GARDNER

Engine Forum

Autumn 2006 Issue

No. 11

Gardner Engine Forum Philosophy

"The aims of the Forum are to promote and foster interest in all Gardner engines"

Subscription

The annual subscription to the forum is £10.00 (This magazine will be published twice a year)

Price of each issue to non-members £2.75

Overseas subscription £18.00

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Contents

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Cover Picture

"G. Rogers & Sons – Amusement Contractors – Sodbury Glos. – 6L2 with genset"

As always we ask the question – does anyone have any information on this vehicle?

Chairman's Jottings

With this autumn issue I am very pleased to announce that the next Gardner Engine Rally will be held on the 9th and 10th June 2007 at Park Head Locks, Dudley, West Midlands.

The site has good access for boats and vehicles alike and excellent hard standing for road and stationery engines. The Dudley Canal Trust has made us very welcome and has offered us the use of the pump house for the Saturday evening. They will also be holding an open weekend to include local crafts and rope making. Park Head was the venue for The Russell Newbury rally last year – their 2007 rally will be held at Baddesley also on the 9th/10th June.

I am very pleased to report that Gardner Parts have agreed to continue their support in the form of judges and trophies for the Gardner Engine Rally. They will also have a stand selling Gardner wares.

I look forward to meeting old friends and making new ones.

The last six months have flown by. Sharpness has slowly cruised the Leeds and Liverpool canal as well as visiting the areas around the corridor. It is a very pretty, underused waterway -- if you see a boat moving it is certainly a major event. We are not looking forward to returning to the busy waterways.

I would like to say a huge welcome to the latest recruits of the GEF, David Cooper and Terry Gibson bringing our membership numbers to 194.

And finally, if you have something to say, or a tale to tell, please get in touch.

Regards

Colin Paillin

Chairman - Gardner Engine Forum

P.S. Just in case you missed my jottings with regard to our new website, please find this below – perhaps a little clearer!

www.gardnerengineforum.co.uk

GARDNER

Engine Rally

9th & 10th June 2007

Between Parkhead Locks & Dudley Tunnel

Road access from Holly Hall Road

Dudley
West Midlands

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INJECTION EQUIPMENT

Part III Calibration ; Overhaul , Specialisation ; Experimental Work and Modification

CALIBRATION

The development of special power plants for pump testing and adjustment has to some extent over-exaggerated the importance of calibration. Power test certainly is indispensable where numbers of pumps are being maintained, for it not only provides a degree of consistency but it also speeds up part of the operation of calibration.

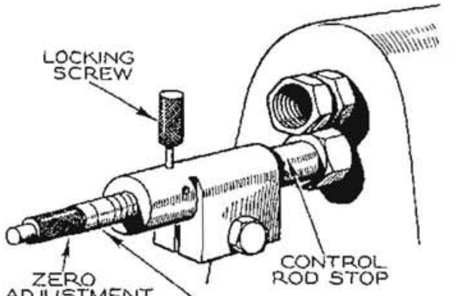
Any suggestion that calibrating a pump is the principal operation to assure maximum efficiency and economy of fuel should be treated with reserve. It will be fairly obvious that reducing the control rod travel to obtain say a 10% reduction in output is a much simpler operation than curtailing the actual maximum output of each element by the same amount. The definition of calibration cannot be termed "simple" when it is applied to fuel pump adjustment, but the real meaning is simple; it is the balancing of fuel delivery of the individual plungers. The need for this operation results from element wear over lengthy mileages, the disturbance of barrels and plungers, or, to a lesser extent, to the slight disturbance following the removal and replacement of delivery valve seatings. Occasionally the clamp screw of an element regulating sleeve loosens and there is a consequent alteration of output. It will be seen therefore, that calibration must be the final operation after any removal or replacement of main components.

Calibration equipment in its simplest form presents no complication being merely an arrangement for hand turning the pump with discharge from the injectors into test tube, such a plant is used in the manufacturer's recognised course of instruction. With reasonable care in operation and an understanding of the principles involved little doubt need to be felt about producing a satisfactorily balanced pump.

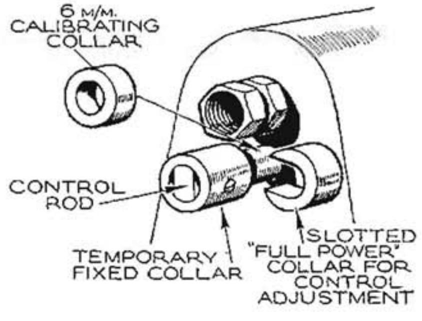
In commencing the operation it is apparent that a supply of fuel must be provided, while air must be eliminated from the injector pipe lines, and the pump control rod must be set in the maximum power fuel feed position.

The point at which calibration is carried out is referred to as "the 12mm position". The pump manufacturers establish this by moving the control rod 12mm towards the open position, measured from the "no fuel" delivery, or closed position. The fully closed point naturally can only be reached with the slow running stop unscrewed.

The total extent of control rod travel from closed to full open position is 25mm and "12mm open" is therefore, approximately half the total movement. CAV service stations use a device which is fitted to the control rod stop sleeve, or, as it is frequently termed, the smoke stop, after removing the adjustable stop plug. A rod graduated in millimetres slides through the setting assembly to make contact with the end of the control rod, and a zero adjustment is provided to coincide the scale with the no fuel position. By moving the control rod in the opening direction the 12mm position on the scale is established and the locking screw will then hold it during calibration tests.



CAV setting jig for holding the control rod in the "12mm open" position



Collars as developed by the author for pump calibration at the 6mm control rod setting. They can be made to suit the 12mm position also. Slotted collars of pre-determined thicknesses are used to establish the full power adjustment of the control lever, which is then sealed.

The same result can be achieved by the use of circular collars of the required thickness (12mm, etc.) on the control rod, but the control rod stop sleeve must first be removed so that the collar makes contact with the face of the pump body. A locating collar is needed on the end of the control rod and it is secured by a pin through the control rod hole.

Examination of a control rod will reveal two centre-pop marks equidistant from each end. These primarily are timing marks for correct assembly of the toothed sleeves. With a control rod assembled in working position these marks when equidistant from the extreme ends of the control rod bushes, will locate the quadrants at right angles to the control rod axis. On the average pump this is an approximate 12mm open position. With a completely assembled pump, however, the mark at the governor end of the control rod is not visible.

