CONCLUSION

The Metro system carries more than one-third of a million passengers each day. It does this with a high degree of reliability, speed, and comfort. The completion of the 101-mile system remains the principal goal of WMATA in spite of funding cutbacks that have delayed expansion of the system.

Only the more significant changes to the trackwork standards that have evolved through 10 design phases have been discussed. Lesser changes and the many standards that have not been changed have been passed over due to lack of time and space.

At De Leuw, Cather and Company, the changes that have been made are viewed as the result of advancing technology and as responses to construction and maintenance as proof of the dynamic nature of the state-of-the-art in transit track. We look forward to the future as an opportunity to further advance the state-of-the-art and to improve on what is already one of the finest transit systems in the country.

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Track Rehabilitation and New Construction in An Operating Environment at BART

VINCENT P. MAHON

ABSTRACT

The Bay Area Rapid Transit District is completing the last phase of a three part construction and track rehabilitation project designed to relieve a bottleneck in the city of Oakland downtown "wye". This paper contains a before, during, and after description of the Oakland downtown junction area in sufficient detail to illustrate the impact of the construction project on system operations. Also outlined are the planning, coordination, management, and cooperation required between all divisions of the power and way maintenance, train operations, and engineering departments to complete the project on time and minimize the impact of construction on revenue schedules. Several innovative railroad construction methods are detailed without which this project could not have been completed within the minimal impact mandate.

Decreasing train headways on the Bay Area Rapid Transit District (BART) system involves several problems, one of which is a bottleneck in the city of Oakland downtown "wye" junction. The BART KE Line Expansion is a three part project designed to eliminate this bottleneck and provide additional operational facilities in support of the Close Headways program.

Project construction began in April 1980, and included the following tasks: building approximately 2.4 miles of track; changing the alignment by approximately 12 ft of more than 700 ft of revenue track; building and installing 15 main line turnouts; precisely locating existing facilities in the work site area; relocating or reconstructing existing facilities in conflict within new work; constructing two aerial structures; installing subsurface raceways and conduits; upgrading traction power facilities; and installing additional train control and communication equipment.

The probability was high that this construction project would interfere with revenue operations because of its magnitude and location. BART management mandated that the project be completed without impact on peak revenue service schedules and with only minimum effect on service during the lightest patronage periods.

BART TRACK SYSTEM DESIGN DETAILS

The BART revenue track system is divided into four double track lines covering a three-county area. The lines are designated as follows: the Alameda (A) line, the Contra Costa (C) line, the Richmond (R) line, and the San Francisco (M) line. Geographically, the system track layout can be visualized as an X configuration, with the Oakland downtown wye area serving as the junction point of these lines (see Figure 1).

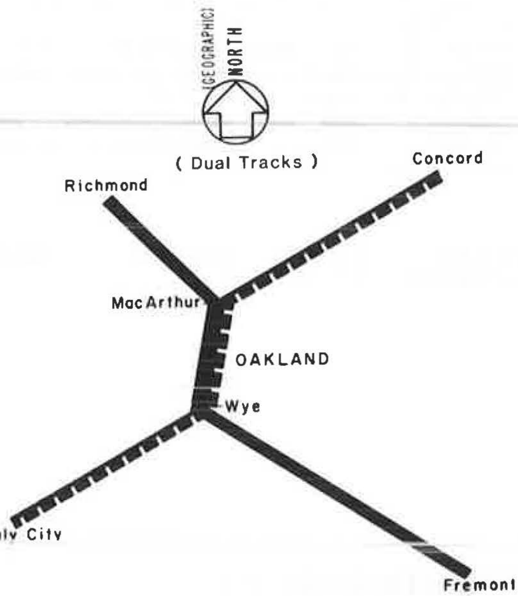


FIGURE 1 BART system simplified track configuration.

The design of the BART track system makes it possible to provide direct (without turn back) train service as follows:

- A-line to M-line and M-line to A-line,
- A-line to R-line and R-line to A-line,
- A-line to C-line and C-line to A-line,
- C-line to M-line and M-line to C-line, and
- R-line to M-line and M-line to R-line.

The junction configuration that makes this possible is shown in Figure 2. This junction covers a distance of more than 2.5 miles. As indicated in Figure 2, the C and R lines merge to a common line, previously designated the K-line, in the area of the MacArthur Station (K30). The K-line tracks then continue through downtown Oakland to a turnout area designated A05 where they diverge to either the A-line or the M-line.

The junction at the north end of the MacArthur Station (K30) where the C and R lines merge and diverge is designated the K35 turnout area. Tracks in this area run at grade, on elevated structure, and underground to provide a no-crossing traffic junction. From this junction four tracks (designated C1, C2, C3, and C4 tracks) serve the four passenger loading platforms at the MacArthur Station.

To the south of the MacArthur Station is a turnout area designated K25. The C1 and C3, and the C2 and C4 tracks merge and diverge here to the common C1 and C2 tracks of the K-line. The K25 turnout area is the north end of the downtown Oakland bottleneck.

The track and automatic train control systems were designed to allow C, K, and R line trains to

