THE VAPORIZING OF PARAFFIN - E. BUTLER

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FOR

# HIGH-SPEED MOTORS

(ELECTRIC IGNITION TYPE).

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BY

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# PREFACE.

The Vaporizing of Paraffin for High-Speed Motors is a subject of paramount importance at the present time, and, in response to the request of the publishers, Messrs. Charles Griffin & Co., Ltd., who are ever watchful to supply topical needs, this small handbook has been prepared.

The persistent upward trend in the cost of petrol, following upon the ever-increasing demand, plainly indicates the immediate importance of substituting a more economical fuel. The developments and progress made in the use of the flash-proof, non-tax, paraffin grades of oil fuel for high-speed motors of the electric ignition type, point to a solution of this problem, and the following chapters are the outcome of many years' experience and study of the subject. The underlying principles involved in the application of this fuel have been dealt with in the light of most recent experience, whilst contributions on the subject by the author to the technical journal, *Ignition — Carburetion — Lubrication*, which met with great acceptance in the United States of America as well as in this country, have served as the basis of the text, and their use gratefully acknowledged. To the several firms who have kindly afforded information regarding their productions, the author also tenders thanks.

It is hoped the little book will prove of service to engineers and designers, as well as to mechanics and others interested.

EDWARD BUTLER.

LONDON, *October*, 1916.

# CONTENTS.

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## CHAPTER I.

### INTRODUCTORY REMARKS.

In the successful use of a flash-proof fuel, such as any of the burning-oils known as "paraffin," there are many difficulties not experienced with the use of petrol or gas, especially for running motors of the high-speed electric ignition type; for a liquid fuel not vaporizing freely at ordinary temperatures is so different from that of gaseous, being composed * of an almost unending series of gradations. Thus, although crude petroleum in the main is only separated into a few principal grades by the process of refining, such as the benzine and paraffin series, intermediate and residual or fuel-oil grades, these again vary in themselves almost indefinitely, according to the origin of the raw material and to the particular method adopted in separating out the various constituents. For instance, no grade, light or heavy, is of regular composition as water is, but is compounded of a blend of different densities and flash-points; for this reason the refining process can and is modified to a

* The reader should refer to "Oil Fuel, its Supply, Composition, and Application" for further information on this subject.

considerable extent to produce the different commercial grades in varying proportions to suit the demand, and, as the more volatile constituents are now required in ever increasing quantity for motor spirit or petrol, the paraffin or lamp-oil grades are now of a more regular composition than used to be the case.

However, the effect of processes having the object of extracting a higher percentage of motor spirit at the expense of the paraffin series, on an oil engine of the vaporizer class, is more beneficial than otherwise, especially in those of the larger series; but conversely, all paraffin grades are, as a consequence of this, more difficult to use satisfactorily in high-speed engines depending on an exhaust-heated vaporizer, and this is more pronounced in engines required to run, as in automobiles, under varying load conditions. This also explains in some measure the reason why so few tractors, motor lorries, and of course ordinary touring cars have hitherto been run on paraffin, despite its much lower cost and freedom from taxation.

But with the enormous demand for motor spirit increasing in a greater ratio than the production, coupled with present curtailments in supply due to shipping restrictions, its price has now advanced to such a point as to practically prohibit its use for stationary and tractor motors, and indeed for all classes of road-car motors used for commercial purposes. In this connection we find that on the Continent, for some two or three years past, benzole has been more extensively used for these purposes than motor spirit; the 1200 motor omnibuses in service before the war in Paris, for instance, were all driven by benzole, and as the difference then existing there in the price of the two fuels was as 11d. to 16d. per imperial gallon, and as the daily consumption amounted to 17,000 gallons or more, when allowing for 1000 buses in active service, means a daily economy in the fuel account of close on £320. The practice, however, of using benzole for power purposes had not caught on to a very considerable extent in Great Britain before the war, although then obtainable at a little over 1s. per gallon at most of the gas works; the reason for this may be partly explainable by reason of this fuel having a slightly corrosive action on the tanks and connections when not carefully purified, and in part, no doubt, owing to the specific gravity often found to fall below that obtaining in ordinary commercial benzole, which should consist of 90 per cent. benzole plus 10 per cent. toluol; however, both of these products are now in demand for explosives; but there is a further reason, and that is that motor spirit is so easily procurable almost anywhere, that the ordinary user sets convenience against the lower price, notwithstanding that to run on benzole no important structural modification is necessary either in the carburettor or in the degree of compression. Alcohol, it is true, might under favourable conditions be considered a more promising substitute as a motor spirit, either used alone, or mixed with benzole, which latter fuel when of equal proportions is found to work well in the ordinary petrol motor; but, as yet, little is definitely known as to the minimum cost of its production on a large scale.

The only other alternative liquid fuel suitable for high-speed internal combustion engines of the electric ignition type is paraffin, or blends of this with petrol. Fortunately, there is as yet little or no sign of any material falling-off in the output, despite the increased production of motor spirit, which has made it necessary by partial dissociation to encroach on a considerable proportion of the distillate previously included in the paraffin grades. Paraffin, again, has escaped the tax-gatherer, and for this and other reasons its cost is never more than one-half, and is now less than one-third that of petrol. As an off-set to this, however, and despite all the modern refinements of modern processes, paraffin is not only comparatively pungent, but difficult of carburetion, so as to run a high-speed motor under variable conditions of load and speed with a clear exhaust, this difficulty being in inverse ratio to the size and speed of the motor, and as a natural consequence of this the successful application of paraffin to motors of the automobile type has been held back to a considerable extent. But owing to the increasing cost of petrol renewed efforts have been, and still continue to be, made by engineers to evolve a really successful high-speed paraffin motor especially adapted for the very trying conditions met with in the running of road cars, motor boats, and for other purposes served so successfully by the petrol motor.

As explained, either an exhaust- or lamp-heated vaporizer, or its equivalent, is necessary for the successful use of flash-proof oils; such may either take the form of a combined vaporizer and carburettor, or be connected up to an ordinary petrol carburettor as a separate fitting. For road-car motors and tractors which usually have to run with a high jacket temperature of 180° to 200° Fahr., and under more widely varying load and speed conditions than required for marine or stationary work, either the combined carburettor and vaporizer should be capable of very perfect automatic mixture and temperature control, or be skilfully manipulated, in order that the full power of the motor may be obtained with open throttle, and complete combustion when running slowed down or declutched.

Paraffin motors of the electric ignition type, owing to their ability for more perfect timing of the explosion effect, are faster and more amenable to a wide range of speed control than motors dependent on a cylinder-head vaporizer, although for the intermediate class of marine craft, such as fishing boats, small cargo boats, and the like, also for stationary work when used under conditions where there is objection to the use of a blow-flame at starting, paraffin motors constructed to vaporize on the explosion-heated or cylinder-head principle have certain advantages for the heavier class of work; but as all motors constructed according to this method must have a separate vaporizer for each cylinder, and, in addition to being heavier, are incapable of the high speeds obtainable in motors of the electric ignition type, the latter method is obviously better adapted for motors required to run on flash-proof oils, wherewith a high-power duty is an important desideratum, which remark applies more especially to motors limited in power to that required for motor boats, tractors, lorries, as well as for touring cars, etc., and, of course, for a number of other applications, such as small electric and pumping installations and the like.

In such motors the external method of vaporizing the paraffin, as by utilizing the heat of the exhaust, is the one most generally adopted, owing to its applicability to motors of the light-oil or motor-spirit type without interference with their *modus operandi.* The method usually adopted for spraying paraffin is very similar to that used for petrol, the flash-proof fuel being subject to the same requirements for a variable supply of a mixture of constant strength as the light oils, in addition to which it is of the utmost importance that the temperature of the vaporizer should be maintained, as nearly as practicable, constant over a wide range of load in order to prevent either overheating of the mixture supply, or incomplete vaporization and consequently imperfect combustion.

## CHAPTER II.

### PETROL CARBURETTORS.

The value of liquid mineral hydrocarbons and vegetable carbohydrates has long been recognised for use in explosion motors of small power, thanks to the ready adaptability of the more volatile products obtained in the process of distillation for paraffin or kerozene, such as used for burning oil. Indeed, the benzine series, benzoline, essence-de-petrole, gasoline, now better known as motor spirit, lends itself so readily for either supplying carburetted air or spray direct to the motor cylinder, that, in spite of the necessary precautions for storage and distribution, spirit motors had already become very widely adopted for general purposes requiring a comparatively small power, before the introduction of the automobile. The method of forming an explosive mixture at first consisted invariably of a specially constructed carburetting chamber, through which the motor aspirated its air supply, and consequently operated on the evaporative principle. The air in an apparatus of this kind became super-saturated, and was mixed with a further supply of air before admission to the motor, the action of which in other respects was not dissimilar to the ordinary motor operating on illuminating gas; but as all such gasifiers, known as surface carburettors, depend for their action on absorption of spirit vapour by the air circulated over or through the liquid, they must obviously be of large capacity, and as they have the further disadvantage of being very sensitive to differences of temperature and to density of the particular grade of motor spirit used, all surface or vapour generator carburettors have long since been superseded by apparatus capable of a more accurately determined admixture of the fuel. Carburettors in great variety have been used since the introduction of the motor car, a circumstance explained by the fact that what is required of it is so very much more exacting than for any other purpose, and are described at considerable length in "Carburettors, Vaporizers, and Distributing Valves"; but as the treatment of paraffin for use in high-speed motors of the electric ignition type conforms so closely to that for motor spirit, a preliminary study of the leading types of petrol carburettors will be instructive in explanation of some of the difficulties met with in the running of a motor under the extremely variable range of load and speed conditions of an automobile.

**Injection Carburettors.**—One of the most effective methods of carburetting air by the direct injection of petrol in the form of a spray consists in the combination of an air-pump, pressure fuel tank, and spraying nozzle, really a development of the common hand-bulb vaporizer; by this method, first used in France by Etève, a most perfect mixture can be produced for varying speeds under the control of synchronized fuel and air-supply throttles, but entails more complexity of apparatus than is compensated for by any commensurate advantage gained. Another method more widely used than now, is to inject the fuel in the form of a spray by a small pump, the principal objection to which is the difficulty of avoiding leakage past the plunger gland; this drawback, however, can be remedied in some degree by using a superstratum of glycerine, and can be avoided altogether by using a diaphragm pump. In operation, the injection feed from a pump carburettor can be regulated

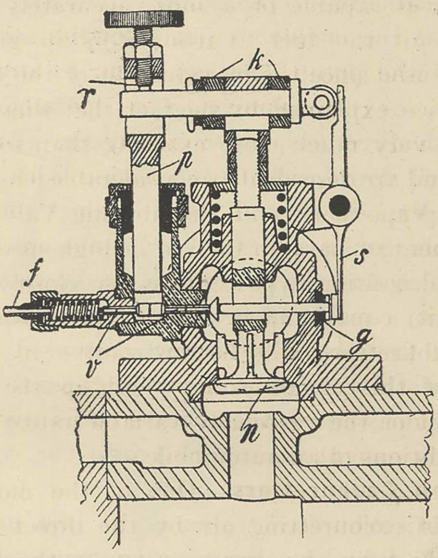



Fig. 1.—Spray Injection Plunger Carburettor with Mechanically Actuated Valves.

either by varying the stroke of the plunger or by a cut-out action; an example of each of these methods is shown in Figs. 1 and 2. In the first—of continental design—one of the difficulties of maintaining an accurate feed is obviated in great measure by two mechanically actuated valves *v*, one of which is held closed to the spraying chamber by a stiff spring, except when, by the action of the governor-controlled stop *g*, the spring lever *s* is permitted to close one valve *v* to the fuel supply *f*, and open the other to the valve *n*, which is opened during the admission strokes by a cam-operated lever *k*. In practice, even with the most accurately constructed mechanism, a variation of injection feed caused by particles of solid matter adhering to the pump valves will, from time to time, cause the engine to run below its rated power; leakage past the pump does not occur to any considerable extent, as the plunger *p* is operated mechanically in both directions, consequently the gland can be tightened well down without interfering with the action of the plunger. In several spirit engines of American make the plunger is operated by a cut-out gear, and the fuel regulated to the pump by a needle valve, and are for this reason capable of more convenient and accurate feed control than by a set-screw *r* as used in Fig. 1. A feature of this engine consists in the use of a weir over the inlet passage to the cylinder, thus any drip from the pump is caught and swirled into the compression space when the inlet *n* opens.

A pump injection feed works at its best in an engine of the single-cylinder, slow-running type, although it has been used with success in high-speed multi-cylinder engines, as exemplified in the Wright and Adams-Farwell aero motors. As, however, the injection from a constant stroke pump is influenced by valve leakage as well as by difference of level in the fuel tank, a pump carburettor having a variable governor controlled stroke has a certain advantage, especially when worked in conjunction with a regulated air supply. With this purpose in view, the pulsator carburettor shown in Fig. 2 was devised by the writer for supplying accurately proportioned mixture to a single-cylinder petrol engine under direct control of a throttle; this method is obviously limited in its application to comparatively slow-running engines, and, even at its best, a very slight tightening down of the plunger gland $p$ materially affects the degree of deflection of the vane $v$, and although since

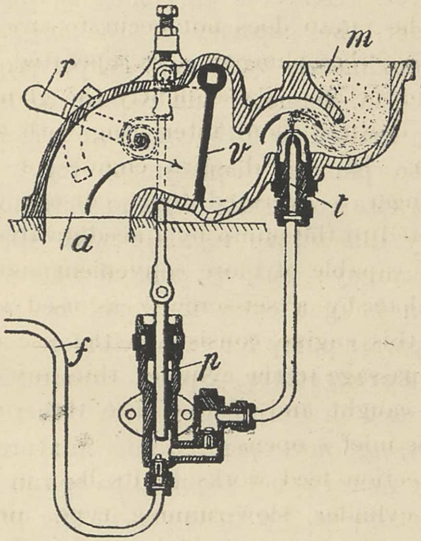



Fig. 2.—Plunger Carburettor with Variable Stroke.

applied in a more direct acting manner to an automobile motor, a pulsator carburettor depending on the action of velocity of mixture flow in combination with a spring return movement cannot be considered a success. The difficulties of applying an injection pump to produce a constant mixture of varying volume will be better realized when it is clearly understood that the liquid combustible to be injected at each pulsation is limited to 1 volume for a minimum of 8000 volumes and a maximum of 12,000 volumes of air; or, in other words, 1 lb. of petrol must be mixed with 15 to 20 lbs. of air to work with anything approaching to a reasonable efficiency; in this connection it is useful to remember that a mixture of 1 to 10,000 produces the most forcible explosive effect. Hence, in an engine having a 6-in. by 10-in. cylinder, the capacity of the injection pump must be approximately 0·028 cub. in. per stroke; *i.e.*, a plunger of 0·5 in. diameter will require to be operated with a stroke limited to 0·156 in., from which it will be seen that the plunger displacement for a high-speed motor of the size commonly used in automobiles would be extremely difficult to regulate with the necessary degree of accuracy; but, as pointed out, even if this difficulty can be got over, it would be necessary to provide a separate pump for each cylinder.

**Snifting Carburettors.**—Spray carburettors of this type, when used in conjunction with either a mechanically or a pressure-flow operated inlet mixture valve, and provided the motor is not required to be run over a wide range of speeds—as, for instance, in the propulsion of motor boats and for many industrial purposes—are capable of producing fairly satisfactory results, and are much favoured by users and makers alike, owing to their simple action and low cost of manufacture. Of this type there is considerable variety, but most resemble in essential construction one or the other of the examples illustrated by Figs. 3 to 5; of these it will be noticed the first is shown arranged with a mechanically operated snifting valve *v* and the cam-lever mechanism *k* for governor control on the hit-or-miss system, the step-block lever *b* being connected by the rod *g* to the

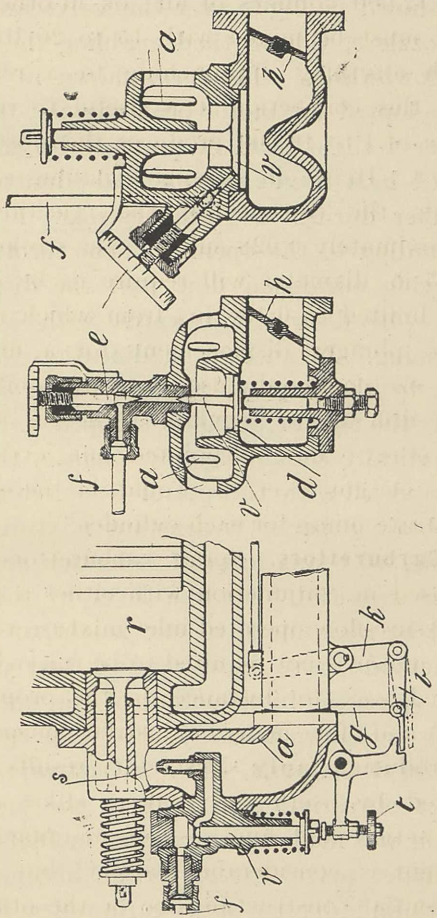


Fig. 5.

Fig. 4.

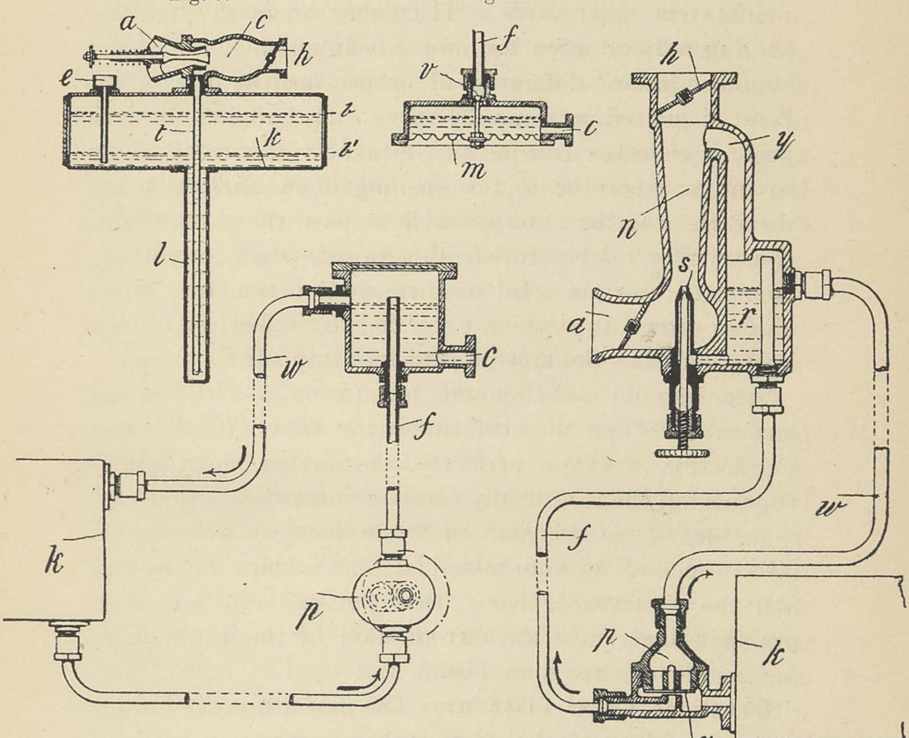
Fig. 3.

Figs. 3 to 5.—Typical Gravity Feed or Snifting Carburettors.

governor. Petrol is supplied by the tube *f* from a tank placed above the level of the motor, the feed being either regulated by a needle valve as at *e*, or by adjusting the lift of the valve as shown at *t*; the spray in some designs is fed to the under side of the valve to an air chamber, as shown in Fig 3, over the valve and thence to a spray nozzle *s*, this method enabling the valve to point stem downwards. The form shown in Fig. 4 is that usually adopted for motor-boat engines, the petrol supplied under a slight head or pressure by the tube *f* being regulated by a needle valve *e*, and admitted to the mixing chamber during the intake strokes in varying quantity, according to the opening of the throttle *h*, the resulting varying admission flow past the disc *d* thus causes this to be drawn downwards with a varying degree of opening. In another modification the petrol is fed direct to the seat of the air valve, as shown in Fig. 5, thus the flow of petrol is stopped to a certain extent automatically should, by any chance, the motor come to a standstill with the petrol feed left on. But in order to obtain a perfectly constant mixture in continuous working with any form of induction action carburettor, it is essential that the level in the supply cistern should be maintained at one height, and to this end many methods have been devised and put to a practical test since the introduction of the automobile, many of which are shown below.

**Constant Level Cisterns.**—The first attempt to minimise the effect of variation in level of the fuel in the supply reservoir was made by the writer in 1885–87, in a small two-cylinder petrol motor for an automobile, in connection with an induction spray carburettor, as shown in Fig. 6, this consisting of a vena-contracta shaped air nozzle delivering into a mixing chamber *c*; in this the spray feed was induced to flow from a tube *t* into an annulus behind the choke-tube, forming a continuation of the air inlet cone *a*. This particular form of carburettor was mounted directly over a shallow cistern *k*,

Fig. 6. Fig. 7.




Figs. 8. Fig. 9.

Figs. 6 to 9.—Methods for maintaining a Constant Level in the Fuel Cistern without a Float-feed Valve.

provided with a compensating well extension *l*, into which the suction tube *t* depended; the feed was regulated by a needle valve, the duct leading into the annulus.

By the action of the well *l*, the increasing suction effect required for a lowering level was diminished in the proportion of the depth of the well to that of the cistern, and with such effect that the auto could be tilted over in either direction, as by road camber or gradient, without appreciably affecting the working of the motor; also the effect of difference of levels, as from *b* to *b′*, in place of requiring some 30 per cent. greater suction effect, was reduced to a 10 per cent. difference; thus the motor could be run with but little slackening of power or speed for a considerable time, without requiring adjustment of the petrol feed. As a further corrective, the cistern was provided with no vent other than by a tube, as shown at *e*, which extended to the bottom of the cistern and thus produced a bird-fountain effect.

According to another method (Fig. 7), Griffin's, a constant level can be obtained by the effect of difference of deflection of a thin corrugated diaphragm, *m*, to which is connected the feed valve *v* from an overhead supply as by the duct *f*; in this manner the diaphragm is caused to rise as the level of the petrol falls, and, being connected with the regulator valve *v*, thus increases the opening correspondingly. In another method for maintaining a constant level, shown in Fig. 8, and used in connection with stationary engines of large size, when it is desired to locate the fuel tank below ground, a pump, *p*, is used to circulate the liquid to an overhead cistern provided with an overflow, *w*, the pump capacity being in excess of the maximum amount drawn off through *c* to the carburettor. This method has the advantage of enabling a large supply of fuel to be kept unaffected by temperature variation, and minimizes leakage and evaporation.

There is yet another method, as shown in Fig. 9, for raising the fuel supply from a low level service tank to a constant level carburettor cistern. According to this rather ingenious device (Olds) the suction effect produced partly by the use of an extra long choke-tube, *n*, is utilized to actuate a small pulsator pump, *p*, through the duct *y* and suction pipe *f*, by which means a flow of fuel is raised at each suction stroke—*i.e.*, provided the throttle *h* is open—along the pipe *f*, the pulsator valve *v* being drawn up to its seat during this period, thereby closing down all suction effect along the pipe *w*, which then takes the place of an overflow from the cistern *r* to the main tank *k*, and in this manner maintains a constant level in the cistern.

The method now most generally adopted in all petrol and paraffin motors is some form of float-feed valve controlled constant level cistern, the earliest application of which for this purpose was made by the writer in a three-cylinder launch motor made in 1888-89; the float cistern for this, of the hinged type as shown in Fig. 10, was not dissimilar to the form of float cistern now used by many manufacturers of stationary paraffin and petrol motors, and also in a number of automobiles of American construction in somewhat modified form, the principal difference being the substitution of a cork float in place of the spun copper ball (*vide* Fig. 21). The hinged float, also adopted in the Binks petrol-paraffin carburettors, possesses points ahead of the more compact form of cylindrical float cisterns (*vide* Figs. 11 to 15), such as more generally used in British and European motors for road cars and motor boats, but is not so compact.

Of the five forms of cylindrical float cisterns shown, there does not appear to be any marked advantage one over another, each form as far as can be seen being equally favoured, with minor differences, such as the

Fig. 10. Fig. 11. Fig. 12.

