

State of California
AIR RESOURCES BOARD

EXECUTIVE ORDER D-75-1
Relating to Exemptions under Section 27156
of the Vehicle Code

CAGLE CORPORATION
"CAGLE MARK II AUTOMATIC FUEL CONTROL" DEVICE

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 Section 39515 of the Health and Safety Code and Executive Order G-30A;

IT IS ORDERED AND RESOLVED: That the installation of the "Cagle Mark II Automatic Fuel Control" device manufactured by Cagle Corporation, 400 Yellowstone Avenue, Pocatello, Idaho 83201 has been found to not 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 1977 and older model year gasoline powered motor vehicles using conventional carburetors and mechanical or electric fuel pumps with and without recirculation systems.

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

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 "CAGLE MARK II AUTOMATIC FUEL CONTROL" DEVICE.

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 Sacramento, California, this 21st day of September, 1977.


Thomas C. Austin
Deputy Executive Officer

State of California

AIR RESOURCES BOARD

September 15, 1977

Staff Report

Evaluation of the Cagle Corporation
"Cagle Mark II Automatic Fuel Control" Device for
Compliance with the Requirements of Section
27156 of the Vehicle Code

I. Introduction

On June 15, 1977 the Air Resources Board received an application from Cagle Corporation, Long Beach, California, requesting an exemption from the prohibitions of Vehicle Code Section 27156 for the "Cagle Mark II" fuel pressure regulator device. (See Appendix A.). The applicant requests that the exemption be granted for all 1977 and older model year motor vehicles that are powered by gasoline engines with conventional carburetors and mechanical or electric fuel pumps with and without fuel recirculation systems.

II. Device Description

The "Cagle Mark II" is a fuel pressure regulator installed between the fuel pump and the carburetor. It has three external fittings: (a) a fitting at the top for measuring intake manifold vacuum (b) an inlet fitting marked "PUMP" for connection to the fuel pump and (c) an outlet fitting marked "CARB" for connection to the carburetor. (See Figure 1 of Appendix A). It is designed to reduce the fuel supply pressure under low demand conditions and also maintain the required fuel flow to the carburetor under all operating modes. The

regulator is controlled by the intake manifold vacuum operating on a spring balanced Buna-N diaphragm. The materials of construction are shown in Table I. (Reference May 18, 1977 letter of DCL Corporation to Cagle Corporation in Appendix A.)

Table I Construction Material of the Parts used in the Device

<u>Part</u>	<u>Material</u>
O-Ring Seal	Viton-70 Shore
Molded diaphragm	Viton 70 Shore
Stamped diaphragm	Buna N-70 Shore
Flat disc	Cold roll steel, cadmium plated
Cup shape retaining washer	Spring steel, cadmium plated
Formed steel shape	Cold roll steel, cadmium plated

Reference is made to Figure 3 of Appendix A. When the engine is idling or cruising, the intake manifold vacuum draws the diaphragm "H" upwards, thus compressing spring "F" and lifting plunger pin "C" away from diaphragm "J". Diaphragm "J" is the fuel regulator diaphragm controlling fuel pressure from the fuel pump to the carburetor in the conventional manner of using opposing spring tensions balanced to maintain a constant fuel supply pressure of 1 to 1 1/2 lbs. per square inch.

During periods of acceleration or heavy demand, the manifold vacuum is substantially reduced which allows spring "F" to force plunger pin "C" down on diaphragm "J" as in Figure 4 of Appendix A. This action then assists spring "O" to override the pressure regulator

At manifold vacuum ranging from 0 to 20 inches Hg. and fuel pump pressures of 3, 5, 7, 9 and 12 psig the graphs in Figure 2 to 7 of Appendix B show that the fuel pressure to the carburetor is generally reduced. In the operating range of 15 to 20 inches Hg. manifold vacuum, the higher the fuel pump pressure the lower the regulator outlet pressure. This is not true for a lower manifold vacuum condition. Hence the device can maintain full discharge pressure when the intake manifold vacuum is low (as in wide open throttle, high speed operation) but can reduce delivery pressure when the intake manifold vacuum is high (as in deceleration or cruise conditions).

Figure 9 of Appendix B presents the DAECO data for a given fuel flow rate (16 lbs. per hour) and fuel pump pressure (7.0 psig.) showing the regulator outlet pressure as a function of steady-state vacuum from 0 to 29 inches mercury. This data shows a linear decrease in pressure to the carburetor between zero and 15 inches manifold vacuum, and constant 1.1 psig regulator outlet pressure at greater than 15 inches.