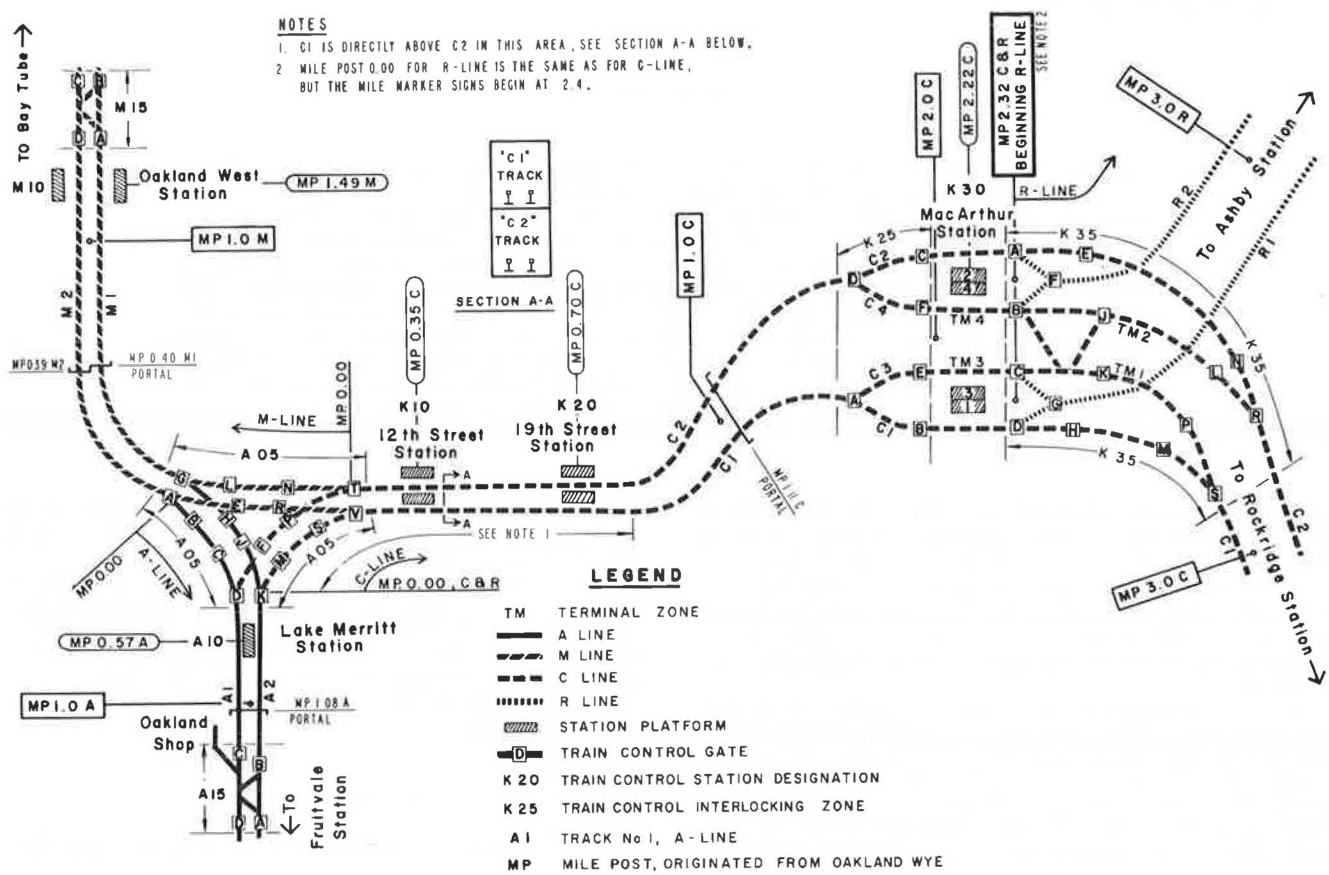


FIGURE 2 BART Oakland Junction detailed track configuration—before KE expansion.

switch tracks and turn back in the K35/K30/K25 area, either automatically or by remote control from the BART Central Train Operations Center (BART Central). The configuration also allows C and R line trains to turn back and reroute between the two lines.

At the south end of the K-line is the A05 turnout area. It is also called the Oakland Wye because of its physical configuration. The Oakland Wye is a multilevel subway no-crossing traffic junction between the A, K, and M lines that allows all combinations of any two lines to merge to the third line. A three-dimensional perspective of this junction is shown in Figure 3. The south end of the downtown Oakland bottleneck originates at A05 gates T and V. The process of merging the A and M lines into the common K-line completes the design problem. The probability is high that malfunctioning wayside or train equipment in the K-line area during peak revenue service would bring the compact BART system to a grinding halt. On the other hand, the two-track K-line limits the maximum train density and minimum system headway of the BART system.

BENEFITS OF THE KE EXPANSION PROJECT

The designers of the BART system recognized the bottleneck problem early in the BART project. A solution was designed, but because of insufficient funding, only the most costly portion was completed during initial system construction. When the subway through downtown Oakland was constructed, a third subway trackway designated the X trackway was built parallel to the C1 and M1 trackways between the 23rd Street and Washington Street portals. It was intended that this trackway would be finished and put into service as the BART system matured and the need for additional train capacity became a reality.

The KE Expansion, as the project is known, provides two major system improvements. First it adds a third revenue track, the CX/MX track. This track originates at the K25 turnout area, proceeds southward through a new turnout area designated K23, through the downtown Oakland subway, and terminates at a new turnout area south of A05 between the M1 and M2 tracks designated the M03 area. The CX/MX track can carry automatically routed train traffic destined for San Francisco from MacArthur Station (K30) or San Francisco-originated traffic destined for MacArthur Station, while the C1 and C2 tracks carry train traffic between the A-line and MacArthur Station. The CX/MX track has full passenger platform services at the two downtown Oakland stations, 12th Street Station (K10), and 19th Street Station (K20). When not used for revenue operations, the CX/MX turnouts provide switching capabilities for cutting bad order train equipment out of the revenue traffic pattern. Alternatively, the CX/MX track may be used to provide storage for standby trains scheduled for use during peak traffic periods.

The KE Expansion project also adds a spur track, with complete automatic routing and turn-back capabilities, in the at-grade and aerial area of the new turnout area designated K23. This gives the train operating department room to store either bad order equipment or standby trains.

The appearance of the completed KE Expansion project is shown in Figure 4. Contrast the junction configuration shown in Figure 4 with that shown in Figure 2 to observe the operational upgrade provided by the KE Expansion project. This project is a major step toward the goal of 72-train peak-period service, Furthermore, this project provides a new and important benefit for wayside maintenance--efficient single-track train operations between K30 and A05. Without the CX/MX track, single tracking operations are highly disruptive to train operations because of the M and A line merge and diverge.

KE EXPANSION PROJECT DETAILS

The KE Expansion project covers a distance of approximately 3 miles. It begins immediately south of MacArthur Station (K30), continues south to the 23rd Street subway portal and through the X subway to the Washington Street portal, then south approximately 0.3 miles to the south end of the M03 turnout area.

