations making compilation and supply of such information obligatory should be made.

Hydro-Electric Power Stations

7. Each Hydro-electric Project should be designed for flexibility of operation and the capability to assist optimisation of power system performance should be built into it.
8. All new projects should permit (i) substantial additions to installed capacity for enabling low load factor operation and (ii) addition of governing and excitation equipment for remote monitoring and control and better system performance.
9. Design capability for planning engineering and designing of hydro-electric projects needs to be built up in a big way.

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10. Each hydro-electric power station must be operated to utilise fully the energy potential available at the site from year to year and season to season.
11. Periodical expert inspection and preventive maintenance must be arranged for all the different components of hydro-electric projects.
12. Every effort must be made to maintain the instrumentation, control, protection and alarm devices in the hydro power stations fully operative at all times.
13. Communication facilities between different portions of hydro-electric project should be watched and improved wherever necessary from time to time.
14. In all power stations, special facilities as well as equipment and tools and tackles required for efficient and rapid maintenance operations should be kept available.
15. The maintenance and overhaul of hydro-electric plants should be carefully scheduled to ensure full plant availability and utilisation.
16. Projects older than about 20 years should be reviewed from time to time to see how the benefits from these could be improved by modernisation.
17. The performance of hydro-electric plant and the water conductor system etc. should be checked every 2-3 years by index methods. The necessary calibration for the index methods should be provided during the initial commissioning tests.
18. A service organisation for the safety of water storage structures should be set up immediately. Its scope should preferably cover water conveyance structures as well, in the case of hydro-electric works.

Steam Power Stations

Efficiency of Energy Generation

19. The causes of decrease in efficiency with increase in energy generation in some of the large power stations mentioned

in section 6, para 4:3 should be investigated.

20. Studies should be undertaken to see if the power stations listed in section 6, para 4:5 could not be backed down and the energy requirements supplied from higher efficiency plants in the region.
21. Concerted efforts should be made to improve the efficiencies of the plants listed in section 6, para 4:3 or to reduce their energy generation in favour of generation at higher efficiency plants in the region.

Coal Prices

22. Pit head Coal Prices need to be rationalised on the basis of heat content of the coals.
23. Long term coal contracts should be drawn up on the basis of standard form to be developed by the Regional Electricity Boards. These should cover the question of prices as well as the quality of the fuel.

Utilisation of By-products from Coal Washeries

24. The working of existing coal washeries should be modified to reduce the ash content to 28-32 per cent and also to ensure removal of stones and other abrasive material from the by-products supplied to the power station as fuel. A practical time schedule should be drawn up for this immediately. Studies and designs for the additional equipment and any changes required in the processes for the above purpose should be started immediately jointly by National Coal Development Corporation, Hindustan Steel Ltd., Central Fuel Research Institute etc.
25. The future coal washeries should be 3 stage ones and the ash content of the middlings should be restricted to 28-32 per cent, and adequate arrangements for removal of abrasive material should be made.
26. The factors responsible for erosion damage to the boiler plant and equipment should be identified by careful

and intensive research through the Central Fuel Research Institute and other appropriate bodies. Apart from identification of these factors, this should lead to improved supply of fuels and also include design and construction of boiler plant and appurtenant equipment for minimising the maintenance outage costs.

27. Design, construction and materials in the boiler plant and its auxiliaries require considerable further work for devising ways and means of operating satisfactorily with washery by-product fuel. The existings installations should be utilised for making field trials of different new innovations or designs of equipment for this purpose.

The equipment requiring particular attention is the coal mills, I.D. Fans, layout and arrangements of superheater and economiser tubes, design and arrangement of burners and ash handling and disposal systems. It is recommended that indigenous boiler plant manufacturers and manufacturers of appurtenant equipment should be asked to tackle this problem in collaboration with the organisations owning and operating the existing power stations.

Transportation of coal to Thermal Stations—Unit Train

28. Considering the volume of coal traffic for individual large power stations, the time is now ripe for the introduction of new innovations such as unit trains in the matter of transport of coal by rail. A study in depth should be undertaken for this purpose immediately by the Railways jointly with the coal and power station authorities.

Rationalisation of freight structure over short distances

29. The freight structure for transport of coal by rail over short distances under 50KM should be reviewed and rationalised.

Petroleum Fuels

30. The pricing of by-product petroleum fuels should be based on the costs of Indian crudes instead of on the basis of import parity.
31. Wherever there is possibility of obtaining supplies of petroleum, firm long term contracts should be made between the suppliers of petroleum fuels and the power station authorities.
32. In the years to come, the by-products of refineries will mostly be required as industrial raw-material. No large power stations should, therefore, be based on petroleum fuels alone. Unless the petroleum authorities assure supply of petroleum on long term contract basis, the siting of the power stations should be decided primarily on the basis of these being coal burning power stations.
33. Commitments made regarding supply of petroleum fuels to power stations should be honoured fully in future also. In case of 100 per cent petroleum fuel based power stations if petroleum fuels are not likely to be available in future, these power stations should be given a warning sufficiently in advance to enable their making alternative arrangements. The Power stations should be compensated for the additional costs involved on this account.
34. Oil is essential for supporting for all pulverized fuel fired installations and its availability in adequate quantities at economic price must be ensured for such installations.

Problems of Operation and Maintenance

35. The thermal power plant equipment should be matched closely to the type of fuel, cooling water temperature and other site conditions.
36. The working of each power plant installation should be continuously watched for removing any snag at the incipient stage and improving the operation and maintenance. Full use should be made of the experience on similar power plants in other parts of the country.

37. A number of common problems in operation of steam power stations discussed in the report should particularly be avoided by proper action in planning, design and operation of the plant.

Relaxation of Boiler Act Provisions

38. The Provisions of Boiler Act should be modified to permit biennial inspection of boilers instead of annual. In fact, it may be worthwhile to have a separate set of rules and regulations drawn up for large project installations of modern steam power stations with unit sizes of say over 30 MW.

Ash Disposal

39. Representatives of the Electricity Supply Industry and Central Water & Power Commission should be invited to participate in formulation of regulations regarding pollution of air and water courses.
40. Intensive research and development work as well as promotional work should be undertaken for utilisation of the ash produced as by-product in the steam power stations. Organisations like Central Building Research Institute, Central Road Research Institute, National Building Organisation, Cement Research Institute, as well as Indian Standards Institution and Central Water & Power Commission should be brought together for devising ways and means for utilisation of the fly-ash and bottom ash.
41. Utilisation of ash should be entrusted to a non-profit corporation to be established co-operatively by the different power station authorities in each region. This corporation, financed mainly from sale of ash, should organise the development and promotional work applied research work (in different appropriate institutes) and the work of marketing and disposal of ash from thermal power stations.

Common Problems

Staffing for Power Plants

42. The pattern of staffing of the large power stations and their appurtenant works such as stores etc. should be standardized on the basis of parameters of the generating sets, their number, type of fuel etc. The standardized patterns should be got approved from the Government as well as representatives of both Management and Labour. The scope of work and the responsibility of each person should be laid down clearly in the standardised staffing patterns.
43. The exact requirement of staff for any installation in the context of the standardized pattern mentioned above, should be specified by the designers of the installation.
44. The staff required for operation and maintenance should be sanctioned with the finalisation of the design and start of construction and in any case at least 18 months before the expected date of commissioning of the first unit. The sanctioned strength should be fully recruited at the earliest, for purposes of training on similar installations during the year preceding the commissioning of the power plant. The full sanctioned strength of the technical personnel should be in position for gaining an understanding of the plant by assisting during the Acceptance and Commissioning Tests and installation of the major plant sub-assemblies.
45. A separate Generation Cadre should be instituted to ensure that adequately trained staff is available at generating stations. A system of incentives or special pay etc. should be introduced for the Generation Cadre to attract and keep suitable persons.

Training of Personnel

46. There should be a requirement preferably statutory that the O&M staff must be qualified by proper training and experience preferably through some recognized training institutes before being

given the full and independent charge of the costly and intricate modern power station equipment. A system of certification of the O&M staff similar to that in vogue in the Civil Aviation Industry could be adopted.

47. Refresher Training Courses should be arranged for all the technical staff in a phased manner so that each person has to go through a course at the interval of 5-7 years. Even the O&M staff at the technical level should be routed through other similar systems.
48. Existing facilities for training of personnel for operation and maintenance of steam power stations are grossly inadequate.
49. Training of personnel for operation and maintenance of power stations should be the responsibility of the Regional Electricity Boards. They should assess the requirements and organise adequate training facilities including in-plant training to suit the requirements peculiar to the respective regions.
50. For the purpose of certification of competency in operation and maintenance, the Central Electricity Authority should formulate the minimum requirements on a nation-wise basis.

Instrumentation for Power Plants

51. Special attention should be given to the adequacy of control protection and instrumentation systems in every installation. Proper operation and maintenance of these systems is of the highest importance for minimising forced outages. Well-equipped instrument laboratories should be provided for each large installation or group of installations. Special Instrumentation Cells should be manned by highly competent trained personnel who should ensure proper functioning of the instrumentation system throughout.

Documentation

52. Detailed completion drawings and reports should be available at each pro-

ject, so that all changes adopted during construction are properly recorded.

53. Comprehensive manuals and instructions complete with drawings, photographs, descriptions etc. must be available for each element of power plant installations. These must cover operation, maintenance and instructions for abnormal conditions. Sufficient number of copies must be available for all concerned and these must be reviewed and brought up-to-date every year.

Manufacturing and Designing Capability of Indigenous Manufacturers

54. There is an urgent need to develop the design capability in the manufacturing units, so that the technology acquired for plant and equipment is fully utilised in a manner suiting the Indian conditions.
55. At the time of commissioning any hydro-electric project, detailed guide-lines for water management, most appropriate for the project, should be laid down.
56. The high cost of plant and equipment from indigenous sources causes an undue burden on the power systems in the country. Equitable methods should be evolved for apportioning the heavy cost of acquiring new technology among the present and future projects. The cost of social benefits like new housing colonies, schooling, hospitals and other facilities need not be a charge on the cost of plant and equipment for new power stations but should be borne by respective States in which the factories are situated.

Import of Spares

57. The following should be done to streamline the procedure for import of spares for operation and maintenance of power systems and to eliminate the procedural delays and difficulties.
- 57.1 The clearance of applications from indigenous angle should be done by Central Water & Power Commission itself.

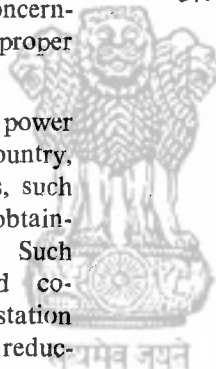
For this purpose, the Directorate General of Technical Development should equip the Central Water and Power Commission with all the information about indigenous availability of spare parts, auxiliaries etc. The Electricity Boards/Project Authorities should adopt modern methods of inventory control for dealing with their replacement of spares. In any case the position regarding spares should be reviewed by them at least every quarter and anticipatory action taken, so that the time normally required for release of foreign exchange, issue of import licence etc. does not come in the way of proper operation of the power installations or execution of projects. A special Cell should be created in the Central Water & Power Commission and the concerned officer should be provided proper facilities for conveyance etc.

- 57.2 Where a number of identical power plants have been installed in the country, some additional emergency spares, such as a spare thrust bearing may be obtained and kept in common reserve. Such common pool of spares, financed co-operatively by the different power station authorities may go a long way in reduc-

ing the loss of energy generation due to forced outages.

- 57.3 The Chief Controller of Imports & Exports should give necessary facilities to the Liaison Officer of the Central Water & Power Commission for expediting the cases of issue of import licence for spares. This can be done by placing an Officer of the Central Water & Power Commission in the Office of the Chief Controller of Imports & Exports for carrying out liaison work. After release of foreign exchange and indigenous clearance Regional Joint Chief Controller of Imports & Exports should be authorised to issue import licences.

- 57.4 Revalidation of import licences in cases on which project authorities have entered into commitments, after clearance of the Directorate General of Technical Development, should be done as a matter of routine by the Chief Controller of Imports & Exports within a week. Any back reference by the Chief Controller of Imports & Exports should be addressed to the Central Water & Power Commission and not to the project authorities.



