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Cogeneration plants for electric power and district air conditioning in Kuwait

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ABSTRACT

The harsh climatic conditions in Kuwait bring the electric consumption of air conditioning machines to more than 70% of the total power consumption. It also induces an uneven electrical daily pattern with a sharp peak that lasts only for a few hours. This pattern puts heavy strains on the authorities in order to meet an annual increase of 200 MW installed-power demand. Beside the high investment involved, inefficient energy utilization results from part-load operation most of the time.

The present study introduces the concept of a cogeneration plant, producing both electric power and process heat to operate absorption cooling machines for air conditioning. This concept offers better utilization of fuel and equipment than a single-purpose power plant which produces electricity to operate conventional air conditioning machines. It also improves the load distribution pattern in the country by eliminating the peak due to air conditioning. The study compares the capital and operating (mostly fuel) costs of a single-purpose power plant and the suggested cogeneration plant. It shows the superiority of the cogeneration plant in saving both capital and operating costs.

INTRODUCTION

The hot climate of Kuwait and most Gulf States makes cooling air conditioning (A/C) a necessity for most of the year (e.g. at least seven months in Kuwait and nine months in Mecca and Jeddah, Saudi Arabia). Installed air-conditioning capacities are continuously increasing in residences, public buildings, and industrial and commercial complexes due to the constantly growing population and the rising standards of living. Electrical power consumption is directly linked to power needed to drive air conditioners. Consequently, the capacities required from the electrical power plants are escalating every year (e.g. 7 to 10% in Kuwait).

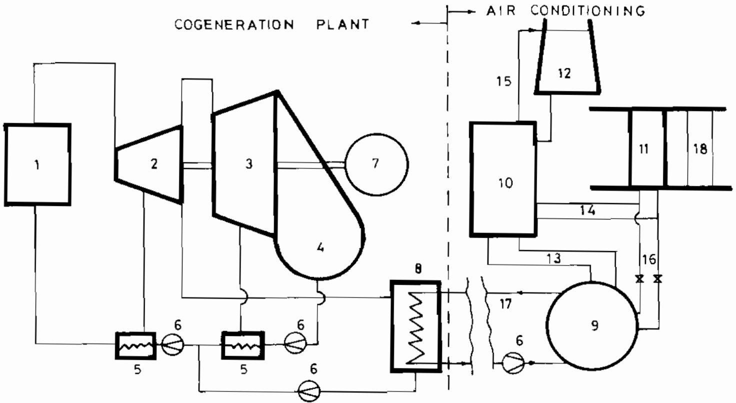
Uneven daily and monthly electrical load distributions that follow the air-conditioning cooling load have been noticed in the whole Gulf region. For example, in Kuwait the maximum electrical peak demand for July 1984 was 2975 MW or 2·5 times the corresponding demand in March 1984 (1260 MW) when neither cooling nor heating was required (Statistical Yearbook 1985). Heating is required in Kuwait for only a limited time (about three months), which does not justify the use of a district heating system.

The escalating power demand, uneven load distribution, and inefficient utilization of energy in power plants due to the varying load requirements of A/C are of real concern in this area. Finding a solution to these three problems is the aim of this study. It suggests using a cogeneration plant to produce electrical power and process heat for air conditioning. In these plants, steam is generated at high temperatures and pressures. It is then expanded in steam turbines to the condition required by the process heat system where it is fully or partially extracted. Unextracted steam continues to expand in the turbine until it condenses and produces more power. The steam can be extracted at any location between throttling and condensing conditions (e.g. at pressures corresponding to saturation temperatures of 100–160°C for driving absorption air-conditioning machines and desalting plants and at 60–150°C for district heating).

The Gulf States have long experience in cogeneration plants that produce electric power and desalted water. In the early days, boilers were used to produce low-temperature steam to operate desalination plants. It was recognized later that this is an unwise use of fuel, and cogeneration plants were introduced. A similar approach is used in cold countries where cogeneration plants are used to produce both power and process heat for district heating. These dual-purpose plants are more efficient and utilize fuel, equipment and space in a better way than two single-purpose plants.

This study proposes the use of a district distribution piping system to transfer process heat, in the form of hot water, from a cogeneration plant producing both electric power and process heat as shown in Fig. 1. The hot water operates H_2O–LiBr absorption A/C machines which can be installed in the buildings to be cooled. Hot water can also be supplied directly to the air handling units when heat is required. The year-round need for hot water to operate both cooling and heating systems justifies the adoption of this system in highly populated areas. The study proves, by considering a real case, that the proposed arrangement can achieve the following goals:

1. More efficient use of energy input (fuel) to produce both electric power and air



1 – STEAM GENERATOR
2 – H.P. TURBINE
3 – L.P. TURBINE
4 – CONDENSER
5 – FEED HEATER
6 – PUMP
7 – GENERATOR
8 – HEAT EXCHANGER
9 – HOT WATER STORAGE
10 – H_2O LiBr ABSORPTION M/C
11 – AIR HANDLING UNIT
12 – COOLING TOWER
13 – HOT WATER PIPING TO ABSORPTION M/C
14 – COLD WATER TO HANDLING UNIT (SUMMER)
15 – COOLING WATER
16 – HOT WATER TO AIR HANDLING UNIT (WINTER)
17 – HOT WATER PIPING TO STORAGE SYSTEM
18 – FAN

Fig. 1. Suggested arrangement of cogeneration and absorption air-conditioning.

conditioning (cooling and heating) than the conventional method of a single-purpose power plant and electrically driven vapour compression cooling system.

