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By-Gudgeon, R.L.

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A comprehensive discussion of single fuel source generation of power and heating requirements is presented. Definition and explanation of system concepts includes--(1) heat pumps, (2) steam turbines, (3) gas turbines, and (4) gas and diesel engines. Concept cost evaluation factors described are--(1) load pattern, (2) campus configuration, (3) fuel cost, (4) operating cost, and (5) equipment cost. Also included are--(1) campus installation factors, (2) comparative cost data, and (3) several charts, diagrams, and photographs. (MH)

TOTAL ENERGY CONCEPTS AS APPLIED TO UNIVERSITIES

By R. L. Gudgeon, H. G. Acres & Company Limited.

1 - INTRODUCTION

The Total Energy Concept has been gaining prominence in the commercial and institutional fields in recent years, primarily due to the increasing availability of natural gas, the increase in summer air conditioning loads and the advent of the gas turbine.

The number of installations in schools, office buildings and commercial establishments grows each year. However, so far, the concept has found relatively little application in universities, probably because of the high first cost in a field where finding money for expansion of the educational facilities alone is a major problem.

This paper reviews the background of total energy systems and the present status of the concept in universities. The factors affecting the evaluation of a total energy concept and their relation to campus utility systems are discussed.

2 - WHAT IS THE "TOTAL ENERGY CONCEPT"?

The term "Total Energy Concept" became fashionable in the early nineteen sixties to describe something that has been a familiar feature of industry for many years. Briefly, it means the ability to provide all the power and heating requirements of a consumer from a single fuel source.

The earlier applications of the concept were mainly in those basic industries having large demands for heat and power, and located remote from a source of cheap power. The single fuel was usually coal or, in the west, oil. A typical example would consist of a boiler generating high pressure steam, this steam being supplied to a back-pressure turbine generator. The low pressure steam exhausted from the turbine was used for process and space heating. Power produced by the turbine generator was used for motor drives and lighting.

This is a very brief description of a simple total energy system. In practice, these industrial steam and power plants were never quite so simple and usually involved several extraction and exhaust steam pressures and, sometimes, condensing turbines. Nevertheless, it does mean that the basic total energy system is not an entirely new concept. In fact, there are still several industrial steam turbine generators operating in Canada and bearing a nameplate stating that the turbine "is not licensed for use in aircraft."

With the establishment of large power generating utilities and power distribution systems, relatively cheap power became available in what had previously been remote areas. This reduced the incentive in many areas to install expensive turbine generators and high pressure boiler plants, especially in the smaller plants. The by-product power, though less expensive than the purchased power, was not cheap enough to offset the high initial investment in power generating facilities.

In recent years, this trend has been reversed. The everincreasing demand for summer air conditioning, combined with the availability of natural gas across the continent, have created economic conditions favourable to the small, high load factor, total energy system. Added impetus has been provided by the increasing availability of highly reliable and efficient gas turbines on a commercial basis.

It was during this period that the term "Total Energy Concept" was created to promote the use of natural gas as the single fuel in combined gas turbine power and heat generating systems.

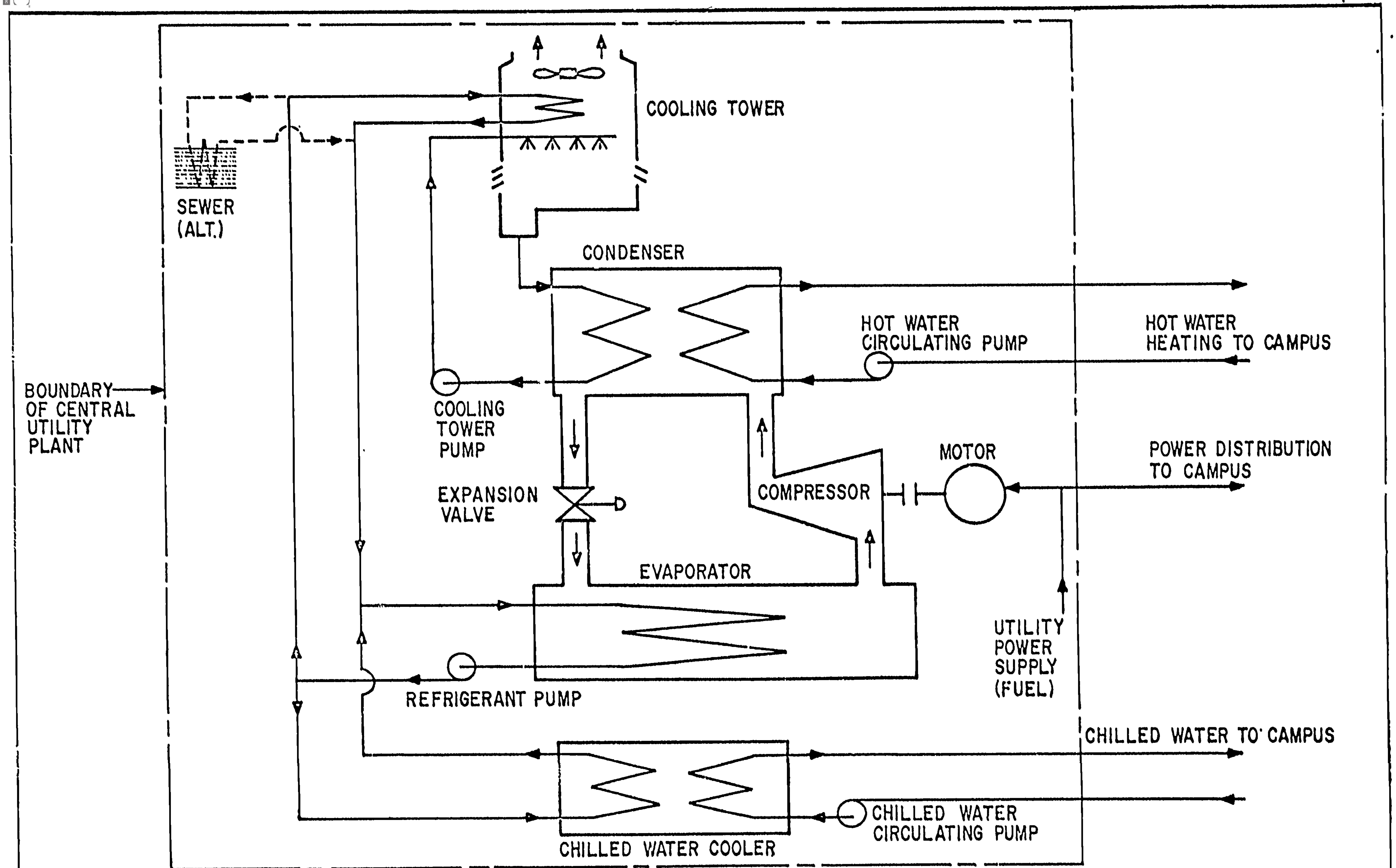
3 - POSSIBLE TOTAL ENERGY CONCEPTS

The total energy concept shows economic advantages and contributes to the conservation of resources by increasing the efficiency of utilization. In a central utility thermal power plant, over 50 per cent of the useful heat in the fuel is lost to the condenser circulating water due to limitations of the termal cycle. In a total energy concept, a large percentage of the surplus heat from the power generation process is recovered, and efficiencies of utilization in the order of 70 per cent are common. The main losses in the cycle are primarily mechanical and stack losses.

The total energy concept can take many forms. The source of energy can be electric power or fuel. The prime mover can be a steam turbine, gas turbine, diesel engine or, in the case of a heat pump, an electric motor. Some typical examples of total energy concepts are described briefly in the following.

3.1 - Heat Pump (Figure 1)

The heat pump is theoretically an attractive concept, however, it relies on the availability of an inexpensive source of heat such as a main trunk sewer or the outside atmosphere. One of the largest air source heat pump systems is a 750 horse-power installation of the Detroit Company for two buildings having a total area of 180,000 square feet. The computed cooling load is about 450 tons and the heating load about 3-1/2 million Btu per hour. Other larger installations are installed in Huntingdon, Indiana (850 tons) and Milwaukee (1,400 tons).



TOTAL ENERGY CONCEPT - HEAT PUMP

FIGURE 1

In general, for economic operation the ratio of maximum heating load to maximum cooling load should be less than one and preferably nearer one-third. The ratio at most Canadian universities would be over two. The system capacities would be many times that of the largest installations already operating and are not therefore considered to be practicable.

3.2 - Steam Turbines (Figure 2)

Condensing of exhaust steam from a turbine leads to a loss of efficiency in utilization of energy. On the other hand, if, instead of condensing the exhaust steam, it can be used for building heating and absorption chiller, then maximum efficiency of energy utilization can be achieved and the complexity and cost of condenser, air ejector, circulating water system are avoided.

The steam cycle conditions would be optimized on the basis of the ratio of power and heat demands. Steam pressures would normally be in the order of 500 to 600 psig, the actual pressure being selected to give an acceptable steam rate. Higher conditions, although leading to a higher efficiency, would be more costly and would become even further removed from normal central heating plant steam conditions. This would lead to additional maintenance and require operators with experience of central power station boilers.

