Energy Sources : Retrospect

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The global energy scene during the past two years has been characterised by unprecedented events, which has led to 'Energy Crisis'. This has resulted in :

— shortages due to controlled supplies, effecting timeliness and adequacy ;

— inability to purchase adequate quantities of petroleum (the most desired resource) due to high prices ;

— industrial recession due to curtailed energy supplies and time-lags in change-over from oil to coal, etc. ;

— consequential world inflation ;

— accelerated efforts by energy-deficient countries to discover indigenous petroleum and natural gas ;

— efforts by all countries to improve efficiency and conserve energy ; and

— efforts to evolve energy policies and life styles, linked to resources and environment.

The problem has become quite serious in different regions of the world for different reasons. Western Europe and Japan have been deficient in energy resources and have, therefore, become heavily dependent on imports to meet their demands. Many countries of Asia are not only deficient in resources but also populous and poor and have, therefore, a large potential demand, if they have to raise their standards of living. They have, therefore, to solve the problems of finding energy as well as financial resources. In this context, a review of the indigenous energy resources, energy consumption pattern and ways and means of economising the use of energy is an urgent necessity for one and all.

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Energy Sources

Energy sources of the world and of different countries have been classified and analysed in several studies. For the purpose of this paper, some important key words and concepts are presented in Table 1, which provides a guideline for discussion on various issues. The key words are listed under three types : primary, secondary, and tertiary. The four primary words are basic and cover the whole field of study. The four secondary phrases are the minimum necessary to explain the implications. The tertiary type elaborates each secondary type.

Table 1 : Energy Management
(Some key words and concepts)

Primary	*Secondary*	*Tertiary*
1. Resource	Nature of resource	1. *Conventional*
		1.1 *Non-recurring-fossil*
		—Coal/lignite/petroleum/natural gas/nuclear
		—Chemical (batteries)/geothermal
		1.2 *Recurring :*
		—Agricultural/hydro/solar drying/bio-energy (gas, animate).
2. Energy		2. *Unconventional*
		2.1 *Nonrecurring :*
		—Oil shale/tar sands/methanol/MHD/Chemical (batteries).
		2.2 *Recurring -*
		—Hydrogen/urban wastes/solar power heat/tidal power/wind power/ocean thermal gradients/fuel cells (hydrogen-oxygen).
3. Conservation	Economic utilisation	—Quality of resource/efficiency in use/appropriateness of resource for use/appliances for use, processes/full use of products, by-products, wastes/policies on saving for future/related supporting inputs (maintenance, lubrication, instrumentation, control), demand estimates.
	Essentiality of needs	—Priorities of uses/sectoral needs (industrial, commercial, domestic/basic human needs/security/prestige.
4. Management	Social issue	—Life-style/income groups (rich, poor urban, rural)/proximity to resource (occurrance of reserves)/environmental quality/effluent treatment and waste recycle/energy policies/economics.

The energy sources are broadly classified under conventional and unconventional types and each is further divided under non-recurring and recurring types. Several alternative words, appearing in literature, are not included here. The words are quite explicit. Lignite includes brown coal and peat. Nuclear source is deemed conventional because one type of it is in practical use, though not in all countries and though fusion energy is not yet commercialised. The non-recurring chemical type refers to lead acid batteries and other batteries used for lighting radios and some instruments. The more sophisticated batteries are considered unconventional. Geo-thermal source is considered conventional because at least four major countries are using it. Methanol is considered non-recurring because its large-scale manufacture requires carbon from depleting sources. Methanol from wood distillation, a recurring resource, is very small though it has been used mostly as a chemical or solvent apart from minor use in spirit lamps.

The whole world is presently dependent on seven conventional sources for the bulk of its requirements. Four sources provide most of the heat and motive power. It is interesting to reflect how dependent the world has become on just one source, petroleum, whose shortage and cost have created a global crisis.

Resource Availability

(i) *Fossil Fuels :* The data on reserves of coal, lignite/brown coal, petroleum and natural gas in several Asian countries is given in Table 2. It is seen that the far and south-east Asian countries are fairly rich in coal reserves. It can be seen that only China and Indonesia are endowed with large reserves of oil in addition to coal. The case of Japan, however, proves that large figures of reserves do not necessarily indicate adequacy. The status of economic development and per capita energy availability and demand have to balance.

The Middle-Eastern countries are practically devoid of coal and lignite reserves but are saturated with oil and gas reserves. Out of the total measured (including economically recoverable) hard coal (including anthracite) reserves, 15.4 percent is in USSR, 29.4 percent in USA and 27.8 in China. The rest 28 percent is distributed in the rest of the world. If indicated and inferred reserves are also considered, USSR has 49 percent of the world's total reserves, USA 28 percent and China 12 percent. Of the world's lignite reserves (measured : $343X10^9$)tonnes), only 8 percent is in Asia, 31 percent in USSR, 38 percent in Europe and nearly 14 percent each in USA and Australia. Of the total lignite reserves, Asia has only 0.5 percent, USSR 66 percent, USA 24 percent. Of the world's peat reserves ($211x10^9$ tonnes), 60 percent is in USSR and 34 percent in Europe, Asia's share being negligible.

Oil shale and bituminous tar sands occur mostly in South and North Americas and China. There is no evidence of their occurrence in Asia, although recently one South-East Asian country is reported to have found some.

Out of the total proved world reserves of petroleum, 54 percent is in the Middle-East, 14 percent in Africa, 9 percent in USSR, 8 percent in North-America. The reserves in China are still not certain. Out of the world's proved reserves of natural gas, USSR has 32 percent, Asia 23 percent, North America 20 percent, Africa 11 percent and Europe 9 percent.

The total uranium resources of the world (4×10^6 tonnes as element) are concentrated mostly in the U.S.A. (nearly 50 percent), Canada, South Africa, Sweden, USSR, China, GDR, and Australia. The estimates for China are placed between 20 and 100 kilotonnes and for India about 62 kilotonnes. Uranium reserves are not clearly reported so far from other Asian countries. Surveys for thorium reserves are not yet exhaustive. The cheaper thorium reserves, extractable at US $ 25 per kilogram element, are mostly in Europe, North America and South America. Higher cost resources mostly occur in Asia and South Africa. Thorium reserves in India are currently placed at 500 kilo-tonnes. Important deposits are also located in the beach sands of Sri Lanka and Korea in Asia.

Thus, North America, USSR and China seem to be abundantly endowed with all fossil fuels. The current total population of USA, USSR and China is about 37 percent of the world total. Barring Middle-Eastern countries and Indonesia, most other Asian countries are severely deficient in fossil fuels, compared, to their potential demand.

(*ii*) *Hydraulic energy :* The Ninth world Energy Conference has estimated the annual amounts of electricity that could be generated at the rates of flow of rivers and streams in different countries throughout 95 percent of the year (Gen 95) and at the overall average rate of flow (Genav). The Genav figures are higher than Gen 95. The total Genav estimate for the world is 9802 Twh/yr (10^9 kwh/yr). Of this, 27 percent is in Asia, 21 percent in Africa, 17 percent in South America, 15 percent in North America, 11 percent in the USSR and 7 percent in Europe. The reserves of China is the largest at 1320 Twh/yr; USSR 1095, USA 701, Zaire 660, Canada 535 and Brazil 519. Only 7.5 percent of the resource potential is now being utilised in Asia while Europe utilises 53 percent and North America 30 percent. The possibility of enhancing production of hydro electricity is very large. Here again, 50 percent of the total resource potential of Asia (2646 Twh/yr) exists in China. India has about 12 percent; Japan, Burma and Indonesia also have substantial possibilities.

(*iii*) *Other resources :* There is no clear estimate of agricultural and bio-sources of energy, mainly because the developed countries have moved away from them and the developing countries are following them. In any case, dependence on agricultural fuels (mostly wood) beyond what can be supplied by well-organised energy plantations, is bound to create ecological disturbances and damage soil and water conservation programmes. These sources can, however, play a useful role in rural sector. The fuel wood resources in India is placed at 120 megatonnes per year.

Adequacy of Resources

The reserves stated in Table 2 and in the above section appear quite impressive at first sight. The adequacy of reserves can be judged only after considering the national populations and present state of economic development. A comparison of some countries and regions is given in Tables 3, 4 and 5.

From Table 3 it can be seen that only USSR and USA have very large per capita reserves of fossil fuels. The per capita reserves of China are much smaller than what the total quantity indicates. Similar is the case with Iran, Indonesia and India. The per capita energy consumptions in different groups of countries are given in Table 4. Comparing

Table : 2 Reserves of Conventional Fossil Fuel Sources In Asia

Area/Country	*Hard Coals ($M_t = 10^6$ tonnes)*			*Lignite/Brown Coal ($M_t = 10^6$ tonnes)*			*Petroleum (M_t = 100 tonnes)*			*Natural Gas (G: cu.m.= 10^9 cu.m.)*
	M[1]	*I*[2]	*Total*	*M*[1]	*I*[2]	*Total*	*Proved*	*Poten-tial**	*Total*	*Proved*
Far and South East Asia										2600
Afghanistan			85							133
Bangla Desh										260
Burma	13	8	21			265	6		6	42.5
China	300×10^3	700×10^3	1000×10^3			700	20000			850
India	21×10^3	60×10^3	81×10^3			2063	130	200?	330?	66
Indonesia	500	345	845	2000		2000	3000	6100	9100	983
Japan	7400		7400	238	1495	1733	4		4	34
Korea (R)	85	1100	1185	2	3	5				
Pakistan	784	877	1661	22	258	280	5		5	462
Taiwan	175	85	260	17	3	20	3		3	28
Vietnam (D.R.) | Vietnam (R) |	200	800	1000							
Middle East							58700	17900	76600	20600
Abu Dhabi							2130		3892	2830
+ Dubai							58			294
Bahrein							7433		8820	11240
Iran			1000				3807		8936	1500
Iraq									2728	850
Kuwait							1902		1902	142
Neutral Zone							18638		18806	2720
Saudi Arabia							176		176	28.3
Syria							28		28	14.2
Turkey	205	1130	1335	251	1630	1881				23200
Total Asia	330362	764345		8000	4000	12000				23200

* From fields discovered and to be discovered. [1] Measured [2]Inferred

Tables 3 and 4, it is clear that developing countries of Asia would be fast depleting their proved recoverable fossil fuel reserves if they aim

Table 3 : Energy Resource Availability in Some Countries and Regions

Country/region		Reserves of oil, gas and coal		
		Quantity (10 Kcal)	*Per Capita (10 Kcal)*	*Per sq. km land area (10 Kcal)*
USSR	M	2154	8.2	96
	T	40240	163	1793
USA	M	2709	19.9	230
	T	21830	105	2330
China	M	2332	2.9	243
	T	7308	8.6	765
Japan	M	54	0.5	146
	T	64	0.6	173
India	M	166	0.3	519
	T	579	1.1	177
Indonesia	M	60	0.5	32
	T	110	3.9	58
Iran	M	189	6 2	115
	T	198	6.5	120
Asia	M	2615	1.2	25
	T	2879	3.7	286
Middle East	M	655	6.6	119
	T	1210	12.1	220
World	M	12112	3.2	0.9
	T	78818	5.8	2·1

Note : 1 tonne coal equivalent = 7.04 × 10 kcal.
M—measured & proved; T—total

Table 4 : Per Capita Energy Consumption by Socio-Economic Groupings of Countries

(tonnes coal equivalent)

	1950	1960	1961	1970
1. Developed private enterprise economies (North America. Europe, Japan and the like)	3.33	4.65	5.44	5.9
2. Centrally planned economies of Europe (developed)	1.66	2.8	3.85	4.40
3. Centrally planned economies of Asia (China, North Korea, Mongolia, etc.)	0.07	3.66	3.46	0.54
4. Developing countries (Asia, Africa, Latin America)	0.13	0,22	0.30	0,33
5. India	0.07	0.15	0.18	0.19

to consume energy at levels comparable to those of developed countries. There is also the problem of finding resources to develop the more difficult solid fossil fuel reserves. Countries which are rich in oil reserves can produce and utilise them more conveniently but would replete them faster. The pollution potential in some countries due to high energy resources and for more rational and efficient methods of energy utilisation is indicated in Table 5.

Table 5: Energy Consumption per Sq. kms. in Some Countries

	Area 10^6 Sq. Km.	*Population density*			*Energy consumption density*			
		1961	1965	1968	1961	1965	1968	1970
U.S.A.	9.363	20	20.8	21.5	170	191.5	222	240
Canada	9.974	2	2	2.1	—	15	17.7	19
USSR	22.403	10	10.3	10.6	36	37	13.2	47
W. Germany	0.243	228	242	243	800	1022	1087	1245
U.K.	0.244	216	223	227	1055	1146	1136	1218
France	0.552	83	88.3	90	199	263	297	341
Italy	0.301	170	172	175	—	301	382	470
Japan	0.370	253	266	277	294	573	696	888
India	3.263	134	153	162	20.10	25.6	29.5	31

Notes : 1. Population density in persons/sq. km.
2. Energy consumption density in t.c.e. per sq. km.

Current Energy Shortages

Shortage of a resource can occur on account of :
—absence of resource altogether;
—excessive demand compared to supply at a time;
—inequitable distribution;
—deliberate restriction of production or supply;
—inability to purchase;
—technological constraints or exploitation, etc.

It is widely acknowledged that there is no absolute shortage of fossil fuel resources in the world as far as the reserves are concerned.

Yet, they may not be adequate in some regions due to demand pressures.

The current energy shortage, symbolised as energy crisis', is attributed to the restrictions imposed on petroleum availability, through either controlled supplies or enhanced prices. They have been caused despite the availability of large reserves of coal, lignite and hydropower. The crisis, therefore, is essentially a petroleum crisis due to excessive dependence on it for war and peace and also private profit. It appears that the root causes were the high mobility and wrongful foreign ownership of this sophisticated and efficient resource. It could be moved on large scale over long distances and oceans unlike coal and natural gas, thereby causing inequitable distribution.

The dual role of petroleum as an efficient source of energy as well as chemicals has also partly caused the imbalance. Interestingly, every conventional source of energy is also a source of chemicals. If energy alone is required, hydrogen, solar energy and hydropower can serve the purpose. Organic chemicals and polymers require carbon also and petroleum has become the preferred source. It is worth noting that carbon is a limited and non-recurring resource on the normal time-scale, except in so far as carbon dioxide is recycled in nature. Hydrogen is a recurring and plentiful source in the form of water. It is, therefore, necessary to distinguish between the demand for energy resources for chemicals and energy.

Remedial Measures

It is clear from the foregoing discussion that the current energy crisis is essentially due to a global imbalance between supply and demand of the most preferred energy source and techno-economic constraints on exploiting available alternative resourcees in the short-term. The remedial measures to meet this crisis can be broadly categorised as; (a) relieve existing stresses; (b) avoid creating new stresses; (c) review policies for energy planning and resource; and (d) review life styles.

(a) *Relieve Existing Stresses :* The immediate problem in countries short of petroleum is to economise on the use of petroleum products.

Improvement of combustion efficiencies (fuels, appliances, maintenance etc.), avoiding wasteful fuel utilisation and change-over from oil to coal and hydropower where possible are priority steps taken in most countries. Efforts are being made to minimise petroleum imports. Particular efforts are made to economise use of high value petroleum products like gasoline, kerosene and diesel fuel, mainly in transport sector.

(*b*) *Avoid New Stresses :* This refers to medium and long term steps for economising on the use of petroleum products, in addition to continuing the current efforts for fuel economy and conservation. Some important steps are :

—improvements in designs of combustion systems and appliances;

—heat transfer and recovery systems;

—development of new designs;

—adopting total energy concept in maximising fuel efficiency;

—developing and selecting low-energy technologies in preference to high-energy technologies, though at the cost of time;

—adopting appropriate measures in all supporting socio-economic sectors (transport, road building and maintenance, working hours, commercial and domestic activities etc.) leading to energy economy;

—waste recycle and recovery;

—indigenisation of energy base as far as possible, etc.

(*c*) *Energy Planning and Resource Utilisation :* Market demand estimates for energy sources, energy demand patterns and practices concerning them require constant review. Although these studies are regularly made in developed countries, this is not the case yet in developing countries. Such studies would help governments to evolve policies on energy planning and rational development and utilisation of indigenous energy resources. An important policy issue for developing countries is whether part of their energy requirements should always be met by indigenous resources where available, giving secondary consideration to economic viability of individual projects. That is, part of the cost is borne as social or national cost. It is worth noting that USSR, China, East European Conntries etc., have developed their energy base by this approach.

For India, a two-tier policy for use of conventional fuels is advocated. The first tier should be based on coal which is the abundant indigenous source, in addition to hydropower. This tier has to serve the energy foundation and infrastructure of the country. Its growth rate should be mostly *independent* of that of oil and gas which are the competitive and sophisticafed resources. This means that there should always be a certain minimum growth of coal utilisation to avoid undue dependence on imported resources, to ensure security and to conserve the more sophisticated valuable energy resource. The second tier should be based on oil and gas which should serve specific, unsubstitutable and high value end uses and peaks of our sophisticated demands, for exmple, automotive fuels, chemicals, polymers, etc. Even if we discover large quantities of oil and gas in our territory, we have to adopt a policy of its judicious use, based on a policy of conservation.

d) *Review Life Styles :* This exercise has now become essential because nations, rich and poor, have been forced to ask themselves whether the ways of living of some of the affluent nations are at all desirable models for progress and peace. Futurologists, doomsday forecasters, and optimists are multiplying their studies throughout the world. Poorer nations need to have a hard look at their life styles, question whether they can afford imitative styles and decide about the future course of development. The author firmly believes that energy conservation is closely tied to the policy of peaceful progress at a slower pace. Nations have to work for a 'no wars, all peace' policy, although, this may be quite unrealistic in the modern world. Shifting theatres of war and not eradicating them, had seriously aggravated the global energy supply problem, as can be seen from the history of the petroleum industry since the second world war. Asian nations have to look to their own self-interest and evolve life styles and energy policies accordingly. A balance has to be created between economic progress, energy demand and environmental quality.

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Energy Feasibility Reports

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Planning is an important tool available to the management to look into the future and take decisions needed to avoid forthcoming problems and thereby attain success. Feasibility study is the first step towards detailed planning. The feasibility study may be divided into various aspects such as : a) Economic, b) Technical, c) Financial and d) Managerial Feasibility.

A feasibility report gives the necessary information on the following :

(i) Details of the organisation,

(ii) Purpose of the proposed project,

(iii) Summary of the proposed project,

(iv) Details of the project,

- (a) plant facilities—land, buildings;
- (b) material requirement;
- (c) labour requirement;
- (d) managerial and technical personnel;
- (e) organisational set-up;
- (f) service facilities;

(v) Plant locations

- (a) map;
- (b) locational facilities—road, rail, communication, proximity to raw materials, manpower, labour situation, topography and geological factors, climatology, etc.

(vi) Raw materials—quantities and availabilities, short-term and long-term physical characteristics, price collection and transportation, storage facilities, supplying agencies and alternative sources;

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(vii) Manpower—social factors, culture community, surrounding skill and educational levels, sources of labour, local rules regarding employment and industrial relations,

(viii) Economics :

(a) Profitability;
(b) National Economic benefits;
(c) Intangible benefits;
(d) Status of the project in the total economy.

(ix) Project Implementation plan :

(a) Phases and stages;
(b) Duration determination;
(c) Network plan;
(d) Resources disposition.

This paper attempts to discuss some of the factors which should be considered in preparing energy feasibility reports, as they play an important role in total energy systems.

Selection of Site

A host of factors must be studied and tempered with the engineering judgement, while selecting the site for a plant. The general area is dictated by the existence of coal reserves, water or other factors. Then make a more specific analysis of the several sites which may be available in the area. This study will usually develop into an economic comparison of several sites and a selection made on the basis of the most economical solution. For the purpose of settling the broad site requirements, it is necessary to know the capacity of the plant that will be required in the particular location—

(a) for immediate development (five to seven years ahead), and
(b) over the next ten to twenty years.

The former provides the information to enable the initial development to be planned and (b) enables site area to be selected sufficiently large for the ultimate development and the services, railway sidings, water supplies, access and transmission connections to be developed in the most economic manner to allow for future requirements and for the full utilisation of the natural resources.

The information required for (a) demands that a decision be taken on the size of site and associated plant to be installed; (b) is a matter for intelligent forecasting (planning) on the basis of past load growth, anticipated future fuel availability and considerations of probable technical development.

Availability of Fuel

Fuel availability and its transportation costs have always been major factors in site selection. Larger capacity units and other factors that have reduced the capital cost per Kw. of generating capability have increased the relative importance of fuel costs. Improved electrical transmission design with consequent cost reductions makes plant location more flexible to take advantage of the lowest fuel cost.

Water Supply

Adequate supply of circulating cooling water is a major site selection factor. Flow requirements vary, but about 0.5 gpm is required per Kw. of capacity. This means that a 1000 Mw plant requires about 500,000 gpm or 110 sec. ft. of water of this about 1.52% will be evaporated and lost. Plant make-up and sanitary water requirements for this size plant are about 15 to 25 gpm. Thus, nearly 7500 gpm are consumed.

The ideal circulating water source is a river whose minimum flow will supply the entire plant requirements with no re-circulation.

Natural waters are a possible cooling water source but are relatively rare in the general areas for which power plants are considered. Artificial lakes are feasible in many areas and can be a good source of cooling water for mine mouth power stations. If no dependable source of circulating water is readily available, consider cooling towers. They may be the most economical installations based on capital investment but the operating and maintenance costs may be more.

Site Area Requirement

The area required for site development can vary a great deal. This depends upon the amount of area which is readily available and the size of the unit to be constructed. About 200 acres is often considered a reasonable minimum site for development of a 1000 Mw coal-fired station with minimum allowance for ash storage.

Ash disposal is a separate problem for each installation. Ash deposited by a 1000 Mw station for 40 years would require about 750 acres for a pile of 20 ft. high.

Problems

A power plant can be built in almost any location, but construction cost can vary greatly at each site. A major cost item in any site is the power station foundation.

A site should be reasonably level, not liable to flooding and not so high above the source of cooling water that excessive pumping power is required to supply water for cooling purposes.

Flood conditions should be studied carefully when evaluating any site. Past records should also be reviewed to find the high water mark. Excavation and grading vary with the site. Some sites require large amounts of fill to raise them above flood levels.

A particular site may be subject to limitations caused by regulatory agencies. Consider the following :

1. Restriction on structure heights close to airports and many areas designated as flyways. These limitations affect not only the

chimney and microwave tower heights, but also the heights of boiler rooms for large modern stations.

2. Air pollution regulations vary with different areas and local authorities. This can be the cause of a major cost variation between two different sites.

3. Sanitary conditions and regulations of discharge will vary with different areas. However. sanitary treatment cost is reasonable and is probably not a significant site selection factor.

4. Anti-noise regulations are becoming more popular. They may produce a significant cost difference between a plant which is designed for noise reduction and a plant which ignores any limitations upon this.

5. Ash disposal may come under the jurisdiction of some regulatory agencies, particularly with respect to stream contamination.

Site Access

Access is required to bring on to site —

(a) the constructional materials and plant;

(b) fuel supplies,

(c) Operational staff, etc.

Good road access is essential for construction, and rail and sea facilities are useful advantages. Direct access to a main trunk road to bring in heavy loads is desirable.

When the station is operating, the over-riding consideration is access to fuel supplies, and the site must be conveniently situated either close to a main railway line to accept rail-borne fuel, or in areas remote from the coal fields on an estuary or the sea coast to take its fuel from ships.

These points should be reviewed with respect to each site and make further search for conditions unique to a site. Then an evaluation can be prepared by analysing the pros and cons of one site over the other. An economic analysis can also be prepared and with this analysis, a proper judgement can be made concerning the best choice.

Design Objectives

The objectives of any aspect of power station design are to achieve the lowest capital cost and ease of construction, together with simplicity and efficiency in the operation and maintenance of the station. In attempting to reach these objectives, a number of features have to be considered. These features are listed below, although all being equally important the order is not intended to denote priority :

Efficient Operation : (a) Reliability of operation, (b) Simplicity of Operation, (c) Safety in Operation, (d) Good working conditions, (e) Ease of maintenance.

Minimum Expenditure : (f) Low capital cost, (g) Minimum operating cost—with both of these it is necessary to take into account : (h) Simplicity in design, (i) A good integrated design, (j) A pleasing appearance.

The objective of the initial design study is to evolve a complete integrated design conceiving the station as a single entity and not a collection of individual piece of plant thrown together in haphazard fashion.

Selection of Equipment

The factors influencing the selection of fuel burning and steam generating equipment are :

Fuel characteristics	Space conditions
Capacity and steam conditions	Cost and individual preference

Fuel Characteristics

Before attempting even a preliminary selection of equipment, complete information should be available as to fuels on which designs and predicted performance are to be used. This information should be established by a comprehensive survey of the market, to determine which fuel is available in sufficient quantities to guarantee a reliable source of supply. This offers the greatest economic value over a long range programme. It usually is desirable to establish a secondary fuel supply for emergency use, which is used, when the supply of the primary fuel is interrupted or changes in the price make the secondary fuel more economical. The equipment should be selected so that its performance with the secondary fuel is equivalent to that of the primary fuel.

In addition to the cost and heating value of the fuel, which are two of the many factors in the average cost per thousand pounds of steam generated, other factors to be considered are the efficiencies and the operating costs obtained with different fuels. The average cost of burning coal in USA exclusive of fixed charges is about 5% of its cost, for fuel oil, approximately, 1.5 percent of the equivalent cost; and for natural gas 0.5 percent.

The type of fuel burning equipment depends on burning characteristics of fuel and the capacity for which the unit is designed. For example, stokers are usually the more economical selection for comparatively low capacity units and pulverised coal for high capacities.

Table 1 shows the adaptability of different firing methods to various commonly used fuels and required stoker and furnace sizes. Table 2 shows the range of capacities for which each type of fuel burning equipment is particularly suitable and most commonly used.

Capacity and Steam Conditions

Capacity is one of the most important factors in determining the type of unit to be selected. Table 3 illustrates the capacity range for which each of the general types of boilers has been found most adaptable,

Table 1 : Fuel Burning Equipment and Furnace Check-List

Type of fuel burning equipment	*Approximate continuous combustion rate lbs/sq. ft./hr (dry basis)*					*Range in Maximum Continuous Furnace Liberation Rates Btu/Cu. ft./hour*		
		Bituminoua						
	Anthracite	*High Quality*	*Low Quality*	*Sub-Bitu-minuous*	*Lignite*	*Coal*	*Oil*	*Gas*
Pulverized Coal	—	—	—	—		15000 22000	—	—
Spreader Stoker	—	40	35	50	50	25000 35000		
Chaingrate Stoker	30	45	35	50	50	40000 50000		
Travelling grate Stoker	30	45	35	50	50	40000 55000		
Stationary grate Stoker	20	20	15	15	18	—	—	—
Special Furnaces	—	—	—	—	—	—	25000 30000	20000 30000

Table 2 : Fuel Burning Equipment Selection Check List—Capacity Basis

Fuel burning equipment	Continuous Capacity Range, lbs. of Steam/hr.			
	1000—15,000	15,000—30,000	35,000—200,000	150,000—1,000.000
	A	B	C	D
Pulverized fuel	—	*	√	√
Spreader stoker—dumping grate	—	√	√+	—
Spreader stoker—continuous discharge	—	—	√	√x
Chaingrate stoker	—	√	√	√x
Travelling grate stoker	—	√	√	√x
Stationary grates	√	—	—	—
Oil burners	√	√	√	√
Gas burners	√	√	√	√

* Occasionally.

\+ Upto approximately 125,000 lbs/hr.

x Occasionally for capacities exceeding 200,000 lbs/hour.

Table : 3 Steam Generating Equipment Selection Checklist

TYPE	*Continuous output lbs/hr of steam*				*Maximum Design Pressure Psig.*	*Max. Temp. °F*	
	A	*B*	*C*	*D*			
Fir Tube Boiler	√	—	—	—	250	150°	Superheat
Three Drum Low head boiler	√	√	—	—	400	150°	,,
Two Drum vertical unit type boiler	√	√	√	√*	1,000	900°	,,
Three or Four Drum vertical unit type boiler	—	√	√	√	1,500	925°	,,
Sectional header boiler	—	√	√	—	2,000	900°	,,
Controlled forced circulation +	√	√	√	√	3,000	1050°	,, ×

* Upto approximately 225,000 lb/hr. on coal and 300.000 lb/hr. on oil and gas.

x Present max. used.

\+ These boilers are designed in various types and sizes for the full range in capacities.

maximum steam pressures for which they are designed and the corresponding maximum steam pressure.

Feasibility of On-Site Energy Systems

A feasibility analysis is the comparison of alternate systems. Feasibility study also establishes the viability of total energy for a prospective site. It compares the running costs of various prime movers and waste-heat recovery combinations with those of a conventional system, usually comprising direct-fired boilers and purchased electricity. The studies entail a great deal of detailed investigation and are costly in terms of the manhours involved, so that it is necessary to sort out the wheat from the chaff at as early a stage as possible. Hence, a fairly standardised and simple initial assessment is made of potential schemes followed by detailed studies of the ones shown to be most promising.

Initial Feasibility Study

The first step is to obtain, or estimate in the case of a new site, the hourly heat (steam or direct heat) and electrical load profiles over as long a period as possible. The probable future trend of loads and profiles must also be considered.

From these data, the fluctuation of the heat to power ratio can be deduced and this will enable a good preliminary choice of the correct prime mover to be made.

Typical heat to power ratios for the prime movers and associated waste-heat boilers are given in Table 4.

Table 4 : Typical Heat/Power Ratios

Prime Mover	Kg. Steam/MJ	lb. Steam/Kwh
Gas Turbines	(0.055 to 0.079) to (0.238 to 0.396)	(7 to 10) to (30 to 50)
Steam Turbines	0.12 to 0.792	15 to 100
Engines	0 to 0.012	0 to 1.5

The gap in the range of heat to power ratios between engines and gas turbines can be filled by producing the additional heat from direct-fired boilers. From the maximum and minimum electricity demands, the size and number of prime movers required can be determined, with an allowance for standby equipment. An initial assessment of both the capital and fuel costs can then be calculated either by using the average efficiency and capital cost figures previously quoted in the paper, or by contacting selected manufacturers of prime movers for any detailed information.

A first approximation of running costs can be obtained by assuming that total electricity produced per annum is generated at 80 percent full-load condition for each prime mover considered. This gives the total running hours of the generator sets, and consequently, the fuel input to the prime movers can be estimated and costed, assuming typical fuel prices.

Knowing the running hours of the prime mover, the waste heat recoverable from the installation can be calculated by using the factors of 0.012 Kg/MJ (1.5 lb/Kwh) for engines and 0.079 Kg/MJ (10 lb/Kwh) for gas turbines. The shortfall, if any, in the heat recoverable and the annual steam demand can then be made up by after-firing at an efficiency of 95 per cent in a gas turbine scheme, or about 80 per cent with a direct-fired boiler.

The total fuel cost for power generation and steam raising can now be calculated and if maintenance is included, then the total running costs will be known. By comparing these costs with those of purchasing power from the public supply system and steam raising by direct-fired boilers, a value of annual savings is obtained that can then be related to the net capital cost of the scheme, to provide an indication of payback. If in this simple study a payback period of, say, less than eight years is obtained, then the scheme is usually of sufficient interest to warrant examination in greater detail. This pre-supposes that the high initial capital investment required is not a deterrent.

Detailed Feasibility Study

On an existing site, hourly steam and electrical demands as well as annual fuel and power costs are often available and then the assessment of loads can be made reasonably accurate, allowing for any future expansion. In the case of new premises, however, these hourly load profiles can only be good estimates and are an obvious weakness in the study.

One other prominent factor that should be considered is that the use of air-conditioning is becoming more prevalent; this allows a certain amount of manipulation of the overall site heat to power ratio, since both steam and shaft horse-power can be used to drive the chillers.

A complete study can then be made after deciding—

a) the type of prime mover, whether turbine, engine or a combination;

b) the size and number of prime movers:

c) the type and size of boilers; and

d) the fuel.

Selection of Steam Turbines

The factors that affect the choice of a steam turbine include the following:

Capability required at time of installation; System growth rate; Steam conditions; Efficiency; Turbine configuration; and any special requirements for a particular application. The overriding factor in all the cases is economics.

The size of the turbine to be selected depends mostly on the needs, for a certain amount of power. However, two other factors that should be considered are:

a) that efficiency increases with size.

b) In going from one size to a larger size the incremental cost per kilowatt is much less than the average cost per kilowatt.

Selection of Gas Turbines

Some of the advantages of gas turbines are:

(1) Ease of installing packaged power plants in various locations.

(2) Adaptability to remote control and unattended operation.

(3) Low first cost.

(4) Small time lag between purchase on equipment and all line operation.

(5) Reduced transmission costs by being located at or near the load centre.

(6) Matches equipment to present-day load growth and provides for delay of larger capacity base loads. This reduces capital cost during the delay period.

To evaluate a gas turbine plant, the following points should be considered:

(1) How much water is available ? If necessary, gas turbine plants can be installed that require no water. The modular units use about 42% as much water as a comparable size steam plant.

(2) What is the equipment to be used for ? Specify intent. This permits the supplier to quote standardised equipment at a more economical cost.

(3) How much power is needed ? If possible, specify range of power requirments rather than a fixed amount. This permits a wider selection of standard plant.

(4) What type of control is required ? Should it be manual, station attended or unattended ?

