THE CONTROL OF GASOLINE ENGINE EMISSIONS AT IDLE AND PART-LOAD CONDITIONS

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ABSTRACT

The air pollution in a big city like Alexandria, 3 millions inhabitants, became a threatening problem to human beings, to the environment, and to the economy. Strict regulations on exhaust emissions must be imposed to overcome this problem. Idle and low load emissions especially carbon monoxide, unburned hydrocarbons and lead compounds let all people complain of chronic headaches, respiratory problems, irritated eyes and nervousness. This study presents the control methods that can reduce the SI engine emissions to the standard levels. The use of positive crankcase ventilation and the use of one of the exhaust treatment devices such as a catalytic converter or a thermal reactor would cut the carbon monoxide and hydrocarbon emissions. Besides, idle engine adjustment would reduce largely the idling hazardous emissions. All SI engine vehicles working inside city must be of the 4-stroke cycle type. The production of ethanol from the sugar cane crop can be used as an alternative fuel additive to produce unleaded gasoline in Egypt.

INTRODUCTION

The air pollution due to automotive exhaust emissions has become a growing problem facing Alexandria city. Exhaust gases coming out of automobiles contain hazardous emissions mainly carbon monoxide, unburned hydrocarbons, nitric oxides and lead compounds.

Decreasing the engine load by smaller throttle opening leads to richer fuel to air ratios due to increasing manifold vacuum and excessive exhaust dilution. Thus, hydrocarbon and carbon monoxide emissions increase largely at idle and part load operation, [1] and [2].

The nitrogen oxides emissions at idle and part load were measured experimentally by Antar [5] and were estimated by mathematical models by Kataoka [3] and Yuen [4]. Figure (1) shows that the nitrogen oxides emissions are minimum at part load (about 400 ppm) and are maximum near full load. Therefore, the study of idle and part load emissions will concentrate on the hydrocarbon and carbon monoxide emissions.

The control of SI engines emissions includes the positive crankcase ventilation since the crankcase emission contributes about 25% of all hydrocarbon emissions [1] and [2]. The exhaust treatment devices such as catalysts and thermal reactors would cut the carbon monoxide and hydrocarbons level by 95%, [6] and [7]. The engine adjustment at idle and low load, [8] and [9], is an important factor to control emissions from SI engines since long lines of vehicles move slowly inside town especially near all strategic intersections.

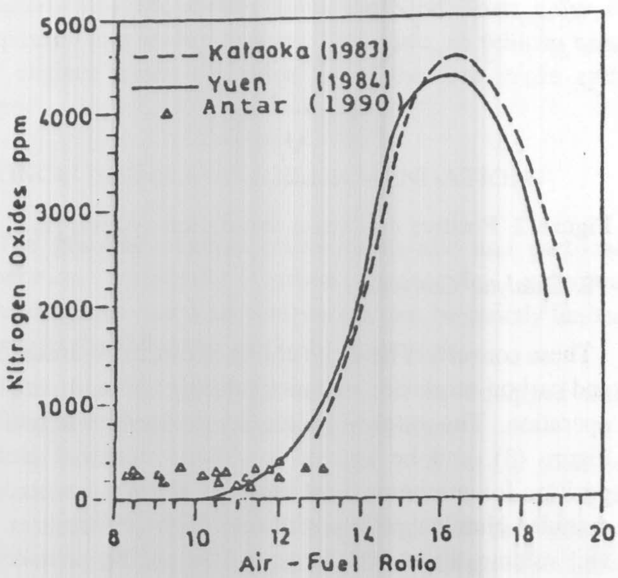

Figure 1. Nitrogen oxides emissions at idle and part load operation, [5].

The evaporative losses would be cut by using charcoal canisters [1]. The lead compound emission originating from the "octane-booster" tetraethyl-lead (TEL) can be eliminated by using ethylalcohol additives instead of (TEL), [10] and [11]. Besides, all two stroke SI engines must be prevented inside Metropolitan Alexandria since this type of engines is one of the main sources of hydrocarbon emissions.

METHODS OF CONTROL

1. Crankcase Ventilation

The crankcase emission contributes about 25% of all hydrocarbon emissions from uncontrolled vehicles. The crankcase gases contain mainly the blowby gases from cylinders into the crankcase during both compression and expansion processes, besides small quantities of lubricating oil vapours. A positive crankcase ventilation system (PCV system) eliminates all the crankcase emission as shown in Figure (2). It recirculates all crankcase emissions back into the induction manifold. All cars especially old ones must be equipped with such (PCV system) to eliminate one of the main sources of air pollution.

