April 27, 1965 | C. C. ANTHES ETAL | 3,180,397

THERMOTREATING METHOD AND APPARATUS

Filed May 29, 1963 | 6 Sheets-Sheet 1

Fig. 1.

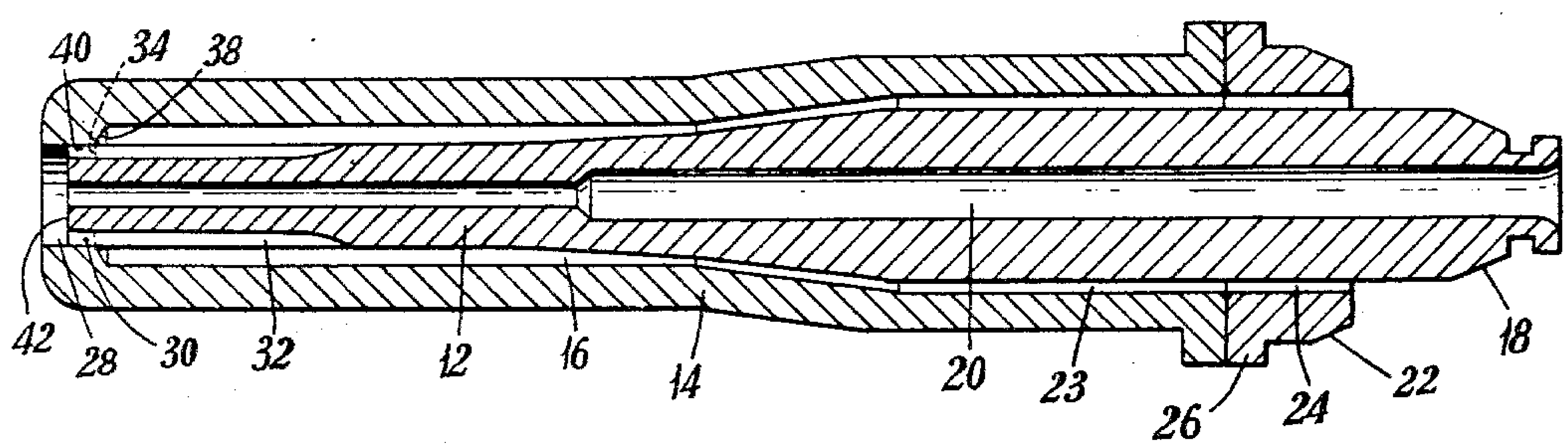
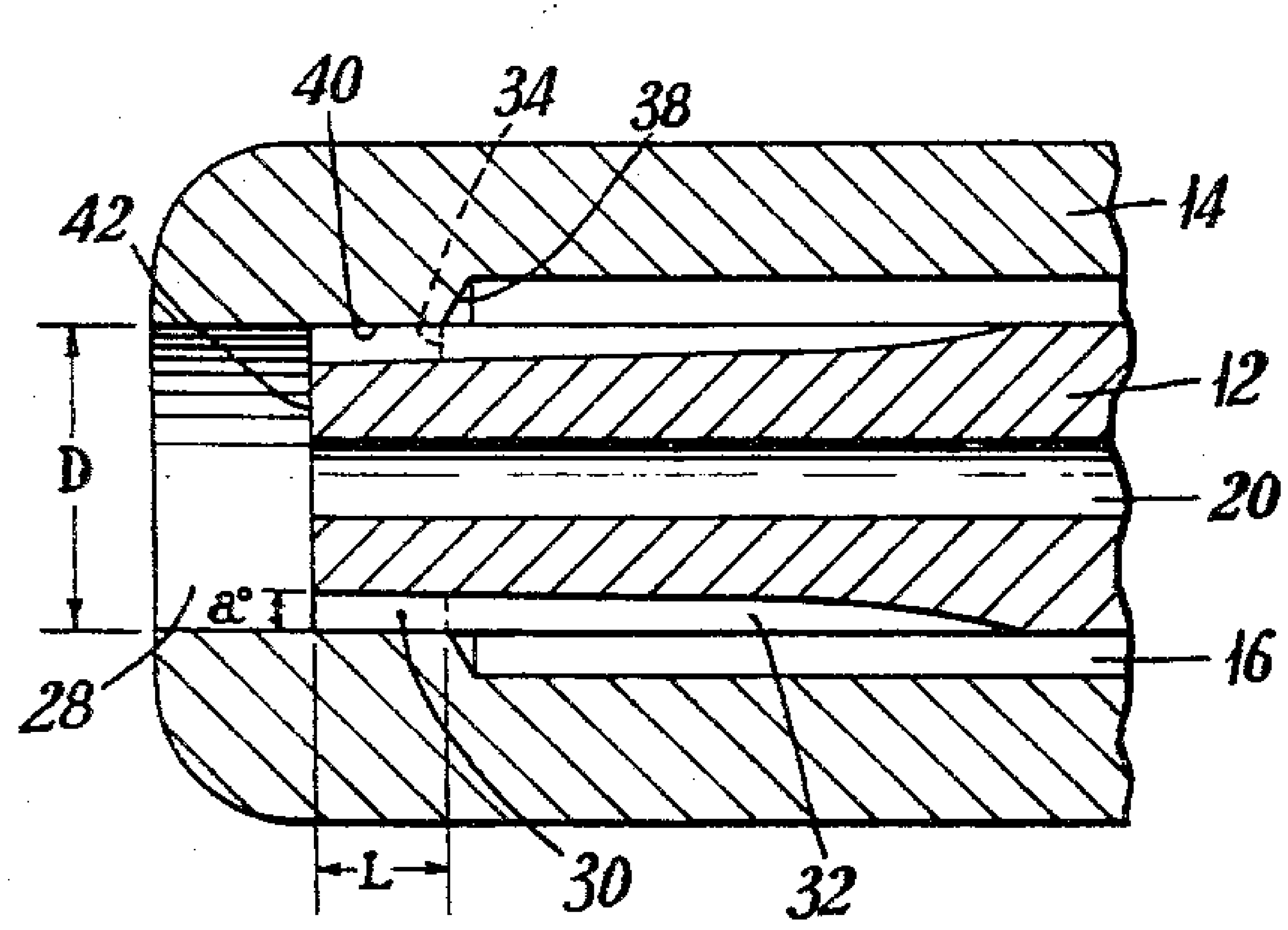


