Spirit of the Future

San Francisco Bay Area, California

Thursday, July 24, 1997

SPECIAL EDITION

BART Declared Historic Landmark

Transit system receives award from American Society of Mechanical Engineers

San Francisco's Bay Area Rapid Transit (BART) system was declared a "National Historic Mechanical Engineering Landmark" today at a festive awards ceremony held at BART headquarters in Oakland, California.

The American Society of Mechanical Engineers (ASME) conferred the internationally renowned award on the BART system, which was developed in the mid-1960's.

Right, BART, the award-winning rail transportation system, spans about 95 miles to connect San Francisco with four other counties throughout the Bay.

1964 Design is still leading-edge Today

Noted in the ASME citation for excellence and creativity are ten design innovations, including the design of train cars derived from aerospace technology and the subtle details of the spectacular Transbay Tube.

National Historic Mechanical Engineering Landmark

San Francisco Bay Area Rapid Transit System

The American Society of Mechanical Engineers International

HISTORIC MECHANICAL
ENGINEERING LANDMARK

1972

BAY AREA RAPID TRANSIT

BART HAS BEEN THE PROTOTYPE FOR MOST MODERN RAIL TRANSIT SYSTEMS. THE INTEGRATION OF MANY NEW ENGINEERED COMPONENTS INTO A UNIFIED SYSTEM WAS A KEY TO ITS SUCCESS. THE FIRST BART CARS INTRODUCED EXTRUDED ALUMINUM CAR BODY SECTIONS, 70 FEET LONG, AND A NEW GENERATION OF TRANSIT-CAR TRUCKS. INNOVATIVE VENTILATION AND FIRE-CONTROL SYSTEMS MADE THE 3.6 MILE TRANSBAY TUBE PRACTICAL.

ASME International
(American Society of Mechanical Engineers)
1997

1997 NL 116

From the Front Line

Thomas E. Margro
General Manager

The San Francisco Bay Area Rapid Transit District is proud to be recognized by the American Society of Mechanical Engineers (ASME) International as a Historic Mechanical Engineering Landmark. To receive recognition from such an esteemed group of engineering professionals is indeed an honor, and it seems particularly fitting that it comes as BART observes its 25th anniversary of revenue service.

This document outlines many of the specific engineering innovations that were pioneered by BART and were considered by ASME's History and Heritage Committee in its deliberations. Mechanical engineering played and continues to play a major role in the viability of BART as a transportation provider. We have attempted to put BART and these innovations in a historical context and to illustrate the importance of a fully integrated system to meet the complex transportation needs of a growing region. Above all, we have attempted to underscore the significance of the era in which BART began — the mid-1960's — when the world, and America in particular, was on the eve of a veritable technological revolution. BART is proud to have been at the vanguard of such innovation in the rapid transit industry.

Today, BART continues to be a prospector, never resting on its past laurels, always pushing the envelope. Currently under way within BART's own research and development group is the development of a whole new automatic train control and protection system — using global positioning technology proven so effective during the Gulf War. This Desert Storm technology, as it has come to be called, is expected to give us the ability to operate many more trains on the system at one time than is now possible — creating a moving block system as opposed to the current static block system. Trains will then be able to operate much closer together, at two minute intervals or less, while maintaining full train protection. When this effort comes to fruition in a few years, it promises to be a major breakthrough in the industry.

Meanwhile BART is moving forward on several other fronts. We are carrying out a $1 billion dollar system renovation program over the next ten years. Also, with almost 24 miles of newly completed extensions now up and running, we are embarking on an 8.7-mile project to extend the system to the San Francisco International Airport. When the project is completed in the year 2001, it is expected to be one of the most heavily utilized lines.

The organization is very proud of its engineering heritage and looks to the years ahead with the same entrepreneurial spirit that created the system in the first place.

T. E. Margro

BART - The Spirit of the Future

The development of BART was revolutionary, embodying a futuristic spirit that produced historic innovations

The San Francisco Bay Area Rapid Transit (BART) system began as a gleam in the eyes of engineers in the early 20th century. Many were entranced with the almost-mystical possibility of bringing mass transportation to a region at whose center lay a big, sprawling Bay.

At the turn of the century, for example, mass transit was in its heyday — marked with a flourish by the opening of systems in Paris (1900), New York (1904) and Philadelphia (1907). Europe had been at the forefront of mass transit development since the London Underground opened in 1863.

Remarkably, more than six decades would pass — when BART opened in 1972 — before another new American system would be created. Such a long lull in development of new rapid transit systems helped to foster an innovative spirit, a "clean slate" mentality which encouraged engineers and others to fashion a revolutionary mass transit system unfettered by preconceptions from the past. A vibrant "spirit of the future" became the cornerstone of BART.

BART leadership defined an aggressive and clear mission for the project: It must capitalize on technology that had made possible the burgeoning space age. And it must address both the present and future, thus putting a premium on creativity and forward thinking.

BART's vision did, however, have strong roots in the decades which preceded its mid-century formal beginnings. As early as 1920 some of the world's foremost engineers had been captivated by the challenge. A front page story that year in the San Francisco Chronicle declared that Maj. Gen. George Goethals — who oversaw construction of the Panama Canal — had visited the Bay Area to formally propose the construction of a transbay tube. It was conceived as a potentially critical mode for linking Oakland and outlying rural East Bay communities with San Francisco. (Ferry boats offered the only transbay transportation at the time.) The transbay tube idea was not pursued, and the Bay Bridge was built a few short years later, opening in 1936. The transbay tube idea resurfaced again after World War II in an Army/Navy report that brought to light the national security benefits of such a conduit.

