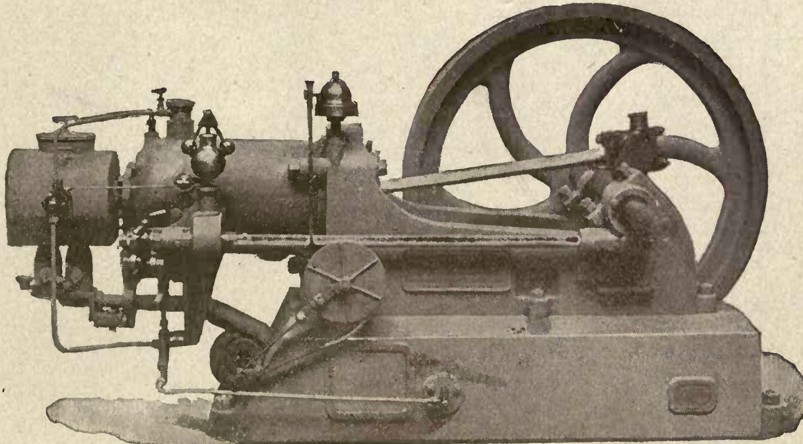
Spon & Chamberlain's Series of Practical Handbooks

Gas Engines



HORNSBY-AKROYD SAFETY OIL ENGINE.

A PRACTICAL HANDBOOK

ON THE

CARE AND MANAGEMENT

OF

GAS ENGINES

BY

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AUTHORIZED TRANSLATION

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WITH INSTRUCTIONS FOR RUNNING OIL ENGINES

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NOTE BY TRANSLATOR.

Believing that the practical instructions contained in Herr Lieckfeld's little book would prove useful to users of gas engines, permission was obtained of the author to translate it. The fact that some of the matter relates to gas engines of obsolete form is not altogether a disadvantage, since it may enable the owners of such engines to prolong their useful life.

At the request of the publishers a chapter on Oil Engines has been added. In the limits allowed, it has only been possible to refer to the "Otto" Gas Engine and the "Hornsby-Akroyd" Oil Engine. They are sufficiently representative, however, to fairly cover the field.

CONTENTS.

CHAPTER I.

CHOOSING AND INSTALLING A GAS ENGINE.

CHAPTER II.

BRAKES AND THEIR USE IN ASCERTAINING THE POWER OF GAS ENGINES.

CHAPTER III.

ATTENDANCE ON GAS ENGINES.

CHAPTER IV.

CHAPTER V.

DANGERS AND PRECAUTIONARY MEASURES IN HANDLING GAS ENGINES.

CHAPTER VI.

OIL ENGINES.

CHAPTER I.

ON THE CHOICE AND PROPER SETTING UP OF GAS MOTORS.

A GOOD gas motor should be of simple construction, with all its working parts well in view, its operation easily understood by any one, and its running quite regular and free from faults. In operation the motor should not make a disturbing noise or vibrate, nor should any irregularity in running strike the eyes or ears.

The consumption of gas and lubricating oil should not be greater than that proper for this class of motors.

The cleaning and keeping in order should be easily and quickly done.

These are in general the points to be kept in view in judging a gas motor.

Entering a little more into detail as regards the construction, it may be said that the outside appearance of the machine should give the impression of solidity and strength.

The frame should have a broad base. The moving parts should be as few as possible, and the special use of each particular motion immediately apparent. The crank shaft and connecting-rod bearings should be adjustable. For oiling the piston and slide valve mechanically operated oilers are preferable ; they are driven by the motor itself, and the oiling is effected independently of the attendant. So-called Oil Drips (self-feeders), in which the oil is not mechanically supplied, must be turned on and off ; besides, they do not oil uniformly, since the number of oil drops diminish as the level of the oil falls ; moreover, such an apparatus easily becomes stopped up.

The working cylinder should be as independent as possible of the frame and removable therefrom.

In horizontal machines those having guide-bar and crosshead (Fig. 1) are to be

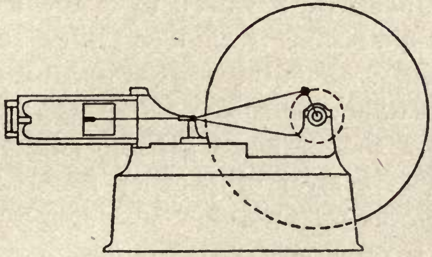

FIG. 1.

preferred to those in which the connecting-rod is coupled directly on to the piston (Fig. 2).

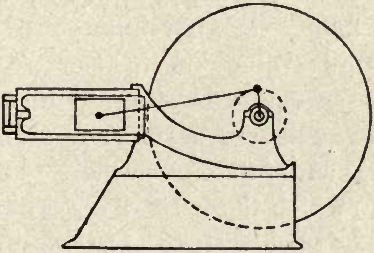

FIG. 2.

Where the room for setting up is limited, requiring contraction of the motor, then the horizontal type without special guide or the vertical type should be chosen. In either case it is well to secure a long and light piston. Pistons and valves should be removable in the shortest possible time, and without difficulty; valve and cylinder covers should make ground joints—*i.e.*, without a layer of packing material between the surfaces.

It is preferable, on examining a motor, to have the piston and discharge valve taken out and put back. These operations ought for a motor of not more than 4 Horse Power to be easily performed by one man in not longer than ten minutes.

The governing mechanism should be well in sight and constructed with the least possible number of links. The pins should be long and fitted in bushes. The hard work to which the parts of a gas motor are exposed demands that the greatest care be exercised in the fitting and that perfect material be employed.

The most ingenious and excellent constructions are worthless when they are not well put together and perfect in running.

The well-known motto of a distinguished manufacturer, "Good work is my best patent," holds for no machine more than for the gas motor, nor are the machines of the latest patent necessarily the best. Caution and care must also be used in the examination of the working of a gas motor.

Whoever has confidence in his ability to distinguish good from bad work will not neglect to dismount each part of the motor with his own hand and put it back again in its place. The conclusions as to workmanship which are reached by this proceeding are often startling.

Even for the less experienced there are certain marks of good work which are not to be mistaken, and their presence may be accepted as an indication that in the rest of the fitting up the necessary care has been bestowed. To these indications belong, before all things, clean-cut threads of bolts and well-fitting nuts—that is, the nuts should neither be too loose nor too tight, but must be turned by the hand without effort ; also the spanners supplied should fit exactly on the nuts.

Further, all the linkages should be worked to a sliding fit ; when a movement is given by the hand to the shanks a uniform and smooth sliding movement should be remarked. Every link pin should be removable from its place by a blow with the hand, although it must be a close fit in the hole to which it belongs.

All pins, bushes, cam rollers, slides, and particularly all parts which are subject to wear (where hardening is not impossible) must be glass hard to the depth of 2 mm.

One can test with a file the hardness, and from fractured parts the depth of the hardening is determined. Makers who pay particular attention to hardening are worthy of confidence.

Next the mode of starting the motor should be examined. The "starting" handle should be pointed out, and when the motor is of less than 6 Horse Power an attempt should be made to start it without help. Without too great an exercise of strength the forward running should be set up after three or four revolutions of the fly-wheel.

When the motor has reached its normal number of revolutions, then its working is to be observed, and no trace of thumping or pounding at the moment of ignition should be heard or felt, when the hand is placed on any part whatever of the cylinder or framework.

The fly-wheel should run perfectly true if the finger is placed on the outer side of the revolving fly-wheel so as to scrape the nail, then neither trembling nor unsteadiness of the periphery should be felt at the moment of ignition; such, if present, would be due to defective fitting or too small crank shaft.

All levers, rollers, and slide rods in connection with the governing should work smoothly ; they should not snap or be forced out of their proper path.

The less noise the cog wheels make the more noiseless the valves, cams, and levers of the regulating gear work, the less the machine hisses and puffs, the less the neighborhood of the motor smells of gas and burned oil, so much the better is the motor constructed and run, and so much more agreeable will it be to have to do with it.

When an opinion has thus been formed as to the solidity of construction and the ease of running there remains the question of economy—that is, the gas required by the motor.

For this purpose let the belt be thrown off and observe the throwing in and out of gear of the controlling mechanism while the motor runs empty.

Nowadays it is to be expected that in such case for one power stroke six omissions will occur, and thereof the gas consumption for no load should not be more than 1-7th of that required for full power.*

The number of revolutions, first for no load, then for full load for the same period of time, about 5 minutes, should be taken. With no load the machine runs faster than when loaded; the difference between the total revolutions should not be more than 5 per cent. The loading of the motor can be done by pressing a wooden beam against the fly-wheel, the full load in which no misfires occur should not be reached by these means.

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* It is here understood the regulation of speed is by periodic full power. There are other methods by which the regulation under variable load is effected, but for no load these are not so economical, while they give more uniform rate. Now read of the gas consumption observed from the dial of the gas meter for a period of about five minutes.

Good gas motors should, if the exhaust pipe is not too long or too small, consume for no load the amounts of gas in the following table:

Horse Power,	½,	1,	2,	4,	6,	8,	10.
Cubic feet gas per hour without load,	6,	9,	13,	25,	50,	67,	72.

The amount of gas required for full load can be exactly ob-

In general, it may be remarked that a guarantee is furnished by the maker as to the maximum power of the motor and as to the consumption of gas per hour per full, 1-2, and 1-4 load. The consumption of gas per hour and Horse Power for 1-4 load at the highest may be double as great as for full power. The less the gas consumption for no load is, so much more economically the motor works in use, when, as is generally the case in small businesses, the power requirement is very variable.