The turbine exhaust steam could be used for heating in winter and for supplying turbine driven centrifugal air conditioning units. This turbine could, in turn, exhaust at about 12 to 15 psig for use in absorption type air conditioning equipment.

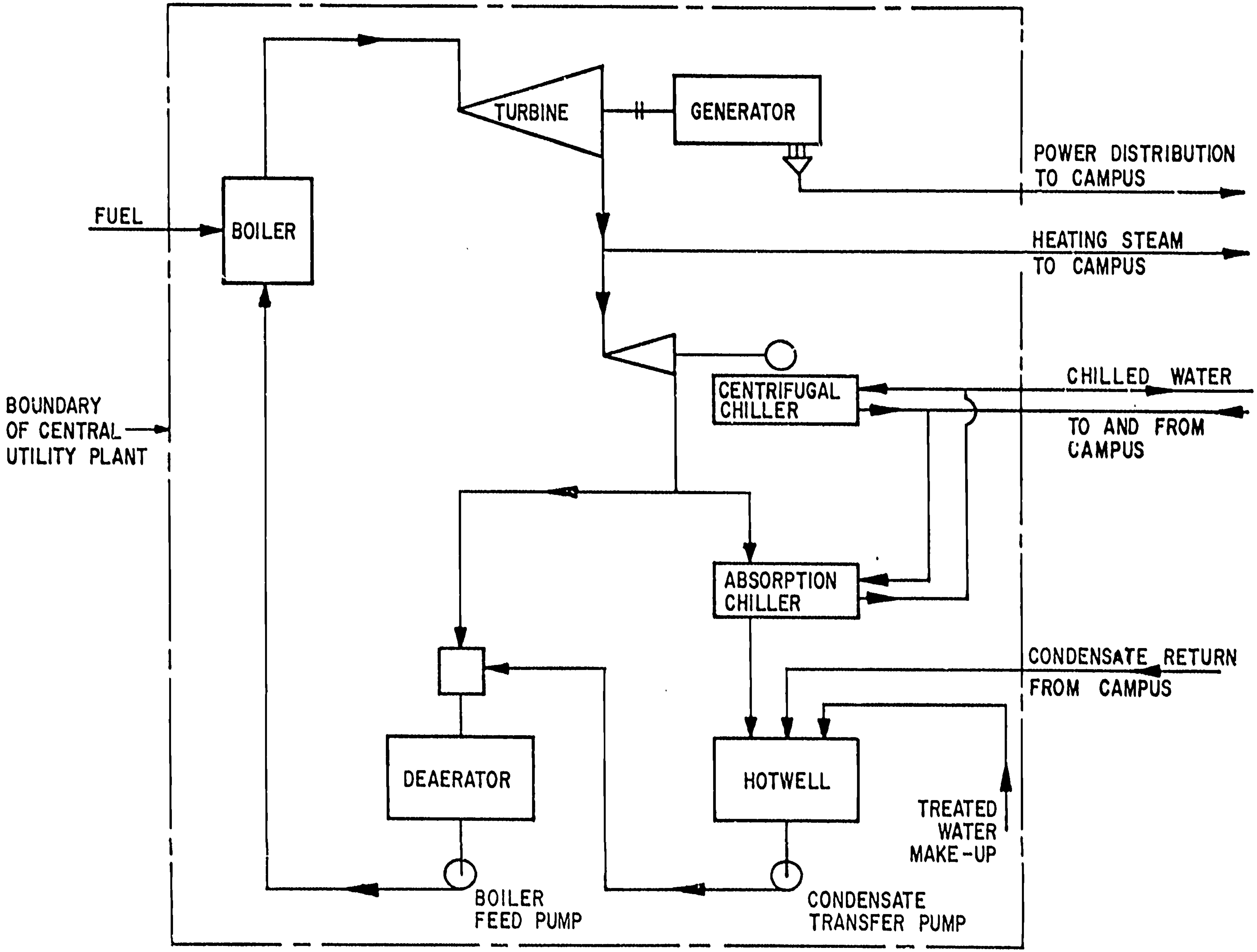
The combination of exhaust pressures, centrifugal and absorption chillers can take many forms and will depend on analysis of the air conditioning demands versus power demands.

3.3 - Gas Turbines (Figure 3)

In modern, commercial total energy concepts, the gas turbine accounts for almost 40 per cent of all the prime movers. Especially when fired with natural gas or a light distillate fuel oil, it has proved to be dependable and easy to operate and maintain. It has a versatility which enables it to be applied to a total energy concept in a great variety of ways, either as a prime mover producing power and driving refrigeration compressors or producing power and waste heat or a combination of both.

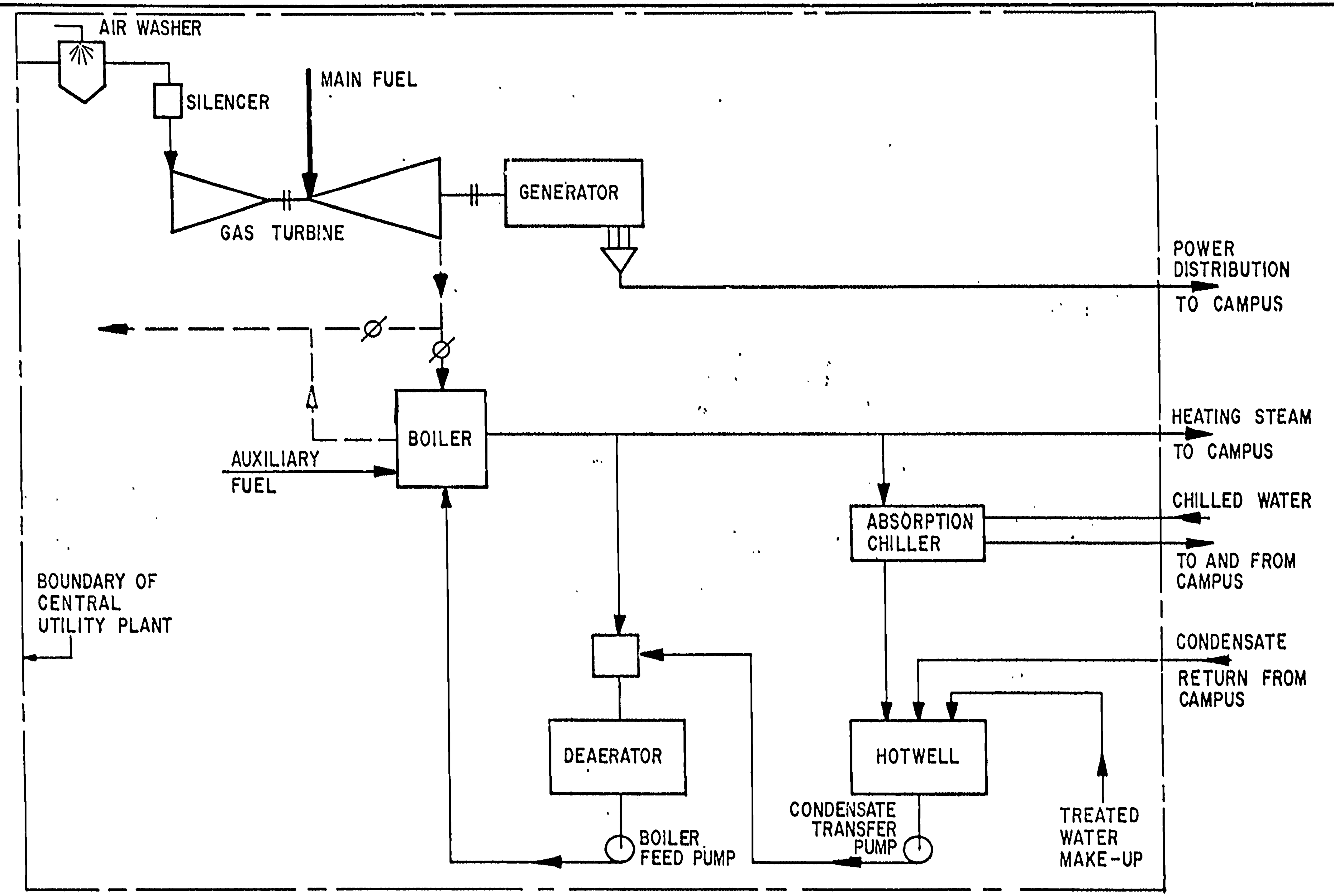
The gas turbine has been perhaps the greatest motivation in the increasing application of total energy concepts.

Gas or distillate fuels are the most suitable fuels for gas turbines. If a cheaper, Bunker C fuel oil is used, there are extra charges for fuel treatment and the unit rating must be reduced to limit the turbine inlet temperature. The use of heavy oil usually results in inferior performance and increased maintenance.



