# Renovation and rehabilitation of Grand Central Terminal

*This immense project is currently estimated at $400 million and is expected to require several more years to complete*

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One of New York City's most famous architectural landmarks is Grand Central Terminal. Built during the golden age of train station construction, the terminal officially opened in February 1913. It is the visible, above-ground part of a mostly underground complex of tracks, platforms and railroad facilities that stretches on 48 acres from 42nd Street to 57th Street and, at its widest part, from Lexington Avenue to Madison Avenue. Today, the Metro-North Commuter Railroad (MNCR, operator of the terminal and its associated train lines) is in the midst of a program to preserve and restore the terminal for another 75 years of use.

In 1913, Grand Central Terminal was a state-of-the-art facility. The age of the new electric or dual-drive train car led to the new terminal's completely covered yard containing two levels of platforms and tracks. Earlier facilities on the same site had an open trainyard with one level, because exhaust for steam engines had to be provided.

The two levels with their semicircular loop tracks at the south end gave the terminal an enormous capacity for train traffic. This capacity was needed because the previous facilities had been loaded to capacity for several years. (The original Grand Central Depot, built in 1869, was expanded into Grand Central Station in 1890.) Expansion of the trainyard began in 1905 and, by 1908, a temporary train station was constructed so that the existing station could be demolished and the new terminal built on its site.

Although many systems are mentioned in this article, the emphasis is on the HVAC system. Climate control was originally (and for the most part, still is) provided by a combination of hot water perimeter heating through radiators and pipe coils, heat-

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ing and ventilating units with hot water coils and, in cases, evaporative spray coils, outside supply fans, exhaust fans and operable windows.

Most major spaces, including the waiting room, lower level concourse, Oyster Bar Restaurant, ticket booths and retail spaces, were served by both heating and ventilating units and perimeter heating. An exception is the upper level concourse, which only has perimeter heating and operable windows. The giant, operable windows on the east and west exposures (which contain glass-floored walkways) allow natural ventilation during much of the year.

A heating and ventilation system for the main concourse is shown as a future addition on the original design drawings, but it was never installed. Roundels that were part of the original construction in the east and west ends of the ceiling were to be return air grills. Outside air fans supplied untreated, unfiltered air to the platform ends near the gates to the concourses. Exhaust fans pulled air from kitchens and huge toilet facilities. All of the original fans were driven by direct drive DC motors, many of which had variable speeds.

