Picking Up No Vibrations

How Suffolk located a gas-fired cogeneration plant under Brigham and Women's imaging suite

WHITEPAPER

Challenge

Brigham and Women's Hospital, one of the top healthcare institutions in the world, needed to locate a 4MW gas reciprocating engine cogeneration plant in its new Hale Building for Transformative Medicine. The only possible spot? Right under the imaging suites. MRIs are highly sensitive to vibration, and gas-fired engines are notorious for producing motion and sound that lead to the vibration the hospital wanted to avoid.

The Team

SUFFOLK

Jason Seaburg, Chief Operating Officer

Jason Lansbury, Project Executive

Kevin Malenchini, Director of MEP Engineering

Larry Malloy, Senior Superintendent

Sabrina Torchia, MEP Project Manager

ARCHITECT

NBBJ

ENGINEERS

Waldron Engineering, cogeneration design

BR+A, infrastructure design

McSal, structural engineer

TRADE PARTNERS

PC Lydon, installer

CAT Engine, manufacturer

Background

Brigham and Women's Hospital had a vision for the Hale Building for Transformative Medicine: a building that could bring together leading clinicians and scientists to promote, collaborate and advance care for patients suffering from neurologic, orthopedic and rheumatologic conditions, such as Alzheimer's disease, Parkinson's disease and rheumatoid arthritis. The 680,000-square-foot facility at BWH, completed in 2016, includes three outpatient floors, eight research floors, and an administrative and imaging floor. It houses about 30 principal investigators, a 240-person research staff, and the Brigham Innovation Hub, a collaboration among leading experts to further enable partnerships within the Brigham and with industry.

To accurately research, diagnose, and treat these conditions, the building is home to some of the most powerful imaging capabilities and precise technologies in the world. The power and precision of the imaging technologies, specifically the MRIs, demand utter stillness. Even the slightest amount of vibration on MRIs, CT scanners, laboratory or operating microscopes, and other types of medical equipment can skew results and put patients at risk. Plus, the thresholds of vibration that impact these sensitive technologies are usually imperceptible.

Vibration requirements vary with MRI vendors, but leading producers have similar site requirements for 1.5T (Tesla – a unit of magnetic force) and 3T units. Vendors require vibration levels below 100-450 µg in the 0.5-100 Hz frequency ranges, with an emphasis on levels below 100 µg in the 0.5-50 Hz range. Suffolk installed a 7T MRI at the Hale Building—one of only two MRIs in the world at this level approved for clinical use—and needed to go above and beyond to ensure the entire suite was unaffected by vibrations.

A typical gas-fired cogeneration plant produces a vibration range up to 300 Hz. Because of the Hale Building's layout, the only space for this 4MW plant was in the facility's 400-space underground parking garage. The plant, which would power 80 percent of the building, needed to go right under the imaging suite.

A 3D modeled cross-section of the Hale building cogeneration plant

Solution

To support the cogeneration plant, the Suffolk team and its partners developed a separate beam structural system that was completely independent from the building's structure and a vibration isolation pad to absorb any movement from the plant's engine.

