ENERGY EFFECTIVE DESIGN.

JANSKE & CUMMING

ENERGY EFFECTIVE BUILDING DESIGN
ENERGIEDOELTREFFENDE GEBOUE-ONTWERP

1987

the joint award in the
die medetoekenning in die

ENGINEERING CATEGORY
KATEGORIE INGENIEURSWESE

is made to
is gemaak aan

JANEKE & CUMMING
partners in / vennote in

HPK M&E GROUP/GROEP

for the
vir die

DEPARTMENT OF POSTS AND TELECOMMUNICATIONS
HEAD OFFICE EXTENTION COMPLEX

DEPARTEMENT VAN POS EN TELEKOMMUNIKASIEWESE
HOOFKANTOORUITBREIDINGSKOMPLEKS

PROMOTED BY/ ONDERSTEUN DEUR

ESCOM / EVKOM

Patron

THE MINISTER OF ECONOMIC AFFAIRS AND TECHNOLOGY

Beskermheer

DIE MINISTER VAN EKONOMIESE AANGELEENTHEDE EN TEGNOLOGIE

Date of award: 4 August 1987
Toekenningsdatum: 4 Augustus 1987

DEPARTMENT OF POSTS AND TELECOMMUNICATIONS

ADDITIONAL ACCOMMODATION, HEADQUARTERS, PRETORIA

AIRCONDITIONING SYSTEM

submitted for the

ENGINEERING SECTION

of the

ENERGY EFFECTIVE

DESIGN COMPETITION

by

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Registration No. 830104

HPK M & E Group Consortium

- Watson, Edwards, Van der Spuy & Partners
- Du Plooy, Bosch & Associates
- Janeke and Cumming

APRIL 1986

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1. INTRODUCTION

1.1 DESCRIPTION AND USE OF THE BUILDINGS

The complex is presently under construction in Pretoria and is located across the street from the existing Department of Posts & Telecommunications Head Office complex. Planned completion date is May 1988. The complex as presently being constructed consists of:

- two parking basements (completed)
- Tower Block 1 consisting of Ground, Mezzanine and fifteen typical floors. This block is to be used as general office accommodation for the Department of Posts and Telecommunications Head Office complex.
- Philately Block consisting of four floors. This block is used for Philatelic storage and distribution purposes.
- A ground floor kitchen and restaurant area
- A mezzanine level Biokinetic centre.

Provision has been made for a future twenty four floor Tower Block 2.

1.2 DESIGN PHILOSOPHY AND DESIGN OBJECTIVES

The building and airconditioning systems were originally designed in 1981/82. The airconditioning system design concept in many ways is similar to that of the SANLAM PLAZA building (Winner Energy Effective Design Award 1984).

As the complex has a single tenant and the working hours of the occupants are relatively regular, a central plant design was decided upon. The unique features of the central plant design are discussed in Section 2.

Particular attractive features of the central plant system in this instance are:

- low energy costs due to greater efficiencies of central plant equipment.
- adaptability to unique energy saving features (See Section 2).
- ease of maintenance
- flexibility for future expansion e.g. Tower Block 2.
- easy adjustment to accommodate possible future higher internal loads. (By dropping chilled water and air supply temperatures).

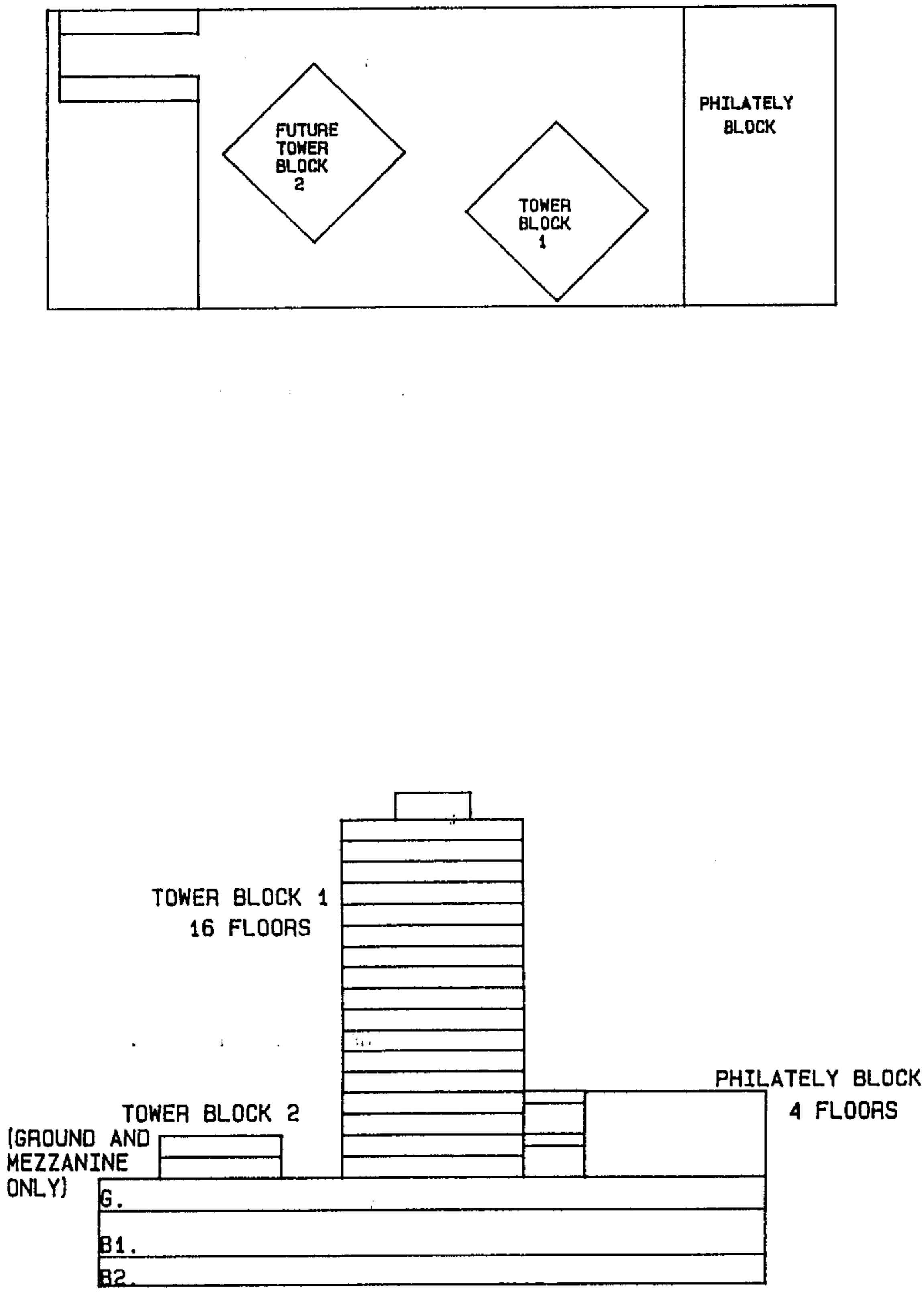


FIG 1.1: SITE PLAN AND BLOCK IDENTIFICATION

As originally conceived, the complex would yield attractive energy results as indicated by KWh per annum or MJ per annum figures. However the consumption characteristics indicated a substantial electrical load peak in summer.
Following a request by the client, an ice storage system was investigated and upon proving financially attractive on a life cycle costing, was incorporated into the design.
In the detail design of the airconditioning system, particular attention was paid to the following:

- Ease of maintenance. Here valuable input from the client's engineering staff was received.
- Maximum flexibility. The system allows for ease in adjusting the installation as floor layouts and internal load characteristics change during the life of the building.

Subsequent to the initial design in 1981/82 the state of the art in control equipment has advanced and the specification has been adjusted to a requirement for a Direct Digital Control system.

1.3 ENVELOPE DESIGN

The Philately Block has minimal window areas and consequently envelope loads are minimal.
The Tower Block has a unique shading scheme designed by the architects and consisting of both vertical and horizontal shading elements. (See detail drawings for detail). The shading scheme results in excellent shading resulting in virtually the total elimination of direct solar loads while still allowing reasonable outside viewing.
Winter conduction losses are controlled using continuous full length skirting type heaters which are especially designed to fit under the window sills. The heaters are accurately sized to counter the conduction losses alone at 500W per 1,5M window length. The heaters are fitted with individual thermostats controlling at 21°C and also under the master control of the digital control system.

2. SYSTEM DESCRIPTION

2.1 GENERAL

The airconditioning system serves three major areas, namely the Tower Block 1, Philately Block and Restaurant area. Design weather conditions are:

Design dry bulb temperature	33,5°C
Design wet bulb temperature	20,0°C
Design direct radiation	796W/m²
Design diffuse radiation	255W/m²

Inside design conditions are:

Dry bulb	23°C
Humidity ratio	10g/Kg

Major design parameters for the three areas are as follows:

	Tower Block 1	Philately Block	Restaurant	Total
Airconditioned area (m^2)	13400	6000	1630	21030
Peak cooling load(room)(KW)	744	487	135	1348 *
Peak cooling load(total)(KW)	1106	646	175	1911 *
Peak cooling load (W/m^2)	82,5	107,7	107,4	
Time of peak January	1400h	1400h	1300h	1400h
Total supply airflow(m^3/h)	250000	144000	41300	-
Total supply airflow($m^3/h/m^2$)	18	24	25	-
Total perimeter heating (KW)	340	0	40	380
Total central plant heating(KW)	480	204	70	754

* Total figure uses restaurant load at 1400h.

Design parameters for the central cooling (ice storage system) are as follows:

Design Peak chilling load (kW)	1600
Design ice storage capacity (kg ice)	108880
Design ice storage capacity (kWh)	10080
Design outside ambient temperature (°C)	33,5
Design condensing temperature (°C)	45,0
Design evaporating temperature (°C)	-5,0
Compressor KW at design conditions	63,2
Condenser KW at design conditions	2x7,5
Pumping (refrigerant) KW at design conditions *	1,5
Cooling capacity at design conditions	197,5
Overall (coefficient of performance) at design conditions	2,48
Overall coefficient of performance at 10°C ambient	4,5
Design ice build time (design conditions)	12,8 hours
Design ice build time (10°C ambient)	9,8 hours

* Note primary water pumping power not included.

2.2 AIR HANDLING PLANTS

The major airhandling plants are located as follows:

	Tower Block 1	Philately Block	Restaurant
Quantity of AHU	4	1	2
Airflow each(m^3/h)	62500	144000	20000

The airhandling units are of the built up plenum type with the exception of the two restaurant airhandlers which are of the packaged type. The following functional description applies to the major built up airhandling units.

The units consist of the folloiwng major subsystems (See Figure 2.1 for a schematic depiction).

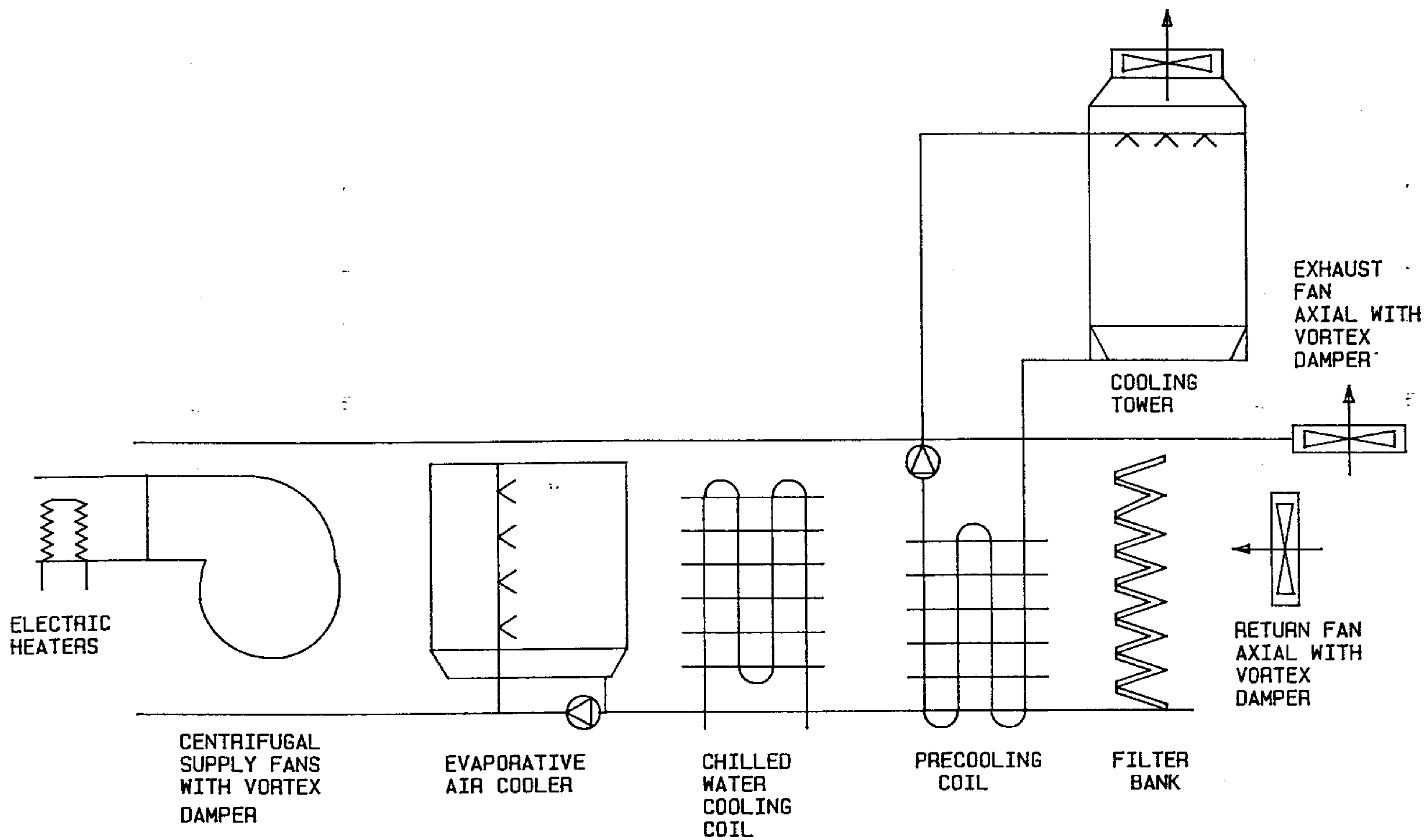


FIG 2.1: AIRHANDLING PLANT SCHEMATIC

2.2.1 Precooling System

The precooling system is the first stage of a two stage evaporative cooling subsystem.

The precooling system consists of chilled water cooling coil (6 rows, 12 fins per 25mm) piped in series with a circulating pump and cooling tower.

The system yields sensible evaporative cooling and is particularly effective under dry ambient conditions. The design approach of the system is 2,5°C (air leaving dry bulb off coil °C - ambient wet bulb temperature °C).

Each airhandling unit has multiple cooling towers as follows:

Tower Block: 2 cooling towers per AHU (8 total)

Philately Block: 4 cooling towers per AHU (4 total)

The precooling system has the effect of reducing the chilling requirement under peak conditions and of virtually eliminating the chilling requirement under intermediate conditions.

2.2.2 Chilled Water Coil

The chilled water coils are fed by a secondary pumping system circulating water in the 9-10°C range. Control at each airhandling unit is achieved by regulation of a 3-way valve.

2.2.3 Evaporative Cooler

An evaporative cooler of the spray air washer type is located after the cooling coils. The evaporative cooler yields a saturation efficiency of 85%. The evaporative cooler, when operated with the precooling system, yields the second stage of a two stage evaporative cooling process. This supplies the full cooling requirement during intermediate (dry) conditions.

The evaporative cooling and chilling are interlocked so that they cannot run simultaneously, and evaporative cooling is interlocked out should the space humidity rise to excessive levels. This should not occur in practice as the evaporative cooling cycle operates on a 100% fresh air condition with no air recirculation.

2.2.4 Fans

Fans selected are as follows:

Supply fan - centrifugal with vortex damper

Return fan - axial with vortex damper

Exhaust fan - axial with vortex damper

Particular care in selection of fans was carried out in an attempt to maximise part load efficiency.

Unfortunately part load efficiency of fans fitted with vortex dampers is poor compared to the other alternative methods of part load control, namely:

- variable speed control
- variable pitch blades

however the more efficient control methods could not be justified on a life cycle costing basis.

Due to the relatively poor part load characteristics of the fans (especially the axial fans) the energy simulations show relatively large airflows under most conditions as this maximises the precool cycle performance, the benefits of which exceed the energy reduction in reducing fan delivery.

2.3 FLOOR AIR DISTRIBUTION

Floor air distribution follows conventional Variable air Volume practice with four zones per floor on the Tower Block and a single zone per floor on the Philately Block.

Two unique energy saving refinements are incorporated (See Fig. 2.2)

2.3.1 Reverse Diffusers

Room air distribution is achieved by using a reverse diffuser (Ventline type KLM-E-R). This diffuser is based upon a conventional Ventline type KLM diffuser with the added reversing feature.

Under daytime conditions the diffuser operates in a conventional fashion, modulating from maximum (100%) to minimum (25%) air flow.

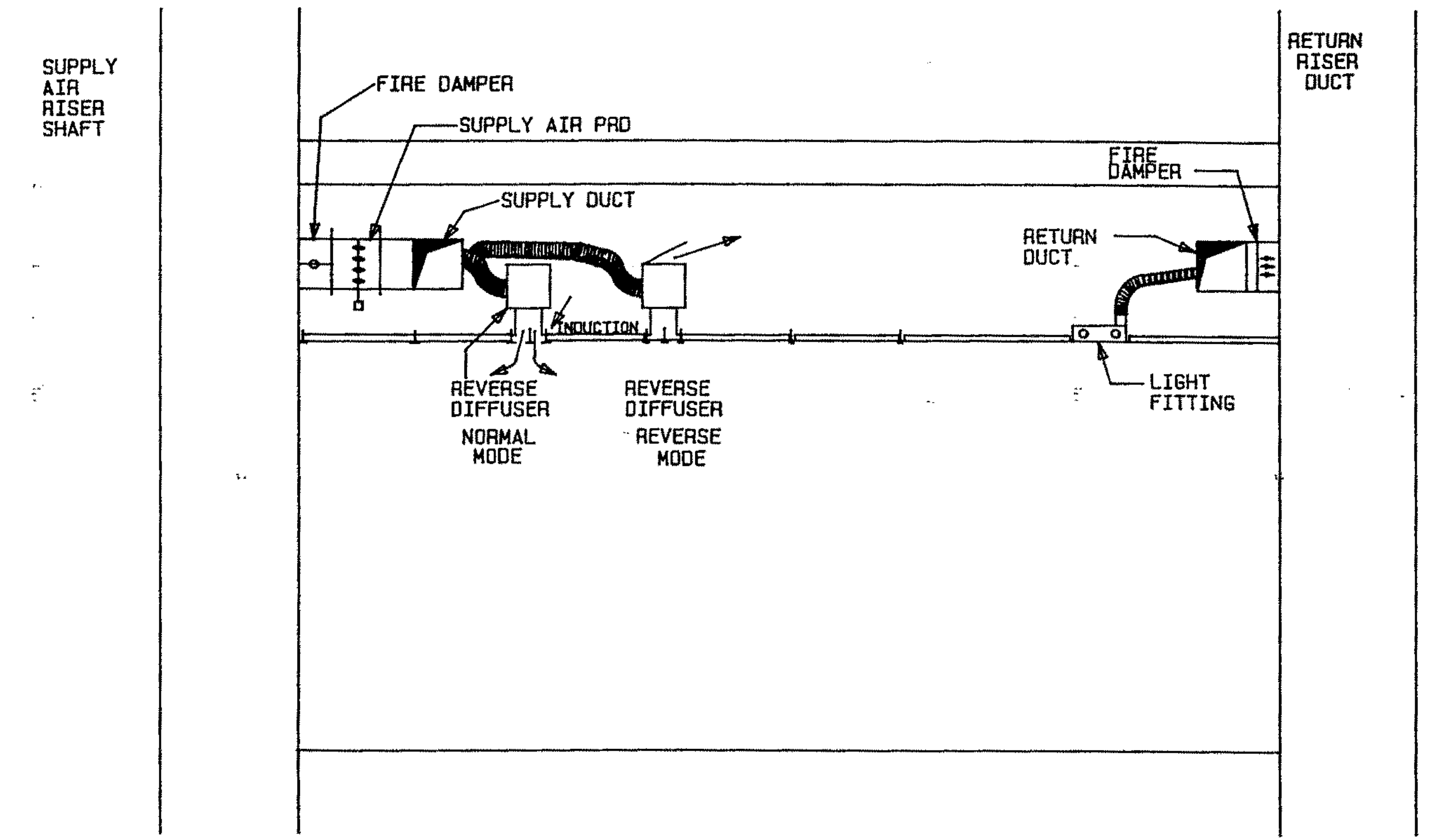


FIG 2.2: FLOOR AIR SUPPLY AND RETURN SCHEMATIC

To reverse the unit, the power supply is switched on and off six times on a 10 second cycle. Upon receiving this signal, the unit motors past its normal minimum stop and opens a top flap of the unit. This allows supply air to be directed into the ceiling void and to impinge against the floor slab above.

The benefit of night cooling is achieved as follows:

- If sufficient cooling load is anticipated the diffusers are reversed by implementing the reverse switching sequence.
- The supply fans are run (usually from 2 a.m. up to the normal start time) using cool night air.
- The structure is cooled.
- During the next day the unit withdraws cool induced air from the ceiling void thus extracting the cooling potential stored in the structure.

This cycle is extremely cost effective as the modified reverse diffuser costs very little more than its conventional counterpart, while the central control of the reverse switching is extremely simple to effect.

2.3.2 Light Heat Extraction

The light fittings, which are of the high efficiency reflector type, are fitted with extraction connections. These fittings are ducted directly to the return air system. This allows 50-60% of the input energy ($25 W/m^2$) to the light fitting to be extracted before reaching the room. The benefits of such a system are:

- reduced room loads
- reduced supply airflows required
- extended economiser possibilities due to higher return air enthalpies.
- recirculation of heat when heating is required
- elimination of heat soak with heat from lights heating the structure.

2.4 ICE GENERATION AND STORAGE SYSTEM

The ice system is schematically depicted in Figure 2.3. The major components are detailed below starting from the top of the schematic layout. The ice system is being installed by GRENCO who are sub-contractors to NORTHERN AIR.