2. More efficient use of equipment by eliminating expensive and inefficient parts of the steam power plants (e.g. parts of turbines and condensers).
3. Reduction of the continuously increasing installed power capacity and A/C capacities by using water storage. As a result, the inefficient old peaking-load plants can be reduced or eliminated.

Moreover, the proposed arrangement uses only commercially available and proven types of equipment with ensured reliability. The system can be installed in either Kuwait University campuses as part of total energy system or industrial complexes where both cooling/heating and electricity are needed.

Steam power plants and absorption cooling machines have some characteristics that constrain the combining process. These characteristics and modern practices in designing and operating these systems are discussed below.

FOSSIL FUEL STEAM POWER AND HEAT PLANTS

The raising of both temperature and pressure of steam throttling condition in modern power plants standardized the use of reheating and regenerative cycles for units of 120 MW or larger capacity. A simplified schematic diagram of a steam power plant cycle is shown in Fig. 2. Typical turbine design efficiencies for high pressure (HP), intermediate pressure (IP), and low pressure (LP) cylinders are 89%, 92% and 80% respectively. The reasons for the relatively low efficiency of the LP cylinder are the use of long blades, very high steam velocities, steam wetness, and the highly flared steam path. The excessive increase of the specific volume with the decrease of pressure due to

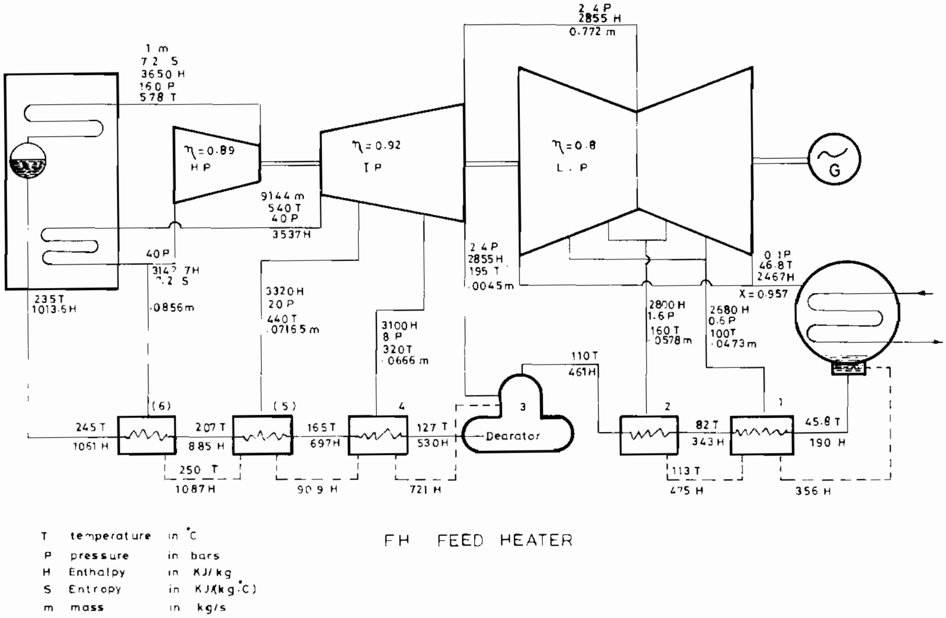


Fig. 2. Typical steam power plant.

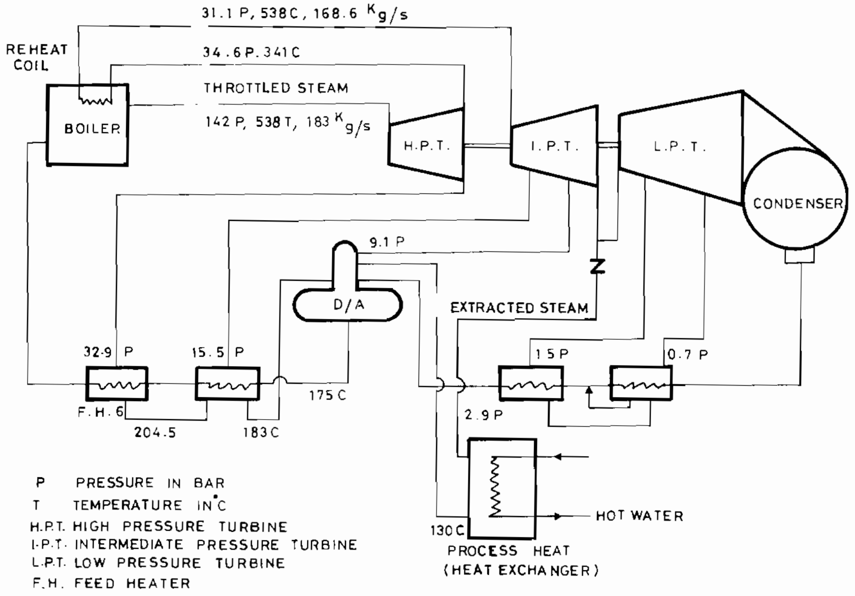


Fig. 3. Typical steam power plant with bleeding steam for process heat.

expansion along the LP turbine necessitates greater increase of the LP cylinder cross-sectional area than that of the HP and IP cylinders. A typical example of the volumetric flow rates leaving the HP, IP and LP cylinders are 97, 156, and 1000 l/s for a 120 MW turbine operating at 100 bar and 540 C throttling condition (Gill 1984).

