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ABSTRACT

Presented is a study of energy conservation opportunities in a Rhode Island high school. With the aid of an infrared camera system, researchers documented heat losses that were not evident to the naked eye. Each infrared thermogram obtained showed one or more types of heat loss and identified the specific sections of the building where the problems occurred. Results demonstrated thermographic inspection to be an effective analytical technique for appraising a building's thermal efficiency. These analyses of heat loss, together with concurrent studies of the facility's heating system and roof moisture, are presented in this report and form the basis for energy conservation recommendations. Offered are low, moderate, and high cost options for reducing heating costs. (Author/WB)

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New England Innovation Group, Providence, RI

Prepared for

National Science Foundation, Washington, DC Engineering and Applied Science

Jul 79

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NEW ENGLAND INNOVATION GROUP

Energy Conservation Measures for the Charles E. Shea Senior High School

Pawtucket, Rhode Island

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The New England Innovation Group operates an intergovernmental science and public technology program linking New England's public sector needs and productive capabilities to national research & development resources

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16. Abstract (Limit: 200 words)

A thermographic audit of a Pawtucket, Rhode Island high school is reported. Conducted with the aid of an infrared camera system, this thermographic study located heat losses not evident to the naked eye. Heat losses were documented and the thermograms analyzed to obtain complete knowledge of the location of all heat losses from the building complex. Each thermogram showed one or more types of heat loss together with the specific section of the building where it occurred. Priorities were assigned to various retrofit processes and a thermographic inspection conducted after retrofitting to confirm its efficacy. The study comprised an analysis and recommendations of heat loss and heating system appraisals plus an analysis of roof moisture inspection. Numerous thermograms illustrate the report. Results demonstrated thermographic inspection to be a highly effective analytical technique for appraising the relative thermal efficiency of buildings. Based on evidence from the thermographic energy audit, low, moderate, and high cost options were prepared for reducing heating costs. The importance of energy management as an ongoing effort is emphasized.

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Buildings	Heat loss
Heating	Energy management

b. Identifiers/Open-Ended Terms

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Energy Conservation Measures
for the
Charles E. Shea Senior High School
Pawtucket, Rhode Island

a public service report by the
New England Innovation Group
39 Pike Street, Providence, Rhode Island 02903
July 1979
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prepared under the direction of
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for the
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FOREWORD

The information in this report, produced by the New England Innovation Group (NEIG), is the result of a cooperative effort between NEIG, the Federal Laboratory Consortium, and local government. This study is part of an ongoing energy conservation technical assistance program designed and managed by NEIG to aid local governments and school districts in reducing heating costs and conserving energy. It will enable school and local government officials to get financial assistance for energy conservation measures provided by Title III of the recently passed National Energy Conservation Policy Act. This Act creates a cost-sharing energy-conservation grants program for schools, hospitals, units of local government, and public care institutions to assist them in identification and implementation of energy conservation measures to reduce energy usage and anticipated energy costs.

The type of technical assistance program conducted in Pawtucket, Rhode Island is unique and innovative. It involves the use of an analytical technique - infrared thermography - to pinpoint excessive heat loss from buildings in order to permit an accurate appraisal of the type and extent of retrofit required to reduce heating costs.

An innovation of this magnitude can be delivered to local governments and school districts only through intense cooperation between NEIG and the Federal Laboratory Consortium. Even more important is the source and extent of funding necessary to promote this intergovernmental program; therefore, recognition of the National Science Foundation and the Department of Commerce in their roles as "prime movers" of technology is important.

The results of this study will benefit the private sector since NEIG has been a leader in promoting the commercialization of infrared thermography for use in energy audits of buildings. The demand for competent cost-effective energy management services affords many new jobs and business opportunities. Individuals interested in becoming involved in this emerging new industry can contact NEIG for assistance.

ACKNOWLEDGMENTS

The opportunity for the New England Innovation Group (NEIG) to introduce its energy management program to the city of Pawtucket and its school system is due directly to the vision and leadership of Mayor Dennis M. Lynch. Mayor Lynch has contributed significantly to the NEIG Intergovernmental Science and Technology Program. As a member of the White House Intergovernmental Science, Engineering Technology Advisory Panel, he is helping to disseminate throughout the country the benefits of the types of projects within the program.

NEIG acknowledges the able assistance of Mr. William B. Rivers, Home Comfort, Inc., in conducting the thermographic inspection of the Charles E. Shea Senior High School and to Mr. Joseph V. McCarthy, P.E., in conducting the roof moisture inspection of that building.

NEIG also extends special recognition to Mr. Frank Zannini, who contributed the section on appraisal of the heating system. His expertise in heating system analysis enabled NEIG to present complete recommendations for the energy management study of this school.

The assistance of Mr. William Malloy, City Clerk of Pawtucket, in providing effective communication between school administration officials and NEIG is deeply appreciated.

NEIG acknowledges the cooperation of Mr. Edward J. Creamer, Business Administrator; Mr. Donald L. Mailhot, Supervisor of School Plant; and the staff of the school plant. Their eagerness to assist NEIG by providing all the data required for the study is greatly appreciated.

CONTENTS

INTRODUCTION

The purpose of this study was to identify cost effective energy conservation opportunities in a high school located in Pawtucket, Rhode Island. The results of this study will assist school officials in developing budgetary priorities in their attempt to reduce operating costs.

The thermographic energy audit is an innovative and unique approach to the study of heat loss from buildings. It is an indispensable analytical technique used in conjunction with a class-A walk-through audit to locate and document heat loss that is not evident to the human eye. This permits the assignment of priority to the various retrofit processes. Prior to any retrofit, a thermographic energy audit is conducted with the aid of an infrared camera system. A thermographic inspection is also used after a retrofit to confirm the quality of the retrofit process to ensure that dollars are properly spent to reduce operating costs.

