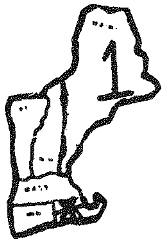
PUBLIC SCHOOLS

ENERGY CONSERVATION

MEASURES



Report Number 1

SCOTT ELEMENTARY SCHOOL
Warwick, Rhode Island

FLACK & KURTZ

Prepared For The

FEDERAL ENERGY ADMINISTRATION

By

AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS

Contract CR - 04 -60711 - 00

The views and conclusions contained in the document are those of the authors, and should not be interpreted necessarily representing the official policies of the U. S. Government.

January 24, 1977

MANAGEMENT SUMMARY

Harold C. Scott Elementary School

Warwick, R.I.

A thorough and comprehensive engineering analysis of ten representative elementary schools across the nation was undertaken to identify cost-effective energy conserving opportunities. The reports of these studies are designed to provide school administrators, engineers, architects, and associated technical personnel with indicators of potential energy savers in similar buildings. The following information is a summary of one of these ten reports.

Scott is representative of a 1960's single level pod or modified open space school located in a 6,000-9,000 degree day climate.

BUILDING CHARACTERISTICS

Size:

27,610 sq.ft.
18 classrooms, library, multipurpose room and administrative area

Occupancy:

400 students, K-6; 25 staff
School day: 9:00 a.m. to 3:00 p.m.
School year: Early September-late June
After hours/summer: 2 days/wk. until 4:00 p.m.
2 days/wk. until 8:20 p.m.

Construction:

Built in 1965. Addition 1967, similar construction.
Walls: face brick, 4" loose insulation, and concrete block with 22% single pane glass
Roof: 2½" Insulrock supported by steel beams

Heating, ventilating:

Unit ventilators for classrooms, library, multipurpose room.
Convectors, radiators, and cabinet heaters for offices, toilets, corridors, entrances.
Heated by natural draft gas-fired boiler

Illumination:

Flouorescent in classrooms; 2.2 watts/sq.ft.
Multipurpose room has (12) 300 watt incandescent and stage has (2) 100 watt incandescent and (6) 100 watt fluorescent
Security lighting: (3) 1500 watt GE quartz, 2 shut off, 1 manual

Energy consumption and cost:

	Gas				Electricity	
Year	CCF	CCF/sq.ft.	DD	CCF/DD	KWH	KWH/sq.ft.
1973-74	25,200	.91	5,554	4.54	127,047*	4.6*
1974-75	21,769	.79	5,559	3.91	87,540	3.17
Cost:	$3.36/MCF				$0.013 KWH	*for 13 months

ENERGY CONSERVING RECOMMENDATIONS

The following recommendations are made for an existing building with the characteristics described above. They offer guidelines for analyzing buildings with similar characteristics; however, suggested energy conserving opportunities (ECOs) must be weighed in terms of the fuel used, its cost and associated savings as well as capital expenditure considerations. While it is not the primary intent of this report to address new construction concerns, the findings do have implications for such work.

- Rebalance unit ventilators to reduce outside air --500 cfm to 250 cfm (R.I. code 10 cfm/student)
- Revise occupied/unoccupied cycle -- 4:00 a.m. - 4:00 p.m. to 8:00 a.m. to 3:00 p.m. with override for night use
- Replace gas-fired boiler with oil-fired boiler
- Add roof insulation during re-roofing

SUMMARY TABLE: Recommended Energy Conserving Measures at Scott Elementary School, Warwick, Rhode Island

ECOs	Estimated Cost	Recovery Rate
1. Reduce outside air	$6000	less than 5 yrs.
2. Revise night setback	0	immediate
3. Replace gas-fired boilers	19,500	9 yrs.
4. Add roof insulation	17,300	7 yrs.
ALL RECOMMENDATIONS:	$ 45,800	7 yrs.

OTHER CONSIDERATIONS

The above recommendations and calculations were based on \$3.36/MCF escalated at 10% per annum with 6% interest. As the cost of fuel exceeds this rate, other ECOs may become cost effective and should be reviewed. Any consideration should not view adjusted energy and dollar savings in isolation; materials, labor, interest rates, etc., must also be assessed. The following ECO may warrant future review:

double glazing windows

Finally, it should be noted that in a free market availability is reflected in cost. However, natural gas has not had such a history. As long as fuel costs or supplies are in any way regulated, actual fuel availability should be part of retrofit considerations. The availability may transcend the cost-effective characteristics of a modification.

PREFACE

The plight of the public schools in the face of rapidly depleting energy resources and escalating energy costs has been a matter of concern to the Federal Energy Administration (FEA) and other government agencies, as well as organizations such as the American Association of School Administrators (AASA). Reports have been published outlining the problems of energy usage in public schools, its impact on school budgets and possible ways to reduce energy consumption in existing buildings. More substantive information is needed to assist school administrators and federal energy/education decision makers in identifying specific cost-effective remedies to existing school buildings.

The schools of America consume eleven percent of the space heating/cooling energy. Over fifty percent of the schools now in use were built in the post World War II "baby boom" when first cost was far more important than energy efficient buildings. A recent FEA report revealed that energy costs to the schools increased 48.3% in a two year period (1972-73 to 1974-75). The continued escalation of energy costs coupled with energy inefficient buildings and exacerbated by general inflation has created a critical problem for the schools.

Since it has been estimated that nearly fifty percent of the space heating/cooling energy consumed by the schools is wasted, it is also a grave problem for our nation. The 1975 Congressional report on energy noted that the most economical, accessible way to "gain" fuel reserves is to reduce consumption.

School people want to reduce this waste and unnecessary expenditure. The development and dissemination of information which will enable school administrators to identify and analyze energy conserving opportunities in existing buildings is badly needed. It is critical that school people have access to the options available to meet identified energy needs, their respective costs, and the associated energy savings.

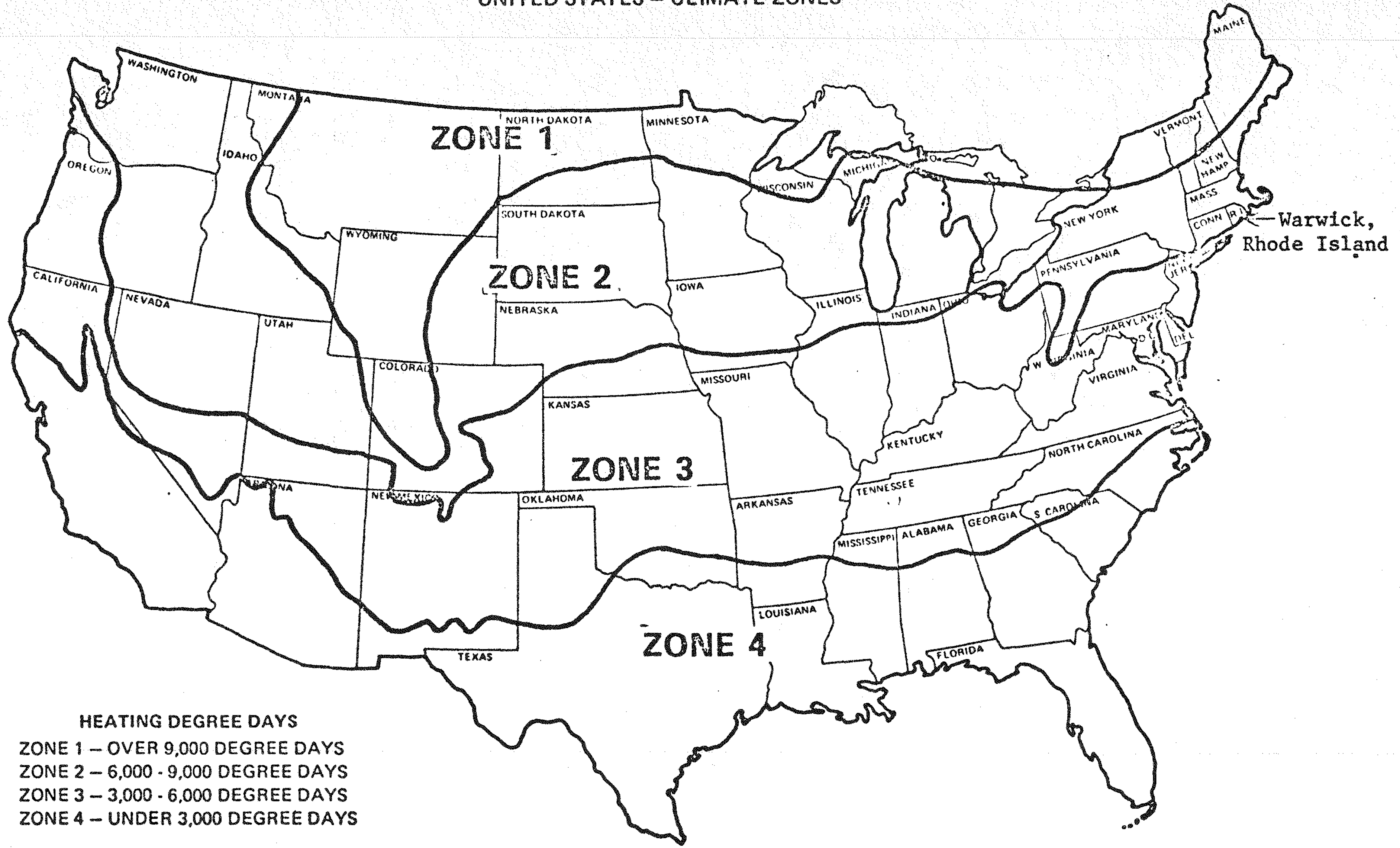
In order to provide such guidelines and to demonstrate the desirability of retrofitting existing school buildings, AASA initiated the project Saving Schoolhouse Energy. The emphasis in this study was placed on the cost effectiveness of capital modifications utilizing "off-the-shelf-hardware." The project was designed in five phases: (1) select ten elementary school buildings and analyze their energy conserving opportunities; (2) undertake needed architectural or engineering design work; (3) install or construct recommended modifications; (4) monitor and record post-modification energy use; and (5) disseminate the findings.

