Heavy-Duty Diesel Particulate Trap Demonstration
For: State of California - Air Resources Board

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ABSTRACT

This is the Final Report that summarizes work conducted for the State of California, Air Resources Board Contract No. A776-179 between July 1988 - June 1992. The project called for the evaluation of various options to control diesel particulate emissions from heavy-duty vehicles, with the final design and manufacture of two particulate trap systems. The systems should withstand durability testing up to 400 hours to verify their operation and performance in removal of particulate matter.

The contract was awarded to Donaldson Company Incorporated (DCI) to provide two electrical trap systems, one system for a transit bus engine (6V-92TAC) and the other for a heavy-duty diesel truck powered by a 4-stroke engine. The trap systems would be retrofitted to the heavy-duty vehicles and evaluated in service for twelve months.

Due to delays in obtaining the heavy-duty diesel truck, the installation and on-road demonstration of the trap system on the heavy-duty diesel truck did not materialize, and eventually this part of the program was cancelled. The on-road evaluation period for the bus was increased to 24 months.

The particulate trap system was tested in the test cell to verify its operation and performance in removal of particulate matter. The test bed results indicated that a two trap, electrically regenerated, system performed satisfactorily under all engine conditions. The results indicated a particulate removal efficiency range of 62% to 80%.

The trap system was installed, together with a datalogger, in Southern California Rapid Transit District Bus #8924 and operated for a period of 24 months. The results from the datalogger indicated a number of successful regenerations conducted during the demonstration period, averaging approximately 4 hours per regeneration. The results showed that the system is viable for application to a bus equipped with a Detroit Diesel Corporation 6V-92TA diesel engine.

Bus #8924 was periodically tested for emissions on a chassis dynamometer. The results indicated a particulate trap efficiency range of 68% to 89%.

EXECUTIVE SUMMARY

This report presents a 24 month field demonstration conducted on Southern California Rapid Transit District (SCRTD) Transit Bus #8924 fitted with a DCI electrical trap system.

Out of several trap manufacturers, the DCI trap system was chosen by ARB to be fitted on two vehicles. The installation of the trap in the tow truck did not materialize and thus, only one vehicle was fitted with the trap system. The DCI trap system was evaluated in a transient test cell at ORTECH to assess the particulate removal efficiency and its operation.

Emission testing was conducted in the test cell with and without the trap installed, coupled with 550 (400 hours minimum requirement) hours of durability and performance evaluation testing. No significant trap system problems occurred during testing and a particulate trap efficiency of 80% was attained.

With satisfactory results achieved with test cell testing, the trap was installed on Bus #8924 for a 24 month field demonstration.

Preliminary bus evaluation and additional road tests were conducted to determine a suitable K-factor which is a function of exhaust backpressure and is used to estimate the trap particulate load.

At the end of the 24 month field demonstration, Bus #8924 had accumulated 31,814 miles and 4,170 hours of engine operation. The total number of regenerations conducted was 1012 at an average of 4 hours per regeneration.

A datalogger was installed on the bus to record the trap parameters, especially exhaust backpressure and temperatures. The recorded data was analyzed on a weekly basis to assess the trap operation and performance.

Chassis dynamometer emission testing at ARB's Haagen Smit Laboratory was conducted periodically to determine particulate removal efficiency and the impact on gaseous emissions. The results indicated that a particulate removal efficiency of 80% was achievable.

During the demonstration period, a number of trap filter failures had occurred. Some were due to trap system malfunction, which resulted in the filters being overloaded with particulates, eventually resulting in a cracked filter when a regeneration was conducted.

Eventually, an improved production type electrical trap system with on-board electronic controller was installed on Bus #8924. A new version of the software was also installed to improve the regeneration control strategy. The above installations reduced the trap failure rates to a minimum.

1. INTRODUCTION

This final report summarizes work performed on the contract entitled, "Heavy-Duty Diesel Particulate Trap Demonstration", ARB Contract No. A776-179 for the period July, 1988 to June, 1992.

This project was initiated to demonstrate durable retrofit particulate oxidizer systems capable of reducing particulate (PM10) emissions from heavy-duty diesel (HDD) engines. The trap system used in this project was a DCI electrical system utilizing dual filters. This system is capable of conducting automatic regeneration (self cleaning) without the driver's intervention, when the exhaust backpressure (load factor) has reached a predetermined level.

Particulate air pollution is of great concern to many cities in the U.S.A., especially so in the South Coast Air Basin of California. The Air Resources Board has adopted particulate emission standards for 1991 and 1994, with a special bus standard of 0.1 g/bhp-hr for 1991 being more stringent than the truck standard in recognition of the contribution of particulate matter from buses in heavily congested areas.

The particulate standards for urban buses will require either exhaust filtration systems or "cleaner" fuels (i.e. methanol, propane, natural gas) to meet the above standards. Particulate traps with ceramic wall-flow filters will be required to meet the 0.1 g/bhp-hr for diesel buses.

In addition, the Clean Air Act has a 24 hour primary standard for PM (particulate matter less than 10 μm) of 150 g/m^3, and many cities are in non-compliance with this standard. Since the penetration of new heavy-duty diesels into the marketplace which meet the new standards will be slow, the impact on urban air quality in the near term will not be great. There is, therefore, considerable interest in accelerating the penetration of cleaner heavy-duty engines in the South Coast Air Basin, and, one way of achieving this goal is to retrofit in-use vehicles with appropriate low emission technology. Diesel particulate traps are compatible with retrofit application, and maintain the diesel supply and engine maintenance infrastructure providing less complications for transit operators. However, there is insufficient experience with trap durability, and life cycle cost.

There has been considerable effort in developing diesel particulate traps to meet future particulate emission standards, and ORTECH has been involved in trap technology development for many years. In response to a Request for Proposal (RFP) from the Air Resources Board (ARB), ORTECH was awarded a contract to carry out a project to demonstrate the diesel particulate trap technology for bus and truck application.

2. PROJECT OBJECTIVES

The objective of the project was to demonstrate durable retrofit particulate trap systems capable of reducing particulate emissions (85+%) from heavy-duty diesel engines used by urban buses and trucks.

The project included design, manufacturing, dynamometer testing and road demonstration of two particulate trap systems. One system was for a 6V-92TAC 2-stroke heavy-duty diesel engine for bus application and the second system for a 4-stroke heavy-duty diesel engine for truck application. The trap system for the bus was for retrofitting purposes. The system for use with the 4-stroke heavy-duty diesel engine on a truck, could be used for retrofitting purposes or new truck application. Both systems would be completely automatic and meet engine manufacturer's specifications for operating the engine, including maximum exhaust backpressure.

3. MAJOR TASKS

In order to achieve the objectives, the project was divided into the following three tasks:

Task 1: An Investigation of Trap Oxidizer Technology.

Task 2: 400 Hour Engine Dynamometer Evaluation of Selected Trap System.

Task 3: On-Road Demonstration.

Each task was further divided into sub-tasks which are tabulated in Table 3.1. ORTECH sub-contracted part of Task 3: On-Road Demonstration, to Acurex Corporation of California.

TABLE 3.1

PROPOSED PROJECT TASKS

Task 1:	**An Investigation of Trap Oxidizer Technology**
Task 2:	**Preliminary Test Bed Evaluation of Selected Trap Systems.**
Task 2A:	Bus Duty Cycle Generation
Task 2B:	Procurement of Bus Trap Systems and Engines
Task 2C:	Data Acquisition Design and Testing
Task 2D:	Bus Engine Emission Baseline
Task 2E:	Bus Trap System (BTS) Installation and Baseline
Task 2F:	BTS Durability (400 Hrs) and Performance Evaluation
Task 2G:	Procurement of Truck Trap Systems and Engines
Task 2H:	Truck Engine Emissions Baseline
Task 2 I:	Truck Trap System (TTS) Installation and Baseline
Task 2J:	TTS Durability (400 Hrs) and Performance Evaluation
Task 3:	**On-Road Demonstration Testing**
Task 3A:	Truck Fleet Negotiations and Selection
Task 3B:	Bus Trap System Installation and Maintenance
Task 3C:	Truck Trap System Installation and Maintenance
Task 3D:	Data Collection and Analysis
Task 3E:	Emission Testing

4. RESULTS AND DISCUSSION

4.1 Task 1: An Investigation of Trap Oxidizer Technology

This task called for the evaluation of particulate trap oxidizer technology available for both bus and truck application. The evaluation criteria for the bus trap oxidizer system, included those stated in the RFP, and additional criteria proposed by ORTECH. In collaboration with the ARB and Southern California Rapid Transit District (SCRTD), weighting factors were assigned to each of these criterion. Table 4.1.1 indicates the resulting criterion and weighting factors for the bus trap system.

In order to obtain a current listing of various trap technologies, ORTECH contacted a number of organizations involved in the development of diesel particulate trap technology. These organizations included heavy-duty diesel engine manufacturers, exhaust product manufacturers, R&D companies and the U.S. Environmental Protection Agency (EPA). ORTECH also contacted companies involved in the development of technologies such as catalysts and fuel additives, designed to improve system performance. Each organization received a letter, together with an abstract, objective and a list of the preliminary evaluation criteria. A sample of this letter, together with contents, is shown in Appendix A.

At a project meeting held on September 28, 1988, the responses from the various organizations involved in trap oxidizer technology were presented to ARB and SCRTD. A summary of these responses are shown in Table 4.1.2. During this project meeting, the evaluation criteria and weighting factors were finalized (Table 4.1.1). A copy of the slide presentation and the Minutes of the Meeting are attached as Appendix B.

Based on preliminary evaluations, two finalists were selected, Engine Control Systems (ECS) and Donaldson Company, Inc. (DCI). At this time, additional information pertaining to the project schedule and tasks was released to the finalists. This information exchange took place with each finalist at a separate meeting for the purpose of obtaining any additional technical information they could provide, to aid in the final selection.

A meeting was held on December 2, 1988. The two finalists presented their trap systems to ARB and SCRTD. ORTECH presented an evaluation ranking the DCI system higher than the ECS system. The DCI system was selected by ARB for the 2-stroke bus engine and the 4-stroke truck engine. The bus and truck systems would use catalyzed traps and on-board electricity for regeneration.

4.2 Task 2: Preliminary Test Bed Evaluation

4.2.1 Task 2A: Bus Duty Cycle Generation

The Advanced Design Bus (ADB) transit coach test cycle consisted of three basic phases:

1. Central Business District (CBD)
2. Arterial (ART)
3. Commuter (COMM).

The Central Business District phase included 14 full load accelerations each followed by a cruise and a deceleration. An eleven second idle period occurred between each repetition.

The Arterial phase consisted of four full load accelerations each with associated cruise, deceleration and sixteen second idle period.

The Commuter phase involved a single full load acceleration, cruise and deceleration followed by 20 seconds of idle.

The various phases were combined to form a total ADB test cycle as follows.

The reference ADB cycle's engine speed, torque and horsepower for each phase are listed in Table 4.2.1 and are graphically represented in Figures 4.2.1.1 through 4.2.1.12.

ADVANCED BUS CYCLE

	Number of Cycles	Time for Each Cycle	Total Time
CBD	14 cycles	40 seconds	560 seconds
IDLE	1 cycle	300 seconds	300 seconds
ART	4 cycles	70 seconds	280 seconds
COMM	14 cycles	40 seconds	560 seconds
ART	4 cycles	70 seconds	280 seconds
CBD	14 cycles	40 seconds	560 seconds
COMM	1 cycle	291 seconds	291 seconds

Total Cycle Length = 2,831 seconds (47 minutes, 11 seconds).

The ADB Cycle was originally adapted by ORTECH International to determine fuel economy on a Detroit Diesel 6V-71IN71C5 diesel engine.

This engine had different torque characteristics than that of the Detroit Diesel 6V-92TA engine which was used in this program.

A Lotus 123 program was written to calculate a new ADB cycle from the comparison of the two engine torque curves. The calculations used in the production of the ADB cycle were as follows:

Cycle Generation for ADB Cycle

(a) Current ADB Cycle for a Detroit 6V-71IN71C5 Engine (Cycle A)

- Idle Speed = Speed at which engine idles.
- Rated Speed = Speed at which maximum horsepower was recorded.
- Cycle Engine Speed = Engine speed at time X in the cycle.
- Cycle Torque = Engine torque at time X in the cycle.

- %RPM

  (Cycle Engine Speed - Idle Speed) * 100
  (Rated Speed - Idle Speed)

- Maximum Torque

  Maximum Torque at Cycle Engine Speed from Torque Curve reference table.

- % of Maximum Torque

  Cycle Torque * 100
  Maximum Torque at Selected Engine Speed

(b) New ADB Cycle for a Detroit 6V-92TA Engine (Cycle B)

- New Speed

  (Rated Speed - Idle Speed) * (% RPM of Cycle A)/100 + Idle Speed

- Maximum Torque

  Maximum Torque at Cycle Engine Speed from Torque Curve reference table of 6V-92TA.

- New Torque

  Maximum Torque * % Maximum Torque (Cycle A)/100

- % Torque

  New Torque * 100/Maximum Torque

- Idle Loading

  The idle loading was identical for both engines i.e. 100 ft.lbs. This was recommended by DDC.

Cycle Regression

In the ADB cycle, engine speeds and torque for each second of the cycle were entered into a Hewlett-Packard 1000 computer. This computer operated the engine over the transient ADB cycle.

The next phase in operating the engine over the transient ADB cycle was to complete a cycle optimization procedure. This procedure involved collection of the actual engine speed and torque as the engine operated over the cycle and compared it through a Lotus regression program to the ADB reference cycle.

The ADB cycle was too large to complete the regression analysis within Lotus. A short ADB cycle composed of 1 CBD, 1 ART, 1 COMM and one 60 second idle phase was constructed. It was presumed that if the short cycle passed the regression, then the long ADB cycle would yield the same results.

The actual engine speed, torque and brake horsepower of the short ADB cycle were compared to the reference cycle and passed all 13 regression parameters, as illustrated in Table 4.2.2. The cycle was, therefore, acceptable.

4.2.2 Task 2B: Procurement of Bus Trap System and Engines

DCI was committed to provide ORTECH with three complete filter systems for the ARB project. At a meeting held between DCI and ORTECH, the trap design and test plan was finalized. The test plan was modified to include durability testing of the uncatalyzed trap for 250 hours on the engine dynamometer, followed by the catalyzed trap for 250 hours.

A DDC 1985 6V-92TA was used as the test engine, however, the engine had a set of injectors which differed from those used by SCRTD. A set of eight injectors were delivered to ORTECH by SCRTD and was installed in the test engine. The test fuel was purchased and analysis showed the sulphur content to be .05%, which was typical of the fuel used by SCRTD.

SCRTD had specified that the lubricant to be used in this project must meet the specification of UNOCAL 40, however, this brand of lubricant was not available to ORTECH locally. ORTECH therefore conducted a brief survey to try to find a lubricant, available locally, with identical properties to those of UNOCAL 40. It was found that Petro-Can 40 had properties that were similar to those of UNOCAL 40, specifically the sulphated ash percentage (1.0 for UNOCAL and .95 for Petro-Can 40). Petro-Can 40 was used as the lubricant for the test engine for the duration of this project.

4.2.3 Task 2C: Data Acquisition Design and Testing

Acurex Corporation recommended Campbell Scientific Inc. as the supplier for the Data Acquisition Unit.

A Campbell Scientific 21 x Micrologger, with hardware accessories and software, was purchased from Campbell Scientific Inc. of Chatham, Ontario, Canada. The datalogger has the capability of collecting analog and digital input, converting the input to engineering values and storing these values to a memory module.

The datalogging program worked as follows: the engine speed would be continually scanned. If the speed was greater than 400 rpm, the datalogger would store all sampled parameter values into a memory module. If the speed was less than 400 rpm, it would be assumed that the bus was not operating and no data would be collected. The engine backpressure, exhaust temperature and four trap temperature data were collected.

The datalogger collected bus trap data every 20 seconds at exhaust temperatures greater than 60°C. The datalogger was programmed and tested to collect the following data:

Ambient Temperature
Exhaust Temperature
Trap 1 Inlet
Trap 1 Outlet
Trap 2 Inlet
Trap 2 Outlet
Exhaust Backpressure.

An Operation Manual for the datalogger was written. The Manual is shown in Appendix C.

4.2.4 Task 2D: Bus Engine Emission Baseline

Baseline transient emission testing using the Advanced Design Bus (ADB) cycle was conducted. The testing consisted of a total of 8 cycles. The engine backpressure was set at 3" Hg (5 cycles) and 7" Hg (3 cycles). The 3" to 7" Hg of engine backpressure covered the range of backpressures imposed on the engine by the DCI electrical trap system under normal bus operation.

The baseline emission results are shown in Table 4.2.4.1. The total particulate emissions were .18 and .20 gr/bhp-hr for 3" and 7" Hg of engine backpressure respectively.

4.2.5 Task 2E: Bus Trap System (BTS) Installation and Baseline

Photographs of the trap system components and the test cell set-up are shown in Appendix D. As shown, the trap system consisted of three filters with individual exhaust pipes. A new exhaust manifold was required to fit the trap system in the RTS bus.

4.2.6 Task 2F: BTS Durability (400 Hours) and Performance Evaluation

During this period, the non-catalyzed, catalyzed 3 trap system and catalyzed 2 trap system were fully tested for durability and went through 250, 228, and 52 hours of test cell evaluation respectively. An additional 130 hours of durability testing were conducted to evaluate non-catalyzed trap filters, as well as catalyzed filters, and to determine the feasibility of a two filter system versus a three filter system.

Table 4.2.6.1 shows engine performance data (2 points check). A quality check was conducted daily at rated power and peak torque engine conditions to verify engine performance. Additional exhaust backpressure sweeps from 3 to 10 " Hg were conducted at rated engine conditions.

Figures 4.2.6.1-3 show scatter point graphs generated from daily check of engine baseline performance. These graphs show rated power, peak torque and Brake Specific Fuel Consumption (BSFC) vs. engine exhaust backpressure. From the above graphs, it can be seen that for backpressure less than 3" Hg, most of the 2 point check lies within 2-3% error band, which was within engine performance requirements. The graphs also show that as backpressure increased, engine performance decreased. If the heaters were also turned on (1 heater for regeneration, 1 heater simulates electrical demand on bus), the performance loss could be as high as 20%. This shows the continuing need to minimize electrical demand during regeneration and to regenerate at a lower backpressure level.

Tables 4.2.6.2-3 show completed ADB cycle fuel consumption results for the non-catalyzed and catalyzed traps. The results showed no significant difference in fuel consumption between the catalyzed and non-catalyzed trap systems.

The results for the catalyzed traps (Table 4.2.6.3) showed that the average fuel consumption increased when regeneration and electric loading were operated simultaneously. With regeneration only, there was only a minor increase in the average fuel consumption. Since the time between regenerations occurred from 45 minutes to 2 hours, the fuel penalty ranged from .5% to 1.4% respectively.

Tables 4.2.6.4-6 show the regeneration data for the non-catalyzed and catalyzed trap systems. The following trap system configurations were used:

(a) Non-catalyzed 3 trap system.
(b) Catalyzed 3 trap system.
(c) Catalyzed 2 trap system.

The traps were instrumented to record regeneration temperatures and time. Tables 4.2.6.4-6 show that whenever there was an increase in heater time, it corresponded to lower inlet temperatures. Comparing the catalyzed 2 and 3 trap systems, the build-up time for the catalyzed 2 trap system was far shorter than the catalyzed 3 trap system. However, the minimum loading time was 45 minutes which was longer than the regeneration time. This showed that a two trap system was feasible for the 6V-92TA engine.

Table 4.2.6.7 shows the bus trap system emission summary table for the non-catalyzed (250 hours) and catalyzed (280 hours) trap systems. The engine was run using the ADB cycle and the emissions recorded were CO, NO_x, THC and total particulates in gr/bhp-hr. With the non-catalyzed trap system, emission testing was conducted at 5, 125 and 250 hours of durability testing. The catalyzed trap was then installed and emission testing was conducted after 8 and 280 hours of operation.

The Table also shows a percentage reduction in emissions with increase in test bed running hours.

Figures 4.2.6.4-7 show emissions plotted against engine testing hours for non-catalyzed and catalyzed traps. The switchover from non-catalyzed to catalyzed traps brought about the following reductions in emissions:

(a) CO 67%
(b) NO_x 3%
(c) THC 69%
(d) Total Particulates increased by 3%.

Comparing baseline emissions before and after catalyst change, the following changes in emissions were recorded:

(a) CO emissions reduced by 38%
(b) NO_x emissions reduced by 10%
(c) THC emissions reduced by 24%
(d) Total particulates reduced by 10%.

The reduction in emission levels after 280 hours of testing of the catalyzed traps compared to initial baseline resulted, as follows:

(a) CO 78%
(b) NO_x 19%
(c) THC 78%
(d) Total particulates reduced by 62%.

Figure 4.2.6.8 shows a scatter point graph of engine backpressure vs. testing hours. From the graph, it can be seen that the minimum, maximum and average backpressures were consistent for the non-catalyzed trap system (0-270 hours) as well as for the catalyzed trap system (300 - 550 hours). The backpressures recorded for the catalyzed trap system were lower than those for the non-catalyzed trap system. This was because of the change in "K factor" used.

Figure 4.2.6.9 shows a graph of particulate removal efficiency vs. testing hours for total and soluble particulates. It can be seen from the graph that the particulate removal efficiency peaks (80%) at the end of testing of the non-catalyzed trap. When the traps were switched from non-catalyzed to catalyzed, there was a drop of about 3% in particulate removal efficiency and drops further as the testing hours were increased. This was believed to be due to production variability of traps, resulting in a low efficiency trap.

Table 4.2.6.8 shows a trap performance summary for durability testing of the bus trap system. The non-catalyzed 3 trap system was tested for emissions and durability. Total hours performed were about 270 and within this time, 53 regenerations occurred. The average "K factor" used within this period was approximately 3.6. A catalyzed trap system was then installed and the system was durability tested. The average "K factor" used for the non-catalyzed trap was 2.8. The total regenerations performed between the non-catalyzed and the catalyzed 3 trap system were 152. The catalyzed 3 trap system was then reduced to a 2 trap system and the system was tested for about 52 hours. A total of 184 regenerations were performed by the 3 trap systems used.

Test Cell testing of the bus trap system was completed during August, 1989. The trap system went through a total of 550 hours of operation. Trap system components performed satisfactorily with the exception of the exhaust diverter valves. After Test Cell testing, the complete trap system was sent back to DCI for inspection and upgrade.

DCI enquired about the typical or average regeneration frequency during Test Cell testing. Figure 4.2.6.10 shows the time between regeneration during the 550 hours of testing. In the worst case (commuter cycle) the trap system regenerated after approximately 40 minutes of loading. Regeneration should take no longer than 30 minutes to complete and thus, the trap system should not call for another regeneration before the last regeneration is completed.

Table 4.2.6.9 compares the trap regeneration parameters for catalyzed and non-catalyzed traps. The 2 catalyzed trap system required longer regeneration time and had shorter build-up time (thus more frequent regeneration). It is not quite clear why the catalyzed traps required longer regeneration time. The shorter build-up time is due to the catalyzed coating on a thin skin substrate which increased the resistance to flow during particulate loading. The trap out temperature for the catalyzed trap was lower, indicating less trap internal thermal stress. This points to a feasible, 2 trap, electrically regenerated, trap system for the 6V-92TA engine.

Appendix E contains graphs detailing regeneration parameters of the two trap system. The graphs were generated during the performance and durability testing of the two trap system. The data showed that the two trap system would achieve project objectives and was approved by ARB.

4.2.7 Task 2G: Procurement of Truck Trap System and Engines

ARB decided to carry out the truck trap system demonstration using a tow truck at SCRTD. The tow truck was equipped with a 1983 Cummins' NTCC 400 engine which was rated at 400 hp at 2100 rpm. The engine was also equipped with a mechanical variable timing device for emission control.

Appendix F shows the tow truck photographs.

ORTECH had located a California company which could supply a rebuilt truck engine at the cost of $12,000.00 U.S. plus shipping. However, the company required full payment in advance and as this was against ARB and ORTECH's policy, no agreement could be reached.

ARB agreed to carry out the truck trap demonstration without the test cell testing. DCI completed the truck trap system fabrication and the system was sent to SCRTD.

4.2.8 Task 2H: Truck Engine Emission Baseline

This task was not conducted due to a change in the contractual Agreement.

4.2.9 Task 2 I: Truck Trap System (TTS) Installation and Baseline

Quotations and parts were obtained for the SCRTD truck installation.

A watertight box was fabricated to protect the Campbell Scientific (CS) datalogger. Pressure transducers and thermocouples were calibrated. A 24" thermocouples for the core face and 18" thermocouples for the core out were required because of the resonator on the trap outlet side. The SM (data module) 716-1632 and 1633 were packaged in the mounting box with the CS. An ARO airline filter was required as a water trap. The filter element required regulator maintenance to ensure the accuracy of the backpressure measurements.

Some questions were raised by DCI regarding the physical requirements. They were as follows:

1. Is the dual voltage regulator installed on the truck?
2. Will the 11" muffler (traps) fit on the truck cab?
3. Are additional muffler mounting brackets required for left (driver's) side of the cab?
4. Is the air dryer (fuel or oil filter) behind the driver's door moveable?
5. What intake air system fittings are required?

Preliminary TTS installation was conducted initially but discontinued later as per renewed contractual Agreement.

4.2.10 Task 2J: TTS Durability (400 Hours) and Performance Evaluation

This task was not conducted due to a change in the contractual Agreement.

4.3 Task 3: On-Road Bus Demonstration Testing

Preliminary road evaluation of Bus #8924 was conducted using a regeneration factor (K) of 5.6. The bus was driven for 3 hours and during that time, the trap system conducted two regenerations at approximately 1 hour intervals. The regeneration temperature profile showed a satisfactory regeneration.

Road evaluation continued with a regeneration factor (K) increased to 6.2. The increase in factor (K) increased loading time before regeneration. During the four hours of testing, the trap system went through three regenerations. The first regeneration occurred after 1-1/2 hours of particulate loading. The last regeneration occurred after only 1/2 hour of particulate loading, which was shorter than expected. However, the bus was operating under continuous highway operation.

No emission baseline testing was conducted on the tow truck due to non-functional mechanical variable timing (MVT). The truck was sent out for repair. This delayed the trap installation on the tow truck until July, 1991.

Due to cost complications and delays in installation of the trap system on the tow truck, it was decided by the parties concerned to discontinue the program and, therefore, no further work was conducted on the truck. As compensation, the bus on-road testing period was increased to 24 months.

4.3.1 Task 3A: Truck Fleet Negotiations and Selection

SCRTD agreed to carry out the truck trap system demonstration using one of their two trucks. However, the tow truck was a service vehicle which accumulated only limited mileage.

The experience and data gained in the bus trap test cell evaluation was sufficient, and ARB agreed to carry out the truck trap demonstration without test cell testing.

ORTECH recommended that the trap system be installed on the truck and the trap system optimization carried out on the ARB chassis dynamometer. The optimization was expected to take 2 to 3 days to complete. Upon completion of the road demonstration, the trap system would then be removed and be transient emission tested in the test cell to quantify the trap deterioration.

The original tow truck had mechanical problems and ARB negotiated for an alternate vehicle for the test program.

ARB held a meeting with the Water Department and there was a possibility that the truck trap system may be tested using a Water Department truck with an NTCC 400 engine. These trucks accumulate more miles than the SCRTD tow truck and would be more appropriate for use in this test program. However, the installation of the trap system on the tow truck never materialized and eventually this part of the program was discontinued.

4.3.2 Task 3B: Bus Trap System Installation and Maintenance

After test cell testing of the bus trap system, an installation schedule was arranged between DCI, SCRTD and ORTECH. The trap system was sent to DCI for inspection and bus mounting design, then to SCRTD for bus installation.

ORTECH prepared an installation flow chart, as shown in Appendix G. The installation including the datalogger, was scheduled to be completed in five days, with personnel from ORTECH, DCI and SCRTD. ORTECH also drew up a preliminary diagram showing the locations for various trap components.

Since the first bus trap system installation schedule had to be delayed due to missing components, Bus #8924 was put back into revenue service. DCI was unable to provide a guaranteed schedule because of the long delay from the exhaust valve supplier (located in England). Also, in order to fabricate the trap inlet and outlet exhaust manifold, DCI required a rear end mock-up of a TMC bus.

A pre-installation meeting was held at ARB. ORTECH gave a presentation on the results of the project and presented a brief trap system installation flow chart. A copy of the presentation is shown in Appendix H.

The installation took much longer than expected (5 days). This was due to the fact that Bus #8924 was not identical to the mock-up at DCI and, therefore, some components had to be re-located, while others had to be fabricated on site.

Bus #8924 was the first bus to be retrofitted with the DCI electrical trap system. Personnel involved had to learn and improvise while installing the system. The trap system installation was completed on December 11, 1989. SCRTD conducted additional non-revenue service testing and was satisfied with the trap system performance.

When the installation was completed, the bus was road tested to check out the system. Tests showed that the regeneration factor (K) and the maximum backpressure had to be adjusted to avoid constant dual trap operation during highway driving. A number of additional road tests were carried out. The final K factor was set at 4.3 with a maximum backpressure setting of 4.9" Hg.

A meeting was held between ORTECH, ARB and SCRTD on December 18, 1989. SCRTD was satisfied with the trap installation. Appendix I shows the location of the traps and controller on Bus #8924. Appendix J contains an Installation Manual. SCRTD installed a light bulb which, when illuminated, signalled trap regeneration. The bus was placed into revenue service on January 27, 1990 after it was emission tested at ARB.

Bus #8924 was emissions tested on January 5, 1990 on the chassis dynamometer and trap performance data was collected (Appendices K and L). The results (Figure 4.3.2.1) suggested exhaust valve leakage.

Appendix M contains regeneration data collected after the suspect valve was replaced. The graphs show the trap temperature profiles (Deg.C) for Trap 1 and Trap 2 and the engine backpressure (in Hg). The face temperatures reached 720°C, which was more than sufficient to start regeneration. The face temperatures showed that the new valve had acceptable leakage during regeneration. Regeneration profiles were satisfactory, showing that the trap system was operating as designed. Bus #8924 resumed revenue service.

The experience gained during the first few months with the DCI trap system highlighted the need for better diagnostic procedures. The system has a provision for connecting a computer to the trap controller to monitor the trap parameters such as exhaust temperature, backpressure and trap regeneration temperatures. The collected data can then be analyzed before concluding the state of the trap system. For effective operation of the trap system and to maintain high particulate trapping efficiency, the exhaust diverter valve must have very low leakage. There is no indication of trap valve performance other than incomplete regenerations.

Initially, light grey smoke was observed exhausting from the trap during regeneration. This suggested incomplete combustion of particulate and the ability to quantify regeneration, especially CO emission(s). Further refinement of the regeneration sequence could eliminate the light grey smoke.

During the initial two months of revenue service, Bus #8924 required limited maintenance. Data acquisition error codes appeared a number of times, but were inconsistent. Analysis of the error codes suggested a defective air flow sensor.

A copy of the modified software was sent to SCRTD and ORTECH by DCI. This software was installed on Bus #8924 in the month of July, 1990 to aid in diagnosis of the trap system. SCRTD informed ORTECH that the traps were not regenerating. ORTECH personnel visited SCRTD to diagnose the trap system. Data collected on July 25, 1990, showed that the trap system was not monitoring the correct trap backpressure. The trap backpressure was much too low compared to engine backpressure. Inspection of the trap system showed that the plastic pressure lines were melted. New heat-protected tubes were installed.

Both traps were loaded with massive amounts of particulate. The traps were sent to Corning Inc. for analysis and safe regeneration in July, 1990. Appendix N contains the technical report from the trap manufacturer (Corning Inc.). The report details the procedure Corning Inc. used to safely regenerate the overloaded traps, removed from Bus #8924. The report showed that both traps had internal cracks but did not detail the causes. Corning also observed that the catalyst coating on the traps did not appear to cover the full length of the trap. The traps were forwarded to Engelhard for further analysis.

Six cores were catalyzed at Engelhard and shipped to Donaldson. After arriving at Donaldson, two of the traps had noticeable cracks and the other four appeared to have minor cracks in the outer core surface. One of the traps was returned to Corning for analysis.

Engelhard and Corning thought some of the traps were usable; however, Donaldson was reluctant to house them. Preliminary analysis of the cracked traps by Corning suggested one possible problem might be skin thickness. Corning produces traps with a thin skin for catalyzing. The traps examined had a thicker skin, which is generally used only for non-catalyst applications.

The non-catalyzed traps used for test cell work were installed in the bus as a temporary measure. Road tests conducted showed the traps to be in working order. All data collected on the 25th and 26th July, 1990, were plotted and are shown in Appendix O. The graph shows the trap temperatures, exhaust backpressure, pressure differential across the filter and the air flow through the engine.

During the month of August, 1990, the trap system showed back-to-back regeneration. Analysis of the trap system data showed Trap 1 regenerated immediately after completion of Trap 2 regeneration. The control system is designed to prevent this occurrence. The face temperature data for the second trap was not recorded by the datalogger. This could be due to a defective thermocouple and/or software problem.

Both traps were removed from Bus #8924. Trap 2 showed a clean inlet, while Trap 1 showed a particulate loaded inlet. It indicated that Trap 1 had not been properly regenerated, causing high backpressure and back-to-back regeneration. Incomplete regeneration is usually caused by (1) defective heater; (2) insufficient air; (3) controller error. Data showed the controller was in working order. It was difficult to know if the heater was working. The blower was turned on manually to check the flow to the trap face. It was clear that there was less air going to Trap 1 compared to Trap 2. The plumbing was inspected and most air line connections were loose. The blower control valves were also inspected. Trap 1 valve was found to be contaminated with particulate and could only be half opened. All air lines were tightened and blower control valves were cleaned. All data collected were plotted and are shown in Appendix P. The graphs show the trap temperature and engine backpressure profiles recorded on the 24th and 25th August, 1990.

The events showed the need for a test controller. The test controller would have allowed manual operation of the trap system (valves open, close and regeneration). This could be used to diagnose the trap system.

The components on Bus #8924 were not withstanding revenue service as expected. This may be because of the location of the components. DCI considered upgrading the Bus #8924 with an up-to-date production unit which was expected to last 24 months.

Particulate leakage from the trap system was detected. Particulate leakage usually indicates no regeneration and the possibility of internal cracks within the trap. There were a number of trap component failures (backpressure lines, blower lines and valves, air flow sensor) indicating that the trap system was not as durable during revenue service as expected.

Bus #8924 was the first bus containing the DDC 6V-92TA to be equipped with the electrical trap system. The regeneration control strategy and some components had not previously been used in the transient bus environment. The 550 hours of test cell testing showed the trap system was feasible for the DDC engine, but was inadequate to show the life expectancy of the trap components.

Testing with Bus #8924 drew attention to two shortcomings of the trap system. Firstly, the control strategy could not recover from minor component failures and secondly, there were no easy diagnostic procedures or tools to pinpoint failed components. The end result was usually a pair of overloaded particulate traps that needed to be removed from the bus for regeneration.

An improved regeneration control strategy which could recover from minor component failures was developed. This new electronic controller, connected to the emission test controller, could carry out individual trap regenerations. This assisted in diagnosing the problems during the operation of the trap system.

The production type trap system was installed on November 8, 1990. New backpressure transducers and thermocouples were installed for the datalogger. A broken wire for the backpressure transducers was reconnected and a fuse for the datalogger was replaced.

After installation, a system check using the Installation Test Fixture (ITF) was conducted and the results were satisfactory. The datalogger also showed the backpressure transducer and all thermocouples were functioning satisfactorily.

A new trap system monitor which could count the number of regenerations for Traps 1 and 2, heater-on time, blower-on time and engine running time was installed. This system could collect data weekly to determine regeneration frequency. After installation, the monitor was tested and was shown to be counting bus ignitions as regenerations. The monitor was repaired and re-installed. It was agreed that the trap system functioned properly with the K factor equal to 6.2. This factor can be adjusted depending on the regeneration data. A datalog form was designed. A copy of the form is shown as Table 4.3.2.1. This form can be used for either daily or weekly logging. Bus #8924 was put back into revenue service on November 12, 1990, equipped with a non-catalyzed production type trap system.

Since first being placed in service, the trap system underwent extensive servicing. The entire trap assembly was upgraded to a production version in early November, 1990. This first version of the Donaldson system used catalyzed monoliths which was meant to improve the overall efficiency of the system and reduce the strain to the bus's electrical system. An early failure of a component in the control system forced the removal of the catalyzed cores. Non-catalyzed monoliths were substituted, while catalyzed cores were being manufactured. Throughout the demonstration period, a number of versions of the Donaldson system were introduced to optimize the system.

Figures 4.3.4.1 - 4.3.4.4 show the backpressure and temperature graphs generated from the data collected on November 8 and 9, 1990. All regeneration temperatures were below 900°C and backpressures were no higher than 8.0" Hg before dual mode operation.

On November 12, 1990, Bus #8924 went back into revenue service. Two days later, Bus #8924 had to be removed from revenue service due to a lack of power and engine stalling. The data was plotted on a daily basis and are shown in Figures 4.3.4.5 - 4.3.4.10. Statistical parameters were also calculated and are shown in Table 4.3.4.1

The November 12, 1990, data showed a total of 7 regenerations over a period of 8-1/2 hours or approximately 70 minutes per regeneration. The trap system was operating satisfactorily. The November 13th data showed three regenerations, with the last regeneration of Trap 1 occurring at approximately 10:00 am. No further regenerations occurred from 10:00 am until the bus was shut down at 11:00 p.m.. There was no regeneration shown on November 14, 1990. It was not clear why the controller did not initiate regeneration and no error code was stored. The trap system did not default into dual mode operation and no error code data could be retrieved from the trap controller.

Bus #8924 was in revenue service operating out of a different depot than the alternative fuel depot. As a result of this, the depot personnel were not familiar with the operation of the trap system and associated troubleshooting procedures. When the trap system failed, the bus was kept in service until the driver complained of lack of power.

It was suspected that the power supply to the controller was either defective or being interrupted for some unknown reason.

Bus #8924 now had two overloaded catalyzed traps. Past experience showed that if the traps were not excessively overloaded, some of the stored particulates could be removed with compressed air and the trap re-installed for safe regeneration. However, backpressure measurements showed high backpressure indicating on-board regeneration of the overloaded traps was not feasible.

There were no catalyzed traps available in stock, therefore, the replacement traps were non-catalyzed. Included with the traps was an automatic re-set fuse to replace the failed heater fuse. The cause of the blown fuse was not determined.

An error light was also installed on the dashboard to warn the bus driver of trap system failure. SCRTD personnel also checked the emergency exhaust release valve. The Installation Test Fixture was used to test the system. A road test was then conducted and initial results were satisfactory.

Figures 4.3.4.11 to 4.3.4.14 show the trap system data collected on December 10 and December 11, 1990. The data was similar to that collected on November 12 and November 13, indicating the problem of overloading traps had not been solved.

Bus #8924 showed an error code during mid-December, 1990. The fault was diagnosed as the trap controller. A new trap controller was installed and the bus was put back into revenue service. As of the end of December, the bus was operating satisfactorily.

In September, 1991, smoke was detected from Bus #8924.

A new set of traps were installed to replace cracked filters. The non-catalyzed traps were borrowed from the truck trap program. The bus was put back in to revenue service on September 24, 1991.

On October 3, 1991, Bus #8924 experienced a trap failure. The analyzed data showed that on October 3, 1991, Trap 1 experienced high inlet and outlet temperature of over 1400°C (see Table 43.4.1). The maximum backpressure exceeded over 11" Hg indicating high particulate loading just before regeneration. Upon examination of the trap, it was found that the inlet and outlet thermocouples for Trap 1 had failed.

The analyzed data also showed that the bus had been been left idling for a long period. The trap control system is not equipped to calculate the K values during idling due to the measurement range of the air flow sensor. This prolonged idling of approximately 5 hours caused the trap to be overloaded with particulates which resulted in the failure of the trap during regeneration.

The temperature and backpressure graphs generated from the data collected on October 2 and 3, 1991 are shown in Figure 4.3.4.15 - 4.3.4.18. The graphs of October 2, 1991 show that both Trap 1 and Trap 2 showed good regeneration temperatures.

The analyzed data showed that Bus #8924 was left idling from 2:30 a.m. until 6:30 a.m. on October 3, 1991. During this period, no regeneration was conducted and the trap system was in dual trap operation loading, both Trap 1 and Trap 2. Trap 2 regeneration occurred at approximately 7:00 a.m. Bus #8924 was shut-off between 9:30 a.m. until 2:00 p.m.

Due to the dual mode operation, Trap 1 now had approximately half of the 8 hours of particulate loading. Between 2:30 p.m. until Trap 1 regenerated at approximately 7:00 p.m., the trap system again stayed in the dual mode operation.

The excessive particulate loading caused a high regeneration temperature which either cracked and/or melted Trap 1. The data showed that Trap 2 regenerated immediately after Trap 1 had regenerated. The trap regeneration data for Trap 2 showed that the trap temperature did not reach critical value and, therefore, was not damaged. Two additional traps were procured and were installed on Bus #8924 to continue the bus demonstration program.

A weekly exhaust backpressure and temperature profile, together with Trap 1 and Trap 2 regeneration profiles, were recorded and the plotted graphs are shown in Figures 4.3.4.19-22.

Table 4.3.4.1 presents the backpressure and temperature data. All regeneration temperatures for the test period were within the acceptable range and backpressures were no higher than 8.0" Hg before dual mode operation. Appendix R contains the backpressure and trap temperature graphs for the test period.

Table 4.3.4.2 shows the weekly mileage and regeneration data collected during the 24 month demonstration period. The in-service mileage and engine hours were averaged weekly (Sunday to Sunday) in order to be presented in the weekly format. Bus #8924 accumulated a total of 31,814 miles and 4170 hours of engine operation. A total of 1021 regenerations were conducted where an average trap regeneration occurred approximately once every 6 hours. Table 4.3.4.3 shows the trap operation during Engine Power Curve Generation with regeneration profile.

The following is a summary of Bus #8924 trap maintenance during the demonstration program.

<u>8924</u>

First placed in service 1/23/90 792 hub miles.

Testing performed:

baseline emissions @ ARB 11/2/89
horsepower/opacity @ SCRTD 12/21/89
emissions testing @ ARB 1/3/90
emissions testing @ ARB 5/90
Delco-Remy electrical system test 6/1/90 @ SCRTD.

Parts replaced to-date:

(2) exhaust diverter valves 1/15/90 @ 315 miles, 19 hours
(2) catalyzed cores 3/5/90 @ 2550 miles, 266 hours
(1) mass air flow sensor 3/10/90
(2) catalyzed cores, (2) pressure transducer lines 7/26/90
(1) circuit breaker, (2) burner solenoids, (1) core,
(1) blower air filter 8/10/90 @ 12379 miles 1137 hours
289 regenerations
(2) catalyzed cores cleaned and re-installed 10/3/90
(1) entire system upgraded 11/8/90 1051 hub
660 regen's 1753 hours
(2) non-catalyzed cores replaced 11/14/90 1393 hub
1774 hours 677 regen's.
(2) non-catalyzed cores replaced, replaced controller 1/3/91
1889 hub 1797 hours 34 regen's.
(regen. counter changed 11/31/90).

Mileage per month.
Note: regeneration counter installed May @ 4362 hub miles.

Jan.	800 miles	80 hours	
Feb.	1307 miles	186 hours	
Mar/Apr.	2095 miles	222 hours	
May	1440 miles	161 hours	
June	3815 miles	357 hours	48 regenerations
July	2124 miles	215 hours	103 regenerations
Aug.	925 miles	91 hours	69 regenerations
Sept.	2524 miles	228 hours	130 regenerations
Oct.	2500 miles **	186 hours	119 regenerations
Nov.	820 miles	62 hours	
Dec.	491 miles	23 hours	
Jan.	2982 miles	170 hours	23 regenerations
Feb.	2013 miles	102 hours	19 regenerations
Mar.	2733 miles	23 hours	6 regenerations

Road Calls
(failures while in service needing assistance).

7/20/90	heavy smoke, low power
11/14/90	stalling
12/14/90	stalling, low power.
12/21/90	core #1 plugged
2/11/91	trap # counter failed
2/21/91	24V alternator replaced
4/1/91	trap #1 regeneration counter and hour meter changed engine hour meter changed
4/24/91	bus failed smoked test (12.5% capacity)
5/2/91	Trap #1 core cracked Trap #2 core overloaded
5/8/91	two cores replaced three thermocouples replaced
5/22/91	no power to the datalogger
7/16/91	error code on datalogger
9/6/91	heater element broken Trap #1 core cracked
9/19/91	changed the following: • two cores • two heaters • one blower • AU datalogger thermocouples
10/15/91	KIP valve leaked, no codes
11/l/91	Trap #1 outlet thermocouple broken Trap #1 and Trap #2 core cracked.

** hub odometer changed mid-October at estimated mileage.

4.3.3 Task 3C: Truck Trap System Installation and Maintenance

The truck trap system was designed assuming the truck demonstration would be using a tow truck. A tow truck equipped with a 14 liter Cummins' NTC 4-cycle engine was selected.

Three design issues were raised:

(1) a manual trap bypass valve with a muffler must be provided;
(2) an error light should be installed on the dashboard;
(3) alternator capability.

The tow truck was inspected. Locations for various trap system components were selected. There was enough space to accommodate the trap system, the bypass muffler and the datalogger. The tow truck was put into service during 1986 and had accumulated 65,518 miles and 2,675 hours of service.

After undergoing an engine tune-up in preparation for baseline emission testing and trap installation, a failed variable fuel timing actuator was discovered. This component was repaired and adjustments to the fuel control system completed. The transmission failed after the tow truck was placed back into service requiring further repairs. After the transmission had been repaired, the engine experienced either a cracked cylinder liner or a cracked cylinder head causing coolant to leak into the engine lubrication system. This resulted in a failed camshaft bearing which required engine rebuilding. An alternate vehicle was sought to be used in the test program.

Trap Installation

The tow truck would be fitted with two vertical traps located on either side of the truck. One of the traps would replace the present muffler position. Additional brackets would be provided for the second trap. The present muffler with the heat shield was about 11" in outside diameter. The trap, with the heat shield, was about 12" in outside diameter. Therefore, the door opening clearance on either side would be a little tight. To facilitate the installation of the trap near the driver's side, the fuel filter/water separator would have to be relocated.

An exhaust pressure relief valve would be installed at the up-stream side of the filter. In the event of a component malfunction, the relief valve was spring loaded and would automatically release the exhaust gas to the atmosphere. This would permit engine operation until repairs could be made, and thus, prevent engine damage. The system would also be located between the two traps and mounted underneath the vehicle chassis. The switching mechanism for the by-pass muffler hadn't been decided, but it seemed likely that it would be manually operated by the driver.

Control Box and Custom Box Installation

The control box which housed the solenoids would be located in the "dog-house" under the truck box. The "custom box' which housed the relays and transducers would be located on the driver's side rail near the batteries.

Intake System Installation

The intake system was fitted with an engine air flow sensor. It was pre-assembled and calibrated.

Electrical System Installation

The electrical system of the tow truck was fitted with a 12 volt alternator. The Donaldson tap system needed a 24 volt alternator. The following changes would need to be made to the electrical system of the tow truck to enable the operation of the traps.

1) Two alternators would be fitted. The second alternator would be installed where the oil pump was located.

2) The present oil pump is belt driven. It would be replaced by a 24 volt 130 amp alternator. A new oil pump with the right specification would be procured and installed in a new position. The new oil pump would be located just below the present oil pump position and would be spindle driven.

3) The present alternator would be upgraded to 24 volts 130 amps.

4) A 24 volt starter motor would be installed.

The above changes would be conducted by SCRTD to their satisfaction before installation of the traps commenced. ORTECH personnel would be made available to assist SCRTD.

However, the installation of the Donaldson traps system in the SCRTD tow truck did not materialize. The delays, coupled with cost implications, prompted the parties concerned to discontinue this part of the program.

4.3.4 Task 3D: Data Collection and Failure Analysis

Data collection from the bus trap system was accomplished using a Campbell Scientific datalogger. The data was downloaded to a PC on a weekly basis, whenever the bus was operated in revenue service.

Table 4.3.4.1 shows a summary of the trap system data.

During the week ending February 25, 1990, Trap 1 reached a temperature of 1192°C. This melted the thermocouple. Exhaust backpressure was also very high (9.2" Hg) during the week ending March 18 1990. The thermocouples were not as reliable as expected and required frequent replacement. For high temperature application, thin wire thermocouples must endure high temperatures during regeneration.

Data showed random high backpressure (10" Hg) during the week ending May 27 and June 3, 1990. The backpressure increased and both Trap 1 and Trap 2 inlet thermocouples failed. The thermocouples were replaced.

Subsequently, the backpressure transducers failed and the new Trap 2 thermocouple was defective. Two new backpressure transducers were ordered and replaced.

The PC used for data collection malfunctioned. The useful space on the hard disk was not sufficient to store data during emission testing. The hard disk was replaced and a virus detection program was installed. An extra set of data collection cables was obtained.

Site visits to SCRTD showed that bus down time could be reduced if data was transferred through the use of modems. This would cut down data analysis turnaround time and ensure better trap system operation monitoring. It was decided to monitor and record fewer parameters (engine backpressure, Traps 1 and 2 outlet temperatures and exhaust temperature) but collect data more frequently (every 10 seconds). This allowed better monitoring of trap temperatures during regeneration.

ORTECH personnel reprogrammed the datalogger in order to collect limited data when the trap was not regenerating (1 record per 2 minutes), but during regeneration, the datalogger was programmed to collect and store the data at the rate of 1 record every 5 seconds.

4.3.5 Task 3E: Emission Testing

A preliminary emission test procedure used by NYC DEP to test the trap equipped bus was proposed. Table 4.3.5.1 shows the proposed test procedure. This procedure allowed for measurement of both exhaust emission and regeneration emission from the two traps. It is necessary to have control of the trap system controller to start regeneration at the appropriate moment. The emission data would then show deterioration of either trap.

The ARB 8-mode chassis-dyno emission testing of Bus #8924 was conducted on January,10th, 1990. Since the emission test controller was not available, emission testing was conducted for Trap 1 with Trap 2 outlet closed. During emission testing of Trap 2, Trap 1 outlet was closed. Tables 4.3.5.2 - 4.3.5.4 show the results. No regeneration emission data was collected. The particulate removal efficiency was only 75%, which was lower than targeted (85%). CO and THC % reduction was higher than expected (50%). It was not clear why NO_x emission was higher (or baseline was low) when the bus was trap-equipped. This was opposite to the test cell results (16% lower). The low particulate removal efficiency shows the need for a set of new catalyst traps, both as replacement and as spare parts.

In May, 1990, after new catalyzed traps were installed, emission testing was conducted. The emission test controller was not available. The PC used was shown to be defective. The emission testing had to be conducted without the trap system data being available. Table 4.3.5.5 shows the emissions results from a chassis-dyno emission testing of Bus #8924 conducted at ARB on May 1st, 1990.

The particulate removal efficiency of 89% was above the targeted value of 85%. Both CO and THC reductions are shown to be higher than the expected 85%. It was not clear why the NO_x emissions increased by 20%. Normally, there would be a slight decrease in NO_x emissions due to higher backpressure imposed by the trap system.

Figure 4.3.5.1 shows the exhaust temperatures during the emission testing. The data was not complete due to thermocouple failures. Available data showed consistent exhaust temperature data and no leakage from either exhaust diverter valve.

During emission testing, it was attempted to trigger regeneration by inducing a higher backpressure (7" Hg) to the transducers. The attempts were unsuccessful. The transducers themselves contained two labels (Trap 1 and Trap 2). The lines were connected to the original state.

A meeting was held between ARB and ORTECH during the month of December, 1990, regarding emission testing of Bus #8924. The emission testing was scheduled to take place on December 10th, 1990. It was decided that since Bus #8924 was equipped with non-catalyzed traps, the first emission test would be conducted with the non-catalyzed traps. The non-catalyzed traps would then be removed and replaced with catalyzed traps. The emissions data collected for the catalyzed trap and the non-catalyzed trap would be compared and any differences would be highlighted. A Y-pipe was designed to connect the dual exhaust from the bus to the dilution tunnel inlet. This produced a slight vacuum at the Y-pipe and thus prevented the engine flow from backflushing during idle and during the trap regeneration. The exhaust could be directed to either Trap 1 or Trap 2. During Modes 2 and 3 of the ARB cycle, the exhaust would go through both traps.

The emission testing did not take place because the Y-pipe with the 5" diameter inlets fabricated by ORTECH, was too small.

The last emission testing of the trap on Bus #8924 was conducted using the ARB 8-mode chassis-dyno cycle during the month of November, 1991. The backpressure mapping was conducted using the Mode-5 and Mode-6 of the ARB cycle. The objective was to determine the backpressure build-up rate and thus determine the time required to load the trap for regeneration using the two modes of operation.

Emission testing was conducted using the Y-pipe set-up. ORTECH fabricated a second Y-pipe with two 6" inlets and one 6" outlet which fitted correctly.