ANNEXURE 2—1

Edison Electric Institute—Prime movers Committee Equipment Availability Data Reporting Instructions

A. Equipment Definitions :

1. Non-header Unit Unit in which a single boiler is connected solely and independently to a given turbine generator.
2. Header Unit Unit in which the turbine-generator is not solely and independently connected to single boiler.
3. Major Equipment Major group of equipment within a unit, such as, boiler reactor, generator, steam turbine, condenser.
4. Component Part within a "major equipment" group, such as : superheater, tube, governor, buckets, boiler feed pump.
5. Maximum Dependable capacity (MDC) The dependable main-unit capacity winter or summer, whichever is smaller.

B. Operation and outage definitions :

1. Available The status of a unit or major piece of equipment which is capable of service, whether or not it is actually in service.
2. Base Loading When a unit is generally run at or near rated output.
3. Cranking Loading When a unit is generally shut down on standby for auxiliary power during emergency.
4. Cycling Loading When a unit is generally run but at a load which varies widely with system demand.
5. Economy Outage (See Reserve Shutdown).
6. Forced Outage The occurrence of a component failure or other condition which requires that the unit be removed from service immediately or up to and including the very next weekend.
7. Forced Partial Outage The occurrence of a component failure or other condition which requires that the load on the unit be reduced 30MW or more immediately or up to and including the very next weekend.
8. Maintenance Outage The removal of a unit from service to perform work on specific components which could have been postponed past the very next weekend. This is work done to prevent a potential forced outage and which could not be postponed from season to season.
9. Non-curtailling Equipment Outage The removal of a specific component from service for repair which causes no reduction in unit load or a reduction of less than 30 MW.
10. Non-operating Equipment Test A scheduled test or required operation of a back up system which is not normally operating.
11. Outage Cause A component failure, preventive maintenance or other condition which requires that the unit or a component be taken out of service or run at reduced capacity.
12. Peaking Loading When a unit is generally shut down and is run only during high demand periods.
13. Planned Outage The removal of a unit from service for inspection and/or general overhaul of one or more major equipment groups. This is work which is usually scheduled well in advance (e.g. annual boiler overhaul, five-year turbine overhaul).
14. Reserve Shutdown The removal of a unit from service for economy or similar reasons. This status continues as long as the unit is out but available for operation.
15. Scheduled Partial Outage The occurrence of a component failure or other condition which requires that the load on the unit be reduced 30 MW or more but where this reduction could be postponed past the very next weekend.
16. Unavailable The status of any major piece of equipment which renders it in-operable because of the failure of a component work being performed or other adverse condition.

ANNEXURE 2-1—(Contd.)

C. Time Definitions :

1. Available Hours (AH) The time in hours during which a unit or major equipment is available ; $SH + RSH$.
2. Demand Period The time interval each day which is the period of maximum demand on a particular system.
3. Economy Outage Hours (see Reserve Shutdown Hours). The theoretical value of Economy Outage Hours (TEOH) is the difference between Available Hours and Service Hours. If the TEOH differs by less than 1% with the Economy Outage Hours reported at the end of the year they are considered equal and flagged with Code 1. If the difference is more than 1%, but less than 10%, they are flagged with Code 3; but the reported Economy Outage Hours are still used. However, if the difference is greater than 10%, the calculated value TEOH is used, and Code 2 is a flag that Economy Outage Hours have been derived.
4. Forced Outage Hours The time in hours during which a unit or major equipment was unavailable due to a Forced Outage.
5. Forced Partial Outage Hours (FPOH) The time in hours during which a unit or major equipment is unavailable for full load due to a forced partial outage.
6. Hours Waiting (HW) That portion of time for any outage during which no work could be performed. This includes time for cooling down equipment and shipment of parts. This is time that could not be affected by a change in work schedule or the number of men worked.
7. Maintenance Outage hours (MOH) The time in hours during which a unit or major equipment is unavailable due to a maintenance outage.
8. Period Outage Hours (POH) The clock hours in the period under consideration. (Generally one year).
9. Planned Outage Hours The time in hours during which a unit or major equipment is unavailable due to a planned outage.
10. Reserve Shutdown Hours (RSH) Reserve shutdown duration in hours.
11. Scheduled Partial Outage Hours (SPOH) The time in hours during which a unit or major equipment is unavailable for full load due to a scheduled partial outage.
12. Service Hours (SH) The total number of hours the unit was actually operated with breakers closed to the station bus.
13. Unit Years (UY) This term is the common denominator used to normalise data from units of the same type with different lengths of service. The following example contains 20 UY of experience from 4 units.

	A	B	C	D	4
Years in Service	8	3	7	2	20
14. Work (Manhours Worked) (MH) The total number of manhours worked on or off site to accomplish repairs.

D. Equations :

1. Average Forced Outage Duration (Summation of FOH) (Number of Forced Outage).
2. Capacity Factor (Total Generation in MW-Hr)/(PH $\times$ MDC)
3. Component Outage Severity Index The average number of forced outage hours of a specific component per incident.
4. Equivalent Forced Outage Rate (EFOR) (for each forced partial outage, an equivalent full load outage duration is calculated to include the effect of partial as well as full forced outages on the forced outage rate).

EFOR is calculated as follows :

$$TE = FPOH (CR/CF)$$

WHERE :

TE is equivalent forced outage time.

CR is size of reduction or derating from full load.

CF is rated capacity

THEN :

$$EFOR = 100 (TR + TES) / (TO + TF + TAS + TPS)$$

WHERE :

TF is total full forced outage time

TO is total operation time at 100% availability.

TAS is sum of actual forced partial outage times.

TES is sum of equivalent forced outage times.

TPS is sum of equivalent scheduled partial operating time.

ANNEXURE 2-1—(Contd.)

5. Forced Outage Incident Rate (Forced Incidents)/(Forced + Maintenance + planned Incidents)
6. Forced Outage Rate FOH/(SH+FOH)
7. Forced Outage Ratio FOH/(Total Unavailable Hours)
8. Operating Availability AH/PH
9. Output Factor (Total generation in MW-Hr.)/(SH × MDC)
10. Relative Mechanical Availability (RMA) . . Relative Mechanical Availability is a form of Operating Availability adjusted to show relative effect. The prime assumption is that most outage time is affected by work schedules and crew sizes. Relative Mechanical Availability uses an adjusted Outage Time (AOT) based on effort. Manhours worked is a measure of effort which is reasonably independent of work schedules and crew sizes. Manhours worked (MH) divided by a standard work force (SWF) gives a derived time worked based on effort. If we assume a round-the-clock schedule, then this derived time worked is almost a derived outage time based on effort. The difference is the amount of outage time which is independent of effort called Hours Waiting (HW). See Appendix C-6. An arbitrary assumption of ten men for the standard work force gives :

$$AOT = HW + MH/10$$

Then substituting AOT for outage time in the equation for operating availability gives;

$$RMA = (PH - AOT)/PH$$

$$= (PH - (HW + MH/10))/PH$$



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ANNEXURE 3—1

Service for the Safety of Dams

The functions of the proposed Service will comprise :

(1) Review of the overall soundness of design from the structural safety aspect; this will particularly be done with special attention to foundation treatment; river diversion arrangements, construction materials, specifications construction schedule and instrumentation.

(2) Inspection of the dam and allied works under construction as often as necessary with a view to ensuring that the specifications and the construction practice followed do not militate against the requirements of the structural safety of the dam and that the specifications and construction practices followed are in accordance with accepted or acceptable norms; such inspections during construction will also aim at a review of the quality control exercised.

(3) A thorough pre-commissioning drill covering all elements of the dam and allied features, particularly the functioning of gates and outlet arrangements specially the surplusing arrangements.

(4) Inspection of the dam and allied features after the work has been commissioned; this inspection will be mandatory once a year for the first few years; there after, such inspections may be timed as necessary; it shall be incumbent on engineer-in-charge of a dam to notify the service immediately of any incipient or actual distress at any stage in the life of the project.

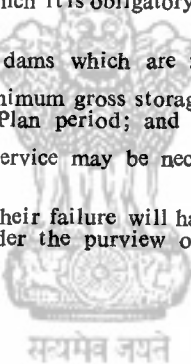
(5) The Service will receive and review the data obtained from the instruments embedded in dams and allied features.

* While the Service is intended to uncover causes and forestall possible failures of dams and allied structures it is not intended to substitute for the control which it is obligatory for a construction and operating agency to have in itself.

It is proposed that the Service attend to dams which are :

- (i) 50 feet or more in height or having a minimum gross storage of 100,000 acre-feet, currently under construction or to be taken up in the Fourth-Plan period; and
- (ii) in special cases, where the help of the Service may be necessary, even though the structures do not qualify under (i).

Structures ancillary to dams, in so far as their failure will have the same catastrophic result as the failure of the dams themselves, will also come under the purview of the Service.



ANNEXURE 4—1

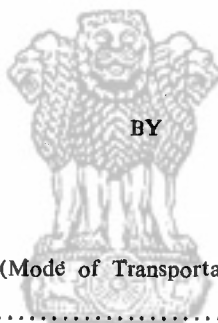
Standard Contract Form for purchase of Coal/Middlings

(Name of Organisation)

.....

SPECIFICATION NO.

FOR
SUPPLY AND DELIVERY OF
TONNES OF COAL/MIDDLINGS



(Mode of Transportation)

.....

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TO

.....THERMAL POWER STATION

(Month)

(Year)

.....

PRICE Rs.

Designation and address of Officer.

.....

(inviting tender)

.....

.....

.....

(Name of Organisation)

.....

Tender No.

Dated

TENDER NOTICE

Scaled tenders are invited by the....., for supply and delivery
tonnes of freshly mined ROM,.....moisture,
 non-coking Gr. Coal/Washery Middlings containing not more than 35% ash
 on air dry basis @.....tonnes per month by Road/Rail/.....
 Transportation to.....
Tenders in-triplicate under sealed cover must reach the (Office).....
(Organisation).....by.....(time) on the....
(date).. Tenders received after the time and date as specified above will not be considered. No ex-
 tension of time for submitting the tenders shall be allowed.

Copies of the detailed specification and Tender Forms may be obtained from the Office of the.....
on production of receipt of payment of Rs.....
 (Rupees.....) per set (not refundable) to the
 Treasury/Accounts Office....., P. O.....Dist.....on
 all working days between(time).....No specification will be issued on the date of opening of the tenders.
 Outside, Firms may remit the amount by.....(any other mode of accepting payment).....

Tenders delivered by special messengers should be deposited in the Tender Box kept in the Office of.....
Nobody is authorised to receive or grant receipt of tenders delivered by hand

Tenders will be opened by.....in his
 office at on.....at.....A.M. in the presence of the tenderers or
 their authorised representatives who may be present.

The.....(name of organisation/Officer).....reserves the right to
 reject any or all the tenders partly or wholly, if considered necessary, without assigning any reason whatever.

(Name & Designation of Officer inviting
 the Tender)

.....

Power Economy Committee

1. General :

(a) Tenders are invited from reputable mine/Washery owners (Public or Private Sector) or Coal Supply Contractors of adequate resources for supply and delivery of large quantities of freshly mined non-coking 'RUN-OF-MINE' coal or middlings of specified classification by road/rail/..... at the coal storage yard of..... Thermal Power Station,.....(Name of Organisation)....., situated in the District of.....

Tenderers shall furnish sufficient evidence of their ability to maintain full supply and delivery of the specified large quantities of coal/middlings. Preference will be given to tenderers capable of supplying the entire quantity of coal/middlings as per this specification. Tenderers offering delivery less than.....tonnes per month shall not be considered by the..... The successful tenderer may be required to start supply of coal/middlings by.....(date).....

2. Quantity and Rate of Supply :

(a) The tenderer shall undertake to supply and deliver by.....(mode of transportation).....to the.....Thermal Power Station..... Tonnes gross or the quantity ordered by the....., in the Letter of Intent of freshly mined, 'RUN-OF-MINE', non-coking coal/middlings of the quality as specified in item 4, at the minimum guaranteed rate of delivery of.....tonnes gross per month of the quantity ordered by the.....(purchaser)..... in the Letter of Intent. The daily supply may be.....tonnes approximately, against as monthly supply of.....tonnes.

(b) The.....(Officer/organisation)..... reserves the right to alter the monthly quantity of supply at its own discretion to suit the prevailing circumstances, without affecting the total quantity under Contract. In such cases, the successful tenderer will be given prior notice of a fortnight by the.....(name and address of Office/Officer).....

3. Source of Supply :

(a) The tenderer may undertake to supply coal from collieries of his own or from those belonging to others. In any event.....(purchaser)..... shall not be deemed to have any dealings with the individual collieries nor shall be responsible for the tenderer's dealings with them. As far as the.....(purchaser)..... is concerned, it shall recognise only the successful tenderer/tenderers on whom the order shall be placed by virtue of the Letter(s) of Intent.

