Scientific Analysis Corporation

CALIFORNIA STEAM BUS PROJECT

FINAL REPORT OF THE PROJECT MANAGER, SCIENTIFIC ANALYSIS CORPORATION, TO THE PROJECT DIRECTOR, OFFICE OF RESEARCH, CALIFORNIA STATE ASSEMBLY

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The contents of this Report reflect the views of Kerry Napuk, Project Manager, Scientific Analysis Corporation, who was responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This Report does not constitute a standard, specification or regulation.

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16. Abstract

The California steam bus project is summarized in this final report of the project manager to the California State Assembly which, in conjunction with the Urban Mass Transportation Administration, financed the development and demonstration of Rankine Cycle external combustion propulsion systems for urban transit vehicles.

Project history, organization, and financing are summarized in detail. Under Phase I, three contractors (William M. Brobeck & Associates, Lear Motors Corporation, and Steam Power Systems) were selected to install steam powerplants in conventional motor coaches, replacing the standard diesel engines. Each contractor was paired with a transit system operator (AC Transit, San Francisco Municipal Railway, and the Southern California Rapid Transit District) during Phase II under which the modified buses were demonstrated in experimental testing and revenue service. Operational experience of the steam buses in each system is reviewed in detail. The report also summarizes the overall technical experience of the demonstration program.

Policy considerations are examined, particularly with reference to additional future pre-production phases.

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Introduction

The California Steam Bus Project was created by a number of events which occurred almost simultaneously.

In October, 1967, a report of the Panel on Electrically Powered Vehicles to the U.S. Department of Commerce Technical Advisory Board stated that "a closed-cycle, reciprocating steam engine power plant can meet the performance requirements of automotive vehicles in sizes of the order of 100 horsepower or less." This conclusion was part of the Panel's larger recommendation "to provide support for that research and development which is necessary to demonstrate potentially attractive alternatives for automobile pollution control."

On January 11, 1968, a report by the Hudson Institute concerning environmental quality in the area of technology and urban transportation touted steam propulsion systems as a potential alternate to the internal combustion engine. This report not only claimed Rankine cycle systems were much less polluting but also that they were "smoother, simplier, peppier and more economical."

These research studies, in turn, prompted legislative interest. In March, 1968, the Transportation Committee of the California State Assembly, the legislature's lower house, held hearings on various alternate propulsion systems. Rankine cycle systems emerged as one of the more promising alternatives. In May, 1968, similar hearings were jointly conducted by the U.S. Senate Commerce Committee and the Senate Public Works Subcommittee on Air and Water Pollution. These hearings led to a Senate Commerce Committee report published in spring, 1969, that concluded "the Rankine cycle propulsion system is a satisfactory alternative to the present internal combustion engine in terms of performance and a far superior engine in terms of emissions."

Project history

During their early investigation of steam power as an alternate system to alleviate California's chronic air pollution, the Assembly considered a number of test-bed vehicles for an initial demonstration of feasibility, including police cars for the California Highway Patrol. City buses finally were selected as symbolic test-beds, because they were available from publicly-owned fleets and because buses would provide an opportunity to test the stop-and-go advantages of steam systems.

Accordingly, staff of the Assembly Office of Research (AOR) contacted officials of the Urban Mass Transportation Administration (UMTA), U.S. Department of Transportation, about demonstrating steam buses. A formal application was submitted on December 17, 1968, by the Assembly Transportation Committee through the AOR. It was approved on February 17, 1969, by Paul Sitton, then UMTA Administrator.

This initial application was designed to test four systems developed by one vendor in four buses contributed by two transit districts in the San Francisco Bay Area, the San Francisco Municipal Railway and the Alameda-Contra Costa Transit District. After initial testing and evaluation, these steam powered buses would operate in public service. In this way, feasibility of steam power and its supposed superiority over diesels was to be demonstrated and proven. A modest amount of $450,000 was requested by the State, and UMTA awarded $244,250 for the first phase of activities.

At the time of the grant award, John Foran, chairman of the Assembly Transportation Committee which held the hearings on alternate systems and who sponsored the legislature's efforts in this project, remarked that "we have every reason to believe that steam power can provide an efficient alternative to the internal combustion engine." He was joined by Assembly Speaker Bob Monagan, who praised the undertaking as "the first major research grant ever made to a state legislative body, and California is proud to have been so honored."