Then came years of legislative deliberations; the formation of a dedicated Commission; and design, development and planning that culminated in the passage of a bond issue. In 1964, with President Lyndon B. Johnson officiating at the ground breaking of the Diablo Test Track, construction officially got under way.

Historians have credited the spirited BART project with helping to wake up a dormant rapid transit commitment in America's cities, resulting in a virtual transportation renaissance in the 1970’s. Public awareness was renewed regarding the importance of solving the strangulation of traffic which had a significant affect on the ability of a city's center to flourish and grow through an infusion of talent and workers from the surrounding region.

In addition to the socio-economic benefits of a rapid transit system, the body of work produced by the BART project provided the seeds of future creativity in the design, engineering and construction industries with a litany of innovations. Many of the BART innovations remain relevant to this day as industry standards-notably in the fields of mechanical engineering, electrical and other system features, and the breakthrough Automatic Train Control system.

A Quantum Leap

From BART's inception, it was a people-oriented engineering project...

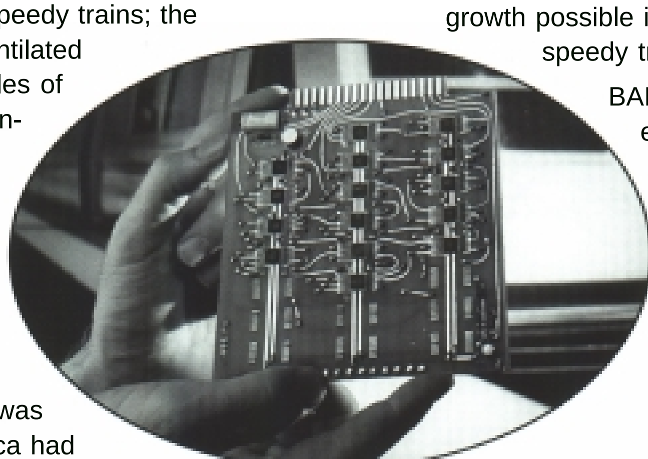
"...to give people more time for leisure, more time to be with their families, to enable them to be non-neurotic in this neurotic age."

Adrien Falk, first president of Bay Area Rapid Transit District

The unique spirit of San Francisco's people and leaders contributed to producing the degree of innovation recognized two decades after BART's opening as a Landmark by the American Society of Mechanical Engineers International. In fact, BART's engineering excellence is not readily noticeable. People primarily see the sleek and speedy trains; the spacious, well lit and fully ventilated underground stations; the miles of underground tunnels or expansive suburban aerial routes. They don't see the historic transbay tube and the scores of engineering details that made BART a revolutionary system.

Imagine San Francisco in the early 1960's. The landscape was considerably different, America had just barely begun a space race with the Soviets, and aerospace technology was in its formative years. Business in the Bay Area was booming, but traffic and transportation issues had reached a near-crisis stage. BART represented a salvation of sorts for the Bay Area. Experts agree that the new BART mass transit system saved the region from strangulation by traffic and congestion — and making economic vitality and growth possible in the Bay Area by facilitating speedy travel to/from the core of its cities.

BART embraced and adapted novel engineering approaches from the aerospace age. New technologies, especially in electronics and building materials, allowed BART visionaries a wealth of opportunities to produce a state-of-the-art system.



Novel mechanical engineering solutions are found in all BART systems.

Vehicle Design Features

Monocoque Body Shell

As the most noticeable signature of BART's forward-looking design philosophy, the train cars embodied space-age styling and technology which was rapidly being introduced in the 1960's as part of the U.S./Soviet space race.

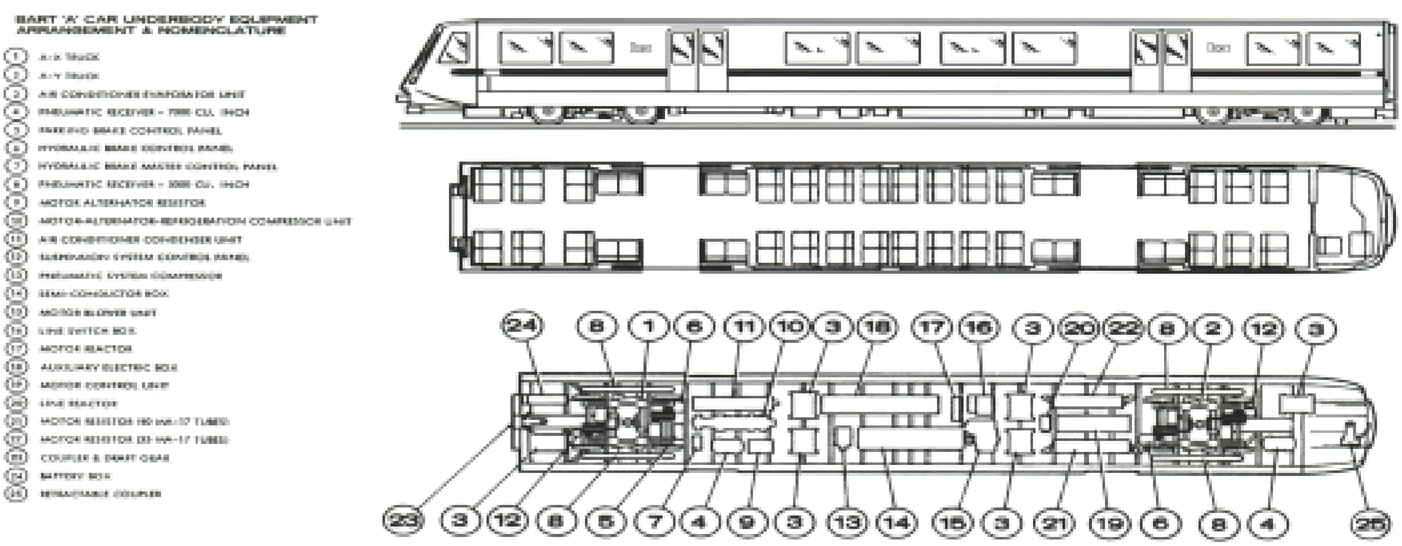
BART used aluminum extrusions—some the full 70-foot length of the car—to produce a fast, lightweight, and more energy-efficient vehicle.