Fig. 2.



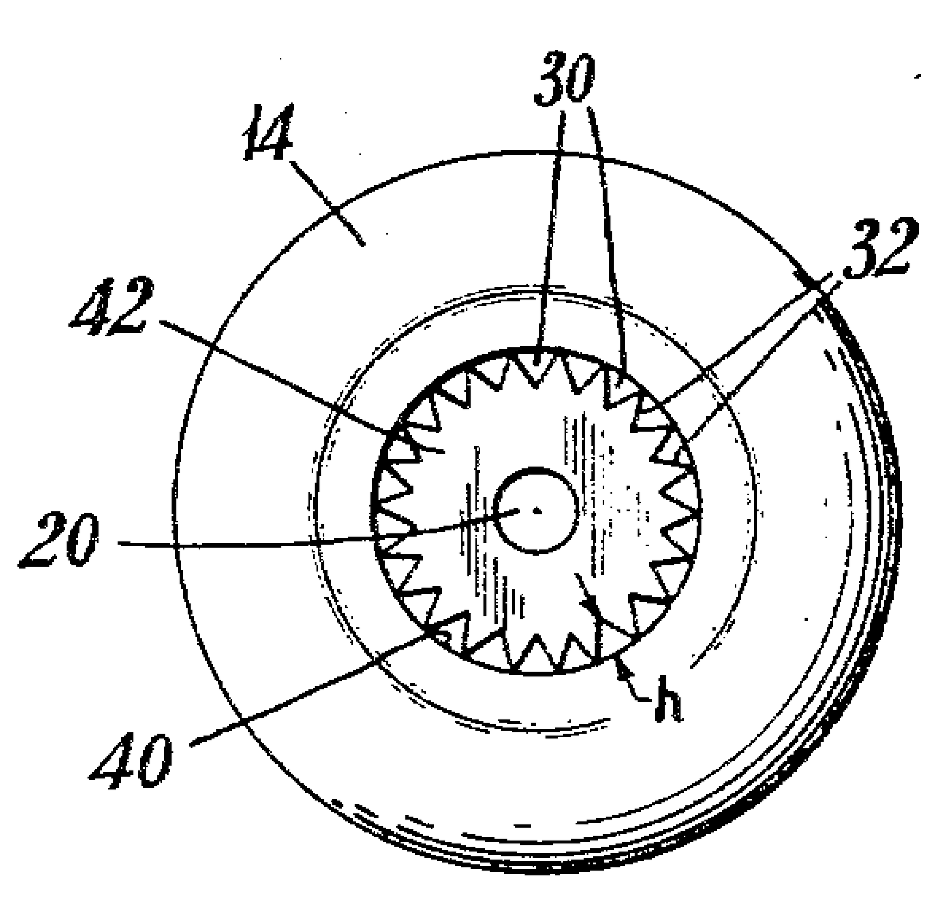


Fig. 3.