TOTAL ENERGY CONCEPT - STEAM TURBINE

FIGURE 2



TOTAL ENERGY CONCEPT – GAS TURBINE

FIGURE 3

The capital cost of a gas turbine burning Bunker C oil is approximately 25 per cent higher than those operating on gas.

In the majority of cases, auxiliary fired waste heat boilers are used to accommodate the differences between the various power and heating demand peaks. The control problem is relatively simple. Depending on the particular relationship between the power generation and heating steam requirements, either surplus heat can be bypassed to the chimney or additional heating requirements can be satisfied by auxiliary firing of the waste heat boilers.

The problem of noise suppression with gas turbines can be effectively resolved, providing allowance is made for this in the conceptual design of the power plant building.

3.4 - Gas and Diesel Engines (Figure 4)

A gas or diesel engine generator can be applied to a total energy concept in much the same way as the gas turbine, the waste heat being obtained from the exhaust gases and the engine jacket cooling.

Since the diesel engine is considerably more efficient than a gas turbine, the amount of available waste heat is reduced. It is sometimes necessary, therefore, to install additional conventional boiler capacity.

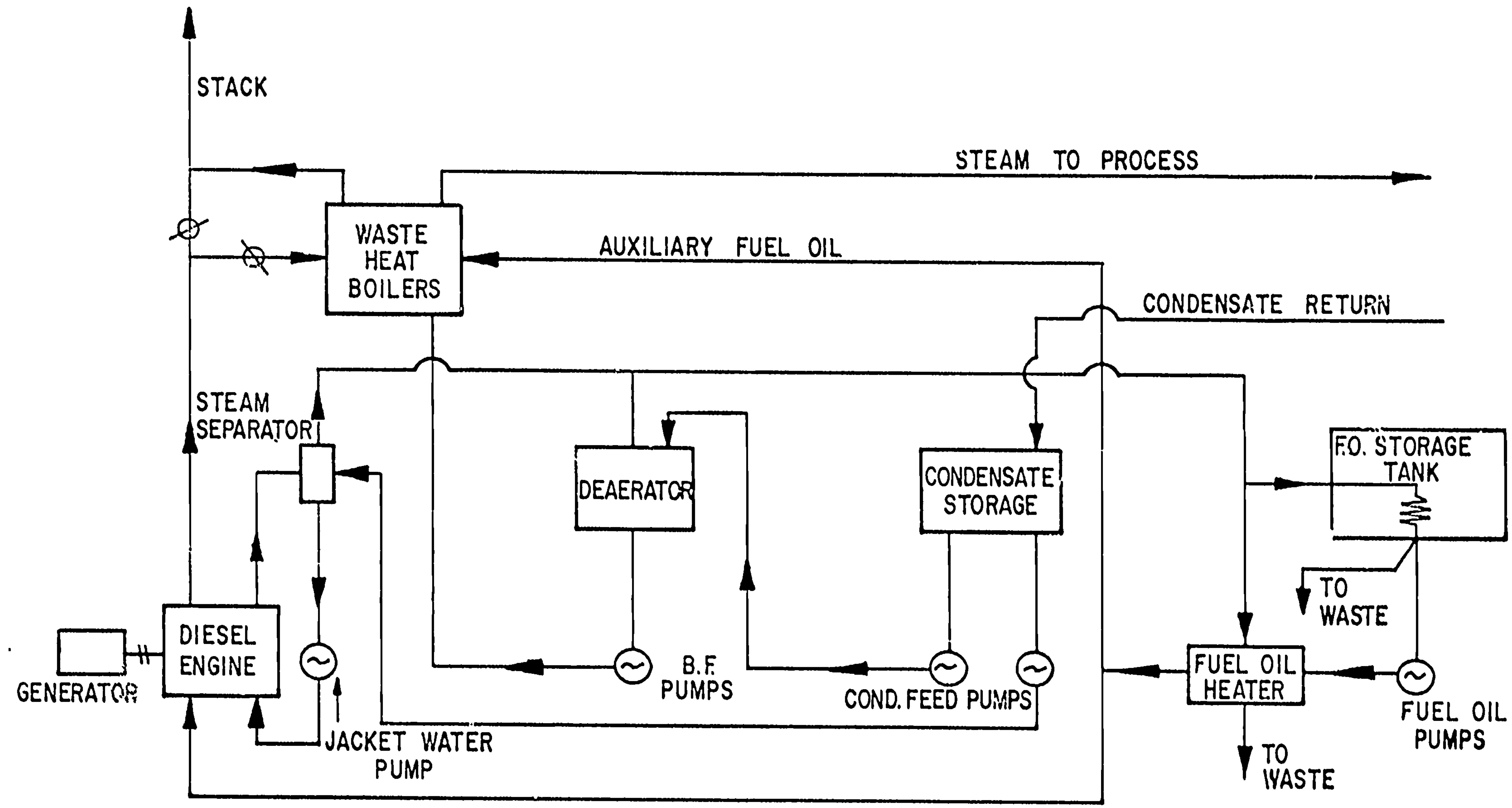
The schemes described here are but a few examples of the combinations of prime movers, heat generation and air conditioning plant. Obviously, the possible different combinations are almost infinite. Furthermore, they can be a combination of in-plant generated power and utility power, taking the advantage of maximum recovery of the fuel energy with the minimum of capital outlay.

4 - EVALUATION OF TOTAL ENERGY CONCEPTS

There are no simple rules of thumb that can be used in determining the suitability of a total energy system for a university campus. Each installation must be evaluated and compared on its own merits. This calls for a thorough study of all the building loads, the operating conditions as well as the cost of providing the money for the project. The climatological conditions at the given university location and the relative local fuel and power rate structures will greatly affect the outcome of the evaluation.

4.1 - The Comparison Between Capital and Operating Costs

Before the effect of any of the operating factors can be determined, the basis of comparison between capital and operating costs must be established.



TOTAL ENERGY CONCEPT – DIESEL ENGINES

FIGURE 4

Essentially, the purpose of the evaluation is to determine whether the outlay of capital money in the additional power generating plant can be justified by the savings resulting from the more efficient use of energy. Therefore, in the final analysis, the annual operating savings must be compared with the cost of financing the project.

The cost of financing includes interest of borrowed money, allowance for depreciation, insurance which is normally a function of the value of the equipment, and taxes. The computations used in determining these individual items vary considerably, especially where depreciation is involved. However, they are usually reduced to an annual charge expressed as a percentage of the capital cost.

An accurate calculation of the annual percentage relies on precise information relating to interest rate, depreciation methods and tax structures. In industrial applications all this information is available. However, in the case of universities the annual charge on capital is not quite so amenable to analysis. Money is obtained from a variety of sources, including interest bearing loans, government loans and grants, and donations. Their tax status can vary from year to year.

In order to enable some appreciation to be made of the relation between differing capital and annual costs, these differences are often reduced to a number of years payoff with annual savings relative to additional capital expenditures. In general, any pay period less than 10 years (which is equivalent to a 10 per cent rate of annual charges on capital) is considered to justify the additional capital expenditure.

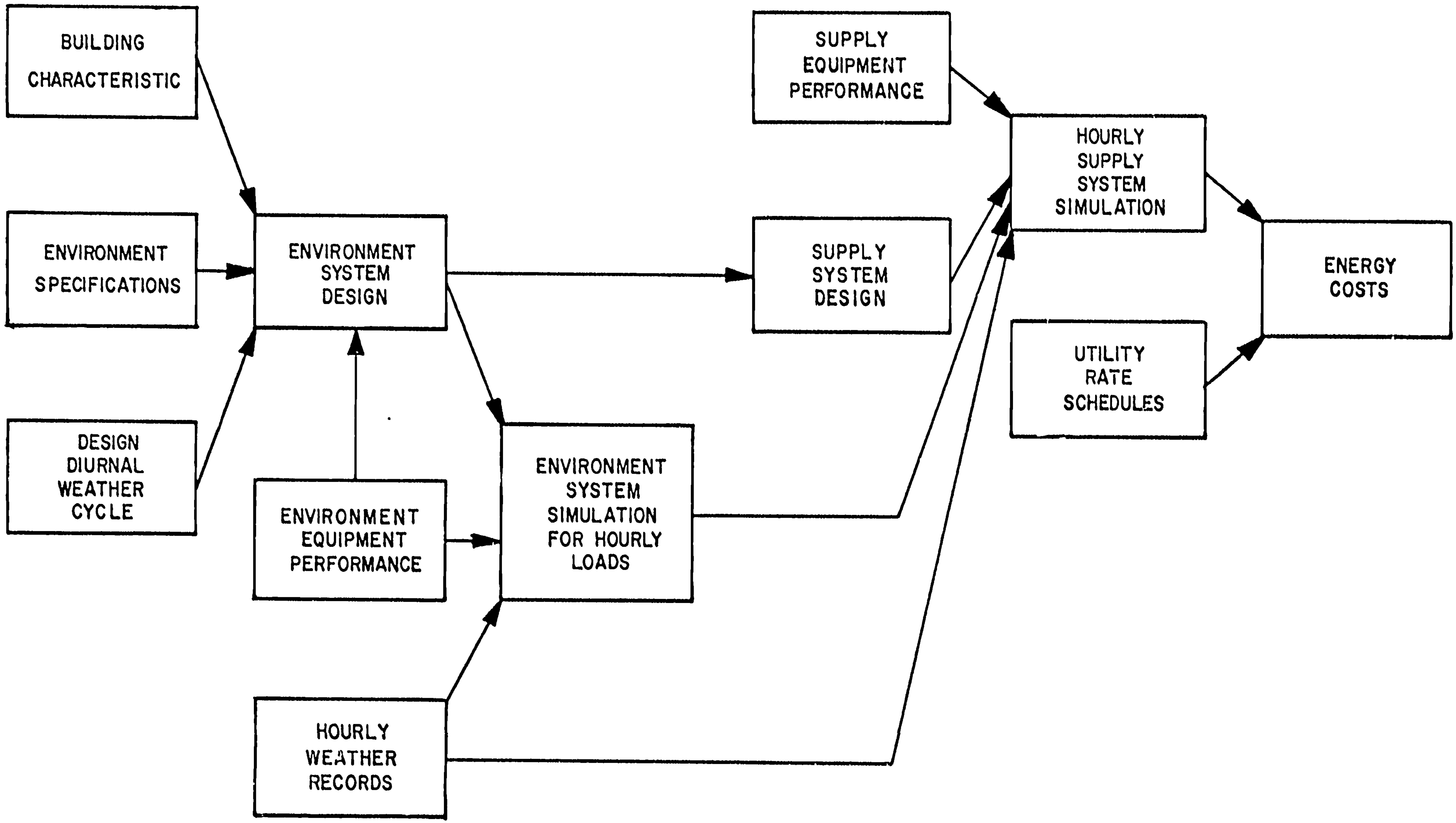
Having established a basis for comparing annual and capital costs, consideration can now be given to the engineering factors.

