REFRIGERATION SYSTEMS FOR AIR CONDITIONING

REPORT TO PROJECT M - NO. ABA-23

STANFORD UNIVERSITY SUBCONTRACT S-128

UNDER AEC CONTRACT AT(04-3)-363

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REFRIGERATION SYSTEMS FOR AIR CONDITIONING

INTRODUCTION

The purpose of this study is to evaluate the relative advantages of various types of refrigeration equipment which may be used for the air conditioning systems to be installed in the buildings for Project M.

REFRIGERATION SYSTEMS FOR AIR CONDITIONING

SYSTEMS ANALYZED

Three basic refrigeration systems are considered in the analysis: (1) local direct expansion type, (2) central centrifugal package water chillers, and (3) central absorption-type chillers. Other systems, such as one using local water chillers, were not analyzed because they are inherently more costly than the ones studied.

THE LOAD

The estimated refrigeration load for the air conditioned buildings is as follows:

	Tons
Engineering and Administration Building	160
Central Laboratory	160
Auditorium	40
Cafeteria	40
	400

The air conditioned portion of the Test Laboratory requires special conditions which necessitate a separate system. It is not included in the load for the systems analyzed in this report.

DIRECT EXPANSION SYSTEM - LOCAL OPERATION

The estimate for this system is based on ten forty-ton electric-driven refrigeration condensing units with four at each of the large buildings and one each at the auditorium and cafeteria. Refrigerant and condenser water piping, condenser water distribution piping, installation costs, and weather-proof housings for the condensing units are included.

CENTRIFUGAL CHILLING SYSTEM - CENTRAL OPERATION

The estimate for this system is based on two two-hundred-ton electric-driven centrifugal-type water chillers, located in Utility Building A, and a chilled water distribution system to and within the air conditioned buildings. Condenser water piping is considerably less for this system because the chillers are located near to the cooling towers.

ABSORPTION SYSTEM - CENTRAL OPERATION

This type of refrigeration system requires a high temperature heat source. The most commonly used is steam. Efficiency is quite low compared to electric motor-driven chillers because boiler efficiency and refrigeration unit efficiency must both be considered. Analysis of the energy cost shows that the fuel required for the absorption-type chillers would cost approximately three times as much as the electricity for the centrifugal units. The following conditions were assumed:

Chilled water temperature	40°F
Condenser water temperature	85°F
Gas cost per 1000 cu. ft.	$ .50
Gas heating value, Btu per cu. ft.	1080
Boiler efficiency	80%
Absorption unit efficiency	50%
Electricity cost per kw-hr	$ .0045
Centrifugal unit tons per kw	1.04
Electric power factor	.88
Electric distribution efficiency	.95

For the above conditions the cost of refrigeration per million BTU is $1.29 for the absorption system and $ .41 for the centrifugal. This difference is equivalent to approximately $3000 per year in operating expense. The equipment cost per ton of refrigeration is higher than that of the centrifugal system, and the piping system required is essentially the same. Since it was determined that both capital cost and operating expense are greater for the absorption system, a more detailed study of equipment and installation costs was not considered necessary.

MAINTENANCE COSTS

The direct expansion system has higher maintenance costs than the centrifugal chillers for two reasons: (1) the larger number of direct expansion refrigeration units require more service, and (2) the reciprocating compressors, used for small tonnage units, inherently require more service than centrifugal compressors. Maintenance costs are estimated at 5 percent of the installation cost for the centrifugal system and 7-1/2 percent for the direct expansion system.

OPERATORS

Both the centrifugal and direct expansion systems are fully automatic and require a minimum of supervision, other than routine checks and adjustments. This is estimated to require 1/2 the time of one man for the direct expansion equipment and 1/4 of the time of one man for the centrifugal system.

REFRIGERATION COST ANALYSIS

AIR CONDITIONING REQUIREMENTS

~~Capital Costs~~ Capital	Local Direct Expansion System	Central Centrifugal System
Capital Costs		
Major equipment	$ 73,200	$ 58,900
Chilled water piping	-	69,900
Refrigerant piping	3,600	-
Condenser water piping	47,640	4,550
Installation costs	22,700	5,500
Housing/Building	5,000	12,300
Total Capital Costs	$152,140	$151,150
Annual Expenses		
Interest 5%	$ 7,610	$ 7,560
Insurance 1%	1,520	1,510
Power (700 eq. full load hours)	4,800	4,340
Operators and pers. overhead	6,000	3,000
Maintenance - 7-1/2% and 5%	11,400	7,560
Total Annual Expenses	$ 31,330	$ 23,970
Total Expenditures for 10 Years		
Capital Costs	$152,140	$151,150
Expenses	313,300	239,700
	$465,440	$390,850

CONCLUSION

Electric refrigeration is more economical than the gas-steam type by reason of the low efficiency of the gas-steam absorption-type refrigeration equipment and the availability of low cost Bureau of Reclamation electric power.

Of the various electric refrigeration systems, the lowest cost local system is the direct expansion type. For Project M, however, this system has a higher 10-year cost than the lowest cost central system, which uses centrifugal refrigeration equipment. The principal cost differences stem from the lower operator and maintenance requirements and the higher efficiency of the large central plant units.

The central plant offers several advantages over the local units in addition to the 10-year costs.

(1) Noisy machinery is not required in or on the buildings.

(2) The chilled water distribution systems of the central system are not subject to corrosion as are air-saturated cooling tower water lines required for local units.

(3) Problem areas in the buildings caused by changes in (a) installed equipment, (b) occupancy, or (c) room size, can be easily handled with the central system by extending chilled water lines and mounting sensible heat units in the space, while direct expansion systems require changes in duct systems.

(4) Local units afford no standby capability during service or repairs. With two central units, fifty percent capacity is available while repairs are made on a unit. This is sufficient to handle the load most of the time.

These advantages as well as the lower operating costs make the central system more desirable than the local refrigeration units.