The considerable kinetic energy of the steam leaving the LP cylinder with no further useful work is considered as energy loss. This amounts to 2·5% of the total work produced by the three cylinders. The use of cogeneration turbines from which steam is extracted just before or from the LP cylinder for process heat (Fig. 3) reduces this loss and the size of the expensive LP cylinder. The cogeneration turbines allow a substantial part of the throttle steam to expand in the turbine to generate electricity before its extraction for supply to the thermal load. The reduction in the electrical energy generated due to steam extraction for the thermal load depends on the pressure, temperature, and amount of steam extracted. The ratio of the electrical power generated with steam extraction to full power (without extraction) is plotted against the ratio of the steam extracted to the amount of throttling steam for the conditions suitable for the operation of lithium bromide absorption A/C machines (Fig. 4a). Also the performance of cogeneration plants is given in Table 1 and Fig. 4b & c. Electrical power production due to steam extraction decreases with increase in pressure and temperature of the extracted steam.

The generating capacities of the power plants are designed to satisfy the high summer power load caused mainly by electrically driven air conditioners. Fig. 5 gives the maximum and minimum monthly loads during 1984 and Fig. 6 shows a typical load during a typical day in July 1984. It is clear that the steam power plants are operating with low power output and reduced efficiency most of the time. Adopting a cogeneration system for power and heat production to operate A/C machines for

Table 1. Performance characteristics of the condensing extraction turbine of the cogeneration plant given in Fig. 3

	Bleed steam kg/s	Work output MW, W	Process heat MW, Qp	Plant efficiency	Utilization factor $U = Q + W/Q$
0·00	0	214·0	0	0·35	0·35
0·10	18·35	207·4	45·80	0·33	0·42
0·20	36·70	198·4	91·75	0·32	0·49
0·30	55·00	189·2	137·60	0·30	0·56
0·40	73·40	180·2	183·50	0·29	0·64
0·50	91·75	171·0	229·40	0·27	0·71
0·60	110·10	162·0	274·80	0·26	0·78
0·70	128·50	152·6	306·00	0·25	0·85
0·80	152·00	143·7	376·50	0·23	0·92

Maximum power production with no steam extraction = 214 MW.
Throttling conditions: Pressure, $P = 142$ bar, Temperature, $T = 538$°C.
Enthalpy, $H = 3450$ kJ/kg, and steam mass flow rate = 183·5 kg/s.
Cold reheat $P = 34·6$ bar, $T = 341$°C.
Hot reheat $P = 31·1$ bar, $T = 538$°C.
Condensing conditions, $P = 0·086$ bar, $T = 42·6$°C, $H = 2300$ kJ/kg.
Steam extraction to feed heater at pressures of 34·6, 18·3, 9·5, 1·59 and 0·74 bar.
Steam extraction to process heat at pressure of 3 bar.
Pressure drop between extraction and feed heater entry = 10%.

cooling would provide: 1. A reduction in the peak electric power demand, which is mainly due to electrically operated air conditioners, by shifting to a thermally operated air-conditioning system (absorption machines); 2. Extraction of steam for the absorption machines at constant rates or during low-demand hours by adopting water storage systems.

ABSORPTION REFRIGERATION MACHINES

The most striking advantage of water–lithium bromide absorption A/C machines is their ability to use low-temperature (a little over 100°C) energy sources in the form of steam or hot water. Absorption machines for air conditioning of buildings can be a better choice than electrically driven air conditioners when: (1) unused boilers are available during summer months; (2) district heating system is available (i.e. a cheap energy source); (3) air conditioning is an absolute necessity and a 100% standby generator system is required, e.g. in hospitals. A central absorption air-conditioning system with very low electrical power consumption can significantly reduce the standby generator cost.

Thermovapour compression absorption machines are relatively quiet and vibration-free compared with vapour compression systems driven by electric motors. Proven absorption machines are available commercially in different capacity ranges, e.g. the Carrier Company produces machines in the range 70 to 815 tons of refrigeration, the York company produces machines in the range of 114 to 1378 tons of refrigeration, the Arkla company produces small units in the range of 3 to 25 tons of refrigeration, and some Japanese companies produce such machines with different ranges.