At the completion of the 8-mode testing, the bus was put into operation under Mode 6 in order to load up the trap prior to regeneration. Once the trap was in regeneration, the bus was operated under idle condition and the regenerated emissions (20 minutes) were recorded.

Emissions testing for the second trap was conducted, followed by regeneration emission testing.

The tabulated results are shown in Table 4.3.5.6. The results show that the average particulate removal efficiency during the ARB 8-mode chassis-dyno testing was only 68%. This low efficiency concluded that the trap had deteriorated. The gaseous emissions show that the level of CO was high. This was most likely due to high trap backpressure. The high CO indicated the need for catalyzed traps to lower CO emissions.

5. CONCLUSION AND RECOMMENDATIONS

1. The DCI trap system has demonstrated that the particulate emissions can be reduced up to 85% from heavy duty diesel engines.

2. The trap system satisfactorily completed the 24 month demonstration period, during which time it demonstrated its capability to reduce particulate emission and its ability to conduct automatic regeneration (self cleaning) without the driver's intervention.

3. During the first few months of installation of the trap system, Bus #8924 experienced trap operational difficulties culminating in filters being overloaded, and often resulting in trap failures. Later, with improved hardware and software designs, the trap failures were reduced.

4. The troubleshooting and diagnosis of the trap system was not well documented. This made the task of SCRTD staff in diagnosing trap failures a little difficult. This issue was later addressed.

5. The data collected was not sufficient enough to assess the advantage of catalyzed traps in assisting regeneration, and thus reducing electrical consumption. Further optimization and field testing of the catalyzed cores is needed to determine the advantages.

Mehboob Sumar
Emissions Engineer.

TABLE 4.1.1

BUS TRAP SYSTEM EVALUATION

	Criteria	Rating Ranges	Rating Points
1)	Total Particulate Removal Efficiency	80% 90% 95%	0 10 20
2)	Visible Black Smoke	Yes No	Fail Pass
3)	Regeneration Emission	Minor increases in HC, CO, SO4. No increases. Possible unknown emission.	0 30 Fail
4)	Durability		
	a) Trap System life expectancy	Less than 300K miles. Over 300K miles.	Fail Pass
	b) Filter element	Up to 100K miles Up to 200K miles Up to 300K miles	0 10 20
5)	Regeneration Control	Automatic Manual Cycle dependent	30 Fail 0/Fail
6)	Trap System Installation	Easy Difficult	20 0
7)	Impact on Bus Maintenance and Service	Low High	30 0
8)	Engine Backpressure Limit	>4" Hg <3.5" Hg <3.0" Hg <2.5" Hg	Fail 0 10 20
9)	Energy Penalty	<4% 4.1 - 6% >8% >10%	20 10 0 Fail

TABLE 4.1.1 (Cont'd.)

BUS TRAP SYSTEM EVALUATION

Criteria	Rating Ranges	Rating Points
10) System Cost	<4000	20
	4000 - 5000	10
	>5000	Fail
11) Annual Maintenance Cost	$ 0- 100	20
	$101- 500	10
	501-1000	0
12) Sound Muffling	Better than Muffler	10
	Equal to Muffler	Pass
	Less than Muffler	Fail
13) Fire (Safety) Hazard	Cause a high increase possibility.	Fail
	Low possibility.	Pass
	Cause a very low increase possibility	20

Organization	Response	Summary
Engine Manufacturers Association	Aug.30/88	Working with ORF.
Cummins Engine Co.	Sept.8/88	Working on Truck + Bus System.
Caterpillar	Aug.30/88	Working on Truck System.
Detroit Diesel Corp.	Oct. 5/88	Working on bus system with ORTECH
Navistar	Sept.13/88	Working on catalyst converter only.
Deutz Corporation	Aug.30/88	Trap systems available in Europe.
MECA	Sept.20/88	Sent info to DCI + ECS.
Donaldson	Aug.10/88	Oral indication of preparing significant response.
ECS	Aug.10/88	- " -
Arvin	Sept. 8/88	Working with Cummins Engine Co.
Mirus	Aug.15/88	System not ready. Will respond to 2nd system request.
Atomic Energy of Canada	Sept.19/88	System not ready. Will respond to 2nd system.
Converter Technology	July 26/88	Technology not tested/system not ready.
Corning Glass Works	July 29/88	Same cordierite wall flow filter.
Matsushita	Aug.10/88	Same mullite fiber filter.
NGK	Aug.19/88	Same cordierite wall flow filter.
Selee Corporation	Sept.1/88	Refining material, will respond to 2nd system request.
3M	Aug.15/88	Responded with Mirus.

TABLE 4.1.2: Organizations Solicited for Trap Systems.

Organization	Response	Summary
Champion Spark Plugs	Sept.25/88	Small prototypes only.
Engelhard	Aug.15/88	Catalyst for filters.
JMI		
Degussa	Aug.4/88	Catalyst for filters.
Ricardo		
SwRI	Oct.5/88	Nothing new.
EPA	Oct.5/88	Nothing new.
Lubrizol	Aug.31/88	Copper based additive.
Econalytic Chemische Betriebe Pluto	Aug.9/88	Testing at ORF under EMA project.

TABLE 4.1.2: Organizations Solicited for Trap Systems (Cont'd.)

TABLE 4.2.1

REFERENCE ADVANCED DESIGN BUS CYCLE

CENTRAL BUSINESS DISTRICT PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
1	872	287	48
2	1183	552	124
3	1298	661	163
4	1337	653	166
5	1390	645	171
6	1444	638	175
7	1496	631	180
8	1553	616	182
9	1617	601	185
10	1677	430	137
11	1510	252	72
12	1510	252	72
13	1510	252	72
14	1510	252	72
15	1510	252	72
16	1510	252	72
17	1510	252	72
18	1510	252	72
19	1510	252	72
20	1510	252	72
21	1510	252	72
22	1510	252	72
23	1510	252	72
24	1510	252	72
25	1510	252	72
26	1510	252	72
27	1510	252	72
28	1510	252	72
29	1510	252	72
30	560	100	11
31	560	100	11
32	560	100	11
33	560	100	11
34	560	100	11
35	560	100	11
36	560	100	11
37	560	100	11
38	560	100	11
39	560	100	11
40	560	100	11

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

ARTERIAL PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
1	872	287	48
2	1183	552	124
3	1298	661	163
4	1337	653	166
5	1390	645	171
6	1444	638	175
7	1496	631	180
8	1553	616	182
9	1617	601	185
10	1691	586	189
11	1630	596	185
12	1513	626	180
13	1538	620	182
14	1564	615	183
15	1588	608	184
16	1620	601	185
17	1652	594	187
18	1680	589	188
19	1714	582	190
20	1747	575	191
21	1778	569	193
22	1805	568	195
23	1676	589	188
24	1718	581	190
25	1753	577	193
26	1802	566	194
27	1844	554	194
28	1883	545	195
29	1922	535	196
30	1961	526	197
31	1998	518	197
32	1476	579	163
33	1496	397	113
34	1510	267	77
35	1510	267	77
36	1510	267	77
37	1510	267	77
38	1510	267	77
39	1510	267	77
40	1510	267	77
41	1510	267	77
42	1510	267	77
43	1510	267	77
44	1510	267	77
45	1510	267	77
46	1510	267	77
47	1510	267	77
48	1510	267	77

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

ARTERIAL PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
49	1510	267	77
50	1510	267	77
51	1510	267	77
52	1510	267	77
53	1510	267	77
54	1510	267	77
55	560	100	11
56	560	100	11
57	560	100	11
58	560	100	11
59	560	100	11
60	560	100	11
61	560	100	11
62	560	100	11
63	560	100	11
64	560	100	11
65	560	100	11
66	560	100	11
67	560	100	11
68	560	100	11
69	560	100	11
70	560	100	11

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
1	872	287	48
2	1183	552	124
3	1298	661	163
4	1337	653	166
5	1390	645	171
6	1444	638	175
7	1496	631	180
8	1553	616	182
9	1617	601	185
10	1691	586	189
11	1630	596	185
12	1513	626	180
13	1538	620	182
14	1564	615	183
15	1588	608	184
16	1620	601	185
17	1652	594	187
18	1680	589	188
19	1714	582	190
20	1747	575	191
21	1778	569	193
22	1805	568	195
23	1676	589	188
24	1718	581	190
25	1753	577	193
26	1802	566	194
27	1844	554	194
28	1883	545	195
29	1922	535	196
30	1961	526	197
31	1998	518	197
32	1476	633	178
33	1494	631	179
34	1512	627	181
35	1529	623	181
36	1547	619	182
37	1566	616	184
38	1583	611	184
39	1600	606	185
40	1617	601	185
41	1634	598	186
42	1651	594	187
43	1667	591	188
44	1683	588	189
45	1699	584	189
46	1713	582	190
47	1728	579	191
48	1743	576	191

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
49	1758	574	192
50	1771	571	193
51	1785	569	193
52	1800	566	194
53	1814	560	193
54	1827	556	193
55	1841	551	193
56	1853	550	194
57	1866	548	195
58	1879	545	195
59	1891	542	195
60	1903	539	195
61	1916	537	196
62	1927	534	196
63	1939	531	196
64	1949	529	196
65	1960	526	196
66	1971	524	197
67	1983	521	197
68	1993	519	197
69	2003	517	197
70	2013	515	197
71	2023	509	196
72	2030	463	179
73	2038	418	162
74	2045	372	145
75	2051	336	131
76	2051	336	131
77	2051	336	131
78	2051	336	131
79	2051	336	131
80	2051	336	131
81	2051	336	131
82	2051	336	131
83	2051	336	131
84	2051	336	131
85	2051	336	131
86	2051	336	131
87	2051	336	131
88	2051	336	131
89	2051	336	131
90	2051	336	131
91	2051	336	131
92	2051	336	131
93	2051	336	131
94	2051	336	131
95	2051	336	131
96	2051	336	131

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
97	2051	336	131
98	2051	336	131
99	2051	336	131
100	2051	336	131
101	2051	336	131
102	2051	336	131
103	2051	336	131
104	2051	336	131
105	2051	336	131
106	2051	336	131
107	2051	336	131
108	2051	336	131
109	2051	336	131
110	2051	336	131
111	2051	336	131
112	2051	336	131
113	2051	336	131
114	2051	336	131
115	2051	336	131
116	2051	336	131
117	2051	336	131
118	2051	336	131
119	2051	336	131
120	2051	336	131
121	2051	336	131
122	2051	336	131
123	2051	336	131
124	2051	336	131
125	2051	336	131
126	2051	336	131
127	2051	336	131
128	2051	336	131
129	2051	336	131
130	2051	336	131
131	2051	336	131
132	2051	336	131
133	2051	336	131
134	2051	336	131
135	2051	336	131
136	2051	336	131
137	2051	336	131
138	2051	336	131
139	2051	336	131
140	2051	336	131
141	2051	336	131
142	2051	336	131
143	2051	336	131
144	2051	336	131

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
145	2051	336	131
146	2051	336	131
147	2051	336	131
148	2051	336	131
149	2051	336	131
150	2051	336	131
151	2051	336	131
152	2051	336	131
153	2051	336	131
154	2051	336	131
155	2051	336	131
156	2051	336	131
157	2051	336	131
158	2051	336	131
159	2051	336	131
160	2051	336	131
161	2051	336	131
162	2051	336	131
163	2051	336	131
164	2051	336	131
165	2051	336	131
166	2051	336	131
167	2051	336	131
168	2051	336	131
169	2051	336	131
170	2051	336	131
171	2051	336	131
172	2051	336	131
173	2051	336	131
174	2051	336	131
175	2051	336	131
176	2051	336	131
177	2051	336	131
178	2051	336	131
179	2051	336	131
180	2051	336	131
181	2051	336	131
182	2051	336	131
183	2051	336	131
184	2051	336	131
185	2051	336	131
186	2051	336	131
187	2051	336	131
188	2051	336	131
189	2051	336	131
190	2051	336	131
191	2051	336	131
192	2051	336	131

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
193	2051	336	131
194	2051	336	131
195	2051	336	131
196	2051	336	131
197	2051	336	131
198	2051	336	131
199	2051	336	131
200	2051	336	131
201	2051	336	131
202	2051	336	131
203	2051	336	131
204	2051	336	131
205	2051	336	131
206	2051	336	131
207	2051	336	131
208	2051	336	131
209	2051	336	131
210	2051	336	131
211	2051	336	131
212	2051	336	131
213	2051	336	131
214	2051	336	131
215	2051	336	131
216	2051	336	131
217	2051	336	131
218	2051	336	131
219	2051	336	131
220	2051	336	131
221	2051	336	131
222	2051	336	131
223	2051	336	131
224	2051	336	131
225	2051	336	131
226	2051	336	131
227	2051	336	131
228	2051	336	131
229	2051	336	131
230	2051	336	131
231	2051	336	131
232	2051	336	131
233	2051	336	131
234	2051	336	131
235	2051	336	131
236	2051	336	131
237	2051	336	131
238	2051	336	131
239	2051	336	131
240	2051	336	131

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
241	2051	336	131
242	2051	336	131
243	2051	336	131
244	2051	336	131
245	2051	336	131
246	2051	336	131
247	2051	336	131
248	2051	336	131
249	2051	336	131
250	2051	336	131
251	2051	336	131
252	2051	336	131
253	2051	336	131
254	2051	336	131
255	2051	336	131
256	2051	336	131
257	2051	336	131
258	2051	336	131
259	2051	336	131
260	2051	336	131
261	2051	336	131
262	2051	336	131
263	2051	336	131
264	2051	336	131
265	2051	336	131
266	2051	336	131
267	2051	336	131
268	2051	336	131
269	2051	336	131
270	2051	336	131
271	2051	336	131
272	2051	336	131
273	2051	336	131
274	2051	336	131
275	2051	336	131
276	2051	336	131
277	2051	336	131
278	2051	336	131
279	2051	336	131
280	560	100	11
281	560	100	11
282	560	100	11
283	560	100	11
284	560	100	11
285	560	100	11
286	560	100	11
287	560	100	11
288	560	100	11

TABLE 4.2.1 (cont'd.)

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

ARB Test Cell 8
Detroit Diesel Engine 6V92TA
April 14,1989

Time (sec)	Speed (rpm)	Torque (ft-lb)	Horsepower (bhp)
289	560	100	11
290	560	100	11
291	560	100	11

TABLE 4.2.2

ADB Short Cycle Regression Results

ADB Cycle 6V92TA Detroit Diesel
April 6,1989
Test Cell 8

			EPA Limits Lower	Upper	
Speed Regression Output:					
Constant		12	-50	50	PASS
Std Err of Y Est		52		100	PASS
R Squared		0.99	0.97		PASS
No. of Observations		461			
Degrees of Freedom		459			
X Coefficient(s)	1.00		0.97	1.03	PASS
Std Err of Coef.	0.004				
Torque Regression Output:					
Constant		13	-15	15	PASS
Std Err of Y Est		39		100	PASS
R Squared		0.94	0.88		PASS
No. of Observations		461			
Degrees of Freedom		459			
X Coefficient(s)	0.95		0.83	1.03	PASS
Std Err of Coef.	0.011				
HP Regression Output:					
Constant		-0	-5	5	PASS
Std Err of Y Est		10		18.2	PASS
R Squared		0.97	0.91		PASS
No. of Observations		461			
Degrees of Freedom		459			
X Coefficient(s)	1.00		0.89	1.03	PASS
Std Err of Coef.	0.008				
Ref Work	14.4				
Actual	14.4				
Ratio	1.00		0.85	1.05	PASS

Table 4.2.4.1

ARB PROGRAM
Donaldson DPF Evaluation
April 26 1989
ADB Cycle (Opr 1)

BASELINE EMISSIONS
ADB CYCLE

ADB Cycle Averages		Test 1 3.0 Hg"	Test 2 3.0 Hg"	Test 3 3.0 Hg"	Test 4 3.0 Hg"	Test 5 7.0 Hg"	Test 6 7.0 Hg"	Test 7 7.0 Hg"	Test 8 3.0 Hg"	Average 3.0 Hg"	Average 7.0 Hg"
Engine Speed	(rpm)	1254	1219	1252	1253	1243	1246	1244	1248	1252	1244
Engine Torque	(ft-lb)	285.9	267.3	285.1	285.9	283.9	281.5	282.5	281.7	284.7	282.6
Engine Horsepower	(bhp)	82.7	71.2	82.6	82.7	82.0	81.2	81.4	81.4	82.4	81.5
Engine Work	(hp-hr)	65.05	56.03	64.96	65.01	64.47	63.84	63.99	64.03	64.76	64.10
Engine Fuel Consumption	(lbs)	29.99	26.68	29.77	29.33	30.43	30.65	30.65	29.77	29.71	30.58
BSFC	(lb/hp-hr)	0.363	0.375	0.360	0.355	0.371	0.377	0.377	0.366	0.361	0.375
Carbon Dioxide	(gr)	46662	41893	41884	47023	47879	47749	47753	46061	45407	47794
	(gr/hr)	59337	53272	53261	59796	60884	60719	60724	58573	57741	60776
	(gr/hp-hr)	717.3	747.7	644.8	723.3	742.6	747.9	746.3	719.4	701.2	745.6
Carbon Monoxide	(gr)	68.7	103.4	103.4	65.3	96.1	91.9	88.9	60.0	74.4	92.3
	(gr/hr)	87.3	131.5	131.5	83.0	122.3	116.8	113.0	76.3	94.5	117.4
	(gr/hp-hr)	1.06	1.85	1.59	1.00	1.49	1.44	1.69	0.94	1.15	1.54
Oxides of Nitrogen	(gr)	358.9	316.7	316.7	368.5	353.2	349.1	342.8	363.2	351.8	348.4
	(gr/hr)	456.3	402.7	402.7	468.5	449.1	443.9	435.9	461.8	447.3	443.0
	(gr/hp-hr)	4.84	4.96	4.28	4.98	4.81	4.80	4.70	4.98	4.77	4.77
Total Hydrocarbon	(gr)	35.5	36.7	35.6	37.9	36.8	33.9	34.0	35.3	36.1	34.9
	(gr/hr)	45.1	46.7	45.3	48.2	46.8	43.1	43.2	44.9	45.9	44.4
	(gr/hp-hr)	0.55	0.66	0.55	0.58	0.56	0.53	0.53	0.55	0.56	0.54
			- Void -								

PARTICULATE EMISSIONS

		Test 1 3.0 Hg"	Test 2 3.0 Hg"	Test 3 3.0 Hg"	Test 4 3.0 Hg"	Test 5 7.0 Hg"	Test 6 7.0 Hg"	Test 7 7.0 Hg"	Test 8 3.0 Hg"	Average 3.0 Hg"	Average 7.0 Hg"
Insoluble	(gr)	6.09	9.79	7.22	7.24	9.63	9.45	9.70	7.42	6.99	9.60
Soluble	(gr)	3.96	4.09	4.62	4.81	3.19	3.22	3.15	4.19	4.39	3.18
Total	(gr)	10.05	13.88	11.84	12.06	12.83	12.67	12.85	11.61	11.39	12.78
Insoluble	(gr/hr)	7.75	12.45	9.18	9.21	12.25	12.02	12.34	9.43	8.89	12.20
Soluble	(gr/hr)	5.03	5.20	5.87	6.12	4.06	4.09	4.00	5.33	5.59	4.05
Total	(gr/hr)	12.78	17.65	15.05	15.33	16.31	16.11	16.34	14.76	14.48	16.25
Insoluble	(gr/hp-hr)	0.094	0.175	0.111	0.111	0.149	0.148	0.152	0.116	0.108	0.150
Soluble	(gr/hp-hr)	0.061	0.073	0.071	0.074	0.049	0.050	0.049	0.065	0.068	0.049
Total	(gr/hp-hr)	0.155	0.248	0.182	0.185	0.199	0.198	0.201	0.181	0.176	0.199
Insoluble	(%)	60.6	70.5	61.0	60.1	75.1	74.6	75.5	63.9	61.40	75.08
Soluble	(%)	39.4	29.5	39.0	39.9	24.9	25.4	24.5	36.1	38.60	24.92

Table 4.2.6.1
ARB Project Quality Control
Bus Trap System Testing
DDC 6V92TA Performance Data

Date	rpm	torq ft-lb	hp	fuel lb/hr	BSFC	BP " Hg	rpm	torq ft-lb	hp	fuel lb	BSFC	BP " Hg	Comment
03-May-89	2105	565	226.4518			2.0	1202	751	171.7862				
04-May-89	2102	561	224.3680	95.5	0.426	1.8	1202	735	168.2159				
05-May-89	2100	558	223.1949			1.6	1203	737	168.7681			1.0	
07-May-89	2100	571	228.1930			2.0	1205	746	171.2054			1.3	
08-May-89	2102	565	225.9690	98.2	0.435	1.4	1205	743	170.5400	65.3	0.383	0.9	
08-May-89	2105	558	223.7263	96.1	0.430	3.4	1202	738	168.9711	64.2	0.380	1.7	
09-May-89	2101	562	224.9814	99.8	0.444	3.7	1201	731	167.2298	65.3	0.390	1.9	
09-May-89	2101	554	221.6210	96.9	0.437	3.1							
09-May-89	2101	549	219.5408	98.2	0.447	4.0							
09-May-89	2101	531	212.5402	98.2	0.462	6.1							
09-May-89	2101	516	206.4996	99.5	0.482	8.1							
09-May-89	2101	493	197.3787	95.8	0.485	9.8							
12-May-89	2097	564	224.9922	98.5	0.438	1.3	1200	748	170.8834	65.4	0.383	0.9	
15-May-89	2100	566	226.1938	98.2	0.434	2.0	1200	740	169.1469	64.5	0.381	1.3	
15-May-89	2097	564	224.9922	98.5	0.438	1.3	1200	748	170.8834	65.4	0.383	0.9	
16-May-89	2105	556	222.9247	95.2	0.427	1.0	1205	728	167.0297	63.7	0.381	0.8	
17-May-89	2106	571	229.1257	95.9	0.419	1.1	1205	745	170.9530	64.6	0.378	0.8	
18-May-89	2103	567	226.8373	97.1	0.428	1.0	1200	737	168.3472	63.3	0.376	0.7	
19-May-89	2100	566	226.3537	95.9	0.424	1.0	1199	744	169.8963	63.8	0.376	0.7	
24-May-89	2107	560	224.4604			1.3							
24-May-89	2102	554	221.6465			3.0							
24-May-89	2100	550	220.0361			4.0							
24-May-89	2107	533	213.6687			6.0							
24-May-89	2095	514	204.9924			8.2							
24-May-89	2097	497	198.2806			9.7							
24-May-89	2095	558	222.3843	96.9	0.436	1.2	1200	725	165.5826	64.3	0.388	0.7	
29-May-89	2102	568	227.2497	96.8	0.426	1.2	1199	745	170.1475	64.1	0.377	0.8	
30-May-89	2099	562	224.4075	95.8	0.427	1.2	1202	736	168.3303	63.2	0.375	0.8	
31-May-89	2102	556	222.6871	95.8	0.430	1.2	1201	733	167.5728	63.2	0.377	0.8	
01-Jun-89	2104	564	226.0638	96.3	0.426	1.4	1206	732	168.1327	64.3	0.382	1.0	
01-Jun-89	2100	533	213.1987	95.8	0.449	1.8	1202	695	159.0384	64.7	0.407	1.1	140A 28 v
02-Jun-89	2100	562	224.8743	96.3	0.428	1.4	1199	729	166.4948	64.1	0.385	1.1	
05-Jun-89	2100	569	227.3134	97.5	0.429	1.6	1201	739	169.0821	64.4	0.381	1.1	
07-Jun-89	2100	539	215.4779	97.5	0.452	1.4	1201	699	159.9122	64.2	0.401	1.1	145 A 28 v
08-Jun-89	2102	536	214.4824	96.2	0.449	1.6	1200	694	158.5224	63.4	0.400	1.1	140 A 28 v
09-Jun-89	2100	542	216.5175	96.5	0.446	1.0	1200	693	158.3853	63.1	0.398	0.8	140 A 28 v
12-Jun-89	2106	564	226.1183	97.5	0.431	1.4	1202	738	168.8109	63.1	0.374	1.0	
13-Jun-89	2103	557	222.8331	96.8	0.434	1.4	1200	729	166.4737	64.2	0.386	1.1	
14-Jun-89	2105	560	224.3275	97.7	0.436	1.6	1200	734	167.7760	63.9	0.381	1.1	
15-Jun-89	2103	556	222.7930	95.0	0.426	1.3	1198	726	165.6716	64.3	0.388	0.9	
15-Jun-89						1.3	1198	702	160.1515	63.6	0.397	0.9	120 A 28 v
16-Jun-89	2100	556	222.4752	94.8	0.426	1.5	1200	724	165.4226	62.9	0.380	0.9	
19-Jun-89	2100	544	217.3172	95.4	0.439	3.1							
	2103	531	212.7425	94.3	0.443	4.1							
	2102	513	205.2371	94.7	0.461	6.1							
	2100	499	199.6439	94.4	0.473	8.0							
	2100	492	196.5651	94.5	0.481	3.1							250 A 28 v
	2103	483	193.3222	94.2	0.487	4.1							250 A 28 v
	2102	469	187.5470	93.7	0.500	6.1							250 A 28 v
	2100	453	180.9710	94.7	0.523	8.0							250 A 28 v
21-Jun-89	2106	565	226.5594	96.8	0.427	2.1	1203	743	170.0737	63.2	0.372	1.3	
27-Jun-89	2105	559	223.9267	96.0	0.429	0.7	1200	729	166.6336	63.6	0.382	0.5	
28-Jun-89	2102	567	226.7294	96.0	0.423	1.3	1200	736	168.0959	63.8	0.380	0.9	
06-Jul-89	2100	553	221.1957	95.1	0.430	1.2	1202	732	167.5522	63.6	0.380	0.8	
07-Jul-89	2105	553	221.7223	94.8	0.428	0.9	1200	738	168.5757	62.8	0.373	0.7	
09-Jul-89	2100	567	226.7936	95.8	0.422	1.1	1197	741	168.8152	62.9	0.373	0.8	
10-Jul-89	2082	572	226.7524	95.0	0.419	0.9	1202	739	169.1084	62.2	0.368	0.7	
11-Jul-89	2100	568	227.2334	95.6	0.421	1.2	1203	748	171.3564	63.4	0.370	0.8	
12-Jul-89	2103	569	227.9184	97.1	0.426	1.0	1200	749	171.1348	62.6	0.366	0.7	
13-Jul-89	2098	572	228.5749	95.9	0.420	1.0	1200	749	171.0891	62.9	0.368	0.7	
14-Jul-89	2100	581	232.3914	96.9	0.417	2.2	1202	764	174.8301	65.9	0.377	1.4	
16-Jul-89	2106	592	237.5465	99.5	0.419	1.0	1202	766	175.2420	64.0	0.365	0.8	
17-Jul-89	2099	586	234.1991	98.6	0.421	1.3	1198	760	173.4499	63.9	0.368	0.9	
18-Jul-89	2102	588	235.4143	98.8	0.420	0.9	1203	769	176.0292	65.5	0.372	0.7	
20-Jul-89	2101	586	234.5023	97.2	0.414	1.0	1200	761	173.8994	64.3	0.370	0.7	
24-Jul-89	2100	583	233.1911	98.0	0.420	0.9	1205	767	175.8630	65.1	0.370	0.7	
25-Jul-89	2100	584	233.4310	97.7	0.419	0.9	1199	757	172.8870	63.8	0.369	0.7	
26-Jul-89	2100	580	231.9516	98.2	0.423	1.9	1202	747	170.9623	64.1	0.375	1.3	
27-Jul-89	2100	554	221.5156	97.9	0.442	5.5	1200	716	163.6862	64.6	0.395	3.2	
28-Jul-89	2100	546	218.3968	97.4	0.446	5.9	1207	714	164.0435	64.7	0.394	3.3	
02-Aug-89	2097	580	231.7001	97.7	0.422	2.0	1200	759	173.3511	64.5	0.372	1.3	
03-Aug-89	2102	569	227.6099	96.8	0.425	2.3	1200	739	168.7814	63.1	0.374	1.5	
05-Aug-89	2107	569	228.1513	97.5	0.427	2.3	1200	763	174.2878	65.2	0.374	1.5	
14-Aug-89	2100	558	223.0350	95.6	0.429	4.9	1202	735	168.2616	64.5	0.383	1.9	
14-Aug-89	2100	588	235.1904	99.5	0.423	3.0							
14-Aug-89	2100	580	231.7117	99.1	0.428	4.1							
14-Aug-89	2100	567	226.5137	97.7	0.431	5.0							
14-Aug-89	2100	556	222.3153	98.5	0.443	6.1							
14-Aug-89	2100	547	218.6367	97.9	0.448	7.0							
14-Aug-89	2100	533	213.1188	96.8	0.454	8.1							
14-Aug-89	2100	527	210.7597	96.8	0.459	9.0							

Table 4.2.6.2
ADB CYCLE FUEL CONSUMPTION RESULTS
NON CATALYZED TRAPS

DATE	(lb/hr) NO Load	Elec Load	Elec +Regen	Regen Only	(lb) NO Load	Elec Load	Elec +Regen	Regen Only
07-May-89	39.3				30.9			
08-May-89	38.5				30.3			
08-May-89	38.3				30.1			
12-May-89	38.6				30.4			
15-May-89	38.7				30.4			
15-May-89	38.5				30.3			
15-May-89	38.9				30.6			
17-May-89	38.1				30.0			
17-May-89	38.3				30.1			
18-May-89	37.6				29.6			
18-May-89	38.1				30.0			
19-May-89	38.2				30.0			
24-May-89	38.3				30.1			
29-May-89	38.0				29.9			
29-May-89	37.8				29.7			
30-May-89				38.6				30.4
30-May-89				38.1				30.0
30-May-89	39.1				30.7			
31-May-89	38.6				30.4			
01-Jun-89	38.6				30.4			
02-Jun-89		39.4				31.0		
05-Jun-89	38.8				30.5			
05-Jun-89		39.5				31.1		
05-Jun-89		40.5				31.8		
07-Jun-89		40.3				31.7		
07-Jun-89		41.1				32.3		
07-Jun-89	38.2				30.0			
07-Jun-89			41.0				32.2	
07-Jun-89		40.2				31.6		
08-Jun-89			41.3				32.5	
08-Jun-89		40.6				31.9		
08-Jun-89	38.6				30.4			
08-Jun-89			41.3				32.5	
09-Jun-89		41.1				32.3		
09-Jun-89		40.8				32.1		
12-Jun-89		40.6				31.9		
12-Jun-89				38.8				30.5
12-Jun-89	38.0				29.9			
12-Jun-89		40.3				31.7		
13-Jun-89			40.6				31.9	
13-Jun-89	38.5				30.3			
13-Jun-89			40.6				31.9	
13-Jun-89		39.7				31.2		
14-Jun-89		39.9				31.4		
14-Jun-89	38.5				30.3			
14-Jun-89				38.8				30.5
14-Jun-89		39.7				31.2		
14-Jun-89			39.9				31.4	
15-Jun-89	37.9				29.8			
15-Jun-89	38.7				30.4			
16-Jun-89	38.7				30.4			
16-Jun-89	39.0				30.7			
16-Jun-89				39.0				30.7
16-Jun-89	38.9				30.6			
16-Jun-89	38.3				30.1			
16-Jun-89	38.5				30.3			
Average	38.5	40.3	40.8	38.7	30.2	31.7	32.1	30.4
STD	0.4	0.5	0.5	0.3	0.3	0.4	0.4	0.2
COV(%)	1.0	1.3	1.2	0.8	1.0	1.3	1.2	0.8
% Inc		4.7	6.1	0.5	0.0	4.7	6.1	0.5

Table 4.2.6.3
ADB CYCLE FUEL CONSUMPTION RESULTS
CATALYZED TRAPS

DATE	(lb/hr) NO Load	Elec Load	Elec +Regen	Regen Only	(lb) NO Load	Elec Load	Elec +Regen	Regen Only
27-Jun-89	38.0				29.9			
28-Jun-89	38.0				29.9			
28-Jun-89	37.9				29.8			
28-Jun-89	37.6				29.6			
28-Jun-89	37.4				29.4			
28-Jun-89	37.5				29.5			
06-Jul-89	38.7				30.4			
07-Jul-89	38.5				30.3			
09-Jul-89	37.4				29.4			
09-Jul-89	37.0				29.1			
10-Jul-89				37.9				29.8
12-Jul-89	38.0				29.9			
12-Jul-89				38.3				30.1
13-Jul-89	38.7				30.4			
14-Jul-89		38.4				30.2		
17-Jul-89	38.8				30.5			
17-Jul-89	38.0				29.9			
18-Jul-89		39.7				31.2		
18-Jul-89		40.0				31.5		
19-Jul-89			42.7				33.6	
19-Jul-89		39.9				31.4		
21-Jul-89		39.8				31.3		
24-Jul-89		40.2				31.6		
24-Jul-89			40.6				31.9	
24-Jul-89		40.6				31.9		
24-Jul-89			40.6				31.9	
27-Jul-89			40.6				31.9	
27-Jul-89			40.6				31.9	
03-Aug-89	38.5				30.3			
03-Aug-89	38.9				30.6			
03-Aug-89	38.2				30.0			
03-Aug-89	38.0				29.9			
03-Aug-89	38.3				30.1			
03-Aug-89	38.5				30.3			
04-Aug-89			40.3				31.7	
04-Aug-89	38.7				30.4			
04-Aug-89	39.9				31.4			
Average	38.2	39.8	40.9	38.1	30.0	31.3	32.2	30.0
STD	0.6	0.6	0.8	0.2	0.5	0.5	0.6	0.2
COV(%)	1.6	1.6	2.0	0.5	1.6	1.6	2.0	0.5
% Inc		4.2	7.1	-0.3	0.0	4.2	7.1	-0.3

Table 4.2.6.4

REGENERATION TABLE

THREE NON-CATALYZED TRAPS

	DATE	TRAP No.	TEMP IN Deg F.	TEMP OUT Deg F.	HEATER TIME Min	BLOWER TIME Min	REGEN TIME Min	BUILDUP TIME Min	MAX BP in. H2O
1	07-May-89	1	1380	1430	7.3	13.9	14.5		
2	08-May-89	2							
3	08-May-89	3	1405	1337	8.9	12.9	14.8		76
4	09-May-89	1	1412	1382	5.9	13.1	25.0		72
5	09-May-89	2	1231	2156	14.8	21.5	23.7	5	52
6	09-May-89	3	1368	1274	6.3	13.0	15.3	20	
7	15-May-89	1	1502	2084	8.2	13.8	18.2	470	54
8	15-May-89	2	1364	2084				376	
9	15-May-89	3	1309	1202				94	
10	16-May-89	1	1247	608	6.2	13.8	18.5	283	54
11	17-May-89	2	1272	1166				182	
12	17-May-89	3							
13	17-May-89	1		725				125	
14	17-May-89	2	1244	1175				230	
15	18-May-89	3	1484	1715	7.0	13.6	15.8	295	56
16	18-May-89	1	1402		5.7	12.7	13.2	190	
17	19-May-89	2	1265	1067	7.2	14.3	16.5	225	59
18	24-May-89	3	1467	1587	7.5	14.9	15.8	279	60
19	29-May-89	1	1430	1378	6.3	14.8	17.3	277	62
20	29-May-89	2	1240	1886				182	
21	30-May-89	3	1480	1607	6.3	13.9	15.5	363	56
22	30-May-89	1	1428	1346	6.3	13.3	15.5	202	62
23	31-May-89	2	1267	1409	6.0	13.2	15.3	217	58
24	31-May-89	3	1458	1598	6.2	13.7	15.6	292	58
25	01-Jun-89	1	1450	1382	6.3	13.2	15.5	167	59
26	01-Jun-89	2							
27	02-Jun-89	3	1511	1652	6.4	13.1	15.2	218	62
28	05-Jun-89	1	1277	1508	5.8	13.3	15.7	235	59
29	05-Jun-89	2	1219	1778	6.4	12.8	15.6	126	59
30	05-Jun-89	3	1411	1558	8.3	14.8	17.4	350	62
31	07-Jun-89	1	1296	1400	6.3	13.7	15.5	187	62
32	07-Jun-89	2	1121	995	8.0	9.4	14.5	114	61
33	07-Jun-89	3	1444	1598	6.9	13.3	15.8	240	60
34	07-Jun-89	1	1282	1445	6.2	13.0	15.0	175	62
35	07-Jun-89	2	1224	1724	9.5	15.3	18.0	190	53
36	08-Jun-89	3	1408	1598	7.4	14.6	16.6	297	61
37	08-Jun-89	1	1282	1436	6.8	13.6	15.7	176	61
38	08-Jun-89	2	1161	1184	15.0	21.1	24.2	156	60
39	08-Jun-89	3	1508	1598	6.5	13.2	15.7	315	57
40	08-Jun-89	1	1298	1387	6.3	13.3	15.6	200	59
41	09-Jun-89	2	1149	1094	15.0	22.0	24.0	145	60
42	09-Jun-89	3	1468	1670	7.5	14.3	16.3	330	62
43	12-Jun-89	1	1416	1458	6.0	12.8	14.8	237	
44	12-Jun-89	2	1206	1796	8.4	15.2	17.2	179	62
45	12-Jun-89	3	1434	1589	6.8	13.8	15.8	293	
46	12-Jun-89	1	1310	1400	6.8	13.8	15.8	234	
47	13-Jun-89	2	1240	1274			23.0	189	
48	13-Jun-89	3	1308	1616	6.6	13.4	15.4	380	
49	13-Jun-89	1	1312	1490	6.5	13.0	15.5	223	
50	13-Jun-89	2	1192	1418	15.7	22.2	24.2	295	
51	14-Jun-89	3	1516	1602	6.3	12.8	14.9	319	59
52	14-Jun-89	1	1311	1440	6.8	13.7	15.8	245	60
53	14-Jun-89	2	1205	1382	7.6	15.2	17.2	194	59
54	14-Jun-89	3	1449	1616	7.0	13.8	15.8	351	62
55	15-Jun-89	1	1366	1562	6.6	12.9	15.0	229	62
56	15-Jun-89	2	1233	1571	6.6	14.3	15.4	223	57
57	15-Jun-89	3	1497	1607	6.8	6.8	15.5	297	54
58	21-Jun-89	2	1263	1625	6.4	13.4	15.4	188	
Average			1341	1475	7.5	14.1	16.8	231	60
Maximum			1516	2156	15.7	22.2	25.0	470	76
Minimum			1121	608	5.7	6.8	13.2	5	52

Table 4.2.6.5

REGENERATION TABLE

THREE CATALYZED TRAPS

	DATE	TRAP No.	TEMP IN Deg F.	TEMP OUT Deg F.	HEATER TIME Min	BLOWER TIME Min	REGEN TIME Min	BUILDUP TIME Min	MAX BP in. H2O
59	05-Jul-89	1	1393	1391	7.0	14.0	16.0	120	45
60	06-Jul-89	2	1328	1598	7.0	14.1	16.2	96	47
61	06-Jul-89	3	1465	1436	6.5	13.3	15.5	190	43
62	06-Jul-89	1	1444	1409	7.2	13.2	15.2	156	
63	06-Jul-89	2	1327	1454	9.8	15.6	18.9	138	49
64	06-Jul-89	3	1424	1337	7.0	15.2	17.1	189	
65	06-Jul-89	1	1449	1418	6.0	13.8	15.8	212	46
66	07-Jul-89	2	1396	1499	7.7	15.9	18.0	193	44
67	09-Jul-89	3	1434	1369	6.8	13.6	15.8	200	46
68	09-Jul-89	1	1451	1463	6.5	13.5	15.5	210	46
69	09-Jul-89	2	1339	1400	8.3	14.3	17.0	175	51
70	09-Jul-89	3	1414	1292	5.8	13.3	15.5	156	46
71	09-Jul-89	1	1425	1346	7.3	15.2	16.3	190	49
72	10-Jul-89	2	1332	1427	6.2	13.1	15.3	184	46
73	10-Jul-89	3	1424	1337	6.8	11.7	13.7	144	49
74	10-Jul-89	1	1449	1463	6.9	14.8	15.8	190	46
75	10-Jul-89	2	1347	1435	7.4	13.3	15.7	176	49
76	10-Jul-89	3	1415	1283	6.8	13.8	15.8	155	47
77	11-Jul-89	1	1431	1359	6.7	13.3	15.8	190	48
78	11-Jul-89	2	1322	1409	7.7	14.3	16.7	164	49
79	11-Jul-89	3	1428	1342	6.2	13.9	15.3	153	48
80	11-Jul-89	1	1419	1346	7.3	14.2	16.2	137	49
81	11-Jul-89	2	1325	1365	7.6	14.6	16.6	148	44
82	11-Jul-89	3	1380	950	5.5	14.6	16.6	156	45
83	12-Jul-89	1	1430	1373	6.8	13.7	15.7	190	
84	12-Jul-89	2	1357	1436	7.8	13.8	16.0	188	
85	12-Jul-89	3	1416	1391	7.0	13.8	15.8	175	44
86	12-Jul-89	1	1428	1283	7.0	14.0	16.0	156	45
87	12-Jul-89	2	1319	1337	7.7	14.4	16.4	140	48
88	12-Jul-89	3	1411	1290	8.5	14.7	16.9	154	47
89	13-Jul-89	1	1427	1382	6.9	14.5	16.7	189	48
90	13-Jul-89	2	1368	1409	7.5	13.5	16.8	176	49
91	13-Jul-89	3	1421	1355	6.8	13.9	15.9	190	48
92	13-Jul-89	1	1422	1238	7.2	13.5	16.0	155	46
93	13-Jul-89	2	1345	1301	7.9	14.7	16.8	129	50
94	13-Jul-89	3	1400	1166	7.1	14.0	16.3	156	47
95	14-Jul-89	1	1397	1400	7.2	14.2	16.2	121	50
96	14-Jul-89	2	1328	1445	7.5	13.5	16.5	172	46
97	17-Jul-89	3	1391	1364	7.1	13.9	16.1	184	50
98	17-Jul-89	1	1440	1562	6.8	13.6	15.8	204	50
99	17-Jul-89	2	1371	1427	7.6	14.3	16.5	159	49
100	17-Jul-89	3	1327	1256	8.1	15.2	17.1	135	42
101	17-Jul-89	1	1347	1342	8.3	15.1	17.5	124	46
102	17-Jul-89	2	1291	1337	14.7	21.7	24.0	97	43
103	18-Jul-89	3	1321	1310	9.0	15.6	17.9	137	49
104	18-Jul-89	1	1439	1427	6.8	13.5	15.6	143	52
105	18-Jul-89	2	1368	1409	6.4	14.2	16.3	128	56
106	18-Jul-89	3	1411	1130	6.9	14.8	16.8	95	50
107	18-Jul-89	1	1409	1243	6.7	13.4	15.7	94	53
108	18-Jul-89	2	1292	1342	14.8	21.8	23.9	106	51
109	19-Jul-89	3	1304	977	8.9	15.7	17.7	94	52
110	19-Jul-89	1	1348	1400	8.1	14.8	17.0	129	49
111	19-Jul-89	2	1300	1292	13.6	19.5	22.5	54	57
112	19-Jul-89	3	1267	1346	15.1	21.8	24.0	90	56
113	19-Jul-89	1	1338	1022	7.9	14.6	16.8	49	55
114	19-Jul-89	2	1174	1310	15.1	22.8	25.0	88	54
115	19-Jul-89	3	1350	743				37	56
116	19-Jul-89	1	1342	1301	7.7	14.3	16.7	96	50
117	19-Jul-89	2	1284	1355	14.7	23.2	25.0	89	51
118	20-Jul-89	3	1352	995	8.2	14.9	17.1	61	56

Table 4.2.6.5(Cont.)

REGENERATION TABLE

THREE CATALYZED TRAPS

	DATE	TRAP No.	TEMP IN Deg F.	TEMP OUT Deg F.	HEATER TIME Min	BLOWER TIME Min	REGEN TIME Min	BUILDUP TIME Min	MAX BP in. H2O
119	20-Jul-89	1	1334	1292	7.2	14.7	17.1	75	57
120	20-Jul-89	2	1239	1306	15.0	21.9	24.1	74	55
121	20-Jul-89	3	1366	1274	7.1	13.6	15.7	111	46
122	20-Jul-89	1	1349	1022	8.1	15.1	17.1	90	53
123	20-Jul-89	2	1361	1382	7.7	14.6	16.6	130	57
124	21-Jul-89	3	1314	1148	7.9	15.5	17.0	91	53
125	21-Jul-89	1	1345	1463	8.1	14.4	16.7	141	52
126	21-Jul-89	2	1345	1310	9.6	15.9	18.7	104	51
127	24-Jul-89	3	1336	1319	7.7	14.6	16.7	142	52
128	24-Jul-89	1	1336	1324	7.3	15.1	17.3	128	50
129	24-Jul-89	2	1302	1386	11.7	18.7	20.9	109	52
130	24-Jul-89	3	1336	1193	7.6	13.4	15.2	142	50
131	25-Jul-89	1	1341	1279	7.8	14.5	16.7	83	56
132	25-Jul-89	2	1122	1058	15.0	22.0	24.7		54
133	25-Jul-89	3	1246	1274	15.0	21.6	24.0	60	53
134	25-Jul-89	1	1338	1130	7.7	14.3	16.7	52	52
135	25-Jul-89	2	1109	1277	15.2	20.7	23.9	53	53
136	25-Jul-89	3	1258	1193	14.8	21.7	24.1	50	51
137	25-Jul-89	1	1350	1121	7.7	13.9	16.9	52	56
138	25-Jul-89	2	1121	1238	14.8	21.7	23.9	50	52
139	25-Jul-89	3	1378	1184	13.3	20.4	23.2	47	55
140	26-Jul-89	1	1346	1355	7.4	14.2	16.4	55	56
141	26-Jul-89	2	1124	1310	15.1	21.8	23.9	54	54
142	26-Jul-89	3	1263	1223	15.0	21.8	23.8	53	53
143	26-Jul-89	1	1342	968	7.9	15.0	17.1	45	52
144	26-Jul-89	2	1297	1292	15.1	21.8	23.9	51	53
145	26-Jul-89	3	1258	833	14.8	21.8	23.7		51
146	26-Jul-89	1	1432	1436	7.4	14.0	16.2	124	56
147	26-Jul-89	2	1371	1337	7.1	13.6	16.0	98	52
148	26-Jul-89	3	1406	1292	6.9	13.5	15.7	105	55
149	27-Jul-89	1	1363	1317	8.2	15.2	17.2	108	52
150	27-Jul-89	2	1301	1373	10.6	17.3	19.4	128	52
151	27-Jul-89	3	1328	1274	6.9	14.8	16.9	103	55
152	27-Jul-89	1	1365	896	8.4	15.2	17.3	90	48
153	27-Jul-89	2	1302	1148	10.3	15.0	19.1	108	55
154	27-Jul-89	3	1327	833	8.3	15.0	17.1		51
155	27-Jul-89	1	1359	932	9.0	13.5	15.5	102	56
156	27-Jul-89	2	1365	1400	9.0	15.7	17.7	94	54
157	27-Jul-89	3	1343	1291	8.2	15.0	17.1	96	49
158	27-Jul-89	1	1353	821	8.6	15.5	17.8	83	52
159	28-Jul-89	2	1304	1321		15.8	18.0	60	
160	28-Jul-89	3		1211		22.0	24.0	90	
Average			1349	1283	9	16	18	123	50
Maximum			1465	1598	15	23	25	212	57
Minimum			1109	743	6	12	14	37	42

Table 4.2.6.6

REGENERATION TABLE

TWO CATALYZED TRAPS

	DATE	TRAP No.	TEMP IN Deg F.	TEMP OUT Deg F.	HEATER TIME Min	BLOWER TIME Min	REGEN TIME Min	BUILDUP TIME Min	MAX BP in. H2O
161	01-Aug-89	1	1371	1283	6.8	14.1	16.1	57	54
162	01-Aug-89	2	1253	1346	8.0	15.1	17.1	91	55
163	02-Aug-89	1	1291	1148	6.8	14.5	16.5	50	56
164	02-Aug-89	2	1143	1243	14.3	21.7	23.7	54	56
165	02-Aug-89	1	1317	1157	7.6	16.3	18.5	62	53
166	02-Aug-89	2	1143	1197	14.0	23.6	25.6		54
167	02-Aug-89	1	1347	1436	7.0	15.8	17.9	102	51
168	02-Aug-89	2	1255	1337	12.7	21.7	23.7	75	55
169	02-Aug-89	1	1340	1274	6.8	15.8	17.8	57	51
170	02-Aug-89	2	1254	1319	8.6	17.5	19.5	45	56
171	02-Aug-89	1	1351	1328	7.3	16.2	18.2	53	51
172	02-Aug-89	2	1203	1427	14.8	23.8	25.9	51	50
173	02-Aug-89	1	1356	1319	7.3	15.6	17.6	83	51
174	02-Aug-89	2	1181	1274	14.8	23.9	25.9	63	50
175	02-Aug-89	1	1352	1310	7.3	15.9	17.9	52	50
176	02-Aug-89	2	1180	1319	14.8	23.9	25.9	57	57
177	03-Aug-89	1	1445	1483	7.7	16.7	18.7	104	
178	03-Aug-89	2	1374	1310	7.7	16.7	18.7	96	
179	03-Aug-89	1	1313	1328	9.1	18.0	20.1	96	43
180	03-Aug-89	2	1295	1202	9.1	17.9	19.9	96	50
181	03-Aug-89	1	1348	1382	9.0	16.3	18.3	68	54
182	04-Aug-89	2	1303	1472	11.5	20.5	22.5	131	47
183	04-Aug-89	1	1357	1346	8.1	17.1	19.1	97	53
184	04-Aug-89	2	1284	1292	10.9	19.8	21.8	95	56
185	04-Aug-89	2	1296	1265	9.1	56.0	58.0	129	57
186	04-Aug-89	1	1431	1409	8.0	15.7	17.7	68	50
187	04-Aug-89	2	1307	1391	9.7	75.8	77.9	106	52
188	04-Aug-89	1	1423	1319	6.3	15.3	17.3	98	50
189	04-Aug-89	2	1353	1265	7.5	16.7	18.8	91	51
190	08-Aug-89	1	1325	1292	7.8	16.5	18.6	65	
191	08-Aug-89	2	1272	1355	14.3	23.0	25.1	144	
Average			1305	1317	9	21	23	81	52
Maximum			1445	1483	15	76	78	144	57
Minimum			1143	1148	6	14	16	45	43

Table 4.2.6.7

BTS Emission Summary
ADB Cycle (gr/bhp-hr)

	Baseline			Non-Catalyzed			Catalyzed		Baseline		
	3"Hg	7"Hg	avg	5 hrs	125 hr	250 hrs	8 hrs	280 hrs	3"Hg	7"Hg	avg
CO	1.15	1.54	1.35	1.38	1.23	1.09	0.19	0.29	0.72	0.94	0.83
NOx	4.77	4.77	4.77	4.49	4.13	4.13	4.00	3.87	4.33	4.21	4.27
THC	0.56	0.54	0.55	0.50	0.53	0.50	0.12	0.12	0.40	0.44	0.42
Total Part.	0.18	0.20	0.19	0.05	0.04	0.04	0.04	0.07	0.15	0.19	0.17

		% Reduction.					% Changes from Baselin		
CO		-3	9	19	86	78	37	39	38
NOx		6	13	13	16	19	9	12	10
THC		9	4	9	78	78	29	19	24
Total Part.		71	78	80	77	62	16	6	10

Table 4.2.6.8
ARB Project : Bus Trap System Performance Summary
Durability Testing