2.4.1 Air Cooled Condensers

Air cooled condensers are utilised for the following reasons:

- no water consumption
- low maintenance requirements

The drawbacks of slightly increased energy consumption over a water cooled system, is in our opinion offset by the above factors. The condensers are silenced by means of inlet attenuators and discharge attenuators to ensure that night time operations do not cause disturbance.

2.4.2 Heat Recovery Condensers

Heat recovery condensers are fitted to two of the compresser circuits. The recovered heat is used for domestic water heating for the restaurant, kitchen and Biokinetic changeroom facilities.

2.4.3 Compressors

Compressors are of GRASSO manufacture and are of the reciprocating open drive type. Specifications are as follows:

Absorbed power	63,2kW
Motor size	75,0kW
Capacity	197,5kW
Condensing temperature	45°C
Suction temperature	-5°C

The system is designed to be non-overloading up to 55°C condensing (equivalent to 41,5°C ambient).

2.4.6 Liquid Accumulators

Liquid Accumulators together with liquid level control hold the excess liquid in this pumped overfeed type system. The system is designed so that there is 100% redundancy where possible and component failure will always leave a minimum of 50% capacity available.

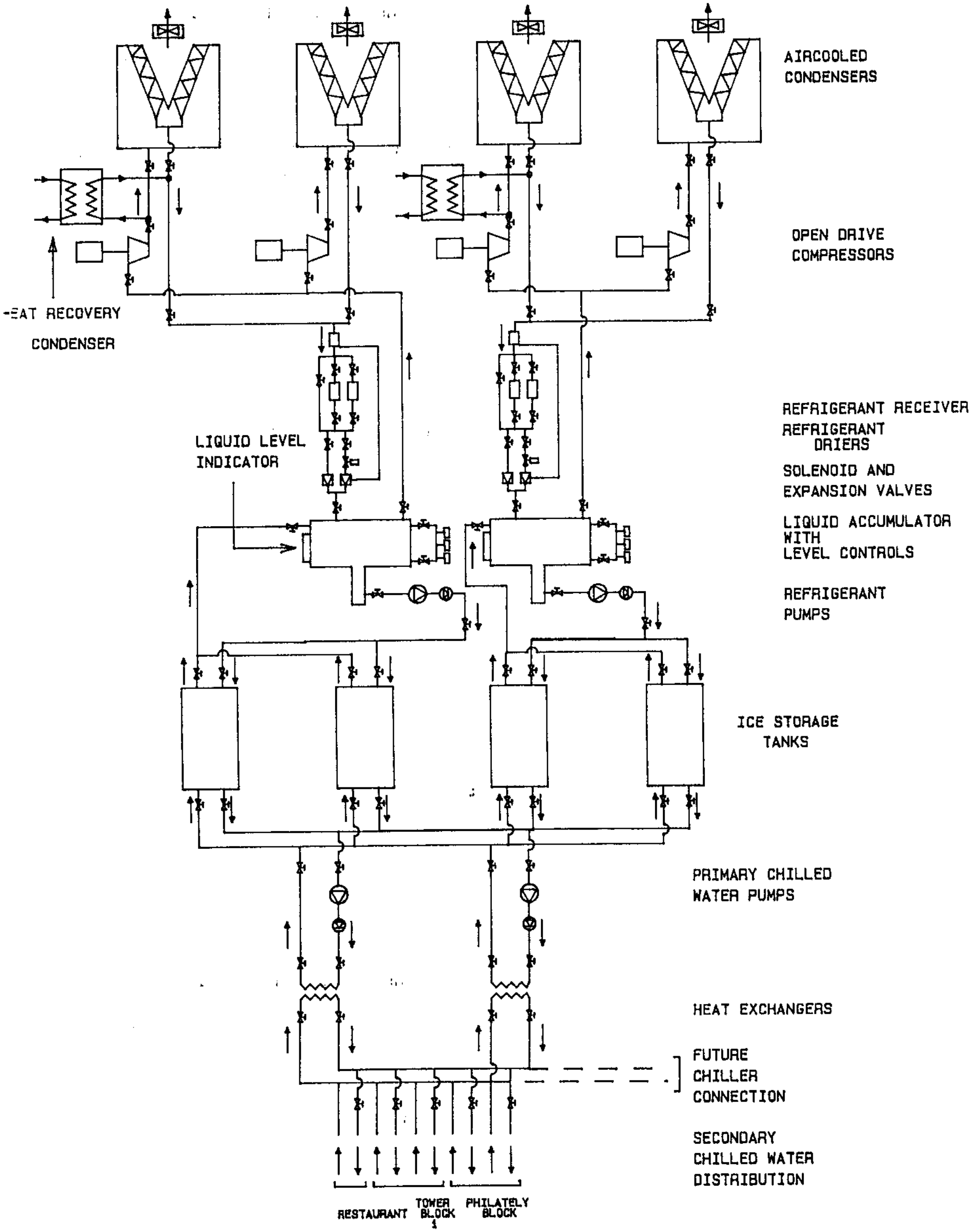


FIG 2.3 : ICE SYSTEM SCHEMATIC

2.4.5 Refrigerant Pumps

Refrigerant pumps overfeed the liquid refrigerant to the ice storage tanks where the ice is built on the evaporator coils.

2.4.6 Ice Storage Tanks

Four separate ice storage tanks are provided, each being capable of being isolated on both refrigerant and water sides.

The ice is built up in a cylindrical fashion on serpentine steel ice coils. The ice coils may be lifted from the tanks for repair by means of overhead lifting equipment provided.

2.4.7 Primary Water Circulation Pumps

Two primary circulation pumps are provided each capable of the full design duty (i.e. 100% standby). The primary pumps circulate water through a GRENCO venturi device which entrains air which results in agitation of the water in the ice tank to facilitate correct ice building and burn off.

2.4.8 Primary Heat Exchangers

Primary heat exchangers of the plate type exchange heat with the secondary circuits.

Investigation was carried out into the feasability of circulating secondary water to the various airhandling plants at low (0-2°C) temperatures instead of the 9-10°C presently designed. The advantages of low temperature circulation are:

- smaller pump and pipe sizes
- lower pumping energy requirements

It was decided to remain with conventional (9-10°C) secondary water temperatures for the following reasons:

- Savings from piping and pump size reduction were computed not to be significant.
- Cost and complexity of special coil design and/or tertiary recirculation pumping at each coil to ensure unnecessary dehumidification did not occur.

- Provision on the secondary water circuit for connection of future chillers for Tower Block 2 as space requirements cannot be met for further ice tank space provision at this stage.

Primary water flow through the heat exchanger is controlled via a 3-way valve to maintain secondary water temperatures.

2.4.9 Secondary Chilled Water Distribution

Secondary chilled water distribution to the various airhandlers is via secondary chilled water pumps with 100% redundancy (See Figure 2.4). Secondary water temperatures will be 9-10°C initially but may be reduced in future if internal loads rise.

2.5 CONTROL SYSTEM

The control system is a JOHNSON DSC Direct Digital Control system. The system comprises intelligent stand alone controllers as follows:

Tower Block 1 - 2 of
Philately Block - 1 of
Ice/Central Plant - 3 of

The systems are linked by a twisted pair date interface which facilitates parameter passing and central communication. User interface is via a DEC PC based front end system to be situated in the ice plant room. Details of control strategies are covered in Section 3.

2.6 SYSTEM COST

The contract for the complete airconditioning installation was awarded to Northern Air by open tender in Mid 1986. The tender price for the airconditioning system including the ice system was :

R4 157 385-00 (ex GST)

and the tender price for the airconditioning system including an alternative conventional aircooled chiller system was :

R3 937 691-00 (ex GST)

A detailed payback analysis was carried out on the two alternatives with the results as follows:

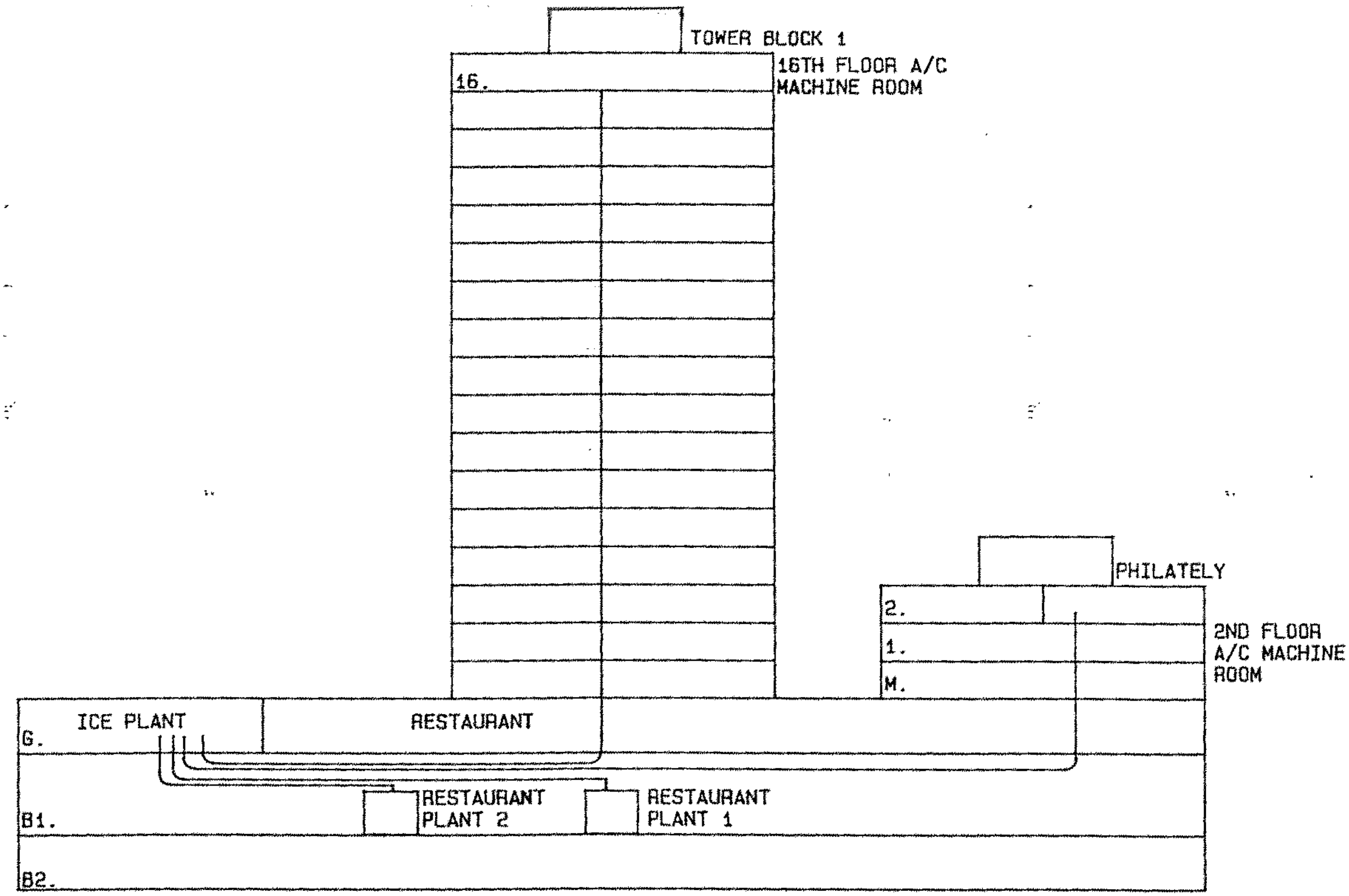


FIG 2.4: SECONDARY CHILLED WATER PIPING SCHEMATIC

Ice System	KWh:	R 8 503.077 (2.244c)
	KVA:	R 3 508.92 (R9.72)
	Total	R12 011.99
Chiller System	KWh:	R10 574.26 (2.244c)
	KVA:	R20 975.32 (R9.72)
	Total	R39 549.58
Difference		R27 537.58

The resultant payback period for the increased capital cost of the ice plant of R246 057 including GST was 8,9 years.

This is not a particularly attractive payback period, but it was decided to proceed with the ice plant for the following reasons:

- Anticipation of future increases in demand (KVA) charges in excess of increases in unit charges.
- Anticipation of possible future reduced off peak tariff structures.

This decision has been confirmed as the present KVA tariff is of the order of R12-00, a 23% increase over the 1 year period following the payback analysis.

Other considerations are that the ice plant is constructed to industrial refrigeration standards and is expected to give a service life in excess of that which can usually be expected from airconditioning central chilling plant.

3. STORAGE AND CONTROL STRATEGIES

3.1 PEAK LOAD REDUCTION

The main reason for incorporating the ice storage system is to reduce peak demand and hence overall energy costs.

The majority of ice plants installed to date have incorporated relatively unsophisticated control strategies and few have incorporated active control of peak demand.

The control system has the following capabilities which will be used to positively control peak demand.

- Measuring of incoming Voltage and Currents and simulation of municipal kWh and KVA metering.
- Monitoring of building internal and outdoor conditions.
- Prediction of future load (for 24h in advance) using an adaptive predictor algorithm.
- Devising of a strategy to meet the predicted load (plus a moderate safety factor) which takes into account:
  - Minimising KVA requirement and achieving a smooth load profile.
  - Running plant at the most advantageous times (lowest outdoor temperatures when COP is highest)
- Control and shedding of heating loads on a similar basis.

3.2 STRUCTURAL STORAGE SYSTEM

The structural storage system, consisting of controlled operation of the reverse diffuser and night ventilation to achieve structural cooling is controlled on the following basis:

- Prediction of future load (for 24h in advance) using an adaptive predictor algorithm. Parameters used are prior building load and outside conditions.
- Reversing of diffusers by performing changeover sequence as required.
- Controlled night ventilation when outside conditions are favourable.
- Control of daytime supply air temperature such that comfort conditions are met, but structural heat withdrawal can be achieved.

3.3 ICE STORAGE SYSTEM

The ice storage system runs under the master control which decides on the amount and times of ice storage. Other control elements include:

- Compressor unloader and compressor section
- Condenser and condensing temperature control
- Compressor safety circuits monitoring
- Refrigerant pumping and level control and safety circuit monitoring
- Primary water pump control
- Primary water temperature control
- Secondary water pump control
- Secondary water temperature control

4. ENERGY ANALYSIS

4.1 DESCRIPTION OF METHODOLOGY

The airconditioning load and energy analysis is a full 24 hour analysis performed on spreadsheet programs as detailed further in Appendix 3. Original peak cooling load calculations as carried out in 1981/82 were confirmed by recalculation to within 5% under this analysis.

The detailed summary sheets for the load and energy analysis are presented under separate cover as:

Appendix 4 : Energy Consumption Summaries
Appendix 5 : Ice System Performance Detail Simulation
Appendix 6 : Airhandling Plant Performance & Energy Analysis
Appendix 7 : Airconditioning load analysis

We believe the results and figures obtained to be conservative ones and likely to be achieved in practice.

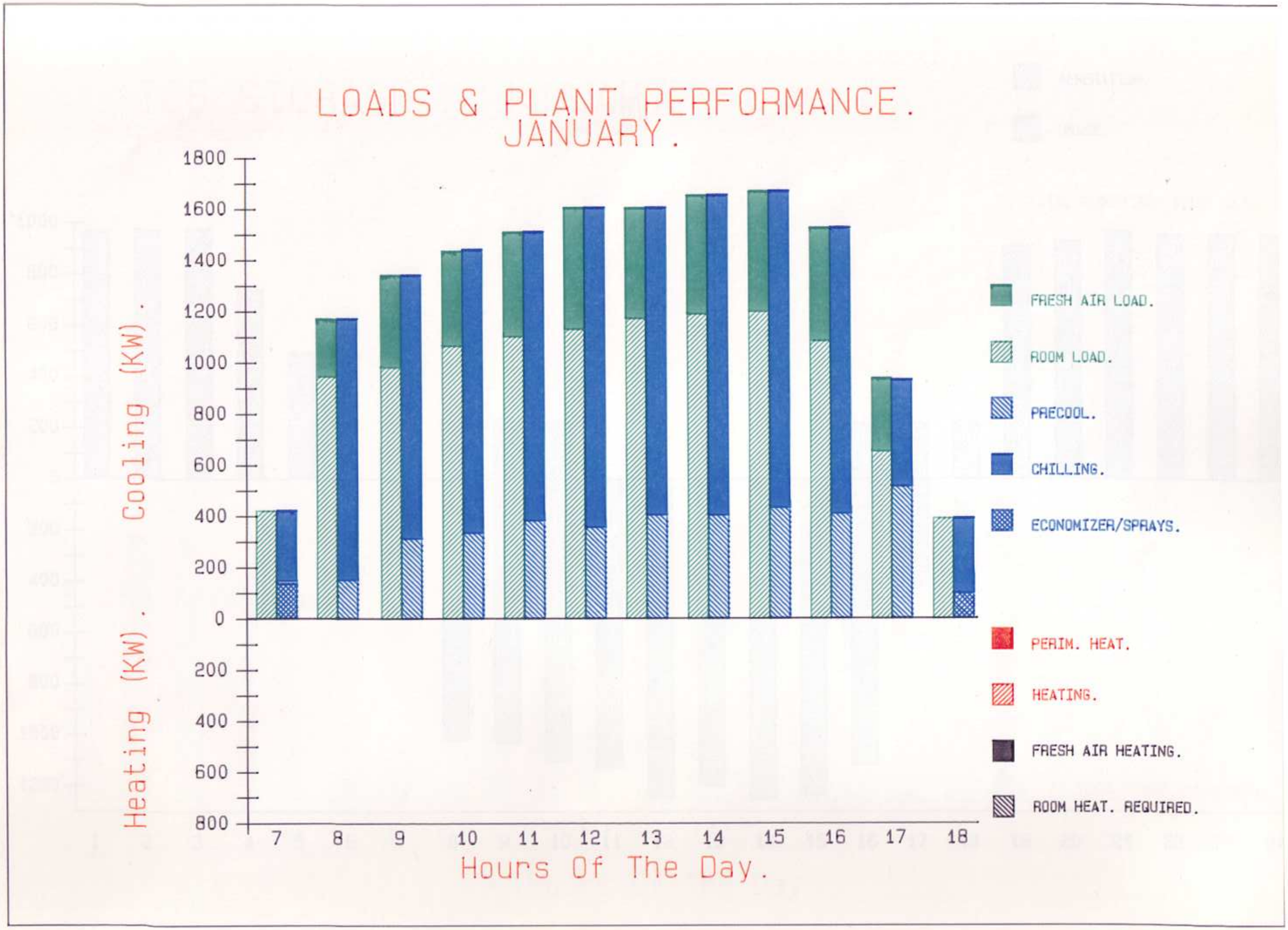
All plant sizes and KW ratings are derived from actual submitted selections by the contractor.

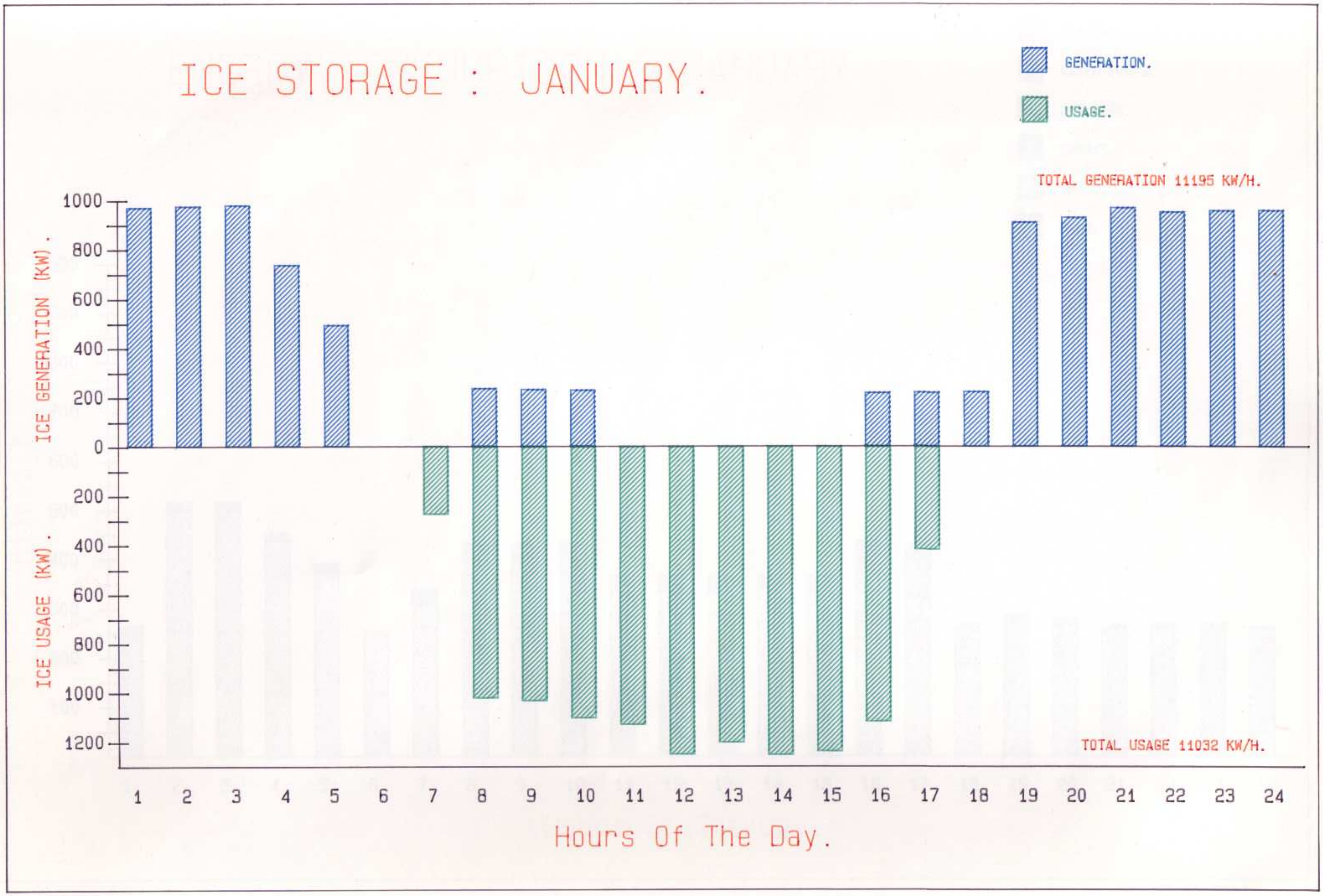
Minor discrepancies and inaccuracies have arisen, especially in the Plant performance and analysis section and these have been manually rectified, but the possibility exists that some inaccuracies have not been picked up and rectified. We believe however that an overall accuracy of at least 5% in all calculations has been achieved.