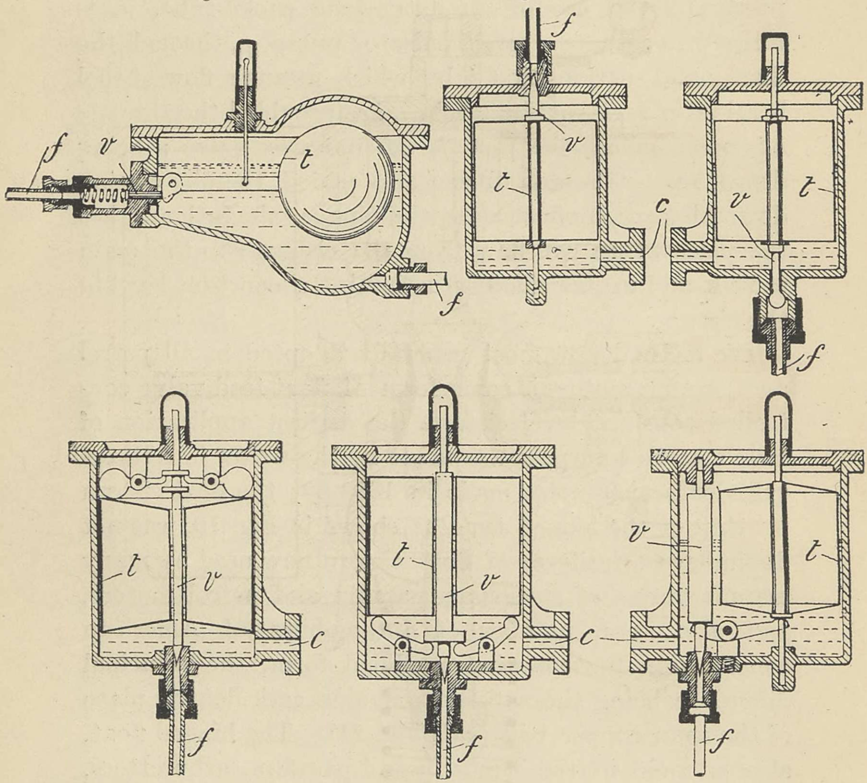



Fig. 13. Fig. 14. Fig. 15.

Figs. 10 to 15.—Various forms of Float-feed Carburettor Cisterns.

method used for clamping down the cistern cover, the size and form of float, and the means for balancing the same. In this latter respect, however, it should be stated that, although the balanced form of float valve, as shown in Figs. 13 and 14, used to be the vogue, there is now a tendency to revert back to the simpler and more direct

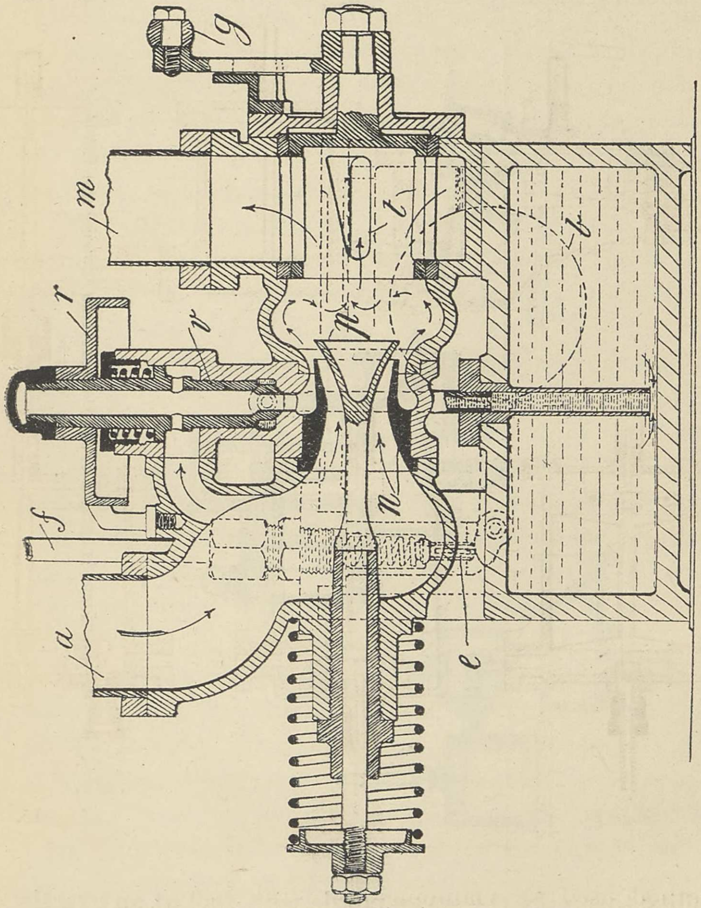


Fig. 16.—Early Form of Automatically regulated Induction Spray Carburettor with Float Feed and Drum Throttle (*Butler*).

forms, such as shown in Figs. 11 and 12; a point of advantage with direct-acting floats is their adaptability for being examined in operation by the removal of the cistern cover.

Side float cisterns, such as illustrated in Figs. 10 to 15, although extremely simple and get-at-able, have not the

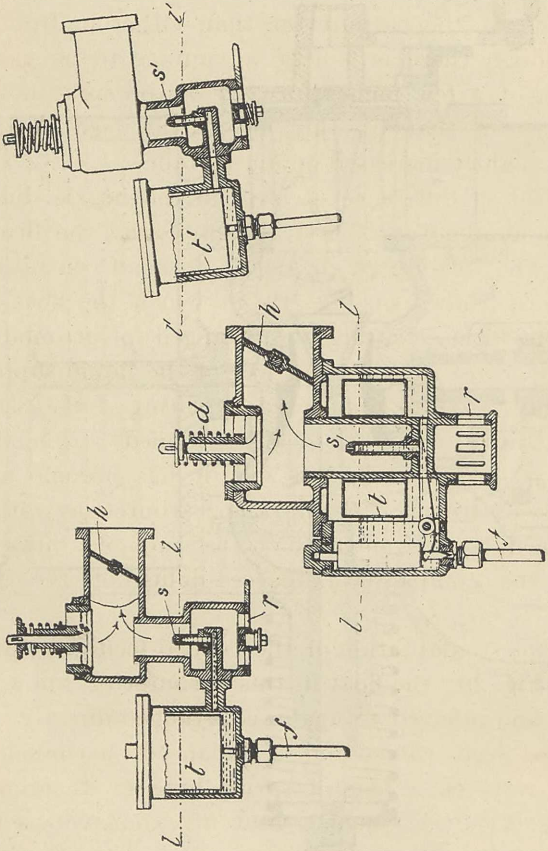


Fig. 17. Fig. 18. Fig. 19.

Figs. 17 to 19.—Sectional Diagrams of Jet Carburettors showing the Effect of Tilt on the Spray Nozzle.

ability to supply the spray nozzle with fuel at an exactly constant level when the carburettor is tilted over in either direction, as for instance, in ascending an incline, or when a car is running along the side of a cambered road; the effect of this can be seen in the two illustrations, Figs. 17 and 18, the latter showing the drop of level in the spray nozzle with a 10 per cent. tilt. For this reason, it is obviously better to fix the float cistern at the side of the carburettor than either in front or rear, although there is a little advantage to be gained by placing it a few inches forward of the spray-nozzle, for the reason that by this means the feed is automatically slightly increased on an upgrade.

The effect of difference of level in the nozzle due to camber or gradient was first recognised by the firm of De Dion, who introduced in 1900 a form of central-feed float cistern, shown in Fig. 19, in which the float *t* is made in the form of a ring and arranged to surround the choke-tube, consequently the level of the liquid supplied to the spray nozzle is unaffected by tilting of the cistern in either direction by the causes named; in modern practice, it is noteworthy to add, it has become more and more customary to fit the carburettor with a central feed, or as near to it as possible, notwithstanding the comparative inaccessibility of the float valve.

The simplest adaptation of the central-feed principle is shown in Fig. 20; the float in this carburettor, known as the Ware and referred to again, is arranged directly over a weighted feed valve, and is balanced, inasmuch as the float rests on a pair of spring hinges. In another form (Fig. 21), the Shebler, and in extensive used in America, the float is fork shaped and made from a solid slab of compressed cork with a hinged suspension; in this, the cork is made impervious to petrol by a coating of varnish and can be adapted to this design quite conveniently, one advantage of which is that by the removal

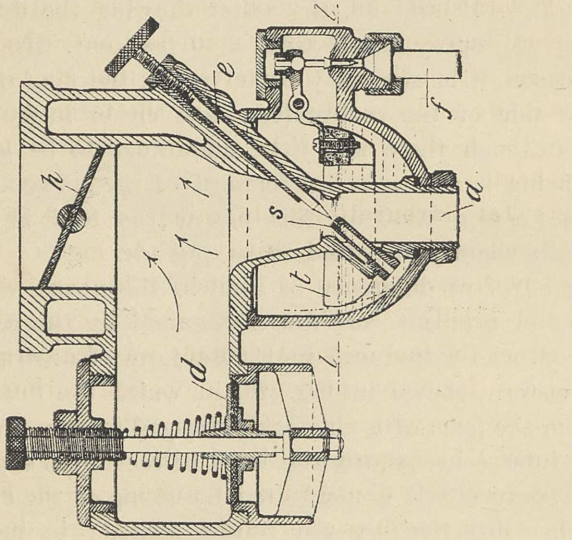



Fig. 21.

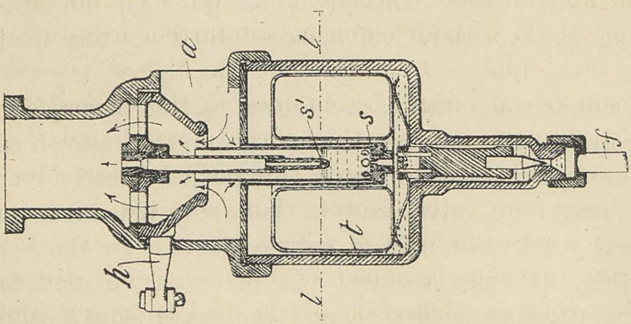



Fig. 20.

Figs. 20 and 21.—Typical Forms of Central-feed Jet Carburettors.

of the cap over the feed valve the level of the liquid can be ascertained and corrected to an exact degree by metal discs, either on the float or over the valve, as may be required. The advantage of a cork float, when properly varnished and of good compressed material, is its constant buoyancy, whereas a spun float has a tendency to leakage, although for the matter of that its replacement is easily and cheaply done. In the form shown in Fig. 21, the feed valve can be removed without taking out the float.

**Single Jet Carburettors.**—In order to work with a throttle-controlled mixture supply to the motor, it was quite early discovered that an induction feed carburettor would not supply a constant mixture at varying speeds unless either the fuel or the air supply was regulated; in the earliest form of float-feed induction carburettor, patented by the writer in 1889, No. 9203, this purpose was achieved by varying the area of the divergent nozzle of a vena-contracta choke-tube, by a plug, *p* (*vide* Figs. 6 and 16), which was drawn forward for a varying distance automatically, according to the volume of mixture supplied, thus enabling the motor to be regulated by a hand- or governor-controlled throttle, and over a considerable range of speeds, without requiring any further adjustment to the fuel supply. In order that the highest possible air-stream velocity might be obtained in the choke-tube, *n*, with a minimum of throttling effect, it was found that a condivergent nozzle answered this purpose more effectively than any other form, that adopted being in accordance with the waist of a Venturi water meter, and to further augment the inductive action of the air stream, and, to avoid any deflection of the fuel spray jet, this was drawn into an annulus surrounding the air nozzle, together with an auxiliary stream of air admitted through a duct in the fuel feed valve, *v*, which was provided with an index dial, *r*, and a cushion spring for taking up any lost motion in the fine thread on the valve stem. In this carburettor or fuel inspirator, the mixture was maintained practically at an equal strength for varying degrees of throttle opening, so essential for a motor to respond quickly either for a heavy pull or for speed when opened out; in running dead slow also, the plug *p* (Fig. 16), in reducing the area of the nozzle, caused the air to flow into the mixing chamber with a vortex effect, and to draw in the correct amount of fuel to keep the engine going, however slow; consequently starting was an easy matter, which is important. The fuel (benzolene) was drawn up from a float-controlled constant-level cistern of the form shown in Fig. 10; in this particular case the inspirator was arranged over the ball-float cistern, and drew its supply up through a pipe shown in dotted lines; the inspirator was also combined with a governor-controlled hollow plug throttle, *t*, and was fitted in a liner seat having a series of slots communicating with the supply pipe *m* leading to the engine.

In the jet carburettor used in the cut-out controlled Daimler motors of 1894-98 no automatic regulation to either the petrol or air supply was necessary, for the reason that the speed of the motor was constant and not under throttle control; the carburettor used was of the simplest possible construction, and closely resembled that shown in Figs. 17 and 18, but had neither air valve nor throttle.

The reliability of the jet carburettor was soon recognised as a great improvement on those depending on evaporative effect, especially for road cars, for which purpose, being alike exposed to jolting and to quick changes in temperature, all forms of surface carburettors proved fickle and at times extremely variable in action, and at their best required skilful manipulation from time to time to compensate for differences in fuel density. With the practice of employing electric ignition and throttle control, carburettors were at first used in which it was necessary to regulate either the fuel or air supply, or both, by hand, thus necessitating incessant attention, and, with all, uncertain results, as no two drivers would be in complete agreement as to the best procedure under the ever-changing running conditions imposed by varying car construction, road surfaces, and other factors. However, soon after the practice of fitting carburettors with some compensating device for varying load and speed conditions, the running of auto-motors became not only much steadier, but much less troublesome; the carburettors principally in vogue following this improvement took the form of that shown in Figs. 17 and 18 for several years. Immediately following this, the De Dion central feed (Fig. 19) carburettor was introduced, then the Longuemare (Fig. 22) with an equivalent action obtained by a pulsating combined air valve and choke-tube, *d*, a method later adopted in the Rover carburettor.

But, with the demand for a greater range of speed control, it was found that the addition of a supplementary air valve was inadequate in the manner then applied—*i.e.*, as fitted with a comparatively short helical spring that imposes an increasing resistance to opening; consequently, attention was directed towards some method for obtaining a more equable regulation by automatic means, and, as a result of this, there first appeared the Krebs carburettor (Fig. 23), with a diaphragm-controlled piston supplementary air valve, *d v*; then followed the Xenia carburettor (Fig. 24), fitted with a mercury-buoyed divided float cistern *m m′* and floats *d d′*, for controlling the admission of supplementary air, by a piston valve through ports *v*; in this, one of the cistern cells was placed in communication at *x* immediately behind the throttle *h*, and the other to the atmosphere. In other respects the construction of these two carburettors is much alike, and the purpose aimed at similar—viz., to obtain a more sensitively compensated action for different throttle openings, and in supplying the correct proportion of diluent air to form an approximately constant mixture over a wide range of speeds.

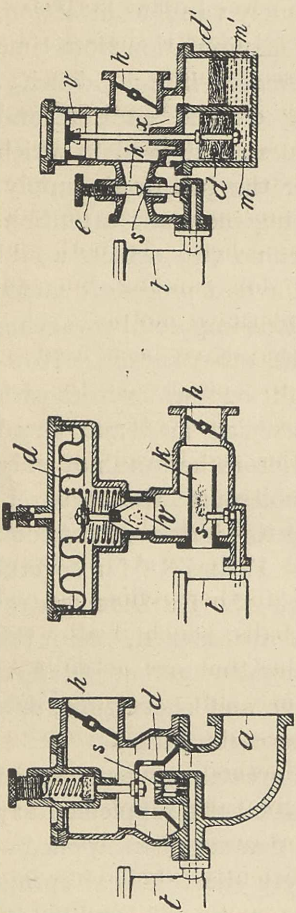


Fig. 22. Fig. 23. Fig. 24.

Figs. 22 to 24.—Typical Forms of Single-jet Carburettors with Automatic Air Supply Regulators.

It will be noted that a large flexible diaphragm is shown in Fig. 23, this exposing a considerable area to the varying depressions caused by difference of suction effect due to varying load and speed conditions and to opening of the throttle *h*; the proportion of air admitted according to the depression of the piston *v* was further corrected by forming the ports leading thereto, delta shaped. In the Xenia, by the use of a mercurial column, the depression of the float *d*, carrying with it the supplementary air piston valve *v* (Fig. 24), is capable of an even more accurate movement, as in this case it is exactly proportionate to the difference of pressure in the mixing chamber *x* and of the outer atmosphere. In both the choke-tube *k* is proportioned for slow running, but not dead slow, as required in more modern car motors.

Other compensating methods that have been used in single-jet carburettors arranged to operate on the air diluent principle may be mentioned—the vena-contracta choke-tube, first used in the Butler, the Decauville, and Excelsior carburettors. Of these the second-named is similar to the first, and in the last a floating ball is used; also in the carburettor known as the G. & A. this same method is adopted, but with a further refinement of action, by the aid of a nest of balls, which if all were of equal weight would act together, but are actually of different weights, and consequently lift in succession, according to the pressure depression in the mixing chamber; a modification of this method is also adopted in the Kingston carburettor. A great deal, however, can be done with a properly proportioned and delicately sprung lift-valve if made of sufficiently large diameter, light and sensitive in action, for a motor not required to run at less than one-fourth its rated speed.

**Variable Jet Carburettors.**—Previous to the more general adoption of variable jet carburettors having an automatically regulated spray action, there had been many introduced from time to time in which an equivalent action was obtained by a hand-controlled obturator located over the spraying nozzle, and connected up in some cases for being operated from the steering wheel—*e.g.*, the carburettor used in the Peugeot cars of 1904, the Jenatzy of 1905, the Shebler of 1908, and others—so that the mixture could be corrected for more easy starting and for steadier and more reliable running at slow speeds, thus providing a more elastic compensating action, and in a very simple manner, too, than possible to obtain by the aid of an automatically regulated supplementary air supply alone.

The first carburettors in which the fuel feed and air supply were simultaneously regulated in an automatic manner, in proportion to the volume of explosive mixture admitted past the throttle to the motor cylinders, were constructed to obtain this effect by means of an air piston and long needle valve, the movement of which in a vertical direction, if correctly proportioned, could be made to regulate the spray feed in an approximately exact proportion to the volume of mixture admitted to the motor. The sectional cut, Fig. 25, represents a Chenard-Walker carburettor as made in 1905 on this principle, from which it will be seen that a hollow piston, *n*, has attached to it a long taper pin *e*, entering the single nozzle *s*, and as the top of the hollow piston mixing chamber *n* is perforated, and as the lower end rests on a series of air ports communicating with the air supply *a*, this piston will be caused to lift in proportion to the volume of mixture admitted past the throttle *h*, the spray induced varying in proportion to the extent the taper pin is raised. Obviously, the lift of the piston *n* can be modified by opposing more or less resistance to its movement by the hand-controlled lever *r*, and in this manner make any necessary correction, as whatever the means employed, it is difficult to obtain a perfect regulation by a single adjustment for all running conditions.

It is possible to obtain a constant mixture over a considerable range of speeds by utilizing the varying velocity of the mixture flow to cause a piston, as in the

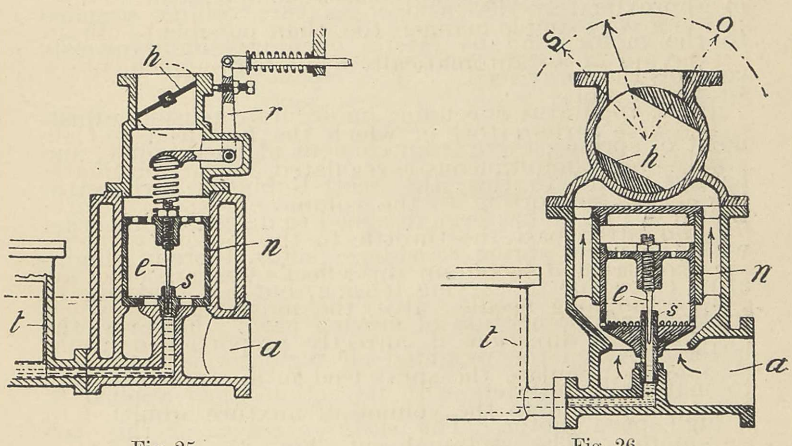



Fig. 25. Fig. 26.

Figs. 25 and 26.—Typical Constant Mixture Single-jet Carburettors with Automatic Variable Pin-regulated Feed.

Brotherhood-Crocker carburettor introduced at about this time, to carry with it a taper choke-tube, thus automatically regulating the air supply and simultaneously by means of a taper pin in the spray nozzle the fuel supply as well, provided the air and fuel ways are accurately proportioned in area. In the Westinghouse variable jet carburettor introduced in 1908, the air and spray admission valves are regulated by a diaphragm of large diameter, with the purpose as before described of obtaining a more accurate movement of the supplementary air valve, the larger area thus exposed to the varying depressions in the mixing chamber enabling a greater range of compensating effect to be obtained. In another variant in carburettor design, as for instance in the B.S.A., a variable jet action is obtained by a thimble over the spray nozzle, which is drawn up by the air flow in approximately the ratio of mixture volume supplied to the motor, and by lateral openings simultaneously controls the spray feed.

In all apparatus depending on accurate tension adjustment of springs, there is an element of uncertainty, and having regard to this, the Scott-Robinson carburettor shown in Fig. 26 has been designed to dispense altogether with the usual spring resistance factor, thereby eliminating error due to varying tension, but not that due to friction and momentum of moving parts; however, the latter effect on the weighted air regulator is not found to materially interfere with its action when applied to a high-speed motor. The *modus operandi* of this carburettor is such that the floating piston *n* is drawn up to a height determined by the admission of mixture past the drum throttle *h*, and carries with it a taper pin valve *e* fitting in the fuel nozzle *s*, the spray entering the hollow piston, and is thence drawn through a series of holes as shown, and mixes with air as it flows up from the neck-shaped choke passage forming the set of the combined air and fuel regulator piston. In running dead slow with this carburettor, the throttle drum *h* is nearly closed, and the piston regulator then rests on the neck over the air inlet chamber, when the necessary air enters through a series of small passages around the base of the piston.

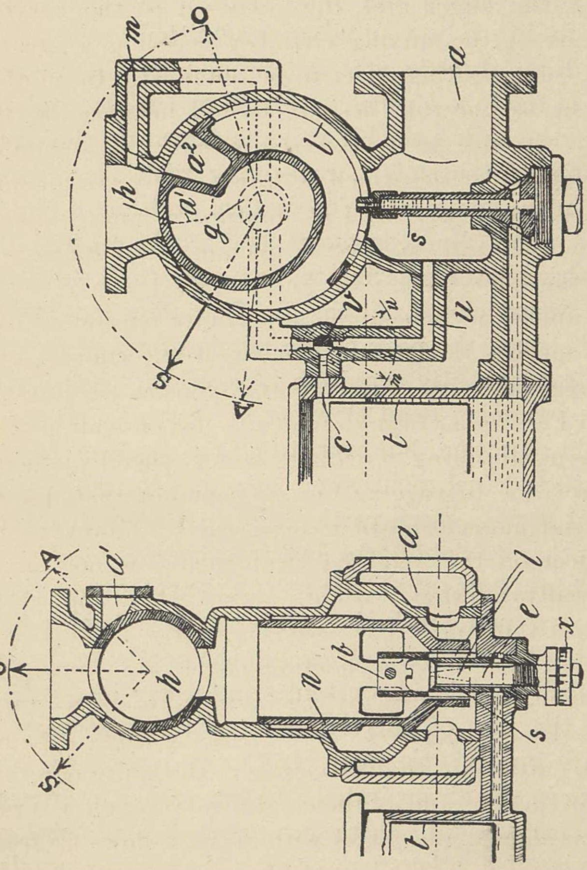



Fig. 28.

Fig. 27.

Figs. 27 and 28.—Constant Mixture Single-jet Carburettors with Shuttle and Variable Pressure Petrol Feed Control.

In still another modification, as exemplified by the "Ideal" carburettor, shown in Fig. 27, and resembling to some extent the one just described in that no springs are used. The opening for the spray feed is a lateral slit, the area of which is determined in an exact manner for different motors and running conditions, by the mitre-headed valve *l* and index dial *x*; the proportion of spray feed to volume of mixture admitted to the motor by the drum throttle *n* is determined by the vertical position of the tube *b* which is carried by the air regulator valve *n*; the higher the air valve is drawn up the wider is the area of the slots *l*, registering with the circular opening in the spray jet. The vertical position of the air regulator *n* and tube *b*, is shown as it would be, with the throttle drum lever pointing to, or nearly to, S, with the throttle almost closed, all the air then admitted having to flow between the neck of the regulator *n* and tube *b*, and will consequently acquire a high velocity, even with the motor running dead slow, or at starting. There is a two-fold objection, however, to all carburettors having sliding air and fuel regulators: one, due to friction and wear, and applies more particularly to the spray valve, and the other, to liability to dust interference.