When staff gathered in February 1969, the first order of business was to sort out project organization. The project was to be directed by the AOR, a group of professionals established to provide the Assembly with a long-range, policy planning and analysis capability. Michael Wenstrom and later James Lane were designated project directors for the AOR, which was to be assisted by two system managers: first, Scientific Analysis Corporation (SAC), a non-profit research firm in San Francisco, which would administer the project on a daily basis, conduct public and patron attitude surveys and supervise making of a documentary motion picture; second, International Research & Technology Corporation, Inc. (IR&T), a Washington, D.C. firm, which would monitor, evaluate and report technical progress through a field office in San Ramon, California. Kerry Napuk was appointed project manager by SAC, and Roy Renner became project technical manager for IR&T. These managers were to represent the State on all daily matters of administration, coordination and evaluation.

The next question to be answered was to find who was capable of installing a steam propulsion system in buses. What was to transpire over the next year was tantamount to conducting an initial feasibility study, because a survey of existing suppliers yielded the knowledge that no adequate hardware existed to install in heavy duty vehicles. A number of events had to occur, of course, before this became evident.

A Request for Proposal was mailed to more than 60 potential bidders on May 1, 1969, which called for four different systems to be demonstrated and provided $150,000 in demonstration funds. On May 12, 1969, a public information meeting brought forth interested parties who were unanimous in their belief that funding was grossly inadequate. When asked for formal cost estimates two weeks later, 23 organizations submitted estimates between $85,000 and $4.5 million. An independent analysis determined that $332,000 per system would be required to build and demonstrate a feasibility power system, if a vendor knew what they were doing within the allotted time period.

The next step was to secure additional development funds. Project staff visited UMTA on June 4, 1969, and received another $300,000 with assurances more funding would be forthcoming. An amended Request for Proposal was issued on August 14, 1969, which called for formal bids even though funding per system was not yet finalized. Eleven formal proposals were received. They were evaluated and selected by a national panel of eight independent experts on September 20, 1969. This selection panel, in order of preference, nominated William M. Brobeck & Associates (Berkeley), Steam Power Systems (Huntington Park and San Diego), Lear Motors Corporation (Reno, Nevada) and General Steam Corporation (Newport Beach), with Paxve, Inc. (Newport Beach) and Steam Engine Systems (Newton, Massachusetts) as alternates.

In September, 1969, a third transit district joined the project, allowing at

least three vendors to be paired with different fleet operators. As Los Angeles was a natural site for such a demonstration, officials of the Southern California Rapid Transit District (SCRTD) participated and made the project a statewide effort.

On November 24, 1969, the Assembly Rules Committee submitted a formal request to UMTA for additional development funds, presenting alternate plans for one, three and four vendors. On March 3, 1970, UMTA Administrator C.C. Villarreal replied by approving funding for three vendors. After one year had passed, development funds rose from $150,000 to $1,100,000, which would later grow to a total of $1,721,586.

Time was required to restructure the project to accomodate reality. Both the federal government and the state legislature were victims of over expectations concerning the availability of steam propulsion systems. A development program, therefore, had to precede any demonstration of feasibility. The project was now ready to provide the earliest possible demonstration of feasibility using standard city buses and to determine the point of technological departure for Rankine cycle technology. Technical perfection and pre-production prototype development would not be possible within the limited demonstration program that was contemplated.

With the California Steam Bus Project finally established on a realistic basis, the Assembly Rules Committee was able to contract with three system vendors and three transit districts. The actual work of designing and developing these steam power systems commenced with the signing of engineering contracts in June, 1970. Each system vendor was paired with a transit district as follows:

1. William M. Brobeck & Associates, Berkeley, California, with neighboring Alameda-Contra Costa Transit District (AC Transit) headquartered in Oakland.