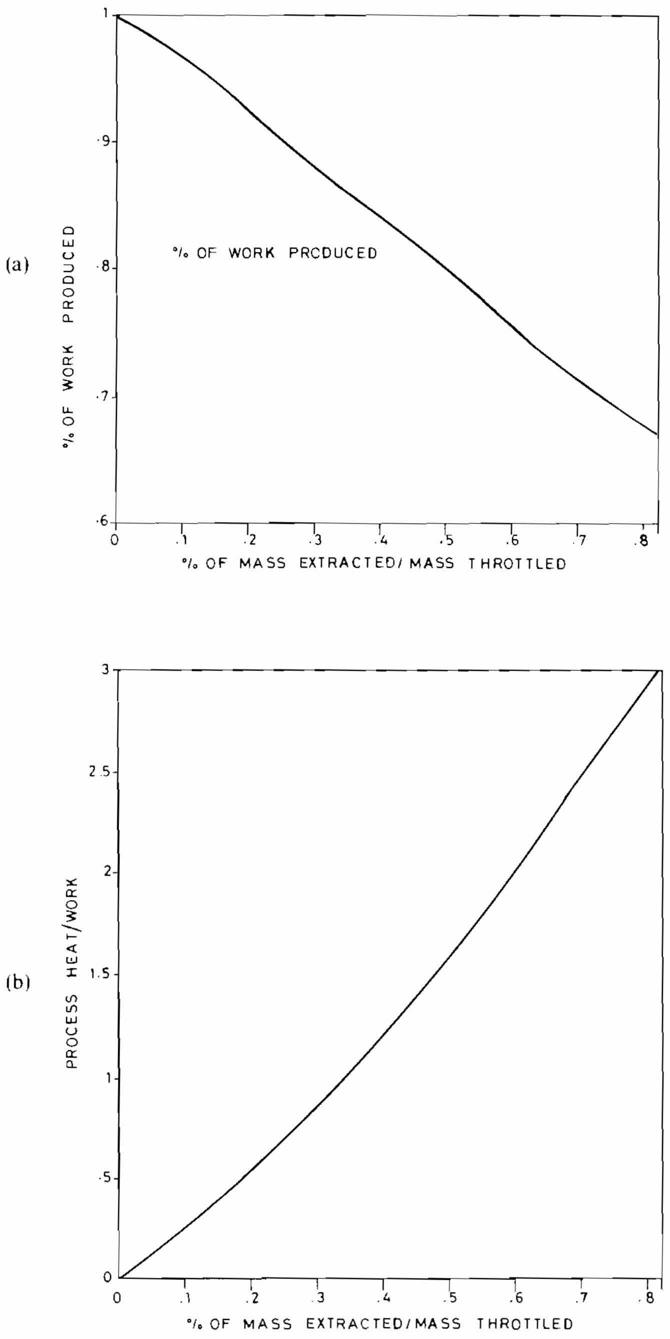
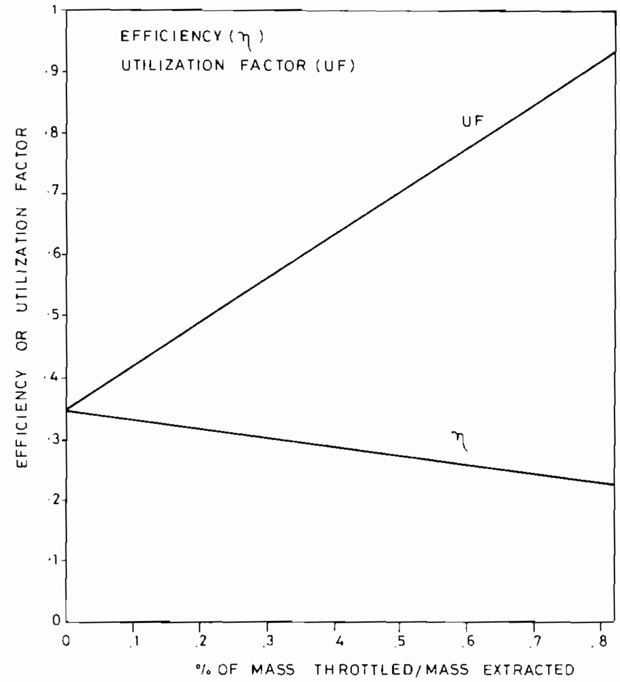


Fig. 4. (a) Reduction of power output as a function of mass extracted to mass throttled. (b) Ratio of process heat to work output as a function of the mass extracted to mass throttled rates. (c) Efficiency and utilization factor as a function of mass extracted to mass throttled.

(c)



An H_2O–LiBr absorption A/C is usually a water chiller type (Fig. 7). It also uses water as the refrigerant, which evaporates in the evaporators at low temperatures (about 4°C) and consequently at low absolute pressure (high vacuum) conditions. The vapour refrigerant (H_2O) is absorbed by the strong lithium bromide solution in the absorber due to the high affinity of LiBr to water and forms a dilute (weak) solution. This dilute solution is pumped to the generator where steam or hot water (main energy source) drives the water out of the solution as vapour to the condenser. The vapour is condensed and returns to the evaporator to complete the cycle through a throttling valve. The operation of the H_2O–LiBr machine is limited by the minimum temperature of outgoing chilled water (4°C) and the maximum temperature of the generator inlet hot water (140°C). Such temperatures should not be exceeded in order to avoid crystallization.

The coefficient of performance (COP, defined as the produced cooling effect in kW divided by energy consumption in kW) of absorption refrigeration systems increases with the increase in the temperature of driving hot water or steam. A typical COP for the absorption A/C is 0·70 for normal operating conditions. This COP seems very low when compared with 3, which is the COP of the conventional electrically driven vapour compression A/C for the same normal operating conditions. However, serious consideration may reveal the contrary.

Whereas the type of energy consumed by the electrically driven A/C is electricity, that used by absorption refrigeration is relatively low-value thermal energy. The real value of this thermal energy lies in its ability to produce mechanical work (or electricity). The theoretical maximum thermal efficiency of converting thermal energy to work is obtained through the Carnot cycle. This amounts to 13% and 17% if the