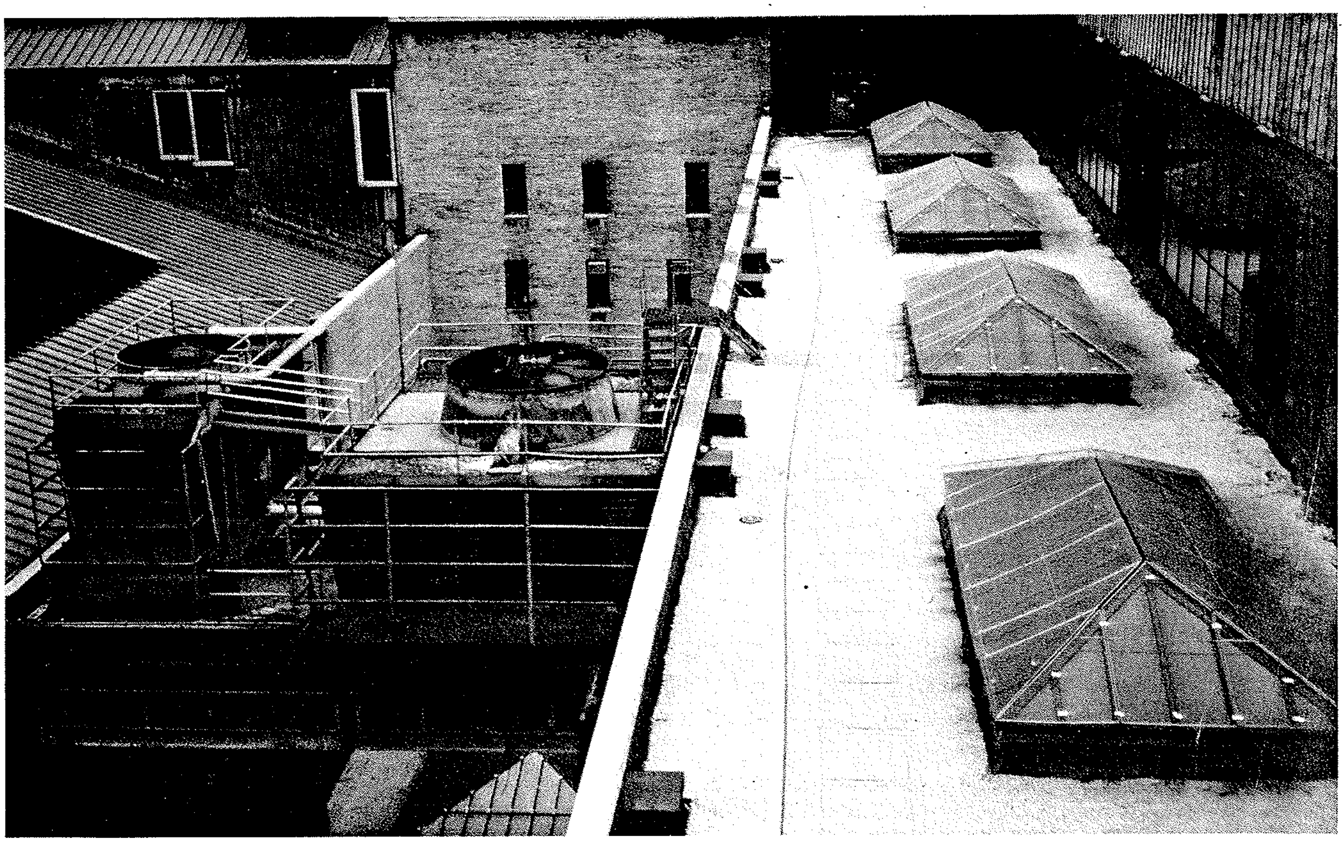
Hot water for heating the terminal and, eventually, 24 buildings was provided by five pumps and five steam-to-hot water heat exchangers. These were in a three-zone arrangement serving low levels (up to the 7th floor), intermediate levels (8th to 15th floors) and high levels (above 15th floor). An early refrigeration plant with two 15-ton compressors, associated pumps and heat exchangers was also installed. The plant produced cold brine that was pumped to cold boxes in the restaurants, candy store and flower shop.

As the trainyard was covered with streets and buildings, general ventilation was provided by natural convection through gratings in the sidewalks adjacent to the buildings, and by masonry shafts called railroad vents running through the buildings. Railroad facilities in the trainyard were served with dedicated supply or exhaust fans, many of which draw air from or exhaust air to the trainyard. Just as the trainyard required access upward to outdoor air through the buildings being constructed above it, those buildings had to gain their utility services downward from the tunnels under the trainyard. For many of these buildings, the trainyard replaces part or all of their basements.

Steam, hot water, compressed air, domestic hot and cold water, fire suppression water and electricity were originally provided by a power plant located on 50th Street between Lexington Avenue and Park Avenue. This was several blocks away from the terminal, but still adjacent to the trainyard. Distribution of these services throughout the trainyard and to the terminal was in piping grids that run through a set of tunnels underneath the lower track level.

The hot water heating and steam systems once served 24 buildings, while 28 buildings received electric power. The terminal and the surrounding neighborhood's infrastructure developed hand-in-hand, although today only 12 buildings still receive services through MNCR. (These are to be phased out over the next few years. Utility services for these buildings will then be provided by Consolidated Edison Company of New York.)

Changes to the systems within the terminal have been moderate. Many of the original air systems are still in operation.



Cooling towers and chillers were added in mid-1930s.

The loads for the vast grids of steam, hot water and compressed air piping are now much smaller than the capacities of the grids, particularly since the departure of the formerly connected customer buildings. Primary equipment serving the hot water and compressed air grids is much larger than necessary, which results in inefficient operation.