Phase 1, selection of the ten demonstration sites and an engineering analysis of energy conserving opportunities for each, was funded by the Federal Energy Administration.[1] This report for Harold C. Scott Elementary School in Warwick, Rhode Island, represents the culmination of Phase 1 for one of these sites and is one of ten (10) such reports. The map on page iv depicts its geographic and climate location. Other sites in the study were Central Elementary School, Glen Rock, New Jersey; Samuel Everitt Elementary School, Langhorne, Pennsylvania; Hindman Elementary School, Hindman, Kentucky; Fairmoor Elementary School, Columbus, Ohio; P. F. Brown Elementary School, Lubbock, Texas; Eastridge Elementary School, Lincoln, Nebraska; Garfield Elementary School, Sioux Falls, South Dakota; Plover Whiting Elementary School, Stevens Point, Wisconsin; Washington Elementary School, Kennewick, Washington.

---

1. Federal Energy Administration Contract CR-04-60711-00, April 20, 1976.

UNITED STATES — CLIMATE ZONES



Under this first phase, ten elementary school buildings were selected, one from each federal region, with the exception of Region 9. Because the criteria established for selection could not be met by any of the applicants or any of the other Region 9 schools which AASA identified through a cooperative search with the respective state departments of education, this region was omitted and, instead, a second school was selected in Region 5 to represent the northern portion of that area. Criteria used for selection of the demonstration schools included: type of structure, predictably consistent usage patterns after modifications, building longevity, building size, student enrollment, available energy consumption data, and expected energy savings as predicted through the use of the Public School Energy Conservation Service (PSECS)[2] computer program. It is important to note that every effort was made to find <u>typical</u> schools, not "bad examples"; for experience has shown "energy and dollar saving retrofit opportunities exist at even the most well maintained facilities."[3]

After the sites were selected, a thorough and comprehensive investigation of energy conserving opportunities for each building ensued. In this study, the PSECS material, the TRACE[4] or Ross Meriwether[5] computer programs, as-built drawings, and on-site surveys were the basis for the engineering judgment as to feasible energy conserving measures to be recommended. Such recommendations considered: (a) changes in HVAC or lighting systems or equipment, including controls; (b) modification in operations; (c) structural

---

2. PSECS was developed by the Educational Facilities Laboratories, Inc. under a Federal Energy Administration Contract.

3. Identifying Retrofit Projects for Federal Buildings, p. 2.

4. TRACE computer program 200 developed by Trane Company.

5. Meriwether ERE computer program.

changes; (d) estimated cost(s) of implementation; and (e) estimated energy savings that are expected to accrue. In addition to their engineering feasibility, the recommendations also considered the possibility of significant cost benefit, educational desirability, and environmental acceptability.

Phase 1 of the Saving Schoolhouse Energy project was completed under the auspices of AASA's Office of Governmental Relations. JCox Associates served as AASA's consulting engineer and coordinated the ten separate studies, in addition to conducting the investigation for one site.

A project of this magnitude requires the contributions and cooperation of many. The team assembled by AASA for Phase 1, PSECM # 1, Harold C. Scott Elementary School include the following firms and individuals:

Project Director: Shirley J. Hansen, AASA

Asst. Project Director: Charlotte Friedman, AASA

Coordinating Consultant:	JCox Associates Vienna, Virginia
	James R. Cox, P.E. Leland Eisenhower, P.E.
Engineer:	JCox Associates Vienna, Virginia

We would be remiss if we did not also acknowledge the fine cooperation and assistance we have received from Michael Pulscak and Faith Lambert of FEA and from Edward Stephan during his tenure at FEA.

TABLE OF CONTENTS

REPORT NUMBER 1

HAROLD C. SCOTT ELEMENTARY SCHOOL

1.0 INTRODUCTION

The purpose of this study, prepared for the American Association of School Administrators, is to identify and evaluate energy conserving measures for the Harold C. Scott Elementary School. This analysis is phase one of a five phase program directed toward reducing energy consumption in existing public schools.

The AASA program will be conducted in the following five phases:

1. Evaluation and selection of ten school buildings for analysis of potential energy conserving modifications.

2. Preparation of architectural and engineering specifications and drawings for the recommended modifications.

3. Installation and construction of the modifications.

4. Monitoring and evaluating energy use after modifications, and development of energy conservation data.

5. Dissemination of the information to school districts and others interested in energy conservation.

Harold C. Scott Elementary School is one of ten representative schools selected from each of the Federal Energy Administration regions. This report summarizes the results of the field investigations, computer simulation and evaluations of the energy conserving opportunities available in this school.

2.0 METHODOLOGY

The emphasis in this study was on cost-effective capital investments for energy conservation. The recommended capital investments in this type of study should not be implemented without first having undertaken a comprehensive operational and maintenance program. This implies that sound energy management procedures is a continuing function and should include scheduling characteristics, periodic inspection and routine maintenance responsibilities. It further implies that the human element (faculty and students) is cooperative and appreciative of the intent of the function desired.

The identification and evaluation of energy conservation measures which could be employed in the Harold C. Scott Elementary School was performed in four steps:

I. Site Visitation and Data Collection

II. Computer Simulation

III. Identification of Energy Conservation Measures

IV. Economic Analysis

Step I involved visiting the school to obtain utility bills, architectural and engineering drawings, operating and occupancy schedules, and field measurements of existing conditions; i.e., ventilation air quantities, and space temperatures. The field measurements were performed to compare the actual mode of operation of the building system to the original design intent.

In Step II the collected data was utilized to model the subject school on a computer. The results of the computer program were compared to the actual energy consumption of the school to insure compatibility of the computer model and the real school. The "Meriwether" computer program was used for this purpose.

In Step III, the computer results were analyzed to determine the energy requirements of the building parameters which constitute the total annual energy consumption of the building; i.e., ventilation air, walls. In addition, retrofit measures which appeared to have an energy conservation impact were identified at this point.

In Step IV, the annual energy savings and the first cost to implement each energy conservation retrofit measure were determined. These costs were compared based on present fuel costs, including a fuel escalation factor and present bond rates, applicable to Harold C. Scott Elementary School, to determine the payback periods (cost-effectiveness) of each item.

3.0 BUILDING DESCRIPTION

Harold C. Scott Elementary School at 833 Centerville Road, Warwick, Rhode Island 02886, is located in Federal Energy Administration Region No. 1. The original building built in 1965 had a four-classroom addition in 1967 which increased the building's total area to 27,610 sq. ft. The present occupancy is 400 pupils, from kindergarten through 6th grade with approximately twenty-five staff members.

3.1 ORIGINAL BUILDING

The original building (see Floor Plan, Figure 3.1) is a one-story building with fourteen classrooms and a library symmetrically located around a double-story multi-purpose room. Figure 3.3 shows the north exposure or main entrance. The raised roof is the multi-purpose room. Each classroom is accessible directly from outdoors through single wood doors or from corridors which encompass the multi-purpose room. Figure 3.4 shows the north exposure of the west wing. The room at the far left is a typical classroom with an exterior door. The center room is the library. The exterior walls are face brick with four-inch loose insulation and concrete block on the interior surface. The heat transfer factor ('U' value) for this type wall is .08 BTU/Hr. sq. ft. degrees F. (Values obtained from "ASHRAE Guide, Handbook of Fundamentals").

The windows are single pane casement type and have a 'U' value of 1.13 BTU/Hr. sq.ft. degrees F. (Values obtained from "ASHRAE Guide, Handbook of Fundamentals"). Approximately 22% of the total building exterior wall area is glass.

The roof is constructed of built-up roofing over two and one-half (2-1/2) inches of insulrock (Figure 3.5 shows the exposed beams below the roof in the library), and is supported by exposed steel "I" beams. The 'U' value for this roof is .20 BTU/Hr.sq.ft. degrees F. Presently, the roof is in poor condition with evidence of leaks throughout the building and an effort is being made to replace it.

3.2 ADDITION

The 1967 four-classroom addition (see Floor Plan, Figure 3.2) is of similar construction to the original building. It is accessible from either the main building or through independent doors to each classroom.

3.3 OCCUPANCY SCHEDULE

Classes are held 9:00 a.m. to 3:00 p.m. from early September through late June, and the building is used two days per week until 4:00 p.m. and two days per week until 8:30 p.m. The school is unoccupied during July and August.

3.4 HEATING/VENTILATING SYSTEMS

The heating energy source for the building is a natural draft gas-fired hot water boiler which has a combustion efficiency of 80%; the estimated seasonal efficiency is 65-67%. The boiler is not capable of burning fuel oil. Hot water supply temperature, scheduled with outdoor air temperature, is reset by a three-way mixing valve. Figure 3.6 shows the front of the boiler and at the upper center portion of the photo, the three-way valve. Two circulating pumps (one standby) which are manually started when the boiler is on, distribute water to unit ventilators, radiators and convectors. Figure 3.7 is a schematic of the heating plant.

Unit ventilators provide for the heating needs of the classrooms and library and are designed to operate as described below:

1. During Occupied Cycle - The fan runs continuously. The heating valve is closed and the outside air damper is open 50%. As room temperature decreases, the heating valve is gradually opened from its closed position to full open. If space temperature does not rise to the thermostat setting, the outside air damper is gradually closed. As space temperature rises, the reverse happens. If space temperature rises above the thermostat setting, the outside air damper opens from 50% to full open.

2. During Unoccupied Cycle - The heating coil valve is full open and the supply fan cycles on to maintain temperature.

Heating and ventilating of the multi-purpose room is provided by unit ventilators located in a room adjacent to the multi-purpose room. Their operation is identical to the unit ventilator description above.

Convectors, radiators and cabinet heaters are used for offices, toilets, corridors, entrances and other miscellaneous area heating.

