PETROLEUM CORPORATION OF JAMAICA BUILDING

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ABSTRACT

New standards of energy efficient building design and construction for semi-tropical climates resulted from the combined efforts of Dubin-Bloome Associates, P.C. and Marvin Goodman and Associates.

The Petroleum Corporation of Jamaica (PCJ) authorized Marvin Goodman and Associates to design their headquarters building with Dubin-Bloome Associates retained as the architectural, mechanical, electrical and energy consultants for the PCJ Building.

The objective of the building design team was to select materials and develop systems and plans for a building that would use less than 25,000 Btu/sq. ft./yr. within the established budget and consistent with the owners' program.

The building design deserves recognition by virtue of its innovative use of energy management principles. Virtually no data had been accumulated for Jamaica and other semi-tropical and tropical climates pertaining to energy management and alternate energy use. The design team compiled available information to establish a data base.

A prototype for energy-efficient office buildings in Jamaica and the Caribbean area, the 108,000 sq. ft. office building will serve to:

- Minimize consumption of non-renewable resources through the reduction of the annual energy requirement for VAV more than 55%, the peak cooling load by more than 35%, the annual lighting by more than 45%, and the peak electrical load by more than 54%, accomplished at no additional capital cost. Actual bids were below base building estimate.

- Reduce operating costs for energy by more than 43%, as compared to a conventional building. Energy costs for multi-story buildings in Kingston average $3.00/sq. ft. compared to the projected energy cost of $1.70/sq. ft. for this energy efficient building.

- Provide a comfortable, safe and productive working environment. The building design is a stimulating natural environment of sunlight, fresh air and foliage.

- Be responsive to the site and the Jamaican climate by reducing building water requirements, using multi-directional daylighting from the atrium and light shelves on the exterior to provide the ambient daylighting, and shading the building exterior to reduce heat gain into the building by 53%.

- Stimulate energy-conscious building design and operation in Jamaica and by example, in Caribbean area.

- Transfer technology appropriate to Jamaica from the United States and other Nations to encourage energy management in future Jamaican buildings. Technology introduced to the Jamaicans included solar absorption cooling, photovoltaics, efficient central cooling equipment, dessicant dehumidification, cooling storage, photocell control, hot gas heat exchanger for heating domestic and service water from the building air conditioning system, enthalpy and economizer control as parts of a complete energy management system and others.

- Set a new standard for reduced energy consumption, 23,000 Btu/sq. ft./yr., encouraging the establishment of EPI's for new buildings in semi-tropical climates.

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BACKGROUND

Existing buildings in Jamaica and those currently in design are not energy efficient. Building design contributes to a significant portion of the energy consumed in Jamaica. Jamaica depends largely on imported oil. The cost of imports adversely affects the balance of payments and the economic and social well-being of the Jamaican people.

Buildings in Jamaica depend mainly on electricity for air conditioning, lighting, motors, power, elevators and in some cases for hot water heating. Oil is used for domestic and service hot water heating and industrial heating applications.

However, there is a growing awareness in Jamaica of the need to retrofit existing buildings and to design and construct new buildings to conserve energy. Under the direction of the Ministry of Mining and Energy and the architectural and engineering professional societies, a concerted effort is being made to conserve energy in existing and new buildings.

In order to demonstrate the potential for energy savings in buildings the Petroleum Corporation of Jamaica authorized Marvin Goodman and Associates, the architects they had retained to design their new headquarters building, to undertake a detailed study of alternative energy conservation measures for the proposed new building. They were instructed to incorporate those that were deemed appropriate for inclusion in the building and mechanical and electrical systems, so that the PCJ Building would conserve energy, reduce operating costs and serve as a prototype, an operating example of energy conscious design in Jamaica.

With the recommendation of Marvin Goodman, J.I.A., the Ministry of Mining and Energy retained Dubin-Bloome Associates as energy consultants for the new PCJ building to prepare guideline for energy conservation construction standards for Jamaica buildings and conduct a two-day workshop in Jamaica for architects and engineers.

The United States Administration for Industrial Development, (A.I.D.) in order to promote energy efficiency in Jamaica and to encourage technology transfer, provided the funding for the Dubin-Bloome Associates contract.

This report details the studies, conclusions and recommendations for the new PCJ Headquarters Building.