Even though most of the loads have fallen, a few such as chilled water and ventilation have risen. Demand for chilled water exceeds capacity because air conditioning is a given today, instead of the novelty it was in the 1930s. On a long-term basis, even more chilled water will be needed as more spaces are air conditioned.

While some of the sidewalk gratings and original exhaust fans ventilating the train room have been removed and other supply and exhaust fans have been added, the heat load in the train room has increased, mainly from air cooled condensers on the train cars. Increased ventilation for the train room and adjacent facilities (such as the service plant) will require greater access to the outdoors for supply and exhaust air.

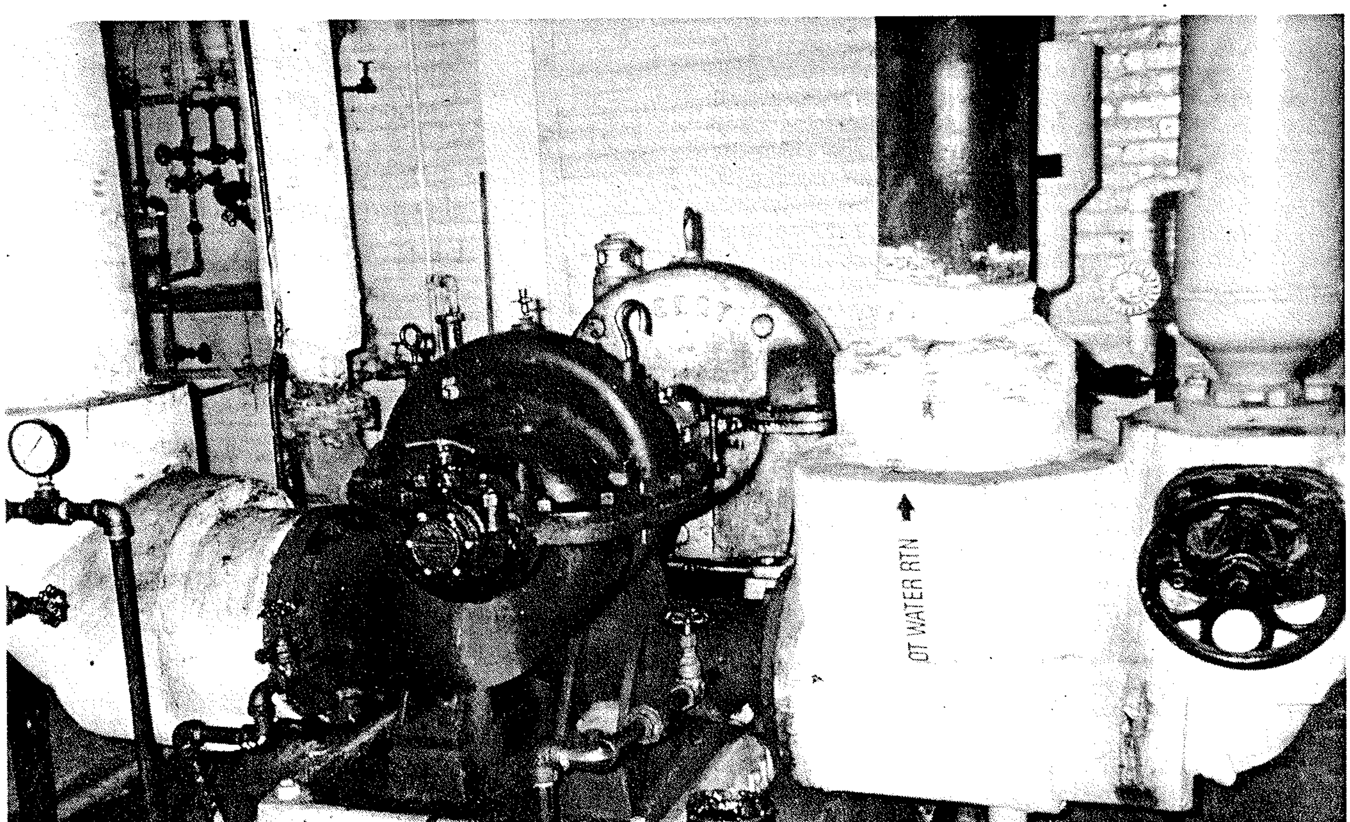
Originally, the terminal served a mix of long distance and commuter passengers and had a modest amount of retail area. Railroad office space was almost all outside the terminal. Now, it serves almost entirely commuter passengers, who spend little time in the terminal. MNCR wants to expand and upgrade the retail areas to make the terminal a retail destination as well as a transport destination. The number of railroad offices and facilities within the terminal has now increased substantially since the original construction.

