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DIESEL ENGINES UNDERGROUND

No. 2

(Calculating the Ventilating air requirement)

by

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DIESEL ENGINES UNDERGROUND

(Calculation of Ventilating-air requirement)

As an appendix to this report, two model approval tests for an entirely mythical engine have been included to serve as examples. To expand the information, the tests have been devised to illustrate the treatment of the same engine both in its naturally aspirated (N/A) form and when it is fitted with a turbocharger (T/C) and after cooler (A/C).

Engine Details

Usually these are supplied by the applicant in the form of trade pamphlets but these cannot always be taken at face value with reference to power output and fuel consumption. For the more commonly used larger engines it is advisable to build up a library of reference material obtained direct from the manufacturer or the principal agent.

Engine ratings alter with the application and the same engine may have a number of ratings. A prime example of this is the Caterpillar D3306 which in its N/A, T/C, and T/C A/C forms operates currently in Tasmania under five different ratings. Rating differences are a combination of loading and transmission requirements when matching the engine to the unit.

Calculation Details

Engine capacity = $0.785.d^2.l.N.10^{-6}$

where engine capacity is in litres

d	=	Bore in m.m.
l	=	Stroke in m.m.
N	=	Number of cylinders.
0.785	=	$\pi/4$
10^{-6}		to convert to m^3

The volume referred to on the test sheet is the combustion air volume of the engine at the rated or set speed. With a naturally aspirated engine this is assumed to be the swept volume multiplied by half the speed (with a four-stroke cycle compression ignition engine), converting to m^3/s. Complications are encountered with turbocharged engines with or without after coolers and information has to be obtained from the manufacturer on the amount of combustion air passing through the engine.

A turbocharger drives air into an engine so that more fuel can be more efficiently burned and therefore more power obtained from the same engine. After cooling assists the passage of exhaust from the engine thereby reducing the back-pressure and again increasing the total flow-through quantity.

As will be seen by comparing the model tests, the N/A engine has a combustion air rate at 1900 r/m of 0.231 m^3/s while its T/C, A/C counterpart has a combustion air rate of 0.454 m^3/s at the same r/m.

The fuel rate must be obtained from the manufacturer or his agent and is critical to the engine application. The fuel rates for the CAT D3306 mentioned previously vary from 20.63 kg/h to 51.78 kg/h and it is important the correct figure be obtained.

Calculation Method

For ventilating purposes, engines display critical speeds, the worst usually being at maximum torque. Engines are normally operated well above maximum torque speed except when pulling away and the usual operating speed is close to maximum power. i.e. maximum r/m. Engines under test invariably demonstrate an ability to run slightly above maximum power speed but come back to that speed when under load hence the slight difference in speed between nil and full load.

CO_2

Take the CO_2 reading obtained from the test and divide the quantity by 0.22. This gives the dilution ratio required to bring the CO_2 emission down to the dilution standard. Similarly for -

CO	Divide the test reading by 50
NO_x	Divide the test reading by 12.5
Aldehydes	Divide the test reading by 5.

Having obtained all the relevant dilution ratios at 2200 r/m it is seen that the highest is 52 for NO_x. If this ratio is used it will therefore dilute the other emissions adequately. At 2200 r/m the swept volume of the engine is 0.268 m^3/s which when muliplied by 52 gives a ventilation requirement of 13.94 m^3/s.

The same exercise is carried out for the test figures obtained at 1900 r/m or full load and here the maximum dilution ratio (again for NO_x) is 67.2 giving a ventilation requirement of 15.52 m^3/s which is what the ventilation requirement or the approval will be set at.

CO_2 and NO_x emissions gave fairly high readings and it is advisable to check out the ACGIH formula.

To obtain the atmospheric concentrations (after dilution) divide the analysis readings in turn by the maximum dilution ratio required. In the case of model test number one each analysis figure will be divided by 67.2 and thus will be obtained the atmospheric concentration of each gas after dilution. Note that the fractions required are AC/TLV and NOT AC/dilution standard. The sum of the fractions should be less than unity and if a result greater than unity is obtained the ventilation requirement should be proportionately increased.

Model test number two is calculated in exactly the same way except that it is the combustion air quantity which is used rather than the swept volume.

These air quantities are quoted at a fixed engine speed and can be calculated pro-rata for any other speed.

In the case of the two model tests approval would be given as follows:

(a) Engine: Welbar 146 N/A

Fitted to: Welbar 'dozer.

Maximum Fuel consumption	=	47.18 kg/h
Maximum engine speed	=	1900 r/m
Minimum ventilation requirement	=	15.52 m^3/s

(b) Engine: Welbar 146 T/C A/C

Fitted to: Welbar dumper.