The graphical figures have been produced from the detailed summaries but in many cases simplifications have been made in order to facilitate graphical presentation.

General Notes:

1. Only airconditioning energy consumption and associated ventilation loads are accounted for in the detailed analysis. Other related items such as basement ventilation and Biokinetic centre ventilation energy consumption are not included, but these areas are also not included in the square metre figures used to derive comparable figures.
2. Power factor is assumed to be unity for the purposes of the analysis. In practice only limited power factor correction is provided.


LOADS & PLANT PERFORMANCE.
JANUARY.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.


ICE STORAGE : JANUARY.
GENERATION.
USAGE.
TOTAL GENERATION 11195 KW/H.
TOTAL USAGE 11032 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
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600
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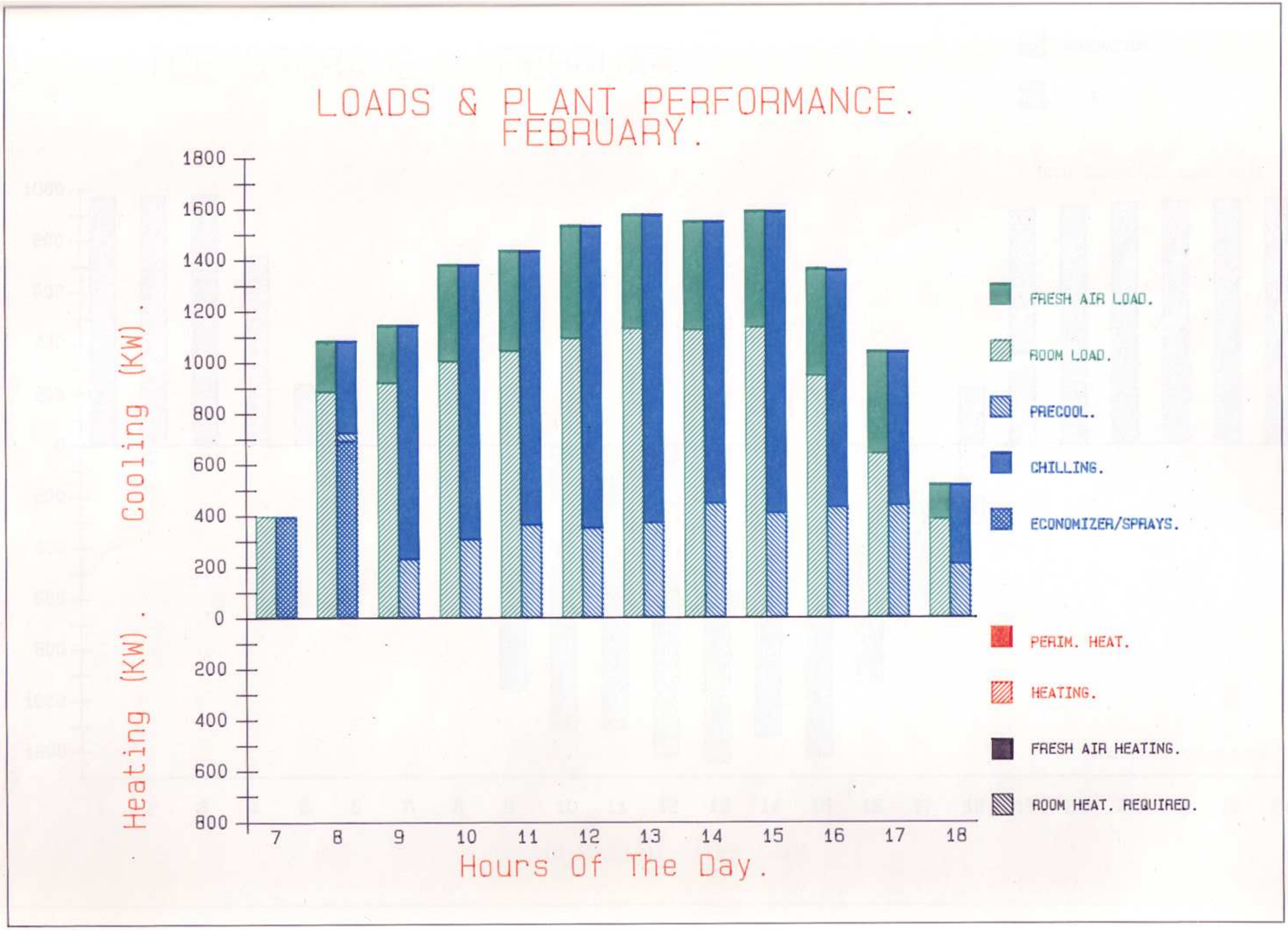
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


LOADS & PLANT PERFORMANCE.
FEBRUARY.
Cooling (KW).
Heating (KW).
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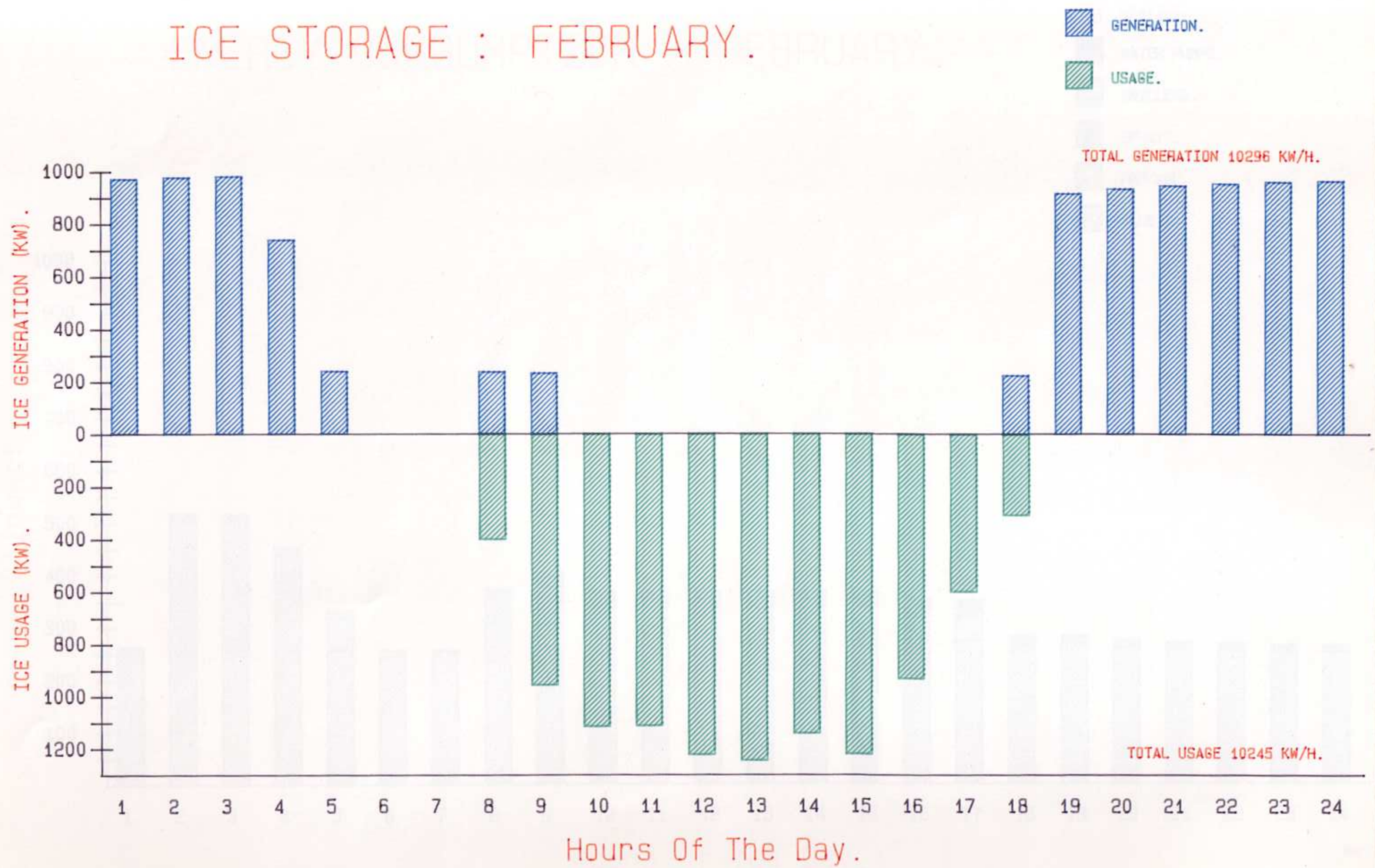
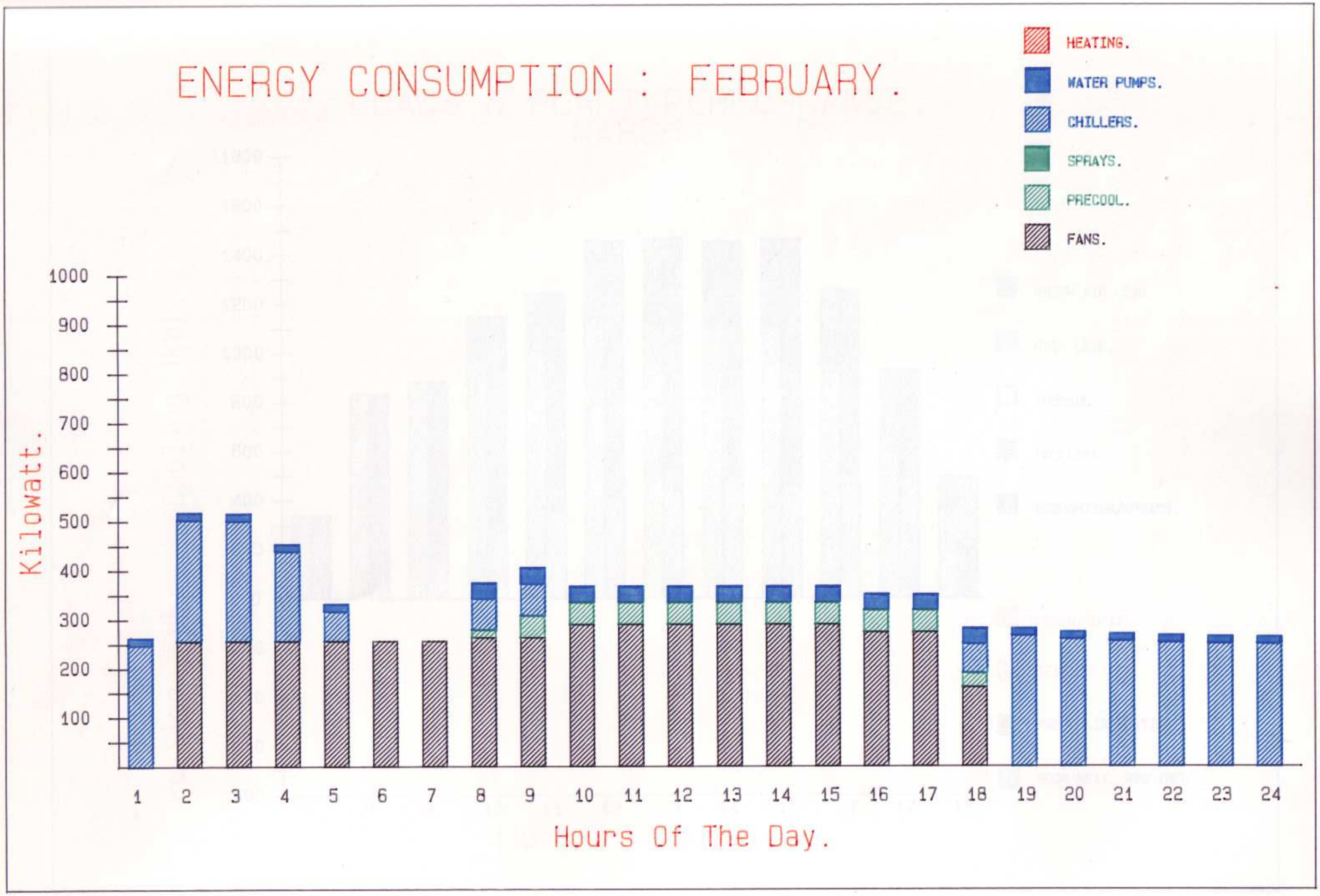
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

ICE STORAGE : FEBRUARY.




ENERGY CONSUMPTION : FEBRUARY.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
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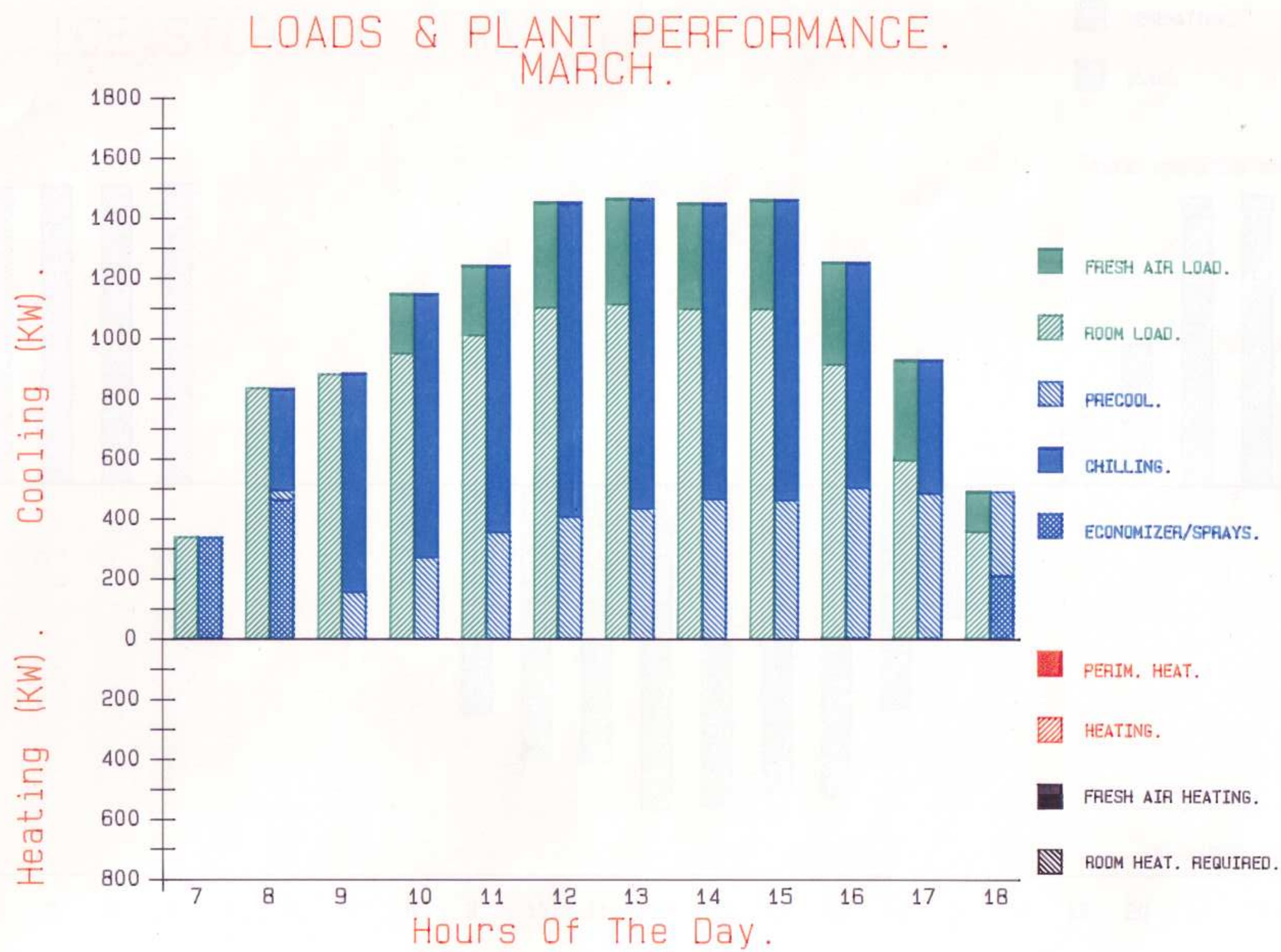
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.



LOADS & PLANT PERFORMANCE.
MARCH.
Cooling (KW).
Heating (KW).
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1400
1200
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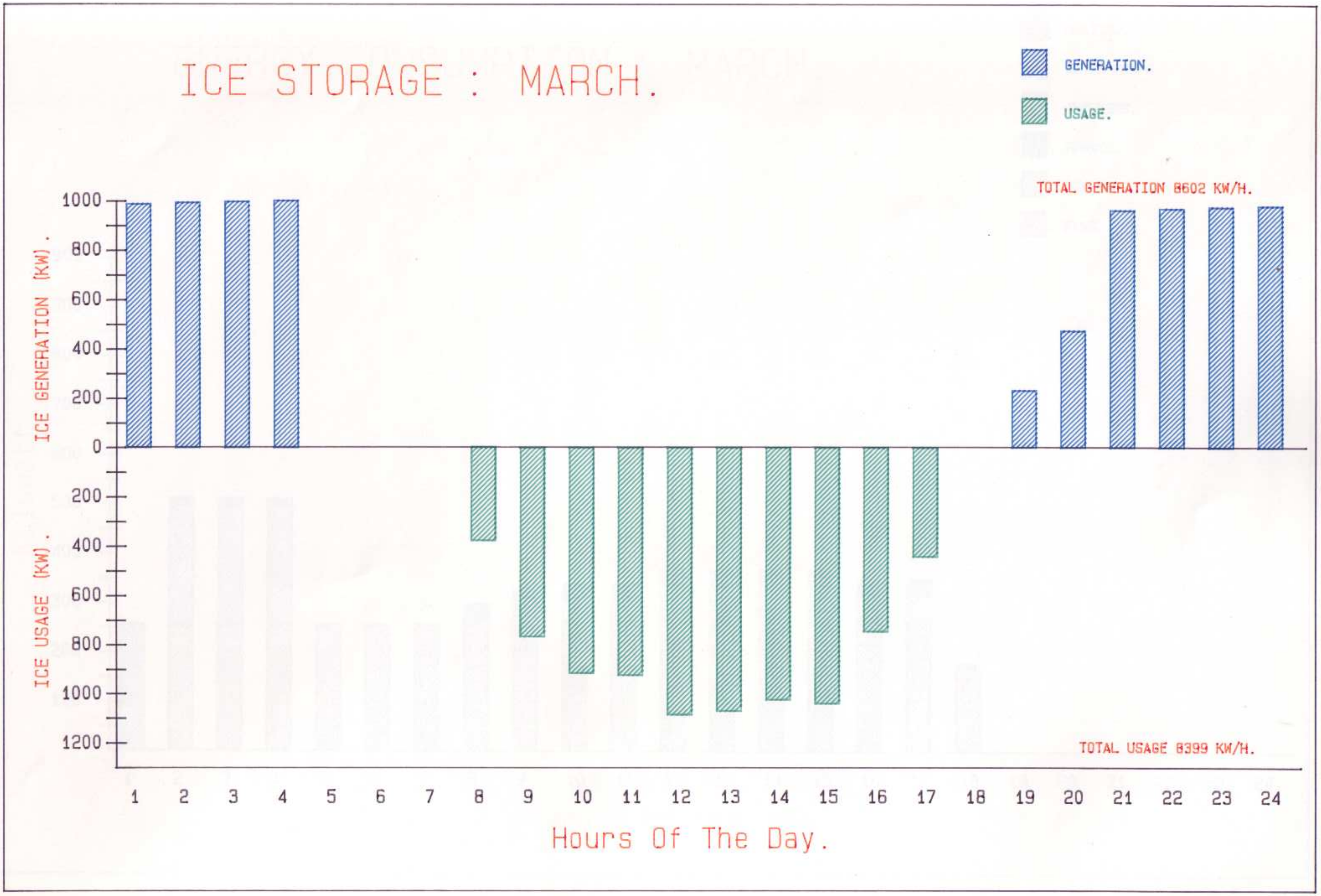
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.


ICE STORAGE : MARCH.
GENERATION.
USAGE.
TOTAL GENERATION 8602 KW/H.
TOTAL USAGE 8399 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
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0
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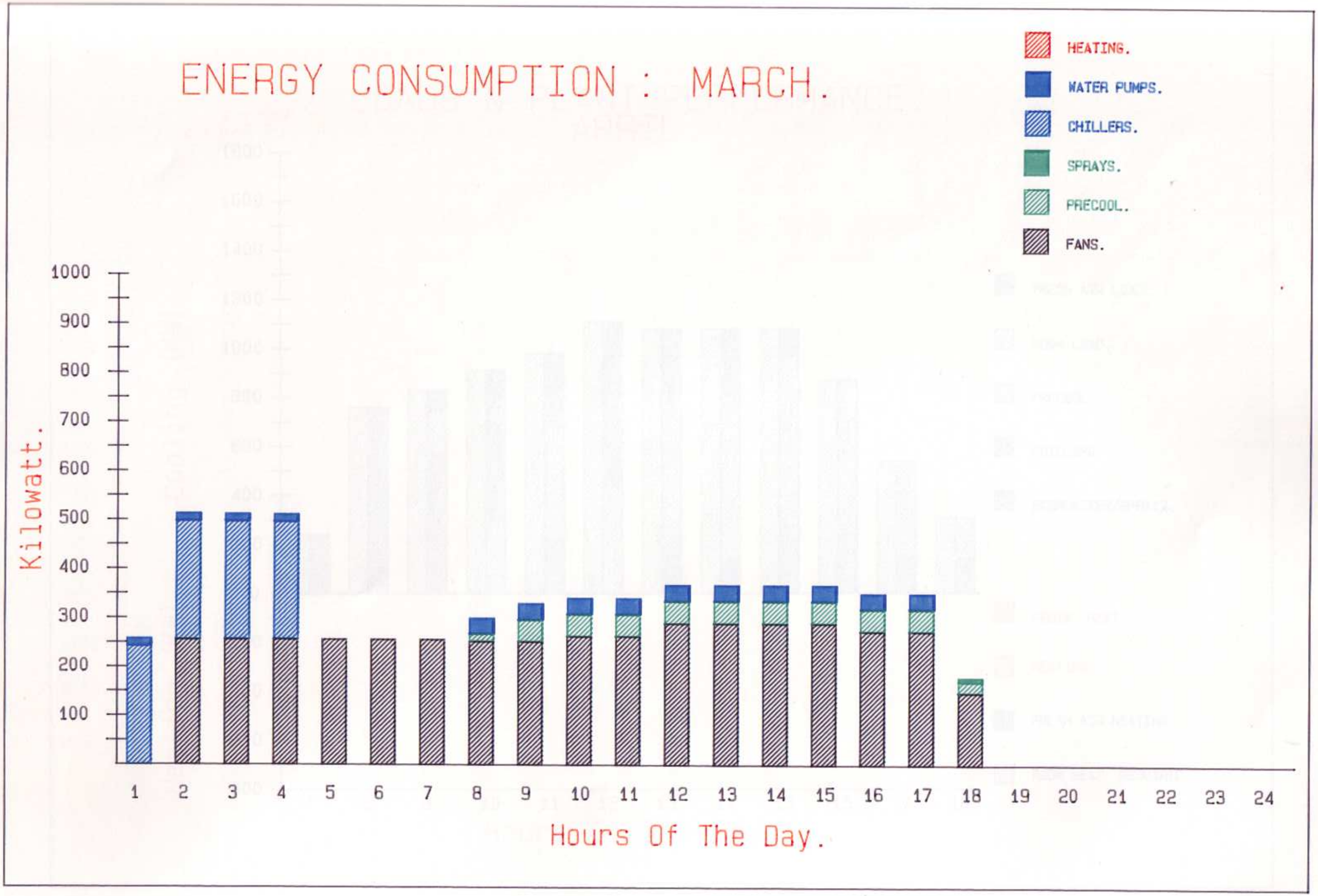
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.