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THERMOTREATING METHOD AND APPARATUS

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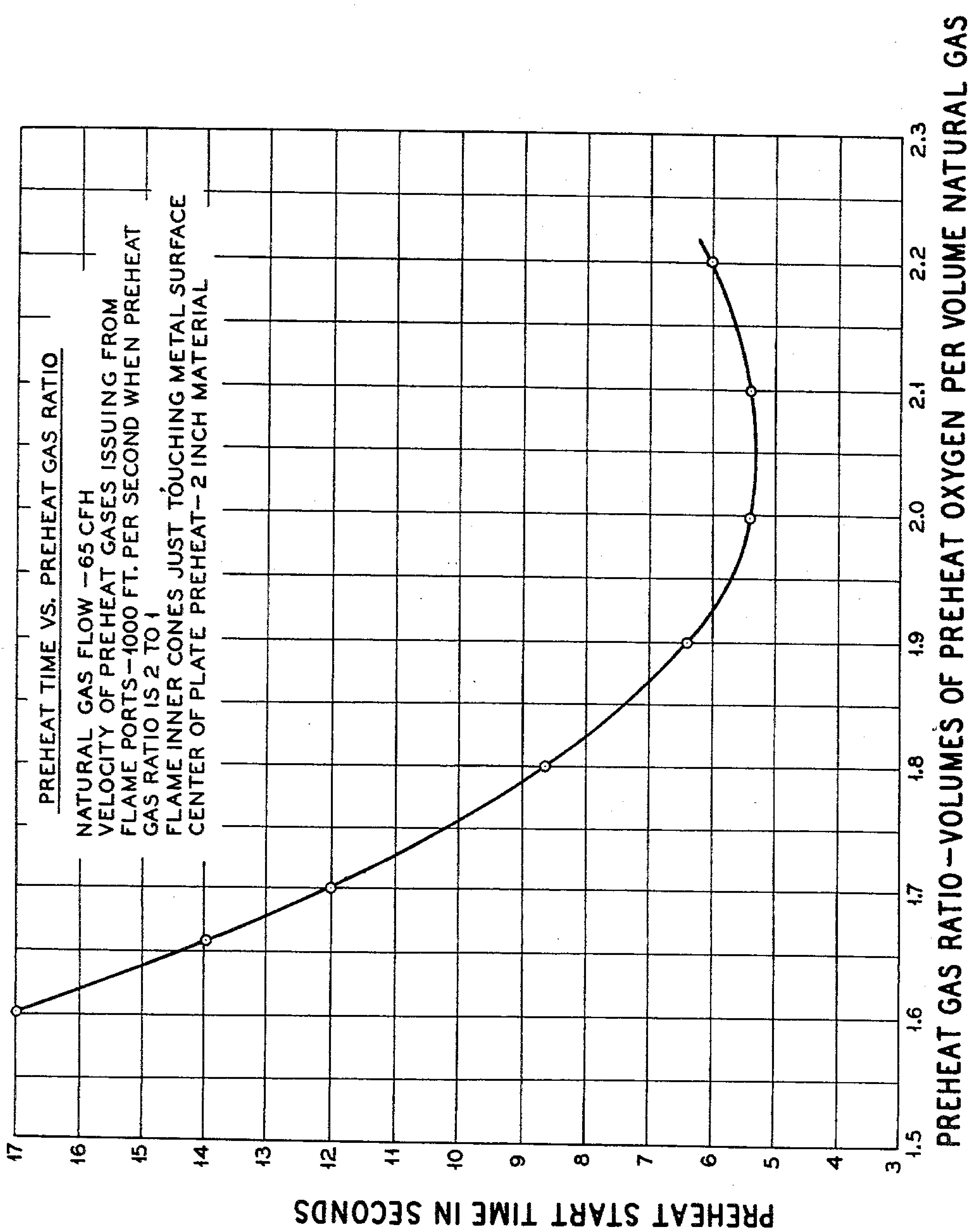

Fig. 4.

