SAN FRANCISCO BAY AREA RAPID TRANSIT

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The San Francisco Bay metropolitan complex covers an area of 7,000 square miles and is the home of 4,250,000 people. In 25 years, its population is expected to grow to 7,000,000 as it expands to fulfill its role of a major port for international commerce and as the regional center of the whole of northern California. The Bay Area is characterized by rugged topography bordering on, and separated by, salt water. On both sides of San Francisco Bay, the major part of the population lives in long and relatively narrow corridors between precipitous hills and the water. These corridors are served by an excellent network of limited access highways which are being extended and improved. Those highways and the city streets, and parking facilities of their terminal areas in San Francisco, Berkeley, and Oakland, are seriously congested with motor vehicles during the morning and evening commuting hours. It has long been apparent to the Bay Area citizens that land does not exist in its narrow corridors for additional limited access highways, nor in its center city cores for massive increases in parking and access facilities sufficient to relieve congestion.

The San Francisco Bay Area Rapid Transit project is conceived of as a bold attack on that congestion. It will provide a regional express mass transportation system which will offer for those travelling to destinations near its stations, speed, comfort, and convenience comparable to that of a private automobile. It is to be integrated with the highway transportation system by generous parking facilities at stations, and by proper facilities for transfer from surface buses and from chauffeur-driven private automobiles. We use the word "chauffeur" in a broad sense to include those devoted ladies who will drive their husbands to and from the stations. The principal role of the transit system will be to serve the intense travel peaks during commuting hours. The initial project, which is now under design and construction, is to serve three counties—San Francisco, Alameda, and Contra Costa. Ultimately, it may be extended to serve all nine counties of the San

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Francisco Bay Area. It is not to be an urban rapid transit system such as we are accustomed to in the east. Its service will be more comparable to that of the commuting railroad. It will traverse, however, the center city cores and give distribution in series of station stops so that the vast majority of its patrons will disembark within short walking distances of their places of employment. The cost of the project is estimated to be $1 billion. Of this amount, authorization for $792 million in general obligation bonds was approved by the voters in November, 1962. The significance of this favorable vote can best be realized when it is understood that the owner of a $16,000 home will have his taxes increased by twenty-six dollars per year. $135 million will be provided by a revenue bond issue backed by the income from tolls of the San Francisco-Oakland Bay Bridge. This amount is allocated to the cost of construction of a Transbay rapid transit tunnel. The two together, the existing Transbay Bridge and the Transbay rapid transit service, will provide, at a cost substantially less than that for a new bridge, a superior service for Transbay travellers. The cost of rapid transit equipment will be met by the proceeds of a revenue bond issue backed by the gross revenues of the rapid transit system. The many hurdles that are interposed during the development of massive public works projects have now been crossed. The public has pledged its endorsement and made adequate funds available, construction of the first elements has already begun, and design of the balance of the system is underway. I shall not, therefore, dwell further today on the history of how this project came about. Rather, I shall speak of the technology which is now mobilized behind it and of the prospects for route and station developments, equipment and operations which the application of that technology will bring about. The thrust of this technology is in many directions.

Its potential for rapid transit progress is being immensely reinforced by a ten million dollar program of test and development which is currently under way and which has been made possible by a very substantial grant of the Housing and Home Finance Agency of the Federal Government. The program is directed toward eight main areas of investigation including train vehicle stability, sound and vibration abatement, propulsion equipment and power supply, transit vehicle trucks, automatic train control, automatic fare collections, and track construction. The first four and one-half miles of the rapid transit project is now under construction and will be completed this spring.

Three laboratory cars are already completed and are being mounted and equipped with the various components and systems proposed by manufacturers. Tests will begin this spring and will in the aggregate comprise a partnership effort of the Federal Government, the Rapid Transit District, we, their engineers, and industry to advance the state of art of rapid transit.