(5) How will the use factor vary ? Will it be high at the beginning, or will it increase as the load grows ? This will determine the relative importance of initial cost and operating costs.

(6) What fuels are available ?

(7) What performance can be expected ?

(8) How is the gas turbine to be started ? Specify the most desirable method.

(9) What will maintenance cost ? If cost is questionable discuss a maintenance contract with supplier to guarantee maximum cost.

(10) When the plant should be in operation ? Specify the date.

(11) Is heat rate or power output more important ? If evaluation numbers for heat rate and power output are known, they should be stated. Gas turbine plants should be evaluated on a station cost per kilowatt basis—giving credit for reliability, performance and maximum capability.

The choice of prime mover type can be determined by the fluctuation of the heat to power ratio, although engines often prove competitive irrespective of this ratio, and consequently, should always be considered in any feasibility study. When assessing the size and number of prime movers, several factors have to be borne in mind:

(1) Maximum efficiency is usually achieved at near-full load. Consequently, in order to achieve a high efficiency, but at the same time allow sufficient capacity to absorb any sudden electrical demand, an operating condition of approximately 80 per cent full load is desirable.

(2) It is necessary to have standby equipment in case of failure or maintenance of one generator set. With gas turbines, only one extra is required, but in the case of engines, with their increased maintenance downtime, two may be necessary. Therefore, the sizing of equipment is adjusted to allow a practical amount of standby.

(3) The sizing of prime movers can also depend on the minimum electrical load, since it is neither economic nor practical to run at low percentage loads.

(4) The larger the unit size of prime mover, the cheaper it becomes in £/Kw, and at the same time it improves efficiency.

It must be rememberd that when generating electricity on site, it produces sufficient electrical power at any one time to satisfy the instantaneous demand and, consequently, the quantity of waste heat recovered at any one time varies. If this quantity should fall below the steam demand at that time, then supplementary heat must be added. In a gas turbine scheme, this would be by after-firing of the waste-heat boiler, and in an engine installation by an increase in fuel input to the direct-fired boilers. When, on the other hand, full use cannot be made of the exhaust heat available, the overall thermal efficiency of the installation is reduced.

Waste-heat boilers are usually coupled to individual prime movers, although, sometimes, coupling to a pair of gas turbines, for example, may prove more practical and economical.

There are several more factors to be considered at this stage that affect the costs and operation of the installation, namely:

— Choice of voltage;

— Choice of manual or automatic operation of the whole, or part, of the installation for stopping and starting of generator sets, synchronisation and load sharing;

— Allowable frequency variation of the site's electrical requirements;

When all the alternatives have been considered, accurate costs and prices should be obtained from each of the suppliers of equipment and fuel. This should, of course, include, contact with the local Electricity Board to obtain the best tariff or to negotiate for the best price of purchased power. Detailed hourly running costs can then be calculated, including rates, insurance, lubricating oil, fuel, maintenance and supervision costs. As in a simple assessment, the profit per annum of the total energy scheme over the annual running cost of direct-fired boilers and purchased electricity has to repay the capital outlay of the scheme. The two factors of annual profit achieved and capital outlay will enable the economic benefit in terms of payback or rate of return to be calculated and presented in the form required by the customer.

The period of payback and amortisation of equipment is very significant and critical in assessing the viability of an installation. The potential purchaser may require a simple payback on the capital in, say five years, whereas, the installation could well operate for, say, twenty years. The implication of a short payback period is that to pay off all the net capital costs in this period requires very low operating costs compared with the alternative scheme of purchasing power directly from the public supply system and producing heat by traditional direct-fired methods. The net capital costs referred to are, of course, the gross costs of the scheme less the total capital costs associated with the alternative scheme.

It is most important that this area of cost-benefit analysis is cleared of any doubts early in the study. Possible lines of approach include :

—Agreement to pay back only a defined proportion of the capital cost in a specified short period;

—Agreement on rate of return either before or after tax on the capital over the period of the proposed fixed-price fuel supply contract ;

—Agreement on a two-price fuel supply contract, one a low price for the capital payback period, the other a higher price for all subsequent years;

—Financing of the installation by a third party or the plant manufacturer on some form of leasing arrangement.

Whatever method is adopted, it must be relevant to the particular study acceptable to all parties concerned and discussed and cleared at an early date.

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Energy and Power Planning Vis-a-Vis Development Process

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The subject of Energy and Power Planning in the context of development process chosen by the National Academy, has a great bearing on the planning process, and has of late assumed tremendous importance in view of the energy crisis prevailing all over the world. Since development itself is a dynamic concept, it is essential to understand what 'development process' is; and in this context an area like Energy and Power Planning, is analysed in subsequent paragraphs.

What is Development ?

The connotation of development is rather flexible. It changes with individuals, as a concept of value-judgement does. For ages the 'status of socio-economic condition' has been recognized as the most commonplace definition of the 'state of development'. With the advent of industrial revolution, a new factor 'technology', has added the third dimension to the concept of development. In the last few centuries, the latter has stolen the march over others, by ushering in more and more sophistication in the development process along with all the consequent complexities in economic activities.

The gross national product of the community, is a direct measure of its prosperity in material terms. The principal production sectors, for providing necessary goods for human consumption and trade, are agriculture and industry, in that order. The essential infrastructures of transport, energy and power are not an end by themselves, but they provide essential services to the principal production sectors as an end-use. Functionally, energy and power have three roles to play : one as a factor of production, the other as a process feedstock and the third as a consumer item. Hence, energy and power are not only components of production cycle, but also elements fundamental to welfare, thereby helping the development process.

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Demand Analysis

In a *laissez faire* economy like that of the highly-industrialised West, the demand pattern of energy and power has stabilised to a great extent, so much so, that it can be predicted with the help of a 'regression equation', depicting more or less a mirror-image of the immediate past projected into the future. But in the case of planned economies, particularly of the developing countries, this method of projection may be misleading and contrary to the concept of planning inasmuch as the fundamental objective set for development process is to 'break away from the past'. In a development process, structural change in the economy is brought about purposely in favour of highly-sophisticated production system, with ever-increasing technological inputs, be they principal production sectors of agriculture and industry or infrastructure such as transport, energy and power.

In the evolution of centralized planning process, a methodology has been developed on the basis of input/output relationships amongst a number of sectors, to determine the impact of growth in one sector on another in precise quantitative terms. Therefore, on a selected growth model with an-inbuilt structural change, the inter-play of different sectors can be more or less predetermined. Through a limited application of a similar methodology, certain 'commodity balances' or 'material balances,' as they are called, may be drawn up to forecast demand for vital inputs to the economy, such as power, coal, oil, steel, aluminium, etc. Material balances take into account targeted capacities of consuming sectors of say, electricity and basing on the observed norms of consumption of electrical energy in Kwhr. per tonne of goods production (say steel, aluminium, fertilisers and so on), demand for electrical energy and power at different points of time during planned development can be forecast.

As a check on the micro analysis of demand, a macro economic approach would be to associate demand for 'total energy' (including electricity, coal, oil, non-commercial fuels, etc.) with the growth of GNP, and commerical energy (electricity, coal, oil, etc.) with growth in targeted industrial output, respectively with which they are found to have a high degree of correlation. The demand picture for the country as a whole will obviously have to be split up into regional demands, for the facility of planning for supply arrangements and selection of generation/production centres and transmission/transportation/distribution to consumption centres.

Energy and Power Resources

An assessment of indigenous energy resources of various kinds and forms, and their spatial distribution, for building up a shelf of viable projects, is a part of the planning process. In India, we have fairly large resources of coal, hydro-electricity, and, of late, proved atomic minerals, for sustaining a rapid development of energy and power for considerable period ahead. However, our indigenous resources of oil, proved so far, are meagre. This makes our planning very much sensitive to fluctuations, in price and availability of petroleum and its products in the international market, and our energy economy vulnerable to the hazards of price hikes and supply bottlenecks imposed by international cartles and oil producing and exporting countries (OPEC).

The total quantum of solid fuel (coal) in the country as estimated today is of the order of 100,000 million tonnes and the current production is about 80 million tonnes per annum. So we can be rest assured of a plentiful supply of solid fuel in the country for a long time to come, although inter-regional transportation within the country has its own problems, since most of the coal deposits are located in the North-Eastern part. Unfortunately, only limited reserves of petroleum crude of the order of 130 million tonnes have so far been located in the extreme north-east, Assam and in the west in Gujarat. Explorations are going on in the off-shore areas in the continental shelves popularly known as 'Bombay High'. The current indigenous production of crude oil is about 7 million tonnes per annum which is barely 1/3rd of the current requirement. Obviously, the rest of the requirement has to be met through imports, which has its implications by way of heavy foreign exchange drain on our development process.

India's reasonably-assured nuclear resources are of the order of 33,000 short tons of uranium and 378,000 short tons of thorium oxide in the monazite occuring in beach sands of the Indian sea board. India is well placed, as far as nuclear fuels are concerned, to sustain an atomic power programme at least of the current and of the next decade.

The hydro-electric potential of India is fairly evenly distributed all over the country, although the major concentrations are to be found in the Himalayan heights of the north, Vindhya ranges in the middle and the Western ghats in the peninsular south. Gross theoretical capability at 60 percent load factor is estimated to be of the order of 41 million kw for the country as a whole. North-eastern region of Assam area has the largest concentration of 12 million kw and the northern region comes next with 11 million kw, the western and southern regions hold 7-8 million kw each, which leaves only about 3 million kw in the eastern region. However, only about 8-9 million kw have been developed by the end of the Fourth Plan.

With the present-day technological imperative of putting the atomic power plants to take up the bottom of the base-load at a load factor of 85 to 90 percent and super-thermal stations run on coal to take the top of the base-load of 60 to 70 percent load factor, hydro power is considered best suited for meeting the peak demand of about 30 percent load factor or so, or at the most, the intermediate position in the load curve with the load factor of about 40 to 50 percent, depending upon the characteristics of the hydel installation, whether a full storage, partial storage or run-of-the-river scheme. Therefore, for meeting peak demand, and to an extent taking intermediate position in the load curves in different regions, the potential capability of hydro resources in the country may better be reckoned at anything between 75 to 80 million kw. i. e., about double of 41 million kw at 60 percent load factor indicated so far.

Energy and Power in the Fifth Plan

The overall requirement of coal by the end of the Fifth Plan is estimated at 135 million tonnes per annum, to meet the requirement of major sectors like power generation, steel plants, railways and other users. The magnitude of expansion in the production of coal, from 79 million tonnes in 1973-74 to 135 million tonnes in 1978-79, will put severe strain on managerial and technological capabilities of the organisations engaged in coal production. In planning additional production of coal, appropriate linkage between the power stations and the coal mines, as well as the development of necessary rail capacity for the movement of coal have been ensured. This kind of synchronisation will require close monitoring, and coordination between railway programme and construction of power stations. The overall provision in the Fifth Plan for the programmes of coal production and related facilities is Rs. 737 crores, as compared to Rs. 110 crores in the Fourth Plan.

The consumption of petroleum products has risen at a fairly rapid rate of 9.4 percent per annum during 1960-61 to 1970-71, and the demand for oil products is estimated to rise to over 36 million tonnes by 1978-79. In order to curb the consumption of oil, the more important steps taken are—the conversion of power stations using oil as primary fuel to coal, reduction of fuel oil as supplementary fuel in power stations, replacement of fuel oil by coal in industries, expansion of rural electrification and rapid switchover to electric traction on the railways. Fiscal measures are also proposed to be taken for curbing non-essential consumption of pertoleum products. Twenty-six Working Groups set up for these purpose by the Planning Commission are going into the details of all these. The refinery capacity target is tentatively placed at 39 million tonnes for 1978-79. On the exploration side, apart from the-on-shore activities, off-shore drilling is being vigorously pursued at Bombay High. The total indigenous production of petroleum crude is expected to reach the target of 12 million tonnes per annum by 1978-79.

In the power sector, an installed generating capacity of about 19 million kw has been commissioned by the end of the Fourth Plan, with an investment of about Rs. 3,000 crores during the Fourth Plan period. On the basis of electricity balance as explained earlier, the estimated requirements of generation in 1978-79 is of the order of 130,000 million kwh. For producing it, the net commissioned capacity is to be raised to 33 million kw by 1978-79. Allowing for derating of old machines and those under erection, a gross capacity of 35.5 million kw is however, targeted, which will require an addition of 16.55 million kw of new capacity during the Fifth Plan. Corresponding programmes have been envisaged for transmisson, distribution and rural electrification for the evacuation and ultimate consumption of electrical energy far and wide. A total financial provision of Rs. 6,190 crores has been made in the Fifth Plan at its draft stage, but all indications are that this investment has to be enhanced substantially in the final stage of the Plan.

Detailed exercises made so far indicate that in the four major power regions, an initial formation of regional grid will start functioning, with the coordinated operation of an installed capacity of the order of 8 to 9 million kw in each region by the end of the Fifth Plan. Only the north-eastern region of Assam, although developing fast, will trail behind with an installed capacity of about half a million kw. Adequate production capacities have been developed in the public sector heavy electrical manufacturing units for supplying plant and equipment for thermal, hydro and nuclear power projects during the Fifth Plan. Import of plant and equipment will be minimal and practically negligible. This is an achievement of planned development leading to self-sufficieny in power generation and transmission/distribution capability.

Energy and Power Crisis

Fifth Plan commenced with serious constraints looming large in the energy and power sector which has to pass through many vicissitudes throughout the Plan period. More than ever, it has become evident that there is a need for coordinated action for developing energy resources, managing the imports and, above all, the substitution of oil by coal, and integrated operation of regional grids for power supply to every nook and corner of the country which may not be postponed any further. For this purpose, a proposal to set up a high-level Energy Board, for pursuing sustained action to meet squarely the energy and power needs of the economy, is under consideration. Energy Board is conceived as an authority with overseeing powers trying to forsee and deal in advance with problems of energy and power supply/demand, particularly, with the object of anticipating and circumventing any crisis as is faced by the country today. The severity of the problem is the collective concern of the government and the Planning Commission. The components of the picture by executive actions are clearly the responsibility of the individual ministries and the Board has to draw on their knowledge and take the fullest account of their plans and thinking. The task of building up a complete and consistent picture and pursuing its translation into action is one involving centralized consideration of all the various elements by the Energy Board.

Even before the formation of Energy Board, Planning Commission has set up a series of Working Groups to go into the question of alternative sources of energy, with the specific objective of substituting petroleum products, which are derived mostly from imported crude oil, by indigenous energy resources, mainly coal and its derivatives like coal gas, etc. For an accelerated development of power capacity, as envisaged in the Fifth Plan, it will require an effective organisation entrusted with full responsibility for planning, development, (including financing), controlling and regulating electricity supply to industry on regional basis to cover the entire country. For this purpose, five regional electricity authorities have been conceived which will coordinate the developement activities within their respective regions in close collaboration with the State Electricity Boards falling within their jurisdiction. The regional authorities are likewise envisaged to function under the overall management of an apex body of Central Electricity Authority. The Central Electricity Authority has been in existence for some time, but it requires to be reinforced with statutory powers for acquiring an executive role under the proposed high-level Energy Board.

Conclusion

In the context of the development process through centralised planning, stretching over nearly a quarter of a century to date, the implications of energy and power for an economy characterized by rapid structural changes, have been ever growing which is borne out by the observation that in India the input of energy and power for the output of one unit of GNP has been more than one throughout (about $1\frac{1}{2}$). There is yet no sign of its abatement as is apparent from the appreciable shortage for a considerable period in the supply of the power, petroleum and coal, though the growth rates in cases of the first two have been sustained at 12.5 and 9.5 percent per annum with heavy investments disproportionate to that in other sectors. Only coal has lagged behind with growth rate at only 2 to 3 percent per annum for obvious substitution by oil. The present policy is to minimise the use of oil and substitute it with coal wherever possible in view of the energy crisis.

Energy and power planning in the development process demonstrates the need for a holistic approach to large-scale problem solving at the national plane in the international backdrop of fast moving scene. It shows that it is not enough to put in the investment of funds in a ready-built enterprise without the appplication of technological innovation, the tools of techno-economic analysis and without the depth of social perspective reflected in the mirror of ever-widening technological horizon.

Energy System Economics

J. N. Karan*

The progress of human civilization is directly linked with adequate supply of energy. The economic growth of a country depends upon how efficiently its natural resources are converted to usable commodities by utilization of energy. Today a country is considered rich by the technical ability it has acquired and the scientific progress it has made and not by the extent of natural resources it possesses as in the past. A glaring example of this is Japan, which is deficient in natural resources. The growth of population also effects the economic progress of the country. In India, whatever economic growth has been achieved by industrial progress, has not made much impact on the standard of living of people due to the growth of population. It has been found that the standard of living goes down with the square of the population.

Generally, per capita consumption of the energy in a country is considered as the barometer of its economic progress. In the USA, the annual energy consumption per head is 11 tons of coal equivalent, whereas in India it is 1/3rd of a ton of coal equivalent per annum. If the consumption of electrical energy is considered, which is directy linked with industrial production, the per capita consumption in India is approximately, 100 kwh as against the average for the world at 1000 kwh and that of USA at 7000 kwh. It is to be appreciated that a rupee worth of electrical power generates goods of the value of Rs. 100 in a developing country. The USA with 6 percent of the world population consumes approximately 30 percent of the total energy output of the world.

Sources of Energy

The sources of energy may be considered in 3 groups : commercial, non-commercial and new sources. Coal, oil and electricity are regarded as commercial sources of energy. The total energy production in the

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world in 1971 from commercial fuels was 7261 million tonnes of coal equivalent, as under:

	million metric tonnes of coal equivalent
Coal and Lignite	2396
Crude petroleum	3171
Netural Gas	1527
Hydro etc	167
Total	7261

The non-commercial sources of energy are vegetable waste products, fire-wood and cowdung, major quantities of which are consumed in rural areas. Exact assessment of non-commercial energy is quite difficult due to their own peculiarities. In India, non-commercial fuels constitute approximately 50 percent of total energy consumption at present. For the last two decades, cheap and readily available oil from Middle East has influenced energy policy in many countries.

Towards the end of 1973, oil supplies were restricted. Along with this, the reliability of supply of oil from Middle East has gone down and nobody knows how oil price will move. The need for energy in developing countries is always increasing and, to meet the same, there is no alternative but to utilize most of the available resources. Under these circumstances, all countries have started looking inwards, to develop substantial indigenous resources of energy. Besides increasing supply from indigenous sources, a lot has to be done in the use of energy itself, i. e. methods will have to be developed for an efficient use of energy. The most efficient use of all resources require a proper balance among the various resources.

Before any source of energy is utilised, it is essential to know the economics of each system and find out whether it is justified. But that is not all, because an economic justification is not the only answer. A lot more depends upon other factors, such as availability of that source of energy. For instance, use of coal is cheaper than others, but a lot more depends on production of good quality coal. Therefore, a balance has to be struck in order to arrive at correct energy system.

Commercial Fuels

Coal : The coal reserves in the world are estimated at 6600 billion tonnes of which USSR has 4100, USA 1100 and China 100 billion tonnes. Of the balance, South Africa has 72, Poland 46, India 83 and UK 16 billion tonnes. Against this, the pattern of mining of coal, in 1971, was as follows :

(in million metric tonnes)

USSR	441	Poland	145
USA	503	Germany	111
China	390	India	70
UK	147	Japan	33

From the above, it is evident that, except USSR, China and USA, the period of availability of coal in all other countries will reduce very greatly.I ndia has a total gross reserves of 82,975 million tonnes of coal of various grades as follows :

		(in million tonnes)
(1)	Coking coal	5650
	Medium coking coal	9431
	Semi to weakly coking coal	5073
		20154
(b)	Non-coking coal	59968
	Tertiary	828
(c)	Lignite	2025
	Total	82975

In India, during 1974-75, the production of coal reached 88 million tonnes and by 75-76 it may reach a figure of 100 million tonnes. With increasing utilization, India may reach a level of 300-500 million tonnes per annum at the end of this century. Considering the losses in mining and washing, which are unavoidable, the net available resources of prime coking coal are estimated at only 1600 million tonnes and this may last for a period of about 40 years only. Medium coking coal may last for a few more years. Since coal is essential for metallurgical purposes, conservation efforts are necessary for prime coking coal in particular, and coking coal n general.

Regarding non-coking coal, according to a rough estimation, the quantity which would be available for exploitation would last for about 100 to 150 years. Thus, the coal deposits in India may not last long. Nevertheless, it is the best and readily-available fuel in India.

It has been forecast that coal consumption will increase from 88 million tonnes in 1974-75 to 365 million tonnes in 1990-91 and the percentage of consumption, sector-wise is as follows :

Sector	1970-71	1978-79	1983-84	1990-91
1. Mining and manufacturing	48.3	44.2	43.1	44.4
2. Transport	22.9	9.4	5.4	2.9
3. Domestic	6.2	7.3	11.3	9.7
4. Energy Sector (Power generation)	22.1	38.4	39.2	42.1
5. Other	0.5	0.7	1.0	0.9
Total	100·0	100·0	100·0	100·0

The share of total coal used in the mining and manufacturing sector will continue to be around 45 percent throughout the next two decades. The share of energy sector will rise very rapidly in the next five years and at a slower rate from there on. The share of transport sector will decline very rapidly.

Power sector will be the most important coal-using sector in the economy in the coming years. A 1000 mw capacity power station may require 3 million tonnes of coal per year, i. e., in other words, the power station will have to receive nearly 10,000 tonnes of coal per day, involving 200 wagons and use of 8/10 locomotives. A locomotive having 5 percent efficiency has coal consumption, on an average, of 1800 tonnes per annum. The coal available for power generation has 30 to 40 percent ash and this affects the economy of the nation as a whole. Several studies have been carried out regarding relative economies of power generation at load centres *vis-a-vis* at pit heads. These investigations show that for a 1000 MW plant even when it is assumed that improvement in railway transport would be brought about, the generation at pit heads and transmission of power to load centres has been found to be more economical than transportation of coal to power stations at load centres (see Annexures I, II and III). Hence, proposals are being mooted for establishment of super thermal power stations at pit heads having capacity 1000 mw and above.

In the present system of power generation with boiler, turbine and generator, considerable economy will be achieved by adopting larger units (see Annexure I). The following table shows the installation cost, operating cost and fuel requirement in thermal plants of different sizes, (values based on 1974 data and relative cost may remain same) :

	200 mw	500 mw
Cost per mw installed	Rs. 3000.00	Rs. 2600.00
Operation and maintenance cost per mw installed	Rs. 120.00	Rs. 120.00
Coal requirement per kwh of energy generated (Kg) (Calorific value of coal 3500 Kcal/Kg).	0.67	0.64

With the increase in unit size, the capital cost as well as operating cost goes down due to more efficent utilisation. If two 500 mw units instead of five 200 mw units are installed for a 1000 mw power station, an amount of Rs. 60 lakhs would be saved per annum on account of fuel only. Further, the staff requirement per mw for the power station will also go down For reliable operation of a 500 mw unit, the unit capacity should be not more than 10 percent of the grid system and hence, 500 mw should be introduced only after the regional grids are in full operation by proper integration of power generation systems of various states in each region and this may be possible in the Eightees. For efficient utilisation of coal in other sectors, quality-wise distribution of coal is the only solution consistent witn the requirement of customer and the availability of coal in various fields. On broad calculations, cement units, railways and about 50 percent of industries will have to be supplied with superior grade of coal, whereas in the rest of industries including power houses, domestic sector and others, inferior grade of coal can be used.

After nationalisation of coal mines, it should be easy to control supply of correct grade of coal to a consumer whom it should serve best. The fixation of a rational price of each grade of coal has an important role to play in making quality-wise distribution effective.

One area where coal is used very inefficiently is railway locomotives, and it has been planned to reduce their numbers gradually and replacing them with electric locomotives.

(c) When new industries will be issued licences, use of fuel oil should be prohibited and enough coal supply to industries will have to be ensured.

(d) Electrification of railways to be expedited so that the use of diesel locos does not increase.

(e) Transport by railways will have to be efficient so that dependence on road transport is reduced and thereby the requirement of High Speed Diesel Oil (HSDO) gets reduced.

Natural Gas

The reserves in the world are estimated at 50,000 billion cu. metres. Of the total gas utilised in 1971, namely 1142 billion cu. metres, the major users were :

(In billion cu, metres)

USA	637	Italy	13
USSR	212	Iran	16
Canada	71	Kuwait	4
Rumania	27	France	7
Germany	15		

In India, 0.6 billion cu. metres of gas is produced, of which 55 percent is used, with the rest going waste. It is expected that with exploratory drilling being carried out at present we strike adequate quantities of oil and gas.

Hydro Power

The total estimated potential in the world is 1500 million kw and in India, it is 41 million kw. So far India has hardly utilised 15 percent of total hydro resources. Hydro power is replenishable and very reliable in comparison with thermal power if rainfall is good. The list on page 183 gives some of the countries where hydro-power has been developed (as of 1971).

A comparative evaluation of the choice between hydel and thermal stations in India, indicates that hydel stations are more economical than any

(in million kw)

World Total	350		
Norway	13	USSR	33
Sweden	11	Canada	30
Switzerland	10	Japan	20
USA	57	Italy	15

other source of electricity at low load factors (Annexure I). Supplying the peak load requires the generating stations to operate at low load factors of even 30 percent and below and under such circumstances hydel power is the best way of meeting the demand. Hydro sources constitute the cheapest source of electricity generation. With the aim to create the maximum generating capacity with the available funds and to generate power at as cheap a rate as possible, construction of many more hydro stations are being planned to be completed during the Fifth Plan. Further, harnessing of hydro resources needs to be given priority so that 70 to 80 percent total known hydel potential in the country are developed by 1990-91.

Nuclear Energy

Other fuels being in short supply, the future generation will have to depend heavily on the Nuclear Power. In 1971, 104 billion kwh. out of 5222 billion kwh. of the electricity generated was from nuclear fuels. The main countries producing this power are :

(*in billion KW*)

USA	38	Germany	6
Canada	4	Italy	3.4
Japan	8	UK	27
India	2.4	USSR	13.5
France	8.7		

The total of the known resources in the world as reported is only 0.76 million tons of U_3O_8. Of this, Canada has 0.21, South Africa 0.18, USA 0.23, France 0.04, Australia and India each 0.02. The fuel being extracted every year is 22,000 tons of which 50 percent is produced in USA, 20 percent in Canada, 17 percent in South Africa and the rest in other countries.

Uranium extracting in India is costly in comparison with world market

But the coal industry itself faces certain problems, which need immediate attention. They are :

(a) Problems relating to increasing productivity in the coal mines.

(b) Developing the transport capacity for coal movement.

(c) Beneficiation of coal to gas.

(d) Equipment supplies for coal production.

It is expected that with adoption of mechanization in coal mined, the productivity will increase and cost of coal mined will decrease.

Transport problems will be solved to a great extent by hydraulic transport of slurry converted from coal. A lot of spade work in this regard is yet to be done.

Gasification of coal and its supply by pipe-line to consumers will result in lesser dependence on railways, reduced cost of coal movement, a substitute for kerosene whose use involves heavy foreign exchange expenditure, and mitigating the problem of pollution.

Gasification of coal can be achieved by several methods. At present it may not be possible to manufacture gas at pit heads and transport through big pipes to various industries or for domestic uses far away from cities due to heavy initial investments involved. However, in big cities like Calcutta and Bombay, installation of these plants of smaller size may be possible. R & D activities are now being carried out in coal gasification technology with a view to reducing the cost of gasification. Coal gasification is also of quite significance since in production of fertiliser, gas produced from coal serves as feed stock.

To meet the needs of the equipment, it seems essential to increase the indigenous capacity for manufacture of various earth-moving and mining equipment.

Oil : The crude petroleum reserves in the world are estimated at 76 billion tonnes but, they are mainly located in a few countries as indicated below :

(in billion tonnes)

Saudi Arabia	18.8	Nigeria	1.4
Kuwait	10.4	USSR	8.2
Iran	8.3	USA	5.4
Iraq	4.4	Indonesia	1.5
UAR	2 2	India	0.2
Venezuela	2.0		

The oil production in the world was about 2400 million tonnes in 1971 with the following break-up with major producers :

(in million metric tonncs)

USA	470	Egypt	15
Iran	224	India	7
Libya	132	Columbia	11
Iraq	84	Maxico	21
Canada	64	Venezuela	186
Nigeria	76	Kuwait	147
Algeria	38	Saudi Arabia	223
Argentina	22	Japan	less than one

At the present rate of oil production, the total oil availability in the world will be hardly sufficient for another 30 to 40 years. USA cousumes nearly 600 million tonnes of oil a year against about 20 miliion tonnes by India. India produces 1/3rd of its requirements and the balance has to be imported.

The Government of India has taken step to curb the consumption of petroleum products, following the rise in their prices in the world market. A combination of increased price and consumption curbs had resulted in the offtake of petrol during 1974-75 falling by 22 percent, kerosene by 17 percent, furnace oil by 6.5 percent, light diesel oil by 16 percent and bitumen by 23 percent. There was increased consumption of other products, such as high speed diesel, but on balance total consumption of products fell by 3 percent. Efforts are being made to increase the share of indigenous crude production from the current 33 percent to 45 percent in next two to three years.

Some of the major areas where oil consumption could be restricted are as follows :

(a) The design of thermal power stations should be such that the technological requirement of oil will be minimum.

(b) New fertilizer projects should be designed to use coal as feed stock.

because of its low concentration in the ore, but this is of no serious consequence as the cost of uranium is quite insignificant in the total cost of nuclear power generation.

At present nuclear power sets of 2×200 mw capacity are in operation at Tarapore, and 1X200 mw set at Kota and 2×200 mw sets at Kalpakkam are expected to be commissioned during the current five-year plan and 2X220 mw sets have been planned to be installed at Narora in Uttar Pradesh in the sixth plan period. These power stations would need a loading of 4 Kg of uranium per kw installed for 30 years of operation. The presently proved and inferred uranium sources in India would support only about 10,000 mw of installed nuclear capacity. The byproducts of these reactors will be plutonium which would be used in fast breeder reactors which are expected to come into operation during 1985-90. Altogether they would create an installed capacity of 600,000 to 11000,000 mw of installed capacity for a life span of 30 years.

We have also thorium reserves amounting to 4,50,000 tonnes and these would be used in fast breeder reactors. Thus there will be no limit to nuclear power generation in India.

Non-Commercial Fuels

Non-commercial fuels such as wood, vegetable wastes and cowdung are used for cooking and lighting in India which is a wasteful method. Cowdung is also used as fertiliser and its use should be restricted for that purpose only, after extracting gases and chemicals not required for the fertilizer. Another important non-commercial fuel is wood which is being consumed at the rate of 130 million tons per year. This has resulted in deforestation which in turn upsets the ecological balance and effects the climate adversely. Since kerosene will not be available abundantly, India should develop new types of plants for use as firewood in villages.

Non-Conventional Energy Sources

With a gloomy picture for availability of commercial fuels in future, mankind has turned its attention towards non-conventional energy sources such as solar energy, geo-thermal energy, tidal power, wind power and chemical sources. The R&D work being done at present in exploitation of all these energy sources, appears to be quite promising. However, the results may not be available for commercial use during the next two decades.

A lot of R&D activities are being carried out in the country regarding utilisation of solar energy. The popular applications of solar energy are solar evaporation in the salt industry, water heating, desalination of water through distillation, solar drying, solar cells. Other fields where solar energy can be applied are refrigeration, air-conditioning, water pumping, cooking, etc. Work in various applications of solar energy is in progress in Central Building Research Institute, Roorkee, Central Salt & Marine Chemicals Research Institute, Bhavnagar, Defence Laboratory, Jodhpur, Auroville School of Environmental Studies at Pondicherry etc.

Exploitation of geo-thermal energy has not made much headway. The largest station in operation at present is Larderello in Italy where about 350 mw of power is installed. To get this power, nearly 150 wells had to be taken down to 3000 metres depth. It appears to be a cheap method of producing power. India is endowed with sources of geo-thermal energy in the form of hot springs. Experience from Puga multi-purpose project under UNDP programme indicates that the total power potential in geo-thermal energy may be several magawatts. Hot springs have been found in Ladakh, Himachal Pradesh, Punjab, U. P., Narmada Sone Valley, Damodar Valley and West Coast.

The power produced by the winds is very limited. In Holland wind power was used to pump out drainage water, since country is below sea level. For installation of wind mills, wind speeds of 10 Kmph are required and this is feasible in Rajasthan, Gujarat, Maharashtra and Mysore in India. Whilst suitable wind mill designs have been developed by NAL, they have not been popularised because extensive field trials to demonstrate their technical and economical viability when put to specific application, have not been conducted.

The tidal power technique is also in an infant stage. The experience gained in its exploitation at La Rance in France has not yet been very helpful. In India, tidal power techniques can be tried at Bhavnagar in the West Coast where the tidal range is of the order of twelve metres, and in the Hooghly in the East Coast where the tidal range is about six metres. But in both places the sites do not appear to be suitable and the cost will be quite high for producing power.

Energy Crisis

Except hydro, other commercial sources of energy are non-replenishable. Even if entire world hydro resources are harnessed, the energy requirements will be met with to the extent of less than 15 percent at the present time. As the demand for energy increases, the percentange contribution of hydro will further decrease.