ENERGY CONSUMPTION : MARCH.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
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800
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


LOADS & PLANT PERFORMANCE.
APRIL.
Cooling (KW).
Heating (KW).
1800
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1400
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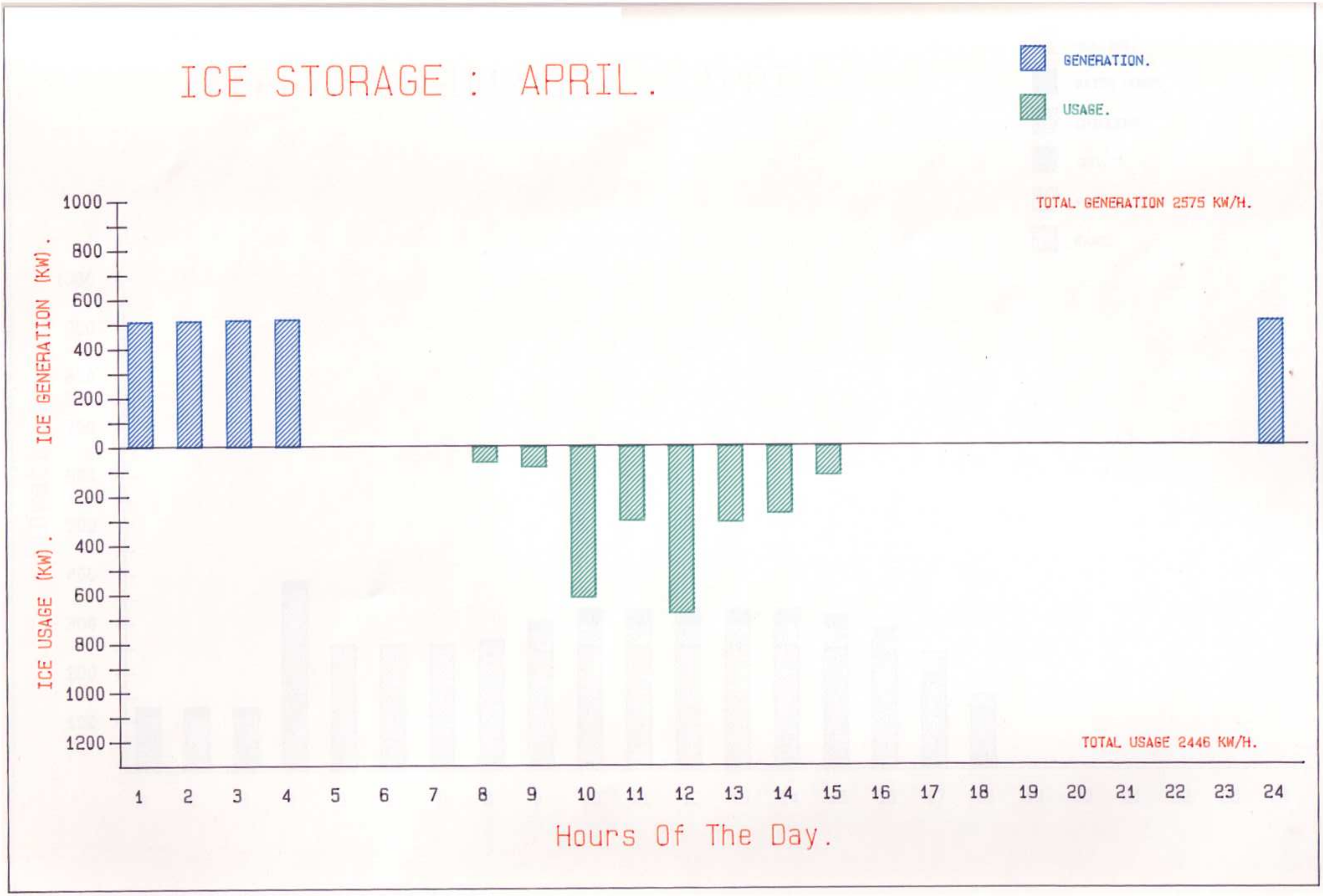
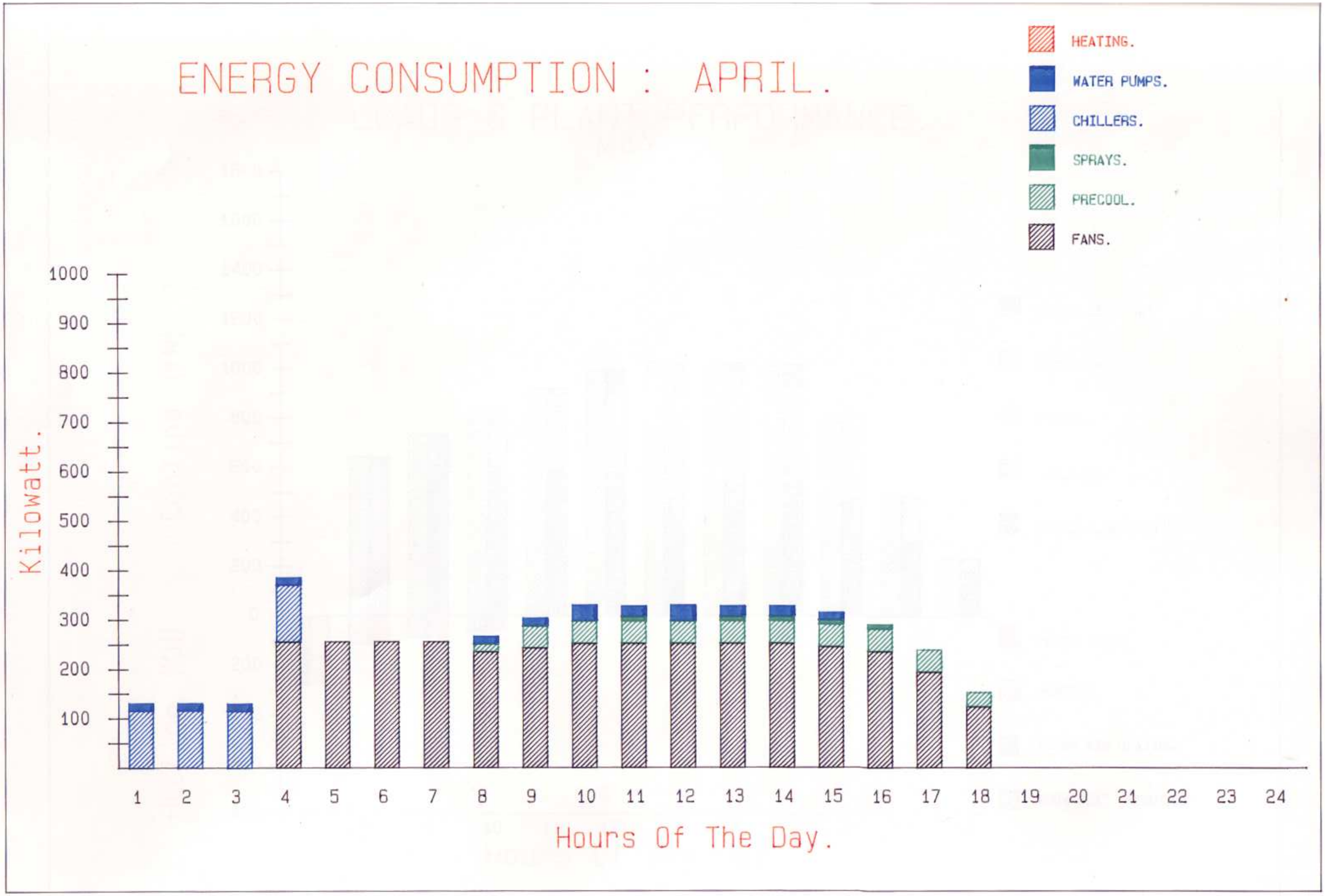
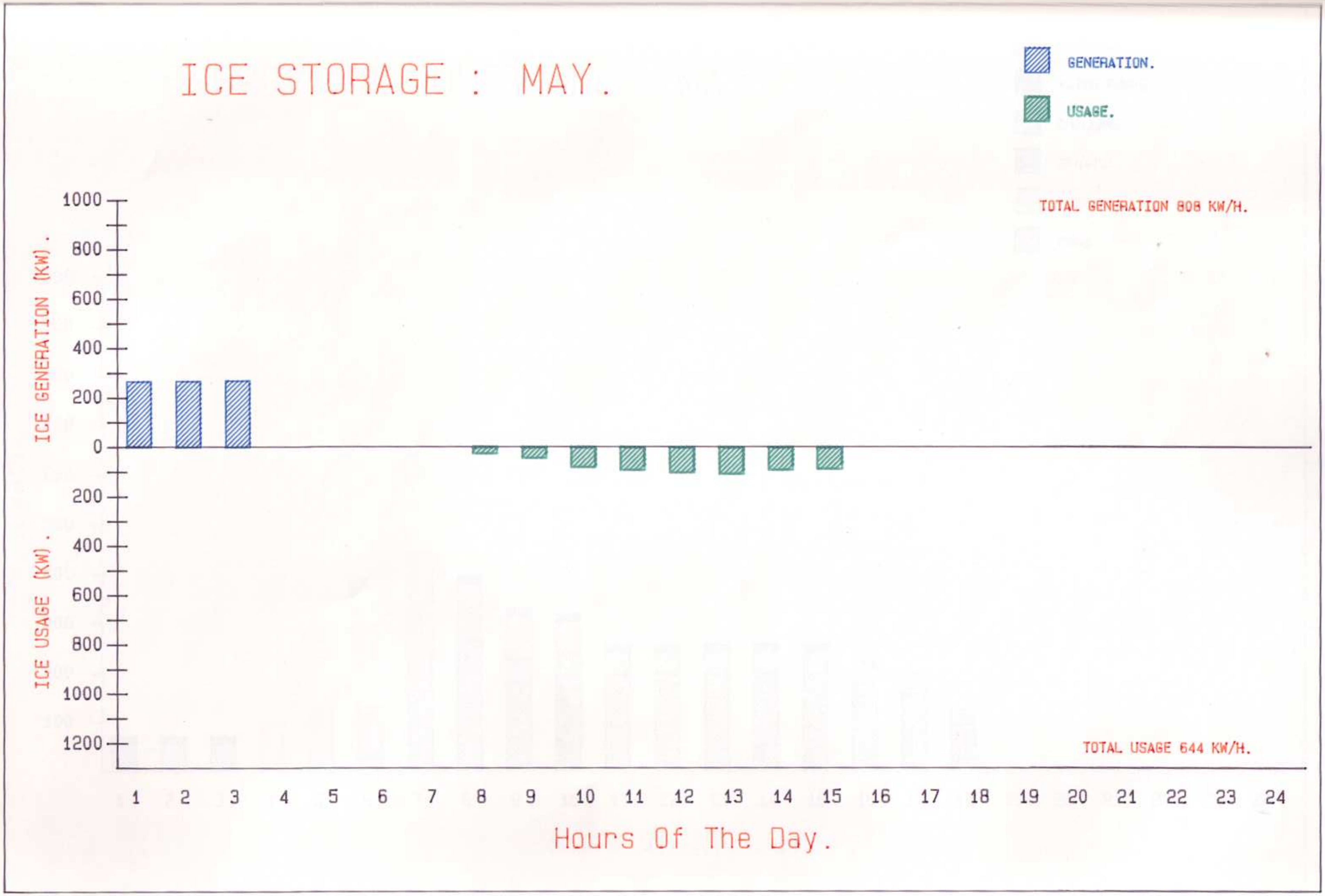
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

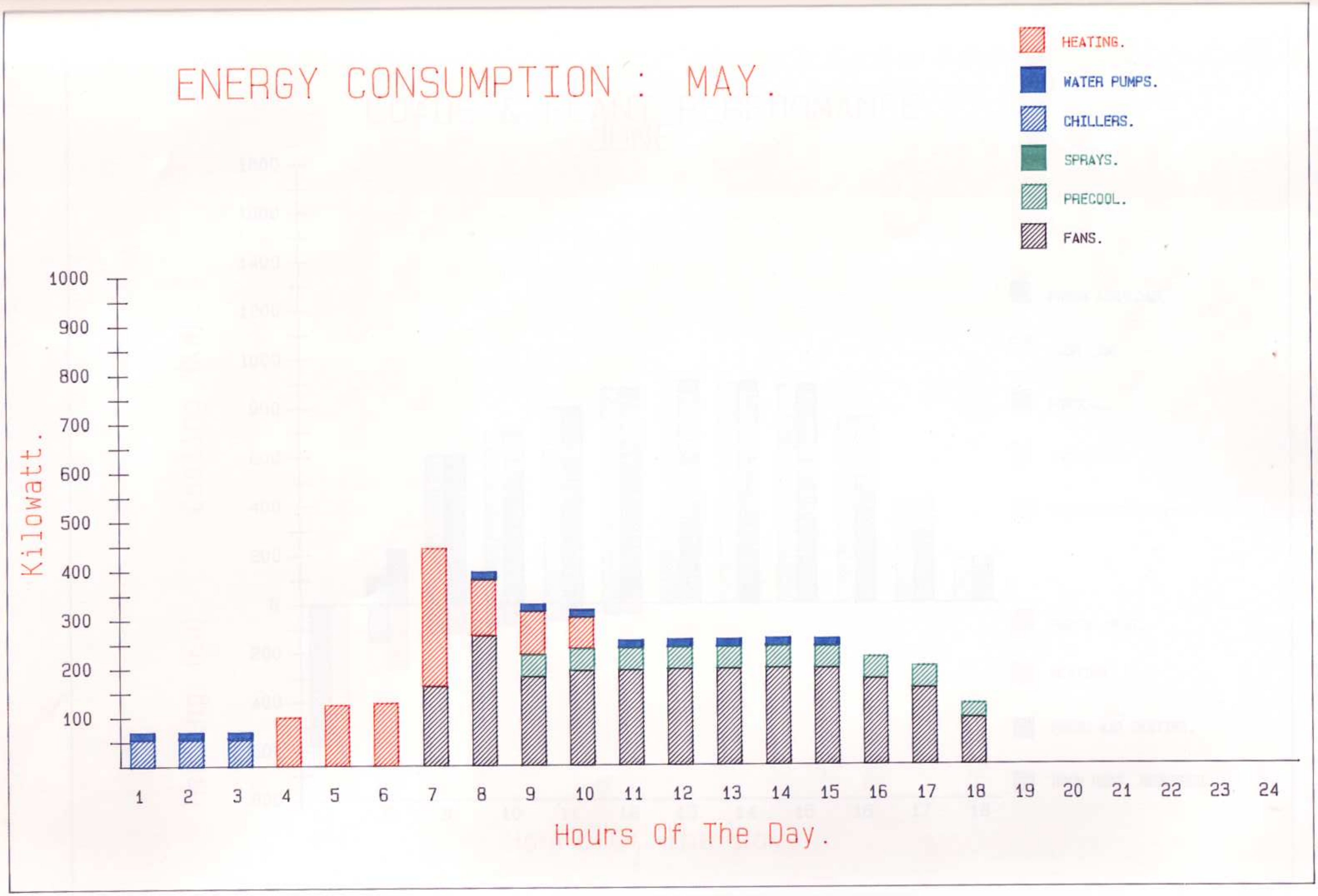


ICE STORAGE : APRIL.
GENERATION.
USAGE.
TOTAL GENERATION 2575 KW/H.
TOTAL USAGE 2446 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

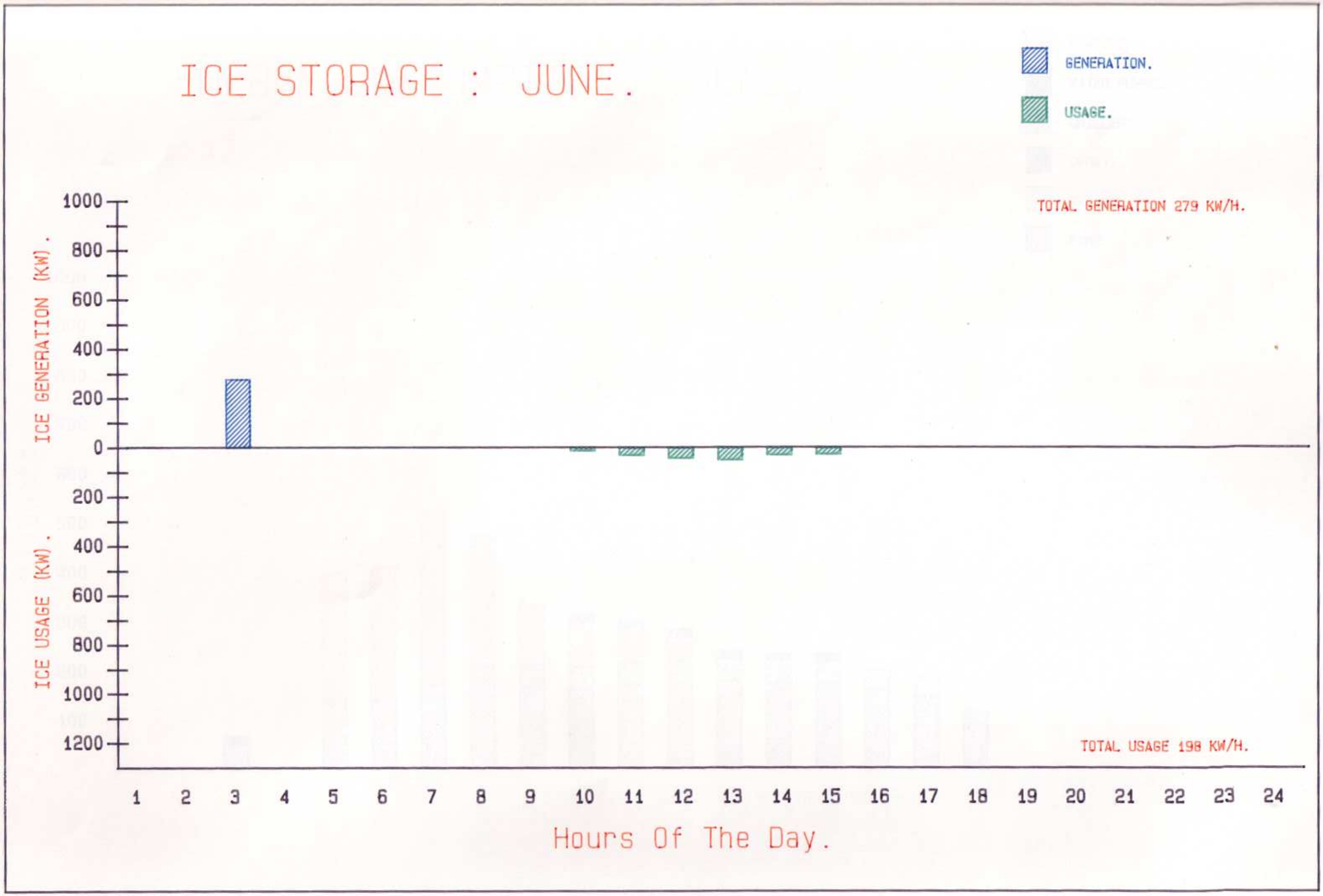

ENERGY CONSUMPTION : APRIL.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


LOADS & PLANT PERFORMANCE.
MAY.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

