B. Operating Costs

In the category of operating costs, initial consideration must be given to fuel selection. There are four common fuels available; gas, fuel oil, coal, and electricity. Because of an extremely favorable electric rate under a basic agreement between the Commonwealth of Virginia and the Virginia Electric & Power Company, electrical energy, which can generally be summarily dismissed as an economical fuel, must be given serious consideration, along with the more conventional fuels.

1. Coal

Information from State authorities quotes coal costs of \$9.25 per ton delivered to a rail siding in Vienna, Virginia. Local trucking to the Fairfax site would average approximately \$1.50 per ton. Site handling and ash removal charges add approximately \$0.17 per ton of delivered coal. This gives \$10.92 per ton which, on the basis of 13,000 Btu/lb, is equivalent to 26.0×10^6 Btu. With a boiler efficiency of 80%, we arrive at:

$$\frac{10.92}{0.80 \times 26.0 \times 10^6} = \$0.53 \text{ per million Btu of boiler output.}$$

2. No. 6 Fuel Oil

Price of No. 6 oil is \$0.0889 per gallon which, on the basis of 0.150×10^6 Btu per gallon and 81% boiler efficiency, gives:

$$\frac{0.0889}{0.81 \times 0.15 \times 10^6} = \$0.73 \text{ per } 10^6 \text{ Btu of boiler output.}$$

3. Gas

Gas rates follow a sliding scale based on the local monthly consumption and therefore vary depending upon demand. There is also a summer "air conditioning" rate which provides more favorable rates during periods of low system demand. For computation, we have used as a base the price of gas if the monthly consumption is 6000 therms (600×10^6 Btu). On this basis, the winter rate would be \$0.1080 per therm. With boiler efficiency of 82%, we get:

$$\frac{0.1086}{0.82 \times 0.1 \times 10^6} = \$1.32 \text{ per million Btu of boiler output}$$

4. Electricity

The basic agreement between the Commonwealth of Virginia and the Virginia Electric & Power Company provides a rate of 1¢ per Kw hr for State agencies with installations having a demand of 25Kw or more. The George Mason College will undoubtedly be served under this agreement.

This favorable rate gives added interest to electric resistance heat or a heat pump installation. At 1¢ per Kw hr, energy is available at $2.93 per million Btu. Even with transmission efficiency of 100% for resistance heating, the cost would be the full $2.93 per million Btu of delivered heat. Hence, resistance heating can be eliminated from consideration. However, the heat pump, based on coefficients of performance of 3.0 or above, gives the following heating costs per million Btu delivered heat:

Coefficient of Performance	Heating Cost/10^6 Btu
3.0	$0.977
3.5	0.837
4.	0.733
5.	0.586
6.	0.489

Summary: Cost of Heating per 10^6 Btu

Electric Heat Pump	Coal	Oil	Gas
$0.489 to $0.977	$0.53	$.73	$1.32

3- .977
4- .733
.244

4- .733
6- .489
.244

Based on the fact that air conditioning in the warm climate of Virginia seems to be an urgent requirement for a modern school, the possibility of using electricity for winter and summer should be seriously considered.

The above analysis of fuel costs may indicate that, of the conventional fuels, coal has an edge over the others for the following reasons:

Based on a budget computation of 1600 hours at full load, as equivalent to the total load for a heating season in Virginia, and assuming a 4 million Btu per hour peak demand for Phase I, we arrive at the following:

<u>Coal Budget</u>

$1600 \times 4 \times 10^6 \times \$0.53 = \$3,328$ Total Annual Fuel Cost

To this cost must be added the cost of ash removal and certain additional expenses for coal handling, which can be approximated at about equal to the fuel budget. Also, because coal trucking and ash removal in the central educational area of the College will be unwelcome, coal as fuel for <u>Phase I</u> has to be eliminated.

As the next best alternates, the heat pump, and then oil, can be selected.

However, as the building program continues and the winter and summer loads become greater and more uniform throughout the entire year, coal may have to be given careful consideration, particularly when a central heating plant is constructed away from the main academic areas. The economic advantages of coal might then outweigh the difficulties of coal storage and handling.

For the present Phase I, electricity by means of a heat pump, is suggested. While heat pump installations were once an oddity with limited application, often unsound from both an engineering and economical standpoint, their increased use in the last 15 years has given operating experience which proves their soundness in certain areas of application.