Date	Total System Hours	BP ("h2O)			K			CF1 (F)			CF2 (F)			CF3 (F)			# of Reg.	Total Reg.	Trap Used
		min	max	avg	min	max	avg	min	max	avg	min	max	avg	min	max	avg			
05-May-89	16.5	2.3	57.6	25.3	1.4	4.7	3.5	331	706	539	250	398	301	96	491	185	1	1	1
07-May-89	24.5	0.0	75.8	34.2	2.9	6.2	4.8	272	1482	569	268	666	410	141	555	181	1	2	1,2
08-May-89	31.5	0.0	75.9	27.9	0.5	6.2	3.9	180	798	344	237	764	452	114	1405	351	2	4	1,2,3
09-May-89	36.4	0.0	101.6	20.7	0.4	7.9	2.9	165	1415	438	208	1231	512	38	1368	462	3	7	1,2,3
12-May-89	41.2	0.0	62.7	16.5	1.4	4.8	3.4	330	708	543	185	429	293	53	435	186	0	7	1
15-May-89	54.2	0.0	76.4	25.7	0.2	6.2	3.6		1503			1364			1309		3	10	1,2,3
18-May-89	78.1	2.3	61.2	25.9	1.4	5.5	3.6	245	1407	508	265	614	369	126	1484	434	2	12	3,1,2
19-May-89	83.5	0.0	61.4	24.3	1.1	5.0	3.3	153	454	205	310	1249	504	237	670	475	1	13	2,3
24-May-89	89.4	2.4	60.1	25.4	1.4	5.1	3.5	249	691	480	234	549	346	169	1467	520	1	14	3,1,2
29-May-89	100.4	1.4	61.5	25.9	0.8	5.2	3.6	146	1430	359	232	1246	435	126	689	409	2	16	1,2,3
30-May-89	109.7	2.6	62.1	26.7	1.4	5.3	3.7	174	1428	447	259	660	441	132	1480	351	2	18	1,2,3
31-May-89	118.4	2.2	60.9	25.2	1.2	5.1	3.4	182	696	454	277	1267	391	135	1458	456	2	20	1,2,3
02-Jun-89	133.7	1.9	63.5	26.1	1.1	5.3	3.6	228	681	514	204	591	370	129	1511	412	1	21	1,2,3
05-Jun-89	145.5	1.8	62.6	25.7	1.2	5.4	3.5	144	1301	429	208	1219	413	126	1411	466	3	24	1,2,3
07-Jun-89	164.5	1.2	62.0	25.8	0.9	5.3	3.5	156	1296	397	208	1224	475	134	1444	458	5	29	1,2,3
08-Jun-89	180.7	1.4	62.1	26.7	0.8	5.4	3.6	146	1299	451	144	1161	454	131	1508	433	5	34	1,2,3
09-Jun-89	190.8	1.7	62.5	25.6	0.9	5.2	3.4	141	701	401	241	1149	432	170	1470	514	2	36	1,2,3
12-Jun-89	208.6	1.9	63.2	26.4	1.1	5.2	3.6	148	1419	426	244	1216	454	114	1434	392	4	40	1,2,3
13-Jun-89	227.8	1.5	62.9	25.4	0.8	5.3	3.4	138	1312	399	316	1214	481	163	1457	453	4	44	1,2,3
14-Jun-89	244.8	1.8	62.2	26.4	1.0	5.3	3.6	162	1311	441	196	1205	448	143	1516	452	4	48	1,2,3
15-Jun-89	258.1	2.1	62.2	26.4	1.4	5.3	3.6	177	1366	433	184	1233	457	144	1497	448	3	51	1,2,3
16-Jun-89	263.7	1.1	62.2	27.0	0.7	5.1	3.5	144	1351	367	201	674	402	115	667	289	1	52	1,2,3
21-Jun-89	269.9	2.8	59.3	27.0	1.5	5.1	3.7	161	546	282	297	1263	511	182	678	479	1	53	2,3
06-Jul-89	304.5	1.3	49.6	20.2	0.8	4.3	2.9	193	1449	435	250	1328	442	182	1465	463	4	57	1,2,3
07-Jul-89	309.8	1.5	48.6	19.6	0.9	4.2	2.7	164	591	306	264	1396	485	193	669	493	1	58	1,2,3
09-Jul-89	324.7	1.1	50.5	19.8	0.7	4.3	2.8	205	1451	486	200	1339	411	153	1434	398	5	63	1,2,3
10-Jul-89	340.1	1.2	49.4	20.0	0.9	4.3	2.8	211	1449	443	219	1347	424	174	1424	465	5	68	1,2,3
11-Jul-89	356.3	0.5	49.3	19.9	0.7	4.3	2.8	209	1431	454	224	1325	437	179	1428	444	6	74	1,2,3
12-Jul-89	373.2	0.8	49.4	19.7	0.8	4.3	2.8	205	1428	469	201	1319	388	180	1424	467	6	80	1,2,3
13-Jul-89	390.1	1.2	51.0	19.8	0.7	4.3	2.8	212	1427	450	200	1363	425	179	1421	448	6	86	1,2,3
14-Jul-89	397.5	1.3	49.2	19.7	0.7	4.3	2.8	216	1397	425	268	1328	471	153	654	404	2	88	1,2,3
17-Jul-89	414.3	1.2	50.6	19.8	0.7	4.3	2.7	195	1440	453	202	1377	446	174	1391	430	6	94	1,2,3
18-Jul-89	427.2	0.8	56.2	20.9	0.7	4.3	2.6	208	1439	447	202	1368	443	161	1411	413	6	100	1,2,3
19-Jul-89	440.6	0.0	57.0	24.8	0.5	4.3	2.7	234	1348	461	190	1300	465	184	1350	462	9	109	1,2,3
20-Jul-89	450.6	1.0	57.2	25.1	0.6	4.4	2.8	219	1349	442	138	1361	446	143	1367	430	6	115	1,2,3
21-Jul-89	458.3	0.9	56.2	19.7	0.4	4.4	2.5	225	1345	432	175	1305	358	186	1319	418	3	118	1,2,3
24-Jul-89	466.5	1.0	56.2	21.4	0.8	4.1	2.7	211	1336	426	178	1301	364	185	1336	437	4	122	1,2,3
25-Jul-89	475.0	0.8	56.9	33.8	0.7	4.3	3.0	291	1350	518	212	1121	530	221	1378	589	9	131	1,2,3
26-Jul-89	482.0	0.9	56.9	28.1	0.8	4.3	2.8	196	1432	473	185	1371	463	172	1406	440	9	140	1,2,3
27-Jul-89	496.6	0.2	55.8	21.2	0.7	4.0	2.6	229	1365	483	195	1365	411	186	1343	381	10	150	1,2,3
28-Jul-89	500.6	1.2	55.6	19.6	0.7	4.0	2.5	120	638	241	206	1304	425	118	1299	497	2	152	1,2,3
01-Aug-89	503.8	0.1	55.4	17.9	0.0	3.9	2.6	275	1371	512	280	1253	622				3	155	1,2
02-Aug-89	523.0	0.1	56.9	29.7	0.0	4.7	2.6	215	1356	580	201	1265	556				14	169	1,2
03-Aug-89	536.5	0.0	56.3	18.8	0.0	4.3	2.7	184	1445	492	134	1374	467				6	175	1,2
04-Aug-89	548.4	0.1	61.0	18.3	0.0	4.7	2.6	195	1431	448	145	1353	469				7	182	1,2
08-Aug-89	552.7	0.1	53.3	21.5	0.0	4.3	3.0	200	1325	398	221	1272	502				2	184	1,2

TABLE 4.2.6.9

Catalyzed and Non-Catalyzed Traps
Regeneration Comparison

	3 Non-Catalyzed Traps	3 Catalyzed Traps	2 Catalyzed Traps
Regeneration Time (Minute)			
Average	17	18	23
Maximum	25	25	26
Minimum	13	14	16
Build-Up Time (Minute)			
Average	231	123	81
Maximum	470	212	144
Minimum	114	51	45
Maximum BP (in Hg)	4.8	4.0	4.5
Trap Out Temp.(F)			
Average	1475	1283	1317
Trap In Temp.(F)			
Average	1341	1349	1305

TABLE 4.3.2.1

Trap System Log Sheet

ARB Trap System Demonstration
Trap System Data Log Sheet
SCRTD Bus 8924

Date _____

Hub Meter Reading _____

Engine Meter Reading _____

SCRTD Regeneration Counter Reading _____

DCI Trap System Monitor

Trap 1		Trap 2
	Regenerations	
Heater		Heater
Blower		Ignition

Indication Lamp Status :

Dash

Continuously On _____ Off _____

Engine Compartment

Continuously On _____ Off _____

Trap Error Code _____ K Factor _____

Hardware Repaired/Replaced :

Trap _____

Bus _____

Replaced Data Storage Module (SM716) ? Yes/No

General Comment : _____

Table 4.3.4.1
ARB Trap System Demonstration Project
SCRTD Bus 8924 Trap System Data Summary

Date	Trap 1 Temperatures (C)						Trap 2 Temperatures (C)						Exhaust Temperature (C)			Exhaust Back Pressure (" hg)		
	Inlet			Outlet			Inlet			Outlet								
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
28-Dec-89	120	85	102	104	65	82	61	39	48	39	28	33	165	60	87	1.1	-0.3	0.1
02-Jan-90	797	34	196	390	13	186	307	33	165	307	23	163	376	60	168	7.1	-0.4	1.2
03-Jan-90	273	43	113	263	19	84	272	35	130	272	23	115	293	60	117	5.0	-0.4	0.2
04-Jan-90	96	34	64	52	10	33	183	32	110	178	11	110	248	60	109	2.2	-0.3	0.1
05-Jan-90	425	11	169	417	12	140	399	26	160	415	14	181	436	60	236	8.1	-0.4	2.3
10-Jan-90	446	107	240	436	102	242	88	36	65	60	20	48	458	118	243	9.2	-0.1	2.8
11-Jan-90	151	89	130	105	61	86	396	151	271	403	155	283	419	147	284	9.0	0.1	3.7
12-Jan-90	264	46	189	258	32	187	262	45	187	259	32	190	292	99	207	4.2	0.0	1.4
17-Jan-90	300	20	196	299	19	201	967	112	237	540	19	226	327	124	213	6.7	0.3	1.3
18-Jan-90	914	156	17	770	219	33	252	175	32	247	172	39	298	196	93	6.3	0.0	1.9
19-Jan-90				285	32	178	286	28	180	288	33	176	314	95	179	6.5	-0.5	0.9
23-Jan-90				312	26	188	753	34	201	894	43	210	337	95	195	6.6	-0.2	1.2
24-Jan-90				811	43	195	665	30	160	424	27	156	585	95	197	7.7	-0.1	1.4
25-Jan-90				734	40	223	470	34	204	396	30	200	600	95	268	7.0	-0.3	2.0
26-Jan-90				821	18	184	675	21	171	426	18	156	595	96	282	7.4	0.2	1.5
05-Feb-90				768	65	231	712	49	205	438	52	200	600	95	222	7.1	-0.4	1.5
06-Feb-90				768	18	165	657	19	130	592	16	119	592	95	152	6.8	-0.4	1.0
07-Feb-90				439	29	176	696	37	169	698	29	171	595	95	183	6.6	-0.3	1.5
08-Feb-90	616	25	178	553	35	209	861	31	198	413	25	193	565	95	163	7.0	-0.4	1.5
09-Feb-90	513	16	119	389	34	189	548	32	191	417	29	184	437	95	141	6.9	-0.3	1.4
10-Feb-90	876	10	193	806	13	209	855	17	237	716	14	223	451	95	132	7.2	-0.3	1.7
21-Feb-90	491	59	69	189	66	107	240	115	172	278	78	129	206	95	143	6.4	-0.4	1.6
22-Feb-90	1192	0	106	304	71	153	628	54	155	411	44	140	307	95	168	6.8	0.0	0.6
23-Feb-90	99	0	35	133	73	98	48	31	35	37	28	32	139	95	107	1.7	0.0	0.4
01-Mar-90	129	0	26	135	78	101	56	28	35	44	25	30	144	95	112	2.1	0.0	0.1
02-Mar-90	83	4	47	263	77	158	253	31	166	253	30	156	266	95	163	6.0	0.0	0.9
09-Mar-90	111	0	55	439	53	274	710	119	278	572	114	230	558	95	254	8.2	0.0	2.2
10-Mar-90	0	0	0	89	89	89	158	146	152	130	110	120	98	97	98	5.5	5.4	5.5
11-Mar-90	108	0	48	855	80	226	709	66	217	288	47	178	588	95	207	8.6	0.0	1.4
12-Mar-90	126	0	46	409	80	194	576	35	167	282	22	131	597	95	203	9.2	0.0	1.0
13-Mar-90	81	0	51	273	67	123	268	104	156	259	58	116	272	95	141	6.1	0.0	0.3
14-Mar-90	94	29	52	276	119	188	270	137	184	242	147	179	163	95	109	6.4	0.0	1.4
11-Apr-90	79	29	37	141	0	105	84	0	30	45	0	40	131	95	110	0.0	0.0	0.0
19-Apr-90	351	129	252	771	154	267	63	43	58	499	137	244	571	97	248	8.1	0.0	1.9
21-Apr-90	324	111	223	843	140	246	58	35	45	326	118	197	592	95	235	8.2	0.0	1.7
22-Apr-90	190	105	128	214	143	183	35	31	33	126	113	119	183	97	158	2.5	0.0	0.4
02-May-90	26	26	26	34	34	34	26	26	26	39	39	39	97	97	97	0.6	0.6	0.6
03-May-90	20	19	20	40	35	38	20	18	19	101	34	84	151	95	117	1.6	0.0	0.5
06-May-90	54	21	40	294	34	194	52	21	39	278	35	170	312	95	172	8.0	0.0	1.1
09-May-90	21	19	20	81	32	67	20	19	19	91	31	70	149	95	108	4.6	0.0	0.5
10-May-90	49	17	30	261	33	148	48	17	30	267	33	143	320	95	147	8.8	0.0	0.7
13-May-90	43	19	27	236	36	142	40	19	26	252	34	132	310	96	141	5.8	0.0	0.8
14-May-90	55	19	39	846	35	278	53	18	37	376	34	172	333	96	180	7.5	0.0	1.3
15-May-90	60	20	32	429	22	107	54	19	31	370	22	99	599	96	388	9.6	0.0	0.6
16-May-90	61	17	37	571	30	152	59	16	35	275	22	115	600	95	414	8.6	0.0	0.8
17-May-90	64	17	44	955	22	201	63	16	43	883	20	173	600	95	322	9.6	0.0	1.5
18-May-90	36	17	24	169	21	56	37	17	23	228	20	39	600	138	434	2.3	0.0	0.2
19-May-90	23	15	20	22	15	19	23	15	19	22	15	19	395	365	378	0.0	0.0	0.0
20-May-90	68	18	33	884	18	137	66	17	32	786	18	105	600	96	407	9.4	0.0	0.7
21-May-90	475	21	94	940	25	195	72	19	46	332	23	168	599	96	357	10.5	0.0	1.4
22-May-90	802	35	155	866	105	162	54	19	32	785	34	86	600	95	349	8.3	0.0	1.0
23-May-90	802	26	167	601	35	206	61	18	45	484	29	185	348	95	202	9.4	0.0	
24-May-90	249	19	71	910	57	144	55	17	34	303	35	109	338	95	150	9.4	0.0	0.9
26-May-90	33	16	22	207	31	67	30	15	21	280	18	117	221	95	129	3.3	0.0	0.6
27-May-90	64	16	48	946	32	247	57	15	45	305	21	197	355	95	220	8.5	0.0	1.3
28-May-90	65	22	47	988	82	228	60	21	45	932	38	190	355	95	210	10.2	0.0	1.5

Table 4.3.4.1 (cont'd)
ARB Trap System Demonstration Project
SCRTD Bus 8924 Trap System Data Summary

Date	Trap 1 Temperatures (C)						Trap 2 Temperatures (C)						Exhaust Temperature (C)			Exhaust Back Pressure (" hg)		
	Inlet			Outlet			Inlet			Outlet								
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
29-May-90	43	20	26	257	35	81	40	19	24	665	34	77	300	95	117	5.7	0.0	0.4
25-Jun-90	88	37	70	858	105	229	86	35	70	353	64	201	381	95	212	6.1	0.0	0.9
26-Jun-90	86	34	67	872	51	246	82	33	66	342	39	206	382	96	225	7.4	0.0	1.2
27-Jun-90	76	26	56	868	49	236	73	26	55	804	39	212	363	95	213	8.1	0.0	1.2
28-Jun-90	73	26	58	899	46	253	72	24	57	837	38	218	356	95	226	9.6	0.0	1.4
29-Jun-90	67	23	51	320	38	236	66	22	51	304	31	210	341	95	220	9.0	0.0	1.3
30-Jun-90	56	24	39	391	33	175	57	22	38	381	33	188	376	95	166	10.2	0.0	1.2
01-Jul-90	76	26	58	974	33	250	72	24	57	727	32	204	355	97	225	8.5	0.0	1.2
02-Jul-90	78	24	58	780	44	259	73	23	57	453	38	213	362	95	232	8.6	0.0	1.4
03-Jul-90	74	21	57	1009	37	275	71	21	56	947	31	220	369	95	238	9.6	0.0	1.6
04-Jul-90	75	26	52	928	58	222	73	24	51	322	49	198	359	95	204	9.0	0.0	1.0
05-Jul-90	66	23	46	925	36	202	60	23	45	309	36	155	354	95	188	6.9	0.0	1.0
28-Jul-90	894	49	259	933	36	247	70	22	56	702	34	249	361	95	239			
29-Jul-90	889	36	279	971	32	258	70	21	58	661	37	255	367	102	248			
30-Jul-90	783	55	215	382	49	194	73	25	49	549	45	204	379	95	189			
31-Jul-90	882	45	242	997	35	228	70	22	52	637	34	229	367	95	219			
01-Aug-90	210	80	106	201	74	101	35	21	29	137	49	90	258	95	116			
05-Aug-90	903	78	283	860	67	237	74	25	55	400	55	236	439	95	239			
06-Aug-90	858	63	270	962	49	240	81	26	60	419	37	231	493	95	251			
07-Aug-90	363	59	243	358	50	236	72	25	54	400	35	210	491	95	236			
08-Nov-90	789	88	273	749	83	291	734	78	249	776	71	273	356	109	242	8.2	0.1	1.9
09-Nov-90	785	112	264	813	108	270	756	76	257	802	65	280	391	113	229	8.4	0.1	2.2
12-Nov-90	850	49	277	871	38	294	912	106	281	931	98	314	397	120	244	9.2	-0.1	1.8
13-Nov-90	853	89	271	817	74	291	1062	60	278	1137	45	300	412	124	265	11.2	0.0	3.0
10-Dec-90	637	61	203	767	103	228	326	23	132	331	28	166	358	120	202	8.9	0.0	1.3
11-Dec-90	327	19	179	328	26	154	731	73	150	1164	98	125	369	121	73	11.2	0.1	1.1
03-Jan-91	302	66	182	300	61	184.0	732	45	216	1032			322	120	206	7.3	0.0	1.3
04-Jan-91	1190	-63	229	1371			1228			992			358	120	237	10.9	0.0	2.5
05-Jan-91	345	91	261	454			820			153			339	120	236	5.5	0.0	1.8
06-Jan-91	341	39	240	455			179			915			338	121	238	8.0	0.0	1.8
07-Jan-91	1121			1070			801			159			359	120	242	8.5	0.0	1.6
08-Jan-91	811	14	281	1055			270			113			326	120	229	6.3	0.0	1.5
09-Jan-91	1047			1355			929			654			367	120	243	9.4	0.0	2.0
10-Jan-91	927			610			947			910			324	120	242	6.5	0.0	1.5
11-Jan-91	1009			727			294			271			369	120	244	9.0	0.0	1.8
12-Jan-91	895			343			1327			97			350	122	245	5.6	0.0	2.0
13-Jan-91	1041			477			1130						384	120	251	6.8	0.0	1.7
14-Jan-91	1352			1286			1275			475			351	122	241	8.1	0.0	1.5
15-Jan-91	1303			754			1100			439			353			5.8	0.0	1.4
16-Jan-91	1107			489			1078						336	0	242	5.9	0.0	1.4
17-Jan-91	1010			1152			920	655	812				123	120	122	0.5	0.1	0.3
18-Jan-91	1241						1116			748			351	120	237	6.3	0.0	1.2
19-Jan-91	1204			752			1234			1210			356	124	248	8.2	0.0	1.8
20-Jan-91	1346			1282			1143			638			372	120	249	7.7	0.0	1.7
21-Jan-91	1381						888			445			344	120	234	5.8	0.0	1.4
22-Jan-91	1342						701			694			348	120	247	6.1	0.0	1.4
23-Jan-91	1321			731			693			964			351	122	244	7.5	0.0	1.6
24-Jan-91	1184			867			413			516			355	122	251	9.4	0.1	2.3
01-Feb-91	1164			1174									363	120	249	8.6	0.0	1.6
04-Feb-91	1169			423			800			593			337	120	242	6.6	0.0	1.4
05-Feb-91	1184			991									369	120	238	8.6	0.0	1.7
06-Feb-91	1300												345	120	238	6.4	0.0	1.4
07-Feb-91	930												360	121	251	8.4	0.0	1.7
08-Feb-91	326	45	218	324	33	173	1391			1366	90	277	367	127	260	9.7	0.1	2.6
09-Feb-91	333	111	229	332	109	230	1394			1296	27	287	344	120	225	5.8	0.0	1.5
10-Feb-91																		

Table 4.3.4.1 (cont'd.)
ARB Trap System Demonstration Project
SCRTD Bus 8924 Trap System Data Summary

Date	Trap 1 Temperatures (C)						Trap 2 Temperatures (C)						Exhaust Temperature (C)			Exhaust Back Pressure (" hg)		
	Inlet			Outlet			Inlet			Outlet								
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
11-Feb-91	346	110	240	350	101	241	303	27	248	300	28	228	368	120	233	9.2	0.0	1.5
12-Feb-91	1245	74	198	1062	62	147	325	32	249	328	30	250	354	120	236	9.2	0.0	1.2
13-Feb-91	322	-89	260	318	-24	242	331	112	252	329	106	252	346	120	241	6.6	0.0	1.6
14-Feb-91	329	40	192	324	35	166	1204			1028	105	258	375	120	239	9.1	0.0	1.8
15-Feb-91	342	66	233	338	51	235	429			313	36	224	359	120	228	6.1	0.0	1.3
16-Feb-91	1146	82	204	1046	61	191	670			342	29	237	382	120	236	8.2	0.0	1.5
17-Feb-91																		
18-Feb-91	300	27	229	296	25	194	382			314	100	252	334	122	237	6.6	0.0	1.3
19-Feb-91	307	29	250	305	26	234	293			297	117	238	318	122	228	6.4	0.1	1.6
07-Mar-91	326	40	251	323	32	212	1245			344	24	257	349	90	240	6.2	0.5	1.4
08-Mar-91	326	24	170	323	21	170	1388			1366	43	246	372	90	221	8.4	0.3	1.5
09-Mar-91	168	35	124	166			213	27	118	35	27	30	185	90	117	1.3	0.0	0.3
10-Mar-91																		
11-Mar-91	1179	35	246	1181	35	242	801			311	23	198	356	90	221	7.4	0.2	1.4
12-Mar-91	318	38	156	314	28	120	739			372	31	195	374	90	202	5.6	0.0	1.4
13-Mar-91	312	27	224	311	21	189	604			329	40	227	337	90	213	5.8	0.0	1.3
14-Mar-91	324	39	255	322	27	232	713			320	43	227	327	90	214	6.9	0.0	1.4
15-Mar-91	320	28	143	318	23	111	1393			1289	42	231	357	90	188	9.7	0.0	1.2
16-Mar-91	325	55	219	322	42	218	808			288	22	142	335	90	203	6.0	0.0	1.0
17-Mar-91	334	66	168	334	47	136	964			344	24	191	349	90	208	5.7	0.0	1.0
18-Mar-91	1264	53	266	1141	42	264	909			303	22	202	353	90	231	9.5	0.0	1.7
19-Mar-91	308	23	217	306	20	200	1021			302	33	216	325	90	184	7.2	0.0	1.3
20-Mar-91	321	41	174	319	28	141				1323	70	229	357	90	190	9.0	0.0	1.3
21-Mar-91	329	66	207	228	46	202				280	22	135	333	90	190	5.8	0.0	1.0
22-Mar-91	313	48	232	209	37	229				308	23	224	327	90	214	6.2	0.0	1.1
23-Mar-91	339	32	236	338	31	236				305	30	216	305	30	216	8.9	0.0	1.6
24-Mar-91																		
25-Mar-91	1308	39	216	1223	37	195				326	33	194	355	90	217	9.1	0.0	1.3
26-Mar-91	305	24	203	303	21	180				321	91	205	334	90	192	6.3	0.0	1.0
27-Mar-91	315	22	227	314	18	204				327	33	219	354	91	206	7.9	0.1	1.3
28-Mar-91	339	22	153	338	18	123				1286	41	201	357	90	190	8.9	0.0	1.1
29-Mar-91	289	83	172	290	72	133				330	25	206	341	90	211	6.1	0.0	1.1
30-Mar-91	267	35	160	258	28	122				280	30	139	296	90	131	5.8	0.0	0.5
31-Mar-91	253	37	150	241	30	115				256	35	152	283	90	142	5.2	0.0	0.5
01-Apr-91																		
02-Apr-91																		
03-Apr-91																		
04-Apr-91	312	76	189	310	62	180				311	83	200	320	90	176	2.61	0.00	0.24
05-Apr-91	352	33	178	350	151					333	31	176	357	90	197	5.75	0.00	0.80
06-Apr-91	355	53	229	353	33	194				341	27	210	363	90	218	5.89	0.03	1.04
07-Apr-91	152	55	109	130	35	105				33	30	30	189	91	108	0.48	0.00	0.27
08-Apr-91	349	52	234	350	33	232				329	26	216	363	90	217	7.34	0.02	1.19
09-Apr-91	1233	110	278	1139	102	266				377	63	228	395	90	235	9.43	0.03	1.52
10-Apr-91	321	42	170	323	27	134				1257	36	272	389	91	232	9.27	0.02	1.37
11-Apr-91	317	44	234	310	31	188				338	73	257	351	90	234	5.74	0.01	1.27
12-Apr-91	311	34	255	310	26	223				325	38	230	356	90	218	7.29	0.02	1.21
13-Apr-91	287	33	163	287	26	122				356	39	259	377	90	233	8.36	0.03	1.60
14-Apr-91	312	61	180	309	32	147				343	27	246	354	92	242	5.98	0.03	1.31
15-Apr-91	318	47	269	311	34	241				323	24	247	343	90	228	6.91	0.02	1.17
16-Apr-91	330	48	206	323	30	162				1287	31	260	382	90	234	9.35	0.02	1.85
17-Apr-91	344	52	233	324	31	230				303	38	233	349	90	220	6.64	0.02	1.22
18-Apr-91	359	44	238	353	31	239				321	38	233	349	90	220	6.64	0.02	1.22
19-Apr-91	1202	55	279	1053	36	280				321	27	207	368	90	239	8.56	0.02	1.60
20-Apr-91	340	80	194	339	68	155				336	26	191	350	90	215	5.68	0.00	1.09
21-Apr-91	330	72	230	328	46	192				341	34	216	367	90	193	5.84	0.02	1.02
22-Apr-91	326	38	232	321	27	208				330	26	222	353	90	207	5.97	0.02	1.01
23-Apr-91	319	46	237	311	32	207				329	58	229	352	90	204	8.78	0.01	1.0
24-Apr-91	311	49	204	306	32	167				1233	66	250	373	90	204	8.67	0.03	1..

Table 4.3.4.1 (cont'd.)
ARB Trap System Demonstration Project
SCRTD Bus 8924 Trap System Data Summary

Date	Trap 1 Temperatures (C)						Trap 2 Temperatures (C)						Exhaust Temperature (C)			Exhaust Back Pressure (" hg)		
	Inlet			Outlet			Inlet			Outlet								
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
25-Apr-91	162	44	113	158	32	104				106	27	53	115	90	111	2.70	0.02	0.17
26-Apr-91	320	53	148	317	37	116				341	38	220	353	90	219	5.77	0.02	1.22
27-Apr-91	86	44	77	48	31	46				179	44	144	219	90	136	3.04	0.00	0.24
28-Apr-91	147	50	80	106	43	61				308	37	211	314	90	199	4.51	0.00	1.02
29-Apr-91	413	57	127	317	34	100				772	32	134	290	90	115	4.10	0.02	0.25
30-Apr-91	145	60	87	104	34	65				314	50	243	318	90	226	4.78	0.00	1.11
01-May-91	309	38	181	308	29	164				315	23	158	320	90	231	5.61	0.00	1.41
02-May-91	305	42	189	303	32	145				329	75	237	335	90	222	5.73	0.01	1.54
03-May-91	289	29	251	281	24	224				308	68	243	315	90	223	5.96	0.04	1.49
04-May-91																		
05-May-91																		
06-May-91																		
07-May-91																		
08-May-91	877	32	302	867	18	297				790	40	275	362	0	173	7.30	0.00	2.40
09-May-91	863	75	264	867	56	265				724	79	241	362	90	221	7.31	0.03	1.72
10-May-91	185	38	84	215	32	60				139	84	106	151	90	107	1.71	0.03	0.75
11-May-91																		
12-May-91																		
13-May-91																		
14-May-91																		
15-May-91																		
16-May-91																		
17-May-91																		
18-May-91																		
19-May-91																		
20-May-91																		
21-May-91																		
22-May-91	817	90	253	787	88	245	64	22	46	865	41	260	365	90	231	6.95	0.03	1.80
23-May-91	864	65	266	824	57	261	61	18	42	731	34	242	343	90	215	7.78	0.04	1.77
24-May-91	887	47	266	846	29	264	64	18	49	745	46	274	335	90	234	7.88	0.05	1.91
25-May-91	820	92	294	791	68	299	73	18	50	742	58	277	352	90	240	7.31	0.03	1.89
26-May-91																		
27-May-91																		
28-May-91																		
29-May-91	933	29	240	895	27	233	659	17	88	797	40	256	351	90	223	7.69	0.03	1.84
30-May-91	327	45	211	331	28	185	796	21	226	747	74	283	333	91	219	6.94	0.00	1.77
31-May-91																		
01-Jun-91	181	106	126	180	107	126	180	23	122	138	99	118	180	90	111	2.69	0.04	0.47
02-Jun-91	201	57	126	198	38	125	30	25	27	33	32	32	182	91	112	2.88	0.03	0.58
03-Jun-91	915	46	255	867	33	245	853	18	250	830	30	244	350	90	225	8.33	0.04	1.90
04-Jun-91	797	51	276	777	30	260	802	20	285	757	44	288	363	90	243	6.61	0.04	1.81
05-Jun-91	1158	51	274	1111	34	270	859	20	274	825	32	270	362	91	246	8.56	0.04	2.01
06-Jun-91	887	43	269	865	27	265	815	56	263	768	47	258	349	91	237	8.13	0.03	1.95
07-Jun-91	889	50	247	857	36	232	1082	19	274	1044	72	276	358	90	234	7.76	0.03	1.82
08-Jun-91	203	112	136	209	114	139	182	55	104	237	152	189	222	90	124	1.76	0.04	0.50
09-Jun-91	952	35	261	915	35	253	847	19	248	824	32	249	348	91	234	7.41	0.04	1.80
10-Jun-91	952	35	261	915	35	253	847	19	248	824	32	249	348	91	234	7.41	0.04	1.80
11-Jun-91	822	58	218	792	51	209	805	22	220	802	43	218	351	90	199	7.30	0.03	1.43
12-Jun-91	863	52	265	844	31	258	854	21	276	830	32	274	344	90	242	7.60	0.03	1.78
13-Jun-91	843	63	277	838	38	272	845	18	262	831	48	288	351	90	252	7.45	0.03	2.04
14-Jun-91	852	63	203	828	47	196	779	23	159	728	42	188	317	90	167	8.03	0.03	1.14
15-Jun-91																		
16-Jun-91																		
17-Jun-91																		
18-Jun-91																		
19-Jun-91																		
20-Jun-91																		
21-Jun-91																		
22-Jun-91																		
23-Jun-91																		
24-Jun-91																		
25-Jun-91																		

Table 4.3.4.1 (cont'd.)
ARB Trap System Demonstration Project
SCRTD Bus 8924 Trap System Data Summary

Date	Trap 1 Temperatures (C)						Trap 2 Temperatures (C)						Exhaust Temperature (C)			Exhaust Back Pressure (" hg)		
	Inlet			Outlet			Inlet			Outlet								
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
26-Jun-91																		
27-Jun-91																		
28-Jun-91																		
29-Jun-91																		
30-Jun-91																		
01-Jul-91																		
02-Jul-91																		
03-Jul-91																		
04-Jul-91																		
05-Jul-91																		
06-Jul-91																		
07-Jul-91																		
08-Jul-91																		
09-Jul-91																		
10-Jul-91				317	62	114				826	62	243	364	90	214	7.14	0.03	1.01
11-Jul-91				321	42	145				332	30	189	348	90	196	5.72	0.01	0.90
12-Jul-91				337	48	174				348	31	212	374	90	198	5.85	0.00	0.99
13-Jul-91				99	41	54	30	20	23	185	31	134	200	90	128	2.20	0.03	0.30
14-Jul-91																		
15-Jul-91																		
16-Jul-91																		
17-Jul-91																		
18-Jul-91																		
19-Jul-91																		
20-Jul-91																		
21-Jul-91																		
22-Jul-91																		
23-Jul-91																		
24-Jul-91																		
25-Jul-91				327	69	202				318	33	193	335	100	197	6.17	0.03	0.94
26-Jul-91				331	79	220				326	36	240	340	100	228	6.72	0.03	1.16
27-Jul-91				338	87	226				336	31	264	353	100	239	8.55	0.03	1.34
28-Jul-91				484	83	222				340	37	192	374	102	215	7.80	0.02	1.24
29-Jul-91				324	94	216				334	38	243	350	101	222	6.08	0.03	1.09
30-Jul-91				322	46	214				325	59	231	352	100	213	6.97	0.03	1.17
31-Jul-91				319	33	190				354	84	243	372	100	221	7.19	0.03	1.32
01-Aug-91				307	32	115				355	71	235	376	101	218	8.21	0.03	1.47
02-Aug-91				343	66	245				826	42	255	374	100	233	8.20	0.03	1.19
03-Aug-91				333	77	247				313	31	255	343	101	233	7.14	0.03	1.36
04-Aug-91																		
05-Aug-91																		
06-Aug-91																		
07-Aug-91																		
08-Aug-91																		
09-Aug-91																		
10-Aug-91				290	153	238				303	149	235	314	100	215	5.97	0.03	1.32
11-Aug-91				200	42	113				136	36	85	246	100	132	4.18	0.03	0.28
12-Aug-91				312	34	129				338	37	179	363	100	167	6.19	0.03	0.70
13-Aug-91				451	33	242				814	55	284	393	100	258	8.15	0.04	1.69
14-Aug-91				465	48	258				338	60	224	390	100	258	7.97	0.03	1.63
15-Aug-91				380	58	238				347	38	235	385	100	235	7.60	0.03	1.38
16-Aug-91				442	45	208				366	43	223	375	100	217	8.10	0.03	1.23
17-Aug-91				355	88	251				331	39	253	367	100	247	8.47	0.03	1.43
18-Aug-91				285	42	143				309	38	94	328	100	145	5.90	0.03	0.54
19-Aug-91				431	50	224				380	39	237	384	100	219	9.76	0.03	1.34
20-Aug-91				373	95	199				790	96	268	382	100	268	10.19	0.01	1.62
21-Aug-91				382	62	230				342	46	236	393	100	228	8.76	0.03	1.33
22-Aug-91				156	91	122				101	35	61	170	100	121	5.37	0.03	1.
23-Aug-91				168	61	116				123	33	56	171	100	114	1.38	0.32	
24-Aug-91				385	81	258				290	35	141	392	100	245	9.16	0.02	1.74
25-Aug-91				489	43	277				353	34	258	383	100	260	8.83	0.04	1.84
26-Aug-91				465	68	252				352	34	233	390	100	233	9.73	0.03	1.52

Table 4.3.4.1 (cont'd.)
ARB Trap System Demonstration Project
SCRTD Bus 8924 Trap System Data Summary

Date	Trap 1 Temperatures (C)						Trap 2 Temperatures (C)						Exhaust Tomperature (C)			Exhaust Back Pressure (" hg)		
	Inlet			Outlet			Inlet			Outlet								
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
27-Aug-91				424	59	276				351	34	195	396	100	260	9.25	0.03	1.83
28-Aug-91				435	78	216				341	44	215	370	100	219	8.65	0.03	1.39
29-Aug-91				356	47	211				316	32	185	362	100	219	8.25	0.03	1.33
30-Aug-91				450	68	270				338	35	269	379	100	254	8.80	0.04	1.53
31-Aug-91				343	78	261				334	36	264	358	101	250	9.15	39.00	1.44
01-Sep-91				317	36	170				320	71	174	330	100	165	6.25	0.03	0.86
02-Sep-91																		
03-Sep-91																		
04-Sep-91				322	60	194				348	35	258	364	100	242	7.70	0.03	1.51
05-Sep-91				477	20	20				879	33	204	391	100	207	10.09	0.02	3.32
06-Sep-91				372	45	212				332	64	241	380	100	229	9.48	0.03	1.72
07-Sep-91				439	45	203				879	52	254	388	100	231	10.09	0.03	1.72
08-Sep-91				187	40	129				151	34	47	229	10	128	3.34	0.03	0.36
09-Sep-91				336	80	218				292	41	229	339	100	209	8.49	0.02	1.53
10-Sep-91				477	20	201					336	33	391	100	208	9.52	0.02	3.20
11-Sep-91				379	68	258				305	54	217	391	100	244	9.52	0.04	1.77
12-Sep-91				477	72	235				318	53	230	370	100	221	9.06	0.03	1.28
13-Sep-91				326	50	178				311	33	157	342	100	189	8.49	0.02	2.39
14-Sep-91				326	50	160				311	34	165	342	100	165	8.49	0.03	0.84
15-Sep-91				166	65	109				108	54	97	172	100	114	4.22	0.03	0.46
16-Sep-91																		
17-Sep-91																		
18-Sep-91																		
19-Sep-91																		
20-Sep-91																		
21-Sep-91																		
22-Sep-91																		
23-Sep-91																		
24-Sep-91	835	49	227	1072	36	273	770	90	247	823	83	270	397	100	239	9.04	0.03	1.86
25-Sep-91	903	95	232	1179	78	255	880	77	248	1021	65	282	392	100	226	9.27	0.03	1.57
26-Sep-91	794	75	270	925	65	295	920	96	285	1074	74	303	410	115	263	8.54	0.03	1.98
27-Sep-91	735	66	225	813	67	246	911	79	246	1048	78	261	394	100	227	9.56	0.03	1.72
28-Sep-91	813	80	255	969	68	272	874	63	268	977	54	299	395	100	242	8.48	0.04	1.78
29-Sep-91	851	55	245	1016	36	273	823	76	237	877	57	247	378	100	227	8.65	0.03	1.45
30-Sep-91	149	85	116	152	82	117	146	73	111	149	62	111	159	100	114	1.17	0.03	0.26
01-Oct-91	825	89	249	963	91	265	799	83	249	850	77	261	376	100	225	9.43	0.04	1.60
02-Oct-91	763	72	246	835	63	265	895	88	254	1024	84	276	408	100	231	8.25	0.03	1.76
03-Oct-91	1414			1410			977	75	213	1185	61	238	423	100	210	11.06	0.04	1.65
04-Oct-91							825	80	239	866	76	252	352	100	216	7.59	0.02	1.22
05-Oct-91							859	80	261	913	69	275	368	100	234	8.24	0.03	1.51
06-Oct-91							280	86	156	281	76	163	293	100	122	4.69	0.03	0.52
07-Oct-91																		
08-Oct-91							923	75	240	1049	56	251	379	100	218	9.06	0.04	1.55
09-Oct-91							854	81	255	921	82	272	385	100	236	8.22	0.04	1.72
10-Oct-91							873	91	247	933	69	264	367	100	225	7.23	0.04	1.34
11-Oct-91							978	83	265	1199	71	286	404	100	241	8.84	0.03	1.52
12-Oct-91							867	101	247	942	110	259	366	100	216	7.58	0.04	1.35
13-Oct-91																		
14-Oct-91																		
15-Oct-91																		
16-Oct-91																		
17-Oct-91																		
18-Oct-91							935	155	278	1101	168	311	395	100	245	8.66	0.04	1.66
19-Oct-91							894	54	268	1008	47	280	386	100	239	7.86	0.04	1.51
20-Oct-91							822	88	276	872	73	291	403	100	250	8.73	0.04	1.66
21-Oct-91							129	55	107	134	39	107	148	101	110	1.45	0.04	0.56
22-Oct-91																		
23-Oct-91							859	91	278	922	85	296	396	101	254	8.14	0.04	1.94
24-Oct-91							775	80	254	835	67	269	378	100	241	8.98	0.04	1.81
25-Oct-91							900	53	245	992	61	258	392	100	231	9.09	0.03	1.89
26-Oct-91							761	85	244	798	73	253	336	100	212	7.89	0.04	1.46
27-Oct-91							847	84	259	909	76	272	332	100	231	6.56	0.06	1.74

Table 4.3.4.1 (cont'd.)
ARB Trap System Demonstration Project
SCRTD Bus 8924 Trap System Data Summary

Date	Trap 1 Temperatures (C)						Trap 2 Temperatures (C)						Exhaust Temperature (C)			Exhaust Back Pressure (" hg)		
	Inlet			Outlet			Inlet			Outlet								
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
28-Oct-91							741	98	192	787	98	197	337	100	169	7.43	0.06	1.31
29-Oct-91								27	195	908	28	204	359	100	201	9.00	0.04	1.42
30-Oct-91							964	48	255	1163	44	278	385	100	227	9.34	0.03	1.69
31-Oct-91							876	98	236	952	98	249	357	100	217	8.84	0.05	1.57
01-Nov-91																		
02-Nov-91																		
03-Nov-91																		
04-Nov-91																		
05-Nov-91																		
06-Nov-91																		
07-Nov-91																		
08-Nov-91																		
09-Nov-91																		
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12-Nov-91																		
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14-Nov-91																		
15-Nov-91																		
16-Nov-91																		
17-Nov-91																		
18-Nov-91																		
19-Nov-91																		
20-Nov-91																		
21-Nov-91																		
22-Nov-91																		
23-Nov-91																		
24-Nov-91																		
25-Nov-91	318	111	229	452	105	231	322	69	205	325	65	206	335	122	216	5.86	0.16	1.70
26-Nov-91	815	72	279	877	58	281	811	69	272	849	57	283	361	122	253	7.25	0.14	2.07
27-Nov-91	786	65	273	836	54	277	803	114	261	833	111	269	357	120	243	7.90	0.03	2.04
28-Nov-91	815	124	286	795	118	294	776	112.6	270.5	852	114	275	367	121	255	8.47	0.06	2.04
29-Nov-91	796	125	267	832	125	273	765	28	259	828	30	266	348	120	242	8.26	0.12	2.10
30-Nov-91	793	118	274	815	113	278	779	39	267	838	43	274	366	120	243	7.95	0.08	1.85
01-Dec-91	145	70	91	131	46	68	225	114	137	225	113	140	236	120	142	4.95	0.15	0.95
02-Dec-91	802	22	258	861	18.7	255	761	91	236	803	74	245	347	120	223	7.76	0.05	1.72
03-Dec-91	143	25	54	121	19	42	219	111	140	230	107	142	244	120	142	5.27	0.19	0.90
04-Dec-91																		
05-Dec-91																		
06-Dec-91																		
07-Dec-91																		
08-Dec-91																		
09-Dec-91																		
10-Dec-91																		
11-Dec-91																		
12-Dec-91																		
13-Dec-91																		
14-Dec-91																		
15-Dec-91																		
16-Dec-91	185	87	138	182	73	134	722	97	256	727	107	255	218	120	139	5.39	0.29	0.66
17-Dec-91																		
18-Dec-91	833	68	274	891	44	278	838	59	277	874	48	287	359	121	250	7.73	0.03	1.79
19-Dec-91	787	79	273	814	53	272	761	60	266	795	65	276	365	120	244	8.45	0.14	2.27
20-Dec-91	780	116	290	795	110	291	749	42	273	794	49	282	381	120	249	8.23	0.14	2.10
21-Dec-91																		
22-Dec-91																		
23-Dec-91	806	113	290	835	110	294	770	62	279	818	57	290	384	120	249	8.04	0.10	1.69
24-Dec-91	785	64	262	799	55	266	771	58	258	821	41	270	386	121	238	8.05	0.22	1.95
25-Dec-91																		
26-Dec-91	270	52	162	261	33	156	261	95	164	268	94	164	277	121	167	5.26	0.31	

Table4.3.4.2
SCRTD Bus 8924 Mileage Summary Sheet

WK #	Date Week Ending	Weekly Mileage Data: Average In-Service Miles	Average In-Service Hours	Average Weekly # of Regenerations Trap 1	Trap 2	Total	Miles Per Regeneration	Hours Per Regeneration	COMMENTS	Cumulative Mileage Data: Cumulative Service Miles	Cumulative Service Hours	Cumulative Service mph	Cumulative # of Regenerations Trap 1	Trap 2	Toatal	Miles Per Regeneration	Hours Per Regeneration
1	30-Dec-90																
2	06-Jan-91	190	6			2.7	70	2		190	6	30.6			2.7	70	2
3	13-Jan-91	595	21			2.1	283	10		785	27	28.8			4.8	163	6
4	20-Jan-91	1917	145			15.2	126	10		2702	172	15.7			20.0	135	9
5	27-Jan-91	261	25			3.3	80	8		2963	197	15.1			23.3	127	8
6	03-Feb-91	261	25			4.7	56	5		3224	222	14.5			27.9	115	8
7	10-Feb-91	485	25			5.6	87	5		3710	247	15.0			33.5	111	7
8	17-Feb-91	244	25			2.2	110	11		3953	272	14.5			35.7	111	8
9	24-Feb-91	244	3			3.3	74	1		4197	275	15.2			39.0	108	7
10	03-Mar-91	244	3			4.0	61	1		4441	278	16.0			43.0	103	6
11	10-Mar-91	863	10			4.0	216	3		5304	288	18.4			47.0	113	6
12	17-Mar-91	863	10			2.0	432	5		6167	298	20.7			49.0	126	6

Table 4.3.4.2 (cont'd.)
SCRTD Bus 8924 Mileage Summary

Date WK ending	Weekly Mileage Data Miles	Hours	mph	TOTAL Regens	Miles Per Regeneration	Hours Per Regeneration	Cumulative Mileage Data Miles	Hours	mph	TOTAL Regens	Miles Per Regeneration	Hours Per Regeneration	COMMENTS
24-Mar-91	765	438.2	1.7	4.2	181	103.9							
31-Mar-91	725	5.9	122.5	4.3	168	1.4	9550	2086.0		92.0	104	23	
07-Apr-91	743	60.1	12.4	3.6	206	16.6	10293	2146.1	4.8	95.6	108	22	
14-Apr-91	746	69.1	10.8	3.5	213	19.8	11040	2215.2	5.0	99.1	111	22	
21-Apr-91	776	70.8	11.0	5.5	142	13.0	11816	2286.0	5.2	104.6	113	22	
28-Apr-91	673	61.4	11.0	17.8	38	3.4	12489	2347.3	5.3	122.4	102	19	
05-May-91	390	35.5	11.0	6.0	65	5.9	12879	2382.8	5.4	128.4	100	19	
12-May-91	159	21.0	7.6	9.6	17	2.2	13038	2403.8	5.4	138.0	94	17	Campbell off 11-21, Batt chn
19-May-91	175	28.0	6.3	11.5	15	2.4	13213	2431.8	5.4	149.5	88	16	
26-May-91	619	47	13.2	31.9	19	1.5	13832	2478.6	5.6	181.4	76	14	No Data Jun 26-28/91
02-Jun-91	665	51	13.2	27.7	24	1.8	14497	2529.1	5.7	209.1	69	12	
09-Jun-91	705	64	11.1	22.5	31	2.8	15202	2592.8	5.9	231.6	66	11	
16-Jun-91	705	64	11.1	22.5	31	2.8	15907	2656.5	6.0	254.2	63	10	
23-Jun-91	631	62	10.2	18.9	33	3.3	16538	2718.4	6.1	273.1	61	10	
30-Jun-91	619	62	10.0	18.3	34	3.4	17156	2780.0	6.2	291.4	59	10	
07-Jul-91	619	62	10.0	18.3	34	3.4	17775	2841.6	6.3	309.8	57	9	
14-Jul-91	387	36	10.8	3.4	114	10.5	18162	2877.4	6.3	313.2	58	9	
21-Jul-91	719	69	10.4	0.0	719	69.0	18881	2946.4	6.4	313.2	60	9	
28-Jul-91	867	84	10.3	1.0	867	84.0	19748	3030.4	6.5	314.2	63	10	No trap data,July 15-25
04-Aug-91	865	83	10.4	0.4	2059	197.4	20613	3113.3	6.6	314.6	66	10	
11-Aug-91	855	76	11.2	2.9	291	26.0	21467	3189.6	6.7	317.5	68	10	
18-Aug-91	855	76	11.2	2.9	291	26.0	22322	3265.9	6.8	320.5	70	10	No Successful Regenerations
25-Aug-91	767	69	11.1	12.9	60	5.4	23088	3335.0	6.9	333.4	69	10	
01-Sep-91	649	60	10.9	26.1	25	2.3	23737	3394.5	7.0	359.5	66	9	
08-Sep-91	590	53	11.1	15.2	39	3.5	24327	3447.4	7.1	374.6	65	9	
15-Sep-91	511	44	11.6	0.6	912	78.8	24838	3491.5	7.1	375.2	66	9	Cores/Elements/TC's Replace
22-Sep-91	543	50	10.8	61.8	9	0.8	25381	3541.9	7.2	437.0	58	8	
29-Sep-91	585	59	10.0	143.5	4	0.4	25966	3600.7	7.2	580.5	45	6	

Table 4.3.4.2 (cont'd.)
SCRTD Bus 8924 Mileage Summary

Date WK ending	Weekly Mileage Data Miles	Hours	mph	TOTAL Regens	Miles Per Regeneration	Hours Per Regeneration	Cumulative Mileage Data Miles	Hours	mph	TOTAL Regens	Miles Per Regeneration	Hours Per Regeneration	COMMENTS
06-Oct-91	454	41	11.1	45.7	10	0.9	26420	3641.5	7.3	626.2	42	6	
13-Oct-91	402	34	12.0	6.5	62	5.2	26822	3675.1	7.3	632.7	42	6	Kip Valve Leak
20-Oct-91	774	69	11.2	14.2	54	4.9	27596	3744.2	7.4	646.9	43	6	
27-Oct-91	791	71	11.1	14.8	53	4.8	28387	3815.6	7.4	661.7	43	6	
03-Nov-91	852	80	10.7	30.4	28	2.6	29239	3895.1	7.5	692.0	42	6	
10-Nov-91	677	70	9.7	63.0	11	1.1	29916	3965.1	7.5	755.0	40	5	
17-Nov-91	387	40	9.7	36.0	11	1.1	30303	4005.1	7.6	791.0	38	5	
24-Nov-91	0	0	0.0	0.0	0	0	30303	4005.1	7.6	791.0	38	5	Out of Service,Emiss. Testing
01-Dec-91	677	70	9.7	63.0	11	1.1	30980	4075.1	7.6	854.0	36	5	
08-Dec-91	193	20	9.7	18.0	11	1.1	31173	4095.1	7.6	872.0	36	5	Bus Out of Service
15-Dec-91	0	0	0.0	0.0	0	0.0	31173	4095.1	7.6	872.0	36	5	Bus Out of Service
22-Dec-91	151	18	8.6	33.0	5	0.5	31324	4112.7	7.6	905.0	35	5	
29-Dec-91	226	26	8.6	49.4	5	0.5	31550	4139.1	7.6	954.4	33	4	
05-Jan-92	263.9	30.8	8.6	57.68	5	0.5	31814	4169.9	7.6	1012.1	31	4	

TABLE 4.3.4.3

ARB Trap System Demonstration Project
Trap operation during Engine Power Curve Generation
June 17, 1991

Engine Conditions		Temperatures					Back Pressure
		Trap 1		Trap 2		Exhaust	
RPM	HP	In	Out	In	Out		in. Hg
650	0	100	102	28	49	103	0.66
650	0	205	205	30	46	205	0.26
650	0	225	229	30	46	233	3.82
650	0	243	244	41	239	250	2.24
650	0	266	266	44	253	270	2.57
650	0	266	267	45	262	270	2.31
2100	40	284	282	50	276	289	2.26
2100	40	307	308	60	308	311	2.28
2100	40	328	329	52	311	342	5.08
2100	40	341	342	53	311	354	5.28
2100	40	370	375	54	388	378	4.15
2100	40	377	381	54	306	382	3.86
1800	103	316	317	53	316	318	2.34
2100	0	264	274	53	271	258	2.36
2100	61	268	269	52	270	277	2.6
2000	83	254	254	54	283	283	2.52
Idle		289	301	59	310	259	0.82
Idle				50	202	158	0.21
Idle					187	182	
1650	106	323					
1500		356					
1500		363					
1400		364					
Idle		746	372	59	204	186	0.211
Regeneration Profile							
Idle		731	422				
Idle		728	448				
Idle		716	516				
Idle		715	555				
Idle		687	726				
Idle		560	717	52	181	153	0.54
Idle		554	717			146	0.37
Idle		548	716				
Idle		463	683	52	135	129	0.37
Idle		468	609				

TABLE 4.3.4.3 (cont'd.)

ARB Trap System Demonstration Project
Trap operation during Engine Power Curve Generation
June 18, 1991

Engine Conditions		Temperatures					Back Pressure
		Trap 1		Trap 2		Exhaust	
RPM	HP	In	Out	In	Out		in. Hg
Warmup		91	84	97	97	103	0.501
		89	77	26	148	125	0.5
		89	76	26	135	121	0.59
1500	20	100	85	30	227		3.3
		100	84		267	277	
Idle		98	78	107	288	229	0.78
2100		283	280		287	300	2.58

TABLE 4.3.5.1

Proposed Emission Test Procedure at ARB

(1) Filtered exhaust emissions from Trap 1 (2 transient cycles).

