CONCRETE RAILROAD BRIDGE AT DANVILLE, ILLINOIS.*

THE increasing utilization of reinforced concrete is nowhere more manifest than in railway construction work. A recent example of concrete bridge structures is found in the Danville arch bridge of the Cleveland, Cincinnati, Chicago and St. Louis Railway, at Danville, Ill., which is not only of considerable size, but is of rather unusual design as well. The bridge is part of the complete reconstruction of the Cairo division which, together with other improvements, forms a direct connection between the coal fields of Indiana and Illinois and Chicago. The valley of the Salt Fork of the Vermilion River which the line crosses is about half a mile wide and from sixty-five to ninety feet below the grade of the tracks, the north side being on a steep slope. The Salt Fork flows adjacent to the south side of the valley, which is formed by a line of precipitous bluffs some 130 feet above the bed of the stream. The bridge crosses the Salt Fork with one end abutting against this steep bank, while the remainder of the valley is traversed by means of a fill 60 to 80 feet high and of sufficient width to carry two tracks.

The bridge comprises three arches, one of 100 feet span in the middle, and two of 80 feet span at each end of the structure. There are two channel piers which carry the central arch, each of which supports one end of an 80-foot arch as well. The outside ends of the smaller arches are carried by the bridge abutments.

of the joints is made only through the rails embedded in those faces, which are separated by layers of felt carried nearly to the top of the joints, the remaining space at the top being filled with asphalt.

The channel piers above the arch rings of the main arches are hollow, each of the sides being formed by one of the bench walls, the top of which carries an expansion joint. The ends are each formed by pilasters carried up from the springing line of the large arch, and formed of reinforced concrete slabs nearly 60 feet long placed on the end.

The footings of the channel piers are carried down ten feet into the shale formation of which the bridge is built, while that of the north abutment is carried down four feet. The south abutment is built on the steep bank of the valley with its top about 12 feet below the springing line of the south arch. The back portion of this footing rests thirty-six feet below the natural surface on a limestone bed rock, while the front half is six feet above the rock, as the thrust from the arch reduces the load on that portion.

As soon as the footings of the piers and abutments were completed, the construction was carried up to the springing line of the three main arches, while at the same time the false work and centering for the center arch were being erected. The false work for each of the three arches comprised six transverse bents, which were carried up in 22-foot stories with caps at each story. The wooden structures were thoroughly swaybraced at short intervals by means of horizontal

The bench walls are 2 feet thick and are 10 to 21 feet high. They are reinforced near their faces by vertical bars spaced 12 inches apart which overlap at the base of the wall with bars which extend into the main arch ring and are anchored by bending. The bars in each wall, at the same time, extend over the haunches of the adjacent arches. The reinforcement bars in the bottom of the wall also extend into the concrete of the arch rings and were placed in position as the latter were concreted.

Difficulty was encountered in the work because of the rough nature of the neighboring country, which almost excluded the possibility of using teams for hauling material. However, a high timber trestle, used for making the fill beyond the bridge, was erected below the bridge structure and curved into the line of the tracks for the new road beyond the north end of the bridge. This was employed for the transportation of the material, but its use was attended with the drawback that there was practically no space for the storing of material, and consequently, it was necessary to construct a spur a mile long for delivery purposes. The concrete mixing plant was so located that it could handle material from the cars on the track or from along the river side of the latter. The 12,000 cubic yards of concrete necessary to complete the structure were made by a Smith mixer set on a platform about seven feet above the ground and located underneath a hopper and connected with a second hopper, for storage purposes. A clamshell bucket on a guide derrick handled the material to the mixer. The latter discharged into buckets on push cars running on a temporary track laid under the platform.

Dressed plank 2 inches thick and from 8 to 10 inches wide, together with timbers of varying sizes for posts, constituted the lagging for the forms of the piers, pilasters, abutments and the bench walls. The lagging for the main arches was of heavier planking and timbers, while that for the spandrel arches was 1 x 3-inch matched flooring. All the pairs of vertical forms were tied together with wires and well braced to hold them in position.

The concrete in the 100-foot arch ring, which was divided into eleven sections, was laid as soon as the blocks over the tops of the two piers were in place. The latter up to the springing lines of the 80-foot spans, which were divided into nine transverse sections, were laid first after the false work and centering had been completed. The south 80-foot arch was built after the 100-foot arch was completed, and the north end arch was finished after that. The transverse sections of the arch rings were laid in successive order, beginning at one end for the middle arch and varying the succession in the end arch. The longitudinal reinforcing bars of the arch rings were always lapped as near the middle of the sections as possible.

