The State Institute of Rehabilitation

Mechanical Redesign, Proposal

Elizabeth C. Krauss | Mechanical Option | September 18, 2013

Executive Summary

The following report is comprised of an in-depth investigation into the current systems of the State Institute of Rehabilitation, alternative means of building operation, and the means by which to study them. The building, though meeting and in some cases exceeding all compliance standards set forth by ASHRAE standard 90.1, is perfectly able to operate at a much higher level of efficiency.

The State Institute of Rehabilitation is an approximately 120,000 gsf addition to an existing building. The three-story addition, though physically attached to the existing facility, operates on a stand-alone mechanical system entirely separate from the existing building's equipment.

The addition makes use of DX cooling in nine (9) separate Rooftop Air Handling Units (RTU's). Both domestic and mechanical hot water are supplied to the building via natural-gas fired boilers located on the first level. A more detailed description of the mechanical systems can be found below in section.

The most important goal of the redesign, in the case of the State Institute of Rehabilitation, is to decrease the overall energy consumption of the building both on and off site. In considering alternatives for existing system replacement, installation cost, maintenance requirements and control were all of equal importance. Additionally, system size, available space, existing system capacities, and climate were also taken into consideration.

The most practical and economic alternative to the existing system is the connection of the addition to the existing building's mechanical plant. The existing plant, located in the sub level of the east wing, produces heat via two oil-fueled steam boilers. Cool water is produced by a 230 ton steam absorption chiller. In an effort to introduce further advances in building operation efficiency, heat recovery from sewage systems will also be investigated, as modeled by the Whistler Athletes Village in BC, Canada.

In studying both efficiency and financial related advantages associated with this particular system redesign, special attention will be paid to acoustical and electrical performance. In expanding the capacity of the existing mechanical plant and possible updates to the cooling tower, focuses on equipment impact and vibration isolation will necessarily be included. Additionally, as this investigation will very likely result in a ductwork reroute and significant changes to or replacement of the air handling units, plenum and ceiling heights will need to be re-evaluated. Thus, as breadth topics, both acoustic systems and construction coordination will be investigated. Essential structural and electrical capacity check will be included.

A detailed work plan can be found below, at the conclusion of the report.

Building Summary

The building The State Institute of Rehabilitation, is a sizeable addition to an existing healthcare and rehabilitation center located in the northeastern United States. Completed in 2005, the addition is an approximately 120,000 ft^2, three story, stand-alone addition to an existing structure dating, at its earliest, to 1949.

The building addition was proposed, designed, and constructed in the early 'oughts', was meant to expand the Institutes' ability to care for its booming inpatient and outpatient populations. The addition, though materially connected to the existing structure, operates on its own mechanical, hot water, and chilled water systems. The decision to build systems entirely separate from existing facilities was in part due to existing operations limits and in part due to a desire to decrease operational costs.

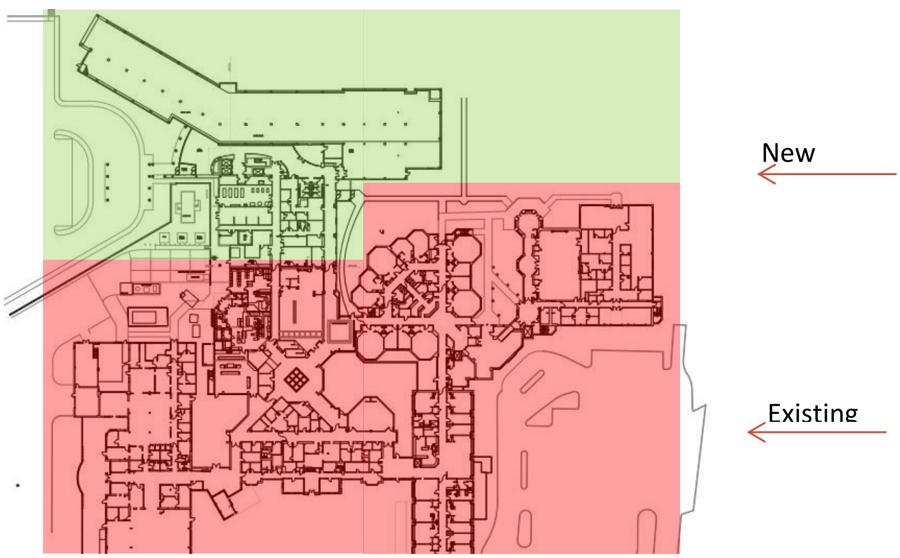

Figure 1: A color diagram depicting the interface between the existing Rehabilitation Center and the new wing

Mechanical Summary

The addition abutting the existing structure is, mechanically, stand-alone. Cooling, heating, and ventilation systems in the new structure are entirely separate from the mechanical plant located in the basement of the existing facility.