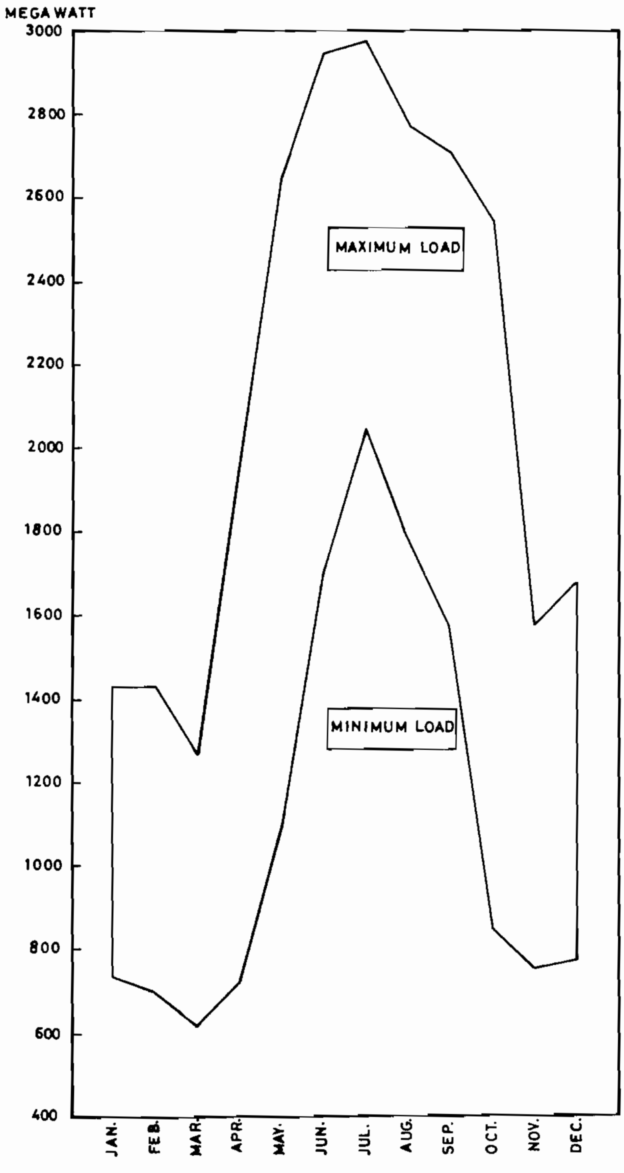


Fig. 5. Maximum and minimum monthly loads during 1984. (Source: Statistical Yearbook (1985)).

energy sources are at 100°C and 120°C, respectively, and the condenser temperature is 50°C. The real Rankine cycle efficiencies are much lower than these values due to irreversibilities in turbines and pumps, leaving losses, and pumping requirements. So the real value of one kW of thermal energy input to absorption machines (at 100–110°C) is less than the value of 0·10 kW of electrical energy. It may be noted here

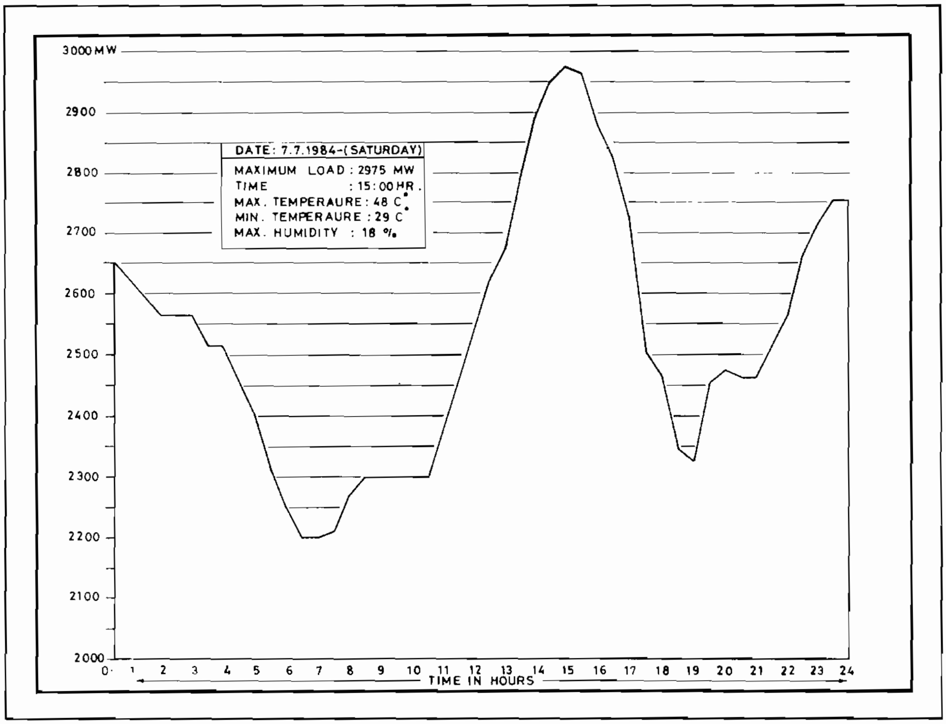


Fig. 6. A typical load during a typical day in July 1984. (Source: Statistical Yearbook (1985)).

that absorption A/C consumes about 25% of the electrical energy required for conventional A/C systems in running the solution pump, condenser cooling pump, cooling tower fan, and other auxiliaries (Suri *et al.* 1982).

Another advantage of the absorption refrigeration system is its ability to store supply energy in hot water tanks or steam vessels. Conventional space-cooling demands in residential and commercial buildings create a large peak load demand on the electrical power plants during the hottest part of the summer days which extends for several hours in the Gulf States. Storing process heat from the power plant at a steady rate or during off-peak periods (early morning and during the night) will reduce the high peak loads during summer days.

THERMAL STORAGE SYSTEMS

In the Gulf countries, the peak power demand and the maximum air-conditioning cooling load occur for a few hours daily and a few days every year. The power plants and air-conditioning systems are usually designed (or chosen) to satisfy those peak demands and have instantaneous control. This means that the capacities of the power plants and air-conditioning systems are much higher than the average demand capacities. Operating these systems under partial load conditions decreases the thermal efficiency of the power plants and reduces the COP of A/C machines.