It must be emphasised that this 12mm calibration position is a locating point to allow reproduction of identical settings. As it is a dimension that is established by pump manufacturers (and in certain cases is quoted as an output standard) it is desirable to adopt it. At the same time if a setting by rule of thumb methods, based on the performance of a particular pump, was required it could be reproduced by means of setting collars of other than 12mm, provided that the dimension was reproduced accurately on each subsequent test. Such setting collars are a simple method of achieving accurate reproduction of any pre-determined setting position.

In those cases where the control rod travel is deliberately limited, and in the absence of the CAV setting jig, the collar method of calibration must be used and this necessitates removal of the control rod stop assembly so that a spacing disc or a suitably slotted collar can be fitted on to the control rod between the end face of the pump body and a temporary collar fixed on the end of the control rod, the position of which is maintained by a light pull-off spring. Fuel spray can be checked by a few turns of the handle driving the camshaft. Test nozzles should be in good condition and set to 2,500lbs. pressure (or about 175 atmospheres) Before making the actual calibration test it is advisable that a trial reading be taken in the test tubes, which are graduated in tenths of cubic centimetres. It is usual to take readings on a hundred revolutions or "shots" and as far as possible a steady rotation is advisable; tripping in and out of the spill tray must synchronise with the agreed number of resolutions. An average of two or three readings should be taken before any adjustment is made. A tolerance of 5-10% is usually allowed and adjustment of delivery is affected by releasing the clamping screw and moving the regulating sleeve clockwise for increasing and anti-clockwise for decreasing on a right-hand pump. This movement is fractional and if the tolerance mentioned is to be attained the adjustment must be recognised as a delicate operation. It will be noted that control sleeves and quadrants have a line scribed on them which defines their original setting and after any re-calibration it is desirable to re-mark them, so that, in the event of the adjustment slipping, an approximate correction can be made without removal. The following table indicates the pump manufacturers, recommended outputs. A table is also given of the corresponding outputs recommended by the makers of AEC engines as an interesting comparison; certain of them, it will be noted, involve greater deliveries than the maxima of the pump makers.

Calibration of pumps fitted to Gardner engines is carried out on similar lines, but Gardner service stations follow the engine makers' recommendations, which call for power test facilities and are not applicable to hand test procedure ; the details are covered in the following section dealing with power test. Leyland calibration procedure also differs slightly from that of the pump manufacturers. Pumps for Leyland engines are calibrated in terms of cc per plunger stroke, based on the output over 250 shots; the reason given is that the output for the generally accepted 100 shots is not considered sufficiently accurate. With the pump running at 500rpm and discharging to atmosphere through pintle nozzles at 2,500lbs pressure (control rod in the 12mm position), the output is 20cc per element, or 0.08cc per shot. As a 7mm element is used transposition of the output to 100 shots (8cc) gives a comparison with the figures tabulated below.

CAV

Plunger size	Element Output Tolerance (100 shots)
6.5mm	6.6cc – 7.3cc
7.0mm	7.3cc – 8.2cc
7.5mm	8.4cc – 9.3cc
8.0mm	9.2cc – 10.2cc

(At 12mm setting)

Engine Make and Type	Plunger Size in mm	Element Output (100 shots) 12mm Control rod, pump speed 600rpm
AEC		
9.6 litre d.i (pot) A185 Passenger	7mm	8.3cc
8.8 litre d.i. (torroidal), A180, A182, goods and passenger	8mm	9.5cc
8.8 litre d.i. (pot), A180, A 182, Goods and passenger	7mm	8.3cc
8.8 litre Comet I, A165, goods and passenger	7mm	10cc
7.7 litre d.i. torroidal, A173, goods	8mm	8.8cc
7.7 litre d.i. torroidal, A173, passenger	8mm	8.2cc
7.7 litre Comet iii, A171, goods and passenger	7mm	8.5cc
7.7 litre Comet iii, A171, goods and passenger	7mm	8.5cc
6.6 litre 7 cylinder Comet III, A172, passenger	6.5mm	7cc
6.6 litre Comet I, A172, passenger	7mm	7.8cc
6.6 litre 4-cylinder d.i. (torroidal), A186, goods and passenger	8mm	11cc
6.6 litre 4-cylinder Comet I, A168, goods and passenger	7mm	11.5cc
5.3 litre 4-cylinder Comet I A166, goods	7mm	9cc

POWER TEST

The use of power-operated test plants does not alter the method of calibration, and the same principles of adjustment as those already outlined are followed. In the data on outputs it will be noted that certain manufacturers recommend outputs in terms of a hundred shots. The CAV and Crypton Hartridge test plants are designed to produce 200 shots or revolutions for each test run, irrespective of the actual pump motoring speed. Spill of fuel into the test tubes is by channels on a movable assembly which is automatically tripped out on completion of the test run. The plants embody a speed control for variation of rpm and they are provided with revolution indicators. An additional feature of the Crypton Hartridge plant allows phasing check by electrical recording of injection intervals by visible spark on a rotary spark gap.

So far as actual calibration is concerned the same principles are followed as those in the hand method, but obviously the power plant increases accuracy and assures consistency in the methods of speed control and duration of test respectively. Operators with extensive experience of power testing are by no means unanimous on what represents ideal equipment. For instance, there is a divergence of opinion on test glasses. The Crypton Hartridge Method rotating the test tube carrier to empty and bring into operation tubes which have drained whilst the previous test has proceeded is attractive. At the same time, where the tube carriers are removable there is obvious advantage in being able to check readings under better lighting conditions than may obtain where the machine is installed. Electrical phasing on the Crypton Hartridge plant is a comparatively simple operation, but the electrical versus the spill method is controversial, even among manufacturers. It will be obvious, moreover, that care must be exercised in checks of the injector tappet operating device with the electric method, as any irregularity will affect final results. It is generally accepted that, given ordinary care, error in phasing by the spill method is almost impossible. Where facilities exist for the use of the electrical method the operator can check against the spill method and his own experience will be the deciding factor.