**Variable Pressure Flow Carburettors.**—These belong to a type recently devised in which the spray feed is regulated by difference of level in the nozzle, so that an automatically regulated constant mixture can be obtained without the aid of mixture-flow adjusted regulators, which are subject to wear, frictional resistance, and impurities in the air aspirated; of this rather interesting type of carburettor, there are several modifications, some having one, others two or even three spray nozzles, but for the purpose of this treatise, which has for its object the general trend of carburettor practice, and a description of the various methods that have been devised and tried to enable a high-speed motor to be run successfully on petrol and paraffin or paraffin alone, one example of each will suffice. Of these, the Gillet-Lehman (Fig. 28) is a single-jet carburettor depending on a variable barometrical depression over the contents of the float cistern *t*, by which the level of the liquid supplied to the nozzle S can be lowered from the maximum height as shown, to such a level as will increase the resistance necessary to compensate for an increasing velocity of air flow around the nozzle. The drum throttle *h*, which is formed with a snail-shaped core, is shown closed or nearly so, and the actuating lever pointing to S, in which position the surface of the petrol in the float cistern is exposed to practically the full atmospheric pressure; also, with the throttle in this position, communication between the float cistern and the mixture supply or suction end of the carburettor, is cut-off from the passage *m*, as shown by the position of the groove *g* on the throttle stem; but on rotating the throttle from S to O, which is the full open position, the groove *g* will be gradually opened to the duct *m* leading to the float cistern, and will in consequence reduce the pressure therein, by reason of the communication straight through to the supply end—*i.e.*, *via* *c*, *v*, *g*, and *m*—the exact depression required to produce the best effect, as ascertained during the process of tuning up, is regulated once for all by an adjustment of the plug *v*, or its equivalent. By rotating the throttle from the closed position to A, communication is opened up direct to the atmosphere, *via* the side port $a^1$ and throttle port $a^2$. By this construction, it will be seen that the surface pressure acting on the contents of the float cistern can be arranged to either correspond with the fluctuations at the supply end *h*, or be modified by the pressure acting from the outside air inlet *a*, through the duct *u*, according to the adjustment of the plug regulator, as from *m* to *u*. The point is that once a carbu̇rettor of this type has been properly proportioned and adjusted to the required running conditions, its action will be independent of moving parts, other than the float, which is common to all.

In the Ware double-jet carburettor (Fig. 21), which also works on the variable pressure principle, the level of the petrol supply will rise to nearly the maximum height of that in the float cistern *t*, when running dead slow, and to the highest possible level just before starting, when the spray will be drawn up the nozzle $s^1$ from the well below supplied by the nozzle *s*, the mixture regulator *r* being meanwhile nearly closed, thus causing a great suction effect by way of the central tube; but as the combined mixture valve and throttle *r* is opened to obtain a greater power or speed, the level of the petrol in this tube will be exhausted below the nozzle $s^1$, when air will be drawn down between the outer and inner tubes subtended from the cistern cover partition, and enter the well space covering the primary nozzle *s*, and assist in carrying up the spray to the space above the neck of the throttle regulator *h*, where it will mix with the main supply of air entering at *a*. Thus it will be seen that the level of the spray feed supplied by the primary nozzle varies from *s* to the line *l*, *l*, according to the throttle opening and volume of explosive mixture supplied to the motor; also, as in the single-jet carburettor just described (Fig. 28), there is neither supplementary nor compensating valve of any kind required in this particularly unique form of carburettor, and further, it has the additional advantage of a central feed, and is, therefore, uninfluenced by road camber or gradient.

In the well-known Zenith carburettor (Figs. 29 to 31), which also works on the principle of a varying level in one of the two spraying nozzles, $s^1$, $s^2$, there is a third or starting nozzle $s^3$. This starting nozzle $s^3$, which is by the way the equivalent of the nozzle $s^1$ in Fig. 20, is shown in action in section (Fig. 31) with the throttle *h*

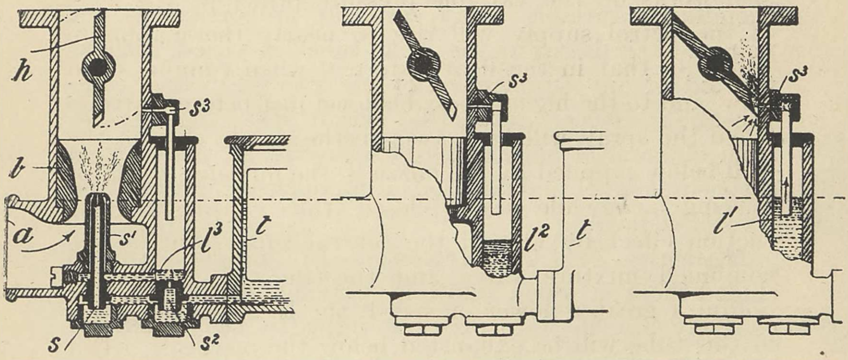



Fig. 29. Fig. 30. Fig. 31.

Figs. 29 to 31.—Sectional Diagrams showing the Effect of Fuel Level in a Multiple-jet Carburettor with different Degrees of Throttle Opening.

closed except for a slight air gap opposite the nozzle; a jet can, therefore, be drawn from the maximum level with a considerable suction effect when pulling over the starting handle, which is important. As a result of further opening the throttle, the two nozzles $s$, $s^1$ will be brought into action by the choke-tube *b*, the inner one of which is fed at constant level direct from the float cistern, and the other from the well *l*, which is in turn fed by the nozzle $s^2$; but as the nozzle $s^1$ is larger than $s^2$, the petrol level in the well $l$ will be reduced by reason of an increased flow of mixture past the throttle on this being further opened; thus, it will be seen in the section (Fig. 30), with throttle opening for half-speed, that the petrol level has fallen from $l^1$ to $l^2$; also, with a still further opening of the throttle as shown in the section (Fig. 29), the level has fallen to $l^3$, and as a consequence of this, the secondary nozzle $s^1$ having to draw its supply from a variable level, will deliver a correspondingly variable spray feed, in proportion as the volume of air drawn up the choke-tube $b$ is varied, without the aid of any supplementary air valve or other compensating device, automatic action resulting entirely from differential functioning of a central jet drawn from a constant level and that of an annular jet drawn from a variable level.

**Multiple-Jet Carburettors.**—In this class are included those in which multiple-spraying nozzles are successively brought into play according to the volume of explosive mixture admitted to the motor, as distinguished from those in which the spraying capacity of one or more nozzles is influenced by a variable depression as in those just described, or by variable induction; or again, a combination of both effects. The greater range and more constant degree of carburetion obtainable with the aid of multiple jets, is now beyond dispute, and is of the utmost value to motors in which flexibility for both power and speed is a factor of importance. What with the exigencies brought to bear by the intense national stress now in progress and the urgent demand for rapid transit, not only do the speed requirements of petrol motors in particular, indicate a more and more pronounced tendency for continual advance, but at the same time a capacity for instant flexibility of action, combined with an ability for running reliably at speeds ranging from one-fifth of normal, to meet modern requirements in high-class motor cars. In the attainment of this result the advantage of a pilot or auxiliary jet was early recognized; the Brooke double-jet carburettor of 1904, for instance, was fitted with a pilot jet in addition to a diaphragm controlled sleeve regulator *d, v*

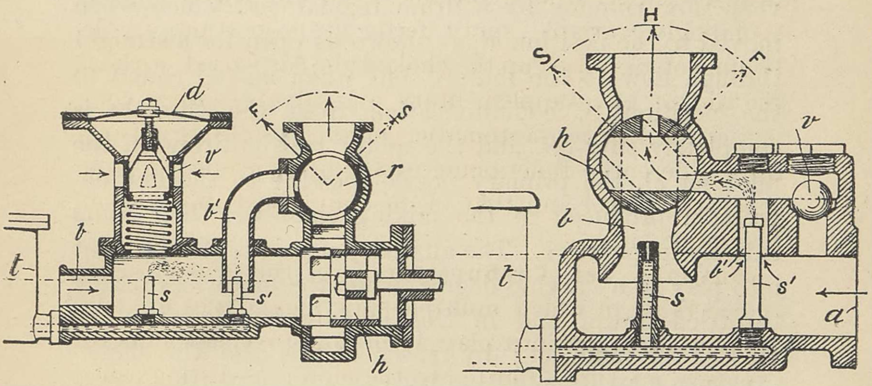



Fig. 32. Fig. 33.

Figs. 32 and 33.—Typical Constant Mixture Carburettors with Combined Action of Automatic Air and Spray Control.

(*vide* Fig. 32), for the purpose of admitting a supplementary supply of air to compensate for the depression around the spraying nozzle, as the result of open throttle and increased volume of mixture supplied to the motor, as by the governor-controlled piston valve *h*, when exceeding a certain predetermined limit. The action of this carburettor, as will be recognised, so far resembles that shown in Fig. 23, excepting in the disposition of the spraying nozzle *s*, which instead of being placed in the choke-tube *b* and subjected to the effect of a cross current, is in this carburettor arranged directly under the supplementary air inlet, and in consequence of the downward flow of air this has the tendency to check an increasing aspiration of spray due to depression in the mixing chamber. The distinguishing feature, however, of the Brooke carburettor is the auxiliary nozzle $s^1$, which is arranged to be brought into play at starting and for very slow running by a drum regulator *r*, which when moved to the position F, as shown, is open for a straight through flow to the motor; but when moved round to the position S, communication from the throttle is completely shut-off, and the motor runs entirely on the pilot jet $s^1$, the primary nozzle *s* owing to the low depression produced in the mixing chamber, then being entirely inoperative. The auxiliary nozzle is also brought into play to a varying degree, while the motor is running throttled down, and in this manner supplements the feed of the main jet; by reason of this also, the choke-tube *b* can be made larger, and thus permit a freer flow of air into the mixing chamber than can be obtained in a carburettor depending on the action of a single jet.

In the Solex double-jet carburettor (Fig. 33) a mixture of constant strength can be obtained in a simplified manner. Here, it will be seen, the auxiliary jet is combined with a small air valve to enable the spray to be automatically shut off, as soon as the motor has speeded up beyond a predetermined limit. In this there is no supplementary air valve used or required, and the main jet sprays direct into a choke-tube *b*, of slightly con-divergent form, arranged immediately under the 3-way drum throttle. As shown in the illustration, the throttle is in position for starting and running slow, and is closed to the main jet, all the air consequently is drawn up through the passage way $b^1$, which acts as a choke-tube for the auxiliary jet $s^1$. Now, on turning the regulator *h* over, from the slow position S, 45° or so, it will then be half open to the main tube *b*, and still be full open to the auxiliary spray inlet, as shown in dotted lines with the pointer at H ; but as a result of the motor speeding up to exceed a predetermined limit, there will follow a greater depression, and this will cause the ball *v* to lift, and thus automatically to put the auxiliary jet partly or wholly out of action ; again, with the throttle moved over to the full-open position as at F, the auxiliary jet is entirely cut out of action ; thus the *modus operandi* of this carburettor is partly due to variable pressure and partly to throttle controlled jet action.

In the Stromber double-jet carburettor, the auxiliary jet is directly controlled by a large supplementary air valve ; the primary jet choke-tube in this instance can, therefore, be comparatively small, thus enabling the motor to be easily started and to run slow when throttled down. Perhaps the simplest and most compact triple-jet carburettor is the Huggins and Parker, better known as the H.P. ; in this, a drum throttle directly controls and in succession, three spraying nozzles which are arranged at slightly increasing levels, and in this manner the jet action is corrected to compensate for the high velocity flow resulting from speeding up with open throttle. In the Smith quadruple-jet carburettor, again, the four jets are brought into play in succession by the lifting of a floating piston carrying four thimbles, which are of such length as to uncover the nozzles at different degrees of throttle opening. A still further refinement of action is produced in the Frier and Martin multiple-jet carburettor, by the use of three or more independent choke-tubes, each separately controlled by a hand-operated slide-valve connected to a throttle piston, a movement of which brings into action the series of jets progressively; in this example, however, the supply of air is corrected for varying speeds of the motor by an automatic valve, and for this reason, strictly speaking, belongs to a class apart from all others.

There is now, however, an increasing tendency to avoid the use of any form of jet or air adjustment depending on automatic action, owing partly to wear and leakage of the regulating device, but more to inconstancy of action resulting from the sticking fast or interference in the free movement of any form of automatic regulator, due to solid particles carried in with the air when travelling over dusty roads, for which reason as dust and finely attriturated grit is alike pernicious to the pistons and cylinders, it would be a great improvement and conduce to a much longer life, if an efficient filter were fitted to all road-car motors, especially as this can be done without materially interfering with the action of the carburettor.

An obvious remedy for the dust met with in many districts in dry seasons consists in the use of an arrester, made to operate either on the cyclone principle, or by causing all the air entering the carburettor to circulate down through a large filter box containing a series of fine gauze trays; the amount of dust that can be collected in this manner during a run of a few hours under road conditions only too commonly met with, is truly amazing; moreover, this dust is more harmful to both cylinders and crank-pin bearings than is generally realized.

In most of the more modern carburettors automatic adjustments are for this reason totally done away with —*e.g.*, in the Binks' multiple-jet carburettor, the mixture is regulated by the lift of spring-loaded valves, which can be ground in without trouble. In this, usually made as a double-jet carburettor, the spraying nozzles are successively controlled by one movement of the operating gear, and each is fitted with a separate choke-tube and air supply; one of which (*vide* Figs. 74-75), the pilot jet—whose tube is about half the diameter of the tube for the main jet—is first brought into action for starting and slow running, when for more power and speed, a further movement gradually brings the main jet into play, the latter then supplementing the former.

The Polyrhoe multiple-jet carburettor in one respect more nearly approaches finality than any other, by reason of the use of a plurality of jets which are successively brought into action together with a directly proportioned air supply, by the equivalent of an expanding choke-tube. In the diagrammatic sections (Figs. 34-35) illustrating this, the spray nozzle *s*, which extends the full length of the air inlet orifice, consists of thin perforated plates, quite easily cleaned, in which fine apertures are arranged to cause the spray feed to be projected laterally by the inrush of air in the form of a series of jets across the opening denoted by the arrows; the extent of this opening is controlled lengthways by a tongue *g*, which is caused to reciprocate in consonance with the varying depression produced in the mixing chamber, corresponding to the opening of the piston throttle *h* and the volume of mixture admitted to the motor. The exact degree of carburetion can be adjusted for all speeds by a movement of the slide *r*, by which means the width of the orifice for the admission of air can be varied to the required extent. Obviously, the number of jets brought into play, as well as the capacity of the air nozzle, could be controlled by a single movement of the throttle, thereby insuring a certainty of action under all working conditions; but could only

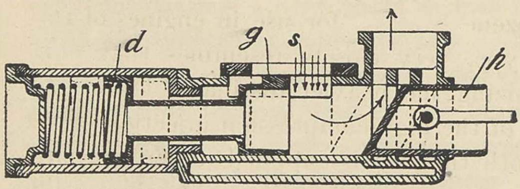



Fig. 34.

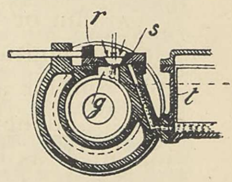



Fig. 35.

Figs. 34 and 35.—Multiple-jet Carburettor with Variable Air and Fuel Control.

be done at some sacrifice of constancy in the carburetion, owing to the reason that the velocity of mixture-flow to the motor does not necessarily correspond to the extent of throttle opening, but is influenced in part by varying speeds at which the motor is running, and while going at its slowest by the pulsating effect of each piston, owing to varying stroke velocity.

# CHAPTER III.

## METHODS OF VAPORIZATION OF PARAFFIN WITH OIL ENGINES.

**Early Methods with Compressed-Air Atomizers.**—The earliest method of vaporizing refined flash-proof oils—paraffin or kerozene grades—for use in engines of the electric ignition type, very closely resembles that now followed for atomizing the heavier distillates known as fuel oil in engines of the high-compression injection type, inasmuch as in both the fuel is supplied under pressure and is atomized by the agency of a stream of compressed air; but here the similarity ceases, as in the injection or Diesel engine, the fuel is supplied direct to the cylinder and against a compression sufficient to cause spontaneous ignition; whereas in the vaporizer engine, known as the Priestman, the fuel is supplied to an exhaust heated vaporizer, whence it is drawn into the cylinder together with sufficient air to form an explosive mixture and ignited under a compression lower than that used in the ordinary gas engine. In accordance with this pioneer system, really a development of one first introduced by Etève for using essence-de-petrole, a comparatively low compression was used, the clearance or combustion space allowed ranging from 40 to 50 per cent. of the sweep of the piston. The most remarkable feature of these engines is their extremely silent action, despite the fact that the total volume of mixture is drawn through a large exhaust heated chamber, such as shown in the sectional elevation (Fig. 36). In this vaporizer, which works efficiently with any of the refined flash-proof lamp oils, the mixture is only heated to the comparatively low temperature of 300° to 400° F., in which connection it is well to understand that the more perfectly an oil is atomized the lower is the temperature necessary for its combustion, which is an advantage,

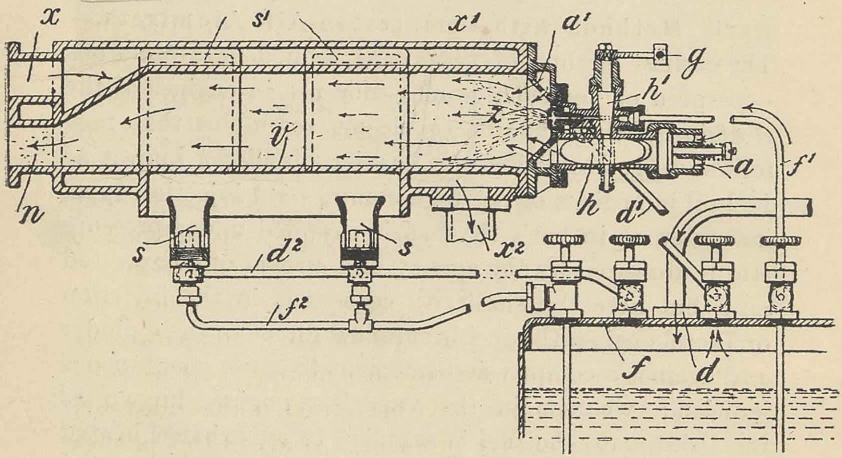



Fig. 36.—Exhaust-Heated Vaporizer with Compressed-Air Jet Atomizer.

if not off-set by the necessity for a more than corresponding complexity of apparatus, which in this case, as will be seen, requires an air pump and for the fuel to be contained in a tank subject to a pressure of 8 to 15 lbs. per square inch; and this again obviously necessitates a separate hand pump, or a pressure supply for starting. For this and other reasons, single- and double-cylinder engines on this system have not been able to compete with simpler methods, such as the direct induction paraffin carburettor type, and a number of others of the explosion heated type requiring also to be lamp-heated at starting, which are in great variety for industrial fixed and portable oil engines, and described at considerable length in *Carburettors, Vaporizers, Valves, etc.*

The efficiency of a compressed-air jet in atomizing heavy oils has been proved to be higher than any other method in large power direct injection engines, and it would seem now that petrol has advanced in price that this system might have possibilities in connection with high-speed engines of the exhaust-heated vaporizer type, in adapting these to run more efficiently on the cheaper grades of flash-proof non-tax oils, known as kerozene, paraffin, and as lamp oil; especially for purposes where perfect combustion with a clear exhaust, so difficult to obtain under variable speed and power conditions, is most desirable. As will be seen, however, there are difficulties in applying this system on a comparatively small scale as required for road-car motors; yet as other systems quite as complex have been tried, in the endeavour to solve this very elusive problem, a study of this pioneer system will not be without interest. Referring, therefore, to the sectional diagram (Fig. 36), illustrating its application to a stationary engine of the slow-running single- or double-cylinder type, and suitable for powers ranging from 5 to 30 H.P. or so, we find the essential features to consist of an exhaust jacketed chamber *v*, a spraying nozzle *z*, and a pressure oil tank *f*. The atomizer is fitted at the remote end of the vaporizer—*i.e.*, away from the motor cylinder—and is usually supplied with paraffin and air under a pressure of 8 to

10 lbs. per square inch, although 12 to 15 lbs. are found necessary when working with oils exceeding 800 to 820 specific gravity; this enters by pipes $f^1$ and $d^1$, connected respectively to the bottom and top of the pressure tank $f$, to which air is supplied along the pipe $d$ by a pump having a capacity of approximately 10 per cent. of that of the power cylinder. The throttle $h$, contrary to usual practice, is arranged to control the admission of air synchronously with that of the oil, and on this account tends to lower the pressure in the fuel tank as the throttle is closed; another effect of this throttle disposition is to assist in the vaporization of the spray while running on reduced loads and when the temperature of the exhaust gases entering the jacket $x^1$ is some hundred or two degrees lower than at full load. The spray throttle $h^1$ is connected by a lever $g$ to the governor, and as the fuel and air throttles are connected, both move together; also, the main air supply entering at $a$ is deflected on to the spray column by a series of converging openings $a^1$, and to prevent back flow during the interval between the suction strokes, a non-return valve is fitted on the inlet to the throttle $h$. The vaporizer is shown with flues $s^1$, to expedite the heating process necessary, as by a pair of pressure burners $s$, which are fitted with compressed-air spraying nozzles similar to the vaporizer spraying nozzle $z$; to these paraffin and air are supplied by the pipes $d^2$, $f^2$, from the main tank $f$, a hand pump being provided to maintain the necessary pressure during the 12 to 15 minutes or so required to raise the vaporizing chamber to the starting temperature. In connection with this vaporizing process much depends on the form of the atomizer, and also on the correct

proportioning of the oil and air supplies at different positions of the throttle ; for this purpose each of the pressure pipes is provided with a pin valve, and by adjustment of these the required pressure can be caused to keep within a small margin of that determined upon —*i.e.*, 8 to 15 lbs., according to the density and flash-point of the oil used. In the Griffin vaporizer, which is a development of the one just described, compressed air is also used, but with a different form of atomizer, the construction of the vaporizer also differs somewhat, but is essentially the same in general principle. The vaporizer is larger and a higher compression is used in the engine, and in the larger sizes the cheaper brands of semi-refined oils, such as solar, gas, and other intermediate grades can be used, the vaporizer being provided with a deflecting baffle for intercepting unvaporized residuum, which in practice varies according to the density and flash-point of the oil used, and also to the load on the engine, and consequently the temperature of the exhaust, and is drawn off from time to time from the base of the vaporizer.

**Early Methods with Induction Atomizers.**—The utilization of the heat of the exhaust in engines required to run on the paraffin lamp grades of flash-proof oils has the peculiar advantage over vaporizing systems depending on a more or less specialized form of cylinder, in that an exhaust jacketed or exteriorly heated vaporizer can be readily adapted to an ordinary one-, two-, three-, or four-cylinder gas or petrol engine, and with comparatively little structural change, as compared with other systems which all involve duplication of the necessary vaporizing chamber and oil feed mechanism for each cylinder. Exhaust-heated vaporizers, now in connection with automobile motors known as paraffin carburettors, have the further advantage of enabling an engine (1) to be started cold on petrol with the same facility as a simple petrol motor, or an ordinary gas engine; (2) to be run with throttle or cut-out control; and (3) to be capable of developing more power with a given weight than can be obtained on any other vaporizing system in engines adapted for running on paraffin oils.