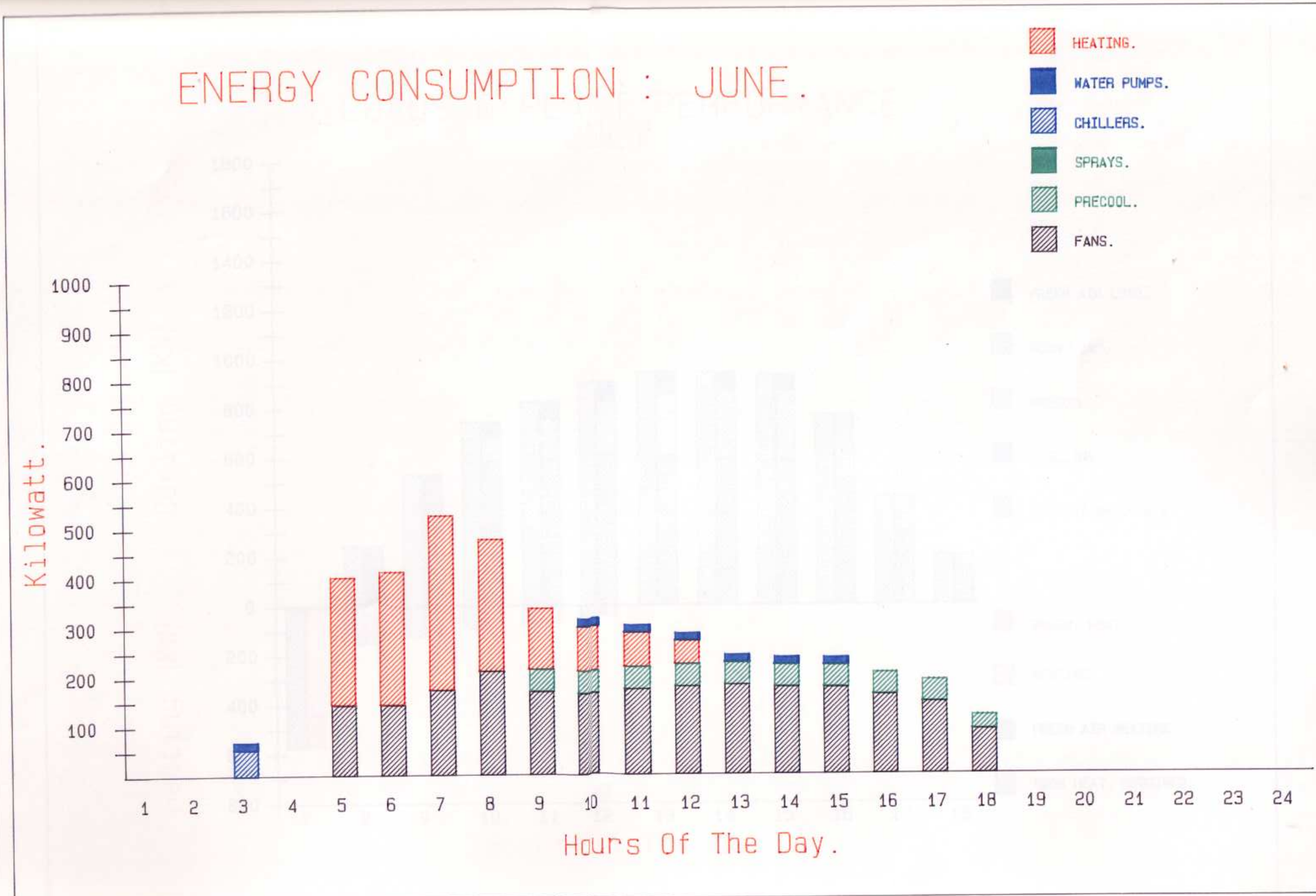

ICE STORAGE : MAY.
GENERATION.
USAGE.
TOTAL GENERATION 808 KW/H.
TOTAL USAGE 644 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

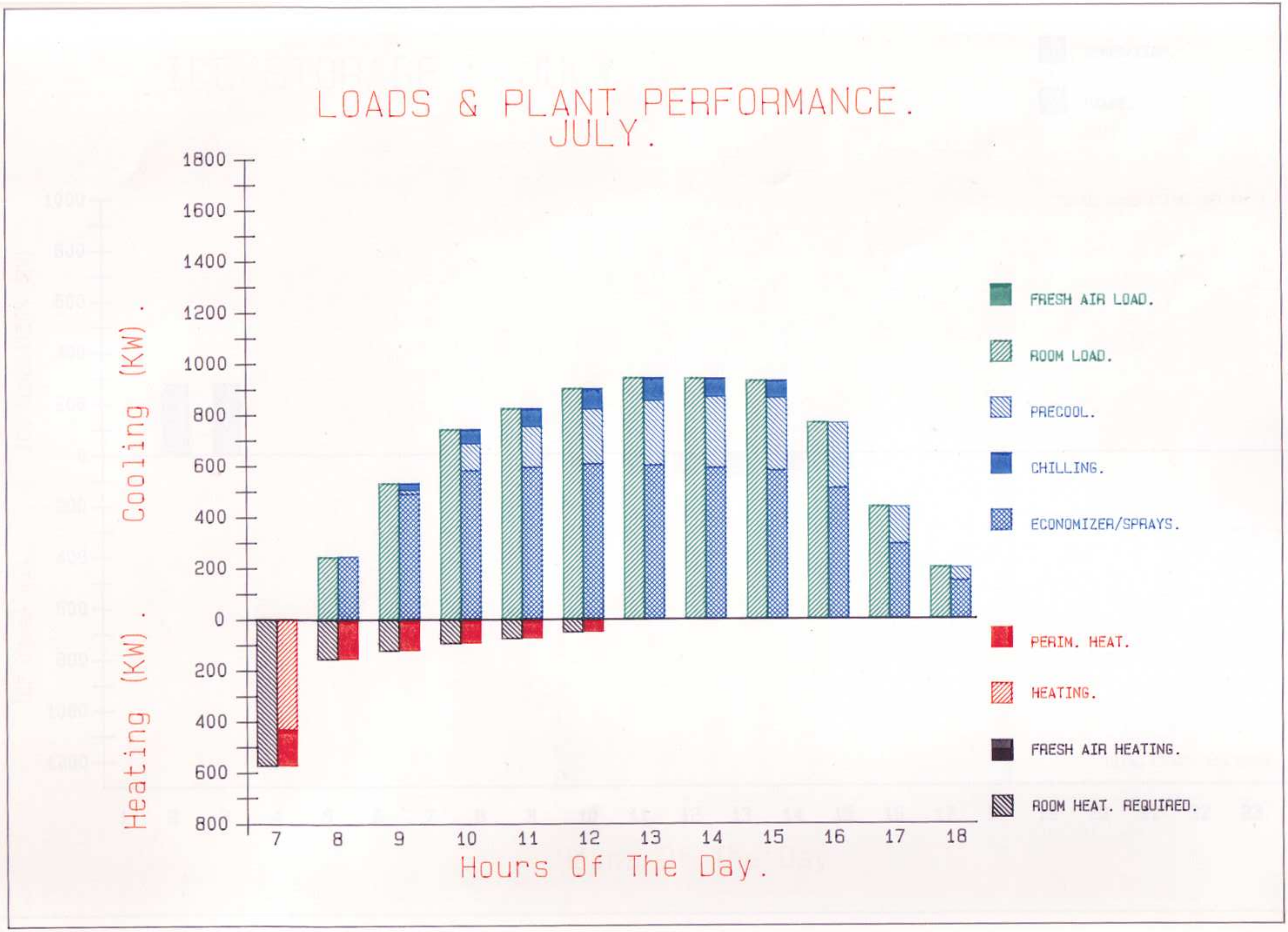

ENERGY CONSUMPTION : MAY.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

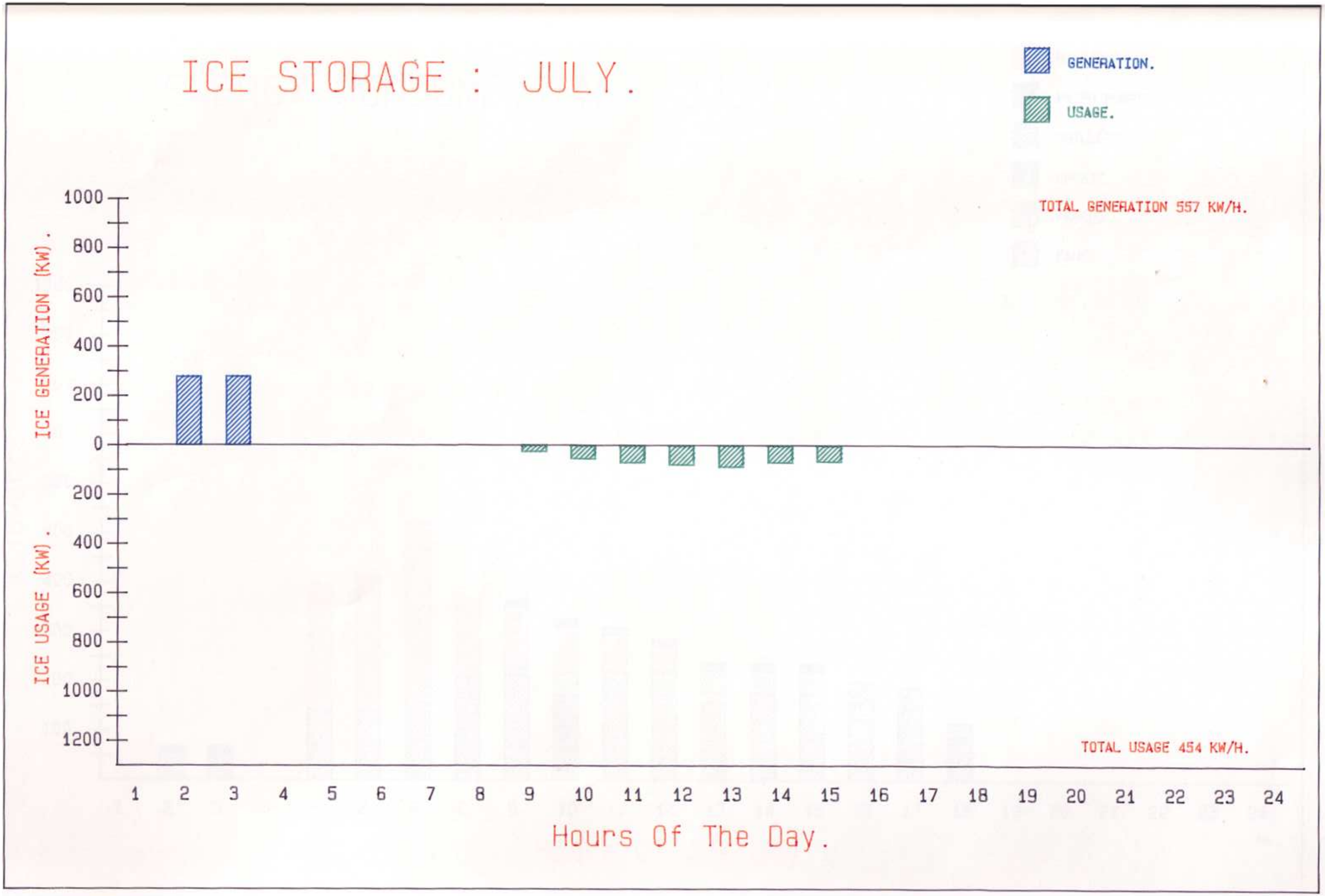

LOADS & PLANT PERFORMANCE.
JUNE.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

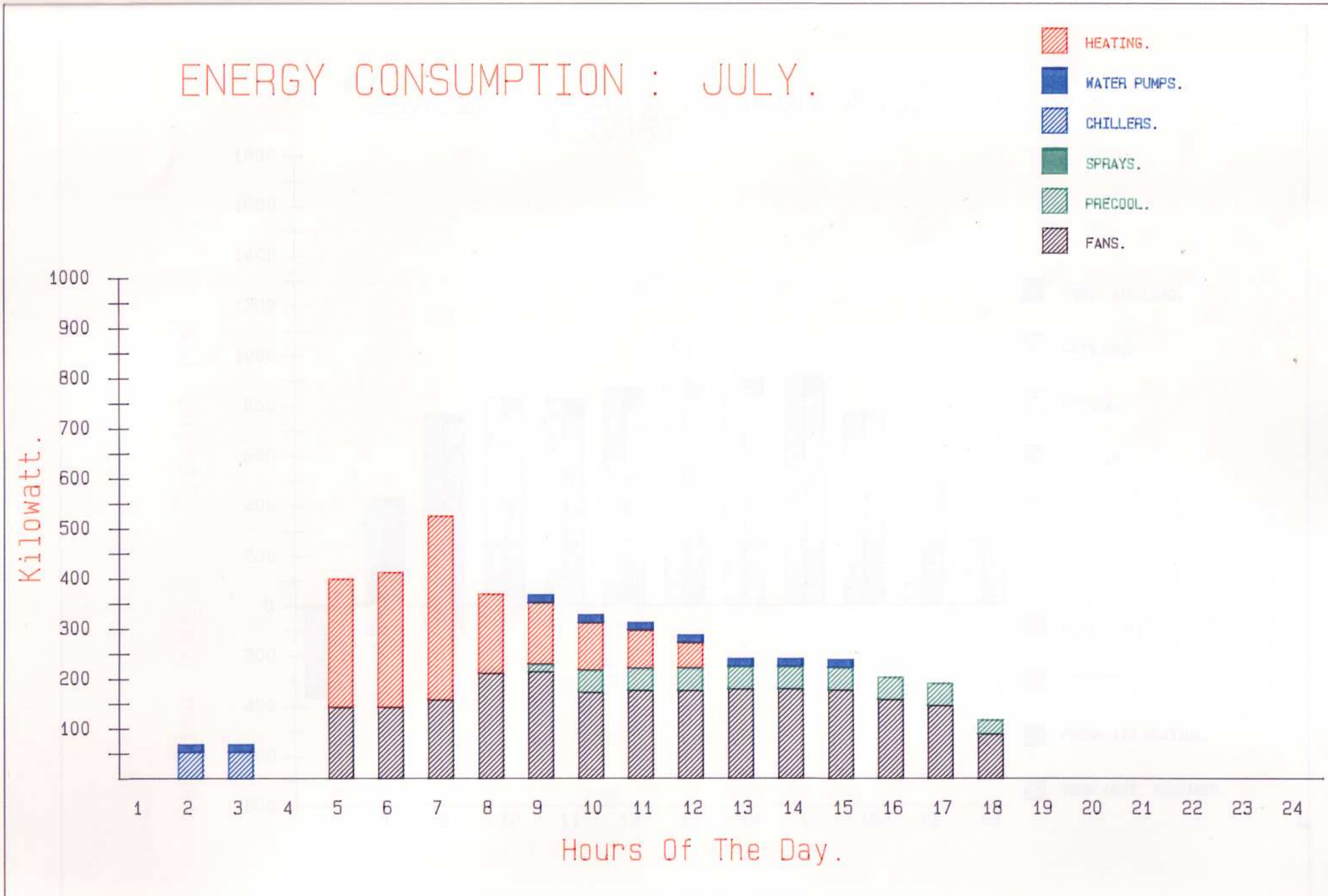


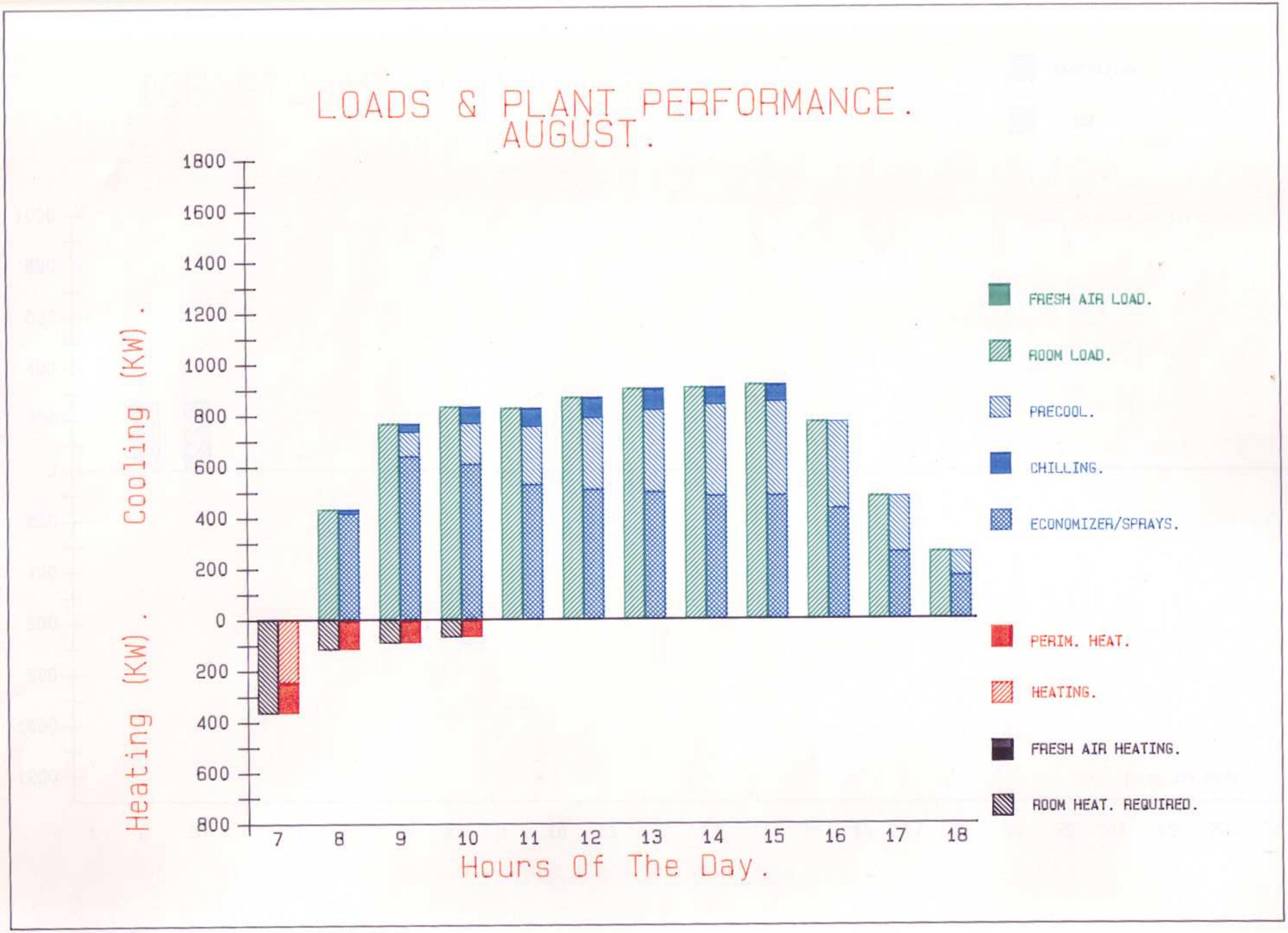
ICE STORAGE : JUNE.
GENERATION.
USAGE.
TOTAL GENERATION 279 KW/H.
TOTAL USAGE 198 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

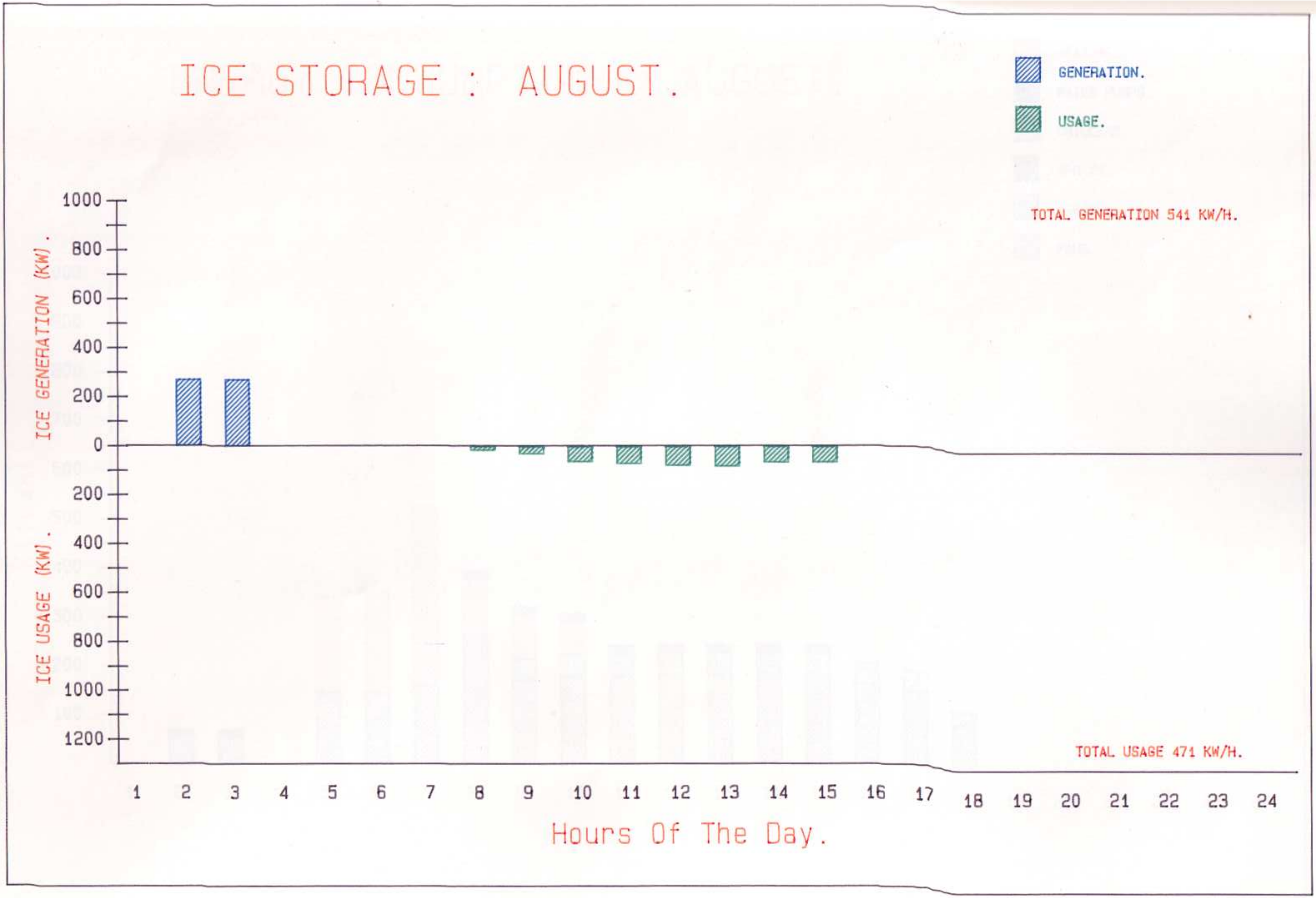

ENERGY CONSUMPTION : JUNE.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

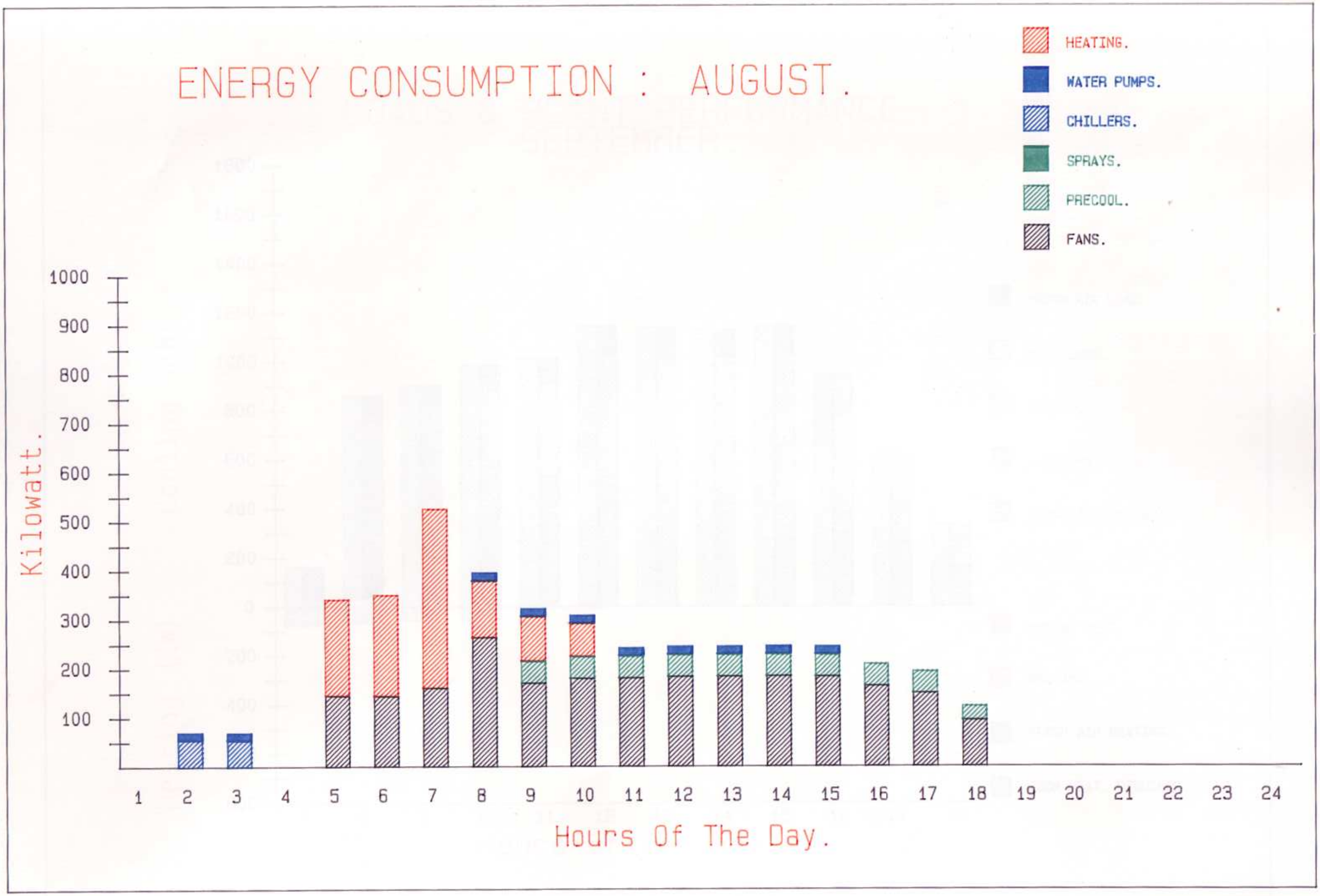

LOADS & PLANT PERFORMANCE.
JULY.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