GOVERNOR TEST

Governor test as previously mentioned can only be undertaken satisfactorily with motoring and speed recording facilities. High speed governor test does not call for any detailed comment. It is only necessary to be able to define the cutting-out speed in conjunction with known rpm. Slow speed check on the other hand is worthy of a certain amount of elaboration. With the pump mounted for test on the Crypton Hartridge plant use is made of a pointer registering on the control rod. Movement can be defined and the appropriate rpm at this point noted. The purpose of slow speed test is to define the speed at which the governor cuts in. If control rod movement only is used as the indication it does not gives a really accurate picture of the commencement of fuel spray; governor test methods wherein the actual spray at the test injectors is visible at the cutting-in-point are to be preferred. Under this method, test injectors, spraying into glass tubes are used. As cutting-in speeds range from 150 to 175rpm (pump speed), the first operation is to motor the pump at a speed within the range. With the minimum speed or slow running control slacked off and the control rod in the closed position, pumping cannot take place. By carefully screwing in the slow-running adjustment the point at which equal pumping begins can be established by observation. The control is then locked and the motoring speed increased beyond cutting-in-point. By operating the test plant speed control and slowly reducing pump rpm the exact cutting-in point by observation of injector spray can be determined. Tests carried out by this method, particularly with control such as that embodied in the Crypton Hartridge plant, simplify the assessment of governor sensitivity of flexibility. Views have been expressed that slow speed governor operation is relatively unimportant and does not justify any extensive tests. Good idling on oil engines is, however, desirable and the relation of governor condition to this point is sufficiently important to justify a comparatively simple test operation such as that outlined.

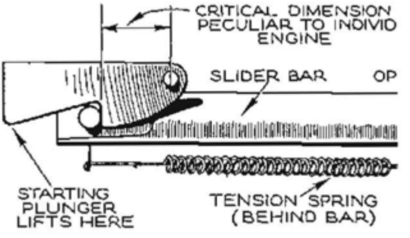
Where bench testing with accurate recording instruments is carried out a discrepancy in engine rpm and the pump test rpm is noticeable. A pump set to cut out at 1,000rpm pump speed would, under engine bench test, give engine cut-off at approximately 1,940rpm, not 2,000rpm. This is due to the fact that under test conditions, where injection is to atmosphere, it is impossible to judge accurately any slight reduction in volume at the critical point of maximum speed cut-off. The average pump at this speed is delivering a sufficiently continuous flow to fill the sight feed tubes which are a necessary protection against splash and waste. On the other hand, with a complete undergoing power test at or about full load, the slightest movement of the high speed governor towards the cut-off position will be reflected in an immediate reduction in power output. Thus engine power test compared with pump test only gives a much more sensitive indication of cut-off speed.

PUMP CONTROLS

Certain adjustments are necessary to complete the foregoing pump operations. Generally speaking, on CAV. pumps, with one exception, the various controls are defined as follows:- The toothed rod which imparts axial movement to the pump plungers through their quadrants is known as the control rod. The screwed sleeve with its pinned adjusting screw or plug situated on the pump housing at the opposite end to the governor assembly and limiting the maximum travel of the control rod, is the control rod stop. The lever attached to the eccentric shaft and coupled with the appropriate linkage to the accelerator control is referred to as the control lever. No special explanation is needed for the idling or slow running stop which is easily identified. Engine makers using complete unit pumps generally use the same nomenclature when referring to the various controls, although Leyland substitute smoke stop for "control rod stop."

Considerable variations are present, however, in the identification of controls on Gardner engines. Slider-bar replaces "control rod" and as travel for maximum power is controlled by an assembly containing a "fuel limiting trigger" and embodying means for obtaining extended slider bar movement to give excess fuel for cold starting, the "control rod stop" of the unit type fuel pump becomes the fuel control box on the Gardner C.A.V. equipment.

Diagrammatic arrangement of fuel limiting trigger in Gardner control box. To allow the slider bar to move to the excess fuel position for starting, the pawl is raised by a finger operated plunger.



In outlining the usual control adjustments it will be recalled that total control rod movement is some 25mm, but the effective useful movement under running conditions does not exceed 12mm. The limitation of this movement is, therefore, achieved by the idling or slow running adjustment on the one hand, and the control rod stop on the other.

It is generally realised that an excess of fuel is necessary for cold starting, but that means must be provided to prevent this rate of fuel delivery recurring under normal full load conditions, otherwise a foul or dirty exhaust with consequent detrimental effect on engine life would result. This correct full-load condition is provided for on the unit type pump by an adjustable stop which limits the movement above idling speed while the smoke stop acts below idling, for instance, when the engine is being turned over by the electric starter, the centrifugal force exerted by the governor weights is sufficient to swing them out to compress the governor idling springs but in this condition the governor operating shaft positions the floating lever so as to hold the control rod in the excess fuel setting, the limitation of the excess movement being decided by the control rod stop.

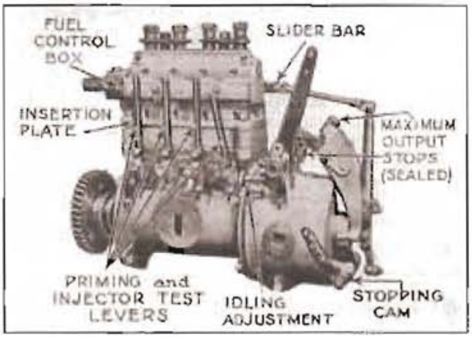
The official method of correctly setting these stops is as follows:- On bench test the engine is run up to its full horse power at the rated speed (Without smoke) and the control lever stop is locked to prevent further control rod movement beyond this position. The control rod stop, after releasing the securing split pin, is screwed in until it touches the control rod, then unscrewed one-and-a-half turns (one complete turn is equivalent to Imm control rod travel), the control meanwhile being held in its maximum position, i.e., with the control lever held at the full open position. Manufacturers stress that control lever stops are set on test to the correct output and that the adjustment is sealed to prevent tampering. An additional adjustable stop is frequently provided alongside the slow running assembly which allows limitation of maximum output if desired without interference with the sealed adjustment.

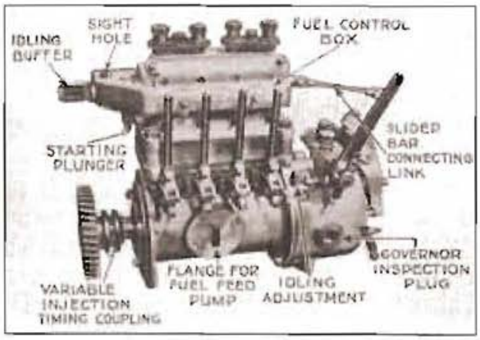
An additional adjustment which is to some extent a refinement is found on modern pumps fitted to direct injection engines. It is a spring-loaded plunger bearing against the end of the control rod stop between the "idling" and "no fuel" positions and its function is to limit control rod surge or "hunting" at idling speeds. On unit pumps it is situated on the governor housing and it must be fully unscrewed before establishing the best idling position, after which any tendency to hunt can be checked by sensitive adjustment of the damping device. Screwing in too far must obviously be avoided, as this will affect the speed at which the engine slows down after acceleration. This can be judged by accelerating the engine, and noticing the rate of deceleration.

