On 23 July 2014 a commercial-grade energy audit at ASHRAE level 2 was conducted by Eastern Building Performance at the request of the Affordable Heat Consortium and in cooperation with the Eastport School Committee. (full report attached)

The purpose of this audit was to understand more about the way winter heating works at Shead, how well the buildings perform, and how future investments in the heating systems (insulation, fuel, mechanicals, distribution, controls, occupant behavior, etc.) can save money while increasing comfort for the students and staff.

As a baseline, it is useful to note that heating season costs are high and rising at Shead High School while occupancy levels ready stable. Here are the heating fuel consumption figures for the last three winters:

winter ’10-’11	10,578 gal #2 oil	$28,067
winter ’11-’12	11,712 gal #2 oil	$38,767
winter ’12-’13	13,194 gal #2 oil	$43,672
3 winter total:	35,484 gal #2 oil	$110,505

During this same period the reliability of the 1965 oil boiler supporting the gymnasium has been actively questioned, while the proper functioning of the unit ventilators (heating devices in each classroom connected to the large louvers under main window units) is increasingly uncertain. The effectiveness of the main windows associated with these unit ventilators is also decreasing, with noticeable drafts and moisture penetration in many classrooms and offices that result in discomfort, low heating efficiency, and low morale.

(left) Typical unit ventilator grill, with evidence of improvised control (screwdriver through to internal adjustment knob) due to improper thermostat control.

(below) Typical main window unit with unit ventilator, exterior and interior views, with evidence of snow penetration due to poor window jamb fitting.

(below left) Shead's gymnasium oil-fired boiler, c. 1965, providing steam to ceiling blower units (below right) where an inline heat exchanger converts the steam energy to hot air, which is forced downward into the 9,000 sq. ft. space.

The attached audit report provides useful information to guide future investments in the heating system at Shead, and it deserves a careful review by all interested parties. A brief summary of the key points is provided below.

1. There is little opportunity to improve the insulation levels of the building, since no wall or ceiling cavities exist and the expense of adding a layer throughout would far outweigh the associated savings (although adding insulation during a routine roof replacement is recommended).

2. There is little opportunity to change the type of heating fuel used to support the hydronic radiant system in the main school building, since bulk fuel storage would require new construction and, as above, the expense of these interventions would outweigh the associated savings (although augmenting the oil-fired radiant system with mini split heat pumps may be a good option, and is address in some detail in the audit report.)

3. There are few advantages to be gained by replacing windows, which is an expensive undertaking with low efficiency gains. The existing shortcomings of the windows during the winter season (cold air and moisture infiltration) can be addressed with interior temporary storm window inserts at a much lower cost.

4. The unit ventilators used to heat classrooms can be retained to advantage is their controls – and especially their automatic air dampers controlling flow of outside air – are properly repaired and adjusted, and that the staff is trained to use them efficiently.

5. The existing heating system's high fuel consumption pattern could be improved by installation of auxiliary heat pump units in those spaces that have highest use and occupancy through the winter. These units convert energy into useful heat much more efficiently, take load off the main system, and provide backup heat in case the main system fails temporarily.

6. The steam boiler supporting the gymnasium could be converted to an oil-fired unit compatible with the boilers supporting the main school building, increasing efficiency and simplifying maintenance. At the same time, surplus heat in the boiler room could be captured and recycled with a heat pump serving the locker rooms.

In relation to audit recommendations #3-6 above, it would be useful to obtain real world estimates from qualified local contractors in order to estimate the relationship of investment costs to anticipated savings. The Affordable Heat Consortium is ready to assist in this process at the request of the School Committee.

EASTERN BUILDING PERFORMANCE

Energy Audit Report: Shead High School, Eastport, ME

Eastern Building Performance LLC
1140 Shore Rd
Lamoine, ME 04605

Audit Date: 7/23/14
Audit address: 89 High Street, Eastport, ME

Recommendations for: The Shead High School

Building Overview:

The Shead High School was constructed to accommodate a student population of approximately 300 and the necessary associated staff and faculty. The student population has decreased over time and energy prices have risen. This has created a financial challenge for the Town of Easport, trying to heat and maintain an oversized building with rising costs and a limited budget. Improving the energy efficiency of the building could alleviate some of this challenge. It is clear that many steps were taken during construction to make the building energy efficient by the standards of the day. The majority of the cost effective upgrade opportunities therefore are in the area of mechanical systems that service the building.