The earliest application of this principle in combination with an induction spray carburettor, now so extensively used for enabling ordinary petrol motors to be run on paraffin, was made by the writer in 1890. According to this, illustrated in Figs. 37 to 39, an inspirator or induction spray carburettor of the kind shown in Fig. 16 is connected up to an exhaust-heated vaporizer adapted for either being heated by a lamp, as shown in Fig. 37 for starting, or as in Figs. 38 to 39 for being started on petrol or ordinary illuminating gas. Referring to the example shown in Fig. 37, which illustrates a form of vaporizer adapted for powers below 20 to 30 H.P., and actually used on a twin-cylinder, vertical, 6″ × 8″, Clark-Chapman paraffin engine fitted in a 15-ton yacht in 1893, and is of interest—in the light of the present and future importance of oil power on land and water to state—was probably the first to make an oil-propelled open sea passage in British waters—viz., from Larne Harbour to Greenock, a distance of some 90 to 100 miles, which was accomplished by a non-stop run in nine hours against a slight head wind. In this instance the vaporizer was adapted for being either heated by a blow lamp or by a preliminary run of two or three minutes on petrol, the fuel being supplied along a pipe $p$ past a two-way cock connecting either with a small cistern containing petrol, or with the paraffin cistern, which latter is fitted with a float constant level valve, as shown in Fig. 10. The oil is drawn past the hollow screw-down pin-valve regulator $r^1$, together with a 10 per cent. air flow down the tube $v$

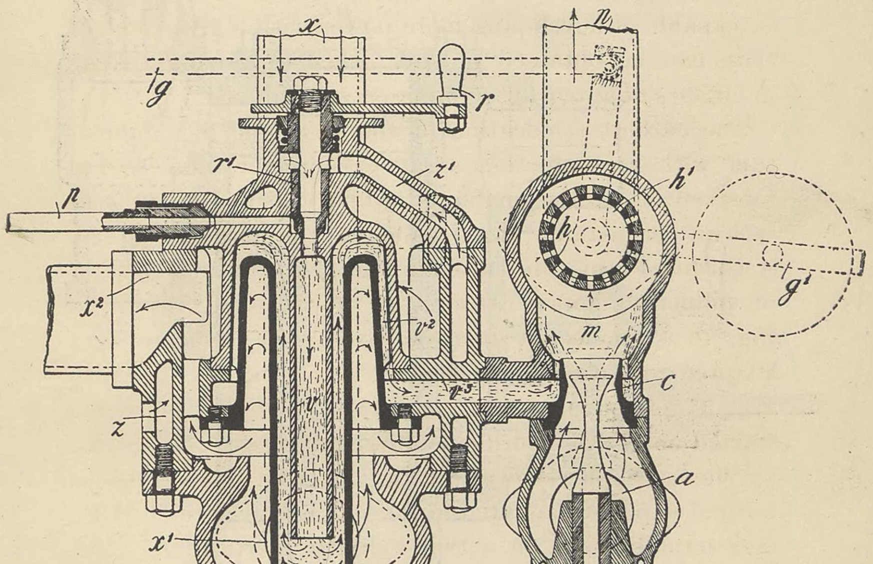



Fig. 37.—Exhaust-heated Vaporizer with Induction Atomizer for 6-inch × 8-inch Twin-cylinder Petrol-Paraffin Marine Engine.

to the bottom of the well $v^1$, whence the vaporized mixture is drawn down between a series of ribs $v^2$ in close contact on both sides with exhaust-heated surfaces ; the heated

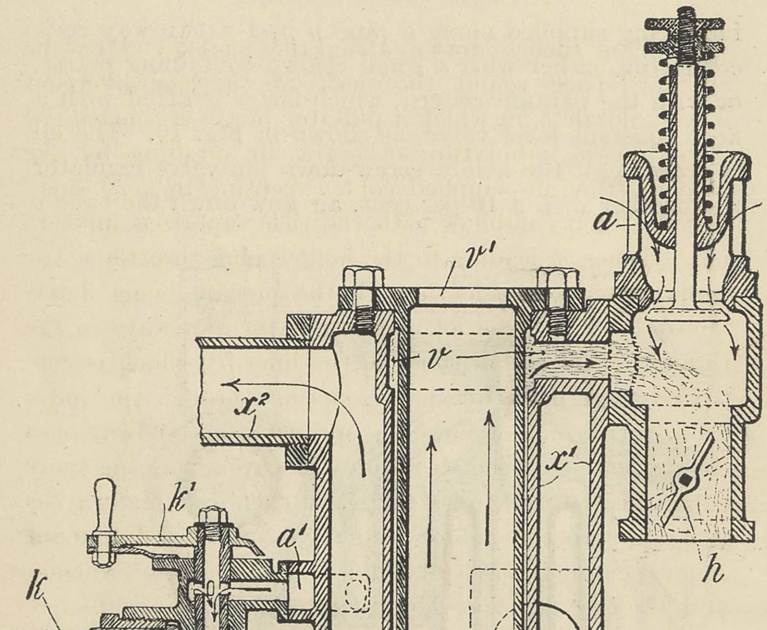



Fig. 38.—Combined Exhaust and Lamp-heated Paraffin Vaporizer with Induction Atomizer.

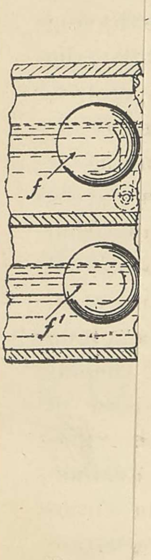
mixture is thence drawn along the passage $v^3$ to the annular space round the neck of the con-divergent mixing nozzle *c*, in which a pulsator plug *t* automatically regulates the admixture of extra air entering by the pipe *a*; this air supplied cold, excepting in very small engines, then combines with the rich vaporized mixture in the space *m* leading to the hollow plug throttle *h*, the supply to the engine through the pipe *n*, being determined by the degree of opening of the slot-ways in the throttle relatively to those in the liner $h^1$, which is controlled by a powerful shaft governor through the rod *g* against the pull of either a spring or, as shown, of a counterpoise $g^1$. The air required for atomizing the spray is first heated by the jacket *z*, and then drawn along the passage $z^1$ to the hollow feed regulator $r^1$. The engine exhaust enters the vaporizer at $x^1$ and leaves at $x^2$, whence, as in the case of a launch or yacht engine, it is conducted, after first passing through a cooling chamber into which the circulating water from the cylinders is injected, down to a long perforated pipe laid alongside the hull of the boat just above the keel, which is a method that serves as a very effectual deodorizer and silencer, and contrary to expectation causes but little back pressure—not exceeding 2 to 3 lbs. For starting, the vaporizer can be either heated by a burner placed under the flue *s*, or by a preliminary run on petrol, the former method, however, was at this time usually preferred on a yacht where a paraffin blow lamp is in continual service for culinary and other purposes, and time is of minor importance to safety.

This form of vaporizer with ordinary grades of paraffin requires cleaning out after a total run of 500 to 700 hours, which means about once a year, if only in occasional use as in a yacht or launch. To clean out the carbonized deposit, the union-nut of the fuel pipe *p* is first unscrewed and the nuts holding down the cover *k* taken off, this allowing the entire vaporizing surface to be opened up. In an engine of this size—*i.e.*, with cylinders 6 inches × 8 inches—no means other than a plentiful supply of cooling water is required to prevent thumping when speeded up to its full power of 12 to 14 B.H.P. at 550 to 600 revolutions per minute ; but when required to run slowed down for manœuvring or declutched, the running is steadier if a by-pass between the delivery and suction of the circulating pump is opened, so that the temperature of the cylinder jackets can be raised. This size of engine when connected up to a cooling tank for thermo-circulation works better if fitted with a by-pass on the exhaust for regulating the temperature of the vaporizer, as illustrated in Fig. 42, in order to subdue the harshness of the explosive action at full load, and in engines of larger size, it is better if supplemented by a second by-pass valve on a pipe connecting the exhaust with the air supply, for the purpose of diluting the mixture with from 5 to 10 per cent. of inert gases, so as to further suppress any tendency to thump ; the method of carrying this into effect is shown in modified form in Fig. 41, where the three-way plug $z$, when turned to the position shown, connects the passage $z^1$, leading to the spray feed regulator $r^1$, direct to the atmosphere through $z^2$, but when turned 90° communicates with the passage $z^3$, so as to draw in exhaust gas in place of air.

In the combined exhaust and lamp-heated induction spray vaporizer shown in Fig. 38, which is a modified form of the one just described, tube ignition is or was used, and the ignition burner utilized to maintain a more regular temperature in the vaporizer than is possible by means of the exhaust alone. In this, known as Barker's, the space *v* is heated on the outside by the exhaust circulated through the jacket $x^1$, and on the inside is heated by the burner *b*. Paraffin is drawn up from the fuel supply tank along the pipe *k*, this tank constitutes the base of the engine, and to compensate for difference of level (no feed cistern being used) the hollow screw-down feed valve $k^1$ is adjusted slightly from time to time; as in the vaporizers described in Figs. 37 and 39 to 41, a small proportion of heated air, about 8 to 10 per cent., is drawn down the centre of the feed valve from the belt $a^1$, and assists in atomizing the spray. By the use of a lamp the vaporizer for engines having a cylinder diameter from 4 inches up to 10 or even 12 inches, can be kept at a sufficiently high temperature for the engine to be able to work with a clear exhaust on reduced loads for long periods, provided the burner keeps going properly, but is not strictly necessary when running at or nearly up to full load. The use of burners is carried another stage further in the Gardner high-speed electric ignition paraffin engines, referred to later (*vide* Fig. 84).

Mention should also be made in this connection to an exhaust-heated paraffin vaporizer brought out by Smyers, as long ago as 1885, for use with the ordinary four-stroke gas engine, in which the feed was supplied by a pump, operated on the all or none principle.

**Suppressing Violence of the Explosive Action.**—In regard to the most suitable means for suppressing excessive violence of the explosive action of heated paraffin mixtures, especially when used in large cylinders: According to the writer's experience, the method of regulating the temperature of the vaporizer as shown in Figs. 41 and 42, is best for engines of moderate size, when using paraffin of specific gravity 780 to 830, although a similar effect can be obtained either by the injection of a water spray, which is the method most favoured, or by diluting the mixture with inert gas; but after having tried each method in combination and separately, the writer has arrived at the conclusion that the temperature of the vaporizer should be maintained as nearly as possible constant for all loads; that when running at less than half-load the whole of the exhaust should be passed through the vaporizer; that at full load, from one-third to one-half the volume, according to size of cylinder, should be diverted direct to the muffler, in addition to which a slight diluent of inert gas, equalling from 5 to 10 per cent. of the total volume of the air supply, should be fed into the mixture in the case of engines having cylinders exceeding 8 to 10 inches diameter; the most suitable amount of suppressing medium is obviously influenced by the temperature of the circulating water, the thickness of the walls, and formation of the combustion chamber. The degree of compression is important also, the lower this is, the quieter the explosive action, but, of course, is not economical in fuel consumption; thus, compressed-air atomizer vaporizer engines, as per Fig. 36, which were constructed to work with compressions ranging from 40 to 45 lbs., ran very smoothly without any suppressing medium. With higher compressions, not only are the temperatures higher, but less spent gases are retained in the clearance space, [To face p. 54.




verted Gas Engine.

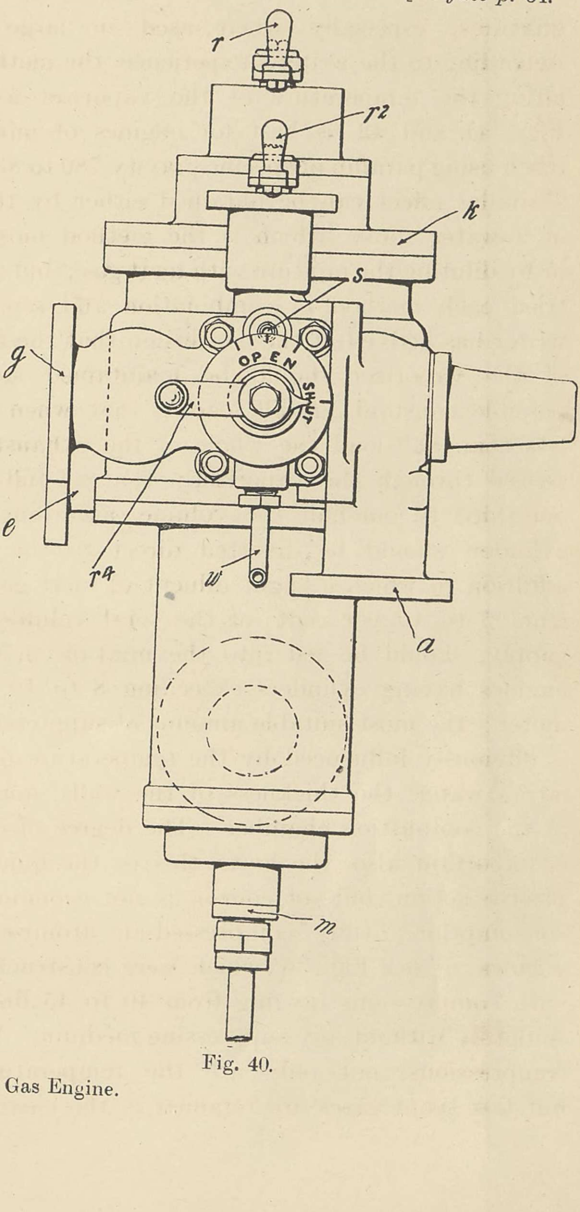



Fig. 40.

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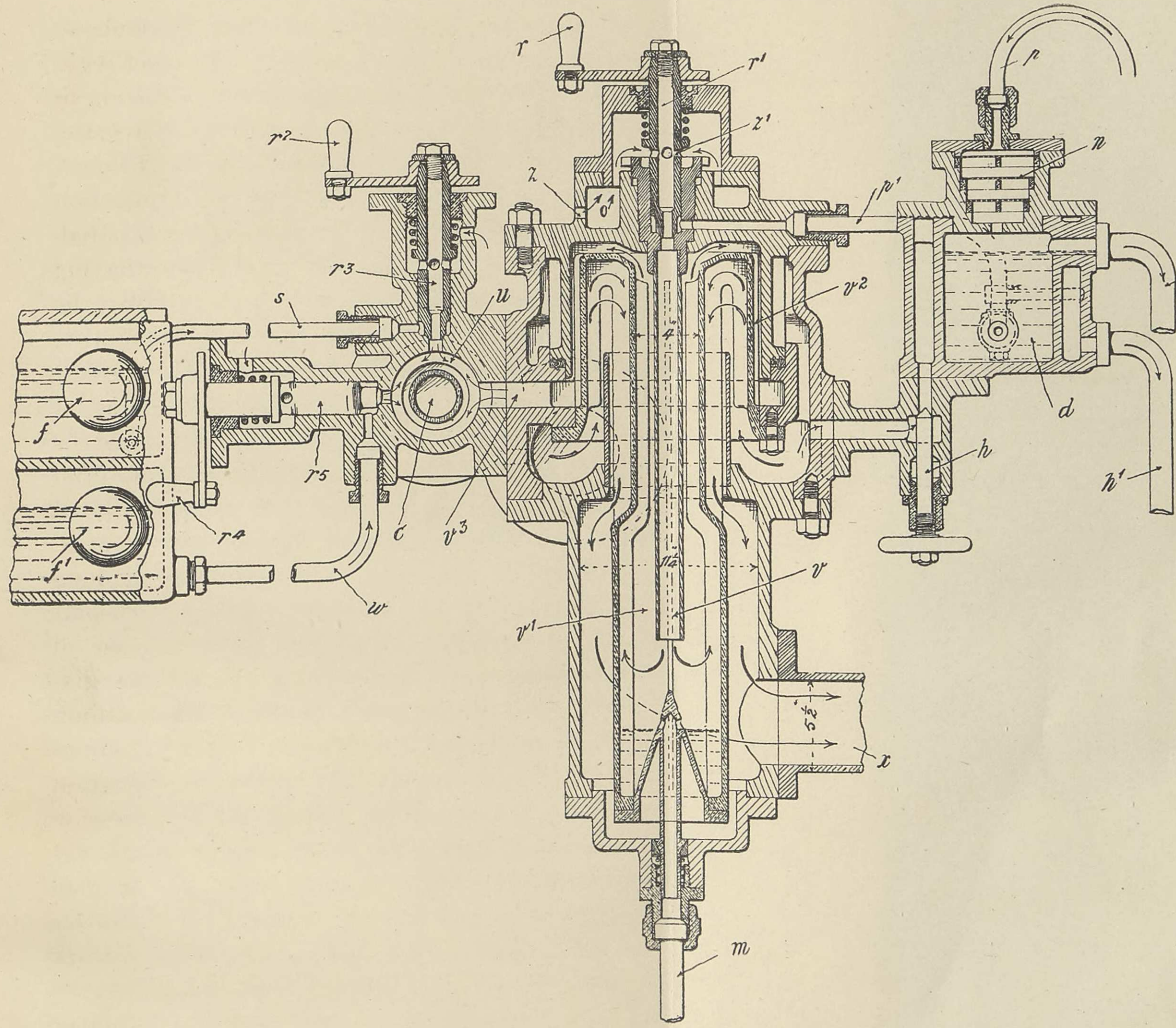

Fig. 39.

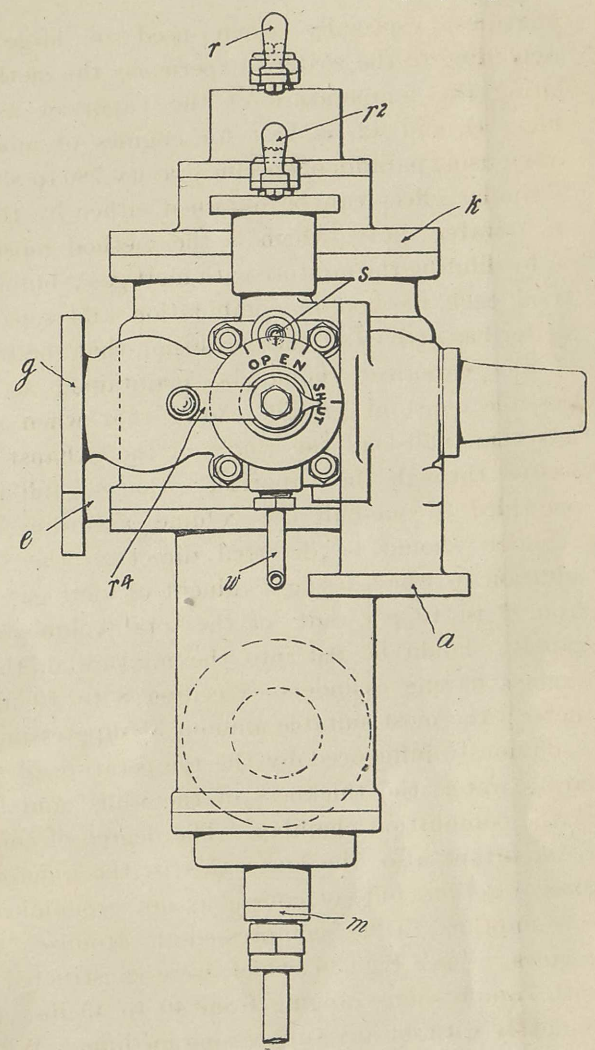


Fig. 40.

Figs. 39 and 40.—Exhaust-heated Vaporizer for 4-Cylinder 16-inch × 20-inch Converted Gas Engine.

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consequently there are under these conditions two reasons for diluting the ingoing heated mixture, either with a water spray or with inert gas. The latter method, however, is not suitable for engines having a cylinder diameter exceeding 13 or 14 inches, and for engines of this and larger sizes the best results can only be obtained by a water spray injection, as shown in Figs. 39 and 40, and if much exceeding this, also by water jacketing the piston head; and even then, if the circulating water is allowed to get much above 120°, whatever the means adopted, when using paraffin, there will still be a more or less violent explosive action, resulting also in a considerable falling off in the power of the engine, compared with what it is capable of developing for the first quarter of an hour or so after being started up.

The worst feature associated with the practice of using a water injection, especially in cylinders of less than 6 to 8 inches diameter, is the liability to quench the mixture when running on reduced throttle opening, unless means are provided as by a float-feed carefully regulated jet to avoid this; another drawback to the injection method if used in connection with an engine in continuous service with impure water, is the liability to fouling of the igniter points, piston head, and walls of the combustion space with hard calcareous deposit. As a case in point, in an installation of three 3-cylinder (13 inches × 18 inches) vertical engines coming under the writer's observation, that were required to run under practically full load by day and three-quarter load by night, the igniters had to be changed once or twice every week, and the combustion chambers scraped after a run of at most six weeks, the vaporizers being cleaned out at the same time, although not strictly necessary. However, deposit from this cause can be avoided by using condensed water, which introduces no particular difficulty in the case of engines of this size, as the necessary water amounting to approximately the same quantity as the fuel used—a grade known as gas-oil—can quite easily be got by connecting the exhaust up to a simple form of evaporator, liquifying the steam in an air-cooled condenser. Water injection, although not so absolutely necessary in engines run on the cheaper grades of semi-refined oils—gas- and solar-oil (specific gravity, 840 to 860)—is an advantage, inasmuch as it enables the full volume of the exhaust to be passed through the vaporizer jacket, and thus to heat the mixture to the maximum temperature available (600° to 800°), which is none too high for efficient vaporization of low-grade oil, even when finely pulverized; and since the use of water injection renders it possible to run with a higher compression (70 to 90 lbs.) than with a diluent of inert gas and with appreciably more power, water injection in engines of this size in which a heated vaporized mixture is supplied is a matter more of necessity than choice. Water is consequently arranged to be used in the specially designed vaporizer, illustrated by Figs. 39 and 40, for converting a 16-inch × 20-inch four-cylinder vertical producer-gas engine to run on intermediate grades of residual oils, which can be obtained at about half the cost of refined oils.

The reason for converting this engine to run on oil was due to the engine only being required in service for a few hours daily, town-gas not being available, starting was thus facilitated as this occasioned no inconvenience with low-grade petrol for the preliminary run necessary to heat the vaporizer. Referring to the illustrations, it will be seen that the running fuel (gas-oil) is pumped from an underground tank along the pipe *p* through a series of fine strainers *n* to an overflow reservoir *d*, the surplus supply returning to the tank by the downtake *t*; this feed cistern is jacketed and connected to the vaporizer so that part of the exhaust can circulate round it, such as is found necessary for rendering the fuel freely limpid, and is under control by a regulator *h*. For this low-grade oil—*i.e.*, in connection with this system of vaporizing—the heating surface is relatively large; also, it is found necessary to provide for a varying amount of unvaporizable residuum that collects in the well $v^1$, by way of an overflow weir *m* connected to a pipe that is continued down to a residuum tank placed at a sufficiently low level to prevent this from being drawn up into the vaporizer again by suction effect. For starting, a regulator $r^3$ feeds petrol from a float-cistern *f* directly over the con-divergent mixing nozzle *c*; at the side of this again there is a second regulator $r^5$ for feeding a water spray direct to the mixture from the float-feed cistern $f^1$; there can, if required, be also a third and larger fuel feed regulator under the annulus *u* surrounding the mixing nozzle (not shown) for the supply of producer gas, thus enabling the engine to be instantly interchangeable from petrol to gas-oil or to producer gas as the exigencies of the occasion may demand. By this feed system also illuminating gas can be arranged to start up on, instead of petrol.

## CHAPTER IV.

### METHODS OF VAPORIZATION IN THE HIGH-SPEED MARINE ENGINE (ELECTRIC IGNITION).

THE progression of the larger powered oil engines for marine propulsion is in some measure away from the carburetion method used in petrol motors, and has resulted in the development of three types: (1) The Diesel, in which the compression is so high that when the fuel is injected in the dynamically heated air, it ignites immediately; (2) the hot-bulb or cylinder vaporizer type of oil engine working on a modified principle, in which the heat required for vaporization of the fuel injected is in part derived from the walls of an unjacketed extension to the combustion chamber; and (3) that type of oil engine characterized as high-speed with electric ignition, in which the fuel is sprayed into air in a form of carburettor and the mixture drawn through either a flame-, electrically-, or exhaust-heated vaporizer. This latter type of oil engine, known as the paraffin vaporizer motor, is peculiarly adapted for motor-boats, launches, as auxiliary power for yachts, also for ships' auxiliaries, despatch boats, etc., and has been used for submarine and torpedo boats of the smaller sizes.