4.2 - Energy Cost Analysis

The detailed analysis of the energy costs of various total energy concepts involves a great amount of energy in itself. This is especially so when applying the concept to a university campus.

Many buildings are usually involved, each having its own particular seasonal heating and cooling requirements. The campus is always growing and changing its characteristics year by year. It is therefore essential that a realistic, but still flexible, schedule of utility demands be prepared on an annual basis so that the utility plant unit capacities can be effectively and economically phased with the campus development.

The various steps in a detailed energy cost analysis are shown in Figure 5. The steps are shown in logic form and are amenable to computer application. It does show just how far back into the basic details of the individual building design the analysis can be carried.



STEPS IN ENERGY COST ANALYSIS

FIGURE 5

The detail shown in Figure 5 is perhaps more applicable to a single building, or at least, to a restricted number of buildings. On a campus where up to a hundred buildings or facilities may be located, it is usually adequate to apply general design parameters based on building area, population and use for heating, cooling and power demands. The diversity among the various demands will provide for any unusual or special demands at a particular building.

More often than not these days, the evaluation is being prepared for a campus which is still in the planning stage. The general information relating to student population, distribution between the arts and sciences and rate of campus development are usually statistical projections rather than hard facts and figures.

In these cases, a great deal of reliance is placed on statistical data obtained from other universities or similar institutions. Even then, the modern university and its needs are increasing in scope and magnitude every year and the available history of utility demand parameters is usually out-of-date before the new university is operating.

Therefore, an evaluation carried out in the planning stages of a university must be based on sometimes arbitrary design factors making allowance wherever possible for the known trends in university building and utilization characteristics. Whatever scheme is adopted, it must incorporate sufficient flexibility to adjust itself to the university development, based on the operating experience obtained as the campus loads grow with the years.

4.3 - Evaluation Factors

Some of the overall factors affecting the evaluation of a campus total energy concept are discussed below. This discussion is not intended to be exhaustive, each factor could be the subject of a paper in itself.

(a) - Load Pattern - A total energy system can be competitive only when maximum use is made of its inherent efficiency. Ideally, the power demand variation should match the heat recovery demand at all times. If the exhaust heat from the prime mover exceeds the demand for recovered heat, either the surplus heat must be wasted or, alternatively, the prime mover output can be lowered to match the heat demand and the deficiency made up from more expensive purchased power.

It therefore follows that the heat demand, whether it be for building heating or air conditioning, should be sustained all year round and remain as close as possible to a constant, even demand. In the past, when building heating was the only requirement, a total energy system was not competitive since no heat recovery was required in the summer and overall efficiency was reduced to that of the prime mover. Further, during the summer vacation period the university was closed and only minimal utilities were required.

Nowadays, air conditioning is the rule in modern universities. To satisfy the ever increasing demand for special summer courses and to accommodate the increasing student population, universities are in full operation the year round. This, of course, means a continuous demand for air conditioning and heating.

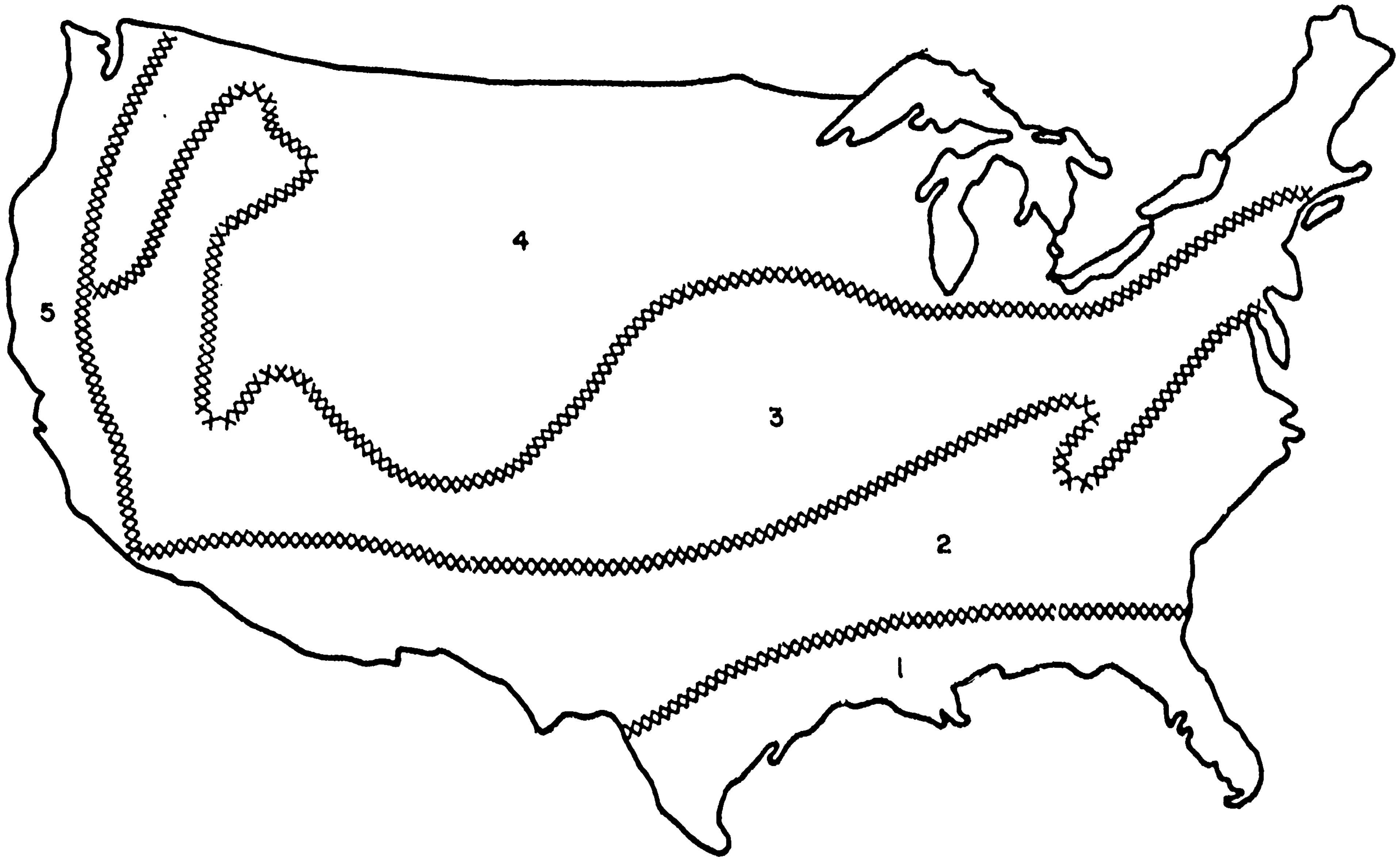
The overall utilization of a total energy system varies with the climatological location of the university. For instance, in the southern states, the summers are long and hot. The winters, by our standards, are hot as well and very little heating is required. The main heat demand is, therefore, for air conditioning only and, since this varies considerably from summer to winter, power demand in the winter usually creates more waste heat than can be utilized for air conditioning, assuming the system to be designed around the maximum summer conditions. Similarly for a university situated in a very cold climate, heating in the winter only would be required, there would be little or no summer air conditioning.