2. Lear Motors Corporation, Reno, Nevada, with the San Francisco Municipal Railway (S.F. Muni).

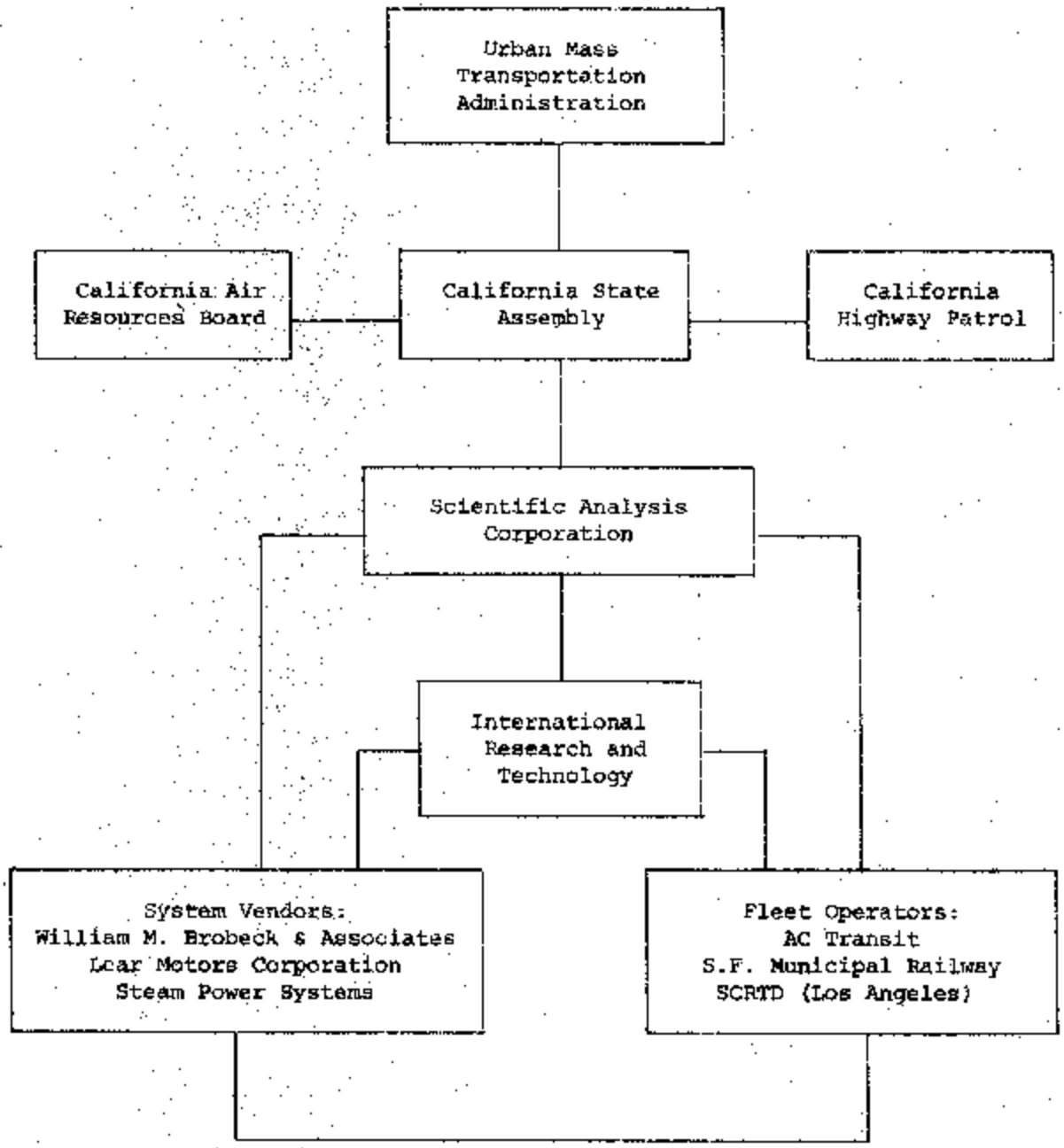
3. Steam Power Systems (SPS), San Diego, California, with nearby Southern California Rapid Transit District (SCRTD) in Los Angeles.

AC Transit and SCRTD contributed late model coaches to be retrofitted to steam power. Lear Motors furnished its own bus and powerplant for lease to S.F. Muni. The Bay Area Educational Television Association, KQED, in San Francisco, was selected in open competition to complete a documentary motion picture of project activities. Exhaust emissions were tested and evaluated by the California Air Resources Board, and sound level measurements and motor carrier safety inspections were performed by the California Highway Patrol. Support also was provided by the Assembly Rules Committee, Office of Auditor General, Division of Highways, State Department of Health and the Insurance Officers of the State of California. During special demonstrations, assistance was provided by D.C. Transit and the Sacramento Transit Authority. Project organization is shown on the chart below.

By direction from UMTA, project work was divided into phases. Phase I was the development phase, requiring system design, component fabrication, system bench tests and system installation in buses over a 12 month period and initial road tests of the vehicles before delivery to fleet operators over a three month period. William M. Brobeck & Associates was the only vendor to come close to project deadlines, as they delivered an operational steam bus to AC Transit on October 1, 1971. Lear Motors Corporation did not technically complete Phase I until August 4, 1972, and SPS not until August 30, 1972. However, much of the Lear Motors and SPS delay

CALIFORNIA STEAM BUS PROJECT

ORGANIZATIONAL CHART



resulted from a revised program implemented at UMTA's request during Phase II.5.

