DIESEL ALTERNATOR TRIALS AND ENGINE TUNING

BY

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Introduction

A Diesel generator installation is required to meet specifications for the following factors:

(*a*) Acceptable speed change after putting on or taking off full load;
(*b*) Maximum variation in speed/load curve from the straight line drawn through 'no load' and 'full load';
(*c*) Cyclic irregularity, i.e., hunting at steady loads;
(*d*) Maximum momentary speed change at change of load;
(*e*) Time taken to recover steady speed after load change.

The limit required for these requirements are laid down in Reference 1.

Possible causes of failure to achieve this performance are:

(*a*) *Bad design*—compare your results with the acceptance trial report;
(*b*) *Electrical-end snag*—has very little effect on engine loading apart from the obvious;
(*c*) *Governing*—adjustment on modern engines is simple and instructions are laid down in the B.R. or Manual.
(*d*) *Engine tuning*—a most likely cause of hunting. No exploratory action should be taken until tuning is proved satisfactory.

Tuning Diesel Engines

Tuning of submarine Diesel engines was discussed by Commander Hollamby in Vol. 1, No. 2 of the *Journal*. His excellent article has guided engineers in tuning the larger engines in service with the Royal Navy.

Since this paper was published in 1947 there have been two major changes in the general service attitude to the Diesel engine:

(*a*) The Diesel-driven generator is no longer an 'emergency' generator, but must now contribute to the ship's load;

(*b*) A.C. installations have superseded D.C. systems.

These changes have demanded greater reliability and availability of the engines and more exact governing.

Governing the Diesel Engine

A turbo generator or alternator governing system amplifies a signal from the speed sensing device to adjust the steam flow to the turbine. Delays occur in the transmission, amplification and in accelerating or retarding the rotor.

The signal from a speed sensing device in a Diesel generator or alternator is used to apply an adjustment to the fuel rack setting and not directly to the working fluid. Before the effect of an adjustment is apparent, the fuel pump must operate at the new rack setting, and combustion must be almost complete. Therefore in a Diesel generator the delay before a variation in speed can be controlled is greater than that of a turbo alternator or turbo generator by the time taken for the fuel pump to operate and combustion to take place (about 30 degrees of crank angle).

The effect on the governing system is to reduce the time available for the governor to make corrections.

Effects of Bad Tuning

In a Diesel alternator with a constant load and a constant fuel rack setting, the speed will vary about a mean value due to the firing interval.

But if we consider an alternator at constant load but with one cylinder out of tune, the speed variation will increase. If the governor can sense this variation a correction will be applied to the fuel rack setting. Regrettably this adjustment is most unlikely to affect the offending cylinder. Instead conditions in another cylinder are affected, the speed variation is again increased but this time in the opposite sense. When correcting speed variations in a badly tuned engine the governor increases the disparity between cylinders. Inevitably hunting results.

The specifications demand that cyclic irregularity in a Diesel alternator shall not exceed 0·25 per cent of the steady load speed. In an A.S.R.1 six or eight-cylinder generator this is less than 2 r.p.m. tolerance for hunting.

Aim of Tuning

The aim of tuning is to ensure equal power output from each cylinder. In main propulsion engines and D.C. generator engines, it has been the practice to tune the engine, with fair accuracy, at a particular power (generally 80 or 100 per cent). There may be variations between the cylinder loading at other powers, but cyclic irregularity is not important in these applications. Provided that no individual cylinder was overloaded at other powers, the tune was considered satisfactory.

However, the alternator demands much finer limits of speed governing. To achieve a consistently steady speed we require an engine in tune at all loads. But when an engine is tuned exactly for one load, then variations are increased at other loads. These variations are due to wear in pumps and injectors, cams and followers, inequalities in bumping clearance, valve timing, valve spring

TABLE I

Cylinder No.		1	2	3	4	5	6	*Mean Value*
Hot Comp. Press								
25% Power	Max. Press							
	Exh. Temp.							
50% Power	Max. Press							
	Exh. Temp.							
75% Power	Max. Press							
	Exh. Temp.							
100% Power	Max. Press							
	Exh. Temp.							

stiffness, piston ring leakage, valve leakage, etc. Satisfactory tune of a Diesel alternator is achieved when the differences of power between cylinders does not give rise to hunting outside the tolerance of cyclic irregularity over the whole range of engine power.