In the proposed cogeneration plant, the process heat to A/C machines can be supplied by varying the flow rates of a constant-temperature hot water supply

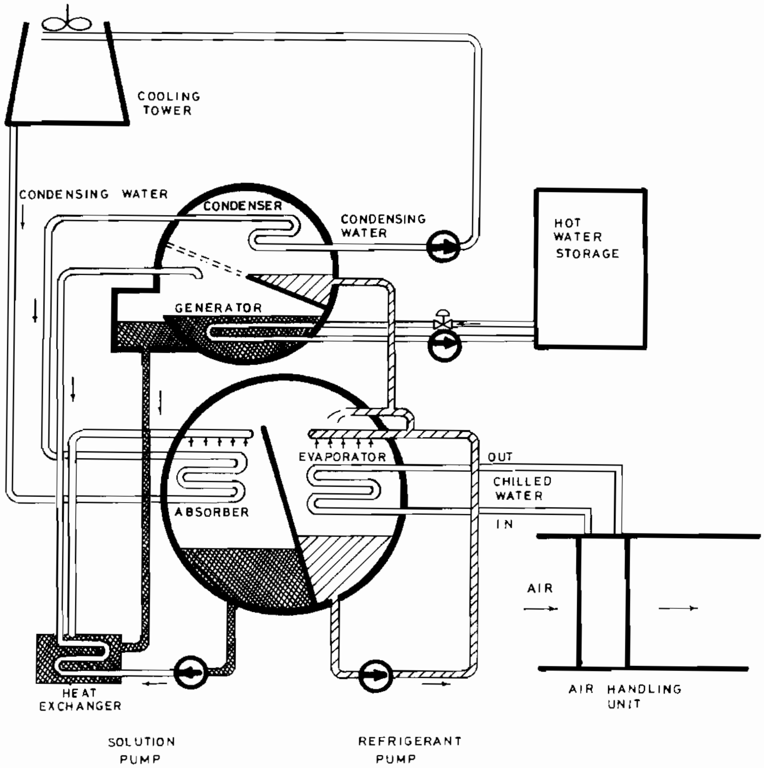


Fig. 7. A typical water–lithium bromide absorption air conditioner.

according to the instantaneous cooling load demand. Consequently, the rate of process heat bled from the cogeneration turbines should be designed to satisfy the maximum cooling demand and should vary according to the instantaneous cooling load.

Full utilization of the cogeneration plant (in terms of flexibility and efficiency) requires a constant supply of process heat at average cooling load rates. This can be achieved by adopting a thermal storage system (hot water storage) at the end of the district piping distribution system. This solution also uses the piping system in a better way, i.e. smaller flow rates and the use of the piping system as a part of the storage system. The storage capacity for the required tanks is 0·8 to 1·5 of the maximum load requirements (Beckman & Tilli 1984). The hot storage tanks supply the A/C machines in accordance with the cooling load demand. This type of storage system is considered in the case study to be discussed later.

When the peak power demand is very sharp (as it is in Kuwait), the supply of the process heat from the cogeneration turbine can be modulated according to the power demand profile. Steam bleeding, or the process heat supply from the cogeneration plant, can take place only at low electrical power demands, e.g. 6 p.m.–9 a.m., and no bleeding occurs during peak power demand. This solution requires that larger hot water storage capacity (about 10 times the maximum load hours) be located in the cogeneration plant (Beckman & Tilli 1984). This would ensure highest power production at the required peak hours and, in fact, satisfy the process heat and power requirements.

Since the hot water storage system allows the process heat supply from the cogeneration plant to fulfill the cooling load demands, it should supply the A/C machines with the corresponding heat required for the cooling load. That is, refrigeration machines with capacities matching the maximum cooling loads are used.

A further step to decrease the capacity of the refrigeration machines to match the average cooling load is to use cold water storage. The average load capacity refrigeration machine would operate continuously to supply cold water to the cold water storage system. This cold storage would supply air-handling units according to the cooling load requirements. This solution gives a better COP for the refrigeration machine for two reasons: (1) it would work at full load most of the time; (2) it would operate at low condensing temperatures at night.

CASE STUDY

The University of Kuwait, which has 18 000 students and about 3000 staff members, is planning to relocate its five campuses into one new campus. The campus would include the following colleges: Medicine, Engineering, Science, Law, Commerce, Education, Literature, Sharia, and Allied Health Sciences. It would also have buildings for administration, gymnasium, printing press, student activities, education hospitals, continuing education centers, and research facilities. These buildings can reach a total usuable area of 10^6 m^2. Buildings for students and staff members to live in are expected to have a total area of 5×10^5 m^2. A district around the new campus of 2000 villas (each with an area of 200 m^2) plus commercial and services facilities of 10^5 m^2 is to be considered. The total area to be air-conditioned, lighted, and provided with a power supply for appliances would be around 2×10^6 m^2. The authorities will be requested to supply the new Kuwait University District (KUD), comprising the campus and its surrounding area, with electricity (or with electricity and hot water) to power the air-conditioning systems, electrical appliances, and lighting. The outside conditions for air-conditioning purposes are: 46°C dbt (dry bulb temperature) and 26°C wbt (wet bult temperature) in summer and 4°C dbt and 2°C wbt in winter.

The Ministry of Electricity and Water (MEW) in Kuwait has set conservation measures that define the maximum allowable electrical power to be drawn for air conditioning and lighting in different types of buildings. The maximum power for A/C systems (in W/m^2 of floor space) is almost equal to the actual power of the installed A/C equipment. As an example, the peak amount for air-cooled air-conditioning equipment in classrooms is set equal to 100 W/m^2. This means that the expected peak cooling demand for classrooms is 300 W/m^2, on the assumption that the COP is equal to 3. In the proposed Kuwait University District (KUD), the building areas are assumed to be utilized as follows: 40% (8×10^5 m^2) as residential area, 40% (8×10^5 m^2) as classrooms, offices, and laboratories, and 20% (4×10^5 m^2) as commercial and public areas. The estimated installed electrical power supply and cooling loads, according to MEW conservation measures, are given in Table 2. For the utility to satisfy the KUD requirements, the following three scenarios were prepared:

A. Installing a conventional steam power plant to supply all power requirements for lighting and electric air conditioners.
B. Using a hot-water driven absorption air-conditioning system and installing a cogeneration plant to supply electrical power for lighting, parasitic power needed for the absorption machines, and hot water for the absorption of A/C system.