The aluminum segments were constructed to produce a single unified car shape, in contrast to other systems requiring a separate heavy undercar support frame.

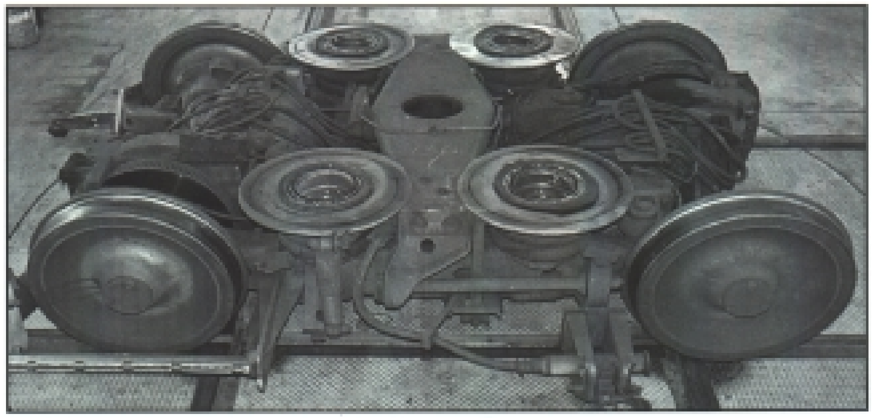
BART's new "monocoque" shell design had never before been used in America for railroad cars. The whole body served as the frame, giving it dynamic resilience. The car shell was reinforced in key areas such as around door frames and at each truck location, where a "body bolster" strengthened the shell to accept the truck.

The new car design was 40% lighter than the average subway car weighing 1,200 lb. per linear foot. Clearly, at 700 lb./linear foot (totaling 59,000 lb.) BART cars required much less power to move—an important overall objective of the design program.

In fact, environmental concerns such as energy efficiency, protection of air quality, reduction of noise, and repair/maintenance issues remained preeminent considerations of the system's designers.



Truck Assembly



Ball joints (not shown) are found below the air springs.

• ball joints

The “riding comfort center” of the BART vehicle is the truck, a complex assembly of wheels, suspension and propulsion systems. Each of two trucks on which the car rests consists of two castings joined together in an assembly that includess the wheels, brake system and power train.

The truck design also affects the stability of the car itself. Another factor is the tracks. BART uses a continuous welded rail, mounted on carefully constructed track beds.

On the truck assembly, designers added a ball joint on each transom, at cross angles to the other transom’s ball joint. This resulted in significant improvement in the distribution of the load to the wheels, plus added ride comfort due to the ball joint’s ability to adapt the assembly to rail irregularities.

Previous systems typically had less flexibility, which resulted in considerable stresses and rigid riding.

• friction braking

Prior to the BART system design, braking in rapid transit vehicles was achieved by an air-brake mechanism. BART chose to introduce hydraulic brakes which were electronically controlled. Again, this innovation became an accepted method.

The BART design objective was to avoid the slipping of wheels when stopping. Hydraulic brakes have the capability to change pressure faster and to regulate pressure faster than air-based systems.

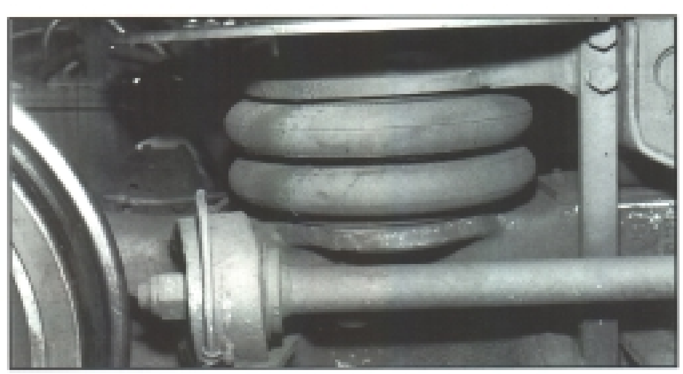
• air springs

With passenger comfort in mind, BART designers sought an alternative to the heavy metal springs which previous systems used to provide suspension between the train car and the trucks.

Taking a cue from both the auto and bus industry, BART became the first rail system in the country to use air as the mechanism for support. Air chambers encased in heavy rubber were placed between the truck and the car body. A control valve was fastened to the car body and connected to the truck frame by a lever system to regulate the amount of air in the chamber pursuant to the ever-changing weight conditions. For example, when the car body goes lower to the truck, the system automatically increases the air in the chamber so that it goes up again. Thus, the car floor level relative to the platform remains constant.