The majority of the buildings cooling loads are handled by the nine (9) packaged, variable air volume rooftop air handling units (RTU) located on the roof. Direct refrigerant expansion coils handle cooling within the RTU's. Split-system air conditioning units, where needed, handle supplemental cooling.

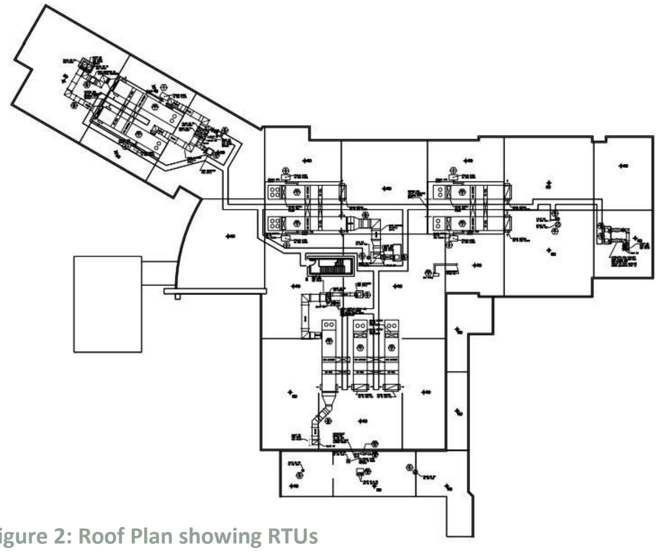

Figure 2: Roof Plan showing RTUs

Hot water coils, routed to the nine RTU's, handle the building's heating loads. Supplemental heating is provided, where needed, by hot-water unit heaters and cabinet unit heaters. Mechanical and domestic water is supplied to the building from the mechanical equipment room by three (3) natural-gas fired, 1600 MBH hot-water boilers. In addition to unit heaters, the boilers also supply hot water to zone reheat coils in a total of 137 terminal VAV units.

