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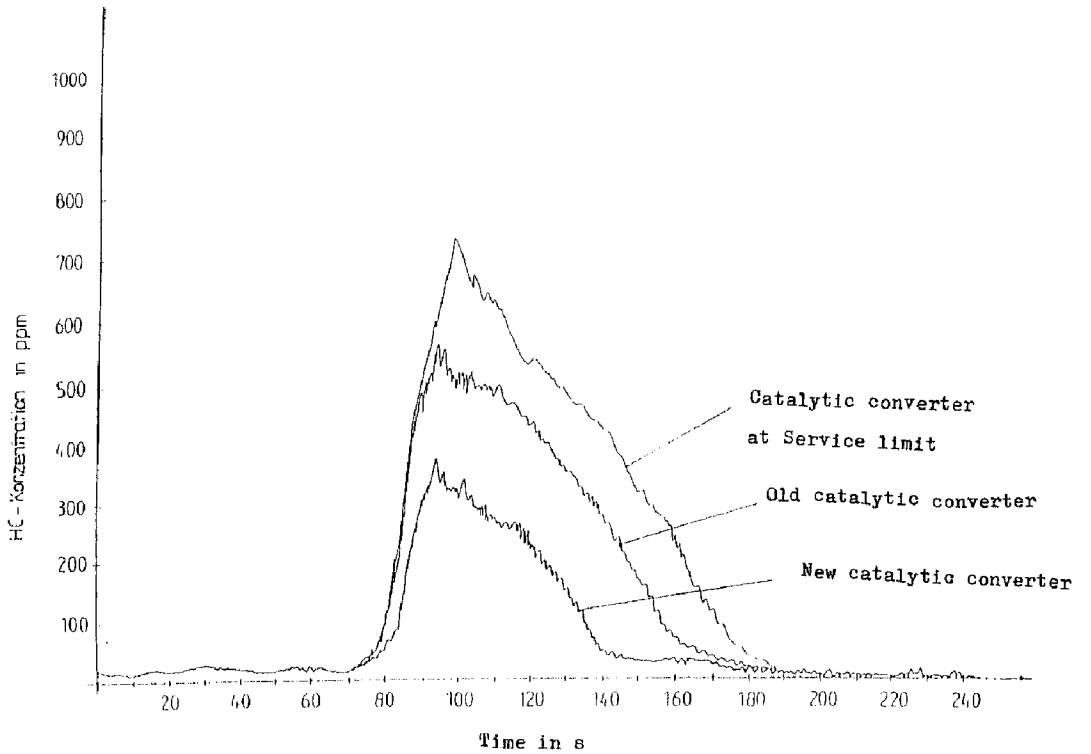
(54) Titre : MESURE DE CONSTITUANTS DE SUBSTANCES NOCIVES CONTENUES DANS DES GAZ D'ECHAPPEMENT ET REDUCTION D'EMISSIONS DE SUBSTANCES NOCIVES AU COURS DU DEMARRAGE A FROID ET DU TRAJET

(54) Title: MEASUREMENT OF CONTAMINANT COMPONENTS IN EXHAUST GAS AND REDUCTION OF EXCESSIVE CONTAMINANT EMISSIONS DURING COLD STARTS AND WHILE DRIVING



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(57) **Abrégé(suite)/Abstract(continued)**:
vehicles, be fitted by the driver. Monitoring low-emission motor vehicles is difficult since different influences cause the measuring signal to fluctuate widely. The largest share of emissions occurs during the cold-start phase. Motor vehicles are fitted with an automatic starting system which by observing different parameters ensures an optimal start. While the vehicle is driving artificial errors are generated in the combustion system and the raised contaminant concentration is detected by the on-board monitoring system. An adsorption system reduces contaminant emission during the cold-start phase, in the case of engine- or exhaust gas treatment-related errors as well as in the event of severe air pollution. To regenerate the adsorption masses the contaminants are desorbed, fed back to the combustion chamber and burned.

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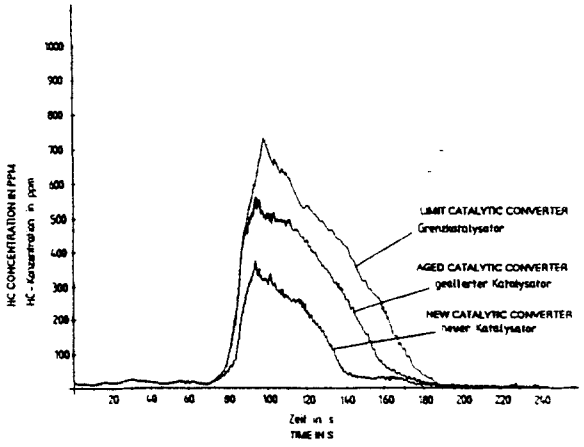
Ohne internationalen Recherchenbericht und erneut zu veröffentlichen nach Erhalt des Berichts.

(54) Title: MEASUREMENT OF CONTAMINANT COMPONENTS IN EXHAUST GAS AND REDUCTION OF EXCESSIVE CONTAMINANT EMISSIONS DURING COLD STARTS AND WHILE DRIVING

(54) Bezeichnung: MESSUNG VON SCHADSTOFFKOMPONENTEN IM ABGAS UND MINDERUNG ZU HOHER SCHADSTOFFEMISSIONEN WÄHREND KALTSTART UND FAHRT

(57) **Abstract**

The invention relates primarily to the monitoring of emissions by motor vehicles, but also to those generated by ships, aircraft and diesel locomotives. The monitoring system can be built into new motor vehicles by the manufacturer or, in the case of older vehicles, be fitted by the driver. Monitoring low–emission motor vehicles is difficult since different influences cause the measuring signal to fluctuate widely. The largest share of emissions occurs during the cold–start phase. Motor vehicles are fitted with an automatic starting system which by observing different parameters ensures an optimal start. While the vehicle is driving artificial errors are generated in the combustion system and the raised contaminant concentration is detected by the on–board monitoring system. An adsorption system reduces contaminant emission during the cold–start phase, in the case of engine– or exhaust gas treatment–related errors as well as in the event of severe air pollution. To regenerate the adsorption masses the contaminants are desorbed, fed back to the combustion chamber and burned.



(57) **Zusammenfassung**

Dieses Patent beschäftigt sich hauptsächlich mit der Emissionsüberwachung von Kraftfahrzeugen, aber auch von Schiffen, Flugzeugen und Diesel–Lokomotiven. Dabei kann das Überwachungssystem bei neuen Kraftfahrzeugen vom Hersteller eingebaut oder bei älteren Kraftfahrzeugen vom Fahrer nachgerüstet werden. Die Überwachung niedrig emittierender Kraftfahrzeuge bereitet Schwierigkeiten, weil das Meßsignal durch verschiedene Einflüsse stark schwankt. Die Kaltstartphase ist die Betriebsetappe, in der die anteilmäßig größten Emissionen auftreten, s. Fig. 5. Die Kraftfahrzeuge werden mit einem automatischen Startsystem ausgerüstet, das durch Beobachtung verschiedener Parameter einen optimalen Start sichert. Während der Fahrt werden künstliche Fehler im Verbrennungssystem vorgegeben, die erhöhte Schadstoffkonzentration wird durch das On–Board–Überwachungssystem erfaßt. Ein Adsorptionssystem mindert den Schadstoffausstoß in der Kaltstartphase, bei motorischen oder abgasnachbehandlungstechischen Fehlern und bei starker Luftbelastung. Zur Regeneration der Adsorptionsmassen werden die Schadstoffe desorbiert und in den Verbrennungsraum zurückgeführt und verbrannt.

Measurement in Contaminant Components in Exhaust Gas and Reduction of Excessive Contaminant Emissions During Cold Starts and While Driving

1 Introduction

In recent years, efforts to reduce the emissions of exhaust gases have been substantially increased. The reason for these efforts is the strong rise in transportation means causing emissions. Therefore, it would be most efficient to develop new transportation means which have low emission levels and consume energy economically.

2 State-of-the-art

During a driving cycle, the exhaust emission of motor vehicles consist of two basic periods:

- the cold-start period with high emission values and
- a subsequent period with low emission values when the engine is warm.

The fact that the emissions of a vehicle driving on the road cannot be established on the roller-type test stand under specified conditions is a major problem. As a result, a test carried out on the roller-type test stand cannot be regarded as being totally complete but rather as a partial examination. In addition to the tests on the test stand, the observance of emission standards for Ultra-Low-Emission-Vehicles (ULEV) as well as EURO III and IV will therefore be ascertained through the use of new in-situ control technologies.