The rubber air bag produces exceptional ride quality and passenger comfort. It is the sole suspension system between truck and car. Rubber bumpers take over if the air spring fails.

The BART-pioneered air-support concept is now a popular design option in the rapid transit industry.



BART

is the only rapid transit system to be deemed worthy of "National Landmark" status by the American Society of Mechanical Engineers International. The heart of BART is in its commitment to service and quality, and in its engineering and other design details. Every day, BART serves a complex geographical area with continuing attention to state-of-the-art technology, engineering and electrical innovation, and the utmost in professionalism.

San Francisco Bay Area Rapid Transit District

• control central - the nerve center of BART

Tucked away in the Oakland building that houses the Bay Area Rapid Transit District's main offices is an unobtrusive door with a red light on the wall beside it. There is no sign on the door, and the hall is nondescript. All this understatement is fitting, because this is the nerve center of BART. Known as Operations Control Center, it is here that one can truly understand the depth, breadth and scope of the BART operation.

Upon entering the large room, one is faced with 65 feet of wall space displaying 96 miles of track and up to 56 trains in service at any one time throughout the system. Numerous schematic displays illustrate everything about the rapid transit system's operations. Colored lights denote electrified rails, moving and non-moving cars, location markers, ventilation settings in the Tube and tunnels, and scores of other tidbits of information.

The calm and hushed atmosphere in the room gives little hint of the organized flurry of activity taking place in the "real world" outside the symbolic one displayed on the walls of Operations Control Center — all geared to helping make BART transportation throughout four counties as smooth, efficient and comfortable as possible. Outside, 1.5 million trips each week are taken by the region's three million inhabitants.

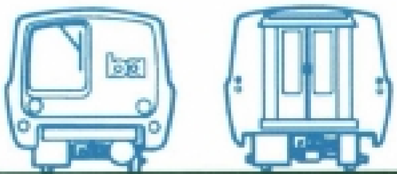
1863 London Underground opens

1900 Paris Metro opens

1904 New York City Subway system opens

1907 Philadelphia rapid transit system opens

NO NEW SYSTEMS BUILT

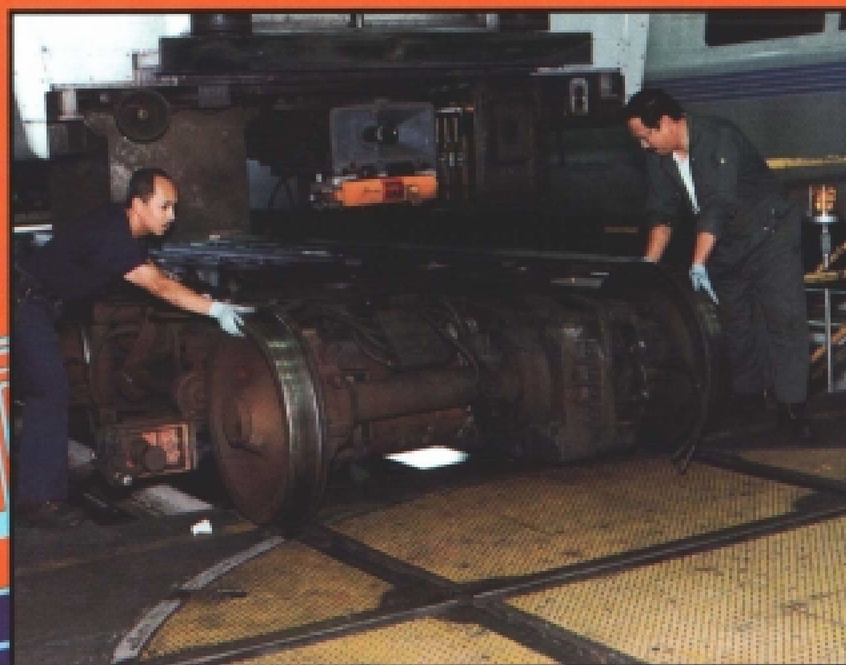


• maintenance & service

A fleet of 670 train cars, 96 miles of track, and all other electrical and mechanical equipment are maintained and serviced by some 3,000 BART employees. Yards in Concord, Hayward, Daly City and Richmond provide efficient and convenient attention to the full spectrum of BART needs.

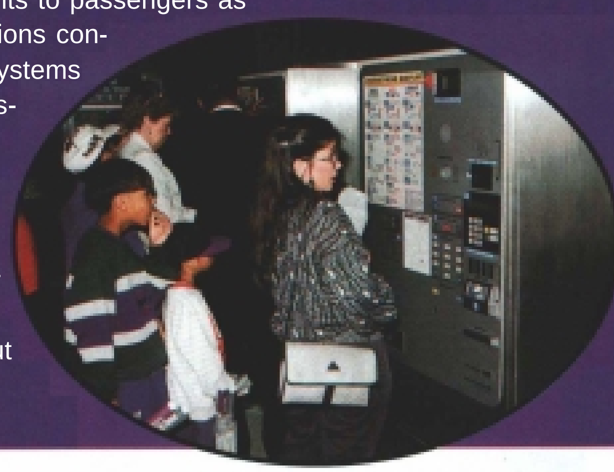
• automatic train control

The nevre centre of the world's first fully automatic train control system is housed in Operations Control Center, a vast room that is dark save for the subdued desk lights of a baker's dozen of U-shaped workstations, including an elevated supervisor's pit. The centerpiece of everyone's attention is the wall display detailing the BART train operation in progress.