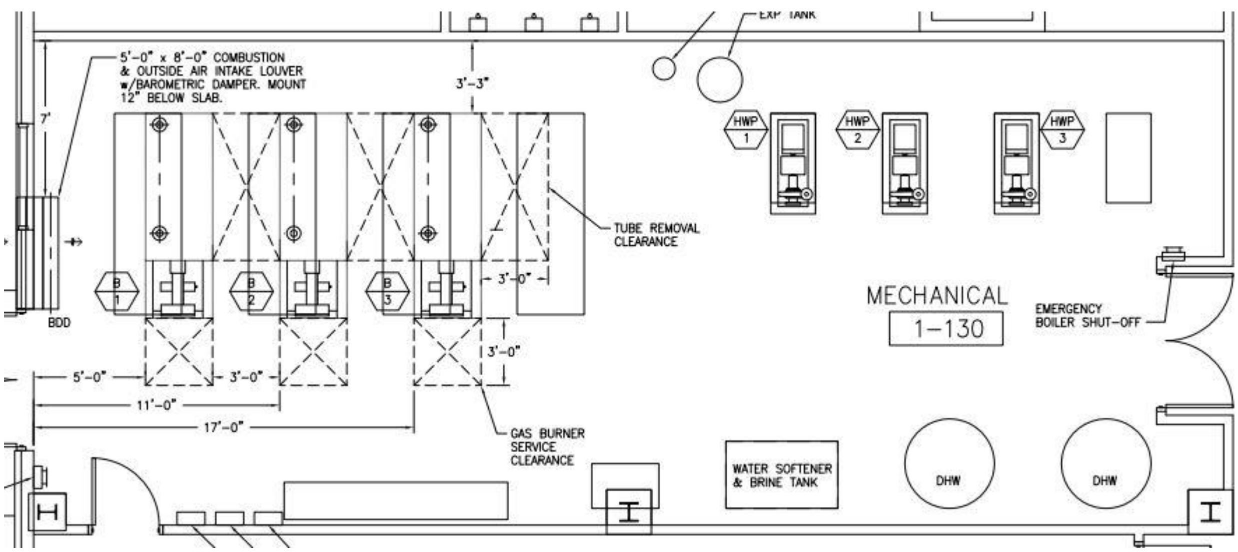

Figure 3: Mechanical Room

Equipment

RTU

The nine (9) Variable Air Volume (VAV) rooftop units (RTU's) and one (1) constant air volume unit provide, between them, approximately 114,000 cfm of air. Approximately 30% of the air supplied to the building is outdoor air. The other 70% of supply air is accounted for by return air. The RTU's are assigned to the building based on the array below in Figure 4.

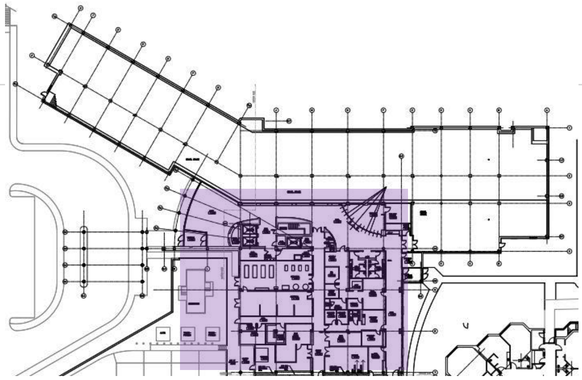
Figure 4: Floor 1

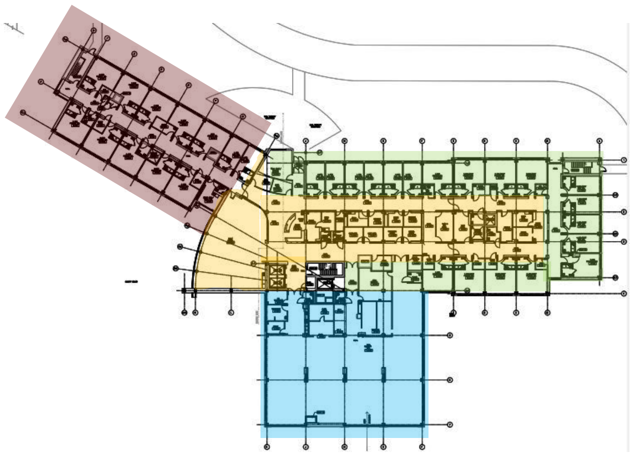
Figure 5: Floor 2

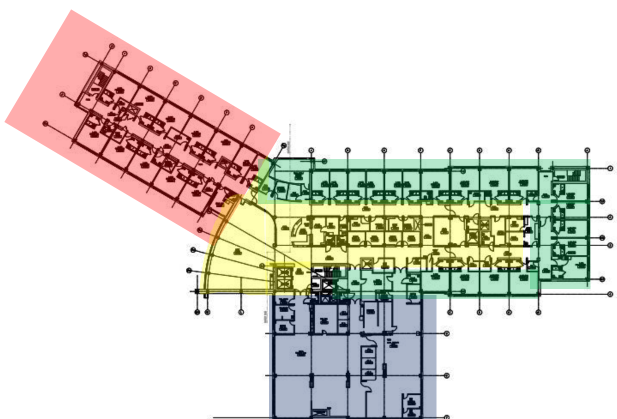
Figure 6: Floor 3

Figure 4: RTU assignments

RTU-Block Assignment; Key Plan

RTU-1; block 1

RTU-2; block 2

RTU-3; block 3

RTU-4; block 4

RTU-5; block 5

RTU-6; block 6

RTU-7; block 7

RTU-8; block 8

RTU-9; block 9

Each RTU operates on 20 MHP variable frequency drive (VFD) supply fans at 460V/3Ø power.