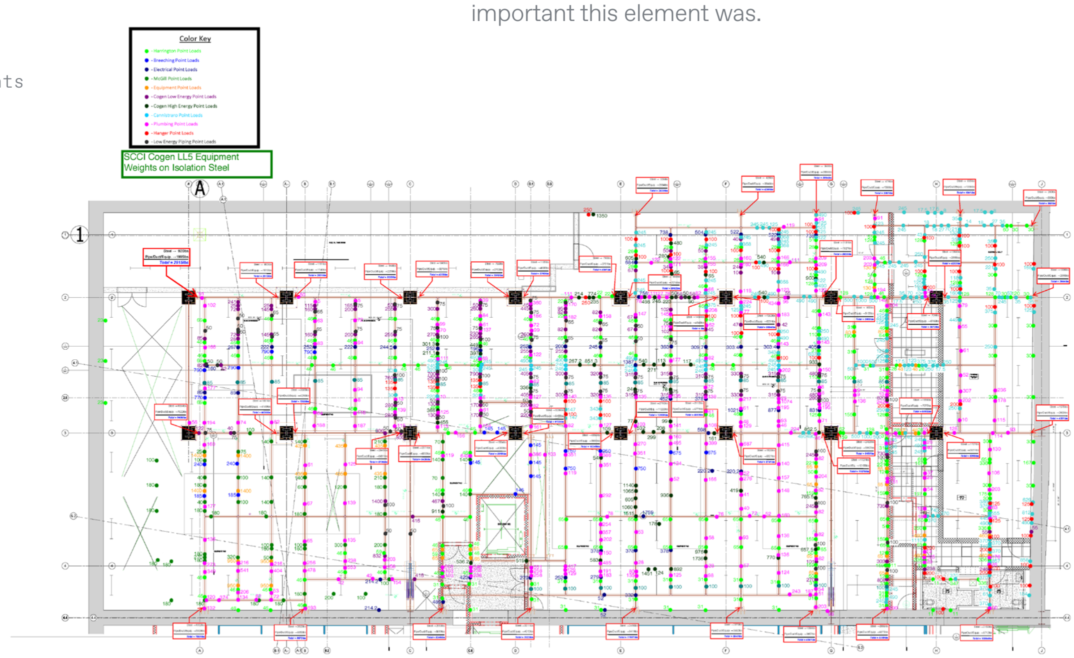
The System

Developing the beam structural system required that the team first complete a full virtual coordination of the plant's floor to determine the location and weight of every pipe and duct. The subcontractors provided Suffolk's team with their various virtual models for their trades, which the Suffolk staff then incorporated into a master model to determine the length of each pipe and duct, along with their intersection points. The team also had to consider what was going through each pipe and vent: water, cables, or air. The material flowing through determined the weight for the pipes and ducts, which translated to the amount of weight the structural system would have to bear.

Suffolk's team used the models, coordinated drawings, and weight charts to go through each trade that was hanging from the steel, establish a hanger point for every trade, and determine the load that each point would bear. In the drawings, they color-coded thousands of hanger points to ensure each total calculation to the beams' intersection with the column had a round vibration isolator that bore the correct weight from all the hanging MEP systems.

Calculations had to be completed in two weeks because Suffolk also had to select the density of the plant's vibration isolation pad based on the weight put into the structural support system. The team added up the hanger points on each beam to identify the total calculated load over to a vibration pad at the beam and column edge. Each pad was made to withstand the calculated load for correct vibration control. If the pad was too dense, it would not absorb the vibration correctly, and if it was not dense enough, it would compress and also not take the vibration correctly. The team worked around the clock to determine the precise weight and density of the pad. They knew how important this element was.

