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Decision No. 83339

ORIGINAL

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Investigation on the Commission's own motion into the safety appliances and procedures of the SAN FRANCISCO BAY AREA RAPID TRANSIT DISTRICT.	Case No. 9445 (Petition Filed June 13, 1974)

Additional Appearances

Morrison, Foerster, Holloway, Clinton & Clark, by Robert D. Raven, Charles R. Farrar, Jr., and Marc. P. Fairman, Attorneys at Law, for San Francisco Bay Area Rapid Transit District, petitioner.

Robert Nesbit, Attorney at Law, for Alameda-Contra Costa Transit District, interested party.

(For other appearances see Decision No. 81248)

FINAL OPINION

The San Francisco Bay Area Rapid Transit District (BART), by petition filed June 13, 1974, seeks authority to institute interim transbay revenue service on a limited basis commencing September 16, 1974 utilizing the Computer Automated Block Systems (CABS) to provide computer enforced train separation.1/ BART proposes to provide transbay service under CABS-1 on an interim basis pending the continued installation and testing of the Sequential Occupancy Release (SOR) system which it intends to incorporate as a part of its train

1/ CABS has been approved by the Commission for local lines operations. The initial CABS operations provided two-station separation between trains(CABS-2). BART is currently operating local lines under one-station train separation (CABS-1).

detection system. BART proposes to apply for final approval of systemwide revenue service utilizing SOR following adequate testing during nonrevenue service and on monitor mode during revenue service with CABS-1 protection in force.

This Commission has safety jurisdiction over BART by virtue of Section 29047 of the California Public Utilities Code.[2/] Decision No. 81248 issued April 10, 1973 in this proceeding, among other things, ordered that any application of BART for service involving merging, diverging, or crossing of trains shall be filed with the Commission at least ninety days prior to the commencement of such service. Transbay operations, as proposed in the petition, will require the merging and diverging of trains at the Oakland Wye (A05) and MacArthur (K25).

Public hearing in the petition was held before Commissioner Vukasin and/or Examiner Mallory at San Francisco on July 15, 16, 17, and 18, 1974. The petition was submitted subject to the filing of late-filed exhibits by the Commission staff and by Lawrence Berkeley Laboratory of the University of California (LBL). Evidence was presented by representatives of BART, the Commission staff, and LBL. No one appeared in opposition to the relief sought in the petition.

2/ It should be clearly understood that the issues presented in this proceeding involve only the technical evaluation of the adequacy of the safety provisions of the BART system, which is the only subject over which this Commission has jurisdiction. In determining whether or not to authorize revenue service this Commission has relied upon expert testimony and analyses as to whether the augmented automatic train control system is safe. Specifically, there are no representations nor should any inferences be drawn regarding the adequacy of the level of service to be provided. This Commission has no jurisdiction over the level and quality of service offered by BART nor any other governmental or publicly owned transit system.

Background of BART's Operations

Prior to the initial commencement of revenue service in 1972 various tests of BART's automatic train control (ATC) systems were conducted. Through these tests, the Commission staff learned that the ATC system could not always detect the presence of a dead car (a live car test was not made). Also, in the opinion of the staff, the testing of the train braking, propulsion, protection, and interlocking systems was insufficient. The staff recommended to the Commission that it not authorize full automatic train operations, but that it require the use of the established and proven manual block override method of operation for train separation protection.

On August 31, 1972 the Commission authorized BART to commence revenue services by issuing Resolution No. S-1358.[3/] Condition No. 2 of this Resolution required the use of manual block override which reads as follows:

> "The train control system shall be supplemented by manual override consisting of a trained operator at the controls of each train with a back-up of supervisory personnel at key stations to provide positive train control in accordance with rules to be agreed upon and filed with this Commission prior to the commencement of revenue service."

BART commenced revenue service on its South Alameda (A) and Oakland (K) Lines using its automatic train control system supplemented by manual override consisting of an on-train operator and backup supervisory personnel at key stations. By Resolutions S-1365 dated January 16, 1973, S-1368 dated May 8, 1973, and S-1378 dated October 10, 1973, the Commission authorized manual block operation of Richmond (R), Concord (C), and San Francisco (M) Lines, respectively.