In the USA, passenger cars may be equipped with the On-Board-Diagnosis (OBD) II-System which requires all emission-related components to be monitored, such as lambda sensor, fuel system, secondary air system, exhaust gas circulation system, tank ventilation and the control of interruptions in the combustion. However, the amounts of pollutants will not be measured, they are rather indirectly correlated with suitable sensor signals.

For the three-way catalytic converter, there exists only one limit value of hydrocarbon (HC) whose observance is indirectly monitored through the ability of the catalytic converter to store

oxygen. Far this purpose, the measuring signals of two lambda sensors respectively located before and after the catalytic converter are compared and the signal ratio will be correlated with the amount of hydrocarbons converted. This technique does not provide results on the actual HC emissions. For vehicles with ever-decreasing emission standards, however, direct measuring of emission quantities is more favourable.

In recent years, catalytic converter systems have been developed which fully reach their operating temperature within one minute. As a result, vehicle emissions are reduced to a minimum as opposed to the former situation where most of the pollutants were released during the cold-start period thus accounting for the greatest share of total emissions. In this case, after-burning, subsequent treatment or electric heating play an important role. Furthermore, reduction systems have been developed in which an additional substance will be added to the exhaust flow to trigger a chemical reaction to achieve the desired change in the composition of the exhaust gases. Absorbent materials serve to retain pollutants during the cold-start period. The retained pollutants will be desorbed when the engine and the catalytic converter are warm. The adsorbent materials are used to retain unburnt hydrocarbons based on activated carbons and to collect nitrogen oxides based on zeolite. However, a process which makes it possible to reduce emission quantities in the exhaust gases not only during the cold-start period but also in difficult situations as, for example, when defects occur in the combustion system or in the exhaust gas after treatment system.

Publication DE 196 45 202 A 1 proposes, in order to ensure improved monitoring of the conversion rate of a catalytic converter for a combustion engine, to total the HC emissions, converted into gram values, that are determined behind the catalytic converter during a predetermined time window covering the time span (dt).

Publication EP-A-9 609 527 A1 describes a method for the checking of the conversion rate of a catalytic converter installed in an exhaust system of a combustion engine, such method initially requiring a first operating condition to prevail for a certain period of time during which compliance with certain framework conditions is required. When said framework conditions are fulfilled, an exhaust signal deviating from this condition is generated during a second period of time, e.g. during thrust operation, and the response of a

temperature sensor installed behind the catalytic converter to this signal is evaluated.

3 Assessment of vehicle emissions

Vehicle emissions will be assessed by means of a monitoring system. This monitoring system may be standard fitted in new vehicles or may be subsequently fitted as a modular device set in older vehicles. To retrofit the set, the existing construction does not need to be modified.

It is very difficult to assess slight changes in the vehicle emissions under the severe daily driving conditions. There are two alternatives:

- assessment of vehicle emissions during the cold-start period and
- measurement of emission quantities in the exhaust system during driving.

3.1 Measurement of emission quantities in the exhaust system

The combustion system of a vehicle basically consists of two elements which include the engine (1) and the exhaust gas after-treatment system (2), see Fig. 1. The values measured after the engine provide information on the combustion process and the measuring signals which develop after the catalytic converter provide information on the condition of the exhaust gas after-treatment system. The quantities of the most important pollutants measured at both locations greatly differ from each other.

The quantities behind the engine are 10-100 times higher than those behind the catalytic converter which properly operates from a technical point of view. The measuring system (3) actively measures at both locations.

Fig. 2 depicts measurement according to the American US 75-cycle in a Low-Emission-Vehicle (LEV) recorded behind the catalytic converter. Despite the effects resulting from braking and acceleration, this diagram hardly shows any emissions after the cold-start period. It is almost impossible to establish minor or slowly proceeding damages in these vehicles exclusively on the basis of these quantity values. This is due to the fact that measuring signals are assessed with respect to the zero point and the signals are also subject to natural fluctuations. It is almost impossible to tell an increase in quantity caused by a minor damage from an increase in the noise level caused by external impacts. In this case, the use of the accumulation method can be helpful. A specified defect may, for example, be simulated in the combustion process. This simulated defect may lead to defined emission quantities established behind the engine. The resulting vehicle emissions can be measured in front of and behind the catalytic converter and may serve as comparative figure, see Fig. 3. Exhaust gases are first measured after the engine but still before the catalytic converter. These exhaust gases are untreated and serve to establish the original measuring signals to determine the characteristic features of the engine condition. The condition of the after-treatment system can be easily determined from the values measured behind the catalytic converter.

The alternating measurement of exhaust gases before and after the catalytic converter and the resulting values which are alternately fed to the analysing system (high and low emission quantities), allow to save means and room in the vehicle since only one measuring instrument with one adjusted measuring range is required. This measuring instrument is designed according to the measuring range of the quantity after the catalytic converter. Concentration before the catalytic converter having a high measuring range can be adjusted by diluting it and, as a result, can be detected by the same measuring instrument featuring a finer resolution.

3.2 Establishment of vehicle emissions during the cold-start period

Fig. 4 discloses the performance of an LEV vehicle determined after the catalytic converter. Except for increased

vehicle emissions during the cold-start period, the concentration of HC is very low. The quantities measured in the first 40-80 seconds after the start are high compared to the low level of vehicle emissions after this time period. They possibly amount to several 1000 ppm. As a result, they can be established easier by measurement than the lower quantities during subsequent operation when the engine is warm.

Measurement during the cold-start period offers the advantage that, during this period, malfunctions in the exhaust gas after-treatment system are reflected in the diagram in a particularly striking fashion. Fig. 5 shows the increase of the cold start peak due to ageing of the catalytic converter. In addition to an extended emission time relating to the required higher temperature of the catalytic converter, there is also a rise in the absolute peak of the vehicle emissions. The efficiency of the conversion process will be decreased due to a loss of active substances in the catalytic converter.

Shape and size of the cold-start peak perfectly reflect performance even with the latest vehicle models. It is recommended to establish the position of the emission maximum on the time axis after the start (4), maximum quantity of measured factor (5), time required for the cold-start period (6) and the area of cold-start emissions (7), see Fig. 6. Leaving the factory or the specialist workshop, each vehicle is equipped with an individual characteristic diagram which is established from the average taken from several cold-starts. The above-mentioned four characteristic quantities are

stored in the vehicle. The corresponding environmental conditions, such as temperature of outer air, pressure, air humidity, etc., will be based on standard conditions. Any further cold-start periods are compared to this characteristic diagram and occurring changes realised on the basis of the above-stated four characteristic quantities (4-7) will be defined. If, in any of these changes, a predefined standard is exceeded, a warning signal must be released.

4 Reduction of vehicle emissions during the cold-start period and in case of malfunctions during driving

In the following, processes shall be described which allow to take measures in order to reduce vehicle emissions to a minimum in case of increased emission values of the exhaust gases (cold-start/malfunction) or increased air pollution (high traffic volume).

To reduce increased emission quantities, an adsorption system can be incorporated in the exhaust system, see Fig. 7. An adsorbent trap consists of at least one but preferably of several chemical substances which do not only retain hydrocarbons but also CO and NO molecules in the course of an appropriate adsorption process. This mixture may consist, for example, of activated coal, brown soil, also called hopcalite, and different zeolite substances.

During normal operation, the exhaust gases freely flow into the air through the exhaust pipe. If, however, the vehicle is started after an extended period of rest or, if problems occur in the combustion (8) or exhaust gas after-treatment system (9), see Fig. 8, the On-Board Monitoring system (10) (OBD or OBM system), in addition to informing the driver on the malfunction, reverts the flow of the exhaust gases by means of a valve (11). In case of high traffic volumes (jams, inner city), the adsorption system automatically operates or it can be added to the exhaust system by the driver according to the directives of the traffic routing system. After

reversion, the exhaust gases are no longer allowed to freely flow into the air, instead they are guided through an adsorption system. The adsorption system consists of two adsorption traps for alternating operation (12 and 13). During the cold-start or in case of malfunctions in the combustion or exhaust gas after-treatment system, the exhaust gas will be guided through an adsorption system. If defects occur in the combustion system, all pollutants will be stored until the defect is remedied. In case of defects in the exhaust gas after-treatment system, the adsorption traps will be operated alternately and regenerated as the desorbed pollutants, after being concentrated, are recirculated into the combustion chamber (under the addition of secondary air) of the properly operating engine. The desorption process is carried out by increasing the temperature with the help of a heating system (14) and/or by decreasing the pressure in the vacuum system (15). This process serves to bridge the time period between error message and remedial actions thereby preventing the vehicle emissions from rising. After the malfunction has been detected/indicated, the driver will be able to drive on for 100 ... 1000 km without problems which means virtually to the next repair shop even in areas which are not very densely populated.