Figure 14 of the DAECO data (see Appendix B) shows the effect of pump speed on regulator outlet pressure at a given constant flow, fuel pump pressure and manifold vacuum. Above 1500 RPM the pump speed has no effect on the regulator outlet pressure. Below that speed value, there seems to be a trend to increasing

spring "N" which opens poppet valve "B" releasing more fuel flow to bring the fuel pressure higher as required. The spring characteristics are shown in Table II. (Reference May 23, 1977 letter of the Precision Coil Spring Company to Cagle Corporation in Appendix A.)

Table II Spring rates and free lengths of the
Springs used in the device

	<u>Free length</u>	<u>Spring rate</u>
Upper regulator spring	.825 inch	4.6 lb/inch
Lower regulator spring	.450 inch	2.1 lb/inch
Vacuum spring	.625 inch	8.5 lb/inch

III. Performance Evaluation

A. Applicant's Test Data

Testing of the device for performance as described in the application was done by Daigh Automotive Engineering Co.

(DAECO) (201 West "D" Street, Wilmington, California 90744).

DAECO used a bench test flow procedure as shown in Figure 1 of Appendix B of the July 15, 1977 DAECO report titled "Flow Test of Cagle Mark II Automatic Fuel Pressure Control". The relationships between regulator outlet pressure, fuel pump pressure, intake manifold vacuum, and fuel flow from the DAECO tests are shown in Figures 2 to 7 of Appendix B. Data for five different fuel pumps with different pressures are shown. (Reference July 15, 1977 DAECO report.)

regulator pressures as pump speed decreased. DAECO attributed this observation to the pronounced pressure and flow pulsations which reduced gauge precision even though gauge snubbers were installed. Since the difference amounts to no more than about 0.3 psig from 1000 to 500 RPM, it is not considered a significant factor.

Appendix B gives figures 11, 12, 13 and a discussion by DAECO of the effects of fuel flow, regulator outlet pressure, intake manifold vacuum and fuel pump pressure on the fuel level in the carburetor float bowl. The data shows that for the particular specific test apparatus used by DAECO (Hitachi ISO Model DAF 328-6-902 two barrel carburetor) the minimum fuel level to which the fuel will drop is 26/32 inch. (Compared to a normal level of 36/32 inch). This assures that the fuel supply to the engine is sufficient during all operating modes to prevent starvation. The decrease in fuel level in the carburetor float chamber would, however, have the effect of leaning the air fuel ratio of the engine.

B. ARB Confirmatory Tests

The ARB flow and emission tests were performed on a 1971 V8 Ford 302, 2V engine installed on the engine dynamometer test stand. (See schematic diagram in Figure 1 of Appendix C and reference Project No. 2V7706, Air Resources Board, 8-9-77). Four operational modes were used to evaluate the pressure

Table III ARB flow and emission data under 4
operational modes using the dyna-
mometer mounted 1971 V-8 Ford 302
2V engine

	18 in Hg 625 RPM	15 in Hg 1000 RPM	10 in Hg 1000 RPM	10 in Hg 2000 RPM
1) Fuel pressure upstream from regulator (lbs per sq in.)	8.3	7.8	7.2	5.5
2) Fuel pressure downstream from regulator to carburetor (psig.)	1.5	1.5	3.0	3.0
3) Fuel flow through carburetor with device (lbs./hr.)	3.83	8.98	13.04	27.27
4) Fuel-Air Ratio (Baseline/device)	.099/.093	.074/.070	.076/.074	.078/.077
5) Per Cent change in Fuel-Air Ratio from Baseline	-6.1	-5.4	-2.6	-1.3
6) HC emissions (gm/min.) Baseline/device	.425/.336	.220/.199	1.063/1.116	1.878/1.834
% Change	-20.9	-9.5	-5.0	-2.3
7) CO emissions (gm/min) Baseline/device	8.56/6.14	1.98/0.98	4.99/2.26	26.65/20.41
% Change	-28.3	-50.5	-54.7	-23.4
8) NOx emissions (gm/min.) Baseline/device	.04/.04	0.50/0.36	3.67/3.98	8.76/9.13
% Change	0	-28.0	8.4	4.2

reductions by the "Cagle Mark II" device: 18 inches Hg at 625 RPM, 15 inches Hg at 1000 RPM, 10 inches Hg at 1000 RPM, and 10 inches Hg at 2000 RPM. The results are shown in Table III.