On Gardner engines this idling damper is termed the "governor bar buffer" and it is on the extreme forward end of the control box; there is a small hole (with a hexagon plug) through which its contact with the slider bar can be observed. When the engine is thoroughly warm after a hard run under load there should be a clearance of 0.003in. between the bar and buffer when the engine is idling; the buffer should not be adjusted to make permanent contact. One word of warning is necessary in the final setting of control rod stops on CAV pumps. If clearance of less than 0.5mm is allowed on the stop there is a possibility of the governor gear being overloaded.

Reference is made at a later stage to a method of calibrating fuel pumps on a smaller control rod opening than the generally accepted 12mm position. As a result of the smaller delivery of fuel position it was found desirable to establish methods of reproducing control rod positions that can be easily repeated. This was carried out by utilising steel collars of the required dimensions relocating them on the control rod by a collar positioned with a pin in the control rod hole. The collar dimensions were established by the recognised method of determining the official 12mm control rod position. To simplify the ready repetition of a standard control lever stop adjustment, a "U" slotted collar was utilised and the final setting was affected by adjustment to allow insertion of the collar during pump test. Briefly, after calibration and governor tests the pump is motored under fuel delivery to atmosphere conditions, at an established speed, in this particular case, of 600rpm.

With the control lever in maximum delivery position control rod travel is limited to the "U" collar dimension by adjustment of the control lever stop. This method means, of course, the removal of the control rod stop assembly and with fixed collar secured by the locating pin in the control rod, it is possible to adjust the control rod stop until it can nib or release the "U" collar inserted between the fixed collar and the pump housing. Motoring a pump under the conditions outlined provides a limited control road float, and by adjustment of the control lever it is possible with a "U" collar inserted to produce a sufficiently sensitive setting to require little more than half a turn of the control lever stop to give the desired power output on road test.





External details of the Gardner pump governor and control box. Adjustment is provided for the idling setting but all screws affecting maximum output are sealed. It is essential that the slider bar connecting link should be adjusted to allow the bar a further 1/32in inward movement when the governor weights are fully expanded by the fingers through the inspection plug.

It will be obvious that reproduction of required pump output for a given road performance with this method is a reasonably simple operation. After establishing a required standard of performance by road test, the removal of the pump and subsequent reproduction of the control lever adjustment by the necessary collar dimensions is a fairly simple method of standardising pump outputs.

In setting controls on Gardner engines, idling speed adjustment does not call for any special comment, except that the speed should be high enough to eliminate float on the slider bar. Maximum output control is covered in the section dealing with the Gardner power test. There are, however, one or two points worthy of elaboration. The makers recommend that a cut-off movement on the slider bar of 3/16in. must be maintained. This is defined as the slider bar clearance from the extreme "stop" or "no fuel" position to the point at which fuel delivery can just be felt to commence, when operating the hand priming levers. This dimension will, of course, be affected by adjustment of control sleeves during calibration, but normal adjustment is unlikely to do so.

Clearance must be maintained between the roller link and the contact screw on the cam lever; it can be influenced by the idling or slow running adjustment and by the length of the two fixed pegs at the end of the cam lever which bear against the governor housing in full load position. However, their length is determined by the makers and must not be altered. There must also be 1/32in. of free movement allowed in any re-adjustment of the slider bar connecting link. This is necessary as otherwise the small ball-race in the governor push rod will be overloaded because the slider bar will be pushed up hard to its "stop" or "no fuel" position before the governor weights reach their limiting abutment. The correct setting is found by parting the governor weights to their full extent by inserting the fingers through the inspection opening in the governor case, so moving the control lever to its idling position. The slider connecting link is so adjusted as to hold the bar in a position approximately 1/32in. from its maximum stroke towards the timing case.

A rough check on this necessary 1/32in. of play can always be made when the pump is on the engine without removing the governor inspection plug as follows:- The engine is revved up to maximum and as the governor pushes in the slider bar connecting link at the extreme in position at the movement the accelerator is released ; this method needs a little practice but it is a quick way of checking up if it is suspected that derangement of stops or unauthorised adjustment has taken place. When dealing with CAV pumps the importance of the control rod stop in the final setting of controls must be emphasised. If a pump is set up with the control rod exposed and lightly held in the "cold start" position, motoring the pump at idling speed will withdraw it towards a reduced fuel or normal position. Obviously if the cold start position of the control rod (particularly when set by the screwed plug in the control rod stop as on CAV equipment) is limited or restricted to approximately the maximum-power running position, end loading of the governor gear will occur. In further emphasising this point, assuming that the control rod stop and the control rod movement for further power by retracting the lever stop would decrease the clearance between the control rod and the stop, also with danger of governor loading; it is to guard this that the lever stop is sealed by the makers.

When dealing with Gardner injection pumps it is essential to remember that although the six-and five cylinder engines have pumps divided into two separate blocks of three and three, or three and two elements, the equipment is treated as a complete unit and is so calibrated, consequently one block alone must never be replaced by a spare. If any change has to be made, a complete set must be used as a service replacement. This service station method adopted for Gardner pumps for actual calibration follows the adjustment sequence previously outlined. The test plant and procedure is, however, different. A motor with a speed regulator and an accurate rpm indicator is used and the injectors discharge directly into graduated test tubes. The design of the flange mounting of the Gardner-CAV pump equipment naturally involves a special arrangement and the Gardner calibrating test bench incorporates a camshaft and housing similar to that embodied on the engine; no governor being fitted. As the pumps on 5 and 6-cylinder engines are in two units these must always be calibrated in pairs and it is important also to note that if the insertion plate between the camshaft and the pump is not of the one-piece type common to both units, the separate plates must always be kept with their own pumps. Furthermore if the insertion plates are separate (this applies mainly to early type LW engines) a distance gauge must be made before removal from the engine to ensure that the two adjacent inner end faces are at the same distance apart on the machine, otherwise their calibration cannot be matched. Pumps with common insertion plates must be transferred to the test machines without removal from the plate. Before carrying out tests the pumps tappets must be adjusted so that the lines on the tappet spring thimbles coincide with the lower lines on the pump windows to within a tolerance of 1/64in. up or down. This tolerance is only permissible for calibration tests; when the pump is fitted to the engine the lines must coincide precisely. In the actual test procedure the calibration is assessed by measuring and comparing the individual element outputs over a given time irrespective of the number of revolutions. The specified outputs per element, speeds and times, are given in the accompanying tables.