Used adsorbent material which can no longer be regenerated anymore will be replaced in a simple manner and assisted by modular technology. The process of replacement is similar to the present oil filter change. Reprocessing of definitely used up adsorbent materials should be effected in an organised manner. Adsorbent bulk material can be disposed of such as waste oil today. The collected adsorbent materials may be further processed according the corresponding state-of-the-art.

Another possibility to reduce vehicle emissions during the cold-start period is the method in which the cold-start action is controlled uniformly and independently of the driver. In this method, all vehicles need to be equipped with an automatic starting device which performs the starting action automatically and in the best possible way. External conditions, such as temperature, air pressure, air

humidity, wind force, wind direction, ice and the values of the On-Board Monitoring System will be taken into account in the control process.

5 Establishment of vehicle emissions in aeroplanes, ships and diesel engines

Amongst the greatest emitters in the vehicle industry are ships, aeroplanes and locomotives with non-electric drives.

All three transportation means have in common that they burn hydrocarbons and that the combustion products are released into the atmosphere in an uncontrolled fashion. For this reason, it is necessary to incorporate a measuring system into the combustion system through which the exhaust gases flow. Contact between measuring system and the flow of exhaust gases can be made directly or by means of a withdrawal location.

With locomotives, data can be stored and transferred by means of a computer connected to the measuring system via corresponding interfaces which collects data on a data carrier (17) and, after each travel, archives them, see Fig. 9. Data can also be transferred by telephone (18) as is the case with today's Intercity trains. Already during travelling, data can be transferred to the corresponding locations where it is evaluated. On ships (19), it may be possible to transfer data collected on storage media, such as discs or various charts, either by means of direct evaluation of the data at the interface or via satellite (20). In aeroplanes (21), the use of micro systems and light weight technology is needed. During flying, data needs to be stored on a micro data carrier. It is recommended to monitor all engines. Jet engines are designed as open systems which force the hot exhaust gases out into the atmosphere at great speeds. The measuring system needs to consider mixing ratios as well as external conditions. The most important aspect is the safe performance of the flying operation. Stored data may be evaluated by means of a data carrier on the

ground or wireless in the air. The method of data transfer via satellite also needs to be considered.

With all three transportation means, the primary task is to inform the ground personnel on non-standard events in the operation process, however, equally important is the collection of emission data. The evaluation systems on board need to be designed in a fashion that they release warning signals on board as soon as the set emission standards are exceeded. These signals may indicate deviations or malfunctions in the combustion or exhaust gas after-treatment system. This on-board monitoring system serves to increase the operational safety of the transportation means.

Each transportation means of above-mentioned categories needs to be equipped with stored characteristic diagrams providing information on emission standards both as individual processes with data on the dynamic behaviour and as added sum. These systems need to contain exact data on allowed emission standards per km or mile. The evaluation device needs to contain accurate set parameters related to selected time segments, such as on the starting and landing operations of the aeroplane, starting or braking operations of diesel engines and manoeuvring of ships in the harbour. These standards will be designed according to the type, year of construction and according to further individual parameters of the transportation means.

In case of an open control system, measuring will be carried out with and without internal control and each current measuring value will be compared to an archived characteristic diagram. If the emission standards are significantly exceeded, a warning signal will be released. In case of closed control systems, the transportation means will be permanently connected to the corresponding process control systems. It may be necessary to adjust the driving or flying standards through the process control system. As a result, speeds may be reduced or increased due to emission reasons and even flying routes can be changed if such a change turns out to be

necessary, see Fig. 10. The process control centre sets the necessary emission standards at times or places where emissions are particularly high. Any resulting advantages or disadvantages related to the fulfilment of the transportation task will be considered in the evaluation system. All stored data will be collected and transferred to an international evaluation system.

11
~~14~~

Figure record

Figure 1 main components of the vehicle combustion system
- 1 engine
- 2 exhaust gas after-treatment system with catalytic converter, silencer and exhaust pipe
- 3 measuring system

Figure 2 drive diagram of an American US 75-test cycle (top) with the corresponding vehicle emissions (bottom)

Figure 3 set-up for comparative measurement

Figure 4 emission during cold-start of LEV vehicle

Figure 5 extension of cold-start period and increase in absolute emission of hydrocarbons due to the ageing catalytic converter

Figure 6 description of parameters decisive for the mathematical analysis of cold-start emissions
- 4 position of the emission maximum on the time axis after the start
- 5 maximum quantity of established factor
- 6 time required for the cold-start period
- 7 area of cold-start emissions

Figure 7 Description of a measure to reduce emissions

Figure 8 Basic position of an adsorption system in the exhaust system of a motor vehicle
- 8 combustion system
- 9 exhaust gas after-treatment system
- 10 On-Board-Monitoring system
- 11 valve
- 12 first adsorption trap
- 13 second adsorption trap
- 14 heating system
- 15 vacuum system

Figure 9 transfer of data between transportation means and control centre

16 locomotive
17 data carrier
18 telephone
19 ship
20 transfer via satellit
21 aeroplane

Figure 10 reduction of the driving speeds of ship due to emission-based parameters coming from the control centre

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for measuring pollutants in the exhaust gases of motor vehicles during the cold-start period and, in a broader sense, during the starting and landing of aeroplanes, the arrival and departure of ships in the harbour and the shunting of diesel locomotives in the railway station area, in which the cold-start period serves to assess the quality of the exhaust gas related factors, the quantities of gas substances, such as hydrocarbons (HS), carbon monoxides (CO) and nitrogen oxides (NO) being established by means of an analysing device for gases and the

- maximum quantity of the substance to be established
- the time of the cold-start period
- the temporal position of the emission maximum after the start and
- the area of the cold-start emissions

being regarded as characteristic parameter for assessing the emission characteristics of the vehicle.

2. The method for measuring pollutants in the exhaust gases of motor vehicles of Claim 1, in which

- each vehicle will be repeatedly subjected to the cold-start period during quality control in the factory or in the specialist workshop, and

- the resulting data of the characteristic parameters established during the test while all exhaust-gas related factors were in proper operating conditions and calculated as statistical mean value will be stored in the on-board measuring and control system and

- in which parameters established during every new cold-start action will be compared to the stored parameters whereby the external conditions shall relate to standardised conditions and any undesired and standard-exceeding changes shall trigger a warning signal.

3. The method for measuring pollutants in the exhaust gases of motor vehicles of Claim 1, in which the starting action is, for the purpose of optimal adjustment of the characteristic parameters, such as

- the maximum quantity of the substance to be established,
- the time of the cold-start period,
- the temporal position of the emission maximum after the start, and
- the area of the cold-start emissions,

automatically controlled by the on-board measuring and control system, ensuring a uniform controlled starting action under best possible conditions which allows for permanent comparison, thereby taking into account the most important environmental parameters such as outside temperature, air pressure, humidity, wind direction, wind force and ice formation, relative to the normal condition, so as to ensure optimal adjustment of the characteristic parameters during the starting process.

4. The method for measuring pollutants in the exhaust gases of motor vehicles of Claim 1, in which

- artificially and purposefully generated malfunctions in the vehicle, which cause a defined and known increase of the pollutant concentration, are predefined in a model setting,

- the high concentrations occurring behind the combustion system are diluted and the lower concentrations behind the catalytic converter are measured undiluted,

- the two series of values obtained before and after the catalytic converter are compared which each other, using the characteristic parameters such as

  - the maximum quantity of the substance to be established,
  - the time of the cold-start period,
  - the temporal position of the emission maximum after the start, and
  - the area of the cold-start emissions.

