Apr. 17, 1923. 1,451,677

G. R. BLODGETT ET AL

PROCESS OF MAKING SPARK PLUGS

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Fig. 3.

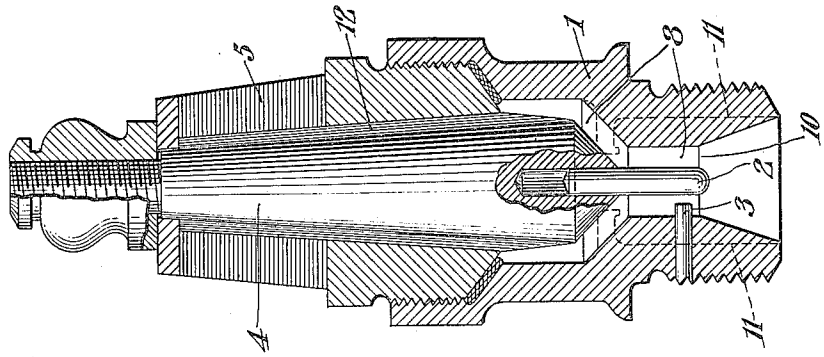


Fig. 2.

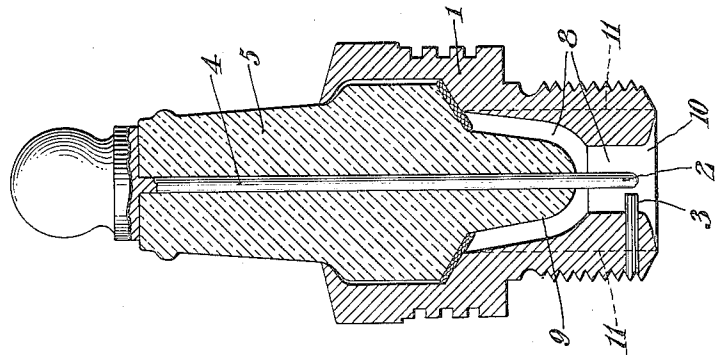
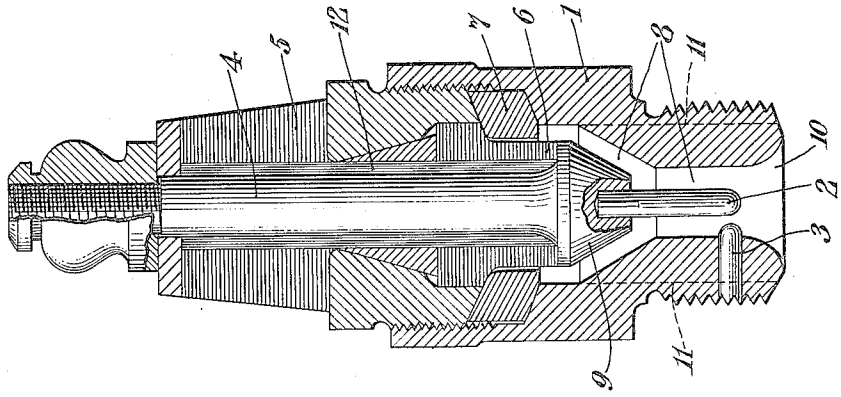


Fig. 1.



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Fig. 4.

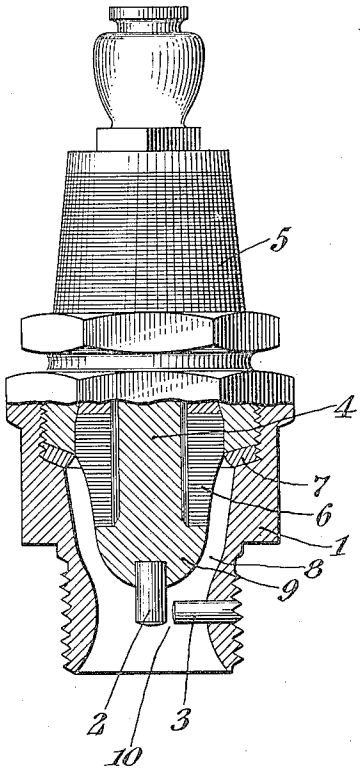
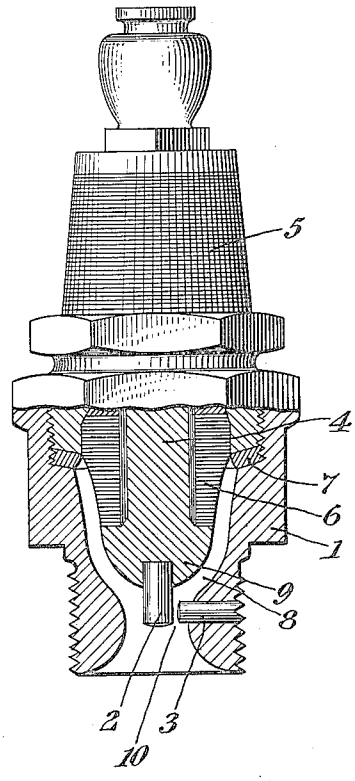