(b) The tenderer shall clearly state the names of the collieries from where he intends to supply coal, their monthly output for the last six months, expected monthly output, grade allotted to it by the Coal Board, name of the railway and Pilot by which they are served and capacity of their railway siding for loading.

(c) No coal shall be accepted from any colliery unless supply from the colliery concerned has been approved by the.....(Name of Officer and organisation)..... The.....(purchaser)..... shall also have the right to inspect at any stage the colliery/collieries/washeries from which supply is intended to be made or is being made. The supply of approved quantity of coal also from collieries other than those mentioned in the tender may be considered by the.....(Name of officer/organisation)..... for acceptance only after the result of the fresh analysis of such middlings by the..... Name of organisation..... Laboratory and/or the.....(Name of Govt. Laboratory i.e. C. F. R. I.)..... is found satisfactory. It may clearly be understood that the successful tenderer cannot claim to secure permission to supply coal from additional collieries as a matter of right ; the decision will rest with the.....(Designation of officer)..... The refusal of such permission shall be no excuse for monthly short-fall, if any.

(d) The permission, if at all, to supply from additional collieries (in addition to those named in the Letter of Intent) shall normally be granted i.e. between January and March, once, between April to June once and so on. If, therefore, supply is desired to be made from additional collieries, the successful tenderer shall submit the request with the originals and copies of their receipt analysis reports from C. F. R. I.,.....(Name of place)..... in respect of all such collieries well in advance. Wherever such analysis reports are not available, the successful tenderers may be asked to take a couple of truck of such coal for sampling and analysis at..... Thermal Power Station whose analysis shall be acceptable to the successful tenderer.

4. Quality :

The supply shall consist of freshly mined, 'RUN-OF-MINE' non-coking, Gr..... Coal/Washery Middlings having ash content not more than 35% on Air-Dry-Basis. The grade of the coal supplied shall be determined on the basis of the ash content, total inert (for high moisture coal) analysis carried out in.....(Name Purchaser)..... at..... Thermal Power Station..... The other qualities of the Coal/Middlings shall conform to the following specification under such penalties for the shortfall as specified in item No. 8.

- (a) Calorific Value (On Air Dry Basis/Equilibrated Not less than.....BUT/lb. Basis)
- (b) Volatile Matter (On Air Dry Basis/Equilibrated Not less than.....% Basis)
- (c) Moisture (Total) Not less than.....%

- (d) Grindability Index Hardgrove grindability Index—Not less than.....
- (e) Size 'Run-of-Mine' but maximum size should be limited to cm. Dust and/or slack coal of minus 3 mm. Size should not be supplied beyond..... % in the days supply.

The Tenderer shall be required to submit along with its tender, recent test certificates in original from a Government institution like Central Fuel Research Institute,..... showing the proximate analysis and Calorific value of the coal/middling on 'Air-Dry Basis' equilibrated basis for High Moisture Coal and total moisture content of the coal, proposed to be supplied for the purpose of assessment of the offer.

Supply of coal from collieries which have been graded as "ungradable" or declared "Not working" by the Coal Board will not be accepted.

The successful tender(s) shall be solely responsible for any violation of the above or the colliery control order or rules as framed from time to time by the Coal Board or Coal Controller or Government of India.

Supply of coal from collieries belonging to Salanpur seam/area shall not be accepted on account of its known low grindability Hard-grove Index and detrimental effect to the boilers.

Sampling Analysis & Classification of Coal/middlings Received :

(a) Coal shall be unloaded in the..... Thermal Power Station Coal Yard. Only one representative sample of the Coal supplied on any particular day by each successful tenderer shall be taken for proximate analysis and C. V. determination. This sample shall be drawn from the running conveyor belt and converted into Laboratory sample by means of automatic sampler if installed and sample crusher. In case the automatic sampler is out of commission, manual sampling shall be resorted to. For this purpose samples shall be drawn manually at regular intervals from the running conveyor belt carrying the coal/middlings. If, for any reason, the conveyor belt is out of commission, sample shall be drawn manually from each truck during and through out the process of unloading. In the case of wagons which may have to be unloaded manually, the sample may be collected from the wagons during the process of unloading. The quantity of gross sample thus collected for the day's supply shall be as follows :—

- (1) Not less than 350 Kg. for total supply upto 500 Tonnes/per day.
- (2) Not less than 500 Kg. for total supply up above 500 & upto 1000 Tonnes per day.
- (3) Not less than 700 Kg. for total supply above 1000 & upto 2000 Tonnes per day.
- (4) Not less than 900 Kg. for total supply above 2000 & upto 3000 Tonnes per day.

This gross sample will be reduced to size 3" and below and quantity reduced by coning and quartering. There after it will be crushed and the produce will be further coned and quartered and finally the laboratory sample will be prepared through the sample grinder. In case of any break down of the crusher and/or grinder, the sample will be prepared with the help of manual labour in the usual process of size reduction an coning and quartering.

(b) The laboratory sample thus prepared should be conforming to IS specification. It shall be divided into three parts, one for daily ash percentage/total inert content determination and the second for composite analysis of VM, CV etc. during a 'period' as specified hereinafter and the third shall be kept at..... Laboratory under joint seal of Contractor's representative and..... representative at..... Thermal Power Station for any further reference in case of any dispute by the Contractor with regard to the analysis result.

(c) For daily total moisture determination, a separate sample weighing not less than 25 Kg. shall be drawn directly in not less than ten increments from the trucks/wagons while they are being unloaded/running belts and sent to..... Laboratory. No dispute shall be entertained regarding the analysis result of total moisture so taken, as no reference sample is possible to be kept for the same.

The entire sample taking, its preparation and tests may be witnessed by the successful tenderers' representatives. These successful tenderers' representative at..... Thermal Power Station shall furnish a schedule in respect of road/rail supply, giving the number of the truck/trips or the wagons which carried coal to..... during the day and state therein about correctness of sample collection from the coal supplied during the day.

The absence of the representative of the successful tenderer will not be accepted as an excuse should any dispute arise regarding sampling and testing.

The daily sample/samples shall be analysed at..... Thermal Power Station Laboratory as per ISS (i) On Air Dry Basis to determine percentage of ash content and moisture and (ii) on "as received basis" for determining the total moisture.

All analysis (except determination of total moisture) of high moisture coal will be carried out on —72 mesh sample after equilibrating under the condition given below for 48 hours :—

- Atm. temperature $40^{\circ}\text{C} \pm 20^{\circ}\text{C}$
- Relative Humidity 60 per cent $\pm 2\%$

The coal received during the particular day shall be classified for determination of its grade on the basis of the above analysis results, for making payment as well as for charging penalty for high ash content/total inert content.

Power Economy Committee

(d) For the sake of item 5, a 'period' of any calendar month shall mean :

- (i) 1st to 7th
- or (ii) 8th to 14th
- or (iii) 15th to 21st
- or (iv) 22nd to end of the month

Normally no coal/middlings shall be accepted on Sundays without previous arrangement with the purchaser /or his authorised representative.

(e) No. tolerance whatsoever shall be permitted on figures obtained by analysis, for classification of coals or in using them for charging the specified penalties.

(f) Random test checks may be carried out to determine the Hard-grove grindability index of a day's supply/supply from individual collieries.

(g) The results of the analysis will be notified to the successful tenderer's representative at.....Thermal Power Station, who may be present to witness such sampling and tests.

The results of analysis at-----Laboratory shall be normally binding on both the parties.

(officer)

In case the.....Thermal Power Station does not hear anything to the contrary from the successful tenderer(s) within seven days of notifying the result, the sample kept under joint seal shall be destroyed.

In case of any dispute raised within a week over the announced analysis results, the sample kept under joint seal will be sent at the successful tenderer's cost to C.F.R.I. or any Govt. Laboratory for analysis to determine percentage of ash/inert content and volatile matter and C. V. only but not for total moisture. These results shall be binding on both, the successful tenderer and the.....(Name of Organisation).....

6. Transportation, Unloading & Stacking of Coal :

The.....(Name of Organisation)..... shall in no way be responsible for arranging either the trucks or the railway wagons for the transportation of coal.

(a) *Road Supply.*—(i) The tenderer shall acquaint himself fully with the site conditions and the approach roads before submitting the tender. The successful tenderer shall get instructions from the.....(officer).....as to wherein the coal yard the trucks are to be unloaded. The unloading and waiting, if considered necessary by the.....(officer).....Thermal Power Station, are to be done by the successful tenderer at price included in the tender offer.

(ii) *Road Permit.*—The successful tenderer shall make necessary deposit with the Reserve Bank of India towards the statutory charges leviable by the Govt. of India and obtain necessary coupons from the Coal Superintendent, Dhanbad for road transportation.

(b) *Rail Supply.*—(i) It shall be the responsibility of the successful tenderer to arrange for the availability and allotment of the Railway Wagons. The purchaser shall, however, render such help as would be possible for it to do so.

(ii) The coal/middlings to be supplied by Railway Wagons by the successful tender(s) shall be booked to the.....(officer).....Thermal Power Station, on *freight to pay/paid* basis to.....Thermal Power Station, *Private siding*. From there it shall be the responsibility of the.....to engage its locomotive for shunting and placement of the loaded wagons on the unloading siding, and also for the removal of the empties to the exchange yard again.

(iii) In case the Railway Authorities decide to weigh the wagons on the power station tippler weighbridge, the tenderer will accept the Railway receipts prepared by the Railway on this basis.

(iv) Normally the coal/middlings wagons shall be unloaded by the.....by utilising its wagon tippler, which is suitable for.....wheeler wagons and hence as far as possible coal should be despatched in.....wheeler wagons.

(v) In case the wagon tippler is not available for unloading the wagons.....(type).....wagons are supplied for which wagon tippler is not available, the tenderer may be required to unload the wagons manually wet the coal/middlings to suppress coal dust and stack the same, if required. For wetting, only water and hose pipes shall be provided by the.....Adequate lighting of the coal yard and unloading surroundings shall be the responsibility of.....The unloaded coal/middlings shall be stacked.....feet clear off the railway track but within.....feet of it i.e. the lead for unloading and staking shall be between.....ft. and.....ft. and the rise about.....feet. The.....(officer).....Thermal Power Station shall give the successful tenderer a 48 hours' notice for undertaking the manual unloading. The loaded wagons shall be unloaded by the successful tenderer and released within five "day-light" hours or any other such free period allocated by the railways from time to time. Every effort shall be made by the successful tenderer to minimise the time of detention of railway wagons. Demurrage, if any, payable to the Railways for not releasing the wagons within the normal time permitted by the Railways, shall be to the account of the successful tenderer who, however, shall not be responsible for the time-loss in exchange yard and for the placement of the wagons and removal of the empties.

(vi) If some of the wagons booked by the successful tenderer get missed and do not reach the.....Thermal Power Stn., it will be the responsibility of the purchaser if the booked on FOR colliery/siding basis. In case the wagon are booked on FOR Power Station basis the responsibility will be that of the successful tenderer.

7. Weighment of Coal :

(a) *Road Supply*.—The.....maintains a truck weigh bridge at the.....
(organisation)

Thermal Power Station.....Coal Yard. Weights shown by this weighbridge only, unless otherwise agreed to shall be taken as the correct weights for computation of quantity delivered. The successful tenderer may provide its authorised representative to be present at the weighbridge for witnessing the weighment.

The gross weight of the coal/middlings supplied shall be obtained by deducting the tare weight of the truck from the weight of the loaded truck. The net weight of coal/middlings supplied shall be obtained by subtracting the total moisture in excess of the allowable.....per cent from the gross weight of the coal/middlings delivered.

The payment for the cost of coal/middlings, statutory charges and road transportation charges shall be made on this *net weight*.

In case.....weighbridge is out of order, the weighment may be made on any other weighbridge, near about.....Thermal Power Station arranged by the.....
(officer)

The coal trucks will be received at.....Thermal Power Station Coal Yard between.....A. M. to P. M.

(b) *Rail Supply*.—The R/R weight of the railway authorities shall be ordinarily accepted for the purpose of payment. However, the railway wagons shall be weighed at the purchaser's weighbridge both for the gross and tare weights. The purchaser's weighbridge shall be properly calibrated and got certified by the Govt. Inspector at regular intervals.

In case of any unreasonable difference between the two weights, the matter shall be settled mutually between the purchaser and the supplier.