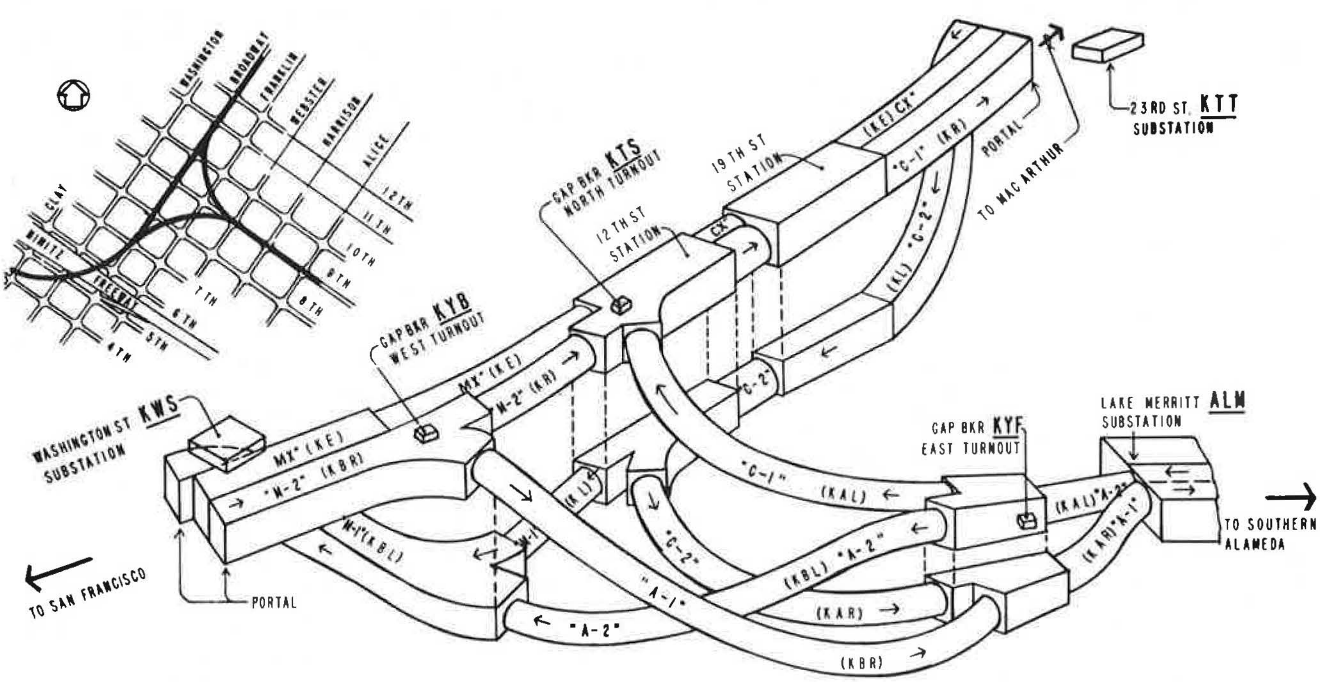


FIGURE 3 BART Oakland Wye perspective.

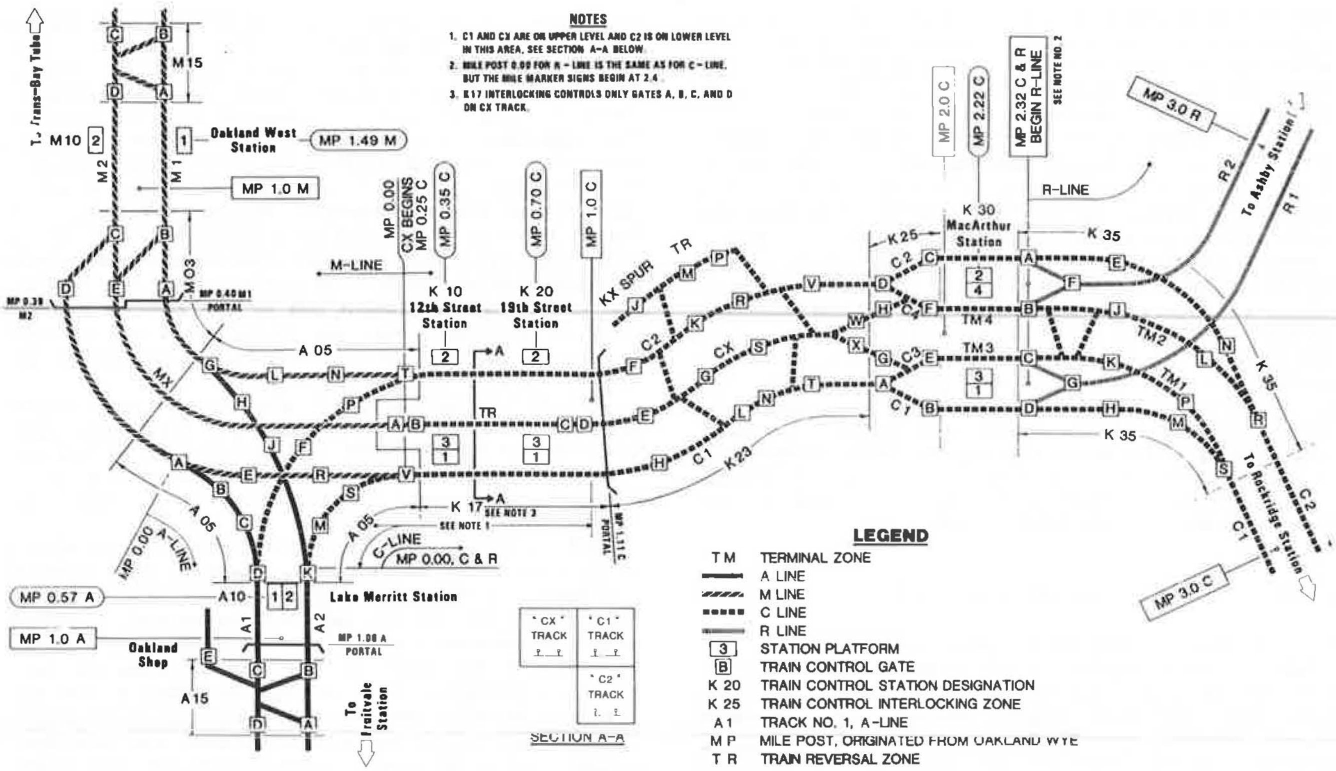


FIGURE 4 BART Oakland Junction detailed track configuration—after KE expansion.