PROJECT OBJECTIVES

The objective of this program is to assist the architect and his design team in the selection and development of cost effective materials, systems and plans for the proposed new PCJ Headquarters Building so that it will be as energy efficient as possible, consistent with established budgets and the owner's functional program. It is intended that this building be a prototype energy-efficient office building for Jamaica and the Caribbean area to:

- o Minimize consumption of non-renewable resources.
- o Reduce operating costs compared to a 'conventional' building.
- o Provide a comfortable, safe and productive working environment.
- o Enhance the aesthetic quality.
- o Be responsive to the site and the Jamaica climate.
- o Stimulate energy-conscious building design and operation in Jamaica and by example, in the entire Caribbean area.
- o Transfer technology appropriate to Jamaica, which was developed in the United States and other Nations, to Jamaican architects, engineers and public and private building owners and operators to encourage and enhance energy management in future Jamaican buildings.
- o To encourage the use of renewable energy sources by demonstrating that the PCJ building, as a prototype, can accommodate those alternative sources and by example, extend their use to other new buildings and retrofit of existing buildings.

EXECUTIVE SUMMARY

On February 1, 1983, Marvin Goodman and Associates had completed preliminary or design development drawings and outline specifications for the Petroleum Corporation of Jamaica's (PCJ) proposed new Headquarters Building. (Refer to Table IV. These documents plus a preliminary selection of mechanical and electrical systems,prepared by Keith Walters, mechanical and electrical consultants retained for this building by Marvin Goodman,became the "base building" (BB) for DBA studies of the following: alternative building configuration, materials, fenestration, insulation, construction methods, shading devices and daylighting, alternative air-conditioning systems, lighting, plumbing and elevator selections and other systems and operating techniques. The study recommended additions to and modifications of the base building to enhance energy efficiency.

Cost/benefits analysis of each energy conservation measure, selected from an extensive list of measures appropriate for Jamaica buildings, resulted in recommendations, which in total are identified as the Energy Efficient

Building (EEB). The EEB Building resulted in a reduction of peak electricity demand as well as in annual energy use documented in the following tables 1, 2, and 3.

Table I. Energy management in the PCJ building.

	Base Building	Energy Efficiency Building
Peak Cooling and Ventilation Load Tons	266	175
Annual Cooling and Ventilation Load Ton-Hours	372,400	245,000
Annual Average Cooling C.O.P. (2)	2.6	4.6
Annual KWH for Cooling and Ventilation	504,000	187,000
Average Watts/Square Foot Lighting	1.5	.8
Annual KWH for Lighting	297,000	158,400
Annual KWH for Elevators	75,000	60,000
Annual Load for Domestic Hot Water BTU (1)	166×10^6	33×10^6
Annual Equivalent BTU/Square Foot		
For Cooling, Ventilation, Lighting, Domestic Hot Water, Pumps, Fans, and Elevators, Conv. Outlets	47,800	25,365
Annual Energy Costs USA $	207,468	115,475

(1) Does not include Kit/Cafeteria

(2) Includes pumps and fans

Table II. Annual loads summary (BTU).

Glazing Options with 2'6 sill and shading device

	Total	Conducted	Diffuse	Direct
Single glaze clear	492,511,504	280,029,856	302,860,523	9,621,124
Single glaze tinted	490,893,740	264,755,500	219,972,380	6,165,860
Double glaze clear	410,781,664	142,560,654	261,416,452	6,804,558
Double glaze tinted	158,547,894	137,191,486	17,534,030	3,822,378

Table III. Peak loads summary Dec. 21

Total N, S, NE, SE, SE, NW

Single glaze floor-to-ceiling glass direct, diffuse and conducted	1,509,359 BTUH
w/ sill clear glaze, single pane	1,167,437 BTUH
w/ sill tinted single pane	726,080 BTUH
w/ sill clear double glaze	706,493 BTUH
w/ sill tinted double glaze	453,221 BTUH
w/ sill and shading device clear single pane	546,492 BTUH
w/ sill and shading device tinted single pane	485,808 BTUH
w/ sill and shading device double glaze clear	385,467 BTUH
w/ sill and shading device double glaze tinted	311,293 BTUH

Note: All calculated using ASHRAE profile angle and azimuth angle data, solar radiation data by exposure applying manufacturers U, SC & transmittance data to direct, diffuse and conducted loads.