Of first importance in the design of the project has been the mobilization of modern concepts and tools for the creation of segregated and grade-separated rights of way. In downtown areas of the center cities, such rights of way will be in subways. This is not because structures for modern rail transit cannot be made as attractive as those for highways or those proposed for monorail, for instance. It is important to understand that the immense costs of rapid transit of any kind are justified only when there is the need for the movement of large volumes of people. This in turn necessitates trains from 500 to 700 feet in length. The accommodation of such trains requires stations of equal length. Such stations, if elevated, will not be esthetically acceptable over city streets in the narrow canyons that characterize the center city cores. They must be in subways. I do not affirm this in an academic way for we have had considerable experience with public officials, city fathers and property owners and know their uniform convictions in this regard. We agree with them.

In 1900, the founder of my firm, General William Barclay Parsons, was Chief Engineer of the first New York City subway. In the preparation for that undertaking, he visited cities abroad, particularly London, whose subways then were the most modern. They had been constructed at a deep level to avoid conflict with building foundations and utilities. Access and egress from the London stations was generally by elevators or otherwise by very long flights of stairs. General Parsons concluded that the vertical circulation from such a deep subway would throttle its otherwise great inherent capacity. He proposed, therefore, to construct subways near the surface of the ground by the method we have come to know over the years as cut-and-cover. In his day, there were some utilities to cope with and numerous horse-drawn carriages and trolleys to keep moving. Since his day, cut-and-cover has remained the usual method for subway construction, despite the fact that the maintenance of traffic and the handling of utilities has become immensely more complex and costly. Today, a subway could be constructed in an open field unhindered by utilities or traffic for $5 million a mile, and probably less. The construction of the same facility under a city street costs $20 million a mile. This puts the matter in proper perspective. It costs four times the inherent value of a subway simply to build it at a point where contractors must cope with modern traffic and utilities. General Parsons, despite calamitous predictions of many of his time, successfully pioneered cut-and-cover construction. We, his heirs, are with equal vigor, seeking to avoid it. Instead, we propose tunnels. Rapid advances are being made these days in tunnelling techniques in terms of modern shields and tunnelling machines, efficient mucking methods, and economical tunnel linings. We have, for instance, under way in the Bay Area now a test of precast prestressed concrete segmental tunnel linings which give some promise of cost reduction if they prove structurally adequate and watertight. There have been advances in the techniques for cast-iron segmental tunnel linings; prefabricated steel segmental linings may challenge precast concrete in cost.

In the light of the state of the art today, however, we see no alternative to cut-and-cover construction at stations, and have adopted that method for the subway stations of the San Francisco Project Nevertheless, the state of the art is advancing rapidly. Much is being done these days with chemical soil solidification, although current costs of $5 per cubic foot make its wide application impractical. I, for one, am more optimistic about the potential of ground freezing. It is quite likely that in the relatively near future, we shall be able to drive tunnels under city streets economically and create stations by freezing the ground surrounding the tunnels and mining out the necessary space with minimum disturbance to the street and utilities above.

I do not wish to intimate that a tunnel subway system can be constructed as close to the surface as a cut-and-cover system, although with modern methods, it is not necessary to construct them as deep as those in London. There is available today, however, a tool, in the form of the modern escalator, which effectively neutralizes the traditional disadvantage of vertical circulation. Thus, a subway ten to twenty feet deeper than one constructed by cut-and-cover methods can be accepted with equanimity.

The cost of subway construction underneath city streets is disproportionate to the value of adjoining land and buildings, except in the center city cores. Outside of these cores, other means of creating a grade-separated right-of-way must be adopted. One very desirable development is the location of rapid transit in the median strip of freeways where both facilities are serving the same corridor. We have had great cooperation in such planning from the Department of Public Works of the State of California with the result that approximately 13.6 miles, or about one-sixth of the San Francisco system will be located on common rights-of-way with the freeways. Agreements have been worked out so that the Rapid Transit District will reimburse the Department of Public Works for the incremental cost of providing right-of-way for rapid transit. The District will, of course, then pay for the cost of rails and stations, and other transit facilities. The net result is a very effective and economical solution for the Bay Area community.

Along other routes of the project, rapid transit will be elevated. The elevated structure will be simple prestressed concrete box girders or steel box girders supported by center column piers. A great deal of architectural and engineering effort has been expended to insure that the elevated structures will be esthetically pleasing.

