MECHANICAL DESIGN BEST PRACTICES FOR THE INTERIOR SUBARCTIC

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1. Introduction

Interior Alaska is a land of extremes with high summer temperature spikes to extensive periods of cold temperatures and darkness during the winter. Building owners have typically been willing to spend first cost dollars on both reasonable energy reduction measures and reasonable comfort measures. For example, typical construction has been documented to far exceed published building tightness criteria for commercial construction. At the same time, meeting specific prescriptive energy code requirements such as night setback and the requirement for heat recovery ventilation can be counterproductive in some cases.

The last significant cold snap in Fairbanks was in the late 1980s with temperatures as low as -50F in low land areas with some areas reaching as low as -65F. Schools were shut down due to the dangers of bussing children in those conditions. In order to prevent freeze up amongst the approximately 50 schools in the district that could result in thousands of dollar's worth of damage, the school district Maintenance Department paid for 24 hour surveillance in a rotating circuit to the schools to prevent any building issues that would lead to potential maintenance issues and building shutdown . The maintenance would visit the mechanical room at each school and spot check individual classrooms. Night shutdown of the heating and ventilating equipment was overridden and equipment was operated continuously. This continued for about a week before temperatures mitigated.

This was the last time these types of measures were required primarily due to rising temperatures but also because of better building construction and the increasing use of direct digital controls (DDC) that provide better monitoring capability.

In order to provide a design that is robust, adaptable, and affordable, it is important to understand the aspects of the geographic location that will impact equipment selections, operating hours, and maintenance needs. Interior Alaska has many challenges that need to be considered in order for projects to be successful and remain in budget. The primary challenges that will be discussed in this paper are the impacts of the Alaskan climate and the unique design and operating challenges presented by remote sites. This paper will draw from Design Alaska's history of building in local communities and highlight the solutions that have been successful in navigating the challenges of the state.

2. Residential vs Commercial Construction

In the discussion of best practices, it should be noted that both requirements and construction techniques can vary significantly between the commercial and residential sectors and that it is ill advised to assume approaches that work well in one sector will work well in the other. For instance, mechanical cooling is rarely used or needed for interior residences, whereas some form of mechanical cooling is a necessity for most commercial facilities.

Highly insulated wall construction is easier for residential construction using primarily wood construction with simple, constructible wall systems and simple constructible air/moisture barriers. The envelope used in commercial construction must meet more stringent fire safety requirements and contend with cold joints associated with steel connection that must penetrate the thermal, vapor, or air barrier assembly.

3. Cost Considerations

While the importance of energy savings cannot be understated, it must be considered within the parameters of the project budget. The most efficient and innovative design is of no use if its construction cost is beyond the available funding for the project. Alaska labor, material, and shipping rates are high and an understanding of the cost impacts of building in Alaska compared to other parts of the country can make the difference between a successful project and one that does not reach completion.

During design, the first cost is often at the forefront when considering design approach and mechanical systems. However, first cost must be balanced with operational cost. Annual savings are an incentive for owners to select efficient systems. In some cases such as light LED lighting retrofits, the annual savings results is a relatively quick payback period and as such, is easy to see value. Other features that have longer payback periods require closer analysis and further discussion of the benefits with owners and operators.

4. Priorities

Critical mechanical systems must be reliable and easily maintainable so that if there is a failure, there is a high likelihood that a repair can be made before loss of occupancy or building freeze up occurs. Boilers (the heat of most heating systems) are typically installed in at least a partial redundant configuration in the commercial sector. Often two boilers each sized at 2/3 of design capacity are installed to provide a good balance between redundancy and energy efficiency that avoids oversized equipment. If failure occurs during conditions near the design temperature, the ventilation system would be shut down or outside air would be closed down until repairs were made. Steam heat exchangers in facilities connected to a district heating utility are typically equipped with a combination of 1/3, 2/3 valves and a manual bypass allowing flexibility if any one control valve should fail.

System simplicity is foundational to easy maintenance. The system designer should carefully think through the design to find the simplest approach while still meeting performance goals.

Most mechanical equipment is located inside the building envelope. Once inside the building envelope, the environment is similar to other areas during cold weather operation except for the following aspects:

1. Low Humidity: Without a mechanical humidification source, interior relative humidity can go below 10% rh.
2. Stack effect: Stack effect is imposed on any heated structure. Stack effect is proportional to the height and temperature difference between the inside and outside. Stack effect can be harnessed to distribute ventilation air, but more often is a challenge that must be overcome to maintain entrance areas or lobbies at a comfortable condition.
3. High thermal flux across the envelope: The selection of the heating terminal unit must address the high temperature differences across the building envelope.

