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Diesel engines underground - 1: Field testing installed engines without a dynamometer.

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# DIESEL ENGINES UNDERGROUND

(Field testing installed engines without a dynamometer)

*Mines Inspection Regulations 1975.*

A copy of the pertinent regulations governing the control of diesel engines underground is attached to the inside front cover of this report.

*Equipment*

(1) Multi-gas detector pump Model 31 manufactured by Dragerwerk, A.G. Lubeck (fig. 1).

(2) Motor vehicle exhaust probe and clamp manufactured by Dragerwerk (fig. 2).

(3) Drager test tubes as follows:

| Gas | Order No. |
|---|---|
| Carbon dioxide | CH 251 |
| Carbon Monoxide | CH 20601 |
| Oxides of Nitrogen | CH 27701 |
| Aldehydes | CH 264 |

(4) Suitable lengths of rubber or plastic tubing for:

(a) connecting the tube and pump to the exhaust probe,

(b) leading exhaust gas from the probe clear of the operator.

(5) A suitably manufactured length of connecting metal tubing sweated on to a 6NB nipple to screw into the engine manifold at one end and to give an aperture for joining on the exhaust probe at the other.

(6) Optional extra, stroke counter (fig. 4).

(7) Tachometer.

*Method*

(1) Remove plug from manifold and screw in connecting metal tube.

(2) The exhaust probe has three openings (fig. 4). One below the cooling fins which is the inlet and two above which are outlets. The outlet in line with the inlet is the main outlet and should be fitted with a reasonably long length of flexible tubing to lead the exhaust gases away from the operator. The second outlet is short and at right-angles to the main tube, just above the cooling fins. This is the sampling outlet and should be fitted with a short length of flexible tubing to give a gas-tight fit between the probe and the test tube.

(3) Fit the locking clamp over the inlet tube with the butterfly nut away from the cooling fins.

(4) Insert the inlet into the connecting metal tube on the manifold, slide the locking clamp down until it completely covers the end of the connecting tube and tighten the butterfly nut on to the connecting tube to lock the exhaust probe in place. Note that there should be a fairly tight fit between the connecting tube and the exhaust probe, with the locking clamp, where possible, sealing the joint and preventing entrainment of the surrounding atmosphere.

(5) Run the engine up to operating temperature.

(6) Engine speed is required to be known and determination can present problems. If the engine is fitted with its own tachometer determine its accuracy. Where none is fitted speed must be measured externally. A photo tachometer is found to be the most applicable when the engine flywheel is available. Only gear driven units can be used where the ratios are determinable, belt driven units suffer from slip. Beware of all moving parts and consider all possibilities however remote when testing under load.

(7) Do not allow engine to idle up to working temperature but have the driver increase revolutions spasmodically to prevent carbon deposit.

(8) On reaching working temperature insert test-tube into pump. Note small ring on one end of pump chain is fitted for breaking off ends of tubes. Broken ends must not be ragged as this will damage rubber seating in pump inlet. After breaking, tube ends can be rubbed on rough metallic surface to even the break. Depress pump and while holding depressed, insert sample end of test-tube into sample outlet.

Release pump and allow bellows to return to normal position. 100 $cm^3$ sample is complete when chain becomes taut. Note before starting test, pump can be tested by closing bellows, placing thumb over inlet and releasing bellows. It bellows return to normal with thumb in place the non-return exhaust valve requires replacement. By holding the pump depressed when inserting, the sample tube you will eliminate any possible dilution of the sample from a faulty inlet valve.

(9) Test-tubes are read in accordance with the instructions enclosed in each packet. In the case of aldehydes the tube has to be broken twice. There are two black dots under a plastic sleeve on the test-tube and it must be broken at this point by bending it. Inside the tube is a sealed glass container of xylene which must also be broken. After breaking the main tube observe if the ampoule is broken. If it is not, bend the tube carefully at the plastic sleeve until the ampoule breaks. Note it is simpler to break the ends off the tube before breaking the tube.