A great number of reserve pieces for this or that part of the motor is no recommendation for it; just as little is a number of special tools for taking it apart and cleaning. Moreover instructions for running prolix, and difficult to understand, do

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tained only by the help of the power brake, respecting the handling of which the next chapter will treat.

The regularity of running can be approximately judged of by listening; more correct conclusions can be attained by counting the revolutions by the watch.

not argue well for an engine; it is well to ask for the instruction book before deciding on the purchase.

Nor should the cost of a journey deter from watching the performance of motors of different systems for a length of time, in order to learn the opinions of owners and drivers and personally determine the merits of the motors.

Only those motors which for years have performed hard duty without derangement in running secure a recommendation for their makers.

It cannot be too often asserted that *durability* and *certainty of running* count before everything, since these are the only grounds upon which certainty of continued undisturbed service of the machine depend. *Cheapness* and *oil consumption* stand in the second rank only.

With regard to the power of motor to be chosen the following point may be noted: the majority of dissatisfied owners of motors will be found to complain of leaking pistons. When the circumstances of running are investigated it is almost uniformly found that a motor of too little power has been chosen and the same has been overworked.

A gas motor which is continually worked with full load, however it may be constructed, is overworked, and will always be ruined in a comparatively short period. The cylinder and piston of gas motors should be cooled not only by water in the jacket, but, especially in large motors, by interior cooling and cool air. This cooling follows naturally in motors in which the regulation is by periodic full charge, when the cut off of the gas occurs in regular succession, and air only is drawn in which is in direct contact with the cylinder walls and piston end.

In running at full load cut offs should occur, and therefore intelligent manufacturers give their motors such dimensions that when running continually with full load, with no cut off, develop 20 to 25 per cent. more power than that at which they are rated in the price-lists.

From these considerations it follows, further, that for those motors which regulate by periodic full charge a longer life is to be prophesied under similar conditions than for those which work with variable charge.

Whoever has had occasion to discuss gas engines with professional dealers will have remarked that they gave the impression that the cost of an installation in running order is limited to the purchase price of the motor. The necessary expenditure, however, is often very considerably greater than this.

The following items in the cost of such an installation must be noted :

(*a*) Capital Invested.

(1) Purchase price of the motor.

(2) Freight and cartage.

(3) Setting up of foundation and special building work.

(4) Cost of erecting piping (gas pipes with gas regulator, water pipe, exhaust piping and overflow for cooling water).

(5) In the case where a water supply is not at the user's disposal the cost of providing a cooling vessel or any cooler with the suitable piping.

(6) Cost of erection, including railway fare, lodging, boarding, and wages for the erector. According to the size of the motor, the time of fitting up may be taken approximately as follows: For motors up to 2 Horse Power, 3 days; up to 6 Horse Power, 5 days; up to 15 Horse Power, 10 days.

(*b*) RUNNING EXPENSES IN USE.

(1) Interest on the capital invested.

(2) Renewal and cost of repairs for the motor 10 per cent., and for the other part of the investment 5 per cent.

(3) Rent.

(4) Cost of gas, cooling water, lubricating oil, waste, etc.

For the gas consumption we may reckon 1.2 cubic meter (42 cubic feet); for small motor, 1 cubic meter (35 cubic feet); for medium size and for the larger sizes, 8 cubic meters (28 cubic feet).*

Cooling water consumption by Horse Power and per hour for small motors, 40 *l.* (9 galls.); medium, 35 *l.* (8 galls.), and larger, 30 *l.* (7 galls.).

The oil consumption varies very much according to the construction of the motor, whether vertical or horizontal, and with or without a crosshead.

Data regarding this will be obtained from the maker furnishing the machine.

(5) Cost of attendance and cleaning of the motors are approximately taken as one hour's wages per day.

Let us pass to the question of the special provisions for the installation.

Of first importance is the choice of the

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* These quantities have been considerably reduced in the better class of modern gas engines. (*Translator.*)

location itself, which must be carefully considered.

When practicable the motor should be placed in a separate room. In carpenters' shops, saw mills, tobacco factories, foundries, and especially in all trades where flying dust is inevitable, the motor should have a separate room ; if this cannot be provided, a room should be boarded off and provided with windows.

This motor room should be well lighted and roomy, so that easy access can be had to the motor on all sides and on the side of the fly-wheel, where the workman has to go to start the engine, at least 3 feet space should be left.

Arrange the setting of the motor for direct driving (a crossed belt is to be avoided). The gas and exhaust piping should be as short and direct as possible. Neighbors of gas motors raise great objections to the smell and noise of the exhaust, and care should be taken that cause for such complaints shall be avoided. Very often the first feeling of satisfaction which the owner of a well-running machine experiences is very properly upset by the complaints of angry neighbors.

These preliminaries attended to, and the ground plan showing the requisite piping supplied, we may proceed with the preparation of the foundation, and finally with the erection of all the piping up to the connections with the motor.

The drawings of the foundation are furnished by the maker of the motor, from whom also may be obtained the dimensions of the different pipes, thickness and width of the driving pulley, direction of running, and many other obvious points.

If the motor is to be placed on the ground the foundation pit must be dug out to the solid earth. This must be taken account of in estimating the cost of masonry.

For small foundations—say for motors up to 2 Horse Power—often a single sandstone slab will answer.

As material for brick foundations, hard-burned bricks, well-binding Portland cement, and clean, sharp building sand are to be employed. Sufficient time must be allowed for the cement to harden.

It is well known that cement is weakened by continued action of oil. Motors should be provided with so-called oil curb to prevent the overflowing of the lubricating oil. As it is, nevertheless, impossible to prevent oil from time to time getting on the masonry, it is usual to replace the upper four or five courses of brick with a block of sandstone.

For setting motors on joists of floors in old houses, full assurance should be had as to the good condition and sufficient strength of the beams. In any case the floor boards should be taken up in the neighborhood, so that all the joists may be inspected. If these precautions are not taken there is danger, sooner or later, of breaking down the floor.

To avoid springing of the joists, the

motor is preferably to be placed in a corner.

Motors of the vertical style above 4 Horse Power should not be placed on the upper floor of ordinary dwelling houses unless the joists and the supporting brick-work are strengthened.

Cellar vaults or the concrete flooring of modern houses should not be utilized for the direct installation of gas motors; in such cases it is better that the foundation should be built from the cellar floor up to the level of the vault with special pillars of sufficient strength.

To place the gas piping, the following hints will be useful:

Above all, choose pipes of sufficient size, and sharp bends should be avoided as far as possible.

Where the neighborhood would be annoyed by the flickering of the gas or where changes in gas pressure are to be expected a pressure regulator should unquestionably be installed.

Leading the gas pipe through rooms of different temperatures is to be avoided as far as possible. At the lowest point of the gas piping, in close proximity to the motor, a ¼-inch blow-off cock and drain pipe should be placed to serve for carrying off the water collected in the pipe; it also serves the purpose of blowing off the gas when, after long standing of the motor, it is diluted with air; it serves also when it is desired to measure the gas pressure or maintain an open flame close at hand.

The rubber bag serves its purpose better the nearer it is to the motor. The pulsating motion of the bag endangers its pulling off from the pipe. As this may cause a dangerous escape of gas, care should be taken to secure the mouth of the bag to the pipe by winding wire around it.

Oil destroys rubber and changes it into a sticky, viscous mass; hence the rubber bag must be placed out of reach of the oil splashing from the connecting-rod and governor or protected with a cover.

In laying out the cooling connections it may be remarked that the piping for conveying the water (under pressure) must be of sufficient capacity. In most systems of motors the water must enter the jacket at the bottom, and the overflow at the top should pass into a funnel, so that it can be seen and be tested as to the temperature of the water at any time, which should not be above 70° C. (158° Fahr.).

Cooling tanks, unless very small, should not be placed in the same room with the motor; the tank is better placed in a cool place where a current of air obtains. The best place is an unused corner of the house floor, as near as possible to the motor. The higher the cooling tank the more rapid the circulation of the water.

The pipe which connects the upper part of the motor jacket with the upper part of the tank must, in all cases, be fixed with a continually rising column. For air coolers the above remark is even more important. The lowest point of the cooler should be at least 1 meter (3 feet, 3 inches) above the lowest point of exit for the water from the jacket.

For driving off of the heated air from the upper end of the cooler and also the drawing in of cold air to the barrel the same care must be taken to provide proper openings in the sides of the same.

The connecting pipes between the cooler and the motor should be as short as possible. All bends must be in the form of well-rounded curves.

As the water contained in a pipe coil cooler by becoming heated is expanded, place for the surplus must be provided for with a so-called expansion vessel. This expansion vessel placed above will be provided with a loose cover, and is preferably connected with a cooler with a small pipe, say ½ inch. The surplus water takes up little room in the expansion vessel, and the loss by evaporation is small, so that refilling is seldom necessary.

The advantages of the pipe coil over the cooling tank lies in the fact that on the cooler heating up a permanent condition is soon established ; it requires less space, a smaller quantity of water is required for filling it, and it may be used with advantages for heating and ventilation purposes.