3.5 ELECTRICAL SYSTEMS

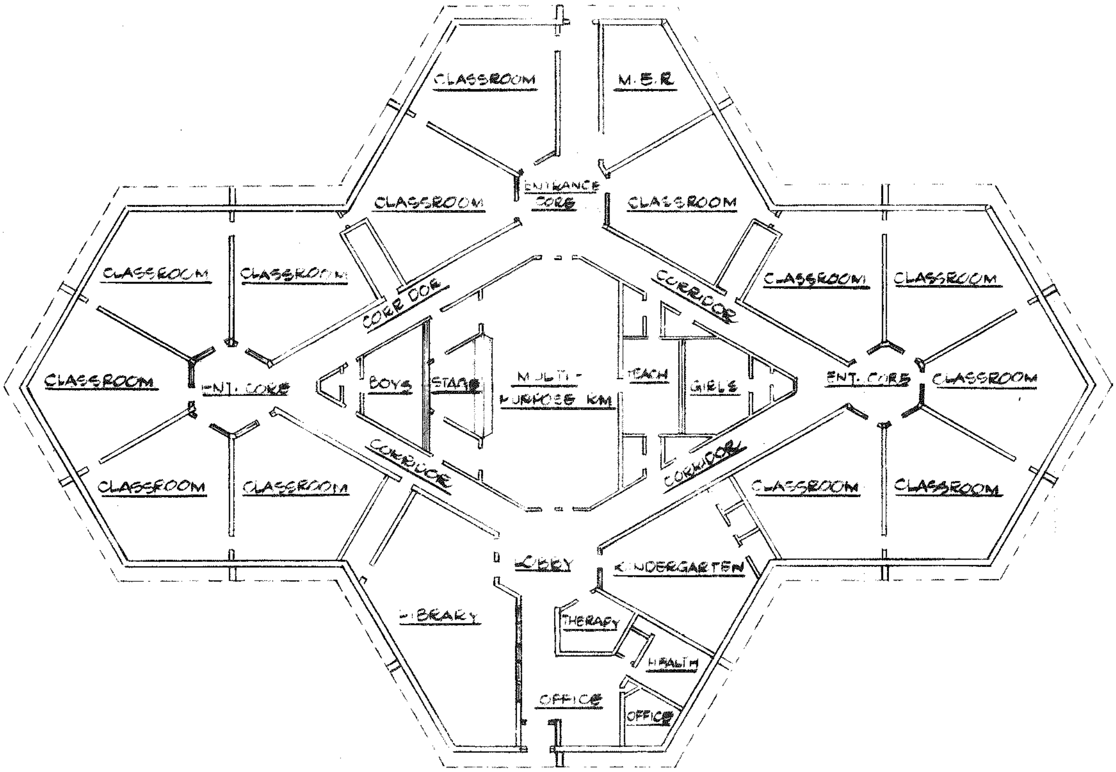
Lighting in the classrooms is provided by surface-mounted fluorescent fixtures with wrap-around plastic lenses (see Figure 3.5). The typical classroom lighting load, including ballasts, is 2.2 watts/sq.ft.. Dropped ceiling with recessed lensed fluorescents have been provided for corridor lighting (see Figure 3.8).

Multi-purpose room lighting is provided by (12) 300-watt incandescent fixtures. In addition, (2) 100-watt incandescents and (6) 100-watt fluorescents provide stage lighting.

Three manually controlled 1,500-watt General Electric quartz lamps provide for the exterior security lighting.

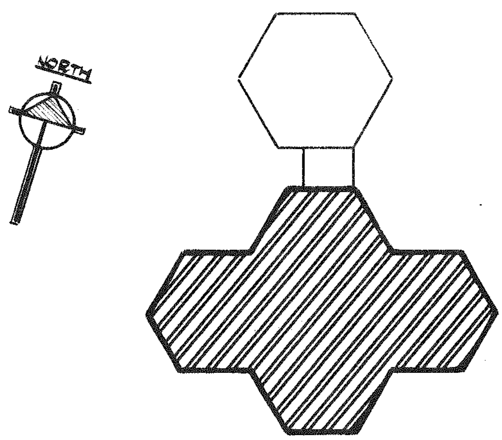
3.6 DOMESTIC HOT WATER

Domestic water for general use in lavatories and classrooms is heated by an instantaneous heater in the boiler. There is no kitchen facility to prepare meals. Hot water at 140 degrees is circulated throughout the building in a closed loop. Excess hot water is recirculated through a 3-way valve at the instantaneous heater.



FLOOR PLAN

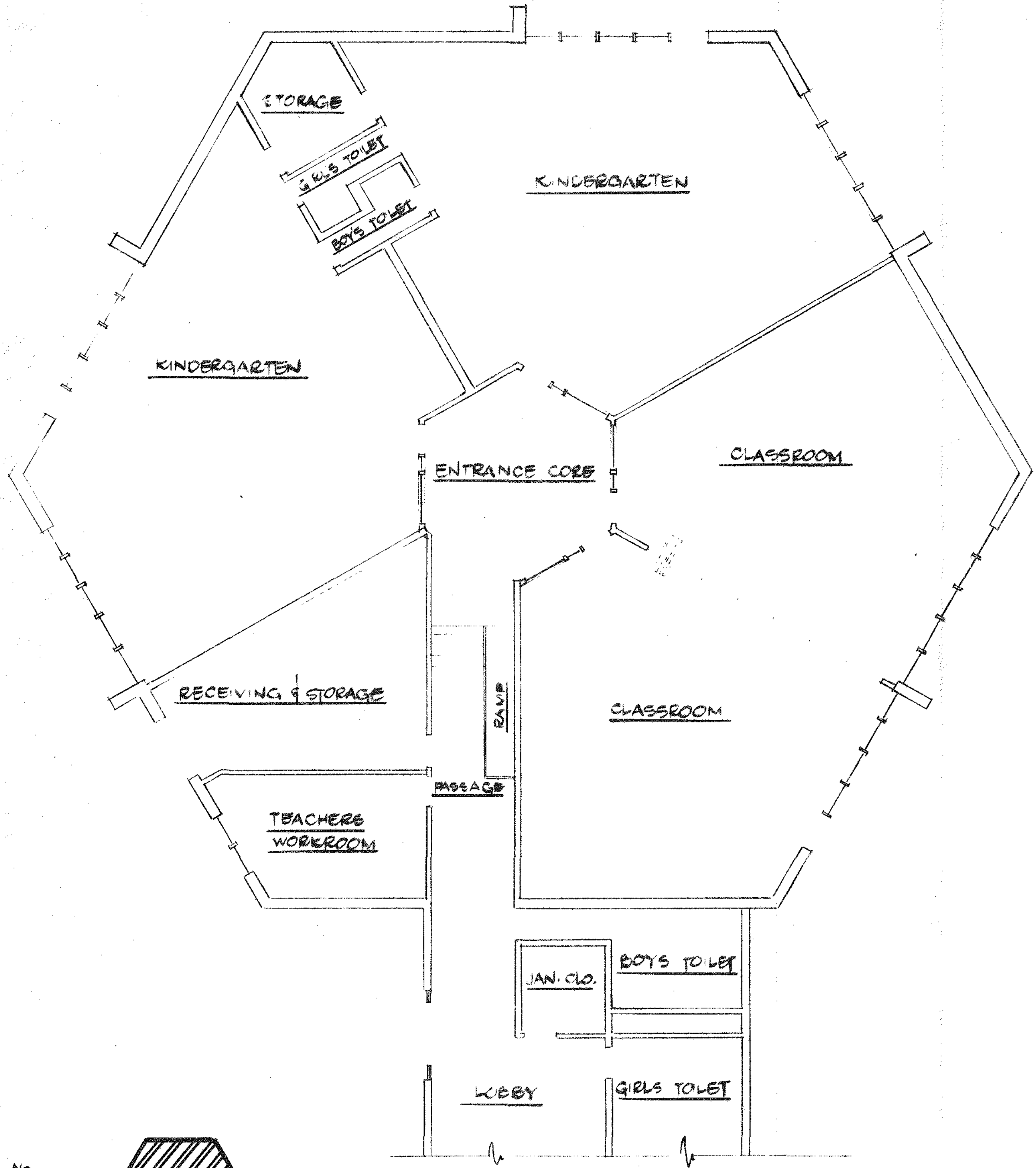
SCALE 1/8" = 5'-0"



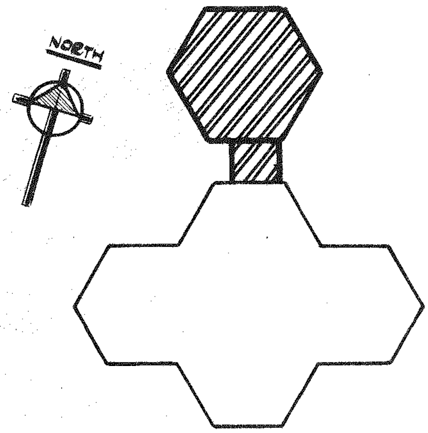
KEY PLAN

FIGURE: 3.1

ORIGINAL BUILDING



FLOOR PLAN
SCALE 1/16" = 1'-0"