Heat loss from the Charles E. Shea High School is documented in thermograms in this report. The thermograms were analyzed in order to acquire complete knowledge of the locations of all heat losses from this building complex. This information provides the building operators with extremely accurate data as input to their energy conservation program.

The thermograms in this report were taken outside the building after sunset unless otherwise noted. In all these thermograms, white represents high building surface temperatures, or excess heat loss. Gray and black represent low building surface temperatures, or normal heat loss. Some thermograms were taken inside the school. In some of these thermograms black and gray represent excess heat loss, and white signifies normal heat loss.

Each thermogram shows one or more of the types of heat loss considered in this study: infiltration, exfiltration, conduction, convection, and radiation. Each shows a specific section of the building in terms of the four cardinal points of the compass.

Based on the evidence from the thermographic energy audit, the heating system of the building is analyzed and recommendations for reducing heating costs are made.

MANAGEMENT SUMMARY

Recommendations

Low Cost Options.

1. Reduce the air temperature in the swimming pool area to 70°F when the pool is not in use.
2. Close vestibule doors during the heating season.
3. Avoid further replacement of the double-hurg windows.

Moderate Cost Options.

4. Install turbulators in the boiler fire tubes.
5. Repair steam distribution equipment.
6. Install automatic temperature control valves on radiators.
7. Install night and weekend temperature set back.
8. Install an optimum heat starter.
9. Connect cafeteria unit ventilators to the master control system.

High Cost Options.

10. Retrofit the classroom unit ventilators to (a) automatically provide controlled heating and ventilating and (b) include an economy cycle to conserve energy.
11. Replace the three existing burners with cleaner burning, more efficient, forced draft burners.

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Conclusions

1. A thermographic inspection is a highly effective analytical technique for appraising the relative thermal efficiency of buildings. For example, with this technique detailed evaluation and documentation of air leakage around the crack lengths of 13 percent of the original windows indicated that this leakage is no greater than the leakage around the newer windows. This analysis, combined with calculations of the heat conduction through the glass, led to the conclusion that further replacement of the original windows is not cost effective.

2. During the thermographic inspection and several subsequent visits to the school the following deficiencies with the heating system were identified which contribute to unnecessary fuel consumption and to the discomfort of the students and staff of the school: (a) the classroom unit ventilators are not capable of operating as designed; (b) there is no means to automatically control the individual steam radiators in the classrooms, auditorium, gymnasium, hallways, stairways, and offices; (c) the rotary cup oil burners are not as efficient and clean burning as the newer air atomized burners available today; and (d) the steam distribution system is in need of repair.

3. It cannot be emphasized too strongly that energy management should be an ongoing effort. Adequate record keeping, including heating consumption and degree-day data as well as fuel unit cost should be an important part of any energy management program.

HEAT LOSS APPRAISAL

ANALYSIS

Building Construction Characteristics

Exterior construction: concrete/face brick

Interior construction: brick/concrete/plaster

Wall thickness: 16 inches

Heated floor space, ft^2: 116,937

Ceilings	Average height, ft	Area, ft^2
Classrooms	10	75,321
Multipurpose rooms	30	16,652
Corridors	10	24,964

Exterior walls, ft^2	North	South	East	West	Total
Below ground	1,230	1,280	3,230	6,680	12,470
Above ground	6,400	6,400	16,150	26,650	55,600
Windows, ft^2					
Classrooms	1,854	1,872	2,478	1,770	7,974
Multipurpose rooms	975	975	9	72	2,031
Corridors	-	-	246	204	450
Crack length, ft					
Moveable	1,935	1,953	1,190	1,764	6,842
Fixed	12	12	1,630	136	1,790
Thermographically inspected	194	138	325	438	1,095
Thermographically inspected, %	10	7	12	23	13
Air leakage factor	Mod	Mod	Exc	Min	-

Min = minimal
Mod = moderate
Exc = excessive

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	North	South	East	West	Total
Doors, ft^2	21	21	147	147	336
Crack length, ft	20	20	140	140	320
Thermographically inspected	(not inspected)				
Thermographically inspected, %	-	-	-	-	-
Air leakage factor	-	-	-	-	-

Roof

Area, ft^2: 37,131

Surface: tar and gravel

Deck: precast concrete planks

A thermographic inspection of the Charles E. Shea Senior High School was conducted on November 29, 1978, from 1700-1930 hours. This school, constructed in 1940, has a swimming pool in addition to the usual multi-purpose rooms. The heated floor space is approximately 117,000 sq ft.

Both the thermographic inspection and the walk-through inspection indicated that the excessive fuel consumption can be attributed to gross overheating of the building. Thermograms 16 and 17 show excess heat loss from the auditorium several hours after classes had been dismissed. Thermograms 20 and 21 show overheated hallways on the second and third floors and one overheated classroom on the second floor, all on the west side of the building.

The thermographic inspection also indicated that a number of faulty damper linkages on unit ventilators are a secondary cause of excessive fuel consumption. All of these malfunctioning unit ventilators were located on the second and third floors of the north, east, and west sides of the building (thermograms 9, and 11-16). A total of nine malfunctioning unit ventilators were identified.

Thermogram 10 shows excess heat escaping from the vent in the swimming pool area after normal school hours. The temperature in the pool area was in excess of $80^{o}F$ at the time of the inspection.