(2) Regeneration emissions from Trap 1.

(3) Filtered exhaust emissions from Trap 1 (2 cycles).

(4) Regeneration exhaust emissions from Trap 1.

(5) Filtered exhaust emissions from Trap 2 (2 cycles).

(6) Regeneration emissions from Trap 2.

(7) Filtered exhaust emissions from Trap 2 (2 cycles).

(8) Regeneration exhaust emissions from Trap 2.

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Table 4.3.5.2
ARB 8-Mode Chassis-Dyno Cycle
SCRTD Trap Bus 8924 (DDC 6V92TA 240 HP)
Emission Testing Results of Trap 1 (Jan 10, 1990)

Mode #	Actual rpm	Road HP	ft-lb	Road Speed (mph)	Engine BP ("hg)	Exhaust Temp (C)	Trap 1 (Opened) Inlet (C)	Trap 1 (Opened) Outlet (C)	Trap 2 (Closed) Inlet (C)	Trap 2 (Closed) Outlet (C)
1	617	0	0	0.0	0.6	192	213	243	74	57
2	2105	129	322	40.2	8.5	337	328	324	86	60
3	2104	85	212	40.3	7.5	305	299	296	99	63
4	617	0	0	0.0	0.6	209	215	229	103	66
5	1300	144	582	24.7	5.0	426	411	404	107	71
6	1327	111	439	25.2	4.4	383	370	361	110	78
7	1307	74	297	24.9	3.7	319	308	301	114	88
8	1302	45	182	24.9	3.1	269	261	257	116	92
Average	1335	74	254	22.5	4.2	305	301	302	101	72

Mode	Baseline Emission(gr/hr)				Trap 1 Only Emission(gr/hr)			
#	Part	NOX	CO	THC	Part	NOX	CO	THC
1	0.07	5.3	1.5	0.7	0.02	6.7	0.1	0.2
2	5.14	95.0	16.0	8.4	1.03	126.3	3.8	2.2
3	5.01	70.6	16.0	8.4	2.13	93.8	4.1	2.4
4	0.12	8.8	1.6	1.1	0.04	10.1	0.2	0.4
5	6.87	134.4	101.7	6.8	2.41	142.5	7.7	0.9
6	3.59	101.5	23.8	6.1	1.13	108.0	2.7	1.0
7	2.97	59.8	9.3	5.2	0.53	65.8	1.7	0.9
8	1.88	41.8	7.3	4.6	0.25	42.8	1.3	1.0
Average	3.21	64.6	22.2	5.2	0.94	74.5	2.7	1.1
gr/hp-hr	0.31	6.29	2.12	0.50	0.09	7.24	0.26	0.11
Regeneration Emission (gr)								

Mode	Trap 1 Emission (gr/hr) Including Regeneration Emission				% Emission Reduction			
#	Part	NOX	CO	THC	Part	NOX	CO	THC
1	0.02	6.7	0.1	0.2	71	-26	93	70
2	1.03	126.3	3.8	2.2	80	-33	76	74
3	2.13	93.8	4.1	2.4	57	-33	74	71
4	0.04	10.1	0.2	0.4	68	-15	88	63
5	2.41	142.5	7.7	0.9	65	-6	92	87
6	1.13	108	2.7	1	68	-6	89	84
7	0.53	65.8	1.7	0.9	82	-10	82	83
8	0.25	42.8	1.3	1	87	-2	82	78
Average	0.94	74.5	2.7	1.13	71	-15	88	78
gr/hp-hr	0.09	7.24	0.26	0.11				

Table 4.3.5.3
ARB 8-Mode Chassis-Dyno Cycle
SCRTD Trap Bus 8924 (DDC 6V92TA 240 HP)
Emission Testing Results of Trap 2 (Jan 11, 1990)

Mode	Actual	Road		Road	Engine	Exhaust	Trap 1 (Closed)		Trap 2 (Opened)	
	rpm	HP	ft-lb	Speed	BP	Temp	Inlet	Outlet	Inlet	Outlet
#				mph	("hg)	(C)	(C)	(C)	(C)	(C)
1	620	0	0	0.0	0.5	167	90	62	181	203
2	2120	127	315	40.6	8.4	331	103	76	320	320
3	2105	85	212	40.3	7.3	302	134	81	295	295
4	599	0	0	0.0	0.6	211	143	80	222	222
5	1302	145	585	24.7	4.8	416	134	86	390	390
6	1316	111	443	25.0	4.1	372	140	93	269	269
7	1314	77	308	25.1	3.4	315	150	100	301	301
8	1292	45	183	24.8	2.9	262	150	103	251	251
Average	1334	74	256	22.6	4.0	297	131	85	279	281

Mode	Baseline Emission (gr/hr)				Trap 2 Only Emission (gr/hr)			
#	Part	NOX	CO	THC	Part	NOX	CO	THC
1	0.07	5.3	1.5	0.7	0.01	8.2	0.3	0.2
2	5.14	95.0	16.0	8.4	1.07	127.7	4.5	2.3
3	5.01	70.6	16.0	8.4	0.75	84.1	4.2	1.9
4	0.12	8.8	1.6	1.1	0.04	9.5	0.3	0.2
5	6.87	134.4	101.7	6.8	2.31	142.4	11.5	1.0
6	3.59	101.5	23.8	6.1	0.87	114.2	3.8	0.9
7	2.97	59.8	9.3	5.2	0.44	73.1	2.1	0.9
8	1.88	41.8	7.3	4.6	0.23	47.6	1.8	1.1
Average	3.21	64.6	22.2	5.2	0.7	75.9	3.6	1.1
gr/hp-hr	0.31	6.29	2.12	0.50	0.07	7.35	0.34	0.10
Regeneration Emission (gr)								

Mode	Trap 2 Emission (gr/hr) Including Regeneration Emission				% Emission Reduction			
#	Part	NOX	CO	THC	Part	NOX	CO	THC
1	0.01	8.2	0.3	0.2	86	-55	80	70
2	1.07	127.7	4.5	2.3	79	-34	72	73
3	0.75	84.1	4.2	1.9	85	-19	74	77
4	0.04	9.5	0.3	0.2	68	-8	82	81
5	2.31	142.4	11.5	1	66	-6	89	85
6	0.87	114.2	3.8	0.9	76	-13	84	85
7	0.44	73.1	2.1	0.9	85	-22	78	83
8	0.23	47.6	1.8	1.1	88	-14	75	76
Average	0.72	75.85	3.5625	1.0625	**78**	**-17**	**84**	**79**
gr/hp-hr	0.07	7.35	0.34	0.10				

Table 4.3.5.4
ARB 8-Mode Chassis-Dyno Cycle
SCRTD Trap Bus 8924 (DDC 6V92TA 240 HP)
Averaged Emission Results (Jan 10+11, 1990)

Mode #	Actual rpm	Road HP	ft-lb	Road Speed mph	Engine BP ("hg)	Exhaust Temp (C)	Trap 1 (Opened) Inlet (C)	Trap 1 (Opened) Outlet (C)	Trap 2 (Opened) Inlet (C)	Trap 2 (Opened) Outlet (C)
1	619	0	0	0.0	0.5	180	213	243	181	203
2	2113	128	318	40.4	8.4	334	328	324	320	320
3	2105	85	212	40.3	7.4	304	299	296	295	295
4	608	0	0	0.0	0.6	210	215	229	222	222
5	1301	145	583	24.7	4.9	421	411	404	390	390
6	1322	111	441	25.1	4.3	378	370	361	269	269
7	1311	76	303	25.0	3.6	317	308	301	301	301
8	1297	45	182	24.9	3.0	266	261	257	251	251
Average	1334	74	255	22.5	4.1	301	301	302	279	281

Mode #	Baseline Emission (gr/hr) Part	NOX	CO	THC	Combined Average Emission (gr/hr) Part	NOX	CO	THC
1	0.07	5.3	1.5	0.7	0.02	7.5	0.2	0.2
2	5.14	95.0	16.0	8.4	1.05	127.0	4.2	2.3
3	5.01	70.6	16.0	8.4	1.44	89.0	4.2	2.2
4	0.12	8.8	1.6	1.1	0.04	9.8	0.3	0.3
5	6.87	134.4	101.7	6.8	2.36	142.5	9.6	1.0
6	3.59	101.5	23.8	6.1	1.00	111.1	3.3	1.0
7	2.97	59.8	9.3	5.2	0.49	69.5	1.9	0.9
8	1.88	41.8	7.3	4.6	0.24	45.2	1.6	1.1
Average	3.21	64.6	22.2	5.2	0.83	75.2	3.1	1.1
gr/hp-hr	0.31	6.29	2.12	0.50	0.08	7.30	0.30	0.11
Regeneration Emission (gr)								

Mode #	Combined Trap Emission (gr/hr) Including Regeneration Emission Part	NOX	CO	THC	% Emission Reduction Part	NOX	CO	THC
1	0.02	7.5	0.2	0.2	79	-41	87	70
2	1.05	127.0	4.2	2.3	80	-34	74	73
3	1.44	89.0	4.2	2.2	71	-26	74	74
4	0.04	9.8	0.3	0.3	68	-11	85	72
5	2.36	142.5	9.6	1.0	66	-6	91	86
6	1.00	111.1	3.3	1.0	72	-9	86	84
7	0.49	69.5	1.9	0.9	84	-16	80	83
8	0.24	45.2	1.6	1.1	87	-8	79	77
Average	0.83	75.2	3.1	1.1	**74**	**-16**	**86**	**79**
gr/hp-hr	0.08	7.30	0.30	0.11				

Table 4.3.5.5
ARB 8-Mode Chassis-Dyno Cycle
SCRTD Trap Bus 8924 (DDC 6V92TA 240 HP)
Emission Testing Results (May 1, 1990)
New Catalyzed Traps

Mode	Actual rpm	Road HP	Road ft-lb	Road Speed (mph)	Trap 1 Only Emission(gr/hr)				Trap 2 Only Emission(gr/hr)				Average Trap Emission (gr/hr)			
#					Part	NOX	CO	THC	Part	NOX	CO	THC	Part	NOX	CO	THC
1	617	0	0		0.00	7	0.1	0.1	0.02	7	0.2	0.1	0.01	7	0.2	0.1
2	2105	129	322		0.72	119	3.5	1.2	0.83	120	3.7	1.7	0.78	120	3.6	1.4
3	2104	82	205		0.44	86	3.6	1.3	0.70	87	3.8	1.6	0.57	87	3.7	1.5
4	617	0	0		0.01	9	0.2	0.2	0.04	9	0.2	0.2	0.03	9	0.2	0.2
5	1300	144	582		1.05	123	6.0	0.8	0.07	127	5.7	1.0	0.56	125	5.9	0.9
6	1327	113	447		0.45	99	2.3	0.6	0.54	102	2.5	0.8	0.50	100	2.4	0.7
7	1307	78	311		0.18	65	1.8	0.6	0.30	66	1.6	0.7	0.24	66	1.7	0.7
8	1302	46	184		0.06	45	1.6	0.7	0.13	45	1.5	0.8	0.10	45	1.6	0.8
Average	1335	74	256		0.36	69	2.4	0.7	0.33	70	2.4	0.9	0.35	70	2.4	0.8
gr/hp-hr					0.04	6.70	0.23	0.07	0.03	6.79	0.23	0.08	0.03	6.74	0.23	0.07

Mode	Baseline Emission(gr/hr)				% Emission Reduction Trap 1				Trap 2				Average			
#	Part	NOX	CO	THC	Part	NOX	CO	THC	Part	NOX	CO	THC	Part	NOX	CO	THC
1	0.09	5	1	0.6	95	-40	90	92	73	-38	89	79	84	-39	90	86
2	6.16	92	15	8.2	88	-30	77	86	86	-31	76	79	87	-30	76	82
3	5.97	68	15	8.1	93	-26	76	84	88	-28	75	80	90	-27	76	82
4	0.15	8	2	1.0	91	-19	86	82	74	-20	87	84	82	-20	87	83
5	7.03	130	105	6.6	85	5	94	89	99	3	95	86	92	4	94	87
6	3.78	93	23	5.9	88	-6	90	89	86	-9	89	86	87	-8	90	88
7	3.32	55	9	5.2	95	-18	80	88	91	-20	82	86	93	-19	81	87
8	2.14	38	7	4.5	97	-17	77	84	94	-17	79	83	95	-17	78	83
Average	3.58	61	22	5.0	92	-19	84	87	86	-20	84	83	89	-20	84	85
gr/hp-hr	0.34	5.86	2.13	0.48												

Table 4.3.5.6
ARB 8-Mode Chassis-Dyno Cycle
SCRTD Trap Bus 8924 (DDC 6V92TA 240 HP)
Emission Testing Results (November, 1991)

Mode	Actual Road			Road	Trap 1 Only Emission(gr/hr)				Trap 2 Only Emission(gr/hr)				Average Trap Emission (gr/hr)			
	rpm	HP	ft-lb	Speed												
#				(mph)	Part	NOX	CO	THC	Part	NOX	CO	THC	Part	NOX	CO	THC
1	627	0	0	0.0	0.02	6	1.6	0.6	0.03	7	1.8	0.7	0.03	7	1.7	0.7
2	1912	124	341	36.4	2.85	113	16.0	6.7	3.70	107	19.9	6.7	3.27	110	18.0	6.7
3	1903	85	235	36.4	2.89	76	16.4	5.9	1.46	70	13.2	5.2	2.17	73	14.8	5.6
4	604	0	0	0.0	0.07	6	1.5	0.7	0.04	7	1.6	0.7	0.05	7	1.5	0.7
5	1318	139	554	24.8	1.95	131	80.2	5.5	1.95	131	80.2	5.5	1.95	131	80.2	5.5
6	1307	104	418	24.7	0.79	88	59.3	3.6	0.76	91	36.5	3.7	0.78	90	47.9	3.7
7	1293	74	301	24.7	0.44	65	14.2	3.1	0.65	63	10.1	3.1	0.55	64	12.2	3.1
8	1310	42	168	25.1	0.26	41	7.1	2.7	0.25	37	5.8	2.7	0.25	39	6.4	2.7
Average	1284	71	252		1.16	66	24.5	3.6	1.10	64	21.1	3.6	1.13	65	22.8	3.6
gr/hp-hr					0.117	6.61	2.47	0.36	0.116	6.74	2.21	0.37	0.116	6.68	2.34	0.37

Mode	Baseline Emission(gr/hr)				% Emission Reduction Trap 1				Trap 2				Average			
#	Part	NOX	CO	THC	Part	NOX	CO	THC	Part	NOX	CO	THC	Part	NOX	CO	THC
1	0.09	6	1	0.5	77	-2	-26	-32	60	-22	-46	-63	68	-12	-36	-47
2	8.37	113	15	6.1	66	0	-5	-10	56	6	-31	-10	61	3	-18	-10
3	8.38	77	16	7.7	66	2	-2	23	83	9	18	32	74	6	8	28
4	0.20	8	2	0.2	66	26	14	-232	79	13	6	-258	72	19	10	-245
5	4.47	146	41	4.5	56	10	-95	-24	56	10	-95	-24	56	10	-95	-24
6	2.69	107	13	2.7	70	18	-367	-33	72	14	-187	-38	71	16	-277	-36
7	2.25	67	7	2.3	80	3	-108	-36	71	6	-48	-38	76	4	-78	-37
8	1.99	44	6	2.0	87	7	-19	-35	88	16	2	-34	87	11	-9	-34
Average	3.56	71	13	3.2												
gr/hp-hr	0.361	7.21	1.28	0.38	68	8	-94	4	68	7	-74	1	68	7	-84	2