The entire KE project is divided into three phases, designated A, B, and C. A detailed scope of each phase is discussed below.

Phase A Scope

Phase A, now complete, consisted of building the M03 turnout area and the CX/MX track from M03 to the Washington Street portal and through the X subway to the 23rd Street portal. The project included all electrical and subway facilities work, as well as station finish work at the two Oakland downtown passenger stations (12th and 19th Street Stations). Included was the BART Central electrification control board revision reflecting the KE Expansion details.

Phase A construction began April 1, 1980. Power and Way Maintenance Department track and traction power division employees installed the three M03 switches into the M1 and M2 revenue tracks and performed the associated electrical work, which was completed on June 21, 1980.

Work Area Considerations

All work not affecting revenue train operations continued around the clock on a closely supervised schedule. Work that affected train or employee safety was scheduled for nonrevenue periods, which normally extends from 0145 hr to 0445 hr (a 3-hr period). If the work required a longer time period, late night single track revenue operations were established to free a single track from 2200 hr, providing an additional 3.75 hr of track time. If an even longer period was required, late night single track revenue operations were scheduled from 2200 hr on a Saturday night until the end of revenue service, then reestablished at the start of revenue service Sunday morning and lasting until 1000 hr. This provided a 12-hr work period during a time when single track revenue operations have a minimal impact on revenue operations and inconvenience the smallest number of patrons.

Safety protection requirements for automatic train single track revenue operations are complex and time consuming to establish. Additionally, most of the wayside work required electrical third rail safe clearance protection for personnel, another time consuming effort. To maximize the work period, close coordination between the issuing authority (BART Central), the establishing agent (train control or traction power personnel, or both), and the requester was necessary. The power and way maintenance controllers stationed in BART Central provided this coordination effort. They worked closely and efficiently with all parties concerned to ensure that the track area was protected and prepared for work, then cleared and released on time for revenue operations.

Contract Work

Following the initial work by BART employees, contractor personnel began work in the X trackway beyond the clear point of the M1 and M2 tracks on April 25, 1980. The initial contractor work involved the construction of safety barricade fencing to isolate the contractor work area from the revenue trackway. From within the fenced area, the contractors built the CX/MX track, installed and completed the traction power third rail system, completed all the subway equipment and services, and performed the passenger station finish work. This work was monitored by a BART resident engineer.

The track, traction power third rail system, and subway facilities were completed by January 1982. The contract as a whole was completed in March 1982, but the barricades were retained until May 1984 for personnel safety and project security. Control of the area was turned over to the BART Train Operations Department, and they currently use the CX/MX track to store bad order trains during the revenue day.

Phase B Scope

Phase B, also now complete, consisted of several major tasks including the following: building and installing eight main line switches into the C1 and C2 revenue service tracks in the K23 and K25 turnout areas; changing the C2 track alignment by approximately 12 ft for a distance greater than 700 ft; constructing two aerial structures to accommodate the KX spur track; installing all traction power third rail system modifications in support of all switch and track construction and modifications; and constructing subgrade to accommodate relocation of drainage and electrical facilities. Work under Phase B was performed in three separate areas (designated A, B, and C) between MacArthur Station and the 23rd Street portal. Specific location detail is shown in Figure 5.

The tasks in Phase B were covered under two different contracts administered in two different ways. The contract covering the construction of two aerial structures to accommodate the KX spur track was a typical construction contract; that is, the contractor routinely performed and supervised the work while a BART resident engineer monitored the contract (same as the contractor work in Phase A).

The remaining tasks in Phase B, that is, those related to track realignment, turnout construction and installation, and subgrade construction, all involved the operating revenue system. Before the contract was drafted, the major concern of BART management was how to make a contractor responsible for performing the work while not interfering with revenue service. All of the usual contractor incentives and monitoring methods were considered, but they all had drawbacks.

It was finally decided that all contractor work would be performed according to work directives issued by the Power and Way Maintenance Department project director during the progress of the contract. The contractor would furnish labor, equipment, and certain materials, and then perform work as directed on a time and material basis. The contractor, in effect, became an extension of the Power and Way Maintenance Department work force. The responsibility to administer the contract was assigned to the department manager, power and way maintenance. A team from among power and way maintenance department personnel was assembled to handle the day to day details--a first at BART.

The contract not only spelled out the technical details and standards of the job, but also all the relevant operation rules and procedures that employees must follow while working in the active revenue environment. Furthermore, it defined the hours of work and the limits of revenue interference. All work was required to be performed after revenue or under late night revenue conditions with special train protection procedures.

Phase B construction began July 20, 1981 in area C. BART and contractor personnel built a temporary road vehicle crossing over the C3 track near Maintenance of Way Access 7 (MW07). This crossing was connected to MW07 and would remain until the completion of Phase C.

With completion of the crossing and road access construction on July 31, 1981, the appearance of areas A, B, and C changed rapidly. During the months of August and September, contractor personnel performed drainage structure relocation and underground trenching construction for electrical conduit installation under and between the revenue operational C1 and C2 tracks. The subsurface construction between the C1 and C2 tracks at the switch locations designated 3, 4, 5, 7, 9, 10, 15, and 16 on Figure 5 had to be completed on schedule. Furthermore, because of the proximity of the excavations to the revenue tracks, extensive shoring and cribbing was required to maintain the stability of the area for normal revenue train activity. The winter rainy season tested this stability, as construction continued through the wettest winter in Bay Area history--a full 200 percent above normal.

In general, all work on the C1 and C2 tracks was performed by BART personnel, whereas work under and between the tracks was performed by contractor personnel under the constant and direct supervision of BART supervisory personnel. Under the contract, all contractor work was scheduled from 2200 hr to 0445 hr. Because the period from 2200 hr to 0145 hr was still in the revenue operations period, unique train safety protection schemes were planned and implemented to minimize effect on train schedules and maximize personnel and train safety.