Tuning Technique for Alternators

Prior to running, check the valve timing and test the injectors and fuel pumps. The fuel pumps are tested on a Hartridge machine at three rack settings. The pump is first run at maximum output, adjustment being made by altering the rack position. When the specified output is achieved, the rack pointer is adjusted (by shimming) to read the maximum setting. Subsequent runs at different rack settings prove the pump's output over the whole working range.

When the fuel pumps are put on the engine a 'spill' test is carried out to ensure that the point of injection and period of injection are correct. This test is most important and upon its accuracy depends the whole of the engine tune.

When the engine is run compression pressures for each cylinder are taken. This is achieved by using the pressure indicator on a cylinder with the fuel shut off.

Provided the compressions pressures are approximately equal (say, within 20 lb/sq in.) and the spill tests are satisfactory, combustion conditions in each cylinder should be identical.

To prove the tuning, run the engine at a range of powers (say, 25, 50, 75 and 100 per cent full power) and record the maximum firing pressure and exhaust temperature for each cylinder. Records tabulated in the convenient form shown in TABLE I enable trends in pressures or temperatures to be easily detected.

Adjustments

No adjustments should be made until all runs and records are complete.

Adjustments are only made on those fuel pumps which show consistently high or consistently low readings at all powers. A cylinder, apparently requiring an adjustment greater than 5 per cent on the fuel pump, should be subjected to a thorough investigation as the fault is unlikely to be in the fuel gear adjustment, unless the spill test was incorrect or the fuel gear was damaged in transit from the test.

The same rules apply: to adjust maximum pressure alter the point of injection by inserting or removing shims under the fuel pump body, or to adjust exhaust temperature, increase or decrease the rack setting to alter the quantity of fuel.

This technique will ensure that the speed variation at steady load over the whole power range is within the tolerance for cyclic irregularity.

The Governor

The governor has two functions:

(*a*) To maintain the speed constant or nearly so over the range of loads;

(*b*) To control the momentary speed variation when the load is changed.

Inevitably there will be some change in the steady speed after a load change with mechanical governors. This speed change is referred to as 'droop'. An adjustment is provided on the governor for 'droop'.

The momentary speed changes at a change of load will be affected by engine tuning, droop setting and the state of the governor (i.e., wear and cleanliness of the oil).

In the two hydraulic mechanical governors now in service, adjustments are provided for (*a*) nominal speed; (*b*) maximum load; (*c*) droop.

Governor Types

The larger and more sophisticated of the hydraulic mechanical governors is the Ardleigh Type 400. This depends on governor flyweights for speed sensing and a completely self-contained oil system for amplifying the signal. These are invariably returned to the makers for refit and test, which coupled with their cleaner oil conditions promotes reliability.

The smaller Ardleigh Type 200 governor depends on flyweights for speed sensing, but engine oil is the hydraulic fluid. Thus wear and dirt can affect performance. These governors are cleaned and replace parts fitted at Blackbrook Farm. But as no test rig is available to the Royal Navy results are not guaranteed. Also the period of flushing the engine lubricating oil system after refit allows dirt to collect on the suction side of the gear-wheel type governor oil pump. When the engine is started this dirt is then pumped to the governor unless the oil supply is allowed to by-pass the governor or pass through a temporary filter during the preliminary running.

The other condition which upsets governor performance is incorrect clearance on the gear drive. Shims are provided under the governor casting to achieve this clearance.

Electronic governors are greatly superior to hydraulic mechanical types but are not in service in the Royal Navy.

Conclusion

The author firmly believes that most so called governor troubles are due to incorrect tuning technique. Unsatisfactory tune is apparent in engine hunting.

In a properly tuned engine, the adjustment of the droop control on the governor should bring momentary and steady state speed changes within the tolerances. If this is not the case a refitted and tested governor must replace the one fitted. Since we cannot test governors of this type, only makers reconditioned or new items should be used.

References

1. Governor requirements: *Specification of General Requirements for Machinery (Engineering)*. D.G.S./T.P.S.E./108. para. 1103, sub.para. (04)(*c*).
2. 'Tuning of Submarine Diesel Engines'—Commander Hollamby. *Journal of Naval Engineering*, Vol. 1, No. 2.