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THERMOTREATING METHOD AND APPARATUS

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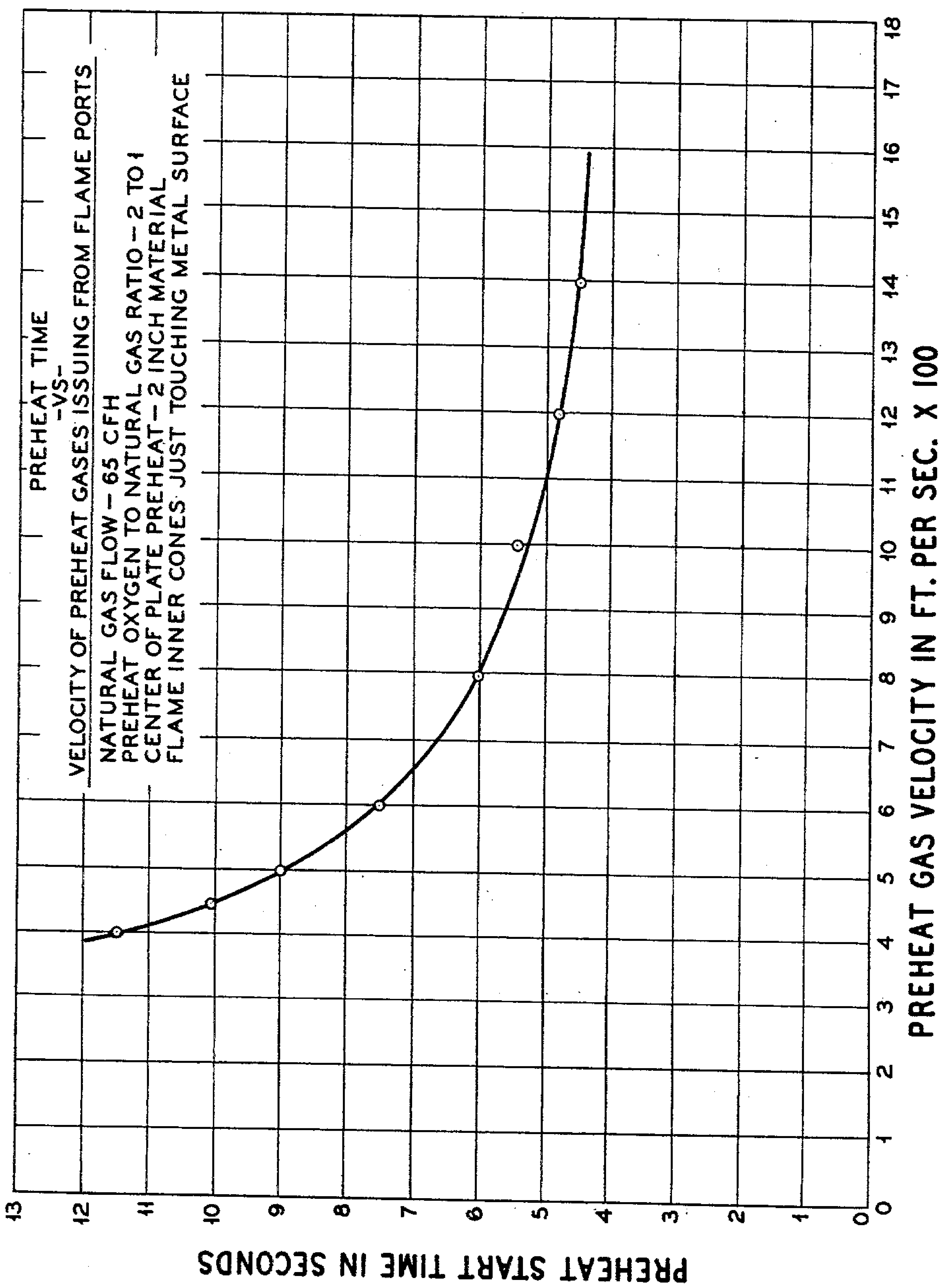

Fig. 5.