 

(10) Testing speeds

Exhaust gas emission is extremely critical of engine speed and three speeds are considered during the test.

(a) No load idle,

(b) no load high speed, and

(c) full load high speed.

There is a further speed to be considered on engines and that is the maximum torque speed. Due to normal operative procedures on decline mining maximum torque speed is usually not critical due to vehicle speed limitations imposed on the operations. The majority of large vehicles have top gear blanked off to limit road speed and thus the vehicles run high revs. in a lower gear. Where however a vehicle is geared such that its maximum speed is acceptable then maximum torque revs. will occur and advisedly the engine should be at least checked at this speed.

(a) No load idle is the speed at which the engine will naturally idle when stationery for short periods. The engine revs. should be increased between gas tests to maintain the engine temperature and to keep down the build-up of carbon deposit.

(b) No load high speed is the maximum speed at which the engine will run without load. It is essential that the operator constantly observe the engine temperature throughout the test to ensure it remains at operating level. The engine should be allowed to cool off between gas tests.

(c) Full load high speed, sometimes referred to as high stall speed the principle is to emulate the loaded situation for an operating vehicle. This can sometimes be done in a static situation for such vehicles as bulldozers, front-end loaders etc., where they have a hydraulic transmission, but great care must be taken to ensure the vehicle cannot move. The engine rpm will normally drop back 200 - 300 revs. on full load.

Where a vehicle is fitted with a dry-plate clutch the above method is inadvisable if a fire or damage to the clutch is to be avoided.

In such a case the vehicle must be operated and the tests taken on the move. No firm rules can be made for this and each situation must be considered on its own merits bearing in mind the safety of the tester. With a travelling vehicle it is usually possible to load the vehicle and then operate it up a suitable length of hill or incline, with a loading type vehicle it is usually possible to put it through its crowd cycle at a location removed from the working area. Due to the time required for some of the gas tests it is rarely possible to test in actual working areas.

All test results are tabulated on a test report sheet, an example of which is attached.

(11) Calculation of Ventilation Requirement

In the four stroke diesel cycle the exhaust valves open only once every two revolutions of the engine *i.e.* for an engine speed of 2400 rpm the cylinders exhaust 1200 times per minute or 20 times per second.

The theoretical volume of exhaust would be total swept volume x 20 per second in this case.

*i.e.* in general $\frac{\text{swept volume x rpm}}{2 \times 60}$ in litres/second (l/s)

Dilution standards are threshold limit values with, where necessary, an additional safety factor and these are the required concentrations *i.e.* a dilution ratio must be applied to reduce the exhaust concentration down to the standard. Note that the standard for $CO_2$ is actually 0.22% to allow for the 0.03% natural content of $CO_2$ already present in the ventilating air.

Whichever gas has the highest dilution ratio will be the governing criterion in setting the ventilation requirement when it is considered in relation to the test speed *e.g.* a dilution ratio of 10.5 at 2500 rpm requires more ventilation than a dilution ratio of 11.5 at 2200 rpm.

Where more than one gas appears critical it is advisable to check out the ACGIH formula.

$$\left(\frac{AC1}{TLV_1} + \frac{AC2}{TLV_2} + \frac{AC3}{TLV_3} + \frac{AC4}{TLV_4}\right) = <1$$

Where $AC_1$ = atmospheric concentration of $CO_2$ after dilution etc.

$TLV_1$ = threshold limit valve for $CO_2$ etc.

If the figure comes out considerably greater than 1 then consideration must be given to increasing the dilution ratio.

Note that the use of ACGIH formula is not obligatory but serves as a guide when a combination of gases affects the dilution and by raising the overall gas content can reduce the atmospheric oxygen content.

Ventilation requirements are quoted in $m^3/s$.

*Points to Note*

(a) Before any test is carried out check equipment, supply of tubes etc.

(b) Applicant should have engine ready for test in the condition it is intended to operate *i.e.* scrubber etc. fitted, manifold drilled and tapped. The applicant should also supply a driver and advisedly have a diesel fitter on standby.

