

TUNNEL MILESTONE, AND MORE TO COME

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To many commuters, the two tunnels that connect New Jersey and Pennsylvania Station in Manhattan seem so ordinary that they barely give them a second thought — except, perhaps, when their train breaks down inside them.

Yet when the Pennsylvania Railroad blasted the final pieces of rock out of the tunnels to complete the underground link a century ago this week, they were hailed by many as an engineering marvel and the product of foresight and gumption.



The Gilded Age tunnels have performed remarkably well and defied skeptics — including some of the engineers who built them and doubted their durability. Each business day, about 150,000 passengers ride the 337 New Jersey Transit trains that roll through the 6,100-footlong cast iron tubes, which are owned and operated by Amtrak, which itself runs 104 trains. Another 39 empty New Jersey Transit trains use the tunnel.

But the tunnels reached their peak-hour capacity in 2003 when the Secaucus transfer hub opened. So New Jersey Transit and the Port Authority of New York and New Jersey are planning to spend \$7.6 billion to build a second set that will more than double, to 48 an hour, the number of trains that can traverse the Hudson.

The project, called Access to the Region's Core, or ARC, is in some ways as monumental as the first tunnels, which cost the Pennsylvania Railroad \$111 million, a price tag that included the old Pennsylvania Station and four other tunnels under the East River. (It's about \$2.5 billion now when accounting for inflation.)

If federal approval is given this summer and grants are secured later this year, construction will begin in early 2009 and take eight years. Contractors will deploy boring machines the length of football fields to drill through granite, schist and other materials, use laser-guided satellite signals to pinpoint their location, and carve a path under 34th Street so wide that commuters will be able to walk underground to 14 subway lines, and to PATH, Amtrak, New Jersey Transit and Long Island Rail Road trains.

The sophisticated machinery dwarfs the equipment used a century ago, when legions of sandhogs, or underground construction workers, risked their lives toiling in high-pressurized chambers slopping silt into carts that were hauled away by mules. But in other ways, the techniques for boring through hard rock and under riverbeds and serpentine city streets remain remarkably similar.

"The principles back then were almost the same except today, things are more mechanized and automated," said Howard Sackel, the deputy chief of the tunnel project.

The ARC tunnels are part of a larger tableau of civil projects that include the construction of the Second Avenue subway and the East Side Access project that will bring L.I.R.R. trains to a station adjacent to Grand Central Terminal. Some pundits have compared these days of largescale projects to when master builders like Robert Moses reshaped New York's landscape with aplomb.

But many of these projects were designed decades ago, when New York's existing bridges, tunnels and rail lines had already reached capacity. In that light, many transportation officials view the ARC project as an urgent necessity, not unlike the first tunnels that were designed so riders could avoid crossing the Hudson by ferry.

"We're still living off the past in many ways, and we have to think big again," said Rae Zimmerman, the director of the Institute for Civil Infrastructure Systems at New York University. "But we also really have to keep up the level of service because these big projects can take 20 to 30 years to build."

Keeping up means raising tolls and fares at New Jersey Transit, Metro-North and the Long Island Rail Road as well as at the Port Authority and the Metropolitan Transportation Authority. In addition, Gov. Jon S. Corzine wants to raise highway tolls by as much as 800 percent. New York State is mulling a plan to charge drivers \$8 to enter a zone south of 60th Street in Manhattan. Drivers entering the city from New Jersey would pay an extra \$3 or \$4, something Mr. Corzine opposes.

Still, the ARC project has its skeptics, just like the first tunnels, which were championed by Alexander Cassatt, the president of the Pennsylvania Railroad. He had to win over shareholders who viewed the project as an expensive folly, as well as politicians in New York City who worried that the vast construction project would dilute their power by displacing so many residents.

These days, critics complain that the project would cost billions of dollars more than is Tunnel Milestone, currently projected and would overburden already crowded Midtown streets. Others say that the project is not ambitious enough, and that it should be extended to Grand Central Terminal. And critics say that the new annex would be too far underground and not part of other plans to redevelop the area around Pennsylvania Station.

"Having New Jersey Transit unilaterally place its commuters in a dead-end dungeon, we lose mobility," said Albert L. Papp Jr., secretary of the National Association of Railroad Passengers. "For billions of dollars, we lose access to Penn Station and don't get access to Grand Central Terminal."

Like agency officials, though, many critics agree that in an era when transportation dollars are in short supply, securing money for new tunnels is critical.

While executives at New Jersey Transit and the Port Authority lobby Congress for up to \$3 billion, a team of 200 engineers and architects has been busy planning every aspect of the project so construction can begin as soon as possible.

The westernmost part of the project is above ground at the Frank R. Lautenberg Station at Secaucus Junction, where a loop will be built so that instead of heading only to Hoboken, some Main, Bergen and Pascack Valley Line trains can head directly into Manhattan.

New Jersey Transit will use much of the rock and silt excavated from the tunnels to raise an 80-acre vacant lot in Kearny by 20 feet. That will create the extra space needed for trains to park at midday.

A second set of tracks will be built parallel to the existing Northeast Corridor route from Secaucus to North Bergen and the western edge of the Palisades. The new tracks, though, will veer south at Tonnelle Avenue and the entrance to the new tunnels.

There, a special hard-rock boring machine will begin its 5,000-foot descent to the river in Hoboken, where the tunnels will enter the Hudson a little more than 100 feet below ground. The distance and depth are no accident. Like the older tunnels, the new ones will have a grade of no more than 2 percent. Anything steeper and a train's steel wheels slip on the steel rails.

"The character of steel has not changed much in the last century," said Arthur D. Silber, the chief of the ARC project.