Pump motoring speeds are set at about the maximum pump speeds for the appropriate type for maximum output calibration test with the slider bar fixed in full load position, while for calibration at idling output the speeds are given at something rather over the true idling pump rpm. A collar and set screw will hold the slider bar when the control box is removed. In either test the test plant is regulated to the appropriate speed before commencement of the collection of the discharge from the injectors is commenced. The time of the test is not important; the object is to verify an equal discharge from all elements over the same period. A further point to be noted is that no special pressure settings are adopted for the test nozzles. A standard set of injectors, preferably, reconditioned is recommended.

GARDNER CALIBRATION TESTS

	TEST A		TEST B	
	Maximum output test		*Idling Output Test*	
Engine Type and Governed rpm	*Camshaft rpm*	*Fuel Delivery*	*Camshaft rpm*	*Fuel Delivery*
LK/2000	1000	Run machine until each line has pumped approximately 70cc	250	Run machine until each line has pumped approximately 20cc
LK/1700	850		300	
L2/1300	650		300	

Test A = Slider bar in fully-open running position (to be checked by measurement prior to removal of control box).

Test B = Slider bar reduced from full opening by 7/32in. (LW type) and 3/16in. (LK and L2 types).

The power or maximum output test is taken by working the pump unit with its control box in position, at the appropriate speed with the slider bar held in the "no load" position, the governor link being disconnected. When the appropriate steady speed is attained the release of the slider bar will allow its spring to take it to the "full load" stop and the watch can be started. When the time expires the bar is pushed in to the "no fuel" or "stop" position and the motor is switched off. Outputs per element should be close to those given in the table and it must be borne in mind that the fuel control box is very unlike the CAV control rod stop in principle and that in particular it does not provide the same ready means of varying the starting output of the pump, for instead of the screwed plug stop, a weighted pawl or trigger is used which drops on to a pin mounted in the end hole of slider bar. When the trigger is in the normal running position the bar cannot pass it, but for cold starting it is raised by a manually operated plunger and the rod slides to the "excess fuel" position. No adjustment either, is provided for limiting normal running delivery such as can be effected by the supplementary (unsealed) control lever maximum stop on the CAV governor. Each trigger is numbered, since it is appropriate to its own particular engine; if a replacement is necessary, due to wear, the number must be quoted so that a correctly dimensioned part can be supplied. Similar, if it is desired to reduce output a longer trigger will be needed. Small and insignificant as it looks, this trigger can have considerable bearing on fuel consumption and smoky exhaust if it is a few thous. too short, or on power if it be long. Wear of the trigger and/or the pin against which it rests will be reflected in excessive output, high consumption, and smoky exhaust, but trouble is not likely to arise from this cause under about 150,000 miles. It must be mentioned, also, that the Gardner fuel control box is not an interchangeable unit, and must never be transferred to another pump.

In the table below are the officially recommended output settings at maximum running position of the Gardner slider bar. The specialist fitter who has been through a course of instruction at the makers' works will know that if these outputs are exceeded they can be limited by the substation of a slightly longer trigger and that if they low they can be increased by a reduction of the trigger length. This is done by careful filing of the operative face of the trigger. The operation is a delicate one, for the face must be kept flat and square, and exceedingly small dimensional changes will affect the output. Small scale maintenance shops without the benefit of skilled personnel in constant practice on such work will be well advertised to leave this adjustment severely alone.

GARDNER MAXIMUM OUTPUT SETTINGS

Engine Type and Governed rpm	Camshaft rpm	Time	Average Element Delivery
LK/2,000	1,000	1½ mins.	74.05cc
LW/1,700	850	1 min.	64.0cc
L2/1,000	500	2 mins.	70.5cc

Although the foregoing summaries officially recommended procedure on fuel pump test and adjustment it will be of some interest to detail briefly the method practiced by the author in connection with C.A.V. pumps, which while not having the blessing of the manufacturers, has proved successful in practice. It has been emphasised previously that efficient injection equipment maintenance is not provided by any single operation, so it must not be claimed that this method is, as a single operation, responsible for the low replacement costs of pump components experienced in a very large fleet, although it is believed that it has a definite relation thereto.

Pump No.	Total Mileage	Replacements
21	255,180	Governor overhaul Bell crank levers, pivot pins and fixing sleeve.
6	209,655	Governor overhaul as above.
20	163,124	Governor pivot pins, pump base tipped.
4	255,286	Governor overhaul, bell crank levers, pivot pins and fixing sleeve

Typical pump mileages obtained by the author on Leeds Municipal Transport services by close attention to all aspects of injection equipment maintenance.

The principle behind the adoption of low-end calibration is one in which all operators agree, viz., that adjustment and repairs are inevitable due to wear. After some experimenting on pump tuning it was found that by adopting recommended methods of calibration at maximum control rod openings, wide variations in element output at minimum positions were recorded. This applied particularly after high pump mileages had occurred. Conditions in the early days and particularly with air cell engines, made good idling not only desirable but essential. Further, it was found that with this type of unit the erratic running immediately following a cold start was improved by low-end balancing. Pump outputs were, therefore, balanced at minimum control rod positions, and it was found that by reversing the procedure, i.e., calibrating at 6mm instead of 12mm on the control rod and balancing the output at this position, improved results were obtained. The design of pump plungers encouraged the view that balancing a major discrepancy of, say, 25% in the minimum position would not necessarily mean the same percentage disturbance at the larger control rod openings, the view being taken that the amount of fuel slip resulting from wear was governed by plunger seal in the former position. This view was borne out in subsequent tests and it was found that a correction of 25% in the 6mm position did not affect the output at 12mm more than three to four per cent. The adoption of this method naturally calls for test plant modification since the lower output at the reduced control rod position makes element adjustment still more delicate, and the small output volume of injector spill may be affected by the retention of some fuel in the normal test plant channels after the trip mechanism has operated. Again due to the small output the number of revolutions or "shots" will not provide a sufficient quantity for accurate measurement, particularly as the pump speed must be limited to 200rpm to approximate to the engine speed of the 6mm control rod opening.