Fig. 5.



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UNITED STATES PATENT OFFICE.

GEORGE R. BLODGETT AND MOSES E. CHENEY, OF BROOKLYN, AND ROY T. HURLEY, OF NEW YORK, N. Y.

PROCESS OF MAKING SPARK PLUGS.

Application filed October 22, 1921. Serial No. 509,481.

To all whom it may concern:

Be it known that we, GEORGE R. BLODGETT, MOSES E. CHENEY, and ROY T. HURLEY, citizens of the United States, the said BLODGETT and CHENEY residents of Brooklyn, county of Kings, and State of New York, and the said HURLEY, a resident of Bronx, county of Bronx, and State of New York, have invented new and useful Improvements in Processes of Making Spark Plugs, of which the following is a specification.

Our invention relates to improvements in processes of making spark plugs. It has for its objects to improve the methods of manufacture of spark plugs, to make them more certain, precise and reliable; to bring about the production of spark plugs better adapted for the particular uses to which they are to be put and to produce spark plugs more efficient and durable and less liable to carbonization and pre-ignition in use than has heretofore been possible. It consists of the novel steps in the process of making spark plugs herein set forth.

Spark plugs heretofore in use are liable to carbonization and pre-ignition in practical use. So far as we know, no precise, accurate or scientific methods in the manufacture of spark plugs have been in use intended to produce spark plugs free from such troubles and defects. Heretofore the manufacture of spark plugs has been carried on on the hit-or-miss theory so far as concerns such trouble. Our improvement is intended to overcome the above troubles incident to spark plugs and to do it in a scientific, standardized manner, by certain steps in processes of spark plug manufacture adapted to make any particular spark plug or plugs adapted for the special uses to which it or they are to be put.

We have discovered that there is a close relationship existing between the volume of the space within the spark plug surrounding the electrode and adjacent parts, into which space the gas flows from the cylinder and in which it is burnt, the area of the walls of such space effective to receive, maintain and dispense heat, the manner and extent of admission of gas into the space, and the compression ratio of the engine cylinder with which the spark plug is to be used, and that, if the proper arrangement and proportions are secured in the manufacture of the spark plugs in these factors or particulars, the resulting spark plugs produced will be well adapted for the particular uses to which they are intended to be put, will be more durable and will function better than ordinary spark plugs and that over a much wider range of compression ratios and under much greater changes in load conditions, will be freer from liability to carbonize or to pre-ignite and will generally give much more efficient and satisfactory results; the gas introduced into the space within the spark plug will be brought into the very best condition for combustion, and the parts of the spark plug with which the gas comes into contact will be under ordinary running conditions brought in- to and maintained within the proper limits of temperature to produce the best results, neither low enough to permit carbonization or high enough to cause pre-ignition. The gas itself will be brought into the most favorable condition, both as to compression and complete vaporization of the fuel, for complete combustion; thus securing the highest efficiency without leaving harmful products of combustion on the electrode, insulation or other parts.

In the drawings accompanying this specification and forming part hereof, we have shown for purposes of illustration and for purposes of clearness, three different forms of spark plugs on the market, illustrated in Figs. 1, 2 and 3, which are open to the objections above stated, and which have been modified in accordance with our improved process.

In these drawings, the dotted lines represent the conformation of the space surrounding the electrode and adjacent parts and the outer walls surrounding such space and the orifice or passageway leading to the interior of the cylinder with which the spark plug

is adapted to be used, as these spark plugs appear on the market. The full lines indicate the conformation of the corresponding space, the walls and orifice as modified by our improved process.