The comparison of air leakage around selected windows on the east side of the building with the leakage around selected windows on the north, south, and west sides was one of the most significant results of the thermographic inspection. The classroom and office windows on the east side of the building are newer windows with aluminum frames, glass blocks in the top 67 percent of the frames, with approximately 30 percent of the amount of single paned glass that is found in each of the wood frame double-hung classroom windows. A comparison of thermograms 1-9 shows that the air leakage around the original double-hung windows is no greater than the leakage around the newer windows.

Twelve percent of the total crack length of the newer windows, or 325 linear feet, was randomly selected for thermographic inspection; 13 percent of the total crack lengths of the original windows, or 770 linear feet, was randomly selected for inspection.

The fact that the air leakage around the newer windows is no greater than that around the original windows means that any reduction in heat loss through the newer windows will have to be made in the heat conduction through the frame, the single paned glass, and the glass blocks. A comparison of the total loss of each of the two types of windows indicates that the difference is marginal at best. These calculations show that the newer windows reduce the fuel consumption by less than one gallon of oil per day when the difference in air temperature between inside and outside is approximately 70°F. This reduction translates into an annual savings of less than $500, based on the current cost of #4 fuel oil. Obviously, the magnitude of this saving would result in an abnormally long payback period.

Figure 1 shows a plot of the fuel oil consumption of Shea High School during the past 5 years. Between July 1975 and July 1976 consumption was reduced by about 16 percent; however, the following year it increased by more than 13 percent with only a small reduction (1 percent) in 1978.

According to National Weather Service (NWS) data the number of heating degree days between July 1975 and July 1976 increased by more than 17 percent. Although historically the NWS heating degree days data have been used quite extensively, NEIG has been studying the use of heating degree day data derived by the DeBlois Oil Company from the Johnson Meter. This device yields a measurement of heating degree days that takes wind and solar radiation into consideration. Analysis of these data shows no significant change in the number of heating degree days between 1975 and 1976, although the number of degree days is about 25 percent higher than reported by the NWS.

Figure 2 shows a steady decrease in electrical consumption at the Shea High School during the 1975-78 period. This 22 percent decrease has resulted in a 21 percent decrease in cost.

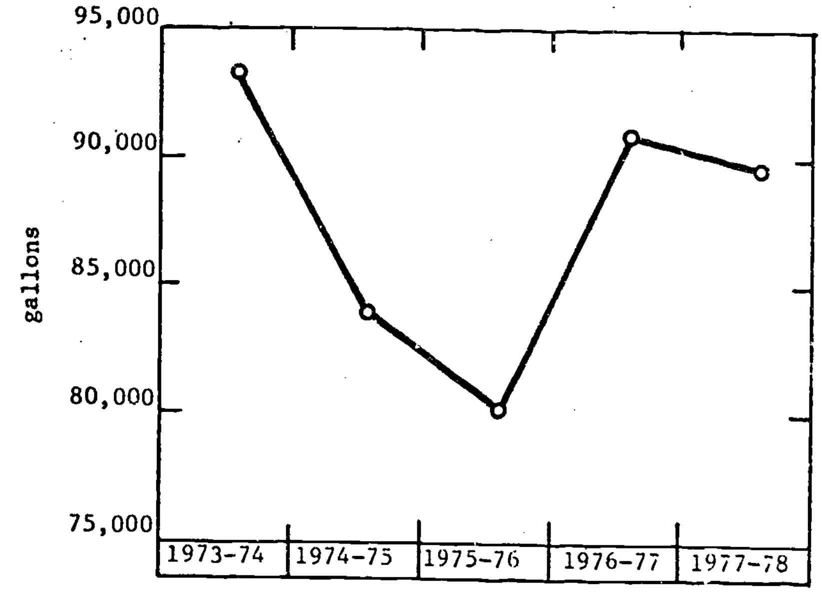


Figure 1. Fuel Oil Consumption, 1973-78

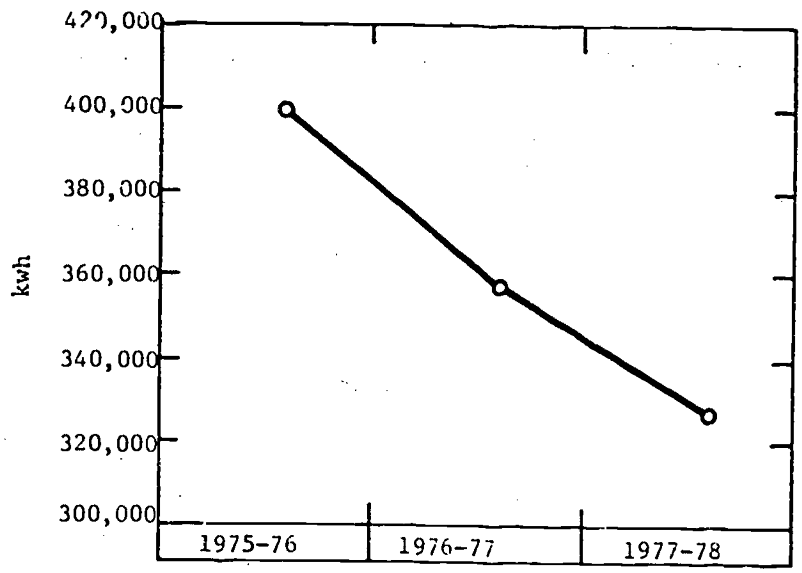


Figure 2. Electric Consumption, 1975-78

Although attempts have been made at Shea High School to reduce the volume of the air changes and to achieve temperature setbacks, Figure 1 shows that a reduction in consumption of only 1 percent has been achieved since July 1976. The difficulty encountered in further reducing consumption is undoubtedly due to the problem of controlling the temperature, a problem caused in part by the malfunctioning of the unit ventilators.