FIGURE 4.2.1.1

REFERENCE ADVANCED DESIGN BUS CYCLE

CENTRAL BUSINESS DISTRICT PHASE

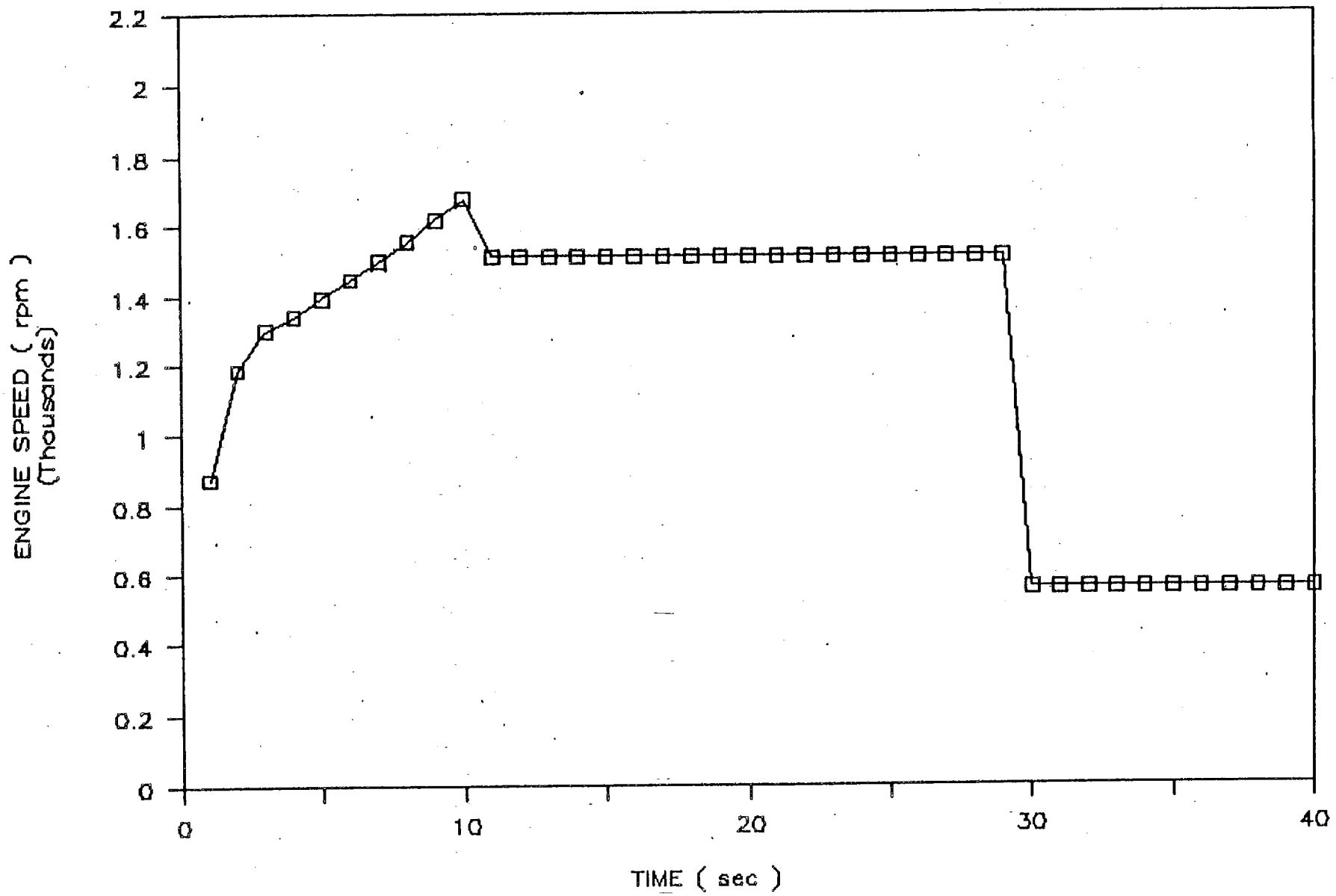


FIGURE 4.2.1.2

REFERENCE ADVANCED DESIGN BUS CYCLE

CENTRAL BUSINESS DISTRICT PHASE

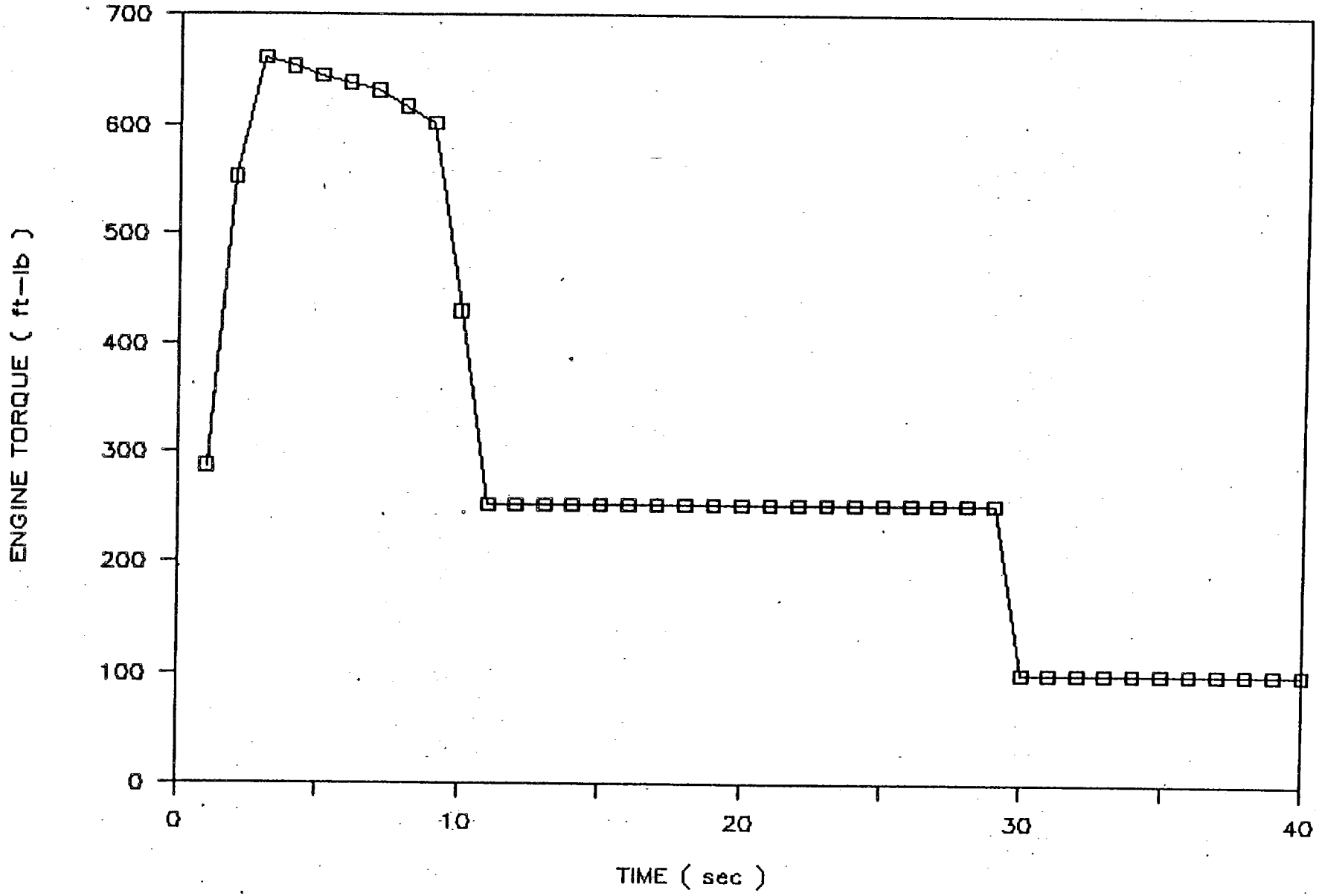


FIGURE 4.2.1.3

REFERENCE ADVANCED DESIGN BUS CYCLE

CENTRAL BUSINESS DISTRICT PHASE

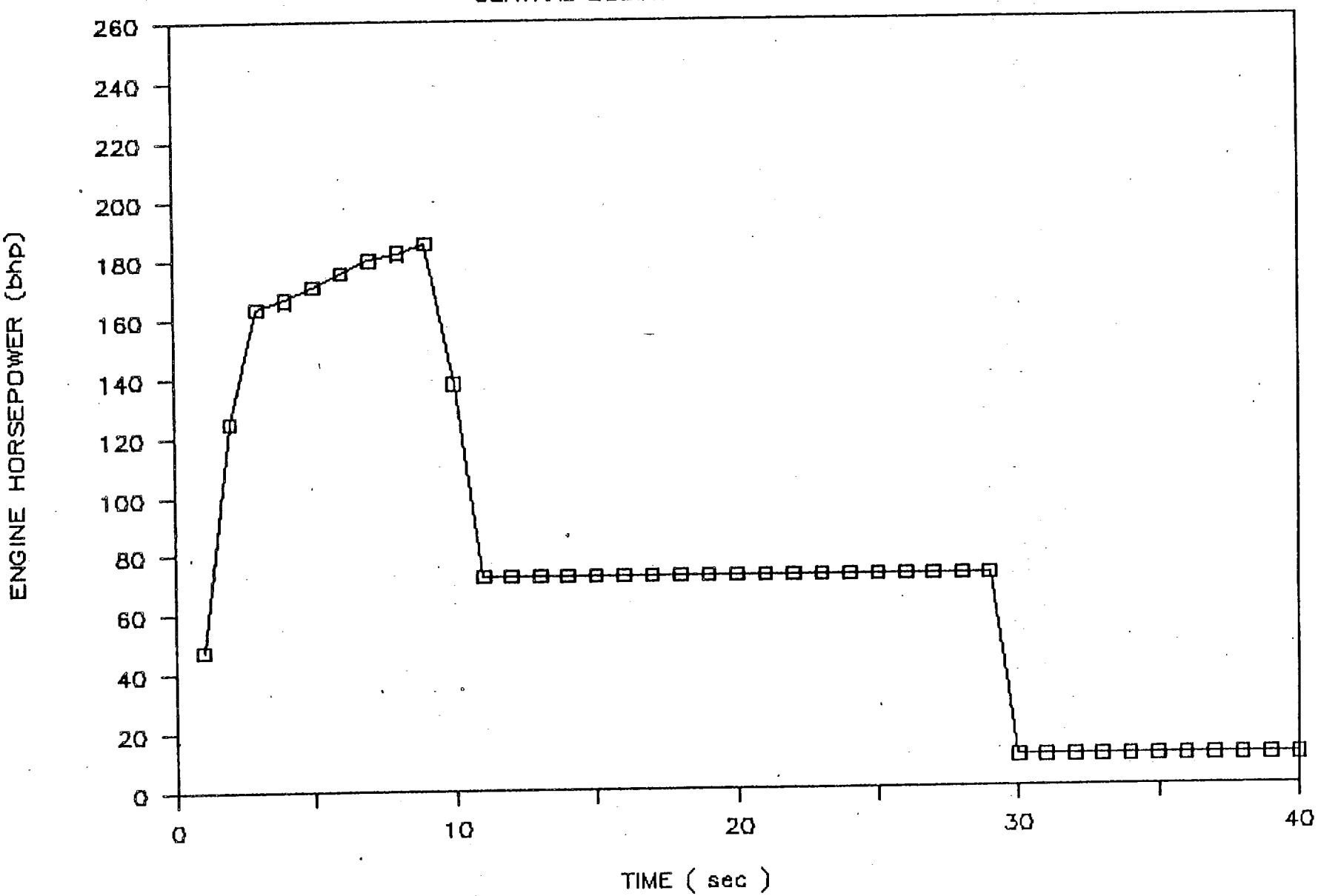


FIGURE 4.2.1.4

REFERENCE ADVANCED DESIGN BUS CYCLE

ARTERIAL PHASE

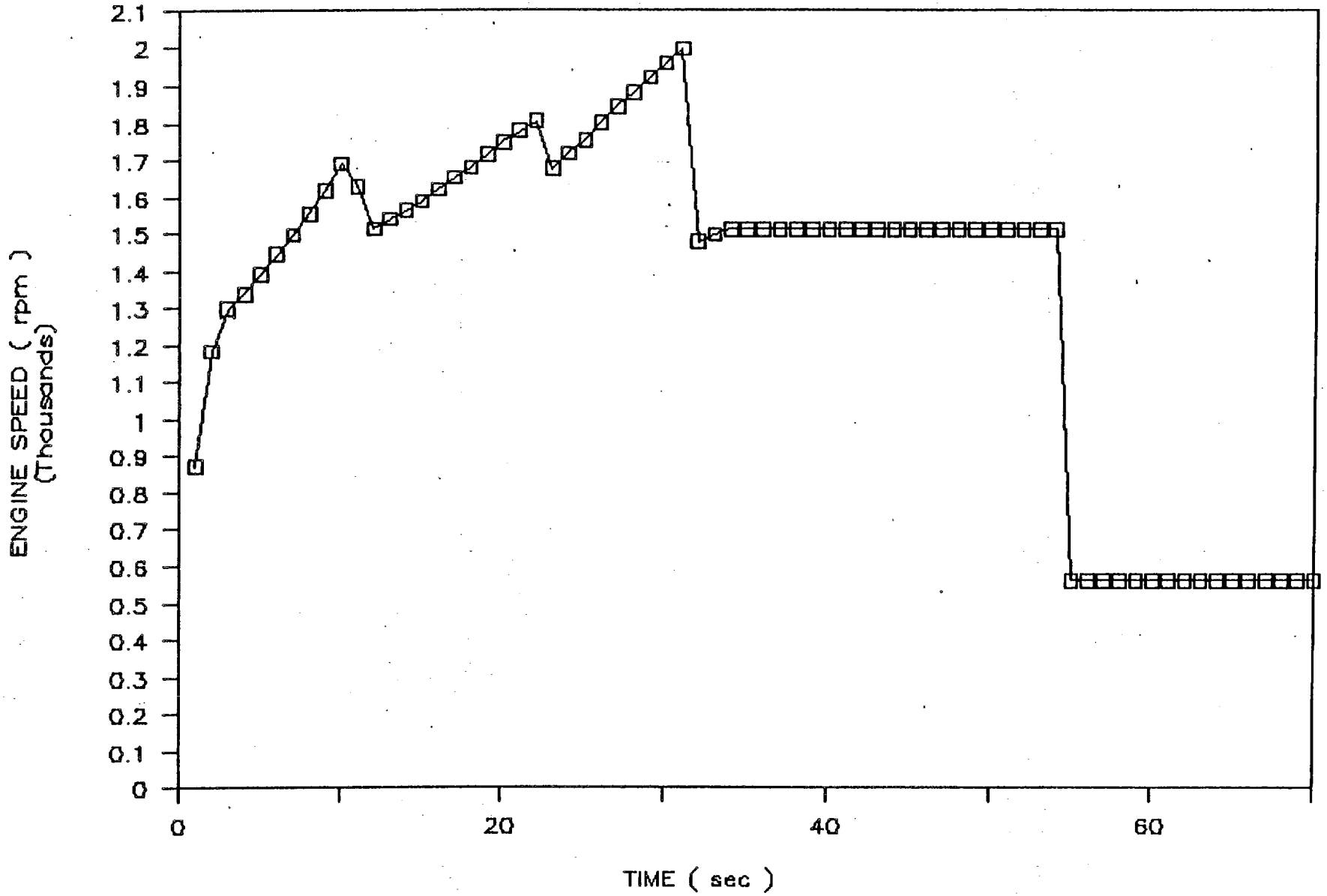


FIGURE 4.2, 1.5

REFERENCE ADVANCED DESIGN BUS CYCLE

ARTERIAL PHASE

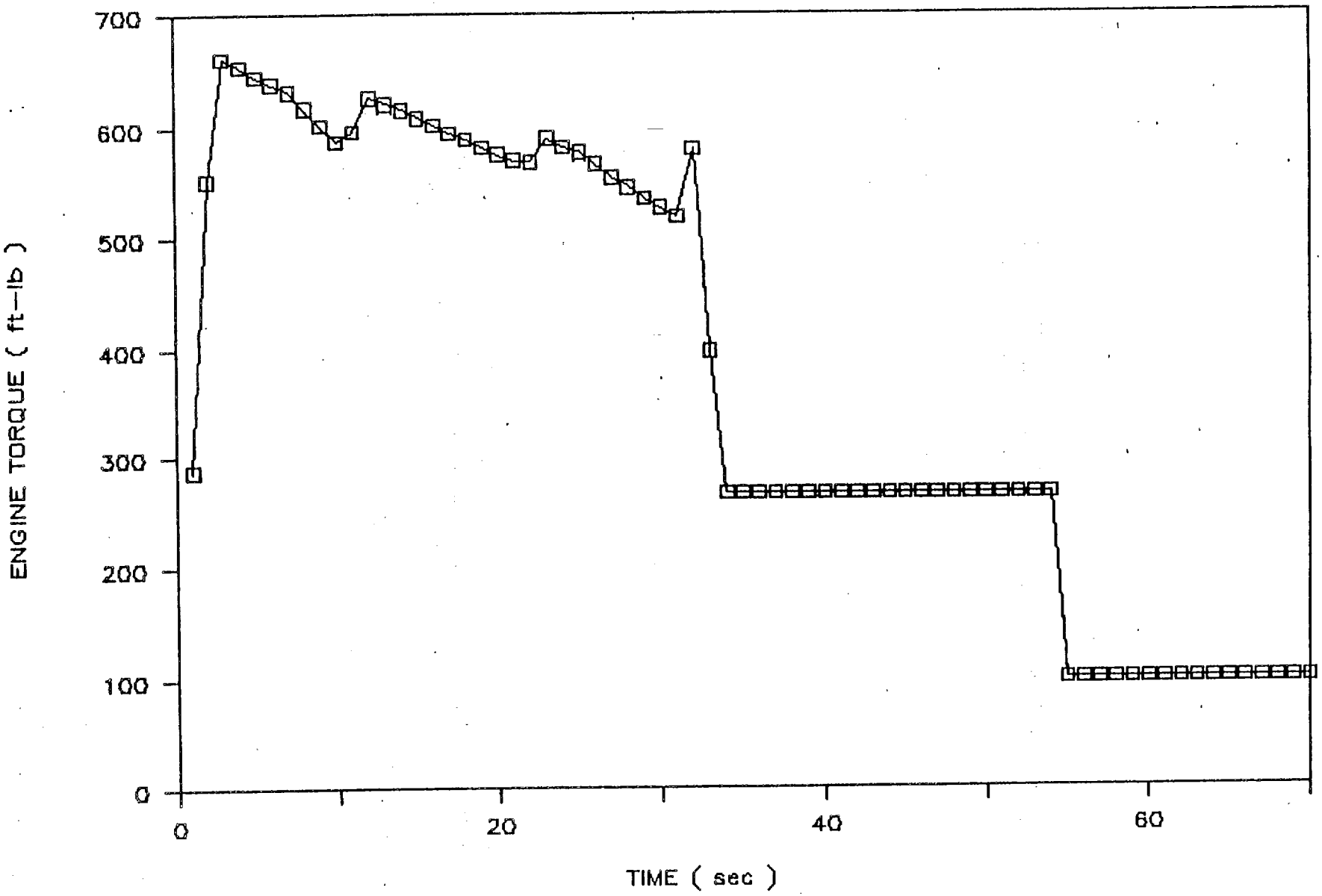


FIGURE 4.2.1.6

REFERENCE ADVANCED DESIGN BUS CYCLE

ARTERIAL PHASE

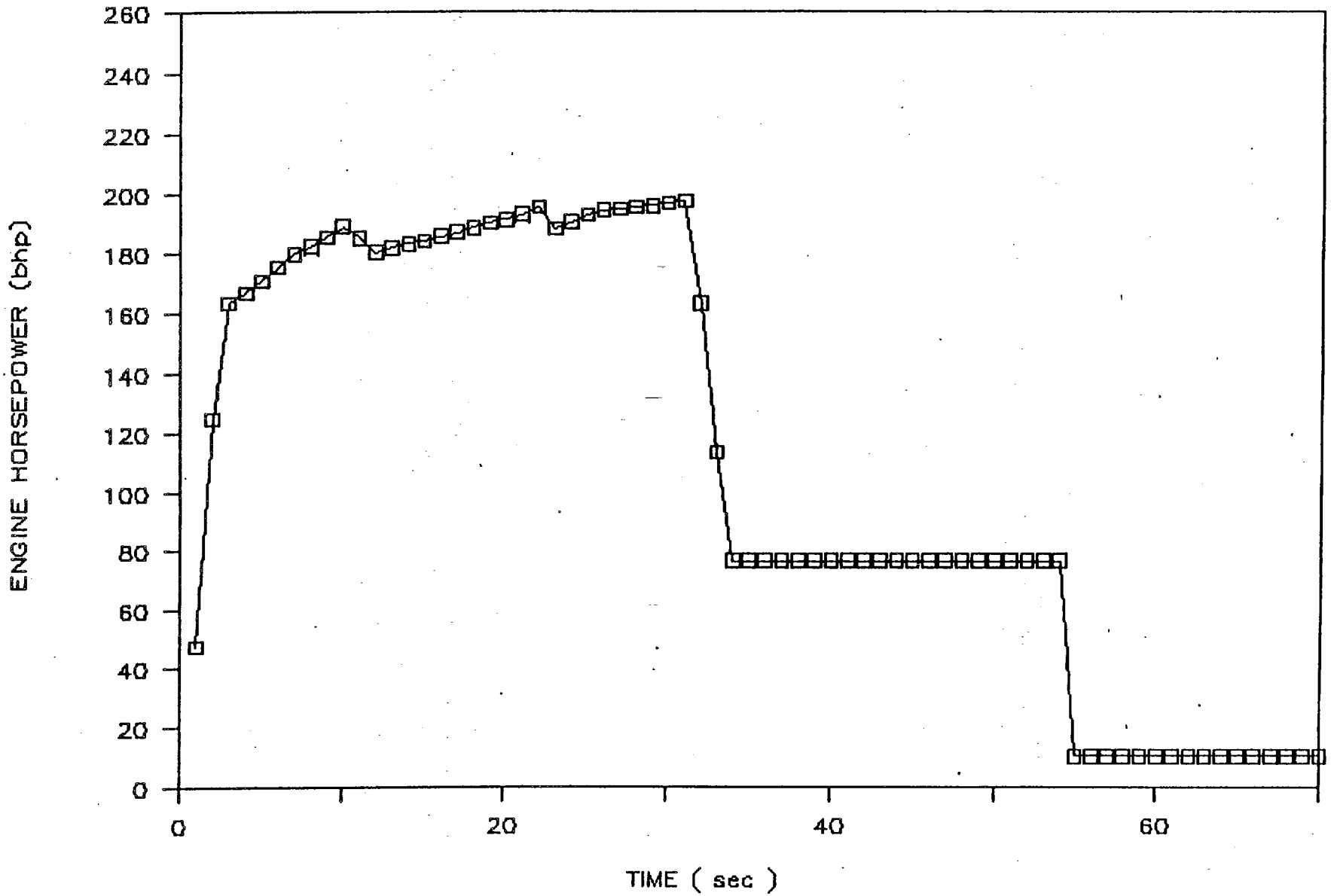


FIGURE 4.2.1.7

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

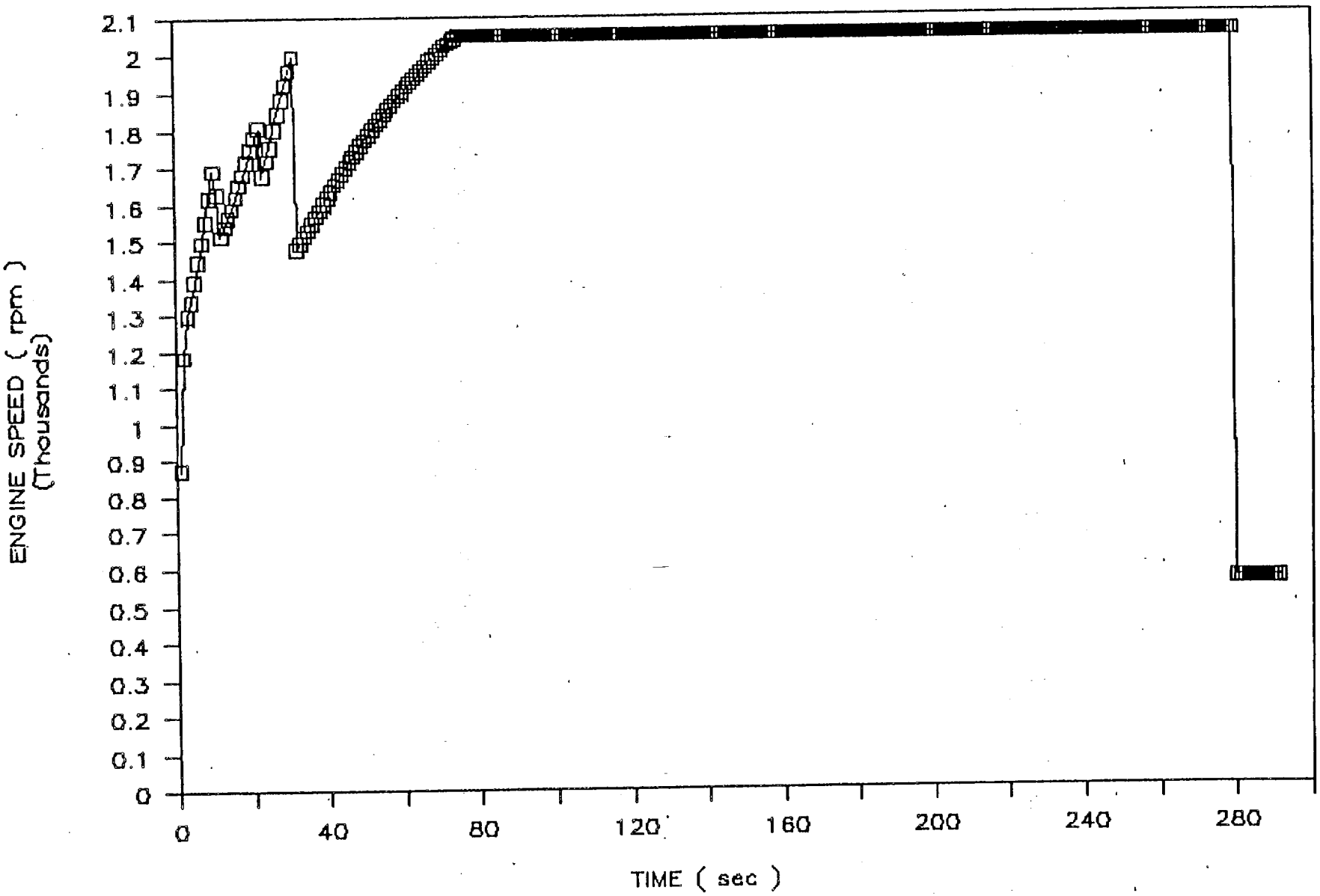


FIGURE 4.2.1.8

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PASE

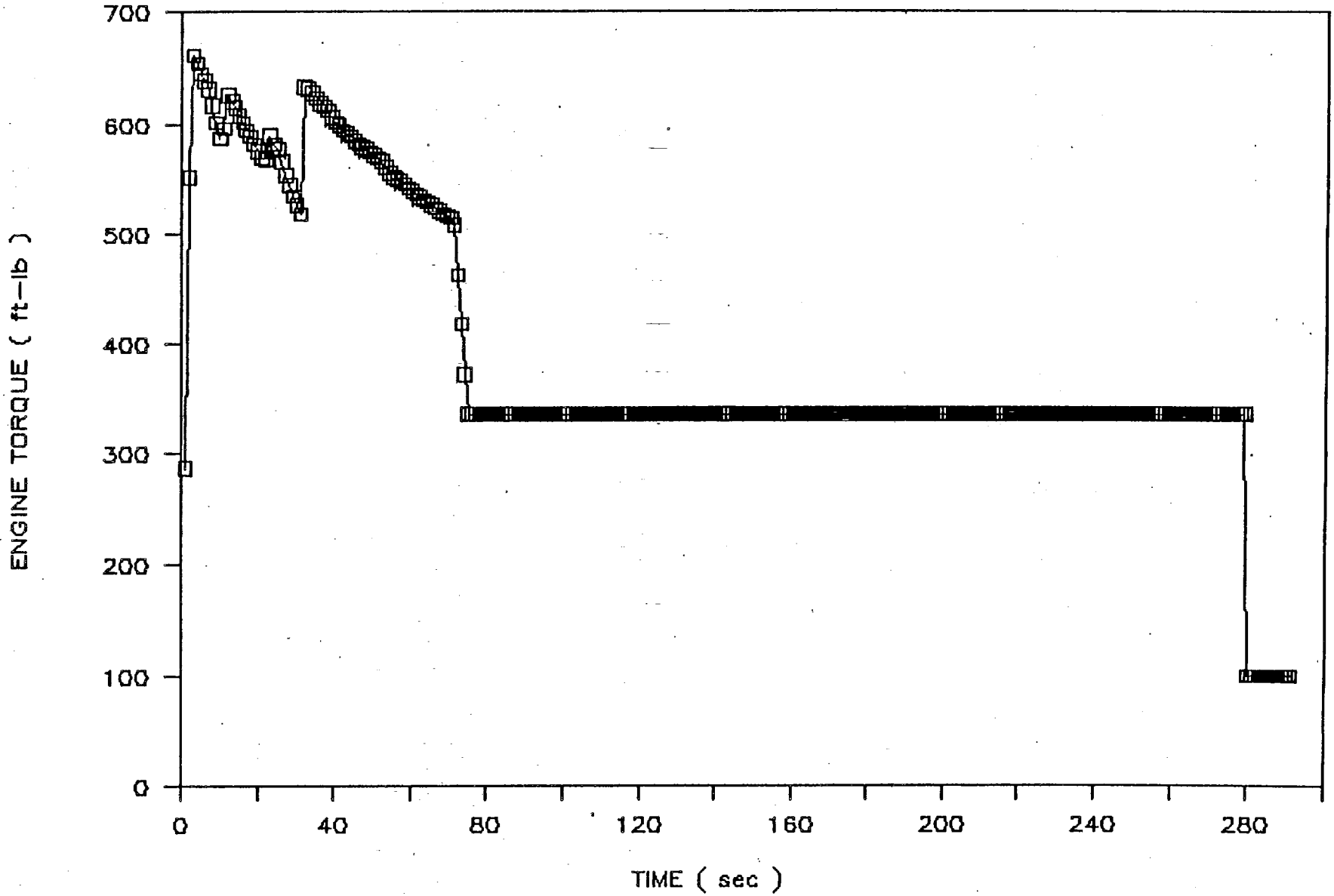


FIGURE 4.2.1.9

REFERENCE ADVANCED DESIGN BUS CYCLE

COMMUTER PHASE

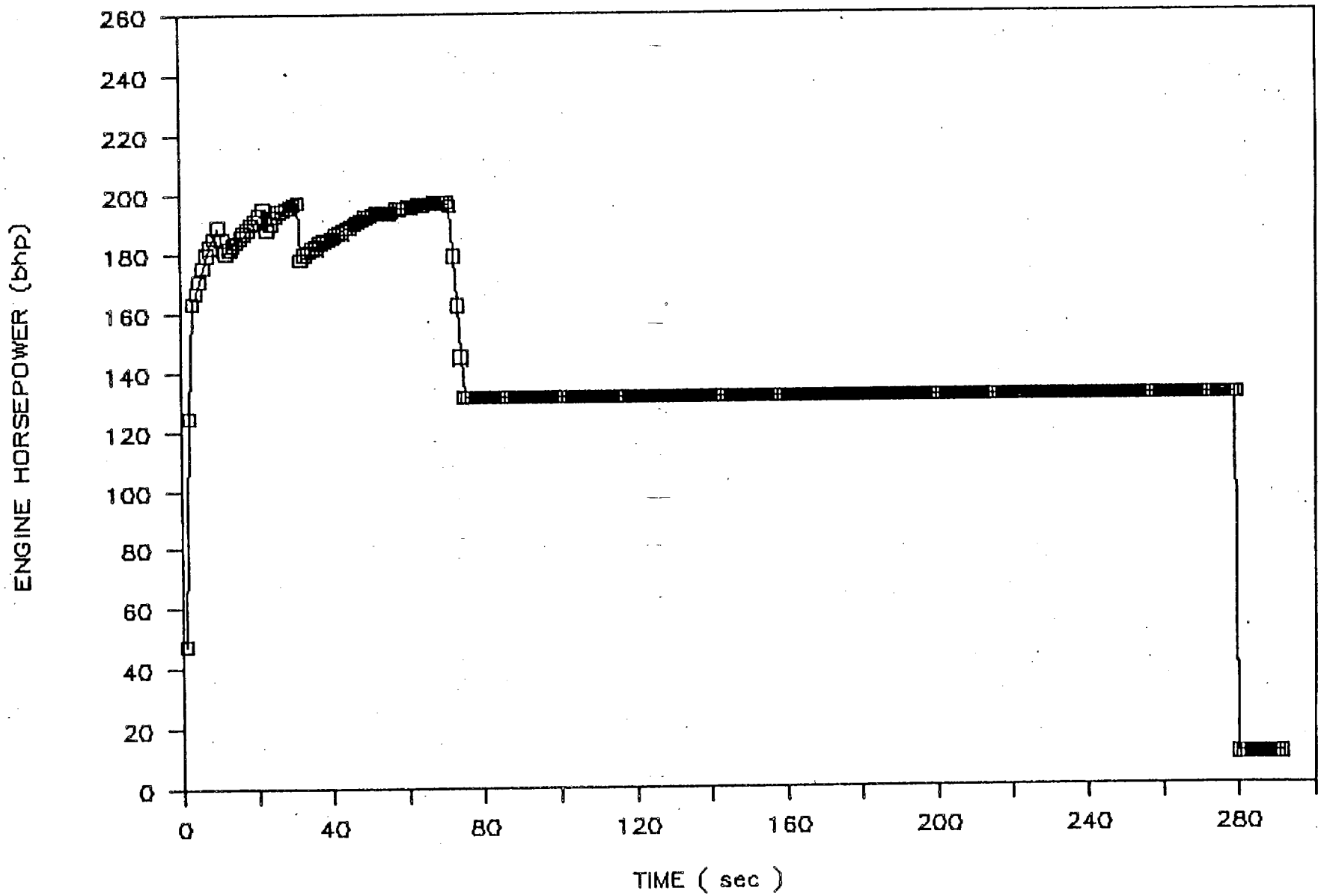


FIGURE 4.2.1 .10

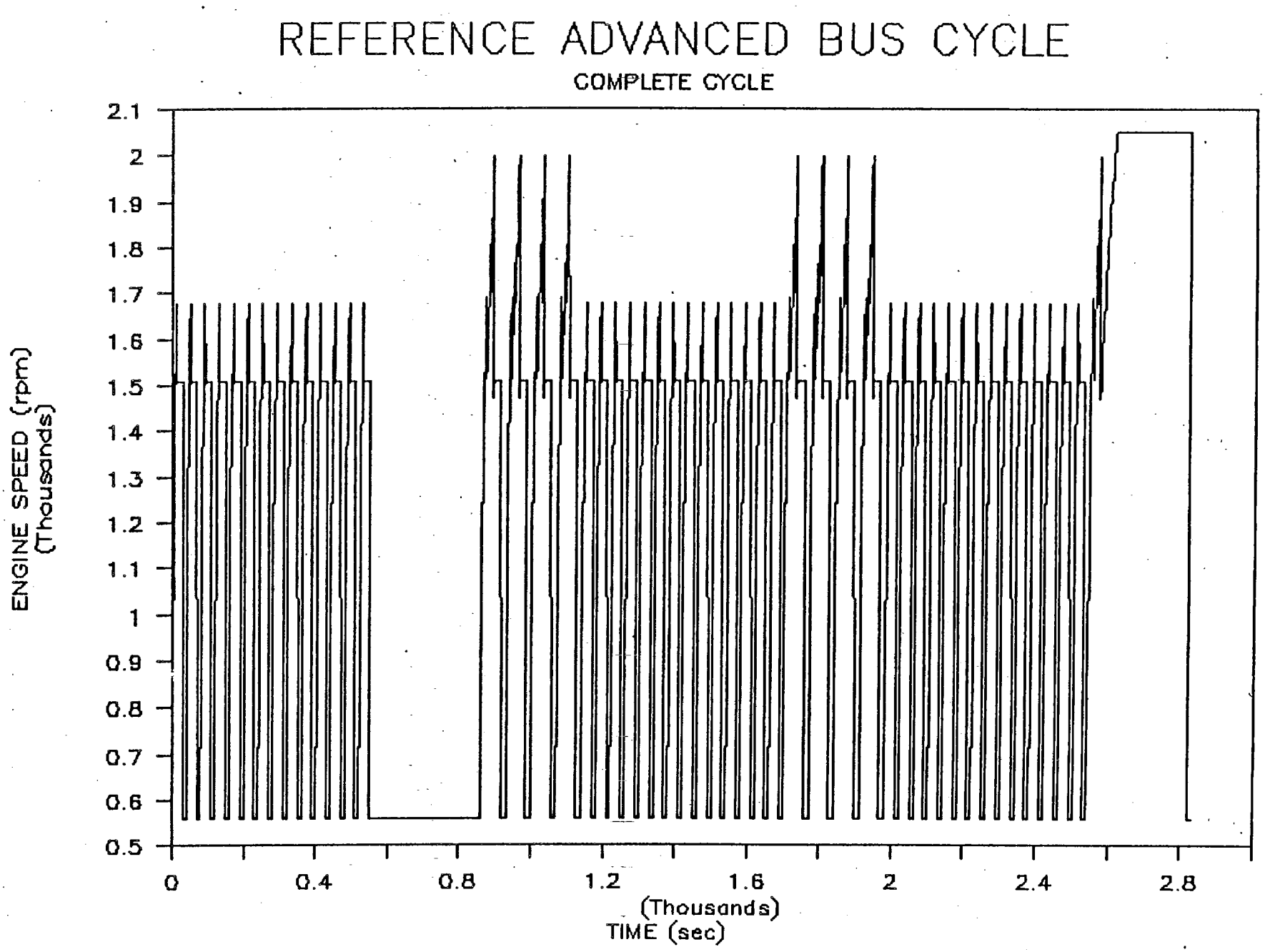


FIGURE 4.2.1:11

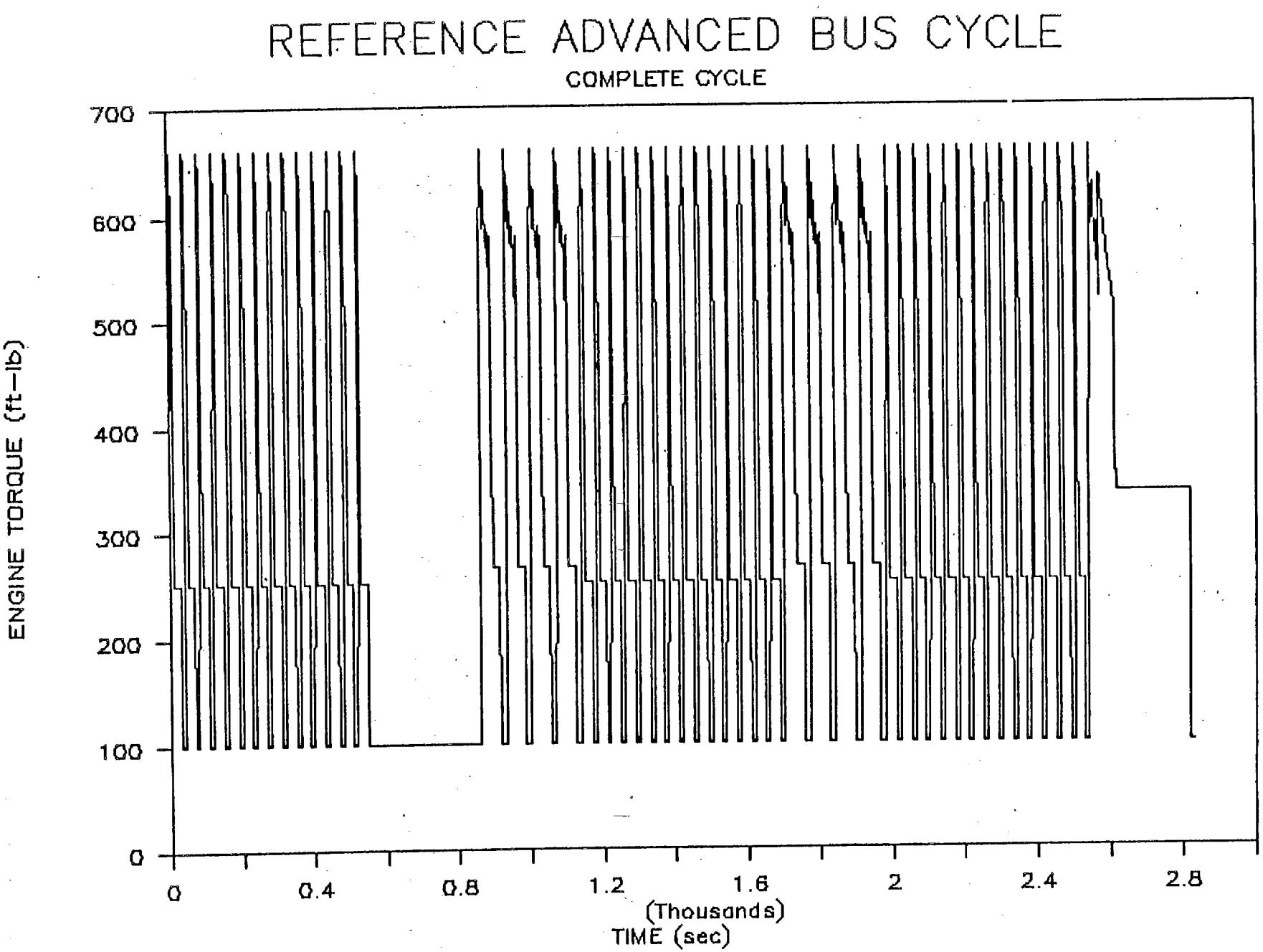
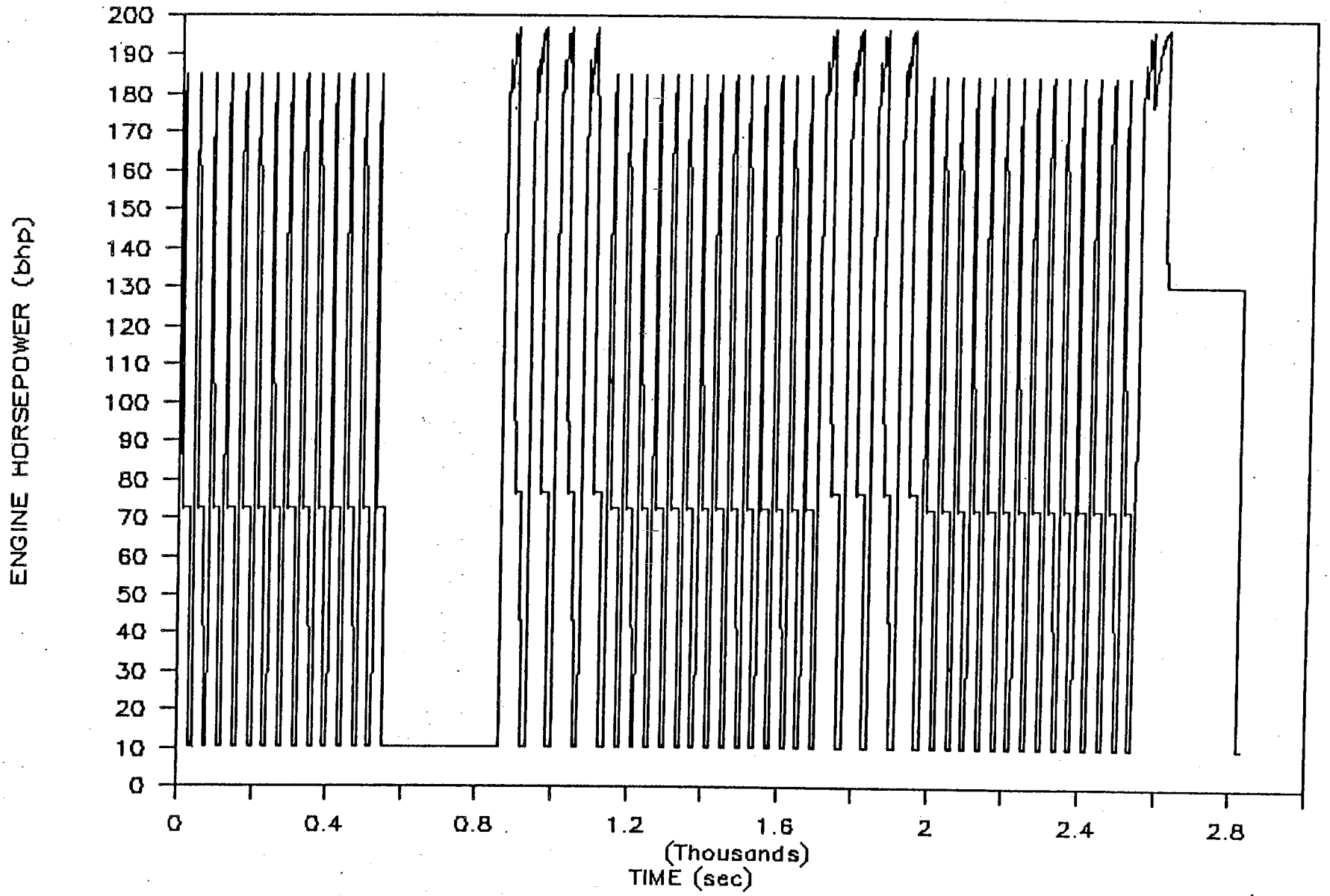


FIGURE 4.2.1.12

REFERENCE ADVANCED BUS CYCLE

COMPLETE CYCLE



ARB Bus Trap System Testing
DDC 6V92TA

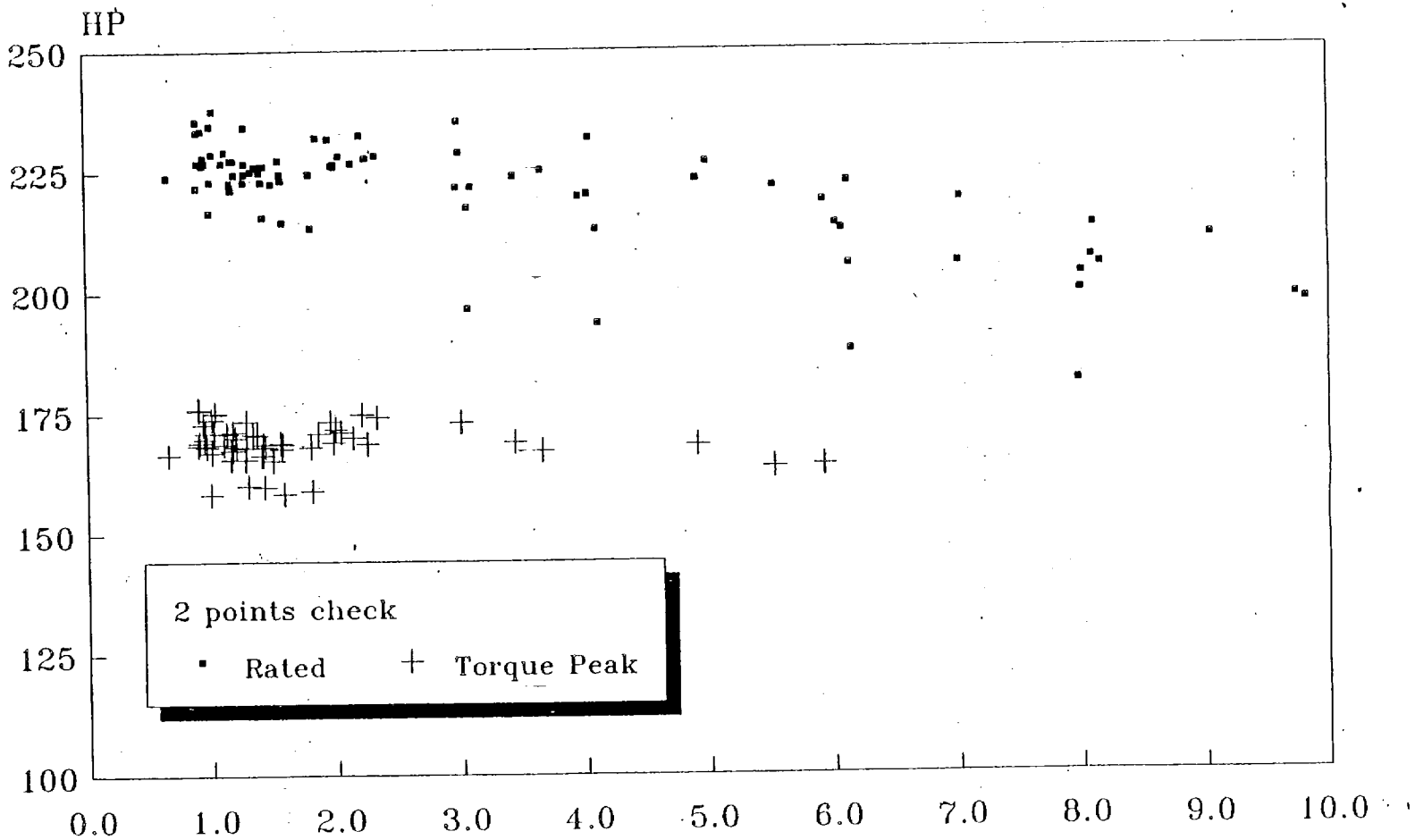


Figure 4.2.6.1

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA

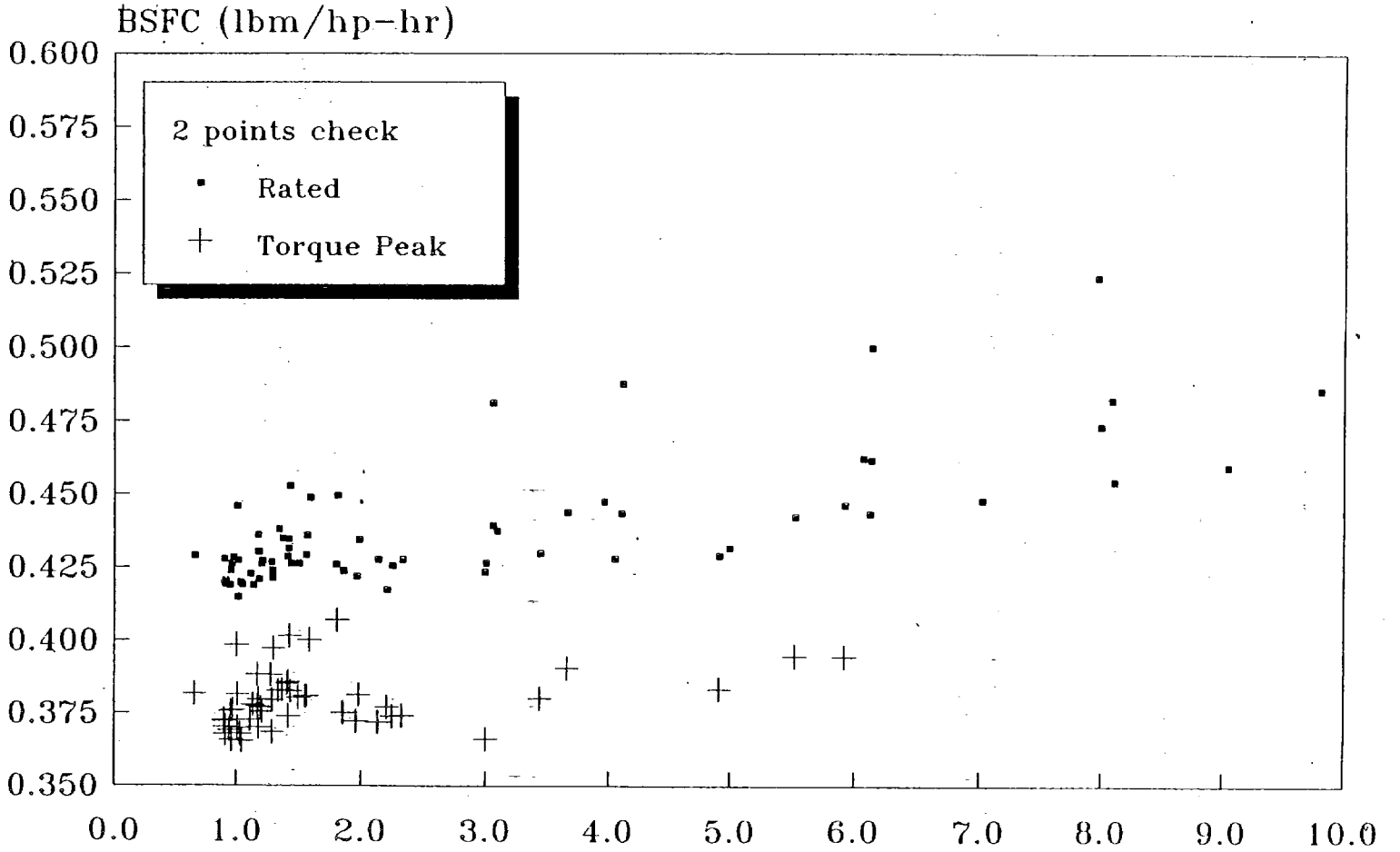


Figure 4.2.6.2

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA

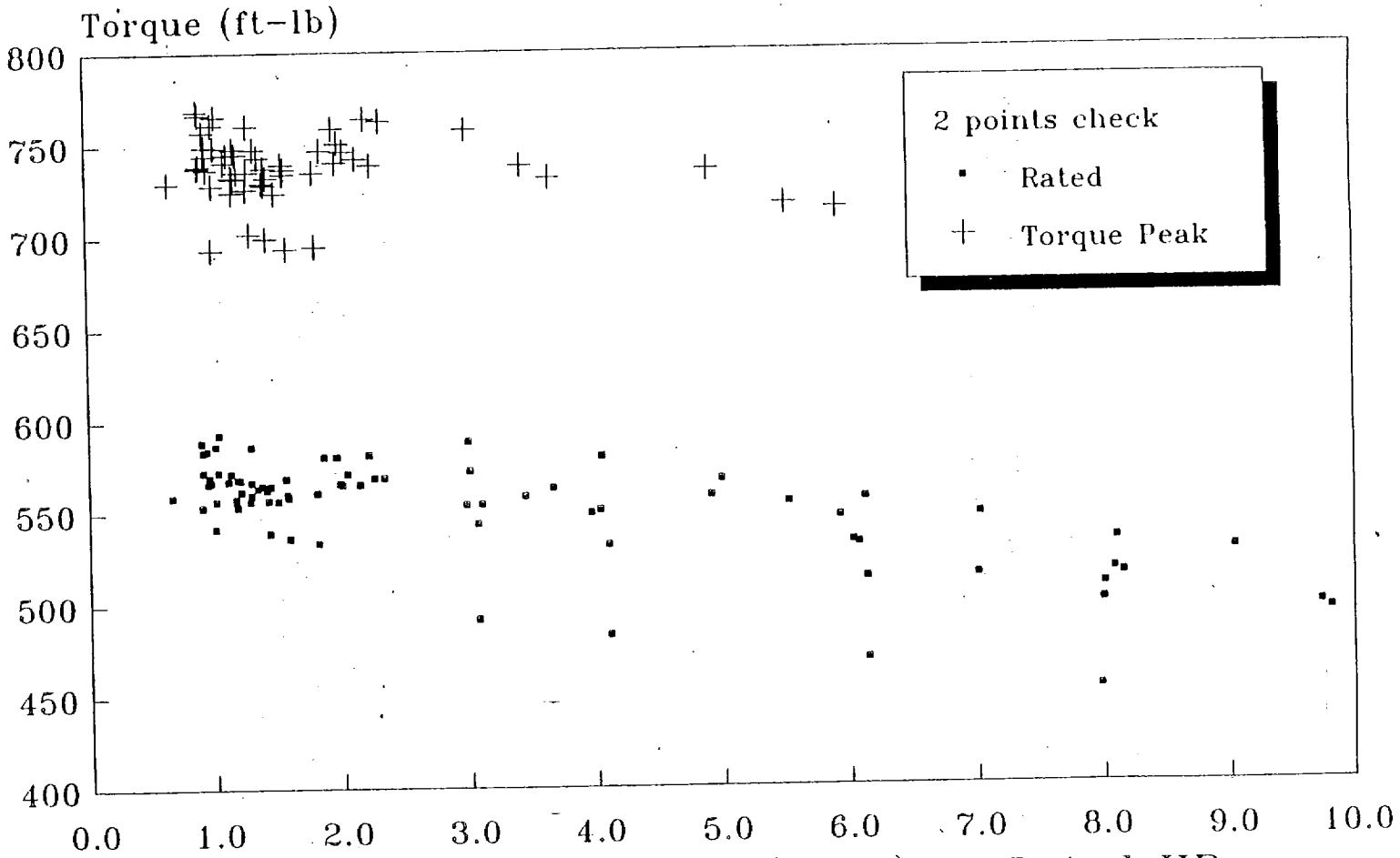


Figure 4.2.6.3

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA + ADB Cycle

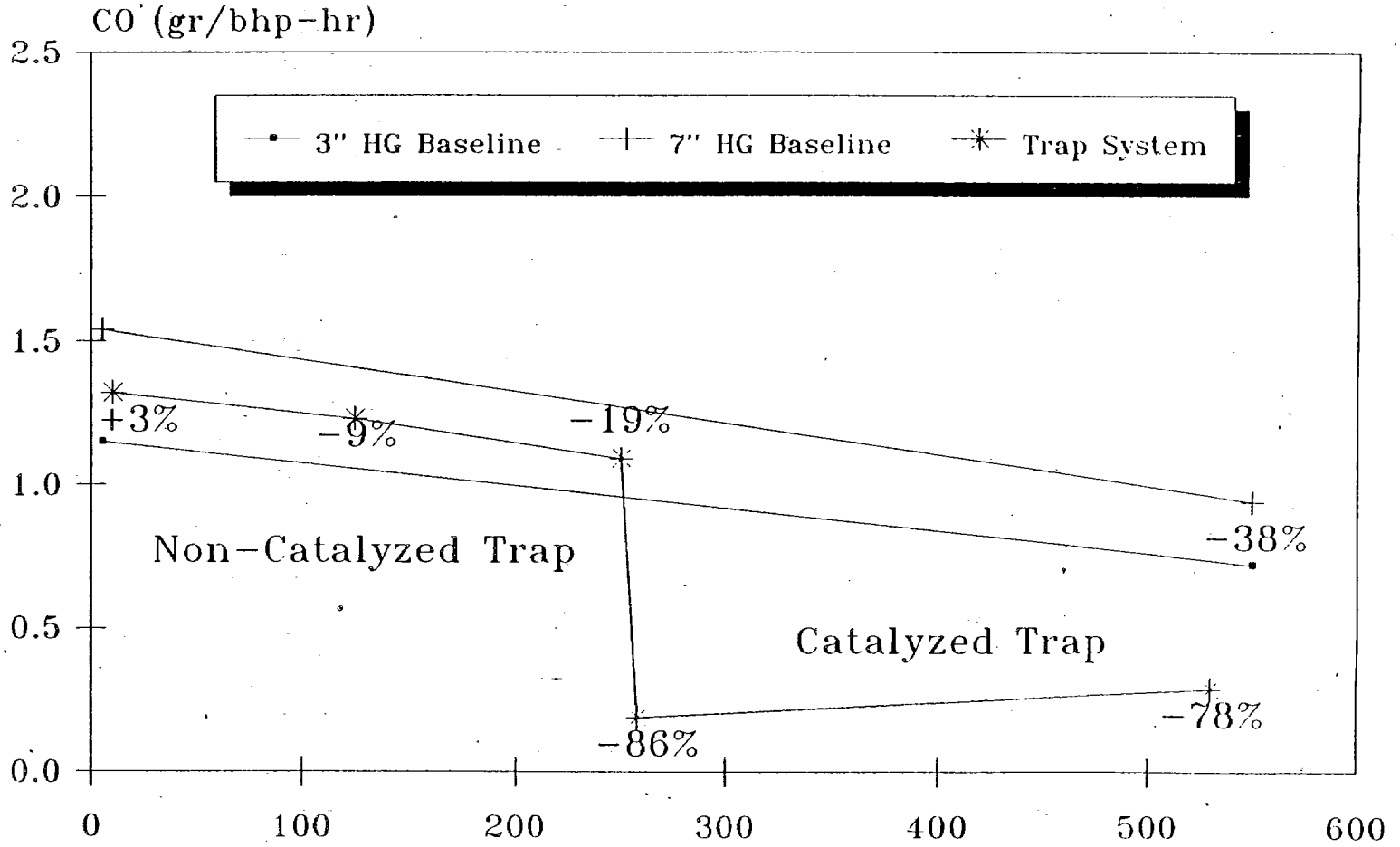


Figure 4.2.6.4

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA + ADB Cycle

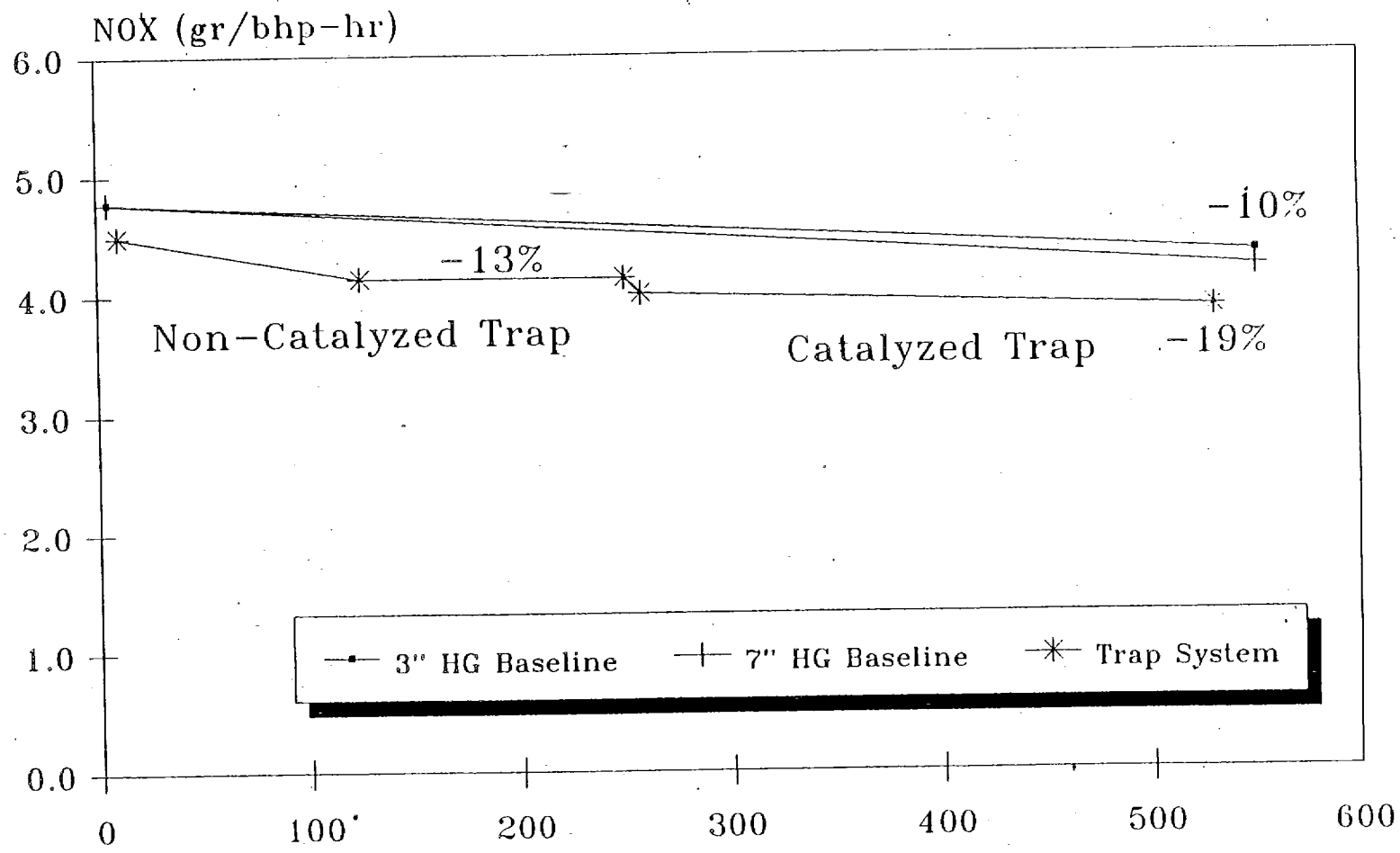


Figure 4.2.6.5

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA + ADB Cycle

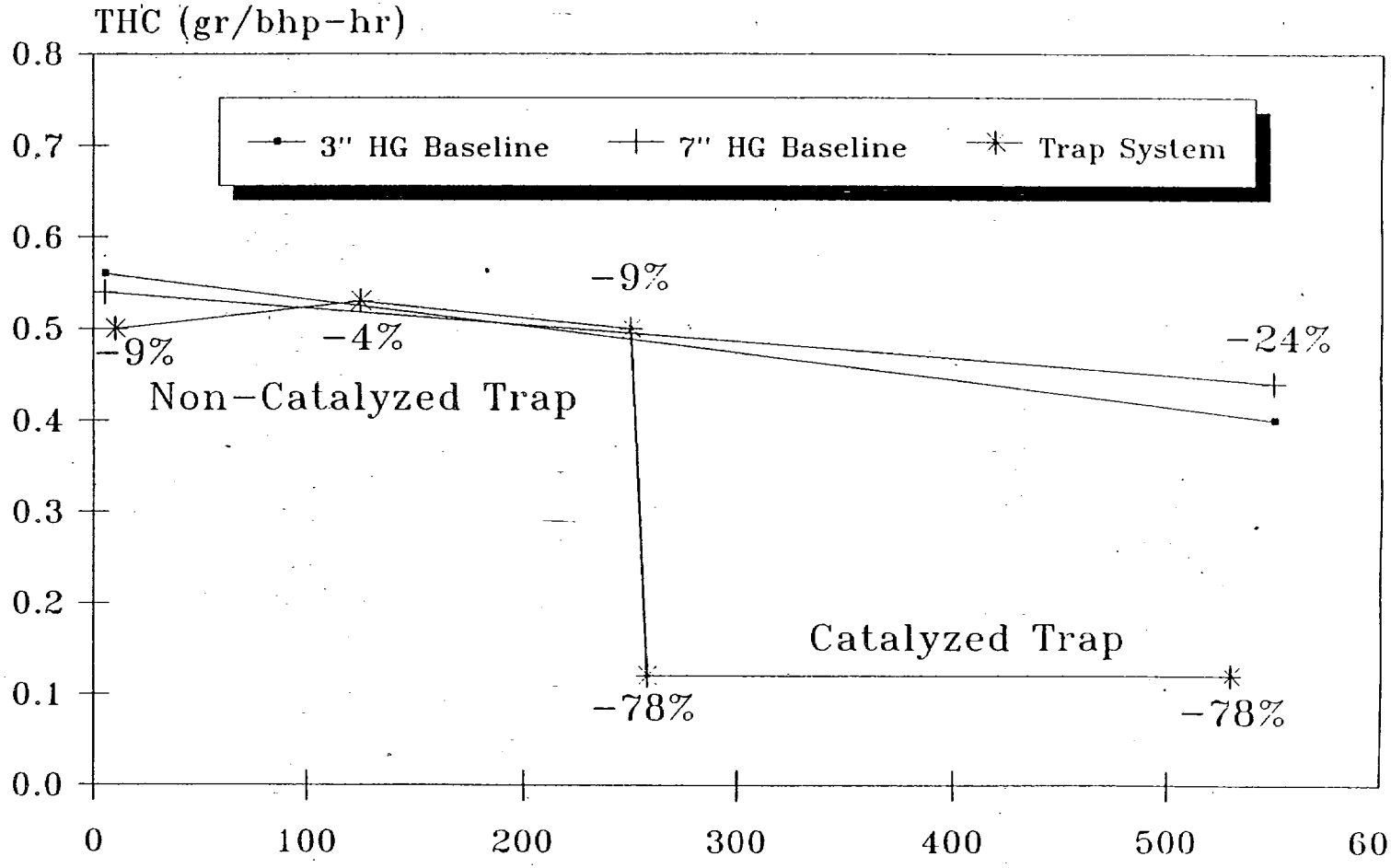


Figure 4.2.6.6

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA + ADB Cycle

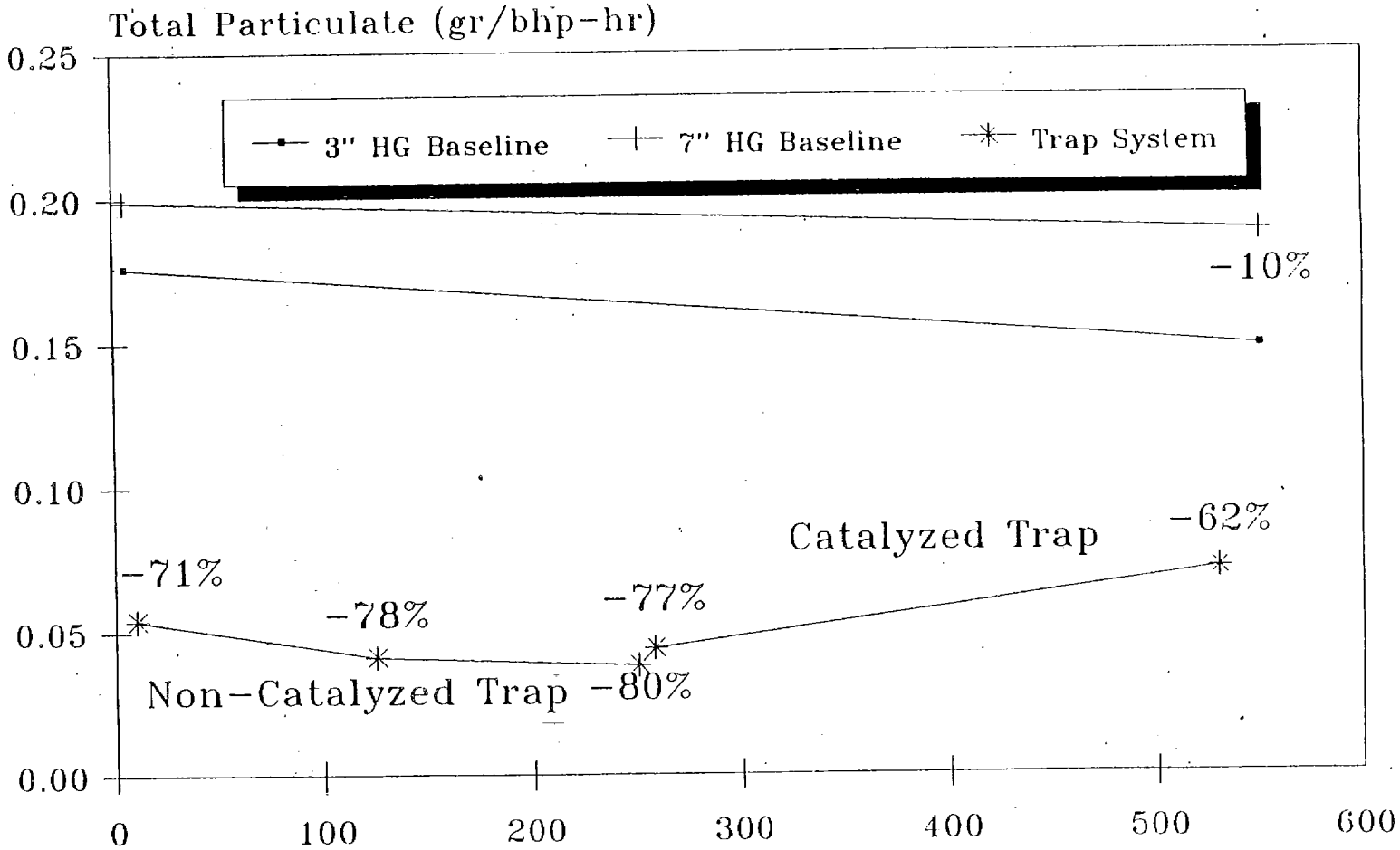


Figure 4.2.6.7

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA + ADB Cycle

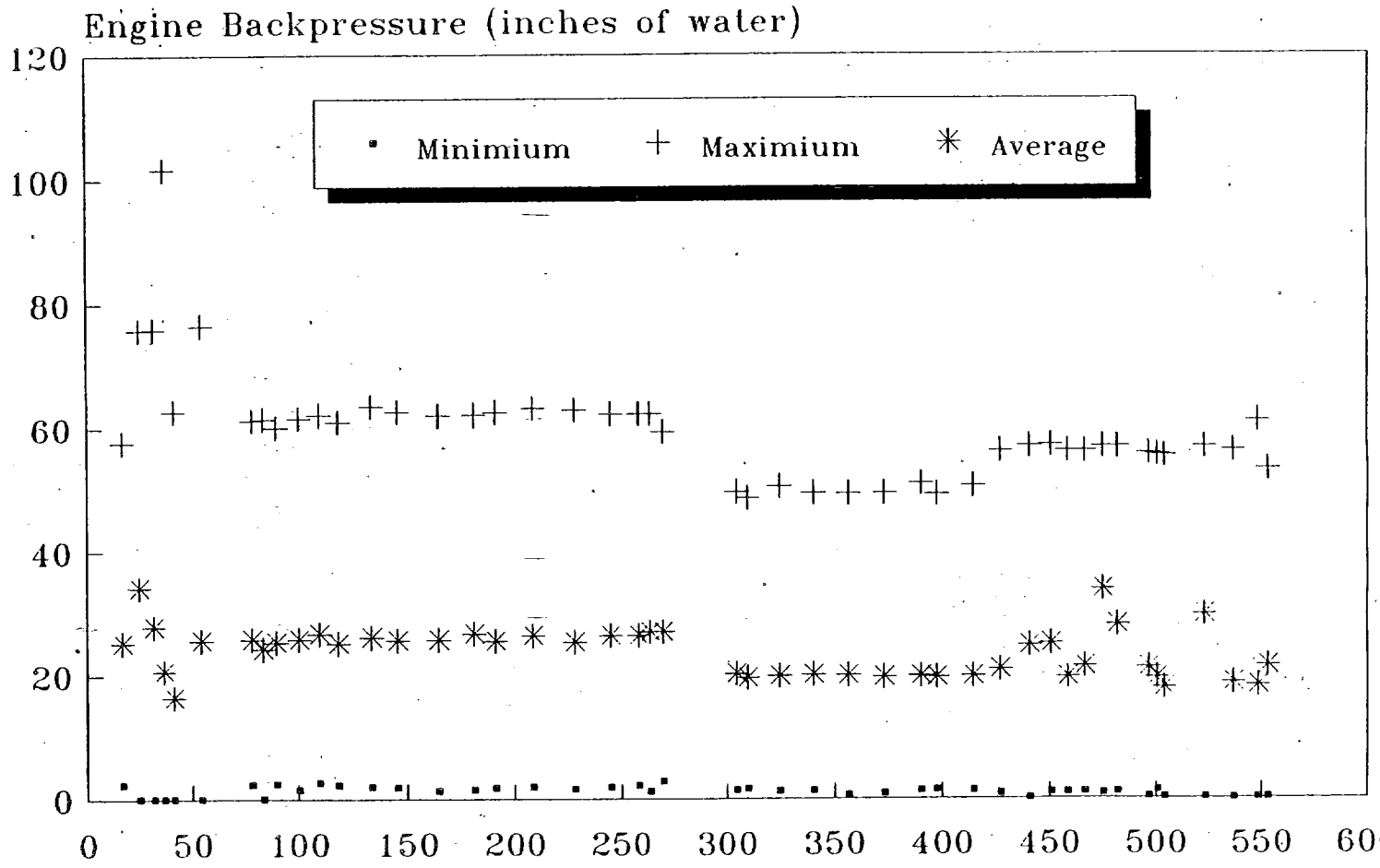


Figure 4.2.6.8

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA + ADB Cycle

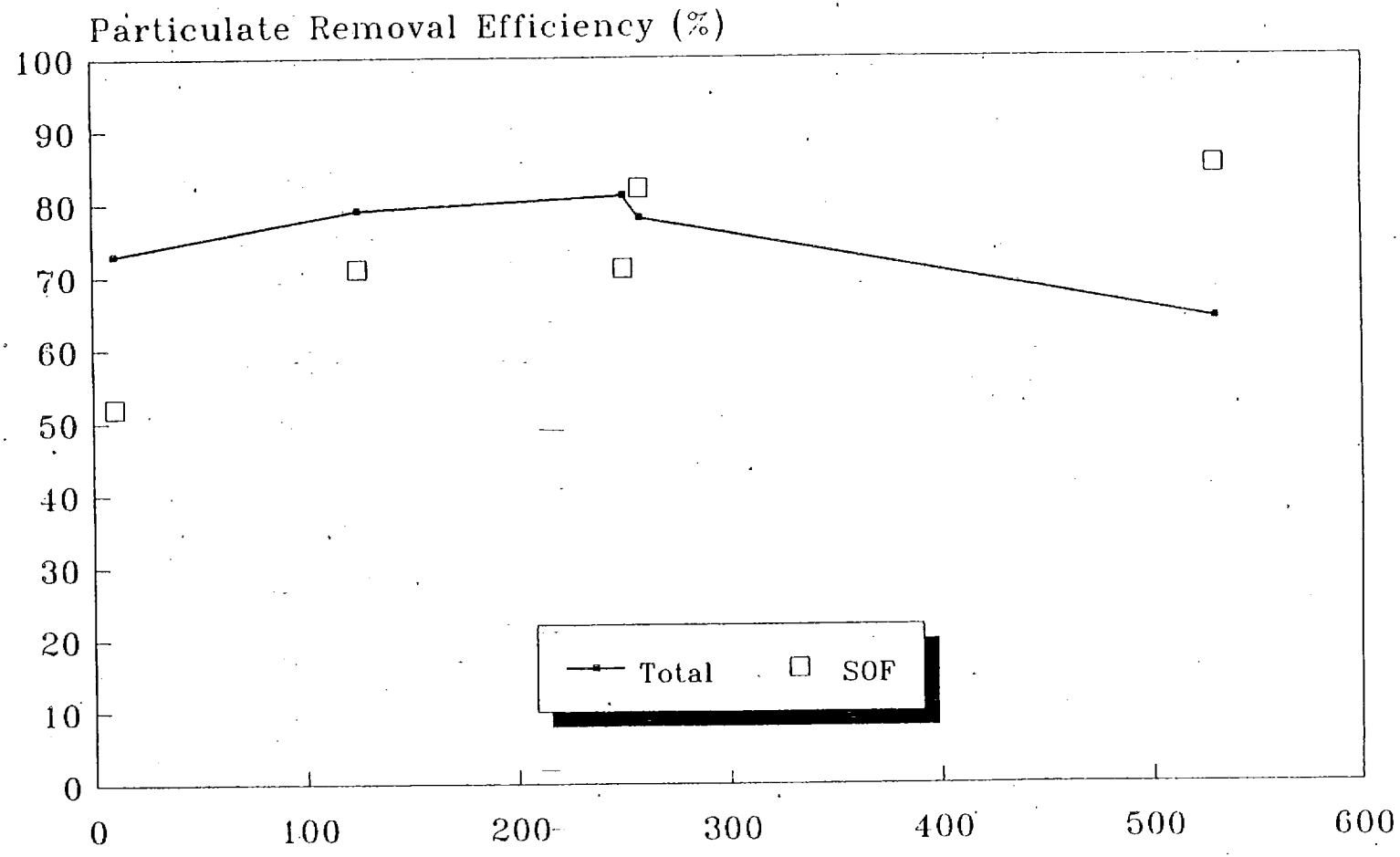


Figure 4.2.6.9

AET-ORTECH International

ARB Bus Trap System Testing
DDC 6V92TA (ADB+Commuter Cycle)
DCI Electrical Trap System

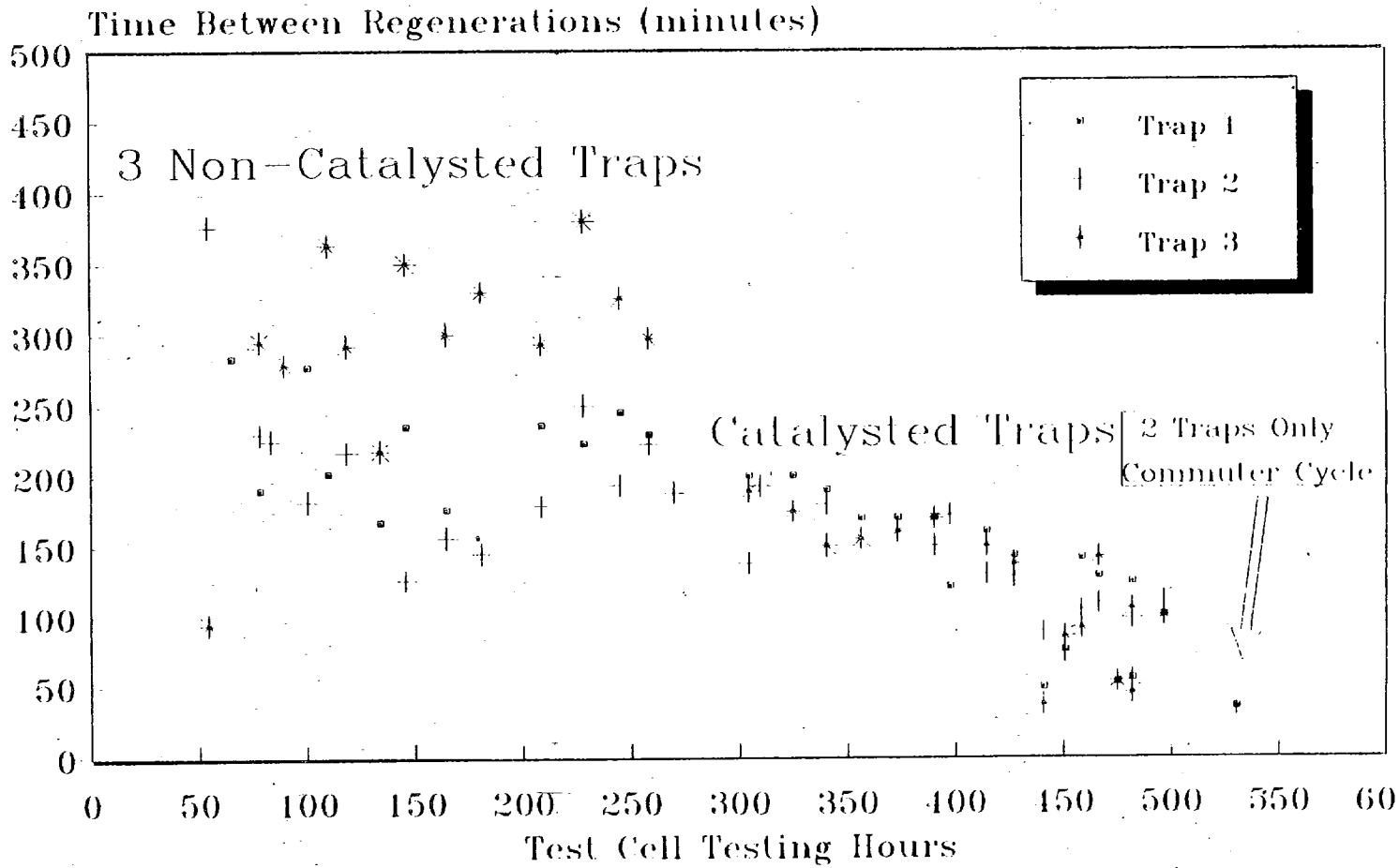


Figure 4.2.6.10

AET-ORTECH International

ARB Trap System Demonstration
SCRTD Bus 8924 with DDC 6V92TA 240 hp
DCI Electric Dual Trap System

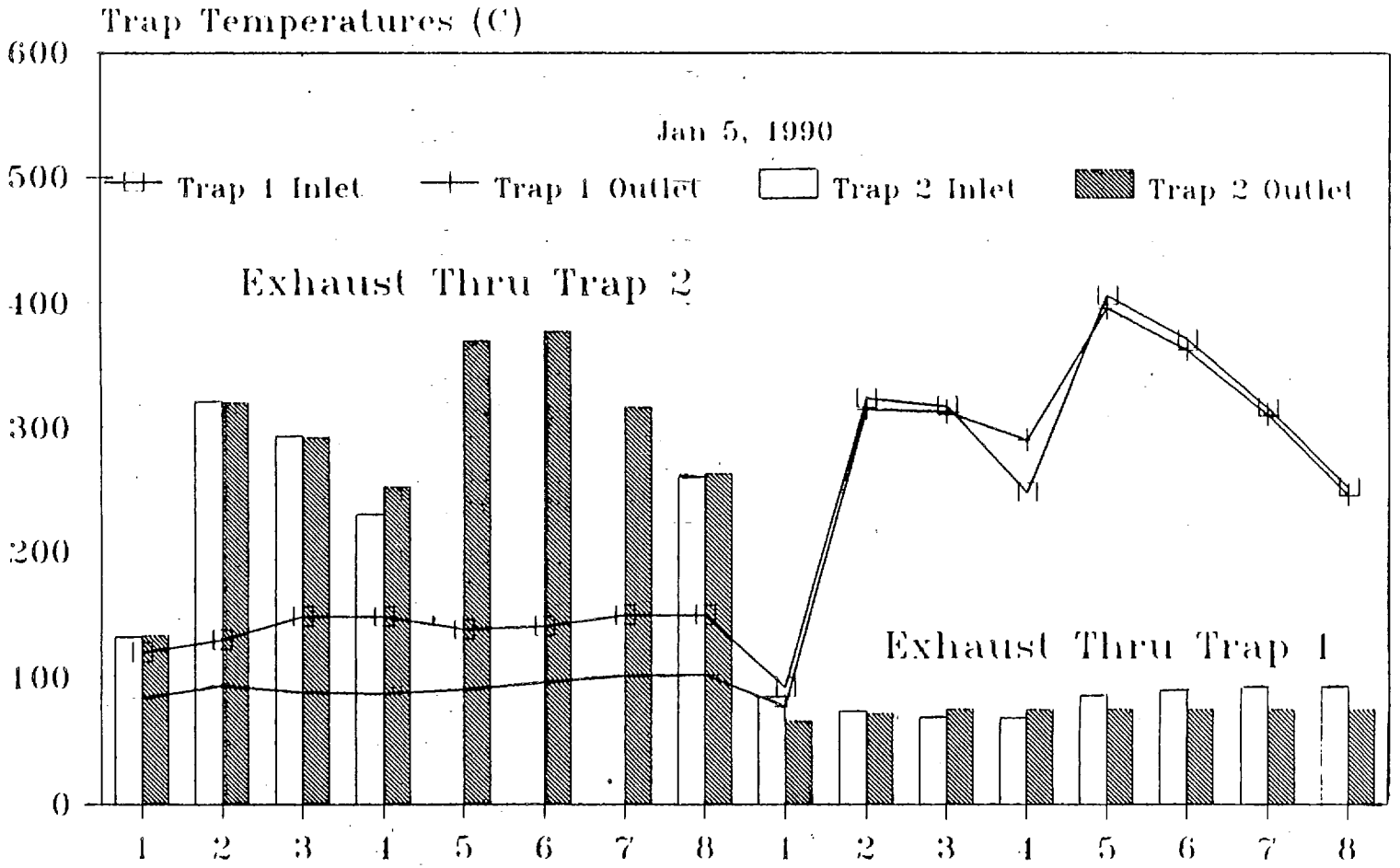


Figure 4.3.2.1

AET-ORTECH International

FIGURE 4.3.4.1

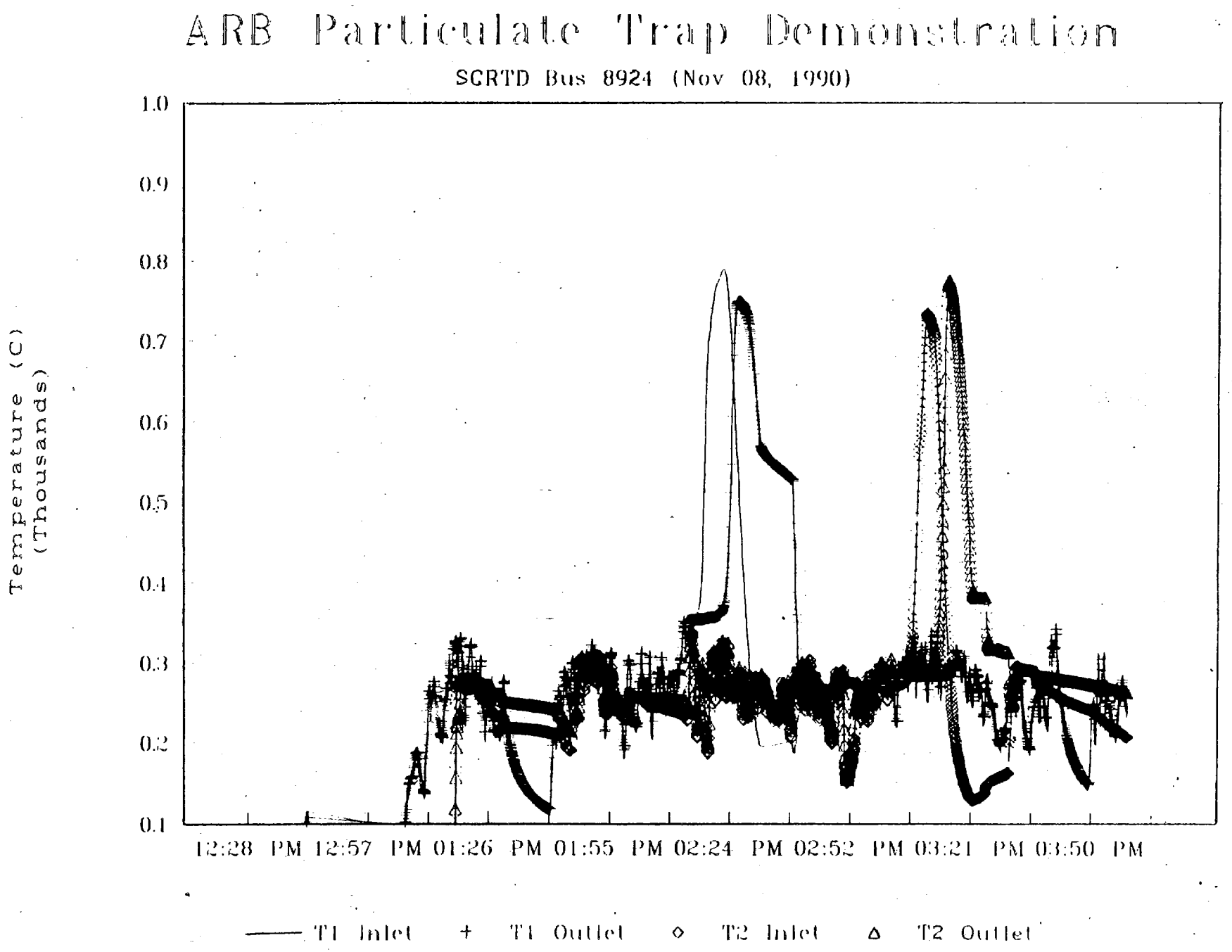

ARB Particulate Trap Demonstration
SCRTD Bus 8924 (Nov 08, 1990)
Temperature (C)
(Thousands)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
12:28 PM
12:57 PM
01:26 PM
01:55 PM
02:24 PM
02:52 PM
03:21 PM
03:50 PM
T1 Inlet
T1 Outlet
T2 Inlet
T2 Outlet