(c) Arrange the test procedure beforehand particularly the details of how the load test is to be conducted.

(d) An engine which has done less than 500 hours will give poor results and these should not be taken as conclusive.

(e) An engine which has had prolonged idling will be full of carbon deposit and give false readings.

(f) CO and $NO_x$ give complementary readings *i.e.* as one rises the other falls. High CO readings along with high aldehydes indicate oxygen starvation due to a blocked air filter or exhaust. High $CO_2$ and CO usually indicate a coked engine which has been idling. High CO and $NO_x$ usually indicate a completely upset fuel pump timing and it is always possible to alter the $CO/NO_x$ distribution by advancing or retarding the fuel pump timing, bearing in mind that the rate of increase of the lower reading gas is always greater than the rate of decrease of the higher reading gas, *i.e.* a slight alteration of the timing may result in a 10% decrease in one gas but in a 60% increase in the other.

Oil filled air filters have a bad effect on sampling and applicants should be advised to fit dry type air filters.

# DIESEL ENGINE APPROVAL TEST

Engine: Toyota H

No. A7/75
Date: 18/7/75

Submitted by: Co-operative Motors, Moonah

Installed in: Toyota Land Cruiser

DETAILS: Cylinders 6 Bore 88 mm Stroke 98 mm

Capacity 3.576 litres

Compression Ratio 20.5 Injection: Direct/~~Indirect~~

| Output | kW | r/m | Fuel kg/h | Volume $m^3/s$ |
|---|---|---|---|---|
| Rated | 71 | 3600 | 20.88 | 0.10728 |
| As set | | | | |

Conditioner:

Rating kW Type: Model ~~Batch~~/Constant level

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## EXHAUST GAS ANALYSES

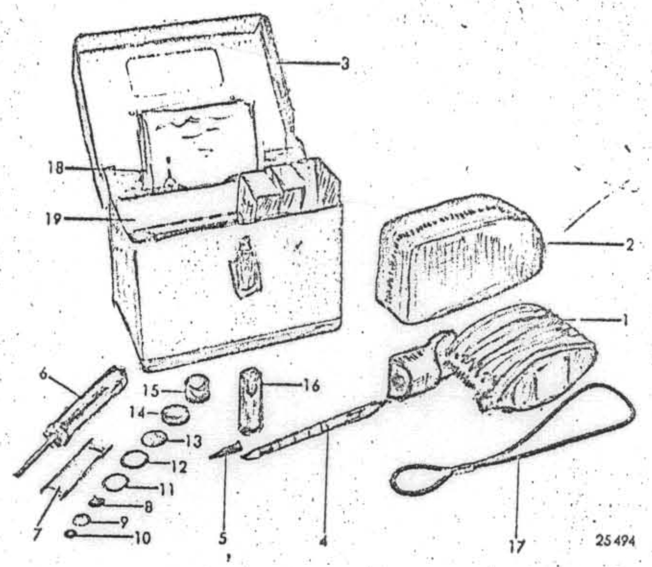
| Speed ~~r/m~~ r/m | load | $CO_2$% | CO ppm | N oxides ppm | Aldehydes ppm | Remarks |
|---|---|---|---|---|---|---|
| 750 | Nil | 2.0 | 400 | 80 | Nil | |
| 3400 | Nil | 4.0 | 500 | 100 | 2.0 | |
| 3400 | Full | 10.0 | 20 | 200 | Nil | |