The color-coded diagram of weights on the isolated steel structure



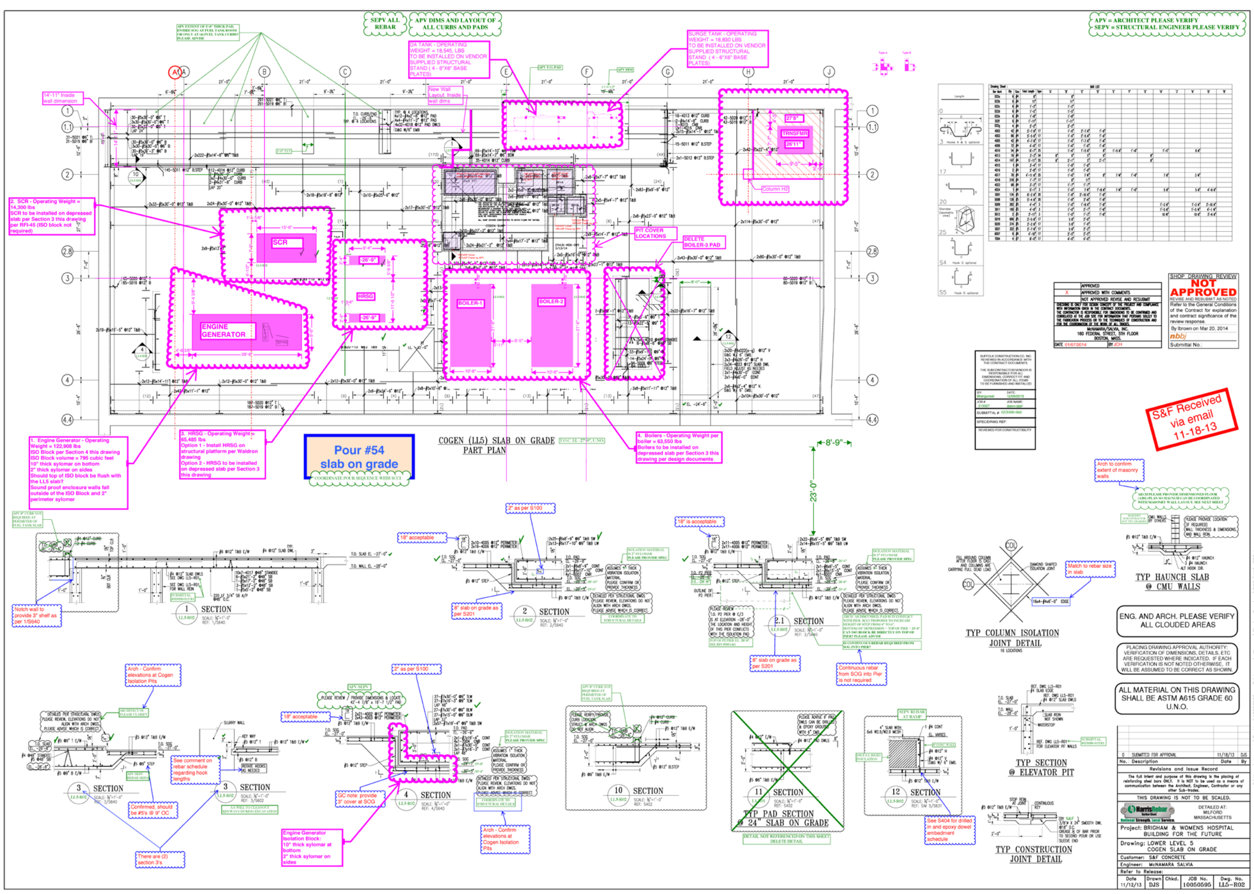
The Pad

The cogeneration engine—the heart of the plant—required its own dedicated set of vibration control measures. Essentially a locomotive engine, the gas reciprocating machinery weighed 250,000 pounds and produced enough noise to match. The engineers, designers, trade partners, and Suffolk came together to make an enclosure for the engine within the cogeneration plant, then took it a step further by building the enclosure to surround the engine's vibration isolation pad. That way, the team was able to analyze every motion and noise penetration through the enclosure, then contain it so no vibration transferred outside. Each penetration had to be analyzed to contain enough flexibility for a hard connection through an enclosure that would be stationary as the engine vibrated and deflected over time.

Design called for the engine to float on a pad of Sylomer, a leading insulation material for vibration isolation, which would sit on top of three-foot concrete pad. The engine, however, did not have same density or weight distribution throughout its machinery. Without extreme care taken in regard to the slab or the pad, the heavier end of the engine would sink, push down the pad, and make the entire apparatus unlevel.

The team worked with the engine's manufacturer to obtain a weight distribution chart and calculated how to vary the density of the pad. The heavier the engine, the heavier the density of Sylomer they needed. Too high of a density, though, and the Sylomer would be too stiff, act similar to concrete, and fail to contain the vibration. The team also could not put the engine

Suffolk's shop drawing with marks for weights on the Sylomer pad



on one edge and drag it over the slab, since that movement would damage the Sylomer and waste their carefully planned calculations, material, and precious time.

To address these various challenges, the team hoisted the massive engine to place it precisely on the Sylomer pad and ensure each length landed on its designated weight range. They also created an inertia block, which lies inside the concrete slab and under the engine. The team placed the block before pouring the slab where the engine sits, which isolates the engine from the building's structural slab. When the engine vibrates, that movement is absorbed by the Sylomer and inertia block, rather than transferring through the ground to the building's steel column and into the MRI suite.

With this care, the Sylomer will last 40-50 years—about the life of the engine.

The Sylomer installation

Conclusion

A commitment to rigorous sequencing, precision, innovative ideas and methods, and collaboration made it possible for Suffolk's team and partners to overcome this challenge and deliver a seamless result to BWH. Since the building's completion in 2016, the cogeneration plant has caused no vibration issues in the Hale imaging suite.

BY THE NUMBERS

300 Hz

Typical range of vibration levels produced by a cogeneration plant

100 Hz

The ceiling of what an MRI can tolerate in vibration

80 percent

How much of the building the cogeneration plant would power

250,000 pounds

The weight of the cogeneration plant's engine

Here's how you can connect with our healthcare experts:

Mark Fulco
Vice President, Business Development, Northeast, Healthcare

MFulco@suffolk.com

508-934-9452

Jason Seaburg
Chief Operating Officer

JSeaburg@suffolk.com

617-807-0175