Phase II was approved on May 28, 1971. Its objectives were to demonstrate feasibility of three steam buses through extensive testing and in actual revenue passenger service, as well as to develop a realistic set of specifications for pre-production prototypes based on project experience with feasibility systems. This phase and all activities were to end on April 30, 1972, but the project was extended into a Phase II.5 which was approved on April 10, 1972.

Phase II.5 extended the project through September 30, 1972, with additional funds to allow all vendors to make as many short term improvements and modifications as possible in their operating systems before the project terminated. While Lear Motors had their bus operational in January and SPS in March 1972, they both elected to work into the summer to improve performance before delivering their steam buses to the assigned transit districts.

Except for Brobeck, who was compensated on a monthly progress payment basis, Lear Motors and SPS were paid on a milestone basis or after completing previously negotiated technical requirements. Lear Motors and SPS activities, on the other hand, were acknowledged to be "best efforts." There were constant conflicts between their desires to make technological breakthroughs on the way towards pre-production prototypes and the State's concern for as early a feasibility demonstration as possible. Eventually these differences were resolved, which is evident from an operational history of the three experimental vehicles.

Brobeck & Associates moved their bus under steam on September 10, 1971, only 15.5 months after work began. This first modern steam bus was presented to AC Transit at their Division II Yards in Emeryville, California, on October 1, 1971. William Brobeck, president of Brobeck & Associates, presented the vehicle to John Burton, Chairman of the Assembly Rules Committee, representing the State, who, in turn transferred it to Alan Bingham, general manager of AC Transit.

After a round of emissions and noise testing by the California Air Resources Board and the California Highway Patrol, respectively, and with only 250 road miles on the system itself, the AC Transit steam bus was shipped by rail to Washington, D.C. late October, 1971. It was demonstrated on November 17, 1971, in conjunction with a Steam Bus Symposium sponsored by UMTA and the U.S. Department of Transportation. During its stay in the nation's capitol, it traveled more than 75 miles and carried nearly 500 people including Secretary of Transportation John Volpe, Undersecretary James Beggs, UMTA Administrator Villarreal and Assistant Secretary of Systems and Technology Robert Cannon. The AC Transit steam bus also was demonstrated to members of Congress, including Senators Muskie, Cranston, Tunney and Randolph and Representatives Vaysey, Johnson, Conte, Rodgers and many others. About 150 symposium guests also rode this experimental vehicle.

The Lear Motors steam bus, the first successful steam turbine ever to operate a vehicle, was unveiled at a press conference on February 11, 1972, in Reno, Nevada, although it was operational in January. It was formally presented to the City and County of San Francisco on August 4, 1972. William Lear presented the vehicle to John Burton, representing the Assembly, who, in turn, transferred it to Mayor Joseph Alioto, members of the Public Utilities Commission and Jack Woods, general manager of the S.F. Muni.

The SPS bus was operational in March 1972. It received widespread attention in Los Angeles when it was formally delivered to SCRTD's Division II Yards. Cornelius Dutcher, president of SPS, presented the vehicle to Frank Lanterman, Vice

Chairman of the Ways and Means Committee, representing the State, who, in turn, transferred it to Jack Gilstrap, general manager of SCRTD.

On April 26, 1972, a project milestone was achieved when all three operating steam buses were demonstrated before members of the State Assembly and Senate in Sacramento, California. At a morning press conference, Assembly Speaker Bob Moretti said the demonstration "proves again how California is the nation's most progressive pollution control laboratory. We've shown it's possible to develop low-pollution engines for big passenger vehicles, and I am very disappointed at this point that Detroit has tried to pooh-pooh the idea of steam buses."

Financial history

The California Steam Bus Project was separated into phases with federal funding approved for each stage. Phase I, from February 17, 1969, through August 31, 1971, was funded by a $1,202,036 grant. Phase II, from September 1, 1971, through April 30, 1972, was funded by a $409,448 grant; and it included some objectives which ran concurrently with the next phase. Phase II.5, from May 1, 1972, through October 31, 1972, was funded with an additional $683,041. Total project funding, therefore, was $2,294,525, of which $1,721,586 went to system development.

UMTA grants require a one-third contribution from project participants, which came to $1,147,263. These "local contributions" were estimated as follows: California State Assembly, $46,042; California Air Resources Board, $12,000; California Highway Patrol, $8,000; AC Transit, $50,000; S.F. Municipal Railway, $50,000; SCRTD, $50,000; and system vendors, the balance, $931,221.