Heat Loss Due To Air Leakage

North Face

1.-2. Around sill of double-hung window in science room

South Face

3. Around rails of third floor windows

East Face

4.-5. Around sill of window with glass blocks
6. Around top of first and second floor windows with glass blocks
7. Around top of second and third floor windows with glass blocks

West Face

8. Around double-hung classroom window

Heat Loss Through Open Vent(s)

North Face

9. Malfunctioning third floor unit ventilators

South Face

10. Vent for swimming pool

East Face

11. Malfunctioning third floor unit ventilator
12. Malfunctioning second floor unit ventilator

West Face

13. Malfunctioning second and third floor unit ventilators

14.-15. Malfunctioning third floor unit ventilator

Potential Heating System Problems

North Face

16. Excess heat loss due to overheating of auditorium after normal school hours

South Face

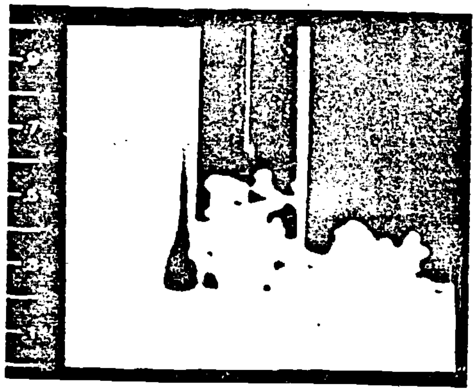
17. Excess heat loss due to overheating of auditorium after normal school hours

East Face

18.-19. Excess heat loss from overheated room

West Face

20.-21. Excess heat loss from overheated hallways after normal school hours



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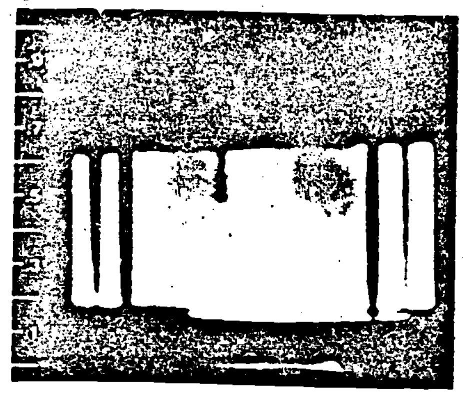

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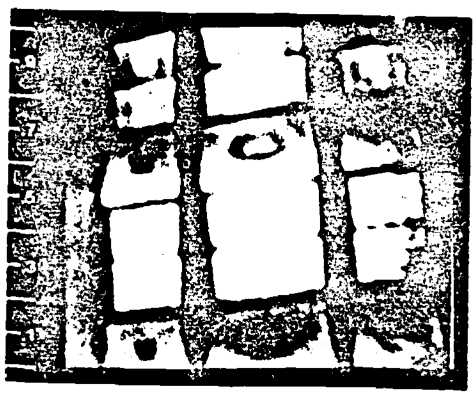

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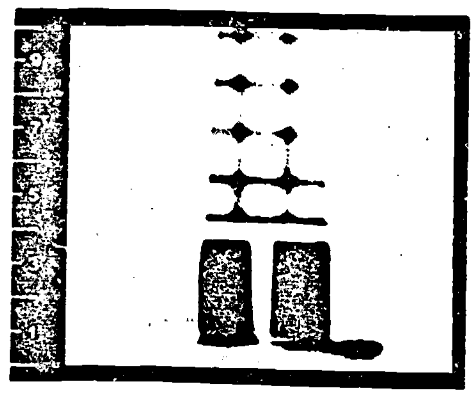

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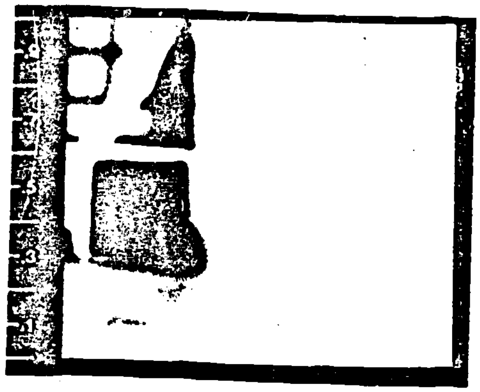

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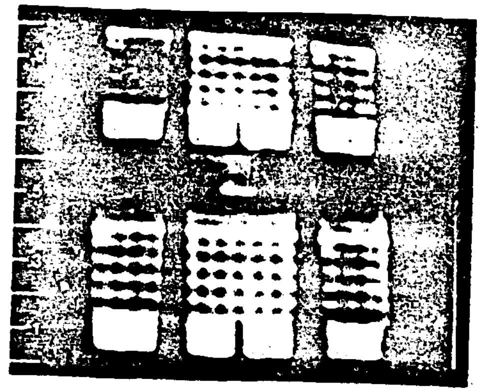

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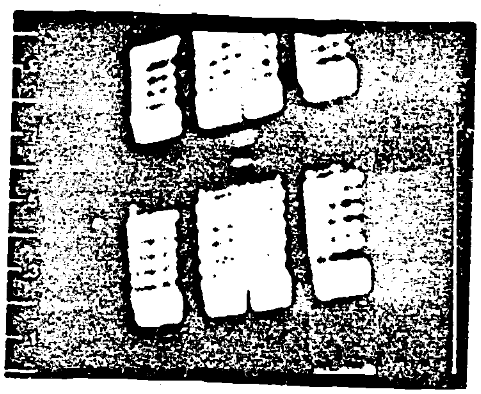