The total energy system appears, by computation, to be most efficiently utilized in the temperate zones where the summer is warm enough to require air conditioning and the winter cold enough to require heating, thus sustaining a year round heating demand. This computation was extended to a number of cities in the United States in general climatological areas. Average efficiencies in total energy systems were computed for each area as shown in Figure 6.

Air conditioning loads are on the rise on university campuses, not only in the summer when the equivalent thermal load can exceed the winter heating load, but also in the winter. The trend to more compact buildings with large core areas keeps the cooling system going even in very cold weather to hold core temperatures at comfortable levels. Most of this heat gain is produced in high intensity lighting.

The trend to more air conditioning throughout the year, added to the normal winter heating load, is producing higher overall system load factors and making the operating costs of total energy system more favourable.

(b) - <u>Campus Configuration</u> - As a general rule, the larger an installation is in terms of unit capacity, the cheaper it will be. Therefore, the ideal arrangement for a university total energy system is in a central utility plant in which is concentrated all the power generation, heating and air conditioning for the entire campus. The heating steam, or hot water, chilled water and power are distributed through the campus, either buried or in tunnels.



CLIMATE

1 LONG HOT SUMMER, NO WINTER

2 HOT SUMMER, MILD WEATHER.

3 HOT SUMMER, COLD WINTER

4 SHORT, NOT HOT SUMMER, COLD WINTER

5 TEMPERATE

CLIMATOLOGICAL REGIONS

FIGURE 6

Not all campus plans are ideal for central total energy systems however. Some campuses can be so large that the thermal losses or gains in the distribution piping can reduce the overall system efficiency to the point that it will be less than the competitive system utilizing purchased power.

Many modern universities are fortunate in that they are developing a new campus on a new site. They can plan ahead making provision for the central plant and distribution systems. On the other hand there are many older campuses still located in downtown areas, interpersed with other buildings and city streets. Centralization, if not originally established is well nigh impossible.

Both the system distribution loss and ability to establish a central plant are factors which must be part of the overall evaluation. Nevertheless, even if centralization is not feasible, smaller plants, similar to those becoming popular in shopping centres and schools, could prove economically attractive for a selected group of buildings.

(c) - Fuel Cost - This includes not only the gas or oil used in the prime mover but also the alternate fuel, electric power. All are sources of energy and are being compared economically. An all electric campus is utilizing the total energy concept, the single fuel being electricity.

The cost fuel is in two parts, its first, purchase cost and its utilization cost. The purchase cost is affected considerably by the location of the campus relative to the fuel source. The utilization costs arise from handling and amenity problems.

The principal fuels are:

Natural Gas - This is the easiest fuel to handle, all it requires is just a pipe to the point of use, there is no storage required. Its utilization cost is therefore almost negligible.

The main disadvantage of gas at the present time, especially in eastern part of the continent, is the relatively high cost of a firm supply. A price schedule obtained this year for a study of fuel costs in an Ontario university, gave a firm supply at 80 cents a million Btu. An interruptible supply was available at 45 cents for 6 months each year to 55 cents for 11 months each year.

To achieve an equivalent price per million Btu equal to that of fuel oil, an interruptible supply must be accepted and fuel oil used as the standby fuel. By the time the cost of the fuel handling system is added, and the fact that a standby oil supply usually has a higher unit cost, it after proves to be cheaper to stay with a straight oil-fired plant without gas.

The only factor in favour of the dual fuel system, is the control of air pollution at least during the summer months. With the new pipelines being added from west to east, a firm gas supply at an acceptable price may become available in the relatively near future. In any event, even if oil is the fuel selected, provision should be made for future gas firing to take advantage in any favourable change in gas costs.

For large users, the rate structure for natural gas is usually based on demand and use. To obtain a realistic estimate of gas prices for evaluation purposes, it is usually necessary to provide the gas company with an estimate of annual, maximum monthly and daily demands.

Fuel Oil - Recent prices obtained for fuel oil in Toronto indicate costs comparable to those for an interruptible gas supply. The relative costs are affected by location. In eastern Canada, the fuel oil is cheaper where it is imported along the St. Lawrence Seaway. Going west, nearer to the source, natural gas becomes less expensive on the west coast, oil imported by tanker gains ground. However, in general, the divergence is never great, the prices being maintained by competition.

Fuel oil has two disadvantages when compared with natural gas. First, it must be stored at the site, pumped and heated. Secondly, the sulphur content is a major cause of system corrosion and air pollution. Both require investment of capital and incur operating and maintenance costs.

With new attention being focussed on air pollution at both the provincial and federal levels, future legislation will tend to restrict the sulphur content in the fuel oil burned in utility plants. The present thinking is 1.0 to 1.5 per cent as compared with the oils now being fired and containing up to 3 per cent. Recent prices for a 1.5 per cent sulphur oil show a premium of about 7 or 8 cents a million Btu, however, if and when large scale production of low sulphur oils becomes necessary, this premium will probably disappear.

Coal - In some areas, coal is competitive with both oil and natural gas. The main drawbacks are the storage, preparation and handling required. Ash disposal and air pollution control add to the cost. This is especially the case in downtown areas.

Electricity - In this context is considered as a fuel, a source of energy to be compared with oil or gas or coal. Again, like the other fuels, cost varies with location and usage. In Canada, electric power, derived mainly from hydroelectric generation has been relatively cheap. The incentive to resort to total energy concepts has been somewhat less than in most of the United States where more expensive thermal generation is the predominant source of electric power.

As with gas, electric power is usually billed on a demand and use basis. Until recently, in some Canadian provinces, most universities were billed on the commercial rate and not on the cheaper industrial rate. However, recently, in Ontario for example, the policy has been changed and the billing will be based on demand and load factor. There will be no class of user such as commercial or industrial. This will tend to reduce power costs to the larger universities for the time being and will affect the evaluation of any total energy concept.

If a standby power supply is provided to a total energy system and is only used in the event of equipment breakdown, the power utility will probably charge for this standby on the basis of so many cents per month for each kilowatt of contracted standby capacity. In Ontario this usually is 50 cents. Therefore for a 10,000-kw standby the charge would be $60,000 per year. This cost is an important factor in evaluating the amount of standby capacity to be incorporated in the utility plant.

The majority of university campuses are using fuel oil or gas as their main fuel. Many of those which have burned coal in the past, are now converted to either oil or gas, or both, mainly to remove stack dust emission problems.

When evaluating a total energy concept, consideration must be given to the abilily of the prime mover to burn the fuel safely and efficiently. An industrial gas turbine can accommodate a cheaper, heavy fuel oil, after suitable chemical treatment. However, for proven reliable operation, natural gas, naptha or a diesel oil are preferred. Similar requirements apply to reciprocating type engines. The evaluation should allow for any special treatment required to make a fuel suitable for use in the prime mover.

(d) - Operating Costs - Assuming that a steam or hot water system is already selected for building heating, in all likelihood the boiler operating staff will also be able to attend to the power generating equipment. Therefore, the total energy system will not materially increase the cost of operating labour.

The case would be different when comparing the fuel-fired total energy system with an all electric system where shift operators would not be required. The fuel-fired system would carry a penalty of about $35,000 per year for each shift of one man.

Maintenance costs can vary widely with the type of fuel burned, type of prime mover and type of operation. As already mertioned higher maintenance costs may be expected from the use of heavy fuel oil. The larger, industrial type gas turbines are cheaper to maintain than the higher rated aircraft type though often contract maintenance can be obtained with the latter type. The frequency of starts and load swings can affect the time between the gas turbine overhauls.

The statistics available on gas turbine and engine maintenance vary with type of engine and manufacturer. With gas turbines, it is only now that sufficient history of operation is being obtained to provide reliable maintenance cost data.

(e) - Equipment Costs - The estimates of equipment costs can be compiled from standard data where the structural, electrical and mechanical auxiliary systems are concerned. Cost estimates for gas turbine, engines, boilers, etc., can be obtained from manufacturers.

An important consideration affecting equipment cost is the provision made for standby capacity were essential services which must be maintained. This is especially true where a medical complex is part of the university and supplied from the central plant. Other buildings may contain experimental work which would be lost if deprived of heat or refrigeration for any length of time. These special areas can either be provided with individual emergency units at the building concerned or there can be sufficient standby equipment in the central plant to maintain essential supplies in the event of failure of the main equipment.

In less essential areas of the campus, the service can be reduced, or shut off completely for a short while, while the condition is rectified.

The loss of generation in a total energy concept would mean loss of electric power supplies and, if auxiliary fuel firing at the waste heat boiler is not provided, steam generation and chiller operation. In any event, without electric power, there would be no pumps available for a fuel oil fired boiler. This is where gas has an advantage over oil.

Standby power could be provided by a battery started auxiliary diesel or gas engine generator or from a stanby supply provided by the electric power utility. Each alternative has to be included in the evaluation, either as a first cost for the standby equipment or as an annual cost for the standby power supply.

