905243

Comparing Ecological Indexes of Diesel and Gas-Diesel Engines

L. M. Tartakovsky

Lately there been conducted intensive research work on creating in the USSR the automobile transport means, working on alternative kinds of fuel, primarily on natural gas. The automobile industry has started alongside with expanding production of gas cylinder automobiles with spark ignition engine, the production of the so-called gas-diesel automobiles, that can work both in diesel regime on liquid fuel and in gas diesel regime on natural gas with liquid fuel ignition doze. The substitution of liquid fuel for gas was first dictated by the necessity to use sparingly fuel resources or, to be more exact, by diesel fuel shortage in some areas of the USSR. The necessary requirement for automobile universality, that is the possibility to work both in diesel and gas diesel regimes, was caused by the shortage of automatic gas-filling compressor stations on the USSR territory.

Gas diesel engine makes it possible to economize up to 80% of liquid fuel while preserving tractive-speed characteristics of an automobile. The real operation economy of diesel fuel amounts to 6-14 tons per year for one automobile.

Lately, however, in the USSR, as in the rest of the world, the problems of automobile means safety, the ecolog ical safety including, are coming to the forth.

Here, in respect to gas diesel, the problem should be divided into 2 interlinked parts. First, the existing in the USSR national and international european standards, limitting diesel engines harmful substances exhaustion, do not regard gas diesels. Taking into account the expanding production of gas diesels in the USSR and in a number of other European countries (according to our data), we regard it as necessary to introduce national standards by all interested parties, limitting gas diesel harmful substances exhaustion, as well as to adopt a corresponding amendment to N 49 Regulations of UN ECE.

However, before realising the first part of the above-mentioned problem, it is necessary to solve its second part - that is to estimate the level of gas diesel engines harmful substances exhaustion, further comparing the data with the corresponding indexes for diesel engines and finally determining the main trends for gas diesel ecological indexes improving and working out the suitable norm-establishing concept.

The present work offers the main results of researches done in scientific research center on testing and automobile technique adjustment in accordance with the exposed view on the essence of the problem. The research works in that sphere have been financed so far and are being actively financed by "KamAZ" - a production complex.

There have been tested on a motor bench according to different programmes two models of 8-cylinder gas diesel engines (without supercharge, with cylinder displacement volume of 10,351. gross capacity of 154 kwt) and one engine of the same size (with turbo-supercharged capacity of 190 kwt). There were defined exhaust gases smoke-level in accordance with N 24 Regulations of the UN ECE, exhausts of gaseous harmful substances CO, CH, NOx, which are norm-regulated in accordance with N 49 Regulations of UN ECE, qualitative and quantative composition of light hydrocarbons, polycyclic aromatic hydrocarbons (PAH), aldehydes and particles shooting.

While conducting gas diesel engine automobile testing, exhaust gases smoke-level and noise-level were repeatedly measured.

There has been noted a 3-6 dB external and internal noise level reduction in the gas diesel regime work.

Automobile exhaust gases smoke-level was evaluated in free acceleration regime, as is adopted in the USSR National Standard (" ОСТ" - state standard N 21393-75), to establish the correlation between automobile production and control in operation.

Table 1

Exhaust gases smoke-level of gas diese automobiles in free acceleration regime (according to 21393-75 Standard, un. Hartridge)

Automobile type	KamAZ-53208	KamAZ-53218	KamAZ-54118	KamAZ-55118	MAZ-5549
Diesel	40	35	37	40	16
Gas diesel	17	9	14	24	7

The testings held in accordance with N 24 Regulations of UN ECE and N 21393-75 USSR National Standard have testified to exhaust gases smoke-level reduction by 2-3 times in case of gas diesel engine as compared to diesel engine.

At the same time the problem of gas diesel engine hydrocarbons shooting has proved to be quite serious and engendered multiple discussions. The testings held in accordance with the standard proceedure of N 49 Regulations of UN ECE, have shown the total hydrocarbons shooting increase in gas regime work as compared to diesel regime (sometimes the increase was tenfold). The greatest total HC concentrations- up to 10,000 $мин^{-1}$, are observed under maximum air-gas mixture degradation conditions. This made it possible to conjecture that appreciable part in gas diesel total hydrocarbons shooting is taken up by metane, which is not burnt down in engine cylinders due to extreme degradation of air-gas mixture and flame extinguishing in the cold near-wall zone.