Figs. 1, 2 and 3 are vertical sections taken through the centers of the respective spark plugs. Figs. 4 and 5 are similar sections through two spark plugs of substantially the same core and shell construction but with orifices of different cross-sectional area used for test purpose as hereinafter described.

Referring specifically to Fig. 1 of the drawings, 1 represents the shell of the spark plug, 2 the central electrode, 3 the other electrode, 4 the spindle carrying the central electrode, 5 and 6 and 12 insulation, and 7 a ring of metal surrounding the lower part of insulation 6. The other parts of the spark plug are not concerned with our invention and will not be further described. 8 is a space enclosed within shell 1, and having as walls the interior of shell 1 and the exterior surfaces of electrode 2 and an enlarged head 9 of spindle 4. 10 is the orifice of the spark plug tending to connect space 8 with the interior of the cylinder when the spark plug is in position. This orifice is shown as more or less restricted in cross-sectional area.

The dotted lines 11, 11 indicate the interior surfaces or walls of the lower part of shell 1 as spark plugs of this character have heretofore been ordinarily made and put upon the market.

Similar parts of the spark plug shown in Figs. 2 and 3 are similarly numbered to those of Fig. 1. In Fig. 2 space 8, as shown in full lines, has walls consisting of the inner part of the walls of shell 1 and the exterior surfaces of the lower part of electrode 2 and the lower protruding part 9 of insulation 5. In both Figs. 2 and 3 the dotted lines 11, 11 indicate the interior walls of the lower parts of the shell of these spark plugs as usually placed upon the market. The full lines indicate these spark plugs modified according to our improved process.

We have discovered that the space 8 inside of the spark plug surrounding the electrode and its adjacent parts, for example, electrode 2, and the bulging part 9 of Fig. 1, and protruding lower portion 9 of insulation of Fig. 2, etc., and the area of the walls of such space, effective to receive, maintain and dispense heat, for example, the inner walls of shell 1, the outer exposed walls of electrodes 2 and 3 and portion 9 and the exposed outer walls of insulation 6 and ring 7 as shown in Fig. 1, and the cross-sectional area of the orifice 10, should be proportioned and arranged with reference to the compression ratio adapted to be developed under ordinary running condition in the engine cylinder with which the spark plug is adapted to be used and, when the proper relationship of the volume of such space and the effective heat area of the surrounding walls of the space and the cross-sectional area of the orifice to one another and to the compression ratio is obtained, the electrode and adjacent parts, and the inner walls of the shell, will under ordinary running conditions be kept within a proper range of temperature properly to condition the gas for the most complete combustion possible at the proper moment, i. e., to bring it to and maintain it within the proper limits of temperature, on the one hand above the carbonization point, i. e., not low enought to permit carbonization, and on the other hand below the pre-ignition point, i. e., not high enough to cause pre-ignition. In general, the volume of such space and the effective heat area of its surrounding walls should be decreased as the compression ratio increases and increased as that ratio decreases, although the rate of such decrease or increase is not exactly proportioned to the rate of increase or decrease in the compression ratio.

Generally speaking, the orifice should be more or less restricted, depending upon the compression ratio. In general, as the compression ratio becomes higher, the orifice should become larger in cross-sectional area, although this does not exactly vary in direct proportion to the rise in compression ratio. In other words, speaking generally, if the compression ratio is high the area of the orifice should be larger and if the compression is lower the cross-sectional area of the orifice should be less.

The area of the walls of the space, referred to herein as "effective area" or "effective heat area," refers not to the total actual physical surface as merely measured in square centimeters but to the total of the heating capacity of those walls. These walls in spark plugs are composed of a number of different substances, such as the inside walls of the shell of metal, the exterior walls of the spindle and electrode usually of a different metal, the exterior walls of insulating material, which may vary in different plugs, etc. These substances have different heat capacity, conductivity, etc., and during normal running conditions one part will run hotter than another part, for example, and thus impart more heat to the unexploded gas in the space. There are thus two factors entering into the effective heating work done by these different parts of the walls of the space, one the actual physical area of a part and the

other the relative capacity of the part to absorb, hold and give out heat to such gas. Manifestly the total of effective heating work or capacity therefor in the walls is the sum of the products of the areas of actual physical surfaces by the said relative heating capacity of each surface, such capacity being the ratio of the actual temperature of the said surface under normal running conditions to the temperature required to condition fuel, i. e., the temperature just below that of the pre-ignition point. This for conciseness we term the "effective area" or "effective heat area," and each of the terms is used with this meaning throughout the specification and claim.