Of the other commercial fuels, we cannot depend upon oil and with the present trend of consumption, it may be exhausted in less than half a century. Only by economising its use, we may prolong its availability. However, as coal is available in much larger quantity than other fuels, it may serve mankind for a longer period than oil and gas. Power from nuclear fuels has yet to be estabilised. Environmental considerations often weigh against location of nuclear power stations. But as the other fules are getting exhausted, man has no other alternative except to produce power from nuclear fuels. With the development of fast breeder reactors and fusion techniques, atomic energy age can start and this can be expected perhaps only from the second half of the next century.

India's Requirement of Energy

Looking at the various factors mentioned above, it is imperative for India to follow a policy for energy consumption which will assume growth of economic activity as well as efficient utilisation of available fuel. It has been estimated that the total energy required at the end of the century, would be 760 million tons of coal replacement that is doubling the present energy consumption. It has been estimated that one-fourth will be obtained from non-commercial fuels. The energy to be produced from commercial fuels is as shown in the Table on next pape

Achieving of the above target is a stupendous task and in addition to the measures for conservation of energy mentioned earlier for coal and

1. Coal.	400 million tons
2. Oil and Gas (30 million tons)	90 million tons
(Taking the equivalent as 3 tons of coal to 1 ton of oil on an average.	
3. (i) Hydro Power 25 million kw=100,000 million Kwh. (ii) Nuclear Power 25 million kw=25,000 million Kwh.	80 milion tons
Total =125,000 million Kwh.	570 million tons

oil, other steps should also be taken to improve thə energy economics in India.

In any power generation and distribution organisation, the economics are best improved only by the proper designing of the power system and by the integrated operation of the system as a whole. In rotgh countries, extra high voltage transmission is already in operation ane bulk transfer of power through DC transmission lines is also beind practised.

This integrated operation has the following advantages :

— Makes it possible to move the load at the lowest overall production cost.

— Availability of mutual assistance in cases of breakdown.

— Lower installed and spinning reserve capacity.

— Installation of large units which lead to low capital and operating costs.

— Possibility of exchange of power to mutual advantage in the peak period.

— Facilities for scheduling maintenance.

— Avoidance of spinning of water from hydel reservoir without financial return.

— Use of incremental load despatch technique which results in economy of operating costs.

In execution of integrated operation of the energy system, installation of a spare thermal or hydro set costing Rs. 3000 per mw capital cost is avoided by incurring capital cost of Rs.400-500 per mw in transmission and distribution.

In India action has already been initiated to operate zonal grids and, as a first step, in the southern zone a local despatch centre has been set up. Setting up of other regional grids and local despatch centres need to be vigorously pursued for improvement in the economy of power system.

At present, the average transmission loss of electrical energy in India is around 17 percent, whereas it is around 9 percent in some advanced countries. This high loss is due to a large number of agricultural low tension consumers. Rural electrification programme has been undertaken with a view to making available the benefits of electric power to the people living in rural areas, which constitute 70 percent of our population. This will also reduce the pressure of domestic sector on kerosene for lighting and diesel oil for pumping sets. Besides, availability of electricity in rural, areas will stimulate growth of production in agricultural sectors and also agro based small and medium scale industries. There are approximately 5-7 lakh villages in India and till date hardly 50 percent have been electrified. Though we have a wide area to cover for low tension consumers, there is a considerable scope for reducing transmission losses by proper planning of the low tension distribution system. There is yet another area where energy economics can be improved, i.e., by maintaining a reasonable inventory in utilities. Though vital spares should be stored for maintenance of generation equipment, there is hardly any justification for maintaining inventory for 8 to 10 months for distribution system. With the increase in indigenous availability of spares, the inventory level could be cut down substantially.

Another most important point which affects energy system economics is skilled manpower. With the installation of high capacity thermal sets, 1 percent loss in efficiency brings a loss of few lakhs of rupees annually. It is, therefore, necessary to train up a large number of engineers, supervisors and workmen in proper running and maintenance of large capacity thermal stations which would be beneficial to the nation at large.

The price structure of the energy also plays a significant part in the energy system economics. Though the price of energy should be as low as possible, the returns on investment in electricity should be adequate. A uniform system of pricing electrical energy will not be conducive for optimal utilisation of power system capability. The load factor should be high enough to bring down the cost of generation. Supplying electricity at peak period will involve a higher cost and hence the tariff structure should be so designed that there is discrimination between use of power during peak period and during off peak periods. This will, no doubt, result in substantial saving in the investment cost in the power sector.

R & D Activities

R & D activites have been initiated in many directions with a view to utilise the existing energy resources to the maximum. In this regard Messers Bharat Heavy Electricals Ltd., a public sector firm has many schemes on hand.

One of the schemes is Magnetic Hydro Dynamic process which is expected to offer thermal efficiency of 50 percent or higher as compared to 34 to 38 percent in a conventional thermal power station. In this process an electrically conducting gas is forced through a duct at a high speed in the presence of a transverse magnetic field. The electromotive force induced in the gas allow current to be extracted. This process requires a very high electron concentration in the gas which could be achieved only with very hot combustion gases (4000° — 5000° F) seeded with materials having low ionization potential like potassium or cesium. The problem areas identified are electrical conductivity of coal combustion gases, materials for high temperature working and corrosion environment, seed recovery and gas cleaning. R & D activities are still going on in USA, UK, Japan and USSR on this line. In USSR one plant of 25 mw capacity operating on natural gas is reported to be working satisfactorily. A study team of the National Committee on Science and Technology of India has recommended a ten-year programme in three phases :

(a) To conduct laboratory scale experiments at a level of 5 mw size.

(b) Design and manufacture of a prototype 25 mw MHD plant.

(c) To develop design for a full scale 500-1000 mw plant.

The & D activities are being carried out jointly by the National Committee on Science and Technology, Bhaba Atomic Research Centre and Bharat Heavy Electricals Ltd.

Another scheme of increasing fuel efficiency in power generation is combined gas turbine and steam turbine power generation system. This system has the potential of improved efficiency, lower installed cost and reduced atmosphere pollution when compared to a conventional steam power plant. Data reported from West Germany for a 800 mw plant show an improvement of efficiency from 39—43 percent, a reduction in capital cost of the order of 15 percent and reduction in atmospheric pollution of the order of 75 percent.

Another technology, called fluid bed technology is also a promising process. For increasing the efficiency of fuel utilization the process consists of combustion of coal at a temperature of 800°—900° C in a fluidised bed operating at an elevated pressure and in direct contact with the heat transfer tubes. The energy in the host compressed product of combustion is utilised for driving both gas and steam turbine. This process will also enable utilisation of low grade coal and may increase efficiency of fuel utilisation by 5 percent.

In the context of present situation of crude in India, it is also worthwhile to examine the economics of development of coal-oil conversion technology under Indian conditions. This may result in saving a lot of valuable foreign exchange.

As mentioned earlier, R&D work on non-conventional sources like solar and geothermal energy should be intensified so that commercial utilisation of these energies could be realised sometime in future.

Priorities in R&D Work

Looking at todays' energy position of India, it appears necessary to give priorities to the following R&D work :

1. Development of Fast Breeder Reactor;

2. Development of Boiler Designs to reduce oil consumption in thermal power generation plants;

3. Fluidised bed technology;

4. Development of SNG production and transport technologies if their economics are justifiable for Indian conditions.

5. Development of combined gas turbine and steam turbine cycle.

Conclusion

The energy requirement will go on increasing all round the globe. And in developing countries it will be at a faster rate to achieve a reasonable standard of living. Though population control through family planning is being advocated, it may not have much impact on the accelerated requirement of energy in the near future. The immediate energy crisis may be met with by utilising fossil fuels according to present practice, but there is no choice except to accelerate R&D Programmes for maximum utilization of existing fuels by MHD Process, gasification of coal, combined cycle system and to evolve a long-term solution such as nuclear fission power system with fast breeder reactors.

Annexure I

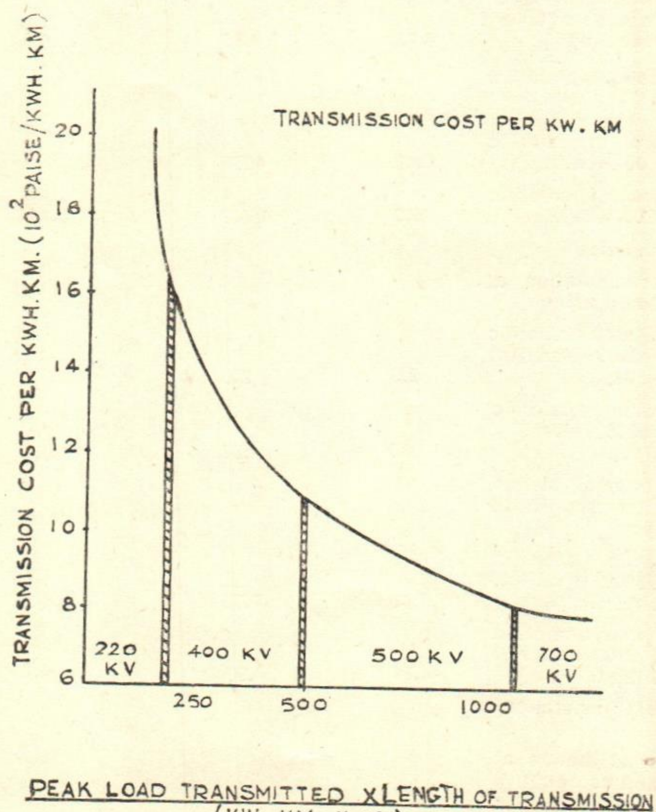
Table 1 : Cost of Power Generation per kwh

Item	*Thermal*	*(Coal Based)*	*Atomic*	*Hydro*
1. Capacity, mw	500	200	235	120-150
2. Capital cost Rs./kw	2600	3000	5000	3000
3. Annual charges				
(i) Interest (%)	9	9	9	9
(ii) Depreciation (%)	3	3	4.5	2.5
(iii) Maintenance (%)	4	4	2.5	2.5
Total (%)	16	16	16	14
Amount, Rs./kw	416	480	800	420
4. Cost/kwh (without fuel), paise with 6 weeks' outage & 90 percent availability*	6.03	6.95	11.6	6.08
5. Yearly Fuel consumption /kw in Kg.				
(i) With coal of calorific value 3500 Kcal/Kg.	4448	4631	–	–
(ii) With coal of calorific value 5900 Kcal/Kg.	2640	2747	—	—
6. Fuel cost/kwh, paise*				
(a) With thermal station at pit-head and using				
(i) Coal with calorific value 3500 Kcal/Kg. at Rs. 38/t.	2.5	2.6	1.0	—
(ii) Coal with calorific value, 5900 Kcal/Kg. at Rs. 47/t.	1.80	1.87	1.0	—
(b) With thermal station 1200 Kms. from pit-head and using :				
(i) Coal with calorific value, 3500 Kcal/Kg. at Rs. 115/t.	7.43	7.75	1.0	—
(ii) Coal with calorific value, 5900 Kcal/Kg. at Rs. 123/t.	4.71	4.90	1.0	—
7. Total cost of generation/ kwh*, paise :				
(a) With thermal station at pit-head and using :				
(i) Coal with calorific value, 3500 Kcal/Kg.	8.53	9.55	12.6	6.08

(ii) Coal with calorific value, 5900 Kcal/Kg.	7.83	8.82	12.6	6.08
(b) With thermal station 1200 Kms. from pit-head and using.				
(i) Coal with calorific value, 3500 Kcal/Kg.	13.46	14.7	12.6	6.08
(ii) Coal with calorific value, 5900 Kcal/Kg.	10.74	11.85	12.6	6.08

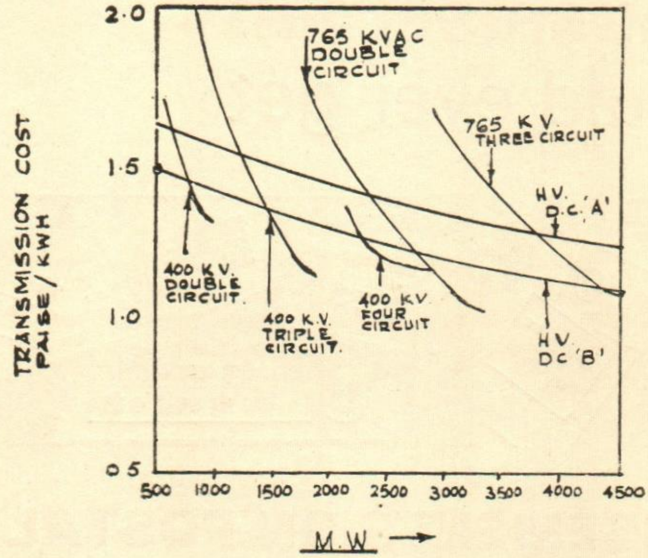
* Approximate power generation of 6900 kwh/ kw per year (with 6 week' outage & 90% availability).

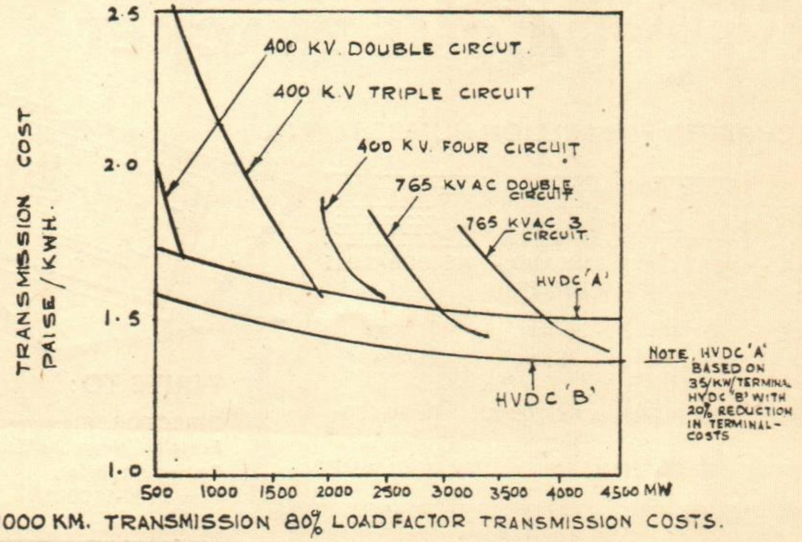
ANNEXURE II



ANNEXURE - III

800 KM. TRANSMISSION 80% LOAD FACTOR TRANSMISSION COSTS





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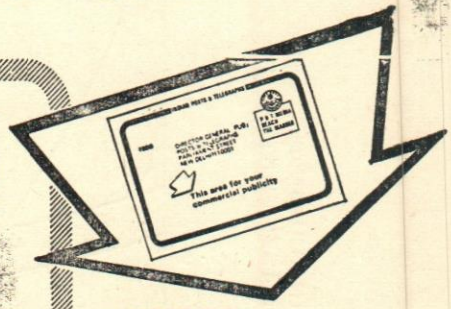

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Energy Substitution : A Macro Perspective

N. R. Srinivasan*

It sounds somewhat illogical, if one recognises the theory of multi-form existence of energy, that the energy shortage should come to be identified so exclusively in terms of the shortage of petroleum products which has come about as a result of the over-reliance, in recent decades, on the latter energy resource to the point of its eclipsing the potential of other forms of energy. The eclipse seems to be lifting, thanks to the fast dissipation of this even otherwise scarce energy resource and latterly its price which has trebled since the end of 1973 and which, incidentally, may never cease to be a subject of apprehensive speculation among the petroleum have-nots and have-less. Dearer petroleum is motivating serious national and regional action-programmes—short term, medium term and long term—aimed at efficiency of management of energy choices and their utilisation and development of alternative energy resources.

It is beyond debate that there are few countries which are in a position to afford to have their economic advance slackened or frozen on grounds of a sudden high-cost energy base. Each country has to evolve its charter of action for management of energy mobilisation and utilisation against the background of national priorities and possibilities, the flexible and the inflexible element of its pattern of energy demand, reorientation of process technology, operational techniques and design concepts of the energy-recipient or the energy-producer equipment, the resources of and accessibility to the less scarce forms of energy and the cost-benefit balance sheet of the programme. Switchover from scarce to less scarce energy resources, fully or partially, on a phased plan, has to be a key element of the charter of action. India is one of the countries which had acted fast in this direction, formulated short-term and long-term policies and created special centralised mechanisms with decentralised counterpart mechanisms. The Energy Conservation Division of the Directorate General of Technical Development in the Ministry of

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Industry and Civil Supplies coordinates with the Departments of Coal, Power and Petroleum, Industry, Oil companies and R&D agencies and functions as the major focal point for this purpose.

The concept of Energy Substitution stems from the basic principle of inter-energy relativity on functional perspective. Sources of energy are several, the energy-mix comprising traditional as well as non-traditional, tested as well as untested, perennial as well as transient, expensive as well as inexpensive. Some are limited and some are limitless. It would, therefore, be pertinent to consider the prospects of energy substitution in terms of specific forms of energy as related to specific usage.

The known sources of energy, in the current and the futuristic perspective, which one has to take into account, may be described as follows:

- Coal, lignite, peat and shale
- Agricultural, animal, human and industrial wastes
- Oil and Natural gas
- Electrical energy
- Solar energy
- Geothermal energy
- Wind energy
- Tidal energy
- Nuclear energy.

The pattern of energy usage too makes a very interesting study. One could perhaps hazard a generalised observation that in so far as highly industrialised economies are concerned, the pattern of energy consumption is conspicuous for the lack of any qualitative distinctiveness as between the urban and the non-urban environments of society, in so far as their accessibility to the three sources of commercial energy, (coal, oil and electricity) is concerned. In distinct contrast with this picture is the position in most countries of Asia, Africa and Latin America where accessibility to these commercial energies is almost totally localised in the urban sector and in their non-urban sector, firewood, charcoal, agricultural and animal wastes – which one may describe as traditional and non-commercial energies, constitute the primary energy resource. Part of the urban sector also uses such energy. In the preponderantly rural character of Indian society, nearly 69 per cent of the total energy consumed in the country was in the form of non-commercial energy two decades ago. Today, even on a reduced dimension, it is still substantial— about 48 per cent. The position is either similar in many of the Asian countries or in some of them, the percentage of non-commercial energy utilisation happens to be higher than in India because of better natural resources endowments in terms of non-commercial energies.

Apropos this, it might appear at first glance that in the current context of global energy shortage in respect of petroleum products and energy shortage of lesser dimension in several countries in respect of coal and electricity, this is somewhat in the nature of a blessing in disguise. In reality, this may not altogether be a matter for complacency when one gets to analyse the components of the non-commercial energy-mix which comprises firewood and charcoal, agricultural and animal wastes presently. In most of these countries, there is heavy non-urban orientation to the population. In the case of India as also perhaps quite a few other countries, there is the further dimension of concentration of increased rate of population growth in the non-urban sections of the society as distinct from the urban. It has been observed in India that the rural segment of society accounts for as much as 80 per cent of the total non-commercial energy consumption in the household sector and that even in urban segment, it is no less than 20 per cent. The sovereign component of the non-commercial mix as it is constituted now happens to be that exclusively rural and age-old energy resource which yields firewood and herein lies, for some countries, a major energy dilemma. The extent of dependence in India on this energy resource is illustrated in the following table:

Consumption of Non-commercial Energy in the Domestic Sector

Year of consumption	Total non-commercial energy *(MTCR)	Firewood %	Agricultural waste %	Animal waste (% share)
1960-61	147.87	65.0	20.0	15.0
1963-64	156.22	65.0	20.0	15.0
1966-67	166.92	65.0	20.0	15.0
1970-71	179.41	65.0	20.0	15.0

Source: Report of Fuel Policy Committee
*MTCR: Million tonnes of coal replacement

It may be noted that as the consumption of non-commercial energy has increased over the years, the percentage of individual fuels has remained steady, implying, however, a quantitative increase in consumption.

The fast rate of depletion of even this energy source is already a matter of serious concern for some countries who are setting out to frame eco-balance policies to curb this trend and introduce reforestation and afforestation programmes for correcting the imbalances of the limitations of forest area with reference to total land area. The status of agricultural wastes is of concern too. For example, nearly 8 to 10 million tonnes of sugarcane waste (bagasse, jute sticks etc.) are being utilised as boiler fuel. This by no means signifies optimum economic utilisation of cellulosic material which is a valuable input for paper and pulp. Consequently, what has hitherto been looked upon as a plentiful energy resource would, in the near future, no longer be so and would, like its petroleum counterpart, necessitate conservation through substitution.

Given the kind of economy pattern, a total and complete substitution of firewood as the source of rural energy may be impractical. The feasibility of transformation of the rural energy base may have to be conceived in terms of partial substitution and the continuity of the use of firewood somehow so regulated that it is strictly in alignment with forest regeneration schedule. Apart from state policies, education programmes and effective enforcement mechanisms, compensatory schemes would have to be initiated to make this a success.

What are the energy options for these countries in terms of non-urban and urban needs? These seem to be limited, at present, to the following :

(a) Commercial energy in the form of kerosene which has gradually entered the energy scene both in the rural and the non-elitist urban sector. Any further tilt towards it would be retrograde from the view point of conservation of petroleum energy, even if considered otherwise socially relevant.

(b) Increased reliance on agricultural and animal wastes—which also constitute traditional non-commercial energy—and purposeful utilisation of urban as well as industrial wastes, on the basis of a back-up of fresh R&D efforts and institutional or infrastructural services for enriching their energy content and for promoting their increased appeal and acceptance. By and large, this is well within the short term capability of most countries.

(c) Extension or creation of production and delivery system for soft coke, coal gas and electricity, wherever feasible. As commercial energy, these programmes have implications of developmental investment, delivered costs and consumer oriented subsidisation. For countries which are blessed with coal and hydel reserves, this falls within their short-term or long-term capability.

(d) Harnessing of unconventional resources of energy such as solar, wind, nuclear, geothermal and tidal. Of these, despite the limitations of seasonal and intermittent character of availability of sunshine, solar energy alone has some very definite possibilities both in the short and in the long run, for specific applications on the basis of its being relatively a more familiar energy and of the considerable applicational work already done in India, Australia, Japan, Israel, Soviet Union, U.S.A., France and Federal Republic of Germany, besides some African and Latin American countries. Others are either far too long-ranging in developmental perspective and premature for commercial dependability during the next two decades or are inhibited by constraints of specificity of occurrence of the basic energy matter such as in the case of wind, geothermal, tidal and nuclear energies.

A solution to the problem of development of national and individual programmes in respect of the type of alternate energy referred to (c) and (d) above, possibly lies in the pooling of technology, inputs and other efforts on a regional and multinational perspective on the basis of geographical contiguity and commonality of interests. This is particularly relevant for land-locked countries. There are notable examples of such inter-country and inter-regional cooperation in African industrialisation programmes relating to hydro-electricity, railway, highway, fertiliser, petro-chemicals etc. perhaps in Asia and Latin America too in these and other fields. Each country or group of countries will have to determine for itself the forward and backward linkages appropriate for its or their conditions.

A question which requires serious attention is whether the emphasis on utilising primary petroleum energy resources for heating and lighting is not misplaced and whether from the viewpoint of economic growth and generation of employment opportunities, it could be better utilised as a process input with value added dimension.

The need, therefore, for transformation of petroleum energy base, involving as it does the more scarce products like kerosene, liquified petroleum gas (LPG), furnace oil and diesel oil is no less demanding. The alternate sources of energy referred to above, for example, soft coke, gas from coal, gas from wastes and solar energy have potential for relieving some of the pressure on the four petroleum products without involving too long a time-span for doing so.

In Annexures I and II an attempt has been made to illustrate the details of energy use, the tools of energy and an estimation of the pattern of energy demand in India. The spectrum of energy demand illustrated below is a useful guide for identifying specific short-term and long-term possibilities of energy displacement or substitution :

Sector of consumption

—Household
—Industry
—Power
—Agriculture
—Transport.

Functions of energy

—Heating
—Lighting
—Motivation
—Process input.

Household Sector

Almost all of the energy consumed in the household sector may be ascribed to the functions of heating (and cooking) and lighting. Considering these functions and the nature of the fuels used (primarily firewood and kerosene), this sector, particularly the non-urban part of it, deserves attention for achieving even short-term results in energy substitution. A conservative estimate of per capita daily consumption of the equivalent of 1 Kwh of energy may be taken as an indicative norm for determining the energy need in this sector. It may further be assumed that, in this norm, heating (and cooking) accounts for 0.7 Kwh and lighting for 0.3 Kwh. If a typical household unit consists of 5 individuals and a typical household sector complex comprises 100 such units, the total daily energy demand of the complex works out to 500 Kwh (350 Kwh for heating and cooking and 150 Kwh for lighting.) The number of villages in India being around 570,000, the annual energy equivalent of this in the rural sector alone would work out to 77 million tonnes in terms of firewood for heating and cooking and 4.2 million tonnes in terms of kerosene. (The energy content of firewood and kerosene is taken as 0.95 Kwh and 8.3 Kwh respectively per kg.) As there is also consumption of kerosene in the urban (non-elitist) sector for cooking, the figure of kerosene energy equivalent would be much higher. Presently the total annual consumption of kerosene in India amounts to 2.5 million tonnes.

(i) Bio-Gas : Earlier in this paper, animal dung or waste has been described as a traditional fuel for cooking in the rural domestic sector. In its ready-to-use form in which it is utilised—that is, as dried cake—its combustion efficiency is reportedly not more than 11 percent; its smoke is a pollutant and an eye-irritant; the nutrient value of the waste for soil enrichment is not fully exploited either. The prudence of burning the waste as such is being questioned and optimum extraction of its latent energy is evoking much interest. In India, the Khadi and Village Industries Commission (also a few other agencies), has been pioneering the promotion of this effort and about 7000 plants have been set up in various states for energy production. The main idea behind this scheme is to subject biological wastes to controlled fermentation and partial gasification and to isolate the resulting gas for combustion and the co-product sludge (which, in the process, gets enriched with about 2 percent nitrogen) for use as a plant-nutrient compost. The gas known as gobar gas or bio-gas contains about 55 percent methane (balance being carbon dioxide). Its contribution to the programme of energy substitution in the rural sector is singular in that it is practically an 'in-community' and 'in-house' energy generator providing a clean, smokeless and odourless domestic cooking fuel and also fuel for gas-lights for adequate illumination, meeting the full energy needs of the rural household for heating and lighting with potential for displacing a very substantial volume of dependence on firewood, kerosene and even electricity. It is a supreme example of decentralised energy generation based on the most efficient utilisation of local wastes (animal, human, and land

aquatic vegetation). The retrievable waste matter put out by cattle has been estimated at about 2.4 Kg. per animal per day or 600 Kg. per day for a whole rural household complex of 500 persons and 250 heads of cattle. Converted to bio-gas, this is equivalent to 3900 cft. (6 5 cft. per Kg.) of gas or 585 Kwh (0.15 Kwh per cft. of gas) or a per capita of about 1.2 Kwh per day. A much higher level of energy availability by this method can easily be mobilised from the same equipment if other materials such as human waste (which yields 1 cft. of bio-gas per individual per day), such agricultural wastes as are not economic process inputs and water plants like hyacinth are also harnessed for supplementing cattle waste and through increased efficiency of gas generation. Part of the additional available energy can be employed for energising agricultural pump-sets for irrigation, thereby reducing the reliance on light diesed oil (a petroleum derivative) and electrification which are otherwise necessary.

The task of waste collection and handling, obviously calls for minimal movement of the waste between its origin and destination. This explains why a completely rural and even a semi-urban environment which, say, houses a large dairy project or cattle development centre as well as a complex of industrial estates or a number of small-scale industries located close to each other which could easily use the gas for low temperature applications including ordinary heating, is an ideal location for the generation of the gas and its simplistic delivery by piping in uncompressed condition to a cluster of closely-located consumers within reasonably short distance. Compression of the gas for delivery over longer distances by piping or by bottling (as done for LPG) is a technical innovation within the realm of feasibiilty but would need developmental time of say a year or two.

The necessity of having to convert the cattle waste into gas as near the source as possible is a real constraint at present in the case of urban sector. Theoretically, urban units such as railway stations, public rest-houses, hostels and even schools, colleges, hospitals and hotels are potential sites for self generation and self-utilisation of bio-gas for meeting, at least partially, the energy needs for heating, cooking, washing and some lighting, if clean cattle-stables could be maintained hygienically close enough to the premises without offending municipal laws. In so far as urban private dwelling is concerned, the constraint is noticeably more complex because of the difficulty of waste collection in bulk. The only possibility in this case for commercial bio-gas generation is in the large multi-apartment residential blocks and that too, on the basis of utilisation of other refuse (primarily human and secondarily municipal organic wastes) for providing energy for hot water, drying and some lighting. However, this is far easier said than done and there may be a long, long way to acceptance of this kind of energy generation, although there are instances of this being done out of sight and odour in some individual Indian semi-urban households.

The cost of a bio-gas generator of 60 cft. per day capacity (equivalent to 10 Kwh per day) is estimated at about 300 US dollars (Rs. 2200) and that of the gas at one US cent per Kwh (8 paise per Kwh). The gas has a calorific value of about 500 BTU per cft.

(ii) *Solar Energy :* As explained elsewhere, this is not an unknown or untested source of energy; its new importance arises in terms of certain new applications which are considered possible under concentrated collection and utilisation of solar energy. The specific applications of interest to the household sector are, heating of water, domestic cooking, and space heating and cooling.

Solar water heaters are fairly simple in design, based on the principle of collecting the sun's rays on a glass-sheet encased black surface metal plate in which water circulates inside tubes and the heated water (temperature about 50 °C) is piped back by siphonic circulation and stored in insulated container for use in household for washing, bathing etc. These can be installed in roof tops or any other open space on the premises and a 140 litre size would be sufficient to meet the daily needs of hot water for a family of about 5-6 persons. The cost of the equipment is presently around US dollars 300 and the expenditure on maintenance is little. Designs have been standardised in India as well as in several other countries. So far as urban dwellings are concerned, this energy system can be introduced in any tropical country almost immediately, with scope for saving about 25%—30% in consumption of scarce energy resources such as electricity, kerosene or LPG. Its output in about 3 hours would be equivalent to a 1000 watt electric storage water heater, for, say, one hour.

In rural household, it is relatively far simpler than in multi-apartment city residential blocks to instal and operate these heaters, but in terms of neither scarce-energy conservation nor economics of individual affordability, this is likely to be a hopeful project for a long time to come. However, on this ground, one should not be tempted to rule out this possibility of energy substitution for this sector. There seems to be a case for trying this out by installing the heater (in large size) as a community welfare infrastructure in rural sector as one would set up, say, a village school or clinic on governmental investment.

Solar cookers faded from the Indian scene rather unfortunately, after a brief debut some thirty years ago, but the drawback of having to cook in the open and in the hot sun has since been overcome with the development of newer designs which enable indoor cooking and which produce steam for cooking at atmospheric pressure. The cost of the cooker is around the equivalent of US dollars 30. Today, it is admittedly an ideal and convenient device for use in tropical urban dwelling, with a significant potential for displacing LPG and kerosene.

Space heating and cooling with solar energy is currently of little practical relevance to most of the developing countries from the viewpoint of energy substitution as compared with countries with advanced economies where a fair amount of petroleum energy is, directly and indirectly, spent on keeping the homes and buildings warm or cool according to the needs.

(iii) *Coal-Gas :* Obviously, this could be thought of as an alternative to kerosene, LPG and soft coke only under the favourable conditions of easy access to cheap coal, by way of its occurrence either within or close proximity to the country concerned. In any case, the gas-producer would have to be set up and operated as a community project, somewhat on the lines of a thermal power station. This could be a slightly expensive energy system but justified in the interests of conservation of petroleum products and suitable for large townships and cities only.

Industry Sector

This sector, as will be seen from the Annexure, accounts for about 30 percent of non-commercial energy in all forms or about 38 percent of commercial energy and 30 percent of non-commercial energy in India at present. Also, of all the sectors, it is the only one which consumes practically all forms of known energy for various applications and like the household sector, is amenable to some restructuring of its energy consumption system. These possibilities are examined below :

(i) *Substitution of Petroleum Products* : The oil product which is of concern on this account is fuel oil. The nature of duties performed by it are :

—Ordinary heating and drying (as in tea. rice, food products).

—Generation of steam for process (as in textiles, sugar, paper, thermal power, chemicals).

—Direct firing of furnaces (as in steel forging and heat treatment, cement, glass, ceramics).

—Process input (as in fertiliser, carbon black).

Fuel oil has, over the years, displaced coal in a number of industrial applications in view of its higher calorific value (10,000 K calories per kg. as compared with 5000 K cal. of coal), and facility of its supply, storage, handling and combustion, and temperature control, apart from avoidance of dust pollution. In reality, very few process operations can lay claim to any technological compulsion for the use of fuel oil as an indispensable energy source. The general pattern of consumption of furnace oil in India is as follows :

Sector	*Percentage of total consumption of furnace oil*	*Sector*	*Percentage of total consumption of furnace oil*
Textiles	15.5	Foop processing industries	4.0
Chemicals	13.5	Sugar	2.2
Power (Thermal)	13.0	Paper	1.8
Metallurgy	10.2	Others (Defence, Railways & others)	14.8
Iron and Steel	8.0		
Glass & Ceramics	6.5		
Fertilisers	5.7	Total	100.0
Cement	4.8		

Basis : 1973 level of consumption of 4.5 million tonnes. (Power sector consumes besides this about 1.5 million tonnes of residual fuel oil).

In the context of shortage of petroleum products, an industrywise study was undertaken in India to determine the possibilities of substitution of furnace oil. It has highlighted the following :

(a) The use of furnace oil for mere drying and low temperature heating is not considered necessary, except where the nature of the product required a very carefully controlled drying (example : tea, milk products, drugs).