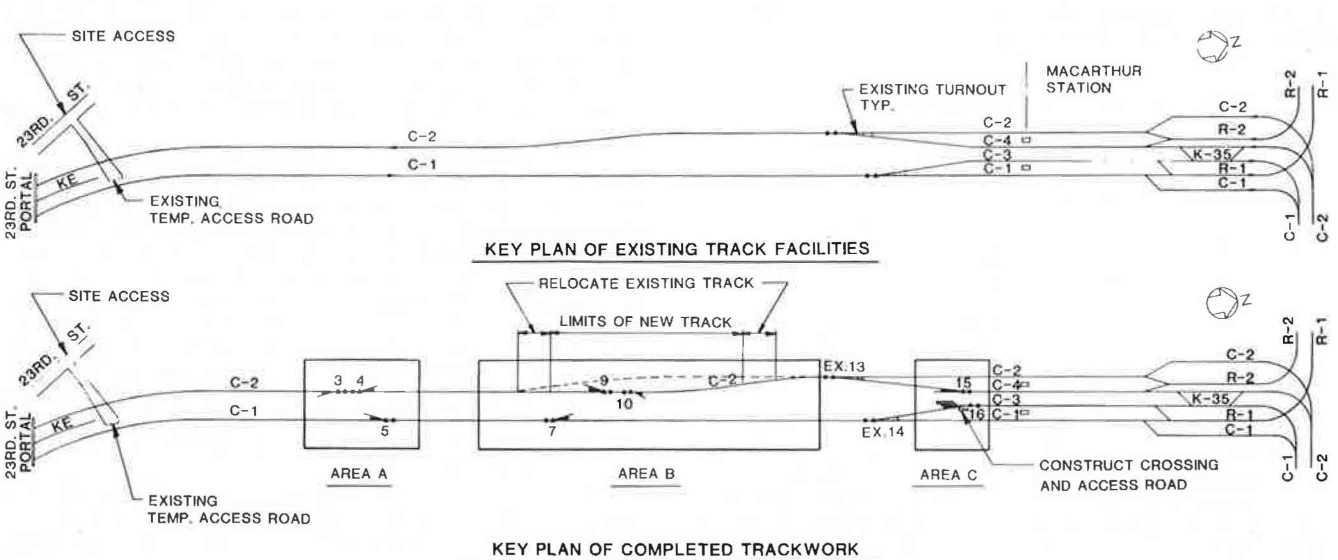


FIGURE 5 Phase B key plan.

Work Area Safety

All train traffic in the construction area was restricted to road manual operation while work was being performed. This safety measure was imposed with three levels of protection. First, BART Central ordered each train to stop at a stated track milepost location. Second, the wayside automatic train control speed encoding equipment (mux boxes) for all track signal blocks in the work area and for 1,000 ft preceding it were adjusted to transmit automatic zero mile per hour speed codes. Third, wayside flagmen were stationed in the work area, and BART Central released each train under the control of the flagmen and with road manual movement orders.

Under normal operating conditions in this area, the automatic train operation (ATO) maximum speed is 50 mph. Under road manual orders, the maximum allowable train speed is 25 mph, with the qualification to proceed with caution. As the trains moved beyond a stated milepost location, they were returned to ATO to proceed at speeds normal for the area. Work area limits were selected to correspond with train control track circuit limits. In this way necessary work area protection was afforded and the length of road manual train movements were minimized.

This level of protection was established every night promptly at 2200 hr and retained until 0145 hr. If either of the revenue tracks were required to be taken out of service, single tracking operations would be established. Frequently, third rail electrical safe clearance protection would be required during single tracking periods and between the nonrevenue hours of 0145 hr and 0445 hr. Regardless of the type or degree of protection needed, establishing and then removing it daily in a timely manner required a monumental coordination effort. The Power and Way Maintenance Control Center performed this coordination with almost flawless precision.

Turnout Construction Considerations

Turnout construction is a time consuming and labor intensive task. Phase B required that eight turnouts be installed in the C1 and C2 revenue tracks. The track in this area is constructed of continuously welded rail (CWR). The locations of all rail welds in the area had to be determined in order to lay out the exact switch placement and determine where the CWR would be cut. The turnouts to be installed included three number 10, three number 15, and two number 20 switches (see Table 1).

TABLE 1 Phase B Turnout Legend

Location Number	Turnout Type	Turn Direction	Remarks
3	15	Left	Curved
4	10	Left	Curved
5	15	Right	Curved
7	15	Left	Straight
9	10	Right	Straight
10	10	Right	Straight
15	20	Right	Straight
16	20	Left	Straight

During the design stage it was decided to build and install jointless switches. This decision required that the heel and toe of the frogs and the heel of the switch points be redesigned. Furthermore, field welds were required in lieu of joint bars throughout the switch area. This feature keeps the rail profile through the switch compatible with the welded rail environment in which it is installed. The quality of the ride through the switch is greatly improved as compared with the ride through a jointed switch.

Constructing the turnouts in place would have continuously disrupted revenue service over a period of several months. The mandate of not disrupting revenue service prevented this approach. Instead, the switches were constructed on special "roller ties" in between the C1 and C2 tracks, immediately adjacent to the location where they would be installed. The switches would then be pulled into place when the existing track was removed.

This decision revealed the need for several other decisions to be made and identified several requirements to be satisfied. Included among these considerations are the following: What is the exact location of the new switch? What is the exact location of the switch construction area? When would excavation construction in the area be complete? How could the revenue rail be cut and the ties and track removed in a short time period? What kinds of skids could be used to help move the switch from its construction site to its installation site? What methods could be used to make the move?

The Rail Removal Solution

Two major innovative ideas dictated solutions for most of the problems. First, the rail removal solution. On some night before the switch installation date, BART track personnel would cut the CWR at two locations, unfasten it from its tie clips and lift it off to the side of the right-of-way (leaving the ties in place). Twenty foot lengths of rail were then installed on the ties, making up 20-ft long rail panels that were jointed together, aligned, and surfaced. The panels were temporarily bonded together using number 4/0 cable welded to rail anchors that were attached to the rail. Upon completion of train control signal testing and adjustment, the area was returned to revenue service.

The second part of the rail removal task took place the night the turnout was to be pulled in. (The rail removal task will be discussed first and the turnout pulling process later.) With a crane on rail and in position to lift a 20-ft rail panel, a flat car was moved up behind the crane (see Figure 6). The panel joints, temporary rail bonds, and third rail sections were disconnected. The rail panel was then lifted, swung to the rear of the crane, and lowered to the flat car. The crane and flat car would then back up to position the crane to lift at the center of the next panel, and the disconnecting, lifting, and loading process would be repeated.