5. Typical Design Practice

<u>Heating:</u>

- Typical commercial construction utilizes boilers. For new construction, if natural gas is available, condensing boilers would be the first choice. In this case, a substantial portion of the heating system should be comprised of radiant in floor heating to allow the boiler return water temperature to be low enough that condensing within the boiler occurs.
- Where natural gas is not available, the boiler must be fired on oil. In the US market, there are virtually no viable commercial condensing boilers fired on oil.
- The residential market has a few more options. If natural gas is not available, there is a viable condensing boiler sized for residential service as well as direct concentrically vented non condensing appliances that greatly reduce stack losses. Even so, use of the more efficient appliances must be weighed against reliability and maintainability. Fairbanks has an abudance of boiler mechanics with vans full of parts that can be used to repair cast iron boilers equipped with separately manufactured burners. The pool of available parts and available technicians greatly decreases for any other boiler type. Often the residential owner overcomes this lack of easy maintainability using a wood stove for back up.

- The high thermal flux across the building envelope is best addressed at the bottom of the envelope with either finned tube radiation (FTR) cabinets or radiant heating. In areas of significant glass such as architecturally appealing entry lobbies this is almost always handled with FTR cabinets. In-floor radiant heating can be used successfully but its output is limited by the allowable surface temperature before it becomes uncomfortable or supports fungal growth where occupants tend to stand in the area for extended periods. Note that heating with FTR cabinets is most economical when using high fluid temperatures of about 180F compared to radiant heating systems that typically should have a maximum fluid temperature of 120F. This makes combining the two systems using a single distribution system difficult. Heating with air in a commercial application should be used with caution. Air heat from above does not do much good unless it reaches the floor and it cannot reach the floor from above without significant velocity. This makes it nearly unworkable in the office environment, with desks and book shelfs often located at the perimeter.
- Heated air curtains within vestibules and at garage doors are used but are not particularly effective. Because of stack effect, the negative pressure at the entrance pulls the air stream off the entrance allowing cold air to rush around curtain flow. Air curtains are particularly bad if the vestibule opens to a space with a high ceiling.In that case the hot air from the curtain flows to the top of the space doing nothing to heat the occupant.
- In the case of a vestibule, it is better to heat the vestibule with radiant in floor heat which is adequate to keep automatic doors from freezing in their door track and adequate to keep the sprinkler head above from freezing. The remainder of the heating capacity should be located on the lobby side of the vestibule. A wall mounted cabinet unit heater selected with a low intake is a good choice. The controls can be set to operate the fan continuously below -20F with the coil valve modulated to maintain space temperature setpoint. This continuously vacuums the cold air off the floor and sends it away. If receptionists or security guards must occupy the area by an entrance door, their counter should be configured so that cold air streaking across the floor must take the longest route possible before it reaches them.
- Heating for garages should be sized for adequate pick up capacity to recover space temperature in a reasonable time. In floor radiant heating is usually used in new construction and is normally augmented with unit heaters. Domestic water piping near garage doors should be avoided, and if required may need to be heat traced.
- Gas fired radiant heaters are sometimes used in garages and box stores. They are effective but comfort is sacrificed if an occupant must stand within its influence for extended periods.

Ventilation and Cooling:

- Typical ventilation systems for light commercial entities would rely on a constant volume system using radiant heating or perimeter finned tube slightly oversized for reheat.
- For buildings over about 5,000 square feet, the typical ventilation system uses variable air volume terminal units. To meet indoor air requirements, minimum ventilation rates are often high enough to cause sub cooling. This is addressed at the perimeter with a slight oversize of the terminal unit. For interior zones, sub-cooling is minimized by in-duct reheat coils or preferred CO_2 sensors allowing minimum ventilation rates to be reduced to the minimum value based on square footage.
- Usually fan equipment is located within a mechanical room or mezzanine. Use of typical roof top units within the interior subarctic is somewhat rare but their use is growing. Problems amplified by the subarctic environment include; significant energy loss if door seals fail, significant energy loss if insulation fails on exposed ductwork or piping, and significant increase in maintenance cost or reduction in preventive maintenance during cold weather operation. However, if the roof top unit is equipped with an access vestibule, the picture changes entirely. Within the vestibule is a warm place for the technician to work from, the associated DDC control panel and motor controllers can be located with the fan equipment, and the number of doors exposed to the exterior is greatly reduced.

- Gas fired outside air preheat systems should be used with caution. Many of these systems will shut down at -40F.