The foregoing is perhaps a rather lengthy review of the factors affecting the choice and evaluation of total energy concepts in universities. No attempt has been made to define any specific design parameters but rather to draw attention to those factors which must be taken into consideration.

5 - THE PRESENT STATUS OF TOTAL ENERGY SYSTEMS

It is in the commercial and educational fields that the integrated energy system has been gaining increasing prominence in the last few years and providing stiff competition for the electric utilities.

The Park Plaza Shopping Centre in Little Rock, Arkansas has been well documented in the technical literature. Other well known installations exist in the McAllen High School, Texas and the Rockdale Village Apartment Development in New York.

In Canada, the Hillcrest Junior High School in Jasper Place, Alberta generates up to 600 kw in two gas engine driven generators and uses the waste heat from the engines to produce up to 1,500 pounds of low pressure steam per hour. The steam is used either to heat the school in winter or in air conditioning equipment in summer.

A recent survey of energy systems in North America lists 75 total energy installations. Of this number, thirty were industrial plants. However, the rest included:

Office Buildings	17
Shopping Centres	11
Schools	9
Hospitals	3
Motels	3
Restaurant	1
University	1

The majority of these systems utilize gas as their single fuel, a few have oil standby. It should be noted that all the office building installations belonged to gas utilities where gas seemed to be the preferred fuel.

Almost 80 per cent of the installation listed had a power generating capacity of less than 2,000 kw. The coresponding waste steam generating was less than 7,000 pounds per hour and the air conditioning capacities less than 550 tons.

6 - THE CONCEPT IN UNIVERSITIES

The statistics given in Section 5 are intended to illustrate the relatively small size of the installations to date, also the fact that almost no installations are listed as being in a university. The sole exception has a generating capacity of only 375 kw.

At first inspection, it would seem that the modern university campus would be an ideal application for a Total Energy Concept. It has a year round demand for electric power together with a constant demand for heat, either for building heating in the winter or air conditioning in the summer.

Even by industrial standards, the energy demands in modern North American universities are large. Steam demands in the hundreds of thousands of pounds per hour, power demands in the tens of megawatts and thousands of tons chiller capacity, put many large industrial installations to shame. Yet, compared with the number of universities, the number of campus total energy system is almost negligible.

Why are universities not taking more advantage of the concept? What are the disadvantages of total energy systems that deter their application in universities?

Perhaps the greatest disadvantage is the fact that it ties up a great deal of capital and valuable real estate. With the current rate of increase in the university population and the corresponding boom in campus development, finding money to build the educational facilities alone is a hard enough task. This does not encourage the investment of money in a noneducational facility to which there is an alternative demanding no down payment, even if its operation may be a little more costly in the coming years. The university is an educational establishment and does not want to get into the power generation business for the sake of it.

The value of the real estate occupied by power generating plant depends on where the university is located. At some, where they are developed on a new and spacious campus, land cost is of minor importance. In a downtown campus however, real estate values are usually extremely high and any generating plant will have to bear a heavy penalty based on the cost of the value of the land space it occupies. This cost can be decisive in most cases. In a recent utility development study fcr a downtown campus, it was found economically feasible to meet the increasing heating load by replacing boilers only twelve years old with new and larger units, rather than expand the utility plant and tie up more real estate.

Another problem is lack of flexibility. A total energy system must be designed on the basis of the conditions known at the time it is installed. These conditions are to a large extent based on projections of future fuel costs, operating cost, rate of campus, developement, etc. A change in any one of these factors could alter the economics of a total energy system to the point that it is added cost to the university operation rather than a saving.

The economic design of a total energy system depends to a great deal on an accurate determination of the building heating and cooling loads and their seasonal variation. This is required not only at the time the evaluation is carried out but also for the projected campus development which may cover many years. Matching the total heat and power demand to the load profile of each installation is an important step in developing the optimum cycle and the phasing of the unit additions to meet future increases in loads. If the situation changes because of unforeseen requirements, the plant capacity may be inadequate or there may be a lot of expensive equipment lying idle or operating at part load and low efficiency.

A review of total energy concepts carried out for York University, Toronto, in 1962, showed that, bases on the ultimate campus developement, the concept would be economically attractive and could repay the additional cost of the generating equipment within 8 years. A brief summary of the comparative costs computed for this study are attached as Table 1.

TABLE 1

ESTIMATES OF CAPITAL AND ANNUAL OPERATING COSTS OF TOTAL ENERGY CONCEPTS

Power	4 x 5,000-Kw Gas Turbines	1 x 5,000-Kw Gas Turbine Remainder Purchased	10 x 2,500-Kw Diesels	Back-Pressure Steam Turbine 3,600-Kw
Heating	Auxiliary-Fired Waste Heat Boilers	Waste Heat Boilers Plus Conventional Boilers	Waste Heat Boilers Plus Conventional Boilers	Conventional Boilers and Exhaust Steam
Air-Conditioning	Absorption/Motor-Driven Centrifugal	Absorption/Motor-Driven Centrifugal	Motor-Driven Centrifugal	Absorption/Turbo-Driven Centrifugal
Capital Costs:				
Power generation equipment	$3,200,000	$ 800,000	$2,500,000	$ 162,000
Additional boiler costs[1]	250,000	62,500	40,000	200,000
Additional building costs[2]	96,000	30,000	192,000	84,000
Additional ducting and piping costs[3]	200,000	50,000	150,000	72,000
Air-conditioning equipment	1,596,000	1,436,700	1,416,000	1,525,000
Fixed equipment	2,271,000	2,271,000	2,271,000	2,271,000
Subtotal	$7,613,000	$4,650,200	$6,559,000	$4,314,000
Contingencies, Engineering etc., ...	502,000	306,000	432,000	284,000
TOTAL CAPITAL COST . . .	$8,876,000	$5,421,000	$7,647,000	$5,029,000

Estimates of Capital and Annual Operating Costs
of Total Energy Concepts

Power	4 x 5,000-kw Gas Turbines	1 x 5,000-kw Gas Turbine Remainder Purchased	10 x 2,500-kw Diesels	Back-pressure Steam Turbine 3,600-kw
Heating	Auxiliary-fired Waste Heat Boilers	Waste Heat Boilers Plus Conventional Boilers	Waste Heat Boilers Plus Conventional Boilers	Conventional Boilers and Exhaust Steam
Air Conditioning	Absorption/Motor-driven Centrifugal	Absorption/Motor-driven Centrifugal	Motor-driven Centrifugal	Absorption/Turbo-driven Centrifugal
Annual Operating Costs:				
Power cost	$ 710,000	$ 678,500* 406,000**	$ 326,000	$ 723,600* 720,000**
Heating cost	327,000	443,000	560,000	157,800
Air conditioning cost	35,700	Included above	42,800	Included above
Additional maintenance cost	60,000	15,000	166,000	5,400
Additional operator cost	-	-	72,000	-
Fixed operation and maintenance cost . .	264,100	264,100	264,100	264,100
Lubricating oil cost .	6,500	3,700	9,000	-
TOTAL ANNUAL COST . .	$1,403,300	$1,810,300	$1,441,900	$1,870,900

* Purchased
** Generated

Comparison of Total Energy Concepts
with Purchased Power Concept

Power	All Purchased	4 x 5-mw Gas Turbines	1 x 5-mw Gas Turbine Plus Purchased	10 x 2.5-mw Diesels	Back-pressure Steam 3,600-kw Plus Purchased
Heating	Oil-fired Boilers	Waste Heat Auxiliary	Waste Heat Plus Conventional	Waste Heat Plus Conventional	Conventional Boilers Plus Exhaust
Air Conditioning	Absorption/Turbo-driven Centrifugal	Absorption/Motor-driven Centrifugal	Absorption/Motor-driven Centrifugal	Motor-driven Centrifugal	Absorption/Turbo-driven Centrifugal
Capital costs	$4,439,000	$8,876,000	$5,421,200	$7,647,000	$5,029,000
Capital cost difference	Base	+$4,437,000	+$ 982,000	+$3,208,000	+$ 590,000
Annual operating costs	$1,932,000	$1,404,300	$1,810,300	$1,441,900	$1,870,900
Annual operating cost difference	Base	-$ 528,700	-$ 121,700	-$ 490,100	-$ 61,100
YEARS PAYOFF		8.40	8.08	6.55	9.68

NOTES: 1 - Additional boiler costs are the costs of auxiliary-fired waste heat boilers additional to the costs of conventional boilers included in the cost of the fixed equipment.

2 - Additional building costs are the costs of building additional to the cost of the Central Utility Building for the conventional plant.

3 - Additional ducting and piping costs are the costs of ducting and piping additional to the cost of ducting and piping for the conventional plant.