Each of the nine RTU uses direct expansion (DX) refrigeration cooling and natural-gas heating. Each packaged RTU is supplied with filter banks, one 30% efficient filter and one 95% efficient filter. These equate in recent classification to, roughly, MERV 5 and MERV 16 pre and final filters, respectively.

Air Terminal Units

The Insititute of Rehabilitation contains, in total, 137 single-duct Variable Air Volume (VAV) units. The VAVs distribute air to individual spaces and are responsible for the reheat of air through hot-water coils. The largest reheat coil installed circulates at 4.5 GPM with an entering water temperature of 180oF. Each VAV is manufactured with a flow sensor. The hot water supplied to the VAVs is supplied by the three natural-gas boilers and the flow controlled by three hot water pumps and, individually, by a three-way bypass valve for when heating is not required (ie. Summer).

Boilers

The three hot water boilers, located in the mechanical room on the ground floor, produce both domestic and mechanical hot water. Mechanically, they supply hot water to the 18 unit and 18 cabinet unit heaters, as well as the 137 VAV units. The boiler itself, comprised of heavy steel, is jacketed by 1-1/2" fiberglass insulation and finished with zinc and enamel. Boiler tube and furnace access panels are encased with 2" ceramic fiber insulation.

Hydronic Pumps

There are three centrifugal, hydronic hot water pumps operating with net positive suction head of 5.1 in. H_2O. Located directly next to the three hot water boilers, they are headered with a hot-water bypass system which allows hot water to return to the boilers when lesser volumes of heating hot water are called for by the building. For flow sequencing, please refer to Figure 9, following.

Cabinet Unit Heaters

The cabinet unit heaters (CUH), of which there are eight, operate at 115V/1 Ø power. The largest CUH is capable of providing 32 MBH to 850 CFM using 2.5 GPM, while the smallest can provide a maximum of 4MBH to 105 CFM at 0.5 GPM.

Unit Heaters

The hot water unit heaters run at a maximum of 1.5 GPM and 575 GPM. The smallest unit heater runs at 0.5 GPM and 250 CFM. They are equipped with integral thermostats and operate at 115V/1 Ø power.

Split-System Air conditioning units

Excess sensible load in the two elevator machine rooms, the electrical room, the data room, and the vending room, respectively, is mitigated by the operation of a split-system air conditioning unit.

System Energy Consumption

Energy use in the State Institute of Rehabilitation was analyzed using Trace 700. Because current utility usage and cost figures for the actual building were unavailable, however, the analysis is limited to those loads identified in Trace 700 and does not provide an accurate comparison between the existing and theoretical building. A more detailed investigation can be viewed in Technical Report 2.

In moving forward with an energy consumption analysis, the IES Vision software will be utilized first to build a more accurate model in terms of the existing facility operations, and then in terms of the proposed redesign. It is these two models which will be compared in determining energy savings.

Mechanical System Evaluation

Though the existing mechanical system is currently able to meet, and even in some cases exceed, the building's heating, cooling, and ventilation requirements, it is not doing so efficiently. The addition to the State Institute of Rehabilitation was designed to be inexpensive to install and maintain. While electric cooling is efficient on the surface, being less expensive and more efficient at part load, it consumes approximately three times as many primary energy units than does a natural gas or oil system operated on site.

To improve the global efficiency of the building, an investigation into central plant ties, coupled with heat recovery, is a worthwhile endeavor. A central plant would yield a higher efficiency and possible long-term savings.

Alternatives Considered

Several alternatives were considered for the redesign of the State Institute of Rehabilitation's mechanical systems. Factors taken into account during the decision making process included climate, system controllability, possible energy yields, system feasibility, and cost. Options considered are listed below:

- Ground Coupled Heat Pump
- Solar-Thermal Domestic Hot Water
- Photovoltaic
- Chilled beam installation in non-critical spaces
- Building Envelope investigation
    - Thermal and Energy performance
- Central Plant integration
- Heat Recovery
- Replacement of existing RTU's with several larger AHU's in the existing building sub-level

Ultimately, heat recovery and central plant integration will be the focus. Many of the typical "green" system alternatives will have to be sidelined due to climactic and site limitations. The size of the site is not conducive to the installation of a ground coupled heat pump. Photovoltaic systems present too high of an initial cost and garner little in terms of sizeable energy savings. Because humidity is arguably a climatic staple in New Jersey, chilled beam installation may represent more disadvantages than advantages. As a result, these options were not investigated any further.