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THERMOTREATING METHOD AND APPARATUS

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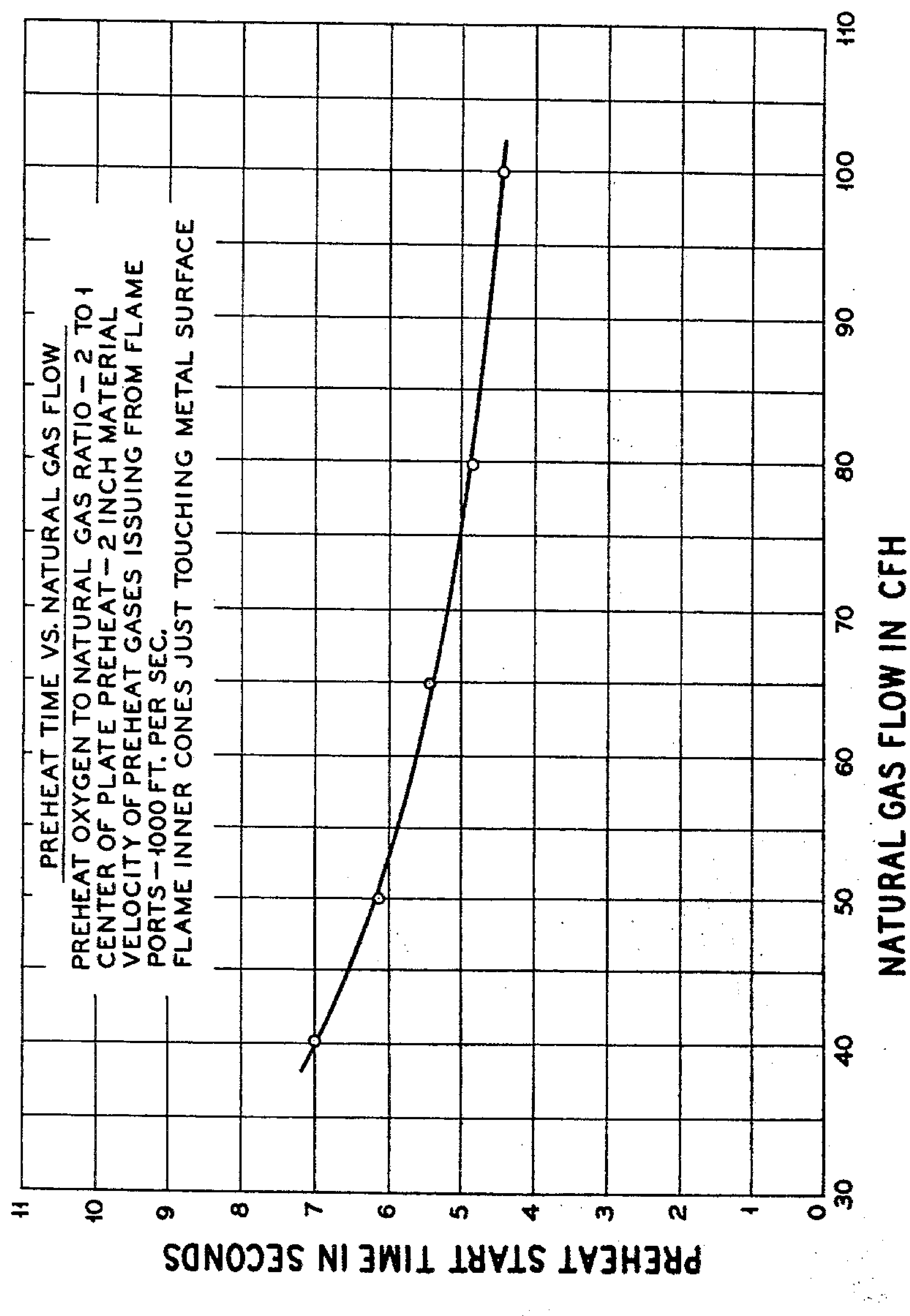

Fig. 6.