This procedure was repeated until all the panels were removed. It was done as rapidly as possible, as this was just the beginning of the night's work and the area had to carry revenue traffic in the morning over a new turnout. After the rail panels were loaded onto the flat car, the crane and flat car would reposition adjacent to the area where the 700 plus feet of realigned C2 track was to be located. The panels were lifted off the flat car and precisely positioned where the C2 track was to be relocated. The short rails were then released, leaving the ties properly spaced for the new C2 track construction and the short rails available for the next CWR rail section removal.

Several factors entered into the decision to make the rail panels 20 ft long. Thirty-nine-foot panels were considered, but when calculated the weight was found to be almost 2,000 lb heavier than the maximum safe load of the crane. A 30-ft panel was within the

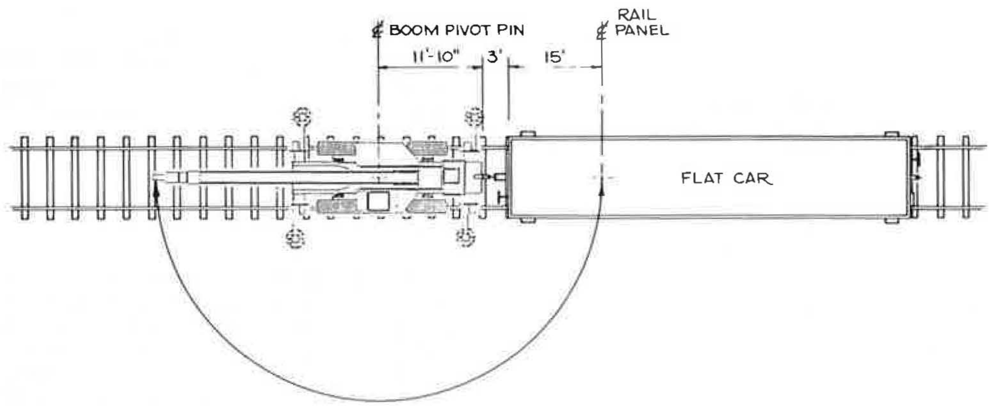


FIGURE 6 Crane and flat car detail.

safe load range, but it was determined that 20-ft (actually 19 ft 6 in., or one-half of the 39-ft rail) lengths were the best compromise because of the locations of the CWR welds and the ties to be moved.

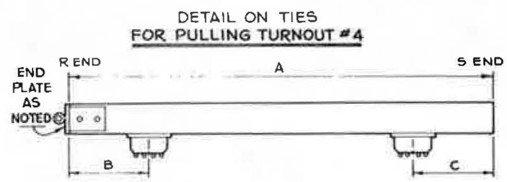
The long sections of rail that were released from service were available to the contractors as construction material. Other turnout construction materials were received at the BART Hayward rail yard, loaded onto the BART rail or work train during the day, and delivered at night to the construction site about 22 miles away.

The Switch Installation Solution

The process of pulling a switch into a space made available by rail removal began before the first turnout tie was ever laid. After the decision was made to build the switches adjacent to where they would be installed, it became clear that the elevation of the area between the C1 and C2 tracks would have to be increased; a survey indicated that the average difference in elevation in the toe of ballast to the top of rail was 2.4 ft for the C1 track and 2.0 ft for the C2 track. Of course, the exact amount of raise depended on the pulling-skidding method.

The pulling-skidding method to be used was a major concern until flat-topped chain-type roller assemblies (see Figure 7) were discovered. The method developed rapidly following this discovery. The roller assemblies were attached to the bottom of 12 and 15-ft long wooden ties to form a mobile platform base on which to build the switch. For turnout number four, the first turnout built and moved this way, seven ties were used in this manner. Refer to Figure 8 and Table 2 for construction details of the roller ties and their specific placement locations. A bridle was attached to the end plates of ties number 2, 3, 5, and 6 to provide a place to pull. The placement of the roller ties, the roller assemblies on the ties, and the bridles was calculated to give the best mechanical advantage and switch stability during the pull.

FIGURE 7 Flat-topped chain-type roller assemblies.



NUMBER	A	B	C	REMARKS
1	12'	3'-2"	3'-2"	
2	12'	3'-2"	3'-1"	END PLATE
3	12'	2'-8"	2'-7"	END PLATE
4	12'	1'-7"	2'-6"	
5	15'	1'-7"	3'-11"	END PLATE
6	15'	1'-7"	2'-6"	END PLATE
7	15'	1'-7"	1'-2"	

FIGURE 8 Roller tie construction detail.

The next consideration was the ballast surface the switch would move over during the pull. To provide a smooth and low-friction surface, 6-in. channel iron was used as a track for the chain roller assemblies. Before any of the ties for the new switch were laid, the required elevation of the channel iron was determined and the elevation of the area between the C1 and C2 tracks was raised. The placement of the roller ties was then determined and the roller tracks (channel iron) were installed. For turnout number four, they were placed between the C1 and C2 tracks and also under the C2 track, all at the proper elevation. To accomplish this, ballast had to be removed from between the ties and under the track (see Figure 9). This was typically done before the rail was cut. Once installed, the ballast

TABLE 2 Roller Tie Placement Detail

Tie Number	Station Location	Tie Length (ft)	Channel Length (ft, in.)	Adjacent Spacing (ft, in.)	PS[a] Distance (ft, in.)
1	990+36.07	12	25-6		10-5.500
				10-5.500	
PS[a]	990+46.53	-	-		-
				9-8.125	
2	990+56.21	12	25-6		9-8.125
				20-8.875	
3	990+76.95	12	26-6		30-5.000
				20-1.875	
4	990+97.11	12	27-6		50-7.000
				20-1.875	
5	991+17.27	15	29-0		70-8.875
				19-2.125	
6	991+36.45	15	31-0		89-11.00
				0-5.750	
PF[a]	991+36.93	-	-		90-4.750
				10-10.625	
7	991+47.81	15	31-6		101-3.375

[a]For reference only; roller ties are not used at point-of-switch (PS) or point-of-frog (PF) locations.