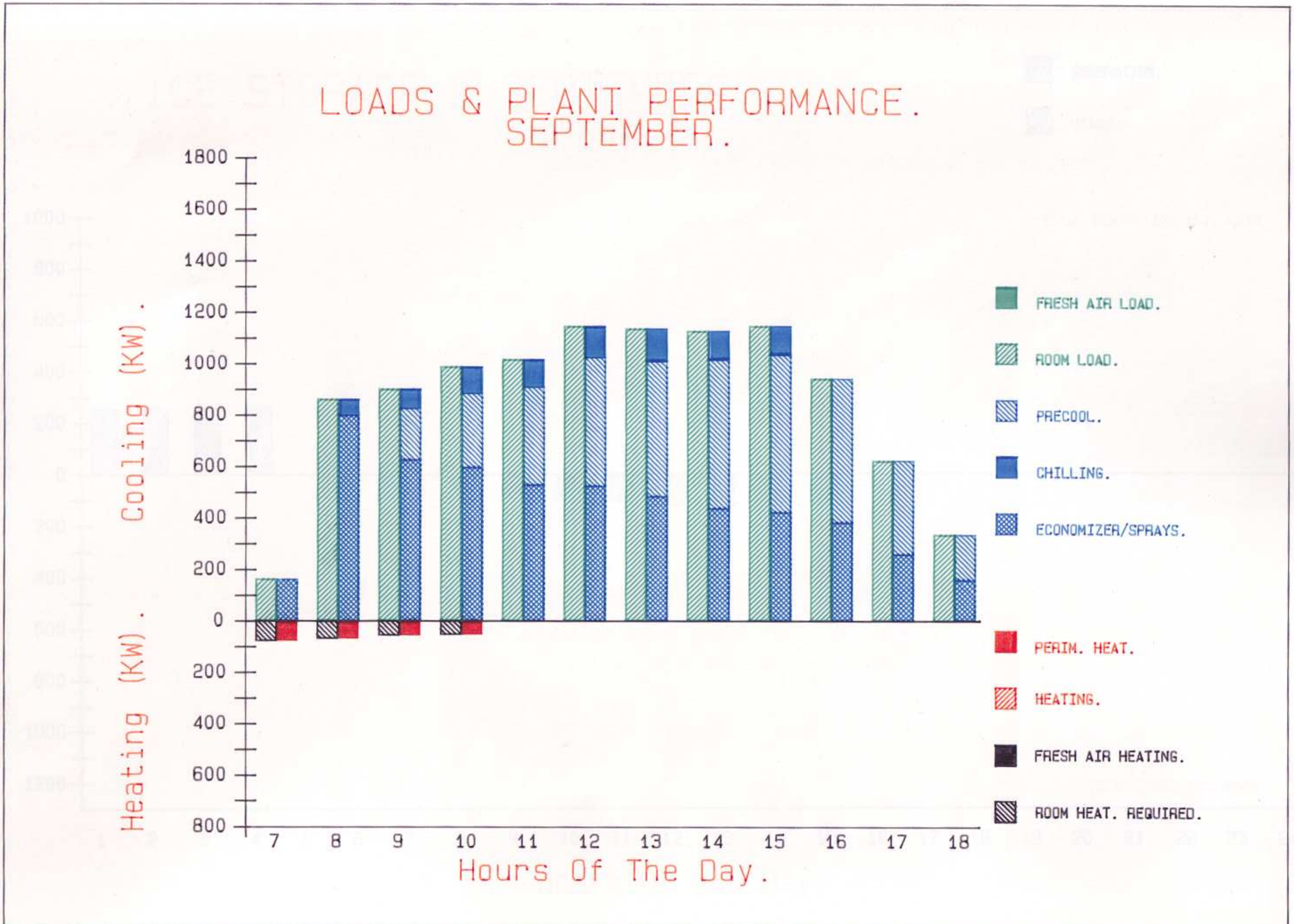

ICE STORAGE : JULY.
GENERATION.
USAGE.
TOTAL GENERATION 557 KW/H.
TOTAL USAGE 454 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

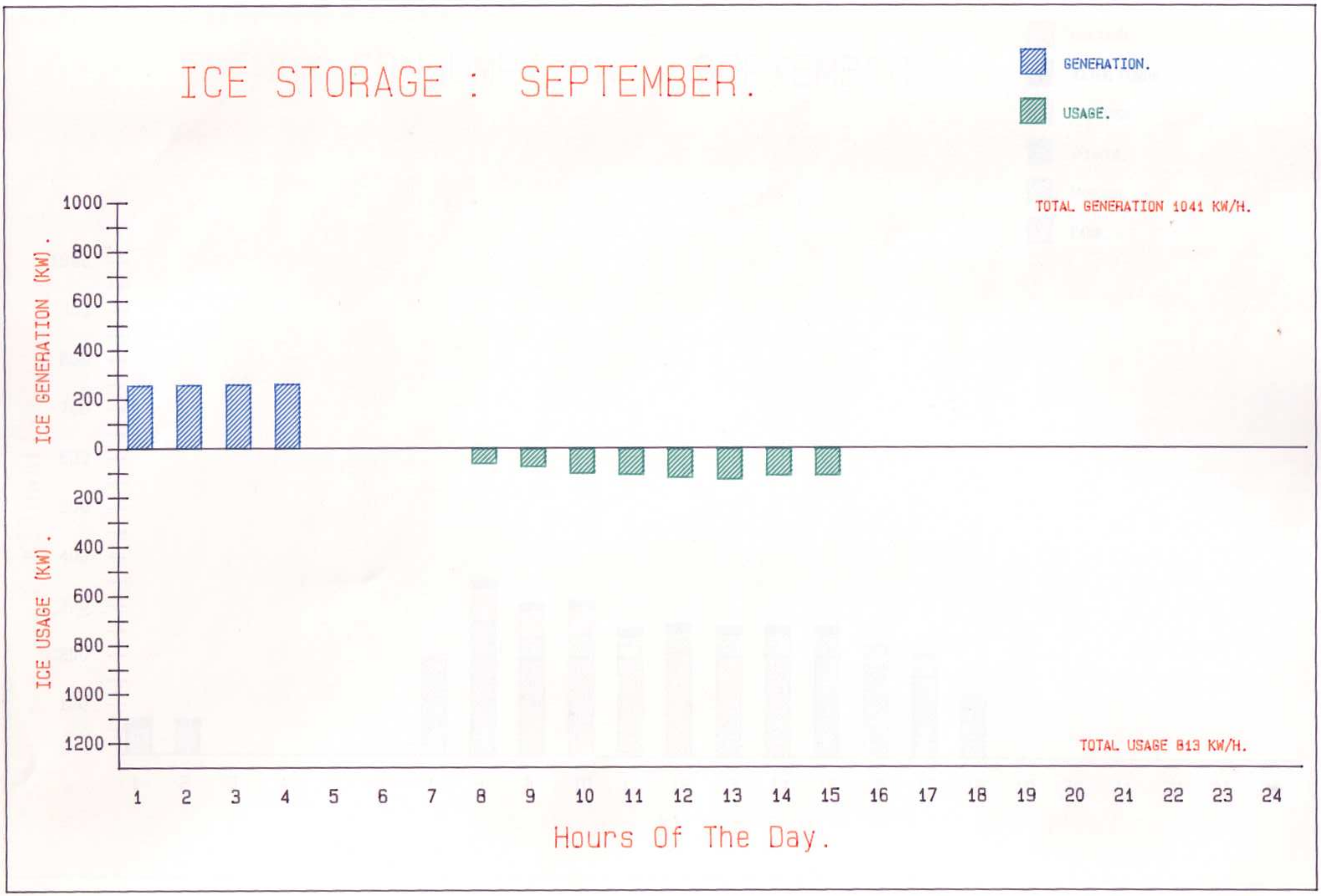

ENERGY CONSUMPTION : JULY.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


LOADS & PLANT PERFORMANCE.
AUGUST.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

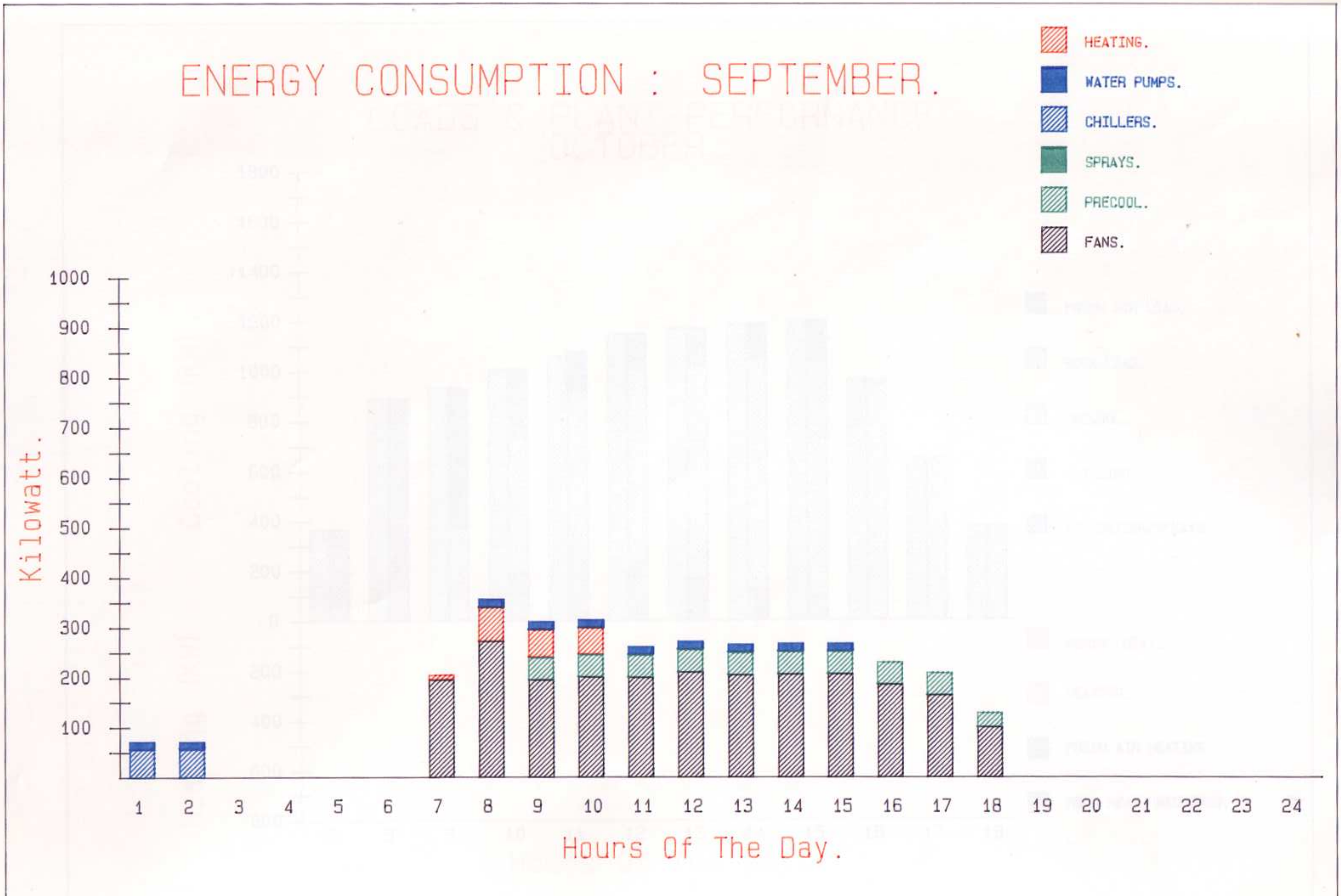

ICE STORAGE : AUGUST.
GENERATION.
USAGE.
TOTAL GENERATION 541 KW/H.
TOTAL USAGE 471 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

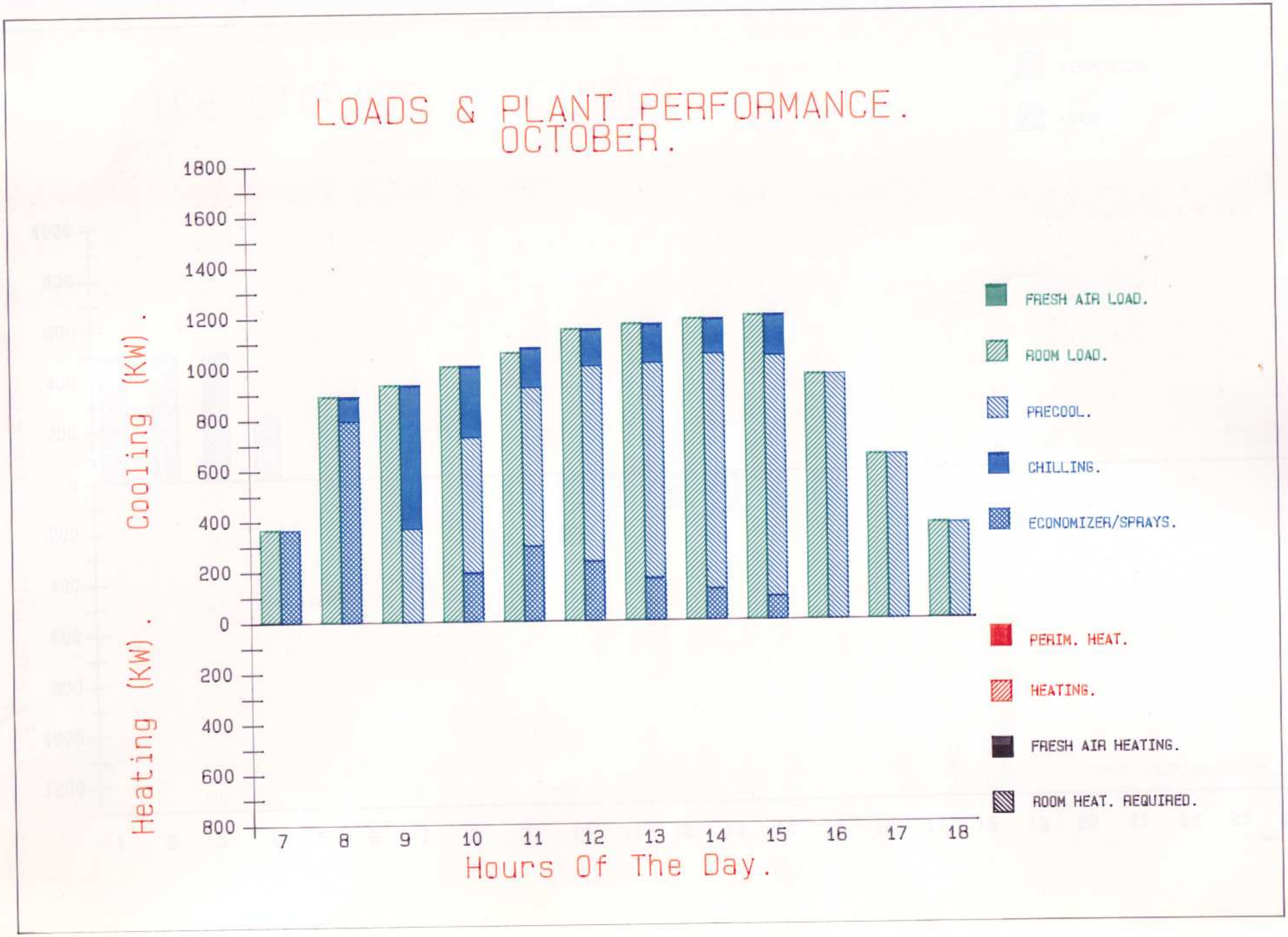

ENERGY CONSUMPTION : AUGUST.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

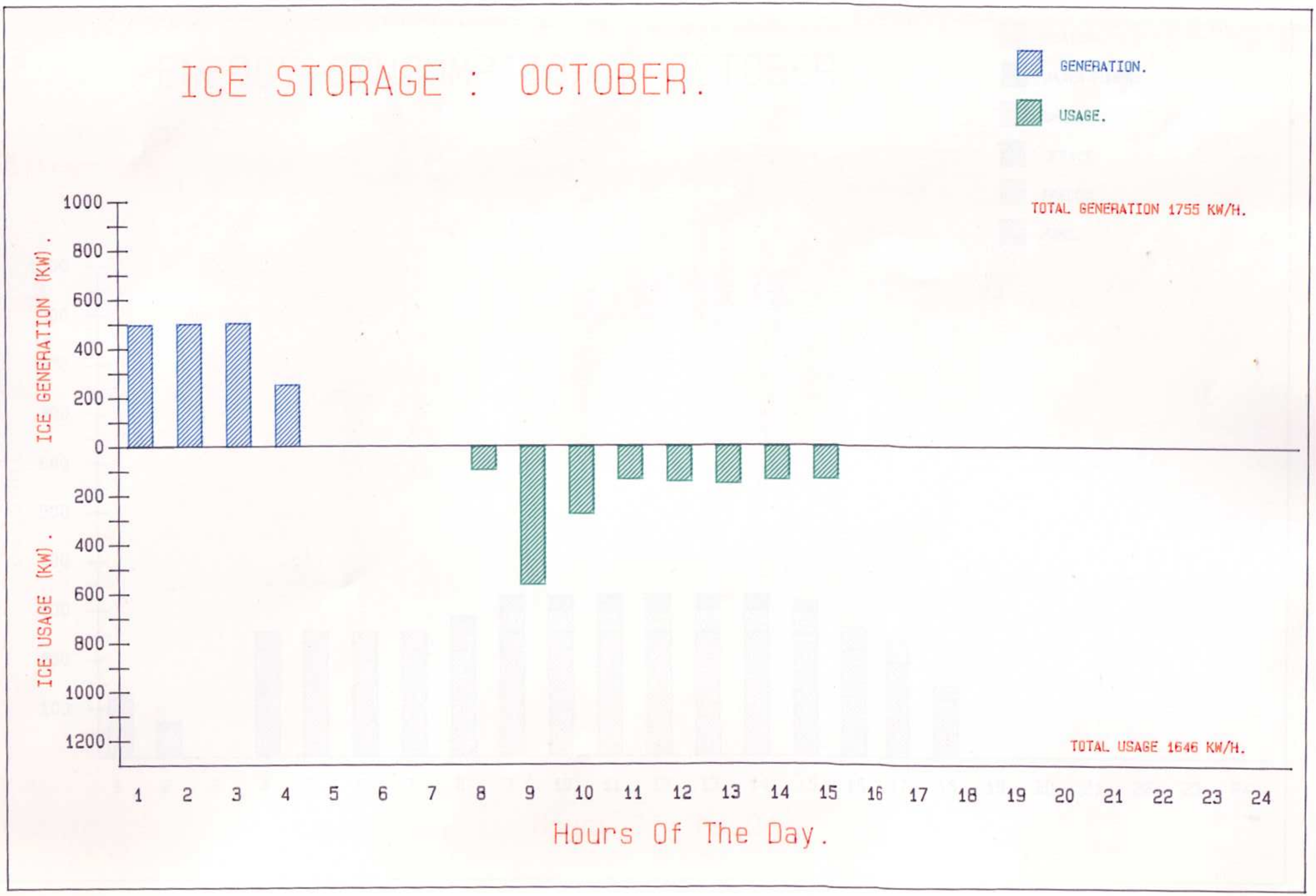

LOADS & PLANT PERFORMANCE.
SEPTEMBER.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