KEY PLAN

FIGURE 3.2
ADDITION

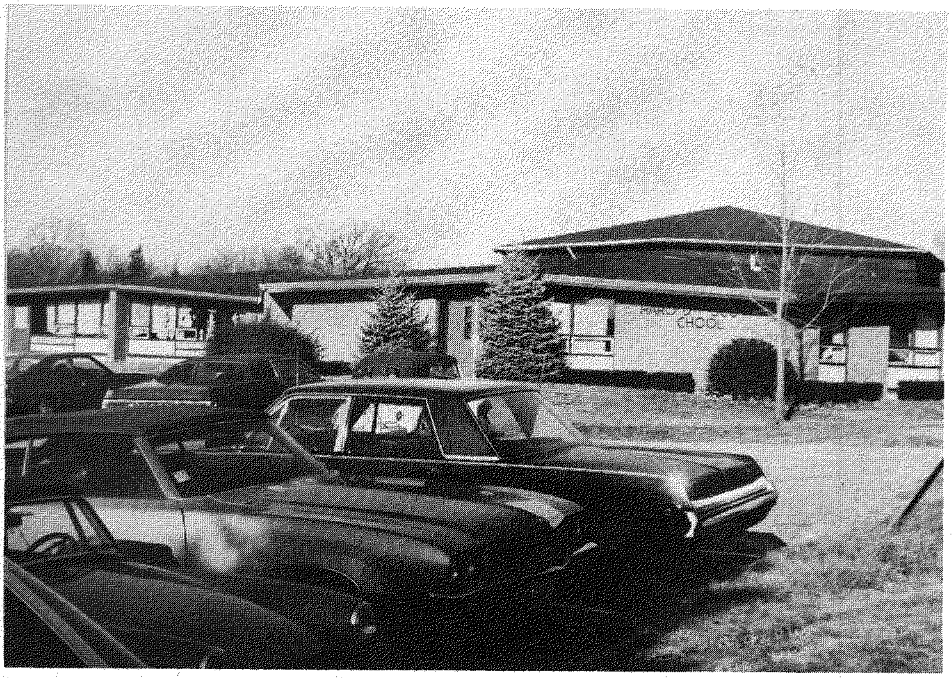


FIGURE 3.3

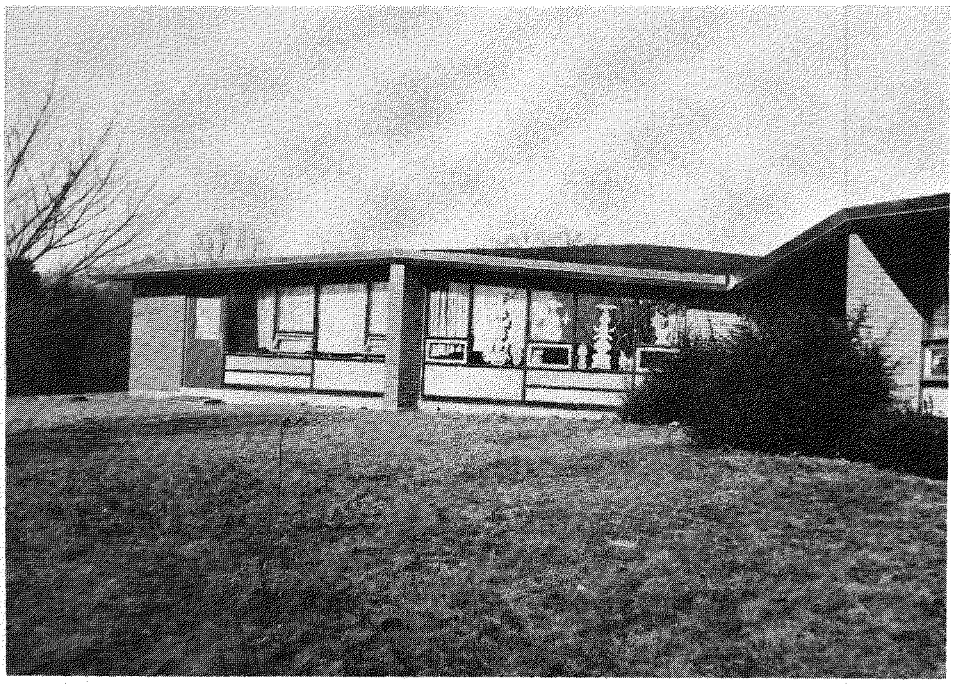


FIGURE 3.4

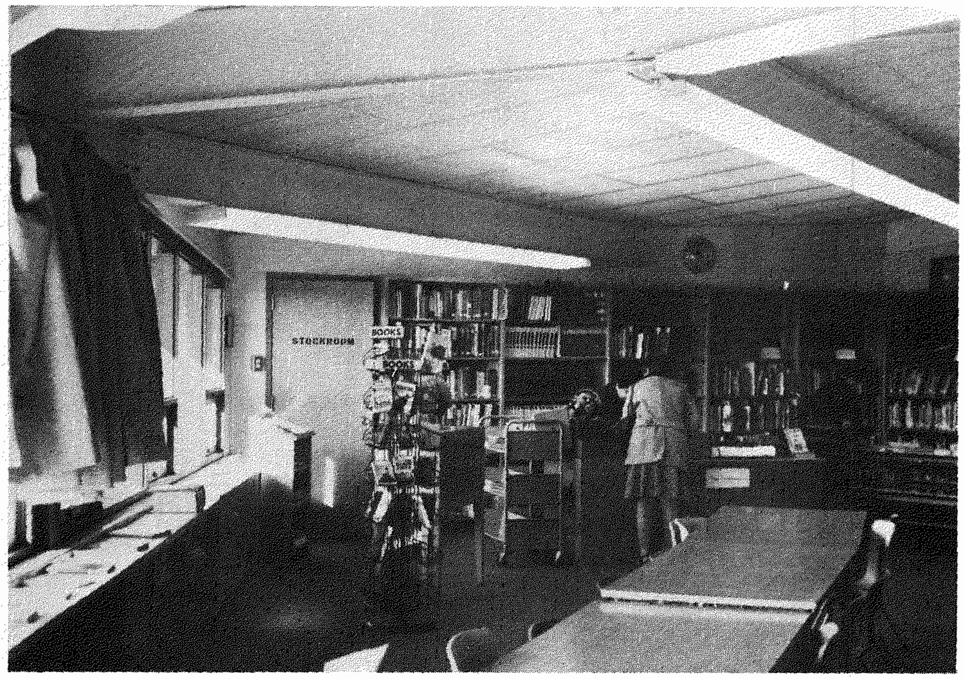


FIGURE 3.5

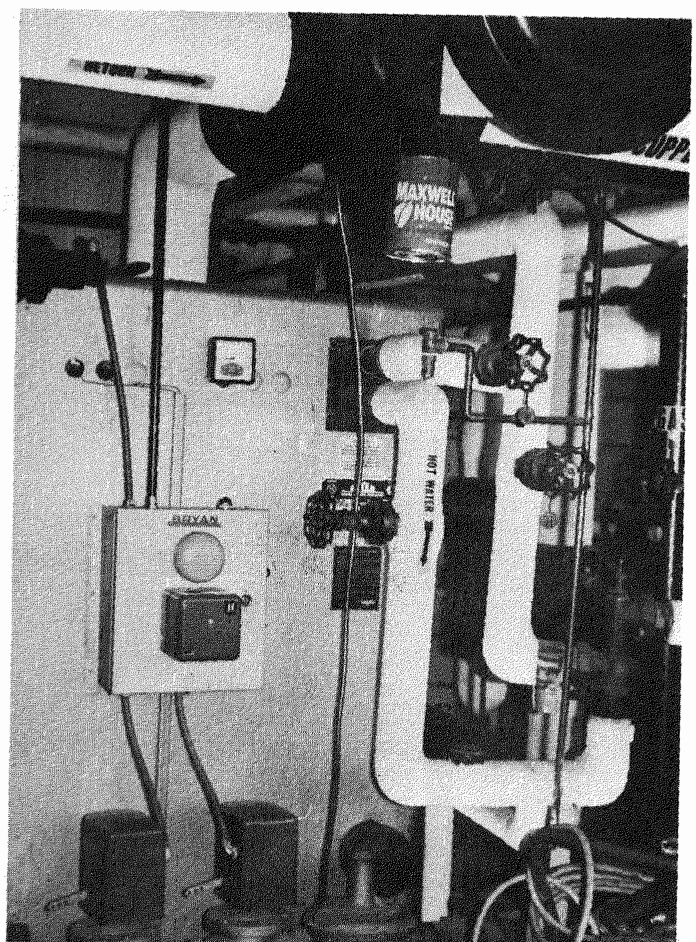


FIGURE 3.6

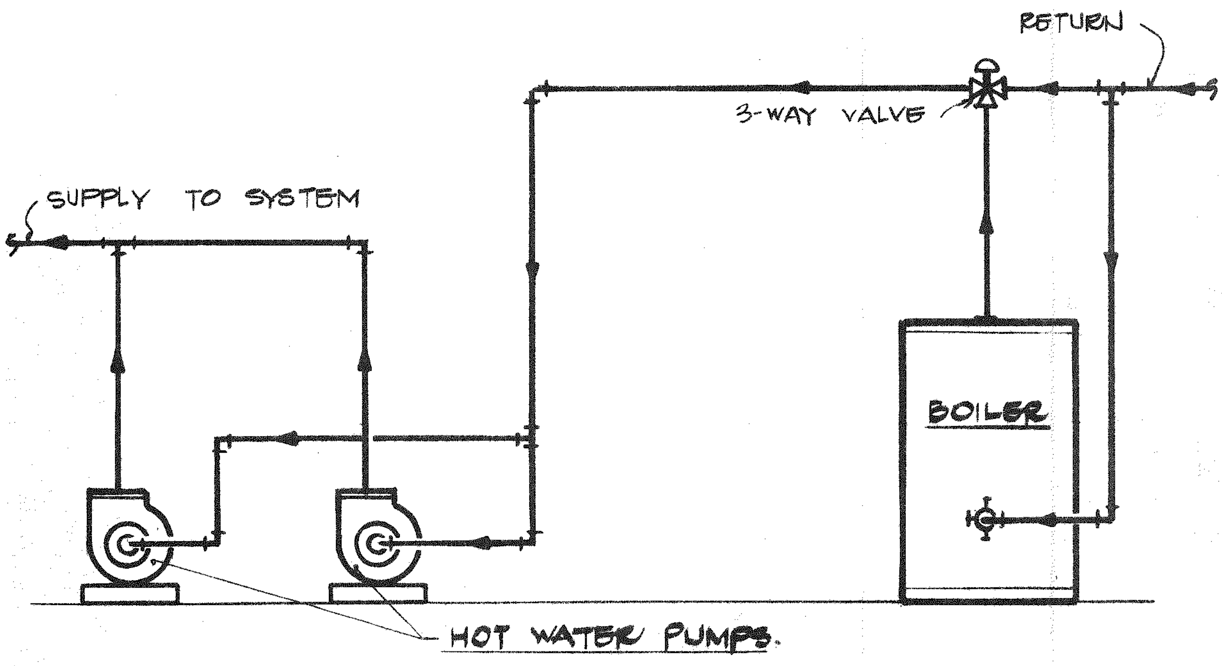


FIGURE - 3.7 - BOILER PLANT SCHEMATIC

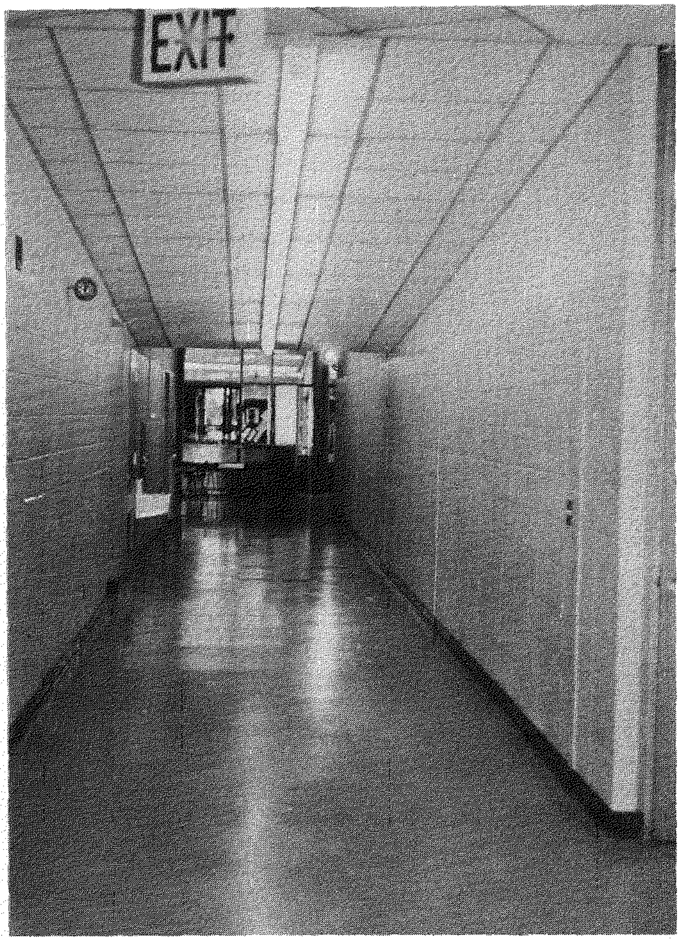


FIGURE 3.8

4.0 DATA COLLECTION AND SIMULATION

A survey of the existing building and an interview with the building operator were conducted to develop input data for the computer simulation of the school. Previous years' utility bills were collected to use for comparison against the computer output. Modifications to the input program were performed to develop a computer model which behaved similarly to the present actual building.

4.1 ACTUAL ENERGY CONSUMPTION

The annual utility bills for the previous two years for fuel oil and electricity were obtained from the school and are listed below:

Fuel Energy - Heating & Ventilating

Year	CCF Gas	CCF/Sq.Ft.	Degree Days	CCF/DD
1973-74	25,200	.91	5,554	4.54
1974-75	21,769	.79	5,559	3.91

Electrical Energy - Light and Power

Year	KWH	KWH/Sq.Ft.	
1973-74	127,047	4.6	(13-month
1974-75	87,540	3.17	billing period)

Monthly breakdown of energy consumption were available for 1974-75 and are plotted on Charts 4.1 and 4.2.

4.2 BUILDING SURVEY

The observations of a building survey performed to determine the actual operating characteristics of the building are summarized below:

Auxiliary Heaters and Exhaust Systems

Cabinet heaters for corridor heating were de-energized as were exhaust fans wherever possible.

Time Clock

The present heating system is indexed to the day cycle from 4:00 a.m. until 4:00 p.m. This resets building temperatures from 65 degrees F. to 70 degrees F. and also introduces outside air through unit ventilators into the unoccupied rooms for six hours more than is necessary.

Unit Ventilators