This data shows that when the device is installed, the pressure to the carburetor is decreased and the fuel-air ratio is decreased by an average 4% under all four test modes. This resulted in leaner combustion.

Table III shows the percent change in CO emissions from the baseline which verifies that the device causes the engine to run leaner resulting in an average 39% decrease in CO emissions. The HC emissions decreased an average of 9.4% which is beneficial to the emission control system. The NOx emissions increased an average of 6% but it is not considered serious because it is within the variability of experimental error. NOx emissions with this device may either increase or decrease depending on which side of stoichiometric the carburetor is predominantly operated. The effect on emissions varied with the test conditions and the overall effect is not considered deleterious to the total emissions control when used on engines operating at an equivalence ratio greater than one. [Equivalence ratio equals Fuel-Air Ratio (actual) divided by Fuel-Air Ratio (stoichiometric)].

The leaning effect of this device can be explained as follows:
(Reference ARB Report May 25, 1976: Evaluation of Alondra, Inc. "Filt-O-Reg" device for compliance with the requirements of Section 27156 of the Vehicle Code).

- a. The carburetor float valve operates as a variable orifice where the flow rate (m) is described by

$$m = C_d A \sqrt{2g\rho\Delta p} = K_z \sqrt{2g\rho P_2}$$

C_d = discharge coefficient

ρ = fuel density

A = orifice area

Δp = pressure differential ($P_2 - P_{atm}$)

g = gravitational constant P_2 = carburetor inlet pressure

$K_z = C_d A$ as a function of the float level, z , where z is the liquid height above a reference.

- b. Reducing the carburetor inlet pressure (P_2) requires a higher K_z to maintain any flow rate (m) into the bowl. This requires a slightly lower float level and fuel level in the bowl (Δz).
- c. The lower fuel level decreases the head required by the main and idle circuits and reduces the fuel flow for any throttle (air flow) setting: this fuel reduction is more significant at low engine speeds where Δp across the venturi is small ($\Delta p \approx \Delta z$). The result is a leaner fuel/air mixture.
- d. Increasing the carburetor inlet pressure reverses the above process and raises the float and fuel level. This results in enrichment.

The leaning of an engine that already runs lean will lead to misfires because the fuel flow out of the main and idle circuits is reduced.

The percent decrease in fuel-air ratio from baseline to device range from 6% at idle to 1% at 10 in. Hg and 2000 RPM. The "Filt-O-Reg" device exempted by the ARB had a per cent decrease of 7% at idle and 1% at 10 in. Hg and 2000 RPM. The pressure reductions of the Cagle device are 7 psig at idle and 2 psig at 10 in. Hg and 2000 RPM. The pressure reductions of the "Filt-O-Reg" are 7 psig at idle and 3 psig at 10 in. Hg and 2000 RPM.

The air-fuel ratio (reciprocal of fuel-air ratio) increased to an average 0.5 from the baseline value which meets the Air Resources Board allowable increase of 1 AFR. Since the device displayed similar characteristics of a device previously exempted by the ARB and since the air-fuel ratio increase was less than one the staff cannot find any reason to deny Cagle Corporation an exemption for their "Cagle Mark II Automatic Fuel Pressure Control" device.

IV. Evaluation of Advertising Claims

The applicant has implied fuel economy as the advertising claim when the "Cagle Mark II" device is installed in a motor vehicle. According to the applicant's July 5, 1977 and June 15, 1977 letters to ARB "marketing will be carried on by demonstration rather than claims." (See Appendix A). Although the applicant has not submitted any supporting data to substantiate fuel economy claims the ARB staff feels that the use of the device may give increased mileage on some vehicles due to the leaning effect on engines which are running rich.

V. Conclusion and Recommendations

Based on the test data, the staff believes that the use of the "Cagle Mark II" device will not lead to increased emissions and recommends that Cagle Corporation be granted an exemption from the prohibitions of Vehicle Code Section 27156 for 1977 and older model year gasoline powered motor vehicles using conventional carburetors and mechanical or electric fuel pumps with and without fuel recirculation systems.

Appendix A

- 1) Letter from Mr. Kilbourne to Mr. Hass 6-15-77
- 2) Letter from Mr. Drachand to Mr. Kilbourne 6-27-77
- 3) Letter from Mr. Kilbourne to Mr. Drachand 7-5-77