State of California
AIR RESOURCES BOARD

EXECUTIVE ORDER D-97
Relating to Exemptions under Section 27156
of the Vehicle Code

BAE
"DODGE 440 MOTORHOME SYSTEM NO. 9-0000"

Pursuant to the authority vested in the Air Resources Board by Section 27156 of the Vehicle Code; and

Pursuant to the authority vested in the undersigned by Sections 39515 and 39516 of the Health and Safety Code and Executive Order G-45-5;

IT IS ORDERED AND RESOLVED: That the installation of the "Dodge 440 Motorhome System No. 9-0000" manufactured by BAE of 3032 Kashiwa Street, Torrance, CA 90505, a division of Turdyne Corporation has been found not to reduce the effectiveness of required motor vehicle pollution control devices and, therefore, is exempt from the prohibitions of Section 27156 of the Vehicle Code for 1979 and older heavy-duty vehicles equipped with the Chrysler 440 CID engine.

This Executive Order is valid provided that installation instructions for this device will not recommend tuning the vehicle to specifications different from those submitted by the device manufacturer.

Changes made to the design or operating conditions of the device, as exempted by the Air Resources Board, that adversely affect the performance of a vehicle's pollution control system shall invalidate this Executive Order.

Marketing of this device using an identification other than that shown in this Executive Order or marketing of this device for an application other than those listed in this Executive Order shall be prohibited unless prior approval is obtained from the Air Resources Board. Exemption of a kit shall not be construed as an exemption to sell, offer for sale or advertise any component of a kit as an individual device.

This Executive Order does not constitute any opinion as to the effect that the use of this device may have on any warranty either expressed or implied by the vehicle manufacturer.

THIS EXECUTIVE ORDER DOES NOT CONSTITUTE A CERTIFICATION, ACCREDITATION, APPROVAL, OR ANY OTHER TYPE OF ENDORSEMENT BY THE AIR RESOURCES BOARD OF ANY CLAIMS OF THE APPLICANT CONCERNING ANTI-POLLUTION BENEFITS OR ANY ALLEGED BENEFITS OF THE "DODGE 440 MOTORHOME SYSTEM NO. 9-0000".

No claim of any kind, such as "Approved by Air Resources Board" may be made with respect to the action taken herein in any advertising or other oral or written communication.

Section 17500 of the Business and Professions Code makes untrue or misleading advertising unlawful, and Section 17534 makes violation punishable as a misdemeanor.

Section 43644 of the Health and Safety Code provides as follows:

> "43644. (a) No person shall install, sell, offer for sale, or advertise, or, except in an application to the state board for certification of a device, represent, any device as a motor vehicle pollution control device for use on any used motor vehicle unless that device has been certified by the state board. No person shall sell, offer for sale, advertise, or represent any motor vehicle pollution control device as a certified device which, in fact, is not a certified device. Any violation of this subdivision is a misdemeanor."

Any apparent violation of the conditions of this Executive Order will be submitted to the Attorney General of California for such action as he deems advisable.

Executed at El Monte, California, this 5th day of May, 1980.

K. D. Drachand, Chief
Mobile Source Control Division

State of California
AIR RESOURCES BOARD

November 17, 1979

Staff Report

Evaluation of the BAE Turbocharger System in Accordance with Section 2222, Title 13 of the California Administrative Code

I. Introduction

BAE, of 3032 Kashiwa Street, Torrance, California 90505 has submitted an application for exemption of a turbocharger system from the prohibitions of Section 27156 of the Vehicle Code. A specialized testing program consisting of steady state raw exhaust gas measurements was conducted instead of the Federal Test Procedure (FTP) due to the limitation of the application to heavy duty vehicles.