Unit ventilator operation varied from classroom to classroom. In one classroom the thermostat was satisfied and the outdoor air damper was fully closed while in another classroom the thermostat was calling for heating and the outside air damper was wide open. Proper operation of the system was further impaired by corroded valves which remained frozen in one position and inoperative thermostats. In an attempt to reduce excessive over-cooling in some rooms, the unit ventilators are manually shut off. The quantity of outside air supplied by the unit ventilators was estimated at 6,000 cfm which is considerably less than the design quantity of 11,200 cfm.

Boiler Plant

The boiler appeared in excellent condition and had a history of satisfactory operation. One pump motor burnt out recently but was replaced and is in operation.

Building Construction

Building construction, except for the roof, was tight with no evidence of excessive infiltration.

Lighting

Independent switches provide the capability to shut the perimeter row of lights in classrooms. In classrooms with substantial natural light, the teachers had shut the lights entirely while others shut the perimeter row only. In unoccupied rooms the lights were off. Two of the three security lights were inoperable thereby reducing security energy consumption to a minimum.

4.3 COMPUTER SIMULATION

The final model which was input into the computer resulted in a simulated annual heating energy consumption within 14% of actual 1974-75 fuel consumption, and a simulated electric energy consumption within 5% of actual 1974-75 electric consumption. These results are summarized below:

Heating Energy	CCF Gas	Degree Days	CCF/DD
Computer	21,250	4,774	4.45
1974-75 (Actual)	21,769	5,559	3.91

Electric Energy	KWH
Computer	91,649
1973-74 (Actual)	87,540

Charts 4.1 and 4.2 compare the actual vs. computer monthly energy consumption.

4.4 ENERGY BREAKDOWN

An analysis of the computer simulation revealed the following breakdown of annual heating and electric energy required for this school in its present mode of operation:

Heating Energy	
Roof Transmission	48%
Infiltrated Air Heating	9%
Walls and Glass Transmission	17%
Outside Air Heating	26%

Electric Energy	
Lighting	75%
Power	25%

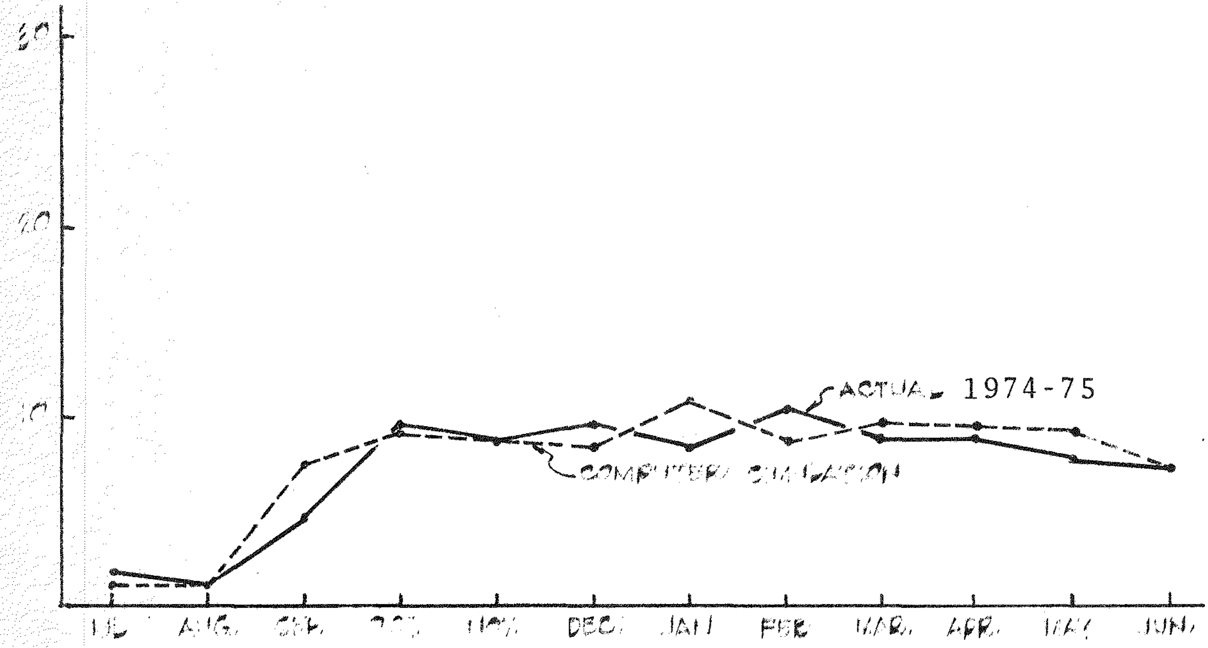


CHART 4.1 — PROFILE OF ELECTRIC USAGE (KWH)