The need to prevent further physical deterioration of the terminal and to return it to its earlier grandeur was apparent by the 1980s. As the terminal celebrated its 75th anniversary in 1988, MNCR launched long-range programs to restore the terminal's utilities infrastructure, architectural appearance and place in the community.

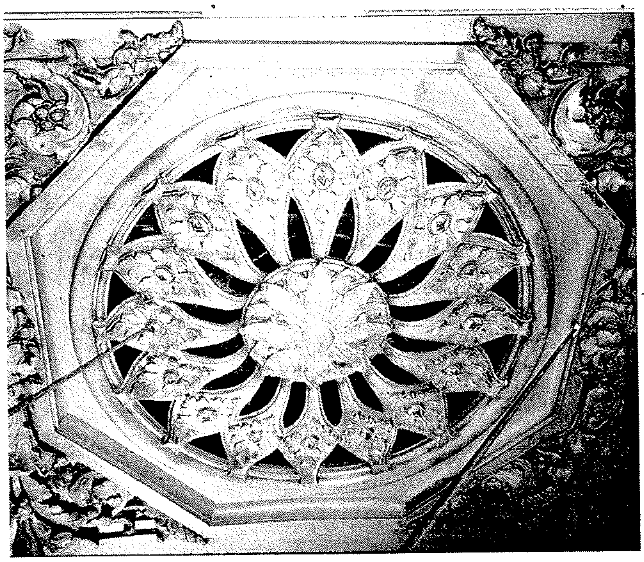
Recognizing that the terminal needed major work designed with a long-term, comprehensive view, MNCR hired an engineering team and an architectural team under separate, multi-year contracts. The scope of work for both teams is to survey existing conditions, develop long-term conceptual designs for rehabilitating and revitalizing the terminal, and produce bid packages to execute the conceptual designs.

Locating and documenting all of the utilities was a major challenge. Over the years, air-conditioning units, fans and other equipment have been tucked in where space would allow. While a large selection of drawings is available from MNCR's archives, documentation of many changes since the mid-1950s is poor. The field survey personnel spent many hours trudging through the tunnels and the train room, sweating in the service plant, and peering into the seemingly endless nooks and crannies of the site. Field notes and sketches were combined with existing drawings to produce an existing conditions report and CAD-based drawings set approximately 15 months after the project began.

Once a record of the terminal's existing conditions was made, a conceptual design was developed. Beyond the straightforward tasks of calculating heating and cooling loads lay the deeper questions of what type of systems should support the terminal for the next 75 years. What systems should remain centralized (heating, hot water and chilled water) and what systems should be decentralized (domestic hot water heaters and air compressors)? Where should steam heating replace hot water heating? What entirely new systems should be added? Would it be possible to provide smoke control, especially in the large public spaces, with the air systems? Where will all this new equipment be located and will it fit? The major HVAC-related features of the conceptual design are as follows:




Steam-driven heating hot water pump in service plant.



Closeup of individual roundel (5 ft. diameter).