5. The method for measuring pollutants in the exhaust gases of motor vehicles of Claim 1, in which the gas flow is, in order to achieve a temporal minimisation of pollutant emissions

- in the case of malfunctions or defects in the engine or the exhaust gas after-treatment system,
- in times of high traffic volumes and
- in times where the use of motor vehicles causing high emissions is forbidden

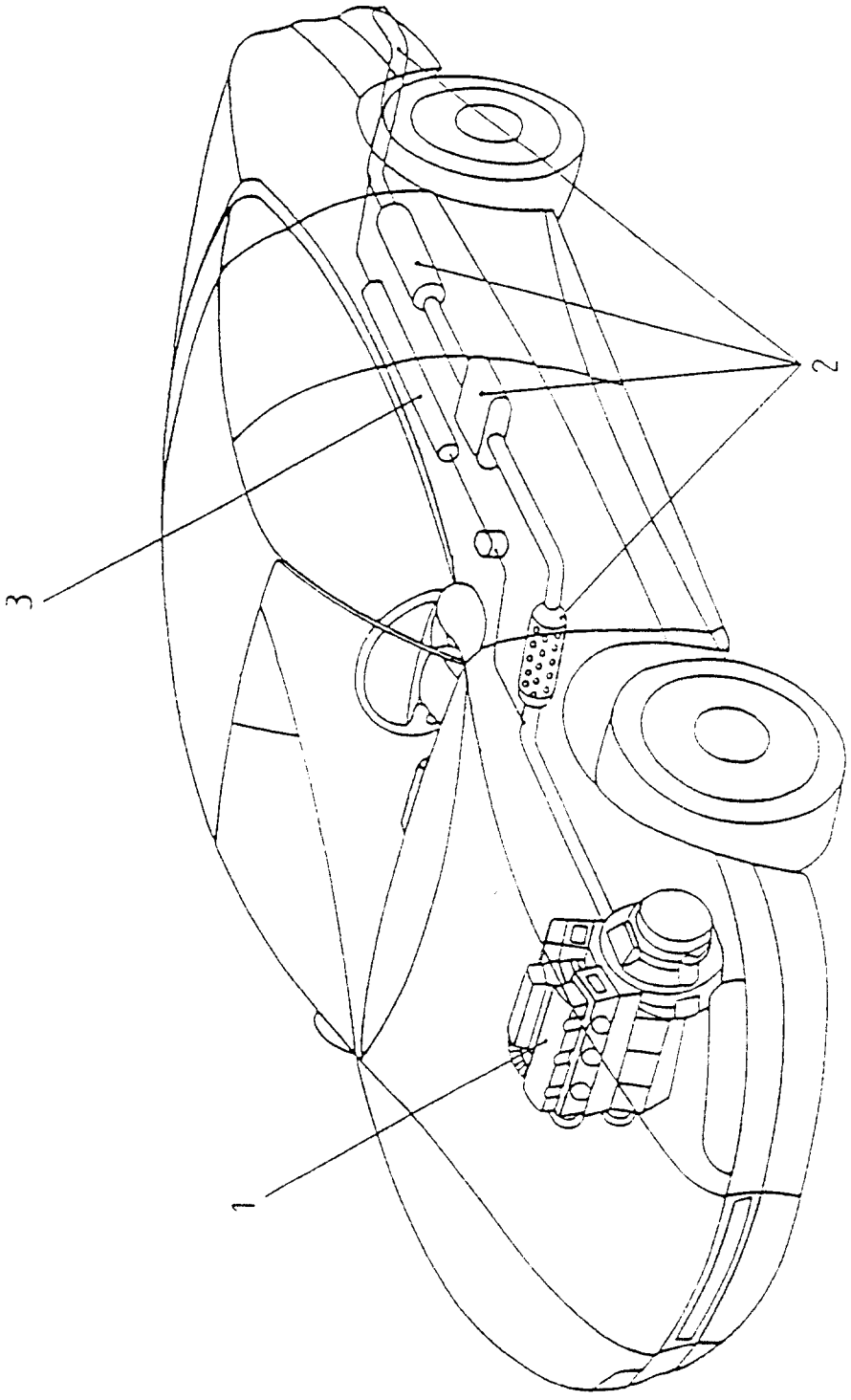
manually or automatically routed from the normal exhaust gas channel to an adsorption system located behind the catalytic converter, in which the adsorbent masses used to reduce emissions differ, depending on the type of engine, vehicle and output, in terms of both quality and quantity and consist of several different substances in differing quantities so that such systems can be used both for Otto engines and diesel engines, and in which

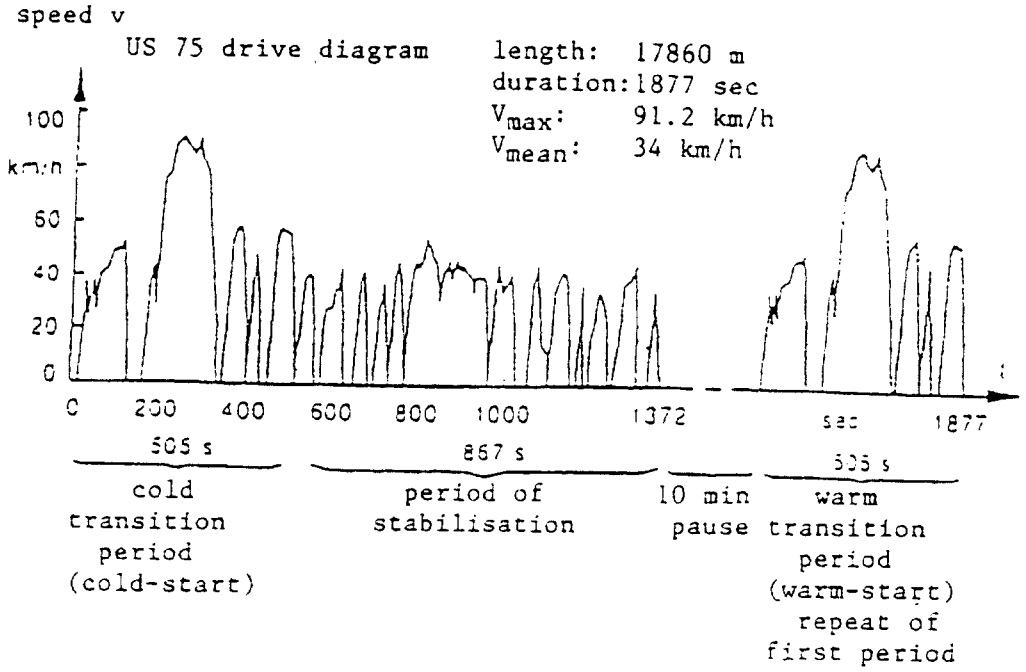
- activated coal is used to retain hydrocarbons,
- hopkalite is used to adsorb carbon monoxide and
- zeolite is used to reduce nitrogen monoxide,

and in which the quantity of the adsorbent masses is adjusted to the average duration needed to cover the distance to the nearest repair workshop calculated for the respective local conditions and the average quantity of emissions expected in the respective type of vehicle in the case of a defect.

6. The method for measuring and reducing pollutants in the exhaust gases of motor vehicles of Claim 5, in which the used adsorbent mass is, after several desorption processes, replaced at a filling station and subjected to recycling or disposal.

Fig.1

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V_{mean}: 34 km/h
100
km/h
60
40
20
0
0
200
400
600
800
1000
1372
sec
1877
505 s
867 s
505 s
cold transition period (cold-start)
period of stabilisation
10 min pause
warm transition period (warm-start) repeat of first period