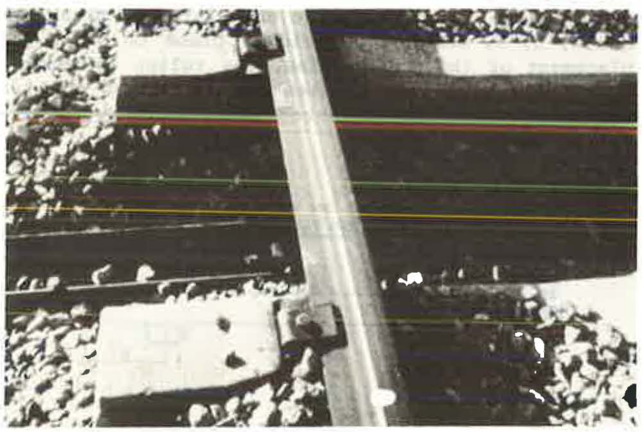


FIGURE 9 Roller channel installation.

was replaced to help hold the channel iron in place during the switch construction period.

The switch construction was handled by contractor personnel under the direction of BART supervisors. The project director issued a roller tie construction detail (Figure 8), a roller tie placement detail (Table 2), and a turnout tie data table for each s itch to be built. When the switch was built and ready to be installed, the switch and channel were jacked up so that the bottom of the ties would have approximately 2 in. clearance above the ballast. The ballast was then tamped tightly under the channel. All that remained was to perform the installation. The installation was typically scheduled for a Saturday night. Single tracking operations would be established from 2000 hr with an estimated completion time of 1000 hr for returning the track to revenue service Sunday morning. The installation was performed by both BART and contractor personnel.

The final consideration was the pulling method. At this point several viable alternatives were available, but one method stood out from all the rest. The entire Phase B construction site sits in the median of a California freeway, at grade level. The California Department of Transportation was most cooperative in closing the left-most traffic lanes, which allowed a heavy equipment wrecker to be positioned to pull the switches into position. After months of research, planning, and preparation, the outcome was anticlimatic. The average pull took less than 4 min to position the switch. We were prepared for less desirable circumstances, however, and had simultaneously developed an alternate plan to pull from the opposite track. In addition, the roller-channel method was designed and installed so that the turnout could be manually moved if necessary.

Important Details

To this point the major highlights of BART's instant track switch installation program have been discussed. However, there are more details that complete the program and without which there would not have been the same measure of success.

While building each switch, the third rail insulators were installed on the appropriate ties and the switch machine was installed and adjusted. Before installation day, the contractor cut and bolt-jointed back the third rail in the future turnout area.

On turnout installation day, the first task was to remove the previously bolt-jointed third rail section. As the rail panels were lifted, front loader tractors began removing ballast from the track bed using the roller channels as an elevation reference. When all the rail panels were removed and the ballast was at the correct elevation, the channels were verified to be free of ballast and at the correct elevation and alignment.

The heavy equipment wrecker was then connected to the bridle cables and the pull was made. Any necessary incremental position adjustment was manually made, the switch was then jacked up and the roller ties were removed. The switch was lowered to the track bed and the ends of the switch were joined to the ends of the existing rail, using hydraulic rail pullers as necessary to close the rail gap.

The end loader tractors were then used to replace the ballast and correct the grade. BART track personnel then manned the BART tamping and lining equipment to precisely correct surface and alignment. Final ballast dumps were made with the BART air-controlled ballast cars; then it was time to complete the rail bond and electrical third rail installation. The area was cleared of all equipment and personnel and made revenue ready. When complete, the train control technicians performed their final tests and adjustments. When they were clear, a test train was brought into the area for road manual and ATO test runs.

This procedure was repeated throughout the installation of all eight turnouts. The only other major task was the realigned C2 track. The contractor built approximately 717 ft of new track adjacent to the existing C2 track using the methods previously mentioned. The ends of the existing C2 track were then cut and pulled into alignment with the new track. This task was as successful as the others.

Phase B was a big success story for the Power and Way Maintenance Department. Everyone associated with the project grew personally and professionally. The final work was completed in January 1983.

Phase C Scope

Phase C work consists of track and turnout construction, electrification and traction power construction and equipment installation, and train control and communications equipment installation. With the completion of this contract, the KE Expansion project will be complete and revenue ready. Work under this contract began in March 1983 and completion is anticipated in November 1985.

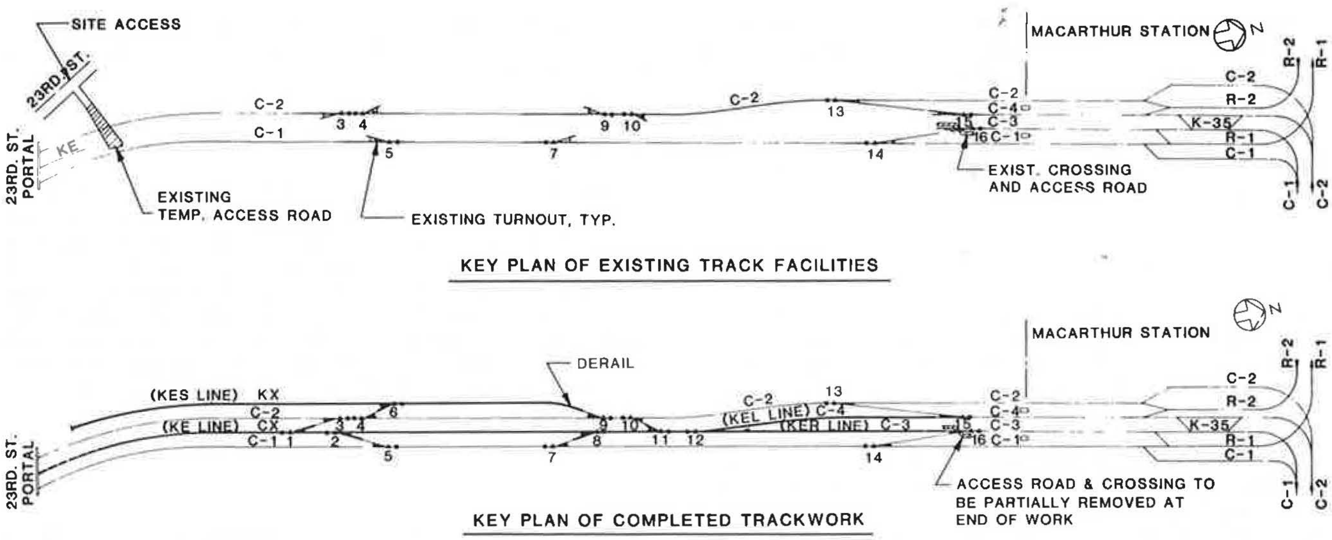


FIGURE 10 Phase C key plan.