6. Exotic Design Practice

- Micro Turbines: Micro turbines are beginning to be used in the Interior. The one example we are familiar with is an oil-fired unit at the Department of Transportation maintenance station located off the utility grid in Paxson. Micro turbines have significant advantages over modern piston driven electrical generators in that they can provide waste heat at a high outlet temperature. Piston generators are limited by a somewhat low maximum water jacket temperature and use airside after coolers, which while greatly increasing overall efficiency, greatly decreases the available waste heat.
- Heat Pumps: Heat pumps have been applied in the residential market in the interior with limited success. Fluid based heat pumps can freeze the area around the buried tubing reducing the coefficient of performance. Outdoor air temperatures are far too cold to make air-side heat pumps viable. Heat pumps have been successfully applied at residences on south facing slopes where the solar gain is high enough to recharge the soil temperature on an annual basis.
- Ventilation and Cooling: Although Interior Alaska has high record temperatures exceeding 90 degrees F, the number of annual hours of mechanical cooling that is required is low with about 70 degree days above a 65 degree base annually. Therefore, the least expensive form of mechanical cooling, direct expansion refrigeration, is typically best. Therefore, while chilled beam technology might save energy the pay back is very low. Evaporative cooling systems also have not been adopted due to increased maintenance and high first cost. Well water cooling systems have been successful, particularly in applications where the rejected water can be discharged to the storm drainage system. Reinjection has been successful as well but is coming under greater and greater regulatory scrutiny due to ground water pollution sources that might be moved or influenced by the system.

7. Lessons Learned Designing for Systems in Remote Villages

Nowhere in Alaska are energy costs higher than in a remote Alaskan village that is located off the road system. Here fuel is either flown or barged into the village with fuel costs 3 to 4 times higher than fuel costs in a city on the road system.

At the same time, a school located in the village must have more systems and is therefore more complex than a school within a city. Besides being required to meet nearly all the same codes, it must also be able to operate in a self-contained mode not relying on a separate municipal utility system to provide power, potable water, and sewage treatment. The school district maintenance department in Fairbanks has approximately 30 technicians maintaining the schools for an approximate population base of 120,000 people. Most of these school district employees have been trained in a trade, and many have specialties and certifications, such as plumbers, locksmiths, boiler mechanics, generator technicians, controls technicians, and fire alarm technicians to name a few. In the village, there is often the school principle, a maintenance employee, and a janitor with roving maintenance employees flying in if there is a major problem.

Therefore, even though energy costs are high, the critical systems must be simple enough to be maintained at a very basic level. Anything not critical for basic existence often fails in disrepair. It can easily cost $1,500 dollars to get a technician outside the village to come for one day’s work.

8. Best Practice for Remote Village (Bush) Applications

- In 1976 the Molly Hootch court case significantly expanded the requirement for high schools in the remote villages of Alaska. Many of the new schools were designed using commercially sized oil fired furnaces, greatly reducing the possibility of heating fluid freeze ups and flooding. This practice has now shifted more to oil fired boilers which can deliver heat far more efficiently, particularly if the combustion side of the forced air heat exchanger is not regularly cleaned.
- The boiler header temperature setpoint should be reset on outside air temperature by the direct digital control (DDC) system. However, there needs to be a labeled switch at each boiler that allows a mechanic to easily override the computer control system allowing the boiler mechanic to be independent of the controls technician.
- Radiant in floor heating is not typically used in remote villages due to permafrost which forces the building to be built on piles. This in turn causes the floors to be plywood. Finned tube radiation then becomes the heating terminal unit of choice.
- Utilities are often run above ground due to permafrost. The interface between the above ground utilities and the building structure must account for differential movement. The sewer or waste piping within a facility is a challenge for a facility built on pilings. The interstitial area below the warm floor and the bottom of the floor structure is typically inaccessible. If piping is routed in this area, the below floor envelope must be cut out to find, and repair any leak. After this is done, the below floor construction is usually not repaired well causing on-going problems. In one successful project, a central interstitial corridor with about 48 inches height was constructed with nearly all plumbing tight to this corridor. Sprinkler piping was avoided by cladding the metal floor joists with insulated metal panels below and with the use of fire treated plywood for the floor structure above. The interstitial cavity was heated at the lowest point within the corridor allowing heated air to circulate out to the perimeter below the occupied floor and then flow back to the corridor on top of the insulated metal panels making up the lower envelope. This provided reasonable access to nearly all below floor piping.
- Room thermostats should be simple low voltage thermostatic switches used in conjunction with two position control valves. Glycol is used as the heating fluid with a relatively high flow prior to turbulent flow. Almost no heat transfer occurs prior to turbulent flow which causes the control to act like two position control whether or not a modulating valve is used. Night setback becomes proportionally less valuable as envelope insulation increases. It is our opinion that the system simplicity gained without use of night setback outweighs the potential energy savings for remote applications.
- The DDC controls controlling the ventilation systems should allow easy manual override to prevent override using wire nuts and vise grips.
- The communications from the DDC system to the outside world is vital and should be through a telephone modem rather than the internet so that it is not subject to poor or inconsistent IT practices.

9. Conclusion

The subarctic interior environment poses many design challenges. Energy conservation is of the highest importance. However, if the systems become so sophisticated they are out of reach for the available maintenance staff or systems fail prematurely due to complex construction, the design has ultimately done a disservice to the end user of the facility. When good design comes together, it resonates throughout the life of the facility.