To get an answer to the problem, the quantative and qualitative comparison of light hydrocarbons composition in diesel and gas diesel engines exhaust gases was done.

The typical example of light hydrocarbones content in exhaust gases is presented on drawing 1. The test results have proved that in case of gas diesel engines the greatest portion of exhaust gases total hydrocarbons falls on metane. Its content varies from 87 to 97 %, the light hydrocarbons share being 91-99 % of gas diesel engine exhaust gases total HC.

With diesel the situation is straight reverse. Light hydrocarbons make up for only a small part of EG (exhaust gases) total HC - 7-37 %, metane content being less than 2 %.

As metane is not a harmful substance, it would be only logical, while estimating diesel harmful substences, to subtract metane from the total quantity of EG total hydrocarbons. In this case the level of gas diesel HC shooting will not exceed that of diesel engine shooting. The analogous approach, as we know, is used in the USA for normalising hydrocarbons shooting. It means there has been drafted a project of the national standart of the USSR, normalising gas diesel engine gaseous harmful substances shooting (CO, HC and NOx). We also think it necessary to make a relevant amendment to N 49 Regulations of UN ECE. Such amendment draft could be presented for consideration already in 1990.

It would be quite natural, taking into account the above-mentioned smoke-level reduction in gas diesel regime, to compare mass particles shooting by diesel and gas diesel. The first stage of this work has been completed and the results of the comparison are presented on drawing 2. The specific particles shooting was estimated while conducting the engine test works according to 13-stage cycle - the proceedure prescribed by the N 49 Regulations of UN ECE. By now it has been proved that gas diesel particles shooting is approximately 2 times than that of diesel engine.

The above-mentioned drawing 2 also shows the comparative results of polycyclic aromatic hydrocarbons (PAH) and aldehydes shooting levels for diesel and gas diesel.

As for aldehydes, drawing 2 shows that their gas diesel level of shooting is about 1,5 times higher than diesel level. The analysis of reasons for getting such a result may be done by making use of drawing 3 data. Drawing 3 presents data on separate aldehydes shooting, from which it follows that 80 % of gas diesel aldehydes total shooting falls on formaldehyde, thus, formaldehyde content in EG being more than 2 times for gas diesel as compared to diesel. This can be accounted for by the sharp increase of CH_4 redicals presence in gas diesel engine cylinders during the process of natural gas burning, the latter being primarily made up of CH_4 metane. The total shooting of other heavier aldehydes differs slightly from diesel to gas diesel engine and the bulk of it falls on ethylaldehyde and acrylic aldehyde. It should be noted that the content of the above-mentioned 3 aldehydes accounts for 90 % of the total EG aldehydes, this figure being practicelly constant both for diesel and gas diesel engines. It should be stressed that formaldehyde content in EG of gas diesel increases sharply in the zone of partial loads, when there is registered unburnt metane augmented shooting. Thus, it may be conjectured that the reduction of gas diesel formaldehyde shooting as well as of unburnt metane shooting may be acieved by means of further development of mixture-forming and burning processes, by creating conditions for gas fuel more full burning.

The high level of shootings of formaldehyde, which is classified in the USSR as a highly toxic substance /its residential areas concentration in air should not exceed 0,003 mg/m^3 per twenty-four hours/, constitutes, to our mind, one of the most serious drawbacks of gas diesel and may hamper gas diesel automobiles expanding production in the nearest future. That's why

the reduction of formaldehyde and other aldehydes shooting level is viewed as one of the most pressing problems to be solved in gas diesel engines perfectioning. Such type of work is planned in the USSR in the most near future.

Drawing 9 presents the comparative shooting of 9 types of polycyclic aromatic hydrocarbons (PAH) by diesel engine and gas diesel engine. Diesel PAH total shooting, as is seen, is more than 3 times more than the corresponding figures for diesel, perylen, benzapyrene and benzepyrene in sum accounting for more than 65 % of diesel total PAH shooting - that is 5-7,5 times more than the given substances gas diesel shooting.

Assuming the independance of each of the above-mentioned harmful substances impact, there has been calculated (reduced to CO) harmful substances total shooting by diesel and gas diesel. The results show that the total gas diesel shooting is 25% less than that of diesel.