The work area of this contract extends from MacArthur Station at the north, south along the C1 and C2 trackway to the X trackway at the 23rd Street Station portal, then south through the X trackway to the Washington Street portal, and south to the M03 turnout area. Also included in this work area are the train control equipment rooms at the 12th Street, 19th Street, MacArthur, and Lake Merritt Stations, and the traction power facilities in the work area.

Work Area Safety

The area between MacArthur Station and the 23rd Street portal and the area between the Washington Street portal and the M03 turnout are revenue-active. To protect contractor personnel, wooden safety barricade fencing is required to isolate the work area from the revenue area. Furthermore, close supervision by the BART resident and field engineers is required when any traction power or train control equipment installations are performed on the active revenue system.

The majority of the work is performed during the day by contractor personnel. To provide them with wayside vehicle access, the C3 track has been removed from service for the duration of the project. To accomplish this, K25 switch number 15 was aligned and spiked in the normal direction (K25 A to B), electronic route prohibits were placed for routes K25 A to E and K25 E to A and through K35 C. In addition, a knife switch was installed to make it possible to isolate the entire C3 track third rail section, and a physical gate was installed across the C3 track behind the clear point of the C1 track. Finally, a safety barricade fence was erected to isolate the revenue operational C1 track from the C3 track crossing and road extension to MW07.

The contractor then had road vehicle and equipment access to the work area. Although the C3 track is scheduled to remain out of service for the remainder of the KE project, all construction and all equipment storage within the C3 track is required to be beyond the C3 track clear point or be mobile such that under BART emergency conditions the C3 track can be cleared and returned to service by BART personnel within 60 min of notification.

Track and Turnout Construction

Track and turnout construction under Phase C was totally different from Phase B. Participation of the Power and Way Maintenance Department in construction under this contract was limited to work train operation (such as delivering material from the BART Hayward rail yard or ballast dumping), operating the BART mechanized track surfacing and lining equipments, installing one derailer, and changing several wood ties that extended into the revenue area. The contractor, on the other hand, built six turnouts and approximately 1.5 miles of track.

In general, the contractor's work consisted of building the second half of the turnouts that BART personnel installed in the C1, C2, C3, and C4 tracks under Phase B as well as the track to connect to them. See Figure 10 and Table 3 for details. The contractor also built all temporary safety barricade fencing and is responsible for all permanent fencing construction. At the end of the construction phase, the contractor will remove all temporary fencing, in addition to all temporary work area access points, including the two temporary access roads at 23rd Street and MW07 and the stairway at the Washington Street portal. Track and turnout construction was completed in April 1984.

Electrical Construction

Electrical tasks under Phase C consists of the construction, installation, and cut over to service of traction power third rail equipments, traction power control system equipments, and electrical utility equipments.

TABLE 3 Phase C Turnout Legend

Location Number	Turnout Type	Turn Direction	Remarks
1	15	Left	Curved
2	15	Right	Curved
6	10	Left	Curved
8	15	Left	Straight
11	10	Right	Straight
12	20	"Y"	Equilateral

The subgrade conduit runs for this work were built during Phase B. The external conduit runs will be built under Phase C. It should be noted that although the contractor pulls in the control cables, the termination of these cables into the working system is to be performed by BART maintenance personnel. The electrical part of this contract was completed in February 1984.

Train Control Construction

The train control tasks under Phase C include the following: the installation and cut over to service of all train control wayside equipment electrical power services; all the additional wayside and train control room equipments needed to provide local and remote supervised and controlled ATO and manual train operations on all new track and through all new turnouts; all new wayside maintenance communications equipments; and the additionally required train destination sign equipment at the 12th and 19th Street Stations. The operational characteristics of the KE Expansion project were previously detailed in Figure 4, completion is expected in November 1985.

SUMMARY

On completion of the KE Expansion project, San Francisco Bay Area commuters will experience an increased level of service even though it is only a part of the Close Headways program. We at BART are confident that the investment of $22,000,000 for this expansion will result in a level of service improvement that will aid BART in continuing to gain ridership through the process of decreasing the perceived advantages of alternate Bay Area transportation methods.

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Estimates of Rail Transit Construction Costs

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ABSTRACT

Reliable estimates of the costs of constructing new rail transit facilities are necessary to evaluate the growing number of proposals to build new rail lines and extend existing ones. Yet the construction cost estimates used in past studies have often been erroneous, even when they have been based on detailed engineering analyses of proposed projects. Further, rail construction costs appear to have increased rapidly in recent years, even after being adjusted to reflect general price inflation throughout the economy. New estimates of the costs of constructing rapid transit and light rail facilities are reported. These estimates are developed by statistically allocating (via regression analysis) total expenditures for 18 rapid transit and 14 light rail construction projects among their individual components. The results include estimates of unit costs for building rapid transit and light rail lines and stations underground, at grade level, and on elevated structures, including construction outlays and expenses for acquiring the necessary land at typical prices. Some uncertainty exists about the cost estimates for individual rail system components (lines and stations) developed here, but the procedure for estimating them allows this uncertainty to be explicitly quantified. Yet the best estimates of line and station costs suggest that local transportation planners and consultants have seriously underestimated the likely expense for building almost every new rail line or system extension now under serious consideration in the United States.

The recent resurgence of interest in major new rail transit investments among both professional transportation planners and political decision makers, after several decades of widespread disinvestment in rail transit facilities, has focused considerable attention on the costs of constructing new rapid transit and light rail lines. Reliable estimates of these costs play a critical role in evaluating the growing number of proposals to build new rail systems or extend existing ones, as their suitability depends at least in part on how those costs compare with the potential resource savings and other bene-