FIGURE 4.3.4.2

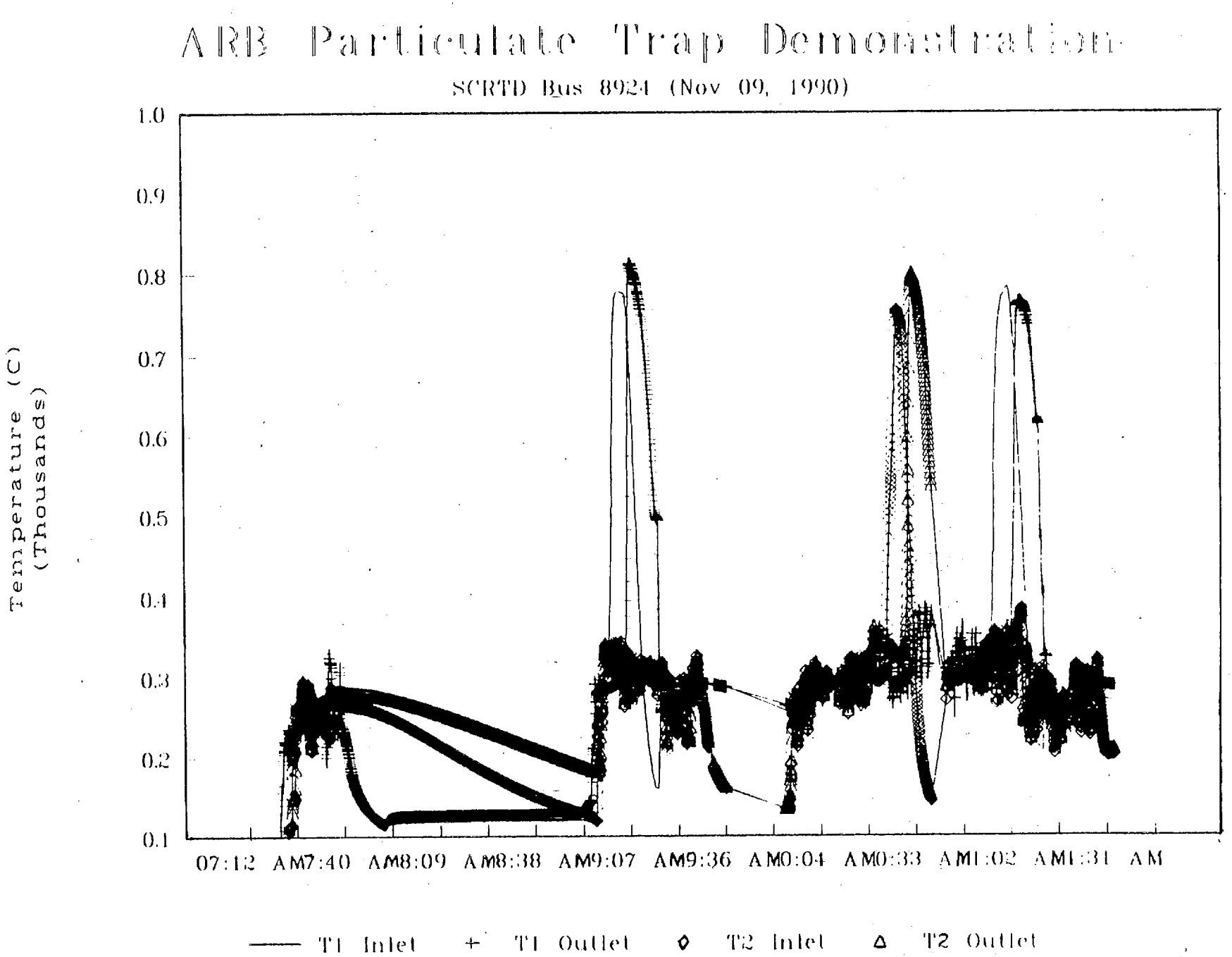

ARB Particulate Trap Demonstration
SCRTD Bus 8924 (Nov 09, 1990)
Temperature (C)
(Thousands)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
07:12 AM7:40 AM8:09 AM8:38 AM9:07 AM9:36 AM0:04 AM0:33 AM1:02 AM1:31 AM
T1 Inlet
T1 Outlet
T2 Inlet
T2 Outlet

FIGURE 4.3.4.3

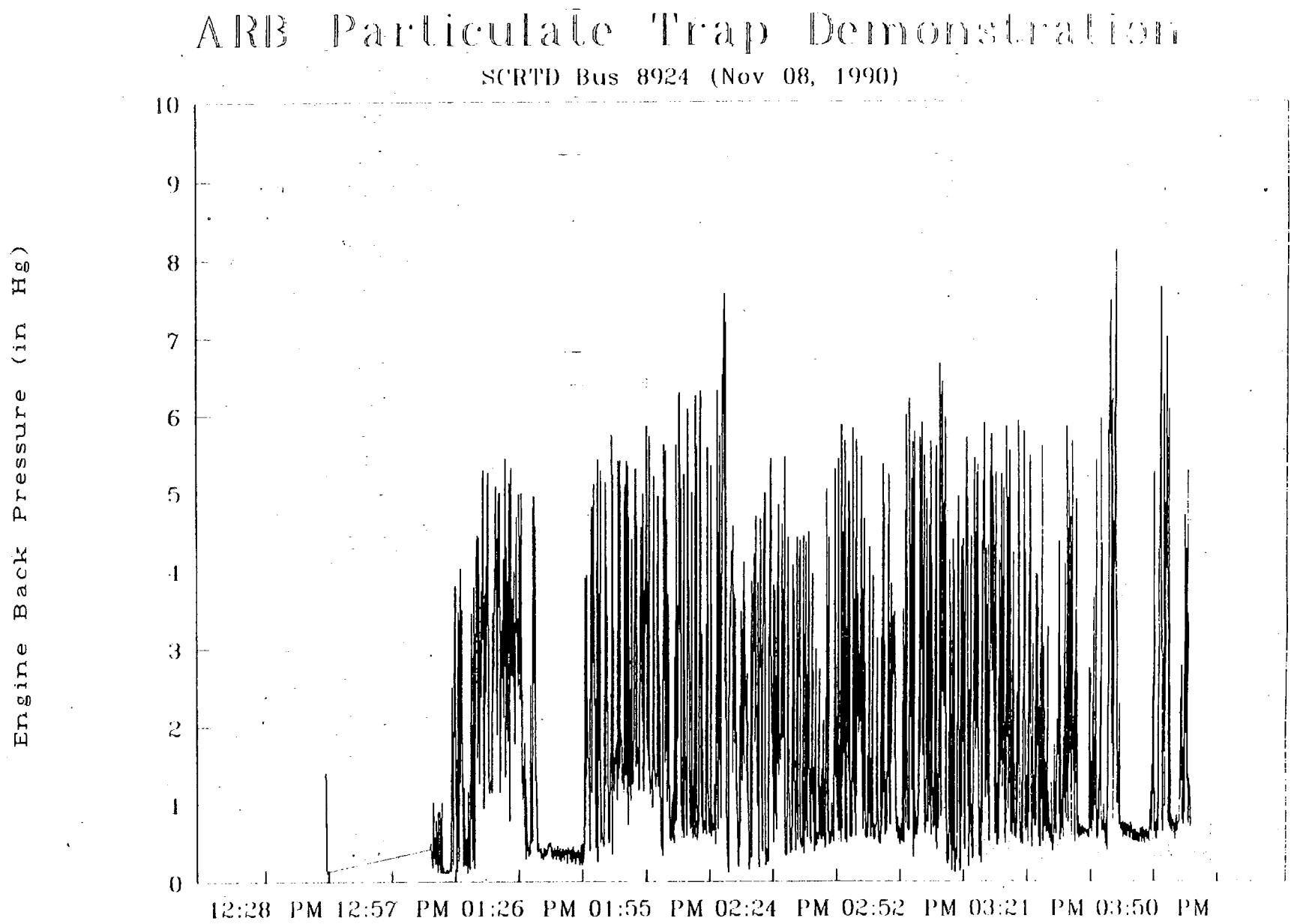

ARB Particulate Trap Demonstration
SCRTD Bus 8924 (Nov 08, 1990)
Engine Back Pressure (in Hg)
10
9
8
7
6
5
4
3
2
1
0
12:28 PM
12:57 PM
01:26 PM
01:55 PM
02:24 PM
02:52 PM
03:21 PM
03:50 PM

FIGURE 4.3.4.4

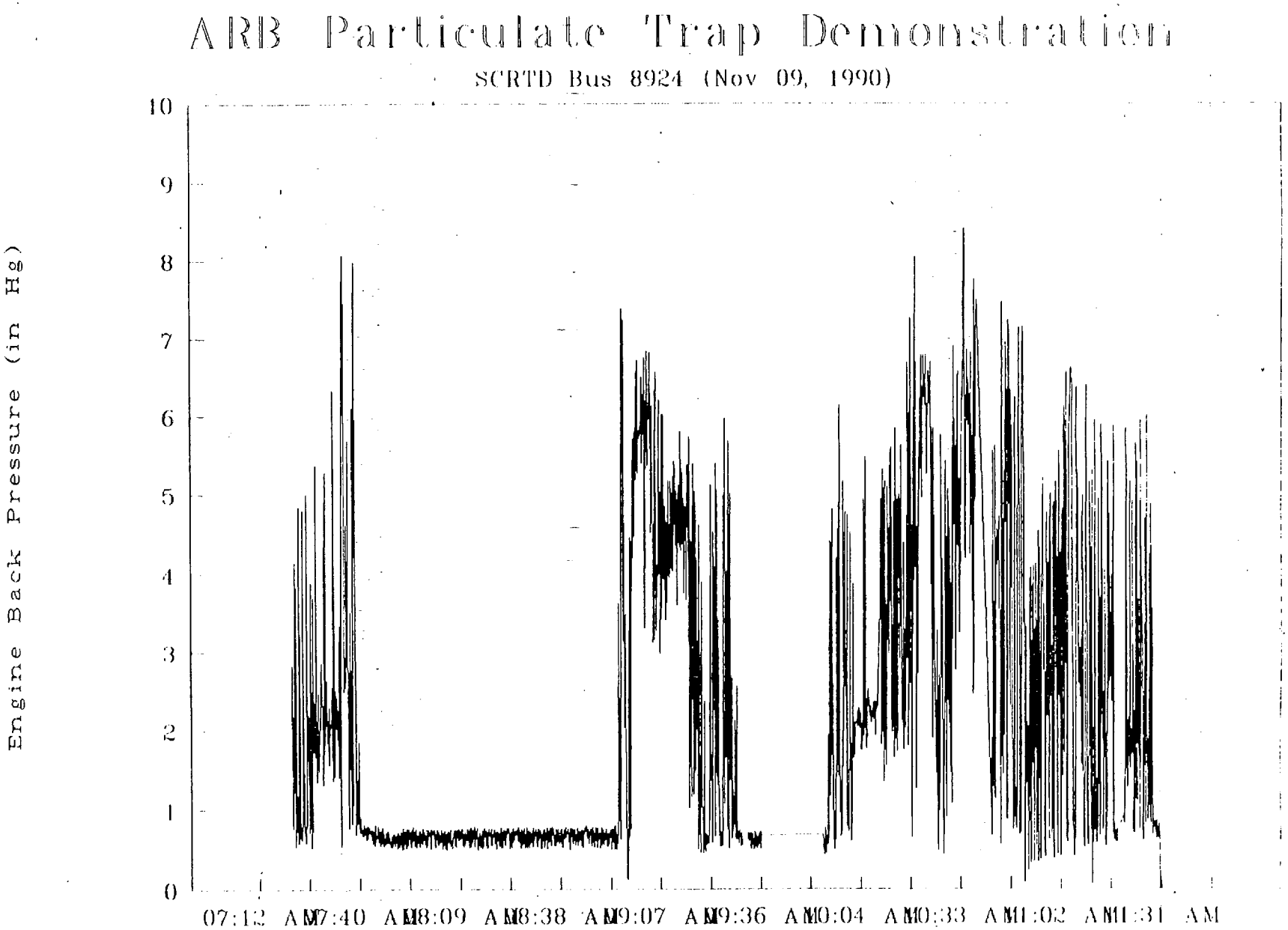

ARB Particulate Trap Demonstration
SCRTD Bus 8924 (Nov 09, 1990)
Engine Back Pressure (in Hg)
10
9
8
7
6
5
4
3
2
1
0
07:12 AM
07:40 AM
08:09 AM
08:38 AM
09:07 AM
09:36 AM
10:04 AM
10:33 AM
11:02 AM
11:31 AM

FIGURE 4.3.4.5

ARB Particulate Trap Demonstration

SCRTD Bus 8924 (Nov 12, 1990)

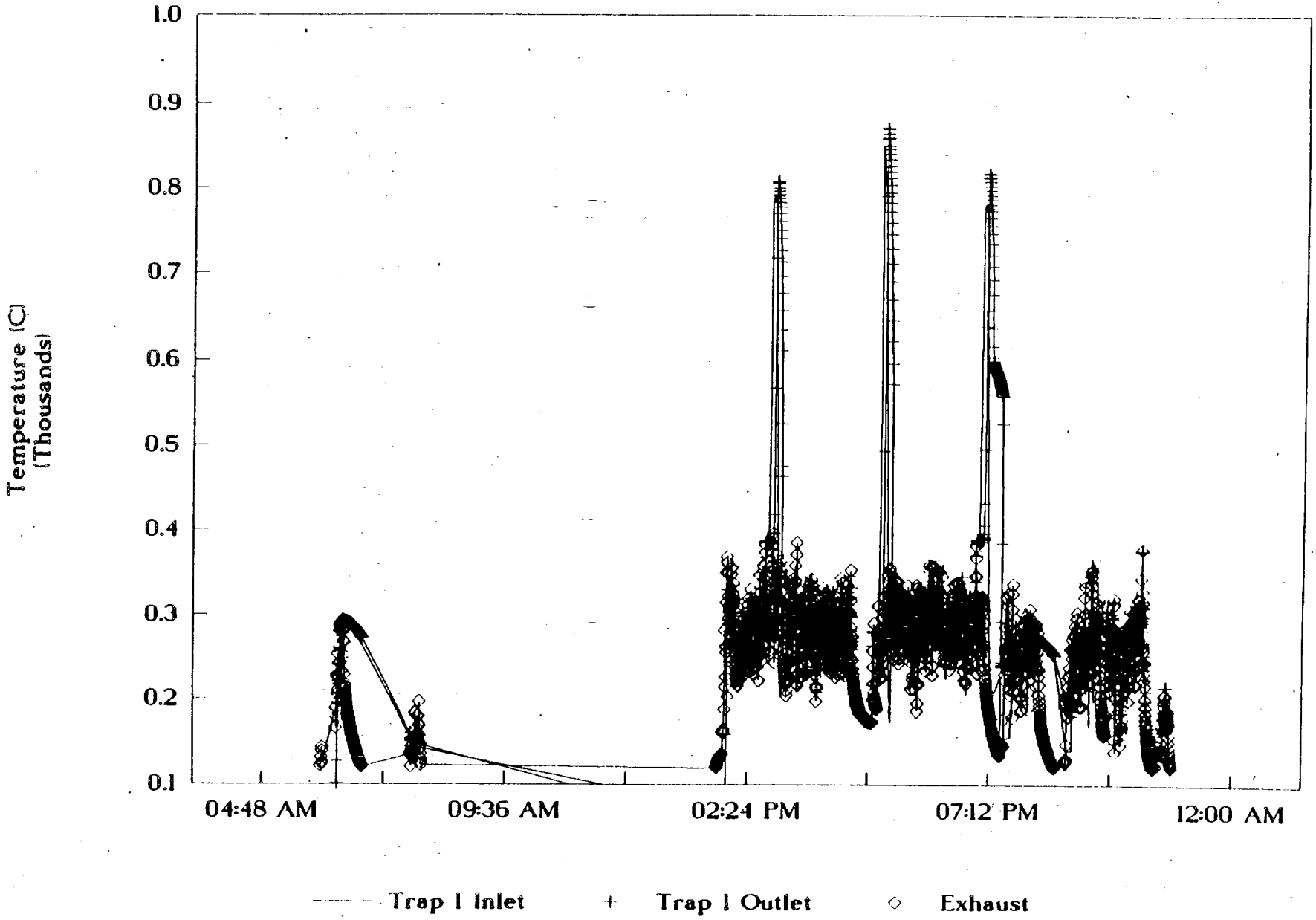


FIGURE 4.3.4.6

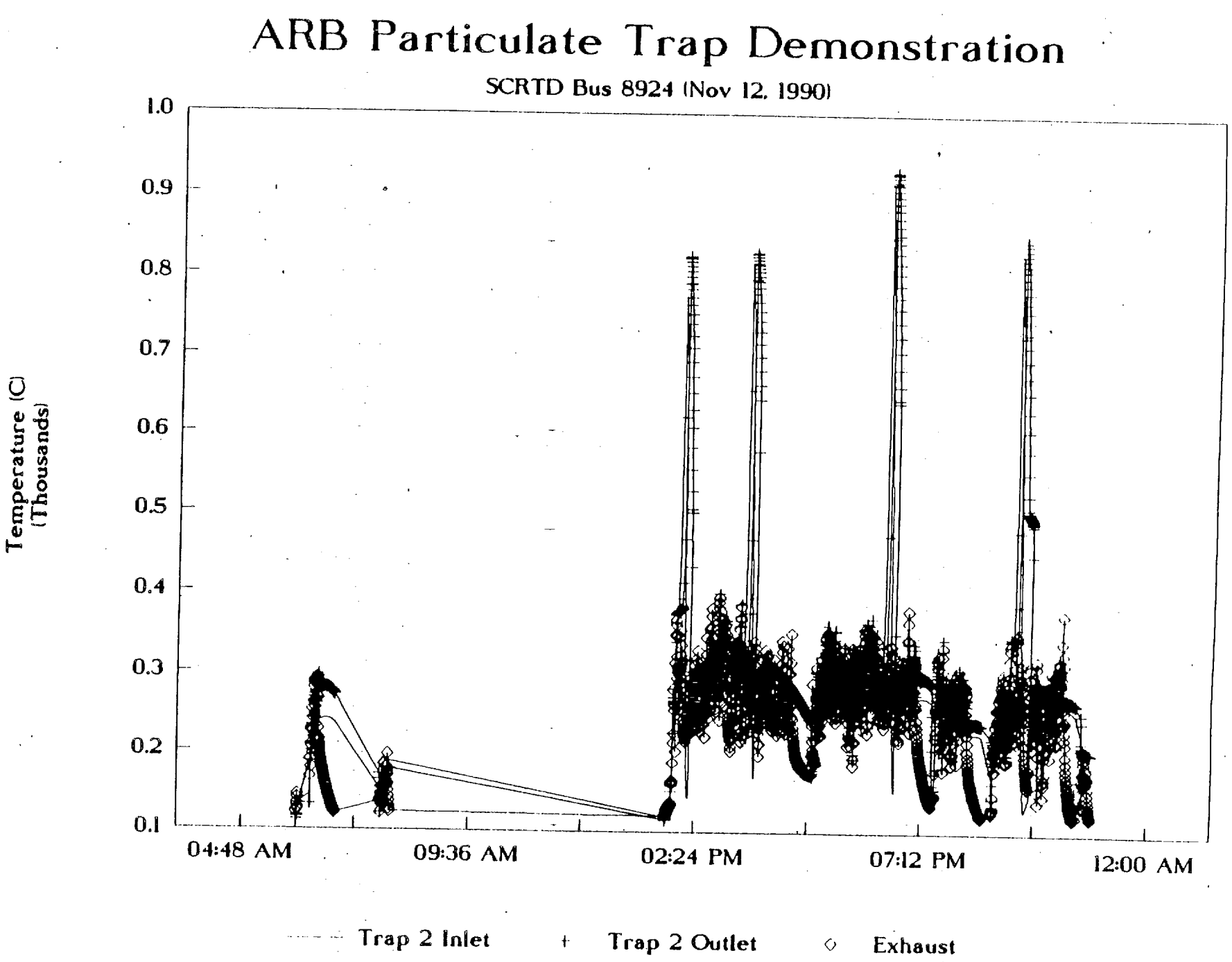

ARB Particulate Trap Demonstration
SCRTD Bus 8924 (Nov 12, 1990)
Temperature (C)
(Thousands)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
04:48 AM
09:36 AM
02:24 PM
07:12 PM
12:00 AM
Trap 2 Inlet
Trap 2 Outlet
Exhaust

FIGURE 4.3.4.7

ARB Particulate Trap Demonstration

SCRTD Bus 8924 (Nov 13, 1990)

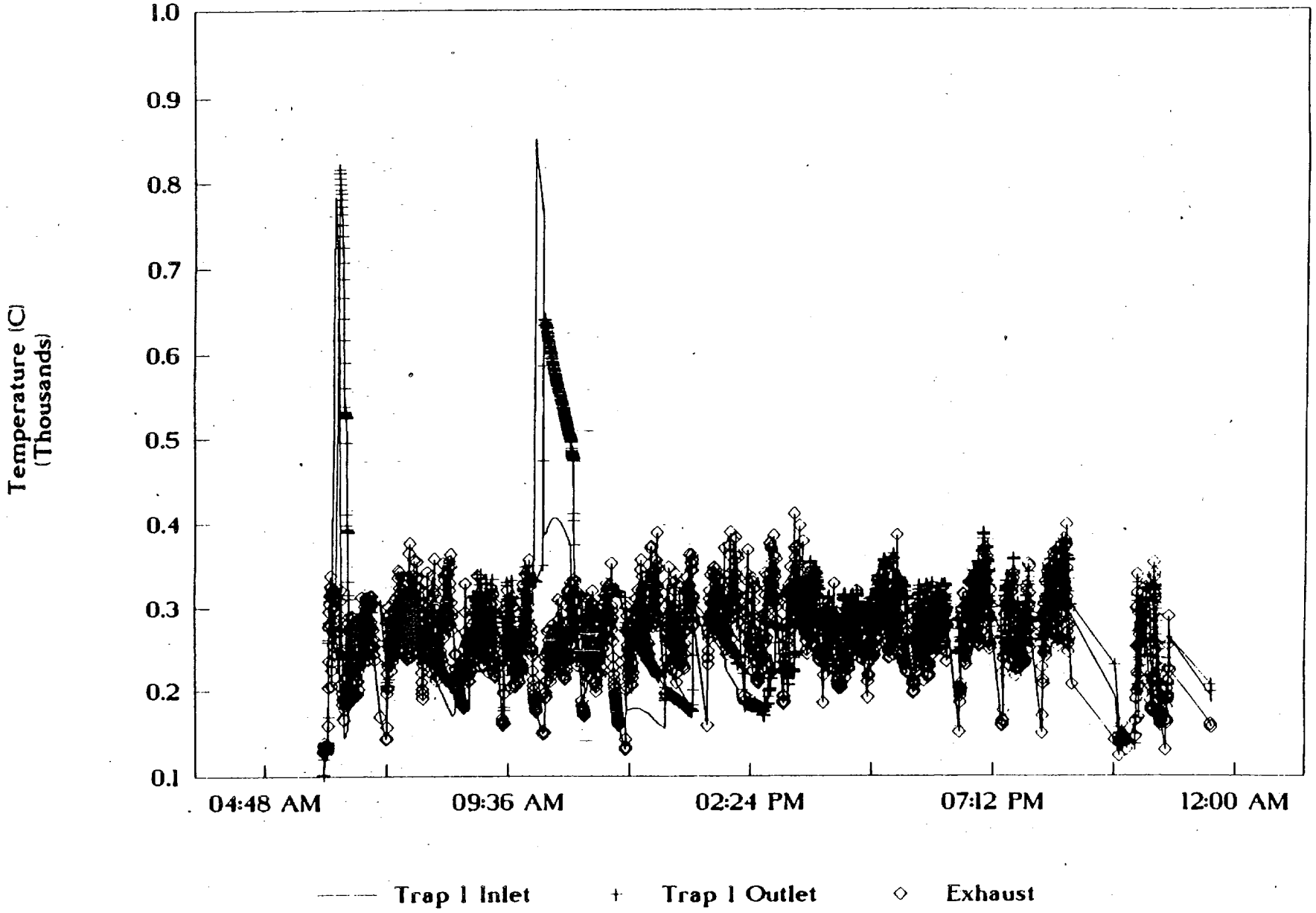


FIGURE 4.3.4.8

ARB Particulate Trap Demonstration

SCRTD Bus 8924 (Nov 13, 1990)

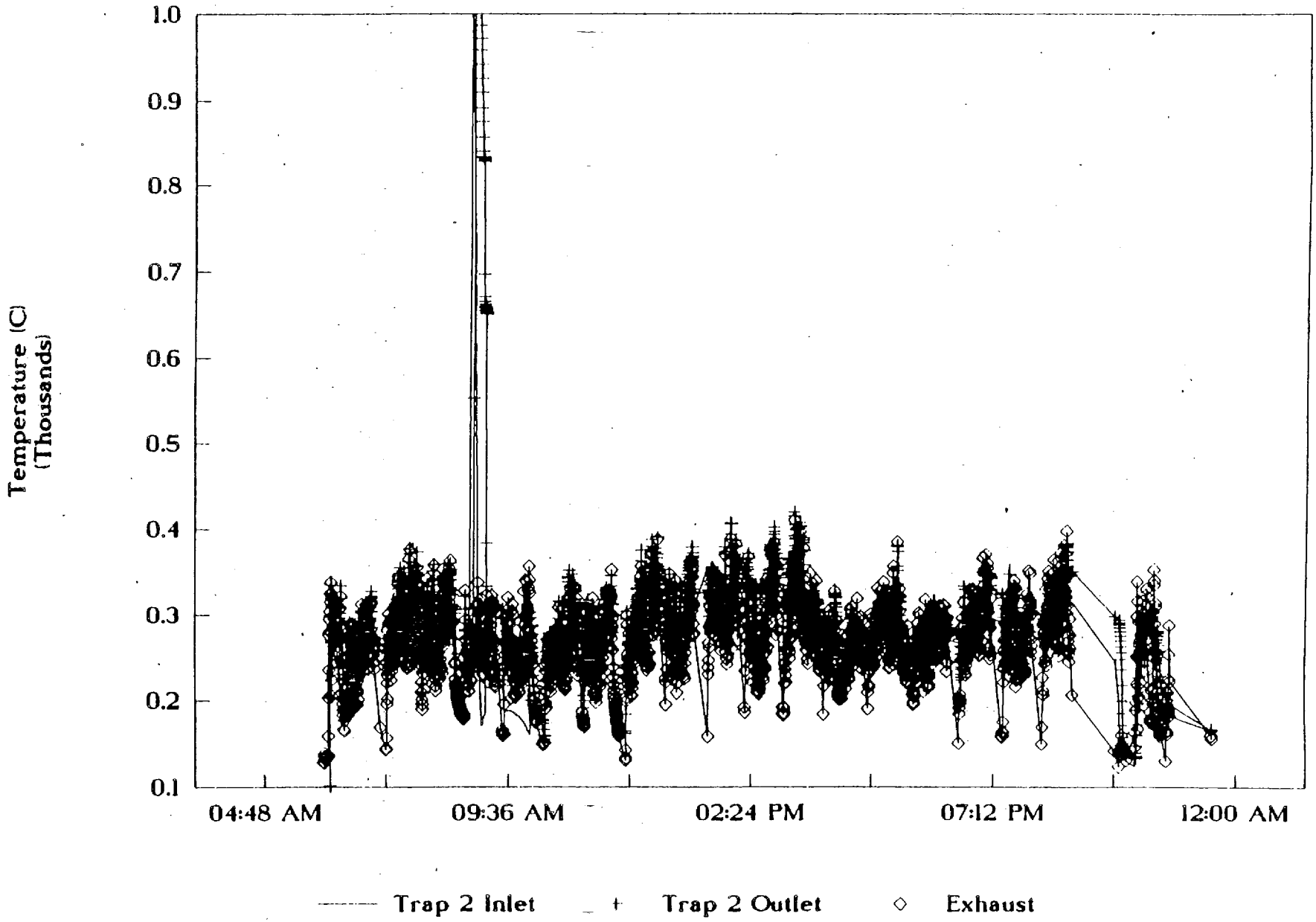


FIGURE 4.3.4.9

ARB Particulate Trap Demonstration

SCRTD Bus 8924 (Nov 12, 1990)

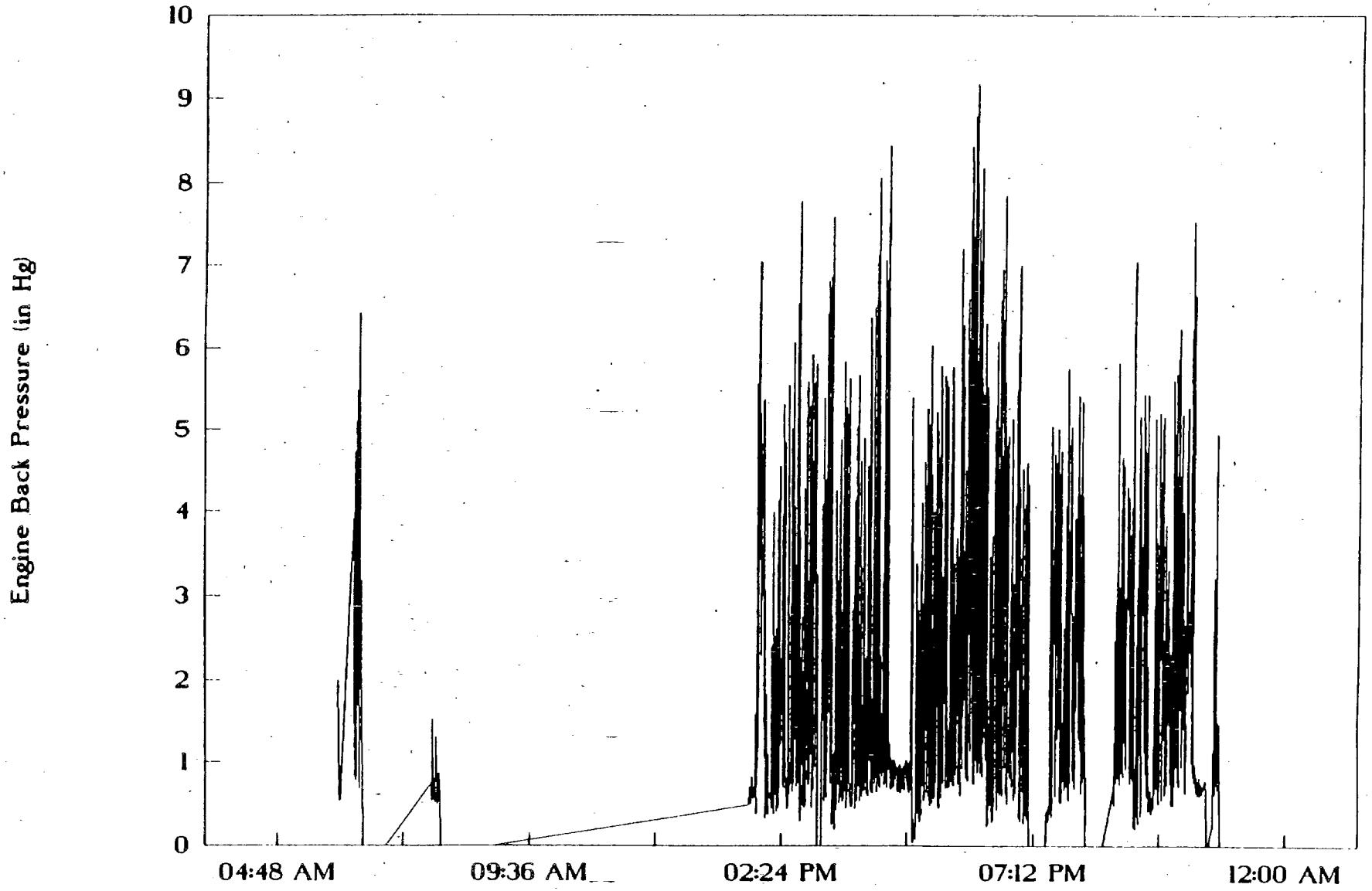


FIGURE 4.3.4.10

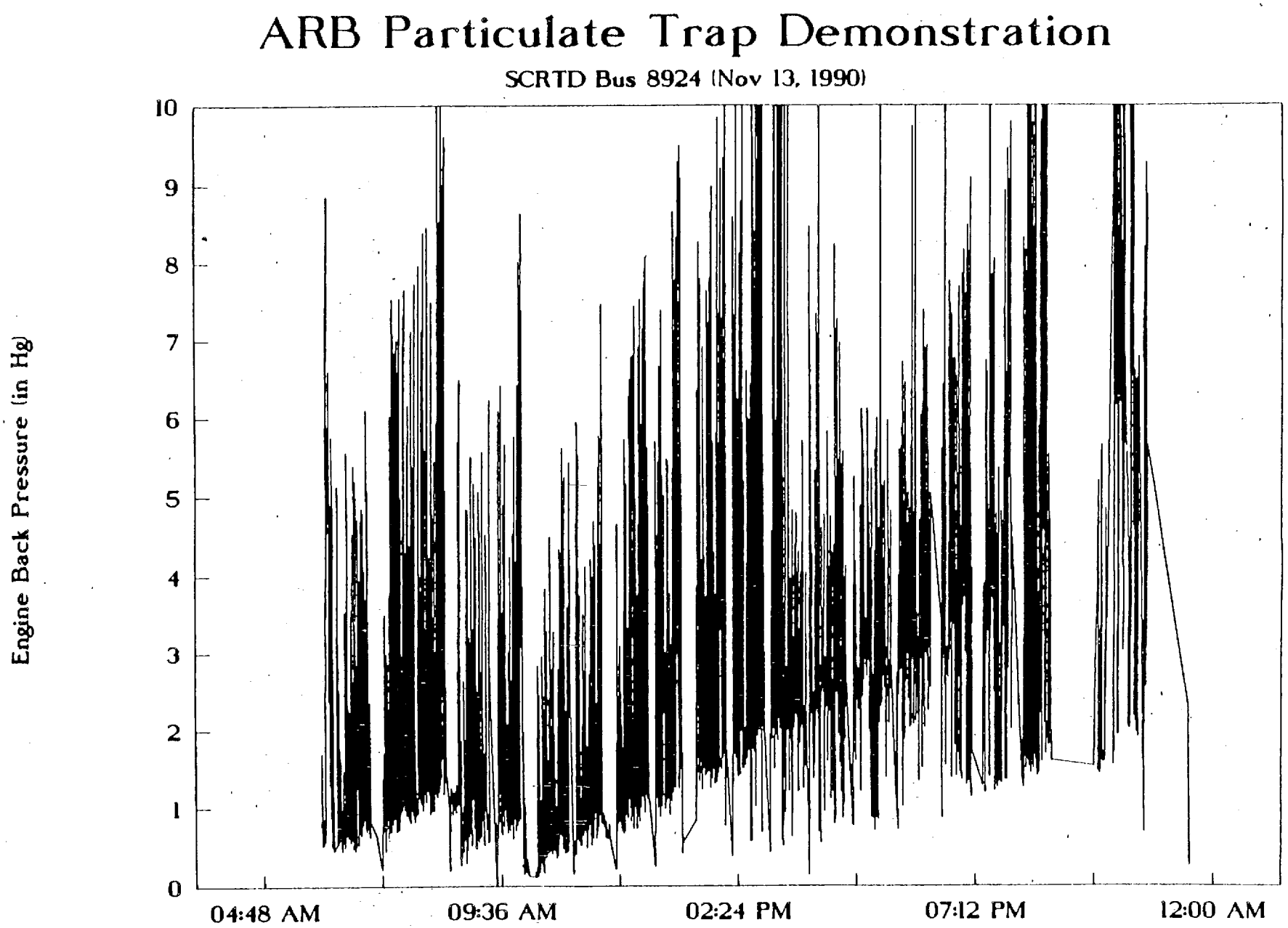
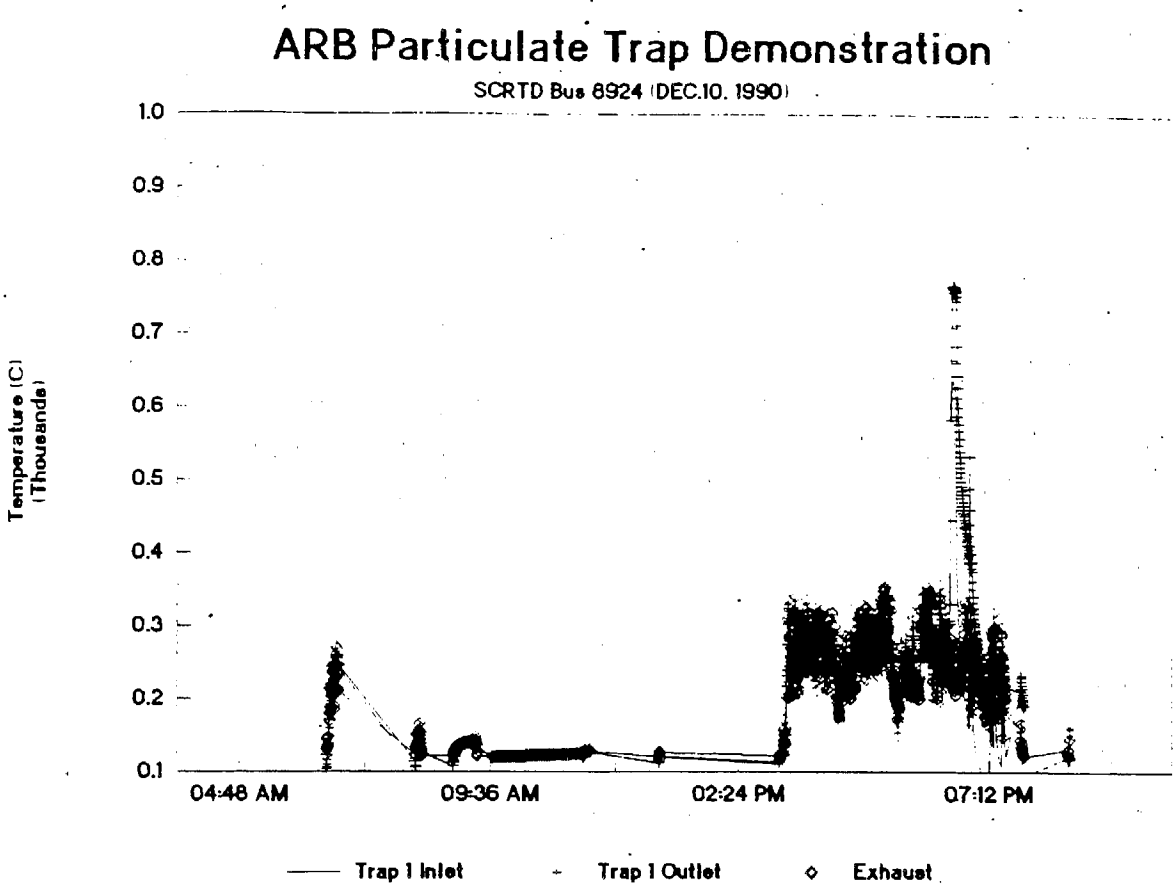


FIGURE 4.3.4.11



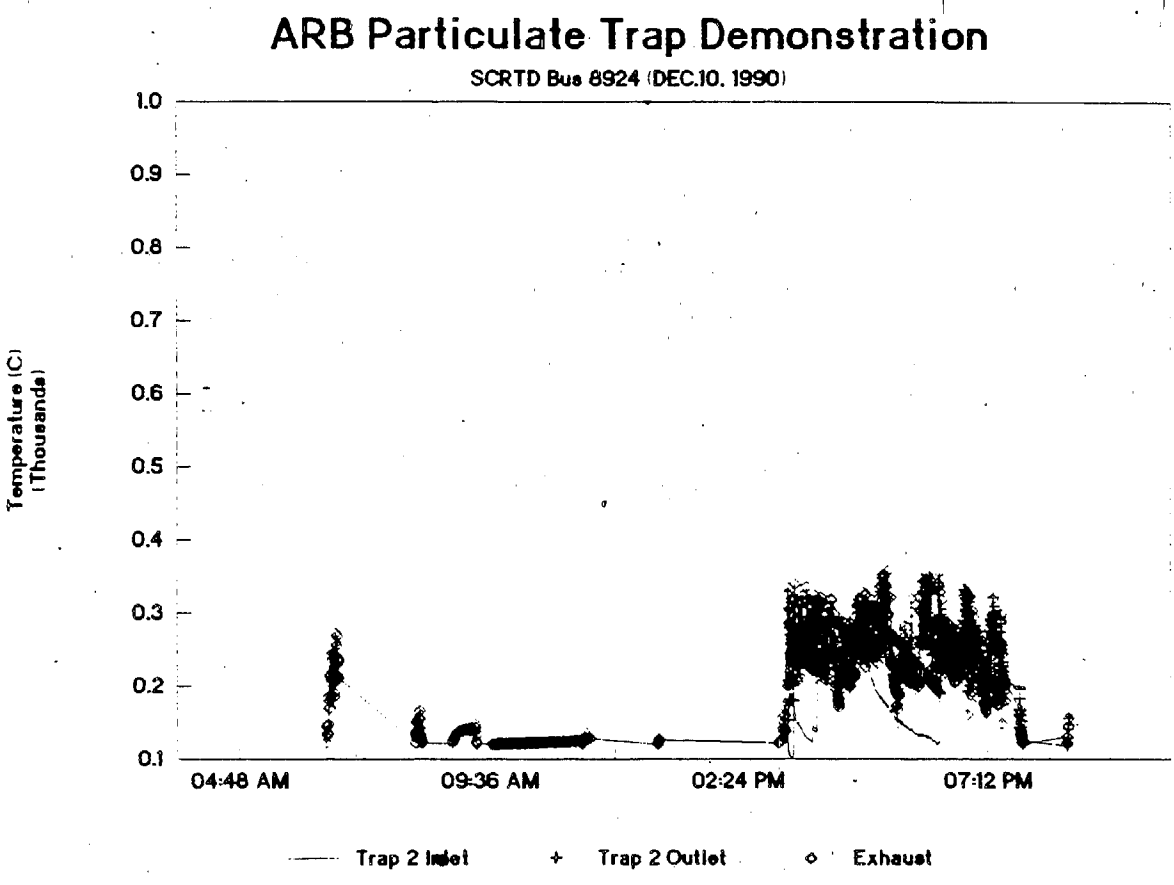


FIGURE 4.3.4.12

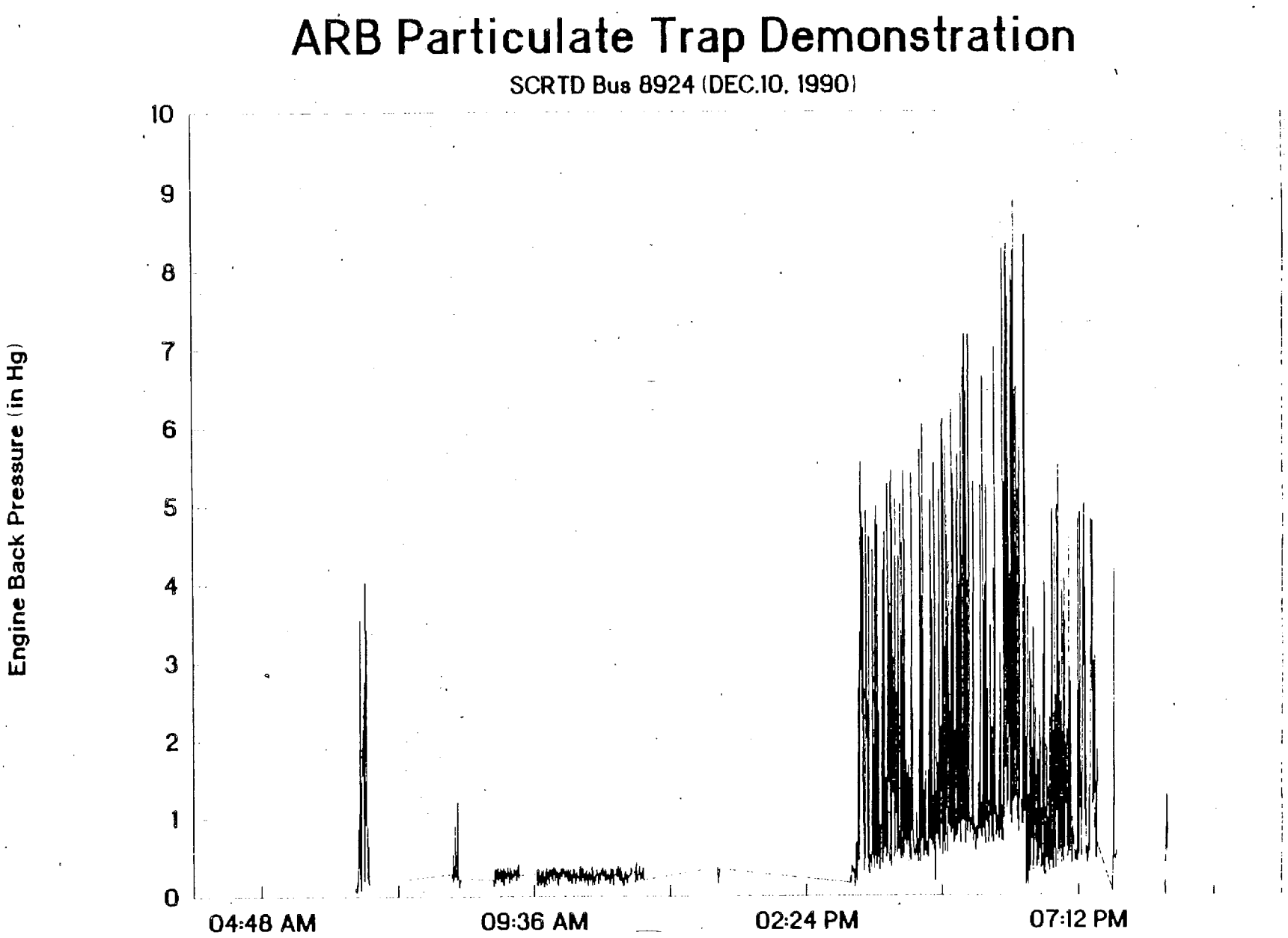
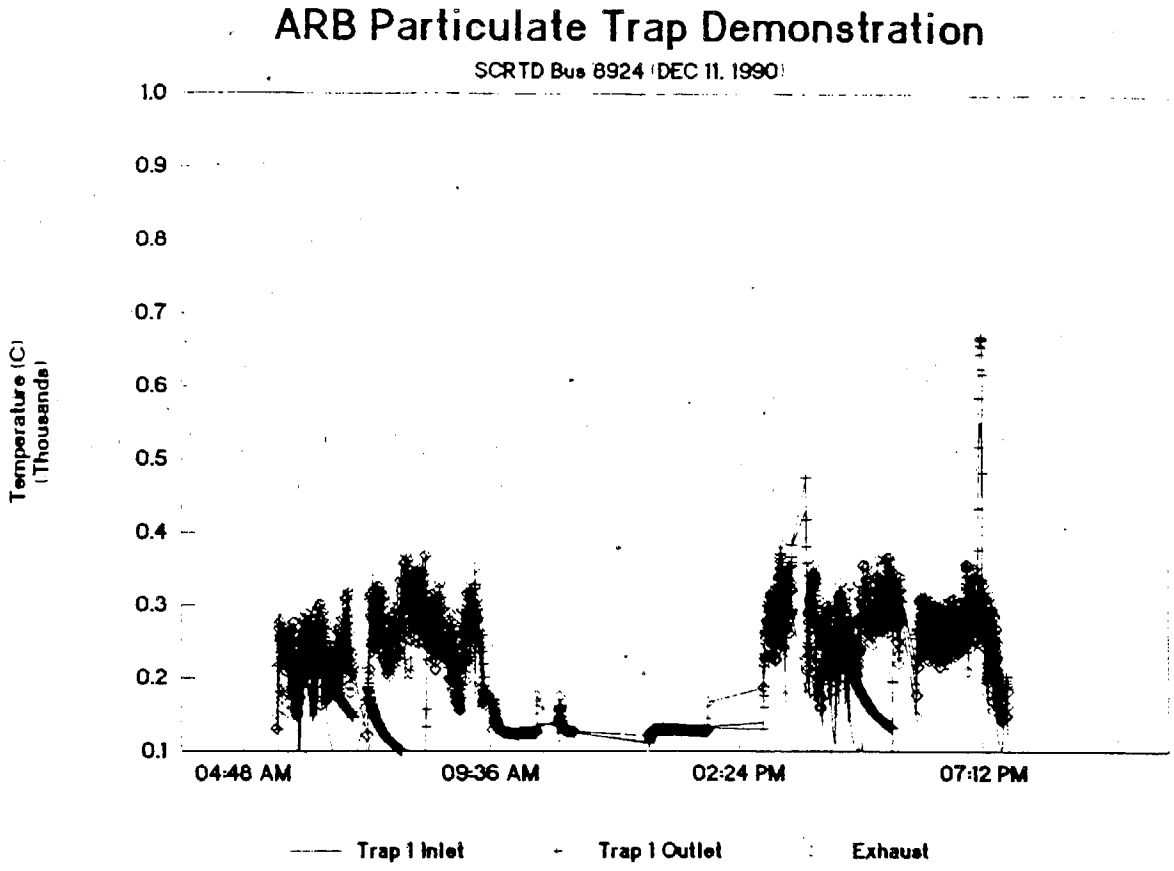