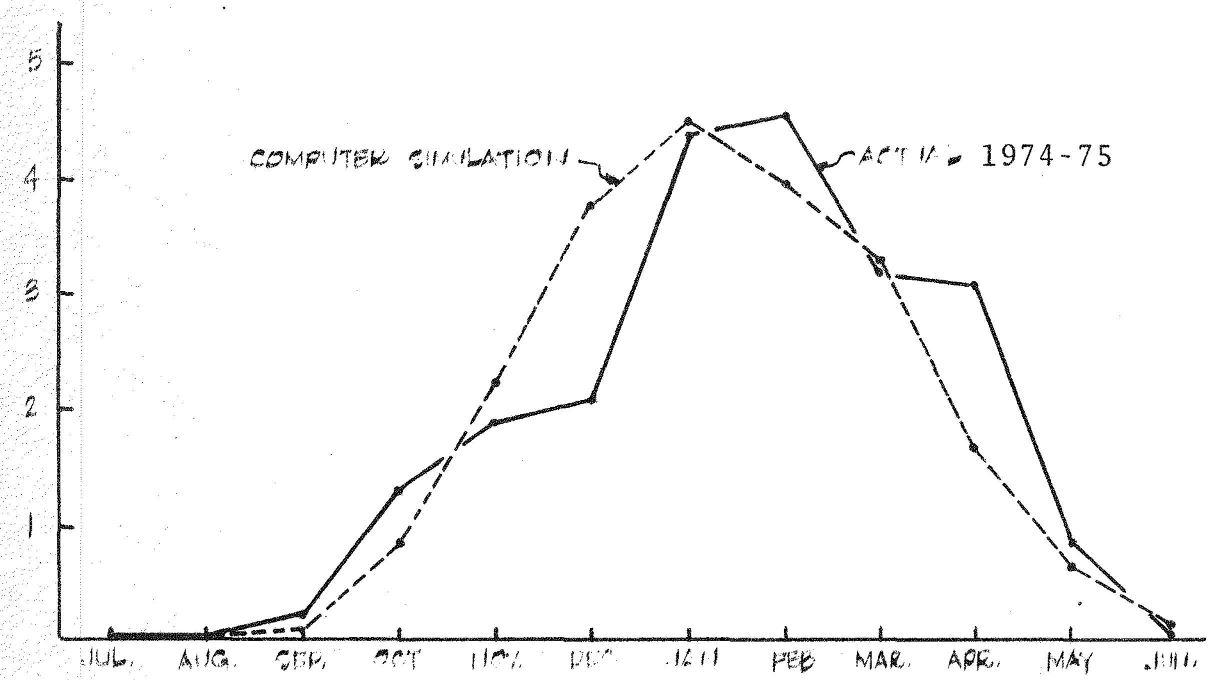


CHART 4.2 — PROFILE OF GAS USAGE (CCF)

5.0 DESCRIPTION OF ENERGY CONSERVATION OPPORTUNITIES

The computer simulation which approximated actual energy use was divided into energy consumption components to determine areas of possible energy savings (see Figure 5.1 and 5.2). Possible energy conservation measures were determined by analyzing the computer simulation and from a field survey of the building.

An examination of the energy consumption breakdown indicates substantial energy, 48% of total heating energy, being used to offset roof transmission losses. In addition, 26% of the total heating energy is used to heat a relatively low quantity of outside air. The heating energy for infiltration and wall and glass transmission losses appears low at first glance. However, if the roof and outside air loads were reduced to acceptable levels, infiltration, glass and wall transmission losses would increase as a percent of the total heating energy requirements.

The items which appeared cost effective from the computer output analysis and field survey are described below and the economics for each item as described in Section 6.0.

5.1 MECHANICAL

The present mechanical systems are basic in design and utilization of items such as exhaust fans and corridor heaters has been minimized. However, three areas of possible energy savings were determined and are summarized below.

Item No. M-1 - Reduce Outside Air Quantities

The present unit ventilator system supplies 500 cfm of outside air per classroom; this can be reduced to 250 cfm per classroom. The State of Rhode Island has issued Public Health Service Bulletin No. 856 which requires 10 cfm of outdoor air per student. This is equivalent to 250 cfm per classroom.

Item No. M-1 would require a rebalancing of each unit ventilator.

Item No. M-2 - Revise Occupied/Unoccupied Cycle

Presently the building heating systems are indexed to the occupied cycle from 4:00 a.m. until 4:00 p.m. by a time clock. During this time, outside air dampers modulate open 50% and the thermostats are reset to maintain 70 degrees F. space temperature. The lugs on the time clock can be revised to index the heating system to the occupied cycle from 8:00 a.m. until 3:00 p.m. During night use when there is heavy occupancy the controls can be centrally overridden at the time clock. During low occupancy night use, forced outside air ventilation is not required by code.

Item No. M-3 - Replace Gas Boilers

The existing gas-fired boilers can be replaced with oil-fired boilers which would reduce the cost of fuel per unit energy from $3.30/MMBTU to $2.50/MMBTU and increase the seasonal efficiency of the boiler plant from 65% to 70% or greater.

5.2 ELECTRICAL

The electrical system does not warrant modification to reduce energy consumption. Classroom lighting has the desired flexibility and appears to be monitored closely by staff members. Exhaust fans have been de-energized wherever possible.

5.3 BUILDING

The existing building has a low percentage of glass to wall area and a minimal amount of operable sash per classroom. In addition, the walls have an excellent heat transfer coefficient. Two areas of possible energy savings were determined and are summarized below.

Item No. B-1 - Roof Insulation

The present roof requires complete rehabilitation. The addition of roof insulation to the new roof would substantially reduce transmission losses compared to the present roof.

Item No. B-2 - Double Pane Glass

The existing inoperable windows in the classrooms can be retrofitted with a second pane of clear plexiglas to reduce transmission losses.