The paraffin vaporizer motor has many of the advantages of the petrol, in that it lends itself for instant starting, is adapted for high speeds, and is comparatively light and compact for the power developed. Successful running of motors of this type is not only influenced, as in petrol motors, by the regularity of the mixture supply under varying conditions of load and throttle opening, but more particularly to the maintenance of a suitably equable temperature of the vaporizer, also to the application of some medium, such as a water spray or inert gas, for suppressing the violence of the explosive action in the cylinder when working on a continuous full load. The running conditions, however, associated with marine propulsion are peculiarly favourable to the paraffin motor, insomuch as the load is comparatively constant and plenty of water for regulating the cylinder temperature is available, and to a great measure in consequence of this, motors of the paraffin vaporizer type have made more headway in this application than any other, as will be seen by the number and variety of vaporizing systems that are in use in motors specially designed for this purpose, as follows:—In order to avoid dependence on hand control to compensate for changes of load, speed, and other conditions, the automatic paraffin vaporiser illustrated in Fig. 41 has been designed by the writer for a marine motor; in this, temperature is regulated by synchronous control of the mixture admission throttle $h$, with another $x^2$, in the exhaust by-pass connection $x^1$, thus diverting more or less of the hot gases according to the opening of the admission throttle $h$, the rod $g$ being connected to a governor, from which is communicated the control movement to the exhaust throttle, through the rod $g^1$; thus, as $h$ is opened, $x^2$ is also opened to a proportionate degree, and allows exhaust to escape to the pipe $x^3$ from $x$, without circulating around the vaporizer tubes $v^1$,

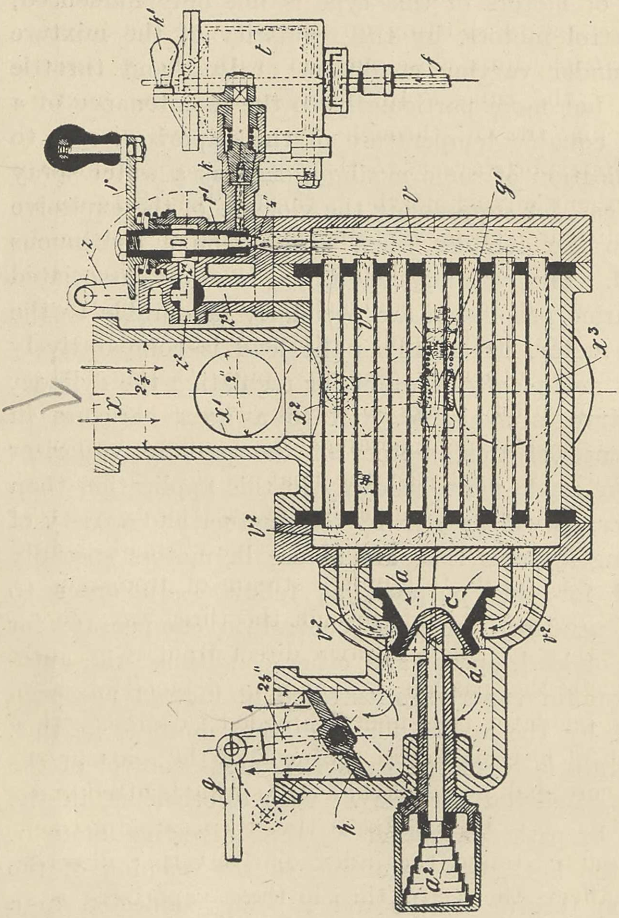


Fig. 41.—Tubular Exhaust-heated Petrol-Paraffin Vaporizer with Induction Feed and Inter-connected Exhaust and Mixture Throttles.

and in this manner the temperature of the vaporized mixture can be automatically prevented from exceeding a certain limit. This method of heating the spray and atomizing air, as also used in the Westmacott vaporizer (*vide* Fig. 65), the Ivel-Boswell tractor paraffin motor, and others, affords considerable heating surface, and has the advantage of splitting up the mixture and bringing every particle into close contact with the vaporizing surface of the tubes. In this vaporizer the mixture, after being drawn through the nest of tubes $v^1$, passes along portways $v^2$ to the annulus surrounding the con-divergent mixing nozzle *c*, through which the main air supply enters from *a*, being regulated in volume by the pulsator $a^1$, which, when the motor is running slow, remains close up to the contracted neck, thus restricting the flow. Two feed supply cisterns *t* are used, one for petrol and the other for paraffin ; pipes *f* connect these to the main supply tanks, either placed at a higher level, or if this is inconvenient, arranged for a sufficient air pressure to force the fuel past the float valves. A two-way plug *k* with handle $k^1$, controls communication from either supply to the atomizing regulator valve $r^1$, made hollow as in Figs. 37 to 40, to admit a stream of atomizing air along the passage $z^1$ and through the three-way plug *z*, whence either air can be drawn direct from $z^2$, or inert gas through the passage $z^3$, or again a blend of each. The feed regulator $r^1$ is finely threaded to screw with a minimum of lost motion in the neck of the seating, but so that there shall be no slack, a stiff spring is fitted under the handle *r*, as in Figs. 37 to 40, thus the least adjustment of the pointer round the index dial in either direction directly affects the feed ; this, in these vaporizers, is an exceedingly fine annular jet, not more than 0·008 inch in thickness, which is, therefore, easily broken up by the centrally contracted air stream ; induced in part by depression below the throttle, but more so by the inspirative action of the mixing nozzle.

In the exhaust-heated paraffin vaporizer, illustrated in Fig. 42, as used in the Thornycroft motor-boats, part of the exhaust from the motor outlets $x$, or the whole of it, can be caused to circulate up one side and down the other of the vaporizer jacket $x^1$, by the throttle $x^2$; or again, as when for any reason it may be desired to run on petrol, the exhaust from $x$ can be made to flow straight

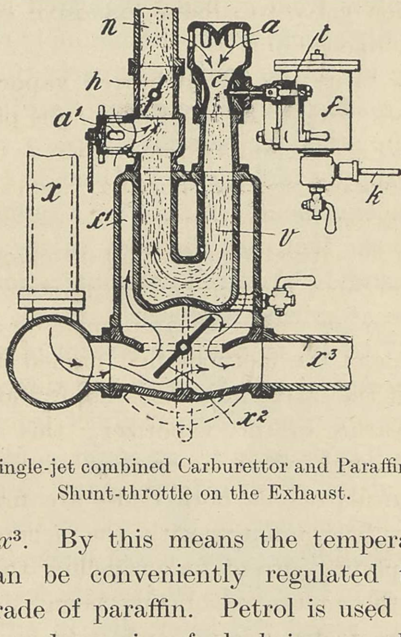



Fig. 42.—Single-jet combined Carburettor and Paraffin Vaporizer Shunt-throttle on the Exhaust.

through to $x^3$. By this means the temperature of the vaporizer can be conveniently regulated to suit any particular grade of paraffin. Petrol is used for starting, the starting and running fuels being supplied to float cisterns $f$ from the main tanks along pipes $k$, and thence either one or the other can be fed to the central jet spraying nozzle arranged to feed direct across the air stream, flowing from $a$ down the con-divergent nozzle $c$

by means of the two-way plug *t*. The vaporized mixture receives a supplementary supply of air through the ported sleeve valve $a^1$, and is thence admitted to the motor cylinders past the usual throttle *h*, by way of the pipe *n*. Petrol-started paraffin motors with this form of vaporizer have been fitted in submarine boats, capable of developing up to 350 B.H.P., such motors having two sets of four 12-inch by 8-inch stroke cylinders, each set having its own vaporizer, and each cylinder a separate water injection valve to subdue explosive violence when running fully opened out.

In another form of exhaust-heated vaporizer for submarine engines using flash-proof oils of the paraffin series, illustrated in Figs. 43 and 44, and known as the Koerting, there is no petrol used for starting, and as, obviously, in an application of this nature, the use of burners is quite unsuitable, either some form of mechanical atomizer working under high pressure in conjunction with a high compression, or an electric heater must be adopted; in place of either of the methods first named, therefore, an adaptation of the latter method is used, and is the most interesting feature of this vaporizer; this consists of a chamber *s* through which a series of wire resistances *r*, carried by insulators at both ends, are first placed in circuit for a few minutes with the accumulator cells used for supplying current for propelling the boat when submerged, the motor meanwhile being slowly moved round by the electric motor, and when by this means both vaporizer and motor cylinders have attained to the necessary temperature, the oil feed and ignition current are switched on. Air is drawn into the stove at *a*, and during its passage in contact with the heated wires $r$, soon attains a high temperature, which it communicates to the vaporizer by way of the two pipes $a^1$, $a^2$ and vaporizer jacket $a^3$, which constitute the air

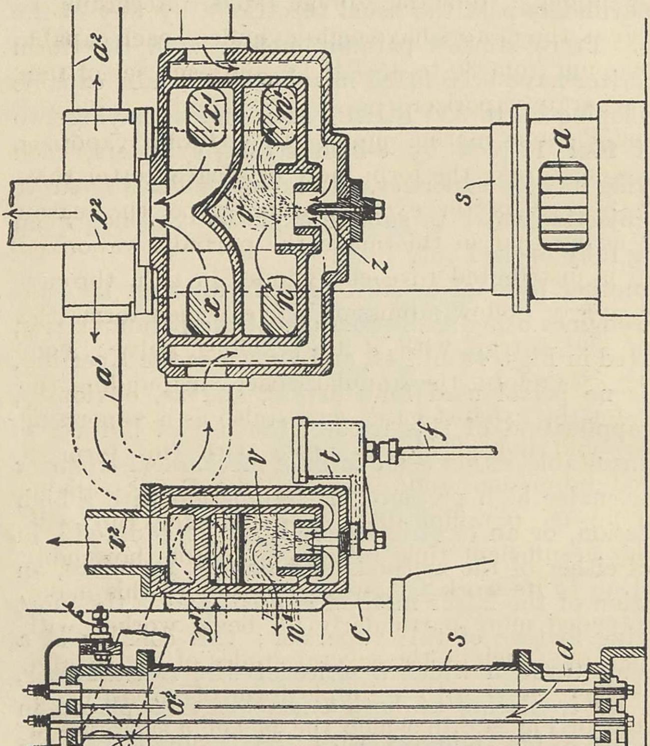



Fig. 44.

Fig. 43.

Figs. 43 and 44.—One of a Pair of Exhaust-heated Paraffin Vaporizers with Electrically-heated Starting Stove for Eight-cylinder Submarine Boat.

inlets to the fuel jet $z$; the spray impinges against the heated wall $v$ of the chamber receiving exhaust from $x$ and $x^1$, and becoming vaporized is drawn into the motor cylinders through passages $n, n^1$; the level of the fuel in the spray nozzle is controlled by a cistern $t$ containing a float-valve supplied under the necessary pressure, with fuel along $f$ from the storage tanks. According to this system, the motors have eight cylinders, each capable of developing from 30 to 45 I.H.P., and each set of four have a separate vaporizer.

In the Parsons marine motor, the paraffin vaporizer will be seen to take the form more of a carburettor than other vaporizers of the exhaust-heated type, the reason for this being that in this make the partially vaporized mixture is distributed to each cylinder in turn through a large ring or hollow admission valve, which forms the seat for and carries with it the exhaust valve; consequently, therefore, the annular space surrounding the passage for the exhaust gases serves also as a vaporizing chamber, and indeed motors fitted with this form of combined admission and exhaust valve * are capable of running on paraffin after a preliminary run with petrol for a sufficient time to get the motor thoroughly warmed up to its work. However, motors of this make, when intended more particularly for being worked with flash-proof oils, such as the several grades of the paraffin series, are provided with a simple form of vaporizer, as illustrated in Fig. 45, in which the jacket $v$ surrounding the exhaust manifold $x^1$ with branches $x$ to the cylinders, constitutes the vaporizer, whence the mixture after passing through a hollow plug regulator $h$, is diluted with an additional supply of air along the pipe $s$ also under control, before entering portways $n$ leading to the admission valves. Starting and running fuel is supplied to a pair

* Illustrated in "Carburettors, Vaporizers, and Distributing Valves."

of float cisterns, from which the feed is controlled by a two-way plug in the manner above described; the petrol or paraffin, as the case may be, after entering by the duct *p* to the well under the spraying nozzle *z*, is drawn up past a needle valve regulator *e*, adjusted to a feed determined by the index *d*, and thence past the multiple sprayer *z*—*i.e.*, a grooved mitre-seated plug as used in the Longuemare carburettors; the issuing spray is carried up by the rush of warmed air entering from *a*, through the choke-tube *c* to the vaporizing jacket.

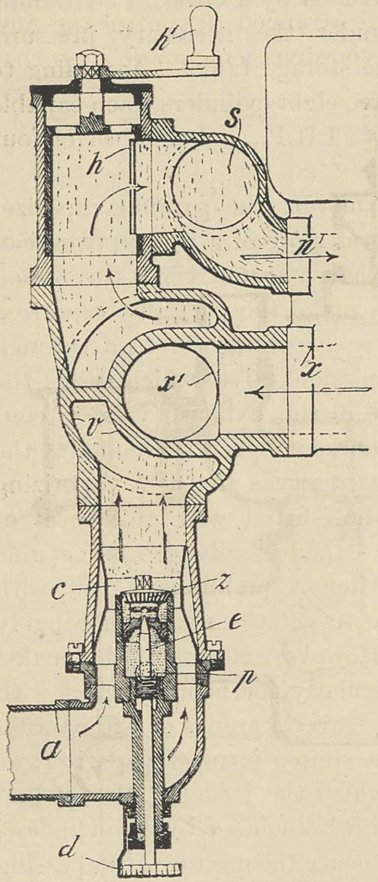


Fig. 45.—Exhaust-heated Petrol-Paraffin Vaporizer with divided Jet and Pin-feed Regulator.

In order that motors fitted with paraffin vaporizers may be run on petrol with a high efficiency—*i.e.*, without being heated—it is a decided advantage for the mixture to be supplied direct to the cylinders without going through the vaporizer; in the Wolseley dual control combined petrol carburettor and paraffin vaporizer this point is made a special feature of, and takes effect by an endways movement of a hollow piston valve, as illustrated in Fig. 46: this valve $t^1$ is arranged to control the flow of mixture formed in the con-divergent nozzle $c$, so that

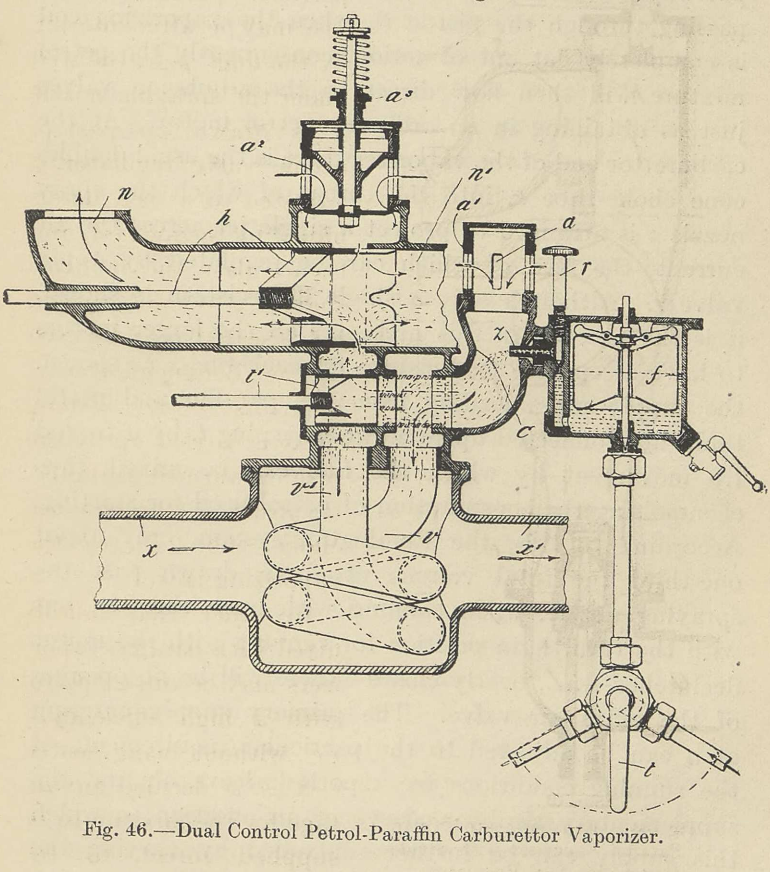



Fig. 46.—Dual Control Petrol-Paraffin Carburettor Vaporizer.

this shall either circulate through the vaporizing coil $v$, $v^1$ as when the piston regulator is moved, for instance, to the position as shown; or when moved to the right, as shown in dotted lines, thus covering the opening leading to the coil, will cause the mixture, as with petrol, to flow direct to the passage communicating with the portways around the piston throttle *h*, the mixture then passing through the piston $t^1$, when the vaporizing coil is completely cut out of action, consequently the petrol mixture will then flow direct to the admission valves just as obtaining in an ordinary petrol motor. At the carburettor end of the vaporizer there is the usual double-cone choke-tube *c*, into the throat of which the spray nozzle *z* is arranged to project a single jet across the air current, the feed of which can be regulated by a pin valve *r*. Although only a single float-cistern is shown, it is the practice in this make for all the larger motors to have a separate feed cistern for each fuel; as shown, the supply pipes leading from the paraffin and petrol tanks are connected up to a two-way plug *t*, by a to and fro movement by which the fuel can be mixed, thus economising the consumption of petrol used for starting. According to this, the Remington system, only about one-third the total volume of air is drawn past the spraying nozzle, when running with open throttle, but with the throttle in position for running with the motor declutched—*i.e.*, nearly closed—there will be no opening of the extra air valve. The primary supply entering at *a* can be adjusted to the particular requirements of the running conditions by a ported sleeve $a^1$, and the supplementary air by a sleeve $a^2$, in addition to which this supply can be further controlled by varying the tension of the air valve spring by an adjustment of the thimble $a^3$. To clear the coil from carbonaceous deposit, which tends to choke and restrict the flow, a good plan is to hold the coil over a fire for a few minutes and then tap it all over, which loosens the deposit so that it can then be shaken or blown out in the form of dust.

The Britannia exhaust-heated induction feed vaporizer, illustrated in Figs. 47 to 50, has points of interest, although not materially differing in method to the foregoing. According to this system, the vaporizing surface is unusually large, and only one-fifth of the total supply of air, with open throttle, is used for atomizing, and as shown in Fig. 46, the petrol mixture is not drawn through the vaporizer, as a separate carburettor *c* is then brought into play. The control from this carburettor or from the vaporizer, as the case may be, is effected by a pair of connected throttles $t^1$, $t^2$, which—as in the Remington-Wolseley system just described, and also used in modified form in the G. C. vaporizer described below—lessens the time required for heating the vaporizer and also for running on petrol, which is important, as the vaporizing surface in this construction is not subjected to the cooling effect of the petrol evaporation. Another advantage of a separate carburettor—first used for large engines of the writer's design, to work interchangeably from petrol or gas to paraffin or gas-oil as required—*vide* Figs. 39 and 40—consists in the ability to change over gradually, instead of all at once, from one fuel to the other, thus avoiding any mischance of the motor firing irregularly and emitting a vaporous exhaust during the process of changing over from petrol to oil.

The illustrations here represented are taken from a vaporizer for a four-cylinder 40 B.H.P. marine type petrol-paraffin engine, in which the two branches $x$, $x^1$ lead each from a pair of cylinder exhausts to the chamber

Fig. 47.

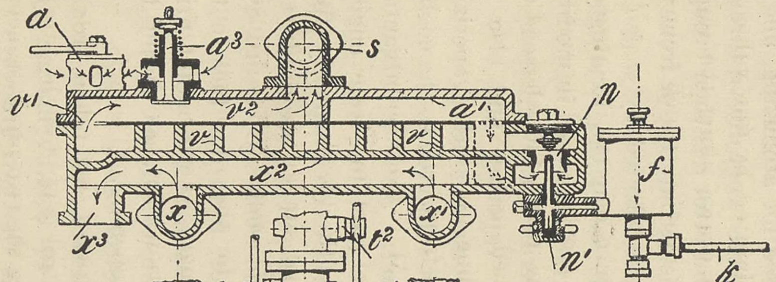


Fig. 48

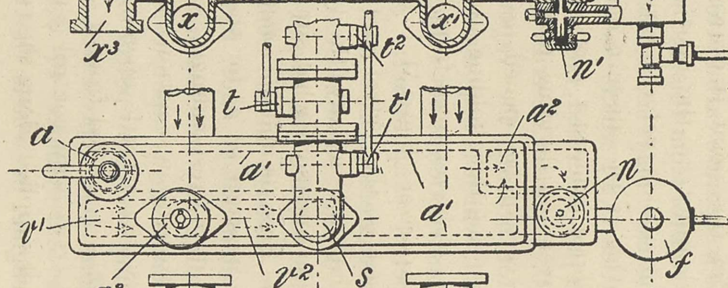
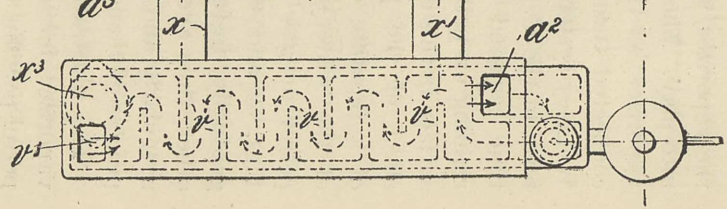


Fig. 49.



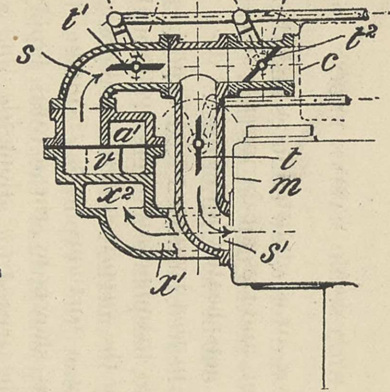
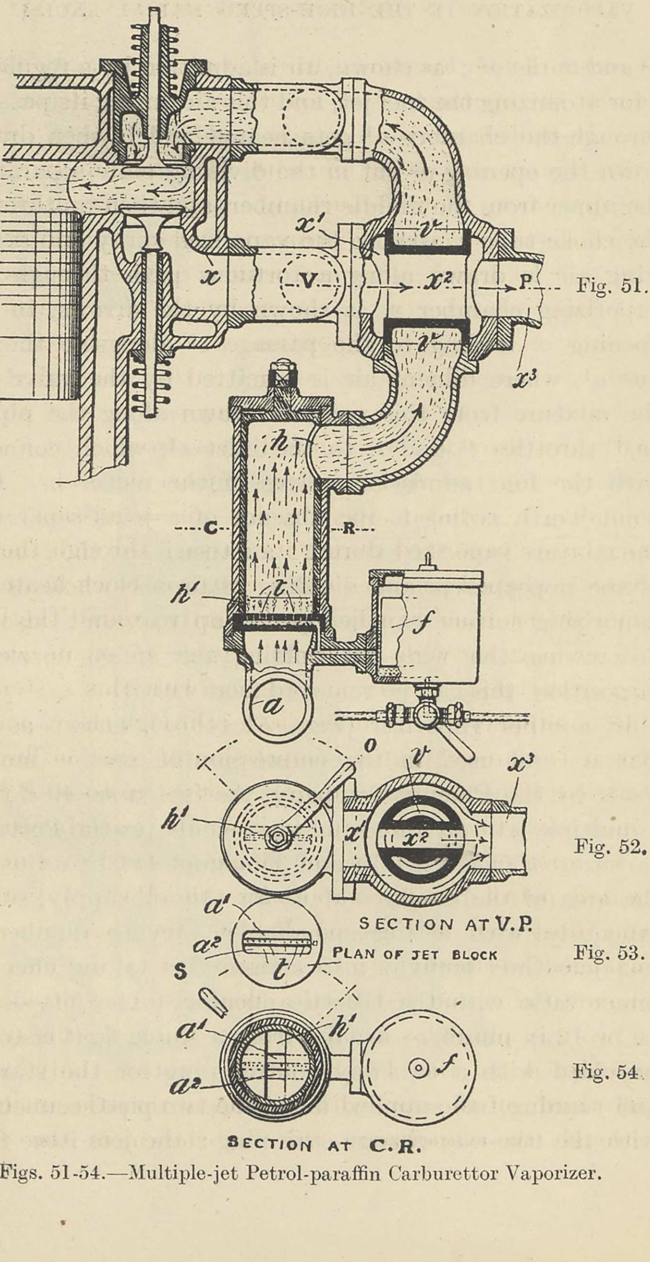


Fig. 50.

Fig. 47 to 50.—Combined Petrol Carburettor and Paraffin Vaporizer with Inter-connected Throttles.

$x^2$ and outlet $x^3$; as shown, air is admitted by a regulator $a$ for atomizing the fuel jet, and this air during its passage through the chamber $a^1$ gets heated and is then drawn down the opening $a^2$ cut in the dividing plate separating the upper from the middle chamber, and then up through the choke-tube $n$, whence the vaporized spray and atomizing air is drawn along a tortuous path through the vaporizing chamber $v$, as shown by the arrows, to the opening $v^1$ leading to the passage $v^2$ alongside the air flue $a^1$, where diluent air is admitted by the valve $a^3$; the mixture from this point is drawn along the pipe $s$ past throttles $t^1$ and $t$, to the inlet $s^1$, which connects with the four admission valves of the motor $m$. One point worth noting is the absence of a joint separating the mixture from the exhaust; another is, by the removal of the upper cover and dividing plate, the whole of the vaporizing surface can be opened up to view; also by unscrewing the wing-nut holding the spray nozzle $n^1$ in position, this can be removed from below.