Each of the transit districts were obligated to contribute up to but not exceeding $50,000, which involved mostly the loan of a bus to be converted to steam power, provision of technical assistance during system installation and training drivers to operate the buses during special demonstrations and actual revenue passenger service. Transit districts also provided vehicle support services after delivery, such as painting, cleaning, maintenance and public relations. AC Transit exceeded their local contribution requirement, and SCRTD came close to meeting their obligation. S.F. Muni did not, which is partially explained by Lear Motors providing both a power system and a bus leased to the City's Public Utilities Commission at no cost.

Each steam bus was covered by $5,000,000 in public liability insurance provided by system vendor and transit district separately. These policies were reviewed and approved by the State's insurance officers. Vendors were responsible for all portions of the vehicles modified during conversion to steam power, and transit districts were responsible for maintaining all unmodified parts of the vehicle and for driver operation.

A project precedent was the reversal of customary cost sharing. What was supposed to be a grant with two-thirds federal share and one-third local share became the opposite. Project participants, overwhelmingly the vendors themselves, contributed 70 percent of costs and the federal government 30 percent.

Local contributions were almost $5.6 million, which, when combined with federal funds of $2.3 million, yielded a total project cost of $7.9 million. While Broback

& Associates contributed $80,256 during Phase I, SPS reported contributions of $1,923,318 through February 29, 1972, and Lear Motors submitted $3,228,928 through September 30, 1972. These contributions were above the contract compensation paid to system vendors for development, improvements and demonstration, which was $518,304 for Brobeck & Associates, $649,782 for Lear Motors and $553,500 for Steam Power Systems.

These financial figures reflect Lear Motors and SPS attempts to take more innovative and thereby more expensive paths to produce their power systems. Both missed most project deadlines only to later compromise technical goals to obtain operational buses.

Why did the individuals who owned these companies invest sizable personal funds in this effort? Perhaps the answer rests in their commitment to the idea that steam power can provide a viable alternative to the ICE and in their personal desire to show the most advanced results possible in the time provided.

Public service experience

Originally, the steam buses were intended to operate in public service for nine months, but revised work schedules, development delays and additional project work requested by UMTA reduced actual public service to less than one month. Phase II objectives were to demonstrate the vehicles long enough to gather data on performance, operating costs, reliability, emissions, noise levels, safety, maintenance and public attitudes.

Data was obtained on most items prior to public service except for operating costs, reliability and maintenance. Because of the very limited service time, maintenance and reliability data were very fragmentary. Moreover, such information would be misleading, because none of the steam buses were ready for a rugged, lengthy endurance test against production line diesels. While no individual steam bus accumulated more than 4,000 miles during the entire project, diesel buses can travel 250,000 miles before their first major overhaul and some are still operating in service after 1,000,000 miles. The diesel, then, is the most efficient, durable and reliable internal combustion engine produced.

Steam buses entered revenue passenger service in the cities of Oakland, Berkeley, Hayward, San Francisco and Los Angeles. The longest individual public service was eighteen operating days; the shortest was two days. However, numerous special demonstrations were provided before and after delivery of the steam buses to their assigned transit districts. These three demonstration vehicles accumulated a total of 8,372 road miles, including about 800 miles carrying paid passengers.

Public experience on a district-by-district basis was as follows:

AC Transit. On January 24, 1972, the AC Transit steam bus, Coach 666, entered its first day of public service, operating on the Number 40 line from East Oakland to Berkeley and back. While completing its third round trip of the day, an engine failure, involving a broken crosshead, forced the vehicle to return to Division IV only three blocks from completing its day's service.

On May 25, 1972, Coach 666 returned to public service, making one round trip per day on the Number 40 and 41A lines between Oakland and Berkeley. On June 5, the bus operated on the Number 60 line from downtown Hayward to Oakland and back. During eight days of public service, thirteen one-way trips were completed and three

were aborted. Numerous operating problems were encountered, including control instability, a blower motor failure, a feed water pump failure, relief valve bellows failure and poor water consumption. The steam bus was withdrawn from public service on June 9 to undergo Phase II.5 improvements over the summer months.

On September 19, 1972, the AC Transit steam bus returned to public service, operating on the Number 82 Hayward Express line between downtown Hayward and downtown Oakland, a distance of 39 miles. It operated on this route for nine continuous days without any operational problem whatsoever, ending service on September 29, the last possible day of operation under a contract which terminated on September 30. Operating at much reduced noise levels, coach Number 666 traveled 353 miles during this period, accumulating a total of 3,465 miles under steam power in one year from September 1971 through September 1972. No stops were required for water or fuel, and only occasional odors from an improper fuel/air ratio marred this otherwise perfect conclusion of revenue service.