(b) Where coal is easily available, it should effectively replace either as solid or gas the consumption of furnace oil for generating steam in boilers. This is very true in the use of textiles, paper, sugar, chemicals, fertilisers (where furnace oil is not used as a feedstock) and even thermal power plants. In some cases, the switchover to coal can take place almost immediately while in others, it may need to be phased over a period ranging from 3 months to 4 months, depending upon the minor or major nature of equipment change, and the delivery period for supply of coal-fired boilers,

(c) Considering the high cost of furnace oil (delivered price is about US dollars 120 per tonne compared to about US dollars 25 of coal) and the adequacy of 2 to 2.2 tonnes of coal for replacing 1 tonne of fuel oil in terms of energy equivalence, the balance of long-term advantage in terms of plant operating costs is clearly in favour of switchover, with very short payback period in the investment for conversion to coalfiring equipment.

(d) The practice in some industries of keeping coal-fired boilers as standby and oil-fired boiler as the normal operating boilers is to be reversed.

(e) Industries such as cement, sugar, textiles and power which have boilers based on dual fuel arrangement (that is, coal as well as furnace oil) should be encouraged to resort to coal-firing in preference to oil firing, as a general rule.

(f) All new industrial proposals and programmes which are likely to involve use of fuel oil would be carefully screened in advance by an official body of Energy Conservation experts for the possibility of utilising alternate fuel and the necessity for authorising the use of furnace oil for the process.

(g) Indigenous facilities for fabrication of improved designs of coal-firing equipment and devices would be strengthened.

In the light of the above, the major consumers have been classified under the following categories* and their furnace oil supply cards depict this status as an advance notice :

Category A (15% of total consumption)—Those who cannot switch over to coal due to technological constraints (e.g., white cement, selected units of some power plants, chemicals, primary steel, metallu rgical, glass and defence).

Category B (30% of total consumption)—Those who can switchover to coal almost on an immediate basis, but incurring some minor capital investment (e.g., thermal power plants, textiles, chemicals, fertilisers, aluminium, paper, glass and ceramics, food processing).

Category C (7% of total consumption) —Those who can switch over to coal in about 6-9 months, time but incurring some modest capital investment (e.g., textiles, cement, chemicals, paper, sugar, glass and ceramics, food processing and thermal power plants).

Category D (8% of total consumption) —Those who can switchover to coal in about 18-24 months but after incurring substantial capital investment (e.g., power plants, cement and textiles).

An inter-ministerical group comprising departments of Railways, Petroleum, Coal, Power and Industrial Development (DGTD, Energy Conservation) is engaged in formulating and monitoring the implementation ofs pecific action-plans in this direction, including measures for increased coal availability, in close cooperation with the consuming sectors. India's coal output (both coking and non-coking) which was 78 million tonnes during 1974-75 is being stepped up by 10 milli on tonnes during 1975-76). About 25 per cent of the additional output of 10 million tonnes of coal during 1975-76 has been set apart for this inter-fuel substitution programme.

Fiscal incentive has also been provided in the form of Development Rebate, for further encouraging the programme of switchover from furnace oil to coal.

*Basis of total consumption : 4.5 million tonnes.

The progress of the programme of substitution already achieved and the clearly forseeable prospects for the next two years in India is highlighted in the following picture :

Sector	*Saving in furnace oil per month (tonnes)*			
	1974—75	1975—76	1976—77	1977—78
Power	18,000	—	20,000	10,000 (flame stabilisation by producer gas)
Chemicals	—	1,800	1,000	—
Glass	—	1,000	—	5,000 (by producer gas)
Tea	—	400	—	—
Foundry	—	100	—	—
Fertiliser	—	—	2,000	—
Textiles	—	—	2,000	—
Small scale industries	—	—	—	10,000
Total	18,000	3,300	25,000	25,000

(ii) *Producer Gas :* Reference was made earlier to the practice of using furnace oil for firing of furnaces in forging, heat treatment, glass, ceramics and some other industries. In as much as it cannot be claimed that these industries have, since inception, been dependent upon furnace oil and since a few plants in these industries are even now using coal, one needs to think in terms of converting the coal into gas in captive or community gas generators, and secure the advantage of temperature control and product quality control, etc.

The composition of the gas is :

Nitrogen	—	—	45—55%
Carbon monoxide	—	—	25—30%
Hydrogen	—	—	11—15%
Carbondioxide	—	—	5—7%
Hydrocarbon	—	—	1—5%

One tonne of coal yields about 3000 cubic metres of gas. The gas has a calorific value of 4700 BTU per cubic metre and is obtained by the action of air and steam through a bed of coal or coke in a closed steel vessel. It is burnt through burners in the same way as furnace oil is burnt. Producer gas is an ideal fuel for reheating furnaces for re-rolling and forging mills, for melting of cast iron and non-ferrous metals and for sheet glass, glass bottles, pottery, as also for drying or baking activities. Furnace temperature up to 1600° C could be obtained and where higher temperatures are needed, a bit of support firing by furnace oil can be resorted to.

Unlike in the case of coal-firing and oil-firing, a separate equipment for gas generation involving as it does additional capital investment (ranging from US dollars 400,000 to 1000,000) would be needed. This is somewhat a disincentive even though several medium scale and large scale industries have set up their own producer-gas generators on captive basis. Considering this and keeping in view the scope for conversion of low grade coals with high grade ash content (which would normally not find easy outlet) into producer gas, serious attention needs to be given to the feasibility of installing what may be described as "community-gas producer plants" of large size, perferably as a state-financed and state-provided infra-structure in the same way as electricity or water is supplied. Industrial estates and areas of concentration of industries would be ideal sites for this purpose. Indeed, the installation of such a facility would itself attract industrial entrepreneurs of that area and contribute to the economic growth of backward and desired areas. As an ancillary to the gas generation, coal dumps would be needed to be set up. Satellite industries can process the bye-product tar.

About 250,000—300,000 tonnes of fuel oil (valued at an import price of about 70 dollars per tonne) are presently being burnt as secondary fuel in some of the coal based thermal power stations in India for the purpose of flame stabilisation to cope with the quality of coal. (the thermal power sector in India which accounts for a little over 50 per cent of total power generation uses about 22 million tonnes of coal annually). Switchover from furnace oil to producer gas for this purpose within the next 2 to 3 years is being considered as a definite possibility.

(iii) *Other Energy :* Even in the short run, it may be possible to supplant a part of the consumption of conventional energy in the industry sector for low temperature duties such as air heating which may be required in chemical, food processing timber processing and ceramic industries for drying greenware, with the help of solar energy, notwithstanding the intermittent nature of its availability. Apparatus designs have already been developed in this direction in U.S.A., France, Australia and India. Bio-gas, too, has some potential, though somewhat limited, in this direction, but even for this, some R&D studies would be necessary for a clearer appreciation of how exactly and how early it can be done.

That solar energy can also be effectively employed for heating substances to very high temperatures has been established. Furnaces capable of temperatures of 3500°c and 5000°c are reported to have been set up in France and USA as part of a major R&D effort. This has far-reaching importance from the point of view of processing of high melting-point minerals and materials, but this programme of energy substitution (in this case, primarily of electricity) is necessarily of long-range character.

Power Generation

Outside the short-term feasibility indicated earlier for substitution of fuel oil by coal as primary fuel and by producer gas as secondary fuel, no major break-through of immediate significance in total energy substitution in this sector can be anticipated, considering the nature of the other alternatives, namely, hydel and nuclear. The concept of limited and local supplementation by wind energy is gaining interest and this may aid partial substitution. However, this hinges crucially, on wind availability and velocity and consequently governed by specificity of location of the facilities for power generation from this source. Considerable work has already been done in this directon in India and elsewhere and there are definite possibilities of introduction of this energy source in near future for some industrial and agricultural applications in coastal and mountain areas. Commercial development of wind mill generators of 5-10 mw size for this purpose is anticipated.

Conversion of solar energy into electrical energy has also been the subject of several studies for some years now and has, indeed, been already introduced in space flight and communication system. At the National Physical Laboratory, India, silicon-solar photo-voltaic cells have been developed and commercial production based on this process is a possibility. The cost of these cells is estimated at 3 US dollars a piece. This will help overcome one of the major problems in solar energy, that us, of its storage. The implications of this vis-a-vis solar power stations are obvious. Incidentally, according to an American esitmate, the installation cost of a solar power station is around one million dollars per mw.

Motivation Energy

Basically, electrical energy would continue for obvious reasons to be the principal means of motivation and it is difficult to visualise displacement of its sovereign position even with the commercial development of near-substitutes like solar and bio-gas energy. Even so, the latter have their merits for practical application in specified directions, especially rural, as for example, lift irrigation or for providing illumination in areas which have poor or no scope of access to normal electrification programmes for unavoidable reasons. Solar pumps capable of transforming sun's energy for mechanical activity of the kind referred to above have already been developed and their commercialised availability should not, according to expert's assessment, pose any major problem.

The potential of bio-gas for heating and illumination in rural household sector has been discussed earlier. This gas, it has been established, can be used to motivate a petrol or kerosene or diesel oil engine and provide power on captive basis, for such duties as pumping of water, grinding of foodgrains, etc. The consumption of gas is about 0.45 cubic metre per hp per hour. One major constraint yet is the corrosive nature of the combination of methane gas and the water present in the gas on account of its source, which effects the engine parts but with R&D efforts, it should be possible to overcome this problem. In some agricultural farms in India, such engines have already been used.

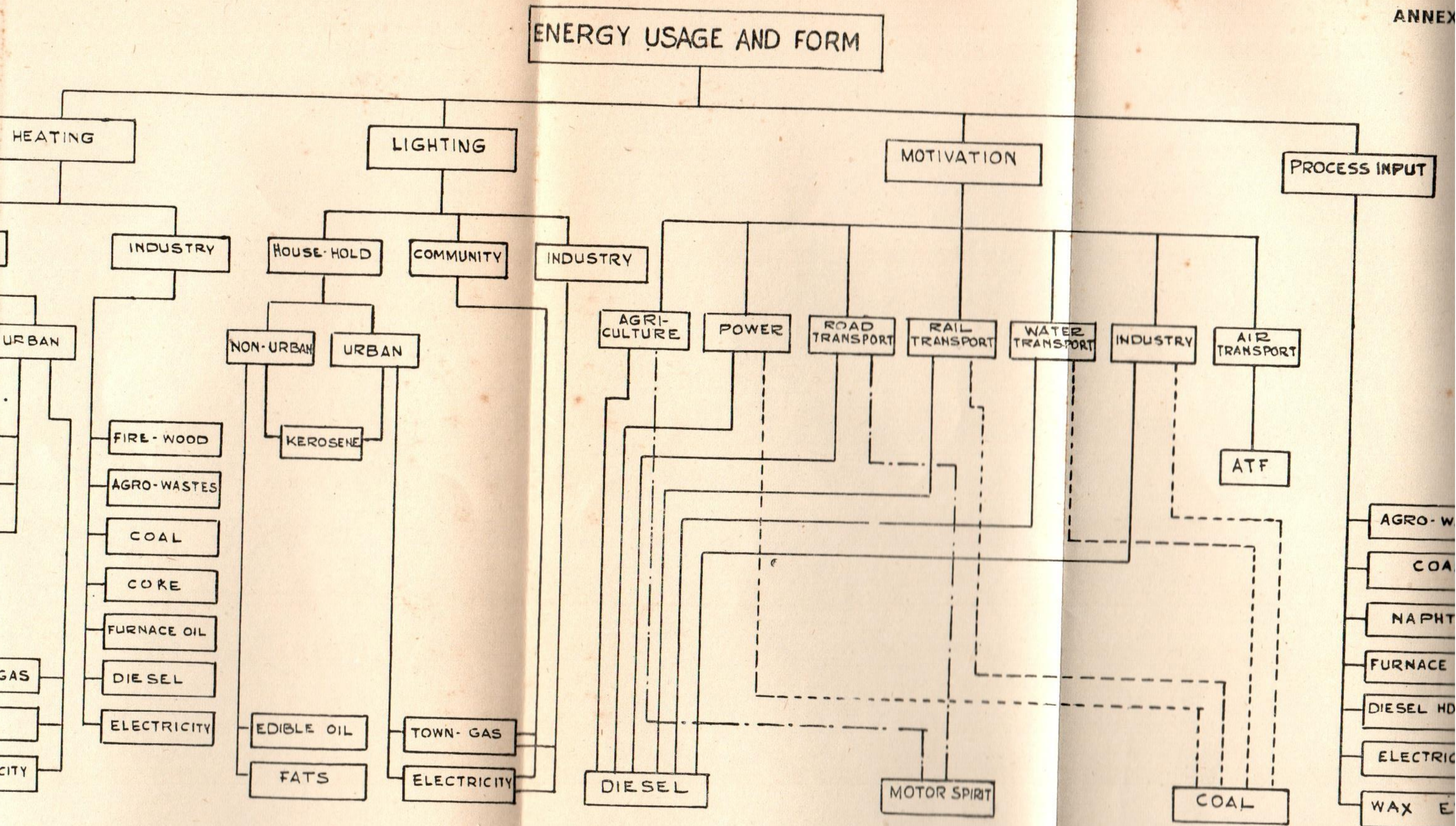
Conclusion

Energy for transport in substitution of petroleum fuel (petrol and high speed diesel) is, at the moment, being considered in terms of electric storage-battery driven vehicles. Experimental trials in respect of passenger-buses and private automobiles are already on in UK and Australia respectively. As a commercial proposition, this development is of very long term cnaracter. Conceptually, however, this energy substitution is considered possible.

The scope for transformation of energy base for process input is somewhat restricted, in terms of the number of industries which would be amenable to this. The specific possibilities as foreseen at present on the basis of earlier experience are petro-chemicals. In India, the industrial licensing policy encourages new production of polyvinyl chloride via calcium carbide, acetylene and synthetic alcohol in contrast to ethylene route which involves utilisation of petroleum base, naphtha. Similarly, production of aromatics (benzene, toluene, etc.) which can be obtained either from petroleum base (naphtha) or coal and coke would in future, whereever it is feasible, from the point of raw material, have to be thought of in terms of the latter process.

The various options indicated in this paper would, however, need to be appraised carefully by each country from the viewpoint of the balance of short-term or long-term advantage and socio-economic considerations.

ANNEX



ENERGY USAGE AND FORM
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LIGHTING
MOTIVATION
PROCESS INPUT
URBAN
INDUSTRY
HOUSE-HOLD
COMMUNITY
INDUSTRY
NON-URBAN
URBAN
KEROSENE
AGRI-CULTURE
POWER
ROAD TRANSPORT
RAIL TRANSPORT
WATER TRANSPORT
INDUSTRY
AIR TRANSPORT
ATF
FIRE-WOOD
AGRO-WASTES
COAL
COKE
FURNACE OIL
DIESEL
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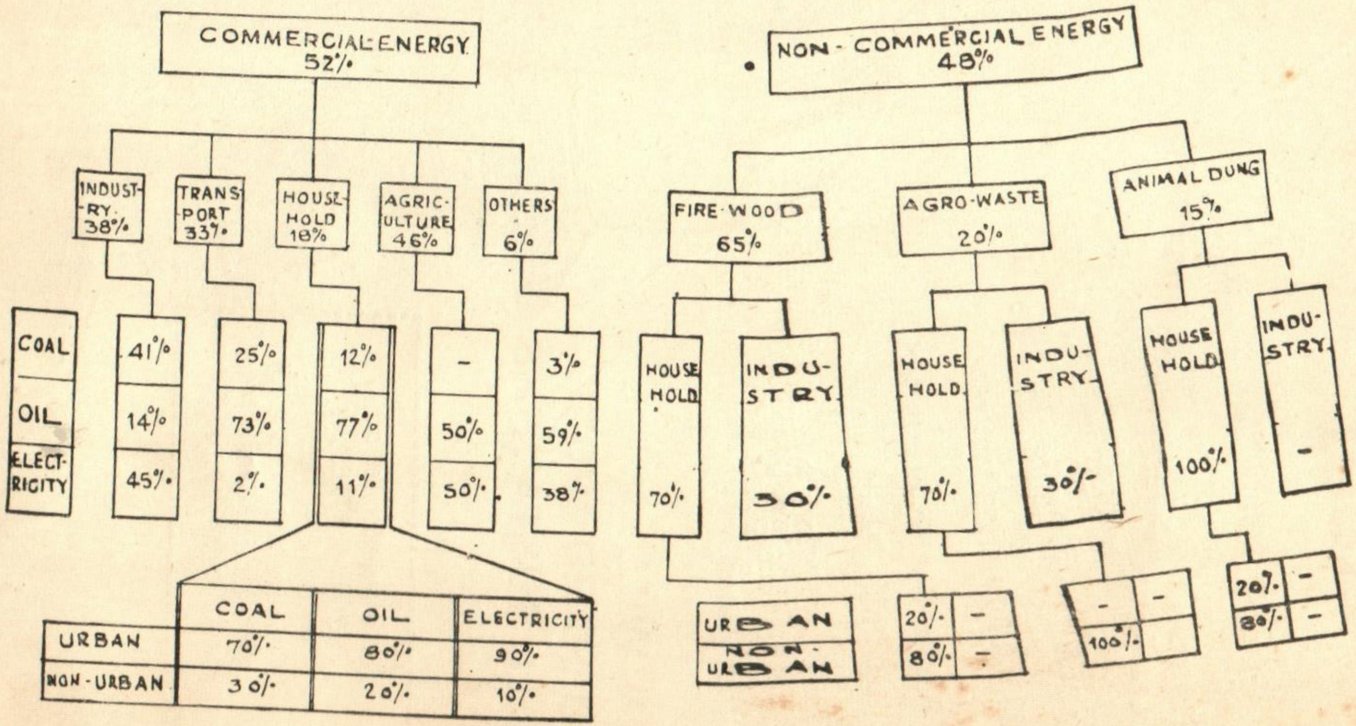
ANNEXURE – II

PATTERN OF ENERGY CONSUMPTION IN INDIA



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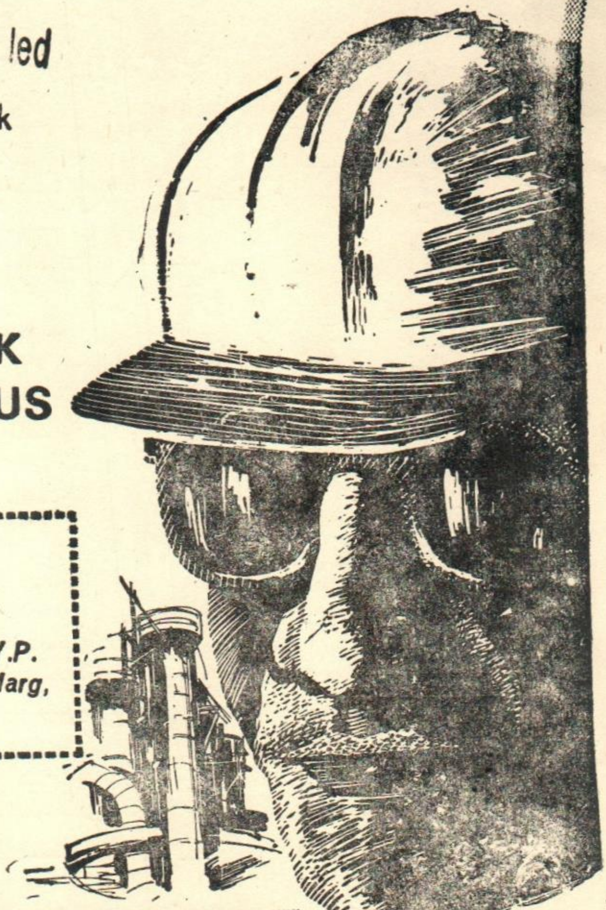

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davp 75/450

Transportation of Energy

K. Ashok Rao*

Energy is the prime mover of development and prosperity, particularly, in this industrial era. Industrial growth is an energy consuming process. In fact, its history can be written in terms of energy consumption. From the age of a unifuel firewood, we have come to a multi-fuel society. Not only can we use the fuels in their primary form, but also in their secondary forms. This ability to transform energy from a primary form to a secondary form has opend up vistas of the primary sources of energy such as hydro power and uranium fuel, which could not have been used in the primary form to any great and useful extent. Even fossil fuels which can be used in the primary form, can play a versatile role in the secondary form of electricity.

Asia's Energy Scene

Even today, the biggest source of commercial energy is fossil fuels, particularly, in Asia and the Far East. The reserves of coal in this region are about 1,159,395 million metric tonnes. Though this sounds big, but it forms only a small percentage of the world resources of coal which amount to 6,712,501 million metric tonnes. There is a tremendous imbalance in its availability, as China accounts for 87 percent of the coal produced, India 9 percent and Korea contributes the remaining bulk. About 13 percent of the word's crude oil reserves is available in this region of which 82 percent is in Iran and 12 percent in Indonesia. The estimated reserves of natural gas in this region are 157,554 billion cubic feet, i. e. 11 percent of the world total of which 70 percent is in Iran. Uranium resources have been located, in Australia, India and Japan and exploration is going on in Indonesia and Pakistan. As for geothermal energy, Japan and New Zealand have made considerable progress. India is a leading nation of Asia in hydro-power followed by Malaysia, Laos and Vietnam.

The above mentioned figures give an idea of the availability of these

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resources. While Brunei, Indonesia and Iran are self-sufficient in liquid fuels, Australia, India and Korea are self-sufficient in solid fuels. In spite of such rich resources, the consumption of energy in this region is only of the order of 935 million tons of coal equivalent, being only 13.3 percent of the world's total of nearly 7,000 million tonnes of coal equivalent. Thus, it can be seen that this region which supports 50 percent of the world's population, consumes only 9 percent of the world's commercial energy. This inordinately low consumption reflects the low level of industrial activity and imbalance in overall economic development of this region.

Under the influene of the developed countries a shift has taken place from solid fuels towards liquid fuels, even in countries which are self sufficient in solid fuels. This has resulted in importation of liquid fuels. On the other hand, the Chiness have built their foundation of solid fuels. According to the United Nations statistics, in 1970, China was producing about 364 million metric tonnes of coal and maybe today they are producing 500 million metric tonnes, with the result that though they are, in comparitive terms, a minor producer of oil, they are a sizable exporter. Japan today is thinking whether they should buy China's low sulphur crude oil because most of their refineries are geared to the high sulphur Arabian crude. Thus, while Australia, India and Korea neglected their own solid fuel resources and became major importers of oil, China based its economy on solid fuel and in the process has become an exporter of oil. In the context of increased oil prices and freight prices, these oil importing nations are now facing a serious economic crisis and are reversing their policy and returning to the ugly Black Gold—*coal*.

Transportation of Energy : Issues

The transportation of different types of energy pose very many problems on account of their nature in which they are found and consumed. For instance, coal can be consumed in the raw form as a solid fuel. It can be washed in order to increase its calorific value and transported as washed coal. It can be made into a slurry and pumped through pipelines. By a process of solvent extraction and hydrogenation it can be transformed into crude oil which after devolatization can become Ammoniacal liquor. Coal can, by a process of carbonisation, and if necessary, methanation, be converted into a gaseous state. It can be converted into a secondary form of energy, that is electricity, and transported as electricity. Thus, depending on the form in which the fuel is used the transportation of energy becomes all the more important, nevertheless, it raises many a problem. However, transport of energy is necessary because :

(a) nations do not have their own fuels or energy resources and have to import them.

(b) nations have shifted from one fuel to another;

(c) the area of generation of energy and the consumption centres are spatially distributed.

International Transport of Energy

The three issues mentioned above generate demand for international transport. Petroleum, coal and natural gas dominate the transport scene. As of 1974, 54 percent of all maritime cargo is energy, i.e., coal, oil and gas (see below) :

	(In Million Tonnes)
Crude Oil	1,385
Oil Products	275
Coal	113
Total of Energy Cargo	1.773
Iron Ore	320
Grains	107
Other Cargo	1,070
	3,270

It is interesting to note that even in terms of dwt tonnage, tankers account for 50 percent of the world's total shipping tonnage, i.e., out of a total of 492.4 million dwt, tankers alone account for 250.1 million dwt. This clearly shows the magnitude of energy transport. Modern ships/

tankers have been specially designed to carry energy from the area of its generation to the place where it is consumed. Different techniques have been adopted to store and preserve energy safely. One such technique is Nitrogen System.

Nitrogen System: Nitrogen is used for sealing LNG compressor glands, purging enclosing gas fuel pipe to the boiler and for inerting the void spaces in critical positions where gas could collect to create an explosion hazard. Two 15 m^3 liquid nitrogen tanks are carried on the main deck for the purpose and the gas is conditioned by dehumidifiers and silica gel dryer bringing the dew point down to —45°C. This technology is capital intensive. It is obvious that most of the Asian countries will not have the capital to buy such ships. Brunei, for example, would have to depend on the importing countries to transport its export to Natural Gas unless, of course, it decides to spend a good portion of its earnings on acquiring such ships. This lack of means of transporting one's resources gives the importing nations, which are generally more developed and organised, an extra handle to exploit our resources very cheaply.*

Socio-Economic Forces Vis-a-Vis Transport of Energy

By and large, it has been noticed that the spatial distribution of resources and the consumption centres are too far from each other, stressing further the need for better transport facilities. However, this distance gap can be traced back to history, where in colonial times the industrial concentration was in and around major ports, because the colonial economy was entirely export-oriented. In a study conducted by Galina Sdasyuk**, this point has been clearly elaborated.

The purpose of dealing with industrial location is to illustrate some of the vital causes that contribute to the spatial distribution between energy production and consumption.

*Tanzer, Michael, "Political Economics of International Oil and the Underdeveloped Countries, Beacon Press.

**Sdasyuk Galina, "Economic Regionalisation of India: Problems of Approaches, " published by Registrar General and Ex-officio Census Commissioner of India, Govt. of India.

In India, coal mines are concentrated in Bihar/West Bengal in North East India, Pench Valley, Madhya Pradesh and other fields in Central India. And small reserves in Frontier states of extreme North East Assam, Jammu and Kashmir on the North West, Godavari Basin in the South. In the case of oil, North East of India in the Upper Bhramaputra Valley we find oil at Nunmat, Digboi etc. and in Gujarat in Ankaleshwar. In the case of Hydropower a more even balance exists but the Ganga, Indus and Bhramaputra basin have 60 percent of the potential, the balance 40 percent distributed over the central Indian rivers and west-flowing South Indian rivers on the one hand and east-flowing South Indian rivers on the other. With this type of a distribution of natural primary fuels one would logically have expected an enormous concentration of industries in the East of India in Bihar, Bengal, Assam etc. Instead, there is a heavy concentration in the port-cum industrial cities of Bombay, Calcutta, and Madras. Rather, ironically Bihar is the richest state in natural resources, a storehouse of minerals, as the Geological Survery of India has called it in its latest report. It has also a high density of population as well as the highest unemployment and poverty in India.

It is quite obvious by an analysis of the major industrial concentration and the availability of primary energy resources, that a tremendous non-productive criss cross of energy is taking place to sustain an unscientific logic of industrialisation. What is more painful is that right decisions are being reversed. For instance, Nangal fertilizer was based near the Bhakra Hydro Electric complex (where 1.16 million kw have been installed), as an electricity intensive fertilizer complex. This logical and scientific situation has been altered by changing the feedstock to oil and imposing a massive transportation of oil. An even worse situation is that of Neyveli complex, which instead of using lignite uses crude oil; and crores of rupees have been spent on this conversion from lignite to oil. This, in a nutshell, proves how the historic forces and the socio-economic forces have influenced the transportation of energy.

An example of planning wherein transportation of energy is minimised by taking men and material to the resource rather than the reverse is the Bratsk hydro-electric complex in U.S.S.R. It has an installed capacity of 4.5 million kw. Upstream of the Angara river is the Irkutsk hydro-electric complex, with a power production of 4 billion Kwh per year. A massive amount of power is being generated in the Angara grid system. The climatic conditions in this area are very severe, with temperatures

−50°C during Winter and + 30°C during Summer. Now, instead of transporting all this energy out of Siberia to where the people live, the people have been taken to where the resources and energy exists and a huge industrial complex is being set up. A cellulose factory which requires 35,000 hectares (86.5 thousand acres) of forest to be cut every year to feed the factory (about 1.22 to 1.62 million hectares, i. e., 3 to 4 million acres of forest are attached to the factory and plantation is done as soon as a block is cut), a million ton aluminium factory, an iron ore washing complex and number of other complexes based on the resources available there. This does not mean that no power is transported out of Siberia; it is done only when it cannot be used in Siberia.

The Soviet Union has been able to achieve this because the basis of the industrial location is purely scientific. The basic thesis for this was provided by prof. N. N. Kolosoyskiy in 1937. According to his theory, "Mass technological processing of raw materials using regional energy resources determines the major lines of economic development of the regions in a country; on the basis of the leading mass production, a number of other connected groups of industry and agriculture grow, and in this way regional territorial production complexes are formed". He gave the definition of energy production cycles, as "the sum total of production processes from initial forms—mining and farming—upto production of all kinds of finished products whch are profitable to produce in regions."

(1) Pyro mettalurgical cycle of ferrous metals.

(2) Pyrometallurgical cycle of nonferrous metals.

(3) Petroleum gas energy chemical cycle.

(4) Group of hydro power industry cycle.

(5) Cycle of processing industries.

(6) Wood-energy production cycle.

(7) Group of agricultural industry cycle.

(8) Irrigation–Agriculture industry cycle.

Physical Factors in the Transport of Coal

This section deals with physical factors which come in the way of transportation. The only fuel considered here is coal and the area is restricted to India alone. Raw coal can be transported by the following means :

(1) Railways
(2) High ways
(3) Inland Water ways
(4) Coastal shipping
(5) Ropeways

The main problem in India of transporting coal is its size, but besides this other factors are :

(1) The concentration in a small area of a large proportion of coal deposits and production. The difficulties are increased in that most of the limited supply of coking coal is found in the same area.

(2) The necessity of moving large proportions of coal from Bengal-Bihar fields by the main lines of Eastern and Northern Railways.

(3) Wide dissemination of small users of coal, throughout the country (Domestic, Brick Kilns etc.)

(4) High ash content of Indian coal which necessitates transportation of useless material.

(5) Growth in the demand for coal.

The subsequent paragraphs deal with the characteristics and limitations of the various modes of transport.

Railways : The usual problems are right of way, line capacity of the track, wagon availability, inability to move goods directly from property of consigner to that of the consignee, unless both have private sidings, single shipment not sufficient to form a one commodity train without remarshalling at intermediate yards. A serious problem arises when a transshipment is required by having a broad gauge, metre gauge and narrow gauge.

The favourable factors for the railways are, that the factor of density of traffic and the ability to transport large quantities of goods over its routes. Also, the railways is extremely cost competitive because through the high density the most efficient and intensive use can be made of plant and equipment involved.

Unit Trains : For the transport of coal in large quantities the most effective method is what is called 'unit train' in U. S. A. and 'Merry go round' in U. K. A Unit train consists of 130 to 140 cars and each complete wagon is specially designed and can be independently tilted. The couplings are designed in such a way that they remain in tact even when the next wagon is being tilted, that is, when unloading by tilting one wagon after another, there is no necessity to remove the coupling. A circular route is arranged for the train. At any time the train is in continuous form and goes round and round. The train is controlled by computer controlled diesel motive power. The trips are 8 to 10 times faster than normal trains. Coal is loaded at the rate of 3000 tonne an hour by a high volume conveyor belt—a 100 tonne car is loaded in 2 minutes. Each train is pulled by 5 locomotives of 3000 hp.

Highways : The most serious problems which one confronts with are ;

(1) bad roads which cause high real cost of fuel, tyres and spare parts,

(2) individual vehicles are heavily overloaded and worked for excessive hours, both of which are wasteful of men and material.

Besides these obvious limitations, there is also a problem that the truck sizes are limited to gross laden weight limit of about 10 to 15 tonnes and are generally two axle trucks unlike those used in U. S. Thus to transport about 500 tonnes of coal we would require about 50-60 trusck.

Coastal Shipping : Recently, the Govrnment of Tamilnadu has formed a shipping company Pumpuhar to transport coal from Halida to Tamilnadu. The main problems in coastal shipping are that the ships available for this are very few, the ports are congested and the whole problem of shore to land transfer is manual.

Ropeways : It is ideal for short distance, continuous flow of material, mountainous terrain of crossing like rivers, mines build up areas, etc. The main disadvantage is, however, its high initial capital expenditure which can be offset only by high intensive use.

Pipeline Slurry : It is possible to make a slurry of coal and transport it over long distances through pipeline. This involves washing coal and crushing it to a desired size, even pulverizing it, then mixing it with a proper quantity of water, pumping it and later dewatering the slurry to recover the solids. The first such pipeline for hydraulically transporting coal over more than 160 kms was made in U.S.A. From the mines in the region of Cadiz, Ohio northwards, coal was transported over a distance of about 173 kms to the power plant of Cleveland Electric Illuminating Company in Cleveland (Ohio) on the shores of lake Erie. The coal slurry is pumped at the rate of 165 tonnes per hour and the total tonnage handled is over 1,500,00 tonnes per year. Besides the fact that this system is capital-intensive the other major constraints are the physical availability of water pumping and pulverizing equipment and, of course, the pipeline equipment which has to be designed to withstand pressures which would require double the wall thickness of pipelines used for gas or oil.