In another vaporizer (Figs. 51 to 54), known as the Barcar, and used in the petrol-paraffin marine motors made by the Phœnix Company, the fuel is sprayed from a multiple jet $t$ on lines somewhat similar to the Polyrhoe carburettor (*vide* Figs. 34 and 35, *ante*)—*i.e.*, by adjusting the area of the passages $a^1$, $a^2$ for the air supply, simultaneously with a correspondingly varying number of fuel jets thus brought into action, this taking effect in direct ratio with the throttle opening. The jets—some 10 or 12 in number—are fed from a single float cistern $f$ provided with a two-way control plug for the starting and running fuel supplied along the two pipes connecting with the two-way change-over plug; the jets issue from




Figs. 51-54.—Multiple-jet Petrol-paraffin Carburettor Vaporizer.

a series of fine apertures drilled in a bar *t* that extends across the openings $a^1$, $a^2$ for the admission of air ; this bar is drilled lengthways and communicates as shown with a duct in connection with the fuel supply. Over the jet-block, shown separately in plan, there is a combined spray chamber, mixture regulator, and throttle *h*, the base of which is formed with a rectangular opening $h^1$, that coincides with the openings $a^1$, $a^2$ when the throttle is in full-open position, as shown in elevation and part plan section, as at V P ; the position of this for running slow is as shown in the part section at C R, with the throttle lever moved over from *o* to *s*, thus leaving only two fuel apertures uncovered and a correspondingly reduced opening for air admission. The mixture is vaporized during its passage through the two crescent-shaped passages *v* in a cast-iron block heated by the exhaust from *x*, which flows partly around the block and in part through a central passage $x^2$, on its way to the outlet pipe $x^3$. In accordance with this system all the air supplied to the motor passes through the vaporizer, yet it is claimed that a compression of over 56 lbs. can be used without a water drip in motors up to 40 B.H.P., when the cylinders, four in this case, are properly cooled.

In another variant of the single-jet type of exhaust-heated petrol-paraffin vaporizers—the P.C., or Cottrell, and illustrated in Figs. 55 and 56—the spray nozzle is arranged vertically in the centre of a double-coned choke-tube *c*, and fed from a float cistern *f* fitted with a two-way plug *t*, as usual ; but according to this system —adopted in the Forth marine motors—only about one-third of the air with full-open throttle is drawn through the vaporizer ; this, as shown in the cross-section, consists of a pair of star-shaped copper tubes $v, v^1$, brazed in a duplex form of chamber, receiving exhaust by pipes $x$ to $x^3$ from a four-cylinder motor. The spray and air entering at $a$ are drawn through the vaporizing tubes from the ends to the centre, where extra air is admitted by a sleeve $a^1$, which presumably is adjusted to the running conditions as required, there being no automatic regulation.

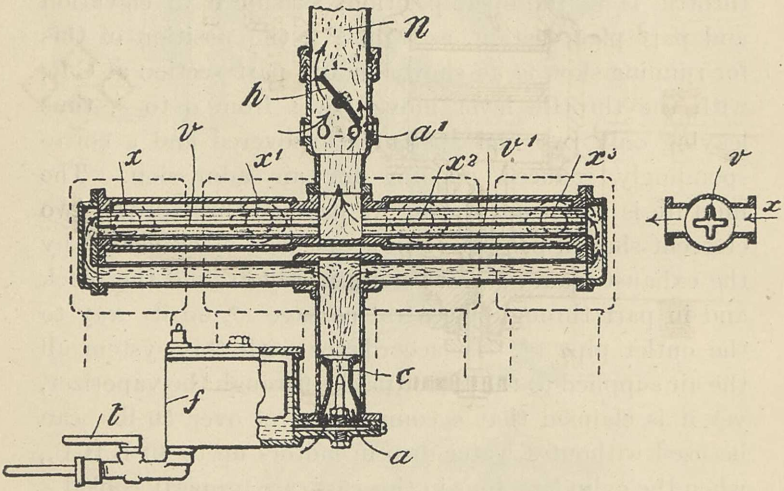
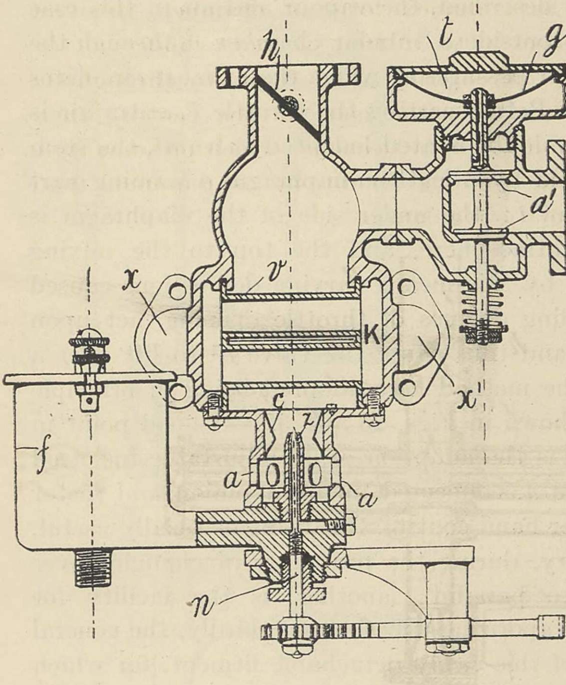



Fig. 55. Fig. 56.

Figs. 55 and 56.—Combined Single-jet Carburettor and Exhaust-heated Star Tube Paraffin Vaporizer.

In still another vaporizer of a somewhat similar form, the Notax, illustrated by Figs. 57 to 59, the spray is fed from one of a pair of float cisterns $f, f^1$ to a single-jet nozzle $z$, arranged to project the spray centrally within a double-coned choke-tube $c$, the necessary air for atomizing and carrying the vapour forward entering by the

Fig. 57.



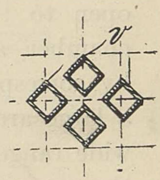




Fig. 58.

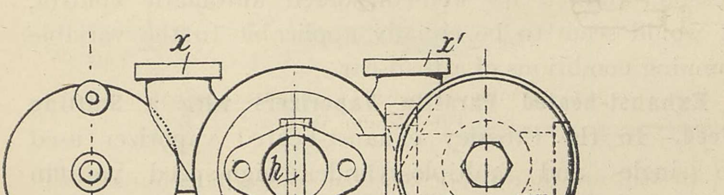



Fig. 59.

Figs. 57 to 59.—Single-jet Induction-feed Carburettor-vaporizer with Diaphragm controlled Air Regulator.

apertures *a*. Contrary to the method adopted in the vaporizer just described, the vapour and air in this case are drawn up outside a tubular chamber *v*, through the four rectangular passages of which the exhaust circulates from *x* to $x^1$. Before passing the throttle *h*, extra air is admitted by a double-seated balanced valve $a^1$, the stem of which is held by a leather diaphragm *g* forming part of the dash-pot *t*; the under side of the diaphragm is open to the atmosphere, and the top to the mixing chamber, and by this means varying depressions caused by corresponding degrees of throttle opening, act upon a large area, and thus cause the valve $a^1$ to lift over a wide range, the method here adopted being in principle the same as shown in Figs. 23 and 32. A good point in this vaporizer is the adoption of an adjustable fuel feed by a pin valve *n*, connected up by a pinion and sector with a lever for hand control, this being especially useful, if not necessary, during the procedure of changing-over from petrol to paraffin; another, is the facility for removing the vaporizing tubes *v*, and thirdly, the general compactness of this easily detachable fitment, for which reason, and to its well-considered automatic control, it would seem to be equally applicable to the variable running conditions of a road-car.

**Exhaust-heated Paraffin Vaporizers with a Snifting Feed.**—In the Crossley exhaust-heated vaporizer used in single- and multiple-cylinder high-speed paraffin motors of the electric ignition petrol-started type, illustrated in Fig. 60, the fuel entering the annular groove *p* from one of a pair of float-feed cisterns, is drawn into the air stream admitted by the valve *e*, in a series of small jets from nozzles *n* during the admission strokes

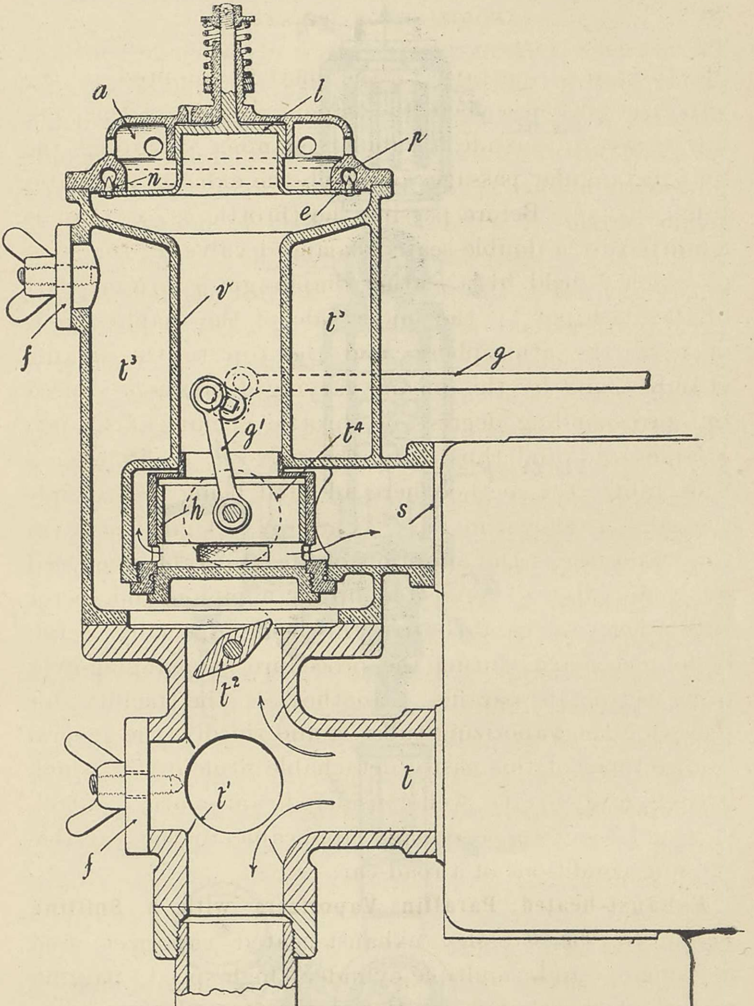
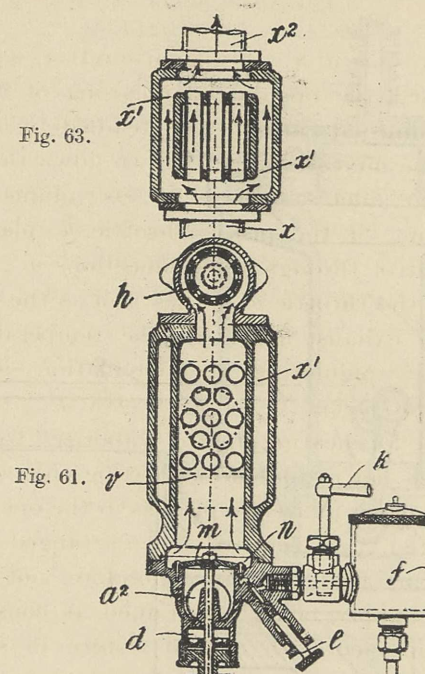



Fig. 60.—Multiple-jet Snifting-feed Paraffin Vaporizer with Piston Throttle.




Figs. 61 to 63.—Cross-tube Carburettor-vaporizer with Float-controlled Snifting Feed.

and thus mixes, as in a snifting carburettor, with the air entering at *a*; the opening and closing of this valve, which is of unusual capacity, is steadied by a cataract plunger *l*; the mixture is then drawn down the chamber *v* to the motor inlet *s*, in more or less volume according to the opening of the piston throttle *h*, placed under governor control through the connections *g*. It will be noticed that the throttle casing as well as the vaporizing chamber are exhaust jacketed, the temperature being controlled by regulating the circulation of exhaust from *t* to the jacket $t^3$ by a throttle $t^2$; two flues *f* are provided for heating-up the vaporizer by a burner when petrol is not available for starting on.

In the following four examples, as in the one preceding, exhaust-heated vaporizers are shown arranged to function with a snifting feed, and are, therefore, not dependent on the fuel supply being maintained at constant level, although combined with a float cistern in some cases, as in the Crossley, Davis, and Allsop vaporizing systems. In the improved Davis petrol-paraffin vaporizer shown in Figs. 61 to 63, which will be seen to be constructed more on the lines of the Westmacott described below, a nest of tubes is arranged transversely across the vaporizer *v* of rectangular form, which is surrounded by an exhaust-heated chamber $x^1$, so arranged with the exhaust inlet and outlet $x$ and $x^2$ opposite the vaporizing tubes that part of this flows through direct. When fitted to a single- or double-cylinder motor, the whole of the exhaust is allowed to circulate through the vaporizer, but in a four-cylinder motor, the exhaust from two cylinders is shunted direct to the muffler. This form of vaporizer is also fitted on the Blake marine motors, a four-cylinder motor of this make, 5·25 inches × 6·25 inches, recently developing 33 B.H.P. at 800 revolutions per minute, without water drip; although this is used in motors having a higher compression, as for instance, when converting a gas engine to be able to run on oil or gas, on the interchangeable system. It will be seen there are a pair of float cisterns *f* to control the two fuel supplies, which are again controlled by two plugs $k$, $k^1$, by which means changing over from petrol as used in starting to paraffin can be effected in less time than when a single cistern is used; the use of two cisterns affords the further advantage, also, of permitting a partial feed of petrol with the paraffin, until the motor has warmed up thoroughly to its work, and avoids the necessity at any time for emptying the cistern of paraffin before a start can be made. On the mixture valve *m* is fitted a small needle-valve *n*, steadying pins being also fitted in this valve at intervals, the valve *n* acts as a snifter and prevents feed leakage even with the level in *f* above the admission valve *m*; the rate of feed to the snifting pin *n* is regulated by an adjustable needle-valve *e* to the requirements of the motor. There is no extra air valve, and all the air supplied to the motor passes through the vaporizer, the only air adjustment found necessary is made by the slotted cap *a*, and this can be locked by the wing-nut $a^1$. It should be mentioned that on the stem of the lift valve *m* is fitted a steadying piston *d* to prevent chatter and undue wear of the pin *n*. Mixture to the motor is admitted past a hollow ported plug *h* arranged for hand or governor control.

In the two following snifting-feed vaporizers fuel is supplied at a slight pressure-head, this in the Barker bi-fuel vaporizer, illustrated by Fig. 64, is by the pipes $f$, $f^1$, and is regulated by needle-valves $r$, $r^1$, and admitted during the open periods of the air valve $a$: the spray and air mixture is caused to acquire a vortex motion during its passage through the vaporizer, by which means it is claimed that the liquid particles of the oil vapour are thrown on to the outer wall, which is heated by the exhaust gases entering at $x$, and in this manner are more

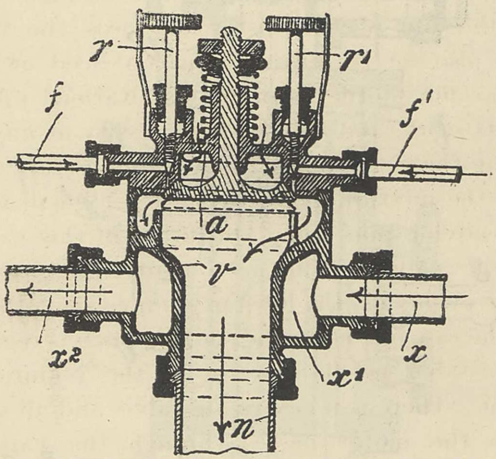



Fig. 64—Dual Control Snifting-feed Carburettor Vaporizer with Vortex Action.

effectually vaporized. In this connection it should be stated that the vortex principle was also adopted in the Davis vaporizer in its original form, the particular method used in this case consisting of a fan which was caused to revolve within the vaporizer by the action of the mixture being drawn through it, and by this means caused un-vaporized particles to be whirled out of the ingoing mixture and to be thrown against the heated outer surface for reheating.

In the Westmacott vaporizer, illustrated by Fig. 65,

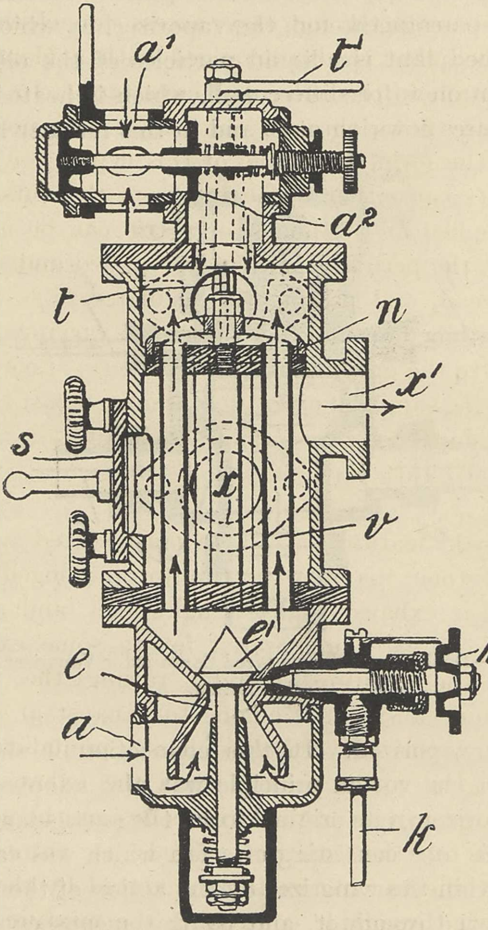



Fig. 65.—Snifting-feed Single-jet Carburettor Vaporizer with Automatic Air Control.

and also of the snifting gravity feed type, only about one-fifth of the total air passes through the vaporizer with the throttle full open. As in Figs. 61 to 63, the vaporizing surface is obtained from a nest of tubes *v*, which are arranged for easy access for cleaning, the upper tube plate is also arranged with a gland-packed joint *n* to allow for differential expansion. In this case the mixture flows through the tubes, and not around them, as the former example of this type; for starting, these tubes can either be heated from the outside by a burner applied at the flue *s*, or petrol can be used. As in Fig. 64, the petrol or paraffin is supplied under a slight pressure-head, and passing the regulator $k^1$ is admitted by the combined air and fuel valve $e^1$ in varying quantity, according to the opening of the throttle $t^1$; a correspondingly varying supply of extra air is admitted past the hand-regulated shutter sleeve $a^1$ and sliding disc $a^2$, the latter being pinned to a stem having at one end a steadying plunger.

The weak feature in all exhaust-heated vaporizer engines is their inability to run for prolonged periods with a clear exhaust under a light load, and although this fault can be compensated for to some extent by retarding the ignition, thereby raising the terminal pressure and causing the engine to exhaust at a higher temperature, this, nevertheless, has a prejudicial effect on the engine, as it unduly heats the exhaust valve. In some large engines of the writer's design, the necessary adjustment of the ignition periods is automatically effected by the varying vacuum produced by the partial closing of the regulator controlling the mixture supply, through the agency of a plunger acting against a spring.

Another remedy is to combine the heating effect of the exhaust with that of a burner as shown in Fig. 38; or again, to rely entirely on a burner for heating the vaporizer as described below (*vide* Fig. 86).

A most unusual process has been adopted in the Allsop petrol-paraffin motor in the endeavour to obtain a more

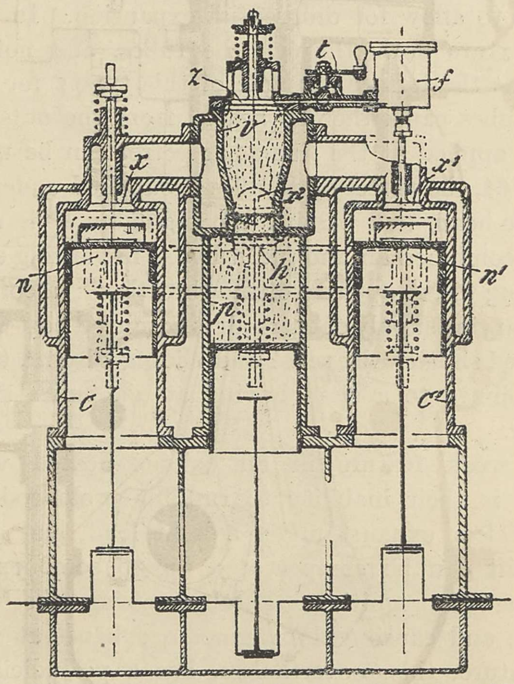



Fig. 66.—Diagrammatic Elevation showing Exhaust-heated Pressure Vaporizer with Petrol-Paraffin Snifting Feed.

perfect combustion from flash-proof oils, so difficult to obtain in small motors working under varying conditions of load and speed by an exhaust-heated vaporizer. In this motor, illustrated in diagrammatic section by Fig. 66, and in cross-section by Fig. 67, the vaporizing chamber

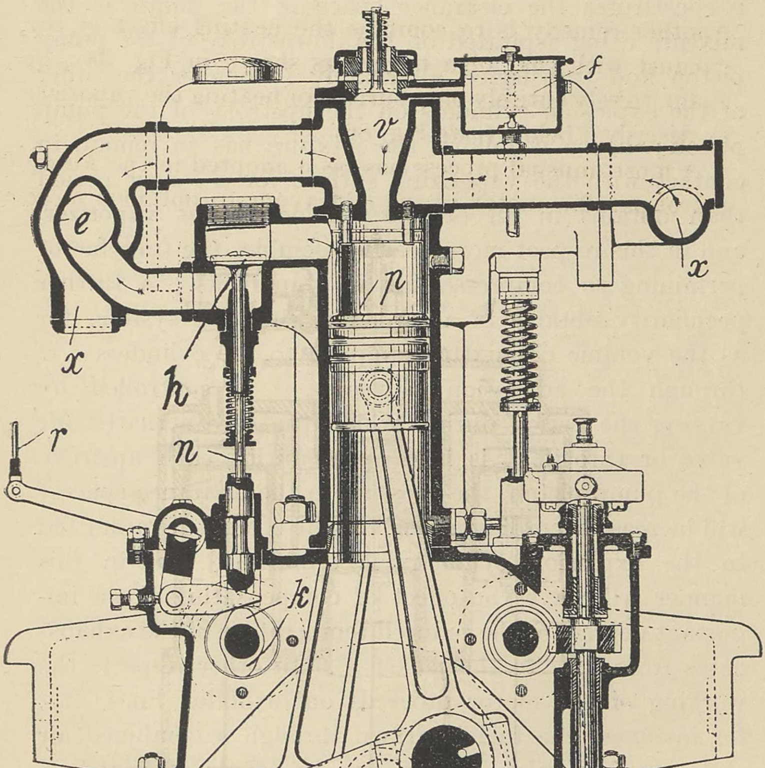



Fig. 67.—Cross-section of Pressure Vaporizer Petrol-Paraffin Engine with Snifting-jet Feed and Variable Lift Mixture Control.

*v* constitutes the clearance space of the pump *p*, the mixture being aspirated on the downstroke of the pump piston and transferred alternately to one or the other of the explosion cylinders on the upstroke of the pump piston; hence it follows the mixture has to remain in contact with the vaporizing surface for a longer period than obtains in an ordinary induction jet vaporizer, and in this respect more nearly resembles the time factor pertaining to compressed-air jet vaporizers. A further peculiarity obtains in accordance with this system, for as the volume of mixture supplied to the cylinders $c, c^1$ through the admission valves $n, n^1$ is controlled by varying the period during which the cam actuated lift valve or throttle *h* is held open, during each upstroke of the pump piston, the pressure in the clearance space *v* will increase according as the volume of mixture admitted to the explosion cylinders is diminished, and in this manner will have the effect of compensating in an important degree for the reduced temperature of the exhaust gases from $x, x^1$ to the jacket $x^2$. In other respects the working of the motor proceeds on orthodox lines; as, for instance, the fuel is drawn through a combined air and spraying valve *z* from one of a pair of float-feed cisterns *f*, which are connected to a two-way change-over plug *t* in the usual way. Admission control by the variable period of opening of the transfer valve *h* is more clearly shown in Fig 67; here is seen the cam *k* made double, as this valve functions at each revolution, the variable lift being obtained by the floating wedge connected to the control rod *r*; the mixture also, after passing this valve *h*, is forced along a jacketed manifold *e*, by which the process of vaporization is rendered still more complete.