S.F. Municipal Railway. On August 7, 1972, the Lear Motors/Muni Railway steam turbine bus, Coach 5000, began its revenue service on the Number 32 line, between the Southern Pacific Station and Fisherman's Wharf and back. On August 9 and 11, it was withdrawn from service to make a boiler repair and to adjust the burner which emitted noticeable smoke. From August 14 through 18, Coach 5000 operated as a commuter shuttle between the Ferry Building and the S.P. Station, making up to four trips a day with a maximum of 98 passengers on board. From August 22 through 25, it operated on a more rigorous route involving ten miles of freeway and a six percent grade, the Number 17 Park Merced Express. On August 25, during the last day of public service, the steam turbine bus attempted two round trips with full loads and lost a fan belt on their combuster air blower on a freeway during rush traffic. This was the only operational problem during eleven days of revenue service, and the bus returned to the 24th and Utah Streets barn under its own power.

On at least two occasions, once with a simulated payload of 4,500 pounds and once with fifteen passengers, Coach 5000 successfully traveled portions of the Number 55 Sacramento route, which includes San Francisco's steepest bus grades of 16 and 19 percent. Underscoring its relatively trouble-free time in San Francisco, the Lear Motors steam bus drove from San Francisco to Reno under its own power on August 31 and September 1, covering 230 miles over the Sierra Nevada Mountains without major problems. During its brief exposure, therefore, Coach 5000 provided early indications of the potential for high system reliability.

Since it became operational in January 1972, this bus accumulated 3,900 miles of road testing and passenger service in eight months.

SCRTD. During its first week of public service, the SPS/SCRTD steam bus, Coach 6200, encountered numerous difficulties. Its first two days of attempted public service on September 5 and 6 were aborted, because a bolt holding the combuster air fan assembly together sheared and a gear mechanism in the oil pump failed. On September 7, it entered public service, but it completed only a one-way trip of 7.3 miles, because a pulley slipped which prevented the fan from turning inside the boiler. On September 8, the bus was withdrawn from public service when a boiler leak was detected. However, the bus traveled 86 miles on September 11 during performance testing until the boiler leak deteriorated, requiring removal of the engine and boiler for repairs the following day.

After the bus was towed to San Diego and the repaired boiler was installed, Coach 6200 returned to Los Angeles on September 28. It re-entered public service on September 29, operating on the Number 83 Wilshire Boulevard line. It completed

a successful 15-mile round trip with air conditioning operational and favorable performance except for a loose battery terminal which caused a 27-minute delay until corrected. Coach 6200 thereby completed its second and last day of public service in Los Angeles, because vendor and fleet operator contracts expired on September 30.

Since it became operational in March 1972, the SPS bus logged 1,007 road miles during road tests and revenue passenger service over a five and one-half months period.

Many people might comment that these systems were shown too early, that they should have waited for a few more years, that they should have remained behind locked doors. But, the Assembly believed the public had the right to see what could be done to help reduce air pollution, especially as this project was partially funded by tax dollars. The system vendors and the legislature could have opted for the easy way out by not demonstrating in public. Most private companies would have shuddered at the risks inherent in showing systems built in only two years and operational for only a few months.

Yet, the feasibility of steam power had to be proven, for better or for worse, in the harsh light of day and before television cameras, because this was its first and perhaps only opportunity to do so. Many media representatives and much of the public were not familiar with engineering development, as evidenced by frequent questions as to production costs and commercial availability. Most people failed to understand the true nature of the California Steam Bus Project, which was to determine feasibility and to interpret the potential from this early point of technical departure.

Technical experience

One way to regard this project is to view it as the first evidence in an inquiry which began in 1967. Project test results offer an opportunity to separate expectations from reality, myths from facts.

The project's goal of demonstrating feasibility of steam power as a low-emission vehicular powerplant was accomplished. The cleanest steam bus registered a 94-percent decline in nitrogen oxides when compared to the cleanest diesel tested, and it beat the 1975 California HC and NO_2 standards for heavy duty vehicles by more than two-to-one. While it is currently rumored that diesel and gas turbine heavy duty engine manufacturers claim they can meet these standards, none of their existing equipment has done so.

Three contractors developed and installed steam propulsion systems in 40-foot urban transit coaches, replacing the original diesel engines. Even though each system vendor employed a different approach, all three had exhaust emissions lower than the 1975 California requirements.