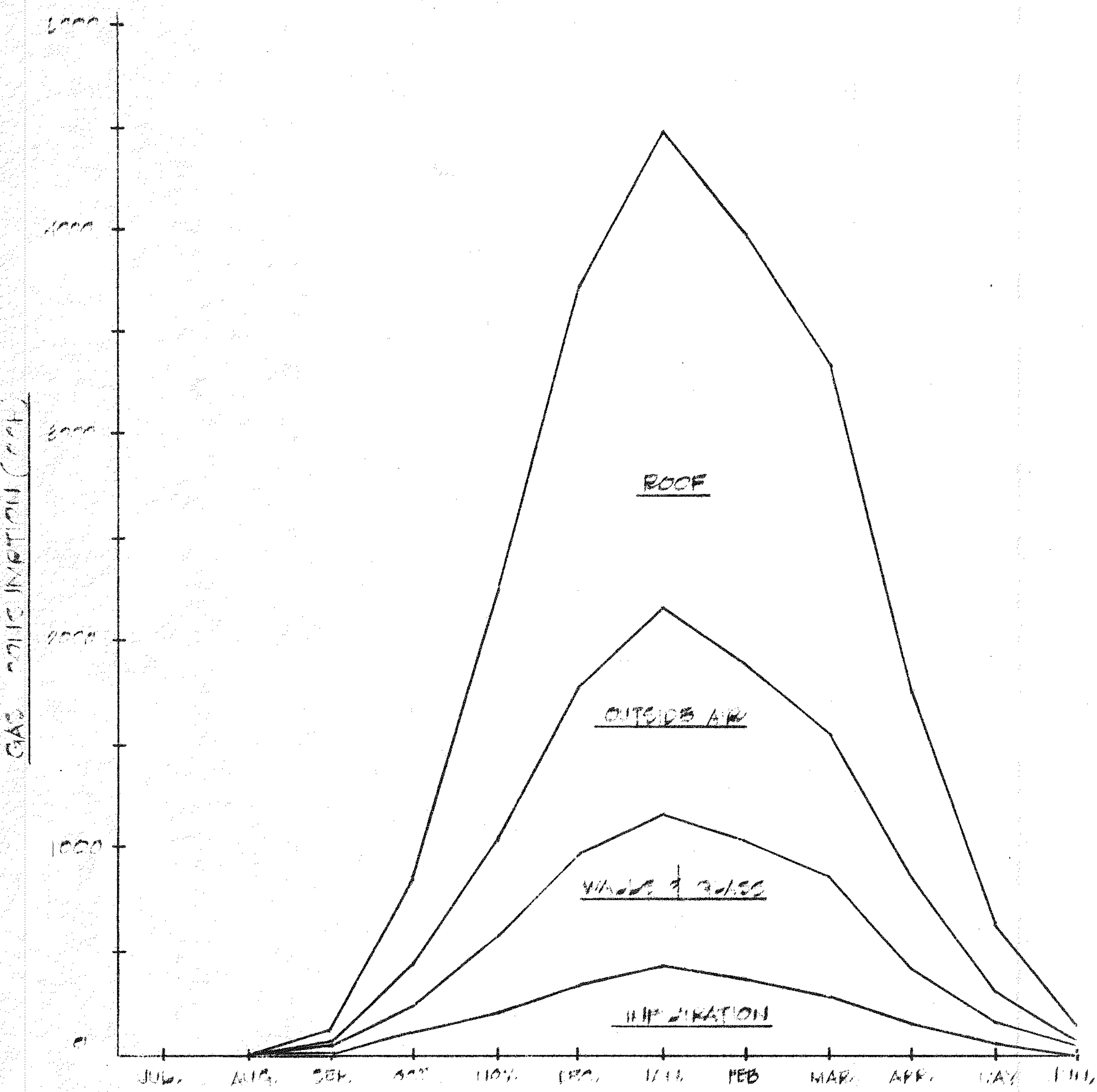


FIGURE 5.1 - BREAKDOWN OF GAS CONSUMPTION

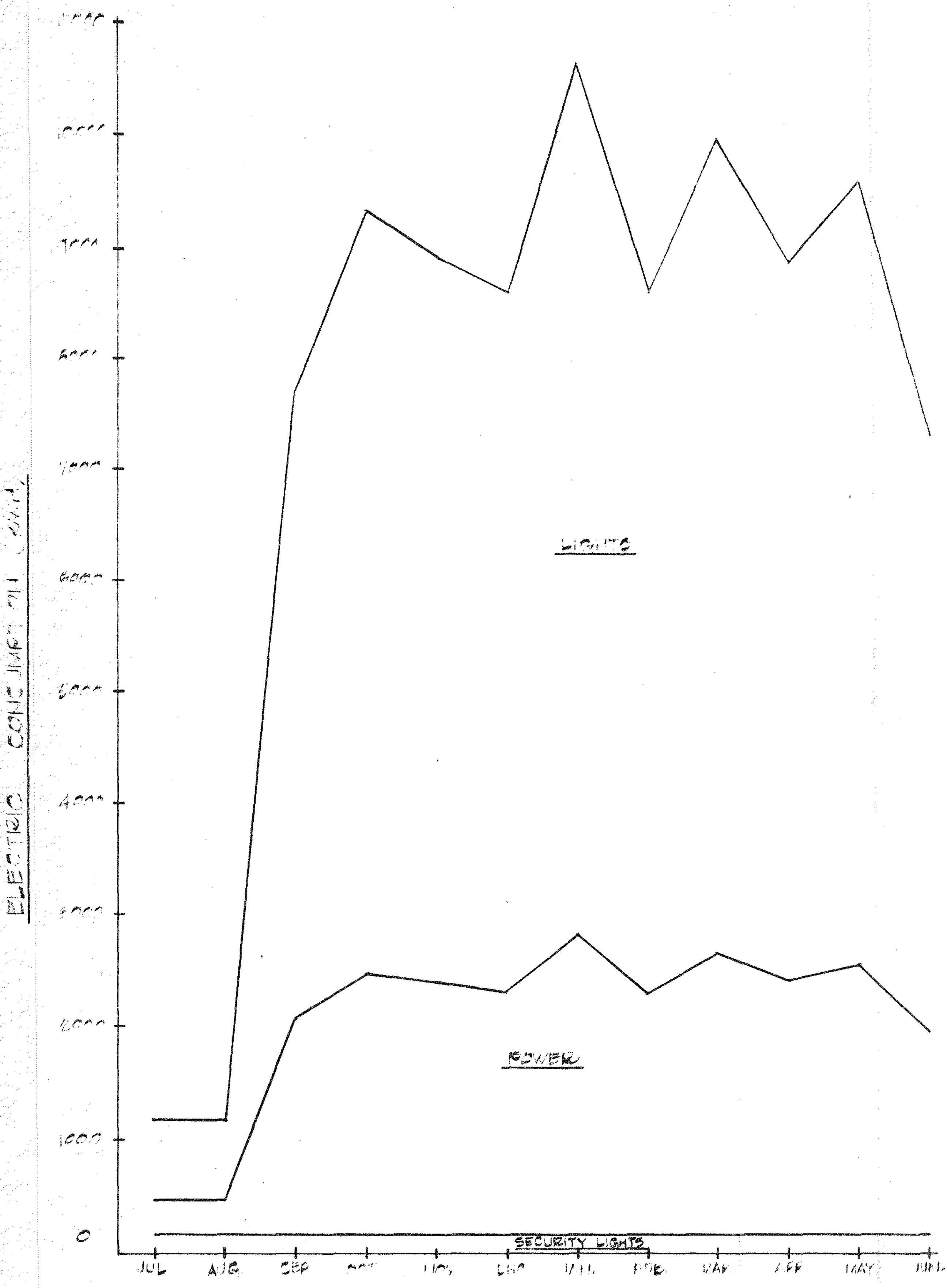


FIGURE 5.2 · BREAKDOWN OF ELECTRIC CONSUMPTION

Flack + Kurtz
Consulting Engineers
29 West 38 Street
New York, N.Y. 10018

6.0 ECONOMIC EVALUATION

An economic analysis of each item described in Section 5.0 was performed to determine the payback period to recover the initial capital expenditure with operating energy savings. The payback period was determined by comparing totalized annual energy savings to the initial capital expenditure plus the totalized annual interest cost. The year in which the total savings equaled the total capital expenditure plus interest is the payback period. The current bond rate for Harold C. Scott Elementary School (6%) and the latest energy costs, with an estimated 10% per year escalation were used to determine the totalized energy costs and totalized interest cost. The first cost, annual energy savings and payback period for each item described in Section 5.0 have been summarized in Table 6.1; these values are independent and not additive.

In evaluating the energy conservation measures described in this report, one must be aware that the present operating characteristics of the school cannot remain indefinitely. The control system must be completely overhauled including thermostat recalibration, control valve replacement and linkage adjustment and replacement. The results of upgrading the control system will be a better controlled environment but increased energy consumption, possibly to the 1973-74 level. In light of this, the cost effectiveness of the energy conservation items described in Section 5.0 have been compared to an estimated level of energy consumption when the control system is upgraded. The cost of upgrading the control system can vary from $5,000 to $6,000 depending on the condition of the existing control hardware; this cost has been included under Item No. M-1.

The savings associated with each item have been calculated individually and care should be exercised in evaluating the total savings of combined items. Table 6.2 summarizes the impact of each energy conservation measure assuming that Item M-3 ("New Boilers") has been initiated.

TABLE 6.1

ECONOMIC EVALUATIONS
(Annual energy savings are independent and not additive)

Item	First Cost	Annual Energy Savings* (Units)	(Cost)***	Payback Period (Years)
M-1 "Reduce Outside Air Quantities"	$ 6,000 (rebalancing only = $1,000)	4,100CCF	$ 1,380	5
M-2 "Revise Occupied/ Unoccupied Cycle"	maintenance staff	4,570CCF	1,535	immediate
M-3 "New Boilers"	19,500	**	2,617	9
B-1 "Roof Insulation" ****	17,300	8,320CCF	2,795	7
B-2 "Double Pane Glass"	30,390	2,650CCF	890	30

* Based on control system being upgraded.

** Existing gas boilers: 25,200 CCF consumption - $8,467
New oil boilers: 16,715 gals. oil consumption - 5,850

Annual Savings - $2,617
(Based on 1973-74 consumption)

***Present Gas Cost = .336/CCF

**** First cost based on insulation as part of a total reroofing project.

TABLE 6.2

ALTERNATIVE NUMBER	DESCRIPTION	ANNUAL ELECTRICAL CONSUMPTION KW-HRS/$	ANNUAL ELECTRICAL SAVINGS KW-HRS/$	ANNUAL* GAS/OIL CONSUMPTION CCF/$ GALS./$	ANNUAL OIL SAVINGS GALS./$	TOTAL ANNUAL UTILITY COST $	TOTAL ENERGY SAVINGS 1st YEAR $	ESTIMATED CAPITAL COST OF MODIFICATION	PAYBACK YEARS
ACTUAL BILLING	School Year 1973-1974	127,047/ $6,098	---	25,200/ $8,467	---	$14,565	---	---	---
ACTUAL BILLING	School Year 1974-1975	87,540/ $4,202	---	21,769/ $7,314	---	$11,516	---	---	---
	Calibration Present Operation Simulation	91,649/ $4,400	---	21,250/ $7,140	---	$11,540	---	---	---
M-3	New Boilers	127,047/ $6,098	---	16,715/ $5,850	**/ $2,617	$11,948	$2,617	$19,500	9
M-1	Outside Air Reduction	127,047/ $6,098	---	13,785/ $4,825	2,930/ $1,025	$10,923	$1,025	$ 6,000	7
M-2	Revise Occupied/ Unoccupied Cycle	127,047/ $6,098	---	13,450 $4,707	3,265/ $1,143	$10,805	$1,143	O/M	immediate

-continued-

ALTERNATIVE NUMBER	DESCRIPTION	ANNUAL ELECTRICAL CONSUMPTION KW-HRS/$	ANNUAL ELECTRICAL SAVINGS KW-HRS/$	ANNUAL* GAS/OIL CONSUMPTION CCF/$ GALS./$	ANNUAL OIL SAVINGS GALS./$	TOTAL ANNUAL UTILITY COST $	TOTAL ENERGY SAVINGS 1st YEAR $	ESTIMATED CAPITAL COST OF MODIFICATION	PAYBACK YEARS
B-1	Add Roof Insulation	127,047/ $6,098	---	10,775/ $3,770	5,940/ $2,080	$ 9,868	$2,080	$17,300	10
B-2	Double Glazing	127,047/ $6,098	---	14,823/ $5,188	1,892/ $662	$11,286	$ 662	$30,390	30+

NOTES:
1. Electrical Costs at $.048/KWH
2. Oil Costs at $.35/gal.
3. Gas Costs at $.336/CCF.
4. Energy costs and savings are for the first year.
5. Energy savings are not additive. The individual alternatives encompass parts of other alternatives and therefore should be considered independently.

* Oil consumption based on Item M-3 being initiated for all energy conservation items.

** Savings based on oil vs. gas boilers using school year 1973-1974 as base (see Table 6.1).

6.1 REDUCE OUTSIDE AIR QUANTITIES

The unit ventilators can be rebalanced by the local control manufacturers to supply the outside air quantity required by code. This would incur a first cost of $1,000 and would generate savings of $1,380 per year. The payback period for this item is less than one year; however, if the rebalancing is performed when the control system is being upgraded, the total cost would be $6,000 and result in a payback period of five years.

6.2 REVISE OCCUPIED/UNOCCUPIED CYCLE

The existing time clock can be adjusted by moving the lugs in the clock. This can be performed by the school maintenance department with no first cost. By revising the settings to 8:00 a.m. for beginning of day cycle until 3:00 p.m. for beginning of night cycle, $1,535 in heating energy costs per year can be saved. In addition some savings in electricity will be realized by running the unit ventilators for a shorter period of time.

6.3 NEW BOILERS

The existing gas boilers are not capable of burning oil. Retrofitting these boilers to burn oil would require complete disconnection from water lines, electric service,exhaust flue and fuel system. The base of the boiler would have to be replaced entirely which would increase the height of the boiler and a new oil burner installed. The expected performance and efficiency of the renovated unit are debatable and therefore, it was decided to estimate the cost of installing a new 2,000 MBH output modular hot water boiler. The first cost of this item,including a new 5,000-gallon fuel oil storage system, would be $19,500. This would generate savings of $2,617 per year and realize a payback period of nine years. The primary savings associated with this item are dependent on the relative costs of gas and oil. At present, the cost of oil is attractive due to the high cost of gas.

6.4 ROOF INSULATION

The present roof must be replaced and the addition of roof insulation should be included in the new roof. This would increase the cost of the roof by approximately $17,300 but would reduce heating energy costs by $2,795 per year. This is a payback period of seven (7) years.

6.5 DOUBLE PANE GLASS

The inoperable sash in each classroom can be retrofitted with a second pane of plexiglas. This would require a first cost of approximately $30,390 and would generate savings of $890 per year in reduced heating energy costs. This results in a 30-year payback period.

7.0 RECOMMENDATIONS

We recommend that the following energy conservation measures be implemented in order to reduce energy consumption in Harold C. Scott Elementary School:

1. Upgrade controls and reduce the outdoor air quantities for each unit ventilator -- Item No. M-1.

2. Revise the time clock setting for the occupied cycle index — Item No. M-2.

3. Replace the existing gas-fired boilers with a modular oil-fired boiler plant — Item No. M-3. (This recommendation may require an evaluation of the future cost of oil vs. gas for final approval -- see Section 6.3).