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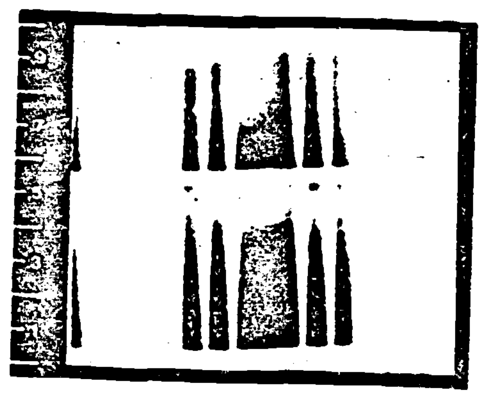

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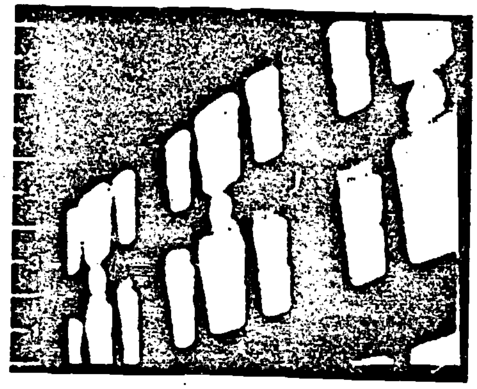

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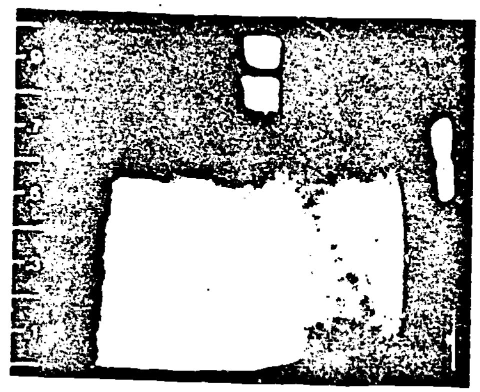

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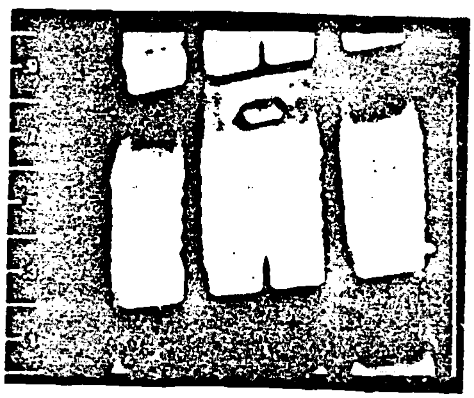

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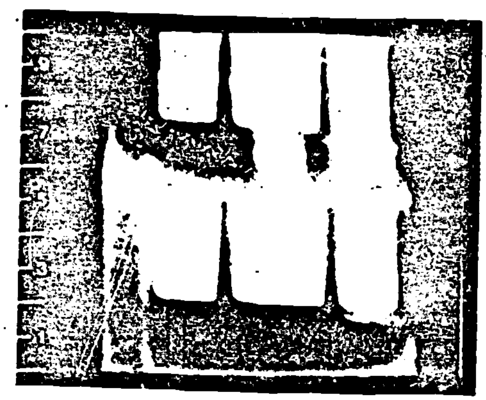

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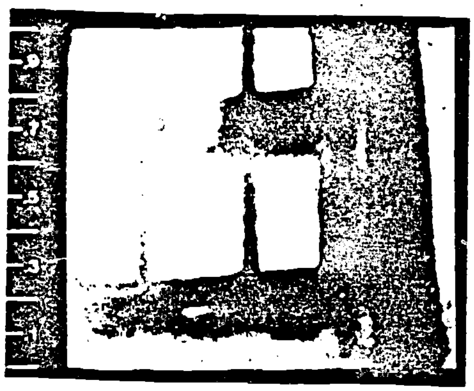

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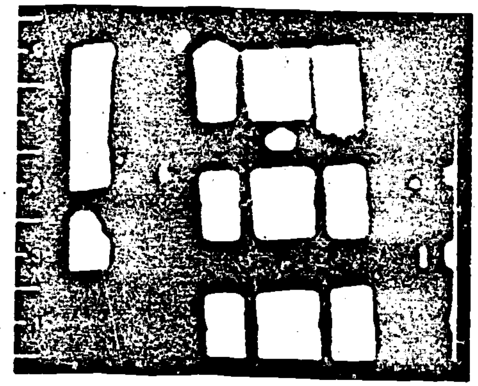

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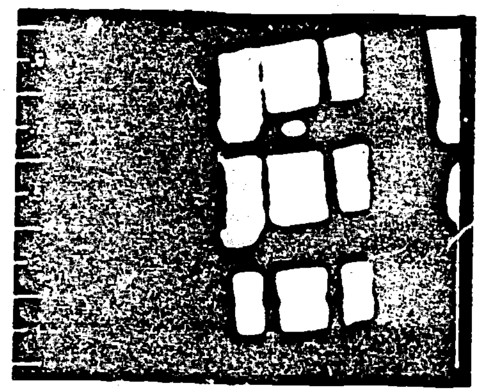

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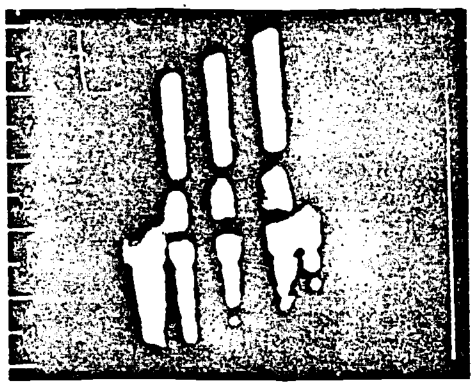