In case the weighbridge at which R/R weight is recorded, goes out of order and the wagons are not actually weighed the weight recorded at purchaser's weighbridge shall be accepted for all payments.

(c) *Belt Conveyer*.—(For washeries and collieries directly linked with Thermal Station).

Weightometer if provided both by the supplier and the purchaser, variation of 1% between the two weights recorded will be allowed and a mean of the two weights will be taken as gross supply made and received.

If the variation exceeds 1% both the weightometers will be checked and the weight recorded by the correct one will be final. If on any occasion, both the weightometers are out of order, then the purchaser and the supplier will develop and mutually agree upon a method to arrive at the approximate quantity supplied. Calibration of the weightometers shall be done jointly once in 3 months, in addition to frequent checks and maintenance recommended by the manufacturers of the weightometers.

8. Penalty for Shortfall in the Specified Quality and Quantity :

The following penalties shall be levied and deductions therefor made from the successful tenders running bills :

(a) *Low Calorific Value*.—If the calorific value of coal/middlings supplied and determined as stated in item 5(b), falls short of the guaranteed value as in item 4, penalty shall be levied and deductions made from successful tenderer's running bills at the following rate :

For a shortfall of every 50 BTU/lb or a part thereof Twenty (20) paise per tonne of the coal supplied during the 'period'.

Further if the shortfall exceeds.....BTU/lb the contract may be determined by the with a forthright's notice in writing.

(b) *Low Volatile Matter Content*.—If the Volatile Matter content of the coal/middlings supplied and determined as stated in item 5(b) falls short of the guaranteed value as in item 4, then for a shortfall of every half of one per cent or part thereof, a penalty at the rate of twenty five (25) paise per tonne on the coal/middlings supplied during the 'period' shall be levied and deductions will be made. Also, when the volatile matter of the coal supplied, falls below.....%, the contract may be determined by....., by giving a fortnight's notice in writing.

(c) *High Ash/Total Inert Content*—(i) *Low Moisture Coal*.

(d) *High total Moisture*.—(i) *For Low Moisture Coal*.—An Allowable tolerance of 2% on total moisture will be given. When the total moisture is in excess of 2% it will be deducted from the gross weight of the supply and all payments will be made on the basis of net weight so arrived.

(ii) *For High Moisture Coal*.—An allowable tolerance of 5% on total moisture will be given. When the total moisture is in excess of 5% it will be deducted from the gross weight of the supply and all payments will be made on the basis of net weight so arrived.

(e) *For Shortfall in Delivery Rate per Month*.—If the successful tenderer fails to maintain the *Minimum Daily/Monthly Guaranteed* rate of delivery of coal/middlings at Thermal Power Station Coal Yard, except for the 'Force Majeure' Clause a penalty shall be levied on the successful tenderer for the shortfall at the following rate :

For Supply of Middlings.—

Short fall	Penalty
(i) 0—upto 15% of guaranteed gross supply daily/monthly.	Nil
(ii) Above 15% upto 25% of the daily/monthly guaranteed gross supply	25 paise per tonne on the shortfall quantity.

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(iii) Above 25% upto 35% of the daily/monthly guaranteed gross supply. 50 paise per tonne on the shortfall quantity.

(iv) Above 35%—of the daily/monthly guaranteed supply. 75 paise per tonne on the shortfall quantity.

The minimum guaranteed quantity can be changed by giving 3 months notice in advance.

(2) For Coal—

(i) From 0—upto 10% of daily/monthly guaranteed gross supply. 25 paise/tonne on the shortfall quantity.

If the percentage of ash content on Air Dry Basis in the coal exceeds the maximum specified limit for the grade then a penalty of Re. 1 per tonne for every one percent or part thereof shall be levied.

If the ash content for the day supply exceeds % it shall be treated to have been rejected. But in view of the fact that by the time the analysis results are known the supply has been consumed and cannot be returned, a token price of Re. 1 per tonne will be made for such supplies.

(ii) *High Moisture Coal*.—If the percentage of total inert (ash+moisture) on equilibrated basis exceeds the maximum specified limit then a penalty of Re. 1 per tonne for every one percent or part thereof shall be levied.

(iii) *Middlings*.—The by products of washeries having ash content upto 35% on Air Dry Basis are termed middlings. If the ash percentage on air dry basis exceeds 35%, then it contains a mixture of middlings and rejects. No price is to be paid for rejects. The quantum of middlings in the day supply of the by-products having ash content above 35% on Air Dry Basis will be calculated as per the formula given below :

$$M = \frac{T(55-A)}{20}$$

M=Middling content in tonnes.

T=Total quantity of byproducts/mixture in tonnes.

A=Ash content in byproduct/mixture in percentage.

If the ash content of middlings is less than 35%, a premium at the rate of 20 paise per tonne for each percent of improvement in ash content will be allowed. This will be allowed for middlings upto 28% ash content.

For middlings having ash content below 28%, the premium will be limited to what may be admissible for middlings having 28% ash on air dry basis.

For the first occasion during the entire supply/first 12 occasion per year rejection clause as stated at (i), (ii) & (iii) above will not be applied. However, on all subsequent occasion the same will be enforced.

Shortfall

Penalty

(ii) Above 10%—upto 20% of daily/monthly guaranteed gross supply. 50 paise/tonne on the shortfall quantity.

(iii) Above 20%—of the daily/monthly guaranteed gross supply. 75 paise/tonne on the shortfall quantity.

(3) Where there is direct linking between the washery/mines and the Thermal Power Station by a belt conveyor/rope-way, an additional penalty of 5 paise per tonne will be levied over and above penalty rates.

(f) (i) *Over-size*.—Coal beyond the size specified may not be accepted and is liable to rejection.

The contractor will be given a chance to reduce the size by breaking during the process of unloading without causing any hold up, to bring it within specified limit.

In case of failure of the contractor to comply with the above provision then a penalty of 20 paise/tonne will be imposed.

The assessment of oversize coal by the representative of the purchaser shall be considered as final for imposition of penalty.

(ii) *Fines (minus 3 mm)*.—If the percentage of fines in daily supply exceeds the specified limit, then a penalty of 10 paise/tonne on the net quantity will be imposed. Assessment of fines by the representative of purchaser shall be considered as final for imposition of penalty.

9. Payment :

(a) (i) Except for the final payment, payments for coal/middlings supplied shall be made monthly by the Thermal Power Station on receipt of the successful tenderer's running bills in triplicate. Payment for the Coal/Middlings supplied during any month shall be made in the succeeding month. This payment will be made to the successful tenderer after deduction of all charges recoverable from it.

(ii) Along with the monthly bills, in case of coal/middlings supply by rail the successful tenderers shall submit the wagon receipt schedule, the details of which can be had from (officer) Thermal Power Station, at the time of starting the supply.

One copy of all bills shall be sent to the (Any higher authority) for information and one additional copy of all the bills shall be sent by the successful tenderer to the (Name of pay office) direct for the purpose of watching timely payment.

(b) The final payment to the successful tenderer shall be made by the.....only after the successful tender has executed and entered into the Contract/Agreement as provided in item (No. 18), hereunder, and also on production of the following certificates :—

- (i) An Income-tax Clearance Certificate.
- (ii) A certificate from the (pay office) Thermal Power Station,..... that all deductions and recoveries to be made from the successful tenderers have been recovered in full from its previous bills or giving the exact amount to be deducted.
- (iii) A Certificate from the (officer)..... Thermal Power Station to the effect that all temporary barracks and sheds built by the successful tenderer have been removed from the Corporation's site and the site cleared to his satisfaction.
- (iv) A Sales Tax Clearance Certificate.

(c) The.....reserves the right to deduct from the amount due to the successful tenderer or its Security Deposit any amount that may be recoverable by way of penalty or any other charges or money due to.....

10. Security Deposit :

The earnest money of Rupees.....deposited at the time of tendering shall be treated as part of the security deposit and shall be refunded only with the final payment to the successful tenderer. In addition, a deduction of— % will be made from the successful tenderer's running bills on account of security deposit upto an amount of Rupees..... only, so that including the Earnest Money the total security deposit is Rs.—— only, for the due performance of its obligations under the contract and observance of the conditions thereof. Alternatively in lieu of the..... % deductions from running bills, (a total of Rs.....) the tenderer may furnish within 15 days of issue of Letter of Intent a Bank guarantee from a Scheduled Bank to be approved by the (purchaser), who will also approve the form of the Bank Guarantee. The total cumulative security deposit will be ultimately adjusted against the final bill of the successful tenderer. In the event of the successful tenderer's shortfall in the fulfilment of any or all the terms and conditions of the contract, the (purchaser) shall be at liberty to confiscate the entire or part of the security deposit for nonfulfilment of the guaranteed contractual obligations.

11. Superintendence :

The successful tenderer shall keep a competent representative in charge of the unloading operation at the Coal Storage Yard of the..... Thermal Power Station. The representative shall be guided by a representative of the (officer)..... Thermal Power Station in respect of placement of trucks, the unloading area etc.

12. Facilities for Labour :

(a) No female labour shall be engaged by the successful tenderer in dark hours. It shall be obligatory for the successful tenderer to abide by all Statutory Rules applicable to the labour engagement and arrangements and the successful tenderer shall pay the labour so engaged by it for the purpose of the work under this contract, such piece rate wages as may be current in the neighbourhood and shall indemnify the (purchaser) against any claim by such labour.

(b) Workmen's Compensation, if any, and conforming to the Statutory Rules, shall be successful tenderer's responsibility.

(c) It shall be the responsibility of the successful tenderer to arrange for labour and staff barracks and sheds and the sanitation thereof for the labour and staff employed by it both at the coal loading and unloading ends. The (purchaser) may however, allow the successful tenderer to use existing facilities at the..... Thermal Power Station, if available on normal rent or to construct these on a site owned by the (purchaser) and approved by the (officer)..... Thermal Power Station. The successful tenderer shall pay such ground rent as may be mutually agreed upon.

These barracks and sheds shall be temporary structures but the successful tenderer shall remove them from the (purchaser) site at its own expenses, within three months from the date of termination of the contract and return the land so occupied to the (purchaser).

In case the successful tenderer fails to remove the barracks and sheds within the said time, the (purchaser) shall have the right to dismantle them and recover from the successful tenderer's dues the cost incurred by the (purchaser) on that account.

Ground rent shall be paid by the successful tenderer until all the barracks and sheds are removed.

A clearance certificate from (officer)..... Thermal Power Station to the effect that all barracks and sheds have been removed by the successful tenderer and the vacant possession of the land given, shall be necessary before the final payment is effected to the successful tenderer.

13. Facility of Mobile Equipments :

If mobile equipments like bull-dozers etc. are available and sparable by the (officer)..... Thermal Power Station, the successful tenderer may upon written request, use them in stacking/moving the coal. For the use of these mobile equipments the successful tenderer shall have to pay the (purchaser's) standard charges etc. as applicable for hiring the equipment to outside parties.

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14. Termination of Supply:

If at any time during the period of contract, supply or part thereof is considered to be unsatisfactory in the opinion of the representative of the purchaser with regard to the quality, the representative of purchaser shall have the right to determine the contract or refuse to accept the supply or part thereof whenever required.

The successful tenderer(s) shall not be entitled to any compensation or damage whatsoever, in the event of such a termination.

15. Arbitration :

Except where otherwise provided in the contract if at any time any question, dispute or difference whatsoever shall arise between the (purchaser) and the successful tenderer upon, or in relation to, or in connection with the contract either party may forthwith give to the other notice in writing to the existence of such question, dispute or difference, and the same shall be referred to the adjudication of the sole arbitrator, Chairman, Eastern Regional Electricity Board or his representative/nominee and the award of the arbitrator, shall be final and binding on both the parties and the provisions of the Indian Arbitration Act, 1940 and the rules thereunder and any statutory modification thereof shall be deemed to apply to and be incorporated in this Contract.

Upon every or any such reference, the costs of an incidental to the reference and award respectively shall be at the discretion of the arbitrator who may determine the amount thereof, or direct the same to be taxed as between lawyer and Client, or as between party and party, and shall direct by whom and to whom and in what manner the same shall be borne and paid.

Work under the Contract shall be continued by the successful tenderer(s) during the arbitration proceedings, unless otherwise directed in writing by the Purchaser or unless the matter is such that the work cannot possibly be continued until the decision of the arbitrator is obtained and save as those which are otherwise expressly provided in the contract no payment due or payable by the Purchaser shall be withheld on account of such arbitration proceedings unless it is the subject matter or one of the subject matters thereof.