Geologists have taken 20,000 feet of core samples and determined that the Palisades here are filled with hard, abrasive diabase and sandstone. Workers a century ago used dynamite and rock drills to claw through the stone.

These days, operators sitting in an unpressurized chamber of a hard rock boring machine do the heavy lifting. They use computers to direct the machine. A drill in front of the shield takes samples of the rock ahead.

In front of the shield, a rotating disc with a diameter of just under 30 feet that is outfitted with about 20 specially designed teeth, chews away at the hill and spits out rocks the size of charcoal briquets. The stones roll past the shield and are carried back along the threads of a giant turning screw, which dumps the rocks onto a conveyor belt.

The machine will cover up to 50 feet a day and it will move with far greater precision and with far less dangerous blasting than a century ago.

The most dramatic changes in construction techniques, though, are those for drilling under the river. A hundred years ago, engineers pushed iron shields that weighed up to 200 tons through the silt and clay. Nine small doors on the shield were opened at different times to allow silt and clay to pass through them like a sieve into a pressurized chamber, where workers loaded the material onto carts.

Workers also removed debris — boulders, wooden poles from wharves — that were blocking the shields' path.

As the shields moved forward, workers installed 11-ton cast iron rings that were bolted in by hand to form the circular body of the tunnel. The liner plates were 30 inches wide and once secured, were used as leverage for pistons that pushed the shield forward by precisely another 30 inches. Sandhogs progressed up to 30 feet a day.

To speed the construction of the tunnels, the Pennsylvania Railroad had teams on both sides of the Hudson race to get to the state line under the river. (The New York team ultimately won.) This meant that each time a plate was installed, the engineers had to determine their location to ensure they were on track to meet the team advancing from the opposite shore.

Charles Jacobs, chief engineer of the North River tunnels, told a reporter at the time that this was a "simple problem of trigonometry." Surveyors would use 100-foot lengths of piano wire inside the tunnel and towers on both shores to confirm that they were on the correct path.

"They would check every five or six rings to make sure they were straight," said Bernie Martin, a professional engineer at Parsons Brinckerhoff and an expert on tunnel construction.

"Nowadays, it's like navigating a space ship. The accuracy is superb."

Surveyors often discovered that they were off course, sometimes by several feet. When one of the tunnels from New Jersey was two feet too high, heavier rings were used in the hope of sinking the tunnel farther. Even after the tunnels were completed and left to settle in the silt, some engineers considered bolting the tunnel to the bedrock if the tunnel shifted too much.

"No one knew if that tunnel was 100 percent safe until trains had been going through it for many years," Jill Jonnes, the author of "Conquering Gotham" (Viking Adult), which details the building of the tunnels and Pennsylvania Station, said in an interview. "They really didn't know how long the tunnels would keep sinking in the mud and whether they would crack. There was no precedent for a tunnel having hundreds of 700-ton trains going through them."

To this day, the tunnels continue to drift ever so slightly in the riverbed.

This time, engineers will use an earth pressure balance machine to bore from New Jersey all the way to New York, and then switch to a hard rock machine to burrow under Manhattan.

The front of the machine, similar to the hard rock borer, absorbs muck and passes it through the shield. As the machine moves forward, 12-inch- and 18-inch-thick concrete segments will be put into the place behind the shield to form the wall of the tunnels. Some contractors use precast segments, while others pour concrete into forms. In both cases, gaskets are inserted in the seams between the segments to keep water and mud from seeping in.

To determine the tunnel's location, lasers send coordinates from the boring machine back to the tunnel opening and up to global positioning satellites. Instead of dozens of sandhogs toiling in high-pressure chambers forever in danger of getting the bends, 6 to 10 workers operate the earth pressure balance machine.

When the original tunnels were built, engineers dug a three-block-wide trench from 12th Avenue to Seventh Avenue to form the West Side railyards and the tracks under Penn Station. They drew up plans for two more tunnels.

The new tunnels will enter Manhattan between 28th and 29th Streets about 150 feet below ground to avoid a bulkhead at the river's edge, the Hudson River Park and what is expected to become the extension of the No. 7 subway line that is supposed to run along 11th Avenue.

The tunnels will run northeast to 10th Avenue and split into lower and upper tunnels that will form a two-tiered cavern with six tracks under 34th Street. The station will extend from Eighth Avenue to Sixth Avenue, with a "tail" to Fifth Avenue for trains to park.

Some transportation advocates say the new station will be a security issue because it will be more than 150 feet deep. They also note that the six tracks will be far from Penn Station, making changing trains difficult.

"There is a perception in public that this is not a deep cavern, that it's just below the street," said Joseph M. Clift, a member of the Regional Rail Working Group. "It sounds like fear mongering, but it's an attractive target."

Other transportation advocates say the construction costs are likely to soar, which could mean many more fare increases. They also question whether New Jersey Transit and other agencies have ensured that the additional 60,000 commuters who are expected to use the new station by 2030 do not overwhelm the nearby streets.

"Where do these extra people go when there's no room for them now?" asked Kyle Wiswall, general counsel of the Tri-State Transportation Campaign. "As much of your commute is getting from the station to your office."

Mr. Silber of New Jersey Transit said that the extra passengers going through the new station would be a "small contributor to the street traffic," and that his agency is working with the city and New York State to develop a comprehensive plan to address the additional pedestrians.

In a report released last month, analysts at the Regional Plan Association called for the tunnels to be extended from 34th Street to near Grand Central Terminal so commuters working on the East Side do not need to clog the subways and streets getting to and from their offices.

But they concede that their proposal is the second phase of the project, and that it is important to set aside differences so construction can begin on the first phase.

"Before you can get to Madison Avenue, let's get the funding in place, get the thing under construction and then figure out what's next," said Jeffrey Zupan, a senior fellow for transportation at the association.