The approximately 9,000 square foot gymnasium was built in 1965 as an addition on the main school building. The basement under the gym houses the boiler room, locker rooms and utility spaces. The above-grade walls of the gym are cinderblock construction and are insulated on the exterior with ¾" XPS foam board (R-3.75) covered with vinyl siding. If the siding is replaced in the future, an additional layer of 2" XPS foam should be installed over the existing material in a continuous layer followed by strapping and new siding. All joints in the new foam should be sealed with appropriate sealant and/or tape. The cathedral ceiling has an interior finish of v-match pine and an exterior of asphalt shingles. The insulation assembly between the interior and exterior finish is unknown and inaccessible. The only feasible opportunity for upgrading insulation in this area would be during roof replacement when the insulation in the roof system could be replaced with superior products or added to by layering rigid foam board over the existing sheathing, followed by new sheathing and roofing.

The main building has approximately 12,000 square feet of floor space. The majority of the building is built on a slab with no room for improvement of below grade insulation. The walls of the building are brick masonry with a single layer of 2" XPS foam board (R-10) at its core. Any upgrade to the wall insulation would need to include a new interior or exterior façade and would therefore not be cost effective. The roof assembly of the school could not be closely inspected due to restricted access as a result of radiation emitted from the radio broadcast antennae. Areas of tapered polyisocyanurate foam board roof insulation on a 1st floor roof were exposed and visible from the 2nd floor library. Assuming the rest of the roof is insulated in a similar manner, it likely has an R-value between R-14 and R-42 depending on the taper of the foam. Once the rubber roof

covering the insulation has outlived its useful lifespan and needs to be replaced, additional insulation could be added to the roof deck in the form of layered polyisocyanurate foam board or spray foam, followed by new roofing.

Windows and Doors:

Most of the windows in the building are double pane side-sliders. Some of the panes have failed causing fog and condensation between the panes. Many of the units do not slide easily in their tracks or fit tightly when closed. Despite these shortcomings, replacing windows would not be a cost effective upgrade. The cost of replacing windows is too high to be paid back in the lifespan of the product with energy savings alone. Adding interior storm panels is a much less expensive option that can eliminate drafts and improve thermal performance as much if not more than a replacement window. "Indow Windows" custom builds high quality storm inserts that retail for \$25-\$40/ft^2 and can be purchased through a network of dealers in Maine. Numerous other online retailers provide similar products at a similar cost.

Heating System:

The heating system for the building consists of numerous oil-fired boilers. When considering upgrades or changes to the heating system, it is important to consider the availability of the fuel source, how it will be stored and how much the new storage infrastructure will add to the cost of conversion. Another important consideration is the availability qualified professionals in the area to service and repair the equipment.

The main building is heated by a series of four residential-grade oil boilers. This system uses hot water radiators for distribution into individual rooms as well as heat coils within an air handler system that converts the hot water into hot air and distributes it to larger rooms and spaces in the building via ductwork. These oil boilers operate at an efficiency near 80%, which is as much as can be expected from an atmospherically vented, oil-burning boiler. A sealed combustion, condensing gas boiler can achieve 95% efficiency, but the cost of replacing the boilers and installing adequate gas storage would likely outweigh the savings over the lifespan of the new units. Therefore, keeping the oil boilers in service and reducing the percentage of the heat load that they provide with supplemental, low-cost, high efficiency heat pumps is advisable. Mini-split heat pumps operate at efficiencies two to three times that of the existing oil boilers and provide zone-heating capabilities that could be beneficial in a building where some spaces are used minimally or not at all. Rooms where the temperature is kept highest for longest would be good candidates for the first round of mini-split installs.

The gymnasium is heated by an oil-fired steam boiler. This unit was installed when this section of the building was constructed in 1965. Replacement of this unit in the near future seems inevitable. A second series of residential-grade oil boilers would be a logical replacement system. This switch would involve conversion of the distribution system from steam to hot water. The ceiling-hung radiators in the gymnasium may be

reusable with hot water, but the piping connecting them to the boiler room will likely need to be replaced.

Two vents on the wall of the boiler room provide fresh air for combustion and to cool the room which can easily overheat from the waste heat generated by the boilers. One of the vents appears to have an electronically controlled damper which opens when the boilers are firing and closes when they are not. The other vent appears to be open at all times. Ideally the waste heat from the boilers would be captured and used to heat the building rather than vented to the outdoors. Since the boiler room is small, having fresh air for combustion is advisable. The electronic damper ensures outside air only enters when it is needed. If the heat from the room can be removed, the vent that does not have a damper could be blocked. The air quality in the boiler room will inevitably be low compared to the occupied space in the building, so simply ducting the hot air from this space into the building is not advisable. Also, any fan blowing air out of the room could depressurize the space and cause a poor draft in the flue. It may be possible to utilize a mini-split heat pump to extract heat from the boiler room and send it into the gym or nearby locker rooms.