Coal in the Liquid and Gaseous Form

As explained earlier, coal can be liquified and gasified. The various liquification and gasification processes are :

Liquification Processes :

(1) Bergious Process

(2) Fisher Tropsch Process

(3) COED Process

(4) H. Coal Process

(5) Synth Oil

Gasification Processes :

(1) Lurgi Process

(2) Koppers—Totzek Process

(3) Hy-gas Process

(4) Bi-gas Process

(5) Co_2 Acceptor Process

(6) At-Gas Process

(7) Kellong Process
(8) Winkler Process
(9) Sythane Process
(10) Low BTU gas by both Winkler aud Lurgi-process by using air instead of oxygen.

Without going into details it would be sufficient to say that the basic difference is gasification at atmospheric pressure or under high pressure using air and steam or oxygen and steam either in a fixed bed or a fluidized bed. All of these processes are capital intensive. A careful evaluation must be made of the need for liquifying or gasifying coal and a detailed analysis must be made of the type of process best suited for the given coal. For example, a process ideal for Indian coals need not be useful for the American coking coals.

Liquified coal would be crude oil or ammoniacal liquor, both of which for the purpose of transportation, would follow the same logic as that of crude oil. Depending on the process of gasification either low BTU or High BTU gas can be obtained. Normally, low BTU gas has a calorific value of 1800 to 4500 Kcal/m^3 (300 to 500 BTU/ft) and high BTU gas about 900 Kcal/m^3 (1000 BTU/ft^3). It is obvious that for long distance transportation low BTU gas would not be economic since for the same volume less heat would be transported.

The fundamental difference between the economics of pipeline transport of gases and liquids arises from the fact that gas is compressible, while with the liquids the pressure drop is constant along the line between the pumping stations, with gases the pressure drop per unit length rises as the pressure falls. This suggests that, in order to reduce the cost of gas transmission, pressure should be as high as possible; however, the materials available and welding techniques limit the pressures which can be actually adopted.

Two examples, that of Synthetic Natural gas (SNG) and coke oven gas would make the above point clear. The economics of SNG generation and transmission depends heavily on the high base load as well as large pipeline capacity. A major project in this area is with the El Paso Natural Gas Company in Texas, U.S.A. Its plans are the most advanced and are to be accomplished by 1977. This would be the first commercial SNG Plant using-coal based technology. Methanation trials are also being conducted in the Westfield plant in U.K.

In India, the Planning Commission has examined the feasibility of a western gas grid serving Bombay and Baroda, based on Chanda coal. Potential SNG, demand in this region is projected at over 150 million Scfd by 1978-79 assuming total fuel oil replacement. These plants are envisaged to operate at 90-100 atmospheres, enabling gas to be sent out at a pressure range of 100 atmospheres, thereby reducing pipeline costs. But without going into details, it would be sufficient to say that on an average a plant that would produce 250 million cubic ft. of gas per day from 16,000 tonnes of coal would cost more than U. S. Dollars 250 million.

Another example is the Durgapur—Calcutta coke oven gas line. Coke oven gas is obtained from the batteries of the Durgapur steel complex and it is transported at a pressure of 18kg/cm^2 upto Bali on the Western bank of river Hooghly. There it is reduced to a pressure of 3.5 Kg/cm^2. The pipeline with an internal diameter of 300 mm is designed for a capacity of 40 million m^3 /day at a pressure of 40 atmospheres, but at present the pipeline is transporting only 18 million m^3 /day at a pressure of 18 atm. on an annual load factor of 0.43. The gas obtained at Bali is further carried across Hooghly by means of a submarine crossing and the medium pressure line ends at the beginning of the gas grid which reaches the end consumers. The project was conceived in 1958 and the gas line was commissioned in 1963. The total cost of the project at the price level of these years was Rs. 48.17 million.

Coal in the Secondary Form—Electricity

Coal can be transformed into electricity and transmitted as electricity. The major question often investigated for the location of a thermal power station is whether it is cheaper to carry coal or to transmit electricity. The factors to consider in the case of electricity is the load factor, line capacity, the voltage level for transmission, AC or DC transmission, line losses, reliability and stability considerations, interconnections in the grid, etc. Thus, the basic requirements of electric transmission can be listed as :

(1) It shouid be economical as compared to other means of energy transportation and desirable from other considerations such as elimination of bottle-necks in the Railway transport facilities or other modes

of transport.

(2) It must be capable of being integrated into the general power picture like the formation of power pools and establishment of inter-connections.

(3) Its reliability should be comparable to that of having the plants located in the centre of gravity of the load.

Any serious investigation of the cost of transmission of electricity must examine the following factors :

(1) Transmission line and electrical equipment costs.

(2) Transmission line capability, i.e., line capacity studies from transient as well as steady state stability considerations.

(3) Line capability variations with voltage.

(4) Line capability variations with distance.

(5) Effects of intermediate switching stations, series compensation, bundle conductors system and line capacity variation due to these factors :

(6) Load factor variations.

Each one of these factors could change the economics of transmission of electricity. The extra high voltage in U.S.S.R. are around 400-500 kv and in Sweden and U.S.A. around 400 kv. In U.S.S.R. a major project of EHV D.C. Transmission at 800 kv from Volgagrad to Donbas to transmit 900 mw is under construction. This is an area of intensive research which is bringing in new develop-ments.

It is clear by now that any reference to cost or attempts to make cost comparisons is deliberately avoided. Costs have to be evaluated and/ or compared for specific projects under the given choice of parameters and for the given conditions. Unless, one is aware of all the factors that contribute to the cost and the procedures of costing, it is hazardous, to draw any conclusions. Especially, for making comparisons of costs by different modes of transport, there should be standardisation both in concepts and procedures of cost computation.

Non-Commercial Energy

The non-commercial energy forms are fire wood, animal dung, vegetable wastes, bagasse, etc. These forms of energy are called non-comercial since they do not come into the monetary circuit. In India, according to the National Council for Applied Economic Research, about 90 percent of the total domestic consumption of energy in the rural areas and about 75 percent in the urban areas is in the form of non-commercial energy. The corresponding figures of the National Sample Survey (Eighteenth Round) are 87 percent and 61 percent, respectively.

It is estimated by the fuel policy committee that in 1978–79, the demand for non-commercial energy in the domestic sector would be 80 percent of the total energy required in this sector, that is about 195.1 million tonnes of coal replacement out of a total demand of 244.5 million tonnes of coal replacement. From the point of view of transportation, there are no serious problems since most of the consumption is localised. Fire-wood is the only one which is generally transported by trucks out of forest and floated on rivers.

Conclusion

To conclude, Asian countries must think more seriously than ever before and act in a big way. Aspects such as rich resources and massive population. We in Asia are notable to progress rapidly. If a judicious selection of resources of energy is made, utilised effectively, streamline transportation system thereby avoiding losses of scarce forms of energy, undoubtedly, India can go a long way in its economic development.

A Decade of Achievement

TRANSFORMING THE RURAL SCENE

Relief for the rural poor and indications of an upswing in the rural economy are the principal achievements of the decade.

- Bonded labour abolished. □ Moratorium on Rural indebtedness. □ Land for landless. □ Increased credit facilities for farmers. □ Better agricultural inputs.
- Bank credit for agricultural development rose to Rs. 7,850 million in 1974-75.
- 28,000 village societies and 1,530 marketing cooperatives distribute consumer articles through 46,000 fair price shops.
- 4.5 million house-sites allotted to the rural poor; housing schemes launched by several states.
- Small-scale industries provide employment to two hundred and seven thousand villagers—an increase of 326 per cent over the decade.
- The number of post offices in rural areas increases to 91,000.
- Village panchayats cover 406.8 million population.
- Electricity covers one hundred and seventy thousand villages—an increase of about 300 per cent over the decade.
- High yielding varieties of wheat and rice now being sown in 60 per cent and 25 per cent of land respectively.

davp 75/740

Material Technology for Energy Systems

T. V. Balakrishnan*

The welfare of any community and its prosperity in economic terms is usually indicated by the consumption of energy, in whatever form such energy is consumed. And, the per-capita consumption is regarded as an index of the standard of living. Further, the total cost at which the energy is consumed has a primary influence on the growth trends, and dictates the directions in which such a growth should take place. Each consumer may still draw his requirement of energy in its diverse forms, depending upon the availability and also the application of such energy. It is well known how the shortage of energy in an economy presents a difficult barrier to economic progress.

Energy sources can be categorised into two : primary and secondary. Coal, natural gas, crude petroleum, hydro power, nuclear energy, solar energy, wind power, tidal power and geo-thermal energy belong to the former category (and some of these forms are still to be exploited fully and some even to be explored), while coke, petroleum products, gases from coke ovens and steels mills, and electricity belong to the latter. The general trend has been to use the secondary sources of energy. Hence utilities may be increasingly set up to harness such primary energy and transform the same into secondary energy for utilisation by individuals. The objectives of any such utility should be :

—to meet the full requirements of the consumer;

—to ensure absolute reliability in the supply;

—to achieve an economic scale of operation.

Types of Energy Systems

Towards the end of the fifties, world consumption of energy was said to be somewhat below 4,000 million tonnes of coal-equivalent per year. By

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the sixties it went up by more than 50 percent, indicating a change in the pattern of fuel-consumption. The consumption of coal which was around 54 percent in 1959 went down to under 40 percent in 1969, while the consumption of liquid fuel went up from 30 percent to 40 percent and that of gaseous fuel declined by 15 percent. The consumption of hydro and nuclear energy remained practically the same, of the order of 2 percent. There are, however, imbalances in the world-wide distribution of energy resources and in the consumption of energy. U.S.A., with just about 6 percent of the world's population consumes more than a third of the total energy, and Asia with a share of 28 percent of the population consumes hardly 3 percent of the energy supplies. Again, in Asia, during the past decade, more numbers of thermal generating sets have been added on to the utilities, and typically in India, the sources of electrical energy will shortly be in the following ratio :

Thermal	...	56 percent
Hydro	...	39 "
Nuclear Power	...	5 "

Fossil fuels and petroleum products are to be considered as non-renewable resources and are fast depleting. Nuclear energy with the fissioning nucleus of the atom and the conventional nuclear reactors have assumed importance, but would take time to occupy a prominent position. At the same time, another technology is fast coming into prominence. The Fast-Breeder Reactor can make more new fuel in the form of fissionable plutonium than it consumes in the course of operation. This Reactor may hopefully come into large-scale commercial operation during the eighties and large units of the order of 500 mw may cater to the needs of the base load operation in many parts of Asia.

The next decade or two will, undoubtedly, witness major technological changes in concepts, particularly, for the generation of power. Direct conversion of heat energy into electrical energy by MHD, thermoionics and the fuel cells, and the fast-breeder reactor in the nuclear field may be developed fully. However, as these are still in various stages of development, it is not expected that the largest unit or the largest power stations constructed in the next decade will utilise any other methods of generation. Except for size, most of the machines would be similar to those in vogue.

The design of any system for energy requires an in-depth study of a wide range of technical and financial considerations, as the high capital costs for energy and long gestation periods, transmission and distribution networks necessitate long-range planning, which cannot be altered frequently. As the energy system gets bigger in size and more complex and intricate with increasing load requirements, and the growing numbers of networks, it reacts quickly to any system disturbances which may pull the entire system out of operation. Therefore, it is essential that protection is ensured against such disturbances.

Any energy system comprises, therefore, essentially the following :

--Collector
--Converter
--Prime-mover
--Electrical Generator
--Auxiliaries
--Controls and protective equipment
--Transmission and Distribution Equipment

The responsibility of utilities is to ensure the availability of energy. whether from coal, oil, gas, uranium or other sources, to meet the ever-increasing levels of demand for industrial, commercial and domestic use. There is a need for all nations to produce and operate a fully integrated energy policy and plan. Fusion power is still to be harnessed, as also the solar, wind, wave or tide or geo-thermal sources of energy. In industrial or commercial operation, the end application is to provide either mechanical movement in some form or heat.

The design of any conventional generating plant or a futuristic source is a delicate balance among conflicting mechancial, thermal, electrical and magnetic requirements. The substantial growth in unit ratings over the last fifteen years has been stimulated by the increased material-capability apart from refined design methods, and some innovatory techniques. Such an interest in *material technology* is important because each component of the total energy system is material-intensive and nearly half of its cost is accounted for by all the materials that go to make the system. These will continue to be exploited, particularly, towards aiding the quest for alternate energy sources.

Special Materials

In the case of high-temperature creep-resistant steels, the industry is continually fed with data on creep, creep-rupture, and stress-relaxation, as these will help to determine design stresses of the steels. These help the designers of boilers, turbines, and associated pipework in systems and the metallurgists to supply products of improved reliability. An enormous amount of data is available with the International Standardisation Organisation (ISO), but the scatter of data is generally +20 percent, which has been found necessary owing mainly to material variation, the range of material specifications and differences in testing techniques among the main contributing laboratories. The designer has often to work with a system, which may be based on extrapolated averages and considered with safety factors as laid down in design codes, or as agreed between the designer and customer. No laboratory is willing to study the possible effects of all the variants but may advise their designers to use steel with less scatter for quick reusults.

In the case of turbines, there is again a great deal of variety. Castings and forgings of carbon-steel and other alloys are the main materials required, with the percentages of chromium, nickel and vanadium from a low to a high value In the high temperature fields, phenomena which require a careful study include crack propagation in creep conditions, fatigue, and facts of environment, and also manufacturing techniques. A number of criteria for turbine blades have to be considered for the selection and among these are :

—Proof strength at working temperature,

—Ductility,

1—Notch toughness,

—Fatigue Strength,

—Damping capacity,

—Resistance to corrosion.

Steel with 12 percent chromium and small percentages of other alloying elements like nickel, niobium, vanadium etc., is constantly under definite improvements as well as commercial exploitation. Electroslag refining is now being increasingly adopted to result in cleaner steels, but the process is still to be perfected. There are well over 200 varieties of blade steels, the main constituents being 12 percent chromium. Advances in design would have been impossible without the simultaneous development of materials demanded by the increasing severe conditions of service.

Similarly, the effect of sodium and helium-contaminants on Nuclear heat-exchanger tubine is a further example, which stresses the need for the collection of more extensive data. The variations in operating conditions, the increasing need for shift operation, etc., will lead to interest in creep-variable load and fatigue conditions. Stainless steel or cupro-nickel has to be used each for conventional heat-exchangers in some cases, in preference to aluminium-brass.

The compatiability of specifications among different materials used in the different elements making up the total system is rather important. If a generating plant is to be developed for giving trouble-free service for 100,000 hours, it is essential that each component of the system is designed with proper material to render that period of trouble-free service.

Considerable work is being done on reinforced plastics, but it is apparent that steel and its alloys will continue to be the predominant material for turbine blading at least for a decade or over, mainly because long-term data based on the requisite testing are not yet available. There can be many applications for plastics to replace metals, which are, however, becoming more and more expensive. Plastics can technically be assumed to replace metals but they may also be expensive as they are derivatives of oil. They have generally high strength-to-weight ratio as well as resistance to atmospheric and chemical corrosion, but their high-temperature mechanical properties are comparatively poor. For such applications, plastics have to be specially developed, after extensive testing for humidity, sensitivity and heat-shrinkage.

For magnetic steels, with silicon, cold-rolled grain-oriented steels are being completely used for transformers while hot-rolled steels and cold-reduced non-oriented steels are used for rotating machines. With better alloying elements and also melting techniques, these have helped in the reduction of losses and also, in certain cases, sizes of machines for the same ratings.

Non-Ferrous Materials

Copper and copper alloys constitute one of the most important requirements for the electrical industry and there have been many significant advances in the application of such material to the technology connected with electrical equipment. The requirements of copper for all the development that is planned by any major manufacturer will be of the order of 4000 tonnes per annum only for electrical machines, and again about 8000 tonnes per annum for transformers and switchgear. The quantities do indeed look attractive for the metallurgical industry, but the varieties of specifications, forms and sizes in which these are required are many, depending upon the end-use.

For turbo-generators, a requirement of five main varieties is normally necessary, like glass braided strips, bare rectangular sections, hollow conductors, grooved copper conductors, and trapezoidal profiles. For hydro-generators, the design parameters are fixed depending upon the, design of the hydro-turbine and these include the output, speed, inertia-overspeed, etc. Normally, the practice is to use resin-impregnated asbestos-woven covered copper strands in the stator windings of hydro-generators. Electrolytic tough-pitch copper has to be used for the conductor material and glass-braided copper strands will find greater application. For the hydrogenerator rotor, the coils are fabricated from bare rectangular sections of flat copper conductors, dovetailed and brazed at the corners to form rectangular coils. In high-speed generators, where the linear speed of the motor is high, silver-bearing copper, with a minimum of 0.06 percent silver, is used to ensure the creep-resistant property of the material. ETP copper is also used for damper bars, and the rings are forged copper, brazed to the bars. In addition, enamelled copper windings, wires and strips and commutator segments for DC machines are two other important categories, with silver-bearing copper being used for the latter purpose.

The basic problem in the design of transformers is the proper disposition of copper or aluminium conductors so that while carrying the rated current, satisfactory thermal and mechanical performance is obtained with acceptable level of losses. The winding wire used for making coils of large power transformers and reactors consists essentially of one or more copper conductors with the surface covered with insulation. Two acceptable grades for such application are electrolytic tough-pitch copper, and fire-refined tough-pitch copper, the former being more commonly used. The presence of oxygen in tough pitch copper cannot be avoided and is tolerated to some extent, but shall be kept well within the limits to prevent gassing, embrittlement and other adverse effects at later stages of processing. However, trace impurities like selenium and arsenic have to be avoided, because these impurities will not only affect the electrical conductivity but will also influence the annealing characteristics and other mechanical properties of the conductor. One of the important requirements of the copper conductor, apart from its size and accuracy of the profile, is a good surface finish. The surface should be bright, smooth, and free from heavy drawing lines as well as sub-surface defects which may give rise to problems during the application of the insulation thereon.

Besides its easy formability including machinability, corrosion resistance and low cost, the superior electrical and thermal properties of copper account for its wide use as contact material in switchgear and control gear, the limiting factor being its low resistance to oxidation and erosion due to arcing. But in many applications, a film developed owing to normal oxidation may be acceptable. Yet, in some other applications such as in drum controllers, sufficient wiping action helps to maintain fairly clean contact surfaces, thus enabling the pair of contacts to perform with low resistances. Oxidation problems do not arise in oil-immersed circuit breakers. Certain alloys of copper such as phosphor-bronze, berylium-copper, nickel-silver have excellent spring properties and are extensively used in switchgear. These are chiefly connected with fuses, controllers etc., where contact is maintained between two parts by means of a spring which carries the current. There are nearly twenty alloys of copper, which are used for switchgear, the main properties in such cases being the high contact pressure, high resistance to the formation of non-conducting surface films, good fatigue properties etc. Copper is also the easiest alloying agent with silver. Silver-copper is widely used to make and break contacts. The addition of copper increases the mechanical strength and hardness. These alloys have a lower tendency to erode under the influence of an are and have better anti-welding properties. Contacts reliability is very important particularly for automated equipment. Electro-chemistry is useful for a number of investigations and there is now a new concept of charge generation by contact between metals and polymer films.

Among the major developments now in progress, the one relating to cryo-conductors and super conductors is the most prominent. The cryo-conductor is a normal metallic conductor which is operated at the low temperature usually below 20° K, based on the principle that the resistivity of a metallic conductor in a strain-free condition, approaches zero at 0° K. The reduction in electrical resistance with decreasing temperature is expressed in terms of the resistivity at 293° K to the resistivity at 4.2° K. This can be very much high. For example, in commercial electrolytic high-conductivity copper, the ratio may be of the order of 300 and in commercial high purity copper is of the order of 1000. The resistivity ratio of copper depends on several factors, like the sources of the ore, nature of impurities present, strain in the material etc., and it has been found possible to attain, by different levels of impurities, values, of ratios between 300 and 1800. The ratio is the highest for high purity copper. Such enormous decrease of resistivity of high purity copper and other metallic conductors like aluminium has aroused considerable interest in developed countries to make use of this property for construction of cryo-cables and with increasing need for underground cables in built up areas for transmission and distribution of power, these cables will find immense application. The manufacture of high purity copper conductors at a reasonable cost, by copper conductor manufacturers, will give the much-needed impetus for fruther research in the field of cryo-cables.

The phenomenon of superconductivity, viz., the virtual disappearance of electrical resistivity of certain metallic conductors when cooled below a particular temperature (critical temperature), has evoked equally high interest and hopes among engineers and scientists. Early in the sixties, it was discovered that certain alloys incorporating niobium, zirconium etc. result in properties of super-conductivity, characterised by high current densities and high magnetic fields and this discovery made the practical applications of super-conductors possible. Present day super-conductors are composite conductors with fine filaments of super-conducting material embedded in a high purity copper matrix, twisted at a regular pitch. Such a construction makes the super-conductors intrinsically stable and highly useful for engineering applications. The incentive to the use of super-conductors in electrical equipment stems from the possibility of eliminating electrical losses, reducing the size and weight of the machines. Commendable work has already been done in the fields of superconducting magnets, and electrical machines, both DC and AC and the work is of importance mainly because of the very significant reduction in sizes and weights for the same ratings of equipment. Notably for equipment of 500 mw rating, a 40 percent reduction in weight and a 4 mw saving in losses are possible. The latter when capitalised results in reduction of half the capital cost of the generator. The major difficulty is the maintenance of the low-temperature environment for the rotor. Similarly the fabrication techniques are also sophisticated and detailed investigations are still in progress.

Materials for Drives

In view of the increasing competition today in motors and drives, there is every need for an optimum choice of materials. Prominent among these would be the increasing use of aluminium or the changeover from copper to aluminium or copper-clad aluminium windings. Also interesting studies are under way for replacing windings by permanent magnets. The emergence of new materials including high temperature insulation, high energy density permanent magnets needs to be taken note of. Motors are required to operate today in more arduous environments than ever before, and there is an increasing use of electronic methods for motor controls which have to be studied along with the possible interactions.

There are many examples in energy systems, where dielectric materials are operated continuously at high electric stresses, like power transformers, and capacitors where, the main consideration is the ability of the dielectric materials to withstand without failure very high A.C. stresses for long periods. The most common liquid-solid dielectric used in such equipment is electrical-quality paper, impregnated with mineral oil or a chlorodiphenyl It has a great affinity for water, but paper is still used because of its ready availability and good mechanical properties. In recent years the trend has been to replace paper by a low-loss plastic material. In power-factor correction capacitors, it has become the practice to use alternate layers of paper and polypropylene film in the dielectric and efforts are being made to develop all polypropylene film dielectrics. For optimal perfomance of a liquid-solid dielectric, three considerations arise including thermal breakdown, electrochemical, deterioration and breakdown due to discharge.

Dielectrics intended for operation at high stresses are normally impregnated with suitable dielectric liquids. The nature of the breakdown process in dielectric liquids is complex and one theory, viz., the cumulative ionization theory is the most accepted one for explaining break-down. Novel dielectrics for power-factor correction capacitors are under development. A number of plastic materials whose dielectric loss is about ten times smaller and whose resistivity is much higher than that of paper are becoming available and the choice will depend upon their compatibility with impregnating liquids and also satisfactory mechanical properties. However, for evaluation of all types, including solid insulation, investigations have to be done on a variety of phenomena including discharge, erosion and breakdown, tracking, thermal instability and deterioration.

The last decade has witnessed a phenomenal growth in materials research, resulting in a wide variety of materials with mechanical, electrical, chemical and other properties unknown hitherto. It is important to consider some of these materials which promise wide applications in energy systems.

Metallurgical Aspects

Until the mid-fifties, technology had depended mostly on polycrystalline materials and since then the situation has rapidly changed. The growth of monocrystals for applications has been an expanding phenomenon, with the varieties, numbers and sizes of crystals increasing daily. The discovery of creep-strength superiority of monocrystals for gas turbine blading has ushered in a technological interest in metal and alloy compositions. Grain boundaries in a polycrystalline aggregate have been recognised as areas of weakness impairing strength under certain conditions such as static loading at elevated temperatures. Monocrystals of nickel based high-temperature alloys have proved themselves superior in gas-turbine blades over polycrystalline structures.

The super strength of small filamentary crystals has been attributed to a near perfection in the sense of freedom from dislocations, crystal imperfections etc., responsible for the low strength of deformable crystals. The weakness of larger structurally perfect crystals apparently lies in the surface condition of these crystals. The atomic roughness of the surface provides sites for the generation of dislocations through stress concentration. These nucleated dislocations, in turn, multiply in the larger crystals to allow plastic flow at low stresses. To obtain ideal strengths in large monocrystals is a challenge with abundant reward but it is one that has not yet been technically realised. Solutions have been contemplated such as achieving ultra-polished surfaces or by selective surface treatments using electron, ion and molecular beam techniques etc.

However, studies have been taken in another direction as well—one of incorporating super-strength filamentary monocrystals in a matrix to form a fibre composite. The preparation of high-strength, low-density filamentary crystals of silicon Carbide (Si C), Carbon (C), Berillium oxide (Beo), Alumina ($Al_2 0_3$), Tungsten (W), Tungsten Carbide (WC) has been successfully achieved with the result that in the near future (1985) one may expect turbine vanes, electrical machines, rotating wheels, blades, nozzles, large turbo-machinery, telephone or power lines to make use of these structural materials to a substantial degree.

Another class of composite materials likely to find increasing applications are the glass, and glass-ceramic composites. The glass ceramic is a porous fine-grain polycrystalline ceramic made from glass. It is not homogenous in the molecular state as is glass; yet it is free from voids, microcracks etc. observed in ceramics. The possibilities of developing prestressed microcrystalline glass-ceramic laminations or built-in prestressing by ion-exchange techniques with tensile strengths as high as 5×10^5 psi have been forecast. These materials are already finding applications as radomes for supersonic missiles, heat-resistant high-strength light-weight consumer ware and as components in low-expansion honeycomb structures for gas burners and heat exchangers. The high ratio of compressive strength to weight of glass independent of special strengthening methods makes glass a material of increasing interest for deep-sea structures that must endure compression and be buoyant at the same time. In spite of (or because of) lack of ductility, glass and glass ceramics will find increasing use in the future.

Electronics

The advances in electronic technology have been phenomenal. The concepts too have changed fast with the descrete components giving way to hybrid, monolithic and large-scale integrated circuit technology. For achieving large packing densities, sophisticated tools for lithography have been developed. Besides the presently used photo lithography, X-ray and electron beam lithography will find wide use in future. Materials based on polymers selectively sensitive to these probes have been under development. It has been observed that if Silicon is the new steel, perhaps these "resists" are the new coals for the manufacture of this steel.

One of the interesting new developments in computer technology is the development of magnetic bubble domain films for memory applications. The two materials which will find use are the single crystal epitaxially grown garnets (Yittrium, samarium, gallium or germanium garnets) and the sputtered amorphous godolinium-cobalt alloys for the bubble material. The garnet approach although probably more expensive per unit area than amorphous Gd-Co alloys and their offspring is more tolerant of the fabircation procedures presently employed because of the chemical inertness of the magnetic oxide systems. One would expect, however, that eventually competition from other technologies such as LSI (Large Scale Integration) and disk would necessitate bubble designs with at least 10^6 bits/chip. This should result from improvements in processing such as featuring by electron beam or X-ray lithography and helped by innovations such as bubble lattice and structure less concepts.

It has been predicted that bubbles will bridge the access gap between LSI, Cores etc., on the one extreme and the drum, disk and tape on the other. High-temperature power rectifiers are highly desirable in a number of specialised systems. An important application is in supersonic aircraft, where, by using rectifiers capable of operating at 300°C substantial savings result in cooling capacity and hence aircraft weight. Another potential application is in nuclear reactor power generation. The range of applications will undoubtedly depend on the cost of these devices, when compared with the cost for the alternative of providing extensive cooling of silicon rectifiers. As the III-V compound technology is further developed, the use of high temperature rectifiers may become economically attractive in increasingly broader areas.

The maximum operating temperature of semi-conducting devices increases with the band gap energy. However, numerous design and technological factors enter into the choice of the semi-conductor. The materials that have been seriously considered for high temperature rectifiers are silicon carbide (Si C), Gallium Phosphide (Ga P), Aluminium Gallium Arsenide ($Al_xGa_{1-x}As$), Gallium Arsenide (Ga As); Gallium Arsenide Phosphide ($Ga\,As_{1-x}\,P_x$). Of these, the latter meterials are technologically the most developed at this time for this application; rectifiers have been fabricated capable of operation (at 300°C ambient) at a current of 50 A with reverse breakdown voltages in excess of 150V. Another material of practical interest is Al_xGa_{1-x} As, in which high voltage diodes have been reported.

Silicon Carbide devices have distinct properties which lead to specific applications; they are operable upto 500°C; they have enhanced radiation resistance and certain particular characteristics such as band gap (2.4 to 3.3 ev) leading to specific devices and applications. The future development of Si C devices probably depends more on engineering perseverence than on semiconductor physics breakthrough. Nearly all fabrication techniques, active devices, integrated circuits that are possible with silicon are possible to be performed on Silicon Carbide.

Materials for New Sources

With the world-wide emphasis on seeking new sources of energy, there has been a spurt in developing suitable materials for converting energy from one form to another. In the realm of direct conversion to electricity, considerable efforts have been expended in thermo-electric processes utilising lead telluride, bismuth-telluride modules, thermionic converter materials such as henium and other refractory materials. A search is also on for suitable solar cell materials besides the well-known silicon and cadmium sulphide for high efficiency performance utilising III-IV group compounds, e. g., gallium phosphide etc. Refractory oxides such as titanis have been one of the more promising materials for direct production of hydrogen through hydrolysis of water under incidence of sunlight. Another trend in most of these efforts is towards achieving a cost reduction. For example, in the case of solar cells, attempts are being made to produce silicon ribbons (polycrystalline) instead of large area single crystals. One will not be surprised if amorphous or vitreous semi-conductors such as chalco-genides i. e. selenides of arsenic, german-ium, thallium etc. become future contenders for this purpose apart from their possible electronic switching applications—mainly from the point of cost reduction and simpler technology when compared with single crystal silicon or epitaxially grown materials.

Several materials in single crystal or polycrystalline form have found applications as transducers. As electro elastic transducers, piezo-elec-tric crystals based on barium titanate have been for long in use. However, newer materials such as niobates and zirconates have come into the field recently. As electro-optic transducers, pottasium dihydro-gen phosphate and ammonium dihydrogen phosphate crystals are well known. Here again some titanates, biobates and tantalates of transition metals hold promise for the future.

With reference to the MHD scheme of power generation, several stringent technical requirements have to be met by the materials that go into these generators. The formidable problems are electrode materials which should have good electrical conductivity and high resistance to mechani-cal, electrochemical erosion due to hot contaminated gases and electri-cal discharges. At the same time these materials should also have good thermionic emission properties, thermal shock resistance and chemical phase stability. The most promising material for such application appears to be stabilised zirconia doped with calcia and yittria. However, even this lacks the required thermal shock resistance. Similar problems exist in the case of insulating materials for this applications. Alternate methods such as utilising argon plasma electrode materials instead of these electrode materials are also being investigated.

Of late, there have been serious apprehensions expressed about the adequacy of the world's material resources by the turn of the century and maybe, about economic exploitation also. With increasing energy costs, the total costs for converting these into useful and vital products for mankind, may also be very high. In this context, it is essential to consider simultaneously an alternate approach to energy conservation and saving. An important field of activity in this direction is the electro-luminiscence phenomena observed with several phosphors, the most promising one being zinc sulphide doped with activators like copper and halogen coactivators. Multicomponent phosphors for producing white light with conversion efficiencies as high as 70 to 80 percent are expected to be developed in the near future The realisation of practical materials and technologies in this direction will no doubt revolutionise the lighting industry with substantial savings in energy consumption.

Conclusion

An attempt has been made above to analyse the growth trends in *material technology* required for energy systems, particularly, in view of the stringency in the specifications and also the costs for development when potential applications cannot exactly be foreseen. For conventional equipment, the costs of materials from half the total costs for such equipment and such materials have for long remained practically the same basic ones, without any major breakthrough. A better understanding of basic phenomena and R&D effort towards more efficient utilisation have resulted in various components in the system becoming individually competitive. It can be predicted that these efforts will continue until the turn of the century.

At the same time, new or unconventional sources of energy are likely to be tapped and it is established to a great degree now that some basically new materials and compositions will be required. Considerable R&D effort is being mounted in various countries. It is expected that such effort will naturally result in breakthrough in certain areas of material-technology and there is a willingness on the part of many laboratories to undertake such effort on a mutal and cooperative basis. Many of the Asian countries are endowed with rich mineral resources and it is possible that many of the results of R&D effort can be successfully applied to result in a better utilisation of such resources and to develop selfreliance in the vital field of *material technology*.


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Waste Heat System

G. V. Ramana* **P. R. Srinivasan****

The present energy crisis has really hit every country, but this could well prove to be a blessing in disguise. Now that everybody is looking into ways of conserving energy and saving money, they are bound to discover just how much they have been wasting in the past. And in most cases it has been a lot.

Considerable heat is being wasted in industries that could be reclaimed by proper use of waste heat systems. Heat dissipation from a process, exhaust heat from the engines and heat of the flue gases from boilers and furnaces are all different kinds of waste heat available which should be recovered for optimum fuel economy. In this context a number of waste heat systems have been applied, depending on the situation and the major heat recovery systems are economisers, air heaters, waste heat boilers, energy wheels, heat pumps and heat pipe. These are general in character but special recovery systems designed for an individual purpose also exist. Only general systems have been discussed here.