• passenger stations

BART stations have won numerous awards for design and functionality. Purposefully airy and full of light, the 39 stations of the system feature electronic processing of tickets — introduced by BART to American rail transportation — and computer monitors and displays which beam information, entertainment and commercial announcements to passengers as they wait for trains. Many stations connect with other mass transit systems to yield an efficient flow of passenger transit throughout the busy Bay Area. An important BART system tenet is to foster integration of a variety of transportation entities in order to serve the ever-changing needs of a vital and spread out business and residential hub.



IN AMERICA

1964 — San Francisco Bay Area Rapid Transit System breaks ground for Diablo Test Track

1972 — BART opens first lIne, Fremont to MacArthur Station In Oakland

1995 — BART extension opens to North Concord

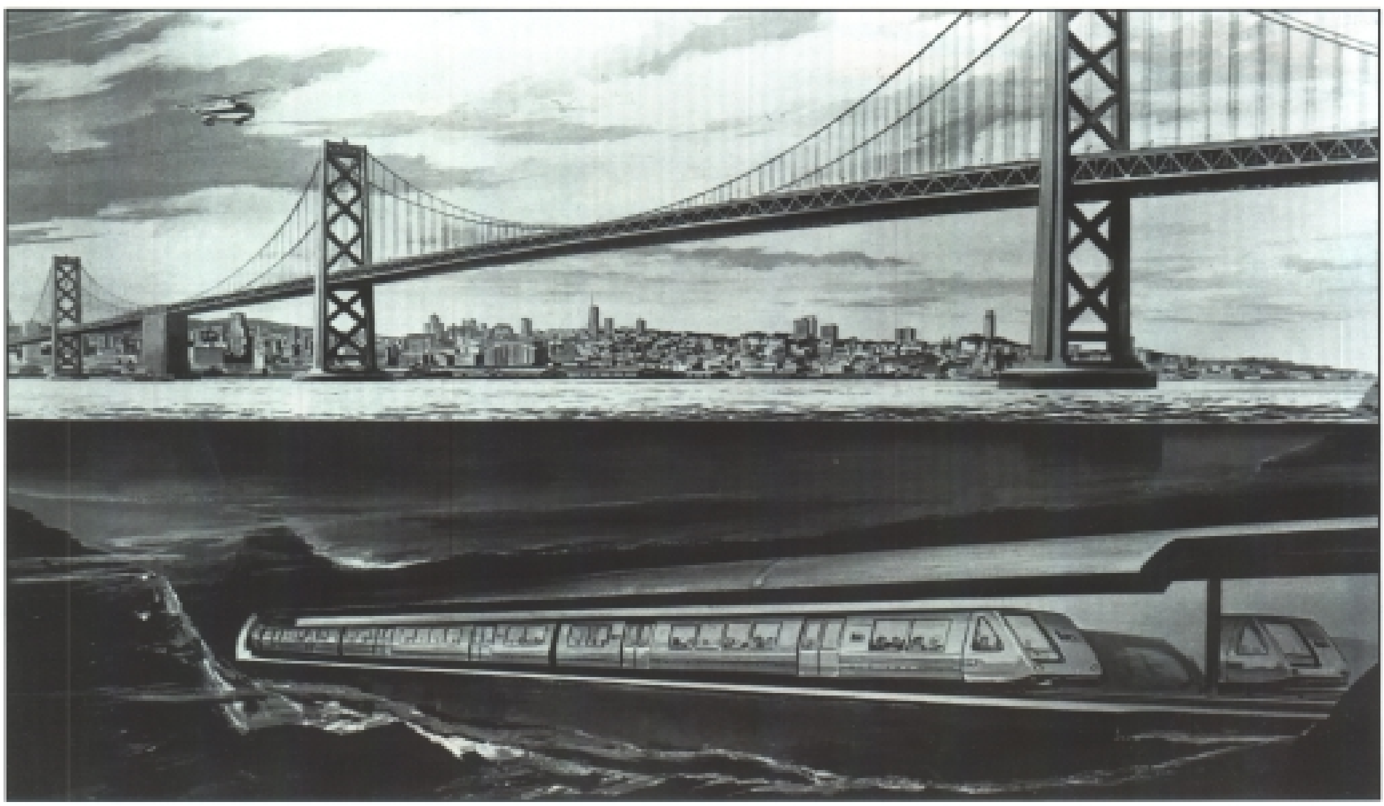
1996 — BART extension opens to Colma

1996 — BART extension opens to Pittsburg/Bay Point

1997 — BART extension opens to Dublin/Pleasanton

The Transbay Tube

The BART Transbay Tube is the longest underwater tube of its kind in the world. It's ventilation system — pioneered by BART — has been adapted by other underwater systems throughout the world.