The actual temperature of any of the parts under normal running conditions can be ascertained in any of the ways known to those skilled in the art, such as by the use of sentinel salts or pyrometers. To give an illustration of the method of computing the effective area of any part such as the surface of the central electrode, we will assume that the actual physical surface of the electrode in any particular case is one square centimeter. The actual temperature under normal running conditions of the surface of the electrode is determined to be 1900° F. absolute and the temperature required to condition the fuel in this particular case is 1135° F. absolute, then the effective heating surface of the electrode would be the product of its area 1 by the ratio of $\frac{1900}{1135}$ which is 1.67 square centimeter. The effective area of each of the other parts is computed in the same way.

The spark plug illustrated in Figs. 1, 2 and 3 of the drawings are all ones adapted to be used with engine cylinders having a high degree of compression ratio. Where the engine cylinders have a low degree of compression ratio, the volume of the space 8 and the effective heat area of its surrounding walls should be increased and the cross-sectional area of the orifice 10 be diminished.

While the limits of compression ratio and corresponding limits of volume of the space surrounding the electrode and adjacent parts and of the effective area of the surface of the walls of said space cannot be stated exactly for the different classes of compression cylinders, we have found that under ordinary running conditions they are about as follows: For high compression engines, namely, those in which the compression ratio under ordinary running conditions will range higher than about 5 to 1 and will generally range from about 5 to 1 to 6½ to 1, the volume of the space should range from about 1.25 cubic centimeters to about .50 cubic centimeters, and the effective area of surface of the walls of the space should range from about 15 square centimeters to about 3 square centimeters, preferably from about 13 square centimeters to about 3 square centimeters; in low compression engines or those in which the limits of the compression ratio under ordinary running conditions will range below about 5 to 1 and generally from about 3 to 1 to 5 to 1, the volume of the space of the spark plug should vary from about 1.75 cubic centimeters to about 1.25 cubic centimeters and the effective area of surface of the walls of said space from an area of about 36 square centimeters to about 13 square centimeters.

Restriction of the orifice and especially in proper relationship to the other factors referred to above, assists in securing the proper amount of gas in the spark plug on each operation and in bringing that gas to the proper temperature and condition for explosion. Where an opening to a spark plug is unrestricted there are apt to be devious currents interfering with bringing the gas into proper condition for explosion, while with a restricted opening there is a positive swirling flow inward before explosion and outward after explosion, and the fuel fluid is more thoroughly brought into contact with the walls of the space inside of the plug, tending to bring it into proper condition.

The restriction of the orifice tends also to separate the space inside of the spark plug from the space inside of the cylinder more than would otherwise be the case, thus preventing too great and sudden rushes from the cylinder of cold gas before explosion and of intensely heated gas after explosion, and also permitting the gas within the space in the spark plug to be brought into better condition for combustion than is possible with the gas in the cylinder generally.

In high compression engines where the compression ratio varies as above stated, the cross-sectional area of the orifice should vary from about 0.20 square centimeters to about 1.0 square centimeters. In low compression engines within the limits of compression ratio above stated, we have found that the cross-sectional area of the orifice should vary from about 0.10 square centimeters to about 0.20 square centimeters.

One application of our improved process is to take any specific core and shell construction of spark plug, meaning by that a special arrangement, form, shape, size, etc., of central spindle, surrounding insulation, central electrode and surrounding shell, etc., and vary or adapt the orifice to cause such spark plug to become fitted for use with any desired compression ratio of engine

cylinder, or to adapt it so that it will cover a wide range of compression ratios. While this can be carried out under the general principles laid down above, we have discovered that the best cross-sectional area of orifice in such instances cited can be derived from the following formula, namely, $O=Kr^n$, in which O represents the cross-sectional area of the orifice, r the compression ratio of cylinder, and in which K and n are constants of the particular core and shell construction. The value of the constants K and n for any particular core and shell construction can be determined by taking two spark plugs of the same core and shell construction except that the orifices in the two cases will vary. The two plugs are then tested upon cylinders of different compression ratios until in each case the compression ratio is determined with which the spark plug gives best results. Such tests are well known to those skilled in the art and need not be described in detail except to say that in making such tests the highest compression ratio in each case is determined with which the spark plug will function without pre-ignition and that compression ratio is taken as that at which, under normal running conditions, the spark plug gives the best results. The phrase "gives best results" is used throughout the specification and claim with this meaning.