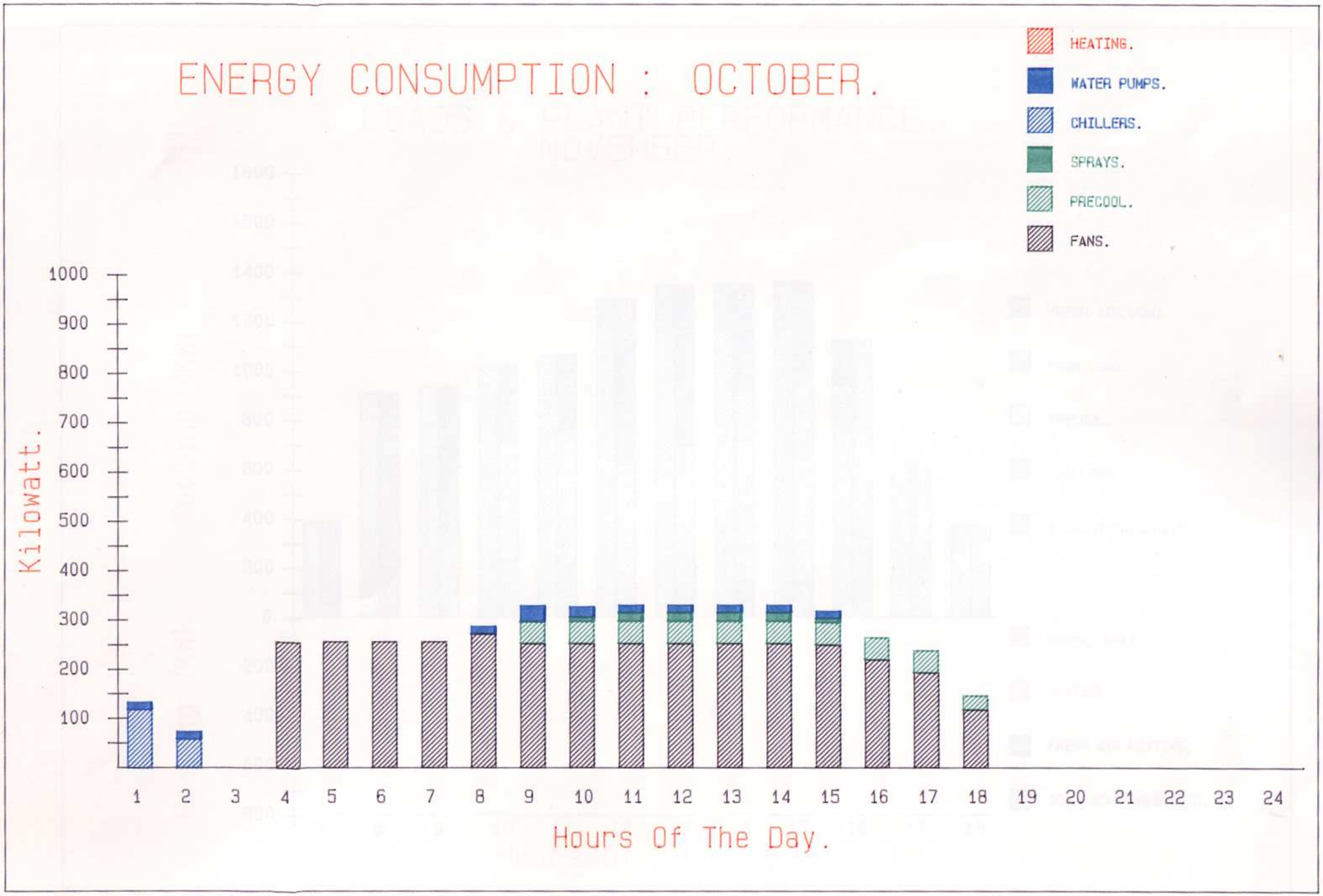


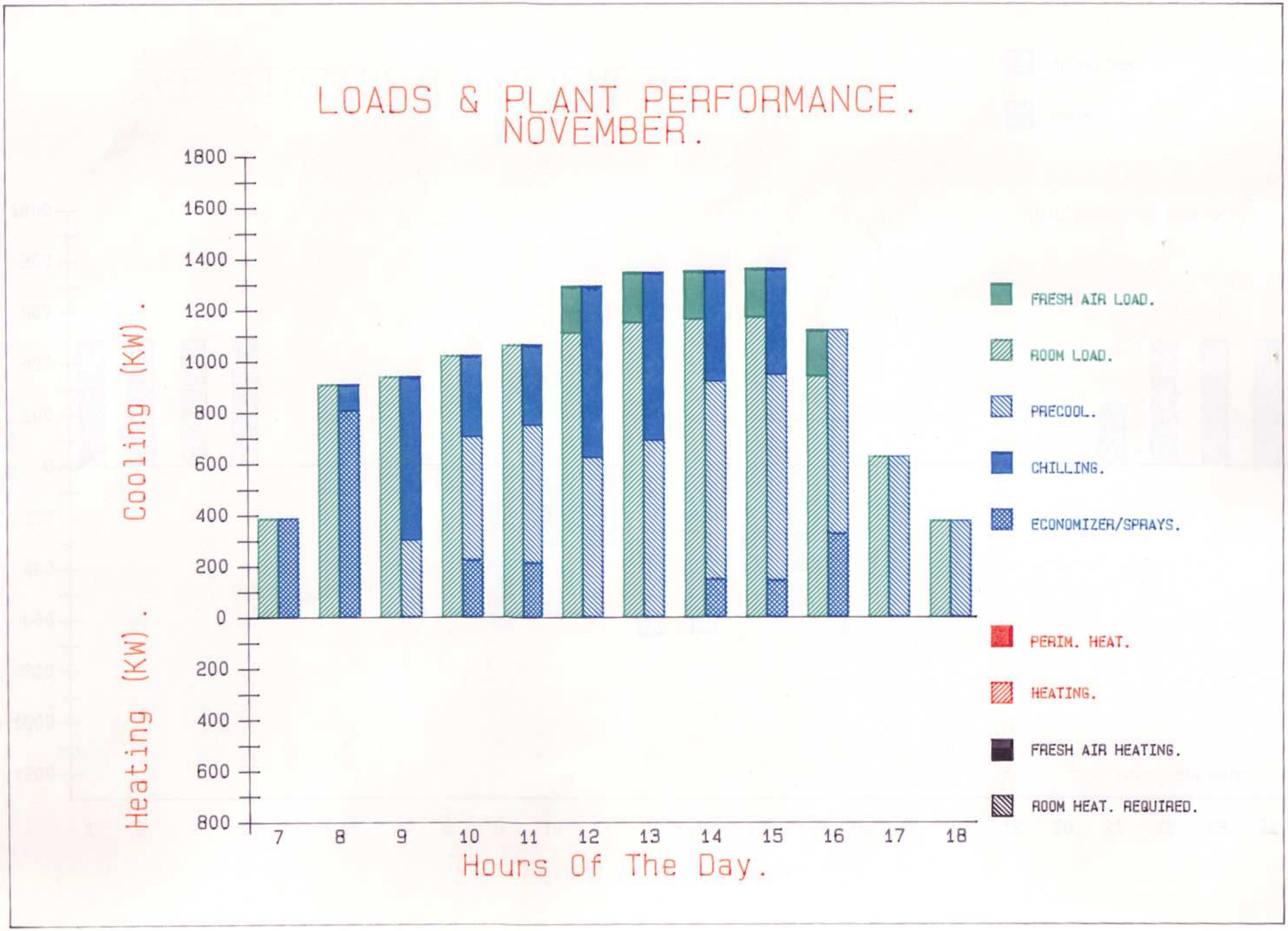
ICE STORAGE : SEPTEMBER.
GENERATION.
USAGE.
TOTAL GENERATION 1041 KW/H.
TOTAL USAGE 813 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

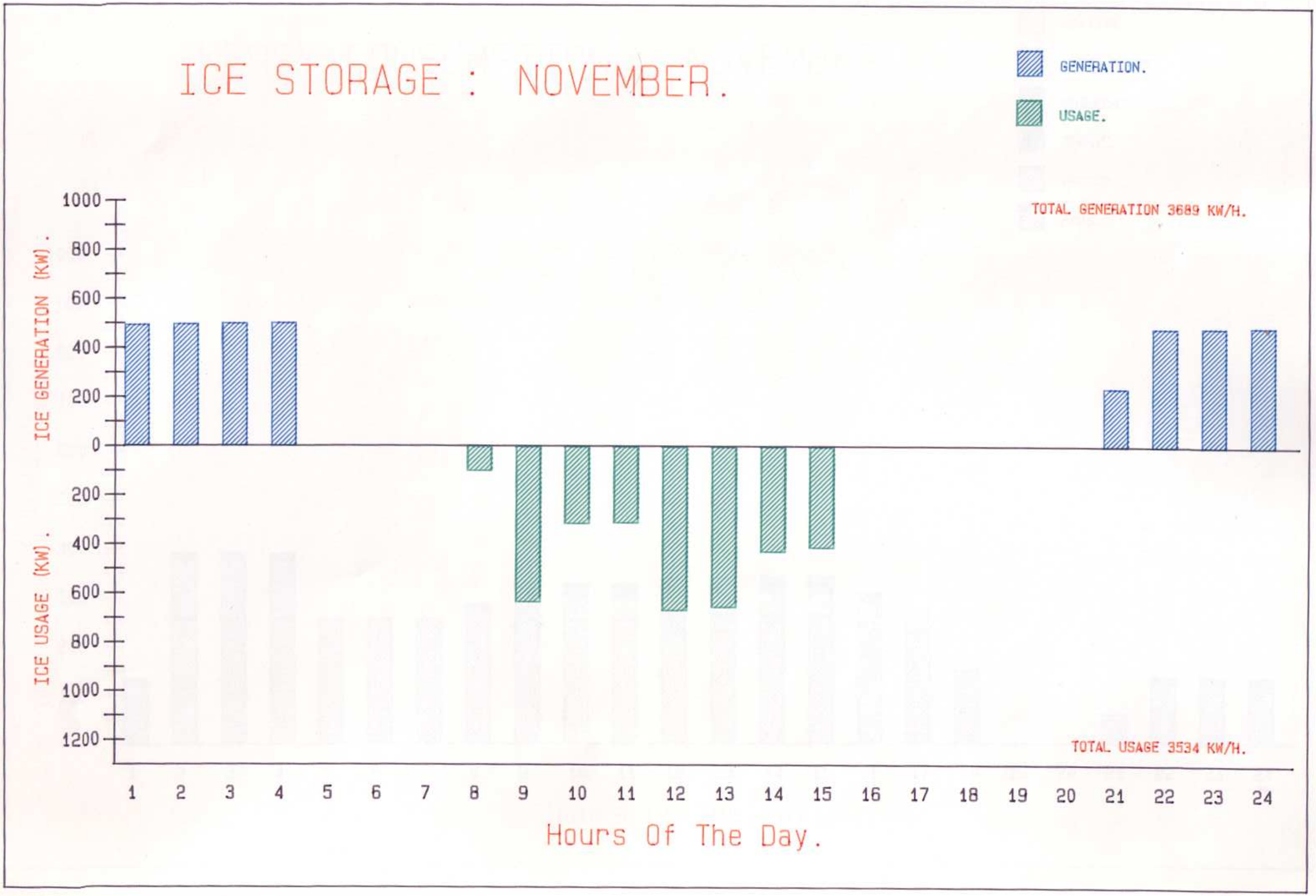

ENERGY CONSUMPTION : SEPTEMBER.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

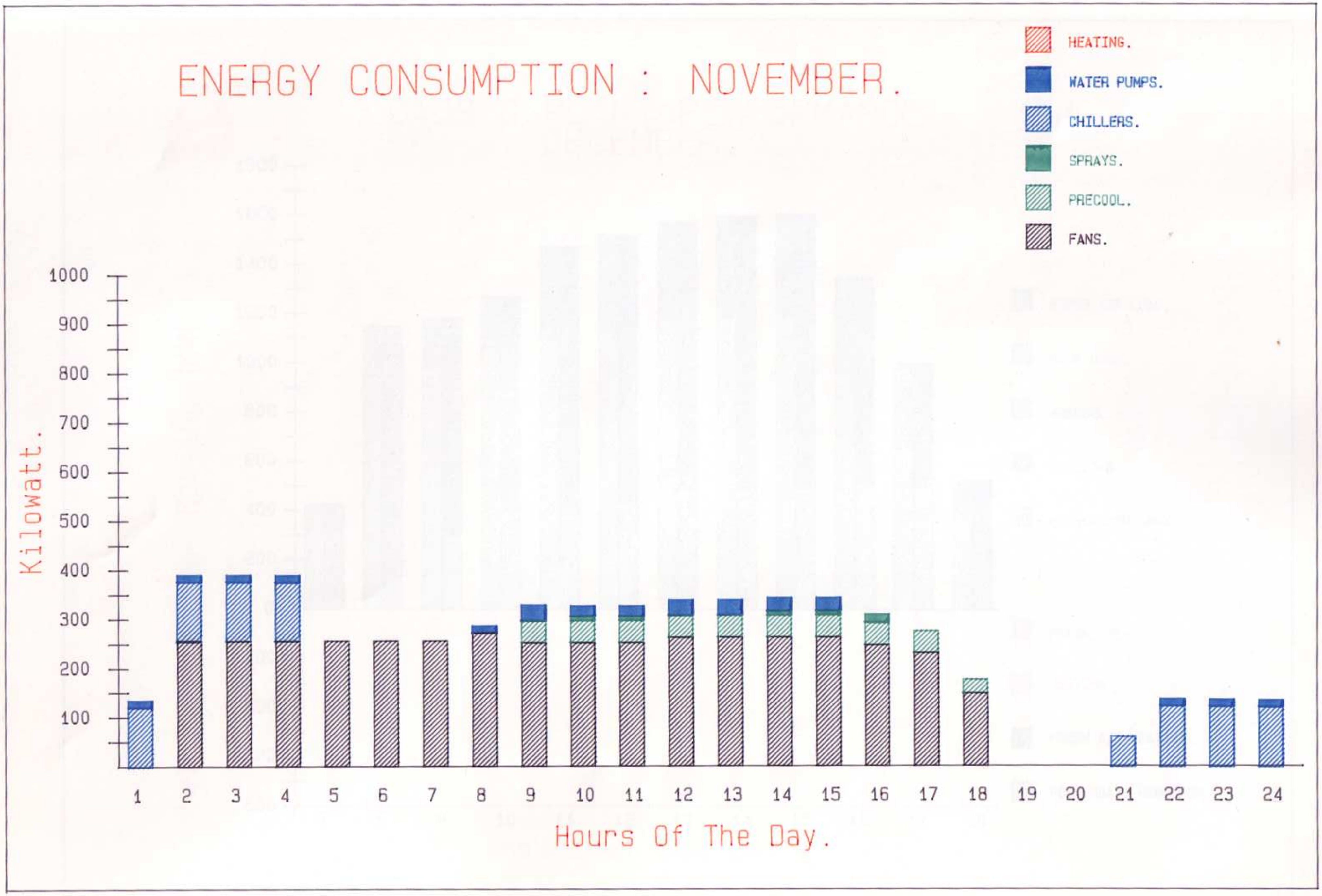

LOADS & PLANT PERFORMANCE.
OCTOBER.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.


ICE STORAGE : OCTOBER.
GENERATION.
USAGE.
TOTAL GENERATION 1755 KW/H.
TOTAL USAGE 1646 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.

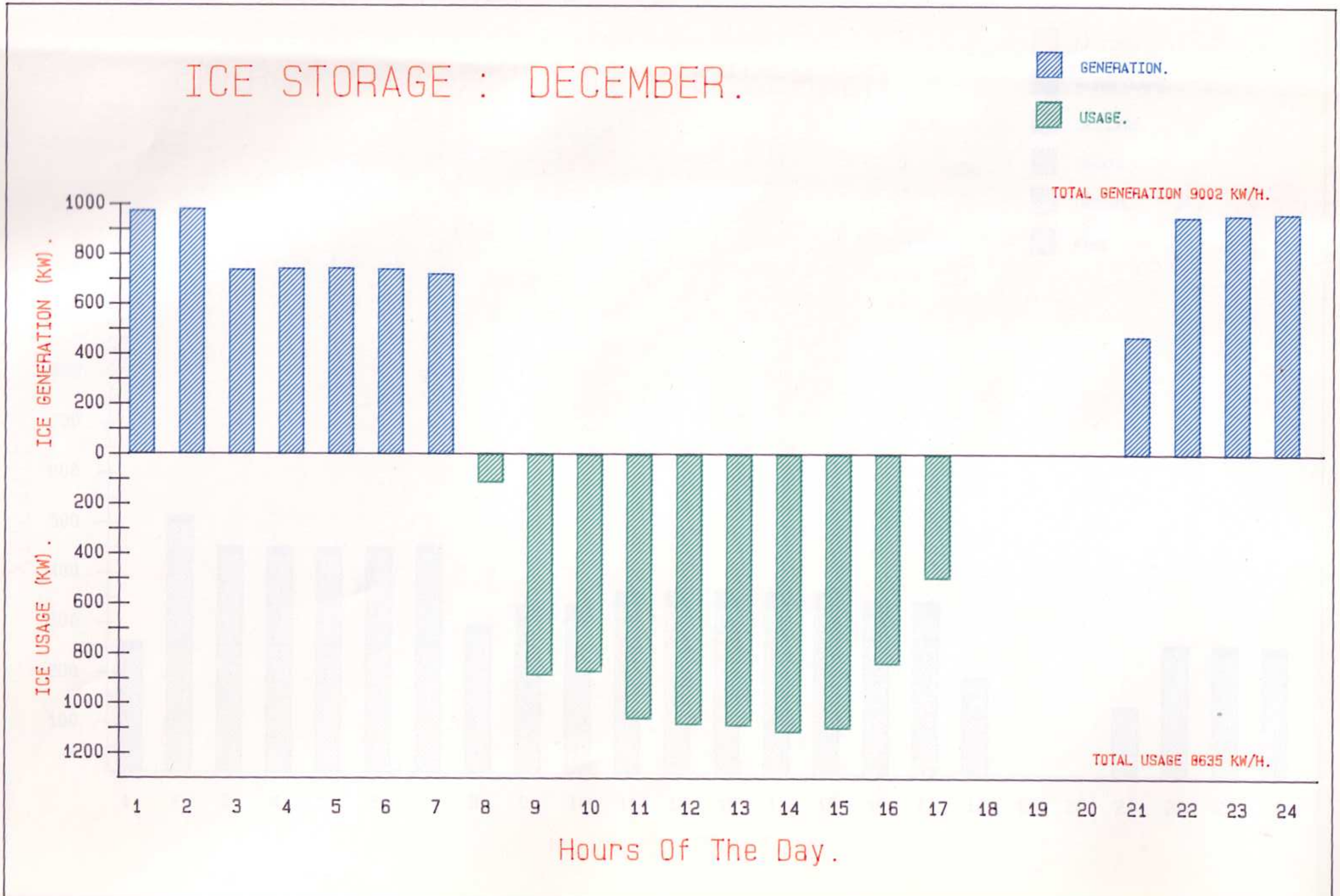

ENERGY CONSUMPTION : OCTOBER.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


LOADS & PLANT PERFORMANCE.
NOVEMBER.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.

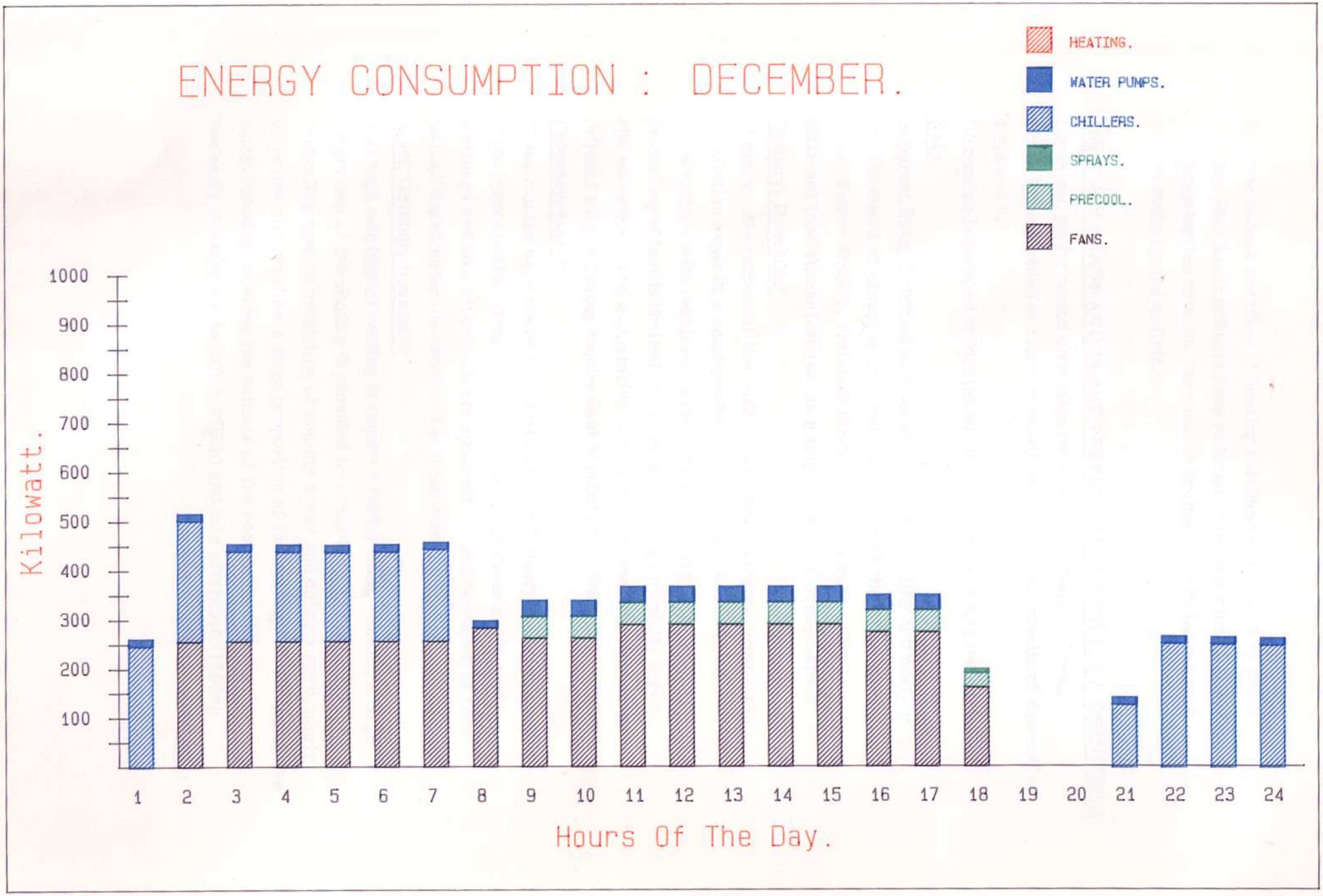

ICE STORAGE : NOVEMBER.
GENERATION.
USAGE.
TOTAL GENERATION 3689 KW/H.
TOTAL USAGE 3534 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


ENERGY CONSUMPTION : NOVEMBER.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


LOADS & PLANT PERFORMANCE.
DECEMBER.
Cooling (KW).
Heating (KW).
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
7
8
9
10
11
12
13
14
15
16
17
18
Hours Of The Day.
FRESH AIR LOAD.
ROOM LOAD.
PRECOOL.
CHILLING.
ECONOMIZER/SPRAYS.
PERIM. HEAT.
HEATING.
FRESH AIR HEATING.
ROOM HEAT. REQUIRED.