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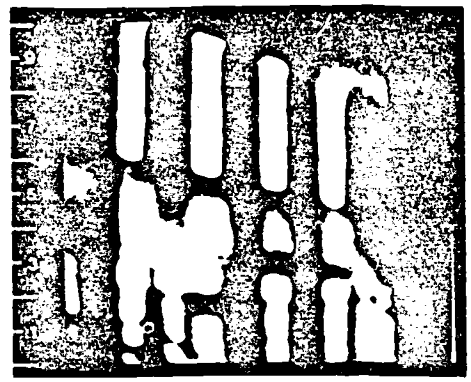

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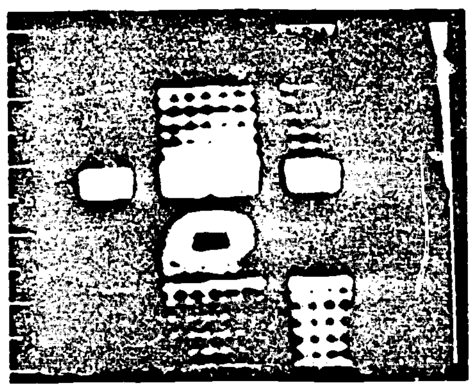

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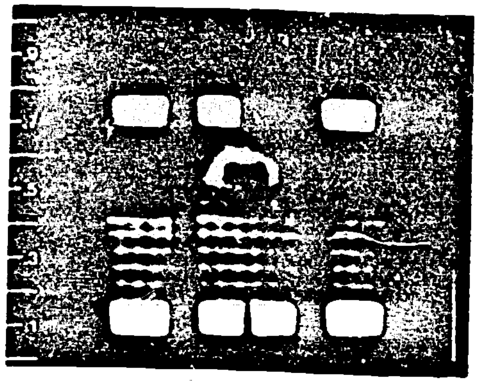

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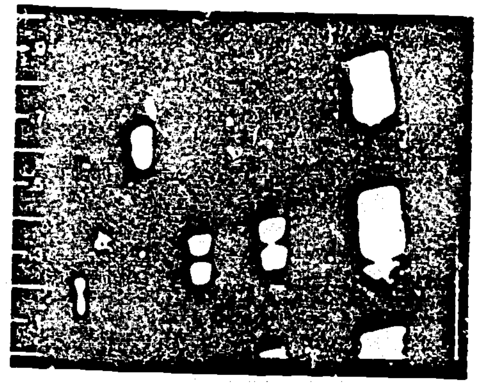

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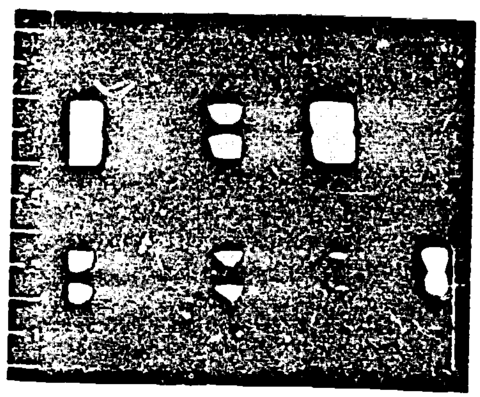

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RECOMMENDATIONS

1. Reduce the air temperature in the swimming pool area to 70°F when the pool is not in use.

   The thermographic and walk-through inspections indicated that this area is being grossly overheated when not in use. Consideration should be given to a temperature set back when the pool area is unoccupied.

2. Close vestibule doors during the heating season.

   During the thermographic and walk-through inspections the vestibule doors on the east facing entrances were always open. This completely defeats the purpose of the vestibule as an air lock.

3. Avoid further replacement of the double-hung windows.

   The thermographic inspection clearly indicated that the air leakage around the original windows is not excessive. Further quantitative analysis showed that the total heat loss through the newer windows is only slightly less than that through the original windows, resulting in an abnormally long payback period.

HEATING SYSTEM APPRAISAL

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ANALYSIS

The Shea High School building is heated by three Fitzgibbons fire tube boilers and fired by Ray #AR-131 size 6 rotary cup oil burners with a firing rate of 12 to 50 gallons per hour using #4 heavy fuel oil. The steam distribution system is divided into five heating zones: north, south, east, gymnasium/auditorium, and swimming pool. A unit ventilator provides heat in each classroom, and an additional radiator is installed in each corner room with two outside walls. The gymnasium is heated by 10 nine-section wall-hung cast-iron radiators. The main line that supplies the gymnasium also feeds the cast-iron radiators in the auditorium above. Two unit ventilators supply heat and ventilation to the cafeteria. Numerous cast-iron radiators provide heat in the stairwells, corridors, offices, and auxiliary spaces in the building.

During several inspections of the building, the following conditions which contribute to unnecessary fuel consumption and to the discomfort of the occupants of the building were identified:

A. Classrooms

The unit ventilators in the classrooms which mix fresh air and heated air for ventilation and automatically control the room temperature are not operating. The air dampers are permanently closed, the damper motors are disconnected, and the thermostats (1938 vintage) are no longer functioning. The condition of this heating equipment compels the students and teachers to regulate the room temperature by manually turning the fan motors on and off or simply opening windows to expel expensive heated air. During the thermographic inspection these rooms were overheated. The room temperatures ranged from 75°F to 80°F at 6 PM, 3 hours after school was dismissed. The radiators that supplement the unit ventilators in the corner rooms were also heating because there are no valves to shut them off.