Conclusions

1. Gas diesel process is a radical method of liquid fuel economy (up to 80 %).

2. According to sum total of evaluated components, gas diesel is more ecologically safe than diesel engine: harmfull substances total shooting (reduced to CO) is 25 % less.

Thus:

- about 90 % of total hydrocarbons, shot by gas diesel, are made up by metane;
- particles shooting is about 2 times less;
- Polycyclic aromatic hydrocarbons (PAH) content in gas diesel exhaust gases is more than three times less as compared to diesel carcinogenic benzapyrene content being 6,5 times less;
- aldehydes content in gas diesel EC insreases by 1,5 times, formaldehyde exhaust being 2 times more, thus, accounting for about 80 % of aldehydes total shooting.

3. Formaldehydes level reduction is now one of the most urgent task of gas diesel engine further perfectioning.

4. It is viewed as useful to introduce an amendment to N 49 Regulations of UN ECE, limitting gas diesel harmful substances (HC, CO, NOx) shooting. While evaluating total hydrocarbons content, it is necessary to subtract metane, which is not a harmful substance. In this case the range of gas diesel possible exhausts may be established in conformity with now standing N 49 Regulations of UN ECE.

Central Automobile Proving Ground
141800 Dmitrov-7,
Moscow region
USSR

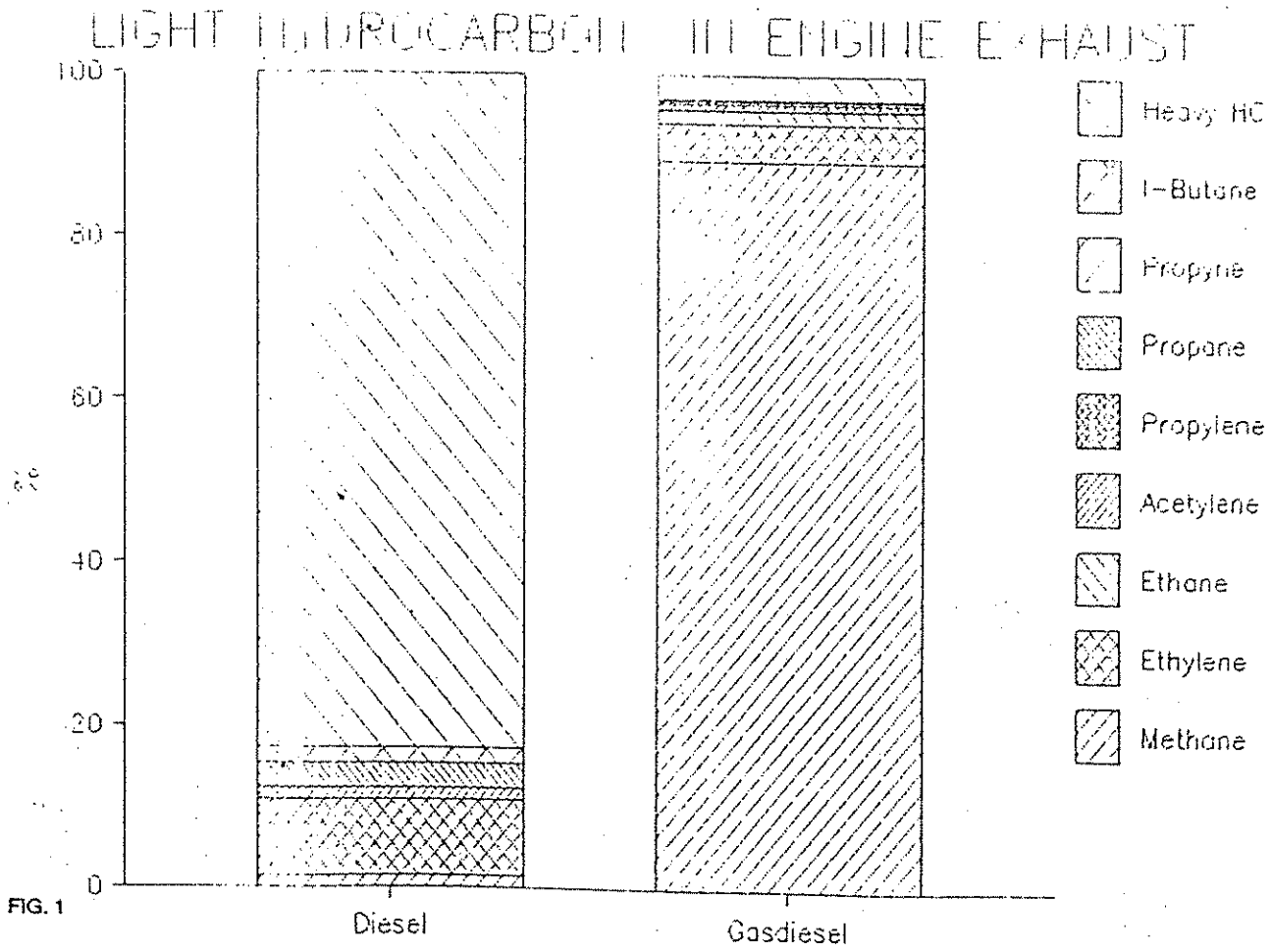
LIGHT HYDROCARBON IN ENGINE EXHAUST
100
80
60
40
20
0
Diesel
Gasdiesel
Heavy HC
1-Butane
Propyne
Propane
Propylene
Acetylene
Ethane
Ethylene
Methane