3/ Decision No. 81248 ordered that the provisions of Resolutions Nos. S-1358 (above) and S-1365 (infra) remain in full force and effect with respect to revenue operations of BART until further order of the Commission.

On October 15, 1973, with manual block override as required by the foregoing resolutions, BART commenced testing computer enforced two-station separation (CABS-2) on its C Line. BART commenced testing by utilizing CABS-2 with manual block override on its A, K, and R Lines on January 14, 1974 and on its M Line commencing April 8, 1974.

Pursuant to Resolution No. S-1382, authorization to replace the manual block system with CABS-2 was granted as to BART's C Line on February 20, 1974, as to BART's A, K, and R Lines on April 23, 1974, and as to BART's M Line on May 21, 1974. CABS-2, without manual block override, has governed BART's C Line since February 25, 1974.

The two station separation provided by CABS-2 and its predecessor manual block operation permits a minimum headway of about ten minutes between trains. A more frequent service is desirable for transbay operations. BART developed a plan for one-station of enforced train separation using CABS which would provide a headway of about five minutes. Evaluation of the initially proposed system showed that it appeared to lack two safety features present in CABS-2 for the case of a program stop failure or inadvertent station run-through; this is: CABS-2 allowed another opportunity at the next unoccupied station for a program stop to occur; and CABS-2 allowed the central train controller more time and opportunity to take corrective actions.

LBL, as part of its services to the State Senate Public Utilities and Corporations Committee, evaluated the CABS-1 concept and in a written report gave general recommendations as to desired features and minimum safety margins in any implementation. Several meetings were held between LBL, BART, and PUC staff members to reach understandings concerning an acccptable system design. As a result thereof, it was determined that the safety protection accorded by CABS should be further enhanced by the incorporation of additional software algorithms and zero speed gate circuitry, as recommended by LBL.

A CABS-1 system design was evolved containing the following additional basic features:

1. The CABS-2 station release software logic was to be extended to include two new features wherein a train would be held at a station platform if the previous train experienced a station run-through of any kind, or was not positively detected as having left the platform area.
2. A specially designed zero speed gate circuit was to be installed at all station multiplex (MUX) controlling locations to enforce a zero speed code "trap" downstream of any station experiencing a station run-through of any kind. This circuit was to act independently of the central computer, CABS-1 station releases being under the local automatic train control and train occupancy signals.

Following the installation of the additional software and hardware components necessary to accomplish the above, and after completion of the preliminary integrity and operating tests on each line, Commission approval was granted for CABS-1 operation of the A-K-R Lines on July 2, the C Line on July 11, and the M Line on July 16, 1974. CABS-1 operation was initiated immediately by BART for each of the three lines in order that operational data could be collected for the transbay phase of system operation.

BART's Evidence

BART described the functions and capabilities of its CABS-1 system of operations, and the additional automatic train control systems proposed to be used in connection with transbay operations. BART also presented the rules to be followed by train operators (Exhibit 37-A) and the central train controller (Exhibit 38-A) in connection with the CABS-1 system of train separation and control.

Exhibit 17-A contains the dates of various tests made by BART with respect to its CABS-1 and CABS-2 control systems and the results thereof. The exhibit shows that all performances and integrity tests were successful except one which involved a deficiency in the computer program which was immediately rectified. Substantial testing has revealed no other defects.

Evidence was also presented by BART to show the steps taken by it to comply with Ordering Paragraph 2 of Decision No. 81248 which required changes in the speed profiles for the southbound track at Fremont Station; the installation of speed signs; and the adoption of operating rules requiring train operators to stop trains when the train speed exceeds the posted speed on the speed sign and testing of stop buttons each time a train is placed in service.

Lawrence Berkeley Laboratory

LBL's report entitled "BART Train Control Subsystem: Summary and Status of Recommendations for CABS and Transbay Crossing", dated July 15, 1974, prepared by Dr. D. Theodore Scalise and Don M. Evans for the California Senate Public Utilities and Corporations Committee, was placed in evidence by the authors.