16. Force Majeur :

Should the progress of supply be delayed due to suspension of coal/middlings supply on account of outage, strike, lock out or closure of the mines whereby the raisings are stopped or closure by an order from the Mines Department, Govt. of India, epidemics, or any act of war or act of God or any other reason beyond the reasonable control of the successful tenderer whereby regular supplies may be effected, then reasonable extension of time may be granted by the (purchaser). In the event of such an occurrence the successful tenderer shall immediately inform the (purchaser) setting out in writing such occurrence in detail and the steps taken by him to minimise such occurrence.

Should the supply of coal to the power station be ordered to be suspended by the (purchaser) or its authorised officer or officers on account of strike, lock out or closure of the Thermal Power Station, damage to the conveying plant or any other reasons beyond the reasonable control of the (purchaser) then reasonable extension of time may be granted by the (Purchaser). The shall not be liable to pay any damage to the successful tenderer on this account.

17. Bribe Etc. :

Any bribe, commission, gift or advantage given, promised or offered by or on behalf of the tenderer (s) or its agent or servant or any one on its or their behalf to any officer, servant, representative or agent of the (purchaser), in relation to obtaining or to the execution of this or any other contract with the (purchaser) shall in addition to any criminal liability which it may incur, subject the tenderer to the cancellation of this or all other contracts entered into with the (purchaser) and also to pay for any loss or damages resulting from such cancellation. The (purchaser) shall then be entitled to recover the amount so payable from the tenderer.

18. Agreement :

The successful tenderer shall be required to enter into an agreement with the (purchaser) within 3 months of the date of 'Letter of Intent' issued. This agreement will be drawn in accordance with this specification and the 'Letter of Intent' and the rates and terms etc. quoted by the successful tenderer and accepted by the (purchaser). Until the execution of the Formal Contract Agreement, the supply shall be governed by the Letter of Intent and this Tender Specification.

19. Submission & Opening of Tender :

3 copies of tender, complete in all respect, in sealed cover should be submitted in the Tender Box kept at the Office of the (Officer opening the tender), (Purchasing Organisation) not later than A. M. on (date, Month, Year). Tenders will be opened by the on (dated), month, Year at A.M. in presence of tenderers or their authorised representatives who may be present. The tenders not accompanied with the earnest money or incomplete in respect of any information asked for are liable to rejection.

20. Documents to Accompany the Tender :

- (a) Annexures A, B & C in triplicate, (ref. item 23) duly filled in.
- (b) Challan from Reserve Bank of India as Earnest Money reference item No. 24.
- (c) Valid Income Tax Clearance Certificate, ref. item 25.
- (d) Valid Sales Tax Clearance Certificate, ref. item 25.
- (e) Labour Employment Certificate, ref. item (d) Annexure 'C'.
- (f) Test Certificate of Coal, ref. item 4.
- (g) Consent letters of Collieries from which supply is intended to be made.
- (h) A certificate from the Regional Labour Commissioner (Central) of the area in which the Colliery/Collieries is/are located that the supplying Colliery/Collieries has/have implemented fully the recommendations of the Wage Board Award for the Mining Industries.

N. B. Copy of this Tender Specification is not required to be submitted along with the tender. Only the annexures are to be submitted.

21. Break up of Price

(a) The tenderer shall quote break-up of the rate per tonne of coal indicating separately price of coal/middlings, transport charges inclusive of all uncontrollable charges, cess and other statutory charges for coal as delivered and unloaded in Thermal Power Station Coal Yard.

(b) The (State) Sales Tax and/or or Central Tax as may be leviable by the (State)Govt. or Govt. of India shall be to the account of the tenderer and the overall rated offered should be inclusive of this element.

22. Annexures :

The tenderes are requested to fill up Annexures A, B & C in triplicate giving complete information in reply to the specific questions or points raised thereunder. In the above Annexures, no column should be left unfilled and unsigned and the tender must be signed and sealed on every page by the tenderer.

23. Earnest Money :

An earnest money of Rupees.....only shall be deposited with the *Reserve Bank of India* into (Purchasing Organisation) Account No.....and the receipted Bank Challan must accompany the tender. The earnest money only in this form shall be acceptable.

This earnest money is liable to be forfeited if the successful tenderer fails to start the work within one month of receipt of the 'Letter of Intent' of the Corporation or to furnish the security deposit as required in the item No. 10.

24. Income Tax and Sales Tax Clearance Certificates :

The tenderer shall furnish valid Income Tax and Sales Tax clearance certificates of the firm/person submitting the tender, along with the tender.

25. Rejection of Tender :

The (purchaser) reserves the right to reject any or all tenders or to accept any tender (s) wholly or partly, if considered advantageous to the (purchaser) whether it is lowest or not, without assigning any reason whatsoever.



ANNEXURE 'A'

Gr Coal/Middling having maximum
35% ash content on air dry basis.

- 1 How much total quantity of freshly mined R.O.M. coal/Middlings in tonnes do you offer by Road/Rail/...../.....?
2. What minimum quantity of coal/middlings do you guarantee to supply *per month* under penalty clause item No. 8 by Road/Rail/.....?
3. What minimum Calorific Value in BTU/lb. do you guarantee under penalty clause item No. 8 ?
4. What minimum volatile Matter do you guarantee under penalty clause item 8 ?
5. Fill the following information regarding the collieries from which the coal will be supplied :

Sl. No.	Colliery Details					Quality		
	Name of State Colliery	Quality	Name of Seam	Name of the pilot Rly. by which served	Capacity of Rly. Siding for loading	Gr. of coal	Expected monthly supply	Previous 6 months monthly output
							Tonnes Mention by Rail/Road/....	

ANNEXURE 'B'

Please offer your best price

Gr.....Coal/Middlings having maximum ash content of 35% on air dry basis.

1. Price per tonne of coal/Middlings *inclusive of Sales Taxes*, at Colliery/ loading end, free on vehicle.

2. All statutory charges, per tonne viz.,

(a) Central stowing excise duty

(b) L. D. C. C.

(c) Rescue cess duty per tonne

3. Transport etc :

(a) *By Road* :

Transportation, unloading, supervision, wetting etc., per tonne.

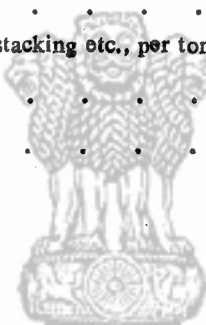
(b) *By Rail* :

(i) Railway freight per tonne

(ii) Manual unloading, wetting, stacking etc., per tonne .

(c) *By Belt Conveyor*

(d) *By Ropeway*



Dated Signature & Seal of the Tenderer

ANNEXURE 'C'

Please confirm that the following documents are enclosed :

- (a) Bank Challan showing that Earnest Money of Rs.....has been deposited.
- (b) Income Tax Clearance Certificate.
- (c) Sales Tax Clearance Certificate.
- (d) Certificate that all labour employed by the Tenderer for coal mining, raising, loading and unloading work etc. is being paid wages and given other facilities in accordance with all the Statutory Awards as issued up to date.
- (e) Consent letters of Collieries from which supply is intended to be made.
- (f) A certificate from the Regional Labour Commissioner (Central) of the area in which the Collieries are located, the Collieries from which the supplies are intended to be made are fully implementing the recommendation of the Wage Board Award for the Mining Industries.
- (g) Certificate that the tenderer agrees to all the items, terms and conditions stated in the specification.
- (h) Confirm that the item regarding forfeiting the Earnest Money and Security Deposit for non-fulfilment of guaranteed contractual obligation, is agreed to by you.

Dated Signature and Seal of the Tenderer



ANNEXURE 4-2

Statement of troubles experienced in last 2 to 3 years due to fly ash erosion and other causes at Bangle

Boiler No. 1

Shut down period

Cause of tube failure

1-1-68 to 22-1-68 . . . Tube failure caused due to defective erection welding.

Note—Considerable thinning of tubes of the saturation Superheater screen tubes was observed.

15-6-69 to 14-8-69 . . . Annual overhaul and modification for prevention of fly ash erosion and repair of eroded tubes.

Boiler No. 2

25-1-69 to 25-2-68 . . . (1) Saturation Superheater Tube leakage due to fly ash erosion.

(2) Primary Superheater tube leakage due to steam impingement.

19-6-68 to 27-6-68 . . . Saturation Superheater tube leakage due to fly ash erosion.

12-1-69 to 28-1-69 . . . Primary Superheater Tube leakage due to fly ash erosion.

13-3-69 to 13-4-69 . . . Boiler modification for protection against fly ash erosion and repair of eroded tubes.

23-4-69 to 29-4-69 . . . Wall tube leakage from defective erection welding.

8-10-69 to 6-1-70 . . . Overhaul and modification for protection against fly ash erosion.

Boiler No. 3

26-9-66 to 9-12-66 . . . Wall tube leakage from defective erection welding.

20-5-67 to 28-5-67 . . . Economizer tube leakage caused by soot blower steam cutting.

15-5-69 to 18-5-69 . . . Reheater tube leakage due to internal corrosion.

1-6-69 to 8-6-69 . . . Modification for protection against tube erosion.

Boiler No. 4

3-6-6 to 30-6-67 . . . Primary superheater tube leakage for defective erection.

17-10-67 to 17-11-57 . . . Wall tube leakage for defective erection welding.

25-6-68 to 4-7-68 . . . Saturation superheater tube leakage due to fly ash erosion.

26-7-68 to 31-7-68 . . . Wall tube leakage due to defective erection welding.

16-11-68 to 24-12-68 . . . Annual overhaul and repair of eroded tubes.

3-6-69 to 26-5-69 . . . Modification for protection against erosion and repair of eroded tubes.

17-8-69 to 7-10-69 . . . Overhaul and modification for protection against erosion.

The signs of tube erosion due to fly ash were detected in early 1968 and after determining the definite pattern of erosion the following measures were taken :—

- (a) It was observed that ash erosion is most pronounced near the boiler outlet expansion joint before the economizer due to constriction of flue path. Primary superheater tubes, saturation superheater screen tubes were enclosed by suitable protection shields fabricated by expanded metal and refractory concrete at the most affected zones. Steel protection shields were also incorporated in certain portions where they could be fitted conveniently. Replacement of the steel shields and refractory concrete shields by suitable stainless steel shields is also in progress and will be done in stages.
- (b) The first row of economizer tube was also covered by semicircular steel shields.
- (c) Steel tube ferrules were incorporated at the inlet end of the Airheater tubes.
- (d) Splitter vents were incorporated in the flue path to uniformly distribute the flue gas before the economizer and an heater.

ANNEXURE 4-3

Extracts from the Note sent along with D.O. letter No. M/192/70 dated 18-7-70 from Shri M. Y. Koli, Member, Madhya Pradesh Electricity Board, Jabalpur to the address of Member-Secretary, PEC.

A COAL TRANSPORTATION ARRANGEMENTS AT THERMAL POWER STATIONS OF M. P. ELECTRICITY BOARD

1.1 Korba-I(100 MW) and Korba-II(200 MW) Thermal Stations :

While considering the arrangements of coal transport in consultation with the Russians for receiving coal at the Korba Thermal Power Station Extension (200 MW) it was felt that wagon tippler would be too slow to discharge the requisite quantity of about 4000 tonnes per shift when the station is extended. This is because considerable time is taken in shunting individual wagons from the train on the wagon tippler and pushing the empties out. Moreover, a wagon tippler would need 100% stand by otherwise in case of some breakdown it can lead to total stoppage of coal receipts. The Soviet Experts, therefore, suggested the use of long track hopper which would accommodate 30-four wheeler or 15-eight wheeler wagons. Side discharge hopper wagons of BOBS type were considered suitable for this arrangement. It was intended that the release lever would be operated by an air cylinder. All the wagons were to be piped for compressed air in addition to the vacuum brake piping. Thus, by giving compressed air supply at one end of the train all the wagons on the hopper can discharge almost simultaneously saving a considerable time of detention of wagons. This arrangement envisaged the use of suitable locomotives which could draw 15-eight wheeler wagons from Manikpur quarry of NCDC to the Power House so that the entire operation of unloading and movement could be done without any shunting between wagons. As the railway track from the Manikpur quarry to the Power House is owned by the MP&EB, the rolling stock was also intended to be purchased by us. It is, however, found that in India the Railway Board has complete control over all the items of Railway equipment including rolling stock and we can only get for our railway siding or for rolling stock whatever the railway Board chooses to release to us. Railways are willing to release only condemned wagons and locomotives which are declared unfit for their operation. The type available is, therefore, dependent on the type of wagons and locomotives that are being condemned with the result that we cannot get the locomotive or the wagons of requisite type and capacity. With great efforts through I & P Ministry we were able to get condemned wagons of CHB and CHT type which have got bottom discharge between the rails and the operating gear is not suitable for operation by air cylinders. For the bottom discharge the area available on the track between the rails is limited and it takes considerable time to clear the wagons. The position is made worse by NCDC supplying large lumps of coal measuring as much as 450 mm in two dimensions which choke up the grate. Thus the wagons which could be emptied within a few minutes take half an hour and four mazdoors to do it. Our efforts to obtain BOBS wagons from market were not successful. Wagon manufacturers could offer the bodies only, but the wheels, axle and axle boxes were controlled items and were not available. The position for the locomotives was as bad. The locomotives released are already condemned and the State Boiler Inspectorate has drastically reduced its working pressure. They can, therefore, haul only half the number of wagons than intended. It will thus be seen that the scheme as intended has not gone through and is not likely unless proper type of good locomotives and good wagons are available. Even if something could be done in this direction it is found that the siding layout of NCDC at their loading point does not permit accommodation of 30 empties before the loading point or 30 loaded wagons after. Moreover, the problem of large lumps would always present a difficulty in clearing the track hoppers quickly and it is doubtful whether it will ever be possible to make the NCDC or supplier to abide by agreed size i.e. 260mm.