As regards the first point no difficulty, apart from providing adequate light at the point of adjustment, was found, and the time occupied in calibrating six elements to the 4.4cc total output ultimately adopted is only 90 minutes, including all fitting up and preparation of test plant. Modification of the apparatus to allow direct spill into the test glasses was carried out, with a trough cut-off operated by the tripping gear substituted for the spill channels. As the plant was shop built and comprised a fixed speed motor with a variable-speed gear box, modification of the trip cams enabled an increased test duration of 300 shots. Finally as output values were lower, steps were taken to assure consistency by the provision of setting sleeves for positioning control rods during tests. Setting sleeves for maximum power outputs were also adopted, as well as a jig for easy location of control rod stops.

In attempting to define economic intervals for pump attention the same principles apply as to the engine unit. Knowledge of performance efficiency in conjunction with regular check enables a reasoned judgment as to the need for adjustment and repair and regular check at established intervals need not be costly.

Pump maintenance has to a large extent been dictated by the experience of the large fleet owners. Their systems are based on regular inspection and repair cycles, under which conditions vehicles are in the shops at definite intervals when it is natural that as many essential units as possible shall be checked over. To some extent pump examination may have been carried out too frequently because such items as worn timing couplings, possibly due to misalignment, made pump removal necessary. Under large fleet conditions, with regular intervals for docking, vehicles are out of service for a couple of days and it is natural that opportunity encouraged examination of the pump. Bearing these facts in mind and also recognising the need for labour economy, the following figures, based on bus operating conditions in town work, can be taken as a guide to routine pump maintenance procedure.

	Mileage	Attention
1	30,000	Governor check. Calibration and Phasing check.
2	60,000	Governor examination. Calibration and Phasing check.
3	90,000	As No. 1
4	120,000	Dismantle for cleaning and reconditioning, followed by calibration and phasing.

A complete cycle of pump maintenance between major overhauls at 120,000-mile intervals.

Given the appropriate knowledge and test plant a fairly accurate idea of pump condition can be established. Whilst governor replacement necessitates a certain amount of dismantling, operating experience indicates that considerable mileages are possible before complete pump dismantling is necessary.

As the correct functioning of the pump is related to cleanliness and freedom from sticking or erratic operation, particularly on the control rod and quadrants, dismantling of the unit for thorough internal cleaning after extensive mileage is unavoidable. Carefully compiled instructions with particulars of the special tools required are supplied by the pump manufacturers, and where the requisite knowledge has been acquired preferably by instructional course, little difficulty need be anticipated in carrying out the work. Manufacturers' instructions officially embrace dismantling such parts of the pump as do not affect the calibration or timing of the injection. To comply strictly with this qualification it is possible, when dismantling for cleaning only, to confine the operation to removal of governor assembly, camshaft, tappet assemblies, control rod and quadrants, and plungers. The removal of the latter obviously demands subsequent replacement in their own particular plunger barrels, the tolerances being so fine that they are not interchangeable.

Provided delivery valve seats are not disturbed, correct reassembly will not call for calibration, neither will reinstatement of the tappets affect or necessitate phasing unless the adjustments are altered. If delivery valve seats are disturbed it is usual and advisable to replace the seat washers. This can slightly alter the plunger body position with consequent variation in output, necessitating calibration check. Replacement of one or more plunger and barrel assemblies by new parts will certainly call for calibration adjustment, although it must be emphasised that plunger and barrel replacement cannot be successfully handled without appropriate instruction. Opportunity should be taken to convert earlier types of pumps during overhaul to the common level lubrication system. This necessitates machining the governor case housing and the dimensions are given in the accompanying diagram.

When topping up pumps with common level lubrication the difference between the shape and size of the governor and camshaft chambers has to be borne in mind. After filling through the dip stick hole in the pump until the correct level is indicated, the engine should be idled for a few minutes and then stopped. A re-check with the dip stick may show a drop in the level and if this is the case more oil should be added and the procedure repeated until the dip reading remains constant, thus indicating that both chambers are fully replenished.

A particularly important governor modification which it is advisable to carry out is to replace the bell-crank pivot spindles with spindles retained by Simmonds nuts instead of by the locating pin through the centre of the fixing sleeve lug in the original layout. This conversion is strongly recommended on direct injection pumps, particularly when they are fitted with quick lift cams. Standard and oversize spindles should be provided, together with appropriate reamers for fitting. It is also desirable during governor overhaul to examine the fixing sleeve shoulders on which the lower spring plates rest. Rectification with a hollow end-mill and balancing the metal removed by suitable spacing washers is the method adopted. Bell crank levers, particularly those of the earlier type in bronze fitted to early type pumps and now superseded, must be examined for flaws. Generally speaking, direct injection governors require more attention than those on air cell engines, owing to the increased injection pressures involved and to the camshaft characteristics. In any case the two types of governors are not interchangeable and when air cell engine are converted to the direct injection type of cylinder head it is recommended by the makers that the governor assembly designated by the design change letter C should be substituted by the D assembly.

The conversion is within the scope of any mechanic accustomed to governor repairs, providing that the following details are observed. (a) The bores in the governor weights which contain the springs must be 33.8mm diameter and if less must be bored out. (b) Clearance between the governor levers and the fixing sleeve should be adjusted to a maximum of 0.1mm, shims being available to do this. (c) The clearance between governor weights and bell crank lever arms should also be adjusted to a maximum of 0.1mm and again shims are available from the makers. (d) The fixing sleeve holes must be reamered so that the oversize pivot pins are a good interference fit. (e) When the pins are fitted the clearance between the Simmonds lock nut washer and the bell crank lever on each side must be not less than 0.2mm. The fitter undertaking this conversion must appreciate that the increased dimensions of the modified bell crank levers may result in binding unless careful filing is done to ensure free movement without contact with adjacent parts.