That report reviews the status of several recommendations made by LBL with respect to the technical merits of the CABS system. Such recommendations were prepared as a result of failure-mode analyses of the CABS system made by LBL. The report shows that continuous communication has been maintained between LBL, BART, and the Commission staff. The LBL recommendations have been adopted in principle by BART. Implementation of all LBL recommendations which are intended for pretransbay operations have been accomplished, except for the installation of certain hardware changes with respect to the "pseudostation" located in the transbay tube (M00)[4/] and with respect to the conduct of full-scale dynamic performance tests under normal full-scale operating conditions utilizing a full complement of 36 trains.

4/ As explained by BART witnesses, the operating time between Oakland and San Francisco is approximately 8 minutes. Under CABS-1, a train would not be released in the tube until a prior train had cleared the first station on the other side of the Bay. The pseudostation (M00) permits the holding of a train in the tube, thus permitting the 5-minute headways desired for transbay operations.

LBL witnesses indicated that integrity testing of the CABS system had been monitored by LBL, and that tests have demonstrated the conceptual adequacy of that system. LBL stated that it would endorse approval of transbay revenue service under conditions proposed by BART if the additional full-scale test of the CABS system under normal operating conditions is satisfactory.

Staff Evidence

The Rapid Transit Unit of the Transportation Division, Operations and Safety Section presented a witness to describe the function of that unit with respect to BART's operations, and to describe the methods employed by the staff to evaluate the safety of BART's operations. The unit is charged with the general responsibility of ensuring that the provisions of General Order No. 127 are adhered to by rail rapid transit districts in California and that employee and public safety is provided for in the operation of those systems. The unit consists of six members with operational and engineering experience. Two of the staff members are assigned to the unit on a permanent basis while the remaining staff members are on temporary assignment to work on the BART project for a duration of approximately one year.

The function of the staff was described as primarily that of working with BART, LBL, and others to verify safety in design and operational procedures, to review BART's implementation of recommended safety features, and to observe BART's daily operations to note any unsafe conditions and to request corrective action if such conditions should occur.

The Commission staff participated in demonstrations of CABS-1 train control systems designed to determine whether such systems operated properly and safely in operational and integrity tests performed during nonrevenue periods as well as in the monitor mode during revenue periods. The results of the tests and inspections

indicated that CABS-1, modified to provide a "pseudostation" at an intermediate point in the tube and a backup capability to regulate entry into and passage through the switches and interlockings at MacArthur Interlocking (K25) and the Oakland Wye (A05) would provide an adequate safe interim method of train operation, pending completion of the contemplated SOR system.5/

The staff witness testified the staff believes that the BART safety devices (both software and hardware) added in compliance with LBL recommendations for transbay CABS-1 operations (Footnote 4, supra) are adequate, inasmuch as all of the demonstrations and

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5/ The following methods were devised to ensure adequate redundant control systems for interim transbay operations using CABS-1:

1. Only the Concord and Fremont Lines will continue into and out of the tube; Richmond Line passengers would be required to transfer for travel to and from San Francisco at MacArthur, 19th Street, or 12th Street Stations in Oakland.
2. Releases to the MacArthur and Oakland Wye interlockings will be placed in central computer control using a logical interlock with the CABS-1 computer algorithm. Train holds will be maintained at the 12th Street, Lake Merritt, and Oakland West Stations, such that conflicting route requests from any two stations will be granted on a first-come first-served basis, and the held train will be detained at the platform until the preceding train had been logically and positively detected as having left the destination station platform. This arrangement prevents the possibility of conflicts with merging trains.
3. In the case of trains proceeding from Oakland West to either 12th Street or Lake Merritt an additional feature is provided; namely, a zero speed "trap" within the interlocking zone to be activated in the event that a conflicting route request was somehow made to the destination platform. This special treatment is adopted for trains entering the Oakland Wye from Oakland West because the I.D. reader for northbound trains leaving Oakland West is located between the station and the Oakland Wye complex; therefore, a check of a train's destination cannot be made prior to its dispatch from that station.