B. Gymnasium/Auditorium

It is difficult to control the temperature in these two spaces because the same steam main supplies both areas. Energy is also wasted because both areas must be heated when one or the other is occupied. It is common practice to open windows to expel heated air to cool the gymnasium because there are no separate control valves to control the heating of this space. The gymnasium contains sufficient radiation for heating purposes; it was noted that only six of the ten sections of the wall radiators are connected.

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C. Cafeteria

Although two fully controllable unit ventilators serve the cafeteria these units are manually turned on and off from the custodians office.

D. Corridors

During the thermographic inspection, the temperatures in the corridors were above 70°F at 6 PM. The radiator in the stairwell was heating when no classes were in session. As is the case in the classrooms the radiators in the hallways cannot be shut down either because the valves are missing or because the valves were never installed in the first place.

E. Boilers

The boiler room is well maintained and the operating routines indicate that the fire tubes are cleaned at least two times each year. From the appearance of the boiler room, one would conclude that the staff is making a great effort to maintain the equipment within their resources. At the present time, one boiler is out of service awaiting repairs.

F. Oil Burners

According to modern standards of performance, the rotary cup oil burners on the boiler are considered less efficient and more polluting thar air atomized burners now being manufactured. Also, replacement parts for rotary cup oil burners are becoming exceedingly difficult to obtain.

G. Steam Distribution System

The steam distribution system includes the condensate return pumps, radiators, traps, valves, and piping. The piping appears to be in good condition, but there are problems with the condensate pumps and valves: (a) the valves on the steam returns fail to hold the condensate, which makes it impossible to isolate a boiler not in use; (b) the zone valves are bypassing steam, so the individual heating zones cannot be isolated when heat is not required; and (c) the condensate pumps leak and are in need of repair.

H. Steam Control System

The control of the steam system has been reduced to a manual function over the years, except that the burners are automatically controlled by pressurestats. The temperature of the building is controlled by the boiler operator. At one time a Variac temperature control system positioned the four zone valves according to the heating requirements of the building; however, these valves and controls were disconnected many years ago.

RECOMMENDATIONS

1. <u>Retrofit the classroom unit ventilators to (a) automatically provide controlled heating and ventilating and (b) include an economy cycle to conserve energy.</u>

The unit ventilators should be restored to optimum working condition by repairing the equipment and installing economy cycle temperature controls. From an inspection of the existing units, a feasible approach would be to add new damper motors and automatic radiator valves, repair the leakages, and replace the thermostats with the new vandal-proof types available. The implementation of this retrofitting program would require the assistance of an organization that specializes in heating and ventilating control systems.

If, after further study, the first recommendation is not found to be feasible, the second approach would be to convert the existing unit ventilators to fan coil units. This would be by far the simplest retrofitting to accomplish, but the fan coil units would not provide automatic ventilation for the classrooms. Conversion to the fan coil units would simply require the blocking of the fresh air intake and the addition of a thermostat and controls to cycle the existing fan motor to control the room temperature.

The economy cycle of a unit ventilator varies according to each manufacturer. The general operation in its simplest mode is as follows: When the room temperature is below the setting of the thermostat (a) the outside fresh air damper is closed and no fresh cold air enters the room, (b) the radiator valve is open and permits full steam heating capacity to the heating coil, and (c) the return air damper is open and circulates room air through the heating coil. When the room temperature is satisfied, that is at the thermostat set point or above, (a) the outside damper opens to a maximum position, (b) the return air damper closes to a minimum position, and (c) the radiator valve closes.

This description is an oversimplification of the economy cycle, and additional steps and controls are necessary to deliver optimum results. The economy cycle saves energy because when heating is necessary no cold air is drawn into the building. The economy cycle only expels overheated air, which is the heat gain resulting from lights, processes, and body heat. On cold days, the economy cycle permits the introduction of only a minimum of fresh air; whereas, on warmer days, the building is made comfortable by full outside air ventilation.

2. <u>Install automatic temperature control valves on radiators</u>.

A. Gymnasium/Auditorium

It is essential that automatic temperature control be established in these spaces because the auditorium may be in use when the gymnasium is not and vice versa. At present, however, both spaces are heated at the same time. This problem could be solved by the installation of electrically or pneumatically operated valves on each radiator, controlled by a separate thermostat in the respective space.

As previously noted, four sets of radiators in the gymnasium are disconnected. It is assumed that they were disconnected because of the overheating problem. They should be reconnected so that the additional radiation will permit quick warm-up just before the gymnasium is to be occupied. This would reduce building heat losses because the space would be heated for a shorter period of time.

B. Hallways, Corridors, Stairwells and Auxiliary Space

These spaces could be maintained at 60°F both day and night. The radiators in these locations could be controlled by either the more expensive motorized valves or the self-activating type, which are self-contained, easy to install, inexpensive, and require no tie back to a master control system. The payback for these valves is less than one heating season.

C. Classroom Radiators

The classrooms with two exposed walls have a radiator in addition to the unit ventilator to provide additional heat. The temperature control for these radiators must be tied into the unit ventilation cycle previously described.

D. Office Radiators

These radiators should be controlled by automatic radiator valves and thermostats in the respective spaces.

3. <u>Install night and weekend temperature set back</u>.

The high school offers a good opportunity to conserve heat by automatically reducing the heat at night and during the weekend when classes are not in session. It is estimated that the school is fully used only 25 percent of the time and should be heated to 68°F only during this time. At other times the temperature should be reduced to 55°F. It is understood that at the present time the boilers are cut back by the operator after school hours.