The fitting up of the exhaust pipe often presents difficulties ; the products of combustion flow through this pipe with a high velocity, great length, small diameter, sharp bends, create considerable back pressure on the piston and a very appreciable loss of power.

At the present there are no motors in which the accidental entrance of unconsumed gas into the exhaust pipe can be counted on as an impossibility ; moreover, as the working principle of the gas motor ensures that sooner or later this escaped gas will take fire, it is necessary that the walls of the exhaust pipe should be strong enough to bear a pressure of 5 to 6 atmospheres (60 to 75 lbs. per square inch). Zinc pipes, drain pipe, masonry chimneys or canals are once for all excluded from use as conducting pipes for the exhaust. Only wrought iron or cast iron of sufficient thickness should be chosen ; the presence of sharp corners, already warned against, may not only diminish the work performed, but may even cause stoppage of the machine. The burned products drive a great part of the lubricating oil in pulverized form through the pipes into the open air, where this oil dust strikes against the hot bend of the wall of the pipe, it is cooled, forming the well-known oil coke, which gradually becomes a perfect wax, and in course of years may fill the whole pipe aperture. Mysterious derangement in running, with falling off of power, great gas consumption knocking in the exhaust pot, often have their cause in this stopping up of the exhaust pipe.*

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* For a certain gas motor, in spite of careful attendance, the gas bill advanced in the course of a year from 23 M. per month to 58 M., without any increase in the work done. All endeavors to find out the cause of the trouble were fruitless. At

The products of combustion, and especially condensed water vapor, cut into the material of the exhaust pipe. The oxidization goes on more quickly in the horizontal stretch of a pipe, and such a disposition is to be avoided.

There are several methods of preventing the noise of the exhaust—choking the orifice of the exhaust pipe, putting in circuit several pots, one behind the other, or a battery of broken stones. By one or other of the two last methods the noise can be entirely suppressed. In all cases, however, the available work is diminished by this procedure.

Pipes for bringing good working air often become necessary; they ought not to be of zinc or tin, since return firing through the air pipe may occur, so

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length, when by accident the exhaust pipe came apart, it was found that instead of a mouthpiece of 2-inch pipe in the exhaust pot, it was so stopped up that the little finger could with difficulty be placed in the hole.

After a thorough cleaning of the pipe the gas consumption went back to the usual amount.

that here also wrought iron should be used.

The air pipes and the part of the gas pipe which makes the connection between the gas bag and the motor should, before fitting up, be most carefully cleared of scale, iron cuttings, sand, etc., by tapping with a hammer and blowing through them.

The setting up of the motor will always be best done by an employé of the firm supplying it; well-grounded complaints cannot then be met by the answer that they are due to faults in connecting. It is only necessary in this place to say with respect to the erection that all parts of the motor, before setting it to work, must be taken apart and cleaned from dust, dirt, and particles of packing material.

The nuts of the anchor bolts must never be tightened up before the complete hardening of the layer of cement filling up the space between the base plate and the foundation; this is particularly the case in horizontal engines. By starting prematurely the engine frame may be sprung, so that after running a short time a heating up or even seizing of the crank pin may occur. Before leaving it the motor should be tried. The tightness of all valves and joints must be tested. Before finally setting the motor to work the air must be blown out from the meter and the gas pipe. This is most easily accomplished by turning over the motor into the position in which it takes in gas. Then open the gas cock and wait till a strong smell of gas is perceptible in the air pipe.

With motors having a self-acting mixing valve it is necessary to hold this open during the blowing through. Of course all open flames in the neighborhood must be put out and the windows opened.

CHAPTER II.

THE DYNAMOMETER AND ITS USE IN ASCERTAINING THE POWER OF GAS MOTORS.

THE apparatus which is most generally used as a means of determining the power of a motor closely resembles the brakes of winches and hoists of all kinds ; these differ only from the dynamometer in that the fulcrum of the latter is movable within certain limits, so that by regulating the weight a pressure can be applied which the fulcrum would have if it were immovable.

If the power brake is fixed on the pulley or fly-wheel of a motor, then by tightening up little by little on the same as much friction work is imposed on the motor as it is able to overcome and for any desired period of time.

The amount of friction work, and hence the power of the motor, is determined by the velocity with which the friction resistance is overcome, and is measured by the product of these two quantities.

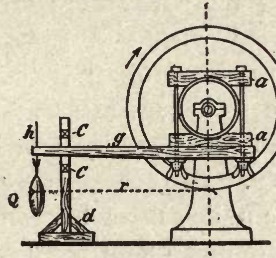

FIG. 3.

The simplest and oldest of the power brakes is that shown in Fig. 3, "The Prony Brake."

In the use of this apparatus the brake blocks *a* are tightened up until the motor at full power moves with the normal number of revolutions, then the balance weight *Q* is so adjusted that the lever swings permanently between the stops *c* of the standard *d*.

In fitting up the brake, the lightest wood possible is to be chosen; the brake blocks themselves should be made of lime or poplar. They should have on the rubbing surfaces deep and wide oil grooves, which must be filled with stiff grease. Wing nuts serve to draw up the blocks, which should have as long wings as possible, so that they can be turned by hand with ease and certainty.

The brake pulley must have flanges, by which the slipping off of the brake at the sides is prevented; it must run perfectly round and be keyed fast to the motor.

For holding the weight a bag of stout canvas may be used. With very small motors the brake weight can be supplied by a spring balance hooked between the floor and the lever. If the brake does not remain in equilibrium, but makes long periodic vibrations between the stops, then it is a good plan to put one or two rubber washers under the binding nuts of the brake blocks. By these means a firmer grip is obtained for the nuts, and the arrangement is fastened up with security even when the pulley is not perfectly round, or the brake lever springs.

Besides the direct loading weight *Q* the resistance on the fixed point is increased by the weight of the brake itself; and the weight of the arm, *q*, must be added to the weight *Q*.

q may be easily estimated by calculation with approximate correctness; this weight can, however, be obtained quicker and more accurately by direct weighing in the following manner:

A light stick is bolted between the brake blocks and a round iron rod inserted in the middle of the same, and the hook of the lever is placed in a scale and weighed while the other end of the brake is suspended in suitable bearing by the iron rod (Fig. 4).

The weight thus obtained indicates the

reduction of weight to be suspended from the hook—viz., q, when the round iron

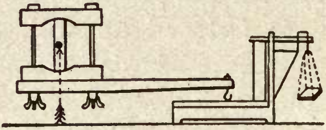

FIG. 4.

fulcrum is so placed that the brake lever occupies the position it will have when in use.

If the distance from the vertical line through the hook to the vertical line through the fly-wheel center is l feet, while

n is the number of revolutions per minute, and therefore

$\pi n l$ ($\pi = 3.1416$) = the number of feet per minute,

$Q + q$ the total weight hanging on the lever, then the work in foot pounds per minute

$$W = 2 \times \pi \times n \times l \times (Q + q),$$

or Horse Power = $W \div 33000$.

The installation of a hanging beam is often inconvenient, and frequently another arrangement of brake, such as shown in Fig. 5, may be seen, especially in gas mo-

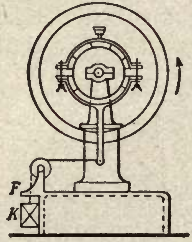

FIG. 5.

tor factories where motors of small power are to be tested.

The brake in this case is made entirely of wrought iron. As the lever of the balance is vertical and the whole apparatus can be made very light, its weight adds very little to the frictional resistance on the pulley, and may generally be neglected.

The bracket *F* serves as a precaution against overwinding of the brake by forming a stop for the weight *K*.

A third arrangement, by the use of which the stop bracket may be avoided, is shown in Fig. 6.

As seen, the brake lever is made with two arms and is provided with a stop, *S t*, at each end, which reaches nearly to the floor, in order to steady the brake lever. Brakes constructed in this manner are very easy

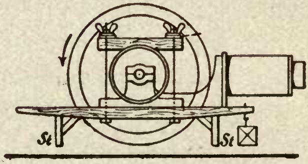

FIG. 6.

to handle, and in most cases can be very easily fixed. In working with them, however, there is one inconvenience, namely, that it is very difficult to obtain a perfect equilibrium.

The momentum of this overhanging apparatus, which is twice as heavy as that of Fig. 3, together with the elasticity of the wood, cause a pendulum action resulting in alternate striking of the feet against the floor.

Most experimenters are satisfied that when this pendulum motion occurs the correct balance is obtained ; this, however, is not the case ; on the contrary, it will be found that with a stationary balance considerably smaller brake results will be obtained.

In this connection the before-mentioned rubber washers perform important service.

Every form of application of the Prony brake demands the provision of a brake pulley with flanges, whose preparation and proper fastening to the motor is often attended with difficulties.

As every motor is provided with a turned and perfectly round fly-wheel, the idea of utilizing it as a brake pulley is obvious. On account of its great diameter and the narrow width of the rim the Prony brake cannot be used in this case, and the band brake must be applied.

The first band brake now in general use was constructed by Professor Brauer in the end of 1870. Fig. 7 shows the same as applied to a vertical gas motor.

a is the brake band of iron or steel (1 to 1½ mm. thick, and 30 to 80 mm. wide ac-

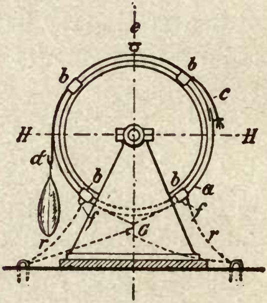

FIG. 7.

cording to the size of the motor) applied to the run of the fly-wheel.