II. System Description

The BAE turbocharger system is an aftermarket kit designed as an add-on unit to the Chrysler 440 CID heavy duty engine. The system consists of a Rajay turbocharger, replacement exhaust manifold and crossover pipe, modified distributor, water injection unit, carburetor-to-intake manifold adapter box and miscellaneous mounting and installation parts. The compressor and turbine are on a common shaft driven by exhaust gas routed from the exhaust manifold through the turbine housing. The

compressor increases the density of the air-fuel mixture passing through the carburetor and supercharges the intake manifold to increase the mass of air and fuel delivered to the cylinders thus producing additional power during periods of relatively high (engine) speed.

The BAE system uses the following modifications and controls:

1. The stock Carter Thermo-Quad carburetor is modified by increasing the length of the metering rod spring and by replacing secondary jets with a larger size (0.143 inch). These modifications increase the fuel delivery capacity to match the increased air flow caused by turbocharging.

2. Initial timing of 8° BTDC is advanced to 12-14° BTDC.

3. A modified distributor replaces the OEM breakerless system. The modified distributor has two pick-ups for the reluctor; one for the normal advance curve, and one to provide five distributor degrees of retard when a diaphragm/micro-switch senses intake manifold pressure of 2 psig or more. The retard is used to prevent detonation during high boost.

An alternate method of providing retard under boost conditions was added later in the test program. A Jacob's Electronic Ignition System may be installed in place of the modified distributor/ microswitch combination to provide graduated retard with increasing engine speed.

4. Water injection is used as a secondary control of detonation in warm weather. A water injector nozzle is located at the top of the air cleaner with water and pressure supplied from the recreational vehicle tap water system. A solenoid allows water to flow when boost pressure exceeds 2 psig. The water injection system was later modified to use two nozzles opening at different pressures.

5. Maximum boost pressure is limited by the size of the passages in the carburetor-to-manifold adapter box and compressor inlet passage. No active boost control is used.

III. Test Vehicle

Emissions testing was conducted on a 1977 Pioneer Class A motorhome (California dealer license 9164) supplied by the applicant. This motorhome is built on a Chrysler M600 chassis and equipped with a Chrysler 440-3 heavy duty engine and three speed automatic transmission. The vehicle is rated at 15,500 pounds gross vehicle weight, and was tested at a loaded weight of 14,400 pounds.

The vehicle was received with approximately 9000 miles on the odometer. Preparation of the vehicle included setting the engine to Chrysler specifications and inflating rear dual tires to 70 psig. All testing was performed using premium tank fuel. Retests were conducted with approximately 16,000 miles on the odometer.

IV. Test Program

Back-to-back steady state tests were conducted on the test vehicle at the following points:

1) idle
2) 20, 40, 50, 60 mph at road load horsepower (RLHP)
3) 20, 40, 50, 60 mph at two times road load (2XRL)
4) 20, 40, 50, 60 mph at three times road load (3XRL)

Road load horsepower was determined to be 46HP at 50 mph and 8.2 in. Hg manifold vacuum by road test. Inlet and outlet temperatures and pressures were measured at the compressor and turbine for all points in the turbocharged configuration during the initial test.

Bench testing was performed to measure the advance and retard characteristics of the OEM and modified distributors. The opening points of the retard switch and water injector solenoid were also determined.

In addition, a brief evaluation was made of driveability and performance in both the baseline and turbocharged configurations.

V. ARB Test Results

A. Distributor Bench Test

The OEM and modified distributors have slightly different centrifugal and vacuum advance curves as shown in Table 1. All data is in distributor rpm and degrees with distributor idle set at 300 rpm. The retard circuit in the modified distributor provides five distributor degrees of retard from the original vacuum advance.