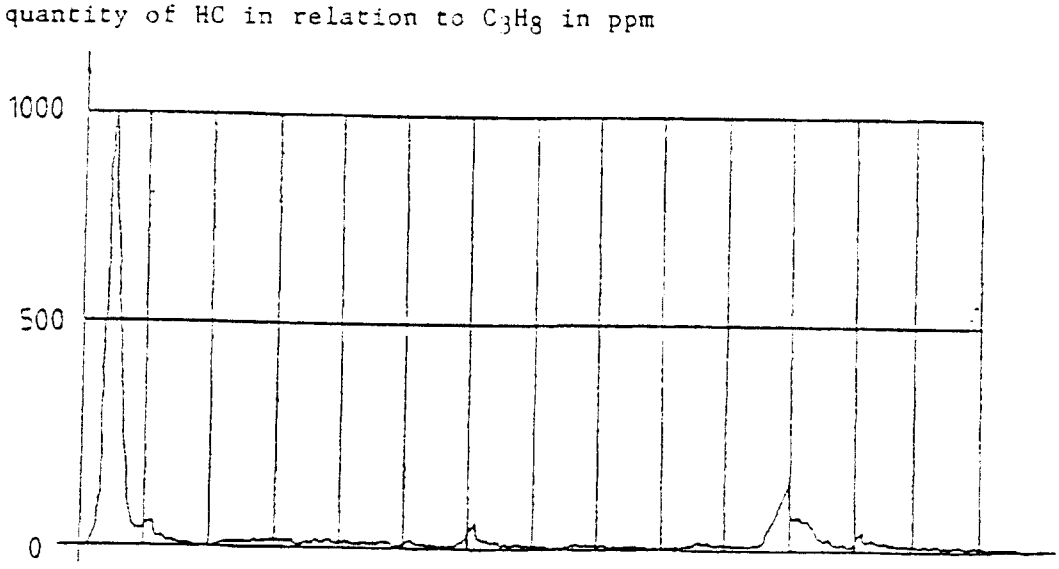
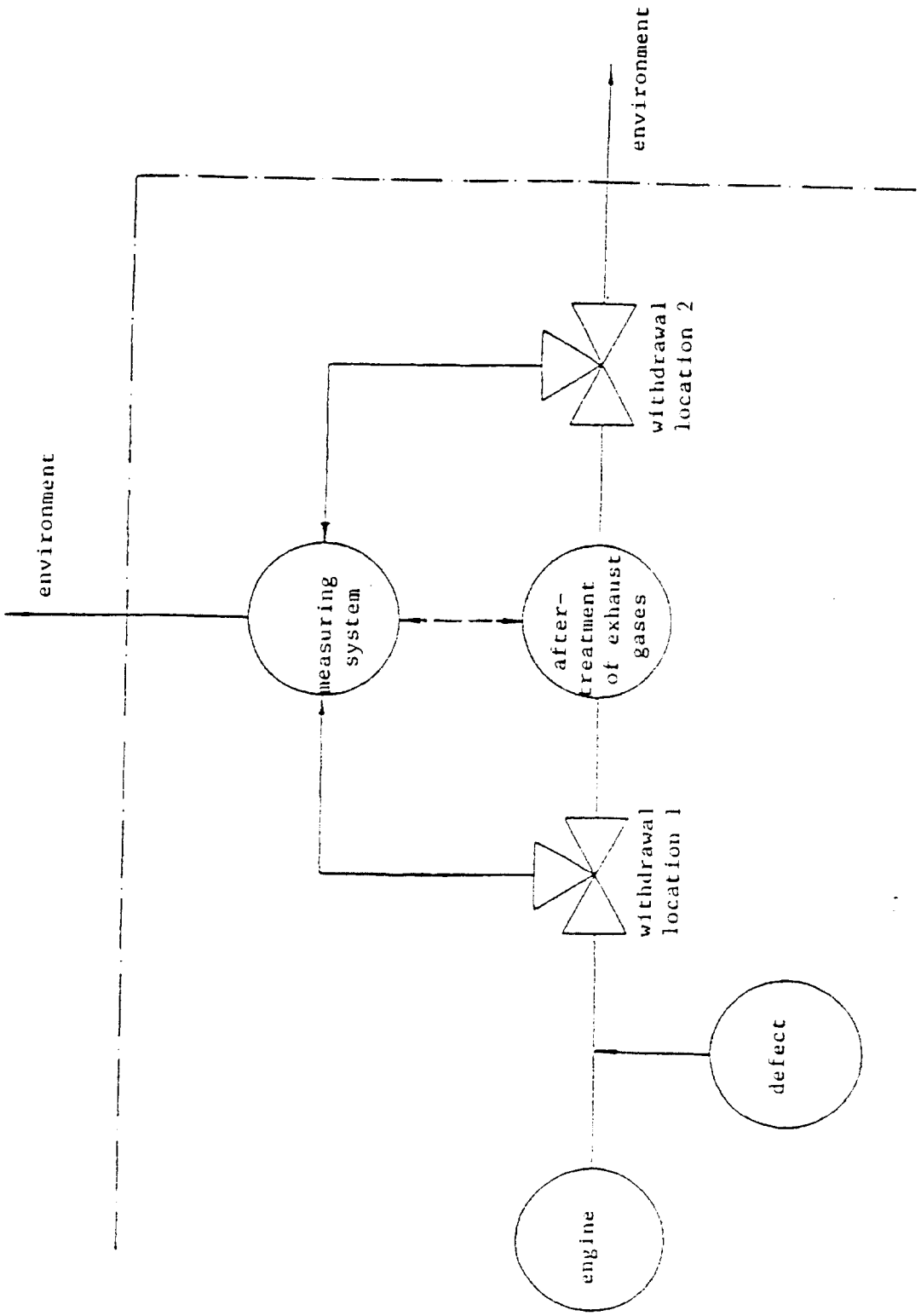

quantity of HC in relation to C_3H_8 in ppm
1000
500
0

Fig. 2

Fig. 3


environment
environment
withdrawal location 2
measuring system
after-treatment of exhaust gases
withdrawal location 1
defect
engine

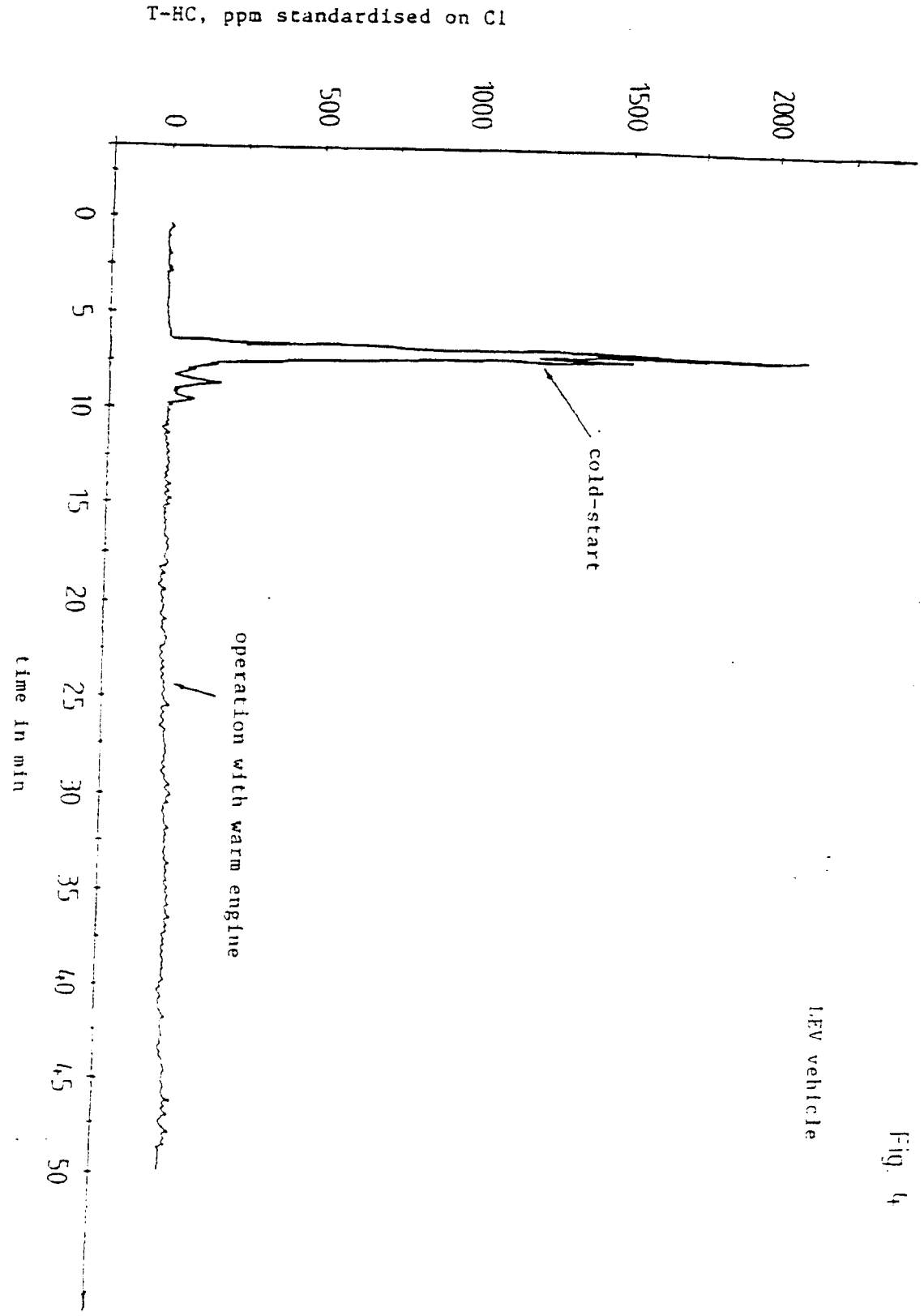

T-HC, ppm standardised on C1
0
500
1000
1500
2000
0
5
10
15
20
25
30
35
40
45
50
time in min
cold-start
operation with warm engine
LEV vehicle