Elevated construction is economical, and has been adopted for 31.2 route miles of the San Francisco project. In my opinion, it has an important role in the future. The question is only one of suitable environments. These include industrial areas, alongside railroad tracks, and otherwise in locations where there is at least 100 feet, and preferably 150 feet, between building lines. In the latter case, where such widths are available, elevated construction can be placed in center malls with appropriate landscaping. In such locations, provisions for it should be esthetically acceptable, and as a result of developments I shall describe later, noise will not be objectionable.

I have dwelt at some length on the development of a segregated and grade-separated right-of-way for the rapid transit project because although less dramatic than the equipment, its creation will pre-empt almost three-fourths of the rapid transit capital cost dollar. An important result of the very high costs of such rights-of-way is the financial impracticality of providing more than two tracks along any single route in the San Francisco area. Thus, there cannot be express and local tracks that generally characterize commuting railroads and such major rapid transit systems as, for instance, that of New York City. Without at least three tracks, there cannot be non-stop service, though some trains may skip some stops. The only way to compensate for the necessity of making many station stops is to minimize the length of time required for each and to achieve high speeds in between. This is being done on the San Francisco project by providing sufficient power to accelerate the trains at approximately 3 miles per hour per second, which is about as high as passengers will comfortably tolerate, and to assure balancing speeds of up to eighty miles per hour. By these means, the average rate of progress of the San Francisco rapid transit trains will be between 45 and 50 miles per hour, including time for station stops. These average speeds we consider adequate for reasonable competition with the private automobile.

Rapid acceleration requires high power for propulsion which in turn will result in high system demand during peak travel hours. Unfortunately, in the evening especially, rapid transit peak demand may coincide with the peak hours of public utilities. To minimize power demand, every effort is being made to reduce the weight of the rapid transit cars. The weight of New York City rapid transit cars is 1300 pounds per foot. Recently, new cars for Philadelphia have been so designed as to reduce weight to 890 pounds per foot. The San Francisco rapid transit cars will be approximately 800 to 850 pounds per foot and perhaps a little less. The major opportunity to reduce weight is in the rapid transit trucks.

The laboratory cars of our test program are now being mounted on rapid transit trucks of new designs proposed by several manufacturers, including the Budd Company, the Westinghouse Air Brake Company, the Pullman Standard Company, the General Steel Industries Company, and LFM Manufacturing Company. After extensive testing in actual operation, final specifications will be drawn. It is already clear, however, that a substantial advance will be made in the state of the art of rapid transit truck design.

I would emphasize that we do not seek lightweight for lightweight's sake, nor do we ask you to believe that a Volkswagen is as comfortable as a Cadillac. Our objective is to reduce mass in order to reduce power requirements to accelerate trains at a rapid rate, and in order to reduce wear and tear caused by decelerating trains from high speeds.

The reduction of weight to the level which I have just described brought an unexpected problem—the stability of rapid transit cars due to wind loads and other dynamic conditions. A contract was let to Stanford Research Institute of Palo Alto, California, to investigate these phenomena. They have done so in the wind tunnel of the Lockheed Aircraft Company. Their conclusion is that for safety and stability, the cars we propose must have wider than ordinary gauge. Their original recommendation was for a gauge of six feet. In reaching a final decision, many other factors came into play. The gauge adopted is 5½ feet which will insure safety and stability, and a better ride for the passengers. It should be kept in mind that the San Francisco project involves a completely new system and does not need to be compatible with any existing rails.

Stanford Research Institute has also assisted in a vigorous search for methods to reduce noise. Their conclusion is that the best way to reduce noise is to prevent it at its source. They have worked intimately with the car builders. Many of the recommendations have concentrated on the mounting of the various elements making up a rapid transit truck. The trucks which will be tested this spring include a variety of rubber mounting to an extent not heretofore used. (See Fig. 1.)