Clamps *b*, which grasp the fly-wheel rim, prevent the side displacement of the band, and serve, on account of their great strength of metal, as plates for riveting securely the band. *c* is the arrangement for tightening, *d* the hook for the weight, *e* the provision for lubricating, *f* eyes to which are attached the holding ropes *r* as security against overrunning of the brake in the case of lack of lubrication.

For the proper understanding and handling of this apparatus the following points

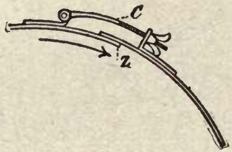

FIG. 8.

may be noted: the band is to be of such a length that even when the tightening nut is at its furthest limit the tongue *Z* (see Fig. 8) will overlap the other end of the band; the direction of the motion of the wheel should not be against the tongue *Z*.

The hook for the weight must be so placed on the horizontal *H H* that the latter will not overrun this line, and the length of the retaining ropes *V* must be arranged accordingly.

If the hook is placed above the horizontal the arm of the lever is shortened and the brake resistance diminished, and the brake stays in this higher position.

A condition of the utmost importance

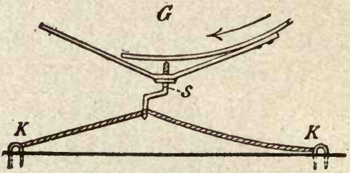

FIG. 9.

for proper and correct carrying out of a brake experiment with a band brake is uniform and abundant lubrication.

The arrangement indicated, at *G*, Fig. 9, should be put in operation as soon as the brake has been fitted up and the motor is running under normal conditions.

Before the beginning of the experiment the handle of the coarse-threaded screw *S* is turned into a position at right angles to the fly-wheel and the arm is fastened right and left to the staples *K* on the floor. Should the condition of lubrication of the brake change, and, for example, the weight tend to rise, the screw *S* also moves forward, and since the arm is attached to the cord, a turning of the screw follows, causing a loosening of the band.

Thus the brake band is tightened when the weight falls and loosened when it rises.

A brake fitted up in the above-described manner can after the proper balance is reached remain untouched during the whole time of the experiment.

Working with the Brauer brake is usually easy, and its fitting up costs very little.

If the armature pieces on the circumference are of equal weight, the weight of the apparatus itself may be neglected. The real leverage is, as in the Prony brake, the distance between the perpendiculars passing through the center of the shaft and of the weight respectively; it would be a mistake to merely measure the radius of the fly-wheel added to the distance of the hook from the circumference.

In gas motor factories where brakes are in frequent use it would take too much time in each particular case to determine the true leverage by measurement and each time to go through a calculation of the load. The installation is so arranged that for each size of motor the leverage remains the same, and is always braked while running at the same number of turns; so the weight of the counterbalance gives at once the power of the motor.

In such factories the arrangement is more or less modified and fitted up as shown in Fig. 10. As there seen, the hook for the weight is attached nearly at the highest point of the brake, the weight hangs by a long steel band, which lies along the outer circumference of the same, and however the brake band may shift in position, the line of suspension remains always the same, the weight may go up or down ; there is always an equilibrium so long as the stay ropes remain slack.

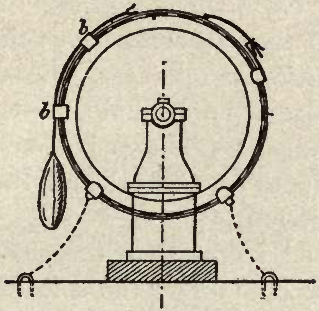

Fig. 10.

In the conduct of brake experiments, especially with band brakes, certain precautions are to be observed. Above all, band brakes must fit well and be kept in a uniformly good state of lubrication. If the lubrication is neglected, seizing of the band is to be feared. In such cases the brake band sticks fast momentarily to the wheel, the stay bolts must either break or pull out, and the weight will be thrown off from the wheel, and whoever should be hit by it would certainly be killed.

Another accident may occur from the breaking of the brake band. A case is known to the author in which the broken band struck the operator with such force on the head from behind as to fell him to the ground, and he narrowly escaped being caught by the fly-wheel and thrust into the foundation pit.

It is to be preferred, therefore, that a single band should not be selected in testing large machines, but several, side by side, bound together by hoop iron so as to form a single system.

In this case the tightening and staying arrangements are to be duplicated.

Further, it has been shown that iron should not run on iron, or steel on iron, but the whole inner brake circumference, as seen in Fig. 5, should be furnished with strong sheet copper plates about 1 to 1½ mm. thick and 10 cm. long and about 15 cm. apart, so that only copper is in contact with the rim. The space between each two copper plates should be well filled with thick grease, which will then be a provision sufficient for a long run.

Only with brakes equipped in such a manner can experiments of long duration be made without danger.

By such an arrangement the lubrication is so uniform that an alteration of the tension during the whole experiment is rarely necessary.

Moreover, a hint may be given in connection with the long hanging weight in Fig. 10, namely, that the hanging band should be screwed and fastened to the encircling band of the fly-wheel by rivets, and that swinging from side to side of the weight should be prevented. If the weighted bag, often amounting to 100 kilos (220 lbs.), should fall under the fly-wheel so as to catch in the arms, it may be thrown out with violence into the neighborhood or the arms of the fly-wheel broken.

With regard to the duration of a brake trial, it may be said that the same, especially in the case of larger motors, is limited by the excessive heating of the fly-wheel rim. If this precaution is neglected serious damage may be done to the fly-wheel arms.

As mentioned at the beginning of this chapter, the number of revolutions made by the motor during the trial is to be accurately counted. This may be done with sufficient accuracy with a revolution counter, an instrument to be found in most mechanics' shops.

Nearly all counters are put in action by pressing their projecting cornered point in the center of the motor axle. It is not often possible at a given moment to strike the center of a quick-running axle with certainty and to hold the instrument in sufficiently correct relation to the same; moreover, it demands a certain effort of the body to maintain the original pressure during the whole time of the trial.

For long trials the correctness of the results of which are important the counter is attached to a lath of wood which is of such a length that when it is perpendicular to the floor the three-cornered point is exactly of the height of the center of the motor axle. If, then, the lath is taken in hand and the foot placed against the lower part of the lath near the floor (see Fig. 11) the center of the axle can always be struck exactly and the counter without effort held in correct position, so that every revolution is counted with certainty.

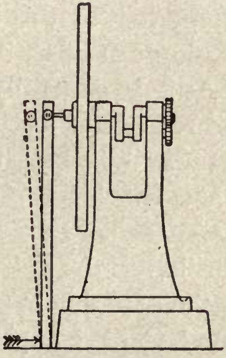

FIG. 11.

Excessive pressure on the counter, whereby bending is caused, is to be avoided on account of the delicacy of the instrument.

Finally the bearing of the spindle of the counter should receive a drop of neatsfoot oil from time to time.

If at the time of the brake test the gas consumption is to be determined, then a gas meter must be so placed that during the period of the test the amount of gas passing can be easily read.

As it is generally impossible to read off the records of an ordinary gas meter at a glance, it is best to choose the moment when the hand passes through zero for commencing the experiment. Then, according to the size of the motor, the time of the experiment may be measured by the number of complete revolutions of the dial.

In connection with brake trials the following remarks may be made :

Above all, everything about the motor, particularly the water cooling and oiling, must be in normal condition before the experiment is begun—that is to say, it must be run the whole time at full power under the brake ; the brake beam must be nicely balanced and the cooling water flow away at constant temperature, and outside of the automatic oiling apparatus no further oiling of the cylinder and connection-rod should be allowed.

If the test is made immediately after the delivery of the motor and only for a short period, say of ten minutes about, a brake result will be obtained which is not warranted by a performance of the motor on long-continued runs, and one much more favorable to the maker than to the purchaser.

Two persons should take part in a brake trial : one to watch the gas consumption and the time, who can indicate the beginning and end of the period by some preconcerted signal such as a call, a blow of the hammer, etc. ; the other manipulates the revolution counter.

As the time of the test must often be determined exactly within a few seconds, a stop watch should be used which can be started or stopped by a pressure of the finger.

However, an ordinary watch may be used if it is provided with a seconds hand. Before beginning the trial the watch is fixed so that the larger hand is exactly over a minute mark when the second finger points to the beginning of a new minute. If the thumb is placed on the watch glass at the moment of commencing, so as to indicate the position of the second finger, it is easy to mark the time of the beginning of the test in minutes and seconds, and by doing the same thing at the end of the trial the required time can be noted with the necessary accuracy.

After the end of a brake trial the loading weight should be again weighed.*

1. The frictional resistance represented by the loading weight.

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* It is well to stop the motor only when the brake is loosened; also the weight bag should be taken away only when the motor comes to a standstill. Then all data are obtained for calculating the power and the gas consumption.

2. The velocity at which the resistance is overcome, obtained by multiplying the effective circumference (in feet) of the brake band by the total number of revolutions and divided by the number of minutes occupied in the test.