Actual completed design may result in slightly higher or lower peak cooling loads and annual consumption for cooling, lighting and domestic hot water. The percentage of savings in equivalent BTU's will remain relatively constant and the percentage of savings in dollars will also be relatively constant. The percentage of savings is about 43% for the building as a whole. The savings for cooling, lighting and hot water will be approximately 45%, without considering the elevators or the convenience outlets in either case. The reduction in peak demand is approximately 396 KW or 54%. This is a significant savings in demand changes and is indicative of the opportunity to reduce the load on electrical generating plants.

The base building energy usage reflects the fact that the original building specification was for condominium office space. Study has shown that the current building design will allow for submonitoring energy usage.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It is possible to reduce (1) the annual energy requirements for air conditioning and ventilation in the PCJ buildings by more than 55%, (2) the peak cooling load by more than 35%, (3) the annual energy requirements for lighting by more than 45%, (4) the peak electrical load by more than 54%, (5) the annual energy requirements for domestic hot water by 100% and (6) the annual operating costs (energy only without maintenance and operation) by more than 43% as explained on the following page:

The reductions in peak and annual energy consumption and energy costs can be accomplished with no additional capital cost and perhaps an actual reduction in initial costs. There is a sufficient data base for evaluating configuration, shading solar heat gains and solar energy for heating domestic hot water and for solar cooling. For future designs additional climatic and insulation data would be useful. It is essential to have an energy management and control system to monitor energy use, reduce peak electricity demand and operate the building and the mechanical and electrical systems in the most energy and cost effective manner. Enthalpy control and economizer control and reset of chilled water temperatures to match the loads are low cost and very cost effective for the PCJ building. The effect of these savings is not reflected in Table I. The base case building with the zig-zag configuration resulting in all windows facing due north and due south (without any east or west facing glass) is energy efficient, provides some self-shading, and provides interesting facades, each responsibe to the exterior environment that it sees.

Mass

Approximately 5-10% of energy required for cooling can be accomplished by using thermal mass and insulation on the exterior of the outside face of solid walls. A six inch concrete roof and solar shading with trees or shrubs will virtually eliminate all cooling load due to the roof. The sol-air temperature of the roof is reduced and the concrete slab with insulation on top will delay heat gain into the space until after 6:00 P.M., when the building is unoccupied.

Night air cooling can remove the load which is imposed upon the building and is manifest after occupied hours.

Glazing

Single tinted glazing from sill height to a combination light shelf/ shading device is more energy and cost effective than single or double glazing, which extends from floor to ceiling. Double glazing reduces the cooling load due to conduction and solar heat gain, but is not cost effective at present for the PCJ building with the exterior shading provided. The savings in energy costs and reduced capital cost for double glazing in the future warrants further analysis for the next building.

Daylighting

Multi-directional daylighting from the atrium on the interior and light shelves on the exterior will provide virtually all of the ambient lighting during daylight hours. In combination with task lighting, and photocell controlled ceiling luminaries, a reduction to approximately 0.8 watt per square foot is feasible. An atrium with a top louvre to diffuse and reflect light to the lower levels reduces conduction cooling loads and lighting loads. The atrium will serve as an effective and pleasant space,as a relief from the interior during lunch breaks, conferences and coffee breaks. Reflective surfaces below the windows in the walls facing into the atrium enhance the daylighting. Task/ambient lighting with photocell control light shelves, and tinted glazing for the windows below the light shelf is cost effective and provides a more comfortable glare free environment. It is essential to provide solar shading, which will completely shade all glazing from 10 A.M. to 6 P.M. and 80% of the window area from 7 A.M. to 8 A.M. for at least 6 months per year.

Central Air Conditioning System

The recommended central multi-compressor chilled water system will require less maintenance costs and have a longer life than the multiple direct expansion air cooled condensing units, which were contemplated in the "base building". The aquifer at the PCJ site is not suitable from a water quantity, quality and cost basis to provide condenser water cooling, but it could be advantageous for industrial applications having large process heating and cooling requirements, which could be served with a heat pump. It is more appropriate to install multi-compressor water cooled (air cooled if no makeup water is available) chilled water air conditioning systems with annual COP of 4.5 or more than direct expansion multiple air cooled condensing units with an annual COP of 2.6, for the following reasons: (a) The system will operate at higher efficiencies at part load conditions, which occur from 80 to 90% of the time, since the central system can operate with one or more compressor units in tandem with oversized condensers, (b) The multi-compressor central system provides more reliable operation. There is always capacity available to supply any one or more air handling units. In the BB, a zone served by a DX Unit, which is inoperative will not be able to be air conditioned. Locating the refrigeration compressors on the lower level reduces the noise and vibration effects in the building. Locating the cooling tower on the same level reduces the extent and cost of the condenser water piping system and the cooling tower enhances the air exhaust system for the garage. Modular pumps sized for 1/3 and 2/3 of the load save energy for the hydronic distribution variable speed fans reduce the energy required for air distribution by about 80%. The PCJ building should be zoned so that each individual air handling unit supplies a zone, which has fenestration on one exposure only.