The essential criterion in selection of heat pump is the Coefficient of Performance (COP), which is actually realizable in a given installation. Generally, heat pump systems are either of the air source or water source type. With air source units, a COP of 3.0 to 3.5 can be realized. With a water source system, the COP depends on supply water temperature. A 50° to 55°F water temperature is to be assumed around Fairfax, so that a COP of 4.0 can be estimated, ranging the heat pump cost about equal to that of coal.

It is impossible to predict the relative economic position of the various fuels at some future date. Prices can vary, technological refinements can alter desirability of one fuel over another. It is, therefore, recommended that equipment selected to meet Stage I requirements incorporate any flexibility which will assist its utilization in future stages.

C. Space Requirements

Space is an important consideration. In new construction, service areas detract from the primary function of the building. Any reduction in space requirements of one alternate over another must be considered as an investment saving equivalent to the cost of construction of a building volume equivalent to that saved.

In existing installations, any space saved by conversion of the heating system must be considered as added income in an amount equal to rental costs for equivalent space in the same locality.

Alternate systems which have been considered do not vary appreciably in terms of space requirements during Stage 1 developments. As the initial load during Stage 1 is of moderate size, a degree of centralization can be procured by having the basic components of the system centrally located in a service area of one of the Stage 1 buildings.

As the College grows and the heating load becomes larger, the possibilities of centralizing at least part of the heating equipment should be considered. The desirability of centralization increases with the heating load and the advantages which would accrue to the College can only be assessed as the building program progresses.

PRIMARY SYSTEMS

By a primary system, we mean the basic heat generating and cooling equipment and the required distribution system, as well as the heat carrying medium. It is best to select, as location for this basic equipment, a service area of a building or building group to be heated.

The distance over which the distribution lines must run to supply outlying buildings will, to a large degree, govern the type of system which is feasible, as well as the temperature level at which the system will operate. Thus, a system which has a very extended distribution system will operate at high temperature levels to minimize the circulation requirements. High temperature water systems have been particularly successful for both large installations and those with long distribution runs. The Air Force makes it mandatory to use central plant high temperature water systems for new installations over 1000 HP, (33 million Btu/hr).

The following alternate primary systems have been considered.

1. Conventional boilers fired with fossil fuels generating low pressure steam.

2. Forced circulation hot water generators fired with conventional fuels to produce low temperature water at temperatures from 160 to 200°F.

3. High temperature hot water generators, producing forced circulated hot water at temperatures up to 400°F.

4. Electrically driven heat pumps with air or water sources supplying low temperature hot water during the heating season and chilled water of 42-48°F. during cooling season.

5. Combination of the above which would increase comfort standards and allow maximum reliability of the system with minimum investment.

A final selection cannot be made at present. The design for Phase I shall be so arranged that any one of the five primary systems can be selected and the equipment presently installed can be modified in case of future centralization, and would not need to be discarded.

RECOMMENDATIONS FOR PRESENT PHASE I

Based on all of the information we have available, and subject to a more detailed analysis of well water available at the site, we make the following preliminary recommendations for Phase I:

A. Primary System

We recommend installation of a heat pump system to serve the 5 buildings of Phase I. This equipment would be installed in the basement of Building "C", with supply lines running to the other four buildings at some convenient sub-surface level. These heat pumps would be sized to meet the base load of the buildings during the heating and cooling season, with some spare capacity.

It is not possible in northern Virginia, to match the winter and summer loads, thereby bringing equipment size to balance. Invariably, the summer load is the smaller of the two. We therefore recommend a peak load standby unit or enlargement of the summer heat pumps required in order to also carry the peaks during inclement winter weather.

B. Secondary System for Balanced Cooling

We recommend as a secondary system, a central fan room located in the attic area of each of the 5 buildings. The heating or cooling medium from the centrally located heat pump system would be circulated to the individual fan room. At this point, air will be passed over coils to condition the air for delivery to the rooms inside the building. Air circulation would be through two ducts, one each supplying heated and chilled air. Mixing boxes located in each room will control various quantities of hot and cold air for proper conditioning of the air to the individual rooms. Each room will, therefore, have its independent control which can be regulated depending on occupancy and use of the room.

To maximize efficiency we recommend air-to-air heat exchanger in each fan room to utilize the waste heat during both heating and cooling seasons.

The hot water supplied by the heat pump will be circulated through perimeter convector surfaces or baseboard heating units, to increase efficiency by decreasing the load on the air system, and at the same time to increase comfort by preventing cold downdrafts, often a source of discomfort in rooms with considerable glass areas.