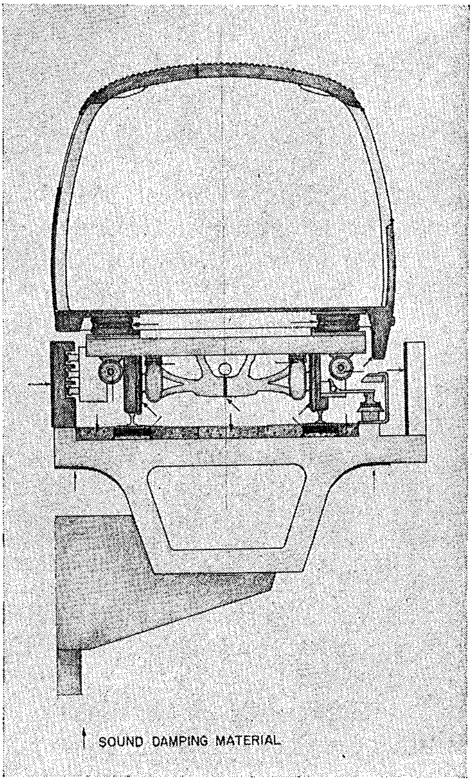

FIG. 1

Strategic locations for sound damping material are indicated in this sketch—one of the many considerations in the design of car and rails.

Attention is also being given to the reduction of noise originating at the wheel rail contact point. Our program includes the installation of elastomeric rail pads, the possible use of acoustical concrete on the roadbed, absorption material on parapets installed along the side of the cars, and suitable material under aerial structures to reduce the transmission of noise from that particular path. At subway stations, a curtain wall between the station passenger and the rapid transit cars is under very active consideration. Such a barrier wall, if it proves practical, will have many advantages. It will insulate the passenger from the noise of approaching trains; it will protect the passenger from being pushed off the station platform; it will improve circulation along the platform because of that protection; it will make possible better control of temperature and humidity in the stations; and it will prevent the accumulation of trash on tracks. The concept of a barrier wall in subway stations, however, introduces various problems, including the accurate positioning of trains in stations so that rapid transit car doors and doors in the barrier wall will match. This and other related problems can only be evaluated on the test track.

Truck performance and noise control depend not only on equipment design but on track and structure also. For the test tracks, rails will generally be mounted on wood ties on ballast. Certain parts of the test track will be on prestressed concrete ties and one part on a continuous concrete slab. Certain of the bridges of the test track are being constructed of prestressed concrete box girders, and others of welded steel box girders similar to those to be adopted for aerial construction. These will be instrumented to measure both noise and stress levels.

The test program has also become of the essence in designing the power system. It is interesting to know that power input will approximate 1,000 k.w. per 70 foot long car during acceleration and 150 k.w. per car at 75 miles per hour. The use of an overhead catenary is not practical for the San Francisco system due to the close clearances in the subway tunnels and the Transbay Tube, and otherwise because of its awkward appearance on elevated structure or at grade. The investigation of power systems has accordingly been confined to third rail. The initial investigations for power included three-phase and single-phase alternating current systems from 600 volts to 4,160 volts, and direct current systems from the traditional 600 volts to 3,000 volts. Of these, the two that show most promise are the three-phase 4,160 alternating current system and the 1,000 volt direct current system.

Both are to be installed on the test track and both exhaustively tested. Little need be said about the potential utilization of direct current. The utilization of three-phase alternating current would be a major innovation in rapid transit power supply. Contracts for the development of both alternating current and direct current propulsion systems of the size and performance required have been let. The alternating current systems require investigations in many areas. The incentives to undertake such investigations are the possibility of lower distribution cost, the possible use of regenerative braking, the reduction of cathodic protection requirements, and the reduction of propulsion equipment weight and the improved propulsion controls needed for automatic train control.

Perhaps that facet of our design test program which is eliciting most interest is the development of a train control and communication system. It is essential that a control system be highly refined and fully integrated for the San Francisco Bay Area Rapid Transit system. This system will provide all aspects of control and operation which heretofore had been considered separate operations in a rapid transit system. Their integration into a single system may be one of the more significant developments of this rapid transit system. The system will provide several inter-related functions. It will provide in the first place for train protection and will function to prevent collision and derailment. It will maintain safe operation for trains running on the same track. Trains will be protected from overspeeding downgrades and around curves of short radius.