Water

Water supply is critical in Jamaica. The low flow fixtures and orifices which reduce hot water flow and energy costs, also reduce the total amount of water including all potable water and rinse water. All purchased energy for domestic hot water can be eliminated by using low flow fixtures, lower utilization temperature, and either solar energy or heat recovered with a hot gas heat exchanger from the building air conditioning refrigeration system.

Dessicant dehumidification reducing the moisture content and total heat from ventilation air is generally cost effective in Jamaica since it performs the complete dehumidification task and permits the refrigeration equipment to operate at higher chilled water temperatures saving about 20% of the energy normally required for cooling.

Solar Air Conditioning

Solar cooling is effective in Jamaica due to the high percentage of solar radiation and the availability of energy efficient absorption cooling units in small 1.5 - 10 ton sizes, although the initial cost is 2 to 3 times that of conventional cooling systems and the pay back period is too long to suit the average investor. Solar cooling of the embassy wing and penthouse is desirable as a demonstration of cooling in tropical climates and as a learning tool for future installations. Yazaki Corporation's SIGMA computer simulation of the 7.5 ton Yazaki Water Fired Absorption Chiller with 76 Yazaki "Super Blue Panel" solar collectors with a total area of 1558 sq. ft. tilted at 10^o and orientated due south predicted an 88% annual solar contribution to the cooling (embassy wing) and hot water load. The simulation was based on 1982 daily weather data for Manley Airport, Jamaica. Dubin-Bloome Associates recommends utilizing the solar unit 7 days a week with 60 collectors and storing for weekday operation using a 3000 gal. tank instead of the 2000 gal tank that was assumed in the SIGMA run. Since the additional cost of the 10-ton chiller is only $700 and storage will enable a larger load to be supplied, it is recommended to use the Yazaki 10 ton absorption unit.

Chilled Water Storage

Cooling storage systems are cost effective in Jamaica at present, but will be more cost effective as utility rates increase reflecting true marginal costs.

Chilled water or ice storage for the PCJ building will be more appropriate to serve both buildings when and if the second building is planned.

It is practical to reduce energy consumption for the PCJ building to use only 23,000 BTU per square foot without increasing initial costs. This compares very favorably with the most energy efficient building and in the hottest and coldest areas of the U.S.A. and Puerto Rico.

Table IV. Building Characteristics and Design Criteria

Dry bulb degree hours above 78^{o}F - 8,200

Wet bulb degree hours above 66^{o}F - 19,057

Occupancy Cycle

800 persons - 8 a.m. - 5 p.m.	Monday - Friday	
40 persons - 5 p.m. -10 p.m.	Monday - Friday	
25 persons - 8 a.m. - 1 p.m.	Saturday - Sunday	

Initial calculations were made assuming an occupancy profile of 800 people average from 8 a.m. - 5 p.m. The Petroleum Corporation has informed us that at any one time, forty to fifty percent of the personnel on two or possibly more floors will be out of the office in the field. This reduced occupancy will reduce the building energy load and reduce the need to size mechanical equipment for a larger peak usage.

Floor Area - Central Building	Sq. Ft.
Total Ground Floor	12,236
2-6th (identical in floor area)	14,390 each
Penthouse	2,500
Embassy Wing	2,700

Zone — Floor areas - Per Zone

Zone	Ground Floor Area		Upper Floor Area		No. of Upper Floors		Zone Total Area
Zone I	3,625	+	(4214	x	5)	=	24,695.
Zone II	2,159	+	(2836	x	5)	=	16,339.
Zone III	2,648	+	(3323	x	5)	=	19,263.
Zone IV	3,764	+	(4025	x	5)	=	23,889.
Penthouse							2,500
Embassy Wing							2,700

Total Building Area 71,950 + 2,500 + 2,700 + 12,236 = 89,386