ICE STORAGE : DECEMBER.
GENERATION.
USAGE.
TOTAL GENERATION 9002 KW/H.
TOTAL USAGE 8635 KW/H.
ICE GENERATION (KW).
ICE USAGE (KW).
1000
800
600
400
200
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours Of The Day.


ENERGY CONSUMPTION : DECEMBER.
HEATING.
WATER PUMPS.
CHILLERS.
SPRAYS.
PRECOOL.
FANS.
Kilowatt.
1000
900
800
700
600
500
400
300
200
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Hours Of The Day.

3. Where load shedding of heating is indicated (June, July 0700) the peak loads indicated are reduced to the shed limits however consumption remains the same as preheating will be required to make up the deficit.

4.2 MONTHLY LOADS AND PLANT PERFORMANCE RESULTS & DISCUSSION

Loads and performance discussion relates to the graphical results which follow, which in turn are based on the detailed results of Appendices 4,5,6 and 7.

Discussion is grouped in Months which have similar characteristics.

Note

Apparent inconsistencies such as simultaneous cooling and heating are the result of grouping together the results of the three main areas, Tower Block 1, Philately Block and Restaurant which have different load characteristics on a single graphical presentation.

January, December

These months represent the peak cooling requirement. Here night ventilation expends a considerable amount of fan power to cool the structure with resultant daytime cooling load reduction. The precooling effect is limited due to relatively high humidity levels, and economiser and evaporative (spray) cooling does not play a significant role. Chilling requirement is substantial from 0700 to 1800h.

February, March

These months have lower temperatures than January but large cooling loads predominate. Greater use of economiser cycle in the early mornings and late afternoons are apparent. Night operation of fans to cool the structure is required for these months.

April, October, November

Although substantial cooling is required during these months, a large proportion of the cooling is provided by other than chilling. The precooling system consisting of cooling tower and coils, is particularly effective and provides a large proportion of the cooling. The evaporative (spray) cooling provides the balance of the cooling requirement in the early morning (up to 0800h-0900h) and late afternoon (1600h).

The small chilling loads are continually required for the restaurant plants which are conventional packaged airhandlers without economiser, precool or sprays, and subsequently require chilling all year round.

May, June, July, August, September

The winter months are characterised by the heating requirement beginning at 0400h-0500h to preheat the building with heating remaining on up to 1200 in some cases. Load shedding for the hour beginning 0700h is indicated in June and July. Cooling requirement is totally provided for by the economiser, precool and spray features, with a moderate amount of chilling required by the restaurant alone.

4.3 ICE SYSTEM PERFORMANCE RESULTS AND DISCUSSION

Mechanical cooling requirements of the various airhandling units is detailed in the loads and plant performance graphs.

Operation of the ice storage system in order to meet these requirements is detailed on the ice storage graphs.

January

The ice generation profile has an uneven appearance due to the total storage limitation of 10080 kWh. This is the only month of the year where, under average conditions, the total storage provision is required.

Under peak conditions it is likely that further compressor assistance during the day would be required, but the peak load as indicated is unlikely to be exceeded.

October, November December, February, March, April

During these months all plants in the complex have chilling requirements. As the peak storage limitation is not reached during these months, discretion can be used as to when, during the 24 hour period, the majority of ice generation/ice plant load can be placed.

Where possible this is carried out in the early hours of the morning as at this time there are two major advantages:

1. Co-incident loads in the complex (lights, lifts, equipment) are at a minimum.
2. Lowest outside air temperatures yield the most favourable coefficients of performance and hence minimum power inputs.

May, June, July, August, September

During the winter months the only chilling requirement is for the restaurant. Here the ice system is ideally suited to satisfy this small load (<100kW cooling).

A conventional chiller plant would have to run continuously at minimal load for the majority of the day to provide continuous cooling, whereas the ice plant can be run for an hour only at night and the stored ice can be used as required throughout the day.

The ice system overall performance is highly dependent on outdoor temperature with an overall COP of:

2,48 at 33,5°C ambient

4,50 at 10°C ambient

In January the average ambient temperature while the ice plant is running is 17-18°C with a corresponding COP of around 3,8.

4.4 OVERALL ENERGY EFFECTIVENESS RESULTS AND DISCUSSION

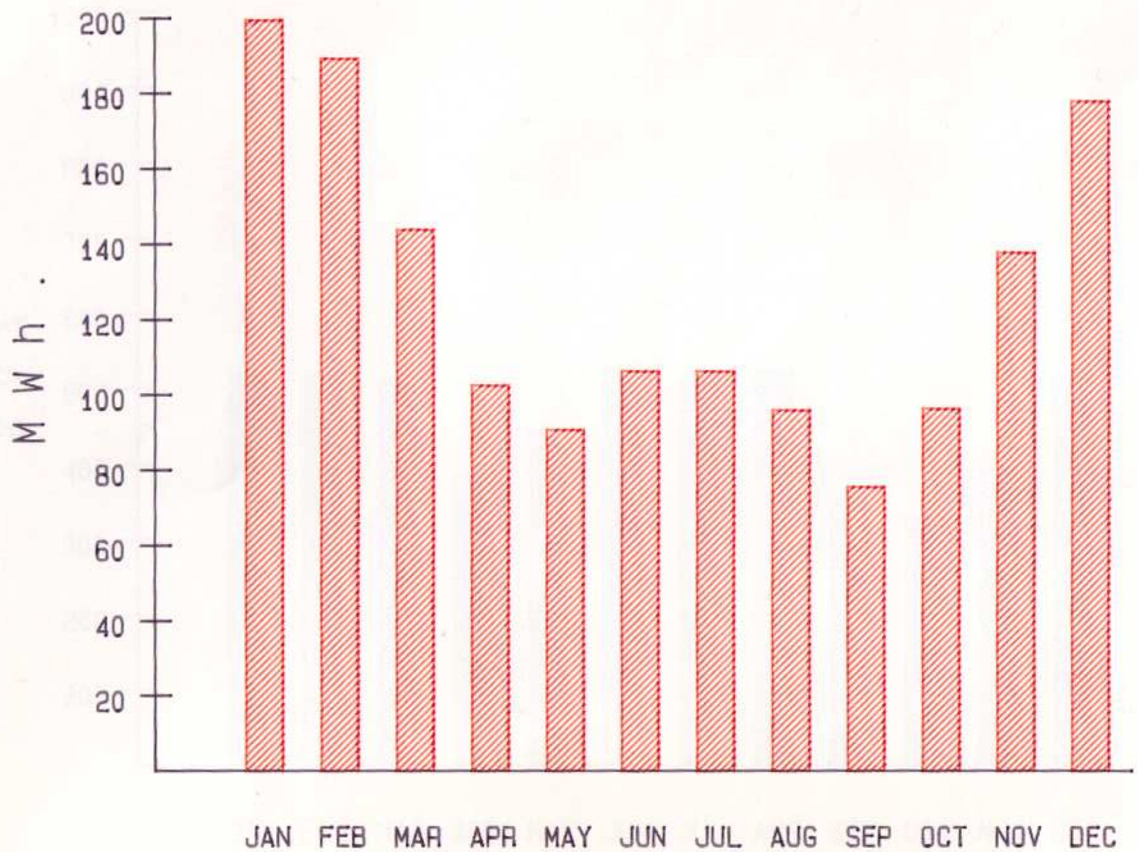
Overall energy effectiveness is indicated by two major parameters, the total energy consumption over a given period and the nature of the energy consumption pattern. These parameters are discussed under the following headings:

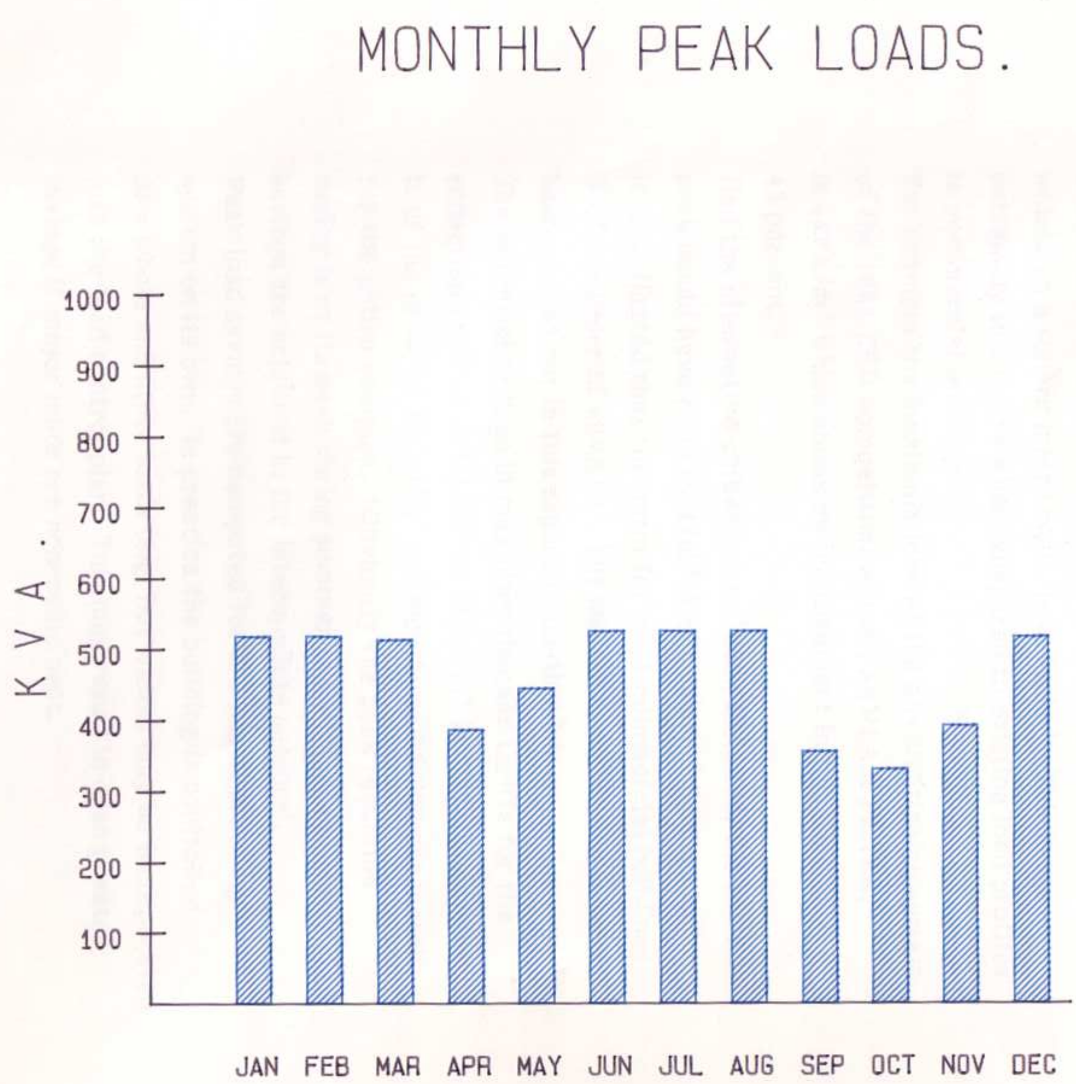
4.4.1 Energy Consumption

Overall energy consumption of the airconditioning system is 72kWh/m^2 annum (259 MJ/m^2 annum). This figure is in line but not an improvement over the 1983 EED winner SANLAM PLAZA of 68kWh/m^2 annum (245MJ/m^2 annum). Increased energy efficiency could not easily be achieved for the following reasons:

- redesign to improve load distribution characteristics with resultant inefficiencies
- average COP for the ice plant of 3,8 is lower than that for chillers which achieve higher COP's due to evaporating temperatures of around +5°C in place of -5°C for the ice plant

MONTHLY ENERGY CONSUMPTION.




MONTHLY PEAK LOADS.
K V A .
1000
900
800
700
600
500
400
300
200
100
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

4.4.3 Overall Energy Budget

Although the other engineering services do not form part of this submission, an overall energy budget is derived as follows:

	kWh/m^2 annum	MJ/m^2 annum
Airconditioning	72	259
Lighting	69	248
Lifts	5	18
Hot water	10	43
Equipment	13	47
	169	615

Comment on other systems is as follows:

- Lighting. This is designed to normally accepted intensity standards but remains a major energy consumer in this building.
- Lifts. High efficiency thyristor drive lifts yield a low overall energy consumption.
- Hot water generation is by means of heat recovery from the ice system together with dedicated heat pumps.

4.4.4 Water consumption

Water is consumed by the precooling system. The condensers are air cooled. Actual working tests have indicated that water consumption of this type of precooling system is moderate and the complex is expected to remain well within any water quotas set. Consumption is estimated at 10-12 kℓ per day.

4.4.5 Conclusion

This design represents a new direction in energy effective design, where in place of the major emphasis placed on total energy consumption in the past, equal emphasis is placed on the timing and magnitude of the peak loads. These priorities are reflected in the rapid rise in KVA tariffs when compared with rises in KWh tariffs. Introduction of off peak tariff structures will cause such designs to possibly become the future norm.

APPENDIX 1 : LETTER REPORT FROM CLIENT

Meld in u antwoord:
In reply quote:

No.

Poskantoor
Post Office

PO Box 2648
PRETORIA
0001

1987-04-29

G.P.O. M & E Group
P.O. Box 2123
PRETORIA
0001

Dear Sirs

RE: ENERGY EFFECTIVE DESIGN COMPETITION

In response to your verbal request we are pleased to approve your entry of our Proes Street Headquarters Building in the above competition.

Our original design brief, although not incorporating specific energy targets, requested that the design be economical in both capital and running costs.

Your initial sketch plan proposals included two features which were accepted on the basis of reduced energy costs and a reduction in life cycle costing.

- The incorporation of structural cooling features
- The incorporation of a multi (two) stage evaporative cooling feature.

At that stage (1982) our primary concern in energy saving was to reduce the total energy consumption of our installations. Subsequently, our efforts have also been directed towards reduction in our peak load requirements. The benefits of this are firstly reduced energy costs for the Department and secondly reduced generating capacity requirements for the country as a whole.

Accordingly, in 1985 we requested that you investigate the replacement of the conventional chilling plant with an ice storage system which would result in greatly reduced peak load energy requirements for the new complex. As the investigation showed a reduction in life cycle costs for the ice system over conventional chillers, approval was given to proceed with redesign to incorporate the ice storage system.

.../2.

It is our intention to closely monitor the operation of the system and to ensure that the energy savings predicted are achieved.

POSTMASTER GENERAL

APPENDIX 2 : ENERGY STANDARDS

For comparative purposes various energy standards and actual figures are listed below:

		$Btu/h\text{-}ft^2pa$	KWh/m^2pa	MJ/m^2pa
1.	ASHRAE Standard 90-75	60000	190	684
2.	California Energy Resources Conservation & Development Commission (ERCDC) 1986	45000	143	515
3.	Pacific Bell. Ashrae Award Winner 1986	30000	95	342
4.	S.A. prior to 1986 - Design Norm (NBRI)		200	720
5.	S.A. post 1986 - Design Norm (NBRI)		100	360
6.	Johannesburg Survey 1986 (NBRI)		327	1178
7.	Pretoria Survey 1986 (NBRI)		404	1456
8.	Survey of 17 Buildings in Johannesburg 1984/1985 D.C.Cumming		298	1072
9.	SANLAM PLAZA EED Winner 1983		155	560

APPENDIX 3 : LOAD AND ENERGY CALCULATION SPREADSHEETS

Cooling load calculation procedures have evolved within the Janeke and Cumming practice in the following fashion:

1. 1970-1979. Apec HCC program and its derivations were acquired and run on IBM mainframes by bureau services. This system required approximately 4-6 hours of data preparation prior to running, approximately 1 hour of card punching and a run time for a yearly analysis of approximately 60 seconds costing R200 odd.

   A locally developed energy analysis module was used for energy analysis which ran together with the main program.

2. 1980-1985. In-house development of cooling load and energy analysis programs written in BASIC which ran on Hewlett Packard micro computers. Procedures were based upon ASHRAE procedures. Full 24 hour analysis was carried out but transient loads (conduction) were not comprehensively analysed. Full detailed solar analysis was incorporated. These programs required approximately 2 hours of data preparation and had a run time for a yearly analysis of approximately 15 minutes.

   The drawback of both of these methods was the tedious nature of carrying out 'what if' type analysis and design. In order to optimise a given building/ design a multitude of permutations of, among others;

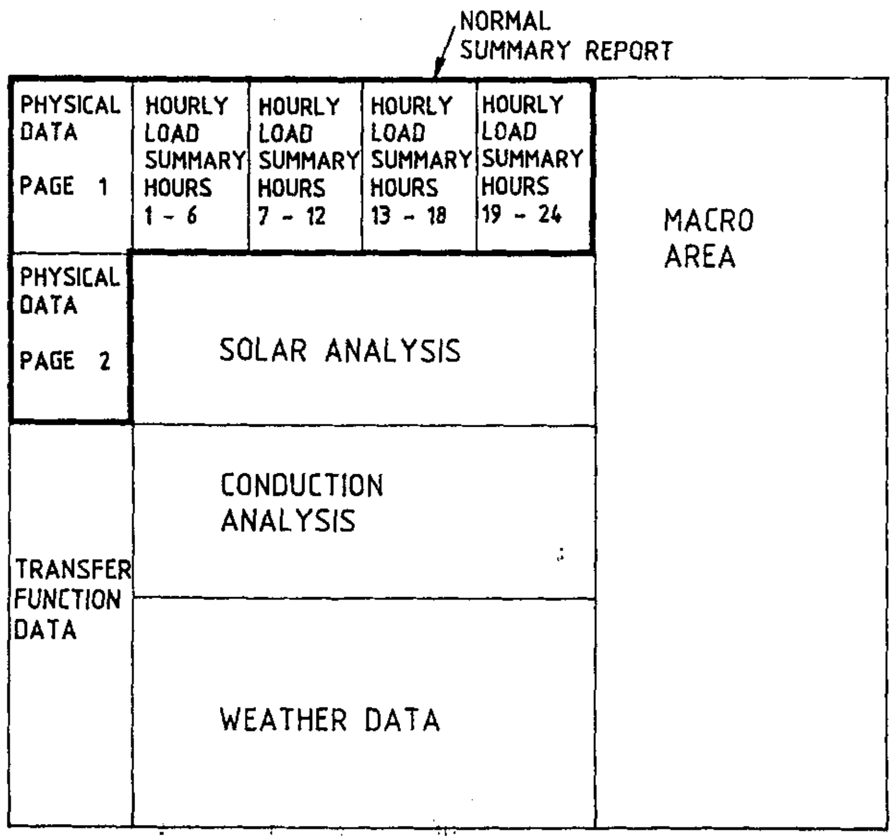
   - shading alternatives
   - wall materials and construction
   - roof materials and construction
   - run times of equipment
   - equipment selection and sizing

   should be analysed to achieve an economical and energy effective design. For these reasons the advent of the spreadsheet has opened up new avenues for interactive design.

3. 1986 - . In-house development of spreadsheet based design spreadsheets. Using the full facility of scientific functions, inbuilt functions and macro facilities of a spreadsheet program, a comprehensive analysis can be carried out using the usual analytical procedures while still allowing inter -

active usage. The two major spreadsheets in use consist of:

THE AIRCONDITIONING LOAD SPREADSHEET



The spreadsheet calculations are based on ASHRAE routines and include the following comprehensive analysis features:

- Full 24 hour, hour by hour analysis for any month of the year
- Automatic loading of climate data
- Comprehensive solar analysis including vertical and horizontal shading elements.
- Conduction analysis using ASHRAE transfer functions. Automatic loading for named walls and roofs

- Structural storage analysis using empirically derived routines
- Sensible/latent load separation
- Full run time selection parameters for internal loads

The spreadsheet size is approximately 360K and recalculation time on a PC is less than 2 minutes.

THE ENERGY ANALYSIS SPREADSHEET

<table>
<tr><td>EQUIPMENT
PHYSICAL
DATA
PAGE
1</td><td>ENERGY
ANALYSIS
HOURS
1 - 6</td><td>ENERGY
ANALYSIS
HOURS
7 - 12</td><td>ENERGY
ANALYSIS
HOURS
13 - 18</td><td>ENERGY
ANALYSIS
HOURS
19 - 24</td><td rowspan="3">MACRO
AREA</td></tr>
<tr><td>EQUIPMENT
PHYSICAL
DATA
PAGE</td><td>HOURS
1 - 6
PAGE 2</td><td>HOURS
7 - 12
PAGE 2</td><td>HOURS
13 - 18
PAGE 2</td><td>HOURS
19 - 24
PAGE 2</td></tr>
<tr><td>EQUIPMENT
PHYSICAL
PAGE
3</td><td colspan="4"></td></tr>
</table>

This spreadsheet uses as input the loads as produced by the airconditioning load spreadsheet. The spreadsheet can be used to analyse varying system types ranging from simple constant volume package units to plants incorporating variable volume and multi stage evaporative cooling.

The following comprehensive analyses are carried out:

- full economiser cycle analysis
- full psychrometric analysis
- full mode of operation analysis
- part load curve analysis

At this stage, automatic load shedding/load spreading is not incorporated and this is done semi-manually.

The spreadsheet size is approximately 250K and recalculation time on a PC is 20 seconds.