Economiser

The economiser can be regarded as heat recovery system placed in the flue path to abstract some of the heat that would otherwise get rejected to the chimney. It may also be regarded as an extension of boiler heating surface which is added as a means of obtaining higher boiler efficiency. It has been established that about 1 percent fuel costs can be saved for every 6°C rise in the temperature of the boiler feed water.

When more heat is available than can be used in increasing the sensible heat of the feed water, it may be necessary to use a steaming economiser or to reject the surplus heat to the chimney or pass it

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through an air heater. In most economisers, however, the feed water is not heated higher than to within 30 to 50°F, of the temperature corresponding to the boiling point of the boiler water, thus preventing steam formation and subsequent water hammer risks.

Type of Economisers

Basically there are two types of design in general use : (1) plain tube type economisers (2) Gilled tube type economisers.

1. Plain Tube Type Economisers : It will be found that plain tube type is widely favoured in Lancashire boiler installations working under natural draught. The tubes are made of cast iron to resist corrosive action of the flue gases and their ends are pressed into top and bottom headers The economiser consists of a group or groups of these vertical cast iron tubes erected in the main flue between the boiler and the chimney. The waste flue gases flow outside the economiser tubes and heat is transferred to the feed water which flows upwards inside the tubes. The external surfaces of the tubes are continuosly and directly cleaned by circular scrapers moving up and down, preventing deposition of soot which is a bad conductor of heat and thus maintaining high efficiency of the economiser.

Plain cast iron tubes are used where space is not a restriction. The economiser tubes available in standard lengths of 9′, 11½′ and 13′ are hydraulically pressed into top and bottom headers to form sections 4, 6, 8, 10 or 12 tubes wide as required. The sections are assembled in groups, the number varying according to the evaporation of the boiler plant and duty required from the economiser. Bare steel tube economisers are used with boilers with high gas temperatures. These economisers are especially suitable with difficult to burn like phosphatic fuels.

2. Gilled Tube Type Economisers : A reduction in economiser size with increased heat transmission can be obtained by casting rectangular gills on bare tube walls. Cast iron gilled tube economisers can be used upto pressure of 650 psi (45 kgf/cm^2) but at the higher pressures, the cast iron is unsuitable. Steel tubes are then used and have cast iron gilled sleeves shrunk into them. The inner steel tube, serves to withstand high pressures while the cast iron gilled sleeves resist any corrosive attack.

The ideal arrangement is for the gases to pass vertically downwards over such a group and water upwards thus obtaining approximately contraflow heat exchange. Trouble with soot deposits has necessitated modifications of the old style circular types of gills and tube body is now approximately "diamond" shaped and is provided with rectangular gills. Welded steel gill economisers should be seriously considered when the minimum feed water temperature is around 300°F and sulphur trioxide is present in the gases. Fig. 1 gives the saving in fuel at different gas temperatures.

Air Pre-Heaters

An alternative method of recovering waste heat in the flue gases consists of installing air-preheaters. The temperature of preheat is limited by the fact that the very hot air greatly increases the rate deterioration of furnace bars. Further, the air heaters are more susceptible to corrosion than economisers and in general, are not so durable if made of M.S. It is common to use C.I. air preheater in boiler practice. The advantages of preheated air include fuel savings, higher flame temperatures, increased heat transfer, complete combustion of fuel, etc. In boiler practice, tubular air heaters are used. It is estimated that every 30° F to 35° F reduction in flue gas temperature results in a fuel savings of 1½ percent.

There are basically two types of air heaters used, namely, (1) recuperative; (2) regenerative. It is necessary to select the appropriate type of air heater, depending on the purpose. The selection depends on flue gas temperature and its quantity, the temperature of preheat required and its quantity.

Recuperators : A recuperator is a heat exchange between the waste gas and air to be preheated. It usually consists of a system of ducts or tubes some of which carry the air for combustion to be preheated, the other containing the source of waste heat. Three types of systems, viz., counterflow, parallel flow and crossflow systems are in vogue. Figs. 2, 3 and 4 show the typical systems. The recuperator may be made of refractory material or metal. For high air temperatures ceramic/tile recuperators are the obvious choice. However, they are bulky and the main difficulty arises due to leaks. In metallic recuperators the leakage

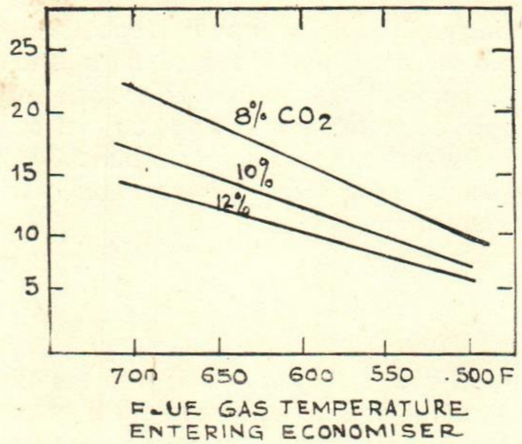

FIG. 1 : SAVING IN FUEL AT DIFFERENT GAS TEMPERATURES

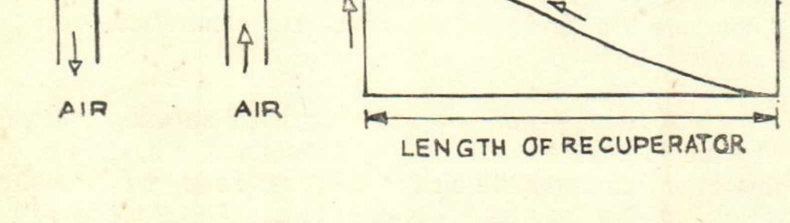

FIG-2: COUNTER-FLOW RECUPERATOR

is prevented. Very high temperatures of air cannot be obtained due to the limitations on the materials available for construction. Recent development in materials permit air temperatures as high as 1000° F and above. Nickel-chromium and other heat-resisting alloys are finding increased application.

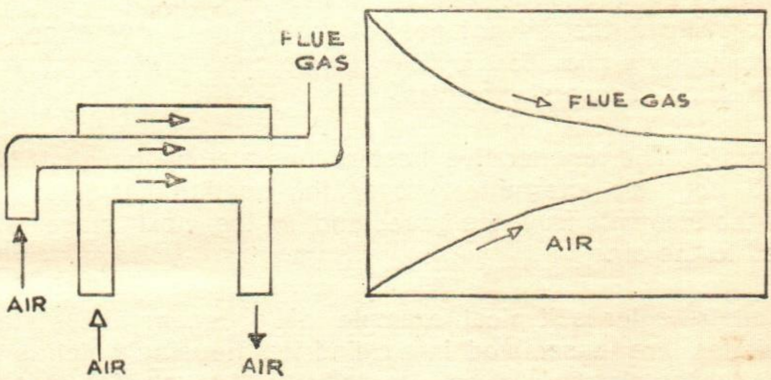

FIG. 3: PARALLEL-FLOW RECUPERATOR

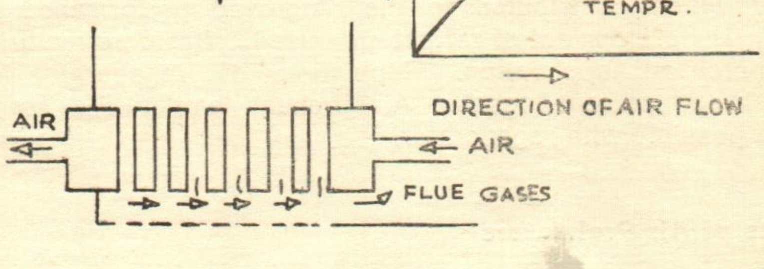

FIG 4: CROSS FLOW RECUPERATOR

A problem normally encountered is the secondary combustion that takes place in the recuperators. It is not advisable to use metallic recuperators in such cases, as high temperatures result in scaling of metallic tubes and their damage. The high gas temperature to the recuperator has detrimental effect on the life of metallic recuperator. Recuperators have the advantages of continuous operation, steady preheat temperature chambers built in single units instead of in pairs and the absence of reversing valves.

Regenerators : The regenerative heaters operate by passing hot flue gases and cold air alternatively over the heating elements. Heat is picked by the elements from the gases and in the next stage of cycle transferred to the air.

Ljungstrom air heater is typical example of a regenerator. Here the element plates are assembled in a cylindrical housing which is rotated slowly so that the elements pass alternatively through the gases and the air during each revolution. The elements are heated by the gases and then cooled by air. Thus, the heat transfer is continuous.

Where very high air preheat temperatures are required, the obvious choice is the generator. It should be possible to time the flow reversals on temperature basis as this ensures correct temperature of air for combustion. This is also necessary to ensure that constant Btu output is obtained in each side of the furnace, as the temperature differential should be minimum.

The factor which contributed to the improved performance of the regenerator is development of refractories used. Basic refractories are finding increased application. Insulation of regenerator is also necessary to reduce heat losses. Air preheat temperatures of 1400°-1500°F are possible with regenerator.

Economics of Air Preheaters

The return of heat to the furnace in the form of preheat renders an equivalent thermal amount of fuel unnecessary and if the fuel supply is not reduced, the furnace becomes overheated. The effect on fuel consumption is greater than bare fuel equivalent, because the volume of waste gases is reduced and the heat lost from the outgoing waste gases is reduced. Table 1 gives percent saving in fuel consumption by preheating air.

Fuel Saving by Preheated Air

Temperature of the gases leaving the furnance °F	Percent saving in fuel consumption by heating air to 1400°F	Percent saving in fuel consumption by heating air to 600°F
2600	48.0	27.0
2400	42.0	22.0
2200	47.0	18.0
2000	32.5	16.0
1800	29.0	14.0

In both regenerators and recuperators, the prevention of condensation within an air-heater is imperative. It is also necessary to provide suitable by-pass arrangements to by-pass the gas during startup, shutdown and low load periods.

Waste Heat Boilers

Whenever a process waste product or gas is continuously discharged at a high temperature, heat recovery by boiler should be considered. Specific process requirements in the production of steel, copper, zinc, cement, paper and the like have resulted in the design of waste heat boilers. These waste heat boilers may be classified in the following manner :

1. Gas tube boiler for relatively clean gases;
2. Water tube boiler for clean or dust laden gases;
3. Bent-tube boiler for very heavy dust ioadings;
4. Three drum low heat boiler for light dust loadings;
5. Water wall, 2 drum boiler for gases laden with sticky particles;
6. Positive circulation boiler for clean low temperature gases;
7. Prsssurized or supercharged boiler for gas turbine exhaust.

Selection of a waste heat boiler is based on the following considerations :

1. Chemical nature, temperature and corrosiveness of the gases;
2. Quantity, amount and nature of dust contamination;
3. Available draft;
4. Desirable location of the flue outlet;
5. Whether the gases are under pressure or suction;
6. Space available;
7. Requirements for supplemental firing for startup, preheating, emergency use, stabilising furnace conditions or added capacity;
8. Other special requirements of the individual process.

Heat Pipe

Heat pipe is a recent development that shows great promise as a heat recovery device mainly because it has not moving parts.

As shown in fig. 5, the heat pipe consists of a hollow tube lined inside with moist fabric wick. One end of the tube is put in the path of either direct heat source or hot waste gases. The heat from the hot waste gases evaporates water from wick lining and the vapour travels to other end of the tube, along the entire length which is well insulated. The other end of the heat tube is located in the path of cold fluid (say water). Heat is absorbed from vapour by this water and the vapour condenses on the wick and condensed water by capillary force travels back to the front and (hot gas side) of the tube. This heat from hot gases travels to cooler fluid (water). The conventional method of transferring heat from hot gases to the surrounding water, would normally give overall heat transfer coefficient of 1000 Kcal/m^2/hr. °C. The figure also indicates the vapour pressure and liquid pressure gradient indicating the pumping pressure, which pumps the heat from the hot gases to the cooler fluid. No gravity is needed. It will be seen that heat pipe is 25 times more efficient heat transmission instrument than conventional ones.

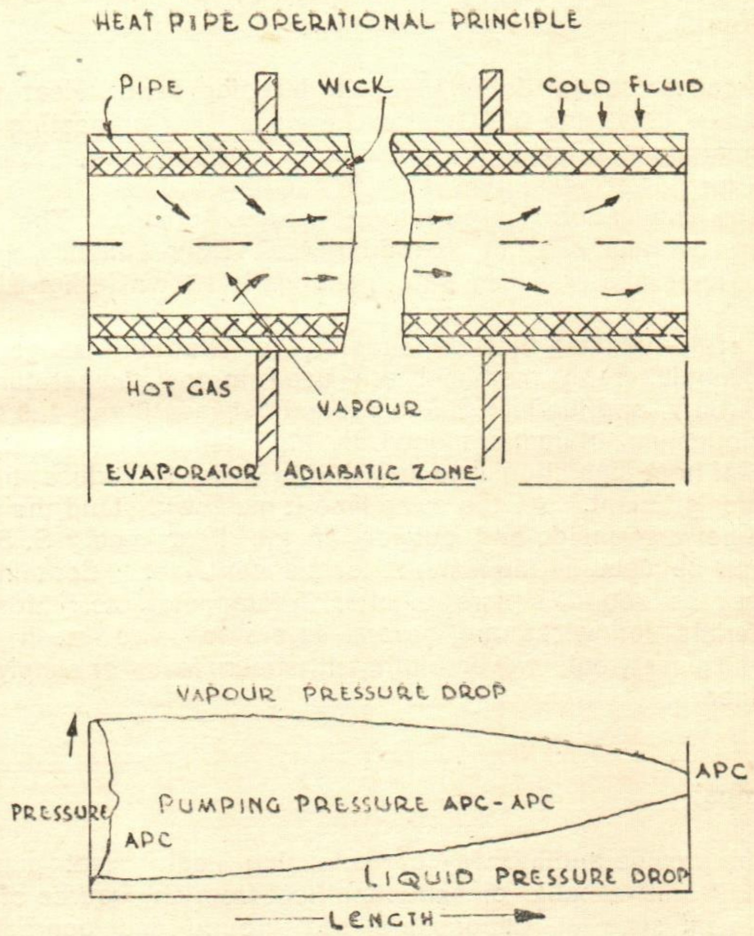

FIG. 5

Heat pipe can be designed for any variety of applications and heat can be transmitted to quite a long distance from a heat source. To get an idea of the transport capability of heat pipe let us consider the following example :

A ½″ S.S. tube heat pipe transfer 1.5 kw heat (exhaust gases at

300°F) to air at 75°F at a distance of 11 feet from the heat source.

Heat pipe can be used in infinite ways to transfer heat. Heat pipe can replace many shell and tube heat exchangers. Air preheating could be done by heat pipe connected to hot exhaust gas in cars. Now-a-days, when fuel for power generation is a challenging problem, we can think of heat pipe application for the total energy concept. The possible application of heat pipe in extracting heat from chimney, gases by concentric heat pipe (for feed water heating) is shown in fig. 6.

Selection of the working fluid depends on the operating range of heat pipe. Ammonia, freon, methanol are used in low temperature range. Water, mercury and thermic fluid is suited between 0 and 4υ0°C. Liquid sodium, pottasium, lithium are used in high temperature applications. Container of heat pipe should be very thin in order to reduce the radial temperature gradient. At the same time it must withstand the pressure difference between inside and outside of the heat pipe. S. S. nickel, copper can be used as the material for the container. Container cross section may be round, square, elliptical, rectangular etc. Most widely used materials for wicks are several layers of wire mesh screens, fibre glass, glass wool, woven cloth, felt, sinter, leads or simply slots in the container.

Heat Pumps

Heat pumps provide another way of reclaiming heat. Heat pump is a refrigeration unit capable of extracting heat from any source of useless low grade heat such as atmosphere, sea, ground and upgrading this heat to a useful temperature. This operation can be visualised as shown in Fig 7.

Starting with compressor, the refrigerant gas introduced into the cylinder is compressed and its temperature rises. The hot gas is now passed through the condenser coil and cooled by the surrounding medium giving up its latent heat. Condensate thus formed is collected in a liquid receiver and from here it passes to a restrictor which can be in the form of a valve or capillary. The performance of the restrictor is of dual purpose, namely to control the amount of liquid admitted to the evapora-

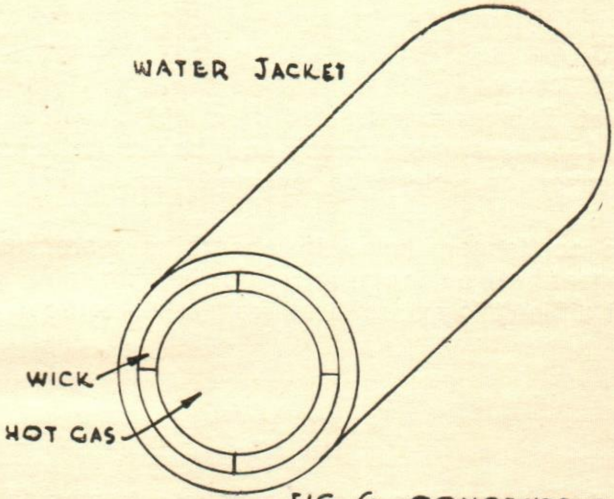

FIG. 6. CONCENTRIC HEAT PIPE

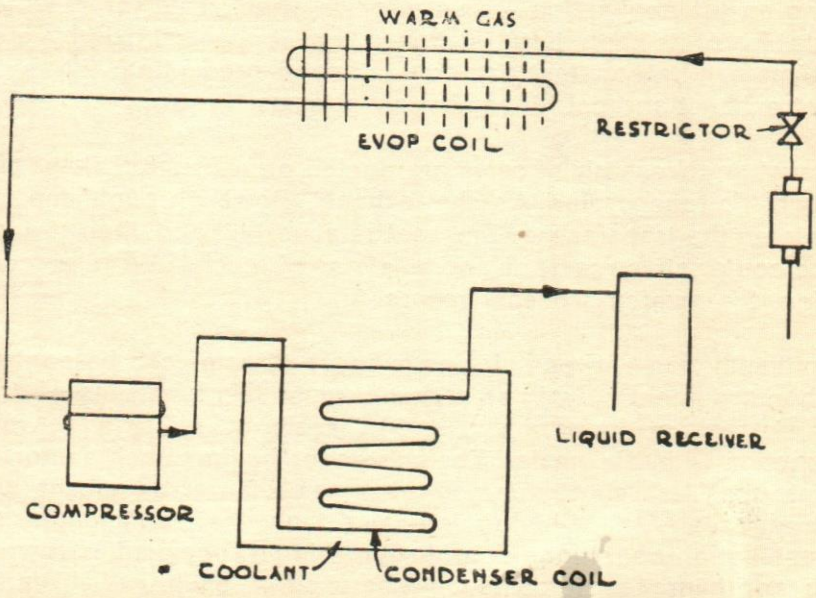

FIG. 7 PRINCIPLE OF THE HEAT PUMP

tor and also to perform a throttling operation, thus lowering the temperature. The cold liquid refrigerant and some vapour is conveyed through the evaporator coil and heat is extracted from the surrounding medium. The surrounding medium can be in the form of warm air, soil, water or any other source of heat. The heat extracted from this source serves to evaporate the liquid in the evaporator coil and the vapour is now sucked back to the compressor for cycle to be repeated again.

Subcooling in the condenser, helps in absorbing more heat in the evaporator. At present heat pumps are used for heating and ventilating units. But it is not difficult to extract heat from other sources.

Energy Wheels

This could be used to salvage the heat in exhaust streams and redirect it for useful purposes. This is nothing but a rotary regenerative heat exchanger. Here an assembly of knitted wire mesh or other material depending on the application form a rotor or wheel. This rotor which is removable from its mounting is driven on its central axis by a small gearhead motor at a constant or variable speed presenting the sectors to the hot exhaust and cold incoming air streams in turn.

The exhaust and fresh air streams are ducted on a counter flow principle through the regenerator. As the exhaust flows through the mesh which acts as the transfer medium, heat is absorbed and then transported to the cooler air stream on completion of cycle. With a cooling application, the reverse process occurs.

Cross-contamination between air and exhaust streams can be controlled to less than 1 percent by volume in standard models by means of double labyrinth air seals at the periphery and internally by utilising scavenger in conjunction with air seals. The scavenger flushes each sector as it rotates into the fresh air stream and presumes a fan arrangement where the fresh air side is at a higher pressure than the contaminator side. Where installation conditions do not allow this arrangement, hardwearing synthetic non-hygroscopic seals must be used at each radial partition and then cross-contamination may be as high as 8 percent by volume. The principle is illustrated in fig. 8.

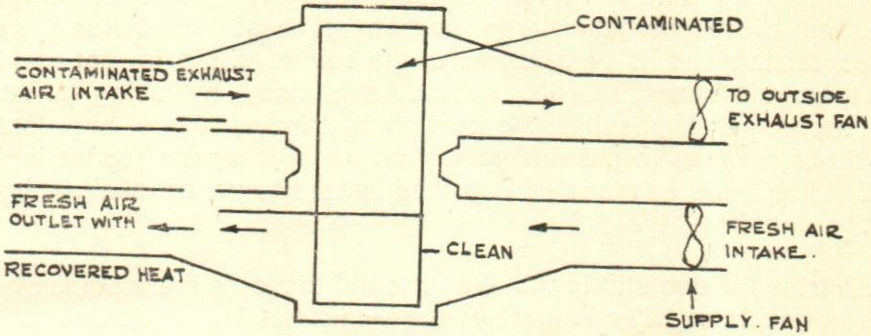

FIG - 8

SCHEMATIC DIAGRAM SHOWING THE PRINCIPLE OF OPERATION AND THE ARRANGEMENT USED TO PREVENT CROSS - CONTAMINATION

The materials from which the motor and heat transfer media are constructed depends on the quality of exhaust air streams in terms of contamination and temperature for pH values of 7 or lower (acidic) and average exhaust temperatures of upto 200°c, the rotor and mesh are made of aluminium. For pH values of 7 or higher (i.e., alkaline) and average exhaust temperature of 425° C, a steel rotor and S.S. mesh are used.

Heat Recovery from Miscellaneous Sources

Boiler blowdown contains a large amount of heat depending upon the working pressure of the boiler. Blowdown is a scale producing and sludge bearing liquid which could cause trouble in shell and tube heat exchangers unless the equipment is designed with ease of cleaning. Continuous blowdown is a more convenient form of operation than intermittent blowdown. A useful compromise can sometimes be made by using continuous blowdown to certain periods, say during the whole afternoon or whole night-shift. If these periods amount to hours, the heat can usually be collected.

Hot waste liquids in large quantities are cotinuously being dumped into rivers and ponds. Thus, heat is lost which must be replaced to heat up new circulating fluids. A suitable heat recovery system can usually be arranged to recover the large portion of heat otherwise wasted. All *condensate* should be returned to the boiler. If this is not desirable due to contamination, the heat should be retained by using a suitable heat exchanger. If possible, the heat content in all vents and leakages should be retained in the system which usually means collecting to a central point and condensing in a feed water heater or similar type of heat exchanger.

One final technique still in the experimental stage is the storage of coolness in panels of entectic salt hydrates—inexpensive crystals that freeze solid at 55°F. By running the a/c system during off-peak night time hours ice builds up in the panels. During the peak loads during the day, the refrigeration compressor is supplemented by coolness stored in the panels which now replaces the evaporating unit as the cooling agent. By evening, the salts have melted and the cycle is repeated. A/c equipment can be smaller and less power is consumed.

Conclusion

The installation of waste heat salvage equipment should be decided purely on merits. The money saved by the salvaged and waste heat is more or less reduced by the interest on investment in the equipment, pipings, ducts and maintenance.

Maintenance in Energy Systems

M. G. Joshi*

In India, today, the utilisation of thermal stations is only of the order of about 4200 kwh/kw. There is considerable scope to improve the utilisation through improved reliability and availability, thus to alleviate the bane of power cuts afflicting most of the country. Improved maintenance practice can greatly help such an effort. This paper describes the goals and working of a good maintenance programme applicable for energy systems.

The advent of pulverised coal firing, improvements in steam generating units, combined cycles, viability of nuclear power, improved manufacturing techniques combined with improved instrumentation and automatic controls have brought about a spectacular increase in the size of energy system units. Further, automation, a necessity for ensuring reliability of large units, has constantly reduced the number of employees required for production. It has concurrently increased the maintenance requirements. Maintenance is now a highly technical and one of the most important functions in energy systems. Improved techniques in observation, planning and control of maintenance work allied with good stores control, maintenance information system and personnel training are the tools to achieve the objectives of good Maintenance in Energy Systems.

Maintenance Goals

1. *Reliability* : Reliability is defined as the probability of a system or a machine performing its purpose adequately for a period of time Intended under normal operating conditions. A high degree of reliability can be ensured by several means such as :

(a) a design, matured through learning process,

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(b) the use of redundancy techniques in ancillaries and protective systems,

(c) periodic marginal testing of equipment,

(d) reliability specifications for critical spares, and

(e) advanced maintenance planning.

While means (a) and (b) are considered during design, once the plant is installed, it is rarely altered. Items (c), (d) and (e) form the basis of observation techniques, maintenance control and stores management.

2. *Availability :* Availability is defined as the degree to which an equipment/component is in the operable state within its rated capacity for a given period of time. Maximum availability can be achieved within a given plant by :

(a) Careful planning of the various activities in the normal day to day work and during outages. (Since most of the auxiliaries have built in redundancy, a lot of maintenance work can be done during off peak hours, nights and week ends.),

(b) Planning of resources of manpower and material in advance, and

(c) Ensuring that the quality of work carried out is of high order.

Observation Techniques

Good maintenance begins with a well-coordinated systems design, established from learning process. Plant equipments are capable of operation within an expected region of performance. From variations in operating parameters it is possible to find out what the equipment is trying to tell about itself. Observation and estimation techniques of an intelligent operating personnel include :

(a) 'On line' observation :

1. of indicated and recorded data from plant instrumentations or from loggers

Example : During rolling of a turbine, it was observed there was a sudden step rise in bearing vibrations. Though the new level was well within permissible limits, turbine was inspected and it was observed two blades were broken. After machining upto blade roots, tests showed several more had root cracks which if continued could have caused serious damages;

2. during special tests conducted to determine capability and efficiency of the plant as a whole or of individual equipments; and

3. during special tests, to monitor, investigate and relate internal equipment/component behaviour or status and induce or simulate normal/abnormal behaviour during abnormal occurrences. In this connection, analysis of occurrences and failures greatly help in avoiding recurrence of such a failure.

(b) 'Off line' observations :

1. during visual inspections of components, alignments, etc.

2. through non-destructive tests such as dye penetration tests, ultrasonic tests, boroscope probing, 'X' ray and chemical analysis etc; and

3. through destructive physical, metallurgical and chemical examinations on failed components.

Observational techniques permit an accurate evaluation of the internal status of a running plant or equipment and help in detecting faults in the incipient state. Estimation techniques help in establishing the optimum maintenance strategy, so that the corrective action can be taken just before the operating condition becomes unsafe or when ideally suited to system conditions. Some of the observational techniques well-known and in practice are enthalpy drop tests, diagnostic tests of transformers and motors including gas analysis using gas chromatography, capability tests, 'signature analysis' such as vibration analysis of bearings and analysis of oils on engines and failure analysis.

Maintenance Planning and Control

Maintenance Control : Maintenance, in the past, as mentioned earlier, had been based on the 'hit or miss' method. It is also known as 'Breakdown Maintenance.' In this type of maintenance, equipment or plant is allowed to operate until it fails, before it is repaired or replaced. No planning is required and involves substantial waste of manpower. All work is generally done on emergency basis and not only downtime is excessive due to non-availability of required spare but also the standard of work suffers. However, it is useful in case of inconsequential parts or components, which have no bearing on the main process and downtime does not effect production in any way because of adequate standby. In such cases components can be used over their full life span.

The growth in size of equipment in industry and associated increase in capital cost gave birth to the idea of preventive maintenance. Its goal is to prevent breakdowns, and thus extend plant operating time by means of scheduled inspections and periodic overhauling of equipment. It achieves the objective of improved reliability but entails great costs. In most of the energy systems, if all equipments are to be inspected according to stringent preventive maintenance schedules, it would involve frequent partial or total outages of units. This would mean big generation losses. Also the possibility of introducing faults inadvertently during inspection is enhanced. Thus, its popularity is on the wane in energy systems.

Predictive maintenance has emerged by combining the strong points from both breakdown and preventive maintenance. It also adds advanced scientific techniques to maximise operating time, increase availability and eliminate unnecessary work. Equipment is run to a point just short of failures based on the maxim, "Similar equipments operating under similar conditions have similar type of life-death curve, thus will have similar predictable type of maintenance requirements". Preventive measures are taken only for equipment whose failure could create a serious hazard or whose operation is especially critical. It helps to catch faults at the incipient stage. Predictive maintenance extends availability without the sacrifice of reliability, eliminates unnecessary work and cost and is easy to follow. Thus a good and economical maintenance programme in energy systems would basically be predictive maintenance schedule with preventive maintenance adopted for equipment which are critical. Such programme can only be determined from failure analysis. The failure of equipment/component can result from :

(a) Normal wear and tear

(b) Consequential failures of equipment/component due to failure of a single equipment/component. This type of failure is often experienced in "Break-down maintenance".

(c) Accidental failures owing to human error, faulty design or operation. Here it should be pointed out that only good operation to maintain operating conditions well within permissible limits alone can give control on expense, over maintenance effort, and

(d) Catastrophic failures occurring at random due to internal or external causes.

Predictive maintenance totally avoids failures due to wear and, tear while the other failures can only be attended to on breakdown basis. However, recurrence of failures from faulty design can be avoided by improved design. Similarly recurrence of failures from human errors and faulty operation can be avoided by good training and imporved/ modified procedures. Though these measures greatly reduce the incidence of breakdowns, they cannot be totally avoided. However, their probability can be greatly reduced through preventive maintenance of critical equipment.

Maintenance Planning : Once a maintenance schedule is drawn, its success depends on its planning. Major maintenance of present day energy systems involve work on many components.

A good example is the overhaul of a large thermal unit. A modernr thermal unit comprises steam generating unit, turbine, generato-condenser, feed cycle auxiliaries such as heaters, pumps and valves, transformers, motors, electrical switchgear, protective circuits, instru mentation and a host of other components.

Since varied and innumerable jobs are involved in such an overhaul, for a successful completion of all work involved in minimum time requires careful planning. Even months ahead of the outage, regular meetings of representatives of various sections in the plant namely, Operation, Electrical Maintenance, Mechanical Maintenance, Instruments, Civil, Stores and Purchasing should be held, In those meetings, work to be carried out during the outage should be broadly drawn out, based on observation and estimation techniques discussed earlier. This will assist every section its role in the overall picture.

This pre-outage or advance planning meeting helps in resource planning, where common resources such as tools and tackles, skilled supervisor and craftsmen are shared judiciously to keep outage time to minimum. The predictive maintenance schedules would help in ascertaining the spares, skill and tools requirement. Equally important are the requirement of gas cylinders, welding machines, scaffolds and other consumables which are common to all including canteen and wash facilities.

To enable correct assessment of resource requirements, work during the overhaul on each equipment/component should be divided into individual activities. They should then be arranged and grouped to find out whether they be run in parallel or in sequence. They can then be drawn in a network form (Critical Path Network—Time Based). The activities which go in sequence and take the maximum time will be the critical path. Also while drawing the network manpower deployment and availability of tools such as cranes for the activities should be carefully considered, as seemingly parallel activities may actually be serious activities due to the common requirement of personnel or tool. Actiivities in this path should be given maximum attention as any delay in any one of the activity will increase the downtime of the units. Sometimes it is possible that a slightly less critical event may become critical as a result of the increase in the magnitude of work decided after inspections.

Meetings of representatives of various disciplines should continue during the outage to review the progress and, if necessary, to modify CPN in light of latest developments. Such meetings greatly help in changes in allocation of resources to avoid less critical items becoming critical.

The CPN should be explained and understood by all those who participate in the outage work, including craftsmen. The CPN charts should be displayed at strategic locations, so that persons involved in outage work can ascertain their own performance and determine whether any additional efforts are required to maintain their schedule.

The availability of spare parts needed during the outage, require attention much earlier to the outage. The planned ones to be replaced should be fabricated or procured and kept ready for use. Those available in stores should be checked for their service worthiness. (occasionally items stored in incompatible atmosphere may be found useless, such as electrodes, electrical equipment such as coils, rubber components, and bearings.) Consumables and heavy parts may even be moved to the job site, in advance.

Lifting tackles, cranes, etc., should be checked and serviced to ensure their reliability during the overhaul. The technicians, craftsmen and supervisors need briefing on the role expected of them and check up tooling required for the same.

Stores Planning

Another important requirement for success in maintenance system is the stores planning. No maintenance system is complete nor can function satisfactorily without a rational stores planning, because the schedule of maintenance works can only be fulfilled when the necessary spares are made available at the required time. The characteristics of spares demand can be described on the basis of :

1. *Criticality :* Some equipment as a unit and some components of certain equipment are very critical, the failure of which can result in a partial or total outage.

2. *Failure type :* As mentioned earlier, replacement may be necessary as a consequence of failure due to wear and tear, accidental or consequential failure or catastrophic failure.

3. *Usage :* Generally during the life span of an equipment, certain components are likely to fail and need to be replaced during the life of the equipment.