4. Add roof insulation — Item No. B-1.

These recommendations which have a total first cost of $45,800 would result in a payback period of seven years at present fuel rates and anticipated escalation.

8.0 CONCLUSIONS

The analysis of the Harold C. Scott Elementary School revealed that a reduction in energy consumption from one year to the next is not necessarily the result of a conscious energy conservation program. In addition, estimated savings from an energy conservation retrofit measure should be analyzed in light of the actual and desired operation of the building in order to determine its true cost effectiveness.

The actual analysis of retrofit measures for the Harold C. Scott Elementary School revealed that energy savings can be realized with attractive payback periods at three levels of energy conservation:

Level I: Minor modifications to mechanical systems which require little or no first cost and can be performed by the school maintenance department -- "Revise Occupied/Unoccupied Cycle."

Level II: Items which require moderate first cost, but have a short payback period -- "Reduce Outside Air Quantities."

Level III: Major revisions to either mechanical or architectural features of the building which result in substantial energy savings -- "New Boilers" and "Add Roof Insulation."

In developing potential energy conservation measures, the analyzer should be aware of the following factors:

- Current design "rules and regulations" applicable to the particular school.
- Interface between building usage (9:00 a.m. and 3:00 p.m.) and system operation (4:00 a.m. to 4:00 p.m.).
- Impact of fuel costs on energy generation cost.

TABLE 8.1

SUMMARY OF CONCLUSIONS

arold C. Scott lementary School - 6th grade 00 students 25 staff	1965 Original Building 14 C.R. + Library Walls: 4" F.B. + 4½" Insulrock + 4" C.B. + P.F. Roof: B.U.R. + 2½" Insulrock Glass: S.P.; 22% wall area	Heating System Gas H.W. U.V. 5500 degree days
	1967 Addition 4 C.R. Walls: Roof: See above Glass:	Lighting Fluorescent

nergy Conservation Item	Initial Capital Cost	Annual Savings
-1 "Reduce Outside Air Quantities"	$ 6,000	$ 1,380
-2 "Revise Occupied/ Unoccupied Cycle"	0	1,535
-3 "Replace Gas Boilers"	19,500	2,617
-1 "Add Roof Insulation"	17,300	2,795
-2 "Double Pane Glass"	30,390	890

APPENDIX A

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

AASA SCOTT SCHOOL WARWICK RHODE ISLAND (Present Building)

MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	300721.	744	0.	0	0.	0.	0.	7943.	0.	2670.	10613.	0
FEB	262659.	672	0.	0	0.	0.	0.	6066.	0.	2520.	8586.	0
MAR	222931.	744	0.	0	0.	0.	0.	7356.	0.	2560.	9916.	0
APR	116558.	[illegible]	0.	0	0.	0.	0.	6437.	0.	2435.	8872.	0
MAY	43570.	[illegible]	0.	0	0.	0.	0.	7650.	0.	1920.	9570.	0
JUN	11005.	341	0.	0	0.	0.	0.	5556.	0.	1755.	7311.	0
JUL	0.	0	0.	0	0.	0.	0.	1190.	0.	0.	1190.	0
AUG	0.	0	0.	0	0.	0.	0.	1190.	0.	0.	1190.	0
SEP	8724.	396	0.	0	0.	0.	0.	5850.	0.	1790.	7640.	0
OCT	68950.	705	0.	0	0.	0.	0.	7356.	0.	2010.	9366.	0
NOV	150057.	720	0.	0	0.	0.	0.	6730.	0.	2100.	8830.	0
DEC	248701.	744	0.	0	0.	0.	0.	5594.	0.	2970.	8564.	0
ANN	*1423377.	4341	0.	0	0.	0.	0.	68919.	0.	22730.	91649.	0

*Heating Energy Required

$$\text{Gas Consumption} = \frac{1{,}423{,}377\ \text{MBTU}}{100{,}000\ \text{BTU/CCF} \times 67\%\ \text{efficiency}} = 21{,}250\ \text{CCF @ } 4{,}774\ \text{degree days}$$

APPENDIX A

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

AASA SCOTT SCHOOL WARWICK RHODE ISLAND

(Increase Roof R by 10)

MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	190497.	744	0.	0	0.	0.	0.	7943.	0.	2255.	10198.	0
FEB	163207.	672	0.	0	0.	0.	0.	6066.	0.	2140.	8206.	0
MAR	137649.	744	0.	0	0.	0.	0.	7356.	0.	1965.	9321.	0
APR	71481.	658	0.	0	0.	0.	0.	6437.	0.	2015.	8452.	0
MAY	26672.	617	0.	0	0.	0.	0.	7650.	0.	1985.	9635.	0
JUN	6084.	341	0.	0	0.	0.	0.	5556.	0.	1775.	7331.	0
JUL	0.	0	0.	0	0.	0.	0.	1190.	0.	0.	1190.	0
AUG	0.	0	0.	0	0.	0.	0.	1190.	0.	0.	1190.	0
SEP	5591.	396	0.	0	0.	0.	0.	5850.	0.	1790.	7640.	0
OCT	35564.	705	0.	0	0.	0.	0.	7356.	0.	1795.	9151.	0
NOV	92011.	720	0.	0	0.	0.	0.	6730.	0.	1790.	8520.	0
DEC	153549.	744	0.	0	0.	0.	0.	5594.	0.	2650.	8244.	0
ANN	* 882304.	6341	0.	0	0.	0.	0.	68919.	0.	20160.	89079.	0

*Heating Energy Required
Gas Consumption = $\frac{\text{882,304 MBTU}}{\text{100,000 BTU/CCF x 67\% efficiency}}$ = 13,170 CCF @ 4,774 degree days

ENERGY REQUIREMENT ESTIMATE PROGRAM FOR

AASA SCOTT SCHOOL WARWICK RHODE ISLAND (Increase Roof R by 10 + Revise Occupied Cycle)

MONTHLY AND ANNUAL LOADS

	HEATING MBTU	HEAT HOURS	COOLING TON-HRS	COOL HOURS	HUMIDFCN MBTU	IND PROC MBTU	DIR PROC MBTU	BS ELEC A KWH	BS ELEC B KWH	BS ELEC C KWH	TOT BS EL KWH	AUX F HRS
JAN	159842.	744	0.	0	0.	0.	0.	7943.	0.	1875.	9818.	0
FEB	139957.	672	0.	0	0.	0.	0.	6066.	0.	1870.	7936.	0
MAR	112210.	744	0.	0	0.	0.	0.	7356.	0.	1595.	8951.	0
APR	55320.	658	0.	0	0.	0.	0.	6437.	0.	1725.	8162.	0
MAY	16441.	617	0.	0	0.	0.	0.	7650.	0.	1595.	9245.	0
JUN	4908.	341	0.	0	0.	0.	0.	5556.	0.	1500.	7056.	0
JUL	0.	0	0.	0	0.	0.	0.	1190.	0.	0.	1190.	0
AUG	0.	0	0.	0	0.	0.	0.	1190.	0.	0.	1190.	0
SEP	5006.	396	0.	0	0.	0.	0.	5850.	0.	1470.	7320.	0
OCT	23166.	705	0.	0	0.	0.	0.	7356.	0.	1410.	8766.	0
NOV	71687.	720	0.	0	0.	0.	0.	6730.	0.	1455.	8185.	0
DEC	134335.	744	0.	0	0.	0.	0.	5594.	0.	2390.	7984.	0
ANN	* 722874.	6341	0.	0	0.	0.	0.	68919.	0.	16885.	85804.	0

*Heating Energy Required

$$\text{Gas Consumption} = \frac{722,874 \text{ MBTU}}{100,000 \text{ BTU/CCF} \times 67\% \text{ efficiency}} = 10,790 \text{ CCF @ } 4,774 \text{ degree days}$$

APPENDIX B

APPENDIX B

BACK-UP CALCULATIONS

I. BUILDING CONSTRUCTION (ASHRAE Handbook of Fundamentals, pages 357-374)

Roof	'R' Value
Outside Surface	.17
Built-up Roofing	.33
2-1/2" Insulrock	4.00
Inside Air Film	.61
	5.11

U = 1/R = .20 BTU/Hr. sq.ft. degree F.

Walls	'R' Value
Outside Surface	.17
4" Face Brick	.80
4-1/2" Loose Insulation	9.9
4" Concrete Block	.31
Plaster Finish	.39
Inside Air Film	.68
	11.86

U = 1/R = .08 BTU/Hr. sq.ft. degree F.

II. BUILDING INFILTRATION (ASHRAE Handbook of Fundamentals, pages 337-338)

Typical Classroom = (1) Door, 7'-0" x 2'-6"
(3) Operable casement windows

Air Infiltration = 27 Cubic Feet per Hour per foot of crack (windows)

= 77 Cubic Feet per Hour per foor of crack (doors)

Air Change = $\dfrac{27 \text{ Cubic Feet} \times 18 \text{ ft. crack} \times 3 + 77 \text{ Cubic Feet} \times 20 \text{ ft. crack}}{7{,}850 \text{ Cubic Feet (Room Volume)}}$

= .40 (for windward side classrooms)

Assume .25 air change for building

Outside Air = $\frac{.25 \times 276{,}100 \text{ cubic feet}}{60 \text{ minutes per hour}}$ = 1,200 cfm

III. DESIGN LOADS (Based on 70 degrees F. indoors, 0 degrees F. outdoors)

Transmission

708 MBTU/Hr. --- Walls, roof, windows

Outside Air

454 MBTU/Hr. --- 6,000 cfm ventilation air

Infiltration

90 MBTU/Hr. --- 1,200 cfm infiltration

IV. WEATHER DATA

1973-74 Degree Days --- 5,554 (U. S. Weather Bureau)
1974-75 Degree Days --- 5,559 (U. S. Weather Bureau)
Computer Degree Days -- 4,774 (New York City Weather Tape)