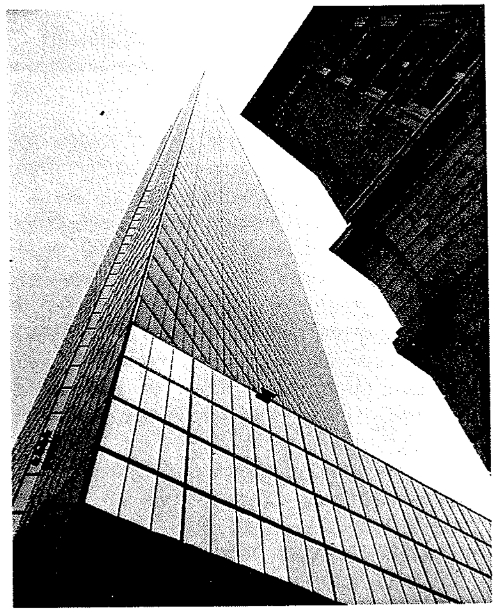
Selected spaces (such as the retail spaces, ticket booths, offices and some tenant spaces) were air conditioned by adding new air handlers, altering existing ones or adding packaged air-conditioning units. None of the large public spaces have been air conditioned. Both supply and exhaust fans were added to improve air movement as spaces within the terminal were modified.

Changes to the plant equipment were extensive. By 1920, a boiler plant had been added underneath 43rd Street, just east of the terminal. It supplemented the 50th Street plant by adding steam to the steam piping grid. In the late 1920s, the railroad decided to purchase all steam and electricity instead of producing it. The 50th Street and 43rd Street plants were demolished and steam and electric connections were made to the local utility companies. Most of the equipment from the 50th Street plant (such as air compressors, pumps and heat exchangers) was moved to a new underground service plant adjacent to the terminal and reconnected to the existing distribution piping grids.

In the mid-1930s, chillers were added to the refrigeration plant, and cooling towers were suspended above an inner courtyard. Chilled water distribution piping was threaded through the track and platform areas and up into the terminal. Chillers and towers have been replaced and added to since then, and the central refrigeration equipment was removed. Tenants now use local packaged cold boxes with air cooled condensers that add to the air-conditioning load.

In the mid-1980s, ventilation systems were added to platforms at both levels of the train room. Air is drawn from just above the tracks and exhausted to the outdoors. In the lower level train room, outside air is supplied at the ceiling. These ventilation systems were designed to relieve heat buildup caused by air-conditioned train cars, which reject their heat near the platforms and cause temperatures to rise quickly during the summer.

The original systems were innovative for their time, but almost eight decades of use, changing technologies, loads and operations have left them overdue for replacement and renovation. Much of the equipment is worn or obsolete. For example, fan and pump drives include steam turbines and direct current, 25 Hz and 60 Hz electric motors. Most of the major air handlers have never had filters. Evaporative spray coils are inoperative. Most of the distribution piping is between 50 and 85 years old. Systems such as building automation or equipment such as self-contained thermostatic radiator control valves were never added as they became established technologies.



*Smoke control.* A study was made of air flow through the large open areas of the terminal to determine what pressurization would be required for smoke control. On-site observations and measurements of air temperature, velocity and differential pressure across exterior walls were coupled with a PC-based numerical model to assess the strength of the stack effect.

The stack effect was predicted and field-verified. During cold weather, enormous quantities of air are pulled from the train room into the terminal and out the upper-story windows and contiguous high-rise buildings. Calculations were made to determine how much pressurization would be required in the terminal to offset this draft, which could draw in smoke from a fire in the train room.

However, after evaluating the costs to pressurize the enormous leakage from the terminal, it was decided that better value would be gained by creating an effective smoke supply and exhaust system for the train room itself. The primary reason is that there are many egresses in the terminal for passengers, but relatively few in the train room. This coupled with the other potential impediments to easy passenger movement inside the train room (limited visibility and impaired walking caused by tracks and third rail) make the train room a better candidate for smoke supply and exhaust.

Ultimately, a conceptual design for the train room using the existing shafts, sidewalk gratings and a carefully orchestrated zoned supply and exhaust system was developed. This would allow areas within the train room to be pressurized and depressurized from a master fire control center.

In the terminal, all air systems will be equipped with smoke detectors. Shutdown will be automatic upon detection of smoke. Starting exhaust fans, supply fans with 100 percent outside air, and moving motorized operable windows open or closed will all be done from the command center.

*Train room ventilation.* Smoke control systems, as previously discussed, will be added. The day-to-day function of these systems will be ventilation. Platform ventilation will be expanded. For facilities within or adjacent to the train room, outside air rather than the train room air will be used to supply ventilation and exhaust air will be carried out of the train room. These measures will require extensive use of the railroad vent shafts for fan forced ventilation instead of as gravity vents.