Tube Construction

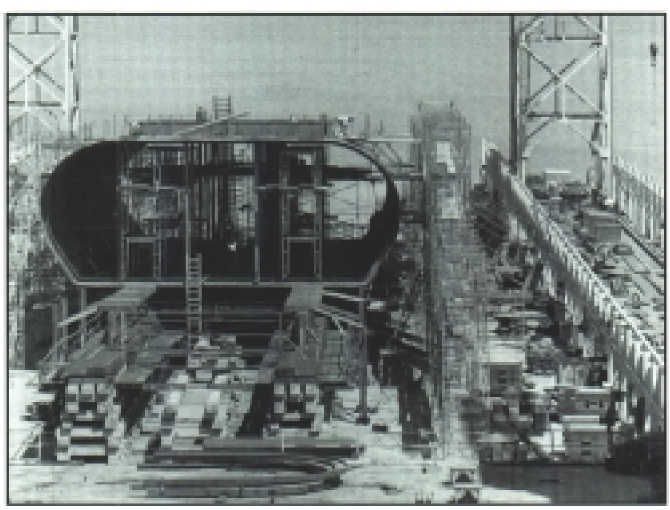
The BART Transbay Tube, opened in 1974, was a remarkable feat. At that time, it was the longest underwater tunnel of any kind in the world, and its design and construction were internationally lauded by engineers and other professionals.

Nestled in a man-made trench and traversing the floor of the Bay for 3.5 miles, the Transbay Tube is comprised of fifty-seven 350-foot exterior steel and concrete-lined sections. Sections were joined underwater using sophisticated mechanical engineering methods. The steel exterior is protected by 20 huge anodes placed in the water to control corrosion.

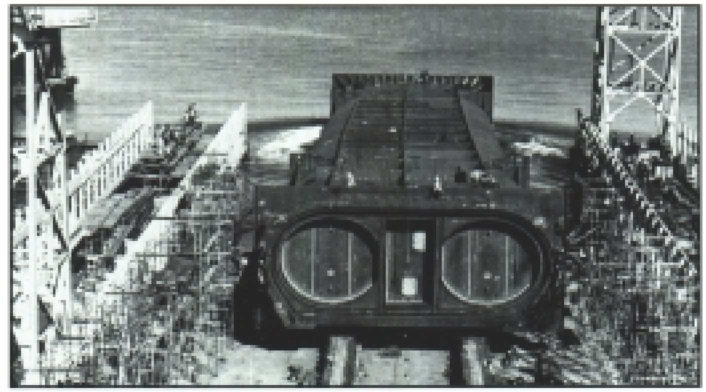
Some 130 feet below the Bay's surface, the tube structure connects San Francisco with Oakland. The structure includes two tunnels with tracks and a "gallery" area running the length of the tube between them. The gallery is divided into two chambers; one serves for maintenance access and the distribution of various electrical and safety systems, and the topmost chamber serves as an air duct for the ventilation system pioneered by BART.

Significantly, the Transbay Tube is considered by many as probably the safest place to be in an earthquake. Says 25-year BART veteran Mark Rubenaker, track department foreman, "The tube is where I want to be when the Big One hits!" The structure was designed to be flexible at each of its 57 sections, and the entire tube can flex naturally as much as 4-6 feet.

In 1989, BART withstood the powerful earthquake which devastated many of San Francisco's highways and bridges. In fact, the system was checked and back up and running within three hours of the record-setting earthquake — as the only fully operational means of transport in the Bay Area.



The BART Transbay Tube under construction.



Transbay Tube section being prepared for launch.

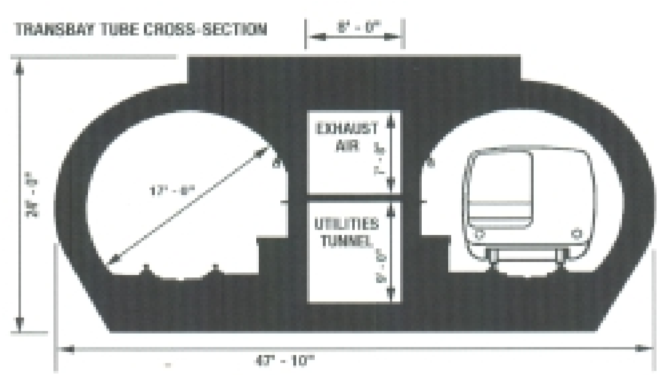
Ventilation System

Of special note is the BART system's ventilation system. Traditionally, tunnels of any type rely on the piston-like action of the vehicles passing through to vent air into and out of the tube.

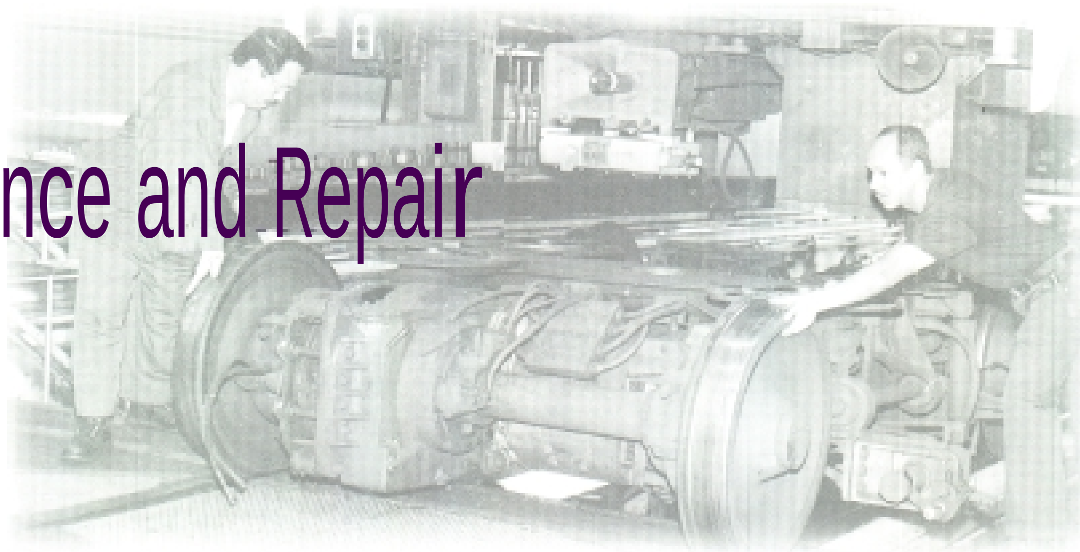
BART designers specified the use of forced ventilation, made possible by power-driven propellers at every transit station, together with a system of dampers in the Tube which could be remotely controlled from Central consistent with the conditions at hand.