The work of concreting the structure was begun on August 8 of last year, but owing to delays in the shipment of materials the work on the main arches was not begun until October 4. The structure was completed by December 17, the work being carried on constantly in ten-hour shifts. A good idea of the size of the bridge is given by the figures of some of the materials used; for instance, 260,000 pounds of corrugated bars, 5,000,000 feet of lumber, the total exposed surface of which was 92,000 square feet, and 700 carloads of materials. It can be seen that it was a difficult matter to handle this material with a storage space capable only of handling eight carloads at a time.

THE PROBLEM OF SMOKE ABATEMENT.*

By WILLIAM H. BRYAN.

ATTEMPTS at smoke abatement are almost as old as the art of burning fuel itself. The subject is almost as attractive to the average inventor as is perpetual motion. To the engineer who works in this field will come many experiences, some pleasant and some unpleasant, but all interesting.

First of all, there is the cheerful crank, whose furnace consumes everything by passing the gaseous products of combustion back underneath the grates. Devices without number of this character have been seriously proposed. It is needless to say, however, that none have been successful. Even those which have been tolerated temporarily have found it necessary to discharge some gases and admit some fresh air.

Then there is the man who sprinkles the smoke with a jet of water—in other words, launders it. Another school mixes with the smoke so large a surplus of air or steam, or both combined, as to practically drown the smoke out, or dilute it to harmless proportions. The effect on the coal bill can be imagined. Other inventors have processes by which they extract from the waste gases by-products of fabulous value.

The trouble is that few inventors realize the complications and difficulties of the problem. The average steam boiler is subject to wide variations in its output, and is often overworked. More often the setting is in bad repair, and was of poor design originally, in grate surface, gas area, and flue and chimney dimensions. Oftener still, the poorest grade of unskilled labor is employed. When, in addition, such a furnace is required to handle the poorest grades of fuel, it is hopeless to attempt to control the smoke.

Not every man, however, is willing to do his share toward reducing the smoke cloud. First, and most important, is often the manufacturer himself. His argument is that a smoky city is a busy city, and that restricting smoke means interference with his business affairs, restricting and hampering his output. He tells us that a smoky but busy city is preferable to a dead

FALSE WORK AND LAGGING FOR THE MAIN ARCHES UNDER CONSTRUCTION.
CONCRETE RAILROAD BRIDGE AT DANVILLE, ILL.

The 100-foot arch has a rise of 40 feet, while the smaller arches have rises 10 feet less. The difference of the rises is equalized by a corresponding difference in the height of the springing lines above the bed of the stream, that of the central arch being 26 feet. The rails are located at a height of nearly 20 feet above the extrados of the crown of the arches, and the tracks rest directly on a five-foot earth cushion carried by the bridge. Series of transverse arches about 2 feet thick at the crowns, and having spans of 8 feet, are carried by the main arches. Usually between the bottom of the earth fill and the extrados of the main arches are longitudinal spandrel walls with the filling between. In this case these are replaced by the series of transverse arches, the crowns of which are in the same horizontal plane and carry a longitudinal coping between which is located the earth filling.

The entire structure above the springing lines is reinforced by means of a corrugated bar system in the usual manner. The series of transverse spandrel arches is built in three sections, one over each main arch ring, and the arches in each section are tied together by reinforcements, while expansion joints separate the sections one from the other. At all the joints, the concrete is worked in as smooth and flat as possible, so that the contact between the adjacent faces

timbers and were cross-braced transversely as well. They were carried on plumb posts placed on piles driven four feet into the shale. The plumb posts and struts were bolted at the top of the ribs, but were not attached to the false work and were only braced against each other near their lower ends. The arch ribs were formed of 12-inch planks, 2 inches thick, bolted together on the ground in sections and hoisted into place by derricks.

The reinforcing of the main arches, as well as of the structure, is very thorough. The longitudinal ribs of the main arches comprised 33-foot lengths of one-inch bar overlapped four feet at the ends and spaced 12 inches apart. The arch rings are further reinforced near the intrados with similar longitudinal ribs conforming to the curve of the arch. The ends of all the ribs are anchored in the masonry of the haunches and the reinforcements are so arranged that each of the three main arch rings is practically a monolith. The pilasters of the channel piers, mentioned above, extend to a five-foot coping at the top of the bridge. The pilasters are reinforced vertically and longitudinally by corrugated bars and are anchored at the top by horizontal transverse rods extending from the slabs over the bench walls. The inner face of each pilaster bears against the end of the two bench walls over the main pier and the end of the slab above the latter, but is entirely separated from all three by sliding joints.