*Service plant.* All piping and equipment will be replaced in phases. Just as the equipment from the 50th Street plant was moved to the service plant in a four-month window in 1929, demolition and much of the renovation will occur on a tight schedule between heating seasons. The new equipment configuration reflects the decreased heating load and the increased cooling load. All major heating and cooling equipment, except for the cooling towers, will then be in one location.

As in many older buildings, siting the cooling towers was a difficult task. In a courtyard near the top of the building (which is surrounded by the angled roof for concealment), the towers will be sandwiched between skylights.

*Utility piping revisions.* The vast grids of steam and hot water piping will be pared back to serve only the terminal, MNCR facilities and a few special agreement steam customers. The remainder of the customer buildings will be served by Consolidated Edison Company.

Steam piping will be run to all of the fan rooms and most of the hot water perimeter heating will be retained. Chilled water piping will increase in size and in extent to serve new air handlers and retail areas. Some of the new utility piping will follow the original paths through tunnels and shafts, while others will run through a train room with limited clearance.

*Air systems.* Almost all of the air systems will be replaced. Existing fan rooms will be used and, in some cases, expanded. The major fan rooms are located near the top and bottom of the terminal. HVAC air handlers with steam coils will replace heating and ventilation units as the air-conditioned areas increase. Although the toilets are much smaller than they were originally, food services are planned to increase, so exhaust air quantity will increase. Large quantities of new and replacement ductwork will be installed.

Fortunately, the terminal was constructed with ample shaft space to allow for future expansion. The large columns flanking the main concourse and waiting room are hollow and were designed to contain ducts. Other shafts ring the perimeter of the terminal. Many of them contain aged or abandoned ducts and pipes. Some have been floored over and converted to storage space or mechanical rooms. Many shafts will have to be cleaned out and, in some cases, reclaimed to complete the conceptual design.

*Monitoring and control.* A command center will be established outside of the service plant with connections to all monitoring, control, life safety and security systems. Local monitoring and control systems in the service plant and fan rooms will be capable of stand-alone operation.

*Additional systems.* Although they are not discussed here, changes to the other systems covered by this project, such as electric power (non-traction), track lighting, domestic and fire suppression water, sanitary and storm drainage, and compressed air, will be as extensive.

Making the conceptual design a reality involves producing bid packages that work within the logistical and financial constraints experienced by MNCR. Grand Central Terminal will have to remain in full operation while being renovated.

One of the major phasing difficulties is to replace and upgrade all of the utilities while sustaining complete operation of the terminal. In many cases, new utility distribution will have to be installed alongside existing distribution to maintain operations. When renovating a space, the utilities passing through the space must be considered in addition to those serving the space. Other major projects such as North End Access (a project to connect the northern ends of the passenger platforms with street level) will also be under construction.

The entire exterior and portions of the interior are landmarked historic spaces. This means that work in these spaces can proceed only after the design has been approved by the Landmarks Preservation Commission. The commission is concerned with preserving the historic integrity and appearance of the terminal, which can make it difficult to replace and extend mechanical and electrical utilities.

Even if the terminal was not a landmark building, the extensive use of marble, ornamental plaster, Caen stone (molded sandstone block) and structural clay tile makes opening the walls and ceilings expensive and risky. For example, in the recently completed waiting room restoration design, it was decided not to open up the south walls to replace ductwork or hot water piping. At the present time, the existing air system will be retained. When it is replaced, the south ducts will be routed outside the waiting room. The hot water piping will be abandoned and heat will be provided by a combination of the existing air system and electric heaters in the windows.

To replace two storm drain lines running above the waiting room's ornamental plaster ceiling, the ceiling will have to be opened up. No alternative routing for the lines is possible and the only access to the lines is through the ceiling.

The total cost of the utility and architectural renovation is estimated to be $400 million and will be a major constraint. MNCR's ability to obtain capital for the renovation will determine the pace of the work to a greater degree than logistical constraints.

**Acknowledgments**

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