Ventilation:

The blower door test that was conducted on the building showed that at -50 pascals, 18,909 cubic feet per minute (CFM) of air flows through the building. This translates to an ACH50 of 10.5. Generally speaking, an ACH50 below 6 is considered tight, over 20 is considered leaky. Therefore, this building is fairly tight and offers limited opportunity for energy savings through reduction of leakage in the building envelope. This also means that mechanical ventilation is likely needed to ensure adequate air exchange and proper indoor air quality during times of high occupancy.

Although the building needs mechanical ventilation at times, preventing excessive mechanical ventilation will reduce heating costs. Two forms of mechanical ventilation exist in the building: a centralized air exchanger integrated into the air handler system on the second floor, and unit ventilators mounted on exterior walls of many of the classrooms and other individual rooms in the building. The current student and staff population is far below what the building was built to house. Since few sources of indoor air pollutants exist in the building other than the occupants, the number of people in the building determines the necessary mechanical ventilation rate to ensure proper indoor air quality. We can reasonably assume therefore, that the building is over-ventilated via mechanical controls.

The unit ventilators have a damper that opens and a fan that pulls fresh outdoor air in through the damper opening, across the radiator, out the top of the unit and into the room. This moderates the temperature of the outdoor air and sends it towards the ceiling where it can mix with the warmest room air. A relief damper opens on the base of the unit at the same time and allows stale room air to exit from floor level. These units were,

and still are, considered an economical means of heating, cooling and ventilating a space. They require no ductwork and can provide for the specific needs of an individual room that might experience different internal and external heat gains than other rooms in the building at the same time of day.

Ensuring that the controls on the unit are in working order and properly adjusted will help control ventilation of the building. Each unit should currently have a controller that keeps the outside air damper closed at night and allows it to open at some point in the day when occupancy has hit its peak and fresh air exchange is needed. The damper position on each unit should be controllable as well, to allow for adjustment of air flow in the "day" position. Unit ventilators in rooms that see little or no use could be fixed in "night" mode so that the fresh air damper never opens. Rooms that get low to moderate use could have the damper position adjusted so that in "day" mode they deliver only a fraction of the full fresh air exchange.

Lighting and Motors:

Although much of the lighting has been upgraded to high efficiency fluorescent fixtures already, replacing the lights in the gym and the exit signs with LED fixtures could yield significant savings. The motors that drive the fans in the primary air handler could be replaced with variable frequency drive (VFD) motors for electrical savings and more precise control of temperature.

Conclusion:

- Cost effective opportunities for improvement to the thermal envelope of the building exist only during roof and siding replacement projects.
- Controlling the ventilation rate of the building with mechanical controls on unit ventilators, the primary air handler, and boiler room air intakes will reduce heating costs.
- Educating faculty and staff on proper use of heating and ventilation system controls will reduce heating costs and improve comfort.
- Supplementing the existing heat system for the main building with mini-split heat pumps will be cost effective and allow for better zone control of the heating system.
- Installing interior storm panels on leaky windows will improve comfort at minimal cost compared to replacement windows.

Suggested Next Steps:

1) Hire a mechanical contractor (e.g. Mechanical Services Inc.) to evaluate and repair or replace the controls on the unit ventilators and the primary air handler/exchanger.

2) Educate faculty and staff on proper operation of unit ventilators to meet but not exceed ventilation needs.
3) Obtain proposals for installation of mini-split heat pumps in offices and classrooms and install units as budget allows.
4) Obtain proposals for lighting upgrades in gymnasium and main building where applicable (e.g. exit signs). Install replacement lighting as budget allows.
5) Obtain proposals for replacement of steam boiler with multiple residential oil boilers and replacement of distribution system components as necessary. Install replacement system when old system fails.
6) Obtain proposal for installation of custom interior storm panel inserts only for those windows that do not close tightly. Install window inserts as budget allows.

Thank you for letting us assess your building, I look forward to reviewing this plan of action with you soon.

Best Regards,

-Willis Beazley

UNDERSTANDING UNIT VENTILATORS

by Joseph T. Kohler, Ph.D., P.E.

Introduction.

Unit Ventilators are a traditional method of heating, ventilating and cooling classrooms. They were developed more than 60 years ago specifically for this application, and have stood the test of time. There are still many schools with 1950 vintage unit ventilators providing comfortable and properly ventilated classroom environments.

Unfortunately, unit ventilators have developed a bad reputation in some circles. This is often due to a misunderstanding of how unit ventilators operate and to poor maintenance. This technical note will provide a description of unit ventilators, a discussion of how they operate, and a summary of some of the advantages of unit ventilators compared to other methods of heating and ventilating classrooms.