integrity tests of the proposed transbay concept using the central train control computer to maintain train separation indicate that this concept is functionally safe. However, a full-scale operational test of the behavior of the entire system had not been made at the time of hearing. The staff witness recommended that a full-scale operational test should be made using the maximum number of trains intended for revenue service to operate under automatic CABS-1 control at designed speeds and routing for a certain amount of time. Such a test is necessary in order, in the opinion of the staff, to determine the reaction of the system under simulated maximum service stress prior to revenue service. The staff witness stated that conclusive recommendations on CABS-1 transbay operations can be made only after the full-scale operation test results have been carefully evaluated.

Systemwide Stress Test

The Commission staff and LBL concluded that performance and integrity tests of CABS-1 system with the supplementing redundant systems recommended by LBL should provide adequately safe train operations through the transbay tube and the Oakland Wye, as proposed in BART's petition. However, as a full-scale system test using 36 trains had not been accomplished at the time of hearing, both the staff and LBL recommended that such tests be conducted and that the results thereof be determined before the Commission acted on BART's petition.

The record shows that such tests were to be scheduled on August 3, 1974, and that the Commission staff and LBL planned to monitor such tests. The Examiner directed that the record remain open so that the reports of the results of such tests by the staff and LBL could be incorporated therein as late-filed exhibits.

Exhibit 42-A, filed by the Commission staff on August 16, 1974, and Exhibit 43-A, filed by LBL on August 26, 1974, contain the reports of the systemwide stress test of CABS-1 operations conducted on Saturday, August 3, 1974. The reports are made part of the record herein. The reports indicate that the Computer Automated Block

Systems (CABS) functioned successfully. The reports, however, state that four potentially unsafe situations arose during the conduct of the stress test, all of which resulted from human error because of noncompliance with operative rules. BART should take all steps necessary to assure that its operating employees are fully familiar with and will comply with its operating rules. Recommended changes necessary to achieve such compliance are contained in the reports of LBL and the staff, and are set forth in the order herein.

Findings

1. San Francisco Bay Area Rapid Transit District (BART) is a public district established to provide rail rapid transit operations within and between points in Alameda, Contra Costa, and San Francisco Counties.

2. Section 29047 of the California Public Utilities Code provides that the Public Utilities Commission of the State of California has safety jurisdiction over rail rapid transit systems, including BART's operations. Pursuant thereto, the Commission promulgated General Order No. 127 effective September 15, 1967, which established regulations governing the construction, reconstruction, maintenance, and operation of automatic train control systems with respect to train detection and separation, route interlocking, speed enforcement, and right-of-way hazard protection on rapid transit systems.

3. Pursuant to the authority contained in Section 29047, the Commission authorized BART to begin revenue operations using BART's automatic train control system, supplemented by manual override consisting of a trained operator at the controls of each train with a backup of supervisory personnel at key stations to provide positive train control in accordance with rules filed with the Commission. Two-station separation between trains was provided in the operating rules. (Resolution No. S-1358 dated August 31, 1972.) Revenue operations began on or about September 11, 1972 on the Fremont-Richmond Line. Revenue operations between Concord and MacArthur Stations were

authorized by Resolution No. S-1368 dated May 8, 1973. Resolution No. S-1368 required the same operating conditions as set forth in Resolution No. S-1358 and required there should be no interface between trains during revenue operations on the Fremont to Richmond Line and Concord to MacArthur Line. Revenue operations subsequently were authorized under similar conditions between Daly City and San Francisco (Montgomery Street Station).

4. By Resolution No. S-1382 dated February 20, 1974, BART was granted permission to remove the manual block override procedures on the Concord Line and provide train separation override of the automatic train control system by means of the central computer, and Condition No. 2 of Resolution No. S-1358 dated August 31, 1972 was amended to read as follows:

> "2. The train control system shall be supplemented by an override consisting of a trained operator at the controls of each train with a backup of either supervisory personnel at key stations or Central computer control at key stations to provide positive train control in accordance with acceptable rules filed with this Commission.
>
> In conjunction with controlling train separation by the Central computer, the computer shall provide a printout for each train showing its schedule number and its arrival and departure times at each control station. These printouts shall be made available for Commission review."