The attainment to a practically perfect method for vaporizing flash-proof oils in high-speed motors of the electric ignition type has engaged a very considerable attention for a number of years, as will be gathered from the widely varying methods already described, but in too many cases the problem has been under-rated, especially where the running conditions imposed, as in road cars, electric lighting, and to a less extent in motor-boats, are extremely variable. Other vaporizing methods that have been tried in connection with four-stroke high-speed engines than those described may be mentioned: (1) The Bryant-Watling system of alternate expansion and contraction of the mixture in an exhaust-heated vaporizer; (2) the Cremorne, in which the heated mixture is caused to circulate with a cycloidal movement; (3) the Davis, having a whirling action communicated to the mixture in contact with an exhaust-heated surface; (4) the Loew system of indicating the temperature of the vaporizer, and the time required for warming up before changing over to paraffin; (5) the automatic method devised by Dorwald for attaining the necessary temperature before changing over from petrol to paraffin, by means of a thermo-electric coil.

**Two-Stroke Petrol-Paraffin Motors.**—Obviously for small two-stroke motors of the enclosed crank-chamber marine type to be run on paraffin, the fuel must either be (1) fed in admixture with air direct to the crank chamber and thence through an exhaust-heated vaporizer during transfer to the cylinder; or (2) be injected by a pump on to a vaporizing plate or bulb in the combustion chamber, or on to a baffle on the end of the piston; or, (3) be forced into the cylinder under air pressure from a spray nozzle, which last method is illustrated in Fig. 68. Accordingly this method, although not arranged to vaporize by the heat of the exhaust, yet depends on petrol for starting and on electric ignition, and can, therefore, be included in this series. In a two-stroke

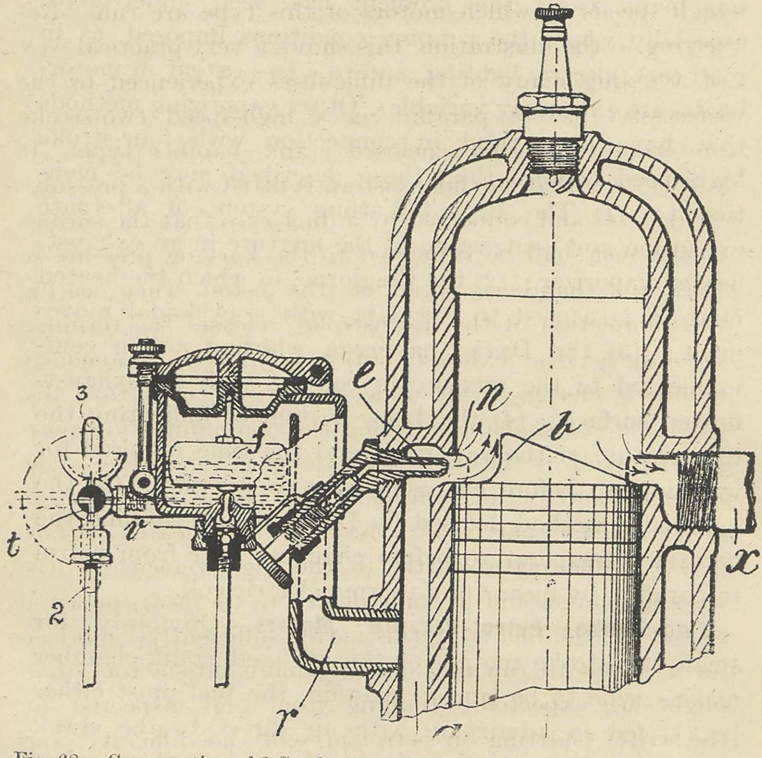



Fig. 68.—Cross-section of 2-Stroke Petrol-Paraffin Motor with Automatically Controlled Single-jet Pressure Feed.

motor the conditions are very different from a four-stroke, as the mixture during transference from the pump chamber to the cylinder is under pressure; also, if an induction feed is used, the mixture must either pass through the crank-chamber, which is bad for the bearings, or be compressed in a cylinder extension; or again, if a fuel injection pump is used, this is necessarily small and ill-adapted for accurate adjustment and the high speeds at which motors of this type are run. Referring to the illustration, this shows a very practical way of avoiding many of the difficulties experienced in the successful use of paraffin, in a high-speed two-stroke motor of the simple enclosed crank-chamber type. It will be seen that the float cistern is fitted with a pressure-tight cover and connected by a duct *r*, so that the surface of the fuel shall be subjected to the varying pressure in the crank chamber. In action, the piston, when nearing the completion of the downstroke, releases the terminal pressure to the exhaust outlet *x*, and simultaneously admits a charge of air under a pressure of 4 to 5 lbs. from the crank-chamber along the communicating portway *a*; and at the same time causes a jet of fuel to be projected on to the baffle *b* of the piston by induction effect; when, partly as a result of the heated surface of the baffle plate, partly to the high velocity of the ingoing charge, and in some degree to the heat imparted to the air, the fuel is by this means sufficiently vaporized for a motor to run in a manner more satisfactory than might be expected. Judging from one inspected by the writer, starting on petrol presents no difficulty, and the change-over to paraffin can be made within three to four minutes—the time required to use up the supply of petrol in the cistern. To start, the two-way plug *t* is first moved over to position 1 for emptying the paraffin out of the cistern; it is then moved a quarter turn to position 2 for filling with petrol, and after this is done, to 3, which is the closed position. A peculiarity in motors vaporizing on this system, especially in those of the valveless three-port type, consists in their ability to work with the paraffin supply located below the floor level, as the vacuum effect produced at alternate strokes in the crank-chamber serves the purpose of pumping the oil past a ball valve *v* up into the cistern at a constant level, regulated by a float-feed control as in four-stroke engines.

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## CHAPTER V.

## ROAD CAR AND TRACTOR MOTORS.

Paraffin, owing to its pungency and comparative difficulty of carburetion, whatever the method used for vaporizing, is an extremely difficult fuel to apply successfully to the propulsion of road cars, especially for touring or pleasure cars, and to this may be attributed the reason that development in this direction has been held back to a considerable extent; but now, owing to the rapidly increasing cost of petrol, coupled with a keener appreciation of the economic advantages of a non-tax flash-proof fuel, renewed efforts have been recently made by motor engineers to produce a really successful high-speed paraffin motor especially adapted for the very trying conditions associated with the running of road cars.

It has been demonstrated that the best results can be obtained with paraffin in a high-speed motor of the automobile multi-cylinder type, when fitted with an exhaust-heated vaporizer of comparatively large capacity, and in which the proportion of air drawn through with the fuel feed does not exceed from 15 to 20 per cent. of the total volume supplied to the motor, when running opened out; also that the air fed into the vaporizer for atomizing, as well as the diluent air added to the mixture, shall be varied in proportion to the fuel feed, thus producing a constant mixture; but even with these conditions complied with, uniformly satisfactory combustion—*i.e.*, a clean exhaust—cannot be obtained under widely varying conditions of load and speed, unless the vaporizer is maintained at approximately a constant temperature, as for instance, by a by-pass throttle on the exhaust connected up to the mixture throttle, and this supplemented by simultaneous ignition control, for the purpose of increasing the temperature of the exhaust when running slowed down and declutched. The temperature found most suitable varies with the vaporizing surface and with the amount of air drawn through the vaporizer, and is also influenced by the method of atomizing—*e.g.*, a mixture temperature as low as 400° to 450° can be used with a vaporizing system in which compressed-air is used; but with an induction feed vaporizer as found more applicable to a motor of this type, the mixture temperature should not fall below 600°, nor exceed 800°, when using ordinary lamp-oil, ranging from a density of 800 to 820. As a consequence of this high vaporizer temperature, it is an advantage to limit the amount of air drawn over the heated surface to that just necessary for atomizing the jet, thus keeping down the temperature of the mixture entering the cylinders to the lowest minimum.

**Bi-fuel Carburettors.**—The simplest solution of the problem is effected by mixing a proportion of the heavy fuel with the light, and using this in an ordinary carburettor, provided either with a jacketed intake or arranged to draw in its air supply from a sleeve surrounding the exhaust pipe. Fairly satisfactory results can be obtained by this means, provided the proportion of paraffin to petrol does not exceed one to four, but naturally varies in accordance with the density of the two fuels, the construction and arrangement of the carburettor, and in some degree by the compression; also again, to the manner in which the motor is handled and the work it has to perform. Many of the London cabs and omnibuses are run on a paraffin-petrol mixture, the motor being usually fitted with a small petrol tank connected with a spring-closed snifting valve on the intake manifold or the carburettor, so that a whiff of unmixed petrol can be admitted just before pulling over the starting handle, which is supplemented by an occasional whiff for the first minute or two when starting cold; also, in order to facilitate the operation, the snifting valve is connected up within reach of the driver when at the front end of the car.

In the opinion of the writer a double-feed system is preferable to the method described of using a mixed fuel of paraffin and petrol, as with a bi-fuel carburettor carefully regulated, not only can the proportion of heavy oil to light oil be increased to one in three, but starting and running throttled down, be made more reliable. The petrol and paraffin supplies, according to this system, are carried in separate tanks and fed to a specially constructed carburettor having independently controlled spray nozzles; such carburettors, known as "bi-fuel," may be either arranged with a hot-air intake, or be provided with a jacketed manifold as shown in Fig. 69; or again, be fitted with a separate vaporizer as shown in Figs. 70 and 71, the latter construction enabling the two fuels to be used in about equal proportions; a separate vaporizing attachment can, of course, be used with either form of carburettor.

The construction of the two bi-fuel carburettors exemplifying this method of using a proportion of the cheaper fuel, will be seen to vary in considerable degree, one having an automatically and the other a mechanically regulated air and fuel control, the fuel in both being fed at constant level from separate float cisterns *f* (Fig. 69).

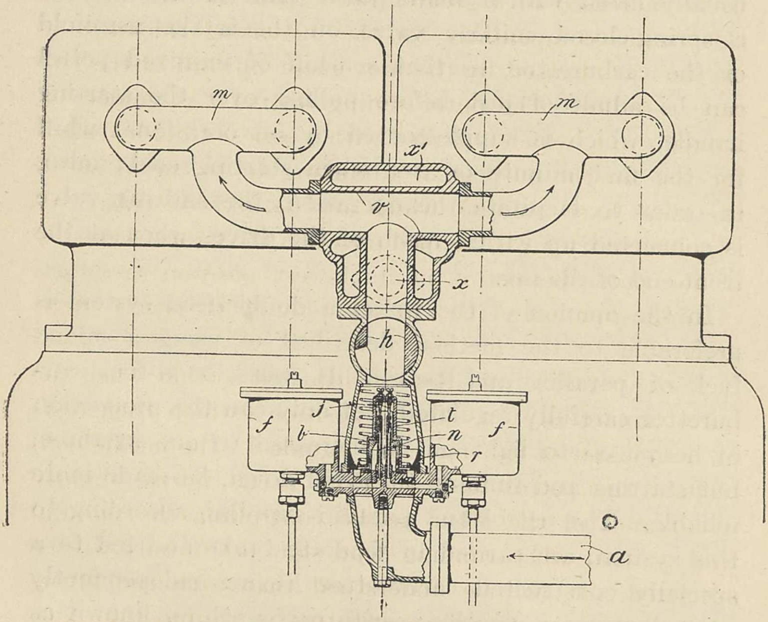



Fig. 69.—Bi-fuel Carburettor Vaporizer with Automatically Regulated Air and Fuel Supplies.

In the Hamilton bi-fuel carburettor, the size and proportion of the two fuel jets are regulated by taper needles *j*, which rise and fall within the nozzles *n* by the action of the bonnet *t*, to which they are attached by adjustable stems. This bonnet at its lower end is provided with a flange, which, when the bonnet is in its lowest position, as shown, closes against the upper edge of the opening in the base of the regulator ring *r*. Immediately following the opening of the mixture supply throttle *h*, the bonnet *t* is drawn up to a varying height, varying according to the speed of the motor, and in so doing causes the air-way to be increased in a greater ratio than the lift, and by this means compensates for the increasing thickness of the fuel jets caused by the movement upward of the two taper needles. The outer sliding bonnet *t* is guided by a fixed cap *b*, which is drilled with a series of holes around its base for the purpose of admitting air to the inside of the inner fixed guide *b*, which acts as a choke-tube ; all supplementary air is stopped off when the flange regulator of the outer bonnet is in its lowest position, as when running slow with the throttle-plug *h* at nearly right angles.

The two fuel-jet needles are adjusted so that when the outer bonnet is at its lowest position—which then rests on a shoulder of the inner fixed guide *b*—the needle controlling the petrol feed is raised in its nozzle slightly in advance of the other needle controlling the paraffin feed, so that when running dead slow petrol only will be admitted. It will be understood that with the lifting of the regulator flange, constituting in conjunction with the curved ring *r* the supplementary air valve, both jets are brought in to action, the proportion of one to the other varying according to the speed of the motor and to relative adjustment of the two needles. A further correction in the strength of the mixture for varying speeds and degrees of throttle opening can be effected by substituting for the ring *r* another having a slightly steeper or flatter curve according as the mixture is required to be richer or leaner. In general practice the mixture is arranged to flow, as shown, through a tee-connection *v*, heated by the jacket $x^1$, connected by a branch *x* from the exhaust outlet.

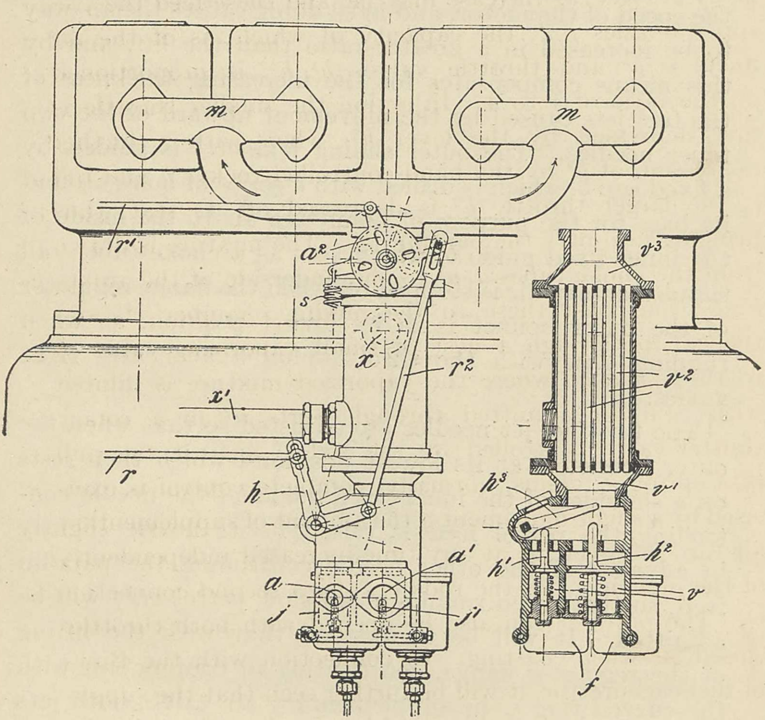



Fig. 70. Fig. 71.

Figs. 70 and 71.—Bi-fuel Carburettor Vaporizer with Positive Control of Air and Fuel Supplies.

In the Binks bi-fuel carburettor illustrated by the sections as per Figs. 70 and 71, the regulation is entirely mechanical, this method having been adopted so that any uncertainty of action due to sticking-up or leakage of any moving part may be eliminated, and for this reason also even the ordinary wing or plug throttle is dispensed with. Petrol and paraffin are supplied to the two float cisterns *f*, either under a slight air pressure or by gravity, as the case may be, and these feed the two spray nozzles $j, j^1$, the capacity of which, as of the air ducts $a, a^1$ and throttle valves $h^1, h^2$, is proportioned on the ratio of 1 to 4. In action the smaller throttle is first depressed by the lever $h^3$, when with a further depression of $h^1$ by the hand-controlled rocker *h* and rod *r*, the larger throttle $h^2$ is depressed off its seat, thus bringing into play the paraffin jet. The mixture is drawn from the choke-tubes $a, a^1$ to the underside of the valves $h^1, h^2$, and past these to the mixing chamber $v^1$, and thence up through a nest of small vaporizing tubes $v^2$ to the space $v^3$, where the vaporized mixture is diluted with cold air admitted through ports $a^2$ in a rotary shutter-valve controlled by the rod $r^2$ against the pull of a spring *s*. Thus, normally, complete control is exercised by a single movement; the amount of supplementary air can, however, be at any time increased independently of the movement of the rods $r, r^2$ by a second connection $r^1$. The ports $a^2$ can also be opened with both throttles closed, as when coasting. In connection with the Binks bi-fuel carburettor, it will be further seen that the supplementary air valve is held closed by a spring when running on petrol; also that the mixture is drawn direct to the motor through the manifold *m*, and that the tubular vaporizer is heated by the circulation through connections $x, x^1$ of part only of the exhaust.

**Carburettor Vaporizers.**—In using ~~paraffin~~ petrol in a road-car motor, the essential factors for a quick start, reliable and steady running under all ordinary conditions are of greater importance than fuel economy, especially in the case of cars required for town work; but for long distance touring with petrol costing from three to four times as much as paraffin, it is worth while to put up with certain inconveniences inseparable even with the most perfect of the known methods of using a fuel that must be vaporized as well as carburetted, and for the heavier commercial cars, it is obviously of still greater importance that the idiosyncrasies of the paraffin motor should be studied, so that its advantage may be fully realised.

As paraffin can be used in any ordinary petrol motor—excepting those of the smaller sizes, for which there would be comparatively little advantage—when fitted with a carburettor vaporizer, *i.e.*, a carburettor combined with a separate vaporizing attachment, and arranged to be heated up by a preliminary run on petrol, a motor so fitted has the advantage that it can be run on either fuel; but in order to obtain the best results, it is obviously necessary to be able to cut out the vaporizer in starting, as by this means not only can the motor be started with a single pull-over, as with an ordinary petrol carburettor—the mixture then not having to traverse the vaporizing space, but can be changed-over to the paraffin feed in less time than when the mixture is drawn through the vaporizer, owing to the cooling effect of the volatilized petrol on the heating surface. Moreover, the motor can, if desired, be run on petrol, and with practically the same efficiency as with an ordinary carburettor of good make. Several forms of carburettor vaporizers have already been described, such being more or less specialized for the conditions associated with motors designed for marine propulsion ; in the following examples, although the same method of vaporizing by the heat of the exhaust is utilized, yet will be seen to differ in detail in the endeavour to adapt a motor of more limited size to the more variable and exacting conditions of road-car propulsion.

Fig. 72.

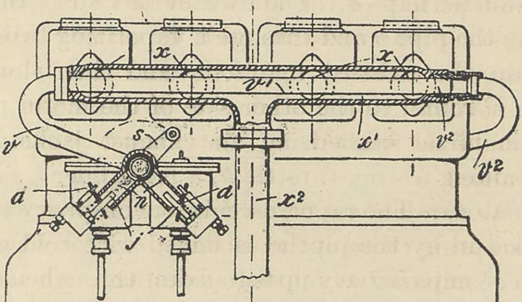
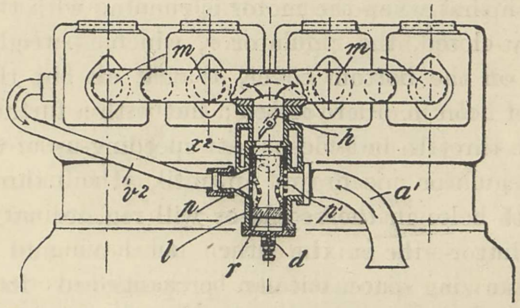



Fig. 73.




Figs. 72 and 73.—Double-jet Carburettor Vaporizer with Automatically Regulated Air and Mixture Supplies.

In this connection it will be seen that the carburettor vaporizer illustrated in Figs. 72 and 73 has some points of interest, this, known as the Noble, is of the automatic mixture-regulating type, and has quite recently been fitted to a Rover four-cylinder 15 H.P. car with apparently satisfactory results. According to this vaporizing method, the starting and running fuels are supplied to separate float cisterns arranged each to feed a single spray nozzle *j* located in the inclined choke-tube *n*, forming part of a three-way change-over valve *s*, to which tubes the admission of atomizing air is regulated by shutter flaps *a*. The carburetted air is thence drawn along the pipe *v* and through a vaporizing tube $v^1$, located within the exhaust manifold, and then along a lagged pipe $v^2$ round to the other side of the motor, to an automatic mixer comprising an exhaust jacketed chamber containing a wing-throttle *h*, a fixed liner *l*, and a sliding regulator *r*. The vaporized mixture of spray and atomizing air led in by the pipe $v^2$ is mixed with cold air from the pipe $a^1$ entering at opposite sides, through series of holes *p*, $p^1$ in the liner and regulator. The action of this mixer is such that when the motor is running with the throttle nearly closed, the regulator *r*, which is weighted, then rests on the bottom cover, so that all but the bottom row of holes *p*, $p^1$ are closed; but with a further opening of the throttle and consequent speeding-up of the motor, the regulator *r* is drawn up until, at full throttle, each row of holes in the regulator will register with a corresponding series in the liner; thus air and vaporized mixture is automatically proportioned for varying running conditions. The diluted mixture passes direct from the throttle to the manifold *m* communicating with the four admission valves in the ordinary way, but in order to damp-out excessive pulsation of the regulator, there is an adjustable air vent *d* on the bottom cover. In this carburettor vaporizer there is no provision for cutting out the heated surface, and in this respect does not comply with the requirements of a motor with a high temperature jacket circulation so as to get the most out of it when running on petrol.

The carburettor vaporizer illustrated in Figs. 74 and 75 is designed for commercial cars, and more particularly for cars in service in remote countries, such as on the west coast of Africa, where not only is the cost of petrol extremely high, but native drivers a necessity. The noticeable features of the vaporizer, known as the Albion, consist in ready accessibility for cleaning and in the absence of all automatic adjustments for mixture control; the vaporizing surface, which is comparatively large, is located on the front side of an exhaust chamber $x^1$, and provided with a series of ribs $v^1$, thus splitting up the mixture in a number of streams and materially adding to the heating surface. Only one float cistern *f* is used, and below this is a two-way change-over plug *t* for controlling the petrol and paraffin supplies; from this cistern the fuel is fed to a single-jet spray-nozzle *j* delivering across the primary air current entering along the bend *a*. The mixture throttle consists of a double-beat valve $h, h^1$ connected to a rod $h^2$, under the control of the driver; the larger disc *h* of the throttle controls the supply of diluent air from the pipe $a^2$, and the smaller disc $h^1$ the supply of vaporized mixture from *v* to the pipe *m* leading to the admission manifold of the motor; the balanced disc valve $h, h^1$ is thus seen to serve as a combined throttle and mixture regulator. An auxiliary air inlet *r*, under the driver's control by a rod $r^1$, is located between the throttle and vaporizer for the further dilution of the mixture, as may be desired under varying running

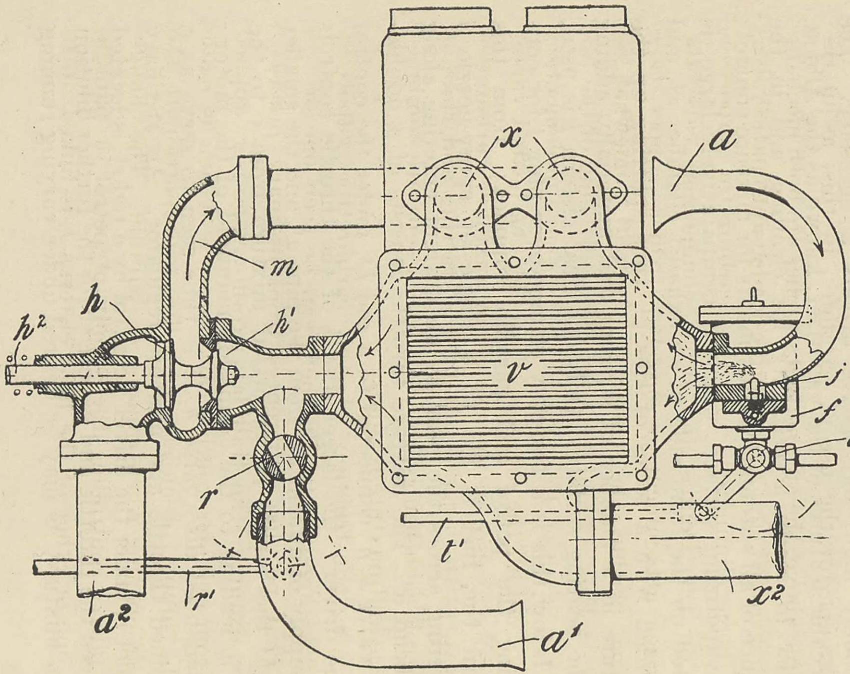



Fig. 74.