Suppose, for example, the effective weight to be 52 lbs., the circumference to be 12 ft., the number of revolutions 1,500, and the time occupied, 4 minutes ; then

$$\frac{52 \times 12 \times 1500}{33000 \times 4} = 7.09 \text{ Horse Power.}$$

The brake results will only be accurate when, as previously stated, the loading weight is kept in perfectly stable equilibrium ; therefore during the trial the tightening nuts should not be permanently set, so that in case of rising or falling of the weight it may be brought to the proper position by a quick tightening or loosening of the nut. A very delicate adjustment may be made by a light tap with a hammer upon the wing nuts on one side or the other. In no case should the wing nut be taken into the hand during the trial, for the weight of the arm will upset all certainty as to the exact balancing of the brake arrangement.

For the purpose of comparing different systems of motors in respect to gas consumption this should be determined for 1 hour and 1 Horse Power. The smaller the motor the greater the gas consumption for 1 Horse Power hour.

By the brake trial the brake power is determined—that is, the useful power which the motor can deliver, the waste work consumed in friction of the motor is not determined.

The total work obtained from the fuel can be ascertained only by an indicator trial.

By comparison of the results of the brake trial and that obtained with the indicator an opinion as to the efficiency of the motor can be formed.

With good workmanship correct running motors of medium power consume in friction from 10 to 15 per cent. of the total work obtained from the gas.

Moreover, from the study of indicator diagrams of medium-sized motors, we obtain the following disposition of the heat generated by combustion :

1. Turned into work.......	18	per cent.
2. Carried away by water jacket.................	50	"
3. By exhaust...............	30	"
4. By direct radiation from the sides of cylinder and water jacket..........	02	"
Total..............	100	"

CHAPTER III.

THE CARE OF GAS MOTORS.

THE cardinal virtue of a good gas motor is simplicity of management. There is a continual effort in this respect to simplify and improve gas motors. In fact there are to-day motors the taking care of which is reduced to filling up the oil cups.

Very little attention is required to keep them in good running order; but every three or four weeks the motor should be thoroughly overhauled, and the exhaust and slide valves, piston, and cylinder properly cleaned from all dirt, lampblack, or congealed and dirty oil.

If the slight attention required by a gas motor is intelligently given there need be no fear of interruption in its running. The first necessity for long-continued efficiency is the choice of a really good oil for lubricating the cylinder and slide valve. For the high temperatures which the cylinder wall and especially the piston of a fully loaded gas motor have to contend with, notwithstanding the water cooling, only such oils should be used as retain their lubricating properties at high temperatures; they should, by this heating up, neither be subject to quick vaporization, nor thicken up nor form lamp-black.

Gas motor oil consists of good mineral oil to which is added a certain quantity of vegetable or animal oil.

Animal oils make the mixture fluid retain its lubricating properties at high temperatures, and form a little but hard oil carbon. The mixture is rendered thicker by the addition of vegetable oil, which tends to make the piston air-tight, filling up the grooves between the piston and cylinder walls; as the oil carbonizes at high temperatures more easily than animal oil, more carbon is formed of a porous, spongy structure.

As the specific gravity of the various oils used for a gas motor oil varies after standing for a long time, a separation may take place; and it is particularly advised that at each drawing off the whole oil be well stirred up. By the use of unsuitable oil the cylinder and piston become covered with a rusty brown layer.

If the piston of a motor lubricated with such oil is withdrawn it is found to be covered over with a layer of rust, the oil will have formed with the rust a thick, streaky mass, which later on cooling becomes set and hard, the grooves are filled with the same, and the rings themselves set fast.

If the piston is lubricated only for a week with such oil it may be confidently expected that the motor will fail to work in consequence of the damage to the cylinder bore.

Good cylinder oil smeared over the cylinder and piston forms a grayish film, which disappears with the warming up of the motor, so that the polished bluish gray metallic color of the cylinder and piston is again visible. All the piston rings, even the farthest in, should always be found to be easily movable when the piston is taken out for cleaning.

Oil specially prepared for gas engines is now to be found on the market under the name "gas engine cylinder oil."

Oil-feeding apparatus, and still more oil-dropping apparatus, which supply less oil than when the same is full, need attention; it is well, therefore, to fill up the cups at brief intervals. In frosty weather the oil should be warmed in the can before filling the oil cups.

It is advisable, in starting the motor, to always manipulate all the necessary handles in the same order. In this manner the attendant accustoms himself to a routine that makes mistakes nearly impossible; and this is the place to say a few words as to the proper order in which the operations should be performed.

For Starting the Motor.

1. Open the cock of the rubber bag.
2. Oil; always in the same order.
3. Clean the exhaust valve spindle with kerosene.
4. Light the gas flame.
5. Put in place the provision for assisting in turning over (starting apparatus).
6. Open the gas cock of motor to the point marked for "starting."
7. Turn the wheel until it starts off.
8. Gas cock full open.
9. Put back starting apparatus.
10. Turn on water; examine the condition of the water in cooling apparatus.
11. Pass belt on to the fast pulley.

Stopping the Motor

1. Turn belt off.
2. Close cock of rubber bag.

3. Wipe off the oil from the slide valve with piece of waste.

4. Shut off the cooling water.

5. Stop the engine.

6. Close the gas cock for the motor and lamp.

7. Place piston on the forward dead point.

8. Draw off water from jacket.

From time to time the water should be drawn from the gas meter and replaced with fresh water.

In frosty weather the water should be drawn off from the water jacket of the cylinder and from the water cooler, and the gas meter should be covered with straw or felt.

Cleaning the motor, which, according to the build of the machine and the quality of the oil used, will have to be undertaken at various intervals of time, is the most serious part of the attendant's duty. In well-constructed gas motors the taking apart, the cleaning, and the putting together again are accomplished without difficulty. Any competent workman will quickly acquire the necessary handiness and be able to do the work in a satisfactory manner. It is necessary to clean off the hardened oil carbon from the exhaust and slide valves and piston from time to time, and also from the interior of the cylinder. The slide valve, especially the igniter, must be well cleaned from thickened oil, rust, and dust.

For breaking up and scratching off the carbon from the exhaust valve box, from the ring grooves of the piston, and from the piston rings, instruments of brass or copper should be used ; for cleaning out the holes and channels in the slide valve, plugs of hard wood dipped in kerosene are best.

At the conclusion the seats of the exhaust valves, piston, piston rings, slide valve, and cylinder should be well wiped with waste moistened with kerosene.

The parts removed for cleaning should

not be placed on a sandy floor or leaned against a whitewashed wall; a grain of sand left sticking is often sufficient to ruin the slide valve or piston.

Nuts set fast should not be removed by force. If kerosene is allowed time to work into them, such nuts can nearly always be easily started. If the bolt is smeared with graphite, or, better, with a paste of vaseline and graphite, setting fast of the nut is not to be feared.

If, on cleaning the exhaust valve box, the aperture leading to the silencing pot is found to be clogged up, the pipe from the valve to the pot must be taken down and cleaned out from oil carbon. After cleaning and carefully remounting the motor, it should be immediately run. The fly-wheel should be braked with a plank until full power is developed and the motor heated up to a normal condition. Only when such precautions are taken can we be sure that it will perform its usual duty without trouble.

The cleaning should never be undertaken a few hours before the time for use, for it cannot be foreseen how much time will be required nor what particular circumstances may arise.

CHAPTER IV.

THE DERANGEMENT OF GAS MOTORS.

NEARLY all the derangements to which gas motors are liable are due to leakage of the valves, slide valve, and piston.

While a steam engine with leaking slide valve, valves, etc., performs its work badly, the gas motor under similar circumstances comes to a standstill. The reason for this peculiarity of the gas motor is quite obvious—it is without the power reservoir which the boiler furnishes to the steam engine.

The gas motor takes its fuel for each particular combustion and mixes it with precisely the required quality of air, and is, therefore, ready at any moment for beginning work. Unfortunately, to this valuable quality a serious condition is appended. It may be said of a gas motor that it lives from hand to mouth ; what it obtains at one moment is expended the next ; when the supply of nourishment is interrupted, or is lost before it can be consumed, the life of the motor is itself interrupted.

As is well known, it is difficult and often impossible to determine by smelling the place of escape of gas, which is not visible, so that it is not easy to locate derangement in running caused by want of tightness. To arrive quickly at a conclusion in this matter it is necessary to go to work systematically. The classification in the last chapter will furnish the necessary hints for a systematic search for faults.

In the first place, a general rule for examining a defective gas motor may be stated.

When a gas motor refuses to operate, the first thing to be done is to turn over the fly-wheel.

In all cases the contents of the cylinder will be compressed. If the motor leaks, then either a slight resistance only is felt or the same disappears very quickly. If by these means the existence of a leakage is established, the same may be easily located by proceeding step by step in the manner subsequently described.

The following are the principal faults met with in a gas motor:

The motor refuses to work.

Difficult starting.

Unaccountable stopping.

Irregular running.

Loss of power.

Knocking in the air-pot (back firing).

Shocks in the motor.

Each particular trouble may be caused by special circumstances; the probable complications must be settled for each case.

1. The Motor Refuses to Work in Consequence of Leaky Exhaust Valve.

Three kinds of leakage may be distinguished;

a. The valve has hung itself up while in operation.

b. The exhaust valve spring is too weak.

c. The slide valve seat is damaged.

(*a*) Hanging up of the exhaust valve is nearly sure to occur after the motor has been standing for some time. The valve must be made of steel or wrought iron to stand the high temperature.

The products of combustion consist principally of water vapor and carbonic acid, from which it is obvious that, after standing for a long time, they must become coated with rust and their freedom of movement hindered.