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April 27, 1965 C. C. ANTHES ETAL 3,180,397

THERMOTREATING METHOD AND APPARATUS

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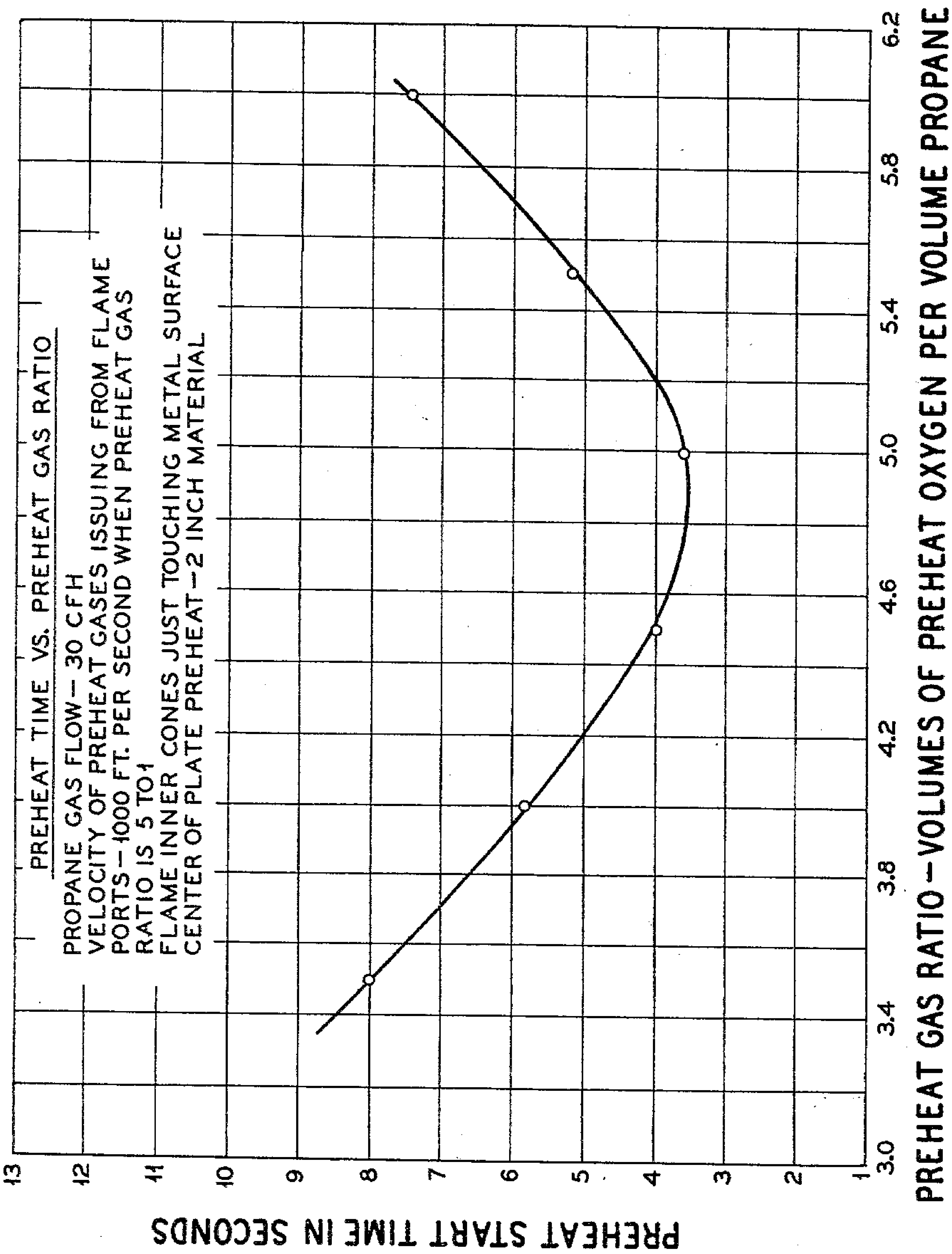

Fig. 7.