FIG. 1

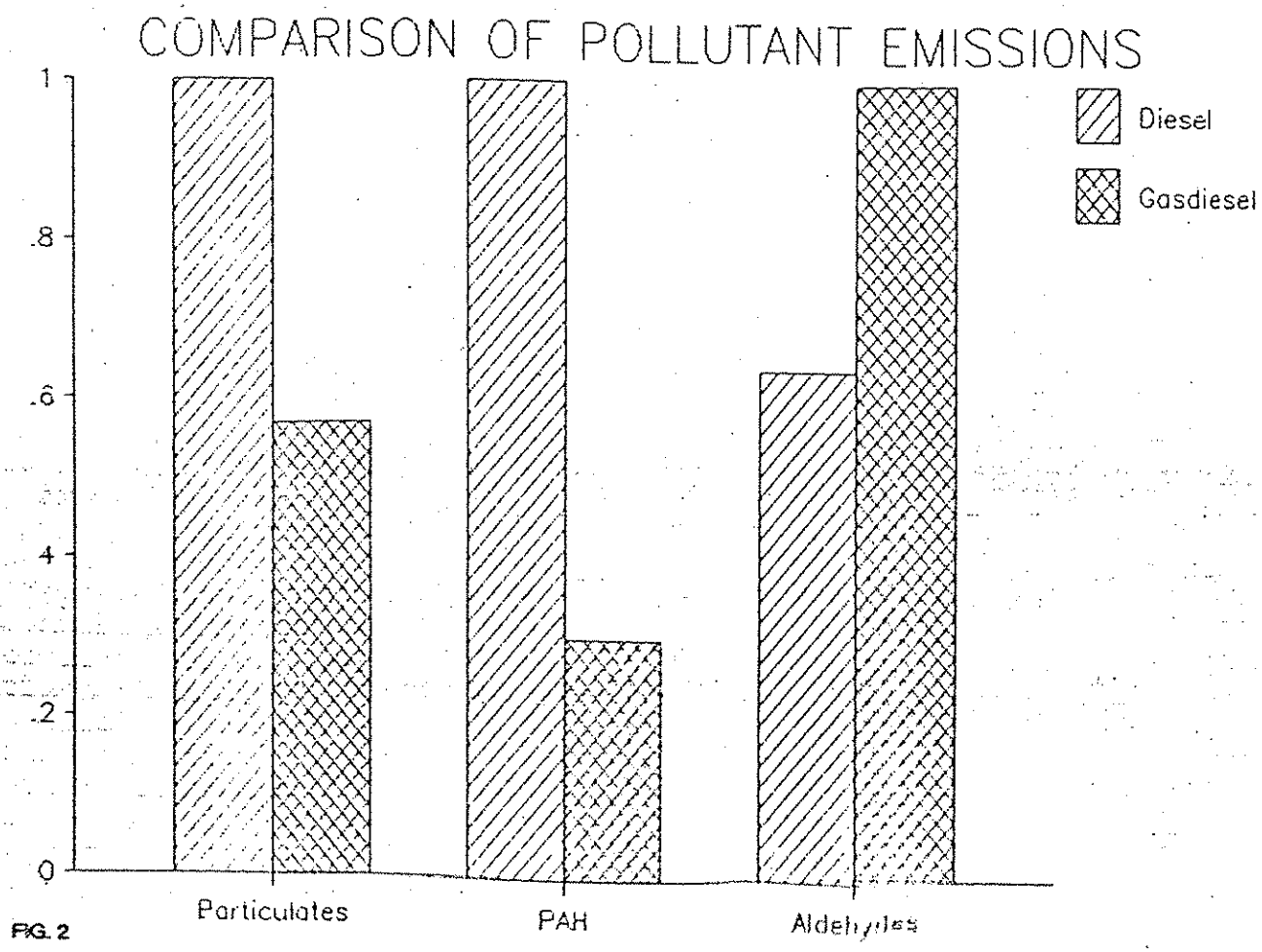
COMPARISON OF POLLUTANT EMISSIONS
1
.8
.6
.4
.2
0
Particulates
PAH
Aldehydes
Diesel
Gasdiesel