It will thus be seen that the idea of "Unit train" or "Block train" which is envisaged for long distance transport of coal over railways though not working at Korba yet it is working in principle or in spirit on that small part of the M.P.E Board's own railway track from NCDC colliery to the Power House. To make the scheme of Block trains successful, difficulties experienced by the M.P.E.B. as explained above which would arise at any power station have to be removed. Moreover, not only transport arrangement of coal but crushing coal to size and handling at the colliery end and at the power house end has to be coordinated so that the loading, shunting emptying and discharging of coal could be done for the whole unit train at one go; otherwise the very purpose of unit train or block train will be defeated if the train load has to be broken up in wagons (individually or in batches) which will take long time at the handling ends.

ANNEXURE 5—1

Report of the Sub-Committee on Standardisation of Mechanical and Electrical Equipment for Thermal Power Stations

BHARAT HEAVY ELECTRICALS LTD., NEW DELHI

Ministry of Irrigation and Power had constituted under their Memorandum No. 32 (25)/66-EL. I, dated 2nd January 1967, a committee to study the problems relating to standard designs for thermal power stations utilising indigenously manufactured equipment. In their first meeting held on 3rd April, 1967, the Committee had recommended that in order to define specific areas of standardisation for thermal power station auxiliary equipment, two Sub-committees be constituted, one for studying mechanical and electrical problems and the other for civil design problems. The former Sub-committee held two meetings on 19-8-1967 and 9-4-1968. The Sub-committee had desired to examine the report of the Working Group on Standardisation and Import Substitution set up by the C.B.I.P. as recommended by the main Committee. As this report has not been finalised so far, the Sub-committee has had to forego this advantage. The report is under finalisation and may be available in the near future. The main Committee may like to consider this report. It is the general view of the Sub-committee that in case of equipment where ample indigenous capacity has been established to meet the requirements of various specifications of the customers, no special attempt need be made at this stage to evolve preferred standards. Such standards would really be of use only in cases where there was limited indigenous capacity or where such capacity had to be developed. Preferred standards in such cases would help in economical manufacture of equipment for the selected ratings. With this in view, the important items of auxiliary equipment in thermal power stations were examined individually and the scope for standardisation defined.

As the designs for the equipment for thermal power stations manufactured in the different plants are based on the developed in three different countries, there are difficulties in standardising even auxiliaries and layouts. Also there are inherent limitations in attempting standardisation of equipment of nearly same rating (for example, sets of 100, 110 and 120 MW) of different designs and steam parameters. As such the Sub-committee desires to record its view that in future the ratings and designs of power generating equipment should be decided only after due consideration of the advantages standardisation. In as much as the main equipment designs had already been obtained and as scope for any modifications to the equipment during the Fourth Plan was rather limited, the Sub-committee devoted its attention only to equations relating to the overall layout and the auxiliary equipment.

1. Heat Cycle :

The Sub-committee is of the view that the standard heat cycles of the manufacturers for the 60, 100, 110 and 120 MW sets may be treated as preferred standards. There is, however, scope in simplifying them and improving them. The Sub-committee therefore recommends to the manufacturers that this should be kept in view for their future manufacturing/development programmes based on operating experience with the units in the different power stations in India.

2. Heaters :

The relative merits of horizontal and vertical heaters were examined and the Sub-committee noted that all the manufacturers of heaters in the country had programmed to manufacture only vertical heaters. The Sub-committee does not find any strong reasons for recommending any departure from the vertical designs. As regards the material for the high pressure heaters, steel tubes are being used and can be standardised. The current practice is to use brass tubes for low pressure heater. The question of replacing brass tubes by material, like stainless or even mild steel, was examined and it was pointed out that at the present stage it would not be possible to replace brass tubes by mild steel or stainless steel tubes in low pressure heaters. Development work was being undertaken at the Hyderabad plant of BHEL but it would need some more time before results can be obtained.

3. Feed Pumps :

The Sub-committee noted that a few manufacturers in the country are in a position to undertake manufacture of feed pumps for the four sizes of generating plants namely 60, 100, 110 and 120 MW. The Hyderabad Unit has a programme manufacturing pumps suitable for all the four units based on actual orders received. The technical particulars of the pumps of Hyderabad Units are given below :

Unit MW	Capacity M/hr.	Feed water Temp. °C	Delivery head of pump MWC	No. of pumps per unit	Capacity of driving motor
60 }	336	145	1550	2 × 100%	1900
100	270	160	1540	3 × 50%	1600
110	490	158	1960	2 × 100%	3500
120	250	165	1720	3 × 50%	1550

The Sub-committee could not obtain details of the designs developed by other manufacturers in the country.

The possibility of using the same pump (with minor modifications) for the 60, 100 and 120 MW installations has been examined by the Hyderabad Unit. It has been found that a slightly modified design of the 150-KHI boiler feed pumps which are being used with 1+1 arrangement for the 60 MW sets can be used for the 100 MW sets also. The design changes required are minor. For the 120 MW sets a new design had to be evolved. However, as the pumps for all these three sets emanate from the standard 150-KHI design with modification to the impeller, diffuser, etc, it has been possible to keep the overall dimensions very nearly same. Standardisation has been achieved to an extent which lends itself for easy manufacture of these pumps as components like the stage body, barrel, etc. have similar parameters.

Power Economy Committee

For the 110 MW set, a 1+1 arrangement with a pump of different design is being used.

Turbine driven feed pumps : The question of using high speed turbine driven feed pump should be considered when turbosets of 300 MW and above are to be manufactured.

Condensate Pumps :

The pumps for the different units have the following parameters :

Unit MW	Capacity M/hr.	Head develop- ped MW	No of pumps/ units	Capacity of drivin motor
60	235	128	2 × 100%	160
100	160	135	3 × 50%	110
110	160	215	3 × 50%	175
120	327	147	2 × 100%	205

The 100 and 110 MW sets envisage 3 condensate pumps of 50% capacity. The Sub-committee would recommend that in future, as far as possible, 2 × 100% capacity pumps should be used as this results in an improved layout.

Condenser and cooling water system :

With regard to the standardisation of the condensers for a cooling water temperature of 35-36°C it was considered that it would be necessary to make incremental cost evaluation before a decision could be arrived at. For the present the manufacturers could continue with their standard designs and as these had a 2-3% reserve for modifications based on local conditions, these might be able to cater to the needs for different parts of the country. More operating and manufacturing experience would be required before any standardisation is evolved.

As far as the circulating water pumps are concerned, indigenous manufacturing capacity was adequate and since local conditions governed the ratings to a great extent, no purpose would be served by standardising this equipment.

6. Deaerators :

It is recommended that the deaerators be standardised keeping in view the maximum capacity required which may be of the order of 500 tonnes/hr. for the 100, 110 and 120 MW units.

Boiler House Auxiliaries :

The milling plants for the boilers of 60, 100 and 110 MW have been standardised by the HPBP, Tiruchi. Attempts are also being made to standardise as many other components as possible. In the initial stages, there can only be limited progress in this direction, M/S, A. V. B., the other boiler manufacturer in the country, are, however, of the opinion that boiler house auxiliaries cannot be standardised as site conditions would play a deciding role.

8. Electrical Drives :

As regards electrical drives, the Sub-committee feels that valuable suggestions have been made by the group on standardisation of motors set up by the C.B.I.P. Manufacturers should add care to these recommendations. If attempts are made restrict to the R-20 series and the recommendations of the I.S.I. on rotating electrical machinery adopted, substantial progress in standardisation would be made.

9. Instrumentation :

the choice for the type of instrumentation, pneumatic or electronic, should be left to the customer and as it would depend on the project (extension or new station), source of main equipment (Bhopal, Hyderabad or Hardwar, AVB or Tiruchi, etc.) it was agreed that at present there was very little scope for any standardisation. Indigenous availability was still in the developing stage and experience over the next few years should guide future progress in standardisation.

10. Layout :

It is noted that the Civil Designs Sub-committee desired to have the recommendations for the Mechanical Design Sub-committee on standardised layouts for thermal stations, as this would enable them to choose standard modules etc. The Mechanical Sub-committee, however, recommends that at the present stage, layouts in power station could not be standardised as local conditions have to be kept in view.

ANNEXURE 5-2

Copy of D.O. letter No. SL : 0944 dated 11th May, 1970 from Shri V. Krishnamurthy of Bharat Heavy Electricals Ltd., Tiruchirapalli-14 to Shri S. K. Sen, Damodar Valley Corporation, Anderson House, Alipore, Calcutta-27.

I had gone through your letter No. EDCON-OM/17-8925 dated April 2, 1970. In your letter, you had recalled that indigenous manufacturers of heavy electrical equipments had certain difficulties to any deviation from their collaboration practice three years ago. This was true with regard to this Unit also about three years ago because we had just then commenced our production activities in this Plant. During the last three years, this position had considerably changed and I am glad to inform you that BHEL, Tiruchi have been initiating several designs to satisfy the specific needs of the power station authorities. I shall detail below the major changes effected by this Organisation during the last three years.

2. The basic design documentation purchased from Czechoslovakia was for manufacture of boilers of 260 t/hr non reheat units, 370 t/hr reheat units with pulverised fuel firing system. As you may be aware, the properties of coal are not the same and varies widely from region to region, for example, the coal for which our boilers are designed for Bhatinda Thermal Power Station (5000 kcal/kg, 27% volatile) differs widely from the coal for which our Patratu boilers (3610 kcal/kg, 20% volatile) are designed. Further, other design factors like the seismic co-efficient etc., have also to be taken in to account in finalising the designs.

3. It may be recalled that Soviets were supplying two numbers 220 t/hr boilers to match their 100 MW units in several places in India like Neyveli, Obra, Patratu. But BHEL went into the question of designing a single boiler of 420 t/hr capacity to match 100 MW unit as desired by the customers. The parameters of the boiler are 420 t/hr capacity, 96 ata pressure, 540 temperature. The design was completely done in BHEL Works at Tiruchy.

4. BHEL are also supplying to the Gujarat Electricity Board matching boilers for 120 turbogenerating sets of Bhopal design. These boilers are designed for multi-fuel firing in that they are capable of working at 100 per cent MCR rating while firing either coal or oil or gas. Further, the boiler is a direct-fired unit. These boilers are being completely designed by BHEL design department.

5. BHEL is successfully executing a foreign order covering supply and erection of two 255 t/hr oil-fired boilers to Malaysia. The parameters are totally different from 260 t/hr boilers being supplied elsewhere in our country. The parameter as follows :—

Capacity	For Malaysia	For use in India
	255 t/hr	260 t/hr
Pressure	70 kg/cm ²	96 kg/cm ²
Temperature	510°C	535°C

6. BHEL is supplying a 150 t/hr boiler suitable for gas-firing to match Bhopal's 30 MW set for Namrup Thermal Power Station in Assam. The boiler with all safety interlocks suitable for natural gas-firing is fully designed in BHEL Works.

7. In addition to the above, BHEL is executing number of industrial boilers of various capacities upto 210 t/hr and pressure upto 106 ata. These include different firing systems such as direct firing with hammer mills, asphalt-firing with suitable burners, gas-firing suitable for natural gas etc.