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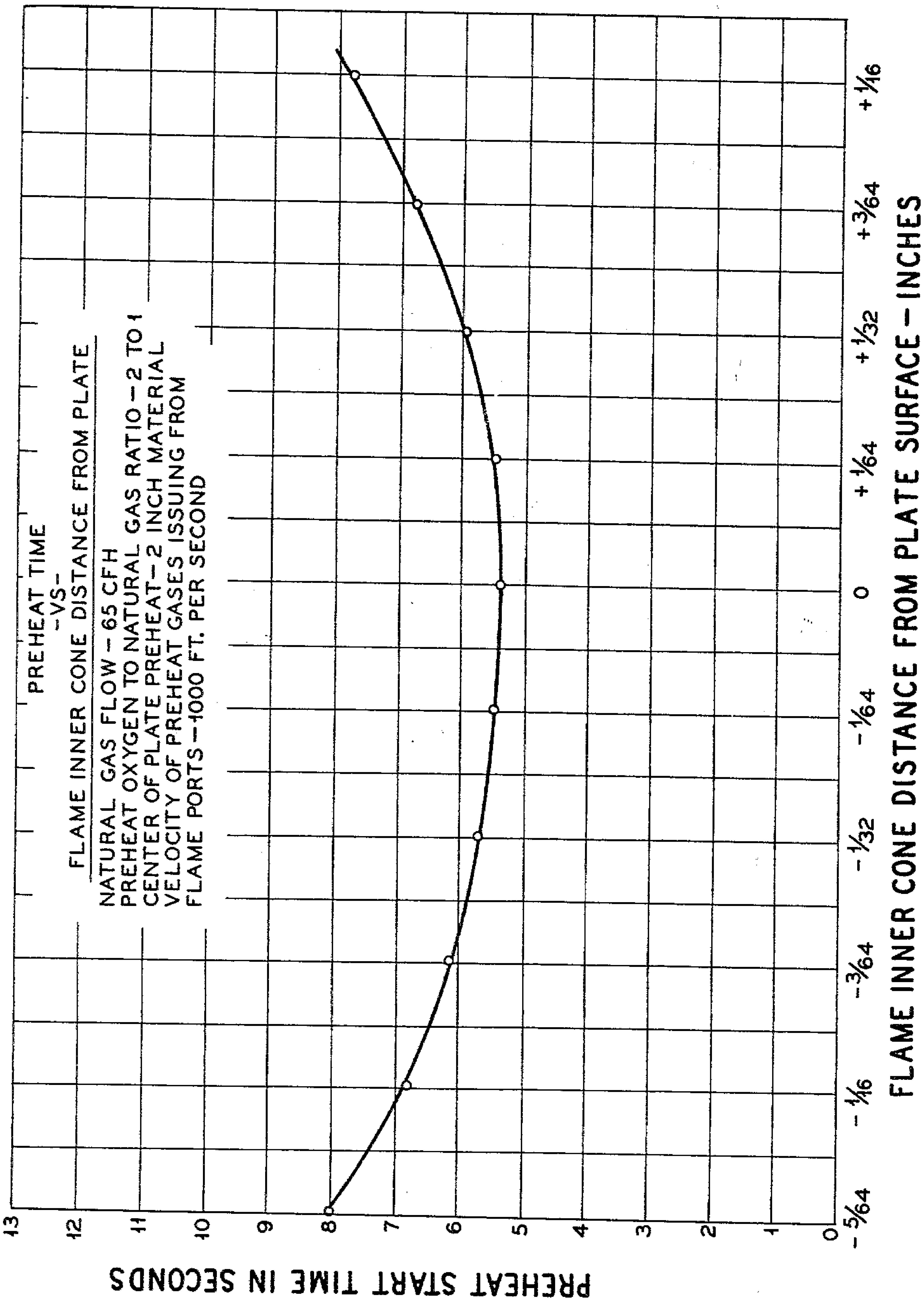

Fig. 8.

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United States Patent Office

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3,180,397

THERMOTREATING METHOD AND APPARATUS

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Filed May 29, 1963, Ser. No. 289,156
7 Claims. (Cl. 158—27.4)

The present invention relates to a blowpipe nozzle or tip for producing a highly efficient heating flame. It relates, more particularly, to a method and apparatus for utilizing a supersonic heating flame in conjunction with metal-treating operations.

For instance, among the various thermo-treating processes contemplated by the present invention, are: metal piercing, cutting, welding, flame hardening, or any of the commercially known methods.

Up to the present time, the most widely-used method of applying heat to a workpiece by means of oxy-fuel gas flames has been limited to the use of flames having relatively low gas velocities, and low ratios of oxygen to fuel gas. In the following description, we use the term "velocity" in accordance with the accepted practice of measuring flow by the formula

$$v=\frac{Q}{A}$$

where v is in feet per second, Q denotes quantity of gas in cubic feet per second, and A is the cross-sectional area in square feet of the port through which the measured fluid passes.