Fig. 4

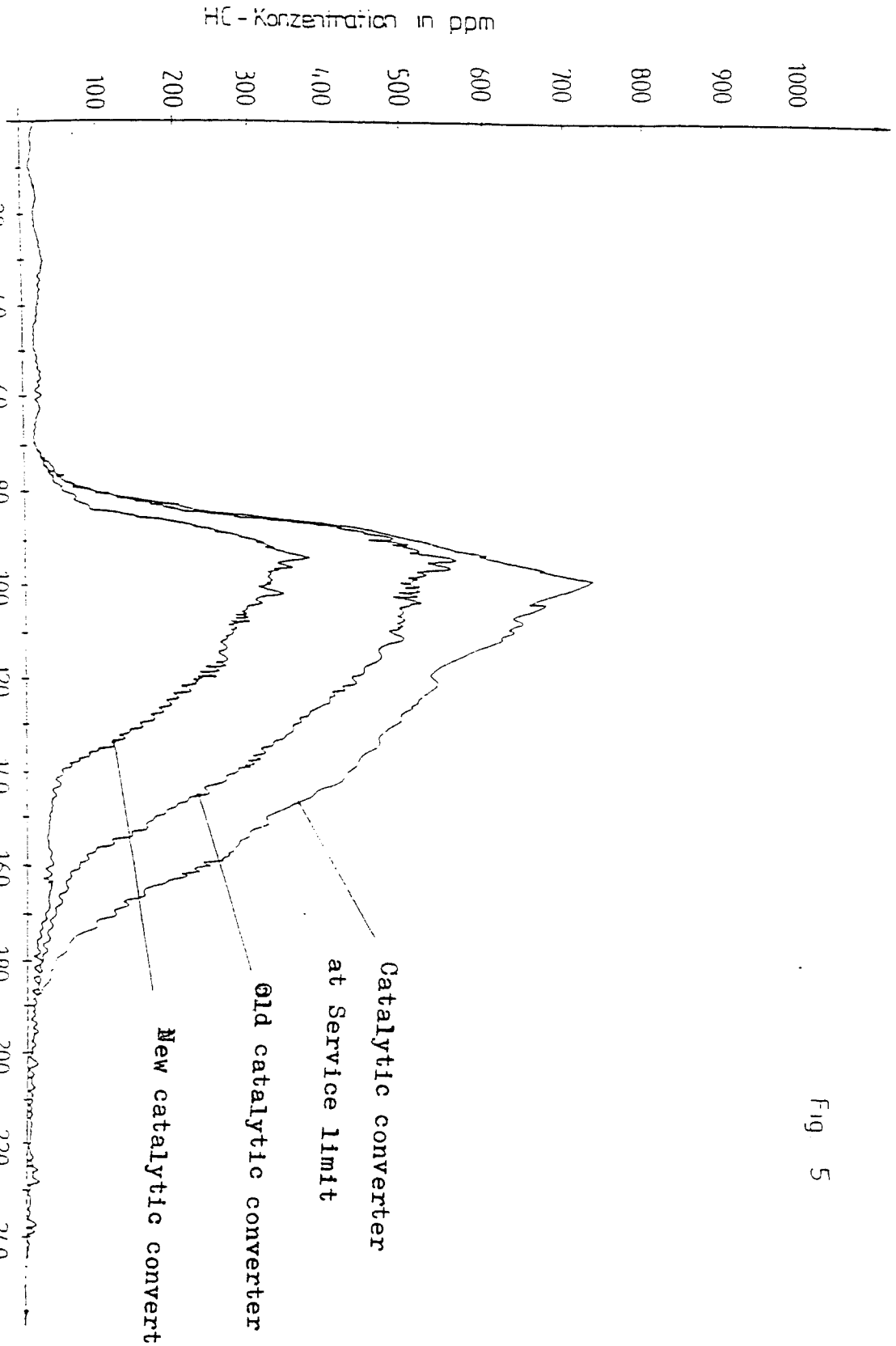

HC - Konzentration in ppm
100
200
300
400
500
600
700
800
900
1000
20
40
60
80
100
120
140
160
180
200
220
240
Time in s
Catalytic converter
at Service limit
Old catalytic converter
New catalytic converter

Fig 5

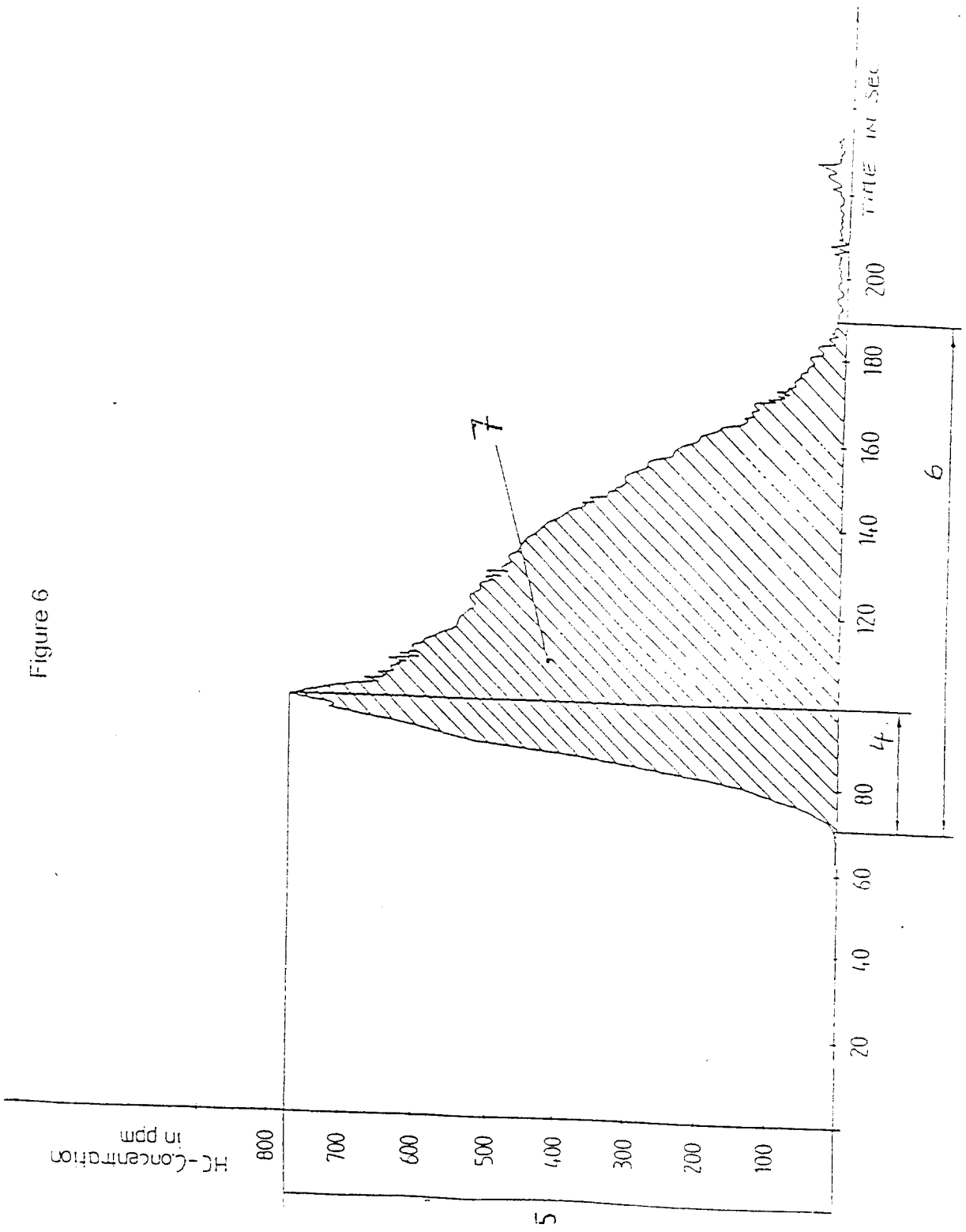

HC-Concentration in ppm
800
700
600
500
400
300
200
100
5
20
40
60
80
4
120
140
160
180
200
6
7
TIME IN SEC