4. *Predictability :* The requirements of spares for components in a plant can be predicted to a certain degree. Generally 2 percent of the components are positively needed, 90 percent may possibly be needed and for the remaining 8 percent the requirement is very unlikely. By proper selection of spares for the 90 percent, based on reliable failure analysis, Inventory cost can be brought down.

5. *Cost of Spares :* Low cost critical items must be stored in sufficient numbers, while the quantity of medium and high cost items should just be the predicted quantity. All essential (not critical) low cost items must be stored. Storing medium or high cost essential items depend on nature of supplies and lead time. Desirable items of low cost may be stored in minimum quantities while of medium and high cost need not be stored.

In addition, two factors that influence the selection for storing spares are whether the item is of a proprietory nature or locally available, and whether it is available ex-stock or with a long lead time.

The spares policy should be drawn out in the form of general rules and cover decision making on six aspects namely form, source, when to stock, standardisation, ordering method and budget.

1. *Form :* Spares may be as complete units (very costly) and assemblies (moderate cost with little downtime) only for very critical equipment or as spare parts (low cost with more down time).

2. *Source ;* Four main sources of spares are repair, make, buy or borrow.

3. *Whether to stock :* Items which have long lead time or are critical, should be stocked.

4. *Standardisation :* Standardisation will enable to keep the inventory low specially on items like fasteners, electrodes, ball and roller bearings, lubricants, oil seals and motor and switchgear. After reviewing the recommendations made by the manufacturers of various equipment in the plant, standard items should be identified.

5. *Ordering methods ;* Ordering methods depend on stock control, maximum/minimum schedules, base stock control (for low annual requirement and lead time) and order on demand.

6. *Budget ;* Self explanatory.

So far an attempt has been made only to detail in general a broad policy for stores management. Even after a thorough review, a judicious decision will have to be made since :

(a) Outage costs (Stop costs) can only be reduced by increased spares provision (high inventory cost), and

(b) Inventory costs can only be reduced at the expense of increased outage costs.

This anomalous situation can be eliminated by adopting changes in plant management whereby both inventory and outage costs are reduced. The changes in plant management that will help are :

(a) Adoption of a good maintenance programme from which spares requirement is accurately predicted.

(b) A proper machinery purchase policy to introduce sound redundancy and standby capacity without much increase in capital cost.

(c) Standardisation of assemblies.

(d) Rate contract for certain stores items to eliminate over-stocking, ordering and stores cost, and

(e) Import substitution, to avoid unduly long lead times in procuring imported items.

Maintenance Information System

A basic requirement of a successful maintenance programme is an accurate and comprehensive maintenance information system. It is essential in such a system that all equipment failures and maintenance actions are reported in suitable work order forms. The work order forms should have details of defects noticed, work done, load restriction if any, manpower utilised and tools and materials used. Such work orders should be made not only for day to day maintenance work (on-line jobs) but also for jobs carried out during major overhauls.

The resulting information can be utilised in spare parts provisioning maintenance work, load planning and maintenance policy evaluation. It helps in reducing component failures by overhauling of complex components at scheduled intervals. The data available can also help in estimating MTBF (Mean Time Between Failures) for components which are exposed to wear and tear accurately, and help in gradual extension of time between overhauls (with failure free operation) with attendant savings. It may be mentioned that it may not be possible to collect data sufficiently accurate to permit scheduling inspection just prior to equipment failure. But with sufficiently good data, frequency of inspection can be reduced and so also the cost of inspection. It can also be used for determining meantime for repairs so that outages can be scheduled with precision. One other advantage is, it promotes confidence in maintenance data collection. Once the reliability of various equipment is well established, it may be possible to review the plant reliability as a complex product of the reliability of individual components. It will then be possible to build mathematical models to establish the relationship and determine whether additions in the plant produce higher reliability—pumps are generally good candidates for this treatment.

With a very large data input, an 'obvious' in energy systems, it is preferaible to use a computer for quick and accurate analysis of data. Maintenance information from various plants can be a good feed-back to he manufacturer, as a guide for improving design for future units or larger units. They can also help in planning maintenance in advance, particularly, during major equipment overhauls and thus cut down outage costs.

The maintenance information systems should include listing of operations (operation history) so that performance of different units can be compared on like to like basis so that maintenance functions, particularly, the predictive and preventive ones can be established.

Training Maintenance Personnel

A successful maintenance programme is only as good as the personnel who are responsible to it. Everyone in the maintenance department should play his role effectively to achieve the objectives. Whatever the set up, if the personnel cannot perform all the tasks which they should, then a training programme is necessary. The Training Programme to be drawn differs depending on the requirement. If training is to familiarise a person to a new task or a new machine, it is simple. But if the requirement is to train a group, and raise their general education level or to work in a new field, the training programme will have to be exhaustive.

Selection : The training programme should not only meet the objective, but also the personnel undergoing training should be those who benefit. This depends on the drive, interests, personality and thinking of the personnel. Their attitude towards the job and relationship with fellow employees influence their reaction. Many programmes fail not because of the content but because the trainees selected are not moved to study and benefit. Therefore, selection of personnel for training should be based on past performance, job satisfaction, interest in advancement, mental ability and subject knowledge. Good maintenance is a matter of attitude and the training programmes should direct the participants in developing correct attitudes.

Training Programme : There are many training techniques, and their usefulness depends on the circumstances. It is preferable to review all methods, before selecting the one suited best for the particular requirement. The various techniques available are summarised in Table 1.

Table 1 : Training Techniques

Sl. No.	*Type of Training*	*Description*	*When to use*
1.	In-plant training (Osmosis)	New employees are assigned to work next to an experienced person and learn through osmosis.	Useful to a limited extent only — Good for familiarising.
2.	Supervisor as Teacher	Supervisor or foreman guides the employee in the job.	Supervisor can teach some skills and shop practices.
3.	Short Courses	Groups taught in a class in theory for a short period and then in actual practice in a specialised area.	Theory and practice is taught only on a single subject. Manual skill is more important.
4.	Class room either in plant or outside	Groups in a classroom for a longer period.	Here, analysis is more important than manual skill.
5.	Higher technical course	Sponsor higher technical education.	Level of competance desired is higher with creativity requirement.

The knowledge gap desired to be filled increase from inplant training to formal technical course. Encouragement to take up such training and incentives such as study leave and fees benefits greatly enhance the knowledge of maintenance personnel.

The above training techniques are useful for training maintenance technicians (the last 2 are adoptable for engineers also). Engieeers during their scholastic career are only taught the technology, and hence, when assigned to maintenance descipline they should be trained in work planning and execution techniques. Maintenance should be made challenging through attractive career opportunities. They should be trained in application of modern management techniques such as observation techniques. Human Relations, Mathematical Programming, Plan and Control with CPN & PERT techniques, Capital Budgetting, Inventory Control and Reliability and Maintainability Studies etc. The selection here also should be based on the person's drive, interests, personality, thinking, job satisfaction and desire to advance. These can be achieved through sponsorship.

Conclusions

Thus it is seen, that maintenance in energy system is a sophisticated and multi-disciplinary technology that must combine higher skills judiciously to achieve high reliability and availability of Units. It can only be achieved through religious devotion of the personnel. In the not too distant future the management of energy systems will have to make critical appraisals of maintenance, and tackling of energy system problems in multi-plant operations. A central staff group visiting each plant periodically, evaluate the maintenance function, recommend improvements when appropriate, and report its finding to both local and central management.

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ANNOUNCEMENT

We intend to bring out a special issue of PRODUCTIVITY (Jan.—March 1977) on Workers' Participation in Industry/Management. We invite articles/contributions from practising managers, academicians, policy makers, trade union leaders and others. The manuscripts in duplicate should reach the Editor : 'PRODUCTIVITY', latest by 30th September 1976.

Designing a Wage Incentive Plan : A Systems Approach

Charles F. James* **Joseph Stanislao**** **Thaddeus M. Glen*****

The purpose of a wage incentive plan is to motivate an employee to do something that yields desirable results for the employer. That 'something' may or may not be extra work. It could be improved quality, decreased downtime, material control, or a myriad of other objectives, or a combination of them. A wage incentive plan is a small but important part of a total compensation system. It can in no instance be treated as an independent element. Any change in any element of a compensation system must be viewed in terms of the influence on the total system. A change in fringe benefit can easily alter an employee's expectation for the items of direct pay. Similarly, a change in direct pay can easily influence the effectiveness of an incentive plan as a motivator. Clearly, when designing an incentive plan the compensation system must be kept in perspective.

Designing an Incentive Plan

When designing an incentive plan, one must give consideration to two basic questions : What is it we are trying to motivate, and, in view of the fact that we are dealing with the total compensation system, what is a feasible motivational plan ? Other critical features are the work measurement system which sets the standards for the incentive plan, and the internal policies under which the plan operates.

The authors, in this paper present a brief cross-section of incentive plans, individually and in combination, briefly analyse each one with pay-output and unit labour cost-output curves, and add to those analyses, the concept of marginal unit labour cost. The objective is to show how incentive plans can be analysed for the purpose of reversing the process

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and use the analytical techniques to design an incentive plan that might best couple with an existing compensation system and cost system. The focus is limited to those plans which attempt to motivate additional output.

Wage Incentive Plan

Any discussion of direct wage incentive plans must begin with the well known one-for-one plan. The basic model for the plan is very simple—a one percent increase in output above standard yields a one percent increase in earnings. Since this plan is considered to be the fundamental wage incentive plan, no further discussion about it will be presented here. It may be instructive, however, to review the appropriate pay formula and graphical analysis. The formula for pay is as follows:

$$\text{Premium percentage} = \frac{\text{Standard hours earned} - \text{Actual hours worked}}{\text{Actual hours worked}}$$

where, Standard hours earned = (Standard time per unit of work) x(number of units of work completed)

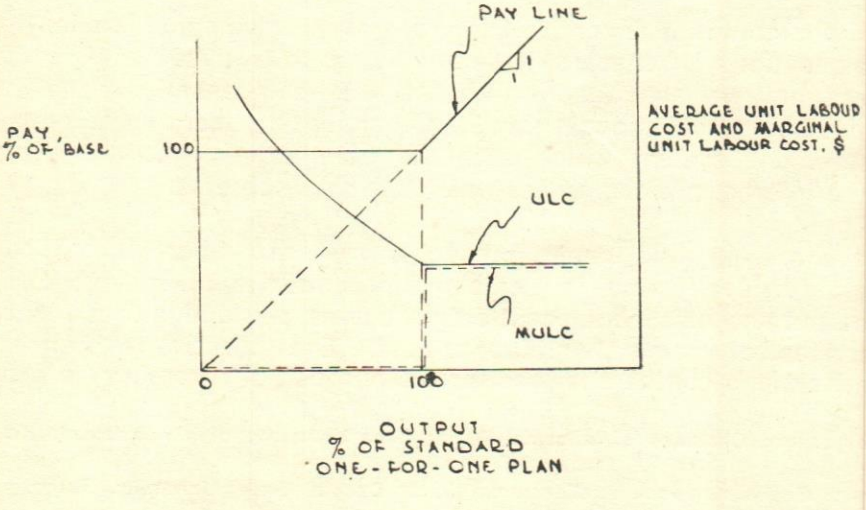


FIG 1

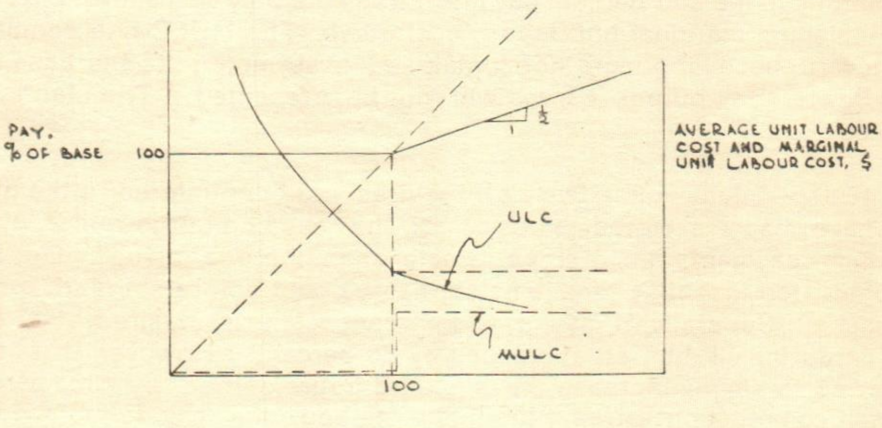
(Guaranteed base pay is assumed on all the plans discussed here.) The pay line follows a 45° line beyond standard output. The unit labour cost (ULC) line is horizontal for output beyond standard; clearly, in a one-for-one plan, the ULC is constant for output in excess of standard. The marginal unit labour cost (MULC) is zero until standard is reached; at standard, the line is discontinuous and then is coincident with the ULC line. The graphical analysis for the one-for-one plan is simple and straightforward, but it does serve as an important reference base for other plans.

Halsey Plan

The Halsey plan incentive premium formula is :

$$\text{Premium percentage} = \left(\frac{\text{Std. hours earned} - \text{Actual hours worked}}{\text{Actual hours worked}} \right) \times (0.5)$$

Although the incentive premium formula is similar to the one-for-one plan, the diagrammatical analysis shows that there are several dissimilarities between the two plans.



50-50 HALSEY PLAN

FIG. 2

The pay line climbs such that for each 1 percent increase in output the pay increases by $\frac{1}{2}$ percent. The MULC line is zero until standard output is reached. At this point, the line is discontinuous and jumps to a level obtained by the following :

(Standard time of job, in hours) X (base wage rate per hour) X (0.5).

That is, for each additional unit of work produced beyond standard, the labour cost for the additional unit is one-half the product of the standard time for the job and worker's hourly pay. The MULC line is again horizontal at this level.

The ULC decreases continuously until standard output is reached. The ULC curve is 'kinked' at this point but continues downward, becoming more horizontal as output is increased and finally becoming asymptotic to the MULC line.

Rowan Plan

The Rowan plan, a sister to the Halsey plan, offers some interesting variations from most other plans. For instance, because the pay line (calculated as standard time less actual time divided by standard time) is a concave curve (with respect to origin) extending upward and asymptotic to the 200 percent pay line, this is the only well known plan with a diminishing marginal unit labour cost curve. The MULC line continues downward, becoming more horizontal, and is asymptotic to the base line. The Rowan pay-output curves will not be presented. The plan is not in wide use.

The 100%+ plans offer two new features not encountered in the plans that have been explored here. First, the pay line in the region of the premium payments has a slope greater than the one-for-one plan, and, secondly, the incentive premiums start to be paid before standard output is reached. Generally, if, say, a 130 percent plan is desired, the time standards for all jobs are increased by 30 percent. However, it is often preferred to simply increase the standard hours earned by 30 percent in each computation. Using the latter method, the pay formula for a 30 percent plan would be :

$$\text{Premium percentage} = \frac{(\text{Std. hrs. X } 1.3) - \text{Actual hours worked}}{\text{Actual hours worked}}$$

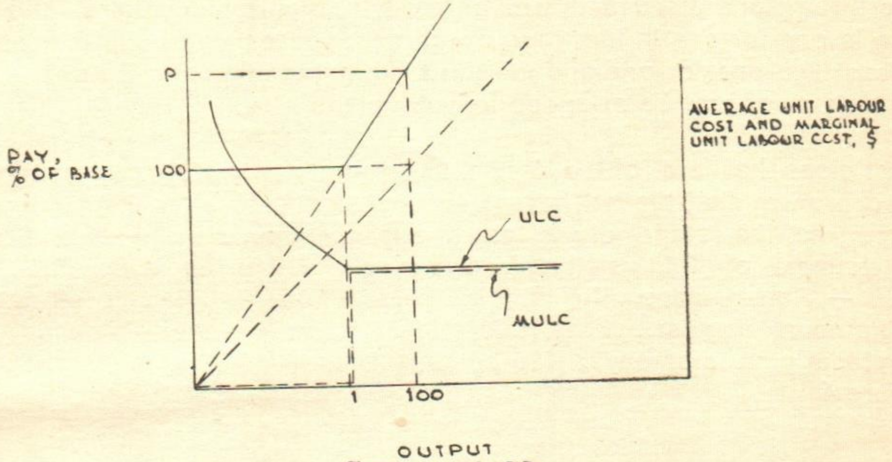


FIG. 3

The diagrams in our analyses are, fortunately, quite simple. Clearly, two questions become quickly of concern now. They are, at what point of output does incentive earnings begin, and, how does the ULC and MULC compare to the one-for-one plan. The first question is elementary if the diagram is examined. A simple ratio is apparent :

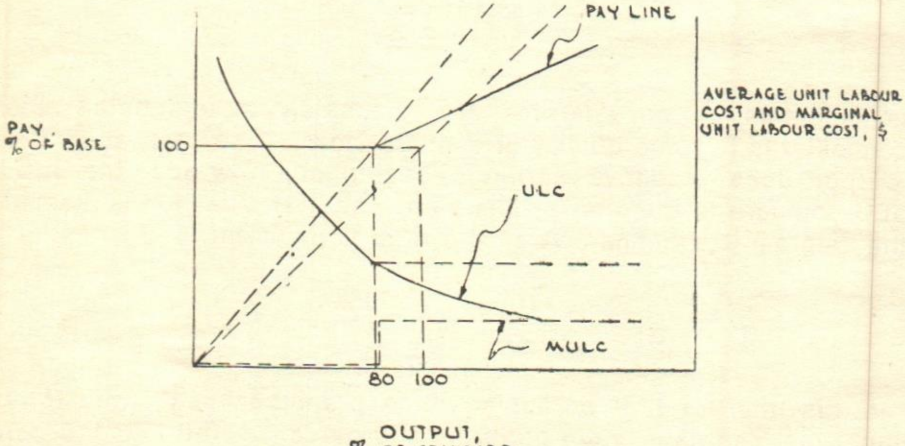
$$\frac{100\%}{I} = \frac{100\%}{P}$$

where I is the level of output at which premiums begin and P is the amount the plan pays when output is 100 percent. If it is a 120 percent plan, then this means that for output at 100 percent of standard the employer is willing to pay 120 percent of base pay. Thus, for this example, P would be 120 percent. I can now be found to be 83.33 percent.

The ULC curve in the region where incentives are paid would be 120 percent greater than the ULC curve for the one-for-one plan (for this example); the MULC would be zero until the first I level of output is reached and then would be discontinuous, jumping to the ULC line and becoming horizontal again at that point. So, what at first appeared to be a complex plan turns out to be elementary.

The three plans discussed form an easily recognizable pattern—the first plan is one-for-one in the region where incentives are paid, the second is less than one-for-one and the third is greater than one-for-one. The analysis must now be extended to other plans.

Most plans that are of the less-than-one-for-one variety can be altered in such a way that the incentive premiums start before reaching standard output, but the slope of the pay line is less than the one-for-one plan. An example of this is the family of plans that could be called the 100% + Halsey plans. In this instance, a 100% + plan is structured in the usual manner but the Halsey 50-50 formula is then imposed. The graphical picture of, say, a 125 percent Halsey 50-50 plan is shown in Figure 4.



125% HALSEY 50-50 PLAN

FIG. 4

In Figure 4, the incentive premiums start at 80 percent of standard output; this starting point can be calculated by ratios, as before. Since the 50-50 Halasey formula is imposed, the pay line bisects the angle formed by the guaranteed base line and the pay line of a normal 125 percent plan. The ULC curve drops steeply until the point is reached where premiums are paid; again, the ULC curve is 'kinked' at this point but continues downward, ultimately asymptotic to the MULC curve. The MULC curve is zero up to the point where premiums begin, then jumps vertically to an amount calculated as follows :

[125 percent x Std. time per unit x worker's base rate of pay] x (0.5), i.e., this formula yields the incremental labour cost per piece in the range of outputs where incentive premiums are paid.

An interesting and meaningful question that can be raised at this point is, where does the pay line of a 125 percent Halsey plan and the pay line for the one-for-one plan intersect ?

A so-called add-on plan is quite popular in some regions. It is essentially a variation of the Halsey plan where incentive premiums begin at standard output but the pay line is permitted to take on any positive slope the principals agree to have between 0° and 45°. This plan can also be coupled with 100 percent + features to begin paying premiums before reaching 100 percent of standard but letting the pay line climb upward less steeply than a 100 percent + plan.

Conclusion

Comparing the diagrams of the four plans, one can see that each one offers something different for both the employer and the employee. A one-for-one plan is the most widely used in the united States and is generally looked upon as a benchmark of fairness. However, one's view of an incentive plan should not be so narrow. For several reasons, it may be economically desirable to try to achieve high levels of output, in which case a 100 percent + plan may be the most effective and realistic tool. Or, perhaps it is very important to the employer to reach a level of production within a given range but not greatly advantageous to go far beyond this range; in this case, an employer might wish to use a 100 percent + Halsey plan or variation thereof. In essence, the diagrams offer an invaluable assessment of the motivational characteristics of an incentive plan.

Nothing has been mentioned in this paper except briefly in the beginning, about time standards or work measurement. Clearly, the time standard is the all-important foundation on which the incentive system rests.

There is the question of propriety and consistency of the work measurement system, there is the question of the classical manipulation of percentages that is forever taking place in so many work measurement systems and there is the question of the concept of normal and how it is implemented into the standard. It has been assumed here that a fair, reasonable, proper work measurement system has been used and that normal performance is considered to be 100 percent or that pace judged to be appropriate for a 'fair day's work'. No attempt will be made here to discuss the widespread practice of percentage manipulations in the work measurement system, in the union contract, as well as the premium computations. The methods and procedures are extremely varied and often quite complex. This topic should be treated in a separate paper.

One of the most important features of any wage incentive plan is the set of policies which control the use of the plan under the various circumstances routinely encountered. For instance, how is machine-paced time handled, how is overtime handled, what happens to a worker's pay during delays that are no fault of the workers, how often are incentive premiums paid ? It is naive to think that the pay formula and the diagrams present all of the system or even most of it. The set of policies surrounding a plan often is the cause of labour difficulties with the plan such as labour disputes, low morale, antagonism, and motivational ineffectiveness.

With all of the facets of an incentive plan and the precision with which it must mesh with the other elements of the compensation, cost, and support systems, it is clear that a successful plan must be carefully designed. In this paper, an effort has been made to advance the proposition that an incentive plan can be carefully designed. Any incentive plan is, admittedly, a complex system with many tentacles but sufficient knowledge exists to reasonably predict and control the outcome.

There are several incentive plans with different characteristics than those presented here (see References 1 and 2). However, the purpose of this paper was to discuss the important variables involved in an incentive system to aid in the design and/or analysis of a system, not to present an exhaustive cross-section of incentive plans.

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India and the Export Processing Zones

Bruno Hake*

Export Processing Zones could earn Rs. twenty billion. But making them function requires top-level decisions. Free export processing zones are an important tool for countries with large, underemployed labour forces to create jobs, improve their economy and earn hard-currency from exports. These goals are of extreme importance in India's present economic situation. What benefits could India obtain from these zones ? What are the 'rules of the game' to make such zones function ? Will the Santa Cruz zone be a success ? In order to find realistic answers to these questions, the following factors have to be considered :

—The criteria for investments in such zones by foreign manufacturers of labour-intensive products;

—the advantage offered by non-Indian zones to foreign firms;

—India's current image with foreign investors; and

—the potential benefits of free export processing zones to India's economy.

Investors and Export Zones

Most industries in export zones do not compete with domestic enterprises, since they make only labour-intensive components or assemblies using the 'extended work-bench' principle, which are then shipped back to the home-country for completion. Or, if they produce finished-products like electric shavers, typewriters or television-sets, the producer sells them through his established sales and service organisation. Host-country manufacturers could not compete in this market, since they would not be able to provide the expensive sales and service network needed.

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The foreign businessmen establishing operations in these zones are generally not willing to buy the parts or products made from local producers, since these could not meet their needs for supply reliability and quality control. This is especially true for 'Original Equipment', parts going into the production of automobiles, typewriters, or machinery. But it is also of importance for consumer items like shirts and shoes. Being able to maintain operating control, therefore, is a vital aspect in the investment decision. It further protects their interests with regard to patents and knowhow. In order to ease the management burden in a foreign environment, many investors prefer joint-ventures, as long as they can maintain a reasonable degree of operating control.

Availability of a low-cost labour force accustomed to industrial work, and also of low and medium management personnel including shop supervisors, designers, engineers and accountants are of vital importance. Since exports to sophisticated markets require the use of components like collar-inserts for shirts, zipper for trousers, cotton-polyester cloth for non-iron textile garments, highly-polished metal frames for leather handbags, and many other components, raw materials and equipment that can only be obtained on the world market, the absence of import--and currency controls in the zone is another vital factor. Since the industrialists make investments in these zones for profit, low income-tax rates is 'must'.

During the last 10 years, manufacturers from the industrialised countries show a strong demand for export zones in developing countries. The reasons for this are high wage costs (currently about Rs. 30 per hour for semi-skilled metal workers in most European countries, USA and Japan) and the shortage of both skilled and unskilled labour in most of these countries. Germany, France, Switzerland, Sweden, Austria, Belgium and England together employ more than 10 million 'imported labourers.' But strong components, for investments in export processing zones has developed from Singapore, South Korea, Taiwan and Ireland.

Typical 'bait' used to lure investors are the guarantee of ownership, liberal procedures regarding availability of hard-currency accounts for imports of machinery and components, low taxes on profits and no limitations on the employment of foreign nationals. Hongkong, for example, has no restrictions on the use of dollar-accounts or the import of materials or equipment, it has wage-costs of about

Rs.8 per hour for semi-skilled labour and a maximum tax rate of 18 percent. Ireland, which has been very successful in obtaining investments from European, Japanese and US firms, offers substantial investment grants, a 15- ear tax holiday on all profits from exports, and labour costs of about Rs. 15 per hour. South Korea, Singapore, and Taiwan offer similar benefits and therefore, provide an attractive investment climate.

How India Can Make Use of Export Zones

How does India score in this competition for the export and job-creating investments of international firms ? India's rating as a desirable place for foreign investors is extremely poor. The internationally renowned Business Environment Rating Index— (B. E. R. I.), which judges the investment climate by 'rating' a total of 18 factors affecting investment decisions in each of 43 countries, places India at the bottom of its list. Lybia together with Pakistan and Singapore and Ireland score high BERI-ratings, of the same level as mature industrial countries such as Switzerland, USA or Germany. If India, therefore, wants to attract foreign investments in free export trade processing zones, a basic reappraisal of attitudes and policies is needed. Otherwise, foreign investors will, continue to by-pass India for better deals in other Asian countries. The Santa-Cruz zone at Bombay does not offer free imports of components or machinery, it does not allow foreign businessmen to carry free dollar accounts. it does not guarantee full or majority ownership for the foreign investor and it does not offer tax reductions. It only offers 'streamlined procedures' for the licensing of imports. For businessmen accustomed to work in liberal economies and who have had a taste of India-style bureaucracy, this is no incentive at all. Santa Cruz, will, therefore, fail to attract foreign investments, and till today has not lured even one single major foreign manufacturer willing to 'put his money on the line'.

Another factor which comes in the way of investing in new areas is the insistence by authorites to know the 'content of technical knowhow'. This has the result that the typical mass-produced staple products which could provide meaningful levels of foreign exchange earnings and employment are kept out. Very few foreign firms would seriously consider building electronic microscopes for export production in India. But many might want to make shirts, typewriters or electric shavers for export. Insistence on 'technology content' for export zones, therefore, is self-defeating as far as the purpose of these zones are concerned.

What could be the benefits of free export-processing zones for India ? With wage cost trends in the industrialised countries continuing to force European, American and Japanese manufacturers into the 'extended work-bench' strategy, it would not be difficult to create employment for 1 to 2 million workers in export processing zones in India's major industrial centres such as Bombay, Madras, Calcutta, Delhi and Bangalore within a ten-year period. Taking a minimum of Rs. 10,000 of annual wage costs plus another Rs, 10,000 per worker for indigenous supplies, materials and services, India would earn 20 billion for each 1 million workers employed in these zones. This is 3 times the volume of India's total export of finished goods in 1973-74. And this business from the zones would not interfere with the regular exports from domestic manufacturers. One million newly-employed people would have a considerable multiplier-effect for the local economy caused by their purchases of domestic products like clothing, houseware etc., thus creating many new job opportunities in the domestic industry.

What is needed to make these benefits available to India and to help it compete successfully for these investments with other countries ? First a thorough reappraisal of the attitude towards foreign investment in froe export processing zones is essential, in order to shun the self-defeating policies. Simplified procedures will enable the private foreign investors not to bypass our country. Such liberal attitude can be implemented without sacrificing domestic policies, since the processing zones are, economically speaking, foreign territory. The ingredients of a policy that will attract the investment needed are :

—establishing these zones in major centres of industrial activity, so that skilled work forces and economic structure, including airports and harbours are available;

—allowing liberal use of free dollars accounts, and no control for import of machinery, components or raw materials;

–iron-clad guarantees regarding equity and operational control for the investor over a period of 20 years;

—no limitations on the employment of foreign nationals;

—low tax rates on export profits, not to exceed 20 percent;

–availability of power, land, building and other services for light industrial operations of all kinds, without insisting on 'technological content'.

Providing such liberal provisions in India requires high-level political decisions. But if 'export or die' is a realistic evaluation of the present economic situation, it becomes imperative that these decisions be taken early and create an amicable atmosphere for more investment, more business and more employment resulting in earning more foreign exchange for India.

Unemployment : Impediment to Economic Progress

B. M. S. Chopra*

Unemployment is one of the gravest ills of our times. The most disturbing single dimension of rising unemployment is its adverse impact on the distribution of wealth within the society. With more and more people joining the band of unemployed, the distribution of income amongst the population has worsened. As the standard of living of the people on the whole rises, while unemployment is increasing, there is a sharp contrast between those for whom the system is working and for those it is not. This results in widening of the gap between the rich and the poor. Unemployment is a wastage of human resources. It represents investment in education which cannot be recouped unless the non-working are productively employed. The growing underutilisation of human resources is a challenge to our development.

Level of Unemployment in India

The level of unemployment in India, according to an I L O report, is estimated to have increased from 11 percent of the labour force in 1951 to 15 percent in 1961, a trend which continued through sixties. During the seventies, India's labour force is projected to increase from 21 to over 27 crores. The country is confronted with 1,00,000 new entrants into the labour force each week.

The growing proportion of educated persons, both men and women, in the unemployed labour force, which, due to rapid strides made in the field of education after independence, is causing widespread discontentment amongst the educated youth, affecting, in turn, the minds of students, for obvious reasons. The country produces about 15 lakh matriculates and 3 lakh graduates every year. Predominently, large number of them remain unemployed. Whereas, these unemployed educated young men and women, on whose education, huge sums of money to the tune of about Rs. 2 crores is spent annually, should be an asset to

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the country, they have become a burden on the society.

There are about a lakh of unemployed engineers, doctors and technologists in the country. About 50,000 of them have turned towards USA, UK, and other countries in search of employment. The gains of investment on their education to the tune of hundreds of crores of rupees made by a poor country like ours, are being enjoyed by other countries. It is reported that about 3,000 engineers and doctors are migrating out of the country every year, causing a net annual loss of Rs. 25 crores on account of expenditure incurred on their education, which may never be recouped by way of utilisation of their services by the nation.

Promoting Employment

Employment can be promoted amongst the educated persons by:

—creating employment potential in every possible field;
—taking measures to improve employability of educated persons by imparting professional training, and
—remodelling of the education pattern to make education vocation-oriented rather than a process for obtaining degrees and certificates.

The employability of the educated can be improved by vocationalising education and organising training in professional fields after completion of education, on the lines of the scheme of training for guaranteed employment under the 'Employment Promotion Programme.' Such training programmes have to be organised on a massive scale, for which special institutional arrangements have to be made, the existing arrangements in the country being grossly inadequate.

Vocationalisation of education could be patterned to make professional and technical training part of education in schools. Further, professional or technical training may be provided to selected persons according to their aptitude. A network of vocational guidance bureaux, where professional/technical expertise is available, must be set up to ensure that proper and timely guidance is made available to all those coming out of the schools, colleges or universities. A system may be devised, whereby these educated and trained persons may be absorbed by the industry and trade, compulsorily for all the requirements of technical and professional personnel. Measures like 'Apprenticeship Act' (already a part of the Prime Minister's 20-point economic programme), if rigidly enforced, would achieve this objective.

Self Employment

These measures apart, the fact remains that jobs in the country are, and will always be, few as compared to the growing number of young men and women, including engineers, technologists and others, coming out of the colleges/universities and technical/professional institutions. The entrants into the job market in the country would outnumber new jobs being created, roughly, by about 2 to 1.

It is impossible for the government to provide or to create job opportunities for every educated unemployed person in the country. Therefore, the majority of them would have to go in for self-employment. In other words, we will have to make them entrepreneurs, rather than employees. By setting up small industries or business enterprises, they would not only employ themselves but also create new jobs for others, instead of seeking them.