The conclusion at that time was that, while the concept showed advantages in the long run, it should be deferred for further consideration until the campus load characteristics could be determined to firmly establish the economic bases. A further consideration was the fact that, for the ultimate installation to be economical, minimum unit capacities would have to be adopted. Therefore, in the early stages of the campus development, the prime mover unit capacity would be far in excess of the campus demands and the university would have been faced with a partly loaded facility operating at low efficiency for a large capital outlay.

Nevertheless, it was recommended that the initial central boiler plant be arranged so that gas turbines and waste heat boilers could be integrated in the central utility building in the future. Further studies are anticipated in the near future to assess the application of the concept in light of the current campus expansion program, electric power and fuel costs.

York University envisage an ultimate campus of over 80 buildings accommodating in excess of 15,000 students by 1980. The contemplated ultimate utility capacities are 600,000 pounds per hours of heating steam, 18,000 tons of chilling and 24,000 kva of electric power. By comparison, the results of a study for a smaller university in Ontario, anticipating a student population of 7 to 8 thousand, showed a payout for a total energy concept of between 12 and 30 years, depending on the plant arrangement. This was achieved for an additional capital outlay of between one and two million dollars. In this case it was recommended that no further consideration be given to the concept.

7 - CONCLUSIONS

The above figures do illustrate the problem of large capital outlay associated with total energy concepts. The larger the ultimate campus, the larger the economic generator unit size and the greater the outlay for what could be, initially, a very small annual saving or, in some cases, an annual loss. However, notwithstanding these apparent limitations, the concept has a place on the university campus. It is considered that a review of total energy concepts is justified for any university campus, if not with the immediate application in mind, then to ensure that the utility system is not developed in such a fashion as to preclude benefits of the concept at some future date.

Looking to the future, both the fuel cell and atomic energy could some day be economical sources of energy for total energy system.

The fuel cell using natural gas is still in its infancy. However, it has a high efficiency and in time will be developed into sizes adequate to take care of a considerable building area.

Considerable investigation into small, pressured water reactors has been carried out by Atomic Energy of Canada. The technology exists for the design of a 100,000 pound per hour steam generator using natural uranium at 16 cents a million Btu. The problem at the moment is the first cost which, for a 340,000 pound per hour boiler, is three or four times the cost of a conventional fuel-fired boiler. However, it is anticipated that by simplification in design, safety control and operator requirements, the cost of such a nuclear boiler will eventually be competitive with the fossil-fired units for base loads with a high load factor. At that time, they would be attractive to universities, not only as a utility, but also as a research tool.

MR. PHILLIPS: We have time for one question and one answer.

QUESTION: I was wondering if there exists at the present time on any campus, either in the United States or Canada, a nuclear steam generating equipment utilising this concept?

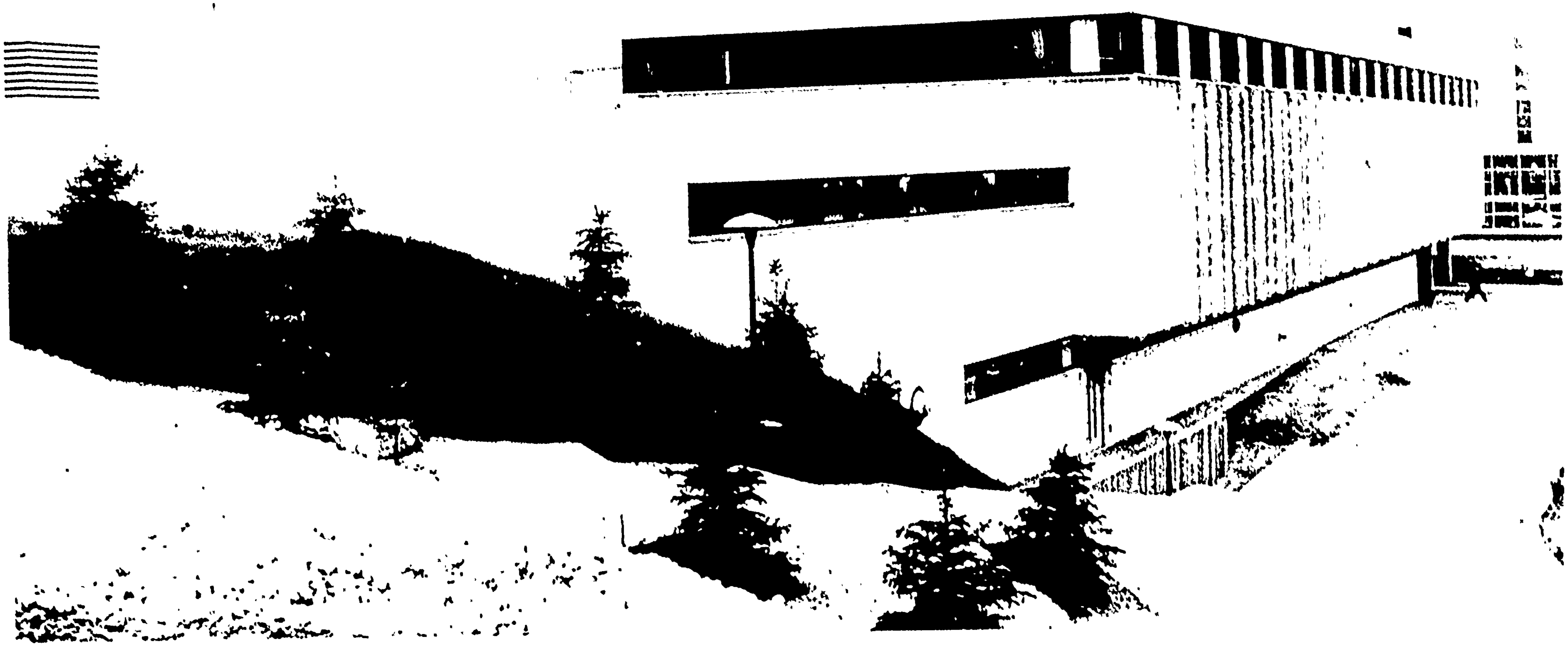
MR. GUDGEON: Not that I know of. McMaster have a research unit utilizing the waste heat.

QUESTION: Not furnishing them total energy for the campus?

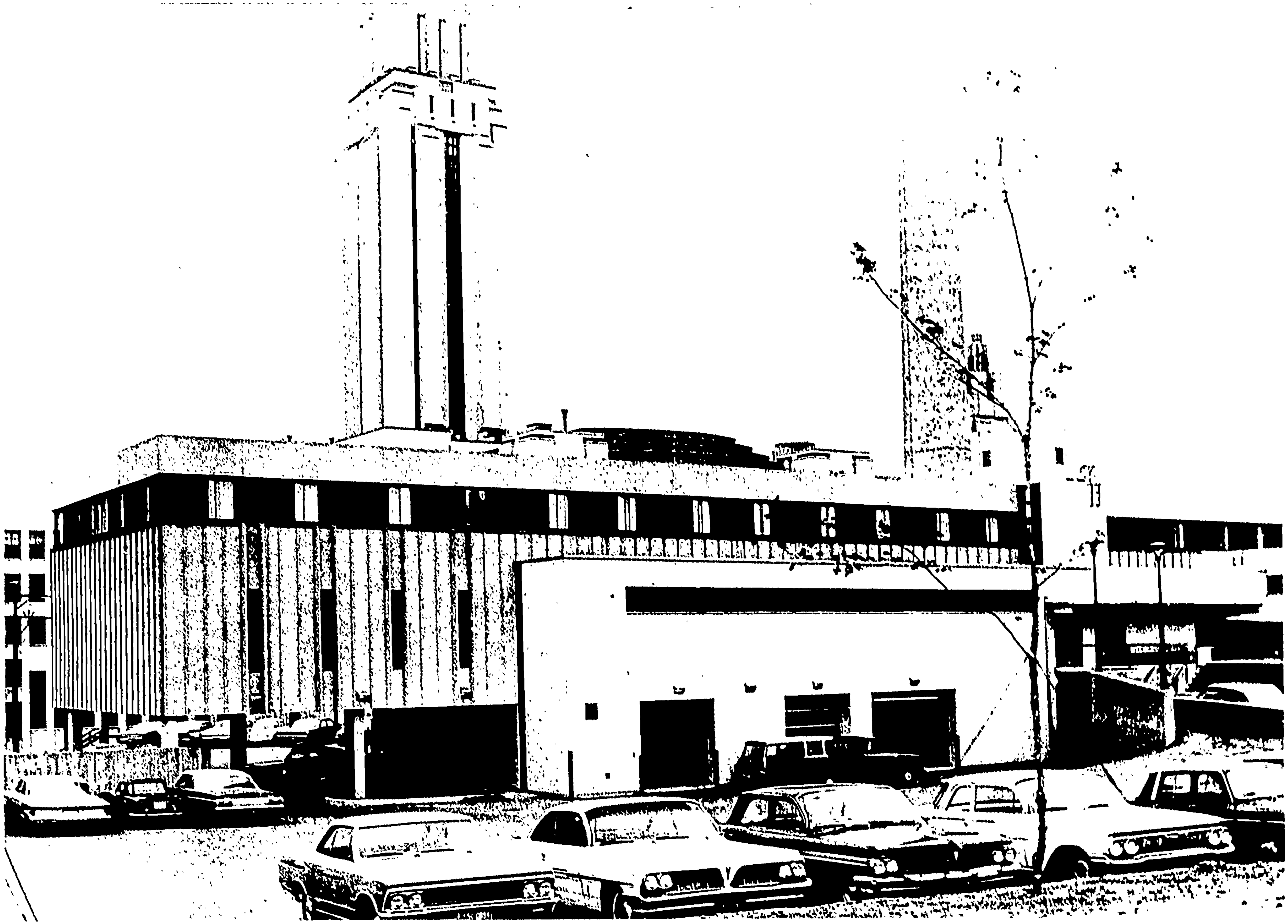
MR. GUDGEON: This is a research unit. I do not think there is anything operating yet. They are trying to develop some compact units; it is still in the development state.