Table 1 - Distributor Bench Test

	Centrifugal Advance			Vacuum Advance		
RPM	OEM (deg)	MOD ADV* (deg)	MOD RET* (deg)	VAC (in Hg)	OEM (deg)	MOD ADV* (deg)
100	0	0	-5.0	0	0	0
200	0	0	-5.0	3	0.5	0
300	0	0	-5.0	6	3.0	0
400	0	0	-5.5	9	5.0	1.5
500	0	0	-5.5	12	7.5	5.0
600	2	1	-4.0	15	9.0	9.0
700	3	3	-2.0	18	9.0	10.5
800	3.5	5	0	20	9.0	10.5
900	4.0	7.5	2.0			
1000	4.5	8.0	3.0			
1100	5.0	8.5	3.0			
1200	5.5	9.0	3.5			
1300	6.5	9.5	4.0			
1400	7.0	10.0	4.5			
1500	7.5	10.0	4.5			
1600	8.0	10.5	5.0			
1700	9.0	11.0	5.5			
1800	9.5	11.0	6.0			
1900	10.0	11.0	6.0			
2000	10.5	11.0	6.0			

*MOD ADV = Modified distributor, advance pick-up
MOD RET = Modified distributor, retard pick-up

B. Advance/Retard Microswitch Bench Test

The advance/retard microswitch added to the vehicle as part of the BAE kit switches from the advance to the retard pick-up at approximately 0.2-0.3 psig. 2.0 psig is the specified switching point.

C. Water Injection Solenoid Bench Test

The original single water injection solenoid closed and allowed water to flow at approximately 0.4 psig as compared to the specified switching point of 2.0 psig. The dual nozzle system specifies water injection at 0.50 psig on one nozzle and 1.5 psig on the other. Actual opening points were at 1 psig and 1.5 psig respectively. Actual closing points were approximately 0.5 psig for both nozzles.

D. Steady State Emissions Tests

The results of steady state emission tests are given in Tables 2 through 4. Two baseline tests were conducted in March followed by two device tests in April; one (4/20/79) with basic timing advanced from 8° BTDC to 14° BTDC, and one (4/23/79) with timing set at the stock specification of 8° BTDC.

High NOx results on the device tests required modifications of the BAE system to correct the NOx rise.

The vehicle was retested in October in two configurations. In the first retest of the system (10/9/79) the turbocharger system was modified with a second water injection nozzle to provide a staged water injection effect. The second retest (10/12/79) was conducted with the staged water injection and a Jacob's electronic ignition system to provide a variable retard under boost instead of the previous single stage retard.

Table 2 - NOx Raw Exhaust Measurements

Mode	Baseline NO, ppm 4/5/79	Baseline NO, ppm 4/6/79	Device NO, ppm 4/20/79	Device NO, ppm 4/23/79	Device Retest NO, ppm 10/9/79	Device Retest NO, ppm 10/12/79
idle	96	136	100	183	79	119
20/RL	688	613	991	1130	350	671
40	978	1033	781	706	1002	1196
50	2186	2186	1861	1653	2046	2161
60	3143	2969	3586	3586	1528	1691
idle	96	136	100	183	79	119
20/2XRL	818	714	1216	1046	553	896
40	2348	2521	2201	1897	2084	2009
50	539	739	4439	4439	1168	647
60	1289	1408	537	225	119	99
idle	116	116	183	100	99	99
20/3XRL	1117	1378	1861	1755	1196	1283
40	1927	1927	4203	3983	2200	2280
50			491	468	99	99
55 (2nd)			537	311	119	180

Table 3 - CO Raw Exhaust Measurements

Mode	Baseline CO, %		Device CO, %		Device Retest CO, %	
	4/5/79	4/6/79	4/20/79	4/23/79	10/9/79	10/12/79
idle	0.79	0.73	0.53	0.99	1.26	0.62
20/RL	0.36	0.30	0.20	0.20	0.46	1.50
40	0.20	0.10	0.10	0.10	0.15	0.20
50	0.20	0.15	0.10	0.10	0.15	0.20
60	0.73	0.96	0.15	0.10	2.30	2.23
idle	2.16	2.09	0.36	0.47	1.26	0.90
20/2XRL	0.52	0.41	0.20	0.20	0.31	1.56
40	0.15	0.20	0.15	0.15	0.15	0.20
50	6.94	6.02	0.47	0.15	4.50	6.13
60	5.38	5.28	4.37	6.22	*	*
idle	2.09	0.79	0.64	0.70	1.69	2.09
20/3XRL	0.90	0.31	0.20	0.15	2.09	1.69
40	2.30	2.09	0.10	0.10	1.25	1.19
50			4.82	5.01	*	*
55(2nd)			6.22	6.78	*	*