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

* Lecture delivered before the students of Purdue University.

town with a clear atmosphere. His argument falls to the ground when we remember that a smokeless chimney is not inconsistent with severe and continuous boiler service.

Other objectors are those who have made attempts—more or less earnest and intelligent—to stop the smoke, but have failed. In most cases the attempt has been only half-hearted, but in others much money has been spent in misdirected effort. Many such people believe that the smoke cannot be stopped, and that it is useless to try.

What is smoke, anyway, and what causes it? The constituents of all fuels may be classified as volatile matter, fixed carbon, and ash. The ash is inert as regards smoke except that when present in large quantities, it impedes the proper handling of the fires, necessitating frequent cleaning, which is always detrimental. The fixed carbon, with which we are familiar in the form of coke, is smokeless. The remaining constituent, the volatile matter, occurs in large percentages in our western fuels, and to it the smoke is due.

When a fuel rich in volatile matter is charged into a furnace, the volatile matter is first set free as a gas, principally in the shape of hydro-carbons. Part of these are of the olefiant series, and are dissociated at a red heat. Part of the carbon is set free, and, if unconsumed, it passes off as smoke. It is possible to burn this free carbon, if sufficient oxygen is present, and the temperature is high. Failing in either of these conditions there will be a smoke.

The free carbon in the densest smoke is very small, from one-sixth to one-half of 1 per cent by weight. It has, however, great coloring power. You may stamp as false all claims of fuel saving due to consuming the smoke. The best furnaces, however, do make savings in fuel, not because they burn the smoke, but because improved construction and better engineering details bring about more favorable furnace conditions. The saving is often more than sufficient to pay a good interest on their cost, besides repairs and maintenance.

Broadly speaking, there are three methods of reducing smoke: First, the closing down of smoke-making plants; second, the use of smokeless fuels; third, the burning of ordinary fuels smokelessly.

Heroic as it may seem, much good has been accomplished by the actual shutting down of plants. A few years ago all large cities were dotted with small factories, each with its smoke-making boiler. To-day such plants are operated by electric motors, supplied with power from central stations located at a distance and provided with smoke-preventing apparatus. Many buildings get their entire service of light and power from the street mains, operating their boilers only during the cold months for heating. This practice may be expected to grow as electricity becomes cheaper, and is distributed over wider areas.

Much has been done in smokeless fuels, particularly for heating in the residence districts, and for many special operations. It is not too much to ask of the average good citizen that he will, if necessary, go to some expense to aid in beautifying his city. This, however, could not be expected under steam boilers, which are the largest smoke producers. It was hoped that oil from the Texas fields could be introduced at something like reasonable cost, but present rates are prohibitive. Oil has many advantages, however, which would justify a considerable increase in cost over coal. In addition to solving the smoke problem it greatly reduces the labor charge, can be handled and controlled more easily and usually permits an increase in the working capacity of the plant. On the other hand, however, the elements of danger and of odor are ever present. As indicating in a general way what may be done under boilers with the various fuels coming to the St. Louis market I prepared a table some time ago, based on St. Louis prices ruling before the recent advances. No claim is made for the absolute accuracy of the figures, but they are believed to be fairly reliable—relatively, at least. A glance is sufficient to show that the smokeless fuels are out of reach in cost, except possibly as the use of powdered coal may be developed.

The deliveries in this table are assumed to be on cars at consumer's switch. The oil weighs 7.43 pounds per gallon, and at the same time cost 3 cents per gallon, 2½ cents of which was freight. This price has since been raised, but even at these figures it falls short of competing with coal, even after adding 40 to 50 cents per ton for handling the coal and ashes. The outlook for oil would be better if, instead of burning it under boilers, it be used in oil engines of the Diesel or other modern type, which consume about ¾ pound of oil per I. H. P. hour. The ordinary Corliss engine uses about 4 pounds of Mount Olive coal per I. H. P. hour. At these figures the fuel cost would be practically the same for oil as for coal.

In the table it is assumed that the powdered coal is made from ordinary slack, at an additional cost of 35 cents per ton for powdering. This charge will be offset by the saving in labor for coal and ash handling.