Though not all of these installations showed every potential attribute of Rankine cycle system, a composite picture did demonstrate that steam buses can equal road performance of diesel buses. One bus was considerably quieter when compared to diesels. One system was lighter in weight than present diesel powerplants. Acceleration, top speed and hill climbing were shown to equal or exceed that of a six-cylinder diesel bus, with the ability to scale powerplant output to equal eight-cylinder diesels if desired. Steam buses usually were able to duplicate time schedules of diesel buses in actual revenue passenger service.

While all systems occupied more space than a diesel, one bus demonstrated that passenger space need not be diminished if the several components are located separately, and another nearly met all requirements within the existing compartment space. Familiar and conventional driver controls were used, minimizing need for special driver instructions. Water consumption was inadequate, but startup times, performance and drivability were equivalent to fleet requirements for existing diesel equipment. But, special knowledge was required for powerplant maintenance. During revenue service, all buses demonstrated satisfactory performance in terms of operational safety and passenger comfort. One bus provided air conditioning, which was effectively driven by shaft power taken from the main expander.

Fuel economy was poor when compared to diesel power, although the discrepancy is not as great when compared to other fledgling systems, such as the gas turbine and spark-ignition engines fueled with natural gas.

As with any experimental devices, a great deal of inspection, rework and maintenance was necessary in the field demonstrations. This may have led some observers to believe that steam engines would always require excessive maintenance, but such an observation certainly is not warranted at this early date.

It must be emphasized, however, that these converted buses were intended only for use in an early demonstration of feasibility and potential. They are not pre-production prototypes, and much engineering development would be required before such power systems could meet transit industry standards for packaging, reliability and operating economy.

Finally, any comparison of three steam buses built in two years at a total cost of $8 million to production diesels developed and produced over forty years at perhaps a total cost of $10 billion raises certain questions. Since the diesel reigns supreme as the most efficient and durable internal combustion engine, how is it that steam systems built in two years are so much cleaner and quieter while delivering equal horsepower? Is this more an indication of steam power's potential or a comment on the state-of-the-art in diesel manufacturing?

Policy considerations

A most unusual aspect of the California Steam Bus Project was its success under political sponsorship, which was supportive at both the state and the national levels even though political parties changed offices completely during the project's existence. This strong bi-partisan support is admirable and encouraging, especially if it indicates a new policy of "political technology."

This early example of political technology was initiated, funded and sponsored by the public sector to attempt a solution to a public problem that the private sector was either unwilling or unable to do itself. The project would not have occurred if a commercial market had to exist before the private sector could be encouraged to act. Rather, if anything, existing markets were a rigidity against such novel exploration, because it threatened stabilized markets with vested interests in maintaining the status quo. But, the public sector acted to determine if technology could be applied to solve this pressing public problem. Moreover, a demonstration project was selected as the correct way to uncover and to evaluate this technology which might otherwise have remained buried.

In this light, then, it becomes an obligation and necessity of the public sector to nurture and sustain technology that might solve public problems, for such activity is clearly and directly in the public interest. While there is little new about this concept when efforts are made in the national defense or for traditional public works, most technology for civilian needs always has been considered a privileged domain of private industry.

These considerations touch the heart of Rankine cycle development efforts, because existing research organizations cannot continue their efforts without public support and encouragement.

A central question, therefore, is whether or not the federal government believes there is a need for continued research in heavy duty vehicle steam powerplants as a step towards clean air. The California Assembly believes both the Legislature and the U.S. Department of Transportation have a stake in continued work.

On November 16, 1971, the Assembly presented a proposal to UMTA to continue work until two pre-production prototypes could be developed to determine technical suitability. These proposed Phase III and IV programs would cost about $11.5 million over 42 months. If successful, the private sector then would determine whether or not to pursue a commercial application.

For its part, the Assembly stood ready to continue, as explained by James Lane, Director of the Assembly Office of Research, at the Steam Bus Symposium one year ago:

"A timely question is where do we go from here. The California Legislature believes a definitive statement of feasibility of steam power systems is being made on this project. The next step is to raise the level of development, improving these systems until they are brought to a production prototype and, eventually, to production.

"We look forward to reviewing future development results to explore incentives for the transit industry to acquire fleets of low emission buses when commercially available. Under such a plan, the State Air Resources Board would certify all low emission vehicles much as it certifies automobile control devices today. This certification process combined with tax or cash incentives would assist development of a substantial market for clean power systems.

"The California Legislature is committed to continue the future development of steam power systems for a number of reasons. First, the urban transit bus can play a significant role in controlling environmental pollution by replacing a large number of private automobiles in downtown traffic. Second, if mass transit is to expand and buses are to play a vital role, it is mandatory that clean buses be developed. Third, if the California Legislature is to continue to improve California's air, we need alternate hardware that will prove a case for tighter standards. Fourth, if steam power becomes feasible for large vehicles, we will press for rapid application to automobiles."