In its second function, the train control system will provide for line supervision and will automatically dispatch trains at terminals of origin and along the lines. In its third function, the train control system will provide for automatic train operation and will function to move trains automatically without an operating crew under all normal conditions. Automatic train operation will achieve selective rates of acceleration, deceleration, and maximum speed in accordance with a proposed speed limit. Trains will make station stops and will operate their doors automatically. There will be an operator at the head of each train to override the automatic controls in the event of his observation of any interference on the track ahead and for such other duties as experience on the test track may indicate.

A communications system will provide for voice communication between the central dispatcher and the trains, for the announcement of train arrivals and departures, and on the station platforms for public address by the central dispatcher. Contracts have been awarded to the General Electric Company, the General Railway Signal Company, the Union Switch and Signal Division of Westinghouse Air Brake Company, and the Westinghouse Electric Company for the demonstration on the test track of systems which they propose to fulfill these purposes. Each company is confident that the system which it will install and test will fulfill the requirements I have just noted.

The purposes of automatic train control should be fully understood. It is not fundamentally a labor-saving program, although reduction in the cost of transit operation will be necessary for its survival or revival. What is more important is that such controls will be necessary for maximum safety, taking into account the high speeds and short headways at which the system will ultimately operate.

I would conclude this review of the technical aspects of the San Francisco project by telling you of the plans and program for the automated fare collection. I cannot over-emphasize the importance of this phase of our program. One of the real handicaps in mass transit has been the single level fare which brings to the transit operator the same reward for short trips as for long trips. The single level fare discourages operations to reach out beyond the thickly populated areas and is the cause of many transit deficits. The proper economic functioning of the San Francisco system will require separate station-to-station fares, the collection of which is simply not practical by traditional methods of fare collection. In studying this problem, our findings to date indicate that it will be possible to install a fare collection system around advanced electronic mechanical concepts and meet system requirements for station-to-station fares. No special difficulties are visualized for those travellers who will want to pay in cash for a single trip. Such passengers would purchase a minimum fare ticket through an automatic vending machine, and use it to activate a turnstile for admission to the system and relinquish it at the exit gate of the station of discharge. Electronic instrumentation in the exit gate would check every ticket, reading the station of origin and almost simultaneously determining if the fare paid were sufficient. If in order, the ticket would trigger the release mechanism. If not, it would activate a device advising the rider what to do. Both the entry and exit gates would operate rapidly, processing and returning the ticket faster than the hand could move from insert slot to recovery slot. There will, however, be many passengers who will want to pay for a number of trips in advance. One concept is that such a traveller will purchase a plastic wallet-size card, on which will be a magnetic coding of stored fare of up to $20, depending upon the purchaser's outlay. After each trip, the value of the ticket will be reduced, in both the machine-readable encoding on the back and in a visible imprinting on the front. This accounting would be accomplished by the gates at both entry and exit. The entry gate would read the value of the ticket and record the name of the station entered and the time of entry. The exit gate would compute the cost of the completed trip, erase the old value and imprint the new residual value. The gates processing such a ticket will have to prove highly flexible and completely reliable. The electronic computer mechanisms required may be located in each of the gates or at central locations in the stations. At the present time, contracts have been let to several companies for the development of alternative hardware for the various components of such a fare collection system. After a final selection is adopted, a trial installation will be made in the Cleveland Transit System in Cleveland, Ohio.

A final word may be of interest concerning the design and functioning of the body of the rapid transit car itself. A contract has been let to a joint venture of Sundberg-Ferar industrial designers, and the St. Louis Car Company to develop the design beginning with sketches of all possible ideas, progressing through models at various scales for the most promising configurations. Ultimately, a full-scale mockup of one half a car will be constructed. Many presentations at the different points in the design process have been made to the members and staff of the Rapid Transit District and to interested car builders. The District has approved a design for a final full-scale mock up. Car widths will be about 10½ feet. Fenestration has been carefully worked. Interiors will be bright, clean, comfortable, and easy to maintain. Plans for air conditioning involving the introduction of conditioned air under the windows have been worked out for us by a Los Angeles firm who are well known for their designs for air conditioning for airplanes.