For example, in Figures 4 and 5, we have illustrated a spark plug having the same core and shell construction but with varying orifices, that of Figure 4 having a cross-sectional area of orifice of .82 square centimeters and that of Figure 5 a cross-sectional area of orifice of .215 square centimeters. The two plugs also differ slightly in some other dimensions, which do not, however, prevent them from being the same general core and shell construction. In Figure 4, the inside diameter of the shell is seven-sixteenths of an inch and in Figure 5 one-quarter of an inch, and the side electrode of Figure 4 is .086 in diameter and had a length of .1212 inches, while that of Figure 5 has the same diameter but a length of .0375. The central electrode had a diameter of .125 inches in each plug. It was found in the tests that the spark plug of Figure 4 was best adapted for use with a compression ratio of 6.5 to 1, while the spark plug of Figure 5 was best adapted for use with a compression ratio of 5 to 1.

With the above specific examples of the core and shell construction in question, the values of K and n are derived from the above formula, as follows: The formula representing the plug of Figure 4 is $O=Kr^n$, and that representing the plug of Figure 5 is $O_1=Kr_1^n$. From these two equations the values of K and n are derived, as follows:

In the first,

$$K=\frac{O}{r^n},$$

And in the second case

$$K=\frac{O_1}{r_1^n}$$

Therefore

$$\frac{O}{r^n}=\frac{O_1}{r_1^n}$$

Multiplying by

$$\frac{r^n}{O_1},$$

we get

$$\frac{O}{O_1}=\frac{r^n}{r_1^n}$$

$$\frac{(r)^n}{(r_1)}=\frac{O}{O_1}$$

$$n\log_{.10}\frac{r}{r_1}=\log_{.10}\frac{O}{O_1}$$

$$n=\frac{\log_{.10}\frac{O}{O_1}}{\log_{.10}\frac{r}{r_1}}$$

Substituting values of O, O_1, r and r_1.

$$n=\frac{\log.\frac{.82}{.215}}{\log.\frac{6.5}{5}}=\frac{\log.\ 3.813}{\log.\ 1.3}=\frac{.581267}{.113943}=5.1$$

$$n=5.1$$

Substituting value of n in equation $K=\frac{O}{r^n}$ above—

$$K=\frac{.82}{6.5^{5.1}}=\frac{.82}{13990}=.0000585$$

$$K=.0000585$$

The values of all the factors now being known, the value of O can be determined in the original formula, $O=Kr^n$.

As a specific example, if it was desired to determine the O most suitable for use with the compression ratio 6 to 1, with the same core and shell construction, it would be done as follows:

$O=Kr^n$
$O=.0000585\times 6^{5.1}$
$O=.0000585\times 9302=.545$
$O=.545$ sq. cm.

This cross-sectional area is net cross-sectional area and of course allowance should be made because of the central and side electrodes. When the cross-section of the

central electrode and the projected surface of the side electrode are added to the net, the gross area becomes .655 square centimeters, requiring a diameter of orifice of .913 centimeters, or approximately .359 inches.

By our improved process the manufacture of spark plugs to suit the different varying conditions of compression ratio in engine cylinders can be carried on with accuracy and certainty, and the spark plugs intended for use with any particular type of internal combustion engine can be made to suit that particular type, and so as to be efficient, durable and not liable to carbonization or preignition in use therein.

What we claim as new and desire to secure by Letters Patent is:

The steps in the process of making spark plugs of any specific core and shell construction suitable to be used with any compression ratio of cylinder of internal combustion engines, which consist in varying the cross-sectional area of the orifice to the spark plug in accordance with the formula $O=Kr^n$, where K and n are constants depending upon the particular core and shell construction and are determinable from two spark plugs of the said core and shell construction but differing from each other in cross-sectional area of orifice, when each is used with the compression ratio adapted to give the best results for said spark plug.

In testimony whereof, we have signed our names to this specification.

GEORGE R. BLODGETT.
MOSES E. CHENEY.
ROY T. HURLEY.