## CALCULATIONS (*Deduct 0.03)

| Speed r/m | Dilution Standards<br>T.L.V. | 0.25*<br>0.5 | 50<br>50 | 12.5<br>25 | 5<br>5 | |
|---|---|---|---|---|---|---|
| 3400<br>No Load | Dilution Ratio reqd<br>Ventilation ($m^3/s$)<br>~~$m^3/s/kW$~~) | 18 | 10 | 8 | – | |
| | Atmo.Concn<br>A.C./T.L.V. | 0.184<br>0.368 | 11.11<br>0.22 | 2.22<br>0.089 | 0.044<br>0.008 | Σ0.685 |
| 3400<br>Load | Dilution Ratio reqd<br>Ventilation ($m^3/s$)<br>~~$m^3/s/kW$~~) | 45<br>4.83 | 0.4 | 16 | – | |
| | Atmo.Concn<br>A.C./T.L.V. | 0.25<br>0.50 | 0.444<br>0.009 | 4.44<br>0.178 | 0<br>0 | Σ0.687 |

TESTED BY..............................

# List of all items belonging to the gas detection programme




1. Gas detector pump, model 31
2. Protective bag
3. Carrying case
4. DRÄGER tube
5. Rubber cap
6. Special screwdriver
7. Special spanner
8. Valve disc
9. Sieve
10. Sealing gasket
11. Support disc
12. Rubber ring
13. Gasket disk
14. Valve seat
15. Rubber bung
16. Break-off cap
17. Carrying loop
18. Instructions for use
19. Table

Fig. 1 DRÄGER Multi Gas Detector®, Model 21/31

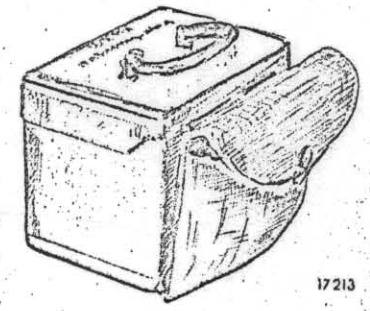



Fig. 2a DRÄGER Multi Gas Detector® Model 21/31 With extension hose in the bag attached to the carrying case

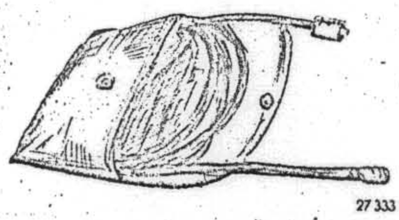



Fig. 2b Extension hose (3 m) with bag for the Multi Gas Detector® (to be used for measurements at inaccessible points).

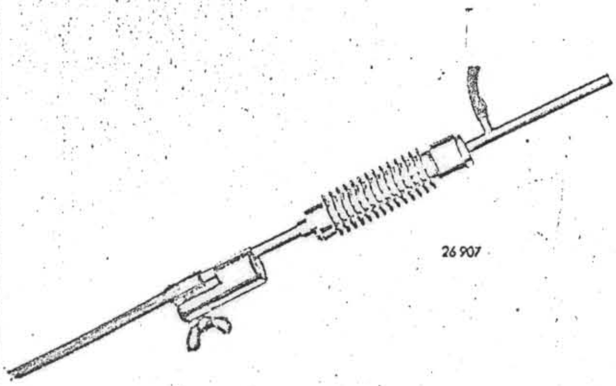



Fig. 3 DRÄGER Exhaust Gas Probe for cooling hot exhaust gases (particularly suitable for the measurement of motor vehicle exhaust gases).

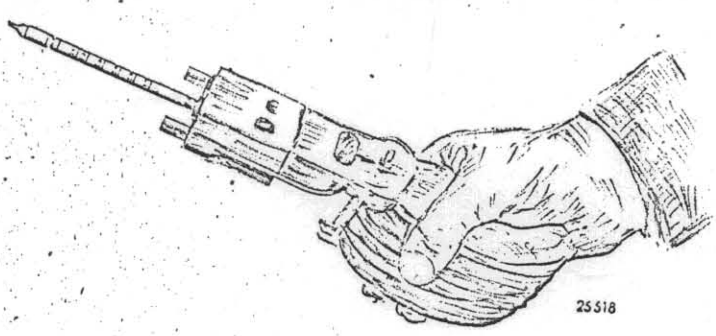



Fig. 4b DRÄGER Gas Detector with stroke counter