FIGURE 4.3.4.13



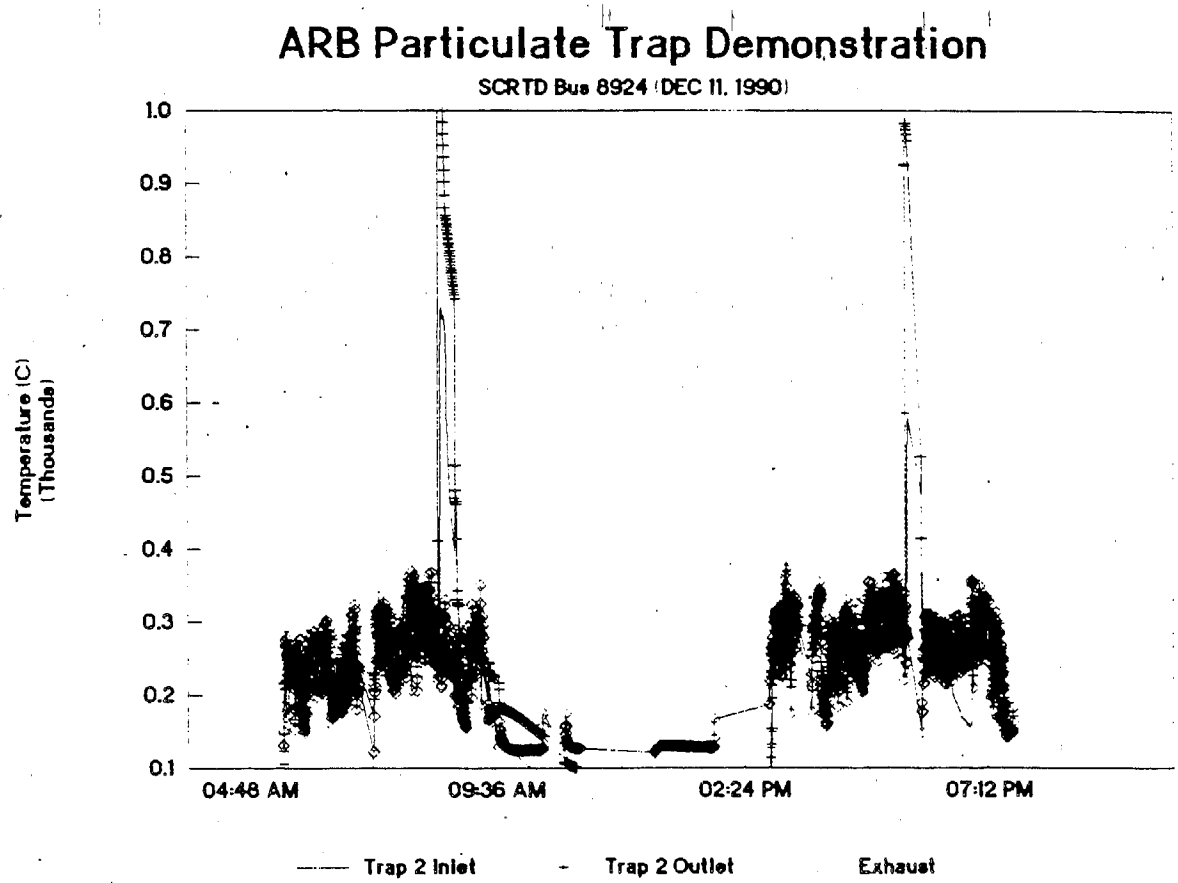


FIGURE 4.3.4.14

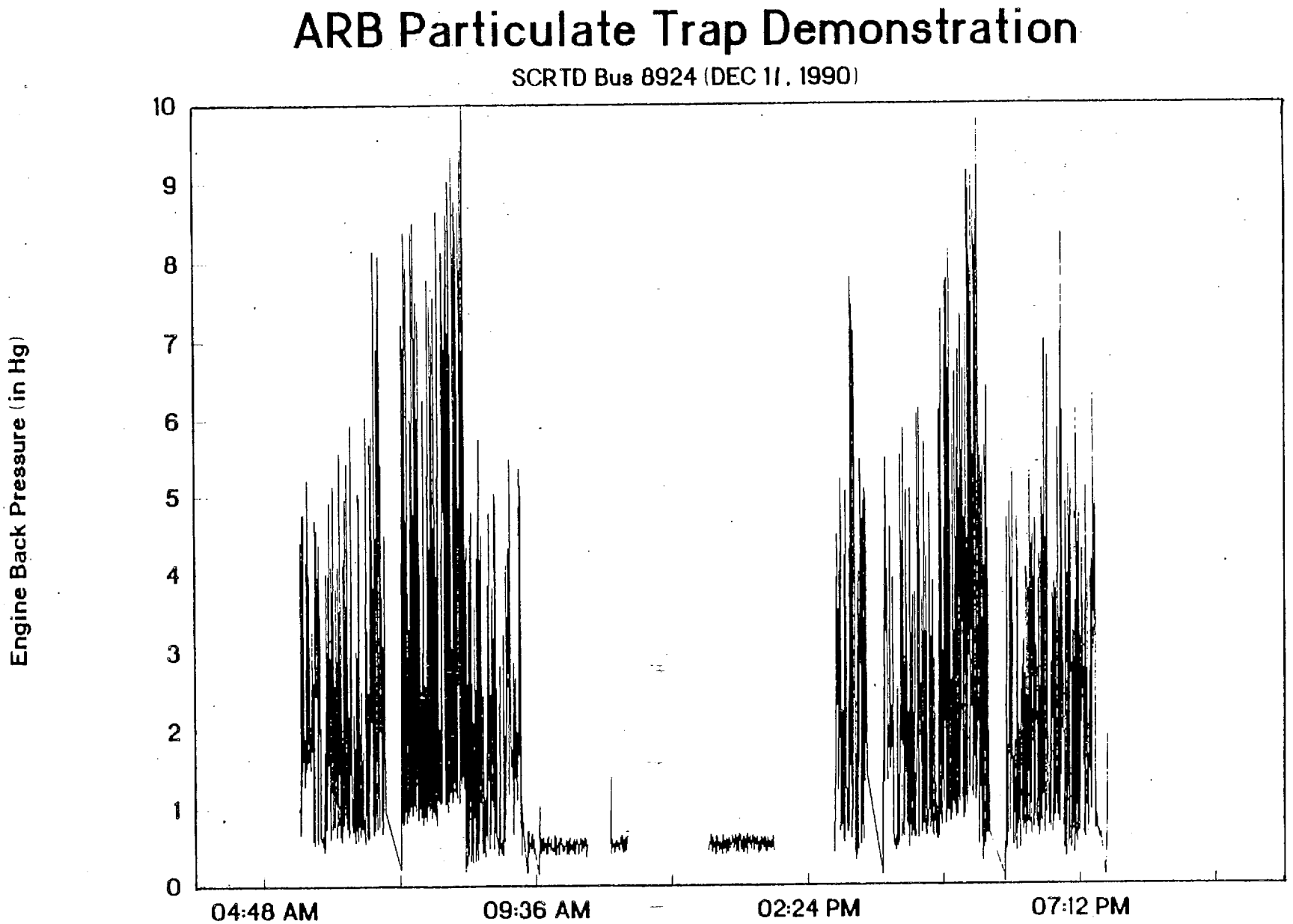
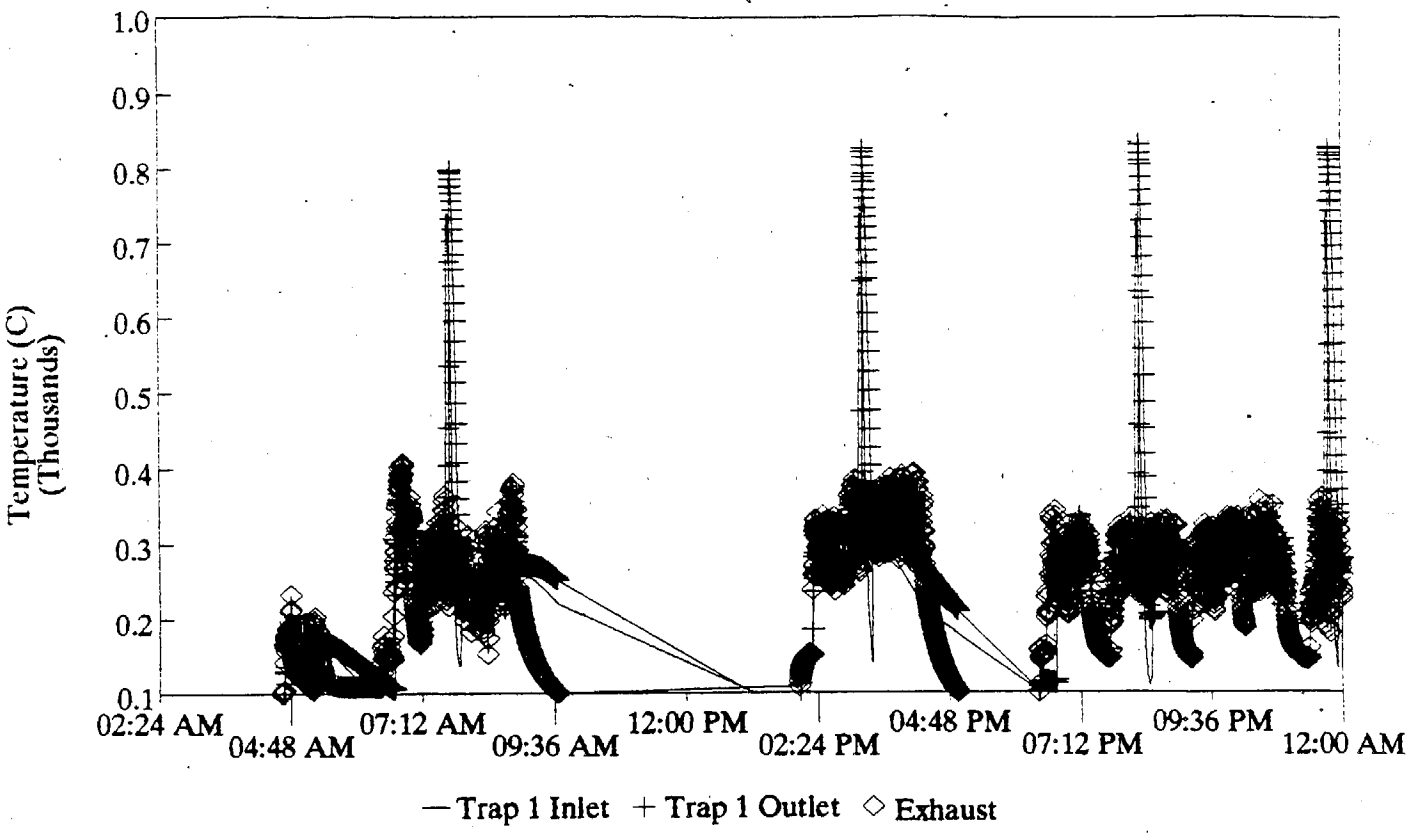


Figure 4.3.4.15



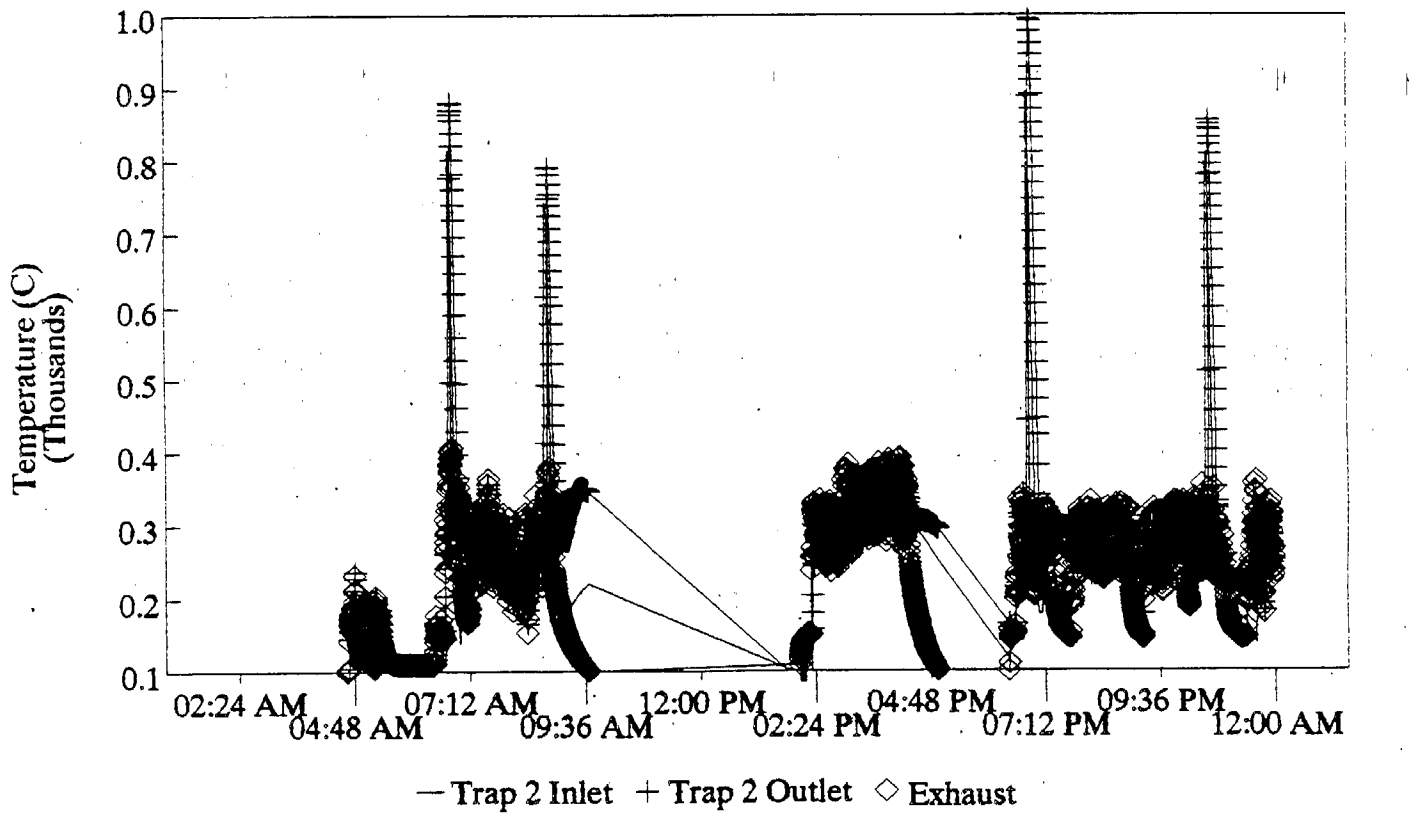


Figure 4.3.4.16

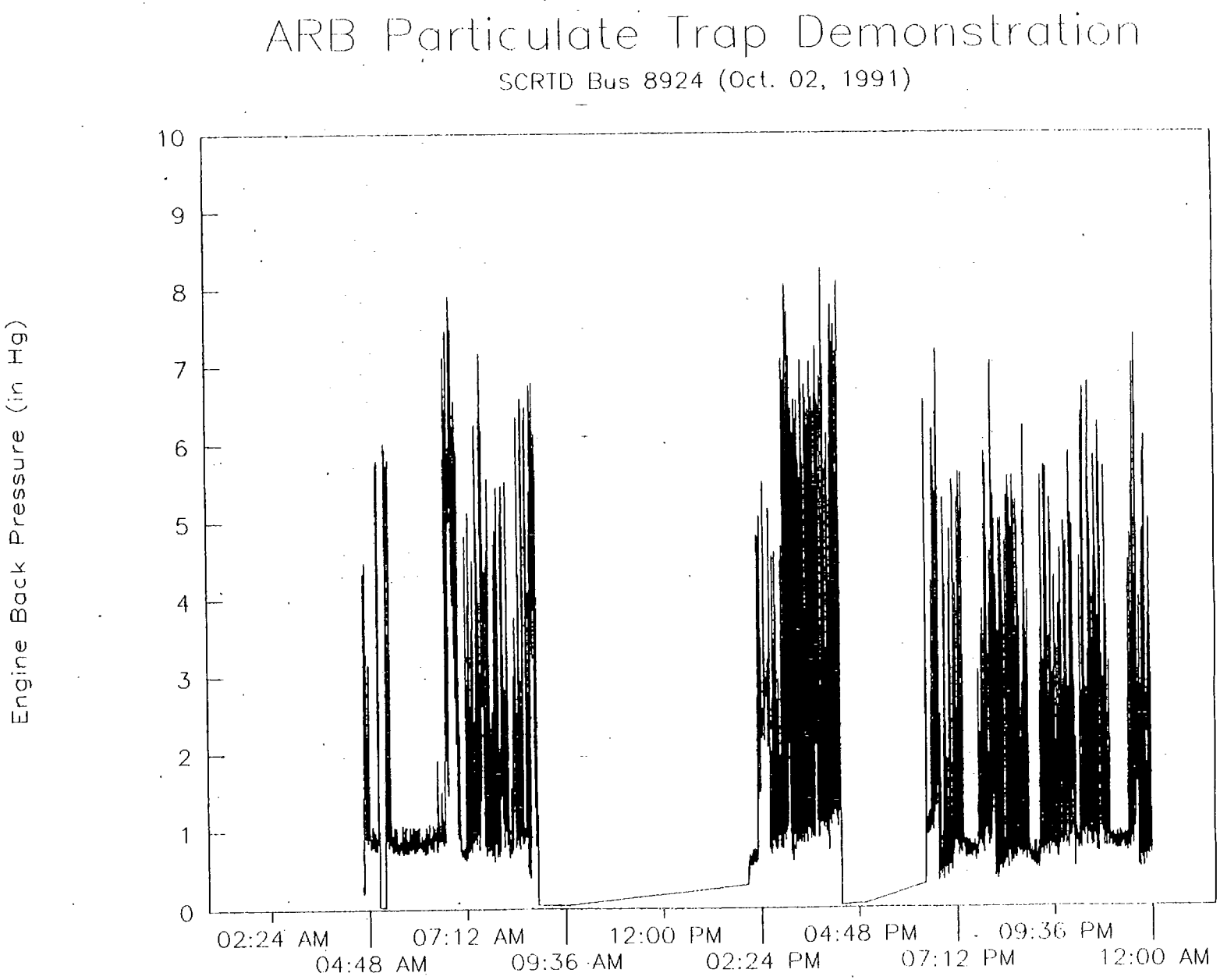
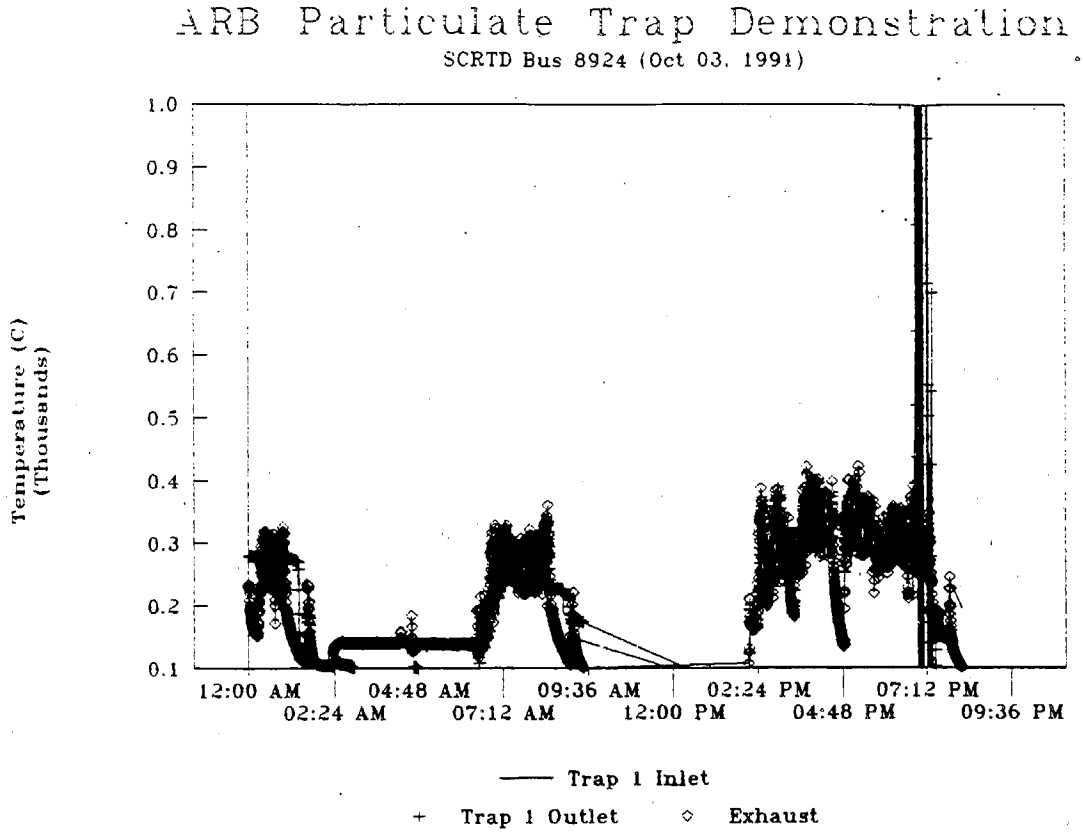


Figure 4.3.4.17



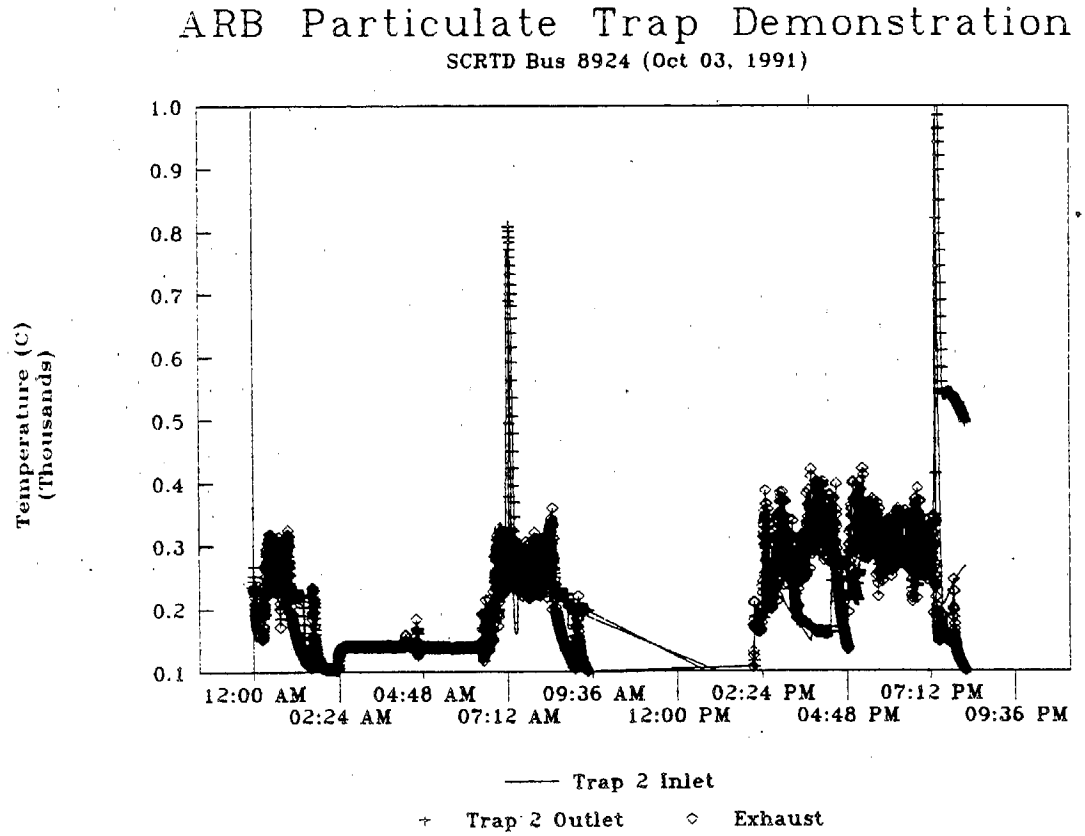


Figure 4.3.4.18

ARB Particulate Trap Demonstration

SCRTD Bus 8924 (Oct 03, 1991)SCRTD Bus

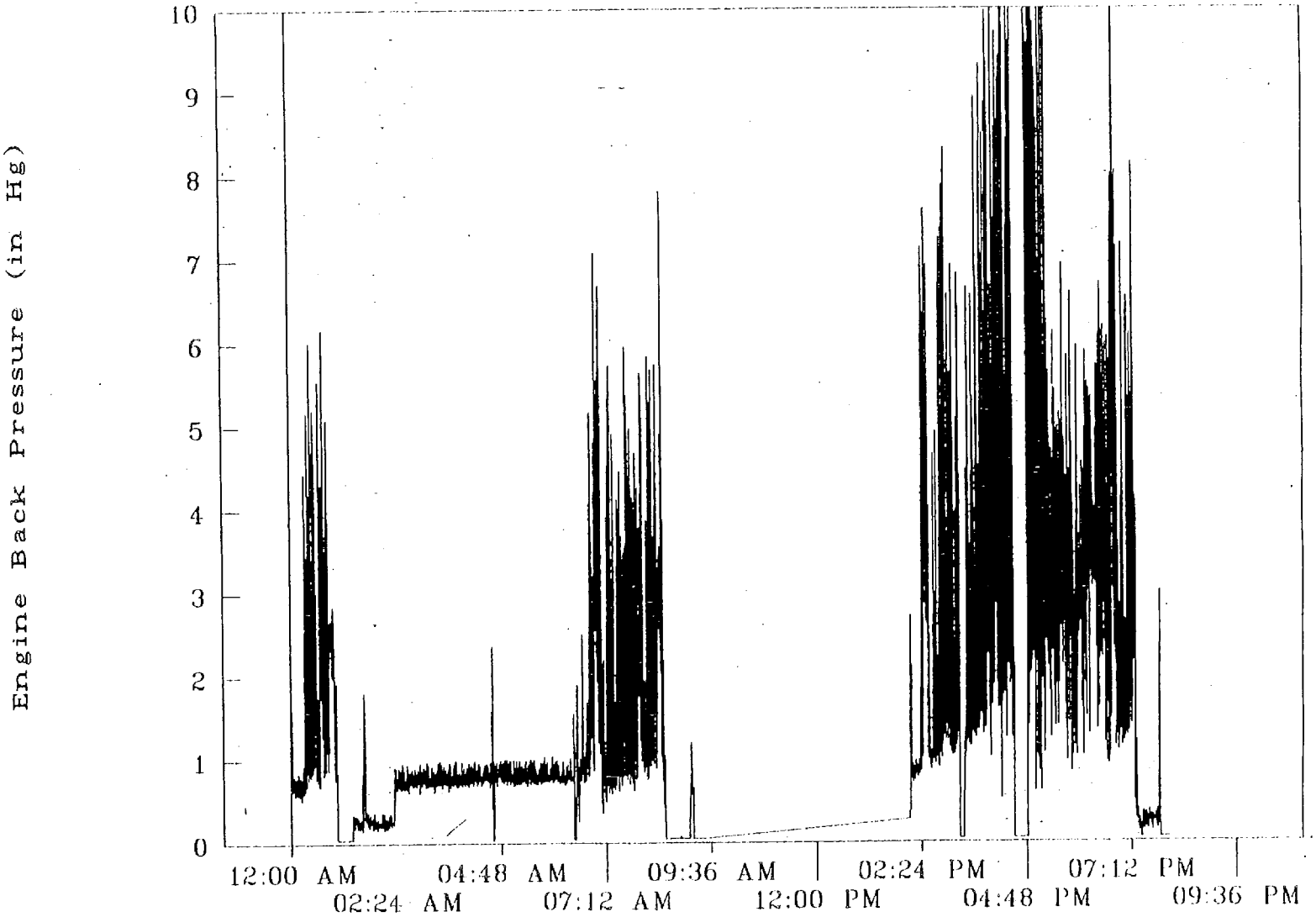


Figure 4.3.4.19

ARB TRAP SYSTEM DEMONSTRATION PROJECT
SCRTD Bus 8924 Weekly Trap Performance
Back Pressure Profile

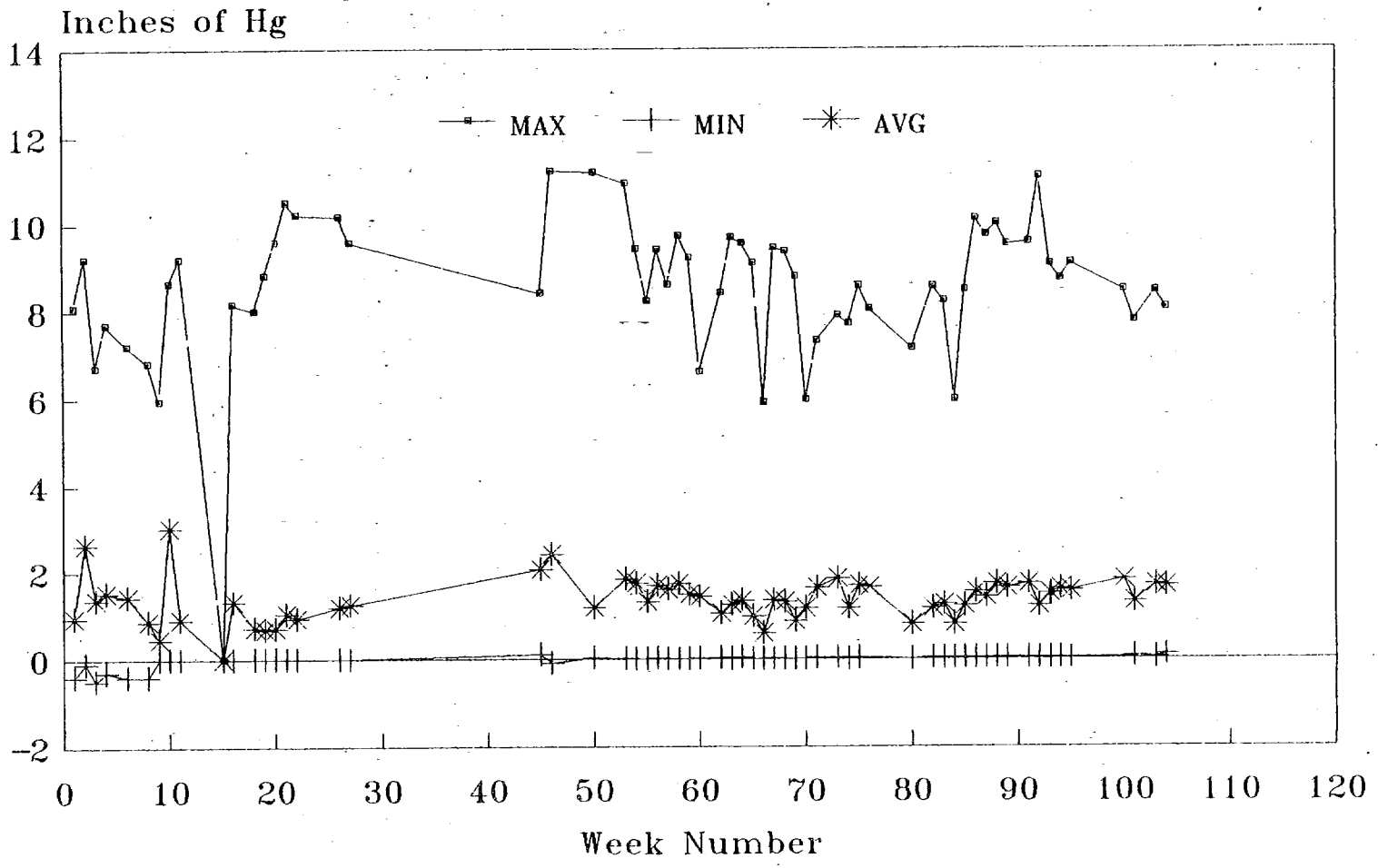


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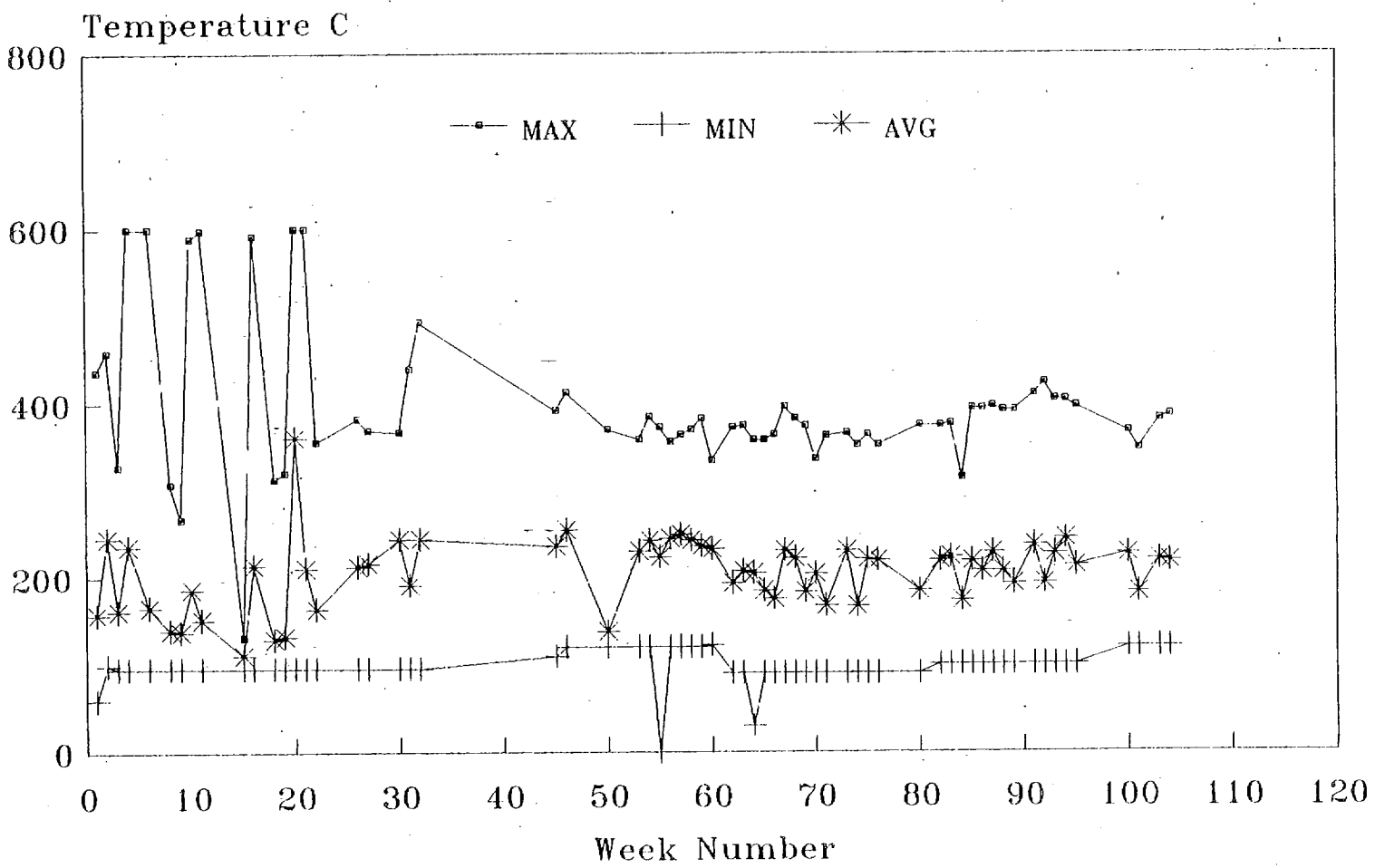
Figure 4.3.4.20

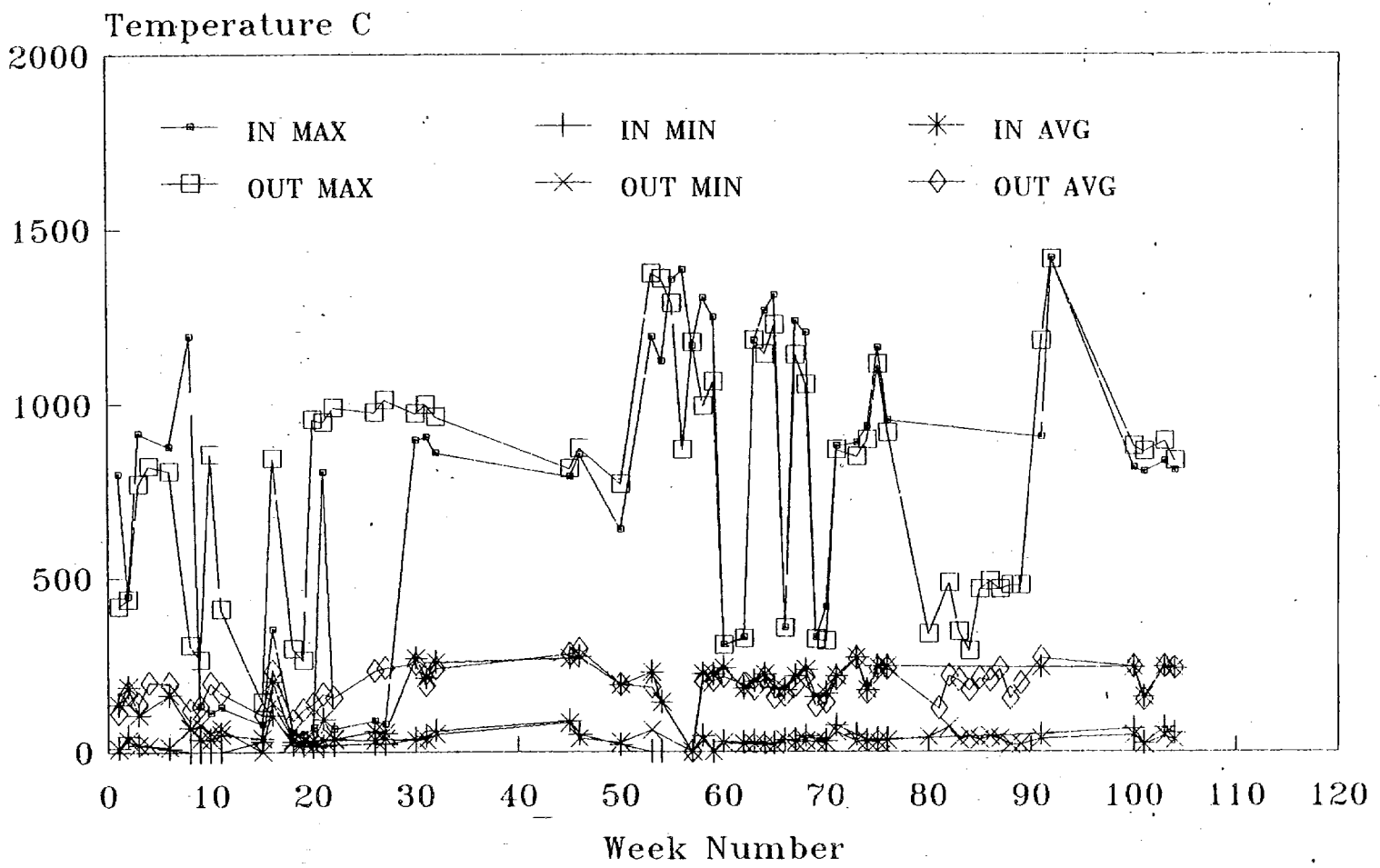
ARB TRAP SYSTEM DEMONSTRATION PROJECT
SCRTD Bus 8924 Weekly trap Performance
Exhaust Profile



Emissions-Ortech International

Figure 4.3.4.21

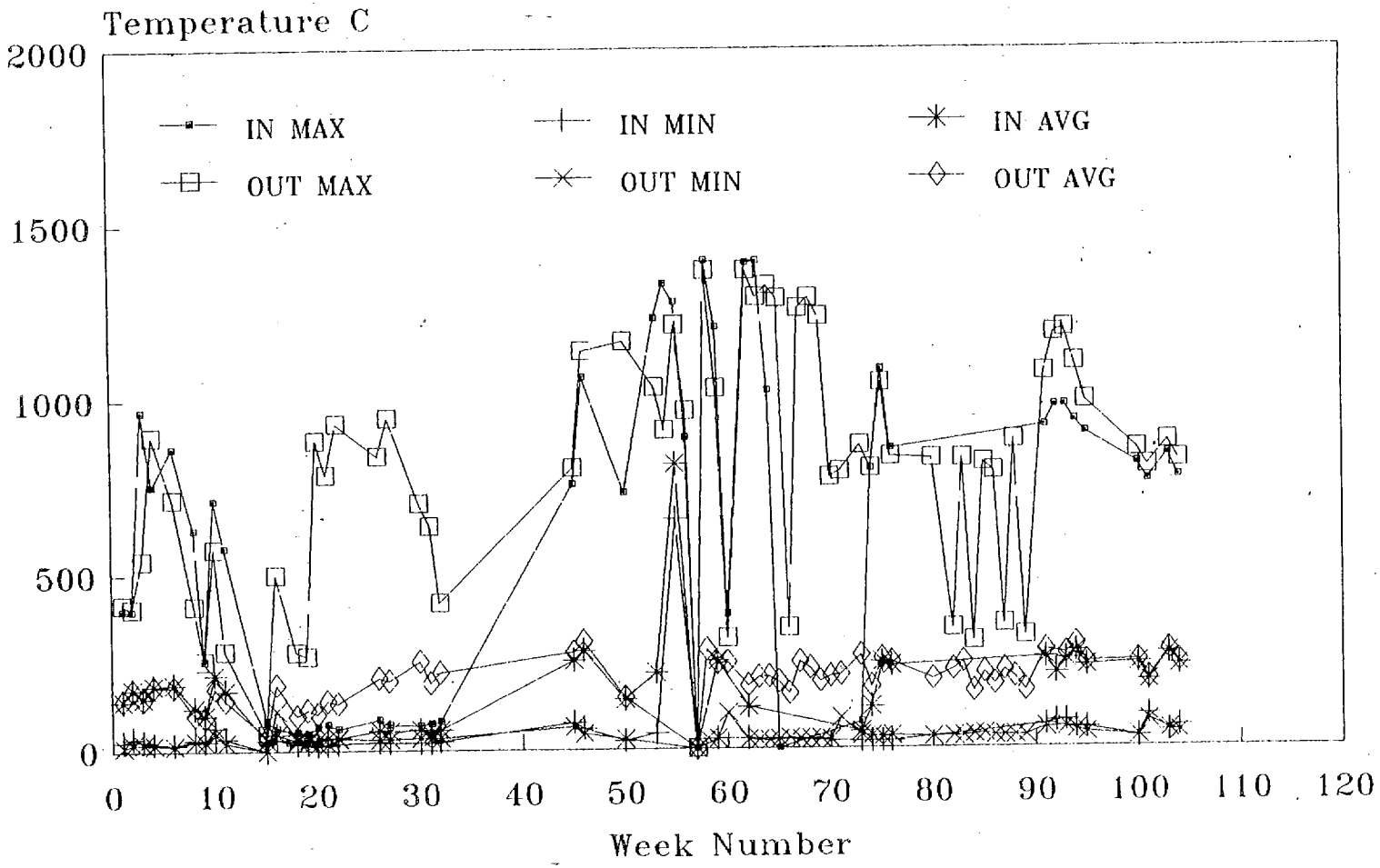
ARB TRAP SYTEM DEMONSTRATION PROJECT
SCRTD Bus 8924 Weekly Trap Performance
Trap 1 Profile



Emissions-Ortech International

Figure 4.3.4.22

ARB TRAP SYSTEM DEMONSTRATION PROJECT
SCRTD Bus 8924 Weekly Trap Performance
Trap 2 Profile



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ARB Trap System Demonstration

SCRTD Bus 8924 with DDC 6V92TA 240 hp

DCI Electric Dual Trap System

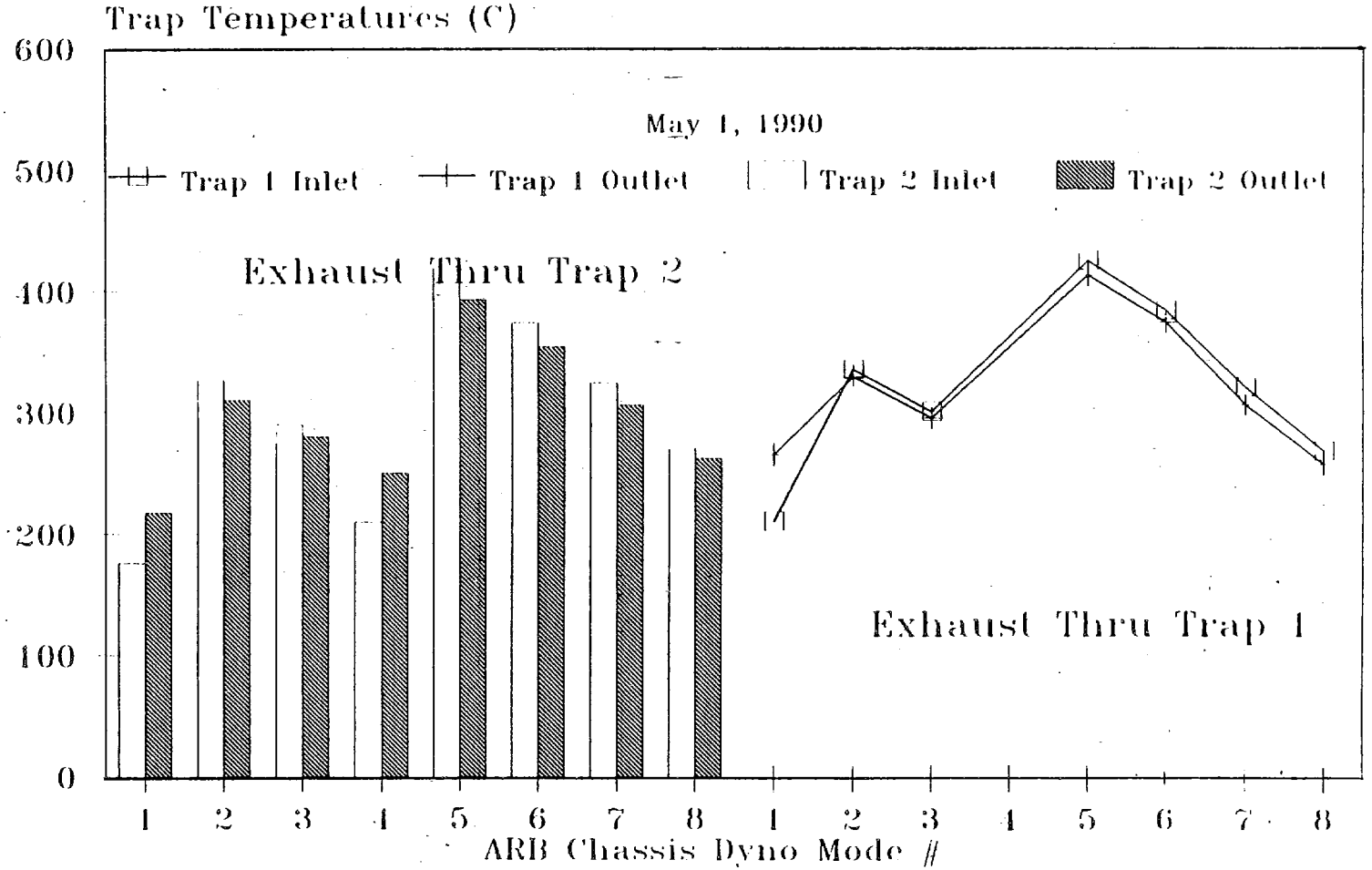

Figure 4.3.5.1

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APPENDIX A

Sample Letter to Potential Supplier

ONTARIO RESEARCH FOUNDATION
SHERIDAN PARK RESEARCH COMMUNITY
MISSISSAUGA, ONTARIO, CANADA L5K 1B3 • (416) 822-4111 • TELEX 06-982311

July 28, 1988.

Mr. J. Imes
Donaldson Company Inc.
1400 West 94th Street
Minneapolis, MN 55440
U.S.A.

Dear Mr. Imes:

ORF has been awarded a contract entitled "Heavy-Duty Diesel Particulate Trap Demonstration" by the Air Resources Board of the State of California. Please find enclosed a copy of the Abstract and Objectives of the project.

ORF is currently evaluating the trap oxidizer technology available for both bus and truck applications. If your company has products (either system or components) which are suitable for the application, please send us as much technical information as possible.

All evaluation will be conducted on a purely technical and system cost basis. An example of the evaluation criteria for the bus trap oxidizer system is enclosed. In collaboration with the Air Resources Board of the State of California, ORF will assign weighting factors to each of these criteria. The weighting factors will differ between buses and trucks.

The project time schedule calls for completion of the bus trap system selection in two months. Therefore, it is essential that we receive your input regarding the bus system at the earliest possible moment. Also, the time schedule dictates that all components of the bus trap system must be commercially available at the present time.

Thank you for your support. If you have any questions, please let me know. Our FAX Number is (416) 823-1446.

Yours truly,

K. Ha,
Manager, Emissions,
Advanced Engine Technology.
Encl.

ABSTRACT

The project described in the RFP calls for the evaluation of various options to control diesel particulate emissions from heavy duty vehicles, and the design and manufacture of 2 particulate trap systems. One system will be for a transit bus engine (6V92TAC), the other will be for a heavy duty diesel (HDD) truck engine (4-stroke). Both systems will use commercially available components. The systems will then be durability tested (400 hours) to verify their operation and performance in removal of particulate matter. The impact of the system on other emissions such as SO_4 will also be quantified. The systems will then be installed on vehicles (one bus and one truck) and operated for a 12 month period. If the 4-stroke engine demonstration is shown to be impractical, a second trap retrofit system will be selected for application to a second bus. Performance testing of the trap system will be conducted on a monthly basis. A final report will contain all the test results, an overall evaluation of the trap technologies demonstrated, together with recommendations for further improvement.

2. PROJECT OBJECTIVES

The objective of the project is to demonstrate durable retrofit particulate trap systems capable of reducing particulate emissions (85+%) from heavy-duty diesel engines used by urban buses and trucks.

The project calls for design, manufacturing, dynamometer testing and road demonstration of 2 particulate trap systems. One system will be for a 6V92 TAC 2-stroke heavy-duty diesel (HDD) engine (bus) and a 4-stroke heavy-duty diesel engine for either a truck or bus application. The trap system for the bus will be for retrofitting purposes. The system for use with the 4-stroke heavy-duty diesel engine on a truck, can be used for retrofitting purposes or new truck application. Both systems will be completely automatic and meet engine manufacturers specifications for operating the engine, including maximum exhaust backpressure.

BUS TRAP SYSTEM EVALUATION CRITERIA
(Additional Criteria May Be Added)

1) Total particulate removal efficiency >85%.

2) No visible black smoke (i.e. no bypass).

3) No increase in emissions during regeneration.

4) Durability of 290,000 miles with filter elements replacement allowed.

5) Completely automatic.

6) Minimum modification during installation.

7) Minimum impact to regular bus maintenance and service.

8) Engine backpressure within limitations specified by DDC for 6V 92TA (i.e. 3-4" Hg.).

9) Minimum energy penalty.

10) Upper limit of cost per system (hardware and installation) during production is $5,000.

11) Minimum maintenance costs.

12) Maintain same muffling effect as muffler.

13) No fire hazard.

APPENDIX B

Minutes and Presentation of
September 28, 1988 Meeting

ORTECH
INTERNATIONAL
2395 Speakman Drive
Mississauga, Ontario L5K 1B3
(416) 822-4111, (800) 268-5390
Telefax (416) 823-1446

October 13, 1988.

Ms. Lauren Dunlap
State of California
Air Resources Board
9258 Telstar Avenue
El Monte, CA. 91731

Dear Lauren:

This letter is to confirm our discussion during the meeting held at ARB on September 28, 1988.

1) SCRTD will provide ORTECH with diesel fuel analysis - ORTECH will locate diesel fuel to match the properties, especially regarding sulphur content. SCRTD will also inform ORTECH regarding lubricant and noise specifications.

2) The test bus will be a 1981 GM RTS-02-04 with a 6V 92TAC engine rated 240 hp at 2100 rpm. ORTECH will investigate the possibility of de-rating the in-house engine (85 .6V-92TAC) to match, or such an engine will be provided to us from SCRTD upon a request by ARB.

3) Each of the criteria for the bus trap system has been assigned either as pass/fail or points. A list is attached. This list, upon approval by ARB, will be sent to all finalists (DCI, ECS and possibly Converter Technology).

4) ORTECH will inform ACUREX of the outcome of the meeting. ACUREX's work will start according to the revised schedule (October, 1988). A meeting will be held with ACUREX to detail the project work and time schedule.

5) ARB tentatively agreed to the revised time schedule. A no-cost contract extension will be signed in the future.

60 Years of Service to Industry
ORTECH Corporation

Please find enclosed a bus trap system evaluation list, together with all assigned weighting factors, for your approval. Please let me have your comments so that the final list can be sent to the selected finalist.

A summary of the responses for the bus trap system is also included.

If you have any questions, please let me know.

Yours truly,

K. Ha,
Manager, Emissions
Advanced Engine Technology.
Encls.

Presentation No. 1

For

Air Resources Board

Heavy-Duty Diesel Particulate Trap Demonstration

AET

ORTECH INTERNATIONAL

September 28, 1988

ARB Trap System Demonstration

Agenda

- 8:30 Project Objectives
- 8:35 Project Outline
- 8:40 Results on Task 1A
- 10:40 Project Management
- 11:00 General Discussion

ARB Trap System Demonstration

Project Objectives

- Demonstrate Durable Retrofit Particulate Trap Systems Capable of Reducing Particulate Emission (85 %+) From Heavy-Duty Diesel Engines Used by Urban Buses and Trucks

- One Bus Trap System for 2-stroke 6V92TA Engine on an Urban Bus

- One Truck System for a 4-stroke Engine on a Class 8 Truck

ARB Trap System Demonstration

Project Outline

- Task 1 – Investigation of State of the Art Trap Oxidizer Systems
- 1a– List Systems and Evaluate
  1b– Report Recommendations and Finalize Task 2 and Task 3
- Task 2 – Preliminary Test Bed Evaluation of Selected Trap Systems
- 2a–Bus Duty Cycle Generation
  2b–Trap Systems and Engines Procurement
  2c–Data Acq. Systems Design and Testing
  2d–Engines Emission Baseline
  2e–Trap System Installation and Baseline
  2f–Trap System Durability(400 hrs) and Performance Evaluation (every 100 hrs)

ARB Trap System Demonstration

Project Outline

- Task 3 – On-Road Demonstration Testing
- 3a-Fleet Negotiation and Selection
  3b-Installation and Maintenance
  3c-Data Collection and Analysis
  3d-Monthly Emission Testing

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ARB Trap System Demonstration

Trap Technology Summary

- Traping Elements/Filters
  - Ceramic Cordierite(CGW)
  - Ceramic Foam(Selee)
  - Ceramic Mullite(MTC)
  - Ceramic Fibre(3M)
  - Wire Mesh
- Carbon and HC Oxidized to water and CO2
- Regeneration (In-line/By-pass)
  - Diesel Burner
  - Electrical
  - Catalyst
  - Fuel Additive
  - Engine Modification

ARB Trap System Demonstration

Task 1a

- List Bus Trap System Criteria
- Contact Potential Supplier
- Primary Evaluations
- Assign Weighting Factors
- Final Evaluations
- Repeat for Truck Trap System

ARB Trap System Demonstration

Engine Manufacturers Contacted

- Engine Manufacturers Association
- Cummins
- Caterpillar
- Detroit Diesel Corp
- Navistar
- Deutz

ARB Trap System Demonstration

Cummins Engine Company

- Working on Trap System For Both Bus and Truck Application
- Bus Trap System for L10 Engine Only
- Will Not Supply Systems Due To Business Reasons

ARB Trap System Demonstration

Caterpillar Tractor Co.