Fuel economy is always of paramount importance both to passenger and haulage operators, and the aim of this chapter is to indicate that a series of correct adjustments on all the associated components of the injection equipment is more likely to achieve major economy than will be achieved by concentrating attention on a single item. On the other hand definite claims to improved fuel economy are frequently put forward by passenger vehicle operators following upon output curtailment by reducing pump control rod travel, or in some cases by reducing the actual pump element output. That this claim can be sustained is undeniable, but it is only feasible where the operating conditions do not demand full power. The same curtailment on certain classes of goods vehicles would probably have the reverse effect. A double deck passenger chassis powered by a 7.7 or 8.6 litre engine has with its appropriate 56-seater body an unladen weight of about 6 tons. The passenger load brings the gross weight up to 10 tons. Against this a good vehicle of 7 tons carrying capacity has an unladen weight of five tons, the gross weight being 12 tons. It will be obvious, therefore, that in the former case under average conditions over well-known routes full power is rarely used and curtailment of performance can be carried out without any serious sacrifice. The goods vehicle on the other hand frequently and invariably is loaded up to and possibly beyond its rated capacity. Under these conditions curtailment of power might easily involve the ascent of gradients in lower gear than would ordinarily be necessary, with adverse effect on consumption. This is a further illustration that actual knowledge of conditions of operation must be studied if a high standard of efficiency is desired.

In considering these two illustrations as broad principles it will be recognised that so-called fuel pump "tuning" can on the other hand produce economy in fuel and on the other hand it is most likely to produce the opposite effects. In exploring the possibilities of output curtailment the large operators, particularly those with sound methods of road testing, have advantages over their smaller brethren. Experimental settings proved and checked against a known set of standard performance conditions by an efficient road test remove the chance aspect associated with "risking it and hoping for the best". Manufacturer's bench test procedure is a highly developed and efficient branch of the industry, but it is designed to produce the best average results and if the operator takes an intelligent interest in and acquires accurate knowledge of his own particular conditions; he can to some extent by experimental work earn dividend for his efforts. There appears little doubt that had it not been for the war, development in pump tuning methods would have been further investigated. The increased service knowledge and the beneficial results associated with the use of power test facilities for fuel pump maintenance was gradually improving the results obtained from a component which in the earlier days was literally left alone. Intelligent adjustment cannot be classed under any circumstances as tampering, and while the performance of fuel pumps has never necessitated detailed knowledge to keep them running, regular inspection and careful adjustment from time to time has amply repaid those operators who have taken the trouble to understand a highly developed piece of mechanism which with reasonable care easily outlives any other component on the engine.

In deciding the method of test and subsequent procedure to be adopted, some responsibility on final choice is on the individual. It is doubtful whether any present system represents finality. Divergence of opinion on the method of defining output even exists between the engine builders, and they are not always in line with the principles which the makers of pumps follow and which ought to represent finality; the operator is, therefore left with the decision as to which method is to be adopted. Whatever the choice, consistency in results on individual units must be the aim. Pump maintenance is a specialist operation preferably carried out under conditions more approaching those of a laboratory rather than a workshop. At the same time care should be exercised when planning the placing of the section not to make a mystery out of what is essentially a commonsense operation; absolute cleanliness and good working conditions must be provided, but this can be done without isolation behind locked doors.

Editor's Note – This extract has been taken directly from the book printed in 1942 and the written word, grammar and punctuation has changed quite significantly over the past 60 years.

ADVERTISEMENT CORNER

X CRAFT & WELMAN CRAFT

This class of vessel was built, during World War Two, for attacking enemy warships moored in protected anchorages, particularly the German battleship Tirpitz. They were towed to the vicinity of the target, usually by submarine, and then released.

Some early boats were built for trials and training purposes before the X5 series were built for operations. Vickers Limited of Barrow, the traditional submarine builders, were overwhelmed with work replacing losses. There had to be a great deal of secrecy surrounding the programme, and manufacturers had to be 'off the beaten track' of German bombers. The companies selected were Markham's of Chesterfield, Broadbent's of Huddersfield and Marshall's of Gainsborough. The extent to which the secrets of the programme had been meticulously guarded was typified by the construction of X4, constructed in early 1942. Half was constructed in Hull and the other half in Bursledon, Hampshire with the assembly undertaken in Portsmouth Harbour.

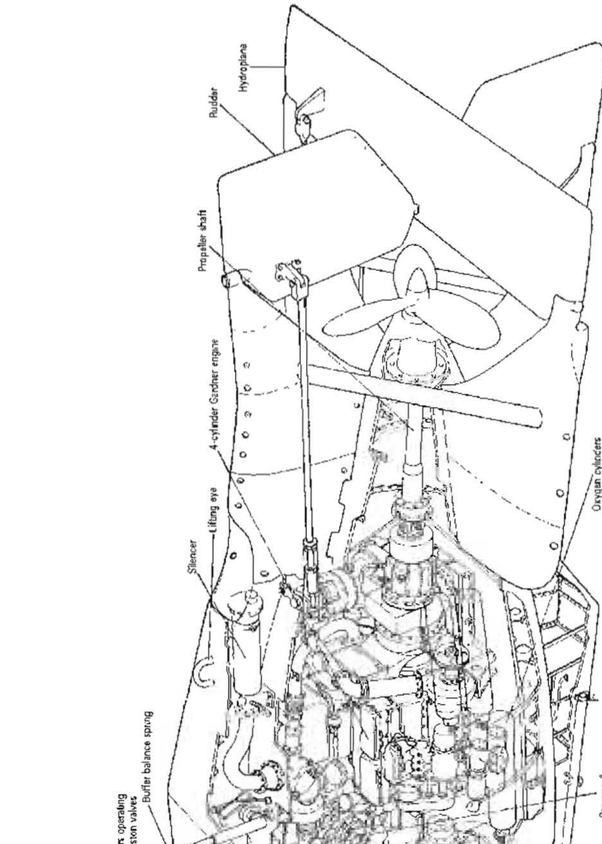
In 1942 a batch of light-weight 4 cylinder 4LK type Gardner diesel engines were ordered by the Admiralty for a top secret weapon, the customer label only read "Admiralty". Gardner engines were chosen for the "X-Craft" because of their excellent record of reliability and economy.

The X-Craft training was conducted in Loch Striven, an isolated Loch in the West of Scotland, on their depot ship, HMS Bonaventure which shared the water with HMS Malaya, an obsolete WW1 Battleship which was used as a training target. The support staff was accommodated ashore near Port Bannatyne in HMS Varbel. The training was rugged and thorough, with the crews exercised in every aspect of an operation, including cutting through nets, and some 'escape and evasion' for the personnel. It also included each X-Craft being subjected to depth charge explosions to familiarise the crews with what it was like being under attack. Nerves of steel were essential for their own protection as well as that of their fellow men. This training carried a price, with two men losing their lives through accident.