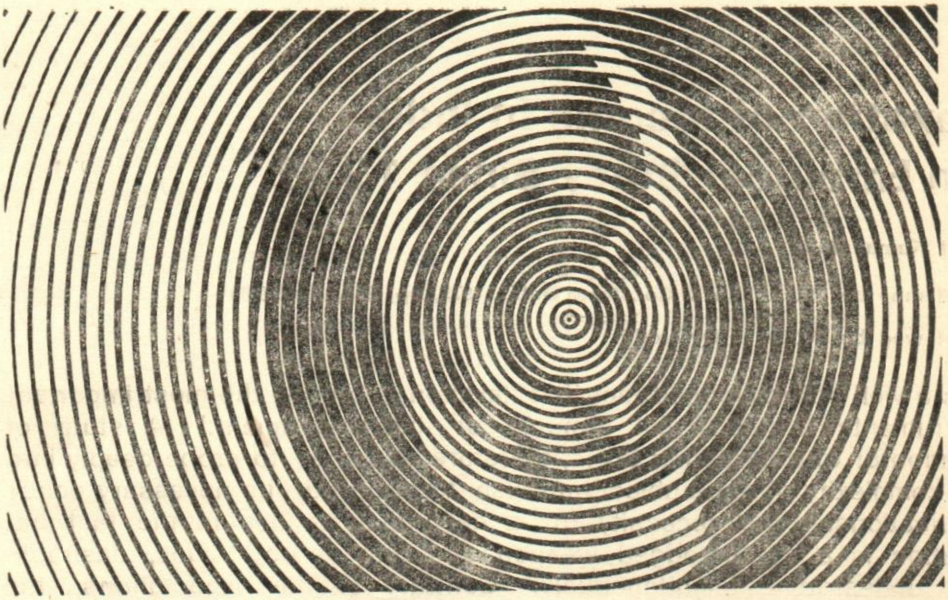
Entrepreneurial Development

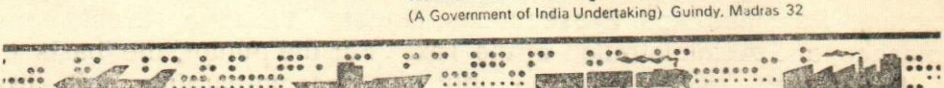
A development economy requires a varied pattern of industry and trade, a balance of large, medium and small firms, as a safeguard against the dangers of concentration of production and distribution into too few hands. The Prime Minister, Mrs. Indira Gandhi, had observed in her inaugural address at the Convention of Young Entrepreneurs, 'We want private enterprise not to be concentrated in a limited number of hands, but to spread as widely as possible. That is why we wish to give special encouragement to small scale industries which offer good scope for young entrepreneurs.'

An entrepreneur would be an asset to the country; apart from earning his own means of livelihood, his success can help the nation in many ways. Firstly, by employing himself, in his own small scale industry or small business venture, he will create employment for others; secondly he would contribute to growth of the country's gross national product, and thirdly, he would engage himself in an industry that might develop a backward area. Young entrepreneurs, engineers, technologists, and other educated unemployed persons, if carefully identified and properly trained, can play a vital role as social and economic change agents.

Entrepreneurial development is a national problem which calls for an all-out and concerted effort during the period of socio-economic revolu- tion which is presently taking place in the country. To tackle the prolb- lem, it would be necessary to create a national organisation which would be promotional in character and designed to provide all kinds of services including infra-structural facilities and consultancy to entrepre- neurs, to enable them not only to set up their enterprises but to run the same successfully also.

The need for such an organisation is obvious as the existing arrange- ments in the country are inadequate and need to be considerably strengthened by having an apex body, for entrepreneurial develop- ment, through state-level and local units with the active support of the state governments and other concerned agencies.





Book Reviews

Taxation of Income in India : An Empirical Study Since 1939

Anil Kumar Jain

Published by Macmillan & Co., New Delhi, 1975, pp, 250, Rs. 50.00

Reviewed by Dr. D. N. Dwivedi*

It is a well acknowledged fact that 'taxation is one of the most important instruments in the fiscal armoury of the government.' A study of taxation or of a particular tax is, therefore, expected to probe deeply into the complexity of the subject and also to bring out its necessary policy implications. The necessity for a deep-analysis lies in the fact that taxation is a double-edged weapon and cuts on both sides, desirable and undesirable, simultaneously. Contrary to the expectations, the book under review presents only a superficial description of income taxation in India.

The specific objectives of the study are nowhere clearly stated. The author has, however, mentioned in the Preface that 'one of the objectives of this study has been to present the various provisions of the Indian Income-tax Act in a simple manner so that it may be easily understood by the students *as well as* the lay reader.' But this seems to be the only objective of this study, which the author has tried to fulfil in 11 chapters spread over 250 pages.

The aspects of income taxation which the author has touched upon are : Basis of Liability, Scope, Computation of Income, Tax Incentives, Rate Structure, Penalties and Prosecutions, Double Taxation, Evasion and Avoidance, and Administration of the Tax. For the author, the 'basis of liability to tax' is not 'income', but the income-earning unit like individuals, HUF, company etc.. In the chapter 'Scope of the Tax', only the kinds of income taxes and surcharges thereon, along with the legal provisions, therefore, have been described, while a reader expects an assessment of the scope of income taxation in India. The author confuses between 'scope' and 'coverage and kinds, of income tax.

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One full chapter of 6 pages has been devoted to 'Taxation of Agricultural Income'. His main findings and recommendations, based, of course, on the works of others (quoted in footnotes 5 through 18), are : (1) agriculture is inadequately taxed, (2) agricultural income should be totally integrated with urban income for the purpose of taxation, (3) the state governments should wilfully surrender their rights to tax agriculture to the centre, and (4) agricultural income tax proceeds be distributed among the states in proportion to their agricultural income. The Author is perhaps, unaware of the implications of distribution pattern of agricultural income. The chapter on 'computation of income for assessment' may be of interest to the students of income tax accounts. The author devotes a considerable length of the book to 'Tax Incentives' and describes possibly all kinds of tax-relief and concessions provided to different kinds of tax-payers, and also the conditions under which they are admissible. No attempt has been made to look into the efficacy of the incentives. He points out 'one serious lacuna in these provisions' i.e., frequent change in the incentive provisions, and suggests that this lacuna should be removed, and desirably a Research Institute be set up to evaluate the impact of tax incentives.

In chapter VII, the rates of income tax applicable to the different kinds of assessees and also the changes in the rates over time have been described. In his opinion, raising the exemption limit to Rs. 7500 ! is not advisable because it will result in loss of revenue to the government. He has not tried to examine the issue in the light of the recent increase in the cost of living or the fall in the purchasing power of money income. The author is in agreement with others supporting the case of clubbing the incomes of husband and wife. A separate chapter on 'penalties and prosecutions' seems to be out of place; it could have been easily and appropriately included in the chapter on Administration.

In chapter IX, the author considers only those cases of double taxation which arise due to multiplicity of the taxing authorities like national, international, centre and state etc. He should have taken care of also the multi-stage taxation by the same authority, like double taxation of company incomes. No attempt has been made by the author to make even a rough estimate of 'evasion and avoidance' of income tax in India. He has simply compiled what has already been published elsewhere, without even commenting on their methodolgy.

Some of the main suggestions advocated by the author are : (1) while assessing the income of a person, the returns from the family assets transferred to major sons should also be included in his income, (2) the religious and charitable trusts should be asked to submit annual accounts and in case of failure, trusts should be penalised, (3) 'like the USA, a School Scheme should be drawn up to help schools to teach their students about taxation so that before they join the ranks of tax payers they are aware of their duties and tax obligations towards the State'. The author should have better suggested a system through which Abhimanyu was tought.

In brief, what the author has done in this book is touching upon certain peripheral aspects of income taxation in India. Instead of adopting a sophisticated methodology for their analysis, he has given them only a text-book treatment. Throughout the book, author's approach towards the subject has been historical and descriptive. At places, he casually compares international tax-figures readily available in various reports and government publications. His main contribution to the subject is compiling in one place the various tax provisions and changes therein from time to time since 1939, and also the views and reviews published in the text books, journals, government reports and statute books. The author has not made any worthwhile suggestions, and if there are any they are in the nature of casual remarks.

It is regretted that some of the extremely important issues which form the subject matter of current discussion on taxation, eg., equity, progressivity or regressivity of rate-structure, distribution of tax-incidence between various income groups, effects of taxation on incentive to work, save and invest, its effects on resource allocation, loss of social welfare, elasticity and buoyancy of a tax, optimality of taxation etc., have not been dealt with by the author. A good deal of literature on the subject is available, which provides technique and methodology for research in the field of public finance. It seems, however, that the author has not benefited from the vast literature on the subject, if the bibliography given in the book is any indicator.

This book, however, makes a useful reading for the undergraduate students of public finance, and also for lay readers, as the author puts it. But the price of the book may prove prohibitive.

Investment and Financing in the Corporate Sector in India

Krishnamurty, K & Sastry, D.U.

Published by Tata Mc Graw Hill Co. Ltd., New Delhi, 1976, pp. 160; Rs. 36.00

Reviewed by N. L. Dhameja*

This study on private corporate sector in India quantitatively analyses investment, dividends and external finance decisions for seven industries and presents the trend in the corporate sector. It is an analysis of time-series of cross-section of companies within an industry for 1960-70 on the basis of published accounts of companies. Dividend, investment, both fixed and inventory, and external finance equations are estimated both by OLS and 2SLS. This cross-section study of the companies is supplemented by time-series analysis for each industry for the period 1956-71.

The first three chapters deal with economic environment and trends in the corporate sector, and the data for the study is dealt with in chapters IV to IX. The estimation of investments, dividends and external finances for each industry and an exhaustive survey of literature is also presented in these chapters.

Chapter IX analyses the determinants of fixed investment expenditure in the context of flexible accelerate model with financial variables. The acceleration principle applies to new investment and is said to work with lags arising due to technological, expectational and institutional factors. Adjustment for replacement investment is considered on the assumption that depreciation provision is a financial entity governed by tax laws and institutional practices. How far this assumption is true, particularly, when the depreciation practices have changed over time and published accounts exhibit the financial depreciation, which is different from tax depreciation in most of the companies. Further, the degree of explanation of investment in fixed assets equalition is low due to low coefficient determination. In chapter V, the inventory investment is explained in the framework of the flexible accelerator with financial variables.

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The study shows that (a) the financial variables, external finance and internal funds, significantly influence investment; (b) the external funds have an edge over internal funds, and (c) there is a presence of substitution between the two components of investments in various industries.

Dividend behaviour and external finance equations are estimated in chapter VI. The companies were found to have stable dividend and their dividend behaviour was well explained by Lintner model, i.e., current profit and lagged dividend as explanatory variables. The permanent income as an alternate measure of current income was not found to explain dividend behaviour. The study shows that dividend decisions are autonomous of investment and external finance decisions, while there is an interdependence between investment and external finance decisions. External finance was explained by retained earnings, debt and investment, both fixed and inventory. The results suggest that external finance jacks up dividends only in those industries where investment expenses have depressing effect.

Estimates by 2SLS method are given in chapter VII, and these estimates indicate that accelerator principle is a less important determinant both for fixed investment and inventory investment under 2SLS. The dividend decisions, like OLS results are found to be autonomous of investment and external finance decisions. The simultaneous character of the decision making process of firms are also presented by flow diagrams for endegeneous variables.

The effects of growth, earning prospects, internal funds position, stock market conditions and access to capital market on dividend behaviour are presented in chapter VIII. This has been tested by relating the parameters estimated for each company (on time-series), with other characteristics of the companies. The study shows some evidence that some parameters of Lintner model are associated with uncertainty of profits and growth considerations of the firms.

In chapter IX, the financial decisions are estimated from RBI data on time-series for 1950-1970 after adjusting for the change in price level at 1960-61 level. 2SLS estimates show almost the same results.

In short, it is a comprehensive study relating to investment and financing decisions of the private corporate sector in India and is of great use to the researchers in the field of industrial economics and finance. However, the study is subject to limitations that it is a study of individual industries and not of private corporate sector, and the results for all the industries collectively are not presented. The classifications on the basis of industrial activity, though said to have low heterogeneity of firm with respect to capital, is not true, as a number of companies have diversified into different product lines and so may differ with respect to technology and other factors. Other classification of companies on the basis of control of companies, size or growth, may have significant influence on investment and financing decisions of firms and the study has not tested for these classifications. The study is based on published data and does not consider the impact of changing accounting practices, revaluation of assets, change in inventory valuation methods, or change in depreciation methods. Lastly, the study presents the growth in financial variables for RBI data describing that the financial data relates to the accounting year July to June. In fact, the accounting year by RBI was changed to April of that year to 31st March of next year with effect from 1966-67.

Productivity & Technological Progress in Japanese Agriculture

Keizo Tsuchiya,

University of Tokyo Press, Tokyo, Japan 1976 pp. xxiv+261, Yen 5800

Reviewed by R. N. Bhardwaj*

In spite of Japan's rapid advance during the postwar period and her emergence as an industrially advanced nation, its agriculture faces with many a problem. Economists have observed that : (a) there is a marked decline in the number of full time farmers coinciding with an increase of part-time farmers, which in turn has reduced the utilizing rate of cultivated land (ch. 1 page 34), (b) there is an overproduction of certain products like rice and mandarin orange, coincident with a shortage of leaf foodgrains, etc. and (c) there is a growing pressure to liberalise

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imports, which in the pace of international incompetitiveness of many farm products, may render farmers unemployed (730,000; ch. X, p. 232). In this book, the author has attempted to dig out the factors giving rise to the above conditions. The author, using a wide range of empirical material (103 tables are presented) and eclectically applying the available economic and econometric tools have sought to analyse the problems and present appropriate policies to remedy the situation. The crux of the problem, according to him, lies in raising agricultural productivity of labour through promoting technical progress and enlarging the size of the farms. This would mean breaking away from the present set up where Japenesse farmer has achieved "rationality", and the existing potential exploited.

Huge migration of labour from agricultural (A) to non-agricultural (N.A.), argues the author, is the result of difference in the relative per capita income between A and M (manufacturing sectors), which was 39.3 percent in 1973. These differences (chapter I) stem from the discrepencies in such structures as technology (capital coefficients in Agricultural and Manufacturing), investment rate and savings rate in the two sectors. Leibenstein and Harrod model is used to estimate the investment coefficient I=DK/Y (where K is fixed capital, Y is income), given a particular growth rate and average net capital coefficient for the two sectors separately. Because of the high capital coefficient in agriculture (3.6) in relation to manufacturing sector (1.4) and less investment demand in agriculture, the author demonstrates that there is an outflow of savings from agricultural to manufacturing sector.

Regarding price policy, the various limitations discussed are : (a) already the contribution of price increase to agricultural income per capita was 95.4 percent in 1960-65 and 60.9 percent in 1970-72, (b) it has entailed large amount of financing by the govt., (c) contrary to the goal, large farmers have found it easier to get government support compared to the small farmers, (d) fiscal support is imbalanced region-wise and product wise (e.g., livestock, fruits, vegetables), and (e) the price policy is a short-term measure. Regarding the policy of raising marginal productivity of capital in agriculture, which the author argues is the long-run solution, it has been found that though some technological progress has taken place in agriculture, it is low when compared to manufacturing.

The technological progress in agriculture is attempted and measured by adopting the Cobb-Douglas production function in chapter II. Rice being the main crop in Japan, technological progress in rice is taken to be an approximation of total agriculture. The period 1922 to 1963 has been selected to measure technical progress. For the period 1922 to 1941 unofficial data and for the post-war period official data is used to estimate the parameters (co-efficients of elasticity of inputs) of the production function. Very low annual rate of technological progress has been estimated in agriculture (0.8 percent for Tokoku, 0.2 percent in Kinki and 0.2 percent Kyushu) as compared to that of manufacturing sector. These figures compare favourably when compared to those of USA. In Japenese agriculture technological progress can be promoted by establishing "capitalistic farming, enlargement of farm size and increased government expenditure."

In chapter III, the factors influencing agricultural land price are discussed. The author is of the view that the internal factors within agriculture like, farm rent and technological progress in rice, account for land's price. The incessant rise in land prices, (chapter VIII) does not make the farm owners to abandon their farm land and only 1.1 percent of the farm owners are willing to give up their land which as a result limits the possibility of expanding the average size of farm in Japan.

Using production functions in analysing the relationship between farm household class differentiation and scale economy, (chapter IV) it is estimated that the sum of the parameters in the Cobb-Douglas production function is nearly unity, implying that scale economic advantages do not exist in situation where farm size is less than 3.0 hectares; consequently, the use of high power tractors and combines would be uneconomical. In chapter V, the author admirably analyses with tools of economic theory, the price formation of farm products and the efficacy of government price policies in meeting the objectives of agricultural diversification in removing imbalances in demand and supply of various products (e.g., surplus of rice, shortage of beef), financial costs of various alternative policies in stabilizing farm incomes, protection of consumer interests, etc. It is concluded that in the case of farm products having zero supply elasticity and low demand elasticity, land limitation programme would be needed. For beef, pork, chicken, which have elastic demand, however, deficiency payment programme would be better.

To increase the farm income as well as to stabilize it, there is a need to reduce marketing cost which is quite high for farm products in Japan (chapter VI). Japan's dairy farming is still on a small scale. Over the period 1968-70, the number of dairy cattle in the categories of 5 or less is found to be constant, whereas in the categories of six or more an increasing trend is visible. This is explained with the help of Benefit-Cost ratio method used in determining optimal investment plan (chapter VII).

In chapter VIII, economic and social aspects of farm mechanization in small farming with reference to the power tiller and large size farm machines such as riding tractors and combines are analysed. Chapter IX discusses how land improvement schemes speeded up the adoption of labour saving technology in agriculture. Finally, last chapter discusses the needs and ways to raise labour productivity in order to make Japanese farm products more competitive. To strengthen Japan's position on this front, the author proposes enormous government investment and suggests the directions for policy measures. The book contains detailed Bibliography at the end. The book would be of immense benefit to the researchers in the field of agricultural economics.

Personnel Management and Industrial Relations in India

R. S. Davar

Published by Vikas Publishing House Pvt. Ltd. Delhi, 1976, pp. 369, Price Rs. 25.00

Reviewed by J. P. Singh*

This book is a welcome departure from the usual text book approach to Personnel Management and Industrial Relations. The author has intended the book as a help to managers in personnel departments and other functional areas of management in "developing appropriate procedures and attitudes" whereby they would succeed in encouraging initiative and foster enthusiasm among their subordinates.

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The book has been organised into four sections. Part I covers the area of Personnel Management and defines functions and objectives of a personnel department vis-a-vis the total managerial function. It also describes the organization of a personnel department and its position in the organization. A part of the section is devoted to the staff line relation in the organisation examining the role of personnel department. The last chapter describes the personnel department of four leading organizations in the country with respect to their organisational function, policies and position.

Part II covers the core functions of Personnel Management. The six chapters in this section cover Manpower Planning, Selection, Training and Development and Performance Appraisal. Specific topics covered include Anticipating Manpower Needs, Planning Job Requirements, Skill Analysis and Job Analysis, Sources of Recruitment, Tests and Interviews, Managerial Development, Training Formulae and Techniques, Career Planning and Promotion Policies, Managerial Appraisals and Appraisal Practices. Once again, considerable emphasis is placed on current practices in various companies.

A special feature of the book is its section on increasing personnel productivity. This section analyses human motivation and how higher productivity can be achieved through individual motivation, appropriate leadership styles, and wages and fringe benefits. The author feels that personnel productivity in India can be increased appreciably through proper manpower management.

The last section is devoted to Human Relations in Industry and covers problems of Labour-Management Relations, Trade Union in India and Avoidance & Settlement of Industrial Disputes. A separate chapter is devoted to employee communication and problems of communication in the organisation. The last chapter covers personnel research, personnel records and personnel audit.

The book is written in an easy style and reads well. The organisation of the material in sections and chapters is generally good, except for one or two topics which are hard to fit. For example, inclusion of Personnel Records and Audit under the Section "Towards More Effective Human Relations" seems somewhat inappropriate. Perhaps, it would have been better to include it under "Increasing Personnel Productivity", emphasising the obvious role of records and forms in improving organizational efficiency. The coverage of material is extensive and issues involved in personnel management are discussed at length.

The emphasis given on personnel practices in various companies in India throughout the book along with the forms in use is at once a survey of present personnel procedures in India and an information guide. The format and get up are fairly good and the book is moderately priced for its value.

The author has brought out a book which will be useful to not only personnel managers but also to managers in other functional areas. As a friend remarked, the book is not only about personnel management but more importantly a book on management of personnel. The practical hints like, *Ten Commandments of effective motivation* and *achieving effective communication* are quite useful. Undoubtedly, this book is the best work of the author to-date.

Economic Expansion and Marketng Motiivation

Sripati Ranganadha

National Publishing House, 1975, pp. iii+147, Price Rs. 30.00

Reviewed by V. S. Mahajan*

The book under review is mainly devoted to marketing, though at times it runs into matters other than marketing. In chapter I, pertaining to 'expert effort', the author states in the opening sentence, 'It should be a matter of satisfaction that our export performance during recent years has exceeded all our expectations in respect of both quantum of foreign exchange earnings and the qualitative changes in the pattern of our exports', (p.1). This is a very high-sounding start, and the reviewer

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feels that the wording should have been selected more carefully. At yet another place, the author writes, 'Ours being a seller's and sheltered market, almost all our goods readily find a domestic market.' This is no longer true. While the author highlights excellent performance of exports, he on the same page mentions that our (traditional) goods are facing competition from the neighbour countries. These two sentences do not go together well.

Subsequently, the author lays considerable emphasis on quality production and export potential of Indian products. He also talks of maintenance imports, the effect of devaluation on our trade, diversification of industrial growth and foreign pioneers. He also mentions measures needed for export promotion and the role of TDA (Trade Development Authority). He adds that sustained economic growth is, by and large, based on exports (p.12). One cannot be sure of it because a lot would depend upon the size, resources and internal market of individual country. Surely, both China and the USSR are not dependent on international commerce for their development.

Chapter II is devoted to 'Import Substitution'. Here, the author lays emphasis on self-reliance and he is correct when he adds, 'To aim at autarchy is economically desirable but it should not be taken for granted that it is an end-all economic objective of a nation', (p. 17). While import substitution is important in the interest of the economy as it provides greater self-reliance, greater scope for employment, and greater saving in foreign exchange, it should be adopted with great care. The experience has already shown that one great impact of import substitution in India has been the rapid increase in the production of luxury and semi-luxury goods (both durable and non-durable.) This is a gross wastage of domestic resources and shows that while steps are taken for import substitution, at the same time the administraton shoud deploy policy measures to see that this substitution leads to worth while production in the country, and further that if production of luxury goods is to be encouraged it should mainly be reserved for the export sector. The author fails to bring out these issues in his analysis.

In chapter III, the author shifts to the competition of textile industry. He concludes that over time competition between cotton textiles and rayon industry is going to grow acute and perhaps, the situation would be in favour of rayon industry. How far this would actually happen is difficult to state. However, while talking of man-made fibres one has to keep in view the recent price hike in basic inputs. In chapter IV, the author advocates the cause of handicrafts which have the largest employment potential. He suggests that these handicrafts should be made technologically more sound. For creating a proper market for these handicrafts there is an urgent need for creating suitable infrastructure in the rural areas (especially providing suitable transport facilities). However, the author fails to spell out how this could be done.

The author makes another useful suggestion in chapter V that there should be an all round audit of the performance of industrial units (which should embrace besides official auditors, engineers, technologists and social scientists). One wishes that the author had spelled out this sort of package audit that he talks of and how it could be introduced in the Indian economy. The reviewer feels that except in large industries and public sector such type of audit would not take the economy far; rather it might result in the wastage of resources. What the country needs is more production of essential commodities at competitives prices. In chapter VI, the relationship between the realiastion of production and employment is brought out and in the next, the author outlines the means for stepping up productivity. He brings out the advantages of automation, materials management, quality control and materials handling in chapter VIII. The basic principles of PERT (Programme Evaluation and Review Techniques) are dealt in chapter IX.

The author talks of employment potential of industrial estates in chapter X. While one agrees that for organised development of small industries—which are also a large source of employment—we need to provide a package of facilities to small entrepreneurs, one should also not overlook the fact that mere supply of these facilities without active response from industrialists would also be of no help. And this has been the experience of working of most of the estates in this country. In a study made by N. Somasekhara of the Indian Science Institute on "Efficacy of Industrial Estates in India", he has come to the conclusion that industrial estates have generally failed in their basic objectives.

The author shifts to planned parenthood, family planning and demographic aspects of consumer demand in chapters XI, XII and XIII respectively. He talks of the reasons why the message of family planning finds difficulty to filter down to rural mases. This, however, should not mean that people in rural areas are irrational. They are rational and perhaps, a sizeable part of them is already aware of the benefits of family planning. But, if they have not seriously responded to family planning, there are reasons behind this. The Khanna Study of the impact of family planning programme, undertaken by Mahmood Mamdani "Family, Caste, and Class in an Indian Village", has found that farmers and artisans are of the opinion that they would be worse off if they took seriously to family planning. In other words, for their multifarious jobs and for social prestige they still have to depend upon large families.

Motivational analysis, packaging and effectiveness of advertising are dealt with in chapters XV, XVI and XVII respectively. The concept of management and significance of performance objectives by managers are dealt with in the last two chapters. The emphasis here is on sound management and proper evaluation of management performance. Certainly, both in production as well as in sales promotion manager has a key role to play.

The book, on the whole, does not follow coherent, well-knit path. The author goes on shifting from one ground to another in such quick succession that the reader does not find continuity of approach. It would be better if the author rearranges the material in a logical sequence in a subsequent edition of the book.

India's Economic Problems : An Analytical Approach

J. S. Uppal

Published by Tata McGraw Hill Co. Ltd., New Delhi, 1976, pp. 425, Rs. 48.00

Reviewed by C. V. Rao*

There are many text books highlighting the problems of Indian economy. Though the authors of these books have vast experiences in teaching, particularly, in colleges at the undergraduate and at the post-graduate levels, they, instead of critically analysing the problems, do away with description of facts, with the result, the students fail to appreciate the causal relations, among the policy variables functioning in an economy.

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The book under review also deals with India's economic problems, but altogether in a different style. The author has, in a way experimented with the new style of attacking various issues, keeping in mind the new trend in teaching the undergraduate students in Indian universities. One thing must be admitted that the book comes as a pleasant surprise to most of us, because what we could not do in bringing out a simple and concise book on Indian economy, the author with the help of a few foreign based Indian economists, has succeeded in bridging the gap.

The book has been divided into seven parts. Broadly, various problems hovering around the Indian economy have been dealt with in 24 chapters, each chapter covering one specific area.

Part I deals with the human factor. The present population explosion has made one and all think twice about its rapid growth. Unless checked, there is every possibility of our attaining a one billion mark by 2000 A.D. In his paper, R. L. Chugh has discussed the causes of population explosion, theory of family formation, population growth and economic development and the theory of demographic transition. In the light of these, a policy for population has been suggested.

In another paper Inder Nijhawan discusses the non-economic factors which come in the way of steady economic development. The theses propounded by Nijhawan in his paper is simple, thought, provoking and unlike most of the text books, provides information about the social set up, cultural and ethical values held by Indians and how they have been impidements in the way of planned economic development. The author stersses on communication and education apart from other policy instruments, in abating the inimical effects of the existing socio-political factors on economic growth. The paper is well quoted (footnotes 90 in number) and an adequate biblio- graphy at the end is useful.

Part II of the book deals with the economic sectors. The five chapters are on agriculture, reorganisation of Indian agriculture and land reforms, large scale industries, small-scale and cottage industries, and lastly the transport system. This part broadly presents a spectrum of all the sectors, primary, secondary and tertiary, to enable a student to comprehend the framework of analysis.

The papers by Ramesh Diwan and Balwir Cheema are of particular importance. The former deals with the agricultural sector and the latter with the large scale industries. Ramesh Diwan's approach to the problem is simple, yet logical. Aspects such as measurement of agricultural output, measurement of productivity, construction of productivity functions, institutional factors influencing the production, and last but not the least, green revolution have been discussed at length. The purpose of dealing a vast subject like agriculture in this style has two distinct advantages: (a) an undergraduate student gets a bird's eye view of the subject, and (b) he/she can develop a taste for the subject and study further. Though ideas may differ from individual to individual and so has been the case with Ramesh Diwan's paper (especially while dealing with production functions, Diwan has avoided extension/modified versions of Cobb-Douglas production functions), one has to admit that the paper has been written with graduate level students in mind and also the syllabi of most of the universities.

In his paper on large scale Industries in India, Balwir Cheema has provided a short introduction to the process of industrialisation, its need and its impact in view of the objectives of the various plans. In remaining pages, a brief survey (including history) of key industries is made 'in order to develop a clear understanding of the rapidly changing industrial scene and its significance in the growth of the Indian economy.' This paper is data-based and adequately quoted from different sources.

The paper by V. Singh on transport system is also quite exhaustive, highlighting different modes of transport, their role and suggests (as recommended by the Committee on Transport Policy and Coordination, 1966) that the transport system should be integrated and coordinated so that, instead of rail and road transport competing, they should be complementary to each other.

Part III deals with economic policy and planning. It consists of four chapters dealing with industrial policy: nature and growth of public sector, socialist society, two decades of planning and structural changes in Indian economy. The last paper by Zaidi and Mukhopadhyay deserves more attention, in the sense that, it presents an expose' of the use of input-output model in identifying the structural changes in an economy. With the help of an illustration the authors have shown that between 1952-53 and 1964-65, there has been more specialisation and increased interdependence between sectors, implying that the Indian economy is on the road to industrialisation.

Part IV deals with yet another crucial sector, i.e., labour. The four chapters included are, the market for labour, economies of agricultural labour, its welfare and the extent of unemployment. The whole gamut of labour, its skills and abilities have been presented.

Parts V and VI expose the students to monetary and fiscal policies of India. Capital formation, banking and monetary system etc. enable a student to know the intricacies of finances and the factors leading to inflation. Fiscal policies such as taxation and centre-state fiscal relations have been dealt with in Part VI.

In the last part, while dealing with International Economic Relations, Jaleel Ahmed focuses his attention on foreign trade and balance of payments, V. N Balasubramanyam deals with private foreign investments in India and Prem Gandhi with economic Integration in South-Asia. With the emergence of Multinationals as giant traders in the world market, so much so influencing the policies of many a developed country, has provided the researches with yet another area to explore the merits and demerits and of the growth of MNCs. Balasubramanyam and Gandhi in their respective papers cordially deal with this issue.

To conclude, the book has been well written and provides sufficient information on major economic aspects. It can be recommended as a text book in Indian Universities at undergraduate level. The only thing coming in the way of students is the cost of the book which is on the higher side.

Corporate Dividend Practices and Policies

This paper analyses the dividend policies and practices relating to equity shares of non-government public limited companies for various industries. It shows that dividend practices vary from company to company, and are, generally related with earnings. The 'reported' dividend rate is biased downwards as compared to the 'adjusted' or the 'true dividend' rate adjusted for bonus and right issue. The former has reduced while the latter has increased over the period. The discrepancy between 'reported' dividend rate and the 'adjusted' dividend rate indicates tendency to understate the dividend rate and to avoid giving an impression of profiteering which a high dividend rate seems to convey......N. L. Dhameja (Page 341)

Environment and Small Industries

Small scale industries in India have made substantial progress in recent years. Small industrialists, by and large, appear to be totally unmindful, and sometimes even unaware of the problems of environmental pollution. The complacence is partly because of the feeling that their contribution to such environmental pollution, compared to larger units is negligible. If no pollution control measures are initiated even where the enlightened management is aware of the problem, it is because of economic, technological and social factors. Naturally, industrialists would not be too enthusiastic to incur the additional outlay on pollution control measures. It would be worthwhile if appropriate incentives are offered to them, besides strictly enforcing the provisions of law. In case of new projects, it should be invariably ensured that pollution control measures do form an inseparable part of the project report .... S. Venkatesh Page (369)

Productivity Trends in Small Scale Firms: Managerial Implications

This paper attempts to identify the determinants of productivity in small firms. By way of analysis, it indicates that technical features such as capital intensity, economies of scale in production and market risks have significant impact on productivity. In addition to these, capital and materials management play an important role in causing productivity to be what it is......... S. Acharya, TVS Ramamohan Rao (Page 381)

Decomposition of Change in Agricultural Production

This is a review article of another paper published in *Agricultural Situation in India,* 1973 by S.S. Narula and Vidyasagar on 'Methodology for Working out Contribution of Area and Yield in Increase in Production'. The author is of the view that the Narula—Vidyasagar approach is not new in the light of the existing literature in evaluating the contribution of area and yield in increase in production .... Chandresh K. Srivastava (Page 389)

Productivity, Human Capital Intensity and Stages of Economic Development

The impact of technical progress on the occupational structure of the labour force is observed when there is a gradual shift from professions with low skills to higher ones. Since this shift is related to the degree of mechanisation, a similar quantitative and qualitative shift in the skill profile of labour can be expected. This paper attempts to establish the above hypothesis and shows that the magnitude and distribution of human capital is highly correlated with the structure and the level of economic development......... Autar Dhesi (Page 401)

Ergonomics : Its Impact on Productivity

This paper shows that ergonomics plays a vital role in enhancing productivity, as it maximises the output potential of labour component. Though ergonomics is a non-manufacturing function, nonetheless, it sets out relationship of man to his working environment. Ergonomics is much more than study of plant layout problems. It uses a systems approach and considers operator, machine, work place and environment as an integrated system. It enables the enterprise to improve not only working conditions but also achieve maximum production and productivity..... P. V. Kulkarni (Page 417)

Productivity Enlargement in Jobbing & Mixed Quantity Production by Group Technology

To achieve higher productivity, it is desirable to implement efficient and effective methods of large mass production techniques such as Group Technology. The authors attempt to analyse various facets of group technology in various sectors and its use in jobbing and mixed quantity production......N. Nangea, R. Choudry & Om Nangia (Page 427)