8. Latest techniques adopted by leading boilers manufacturers in other countries are also introduced in this Plant. These include membrane wall construction for the combustion chamber in place of tangential tube construction, skin casing of the combustion chamber, pressurised combustion chamber eliminating ID Fans etc.

9. From the above, you could see that BHEL, Tiruchy has, to some extent, been able to accommodate the specific requirements of the customers in designing boilers to suit local conditions.

10. BHEL utilises the services of early 300 engineers/technicians in their design organisation to produce suitable designs to meet the varying needs of customers. It may also be pointed out that each of the Electricity Boards has their own preferences on equipment coming within the boiler house. It is not only the change of coal that require design modifications mentioned by you, but a number of other factors affecting boiler house auxiliaries on which the consulting Engineer have a say. To a great extent, we respect these requirements.

11. In view of the progress made by the manufacturing Units, it will be worthwhile if the Committee makes a visit to different Units to assess the present stage of development in India.

With regards,

ANNEXUR 5—3

Sl. No.	Control No.	Particulars of equipment	Amount Rs.	Date of receipt of proposal	Date of first reference to DGTD
1	2	3	4	5	6
1	P/Mad-4344/M/68	Components for Wave Traps After obtaining the clarifications from the Board, the case was referred to the DGTD on 1-11-68, on 15-11-68, the DGTD called for additional information and the same was supplied on 27-11-68. DGTD was reminded on 20-2-69. In reply, DGTD on 16-4-69 requested us to furnish them detailed specifications of all the items and their individual CIF values. The information was called for from the Board and was furnished to the DGTD on 6-6-69. Since no reply was forthcoming from DGTD, a D.O. reminder was issued on 2-9-69. DGTD in their reply letter dated 21-10-69 again requested us to forward them duplicate list of items to be imported for their reconsideration. The information was furnished to the DGTD on 29-10-69. The DGTD on 4-11-69 again approached this Commission to forward them duplicate list of components for import and the needful was done on 27-11-69 and the clearance was finally accorded by the DGTD on 10-12-69.	25,000	21-8-68	1-11-68
2	P/Mad-4324/M/68	Governor Kasing for Pykara Power House. The case was taken up with the DGTD on 18-5-68. DGTD in their reply dated 11-6-68 advised this Commission that the equipment in question has an indigenous angle but did not indicate the name of the indigenous Suppliers. Hence it was essential to refer the matter to the Project authorities for ascertaining the possibility or obtaining the spares from indigenous sources. After obtaining their reply, the case was referred to the DGTD on 19-12-68 for reconsideration. Since no reply was forthcoming from them in a D.O. reminder was issued on 27-2-69 and in their reply dated 13-3-69 they asked this Commission to send them a duplicate list of the items to be imported. This was sent on the same day and duplicate copies were again sent to them on 20-3-69 in response to their letter dated 13-3-69. Since there was no response, a reminder was issued to DGTD on 20-12-69. DGTD in their reply dated 1-1-70, stated that the duplicate list sent to them on 20-3-69 was not traceable and wanted copies again to be sent to them. In view of the circumstances of the case, it was necessary to obtain additional authenticated copies from the Project authorities which were received on 3-3-70. The case was again referred to DGTD on 16-3-70 and the clearance is still awaited.	40,000	9-5-58	18-5-69
3	P/Mad-4339/9/69	Spares for spherical valves The proposal was referred to DGTD on 2-1-68 followed by a D.O. reminder dated 18-9-68. Since no response was forthcoming, another D.O. reminder was issued on 27-11-68. As sufficient time had lapsed and the Project authorities were pressing hard for early release of foreign exchange, a D.O. was addressed to Dr. Vakil Ahmed, Development Officer, on 14-3-69 and the clearance was finally Issued by the DGTD on 24-11-69.	1,900	26-7-68	2-8-68

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1	2	3	4	5	6
4	P/G-8810/M/68	Spare parts for Skoda Turbines The proposal was referred to DGTD on 2-4-69. Since no response was forthcoming, DGTD was reminded on 2-7-69, followed by another reminder on 16-10-69, and final clearance was received only on 15-11-69.	48,150	28-3-69	2-4-69
5	P/G-8819/M/69	Fog type tension insulators The proposal was referred to DGTD on 24-4-69. As no response was forthcoming, a reminder was issued on 17-6-69. As the requirement was urgent and we have not received the comments of DGTD, a D.O. reminder was issued on 31-7-69 and another on 16-9-69. DGTD in their reply letter dated 16-10-69 informed us that the party should be advised to contact the indigenous manufacturers. In our initial request to DGTD, we had advised them that tenders were invited by the Project authorities and that the indigenous offers received were not technically suitable, but DGTD after a lapse of 6 months insisted that the indigenous manufactures should be contacted again. However, the whole case was once again presented to DGTD on 31-10-69 and the final clearance was secured on 15-11-69.	66,000	16-4-69	24-4-69
6	P/G-8369/M/67 (24/30 (SP)/70)	Spares for Steam turbine at Dhuvaran The proposal was referred to DGTD on 27-11-67 for clearance from indigenous angle. Partial Comments were given by DGTD on 4-1-68 and the case was referred back to DGTD again on 27-1-68. DGTD was reminded on 30-3-68 followed by another reminder on 30-4-68. A self-contained note was given on 22-6-68 requesting DGTD for expeditious action and granting clearance from indigenous angle and the clearance was accorded on 18-6-68 after a lapse of nearly 7 months. Certain items were deleted by the DGTD and the Project authorities were communicated on 5-7-68. The Board again approached this Commission on 18-11-68 giving justification for import of the deleted items and after examination the case was again referred to DGTD on 23-12-68 for reconsideration. DGTD reminded on 22-1-69 followed by a D. O. reminder on 27-2-69. As no response was forthcoming, the matter was taken up with the DGTD on 4-6-69 followed by another reminder on 30-7-69. DGTD in their reply dated 23-9-69 requested us to forward to them again duplicate copies of the list of the spares to be imported. The information was conveyed to DGTD on 1-11-69 and the final clearance was received only on 21-11-69.	8,50,390	24/10/67	27/11/67
7	P/Mad-4346/M/68 (P/Mad-4346/M/68).	Electronic valves. The proposal was referred to the DGTD on 28-9-68 and they on 2-11-68 advised this Commission that BHEL should be contacted in the first instance. It was clearly indicated in our reference to DGTD on 28-9-68 that when the tenders were invited by the Project authorities M/s. BHEL did not participate in the tenders and also indicated their inability to supply the equipment. In spite of this fact, DGTD again requested us to contact BHEL. However, on our taking up the matter with the Project authorities, the DGTD was again addressed on 24-11-68 wherein we forwarded BHEL's letter	43,810	16-9-68	28-9-68

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1	2	3	4	5	6
7	P/Mad-4346/M/68 (P/Mad-4346/M/68).	indicating their inability to supply. As no response was forthcoming to our reference dated 24-11-68, a D. O. reminder was sent on 13-2-69 followed by another D. O. reminder on 25-3-69 and a personal reminder through our Liaison Officer on 1-4-69. The final clearance of DGTD was received on 5-4-69.			
8	P/G-8730/M/68	Spares for 33 kV OCBs The proposal was referred to the DGTD on 10-9-68. The DGTD in their comments, dated 24-9-68 accorded partial clearance. The Project authorities were advised to contact the indigenous manufacturers and arrange for the procurement of the deleted items. A reference was again made to the DGTD on 7-11-68 stating that the spares being of proprietary nature, no indigenous supplier was prepared to undertake the manufacture in view of the very small quantity required. DGTD, on 20-11-68 again advised to contact HEL, Bhopal for procurement of these spares. The Project authorities were unable to get any positive response from HEL and accordingly a back reference to DGTD was made on 2-4-69 intimating them the inability of HEL to manufacture and supply these parts. As no response was forthcoming, DGTD was reminded again on 22-9-69 followed by a reminder on 14-10-69 and again a D.O. reminder dated 4-11-69. The final clearance was received only on 15-11-69.	4,095	24-8-68	10-9-68
9	P/Maha-9645/M/68	Fisher valves for Khaperkheda Power Station. The proposal was referred to DGTD on 19-7-68. The DGTD in their reply dated 2-8-68 requested us to advise the party to approach the BHEL, Hyderabad, for indigenous procurement. The matter was taken up with the Board and after ascertaining their views, the DGTD was again approached on 1-2-69 for reconsideration of the proposal since BHEL was not in a position to supply the equipment in question. As no reply was forthcoming a D.O. reminder was issued to DGTD on 6-3-69 followed by a reminder on 16-6-69. Since sufficient time had lapsed, the DGTD, was again reminded on 6-11-69, followed by a D. O. reminder on 24-11-69. DGTD in their letter dated 10-12-69 informed this Commission that as all the previous papers did not appear to have been received in their office, duplicate copies of the same may be sent to them. Duplicate copies were sent to DGTD on 10-12-69 and the clearance was accorded finally on 15-12-69.	34,324	6-7-68	19-7-68
10	P/Maha-9646/M/68	Spares for BJD make Crusher for Ballarshah Power Station. The proposal was referred to DGTD on 18-7-68. They were reminded on 18-9-68. Since no response was forthcoming and the case had been pending with them for 6 months, a D. O. reminder was issued on 19-12-68. On 27-12-68 the DGTD wanted duplicate copies of list of items required to be imported for their consideration. Needful was done on 6-1-69. They were reminded on 1-2-69, followed by a D. O. reminder on 11-3-69. The final clearance was received only on 30-4-69.	15,840	6-7-68	18-7-68

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1	2	3	4	5	6
11	P/O-4817/M/68	Spares for Heavy Duty Trailer DGTD was requesteed for indigenous clearance on 16-11-68. The clearance was received only in March, 1969 after reminders in December, January and February.	58,870	25-8-68	16-11-68
12	P/O-4901/M/69	Spares for Turbo generator DGTD was requested for indigenous clearance on 28-1-69. DGTD did not clear item from indigenous angle in March, 1969. DGTD was again requested to reconsider on 8-4-69. Inspite of reminders no reply was received. On 17-11-69 DGTD requested for previous papers as the same were not traceable in that office. These details were sent on 15-12-69 and no clearance has so far been received. The last reminder was sent on 13-2-70.	36,266	6-1-69	28-1-69
13	P/O-4909/M/69	Meter Relay Testing Equipment. DGTD was requested for indigenous clearance on 25-3-69. On 3-5-69, the DGTD asked to inform the applicant to contact indigenous manufacturers. After certain clarification from the applicant, DGTD was requested in November, 1969 for indigenous clearance. The DGTD after reminders intimated on 3-1-70 that the previous papers are not treceable. The DGTD was given the details in Jan., 1970. Their clearance was received in the same month.	4,18,630	18-3-69	25-3-69
14	P/AP-7749/M/69	High bond tape for Nellore Power Station DGTD was requested for indigenous clearance on 5-6-69. On 24-6-69 DGTD asked for the detailed specifications and the same were furnished on 18-7-69. The DGTD did not clear the same from indigenous angle in September. On receipt of further clarifications and non-availability of material from indigenous sources, DGTD was again requested in November, 1969. The clearance was finally accorded on 6-12-69.	5,695	26-5-69	5-6-69
15	P/MP-4008/M/69	Spares for PLCC equipment DGTD was requested for indigenous clarence on 3-5-69. On receipt of regrets from indigenous manufacturers, the DGTD was again requested to reconsider the indigenous clearance on 23-6-69 and was reminded in August, 1969. In September, 1969 DGTD asked for duplicate list of the items to be imported which were furnished on 23-9-69. DGTD clearance was received on 7-10-69.	23,000	25-4-69	3-5 69
16	P/MY-6708/M/68	Spares for transformers DGTD was requested for indigenous clearance on 2-4-69. DGTD informed the availability from indigenous manufacturers, On 2-7-69 DGTD was again requested to reconsider as the materials were not available from indigenous sources. DGTD was reminded on 18-9-69 and DGTD asked for further details as the original papers were not traceable in their office. These details were supplied on 28-10-69 and DGTD cleared the same after deleting some of the items on 26-11-69. In January, 1970, DGTD was again requested for to clear the items objected to by them as the applicant could not get from indigenous manufacturers. DGTD has been reminded on February, 1970 and their reply is still awaited.	63,790	19-3-69	2-4-69

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1	2	3	4	5	6
17	P/MY-4626/P/68	Steel jacks for Sharavathy H.E. Project	81,200	11-6-68	2-6-69
The case has been referred to DGTD on 2-7-68. The reply received on 3-9-68 as to why the indigenous offers are not suitable. Comments of DGTD referred to State on 9-9-68. Reply on Comments received on 13-11-68. Comments of State referred to DGTD on 20-11-68; reminder on 31-12-68 and subsequent reminders were issued on 10-4-69, 28-6-69 and 5-8-69. Reply received on 20-8-69 asking for duplicate list of goods. Copy sent on 28-8-69. On 24-9-69, we have been advised to refer to State to procure from indigenous sources. On 15-10-69 State has been referred and reminded on 13-11-69. Reply received on 26-11-69. DGTD was addressed on 9-12-69; reminded on 28-1-70. Reply received on 30-1-70 to procure indigenously. Referred to C.E. on 10-2-70.					