If it is attempted to start the motor under such circumstances, the exhaust valve not being tight, a portion of the unburned mixture escapes during the compression period into the silencing pot and the exhaust pipe. As the firing necessarily follows, this is communicated to the mixture drawn out through the leaking valves, and a strong explosion takes place through the exhaust valve. If several revolutions occur before the igniting apparatus operates, the explosion may have the force of a cannon shot and alarm the whole neighborhood.

Every good gas motor should be provided with a means of avoiding this fault. It consists in an oil groove for the exhaust valve spindle.

Every morning, before starting, a little kerosene is to be trickled into this oil hole and the valve moved backward and forward.

By these means the proper starting up of the motor is ensured, nor is a derangement to be feared.

For applying the kerosene, it is best to use the ordinary squirt can, such as is generally used for sewing machines. Oil should not be used for lubricating the exhaust valve spindle, for this would produce an effect the opposite of that desired; for, while kerosene is evaporated without residue when the valve is warmed, oil leaves a carbon deposit which impedes the action of the valve as much as rust.

(*b*) The indications are different when the spring of the exhaust valve is so weakened by the heat or otherwise that the valve is lifted during the suction period by the inflowing air. In this case none of the mixture passes into the exhaust pipe, but the proper gas proportions will be influenced.

Together with the gas mixture drawn through the mixing apparatus a back draft through the exhaust valve comes which makes the charge inexplosive. On further revolutions of the fly-wheel the same is repeated, with the difference, however, that now the unexploded exhaust forms a strong mixture, and the new charge is formed, not with pure air, but with this already strong mixture. With each misfire, the gas mixture in the cylinder becomes richer, until at length it is fired and a power stroke comes about. The motor, however, does not operate continuously, but after a time the above-mentioned conditions recur.

After four, six, eight, or more revolutions the charge is enriched to the firing point. It is possible that the power stroke is sufficient to give the motor momentum enough to carry it over the misfires ; the motion will then be kept up, but little or no power will be rendered.

The phenomenon of periodic misfires may be brought about by other faults ; it alone, therefore, is not a proof that an exhaust valve spring is weak ; this may be seen to be the case when the suction period is accompanied by a vibration of the valve on the valve seat.

(*c*) Finally, if the valve face is damaged or the closing of the same hindered by foreign matter, the thumping in the exhaust pipe is the same as when the valve is set fast ; simply freeing the spindle with kerosene is not now sufficient. If the pounding in the exhaust valve is heard and a vibration of the valve spindle is felt, then the valve surface is damaged, and the valve must without further waiting be taken out and wiped; the substance imbedded in the valve seat can by firm rubbing of the valve cone be discovered and easily removed.

2. THE MOTOR STOPS WORKING BY REASON OF LEAKING INLET VALVE OR SLIDE.

It is evident that with a leaking inlet valve the unexploded mixture will, during the compression period, be forced back through the air pipe. The next inspiration, therefore, is made up, not of a mixture of gas and air, but of gas mixture and gas, for the air pipe contains a gas mixture of such richness that it burns either not at all or with slight change of pressure.

External indications of this fault are yellowish red exploding flame in the lighting apparatus and a smell of gas in the exhaust pot. If a thread of waste or strip of paper is held over the air opening during compression a back draft will be felt.

3. Interruption of the Motor in Consequence of the Setting Fast of the Lighting Valve.

When the motor stands for some time without working the suction valve, like the exhaust valve, may be rusted up, and so remain hung up when the engine is started. Slide valve igniters easily cut in running, and the metal cuttings fall on to the valve surface, set fast there, and give rise to leakage.

The indications of these faults are very characteristic : sharp hissing of the igniter during the whole compression period, drawing in of the ignition flame, and thumping or gurgling in the air pot during the suction period.

4. Failure to Operate in Consequence of Increased Gas Pressure.

For every gas motor, after the fitting up is finished, during the first trial run, the gas mixture will be according to the quality of gas and corresponding to the regular gas pressure, and the proportion of the air charge exactly regulated. If these conditions are changed the proper running of the motor will be upset.

If, for example, the gas pressure increases, then on suction the mixture is too rich in gas, so that though it may be inflammable, the explosion follows without the change of pressure necessary for actuating the motor.

Other indications of this derangement are as follows: In the exhaust period a thick black smoke is discharged without much noise, the rubber bag is inflated, the ignition flame burns higher, and the flame in the ignition apparatus has an unusually yellow color.

To operate the motor in spite of the increased pressure, which can hardly be altered, the attendant requires a helper whom he should station at the gas cock with instruction to open the same slowly while he himself vigorously turns the flywheel. The gas cock should not be opened until three or four revolutions have been made. The cock must be adjusted until the motor runs as before, and even for the normal speed of the motor the cock will not be full open. This kind of disturbance cannot occur when a pressure regulator is used.

5. STOPPAGE BY REASON OF DERANGEMENT OF THE GAS METER.

If the drawing off of the surplus water from the meter and refilling with fresh water have been neglected the gas is cut off and the motor cannot operate. The shrunken gas bag indicates at once the cause of the trouble ; the gas bag should be the first thing to observe. Very frequent cause for stoppage of the motor is that the main cock or the gas bag cock has not been opened, which circumstance is also indicated by the shrunken condition of the gas bag.

6. STOPPAGE OF THE MOTOR ON AC-

COUNT OF WATER COLLECTED IN THE EXHAUST POT.

If we neglect to draw off the condensation collected as water in the exhaust pot it may often happen, especially in winter, that it reach such a height as to stop up the exhaust pipe. When the motor runs slowly, as at the starting, the water runs by the open exhaust valve directly into the cylinder. Under such circumstances, if the first ignition takes place, the pulverized or vaporized water hinders the further formation of an explosive mixture and the motor will not start.

Indications of this fault are: spurting out of water from the ignition port between the slide valve; dampness of the cylinder walls—water jets out of the exhaust pipe; when a porcelain ignition tube is used it is frequently burst. For remedying this accident the cock of the exhaust pot should be opened; the water in the cylinder and all valve boxes cleared out with waste.

When this accident occurs for the first

time there is usually a fear that the cylinder may have burst; this is, however, very seldom the case.

7. Difficult Starting of the Motor in Consequence of Leaky Piston.

Every gas motor cylinder must in the course of years deteriorate and the piston become leaky. This want of tightness influences the mixture of gas and the condition of compression, particularly at starting, at which time the movement of the piston, in comparison with the normal velocity, is very slow. A small space between the piston and cylinder wall is then sufficient for bringing into the cylinder during suction a considerable quantity of "side draft," while during the time of compression a still greater quantity of the unburned gas mixture escapes. At the moment of ignition we have a slightly compressed weak mixture, which often is inexplosible.

Only after a considerable number of revolutions, when the piston reaches a greater velocity through energetic turning of the fly-wheel, and the influence of leakage is thereby weakened, is it possible to obtain a better mixture which is explosible and which expands with sufficient force to set the motor going.

As remedies for this fault, when chronic in a gas motor, may be mentioned :

1. Leaving out of use the starting gear so as to compress the whole volume of the cylinder.

2. Use of thick lubricating oil. Before starting smear the piston with rich oil and run it slowly backward and forward several times, keeping the gas cock closed so that the cylinder wall and piston are coated with a thick layer of oil.

3. Lifting the (inlet) valve with the hand during the suction period. By this means the vacuum caused by the suction is lessened, a greater quantity of the mixture taken in, and the first starting stronger.

This last means generally acts with remarkable promptness.

8. Difficulty in Starting in Consequence of Dirty Slide Valve.

In many motors the lubricating oil is led from a general lubricating apparatus to the slide valve and piston. On stopping, the pipes are filled with a considerable quantity of oil, which gradually leaks out, and the channels and grooves of the igniting apparatus in the slide valve are filled. If after standing some time it is attempted to start up the engine many futile turns may have to be given in order that the oil may be blown out from the main channels and grooves of the slide valve. As must be well known to many owners of gas engines, this fault may be easily remedied if on stopping a small piece of wood, which will absorb the escaping oil, be placed under the mouth of the tube feeding the slide valve.

9. Difficulty in Starting in Consequence of Air in the Gas Pipe.

It is a matter of common experience that unused pipes leading from the street mains in time fill with air. It would be a difficult undertaking to attempt to start up at once a motor which has been idle some time. The total contents of the piping would have to be pumped out by turning the motor by hand before ignition is to be thought of.

In all such cases the piping must be blown out before starting by holding open the gas valve, mixing valve, etc., or a cock especially provided for that purpose.

Moreover, a small leak in the gas piping which cannot perhaps be detected by lighting is often sufficient to fill the connecting pipe over night with air. If it is noticed that the motor, notwithstanding careful preparation, starts with more than ordinary difficulty in the morning, we may be pretty sure that there is air in the pipe. A good blowing out before starting will always be advisable.

10. UNACCOUNTABLE STOPPING OF THE MOTOR.

Without counting stoppages which arise from the breaking of springs, stoppage in gas meter, etc., we shall in this place speak only of such derangements as arise from the extinction, flickering, or fluttering of the igniting flame.