Maximum Fuel consumption	=	74.98 kg/h
Maximum engine speed	=	1900 r/m
Minimum ventilation requirement	=	12.71 m^3/s

As will be seen by comparing these approvals, although the second engine has a higher fuel consumption figure it is more efficient and requires less ventilation.

The maximum engine speed quoted in the approval is for fuel setting purposes and is the maximum full-load speed which is slightly lower than the maximum no-load speed.

De-rating

Where an engine fails to meet the requirements for approval it can be de-rated i.e. it can be re-set to operate at a lower output by reducing its maximum governed speed and fuel consumption figure. Manufacturers engine characteristics curves are invaluable when this situation arises. The information required to be shown on the curves includes the inter-relationships between power output, r.p.m. and specific fuel consumption. It must be borne in mind however that other factors have to be considered when de-rating. e.g. a number of hydraulic transmissions have critical engine speeds; the conditions of operation may invalidate any reduction in speed where loss of maximum power is critical or the construction of the engines ancillaries may be such as to defy adjustment.

The last example is quite common on small engines and here it is usual to quote speed and fuel "as set" at the time of test.

DIESEL ENGINE APPROVAL TEST

Engine: Welbar 146 N/A

No. M1/75
Date: 14.10.75

Submitted by: Grotto Mines

Installed in: Welbar Dozer

DETAILS: Cylinders 6 Bore 137 mm Stroke 165 mm

Capacity 14.6 litres

Compression Ratio 16.8 Injection: ~~Direct~~/Indirect

Output	kW	r/m	Fuel kg/h	Volume m^3/s
Rated	157-228	1900	47.18	0.231
~~As set~~		2200		0.268

Conditioner:

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

EXHAUST GAS ANALYSES

Speed r/m	load	CO_2%	CO ppm	N oxides ppm	Aldehydes ppm	Remarks
700	Nil	3.0	400	400	2.0	
2200	Nil	6.0	380	650	1.0	
1900	Full	8.0	300	840	Tr.	

CALCULATIONS (*Deduct 0.03)

Speed r/m	Dilution Standards T.L.V.	0.25* 0.5	50 50	12.5 25	5 5	
2200 No Load	Dilution Ratio reqd Ventilation (m^3/s) $m^3/s/kW$)	27.27	7.6	52 13.94	0.2	
	Atmo.Concn A.C./T.L.V.	0.09 0.18	5.65 0.11	9.67 0.39	0.01 0.002	Σ0.68
1900 Load	Dilution Ratio reqd Ventilation (m^3/s) $m^3/s/kW$)	36.36	6	67.2 15.52		
	Atmo.Concn A.C./T.L.V.	0.12 0.24	4.46 0.09	12.5 0.5		Σ0.83

TESTED BY....A.N. Other..............

DIESEL ENGINE APPROVAL TEST

Engine: Welbar 146 T/C. A/C.

No. M2/75
Date: 14.10.75

Submitted by: Grotto Mines

Installed in: Welbar Dumper

DETAILS: Cylinders 6 Bore 137 mm Stroke 165 mm

Capacity 14.6 litres

Compression Ratio 16.8 Injection: ~~Direct~~/Indirect

Output	kW	r/m	Fuel kg/h	*Volume m^3/s
Rated	235-343	2200	–	0.526
~~As set~~		1900	74.98	0.454

Conditioner:

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

EXHAUST GAS ANALYSES

Speed r/m	load	CO_2%	CO ppm	N oxides ppm	Aldehydes ppm	Remarks
700	Nil	2.0	320	80	<1	
2200	Nil	5.0	200	200	2.0	
1900	Full	6.0	80	350	Nil	

CALCULATIONS (*Deduct 0.03)

Speed r/m	Dilution Standards T.L.V.	0.25* 0.5	50 50	12.5 25	5 5	
2200 No Load	Dilution Ratio reqd Ventilation (m^3/s) $m^3/s/kW$)	22.7 11.9	4	16	0.4	
	Atmo.Concn A.C./T.L.V.	0.18 0.36	7.14 0.14	7.14 0.29	0.07 0.01	Σ 0.80
1900 Load	Dilution Ratio reqd Ventilation (m^3/s) $m^3/s/kW$)	27.27	1.6	28 12.71	–	
	Atmo.Concn A.C./T.L.V.	0.21 0.42	2.86 0.06	12.5 0.5	–	Σ 0.98

TESTED BY...A.N..Other..............

* Combustion Air Requirement for T/C. A/C. is 430 l/s at 1800 r.p.m.