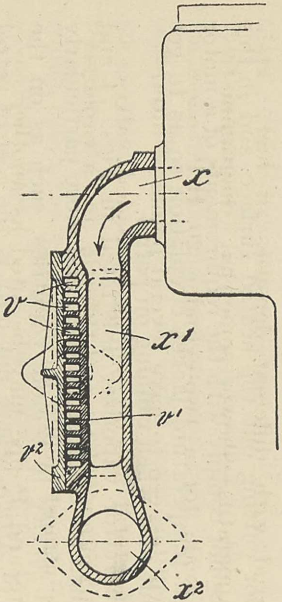



Fig. 75

Figs. 74 and 75.—Single-jet Carburettor Vaporizer with Positive Control of Air and Mixture Supplies.

conditions and with different densities of fuel. The complete apparatus—shown somewhat diagrammatically—is to scale for a two-cylinder 20 H.P. one-ton lorry, and will be seen to have several points of interest, including the total absence of spring-loaded valves, a combined mixture regulator and throttle, and a vaporizer affording the utmost facility for cleaning.

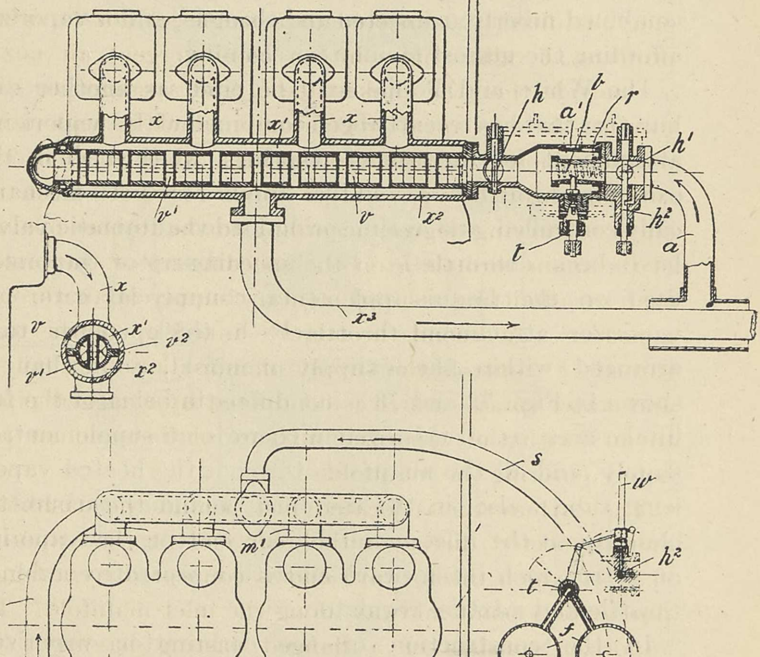
The White and Poppe may be cited as another carburettor that has recently been combined with a vaporizing attachment for the use of paraffin; in this, as in the example above, the air and fuel supplies are both mechanically controlled, and again, spring-loaded automatic valves have been eliminated. In this carburettor vaporizer, used on the Dennis and other commercial cars, the vaporizer attachment is merely a thick copper tube arranged within the exhaust manifold, somewhat as shown in Figs. 72 and 73; but differs in being of the full intake area, as on this system there is no supplementary supply, and all the air passes through the heated vaporizing tube; also, in the use of an auxiliary carburettor close up to the inlet manifold, for starting and running on petrol, each being provided with a separate combined throttle and mixture regulator.

In the construction of the carburettor vaporizer, shown in Figs. 76 to 79, there can be seen one or two somewhat peculiar differences from ordinary practice; in this example, the Halliday paraffin vaporiser, applied to a four-cylinder touring-car motor, provision is made for the supply of moist air in direct proportion to the throttle opening when running on paraffin. The change-over plug *t* controlling the supply of petrol or paraffin from one or other of the float cisterns *f*, is linked up to the spindle $h^2$ of the primary air throttle $h^1$, on which is cut a passage way to serve the purpose of controlling the admission of a water-jet in advance of the fuel-jet

Fig. 76.

Fig. 77.

Fig. 79.




**Figs. 76 to 79.**—Single-jet Carburettor Vaporizer with Inter-connected Fuel, Mixture, Air, and Water Spray Supplies.

nozzle, and to which heated air is supplied from the bend *a*, terminating in a sleeve surrounding the exhaust pipe $x^3$; the groove on this spindle is so arranged that the water supply is automatically cut-off when starting and when running on petrol. The change-over fuel plug *t* is directly connected to a single-jet nozzle, which projects at right angles into a con-divergent air nozzle *b*; outside this, the choke-tube *b*, and arranged to slide over it, there is an air regulator *r*, which is held in the position shown by a pair of springs, when the motor is running throttled up; but is drawn forward by suction effect in varying degree, according to the further opening of the main throttle *h* on the speeding-up of the motor, thereby admitting a supplementary supply of air through a port $a^1$. A second throttle $h^1$, linked up to the main throttle *h*, controls the supply of moist air—*i.e.*, hot air and water spray—which is conducted by a lagged pipe *s* to mix with the vaporized mixture of fuel and air just before entering the manifold.

The carburettor is located just behind the dashboard and connected direct to the rear end of the vaporizer $v$, $v^1$, of which the forward end is connected by a lagged pipe *m* to a point midway along the inlet manifold. The vaporizer consists of a flanged casting having a rib running along at each side, for the purpose of dividing the exhaust manifold, into an upper and lower chamber $x^1$, $x^2$, to which exhaust from the motor enters along branch pipes *x*; the exhaust then passes from the upper chamber $x^1$ to the lower half $x^2$, by way of a series of cross tubes $v^1$, so arranged that the mixture in its passage from the carburettor to the outlet pipe must impinge against several tubes. The heating surface is considerable, which is a good feature; indeed, it is claimed for this system that it is the only one in which a stop of an hour can be made without having to restart on petrol; in point of fact, there appears to be no difficulty at all in restarting on paraffin after a stop exceeding half an hour, which is an important consideration, as for many purposes, such as motor cabs, shopping and town calls, this means, of course, a material saving in petrol; it also simplifies manipulation.

Many of the conditions pointed out above are complied with in the Contanesco carburettor vaporizer, shown in Figs. 80 to 83, inasmuch as the vaporizing capacity is large, and the amount of atomizing air is limited to within 10 to 15 per cent. of the total volume supplied when running full out. A peculiarity in this, better known as the G. C. paraffin vaporizer, is that it takes the form and function of a muffler, somewhat after the manner of the Bassford, but differs from this in having separate diluent and mixture throttles $t, t^1$. Another feature in the G. C. consists in its location under the frame of the car; indeed, on account of its size, it would be difficult to otherwise place it. The exhaust from all the cylinders of the motor passes through it, and first enters by the pipe $x$ to a thick star section cast-iron radiator $x^1$, enclosed in a thin wrought-iron pipe. Paraffin fed from a float cistern $f$ enters along a perforated pipe $k^1$, laid along between one pair of ailettes over the exhaust radiator $x^1$; between another pair of ailettes is laid a second pipe $a^1$ for the supply of atomizing air from $a$, supplied in volume varying directly as the fuel feed. Both pipes are perforated for about one-half their length, and the vapour and air are drawn along the spaces between the ailettes to the vaporizer head, whence the mixture passes through the outlet $v^1$ and the pipe $v^2$

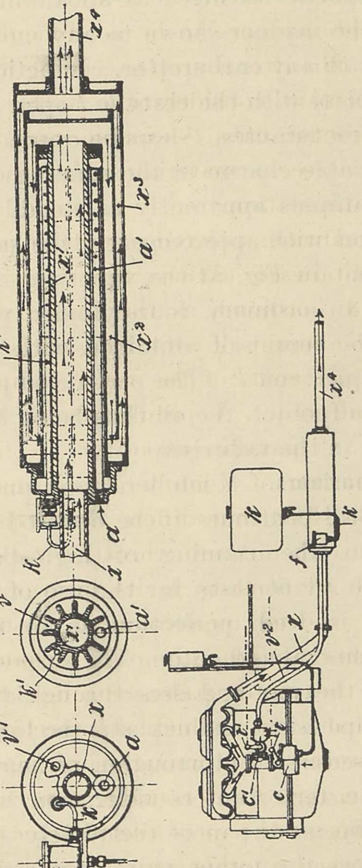


Fig. 80. Fig. 81. Fig. 82. Fig. 83.

Figs. 80 to 83.—Exhaust Muffler Vaporizer and Carburettor with separate Petrol and Paraffin Mixture Throttles.

to the mixer $c^1$ containing the diluent throttle $t^1$. In order to further conserve the heat of the exhaust, the radiator $x^1$ is enclosed within two chambers $x^2, x^3$, of which the outer casing is asbestos lagged, as also the pipe $x$ leading thereto from the motor. According to this system, the vaporizer is fitted as an auxiliary, and can be applied in the manner shown to any motor, and with little alteration to any carburettor. In action, the motor is started on petrol with the throttle $t$ open and $t^1$ closed, when, after a few minutes, $t^1$ can be opened and $t$ closed without appreciable change in the running of the motor, which then continues apparently as steadily on paraffin as on petrol, and with approximately the same economy in consumption. In Fig. 83 the vaporizer is shown connected up to an ordinary four-cylinder petrol motor, and is, it will be seen, self-contained with its own float cistern and supply tank $k$. The perforated pipe $k^1$ serves the purpose of a fuel jet, the oil thus being heated before mixing with air in the vaporizer.

**Injection Vaporizers.**—Much scheming and endeavour has been and still continues to be devoted towards the improvement in the running of high-speed paraffin motors, so as to adapt them for the use of this cheaper and safer fuel in such perfection as to render them suitable for all general and automobile purposes. But the difficulty is, the heavier and denser a liquid, the greater is its molecular cohesion, and explains the higher function played in the process of atomization of heavy oils than light; this is an important consideration in the vaporization of paraffin, as the more completely an oil can be atomized, the less the temperature required for perfect vaporization. In the first successful engines to run on paraffin, the vaporizer (*vide* Fig. 36) consisted of a comparatively large exhaust jacketed chamber, into which the fuel was sprayed under pressure by a compressed-air jet. Again, in the largely increasing number of fuel-oil engines operating on the direct injection system, the fuel is sprayed into the cylinder by a compressed-air jet, but in this case at a pressure exceeding a compression of 33 atmospheres. It would, therefore, only be consistent to presume that were it not for the difficulty experienced in the application of this principle, coupled with many inherent complexities involved in the process, this method would ere now have been adopted for automobile motors.

The Stewart-Morris method of pressure injection is, however, the nearest approach to air or mechanical pressure atomization as applied to high-speed motors up to the present. According to this vaporizing method, shown in Figs. 84 and 85, illustrating its application to a four-cylinder 20 H.P. ordinary touring car, the fuel will be seen to be sprayed under pressure and quite independently of suction effect or fuel level, and that no float cistern is, therefore, required; the starting and running fuels—petrol and paraffin—are supplied from separate tanks maintained at a pressure of 4 to 6 lbs., by an ordinary hand pump. The change-over from petrol to paraffin is effected by a pair of gland-packed plugs *t*; thence the fuel is automatically regulated by a vertical movement of the taper needle *j* within the spray nozzle, this needle being hinged on to the guide stem of the mixture regulator *r*.

In action, primary air is drawn in by the motor pistons along the pipe *a* and across the fuel jet, which issues in a continuous and attenuated angular stream; the air thus carburetted is then drawn through the pipe *v* to the vaporizer $v^1$, which, as shown, consists of a plain

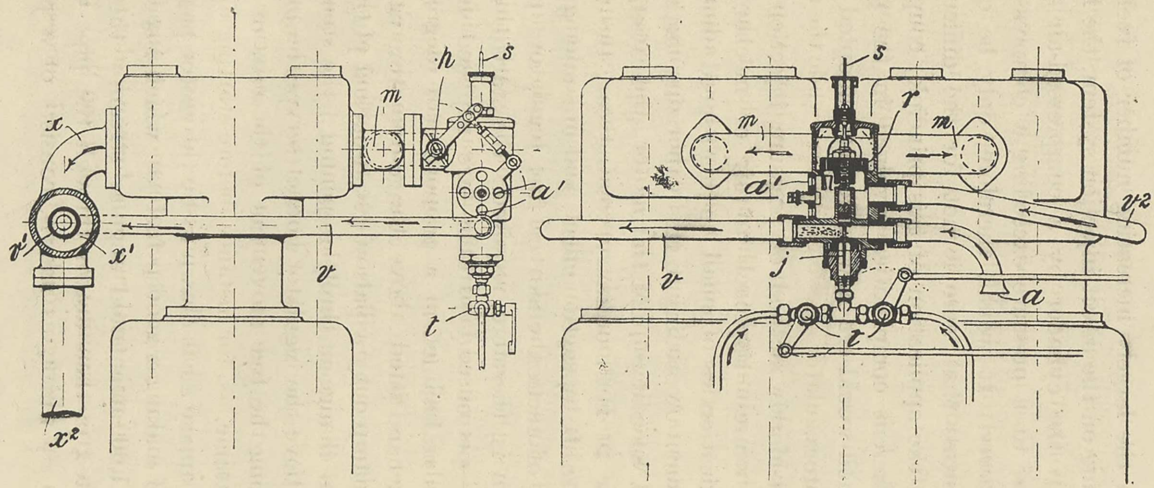



Fig. 84. Fig. 85.

Figs. 84 and 85.—Carburettor Vaporizer with Automatically-regulated Pressure Jet and Inter-connected Air and Mixture Throttles.

copper pipe, but may be arranged in the form of a coil, and in either case is located within the exhaust manifold $x^1$; the vaporized mixture is then drawn along the lagged pipe $v^2$ to a mixing chamber under the regulator $r$ of the carburettor; here the rich mixture is diluted with supplementary air admitted by the rotary shutter-valve $a^1$ in direct proportion to the extent to which the main throttle $h$ is opened, these two valves being proportioned to this end and linked together.

The mixture regulator $r$ is weighted, and while the motor is running dead slow rests on its seat, and the vaporized mixture is then admitted to the upper side of the regulator through a series of small holes without admixture with supplementary air; but on further opening of the throttle and speeding-up of the motor, the rotary air-shutter $a^1$ is proportionately opened, thus causing the regulator $r$ to lift by suction effect, and in so doing carry the series of slots in the skirt of the regulator up to a position above the seat. Simultaneously with this, the taper needle $j$ is raised, and thus increases the thickness of the annular fuel jet in a proportionate degree. A small plunger is fitted above the automatic regulator in order to damp out oscillation due to jolting of the car, or to sudden change in throttle opening; the stem seen to project above the regulator bonnet serves the purpose of ascertaining the free movement of the mixture regulator at any time, as, for instance, before starting up.

It would appear that this pressure atomizer vaporizer is capable of making a good performance, judging from a certificated 1,000-mile trial run on a four-cylinder touring car having a gross running weight of 3,800 lbs. During this run on an average road surface and succession of gradients, the quantity of paraffin used was 47 gallons, which works out at over 20 miles per gallon, plus 1 gallon of petrol for starting. The motor was started 16 times on petrol and 18 times on paraffin ; the longest stop for restarting on the heavy fuel was 17 minutes, and the longest with temporary injection of petrol 45 minutes. In starting all cold, the longest period before changing-over was 4 minutes 20 seconds, and the shortest, with the motor and vaporizer warm, 10 seconds.

**Flame-heated Vaporizers.**—The outstanding feature of vaporizing by externally or internally applied heat, whether from blow-flame burners, or by the combustion of a portion of the mixture, is the entire independence of petrol for starting. An example of the first of these methods is illustrated in cross-section by Fig. 86, shown applied to a four-cylinder motor designed for either auto or marine propulsion, and under conditions where the use of petrol would be prejudicial, as, for instance, for inland navigation, or for road or rail cars in Burmah, South China, Siam, India, and other tropical countries, where, for reasons of safety in handling by unskilled attendants, a flash-proof oil is desirable. The essential feature of a motor fitted with the paraffin vaporizing system—known as the Gardner—consists in the use of a separate lamp-heated vaporizer *v* for each cylinder, the motor in other respects conforming to the automobile or electric ignition type. The vaporizers are each provided with a separate float-fed single-jet spray nozzle *j* and burner *b*, which latter is encased in an aluminium wind shield. The burners which each project a silent blue flame around the base of the admission valves are, together with the float cisterns, fed from a supply tank, maintained under a continuous pressure by a small fuel pump drawing its supply from the main tank.

Perhaps the most important feature of this lamp-heated vaporizer, apart from its independence of petrol,

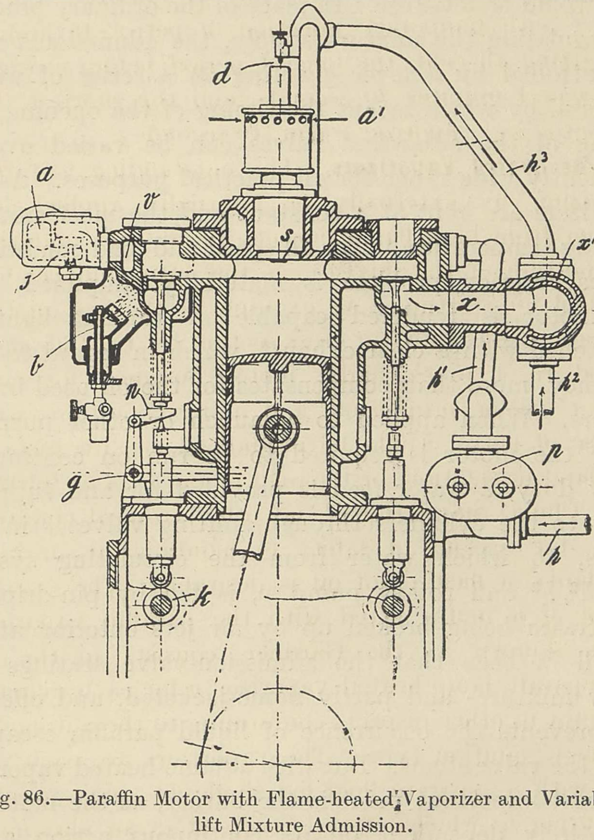



Fig. 86.—Paraffin Motor with Flame-heated Vaporizer and Variable-lift Mixture Admission.

is that no special adjustment of the fuel feed is required at starting; there is, moreover, no supplementary air feed nor mixture regulator used, owing partly to the constant temperature maintained and partly to the special method of admission control; for these reasons such motors can be handled with success under circumstances wherewith motors of the change-over bi-fuel type would be a failure. In place of the ordinary practice for regulating the mixture supply, the admission period is controlled by a lever *g* acting on a series of wedge blocks *n*, by which means the timing of the opening and closing of the admission valves can be varied over a sufficiently wide range for all practical purposes. As the vaporizers are kept at a constant and the most suitable working temperature under all speed and load conditions, the carburetion problem is materially simplified, also the motor is rendered capable of running light or declutched with a clear exhaust, which in regard to fuel efficiency, more than compensates for the oil used in the burners. When applied to a launch or other purpose, where the motor is required to be run on continuous heavy duty, a water feed is provided for and supplied direct to the cylinders through snifting valves *s* in the covers, to which water from the circulating system $h, h^1, h^2, h^3$ and rotary pump *p*, is fed by pin-drips *d*, the stream being broken up by air jets entering at $a^1$. It will be seen that the admission-valve seatings are partly mixture- and partly flame-jacketed, and effectually prevents the occurrence of liquid paraffin escaping down the valve stems. But with a flame-heated vaporizer the most important point is the burner, as the motor is as entirely dependent on its continuous action as is ignition on properly timed sparking at the igniter; however, judging from the number and variety of purposes to which these motors are used, this difficulty has been got over; the burner jet projects horizontally against a perforated disc, whence the vapour issues together with sufficient air to produce a smokeless blue flame in the manner shown.

From the number and variety of methods that have been evolved for vaporizing paraffin for running motors of the high-speed electric ignition type, it would seem that one of them must sooner or later show up to sufficient all-round advantage to take the lead; but, so far, it cannot be said there is any line, indicating the final solution of this really difficult problem, yet in sight. Before, however, concluding the study of this very interesting and elusive subject, mention should be made of a vaporizing system that takes a wide departure from the well-trodden track, and which from the following description will be seen to resemble in some measure, perhaps, the reactions taking place in an ordinary gas-producer.

**Electric Vaporizer.**—In this, known as the Southey paraffin vaporizer, illustrated by Figs. 87 and 88, the combustion of part of the fuel sprayed into a chamber is claimed to have advantages both of the exhaust- and flame-heated vaporizer, as being independent of an externally applied flame as well as petrol. The essential features of this apparatus—fulfilling the function partly of a gasifier and partly of a vaporizer—consist of a fuel circulating pump, an atomizer, a specially adapted high-tension igniter, and a float-feed regulator. The first of these—the fuel pump *p*—has a capacity equal to some twenty to thirty times the consumption of the motor, and circulates the paraffin under a slight pressure past a needle-valve regulated spray nozzle *j*; the finely atomized spray falls within the cone-shaped hood *n* and mixes with a limited volume of air entering through

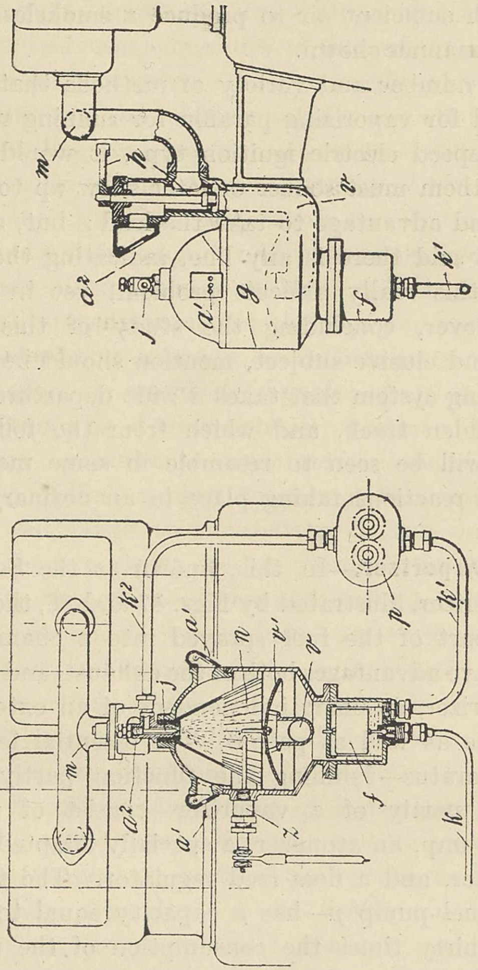


Fig. 87. Fig. 88.

Figs. 87 and 88.—Combined Arc-flash and Flame-heated Paraffin Gasifier with Throttle-controlled Air and Mixture Supplies.

the two flap-controlled inlets $a$, $a^1$, and thence, by way of a series of narrow slits cut around the bottom edge of the hood. In the centre of the space enclosed by this cowl-shaped hood, which constitutes a sort of combustion chamber, a rather powerful sparking current plays across the points of an igniter, one of which, the positive, extends from the plug *z*, the negative being secured to the deflector disc, guarding the gas outlet *v*. The gaseous mixture generated by the partial combustion of a small proportion of the vapour generated, consists partly of carbonic oxide, and partly vaporized spray and air, the proportions varying according to the amount of air admitted, and to a certain extent also to the intensity of the kindling spark. For instance, with sufficient draught, the gasifier would become a sort of oil furnace, and use up fuel extravagantly; this, as shown, is fed from a supply tank along a pipe *k* to a float-regulated valve *f*, to compensate for the amount consumed in the gasifier and carried over as gas and vaporized mixture to the motor. The combustible from the gasifier *g*, together with the necessary supplementary air admitted by the flap-controlled inlet $a^2$, passes to the inlet manifold *m* of the motor in regulated volume according to the opening of the combined plug-throttle and mixing valve *h*. No preliminary interiorly or exteriorly applied flame is required before starting up, which is a remarkable feature of this very wide departure from the accepted methods of producing combustible mixture from paraffin, as in pulling over the motor the spray injected is sufficiently atomized for it to flame and thus at once generate gas and vaporized mixture.

πr²

150. 200.
075

0,075 × 0,075 × 3 + 0,2 × 1000

75.75
375
525.
5625.3
168.75.2
3,375000

2.7. 3.3.60 200.60
19.8 1,2
2.60
12000.

200.00
20.000

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