After all, however, our greatest hope for relief lies in burning ordinary fuels smokelessly. As the worst offenders are the steam boilers, they only will be discussed. Devices without number have been invented for this purpose, but, unfortunately, most of them have failed to meet the exacting requirements of regular service.

It should be remembered that a good ordinary boiler furnace without a special device can be so handled as to greatly reduce the smoke, provided, of course, it is not overworked. It is not necessary, therefore, to buy somebody's patent furnace. Nor will the installation

of improved apparatus of itself control the smoke. A deep furnace, high bridge wall, ample grate surface and good draft are essential to a good smoke record. Such a furnace, skillfully fired, will make no serious smoke when working up to, say, two-thirds of its rated capacity. By skillful firing is meant the charging of alternate doors with small and uniform quantities of fuel, particularly if the coking system of firing is used. The firing of consecutive doors, at long intervals, with large quantities of fuel, and by the sprinkling method, is responsible for a very large proportion of our smoke.

If the furnace, however, is not well designed, or is overworked, no amount of skill or care will keep the smoke within bounds. In such cases resort must be had to special apparatus. Successful processes may be divided into five classes:

First, Steam Jets.—These are the simplest devices in use, and can be put together by any engineer at small expense. Sometimes they are placed under the grates, discharging into the ash pit, but more often they are above the grate, immediately over the fire doors or in the side walls, discharging backward or across and slightly downward. The jet draws in air and discharges it at high velocity immediately above the fire, where it meets the gases being given off by the disintegrating fuel.

Devices of this character have come into extensive use. They are reasonably effective in reducing smoke, but are not usually economical in fuel. The jets are often allowed to blow continuously, but it is better to turn them on at the time of firing and then shut them off in two or three minutes, after the fresh fuel has been ignited. In some devices this is done automatically, the act of opening the fire door turning on the jet admitting steam and air, and clockwork or dash-pot mechanism gradually closing it.

Second, Coking Furnaces or Firebrick Arches.—These come next in first cost, and are capable of giving almost perfect results in smoke abatement if properly designed and intelligently operated. The fire-box is kept well away from the cooling effect of the heating surface, and can therefore be maintained at high temperature. Contracted checker work, or throat areas, insure a thorough mixture of air, which is often preheated. These are built in many forms, many of which are capable of burning very inferior fuels. They are excellently adapted to plants where the service is reasonably uniform. The objections are that some

Fuel.	Cost, Dollars.	Calorific Value Heat Units.	Efficiency, Per cent.	Equivalent Evaporation in Lbs. of Water.	Cost of Evaporating 100 Lbs. of Water.
	Per 1000 Cu. Ft. 0.10	Per 1000 Cu. Ft. 240,000	80	Per 1000 Cu. Ft. 198.8	Cents. 50 30
	Per ton of 2000 Lbs.	Per Lb.		Per Lb.	
Anthracite.....	6.75	14,000	75	10.87	31.08
Texas oil.....	8.08	15,950	80	13.22	30.56
Coke.....	4.50	12,500	70	9.05	24.87
Pocahontas.....	4.75	13,300	72	9.90	24.00
Big Muddy.....	2.50	12,200	68	8.57	14.60
Mt. Olive, lump.....	1.60	11,200	65	7.53	10.62
Powdered coal.....	1.25	10,000	80	8.28	7.55
Common slack.....	0.90	10,000	60	6.20	7.25

forms require an increase of space, and the brickwork, if not properly constructed, may not be durable and repairs may be large. These objections, however, have been very largely remedied in the best types. There will usually be a material saving of fuel over the common setting if properly constructed and operated.

Third, Down-Draft Furnaces.—These have proved very successful in many instances, and have come into extensive use, particularly where excessive demands for overwork are frequently made.

In the Hawley, one of the best known forms, there are two grates, one above the other. The upper grate is a row of water tubes, single or staggered, so connected as to form part of the circulation system of the boiler. Grates of the ordinary pattern would not withstand the high temperatures. The tubes are inclined upward to the rear to insure rapid circulation. The space above the rear drum is closed off, and the gases must make their exit downward through the bed of fuel. Considerable partly burned fuel falls to the lower grate, where its combustion is completed under very favorable conditions. The two flames unite at the rear of the grates, forming a throat through which it is almost impossible for the particles of free carbon to pass unconsumed. Somewhat greater draft is usually required for this furnace than for the common setting. Most of the air required for combustion enters through the doors above the upper grate, a small amount being admitted under the lower grate. The furnace is independent of the skill or ignorance of the fireman to greater degree than many others. The objections are its first cost, and the fact that it is part of the present system of the boiler. With bad water or careless or insufficient handling, there is great liability to tube and drum repairs. It usually effects a considerable saving in fuel.