In the ignition apparatus most in use at the present time the flame can be easily put out by the operation of the engine itself. If the springs of the slide valve or ignition valve are too weak, the latter may by great increase of pressure, such as occurs after misfires in the cylinder, be thrown off their seats. The excessive amount of igniting gas now flowing out may be sufficient to blow out the jet. The same thing occurs when the ignition valve is not tight. The jet may also be blown sufficiently to one side to miss the ignition, and thus cause stoppage. The opening of doors or windows, the motion of the fly-wheel may cause drafts which bring about such a condition.

A stoppage quite unintelligible to the attendant often occurs when the motor is working with a full load, arising from the falling off of the gas pressure caused either by increased consumption in the neighborhood or by some derangement at the gas works.

If a rapid examination of the motor is made, everything appears to be in order; the ignition flame is burning and the motor is easily set in motion again, and there is no indication of anything unusual. If the attendant waits a short time, however, after starting the motor he will observe that the ignition jet becomes weaker and weaker, until finally misfires occur.

Provided that the gas piping is large enough, this fault may be remedied by putting in two or three gas bags.

11. Irregular Running Brought about by Misfires.

Leaking or dirty slide valves, leaking

ignition valve, flickering or low-burning ignition flame are generally the cause of misfires.

The indications of this kind of trouble are very characteristic and easily recognized. Dull noises are heard in the motor followed by a whistling noise. Slide valve or ignition valve may be thrown off its seat and the highly compressed explosive gases rush out with a loud noise.

This trouble may be obviated by proper installation and protection of the ignition flame, cleaning the valves, or adding a second gas bag.

12. Irregular Running in Consequence of Defective Operations of the Governor.

Thickened lubricating oil or sticking of the governor spindle often occasions a considerable irregularity in the rate of running of the motor. Sticking may occur through worn-out pins of links or omission of oiling.

The cause of this trouble is easily found out by the fact that the periods of regulating are lengthened, due to sluggish action of the governor.

13. Loss of Power by Leaky Piston.

The leaky condition of the piston is discovered by the hissing and knocking in the cylinder, by the peculiar smell of gas and burned oil, by a heavy atmosphere in the neighborhood of the motor, and, above all, by the constantly increasing gas bill.

The remedying of the evil may become a serious matter ; above all things, as already stated, the use of improper oil is likely to cause this, also the blame may be placed to insufficient oiling on account of oversight or neglect, in cleaning the cylinder oiling apparatus, as well as insufficient cooling of the cylinder. The water should flow away at a temperature not above 70° C. (160° Fahr.) in the cooling tanks ; the water, even in the hottest summer, should never rise above 70° C.

For some time the loss may be cured by putting in new piston rings; finally, however, the cylinder must be rebored and a new piston provided. If the motor is chosen of such a size that the full power is easily furnished, so that the cut-off of the governor operates after moderate periods of rest, the engine not only works cooler, but in a manner most favorable to the proper distribution of the lubricating oil in the cylinder.

A gas motor under such circumstances remains a long time in good condition, and a reboring of the cylinder is often necessary only after ten years of service, while one driven too hard may require this costly repair after two or three years' running.

14. LOSS OF POWER BY FORMATION OF WEAK MIXTURE.

Diminished gas pressure, stopped-up gas piping or too small opening of the gas cock may give rise to weak gas mixture. The mixture is indeed explosive, but burns slowly and with less change of pressure.

Indications: Sharp reports in the exhaust; from time to time a gurgling sound or weak crackling in silencing pot.

15. Loss of Power through Throttling of the Supply.

The cause of diminished supply in the suction capacity of the motor arises from the spring of the mixing valve or suction valve being too strong.

The mixture itself is normal in constitution and burns sufficiently promptly, but the ignition pressure is less.

Indications: Weakened noise in the exhaust.

16. Loss of Power through Back Pressure of the Burned Products.

By diminished area of the exhaust pipe a back pressure is set up on the piston; moreover, since a large quantity of the burned products remain in the cylinder, the quality of the mixture is changed.

By the wear of the motion pin of exhaust valve the time of exhaust of most motors is shortened, and in consequence there remains behind in the cylinder a greater quantity of burned gas.

Indications: Long-drawn-out exhaust from time to time; gurgling in the exhaust pot; smoking of the piston; dry cylinder walls.

17. Loss of Power through Late Ignition.

By the metallic wear and tear of the ignition mechanism the alteration of the time of ignition is usually such as to make it later. Even a slight lateness in the ignition operates disproportionately unfavorable in the utilization of the burning mixture. From time to time the condition of the lighting should be regulated.

Indications of late ignitions are exhaust with loud noise and thumping in the motor.

18. LOUD REPORTS IN THE EXHAUST POT (BACK FIRING).

Arise generally from the neglect to open the gas cock fully after starting up. A weak, slow-burning mixture is formed which continues to burn in the clearance space during the following period of suction when the gas mixture comes in. This latter, as soon as it comes in contact with the burning gas, is ignited and rushes with a loud thump into the exhaust pot.

In motors with slide valve ignition this circumstance is already referred to ; it may also be sought for in the leaking of the ignition slide valve. It can be easily seen in such cases, for the ignition flame is drawn into the valve and the charges ignited while it is passing in through the open mixing apparatus.

19. KNOCKING AND THUMPING IN THE MOTOR.

A loose key of the fly-wheel, loosening of the main bearing cap or of the bolts used on the piston cause a severe shock in the motor at the time of ignition. It is not always easy to find the seat of the evil. A proceeding likely to aid is as follows: Turn off the light and the gas cock and give a jerking backward motion to the fly-wheel, at the same time laying the hand carefully on all those parts where it is believed the knocking can be found. The blowing out of oil from the joints of the connections in question which, during the jerking motion, ooze out and flow back, often indicate the origin of the trouble.

Early ignition likewise causes severe thumping in the motor, which is particularly observed at slow speed shortly after starting or after a misfire.

If the under side of the cylinder bore is much worn a dull thud is heard in the motor. At each working stroke the piston is thrown violently from one side of the cylinder to the other.

When this noise is heard it is high time to have the cylinder rebored.

CHAPTER V.

DANGERS AND PRECAUTIONS IN CONNECTION WITH THE RUNNING OF GAS MOTORS.

LIKE every other machine, the gas engine has dangers peculiar to itself, of whose existence every one who has to deal with it should be acquainted.

The dangers which leaking gas fittings occasion are well known; their prevention in the case of a gas engine demands greater care than that of ordinary gas fixtures, which are usually tested and carefully erected. In the gas engine it is frequently necessary to loosen them. After each new assembling of valves and gas pipes, etc., all joints should be carefully tested as to their tightness, and especially the freedom from leakage of the gas bag maintained.

Here it may be remarked that when gas piping is once coupled up it is very difficult to locate leaks by lighting up the escaping gas. Small leaks especially cannot be found at all in this way, for the opening immediately after the putting up will pass only air or an incombustible gas mixture.

Better evidence of leaking is obtained by the use of soapsuds or oil, with which bubbles are made when placed over even the smallest leak.

The gas mixture remaining behind in the clearance space and the valve chambers of a gas engine during a period of rest retain perpetually their explosive capacities.

When proceeding to examine a gas motor, therefore, it should always be taken for granted that all the clearance spaces without the same are filled with explosive gas. Before anything is opened or taken apart the gas flame should always be put out and the gas cock on the supply pipe to the motor closed. *Only after giving the fly-*

wheel five or six turns can one be sure that there is no explosible gas mixture in the interior of the motor.

It may be specially mentioned as a very dangerous proceeding to take out the piston without first putting out the light and closing the gas cock.

It is always possible that the motor stops in such a position or is turned over in such a manner that while the piston is being drawn out the ignition flame may be drawn into the interior of the cylinder, and the consequent explosion of its contents may throw the piston out with such force that a serious accident may be caused.

Equally bad consequences may follow when, on taking out the exhaust valve of a motor at rest, a flame is introduced into the valve casing, as is frequently necessary for examining more closely into the tightness of the valve. The gas mixture ignited in this manner will shoot out as a long flame from the valve opening and may give rise to serious burning.

It should be a universal rule never to look into an opening in a gas motor without first holding a flame in front of the opening for a certain time, keeping meanwhile at a safe distance.

In the case of the ignition valve most commonly used it is conceivable that with large motors the person who is starting the motor failing to overcome the compression, and holding on to the wheel, may be thrown over the engine. Such ignition apparatus operates not only at the dead point, but also during the compression period about the middle of the stroke in case the motor goes backward.

As with other machines, so with gas engines it is a very proper precaution never to touch anything in motion, and to reserve the cleaning and wiping off of the engine until it stops. Moreover, the fixed parts of a motor should be disturbed as little as possible while running.

A nut should never be tightened up or loosened while the motor is running ; even if one is apparently entirely out of reach of the moving parts, the spanner may slip and the body be thrown within the range of danger. The warning to let alone the connecting-rod cannot be too emphatically stated.

If the rod is tightened up too much it will grind on the crank-pin, and serious cutting is inevitable.

The fly-wheel ought to be surrounded with a rail one side of which is removable. The crank, the governor, and all gearing should be protected with suitable coverings.

A bad practice which is very general in starting small motors is that of throwing off the belt, and later, when the motor is set in operation, to put the belt on again by hand. Even the most experienced may slip and the hand may be caught between the belt and the pulley, or even by the arms of the fly-wheel ; where the belt pulley is as high as the head the danger is particularly serious of having the belt thrown off sideways and striking the face.

CHAPTER VI.