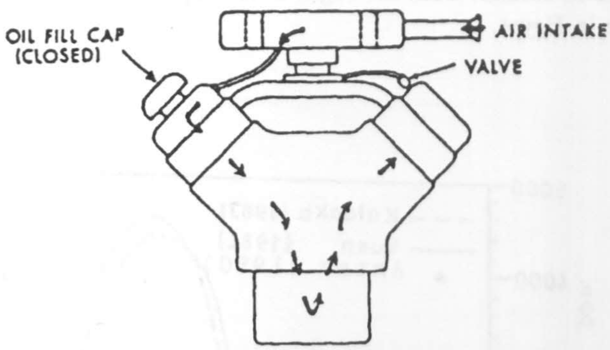

Figure 2. Positive crankcase ventilation system, [1].

2. Catalytic Converters

These converters have the ability to oxidize hydrocarbons and carbon monoxide emissions during idle and part load operation. The catalytic container looks like a muffler, Figure (3), and be located in the conventional muffler position for minimum heat losses. Catalysts are made of granular alumina pellets with very high surface area per unit volume, about 100,000 sq. meter per Kg of material, [1]. The catalyst material is deposited upon the surface of the pellet. Usually a noble metal such as platinum, or an oxide, is used. Typically 2.5 to 3.5 Kgs of catalyst are used.

The main problem with a catalyst is that the lead compounds in the exhaust coat the active surface and deactivate the catalyst after a short milage operation. Thus, the use of tetraethyl-lead (TEL) in gasoline fuels inhibits the activity of catalytic converters. It is recommended to increase the octane number of gasoline fuels by using ethyl-alcohols instead of (TEL).

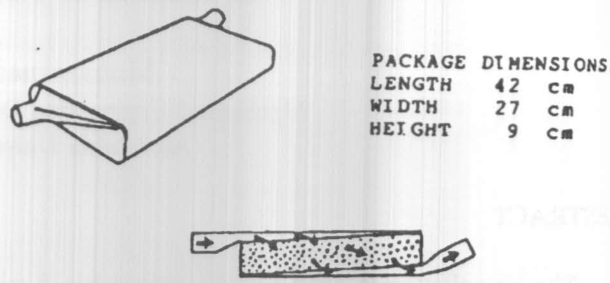

Figure 3. A catalytic converter, [1].

3. Thermal Reactors

Thermal reaction is an effective method for reducing carbon monoxide and hydrocarbon emissions at engine rich mixture operation. It is achieved by injecting air into the exhaust system to complete the CO and HC combustion. A thermal reactor includes a shielded exhaust volume, called the reactor core, to permit a residence time enough to complete reaction rates as shown in Figure (4).

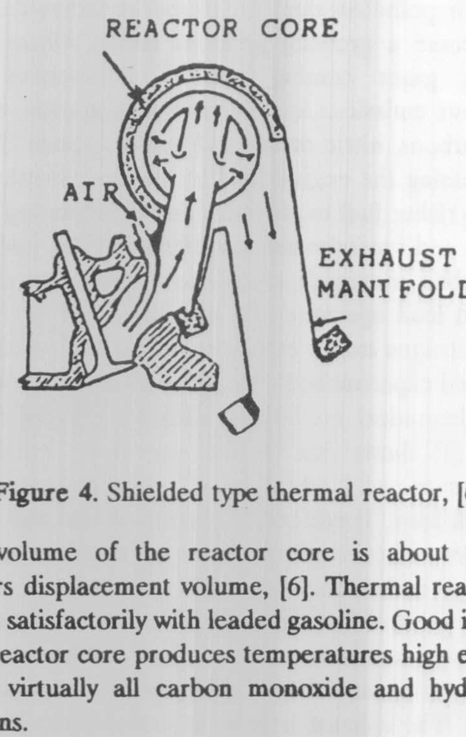

Figure 4. Shielded type thermal reactor, [6].

The volume of the reactor core is about the total cylinders displacement volume, [6]. Thermal reactors can operate satisfactorily with leaded gasoline. Good insulation of the reactor core produces temperatures high enough to oxidize virtually all carbon monoxide and hydrocarbon emissions.

4. Idle Adjustment

Hydrocarbon and carbon monoxide emissions are largely reduced by leaner idle operation. This can be accomplished by increasing throttle opening, increasing idle speed and retarding spark timing, as shown in Figure (5). Each carburetor is checked on a flow stand and an adjustment is made so that excessively rich mixtures at idle cannot be obtained.