Table 2. Characteristics of cooling and power demands for different buildings

	Residential	Classes, labs, offices	Commercials, public	Total
Total areas of buildings ($m^2 \times 10^5$)	8	8	4	20
Peak power density (MEW measures) for lighting (W/m^2)	15	30	60	
Peak power density (MEW measures) of air-conditioning (W/m^2)	65	100	90	
Max. installed power for lighting (MW)	12	24	24	60
Max. installed power for conventional A/C (MW)	52	80	36	168
Max. cooling load demand (MW)	156	240	108	504
Ratio of average to maximum cooling loads	0·65	0·21	0·34	
Average cooling load demand (MW)	101·4	50·4	36·7	188·5
Max. installed power for lighting and electric A/Cs (MW)	64	104	60	228
Max. electric power consumption by absorption A/C	13	20	9	42
Max. installed power for lighting and absorption A/Cs (MW)	25	44	33	102

C. Using a hot-water or steam-driven absorption A/C system and installing: (1) a conventional steam power plant to supply the power needed for lighting and absorption A/C system auxiliaries; (2) boilers to supply hot water or steam to the absorption A/C system.

In the following sections, the three scenarios are outlined and compared.

SCENARIO A

This is the conventional solution. A power plant is required to supply electricity at a net rate of 228 MW to satisfy the requirements for A/C and lighting at the peak demand time (Table 2). By assuming 10% line transmission losses and 10% power plant auxiliary requirements, the gross power output rate is 273·6 MW. This is a medium-sized power plant (Fig. 2) with a heat input rate of 760 MW (for 0·36 thermal efficiency). The fuel (oil) consumption at the peak, assuming 85% boiler efficiency, is estimated at 22·353 kg/s. Yearly fuel consumption for a 60% load factor is 423 × 10 t/yr at a cost of 17·765 million KD/yr (1 KD ≈ U.S. $3·33). The cost of fuel is estimated to be 42 KD/t ($20 U.S. per barrel). The capital cost of the plant is 114·24 million KD (on the assumption that the cost per kW is 400 KD (Suri *et al.* 1986).

SCENARIO B

This arrangement is proposed in the present study. Hot-water driven water-chiller absorption machines are used for summer air conditioning. The estimated COP is 0·7. Electrical power is required to drive pumps and cooling tower fans (parasitic power) and is estimated to be 0·25 of the power consumed by conventional electric air conditioners of the same capacity (Suri *et al.* 1982). So a cogeneration plant producing electrical power at the rate of 102 MW for lighting and absorption machine parasitic power is required (see Table 2). This plant also supplies hot water (130°C) 24 hours a day to a storage system. The steady rate of heat addition to the hot storage system is 270 MW. This is based on the assumption that the ratio of the average to the peak cooling demand of classrooms, residential, and commercial installations are 0·21, 0·65, and 0·34, respectively. By assuming the same percentages of electrical losses and power plant auxiliary requirements and 15% thermal losses from hot water piping and thermal storage, the capacity of the required cogeneration power plant is 122·4 MW (electrical power) and 310 MW (process heat at 137°C). The ratio of process heat to electric power is 2·575. This ratio dictates the use of a back pressure turbine plant (Fig. 8). Commercially available back pressure turbines are in the range of 20–200 MW (Perry 1984). If a smaller process heat (or cooling demand) to electric power ratio is needed, a condensing-extraction turbine arrangement can be used (Fig. 3).

The 122·4 MW electric power and 310 MW thermal cogeneration plant is considered a small steam power plant and can have the conditions shown in Fig. 8. The plant can produce 123 MW electric power and 310 MW process heat (corresponding to 217 MW cooling effect). The total thermal energy input at the boiler is 436 MW. This energy supply is almost totally utilized by producing electric power (123 MW), process heat supply to storage (310 MW), and losses to the environment (3 MW). The fuel (oil) consumption of this plant at peak time demand is 12·82 kg/s on the assumption of 85% boiler efficiency. The yearly fuel consumption with a 0·7 load factor is 283 × 10^3 t/y. The yearly fuel cost is 11·88 million KD.

The capital cost of this plant/kW is less than the cost of a conventional power plant, which was estimated in Scenario A to be KD 400/kW. The reasons are: (a) the condenser was replaced by a hot water heat exchanger (similar to a large feed heater), which has a much smaller size than the condenser; (b) the huge LP cylinder turbine was completely eliminated; (c) the use of lower pressure steam (100 bar corresponding to 160 bar in Scenario A) and consequently, cheaper steam generator and boiler feed pump; and (d) low pressure feed heaters were eliminated. A conservative cost estimate of KD 320/kW would bring the capital cost of this plant to KD 39·36 million.