A slightly gung-ho film, 'Above Us the Waves', starring the ubiquitous John Mills, was made shortly after the war and purports to tell the story of the X-Craft's development and the raid on Tirpitz.

The original X-Craft (X-1 to X-4) were never used for operations. X-5 to X-10 were used in the attack on Tirpitz, none of them surviving. These were followed by the six XT class boats – designed for training purposes only and with less complicated equipment.

Next came the X-20 series of six boats (X-20 to X-25): X20 and X23 were used for beach reconnaissance on the coast of Normandy (Operation Postage Able), followed shortly afterwards by the arduous duty of acting as markers for the first landing craft on D-Day, codenamed Operation Gambit.


Hydroplane
Rudder
Propeller shaft
4-cylinder Gardner engine
Lifting eye
Silencer
Buffer balance spring
Levers operating Kingston valves
Steering wheel
Hatch
Night periscope
Day periscope
Hatch
Safety tube
Induction trunk
Bunk
WC
Pump for 'Wet & Dry' compartment
Side cargo release
Gyro compass
Steering & hydroplane control
Oxygen cylinders

The British X-Craft unit was finally disbanded in 1958. X24 was preserved at HMS Dolphin, Gosport. A Gardner 4LK engine can be found on display at the Anson Engine Museum, Poynton.

The facts and figures for X-Craft from X5 were:

- Displacement:27 tons surfaced; 29.5 tons submerged
- Length: 15.7m (51' 7")
- Beam: 1.8m (5' 9½")
- Propulsion: Gardner diesel engine; single electric motor; 42hp surfaced; 30hp submerged.
- Speed: 6.5 knots surfaced; 5 knots submerged
- Range with charges; 1,100 miles at 4.5 knots surfaced; 85 miles at 2 knots submerged
- Surface range without charges; 1400miles. Gradual improvements in range for newer boats.
- Armament: 2 x 3570lb charges of Amatol (high explosive). Limpet mines in later craft.
- Crew 3 men (passage) 4 men (operational)
- Numbers delivered: 14 X-Craft, 11 XE-Craft, 6 XT-Craft (for training)
- Fuel: Approx. 1 ton

The success of the X-Craft attack on Tirpitz, albeit at great sacrifice, led to two operations by X24 on attacks in Bergen harbour, Norway in 1944, and with the example of successes in Europe in mind, they were called on for tasks in the Far East.

It is worth recording that during the war, the following awards and decorations were won by X and XE-Craft submariners:

- 4 Victoria Crosses
- 8 Distinguished Service Orders (DS0)
- 15 Distinguished Service Crosses (DSC)
- 4 Distinguished Service Medals (DSM)
- 2 Conspicuous Gallantry Medals (CGM)
- 26 Mentions in Dispatches (MiD)

23 men died in service with X-Craft

(Facts complied by the Anson Engine Museum, Anson Road, Poynton, SK12 1TD)

Marine Engine Workshop
By Charles of CMD Engineering

Gearbox Clatter

Many Gardner owners have queried the problem of gear clatter with me - a phenomenon which manifests itself at the lower register of the engine rpm range. A review of the condition, without delving too much into the laws of physics and quantum mechanics, may be of interest to Forum members.

The Basic Causes

Low frequency torsional vibration emanating from the engine and driveline torque reversals sourced from the propeller.

The above factors serve to interrupt and reverse the torque flow from engine to driveline. This constant switching of torque direction results in a rapidly alternating load between the 'drive' and 'coast' sides of the transmission gear teeth via the backlash in the gearing. This is the source of the audible clatter or rattle. A worn or mismatched gearbox drive plate may exhibit similar symptoms due to the same problem.

Factors relevant to the condition

1. 1, 2 and 3 cylinder engines are more prone to the problem due to the increased 'dwell' period between firing strokes, resulting in greater torsional vibrations at a lowrpm.

Firing Interval	720 o	180 o /540 o	240 o
'Dwell' angle of rotation between power strokes	540 o	0 o /350 o	60 o

Note - The uneven firing interval of the 2L2 and 2LW engines is due to the 180 o phasing of the crank pins in order to facilitate a harmonic 'couple' for balancing purposes.

2. Recommended idling speed for type L2/LW/LX etc., is around 400-420rpm. Many marine applications, particularly inland propulsion engines, operate at idle speeds well below this. The increase in 'dwell' time between power strokes and therefore torsional vibration is proportionate to the reduction in idle speed. The lower the idle the more likely the occurrence or worsening of gear clatter.

3. Lightweight, automotive type flywheels, whilst allowing an engine to ramp up to speed faster, are less efficient at dampening the torque spikes from the engines power strokes and distributing that energy over the engine's 'dead' cycles. Heavy, marine type flywheels are an advantage. Automotive flywheels, with care and calculation, can be modified to raise their inertia.

4. A correctly matched drive plate will help absorb torque fluctuations transmitted from the engine prior to them entering the gearbox. A 'stiff' coupling will not absorb this torsional activity, whereas a type soft enough to suppress these low speed torque characteristics may not be able to handle rated horsepower. 'Loop' type couplings, which have a 'wind up' elastomeric element may be of use and of particular benefit are the 2-stage type that utilise high deflection soft stage.

5. Gearboxes with excessive tooth backlash or free play due to worn splines, etc., will both contribute to and amplify the condition.

6. Long prop shafts of narrow diameter and thin section, are 'tortionally elastic' and will wind up then accelerate when subjected to torque reversals. This will compound and amplify any gear clatter. Universal joints installed 'out of phase' will induce angular accelerations in the driveline. Prop shafts of 31/2" diameter and 3/32" wall should be considered a minimum, along with 2" diameter stern shafting. Prop shaft length should be restricted to 8' between bearing locations.

7. The propeller can be viewed as a second flywheel, suspended in a fluid medium. The unit possesses a mass and a diameter and therefore inertia. As with the engine flywheel, the propeller resists acceleration but once spooled up to speed, resists deceleration. It is this feature that is a major cause of the torque reversals transmitted via the driveline to the gearbox. The bigger the propeller, the higher the inertia and the greater the magnitude of torque reversal.

I hope this article is of use or interest to fellow members of the Gardner Engine Forum. Unfortunately, due to pressure of work, I cannot respond to queries or requests for advice via phone or mail.

All the best
Charles.