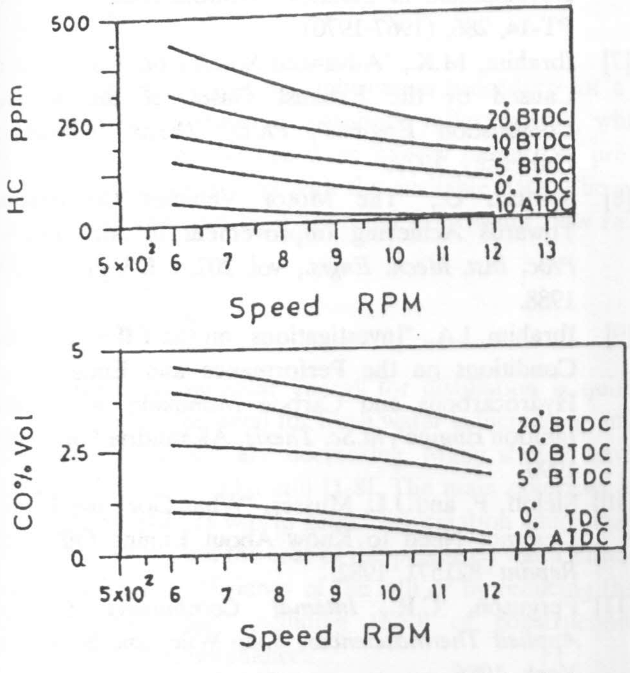

Figure 5. Effect of engine speed and spark timing on hydrocarbon and carbon monoxide emissions under no load condition, [9].

Leaner average operation can be also accomplished through better atomization and mixing of the fuel with air. This can be achieved by using double or triple venturi carburetors. Also two or three barrel carburetors have better leaner mixture operation.

5. Charcoal Canisters

Evaporation losses from the fuel tank and carburetor reaches about 16 liters per year from each car, [1]. During running, tank and carburetor vapours are vented to the intake system. During hot soaks, fuel vapours are routed to a storage device. The charcoal canister contains activated charcoal which has an affinity for hydrocarbon vapors. Upon engine restart, filtered air is drawn through the stored vapours and the mixture is metered into the intake system and burned in the engine. Each 100 gm charcoal can store about 35 gm of fuel vapors. Typically about 800 gm charcoal can be used in a vehicle system, [1].

6. Fuel Additives

The lead compounds originating from the use of tetraethyl-lead (TEL) have serious and long-range effects on both health (e.g. mentally-retarded people) and atmospheric processes. Alternative additives such as ethanol and methanol are in use today in many countries as octane-boosters, [10] and [11]. The sugar cane is one of the most efficient crops for producing ethanol. Locally manufactured ethanol from sugar cane crop can help to produce unleaded gasoline in Egypt.

7. Two-Stroke SI Engines

In two-stroke cycle gasoline engines a main source of hydrocarbon emissions results from the scavenging process. When scavenging the cylinder with a fuel-air mixture, part of which blows through the cylinder directly into the exhaust and escapes the combustion process completely. Hydrocarbon emissions from this type of engines may be several times than that from naturally aspirated four-stroke engines. Therefore, all vehicles using SI engines inside city must be of the four-stroke cycle type.

CONCLUSIONS AND RECOMMENDATIONS

The gasoline engines emissions at idle and part-load operation especially carbon monoxide, unburned hydrocarbons and lead compounds can be strictly limited through the following methods of control:

1. All cars especially old ones must be equipped with Positive Crankcase Ventilation system.
2. An exhaust treatment device such as a catalytic converter or a thermal reactor can be used. It is noticed that the lead compounds in the exhaust deactivate the catalyst after a short milage operation, while thermal reactors can operate satisfactorily with leaded gasoline.
3. Idle adjustment by increasing throttle opening, increasing idle speed and retarding spark timing will accomplish leaner idle operation and thus decreasing the carbon monoxide and hydrocarbon emissions. Besides, carburetor adjustment to avoid excessive rich mixtures at idle reduces largely the idling engine emissions.
4. Evaporation losses from the fuel tank and carburetor especially during hot soaks can be stored by using

charcoal canisters. Upon engine restart the stored vapors are metered back into the induction manifold.

5. Alternative fuel additives such as ethanol can be used to produce unleaded gasoline. The production of ethanol from the sugar cane crop in Egypt can replace the tetraethyl-lead (TEL) as an octane-booster.
6. The two-stroke gasoline engines must be prevented inside Metropolitan Alexandria and can be replaced by four-stroke cycle engines.

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