What is a Unit Ventilator?

A unit ventilator consists of a heating coil, fan assembly, dampers, filter and controls contained in a metal cabinet. Unit ventilators are usually located on the outside wall of classrooms, although they are sometimes suspended at or above the ceiling level.

Outdoor air is brought directly into the cabinet via a grille located on the outside wall of the classroom. The unit ventilator is designed to mix room air with outside air, heat the air if necessary, and deliver it to the classroom through a grille located in the top of the unit ventilators. The proportion of outside air is controlled by the position of the fresh air damper. This damper can be adjusted to provide as much or as little fresh air as desired. A typical unit ventilator will circulate a total of 1000 or 1250 cfm (cubic feet per minute) of air, of which a minimum of 400 cfm is outdoor air. With a unit ventilator, 100% of the airflow can be outside air when it is needed for "free cooling" (also called "economizer cooling").

With any system, it is necessary to balance the air flow in the building, i.e., to exhaust an amount of air equal to the fresh air supply. In a unit ventilator system, this is often accomplished by a "gravity" relief damper in the outside wall, which automatically opens to relieve the proper amount of stale air. Sometimes, exhaust is accomplished with a ducted exhaust fan system.

How a Unit Ventilator Operates.

The key to a unit ventilator is a straightforward control sequence designed to automatically provide heating or cooling as required. To understand the controls, it is essential to understand the heating and cooling requirements of a typical classroom. At night a classroom requires heating, especially in the early morning when the temperature setpoint is raised in preparation for the school day. However, at some point in the day the combination of internal heat gains from students and lights, along with solar gains, may cause the classroom to need cooling instead of heating. *This can occur even during a cold winter day.*

Unit ventilator controls will provide hot water to the coil to heat the room to the desired temperature at the beginning of the school day, but keep the outside air damper closed until occupants are scheduled to arrive. Then the outside air damper will open to the preset minimum ventilation

position to assure an adequate supply of fresh air.

As internal and solar gains increase, the unit ventilator will gradually turn off heat to the coil and then begin to further open the outside air damper to bring in more cool air to keep the classroom from overheating. The temperature of this air supplied to the room is often near 65° F, slightly cooler than the room temperature. A properly operating unit ventilator should be able to keep a room within a couple of degrees, plus or minus, of the thermostat's heating set point. *It is essential to realize that it is entirely proper for a unit ventilator to deliver cool air, even on a cold winter day.*

Vertical Projection Ventilation.

Floor mounted unit ventilators provide what is referred to as Vertical Projection Ventilation. Fresh air is mixed with room air and projected vertically near the outside wall/window of the classroom, and then across the ceiling and to the inside wall of the classroom. This achieves very thorough distribution of the fresh air, without creating drafts (except immediately above the unit ventilator). Vertical Projection Ventilation is a very effective means of providing heating, ventilation and cooling to the classroom.

Advantages of Unit Ventilators.

The ability to heat, ventilate and cool individual classrooms from a single piece of equipment is unique to unit ventilators. Alternative systems, such as those employing baseboard radiation with central ducted fresh air ventilation, do not have full ability to cool classrooms. (Typical central ventilation systems supply only, say, 400 cfm of outside air per classroom, not the full 1000 or 1250 cfm.) Classrooms with these systems are prone to overheating, especially in the spring and fall.

Another advantage of unit ventilators is that there is virtually no ductwork involved. The fresh air enters the unit ventilator directly from the outdoors. Each room has its own independent system. There is no need to be concerned with dust or mold in long runs of supply air ductwork with unit ventilator systems. Stale air is often relieved directly through the outside wall. The slight positive pressure in classrooms reduces the possibility of radon entering the room.

A third advantage of unit ventilators is that the amount of outside air can be easily adjusted. For example, if building codes change to require more outside air, or the occupancy of a classroom is increased, or the use is changed to a classroom requiring more ventilation (e.g., a science or art classroom), the minimum position of the unit ventilator's outdoor air damper can be adjusted accordingly.

A fourth advantage of unit ventilator systems is that it is simple to adapt the system to summer cooling by circulating chilled water through the mains. This is applicable only to new systems which have the appropriate pipe insulation and condensate drains in the unit ventilators.

A final advantage is simple maintenance. Like all systems, unit ventilators require periodic maintenance and regular filter changes to insure proper operation. However, any maintenance or repair affects one room only, and involves small, readily available components. Properly maintained unit ventilators have provided more than a half century of service in classrooms throughout the country.