Fourth, Automatic Stokers, with which may be classed chain grates and underfeed devices. These have come into extensive use, particularly in large modern plants. While they are built in many forms, they all operate on the same principle—that of feeding the coal automatically to the grates in continuous and regular amounts. Most of them are designed for the use of the finer grades of coal, such as nut, pea,

or slack. In many localities there is a surplus of this fuel, and its cost is low, but the increasing demand is raising the price and reducing the supply. Many recent stoker plants are provided with crushers to permit the use of the larger sizes of coal when necessary. When accompanied by coal handling and storage plants the automatic stoker reduces the labor required in the fireroom, and this arrangement has been adopted in many large modern plants. The ability of the stoker to maintain practically uniform steam pressure, and the fact that the air supply is nearer theoretical requirements, are features which have contributed largely to its success.

The objections to automatic stokers are: First, their great cost; second, the complication of parts and the necessity of repairs; third, the steam required to operate them. Under proper conditions there is a material saving both in fuel and labor. That the objections named are not serious is shown by the fact that their use is constantly increasing. The fuel to be burned should have expert study, however, before a device of this kind is selected, as they are not equally well adapted to all fuels. Some do not respond to fluctuating loads, and to overwork, as well as other types of furnaces.

Fifth, Powdered Fuels.—These have recently attracted much attention, having for years been employed successfully in rotary cement kilns, and more recently under boilers to a limited extent. Experiments along this line have been under way for some time in European countries with considerable success. In the most satisfactory devices the coal is reduced to an almost impalpable powder, and is then forced into the furnace under pressure, exactly as would be done with oil or gas. Among the greatest advantages of this fuel is the fact that it may be made of slack or mine waste, which can be had at very low cost. While the apparatus for burning fuel is simple and inexpensive, the plant necessary for preparing the fuel is somewhat elaborate. As the fuel is explosive and liable to spontaneous combustion, it cannot be stored or handled in quantities, but should be used as fast as made. This would seem to call for a powdering plant at each point of use. There is reason for hoping, nevertheless, that good results may be looked for in the not distant future.

Space will not permit a discussion of all the methods which have been proposed, but the foregoing covers in a general way the devices which have been more or less successful. The list would not be complete, however, without mentioning double combustion furnaces, and mechanical draft, which has come into limited use with encouraging results, both alone and in combination with others of the above named types.

The classifications enumerated above are not always clear and distinct, as the types named are often found in combination. The fire-brick arch, for instance, is nearly always found in combination with the stoker, and often with the steam jet.

The fireboxes of locomotives and of steamboats require special treatment, but brick arches and steam and air jets have given good results. The best work is done when the two are combined. Some experiments have also been made with downdraft furnaces, with promise of success. Oil is admirably adapted for locomotives and is already in extensive use where the cost will permit. It is urgently recommended that large grate and heating surface be provided wherever possible.

I am unhesitatingly of the opinion that at least one—usually more—of these devices is applicable successfully to every smoke-making boiler, and that, too, without hardship. Great care, however, must be exercised; first, in selecting the apparatus, to insure that it is properly adapted to the service, second, in seeing that it is carefully applied, so as to be reliable and durable, and, third, that it is intelligently operated and maintained. The last is perhaps the most important of the three. No apparatus, however efficient, can be expected to run itself. Give it a chance; see that it is taken care of and kept in repair, and not abused.

Incidentally the smoke-abatement movement has led to a closer study of boiler conditions, with the result that the modern boiler room, in arrangement, lighting, ventilation, and general efficiency, is a creditable piece of engineering. It is entitled to be given at least as much attention, both by the designing and the operating engineer, as any other part of the plant. Hardly less important is the proper care and management of the boilers, and particularly of the fire itself. A good fireman should be encouraged. It pays to keep a good man, even at an advance in salary, for his hand is in the owner's pocket all the time.

The following directions regarding intelligent methods of firing with a view of securing efficient and smokeless performance may be of interest:

Fire frequently and in small quantities. Break up the lumps to the size of a man's fist. Carry a level fire over the entire grate surface, not too thick. Avoid thin or bare spots. Keep the fires clean.