The above-described method of train control is referred to in the preceding opinion as Computer Automated Block System (CABS). Operating rules initially established pursuant to Resolution No. S-1382 required two-station separation of trains (CABS-2).

5. Lawrence Berkeley Laboratory (LBL), as consultant to the California Senate Public Utilities and Corporations Committee, conducted failure-mode analyses as part of an independent evaluation of the technical merits of the CABS system. The objective was to make CABS one-station separation mode (CABS-1) proposed for transbay operation at least as safe (or safer than) CABS-2 operations, and

that the "worst case" failure should be an "uncovered failure-mode", that is, the protection should revert to that provided by the basic automatic train control system in the event of a CABS-1 failure.

6. As a result of its evaluation, LBL recommended several modifications and additions to the train control system designated herein as CABS-2. Such recommendations include the establishment of zero speed gates to automatically stop a train in the case of station run-through; a revision of computer algorithm to require positive detection of a released train in the block past a station platform before the release of a following train; the revision of the existing hardware for the transbay tube "pseudostation" (M00); integrity tests to ensure that the computer hardware and software actually perform their intended functions; abnormal operations performance tests; and a full-scale (36-train) dynamic performance test. LBL recommended that all tests be adequately documented.

7. All system modifications recommended by LBL have been adopted and incorporated into CABS-1 train control system by BART. All testing has been completed of the CABS-1 method of train control. Pursuant to Ordering Paragraph 4 of Decision No. 81248 in this proceeding, BART requests authority to place CABS-1 train control system into effect, and under that method of train control to begin operations between Oakland and San Francisco through the transbay tube.

8. Representatives of the Rapid Transit Unit of the Commission's Transportation Division, Operations and Safety Section, and representatives of Lawrence Berkeley Laboratory have observed computer automated block operations, witnessed operational testing, and have reviewed the operating procedures of BART in connection with its CABS-1 method of train separation. It is the view of the Commission staff and LBL that the CABS-1 method of train separations herein described will provide train operations at least as safe as the two-station separation mode heretofore authorized by the Commission (CABS-2 and its predecessor manual override with two-station separation).

9. CABS with the incorporation of modifications recommended by LBL, using one-station separation (CABS-1), will provide safe operations under acceptable standards for BART's systemwide operations, including operations through its transbay tube.

10. Additional changes in operating methods are necessary to reduce potentially unsafe conditions made apparent in the stress test conducted on August 3, 1974.

11. BART has complied with Ordering Paragraph 2 of interim Decision No. 81248 by establishing the operating rules required therein. The requirement of Ordering Paragraph 1 of said decision has been superseded by Resolution No. S-1382 authorizing the substitution of computer-enforced train separation in place of manual override.

Conclusions

1. BART should be granted authority to begin transbay operations utilizing CABS-1 system of train separation pending completion of its Sequential Occupancy Release (SCR) train control system now under development, subject to the conditions set forth in the following order.

2. BART should be ordered to implement the changes in operating rules, and software and hardware components of CABS-1 before transbay service is commenced.

3. BART should provide a continuing program to accomplish the post-transbay recommendations contained in LBL's report dated July 15, 1974 to the Senate Public Utilities and Corporations Committee which include: (a) review of software for its CABS and Central Computer programs, (b) effort to increase effectiveness of recoveries from computer malfunctions and failures, (c) periodic integrity tests to continuously maintain a high level of system safety, and (d) eventual replacement of CABS with SOR.

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4. Inasmuch as the operating conditions which resulted in the accident which gave rise to initiation of the investigation in Case No. 9445 have been corrected and/or superseded, and as BART has complied with the interim order in Decision No. 81248, Case No. 9445 should be discontinued. A new proceeding should be instituted when request is made by BART to initiate operations with SOR or other replacement for its CABS system of train separation.