Proposed Redesign

The following alternatives are those which best suit the State Institute of Rehabilitation. Some aspects of the redesign were chosen, in particular, for their educational benefit.

It is important to note that the following system recommendations do not in any way imply operational deficiencies within the State Institute of Rehabilitation, and they are being suggested merely for the every savings they present.

Depth

Central Plant Integration

The existing sub-level mechanical equipment room houses both a steam absorption chiller and two oil-fueled steam boilers.

The steam boilers are reaching the ends of their life cycle, as they date back, approximately, to the 1970's. Attaching the State Institute of Rehabilitation addition to the existing building would require system upgrades in order to match capacity with demand. The replacement of the existing boilers will become a necessity within the next five years, however, regardless of system integration. In order to maximize the efficiency of the facility operations as a whole for the owner and, additionally, to keep the operations of the existing structure up to code, the replacement of the existing boilers coincides well with a size upgrade.

The steam absorption chiller may also require size upgrades. Though newer than the boilers by approximately 18 years, having been installed in the late 1980's, it also may represent life-cycle cost savings to the building owner by replacing it now with a larger chiller.

Heat Recovery

Between the existing building and the addition, the State Institute of Rehabilitation is a 152 in-patient facility, with twice as many out-patients. Combined, this represents a high volume of sewage compared to the size of the facility. Though not exactly glamorous, heat recovery from sewage piping may represent a significant heat source for the building. It may even reduce the necessary size of the boilers.

RTU Replacement

It may be prudent, alongside the above mentioned upgrades, to replace the existing nine RTU's with two larger basement air handling units. Because the sub-level of the existing facility has direct access to the outdoors, as well as a significant amount of unutilized space, the relocation of air side mechanical systems may open the roof to the possibility of heat and cooling load mitigation by 'green roof' installation.

Impact

Chilled and hot water flows to the addition will need to be piped. Pressure losses, pump requirements in terms of placement and electricity, and pipe-routing possibilities will need to be evaluated in terms of cost, space and electrical demands, and layout.

Additionally, each of these proposed system replacements and updates will need to be further evaluated for initial vs life-cycle and maintenance costs.

Ceiling cavity coordination will necessarily be checked against pipe routing and equipment requirements.

Breadth

Acoustics

The size upgrades to the existing mechanical equipment may present structure-borne noise contributions. Vibration and impact isolation investigations will necessarily need to be evaluated and, if a problem arises, mitigated.

Additionally, the relocation and size upgrade of the air handling units to the basement will require a reroute of ductwork previously originating in the roof. An acoustical analysis will investigate the impact on background noise level (BNL) and noise criteria for critical and non-critical spaces.

Construction

Because the reroute of ductwork will affect the existing ceiling cavities above occupied spaces, a coordination of lights, structure, ductwork, and piping will need to be completed. Additional costs arising from increase in materials due to routing and layout will be analyzed.

Tools

Depth

The change from DX and hot water, respectively, to chiller plant and steam generated cooling and heating will represent a significant operational change. Additionally, heat recovery systems would introduce a mechanical operations savings. These things will be modeled, primarily, in IES Virtual Environment (VE). It will first be used to model the building as it currently stands and then, later, with the installation of the redesigned systems. The results of these two models will be compared.

Breadth

The acoustic changes, concerning the ductwork, will be modeled in Dynasonics AIM.

The coordination of mechanical, plumbing, and lighting systems will be done using Autodesk Revit, 2014.

Schedule

The attached schedule, in Appendix A, outlines in detail the plan for work completion during the Spring 2014 semester.

References

ASHRAE (2010), Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society ofHeating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta,GA, 2009

Perry, Richard, Ren, Tom. “Sewage Plant Heats Village.” ASHRAE Journal, vol. 55, no.11. November 2013. < https://www.ashrae.org/resources--publications/periodicals/ashrae-journal/features/sewage-plant-heats-village>

Appendix A- Work Schedule