Fire one door at a time, and wait until that fire is in good shape before charging the other door. Keep the time intervals between firings as nearly uniform as possible.

Fire not over three shovelfuls per door to begin with. If this makes no serious smoke, increase to four shovelfuls, and then to five or six shovelfuls until the smoke from the chimney shows that the limit has been reached.

Immediately after each firing leave the fire door slightly ajar for three or four minutes, thus admitting a little fresh air above the bed of fuel.

Our sympathy goes out to that individual who complained in a newspaper recently that the soot from the

smoke so soiled the snow that he could not play snowball, as in childhood's happy days. Nor can we answer that individual who expects the smoke department to do away with our river fogs. More interesting but even less tractable, is our friend who, when the banquet is over and cigars lighted, dares us to do our worst in preventing smoke.

Seriously, however, it is not a losing fight. Most cities now have strict ordinances controlling the smoke question, and more or less effort is being made toward their enforcement. As a rule, the courts are sustaining these laws. Some eastern cities, among them New York and Washington, prohibit the use of soft coal altogether, and I am informed that it is an offense in New York to even have it on the premises. More good, however, is done by moral suasion than by legal procedure, appealing to the civic pride of the average good citizen, and pointing out that the best methods insure a fuel economy amply justifying the original outlay.

Mishaps and discouragements are not unknown in the work, but the appeal to good citizenship, the education of the public, and—more than all—keeping everlastingly at it, will surely bring relief to any smoke-encompassed town.

ALCOHOL AS A FUEL.

THE passage of the "denatured" alcohol bill is likely to have a somewhat important effect upon power production upon a small scale. The fact is that alcohol, in spite of a thermal value more than 30 per cent below that of gasoline, has still some practical advantages of a very valuable character. During the many hearings upon the bill much important information was elicited. It seems to be generally agreed that in an engine of given cylinder dimensions and speed alcohol, when properly used, will produce a greater output than gasoline—in the opinion of one of our best-known engine builders, to the extent of some 20 per cent. The gain is mainly due to the greater compression at which it is possible to work the alcohol without producing auto-ignition, hence the greater the expansive action obtained, the lower the temperature of the rejected gases and the higher the thermal efficiency. It is understood that with a proper engine the thermal efficiency may be raised to and above 30 per cent, while with gasoline the efficiency would be nearly 10 per cent lower. In point of safety, too, the alcohol has a very considerable advantage in that it has a very much lower flashing point than any petroleum product that can be readily worked in an internal combustion engine. Of course, even crude petroleum can be so used if necessary, but far less easily than the hydrocarbons of lower boiling point.

Alcohol, too, burns with a pale-blue flame that radiates little heat and produces no soot. Its heat is delivered mainly by convection as in the case of a Bunsen burner, so that the danger of overheating objects near the flame but not above it is really lessened; and an alcohol fire can be put out with water, which a gasoline flame resists, since the fuel floats on water instead of mixing with it. More than this, alcohol has an odor at least inoffensive, while gasoline has an effluvia which Coleridge in enumerating "the two and seventy stenchies, besides several stinks," of Cologne, would have placed quite in a class by itself. So much for alcohol in the open air or in storage. In engines it works admirably, giving very clean combustion, of which the main product is water vapor. Less easily vaporized than gasoline it still is readily enough managed, and as we have seen, gives excellent efficiency. As to actual costs in operating alcohol engines, data differ somewhat. A few engines have been sent from this country to Cuba, where they are worked on alcohol costing 10 to 12 cents per gallon for a spirit quite good enough for the purpose. At this price gasoline would be at rather a disadvantage assuming equal dynamical value per gallon. Prior to the passage of the recent bill such spirit would have carried a prohibitive tax, some \$4 per gallon. Even now it will have to carry some extra charge for denaturizing. Wood spirit, much used for this purpose, is much more expensive than the alcohol itself, and pyridine, the other substance considerably used for "denaturizing," is far from cheap and has a most infamous odor.