FINAL ORDER

IT IS ORDERED that:

1. Condition No. 2 of Resolution No. S-1382 dated February 20, 1974 is hereby amended to read as follows:

> 2. The train control system shall be supplemented by an override consisting of a trained operator at the controls of each train with a backup Central Computer Control at all stations to provide positive train separation in accordance with acceptable rules filed with this Commission.
>
> In conjunction with controlling train separation by the Central Computer, the computer shall provide a printout for each train showing its schedule number and its arrival and departure times at each control station. These printouts shall be made available for Commission review.

2. The computer automated block system for single station separation (CABS-1) shall include all of the modifications recommended by Lawrence Berkeley Laboratory, as more specifically described in Exhibit 40-A (so-called "A" recommendations), and in Exhibit 43-A.

3. Regular periodic integrity and performance tests of the CABS-1 system shall be performed at intervals and in accordance with such rules as hereinafter may be specified by the Commission staff.

4. The following shall be implemented by BART prior to commencing transbay revenue service [except (e) and (j)]:

> a. Align and spike or lock with power removed the switches in the MacArthur (K35) Interlocking necessary to align routes R to N, F to B, D to G, and C to K.

b. Correct the transbay tube occupancy display malfunctions which frequently indicated erroneous occupancies during the test period.

c. Establish a policy that operational Train Control Computers shall be maintained in an on-line/backup configuration for performing train control work during revenue operations. Consistent with this objective, other work relative to the computers, except for repairs, should be performed during nonrevenue hours.

d. Revise the zero speed gate circuitry to prevent the one-shot timer from causing unnecessary train delay. This will reduce schedule delay without affecting the level of safety.

e. Install switch lights that indicate switch direction in the Oakland Wye (A05) Interlocking adjacent to the three (3) switches where trains normally diverge. (This should be accomplished as soon as possible. Transbay operations should not be held up if necessary materials are not immediately available.)

f. System Startup:

   1. Provide means to verify the correct entry of train identification and location into the computer system using feedback or redundancy.

   2. The order of identification and release should not allow any train to approach an unidentified train.

g. Computer Images to Central Operator:

   1. Train and Station Status Information: Investigate the type and format of information that can be useful to guide Central Operators especially when making decisions for manual releases.

   2. Train Release at the Wye and K25: Make available the CABS reservation status at the 3 merge points in the Wye and the merge at K25. Unless purposely re-sequencing, necessary manual releases in the Wye are to be made in the same logical sequence as that of CABS.

h. Control at Terminal Zone: Do not manually override the CABS-1 control system at the terminal zone on a routine basis. If it is necessary to operate the system with an alternate terminal zone (i.e., two terminal zones), then changes should be made in the software such that an additional reservation table be incorporated into the CABS program (similar to that at the Wye and K25) to handle the special condition existing at the terminal zone.

i. CABS Dispatch: Remove the automatically transmitted dispatch signal to trains awaiting dispatch in Transfer Zones. This will require manual dispatch, thus changing the quiescent mode from one which can create block violations to one which cannot. To maintain the automatic dispatch, the transfer zones can be included in CABS in the same manner as station platforms.

j. Isolation of Redundant Elements of Computer Control System: Investigate the degree to which isolation between system elements now exists, in terms of (1) complete isolation for repair purposes, and (2) isolation sufficient to prevent undesirable interaction between elements, when in the on-line/backup configuration. Provide any reasonable protection found lacking.

5. San Francisco Bay Area Rapid Transit District may begin transbay operations under the conditions specified in Ordering Paragraphs 1, 2, 3, and 4 hereof on the effective date of this order.

6. This proceeding shall be discontinued on the effective date of this order.

The effective date of this order shall be September 16, 1974.

Dated at San Francisco, California, this 27th day of AUGUST, 1974.

President

Commissioners

Commissioner J. P. Vukasin, Jr., being necessarily absent, did not participate in the disposition of this proceeding.