An automatic night setback with a 7 day timer should be installed to reduce the heat on weekends. The system should be designed to provide for separate control of the gymnasium, auditorium, cafeteria, pool, and each floor level. By zoning the school as described, only specified areas would be heated when in use, while the rest of the building could remain at the cooler temperature when unoccupied.

4. Install an optimum heat starter.

In addition to the master clock for night and weekend temperature set back, the system should include an optimum heat starter. The addition of this control would cause the building heat to be turned on according to the outside temperature. Energy would be saved on warm days by starting the heat later in the morning; on colder days the heat would be started earlier to ensure that the temperature rose to a comfortable occupancy level.

5. Replace the three existing burners with cleaner burning, more efficient, forced draft burners.

Further economies can be realized by replacing the existing rotary cup oil burners with modern air atomized oil burners. The oil burner industry projects a minimum of about 15 percent savings in fuel consumption by changing to the new burners. The State of Rhode Island is in the process of passing legislation to require the replacement of rotary cup oil burners.

6. Install turbulators in the boiler fire tubes.

The installation of these unique baffles in the fire tubes could result in savings in fuel consumption of up to 15 percent.

7. Connect cafeteria unit ventilators to the master control system.

A separate clock system should be installed for the cafeteria when the night/weekend temperature set back is installed.

8. Repair steam distribution equipment.

The steam valves and condensate pumps should be repaired and restored to good operating order. The repair of the valves would make possible the isolation of boilers when they are not needed for heating. Isolation of the boilers prevents heated water from being transferred to the standby boiler, saving fuel by not allowing heat to radiate from the surfaces of the standby boiler and escape up the smokestack.

The estimated cost of implementing the recommendations is $95,000. This figure should be used for preliminary budgeting only. Final cost figures can be accurately determined only after the specifications for the retrofit program have been prepared. Table 1 is an outline of the estimated cost and recovery periods that can be anticipated, based on the experience of the heating and ventilating industry with other similar retrofit programs. The determination of the years required to recover the investment is based on an annual consumption of 88,000 gallons of fuel and an annual 8 percent inflationary increase in the price of oil.

TABLE 1

ESTIMATED RETROFIT COSTS, FUEL SAVINGS, AND PAYBACK

Recommendation[a]	Cost, $	Fuel savings, %	Payback, yrs	Annual savings[c]
Retrofit classroom ventilators, include economy cycle, add automatic control valves	32,000	15	4.25	7500
Install night/weekend set back, optimum time start, new controls	12,000	15	2.10	5750
Install new oil burners	38,000	15	6.70	5700
Install turbulators	6,500	11	1.50	4300
Repair steam distribution system	7,500[b]	-	-	-
Total estimated cost	95,000			

[a] The payback period is estimated by following the recommendations as presented. Slightly different values would be obtained if it were decided to implement the replacement of the burners as the first item.

[b] It is difficult to assess savings, but the system must be repaired in order to operate effectively.

[c] During payback period.

ROOF MOISTURE INSPECTION

INTRODUCTION

Most large buildings are constructed with flat roofs. Because of roof design and construction deficiencies, improper drainage always creates problems. Moisture that permeates the roof membrane is usually absorbed by the nonrigid insulation underneath and retained. When this occurs the insulation loses its insulating characteristics and excess heat is lost through the roof. If the insulation becomes saturated the excess water will find its way through the roof deck and begin leaking into the interior of the building. The exact location of the leak will not necessarily coincide with the location of wet insulation.

It is extremely difficult to pinpoint the location of wet insulation under a roof membrane. Cores can be taken from the roof for visual inspection; but, without a previous knowledge of where to extract the cores, the wet or deteriorated insulation may or may not be found.

If an infrared camera system is used after sundown to inspect the roof, locations of deteriorated insulation under the membrane can be detected. Solar heat warms the roof during the day. After sundown the roof areas with wet insulation lose heat more slowly than the dry areas because of the capacity of moisture to retain heat. Consequently, the locations denoting the presence of moisture or moisture laden insulation appear as bright areas on the TV monitor of an infrared camera system. The operator of the system can then direct personnel on the roof to outline these bright areas with paint. During the day a roofing contractor can cut into the roof and extract cores from the outlined suspect areas.

Our experience to date indicates that the infrared camera system is capable of detecting evidence of moisture under a roof membrane months after moisture has disappeared. This information can be used by building managers to assist them in locating the source of future leaks, should they occur.

ANALYSIS

Thermographic inspection date	May 15, 1978
Thermographic inspection time	2030 hours
Roof deck material	concrete
Insulation type	not applicable
Insulation thickness	0
Roof area	37,131 sq ft
Insulated/uninsulated area of deterioration	235 sq ft
Insulated/uninsulated area of deterioration, %	1

Comments

The thermographic inspection indicated the presence of seven relatively small and three slightly larger locations of potential water entry under the membrane. Cores were taken from the three larger locations. Evidence of water penetration was found in an area approximately 20 sq ft at the northwest corner of the north section of the building. There is evidence of extensive patching of the membrane at this location. Evidence of water penetration was found at the northwest corner of the auditorium stage roof. The felts at this location were badly wrinkled and deteriorated. Evidence of water entry was also found in an area about 200 sq ft on the roof over the swimming pool. This area was not marked, but it includes a five foot wide strip extending from the northeast section to a point about half the length of the roof and then in a five foot wide strip across the width to the west side of the roof. There is evidence of extensive patching near the hatch on the west side of the roof.

No corrective action is required since the amount of membrane deterioration due to water entry is less than 1 percent of the total roof area.

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