Figure 6

Fig. 7

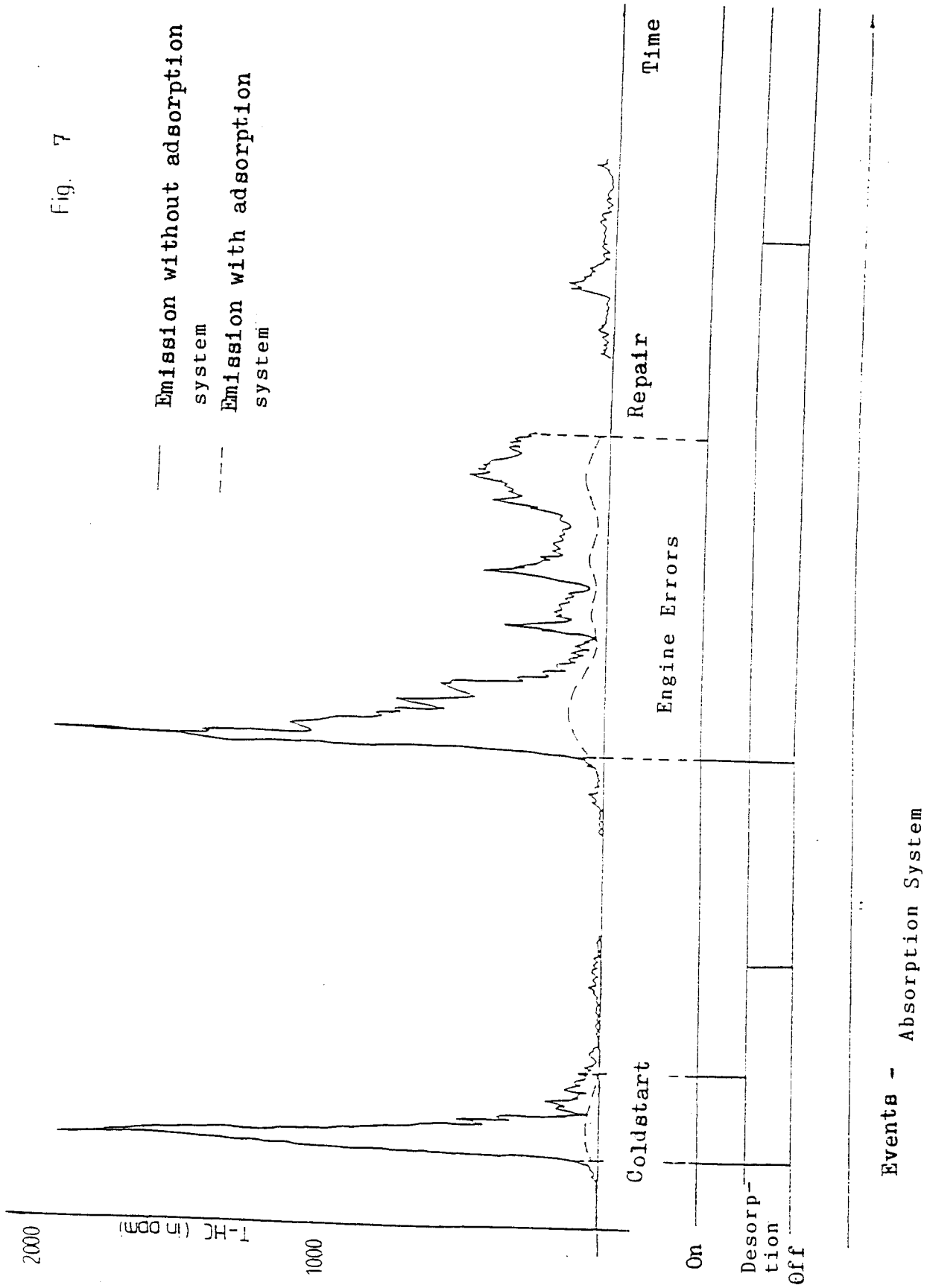

Emission without adsorption system
Emission with adsorption system
2000
1000
T-HC (ppm)
Coldstart
Engine Errors
Repair
Time
On
Desorp-tion
Off
Events - Absorption System