*Exceeds instrument capacity of 8.32%

Table 4 - HC Raw Exhaust Measurements

Mode	Baseline HC*, ppm 4/5/79	Baseline HC*, ppm 4/6/79	Device HC*, ppm 4/20/79	Device HC*, ppm 4/23/79	Device Retest HC*, ppm 10/9/79	Device Retest HC*, ppm 10/12/79
idle	347	240	637	612	148	121
20/RL	196	133	72	106	34	104
40	46	26	267	26	8	8
50	46	53	21	45	17	17
60	46	53	59	98	43	34
idle	601	267	847	499	148	139
20/2XRL	347	133	87	69	25	104
40	46	26	74	53	17	25
50	347	160	87	66	77	77
60	196	80	168	192	95	157
idle	647	240	554	452	166	139
20/3XRL	445	106	146	53	130	104
40	196	106	69	50	69	60
50			154	135	148	203
55(2nd)			133	106	86	112

*HC as carbon (not hexane)

V. Discussion of Results

The first set of tests (4/20-4/23) with the BAE turbocharger system installed indicated appreciable increases in NOx at 20 and 60 mph at road load horsepower, at 20 and 50 mph at two times road load, and at 20 and 40 mph at three times road load as shown in Table 2. There were also scattered increases in HC.

The NOx rise is caused by higher cylinder temperatures and pressures resulting from turbocharging. There are a number of modifications that can be made to reduce NOx from a turbocharged vehicle such as reducing compression ratio, retarding timing, or injecting water or fuel into the incoming air-fuel charge. Most manufacturers already incorporate one or more of these methods to eliminate preignition or detonation, which are also directly related to high cylinder temperature and pressure.

BAE elected to change their water injection system, for NOx control, from a single nozzle opening at two psig to a two-stage system with two nozzles, one opening at 0.5 psig and the other at 1.5 psig.

A second change for NOx control is the option of adding a Jacob's Electronic Ignition System which gives gradual retard under boost. The Jacob's system replaces the retard diaphragm and is used with the two-stage water injection.

The results of tests conducted 10/9/79 and 10/12/79 (see Tables 2-4) shows that BAE has generally solved the NOx and HC problem which appeared in previous tests. A comparison of the baseline and 10/9/79 device test shows higher device NOx at 50 mph, 2XRL, and at 40 mph, 3XRL. These values are substantially reduced from the values found in April, and appear to be a result of a slightly different entry point into the power enrichment circuit. The turbocharged configuration is beginning enrichment at these points, evidenced by the increase in CO, while the baseline is already rich. Because larger amounts of fuel (denoted by higher CO) are being consumed by the baseline engine, lower NOx values would be expected. However, this occurs during a period of rapid transition from cruise to power enrichment modes; therefore, the turbocharged engine should give CO and NOx values equivalent to the baseline at a slightly higher speed, perhaps 51 or 52 mph (note the NOx and CO values of the 10/12/79 test at 50 mph, 2XRL). For this reason, the NOx and CO increases at the higher loads and speeds are considered to be transitory and negligible.

The test conducted 10/12/79 with the Jacobs ignition control unit indicates a questionable NOx value at 40 mph, 1XRL which is about 20% over the baseline figure. This point may be a result of the Jacobs system, but it is unlikely since other points do not show the same discrepancy.

VI. Conclusion and Recommendation

It is the staff's opinion that the BAE Turbocharger System for the 440-3 heavy duty Chrysler engine will have no significant adverse effect on emissions from a vehicle when installed in accordance with BAE instructions. It is recommended that the Board grant BAE an exemption from the prohibitions of VC 27156 for this system using either the retard pickup/microswitch, or the Jacobs ignition system to provide the necessary retard.