Evidently there is room for improvement in the process of denaturization, and the time before the bill goes into effect can be utilized to good purpose in working over the problem. Even using wood spirit for the purpose still leaves a fair margin of cost in favor of alcohol when the manufacture gets fairly under way. All sorts of vegetable waste, such as refuse from the beet sugar process, can be utilized for alcohol making, as well as surplus grain in times of exceptional crops. To take full advantage of all this the denaturizing process must be simple, cheap, and effective, and watch should be kept lest some of the chief gains of the bill be nullified by regulation for denaturization, such as would practically throw the industry into the hands of a monopoly. Given the spirit at anything like the price claimed by its advocates, and we would seem to have a fuel peculiarly well adapted for many cases of small power production, for subsidiary heating purposes so important in many industries, and for auxiliary residence heating. To make the best use of it in explosion engines, special machines will have to be produced, although foreign experience shows that the same engine can use either alcohol or gasoline without so great losses as have sometimes been alleged. One large German maker gives the difference in weight of fuel as about 10 per cent in favor of gasoline in an engine adapted for the use of either. However, the special engine is the proper thing to use for high econ-

omy, and it will come along quickly enough when there is a demand for it. It would seem, too, that it should be easier to make a successful two-cycle engine for alcohol than for gasoline on account of the cleaner combustion. It is hardly to be expected that alcohol can be used economically for power production on any large scale, producer gas being too severe a competitor. The real gain in using alcohol is ultimately in the fact

In the duplex motor we have a piston which is made double, as will be noticed in the section. The upper part of the piston has a smaller diameter and works in the top cylinder, A, while the lower part is enlarged to form a second piston, working in a second cylinder of larger diameter, B. The two cylinder chambers are so proportioned as to have an equivalent capacity. Thus we find a single piston moving in two distinct

FIG. 1.—VERTICAL SECTION OF ONE OF THE CYLINDERS.

c, Transverse half-speed cam shaft; d, plate carrying lever arms; e, f, spiral gears for driving cam shaft; i, j, lever arms for operating valves; o, o, rollers of lever arms; p, q, valve-operating rods; s, t, brackets for operating valves.

that one is employing a material which can be reproduced in the cycle of the seasons instead of drawing upon the stored energy that is so rapidly being depleted.—Electrical World.

A NEW DUPLEX FOUR-CYCLE GASOLINE MOTOR.

By the PARIS CORRESPONDENT OF SCIENTIFIC AMERICAN.

THE Boudreaux-Verdet motor, which has lately been placed on the market in Paris, is of somewhat novel design. It is intended to obtain the advantages of a

chambers and the effect of the explosion is transmitted to the crankshaft of the motor by a single connecting rod and a single crank. The explosions of the two cylinders are successive, like those of an ordinary two-cylinder four-cycle motor, but they are distanced equally. The upper cylinder of the duplex motor works like the ordinary form of cylinder, while the lower one is made to operate practically and give an efficiency equal to that of the upper one by means of a pair of explosion chambers formed in the outer casting and containing the spark plugs as shown in Fig. 4. In the lower cylinder, when the piston arrives at the end of the stroke, its upper end reaches almost to the top of the cylinder, and the gas is practically all compressed in the outer explosion chambers. The lower cylinder thus serves only for the expansion of the gas due to

FIG. 2.

c, Transverse half-speed cam shaft; d, plate carrying lever arms; e, f, spiral driving gears; g, depressed and raised cams for operating lever arms; h, i, lever arms pivoted at l and k; o, o, rollers of lever arms; p, q, valve-operating rods moved by lever arms; s, t, brackets on valve-operating rods.

two-cylinder or a four-cylinder motor, while at the same time the number of parts is much less. The simplest form of the motor is the duplex, and by combining two of these, a bi-duplex or quadruplex motor is obtained.

FIG. 3.—PLAN VIEW OF LEVER ARMS AND DIAGRAM SHOWING ARRANGEMENT OF FOUR DOUBLE CAMS.

c, Cam shaft; d, supporting plate of cam shaft; e, f, lever arms; g, h, i, j, pivots of lever arms; k, l, m, annular part of lever arms carrying rollers; n, vertical push rods resting on lever arms; o, upper rollers of lever arms.

the explosion. Care is taken to design the form of the explosion chambers so that the speed of ignition is rendered high, due to the compact form of the chamber which brings all the gas near the spark plug. The ignited gas does not surround the part of the piston which has the smaller diameter until the piston is moving downward, owing to this disposition, and this part is thus prevented from heating to an abnormal degree by coming in contact with the burning gases when they are hottest.

On the above principle a double or bi-duplex motor may be formed by placing two such motors side by side. The two piston rods are connected to a common crankshaft by two cranks situated at 180 deg. In this way we secure on the four-cycle principle the advantages of a 4-cylinder 4-cycle motor, but only use two