FIG. 2

ALDEHYDE EMISSIONS

13-mode test cycle, mg/kWh

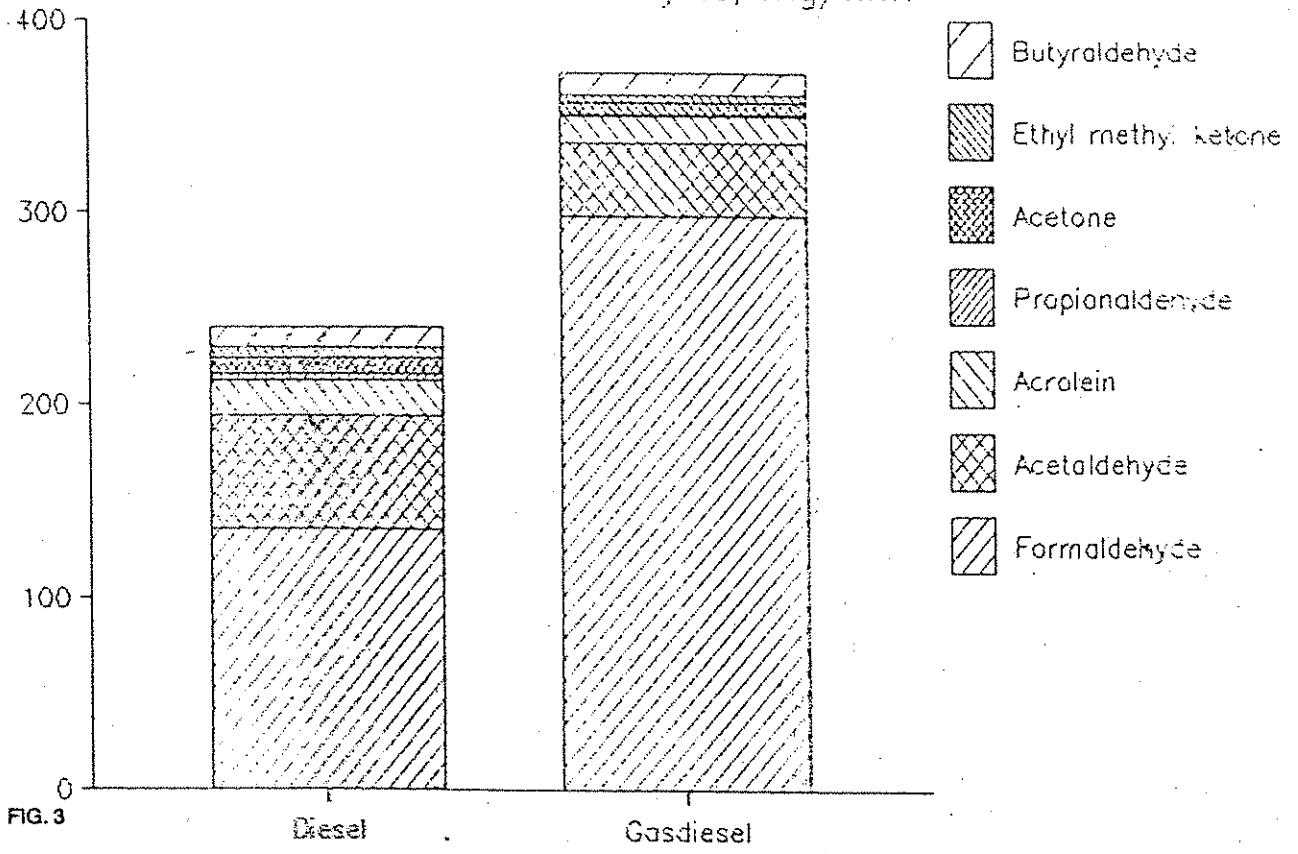

FIG. 3