OIL ENGINES.

THE use of the gas engine requires that a supply of gas should be at hand, and it is therefore unavailable in country houses or villages where gas is not to be obtained. In such cases it becomes necessary to manufacture the gas one's self. For a very large engine, say 100 Horse Power or above, it pays to put up a gas-making plant which resembles in its essential details the modern apparatus for making water gas. The process, however, is a continuous one, and the result is a much poorer (or more dilute) gas, which has received the name of "producer gas."

For use in a gas engine, however, this dilution is not a disadvantage, since illuminating gas has to be diluted in this case.

When producer gas is used, about four times the quantity, as compared with ordinary gas, is taken for each charge of the cylinder, and proportionally less air. The mixture when made has, however, about the same calorific power per cubic foot as the ordinary explosive mixture. It can be used, therefore, in the ordinary gas engine to produce the same effect, but a somewhat higher degree of compression is advisable, and electric ignition is found, in this case, to be more certain than tube ignition.

For moderate sized engines some simpler means of producing the gas must be found. Hence the gasolene and oil engines, which are essentially gas engines, for which the gas is produced on the spot, and used as fast as produced. In some forms of these engines no gas is produced anywhere outside of the engine cylinder. When the volatile products, such as naphtha and gasoline, are used, it is sufficient either to draw air through the liquid or to inject a small portion of it at each alternate revolution into the warm cylinder. The very facility with which naphtha and gasolene volatilize is a source of danger, and the use of the oil engine proper, which uses a safe heavy oil flashing at 150° to 300°, is rapidly growing in favor.

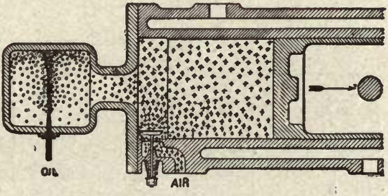

FIG. 12.

To this class of engines the "Hornsby-Akroyd" oil engine stands in about the same relation as the "Otto" does to gas engines, or rather did before the "Otto" patents expired. This engine is characterized by extreme simplicity, which renders it more easy to handle than a gas engine, and allows of its being left to itself for much longer periods. The most striking peculiarity of the " Hornsby-Akroyd" oil engine is the total absence of ignition apparatus. The manner in which the automatic ignition is effected will be easily understood from figs. 12, 13, and 14.

The first of these represents the period of suction during which air only is drawn into the cylinder, and oil is at the time in-

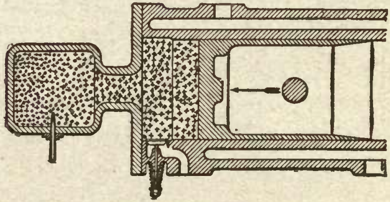

FIG. 13.

jected into the chamber forming an extension of the cylinder and connected with the same by a narrow neck. This extension to the cylinder is the combustion chamber, and is not water jacketed, so that it remains at a temperature approximating a dull red. The oil is forced into it in a thin stream by a pump actuated by the same lever that opens the air valve.

At the end of this first operation we have :

(*a*) The cylinder full of pure air.

(*b*) The combustion chamber full of oil vapor.

Neither of these alone is explosive, but

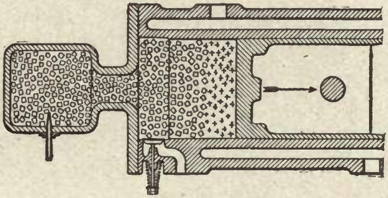

FIG. 14.

on the return stroke of the piston, represented by fig. 13, the air is forced through the narrow neck into the combustion chamber, forming there a mixture of vapor and air, which, at the completion of the stroke, ignites. We now have the third period in which the expanded air drives out the piston, as seen in fig. 14. The fourth period, not shown, is that during which the products of combustion are swept out of the cylinder by the return stroke of the piston.

Before starting the engine the combustion chamber or "vaporizer" must be heated; this may be done by a "Bunsen" burner where gas is obtainable, but an oil lamp is supplied for use where this is not the case. The lamp is placed on a bracket immediately below the vaporizer, and the flame is blown up with a little fan driven by hand, all of which are clearly seen in the cut of this engine forming the frontispiece. The vaporizer is protected from air currents by a hood which is removable, and which itself has a small cover forming a damper.

The regulation is effected not by the hit and miss principle, but by allowing more or less of the oil to flow back to the oil reservoir, usually in the base plate of the engine. This is effected by a sensitive governor, which opens a by-pass in the valve box attached to the vaporizer, when the speed momentarily increases. If the engine is to be run continuously at less than full power, the stroke of the oil pump can be readily adjusted to the work required of the engine, and less work will be thrown upon the governor.

To Start the Engine.

(*a*) Fill and light the lamp.

(*b*) Oil engine all round, fill up oil cups.

(*c*) Blow up lamp, gently at first, then briskly, until the lamp goes out, when the vaporizer should be hot enough.

(*d*) Throw out compression by turning lever to position marked "To start."

(*e*) Try oil pump.

(*f*) Turn over fly-wheel till explosion takes place.

(*g*) Turn back starting lever to position marked "To work."

(*h*) Throw on belt.

Remarks about Starting.

In this order of procedure the lamp is

lighted before oiling the engine, in order to give it time to warm up. In turning over the fly-wheel there is a certain knack, which is easily acquired, and renders the starting up of even large-sized engines tolerably easy. The wheel may be turned backward, and the compression will often cause an explosion and start the engine ; if not, the rebound thus obtained from the compressed air will assist in turning the fly-wheel in the forward direction.

If the engine starts up in the wrong direction it will generally reverse itself after a few turns, and at the moment of reversal it may be helped along by hand. After a few trials the attendant will find that very little actual work is required. If he prefers to simply turn the fly-wheel in the forward direction, he will find by trial that a certain one of the spokes is more favorable to his effort than the others. It is the one which he reaches by stooping down to effect the compression. This should be laid hold of and followed around.

To Stop the Engine.

Turn over the crutch-handled regulator on the governor bracket to position marked "Shut." To stop quickly, hold down the air valve lever at the same time. If the engine does not stop readily the spring of the horizontal check valve of the vaporizer valve box is too weak, or is broken, and part of the oil enters the vaporizer instead of all coming through the overflow valve, as it should do when the handle is turned to "Shut."

Failure to Start.

In nine cases out of ten this is due to either not having heated the vaporizer hot enough or to having left it time to cool off before starting. See that the lamp is in good order, refill it and heat up again. If the engine still fails to start, make examination of its condition in the order given below until the source of trouble is found, then start again. *But first of all see that the oil reservoir is not empty.*

EXAMINATION OF ENGINE IN DETAIL.

Oil Pump.

(*a*) Turn over crutch-handled regulator on governor bracket to position marked "Shut," when all the oil will pass through the by-pass valve, and work the pump by hand. If a full stream of oil, free from air bubbles, is thrown out, the pump is probably all right; and this test should always be applied at the time of starting. If the oil pump does not work satisfactorily, proceed as follows:

(*b*) Open the three-way cock on oil reservoir; if oil flows out freely the filter is all right; if not, take it out, clean, or renew it. If, after fixing the filter, the pump is still unsatisfactory, test it for air as follows:

(*c*) Disconnect oil delivery by the union attached to vaporizer valve box; pump up oil till it overflows, then press thumb over outlet and try the pump with sudden jerk. If the plunger yields and yet no oil escapes past the thumb, air is in the pipes. This fact may be further proved by making several sharp strokes with the pump, when, on releasing the thumb suddenly, the oil will be projected a considerable distance above the pipe by the elastic force of the air contained within the pipe.

If no air is found in the pipes, examine action of valves.

(*d*) Give the pump a steady pressure while the thumb is held on the outlet. If the plunger yields under this steady pressure, but not under a sudden jerk, then the suction valves are not tight. If after *carefully washing out* the pump and valve boxes with oil, the fault is not remedied, tap the steel ball valves slightly on their seat with a copper punch.

(NOTE.—The pump being provided with two valves in series, both for suction and delivery, of which the steel balls are critically examined before putting in, derangement of the pump is of rare occurrence.)

Vaporizer Valve Box.

In this box there are two valves. The vertical one is regulated by the governor, and when the engine runs faster than its proper speed, the governor pushes it down, thus opening it and allowing some oil to overflow into the little conical dish for catching it. The horizontal valve in this box is a back-pressure valve, and if at any time this valve should not be working properly, vapor would be seen coming out of the overflow pipe, and in that case the valve should be looked to. By screwing off the outside cap, the tail of this valve can be seen, and if the valve is turned round a few times, it will probably dislodge any dirt that may have got under it; if, however, this does not stop it leaking, then the valve had better be taken out for inspection.

(Note.—*In all cases where packing is removed from joints, renew it with packing of exactly the same thickness.*)

To test the vaporizer valve box, take it off and connect it up to its oil supply pipe from the pump, so that the jet out of its spraying hole or holes can be directed in any convenient direction where it can be seen. Now stroke the pump at as near the actual working speed as possible. The jet or jets produced should be clear, with distinct and abrupt pauses between each delivery, as, if oil dribbles into the vaporizer on the working and exhaust strokes of the engine when it is not wanted, a waste occurs. *This condition is very essential for economical working.*

With ordinary care the oil engine is subject to very little derangement, and if trouble occurs it can very readily be located and corrected by proceeding in a systematic manner.

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