In the Transbay Tube, large blowers move 300,000 cubic feet of air per minute along a shaft located along the topmost duct-type chamber of the tube structure. Reversible 6'x12' louvers, each with a motor and controlled by Central, are located every second section of the 57 total sections.

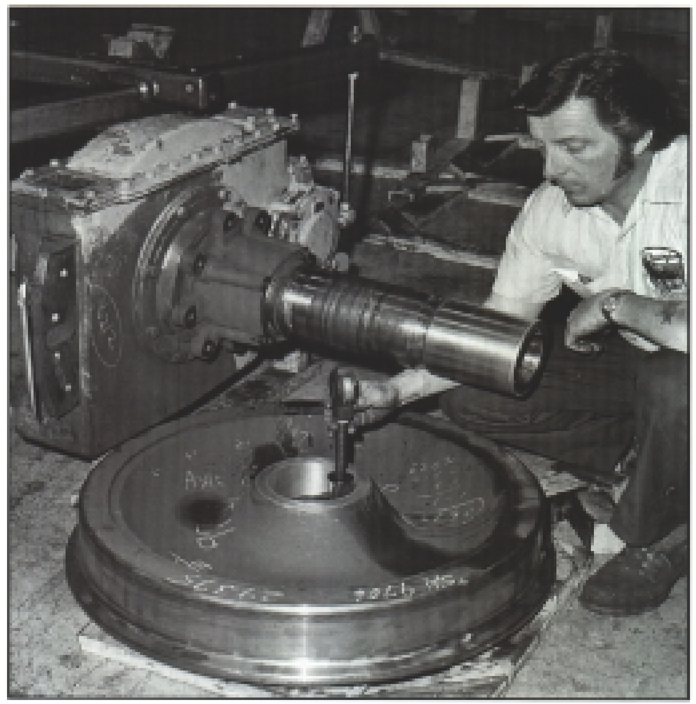
In testimony to the lasting efficacy of BART designs, the England-to-France "Chunnel" (completed more than 20 years later) utilizes the same concept.



Maintenance and Repair



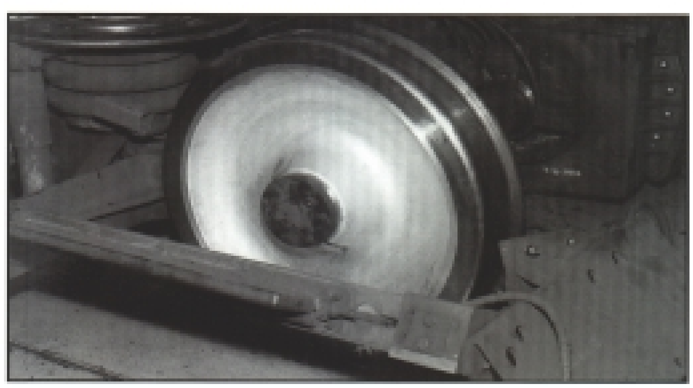
Nickel-Plated Axles



An important concern of BART is its ability to address complex operational issues such as maintenance and repairs. In the developmental stages of BART, a variety of factors was considered in specifying specific materials and procedures to be used.

For example, BART recognized that a large inventory of spare wheels to fit the normal variances of each axle would not be financially feasible. Typically, larger transit systems press steel wheels onto the axles with a press that exerts from 50-80 tons of force. Conscious of the importance of fiscal responsibility and maintenance efficiency, BART developed a new process for mating wheel to axle, one which used the latest advancements in materials science being utilized by the burgeoning electronics industry of the 1960s. The ends of axles are built up with nickel plating to allow for a perfect fit with each wheel's opening size.

Aluminum-Centered Wheels



BART also specified aluminum-centered wheels in place of the traditional all-steel wheels used by other systems. The objective was to reduce weight. To address any scarring of the aluminum when being pressed on/off the axle, an 1/8-inch hole is bored in the center of the wheel, into which is put 10,000 PSI of hydraulic fluid between the bore surface of the wheel and the surface of the axle.

Eye-bolt Connections for Lifting Cars

BART considered even the most minute aspects of servicing and maintaining its rolling stock when developing its designs. For example, traditional methods of picking a car up in the service yard involved large steel arms hung from a crane; the process required as many as six people to pick up the car.

BART incorporates eye-bolt fittings into the aluminum shell at the reinforced areas near each door frame. Then, a two-bridge crane uses eye-bolts on each side to raise the car. Only two people are needed for this operation. The car's construction is adapted specifically to accommodate this type of operation, in particular the car is built so that those points on the roof support the weight of the car.