- Working on Truck Trap System with an Exhaust Product Manufacturer
- No Trap System For Bus Application
- Will not supply Either Truck or Bus System

ARB Trap System Demonstration

Detroit Diesel Corp.

- By-Pass Trap System For Series 60 Engine
  - By-Pass
  - CGW Filter
  - Diesel Burner
  - Electronic Control
- Starting Trap System Programs For 2-stroke Bus Engines
- Participating in New York City Trap System Demonstration Program with ORTECH

ARB Trap System Demonstration

Navistar International Corp.

- Not Working on Trap System
- Effort on Catalytic Converter + Engine Combustion Modification
- Not Ready to Provide System

ARB Trap System Demonstration

Deutz Corp. (KHD)

- Cordierite Wall-Flow Filters
- Off-board Regeneration (oven) for Utility Equipment
- On-board Regeneration (burner) for over-the road vehicles
- Available in Selected European Countries
- Available in U.S. by Summer 1990
- Can not Provide and Support Prototype

ARB Trap System Demonstration

Emission Control Manufacturers Contacted

- Manufacturers of Emission Controls Association(MECA)
- Donaldson
- Engine Control Systems(ECS)
- ARVIN
- MIRUS
- Converter Technology, Inc.
- AECL

ARB Trap System Demonstration

Donaldson Company Inc.

- 2 + 1/2 CGW Filters
  10-1/4" Dia. by 12' Long
- Electrical Regeneration
- 90 % Particulate Removal Efficiency
- Complete Electronic Control
- Good Sound Muffling
- Will Submit Formal Response

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ARB Trap System Demonstration

Converter Technology, Inc.

- Wire Mesh Filters
- Embeded Electrostatic Precipitators (ESP)
- Catalyst Coated Pre-Converter
- By-Pass Only
- 85% to 95% Efficiency Claimed(no Data)
- Good Pressure Drop, Muffling Claimed
- No system available or tested on 6V92TA
- Reliability of ESP is of Concern
- More Development work is needed
- Limited Resources

ARB Trap System Demonstration

Corning Glass Work (CGW)

- Cordierite Wall-Flow Filters only
- Particulate Removal Efficiency ranges from 90+ to 60 + %
- 3000 hrs+ Underground Mining Application
- Vehicle Demonstration Programs in U.S. and Europe
- Testing being conducted in U.S., Europe and Asia
- Dominant Market Position

ARB Trap System Demonstration

NGK

- Cordierite Wall-Flow Filters only
- Properties almost identical to CGW
- Can Produce 12"Dia X 14" Long single unit filter
- Tested by Major Engine Manufacturers and other Companies
- Long Delivery Time
- 2-3 Time CGW Price

ARB Trap System Demonstration

MTC (Matsushita)

- Mullite Fiber Ceramic Filters only
- Good Efficiency and Back Pressure
- Better Light-off Characteistics
- Poor Mechanical Stress Limit
- More Development Work Needed

ARB Trap System Demonstration

SELEE Corp.

- Ceramic Foam Filters
- Lower Thermal Stress Than CGW Filters
- Lower Regeneration Temperature
- Particulate Removal Efficiency now at 40 % over EPA Cycle
- Targeted 70 % Efficiency by November
- Testing being conducted by European Engine Manufacturer
- More Data Forthcoming
- Same Cost as CGW Filters

ARB Trap System Demonstration

Catalyst Manufacturers Contacted

- Engelhard
  Catalyst Available for CGW Filters
- JMI
  Awaiting Response
- Degussa
  Catalyst Available for CGW Filters
- Econalytic
  Fuel Additive Testing at ORTECH
- Lubrizol
  Copper Based Additive
  No New Heavy-Duty Engine Data

ARB Trap System Demonstration

Awaiting Response

- Ricardo
- SwRI
- EPA
- AECL

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ARB Trap System Demonstration

Bus Trap System Evaluation Points

- 6)Trap System Installation
  Easy - 20 pts
  Difficult- 0 pts
- 7)Impact on Bus Maintenance and Service
  Low - 30 pts
  High - 0 pts
- 8)Engine Backpressure Limit (4" Hg)
  Pass/Fail
- 9)Energy Penalty
  4 % - 30 pts
  6 % - 10 pts
  8 % - 0 pts

ARB Trap System Demonstration

Bus Trap System Evaluation Points

- 10)System Cost
  Pass/Fail at $5000
- 11)Maintenance Costs(Annual $)
  0 - 30 pts
  500 - 15 pts
  1000 - 0 pts
- 12)Sound Muffling
  Pass/Fail
- 13)Fire Hazard (Safety)
  Pass/Fail

ARB Trap System Demonstration

Task 1a–Summary to Date

- Defined Bus Trap System Criteria
- Contacted Potential Suppliers
- Awaiting for ECS Response
- Started Primary Evaluation
- Final Selection for the Bus Trap System Seems to Be Between DCI, ECS and ORTECH.

ARB Trap System Demonstration

Project Management

- Revised Time Schedule
- Revised Sub-Tasks
- Contract Signed Between ORTECH and ACUREX
- Task 1 on Time and on Budget

ARB Trap System Demonstration

General Discussion

- Bus Trap Evaluation
- Revised Schedule
- Bus Selection

APPENDIX C

Data Acquisition Unit (Campbell)
Operation Manual

ORTECH
INTERNATIONAL
2395 Speakman Drive
Mississauga, Ontario L5K 1B3
(416) 822-4111
Telefax (416) 823-1446

PROJECT
ARB PARTICULATE TRAP SYSTEM DEMONSTRATION

DATA ACQUISITION UNIT MANUAL
FOR
SCRTD TRANSIT BUS

W. Drummond
I. Carmichael

We, ORTECH Corporation, conducting business as "ORTECH International", stipulate that this document is subject to the following terms and conditions:
1. Any proposal contained herein was prepared for the consideration of the addressee only. Its contents may not be used by nor disclosed to any other party without our prior written consent.
2. Any testing, inspection or investigation performed by us will be conducted in accordance with normal professional standards. Neither we nor our employees shall be responsible for any loss or damage resulting directly or indirectly from any default, error or omission.
3. Any report, proposal or quotation prepared by us refers only to the particular material, instrument or other subject referred to in it. No representation is made that similar articles will be of like quality.
4. No report issued by us shall be published in whole or in part without our prior written consent.
5. Our name shall not be used in any way in connection with the sale, offer or advertisement of any article, process or service.
6. We reserve the right not to commence and/or continue any work until payment arrangements satisfactory to us are established.

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CAMPBELL SCIENTIFIC DATALOGGER MANUAL

TURNING THE DATA LOGGER ON

Turn Data Logger on with the switch on the side.

"HELLO" followed by "11:11111.11" should appear

The "1s" indicate all 8 chips are OK.

DOWN LOADING ARB PROGRAM TO DATALOGGER (DOWNLOAD)

Connect computer to data logger as illustrated:

[Computer]-[RS232 cable]-[SC32A]-[9 pin cable]-[Data logger]

Type **DOWNLOAD** and press **Rtn.** The ARB program will be sent to the datalogger.

MONITORING THE ARB PROGRAM WITH DATA LOGGER (MONITOR)

Connect computer to data logger as illustrated:

[Computer]-[RS232 cable]-[SC32A]-[9 pin cable]-[Data logger]

Type **MONITOR** and press **Rtn.** The data collected by the data logger will be shown on the computer screen .

DOWNLOADING AND MONITORING THE DATALOGGER (DM)

Connect computer to data logger as illustrated:

[Computer]-[RS232 cable]-[SC32A]-[9 pin cable]-[Data logger]

Type **DM** and press **Rtn.** The program will be downloaded and the data collected by the data logger will be shown on the computer screen .

DOWNLOAD AND MONITOR EACH 1,5,10,20 SECOND (TEST1-TEST20)

Sometimes it is necessary to trouble-shoot the system. A program to read the inputs 1,5,10,20 times a second has been written.

Connect computer to data logger as illustrated:

[Computer]-[RS232 cable]-[SC32A]-[9 pin cable]-[Data logger]

Type **TEST#** and press Rtn. The program will be downloaded and the data collected by the data logger will be shown on the computer screen .

TEST1 = 1 second collection 60 C trigger
TEST5 = 5 second collection 60 C trigger
TEST10 = 10 second collection 60 C trigger
TEST20 = 20 second collection 60 C trigger

TROUBLE-SHOOTING INPUTS (TEST)

The program **TEST** has the trigger temperature set at 5 C and the collection time at 1 second. This program can be used to test the analog inputs when the bus is not operating

TEST = 1 Second collection 5 C trigger

TO GET THIS MANUAL **(MANUAL)**

Type **MANUAL** and press Rtn to bringup this help manual (manual2).

TO GET THE HELP SCREEN **(HELP)**

Typing **HELP** brings up the help screen.

CLEARING THE SM 716 STORAGE MODULE (CLEAR)

Connect the memory module to the computer system as shown in the following sequence:

[Computer] - [RS232 Cable] - [SC532] - 9pin connector - [SM 716]

Type **CLEAR** and press **Rtn**

Place SM232 or SM232A switch in TRANSPARENT then UNLOAD position.
Strike any key when ready ...Rtn

If the program bombs out at this point run the program again and disconnect and reconnect the 25 pin RS232 Cable at the SC532 interface.

The screen should look like this:

```
%A
V1 S1401 P0 M14 E0 A227392 F1 R2 L2 C2069
%
```

Type **1248K** and **Rtn** after the first line of data appears

The screen should start to show (+'s and -'s) as the module is being cleared as illustrated below.

```
%A
 V1 S1401 P0 M22 E0 A358336 F1360 R1361 L1361 C2530
%1248K

++++++++++++++++++++++----------------------
----------------------
++++++++++++++++++++++----------------------
```

When the line below appears the module has been cleared.

```
V1 S1401 P0 M22 E0 A358336 F1 R2 L2 C7219
%
```

Type **1401 Rtn** for Ring Memory or **1411L Rtn**
for Fill and Stop memory.
(Ring Memory is the default mode.)

Type **CTRl _** to exit to menu.

Type **Q** to quit SMCOM.

SETTING TIME ON DATALOGGER

The time is set using the datalogger keypad

To set the time to the following:

Press * 5

Time will be shown.

Press A (year will be shown)

Press A (julian day will be shown)

Press A

Enter time hour:min (seconds will be zeroed)

Press A

Press A

Enter year 89 (2 digits only)

Press A

Enter Julian Day from blue prompt sheet

Press A

Press * O to start logging

SETTING A SECURITY CODE ON THE DATALOGGER

The Security code is set using the datalogger keypad.

Entering a Security Code on Data logger keypad.

Press * C

Press 01

Press A

Enter 4 digit security code

Press A

To Remove Security Code

Press * C

Input same 4 digit security code

Press A

Press 00 (disables code)

Press A

SIGNATURE PROGRAMS

The data logger signature number is a number that indicates whether the program in memory has been changed.

Using the datalogger keyboard do the following

Press *B

Press A and record number 01:(number)

Press A and record number 02:(number)

Press A and record number 03:(number)

Press A and record number 04: (number)

TO START THE DATA LOGGER SAMPLING

Press * 0

The data logger will show : LO61 on the screen

TO CHANGE THE ARB DATALOGGER PROGRAMS (EDIT)

Type EDIT and press Rtn

The program can now be edited

[F1] gives specific help. The arrow key (down) clears help off the screen but remains in the edit mode.

[F2] gives file comands.

THE ARB TEMPERATURE PROGRAM

The program does the following:

If the temperature in channel 5 goes over 60 C then all data is recorded and sent to the storage module. If the temperature is less than 60 C then the data is not recorded

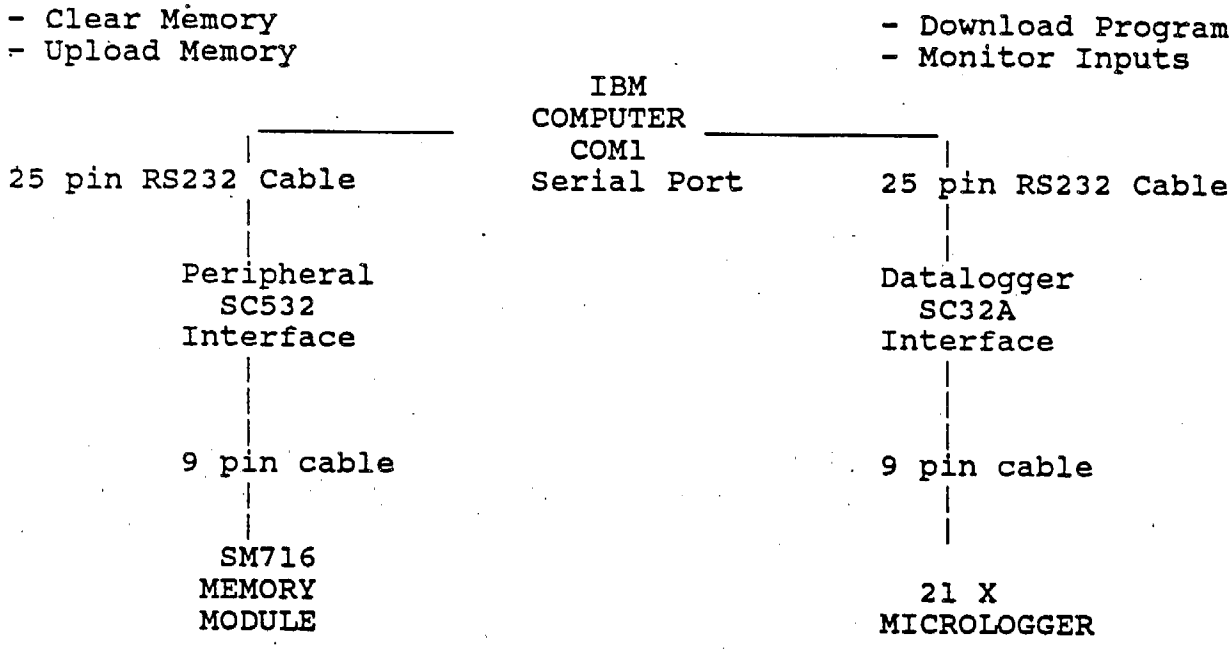
The programs is as follows:

```
Program:TEMP
Flag Usage:
Input Channel Usage:
Excitation Channel Usage:
Continuous Analog Output Usage:
Control Port Usage:
Pulse Input Channel Usage:
Output Array Definitions:


Sample Execution Time = 20 Sec


*      1        Table 1 Programs
  01: 20        Sec. Execution Interval


Collect Channel 5 Temperature

01:  P14        Thermocouple Temp (DIFF)
  01: 1         Rep
  02: 3         50 mV slow Range
  03: 5         IN Chan
  04: 3         Type K (Chromel-Alumel)
  05: 1         Ref Temp Loc REFERENCE
  06: 6         Loc [:TURBO     ]
  07: 1         Mult
  08: 0         Offset


Collect Reference Panel Temperature

02:  P17        Panel Temperature
  01: 1         Loc [:REFERENCE]


If Channel 5 is > 60 C then Sample

03:  P89        If X<=>F
  01: 6         X Loc TURBO
  02: 3         >=
  03: 60        F
  04: 30        Then Do
```

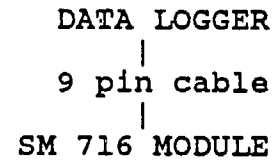
```
Collect First 4 Channels of Temperature

04:  P14          Thermocouple Temp (DIFF)
  01: 4           Reps
  02: 3           50 mV slow Range
  03: 1           IN Chan
  04: 3           Type K (Chromel-Alumel)
  05: 1           Ref Temp Loc REFERENCE
  06: 2           Loc [:TRAP1 IN ]
  07: 1           Mult
  08: 0           Offset

Collect 1st Channel of 0 - 5 volts Input

Page 2   Table 1


05:  P2           Volt (DIFF)
  01: 1           Rep
  02: 5           5000 mV slow Range
  03: 6           IN Chan
  04: 7           Loc [:T1 BACKPR]
  05: 1           Mult
  06: 0           Offset


Collect 2nd Channel 0-5 VOLTS INPUT

06:  P2           Volt (DIFF)
  01: 1           Rep
  02: 5           5000 mV slow Range
  03: 7           IN Chan
  04: 8           Loc [:T2 BACKPR]
  05: 1           Mult
  06: 0           Offset

07:  P86          Do
  01: 10          Set flag 0 (output)

08:  P77          Real Time
  01: 111         Day,Hour-Minute,Second

09:  P70          Sample
  01: 10          Reps
  02: 1           Loc REFERENCE

10:  P96          Serial Output (Extended)
  01: 12          ASCII/9600 Baud

11:  P95          End

12:  P            End Table 1


*     2           Table 2 Programs
  01: 0.0000      Sec. Execution Interval

01:  P            End Table 2
```

```
*     3        Table 3 Subroutines

01:   P        End Table 3


*     4        Mode 4 Output Options
  01: 00       Tape/Printer Option
  02: 00       Printer Baud Option


*     A        Mode 10 Memory Allocation
  01: 28       Input Locations
  02: 64       Intermediate Locations
Page 3    Mode C


*     C        Mode 12 Security
  01: 00       Security Option
  02: 0000     Security Code

Page 4     Input Location Assignments (with comments):


 Key:
 T=Table Number
 E=Entry Number
 L=Location Number

 T:   E:   L:
 1:   2:   1:   Loc [:REFERENCE]
 1:   4:   2:   Loc [:TRAP1 IN ]
 1:   1:   6:   Loc [:TURBO    ]
 1:   5:   7:   Loc [:T1 BACKPR]
 1:   6:   8:   Loc [:T2 BACKPR]

Page 5     Input Location Labels:

1:REFERENCE      3:TRAP1 OUT      5:TRAP2 OUT      7:T1 BACKPR
2:TRAP1 IN       4:TRAP2 IN       6:TURBO          8:T2 BACKPR
```

CAMPBELL SCIENTIFIC DATALOGGER SETUP



FIELD SAMPLING SETUP



CAMPBELL SCIENTIFIC DATALOGGER INPUTS

ANALOG INPUTS

1	2	3	4	5	6	7	8
H L G	H L G	H L G	H L G	H L G	H L G	H L G	H L G
DPF #1 In	DPF #1 Out	DPF #2 In	DPF #2 Out	Turbo In	DPF #1 BP	DPF #2 BP	

EXCITATION	CAO	CONTROL	PULSE INPUTS	12 volts
1 2 G 3 4 G	1 2 G	1 2 3 4 5 6	G 1 2 G 3 4 G	G 12 G

*Note Type "K" Thermocouples connect red to low and yellow to high

DOWNLOAD.BAT

```
term arb d arb q
cls
help
```

MONTITOR.BAT

```
term arb m arb
cls
help
```

MANUAL.BAT

```
echo off
cls
br manual2
help
```

CLEAR.BAT

```
echo off
cls
echo CONNECT THE STORAGE MODULE TO THE COMPUTER AS FOLLOWS
echo.
echo [Computer] - [RS232 Cable] - [SC532] - 9pin connector - [SM 716]
echo.

echo.
pause
smcom 1 y clear t
cls
help
```

TEST1.BAT

```
term arb d test1 m
cls
help
```

TEST 5.BAT

```
term arb d test5 m
cls
help
```

TEST10.BAT

```
term arb d test10 m
cls
help
```

TEST 20.BAT

```
term arb d test20 m
cls
help
```

DM.BAT

```
term arb d arb m
cls
help
```

EDIT.BAT

```
edlog arb
cls
help
```

TEST.BAT

```
term arb d test m
cls
help
```

HELP.BAT

```
echo off
cls
echo DOWNLOAD "ARB" PROGRAM TO DATALOGGER ..... DOWNLOAD
echo.
echo MONITOR "ARB" PROGRAM ..................... MONITOR
echo.
echo DOWNLOAD AND MONITOR "ARB" PROGRAM........ DM
echo.
echo TO EDIT "ARB" PROGRAM ..................... EDIT
echo.
echo CAMPBELL SCIENTIFIC MANUAL ................ MANUAL
echo.
echo DOWNLOAD AND TEST SYSTEM ................  TEST
echo.
echo DOWNLOAD AND MONITOR 1 SEC RESPONSE ...... TEST1
echo DOWNLOAD AND MONITOR 5 SEC RESPONSE ...... TEST5
echo DOWNLOAD AND MONITOR 10 SEC RESPONSE ..... TEST10
echo DOWNLOAD AND MONITOR 20 SEC RESPONSE ..... TEST20
echo.
echo CLEAR MEMORY MODULE  ...................... CLEAR
echo.
echo TO GET THIS MENU........................... HELP
ECHO.
ECHO.
```

DOWN LOADING PROGRAM TO DATALOGGER

Turn Data Logger on.

"HELLO" followed by "11:11111.11" should appear

The "1s" indicate all 8 chips are OK.

Connect computer to data logger as illustrated:

[Computer]-[RS232 cable]-[SC32A]-[9 pin cable]-[Data logger]

Type "TERM" and press "RTN"

The following prompts will appear:

Station Name (add /E to edit parameters): **ARB**

If the ARB program is not found the following messages will be shown. If the ARB program exists the program will jump to TERM OPTIONS

```
Telecommunication Parameters For Station: ARB
                          Datalogger Type: Extended 21X; CR7X
 Use Asynchronous Communications Adapter: COM1
                Communications Baud Rate: 9600

Interface Device:
#1: End


Station editing options:
   S = Save and quit editing
   R = Re-edit
   Q = Quit editing

Enter option: S



TERM OPTIONS
C - Call station ARB
T - Terminal emulator
D - Download program to datalogger
S - Save program from datalogger
K - PC time to datalogger clock
M - Monitor Input Locations
R - Receive a file
E - Edit station parameters
Q - Quit
Option: D
Name of file to download?  ARB
Once the file has been downloaded press "CTRL _ " to break.
```

This menu should be activated :

```
TERM OPTIONS
C - Call station ARB
T - Terminal emulator
D - Download program to datalogger
S - Save program from datalogger
K - PC time to datalogger clock
M - Monitor Input Locations
R - Receive a file
E - Edit station parameters
Q - Quit
```

Type "M" to monitor the inputs.

This monitoring screen should appear:

```
                          1:_________   .000
                          2:_________   .000
                          3:_________   .000
                          4:_________   .000
                          5:_________   .000
                          6:_________   .000
                          7:_________   .000
                          8:_________   .000
                          9:_________   .000
                         10:_________   .000
                         11:_________   .000
```

Flags: [F1] [F2] [F3] [F4] [F5] [F6] [F7] [F8]

"CTRl_ "exits monitor to the TERM Options Menu

"Q" Quits the TERM program.

CLEARING THE SM·716 STORAGE MODULE

Connect the memory module to the computer system as shown in the following sequence:

[Computer] - [RS232 Cable] - [SC532] - 9pin connector - [SM 716]

Type "**SMCOM**" and press "**Rtn**"

The following menu will appear:

```
Serial Port Options:
     1 -- Com1
     2 -- Com2
     3 -- Com3
     4 -- Com4
Option: 1

Is the SM232 or SM232A interface being used? (Y/N): Y
```

Place SM232 or SM232A switch in TRANSPARENT then UNLOAD position.
Strike any key when ready ...**Rtn**

Root collection file name (6 characters max): **CLEAR**

The following menu should appear.

```
SMCOM Options:
     T -- Terminal emulator.
     A -- Collect all data files.
     U -- Collect uncollected data files.
     M -- Collect most recent 5 data files.
     N -- Collect newest data file.
     L -- Collect one data file starting at display pointer L.
     P -- Collect program files.
     D -- Store a .DLD program file.
     F -- Store a file.
     Q -- Quit
```

Type "**T**"

The following should happen:

```
Terminal Emulator.
Press Ctrl_ to exit.
```

Type "**1248K**" and "**Rtn**" after the first line of data appears

The screen should now look like this:

```
%A
 V1 S1401 P0 M22 E0 A358336 F1360 R1361 L1361 C2530
%1248K
++++++++++++++++++++++----------------------
```

```
----------------------
++++++++++++++++++++++----------------------
 V1 S1401 P0 M22 E0 A358336 F1 R2 L2 C7219
%
```

The module has been now cleared.

Type "1401" for Ring Memory or "1411L" for Fill and Stop memory.
(Ring Memory is the default mode.)

Type " CTRl _ " to exit to menu.

Type "Q" to quit SMCOM.

DOWN LOADING SM 716 MEMORY MODULE TO COMPUTER

Connect computer to data module

[Computer]-[RS232 cable]-[SC532]-[9 pin cable]-[SM 716]

Type "**SMCOM**" and press "**RTN**"

This menu should appear:

```
Serial Port Options:
     1 -- Com1
     2 -- Com2
     3 -- Com3
     4 -- Com4
Option: 1


Is the SM232 or SM232A interface being used? (Y/N): Y


Place SM232 or SM232A switch in TRANSPARENT then UNLOAD position.
Strike any key when ready ...    RTN

Root collection file name (6 characters max): TEST

(enter a test name , a "1" is added to the test name
 thus test = test1.dat )


The following menu should appear:

SMCOM Options:
     T -- Terminal emulator.
     A -- Collect all data files.
     U -- Collect uncollected data files.
     M -- Collect most recent 5 data files.
     N -- Collect newest data file.
     L -- Collect one data file starting at display pointer L.
     P -- Collect program files.
     D -- Store a .DLD program file.
     F -- Store a file.
     Q -- Quit

Type the appropriate letter and press return.
```

The next menu to appear is:

```
File Formats:
     F -- Final storage (FS) format
     D -- FS converted to ASCII arrays with IDs
     C -- FS converted to comma delineated ASCII arrays
     A -- As stored (8 bit data)
     P -- As stored but ignore parity bit
   Esc -- Escape

Type "C
```

The "C" option (C -- FS converted to comma delineated ASCII arrays) should be chosen, the commas will not be picked by Lotus and the data can be easily inputed into Lotus.

After downloading the data type "Q" to Quit.

Checking Test Data

The data file can be observed by typing "test1.dat", the data would look like if "D" is chosen:

type test1.dat

```
01+0106.  02+0135.  03+1459.  04+040.3  05+26.32  06+24.66  07+24.91
08+24.75  09+24.75  10+24.83  11+24.75  12-294.8
```

The data would look like the following if "C" is chosen

```
107,0,454,10.3,25.67,24.51,24.51,24.59,24.42,24.41,-1302,-1189
```

The flow of data can be stopped by pressing **Ctrl Break** keys simultaneously.

The data is as follows:

Location		test identifier	01+
		julian day	02+
		hours:minutes	03+
		seconds	04+
Location	1	Reference Temp	05+
	2	Channel 1 (temp 1)	06+
	3	Channel 2 (temp 2)	07+
	4	Channel 3 (temp 3)	08+
	5	Channel 4 (temp 4)	09+
	6	Channel 5 (temp 5)	10+
	7	Channel 6 (analog 1)	11+
	8	Channel 7 (analog 2)	12+

CREATING LOTUS IMPORT FILES

The "SPLIT" program creates a .prn file for lotus import when the (D -- FS converted to ASCII arrays with IDs) is used to collect data from the storage module. It is best to collect the data from the storage module using the (C -- FS converted to comma delineated ASCII arrays) option. The split file can be used to manipulate the collected data. It is HIGHLY recommended that this program be learned, all prn files can be manipulated using this program. READ the SOFTWARE MANUAL, LEARN this program it will make life easier.

Type "SPLIT"

The following menu appears

```
       Name(s) of input DATA FILES(s):
     Name of OUTPUT FILE to generate:
          START reading in testl.dat:
           STOP reading in testl.dat:
                 COPY from testl.dat:
SELECT element #(s) in testl.dat:
                HEADING for report:
```

Press "ESC" and L(load) . The following message will apear on the screen:

Name of parameter file (*=help) **ARB**

The following menu appears

```
       Name(s) of input DATA FILES(s): testl.dat
     Name of OUTPUT FILE to generate: test.PRN
          START reading in testl.dat:
           STOP reading in testl.dat:
                 COPY from testl.dat:
SELECT element #(s) in testl.dat: date(2;1989.),3..12
                HEADING for report:
```

Changing the name of the input and output data files can now be made. The input file is the name of the file previously downloaded. The output file must have the extension .prn so Lotus can import it.

Press "ESC"

Type "R" to run the program

Type "Q" to quit the program

The data throught "type test.prn" would look like:

type test.prn

```
5 15    1459    40.3   26.32   24.66   24.91   24.75   24.75   24.83
2.94    319.2
```

Type EDLOG and press rtn

Enter Datalogger Type (10, 21X, 7, or 7X): **21X**

The program can now be edited

[F1] gives specific help. The arrow key (down) clears help off the screen but remains in the edit mode.

[F2] gives file comands.

CAMPBELL SCIENTIFIC

DATA-LOGGING

PROGRAMS

```
Program:ARB
Flag Usage:
Input Channel Usage:
Excitation Channel Usage:
Continuous Analog Output Usage:
Control Port Usage:
Pulse Input Channel Usage:
Output Array Definitions:


Sample Execution Time = 20 Sec


*      1        Table 1 Programs
  01: 20        Sec. Execution Interval


Collect Channel 5 Temperature

01:   P14       Thermocouple Temp (DIFF)
  01: 1         Rep
  02: 3         50 mV slow Range
  03: 5         IN Chan
  04: 3         Type K (Chromel-Alumel)
  05: 1         Ref Temp Loc REFERENCE
  06: 6         Loc [:TURBO     ]
  07: 1         Mult
  08: 0         Offset


Collect Reference Panel Temperature

02:   P17       Panel Temperature
  01: 1         Loc [:REFERENCE]


If Channel 5 is > 60 C then Sample

03:   P89       If X<=>F
  01: 6         X Loc TURBO
  02: 3         >=
  03: 60        F
  04: 30        Then Do


Collect First 4 Channels of Temperature

04:   P14       Thermocouple Temp (DIFF)
  01: 4         Reps
  02: 3         50 mV slow Range
  03: 1         IN Chan
  04: 3         Type K (Chromel-Alumel)
  05: 1         Ref Temp Loc REFERENCE
  06: 2         Loc [:TRAP1 IN ]
  07: 1         Mult
  08: 0         Offset
```

```
Collect 1st Channel of 0 - 5 volts Input

Page 2   Table 1


05:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 6          IN Chan
  04: 7          Loc [:T1 BACKPR]
  05: 1          Mult
  06: 0          Offset


Collect 2nd Channel 0-5 VOLTS INPUT

06:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 7          IN Chan
  04: 8          Loc [:T2 BACKPR]
  05: 1          Mult
  06: 0          Offset

07:  P86         Do
  01: 10         Set flag 0 (output)

08:  P77         Real Time
  01: 111        Day,Hour-Minute,Second

Add more reps to store more data


09:  P70         Sample
  01: 8          Reps
  02: 1          Loc REFERENCE

10:  P96         Serial Output (Extended)
  01: 12         ASCII/9600 Baud

11:  P95         End

12:  P           End Table 1


*     2          Table 2 Programs
  01: 0.0000     Sec. Execution Interval

01:  P           End Table 2


*     3          Table 3 Subroutines

01:  P           End Table 3

*     4          Mode 4 Output Options
  01: 00         Tape/Printer Option
  02: 00         Printer Baud Option
```

Page 3 Mode A

```
*     A        Mode 10 Memory Allocation
  01: 28       Input Locations
  02: 64       Intermediate Locations


*     C        Mode 12 Security
  01: 00       Security Option
  02: 0000     Security Code
```

Page 4 Input Location Assignments (with comments):

```
 Key:
 T=Table Number
 E=Entry Number
 L=Location Number

 T:  E:  L:
 1:  2:  1:  Loc [:REFERENCE]
 1:  4:  2:  Loc [:TRAP1 IN ]
 1:  1:  6:  Loc [:TURBO    ]
 1:  5:  7:  Loc [:T1 BACKPR]
 1:  6:  8:  Loc [:T2 BACKPR]
```

Page 5 Input Location Labels:

```
 1:REFERENCE     3:TRAP1 OUT     5:TRAP2 OUT     7:T1 BACKPR
 2:TRAP1 IN      4:TRAP2 IN      6:TURBO         8:T2 BACKPR
```

```
Program:TEMP
Flag Usage:
Input Channel Usage:
Excitation Channel Usage:
Continuous Analog Output Usage:
Control Port Usage:
Pulse Input Channel Usage:
Output Array Definitions:


Sample Execution Time = 20 Sec


*      1        Table 1 Programs
  01: 20        Sec. Execution Interval


Collect Channel 5 Temperature

01:  P14        Thermocouple Temp (DIFF)
  01: 1         Rep
  02: 3         50 mV slow Range
  03: 5         IN Chan
  04: 3         Type K (Chromel-Alumel)
  05: 1         Ref Temp Loc REFERENCE
  06: 6         Loc [:TURBO     ]
  07: 1         Mult
  08: 0         Offset


Collect Reference Panel Temperature

02:  P17        Panel Temperature
  01: 1         Loc [:REFERENCE]


If Channel 5 is > 60 C then Sample

03:  P89        If X<=>F
  01: 6         X Loc TURBO
  02: 3         >=
  03: 30        F
  04: 30        Then Do


Collect First 4 Channels of Temperature

04:  P14        Thermocouple Temp (DIFF)
  01: 4         Reps
  02: 3         50 mV slow Range
  03: 1         IN Chan
  04: 3         Type K (Chromel-Alumel)
  05: 1         Ref Temp Loc REFERENCE
  06: 2         Loc [:TRAP1 IN ]
  07: 1         Mult
  08: 0         Offset
```

```
Collect 1st Channel of 0 - 5 volts Input

Page 2   Table 1

05:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 6          IN Chan
  04: 7          Loc [:T1 BACKPR]
  05: 1          Mult
  06: 0          Offset

Collect 2nd Channel 0-5 VOLTS INPUT

06:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 7          IN Chan
  04: 8          Loc [:T2 BACKPR]
  05: 1          Mult
  06: 0          Offset

07:  P86         Do
  01: 10         Set flag 0 (output)

08:  P77         Real Time
  01: 111        Day,Hour-Minute,Second

09:  P70         Sample
  01: 10         Reps
  02: 1          Loc REFERENCE

10:  P96         Serial Output (Extended)
  01: 12         ASCII/9600 Baud

11:  P95         End

12:  P           End Table 1


*     2          Table 2 Programs
  01: 0.0000     Sec. Execution Interval

01:  P           End Table 2

*     3          Table 3 Subroutines

01:  P           End Table 3

*     4          Mode 4 Output Options
  01: 00         Tape/Printer Option
  02: 00         Printer Baud Option

*     A          Mode 10 Memory Allocation
  01: 28         Input Locations
  02: 64         Intermediate Locations
```

```
Page 3   Mode C

*      C        Mode 12 Security
  01: 00        Security Option
  02: 0000      Security Code

Page 4     Input Location Assignments (with comments):


 Key:
 T=Table Number
 E=Entry Number
 L=Location Number

 T:   E:   L:
 1:   2:   1:   Loc [:REFERENCE]
 1:   4:   2:   Loc [:TRAP1 IN ]
 1:   1:   6:   Loc [:TURBO    ]
 1:   5:   7:   Loc [:T1 BACKPR]
 1:   6:   8:   Loc [:T2 BACKPR]

Page 5     Input Location Labels:

 1:REFERENCE      3:TRAP1 OUT      5:TRAP2 OUT      7:T1 BACKPR
 2:TRAP1 IN       4:TRAP2 IN       6:TURBO          8:T2 BACKPR
```

```
Program:TEST
Flag Usage:
Input Channel Usage:
Excitation Channel Usage:
Continuous Analog Output Usage:
Control Port Usage:
Pulse Input Channel Usage:
Output Array Definitions:


Sample Execution Time = 1 Sec


*      1        Table 1 Programs
  01: 1         Sec. Execution Interval


Collect Channel 5 Temperature

01:   P14       Thermocouple Temp (DIFF)
  01: 1         Rep
  02: 3         50 mV slow Range
  03: 5         IN Chan
  04: 3         Type K (Chromel-Alumel)
  05: 1         Ref Temp Loc REFERENCE
  06: 6         Loc [:TURBO     ]
  07: 1         Mult
  08: 0         Offset


Collect Reference Panel Temperature

02:   P17       Panel Temperature
  01: 1         Loc [:REFERENCE]


If Channel 5 is > 5 C then Sample

03:   P89       If X<=>F
  01: 6         X Loc TURBO
  02: 3         >=
  03: 5         F
  04: 30        Then Do


Collect First 4 Channels of Temperature

04:   P14       Thermocouple Temp (DIFF)
  01: 4         Reps
  02: 3         50 mV slow Range
  03: 1         IN Chan
  04: 3         Type K (Chromel-Alumel)
  05: 1         Ref Temp Loc REFERENCE
  06: 2         Loc [:TRAP1 IN ]
  07: 1         Mult
  08: 0         Offset
```

```
Collect 1st Channel of 0 - 5 volts Input

Page 2   Table 1


05:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 6          IN Chan
  04: 7          Loc [:T1 BACKPR]
  05: 1          Mult
  06: 0          Offset


Collect 2nd Channel 0-5 VOLTS INPUT

06:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 7          IN Chan
  04: 8          Loc [:T2 BACKPR]
  05: 1          Mult
  06: 0          Offset

Set 10 to output to data file
Change this if more files are added

07:  P86         Do
  01: 10         Set flag 0 (output)

08:  P77         Real Time
  01: 111        Day,Hour-Minute,Second

09:  P70         Sample
  01: 8          Reps
  02: 1          Loc REFERENCE

10:  P96         Serial Output (Extended)
  01: 12         ASCII/9600 Baud

11:  P95         End

12:  P           End Table 1


*     2          Table 2 Programs
  01: 0.0000     Sec. Execution Interval

01:  P           End Table 2


*     3          Table 3 Subroutines

01:  P           End Table 3


*     4          Mode 4 Output Options
  01: 00         Tape/Printer Option
  02: 00         Printer Baud Option
```

```
Page 3   Mode A

*      A        Mode 10 Memory Allocation
  01:  28       Input Locations
  02:  64       Intermediate Locations


*      C        Mode 12 Security
  01:  00       Security Option
  02:  0000     Security Code
```

Page 4 Input Location Assignments (with comments):

```
 Key:
 T=Table Number
 E=Entry Number
 L=Location Number

 T:   E:   L:
 1:   2:   1:   Loc [:REFERENCE]
 1:   4:   2:   Loc [:TRAP1 IN ]
 1:   1:   6:   Loc [:TURBO    ]
 1:   5:   7:   Loc [:T1 BACKPR]
 1:   6:   8:   Loc [:T2 BACKPR]
```

Page 5 Input Location Labels:

```
 1:REFERENCE     3:TRAP1 OUT     5:TRAP2 OUT     7:T1 BACKPR
 2:TRAP1 IN      4:TRAP2 IN      6:TURBO         8:T2 BACKPR
```

```
Program:TEST1
Flag Usage:
Input Channel Usage:
Excitation Channel Usage:
Continuous Analog Output Usage:
Control Port Usage:
Pulse Input Channel Usage:
Output Array Definitions:


Sample Execution Time = 1 Sec


*      1        Table 1 Programs
  01:  1        Sec. Execution Interval


Collect Channel 5 Temperature

01:   P14       Thermocouple Temp (DIFF)
  01:  1        Rep
  02:  3        50 mV slow Range
  03:  5        IN Chan
  04:  3        Type K (Chromel-Alumel)
  05:  1        Ref Temp Loc REFERENCE
  06:  6        Loc [:TURBO     ]
  07:  1        Mult
  08:  0        Offset


Collect Reference Panel Temperature

02:   P17       Panel Temperature
  01:  1        Loc [:REFERENCE]


If Channel 5 is > 60 C then Sample

03:   P89       If X<=>F
  01:  6        X Loc TURBO
  02:  3        >=
  03:  60       F
  04:  30       Then Do


Collect First 4 Channels of Temperature

04:   P14       Thermocouple Temp (DIFF)
  01:  4        Reps
  02:  3        50 mV slow Range
  03:  1        IN Chan
  04:  3        Type K (Chromel-Alumel)
  05:  1        Ref Temp Loc REFERENCE
  06:  2        Loc [:TRAP1 IN ]
  07:  1        Mult
  08:  0        Offset


Collect 1st Channel of 0 - 5 volts Input
```

```
05:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 6          IN Chan
  04: 7          Loc [:T1 BACKPR]
  05: 1          Mult
  06: 0          Offset

Collect 2nd Channel 0-5 VOLTS INPUT

06:  P2          Volt (DIFF)
  01: 1          Rep
  02: 5          5000 mV slow Range
  03: 7          IN Chan
  04: 8          Loc [:T2 BACKPR]
  05: 1          Mult
  06: 0          Offset

07:  P86         Do
  01: 10         Set flag 0 (output)

08:  P77         Real Time
  01: 111        Day,Hour-Minute,Second

09:  P70         Sample
  01: 8          Reps
  02: 1          Loc REFERENCE

10:  P96         Serial Output (Extended)
  01: 12         ASCII/9600 Baud

11:  P95         End

12:  P           End Table 1


*     2          Table 2 Programs
  01: 0.0000     Sec. Execution Interval

01:  P           End Table 2


*     3          Table 3 Subroutines

01:  P           End Table 3


*     4          Mode 4 Output Options
  01: 00         Tape/Printer Option
  02: 00         Printer Baud Option


*     A          Mode 10 Memory Allocation
  01: 28         Input Locations
  02: 64         Intermediate Locations
```

```
Page 3   Mode C


*      C        Mode 12 Security
  01: 00        Security Option
  02: 0000      Security Code

Page 4     Input Location Assignments (with comments):


 Key:
 T=Table Number
 E=Entry Number
 L=Location Number

 T:   E:   L:
 1:   2:   1:   Loc [:REFERENCE]
 1:   4:   2:   Loc [:TRAP1 IN ]
 1:   1:   6:   Loc [:TURBO    ]
 1:   5:   7:   Loc [:T1 BACKPR]
 1:   6:   8:   Loc [:T2 BACKPR]

Page 5     Input Location Labels:

 1:REFERENCE      3:TRAP1 OUT      5:TRAP2 OUT      7:T1 BACKPR
 2:TRAP1 IN       4:TRAP2 IN       6:TURBO          8:T2 BACKPR
```

CROSSTALK (XTALK)

The program crosstalk (xtalk) can be used to capture the data outputted by the Campbell Scientific Datalogger.

To capture data with Crosstalk do the following:

Set up the system as indicated in the diagram " XTALK DATALOGGER SETUP". Note the SM 716 Storage Module is not necessary for communications between the computer and datalogger. The storage module is recommended as it will store all the data and can be used as a backup.

A/ Download a program to the Datalogger.

B/ Boot up xtalk by typing xtalk. The datalogger parameters have been set for xtalk.

C/ The HOME key switches the display between the capture screen and parameter screen. When capturing data the capture screen should be activated.

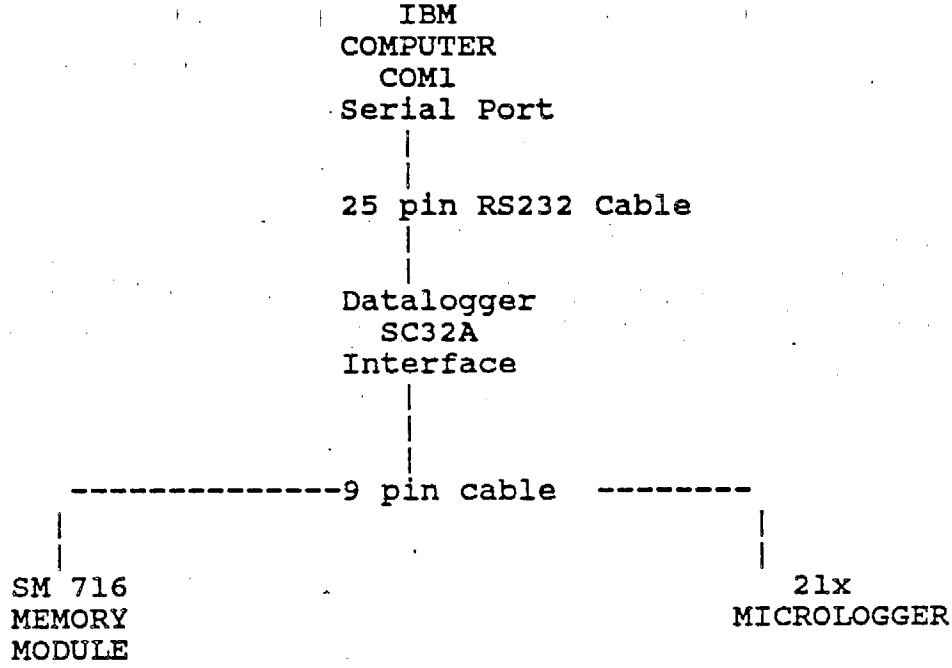
D/ To capture data type CA Filename (example: CA TEST.PRN). The disk drive light will light up as the data is stored to it.

E/ To stop capturing data, type CA OFF and the file will be close.

F/ For help with Xtalk type "Help" while in Xtalk.

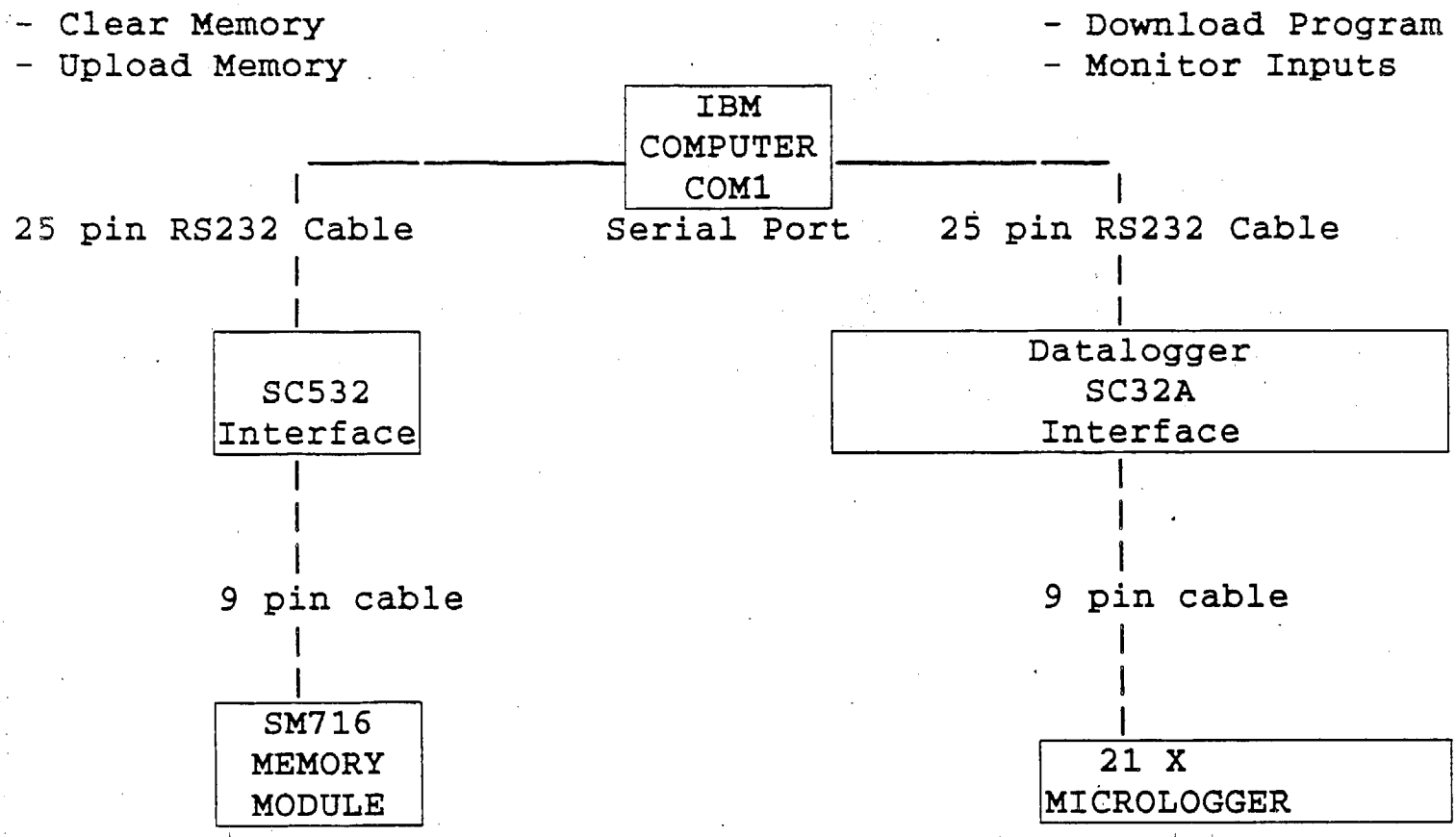
G/ To leave Xtalk type "quit".

XTALK DATALOGGER SETUP

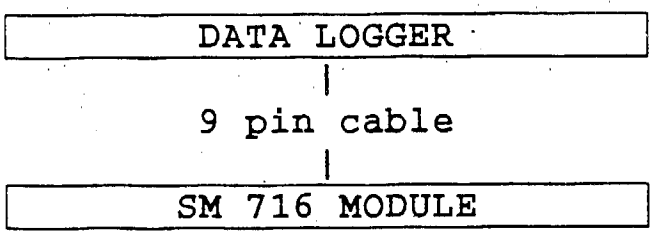


The Storage Module is not necessary for direct communication with th datalogger.

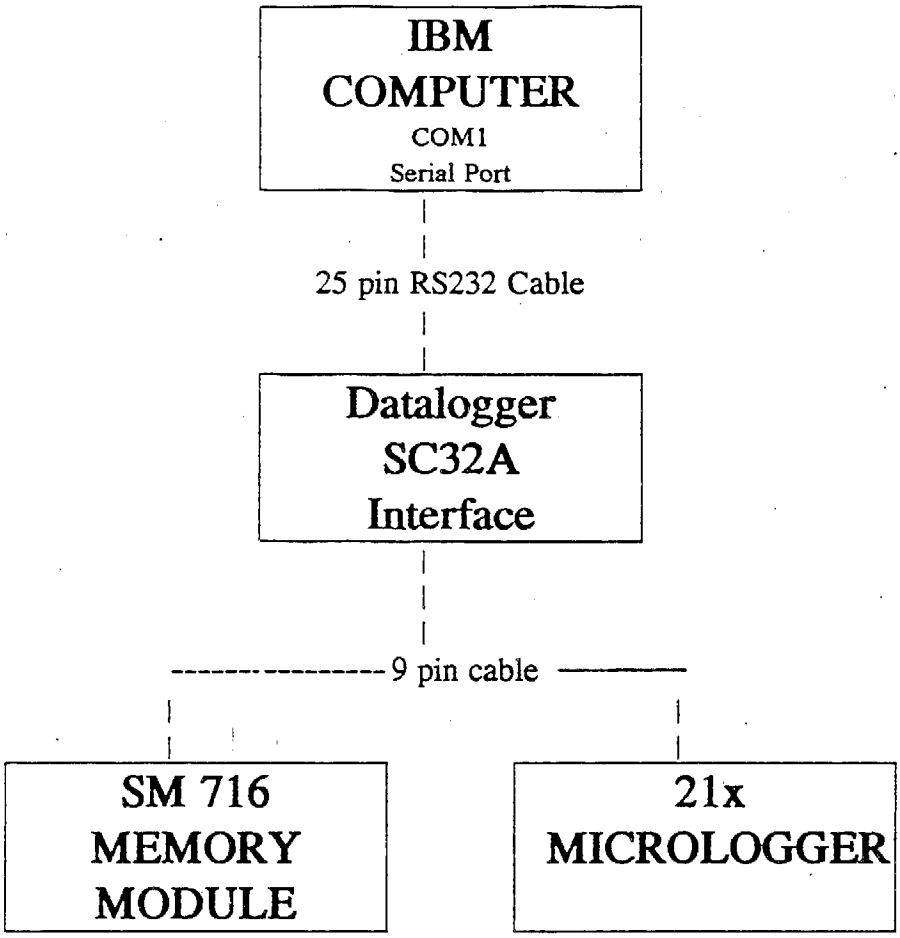
CAMPBELL SCIENTIFIC DATALOGGER SETUP



FIELD SAMPLING SETUP



XTALK DATALOGGER SETUP



The Storage Module is not necessary for direct communication with the datalogger.