MR. HASTIE: I would like to thank you very much for a very informative paper on a very complex problem.

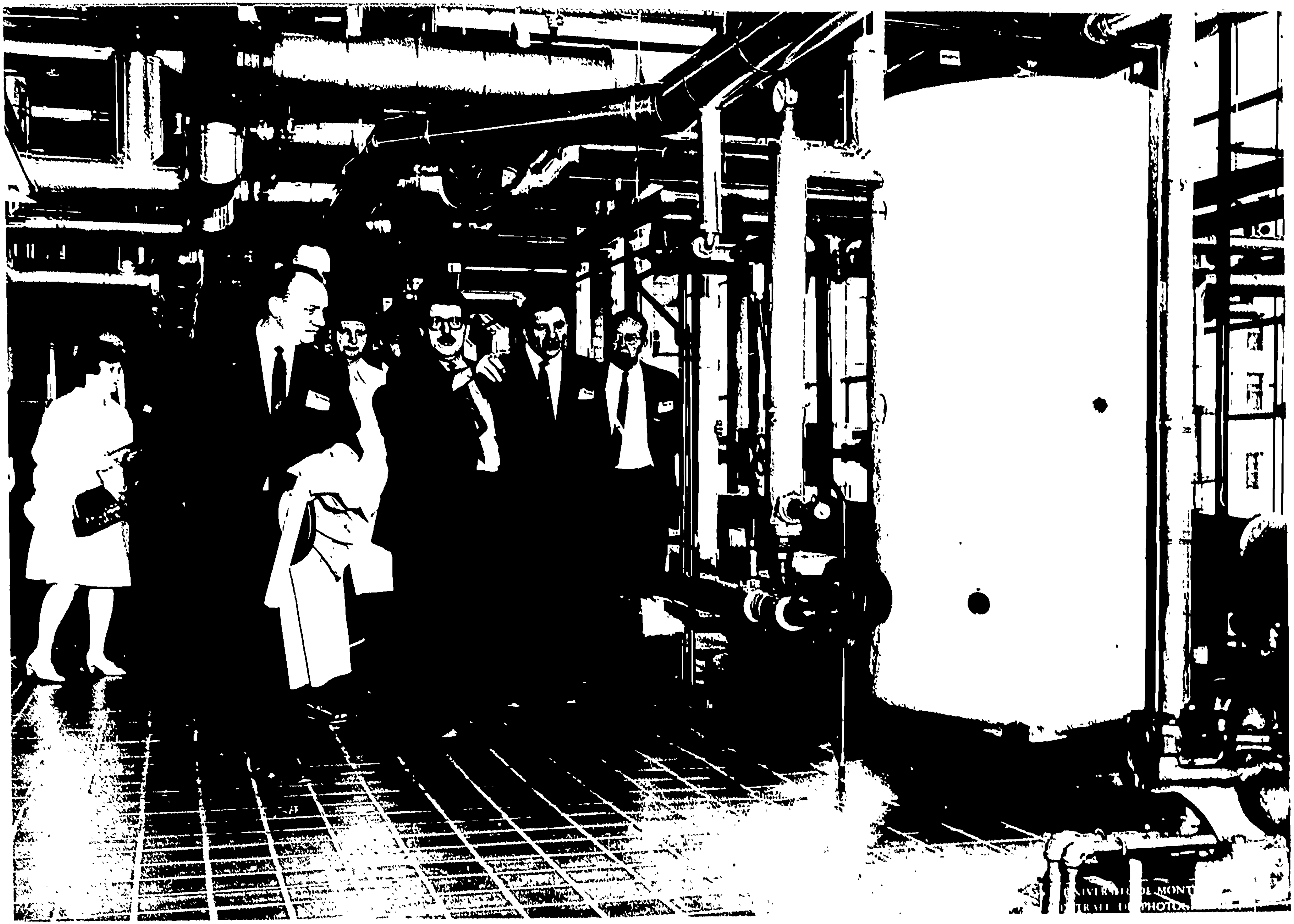
MR. PHILLIPS: I know many of you probably have other questions you would like to ask and I wonder if you can catch him later.



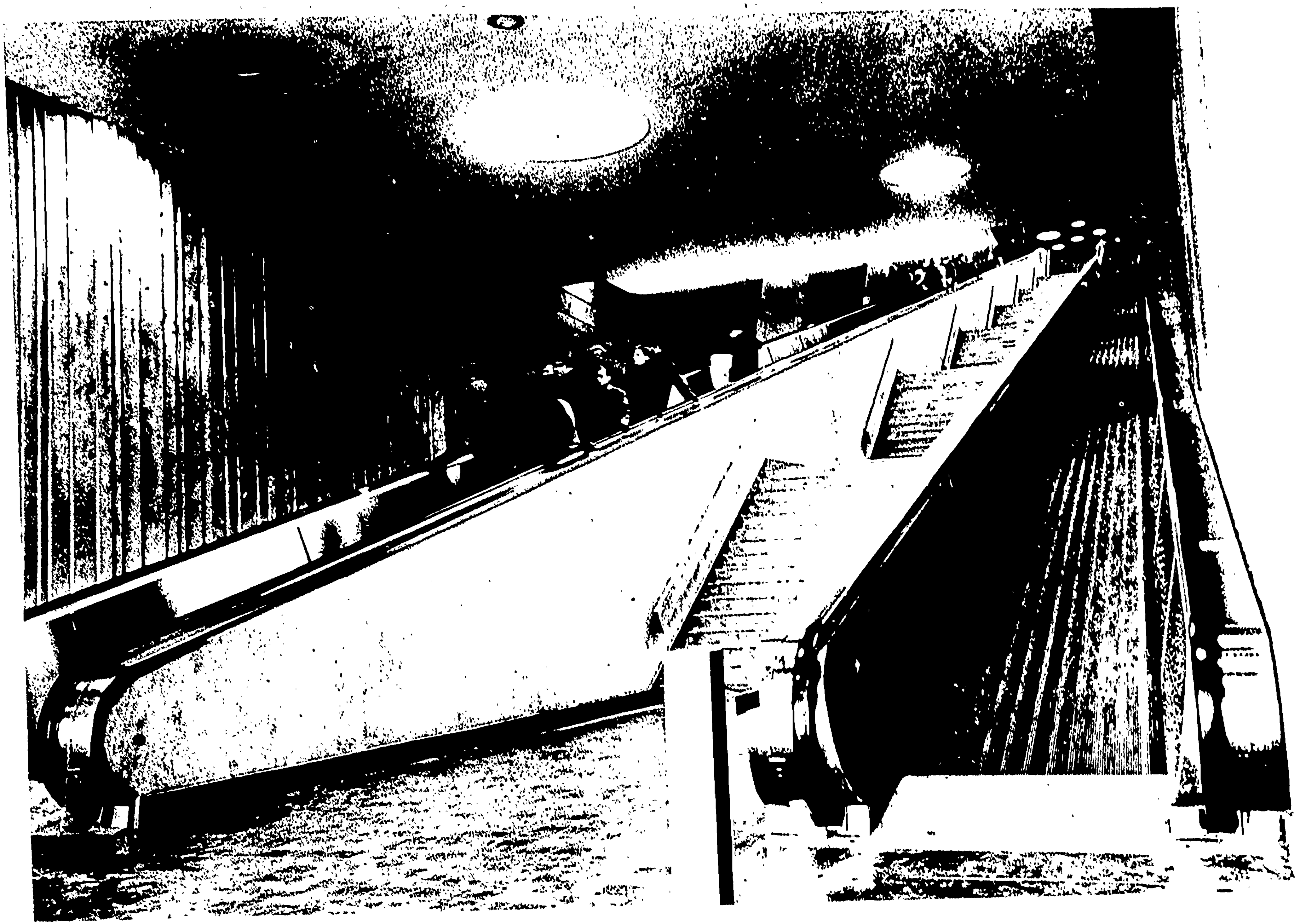
Université de Montréal - Service Building



Université de Montréal - Service Building



Université de Montréal - Visit of the H.T.W. Power Plant



Université de Montréal - Moving Ramps