Yard Turntables

Once BART was in operation, several new design challenges presented themselves. For example, it had been clear that the limited space in the yards would preclude looped tracks for turning trains around. Since the control cars have controls on only one end of the car, they may need to be turned 180° for proper orientation. It had become apparent that better efficiency could be realized if trains could be more easily made up in different configurations — such as ten-car trains during rush hour and shorter trains off peak — on an instant need basis. Also, breakdown incidents could be better handled if quick shifts of cars and train make-ups could be achieved.

In the typical spirit of BART innovation, engineers came up with a solution which introduced a new technology to the railroad industry, one which has become mainstream today for new systems. A turntable was located at the end of a track in the service yards. But, unlike the traditional turntables which utilized an enormous pit in which a complex bridge-like turning mechanism was constructed, the BART turntables took advantage of newly developed "air bladder" or "air caster" cushions used to move airplanes and heavy industrial equipment.

As a car approaches the turntable, it rolls up a 1% grade to join with tracks situated on a coated concrete slab. Beneath the slab are several large neoprene and cotton deflated bags, into which air can be fed from above by a system of pipes.

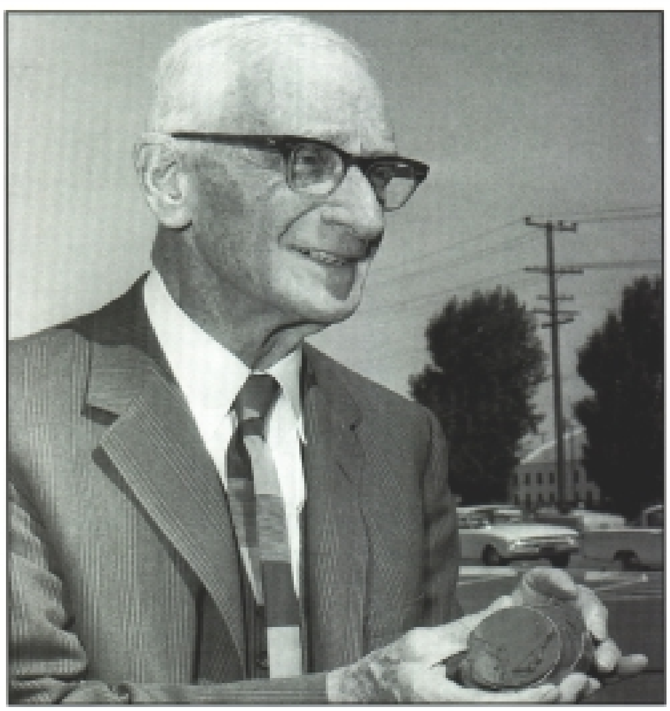
After the car is locked in place on the turntable, the air is turned on and the "air casters" expand by filling with air. A continuous layer of air is expelled from an opening in the bottom of each caster.

Effortlessly, the bridge structure with the 60,000-pound car is lifted up on the air cushion, whereupon a simple 3/4 HP hydraulic motor easily pushes the structure around and deposits the car to face the opposite direction on the main track.

A Team Charged with Imagination

BART leadership defined an aggressive and clear mission for the project: It must capitalize on technology that had made possible the burgeoning space age. And it must address both the present and future, thus putting a premium on creativity and forward thinking.

BART was brought to reality by a team headed up by Adrien Falk as president of the Bay Area Rapid Transit District. At eighty years old, he was the "grand old man of the San Francisco municipal scene." The essence of his vision was a vibrant respect for the magic of infinite possibilities and a commitment to futuristic approaches which would stand the test of time. Among scores of individuals who made key contributions to the creation of BART were Bill Stokes, General Manager from 1962-1974, and three acclaimed engineering firms (Parsons-Brinckerhoff-Douglass McQuade, Tudor Engineering, and Bechtel Corporation) which created a joint venture known as Parsons Brinckerhoff, Tudor, Bechtel (PBTB). In addition, more than 200 area businesses were involved, plus over twenty teams of architects and landscape architects used for the design of BART stations.



Adrien Falk

Adrien Falk's leadership was luminous. "He is almost 80 years old, yet he spends every working day on a young man's project, the most futuristic of all civic enterprises," said the San Francisco Examiner in a late 1964 profile of the former president/CEO of S & W Fine Foods and a popular, mainstream community activist.

"Because of his vision and his people skills, innovation was the hallmark of his work," says Bill Stokes, BART's first General Manager. "Adrien Falk's influence was as a catalyst for spirited, imaginative approaches to engineering challenges. He created a dynamic environment in which creative energy could soar. People could look for quantum leaps in innovation."

Acknowledgments

ASME International – History and Heritage Program

The ASME History and Heritage Program began in September 1971. To implement and achieve its goals, ASME formed the History and Heritage Committee, initially composed of mechanical engineers, historians of technology, and the curator (Emeritus) of mechanical and civil engineering at the Smithsonian Institution. The committee provides a public service by examining, noting, recording and acknowledging mechanical engineering achievements of particular significance. The History and Heritage Committee is part of the ASME Council on Public Affairs and Board on Public Information.

Since the ASME History and Heritage Recognition Program began, 181 Historic Mechanical Engineering Landmarks, six Mechanical Engineering sites, and six Mechanical Engineering Heritage Collections have been designated.

The ASME History and Heritage Program illuminates our technological heritage and encourages the preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians, and travelers and helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

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