The objectives of the San Francisco project are clear. They are simply to provide comfortable, high-speed, public transportation serving the principal corridors of the region which will deliver a major proportion of home-to-work travellers, and others also, to within convenient walking distances of their destinations, with comfort and at speeds comparable to that available by private automobile.

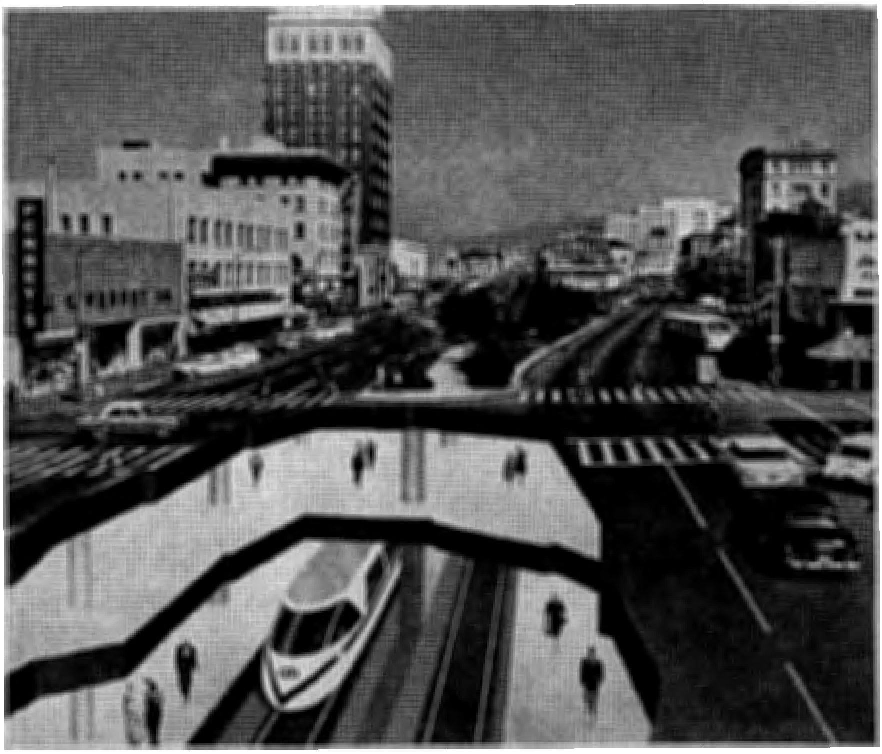

FIG. 2.

The proposed Bay Area Rapid Transit system will provide for a subway beneath Shattuck Avenue in Berkeley, with a station located just south of University Avenue. As depicted in the above photo-rendering, the two-level subway station will provide direct delivery to downtown Berkeley and the University of California, with feeder bus lines, as shown, also making a direct station connection. Assured peak-hour rapid transit travel times to and from the downtown Berkeley station include Richmond, 10 minutes; Broadway and 19th, Oakland, 7 minutes; 77th Avenue, Oakland, 15 minutes; San Leandro, 18 minutes.

Bay Area Rapid Transit Photograph

The engineering goes forward in an orderly, and yet to us, an exciting way. Because of the long lead construction time of major physical features, and the availability of funds, the design engineering is being supplemented by the comprehensive test and development program which permits designers to work on the frontiers of today's technology without gambling on the untried.

The human relations aspect of the project goes forward apace and in point of fact, is more exciting than the engineering. We are playing for keeps now. Routes and station locations, architectural design, landscaping, all have their impact on the welfare and lives of thousands and thousands of people. Having come to understand it, their ambitions are being pressed upon the Rapid Transit District with skill and persistence by their various political and other representatives. The reconciliation of such ambitions with each other, where they conflict, and with the project itself where cost control must be exerted, is a major job in public relations, skillfully conducted by the members of the District, their President, Mr. Adrien Falk, and their General Manager, Mr. William B. Stokes. As their engineers, we are bound to be projected into the thick of the fray; our head is bloody, but unbowed.

So, as I conclude this afternoon, let me invite you all to come out to the test track this summer in the hopes that perhaps you may witness in progress significant advances in the technology of public transportation.