Is it valid to raise market questions now as objectives to continued research and development? Markets may be what motivates private industry to develop products, but the public sector should be ruled by different concerns. What must be important to the public sector is public needs. These needs should motivate government into any action, including the development of a competitive product

that serves the public interest if such products do not exist. The public need for clean air and quiet propulsion is imperative. Markets will emerge or can be created, if a product can be made competitive. The overriding necessity to find a clean source of vehicular propulsion should transcend questions of jurisdiction, mandates and justifications raised in the public sector, simply because the larger public interest is at stake.

What value is there in developing any alternate system if present powerplants can be improved to meet emission and noise standards? While diesel and gas turbine heavy duty vehicle manufacturers claim they can meet the California 1975 standards and any contemplated federal limits, none of their existing equipment has done so. In this situation, then, who can say their claims are guaranteed? If future standards are not met, precious development time will have been lost. Moreover, the public will have foresaken their leverage to motivate private industry to commit resources to make heavy duty engines cleaner and quieter. In this event, the only alternative to be presented will be to reduce the standards, which hardly is attractive from the public's interest.

An impending energy crisis has been raised as an additional parameter against which future decisions must be made. Briefly, this problem pits present excessive fuel consumption of steam buses against limited future petroleum supplies expected to be surpassed by demand in the early 1980's, which, in turn, involves the international balance of payments problem, because most petroleum will have to be imported in the next decade unless adequate domestic sources are discovered. This is a valid concern, but it involves a decision point somewhere in the future when tradeoffs between clean air and petroleum supplies can be better understood and evaluated. It also does not reflect any appreciation that fuel consumption of steam powerplants can be improved with additional development. Moreover, there are other variables that may affect future energy supplies, which are unrelated to this development effort, such as discovery of new petroleum sources, development of other fuels or, more important, changes in present consumption patterns as a result of public policy. But, from a strictly vehicular air pollution point of view, the decision to continue Rankine cycle development work must be decided in 1972, not in 1984.

Are we restricted to an application and market for buses only? The Assembly selected buses for a number of reasons: first, they are identified public symbols; second, they provided an easier test-bed to determine feasibility because space was maximized; third, they were available from publicly operated fleets which were linked to the Legislature through charter and legislation; and fourth, UMTA was the funding source and UMTA deals with buses. There is nothing magical or binding, then, about considering only buses as the eventual market which must be sufficient to support production tooling and concomitant production numbers on a scale needed to attract private capital. An application to all heavy duty vehicles opens a much larger market. But, the Assembly remains interested in any viable alternative that can be applied to vehicles used in urban areas where air pollution is a chronic problem. Obviously, the Assembly is most concerned about reducing smog in California's cities. It is also abundantly clear that air pollution can not be legislated away.

The hard and difficult course of technological support carries with it some equally serious questions about future commitments. If UMTA continues its funding support, will it be willing to use Capital Grant funds in the future to assist transit users to purchase low-emission systems it helped develop? If the State continues to participate in developing an alternate system, will the Legislature be willing to pass legislation that can foster a market for the introduction of such

a propulsion system? Is the public sector willing to assume the costs required to build an attractive mass transit industry after years of shameful neglect and decades of decay in existing systems? Are the Federal Executive Branch, the U.S. Congress and the California Legislature ready to consider restricted use of private passenger vehicles to create ridership needed to make mass transit a success and to reduce air pollution and noise ruining our cities? Will elected and appointed public officials find the courage and conviction to carry such an unpopular course of action?

Answers to these questions will shape the future of clean propulsion systems, the definition of a real energy crisis and the very living style of millions of citizens. Sometime and somewhere positive decisions must be made to correct the abuse caused by the overuse of private automobiles and to create an effective mass transit network as a viable, attractive substitute. Rankine cycle powerplants may have a role to play in this future by providing clean and quiet vehicular transportation.

Steam propulsion systems are the first alternate power systems to be supported by the public sector. The manner in which they are supported will signal the public sector's commitment to really address the cause of most air pollution. Continued development will insure that at least one alternative can be explored fully. It also will inform manufacturers of engines that the public sector's concern over smog is not limited to controlling emissions of existing vehicles on a scale and in a way the manufacturers themselves dictate is possible. Continued research and development is essential, if not for steam alone, then to legitimize other possible alternatives that might follow in its footsteps.