Use of the cogeneration plant offers specific advantages over the conventional solution (Scenario A), such as: (1) the peak power demand (102 MW) is less than 50%

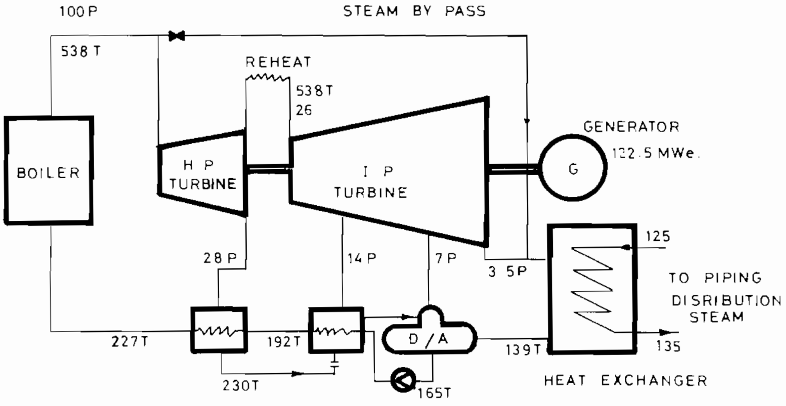


Fig. 8. Back pressure turbine arrangement.

that of the conventional solution (228 MW); (2) the capital cost of the cogeneration plant (KD 39·36 million) is less than 35% that of the conventional power plant cost (KD 114·42 million), a saving of KD 75·06 million; (3) the saving in fuel cost over the plant life (expected to be 20 years) is KD 117·7 million. These advantages certainly outweigh the additional cost required for constructing the district piping system and hot storage system. One of the potential sites of the new campus is Doha West on the Bay of Kuwait. This will be an excellent choice for this solution because of its proximity to the power plant sites and the possibility of using seawater for cooling the absorbers and condensers of the absorption machines.

SCENARIO C

Steam or hot-water driven water-chiller absorption machines are chosen for air conditioning. Separate boilers of 300 MW steady rate of heat supply hot water to the hot storage system (only 10% heat loss in storage and distribution piping system is assumed). A conventional power plant of 122·4 MW is used to supply the parasitic power for the absorption machines and power for lighting. A heat input rate for this power plant is expected to be 350 MW. Assuming 70% load factor and 85% boiler's efficiency, the full consumption of the two separate plants (power plant and boiler plant) is 422×10^3 t/y. The annual cost is 18·564 million KD. The total capital cost includes the power plant cost (based on 400 KD/kW) of KD 48·96 million and boiler plant cost (based on 50 KD/kW) of KD 15 million. The total capital cost is KD 63·96 million. Comparison of fuel consumption in the three scenarios indicates a significant saving in the cogeneration plant (Table 3).

CONCLUSION

The case studied is not isolated. It represents the pattern of energy consumption in Kuwait where 70% of the electric peak demand is used to operate conventional

Table 3. Comparison of Scenarios A, B, and C

Arrangement	Scenario A Conventional power plant	Scenario B Cogeneration power plant	Scenario C Conventional power plant + boiler plant
Peak electric power demand (MW)	228	102	102
Gross electric power production (20% losses and auxiliaries)	273·6	122·4	122·4
Average heat rate demand for hot storage system (MW)	–	310 (15% losses)	300 (15% losses)
Total rate of energy input (MW)	760	436	350 + 300 = 650
Fuel consumption/year (10^3 ton)	423 (60% load factor)	283 (70% load factor)	422 (70% load factor)
Fuel cost/year (million KD)	17·765	11·880	18·564
Capital cost (million KD)	114·42	39·36	63·96
Saving in peak power demand (%)	0	55	55

electrically driven air conditioners. The Ministry of Electricity and Water (MEW) in Kuwait usually builds one 2400 MW dual-purpose power-desalter plant every few years (e.g. Doha West and El-Zoor). Using a cogeneration plant to produce electric energy and process heat for hot water-driven absorption-type air-conditioning systems (and desalination plants) will decrease the capacity of one plant from 2400 to 1200 MW. A capital saving of 480×10^6 KD and fuel cost saving of 47×10^6 KD annually can justify the extra cost of the central cooling system and its district piping network.

The proposal deserves serious consideration from MEW. More comprehensive studies are needed to embark on such a scheme.

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المحطات الثنائية لتوليد الطاقة الكهربائية وتكييف الهواء

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خلاصة

يسعى هذا البحث لايجاد حل للنمط الصعب الذي يتم به انتاج الطاقة الكهربية في الكويت والمتميز بالطلب المستمر على زيادة طاقة تلك الوحدات ، والتباين الشديد في توزيع الاحمال المرتبط مباشرة بالطبيعة المتغيرة لاحمال التبريد على مكيفات الهواء ، مما يؤدي إلى تشغيل محطات الطاقة بأحمال متدنية وبالتالي بكفاءات منخفضة معظم الوقت .

ويقترح البحث حلا يقضي باستخدام نظام تكييف هواء (تبريد وتسخين) مركزي لمناطق كاملة بالكويت ، تستخدم فيه وحدات تبريد بالامتصاص لانتاج ماء بارد ، تدار بواسطة مياه ساخنة تضخ من محطات مزدوجة الغرض لانتاج الطاقة الكهربية والحرارة اللازمة لانتاج تلك المبردات (وحدات امتصاص ماء ـ بروميد الليثيوم) ، كما تستخدم المياه الساخنة للتدفئة مباشرة في الشتاء . وقد تم عمل دراسة مقارنة بين الحل المقترح والحل التقليدي الذي يتبع حاليا (انتاج الطاقة لتشغيل وحدات تكييف تدار بالكهرباء) لحالة حقيقية بالكويت ، وظهرت مزايا الحل المقترح في تخفيض طاقات محطات الكهرباء المراد انشاؤها الى أقل من النصف وكذلك تكلفة الوقود المستخدم .