POLYCYCLIC AROMATIC HYDROCARBONS EMISSION

13-mode test cycle, mg/kWh

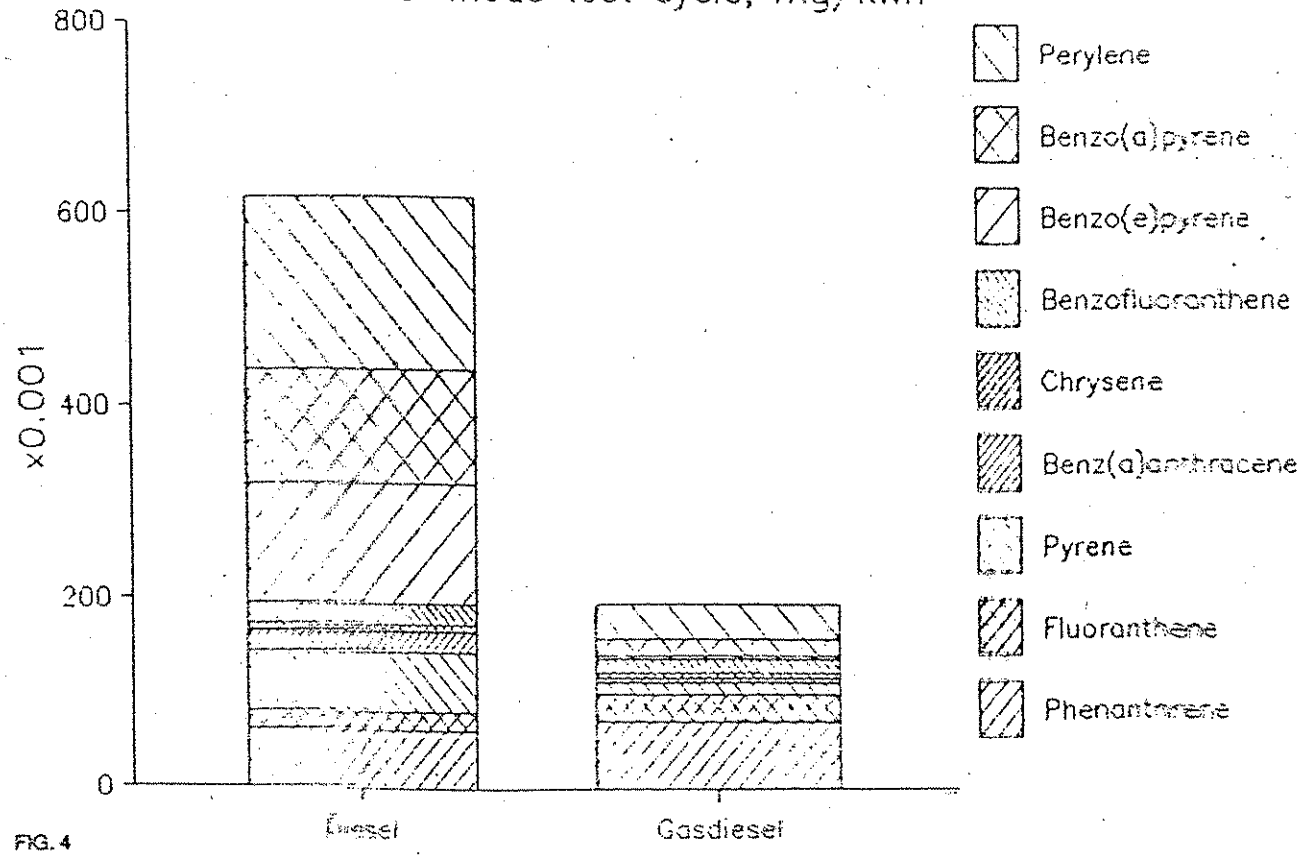

FIG. 4