ANNEXURE 5-4

*Experience of DVC regarding Import of Spares
under USAID Loans*

Altogether 9 sanctions were received by us under U.S. Non-project AID Loan No. 386-H-155. Of these only 1 sanction could be utilised by us against Import Licence No. G/AU/1029630 /R/DL/23/C/H/23 dt. 18-11-66 granted under US Non-project AID Loan 386-H-155 revalidated against loan No. 386-H-160 and again revalidated under Loan No. 386-H-168. This case relates to some proprietary spares of IGE, New York for which order was placed on them in 1963. As IGE could not ship the materials within the validity of the original licence which was granted against free resources, request was made for revalidation of the licence which was superseded and in its place new licence was issued under Loan 386-H-155.

As the original Purchase Order was placed a long time ago it was not possible to go through the formalities for a small business Notification to US firms as required in the Public Notice. Instead, a waiver was obtained from the Under Secretary, to the Government of India, Ministry of Industry, A.I.D. Section, New Delhi, dated 17-1-67.

Eight other sanction orders were issued in our favour under US Non-Project AID Loan No. 386-H-155. The licences were dated August, September, October in different cases and it was stipulated in the FERI for Loan 386-H-155, that the terminal date of the Loan was 31-8-67 which would not be extended under any circumstances. As the delivery date of the U.S. suppliers in each case ranged between 8 to 10 months it was not feasible to get the shipment within the terminal date of the loan No. 155 and so all these licenses could not be utilised by us and our Purchase Deptt. requested CWPC to revalidate the licences,

if possible. In April, 1967, after the expiry of the terminal date as given originally, DVC was informed that the terminal date had been extended by 6 months. Had that decision been taken earlier we could have placed the orders against the above loan and could have obtained the shipment within the validity of the terminal date of the loan. We informed the CWPC about it and requested for evaluation of the licences. After protracted correspondence over 7 months the licences were finally revalidated under Loan No. 386-H-160 on condition that the order should be placed with a specific assurance of the suppliers that materials would be supplied within stipulated terminal date of loan 160 which it was stated was valid up to 31-12-67. Actually we found in the FERI that the date was 31-3-1968. Even then as we were advised that we should operate the licences only if the suppliers guaranteed shipment of the materials within 31-3-67 and as that was not found practicable by any of our suppliers we could not utilise any of the licences.

The procedural delay to obtain revalidation etc. through the CWPC and also to obtain waivers from Ministry of Industry and to obtain sanction for opening of L/C from Ministry of Finance, often stand in the way of utilising the licences issued under Non-Project AID Loan as the US Suppliers' delivery schedule in most cases extends over a long time from the date of placement of order and opening of the Letter of Credit. Difficulty is also felt sometimes due to the categorical stipulations of the terminal date of the loans which stated not to be extended under any circumstances, but in fact were invariably extended subsequently or held valid against some subsequent loan, with a loan validity period of the

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terminal date. If even some hint of the possibility of such extension were mentioned in the FERI instead of the categorical deterrent that terminal date would not be extended under any circum-

stances we could have utilised 8 licences against US AID Loan 386-H-155 which had to be surrendered.



ANNEXURE 5-4(A)

Cases that have been abandoned

(I/L was recd. against U. S. Non-Project Loan); but which could not be utilised.

	F. E. requested on	F. E. released vide	Remarks
1	2	3	4
1. Spares for Flue-gas by pass damper for super heated steam temp. control flame indicator etc.	28-10-65	P/DVC-4675/65-DW-III-217 dt. 18-8-66. After this correspondence continued nothing useful so far.	The instruments & control for which the spares are intended are not working satisfactorily. For want of spares they cannot be maintained and may go out of service at any time with the result that at some stage it may not be safe to operate the boiler without the availability of these controls.
2. (i) Spares for L & N Flue gas by-pass damper control. (ii) Other Misc. boiler controls.	9-4-65	P/DVC-4566/65-DW-III-96 dt. 19-7-66.	Without proper maintenance of the relevant controls it would be unsafe to operate the boilers at their rated full load capacity. Unsatisfactory working of control reduce the efficiency of the plant.
3. Finned Tubes for Boiler Feed Pump oil coolers.	11-11-65	P/DVC-4684/65-DW-III-62 dt. 4-6-66.	In absence of replacement tubes we are obliged to plug the tubes that are found leaking. This affect the cooling system of the B. F. P. Lubricating oil with increase in the number of leaky tubes a stage has reached when the affected boiler feed pump motors are failing and resulting in impairment of generation capacity.
4. Spares for 65 MVA Main Transformer & its Oil Coolers.		P/DVC-4521/M-65-DW-III-63 dated 4-6-66	For want of the spares it may not be possible to maintain the transformer in satisfactory condition. At this is the main generator transformer for unit at Bokaro, its failure would result in reduction in generator capacity.
5. Ash Water Pump and Raw Water pump. Bowl assemblies etc.	31-8-65	P/DVC-4673/65-DW-III-361 dated 3-9-66.	For want of these spares the existing pumps cannot be maintained properly. This condition of the ash water pumps specially is causing us a great daily anxiety, as their failure effects generation.
6. Spares for Superheated steam & Flue-gas temp. records (MAN Units).	17-4-65	P/DVC-4574/M-65-DW-III-136 dt. 18-8-1966.	For want of these spares it is not possible to keep the concerned controls in healthy condition. These instruments are essentially reqd. to monitor the final steam temperature. If their performance is not reliable there is considerable risk in operating the boiler specially at full load or near about it.
7. MAN Turbine spares. Valve seats Plunger assys. Gaskets & Packing etc.	27-9-65	P/DVC-4664/M-65-DW-III-60 dt. 4-6-66	In absence of the turbine spares it is not possible to keep the turbine control valves in a healthy condition. Naturally during the start-up of machines we are experiencing some difficulty and there is some risk involved in operation of the turbosets.
8. Instruments etc. for Temperature recorders for MAN Units.	20-5-65	P/DVC-4595/65-DW-III-61 dt. 7-6-66.	In absence of the instrument spares it is no longer possible to keep the temperature recorders in proper condition. Without these recorders it would not be possible to operate the MAN machine on full load.

ANNEXURE 5-5(A)

Experience of U. P. State Electricity Board regarding Import of Spares
(STORE PURCHASE SECTION)

Brief Description of material	C. I. F. Value	Date of application	Date of F/E release by CW & PC	Date of issue of I/L
1	2	3	4	5
1. Hopkinson Patent Stenstil valve	706.00	2-3-65	28-1-67	4-3-67
2. Grate Carrying Bars	8,953.00	20-3-65	26-3-65	11-3-66
3. Recording Charts	7,500.00	10-4-65	27-8-65	2-1-67
4. Special light Glass & Filter Frame	3,773.00	7-5-65	26-5-65	9-1-67
5. Gauges & accessories	4,234.00	14-3-67	28-1-67	4-3-67
6. D. C. Circuit breaker	15,120.00	19-3-66	..	28-11-67
7. Naphthline mineral oil	32,188.00	13-3-67	..	18-4-68
8. HRC Fuses	105.00	16-6-67	..	19-7-68
9. Spares for T/A 7 & 8	5,97,850.00	24-6-67	19-3-68	13-5-68
10. Anode fuse refills	9,030.00	17-7-67	..	26-4-68
11. Hopkinsons Water level indicator and spares	23,196.00	26-4-68	22-2-69	12-3-69
12. Spares for Turbines 5, 6 & 8	7,01,024.00	13-11-68	Not yet received	..
13. Rotor for 238 HP Motor	13,753.00	1-4-69	Not yet received	..
14. Spare Tube nests for Oil & Air cooler	1,31,186.00	7-11-69	Not yet received	..

ANNEXURE 5-5 (B)

APPENDIX III (B)

Panki thermal power station and 2 Nos. 30 MVA Transformer

Brief description of material	C. I. F. Value	Date of application	Date of received F/B release by CW & PC	Date of Issue of I/L.
1	2	3	4	5
1. Damaged/missing parts of 30 MVA Transformer	10,704.00	1-4-67	..	Not yet issued.
2. Damaged/missing parts of 30 MVA Transformer	14,000.00	14-9-66	..	28-2-67
3. Oil Rosin Compount	..	11-2-67	25-3-67	7-4-67
4. Damaged/missing parts of 30 MVA Transformer	4,538.00	11-5-67	..	1-1-69
5. 6 Nos. C. T.'s for 750 MVA Switchgear	2,000.00	5-3-68	10-4-69	3-5-69
6. Damaged/missing parts of 30 MVA Transformer	2,380.00	27-11-68	..	11-6-69 (letter of authority) on 22-7-69
7. Revalidation of Import Licence No. 219015 dated 22-7-63 for import of spares	..	6-2-69	..	25-9-69
8. Spare parts of instrumentation	55,301.00	13-2-69	13-3-69	19-7-69
9. Spare parts of Buldozer Tractor	3,400.00	5-6-69	Not yet released	..
10. Cartridge fuses, fuse blocks, double oil filter type etc.	25,976.00	13-9-69	Not yet released	..
11. Governor Motor for T/A Sets	1,230.00	13-9-69	16-10-69	Not yet issued.
12. Spares for Boilers	1,63,920.00	28-10-69	Application being routed through Board on request of CW & PC.	..
13. Spares of T/A	1,05,516.00	3-11-69	Not yet released	..
14. Enhancement of value of 6 Nos. GEC C.T.'s	6,050.00	14-11-69	Not yet released	..

ANNEXURE 5-6

Proposals of various State Electricity Boards for the issue of Imports Licences delayed in the Office of the Chief Controllers of Imports and Exports

Sl. No.	Control No.	Release of Foreign Exchange		When referred to CCI & E & by whom	Date of issue of import licence	Remarks
		Date	Amount (Rs.)			
1	2	2	4	5	6	7
1	PAP-7550/M/68	16-10-68	25,645	19-11-68—CW & PC	21-2-69	C. C. I.&E. was reminded on 10-2-69.
2	78/3/M/68	8-8-68	13,535	14-10-68—CW & PC	8-1-69	Reminded C.C.I. & E. on 14-11-68. 22-11-68 and 9-12-68.
3	7578/M/68	19-9-68	3,320	19/28-9-68—CW & PC	22-2-69	Treasury Challan sent on 8-10-68. Verification dated 24-11-68 for C.C.I. & E. regarding validity of D.G.T.D. of 11-3-68 and I.T.C. clarification replied on 14-11-68. C.C.I. & E. requested again to give the latest instructions regarding validity of D.G.T.D's clearance on 16-12-68.
4	PB-7816/M/68	30-8-68	4,800	12-1-70—Min I & P	Not received yet.	C.C.I. & E. was reminded by applicant on 4-2-70.
5	PK-9114/M/68	25-3-69	7,606	27-5-69 Min. I & P	9-9-69	Fresh D.G.T.D. clearance sent to C.C.I. & E by Ministry on 25-8-69.
6	PDVC-8503/M/68	31-5-68	14,848	16-10-68—C.W. & P.C.	4-6-69	C.C.I. & E. reminded on 21-1-69 by Applicant, by C.W. & P.C. on 1-2-69, 6-3-69. Telegram by applicant on 11-3-69.
7	PAP-7559/B/68	18-9-68	8,48,541	28-10-68—Min. I & P.	3-4-69	The duplicate set of Import Licence application was sent on 24-1-69 by the Ministry as this became known that the original application was misplaced in C.C.I. & E.'s Office.
8	PMP-9912/D/68	3-9-68	1,85,000	24-10-68—C.W. & P.C.	5-3-69	On 24-12-68 C.C.I. & E. asked for.. I.D.C. No. & credit of I.B.R.D. loan 416-1.M. These were furnished on 28-1-69.