Fig. 8

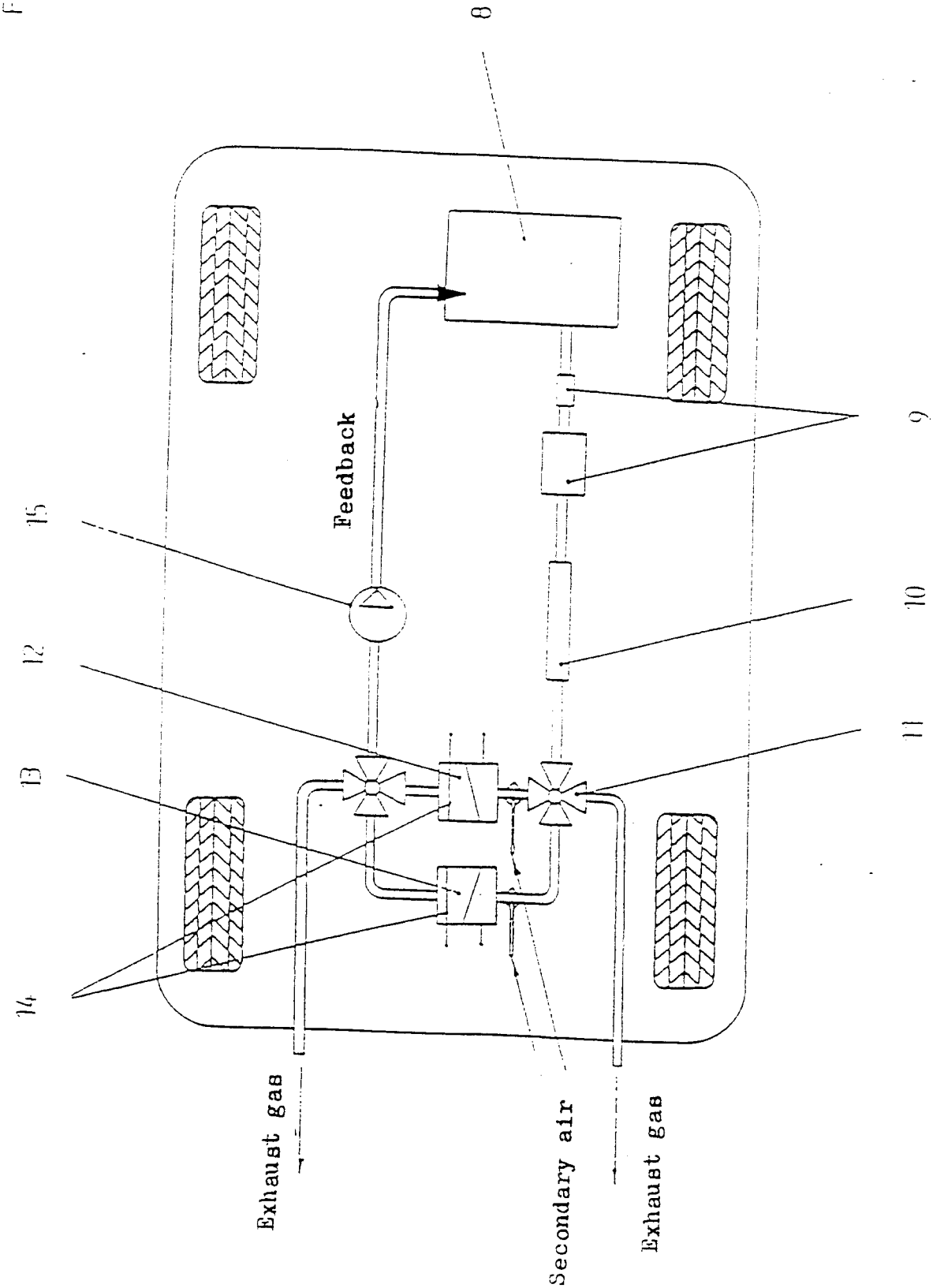

8
9
10
11
12
13
14
15
Feedback
Exhaust gas
Secondary air
Exhaust gas

Fig. 9

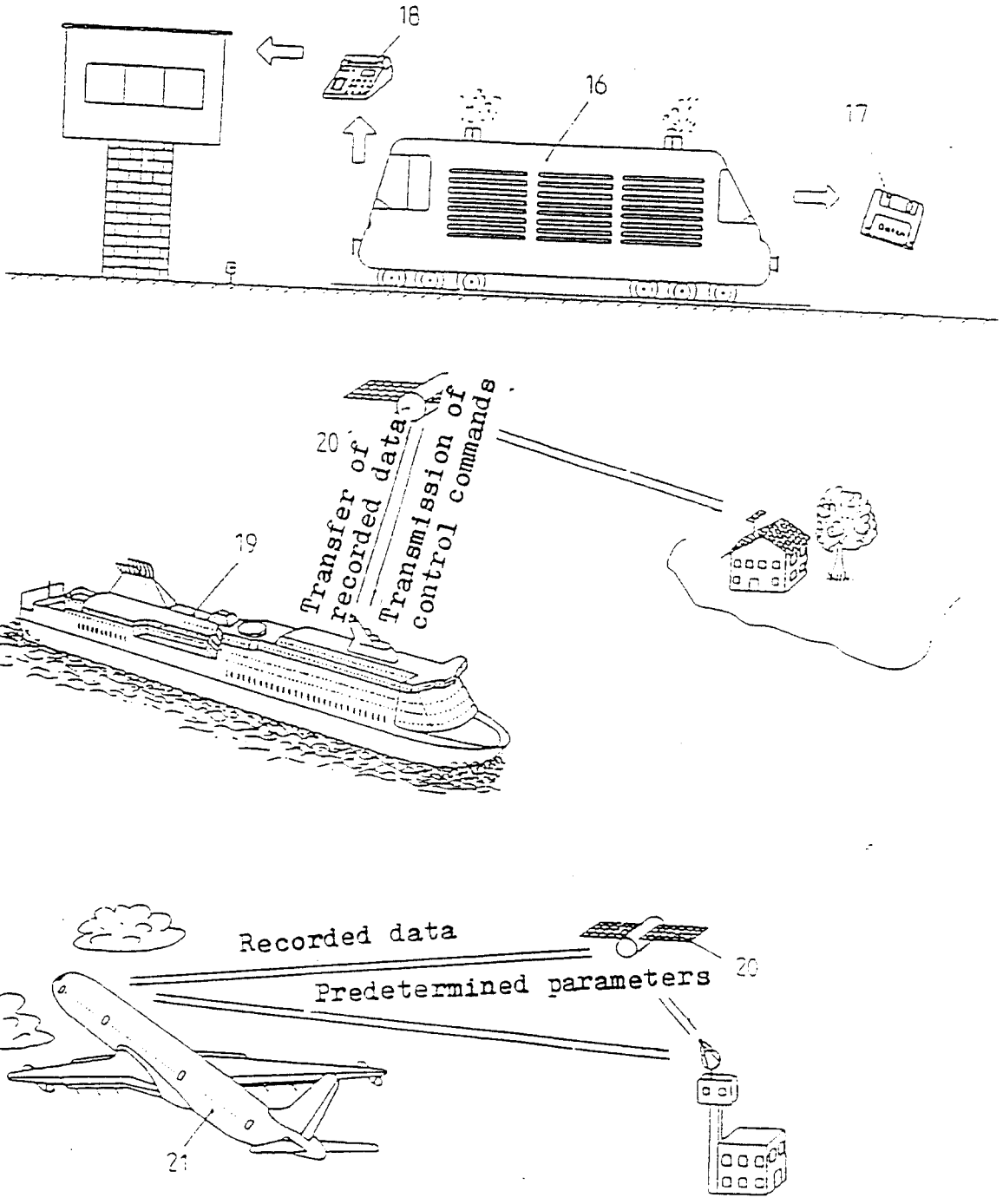
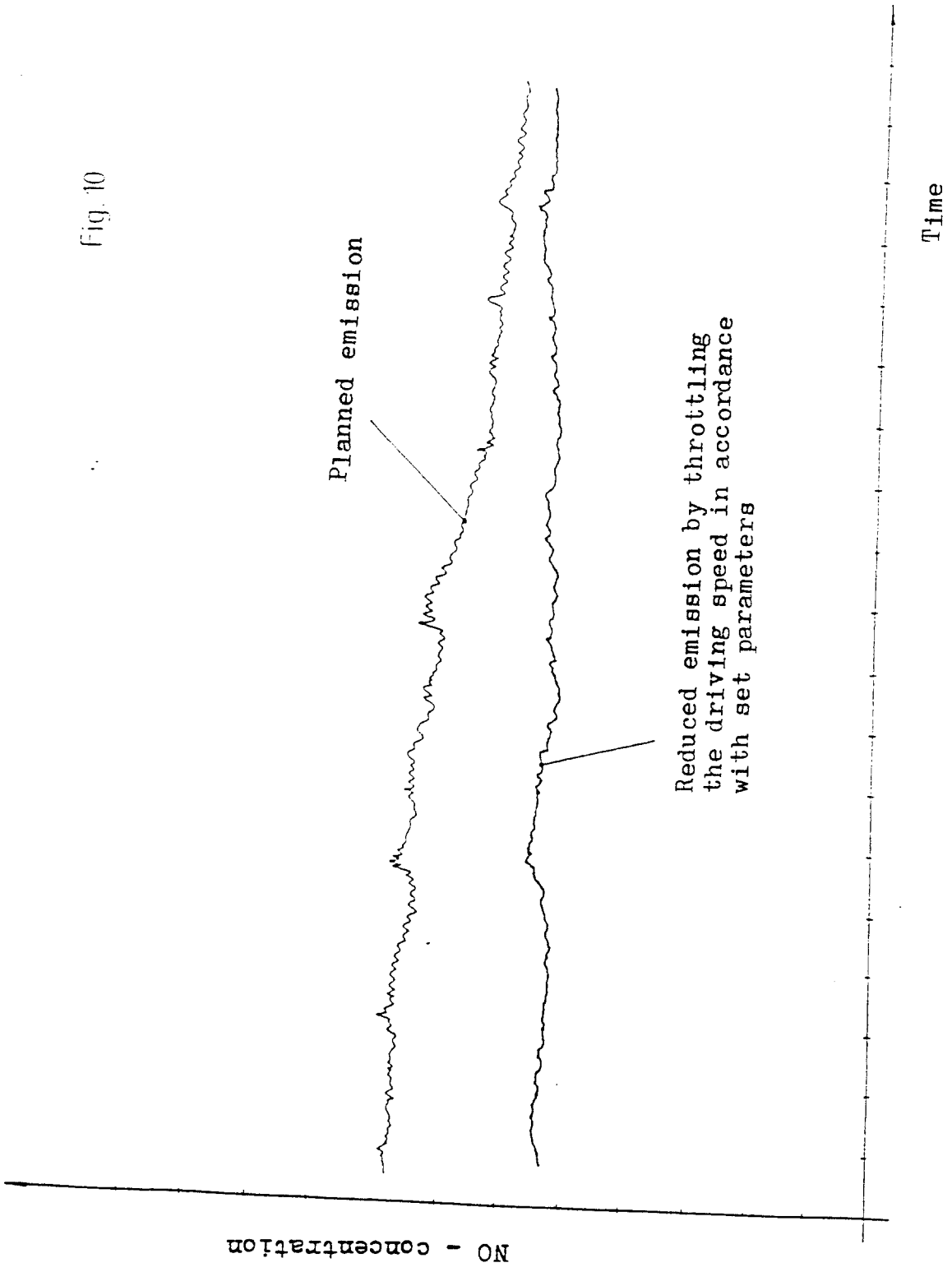
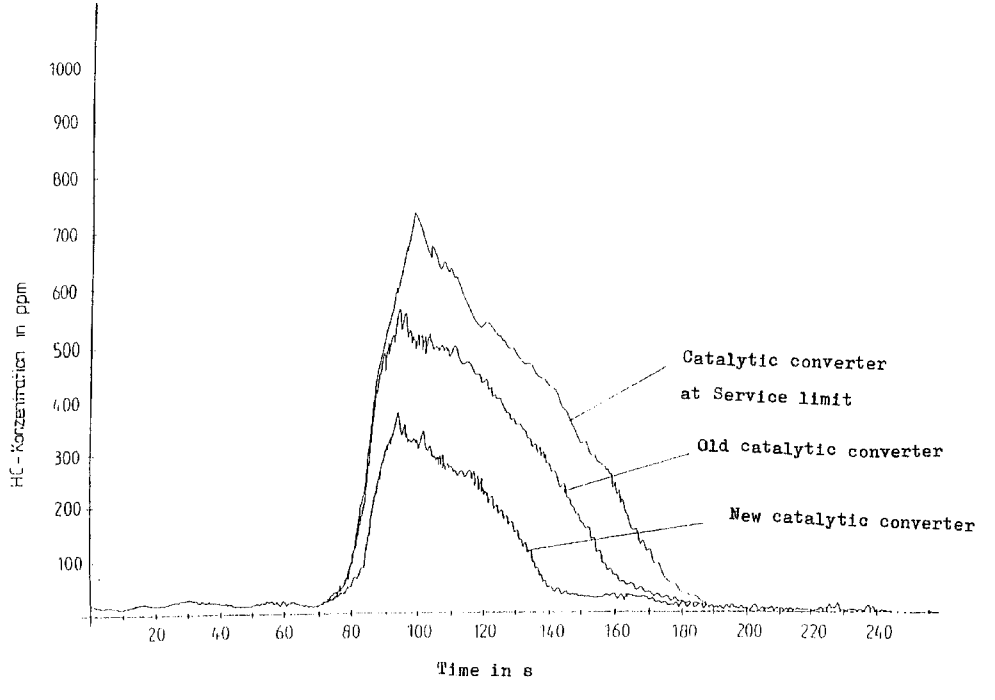

18
16
17
20
Transfer of recorded data
Transmission of control commands
19
Recorded data
Predetermined parameters
20
21

Fig. 10


NO - concentration
Time
Planned emission
Reduced emission by throttling
the driving speed in accordance
with set parameters


HC - Konzentration in ppm
1000
900
800
700
600
500
400
300
200
100
20
40
60
80
100
120
140
160
180
200
220
240
Time in s
Catalytic converter
at Service limit
Old catalytic converter
New catalytic converter