Generally, the typical oxy-acetylene preheat flame, commonly referred to as a neutral flame, has a maximum ratio (by volume) of oxygen to acetylene of approximately 1 to 1. For fuel gases other than acetylene, the ratios commonly used may vary from 1.3 to 1 to 1.7 to 1 for natural gas, and 3.5 to 1, to 4, to 1 for propane. The velocity of the mixed gases leaving the nozzle flame ports generally ranges between 350 and 550 ft. per second. Such low exit velocities are considered essential in order to maintain the low-ratio gas flames on the flame-ports, that is, to avoid their being blown off, a phenomenon usually associated with higher velocities.

These low-velocity, low-ratio preheat flames are in accordance with the most popularly accepted theory of providing effective preheat. This theory is based on the concept that the greater the volume of preheat gases used, the shorter will be the preheat time required to raise a metal workpiece to its ignition temperature. In other words, more preheat gas is supplied and the size of the preheat flame ports is increased. Little, if any, consideration is given to what has been found to be a far more important factor in achieving effective preheat, namely, the combination of the gas-exit velocity and the ratio of oxygen to fuel gas.

The result of the wide application of this popularly accepted theory, particularly in the case of oxy-fuel gas cutting operations using the conventional low-velocity, low-ratio preheat flames, is that the preheat times generally required are relatively high. For instance, in order to start a cutting reaction in a steel plate at room temperature, it is usually necessary to raise the temperature of the metal to its "sweat" temperature, approximately 1800° F. Using the aforementioned low-velocity, low-ratio preheat flames, the preheat time required to bring a steel plate, ½ in. thick or over, to its "sweat" temperature varies between 15 seconds and 1½ minutes for pierce start, i.e., when the cut is started by piercing a hole in the interior of the plates. For edge starts, 5 to 20 seconds is usually required depending upon the actual velocity, ratio, and volume of gases used.

To consider the economic aspects of metal cutting, for

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many years, during which the cost of materials was the primary economic factor, preheat times ranging as high as 1½ minutes were accepted in the trade. However, with the rising cost of labor making man hours the all-important factor in cost analysis, such lengthy preheat times have become extremely undesirable. For example, in mechanized operations the largest percentage of metal cuts are initiated by the pierce start method which requires the longest preheat time. Combining this mechanized operation with a cutting application on which a multiplicity of short-length cuts are to made, will result in the preheat time becoming a large percentage of the overall cutting time per cut, such that the preheat time will become a large-cost factor in the operation.

Recent experimental work has led to a clearer understanding of the importance of preheat gas-exit velocity, and the ratio of oxygen to fuel gas, to achieve a more effective heating flame. It has been found that one way of increasing preheat flame effectiveness is to increase the ratio of oxygen to fuel gas in the flame above the neutral or molar ratio thereby increasing the flame temperature. This also permits using somewhat higher gas-exit velocities, which is seen to increase the heat-transfer rate. However, full utilization of the benefits to be derived from higher velocity flames normally requies the use of flame holders, such as low-velocity pilot flames or skirted nozzles, which maintain the preheat flames on the flame ports. By utilizing such features, exit velocites as high as 1000 f.p.s. can be attained. However, these velocities so far have been limited to use with fuel gases other than acetylene due to the high fuel gas pressures required in order to achieve such velocities with the torch and nozzle apparatus commercially available. For the same reasons, the requirement for high fuel gas pressures has eliminated the possibility of using these higher gas-exit velocities with low-pressure fuel gases, i.e.: fuel gas supplied from low-pressure gas lines of about ½ p.s.i. or less.

A further disadvantage of the above procedures resides in the auxiliary equipment required to achieve such velocities. The use of low-velocity pilot flames to maintain the main heating flames on the torch nozzle generally necessitates either incurring the added expense and complications inherent in the use of two separate gas systems to supply the required fuel gas and oxygen for the two sets of flames, or the inclusion of gas restricting passages leading to the pilot flame ports. The usefulness of the skirted type nozzle to maintain high-velocity flames on the nozzle ports is limited by the fact that the effectiveness of the skirt in retaining the flames is a function of its depth. A skirt which is sufficiently deep to be really effective in retaining the higher velocity flames is soon destroyed by these flames.

It may be readily seen, then, that prior to the present invention it has been virtually impossible to take full advantage of the possibility of improving the preheat flame by the use of high-velocity and high-ratio gas mixtures. In the case of acetylene and the low-pressure fuel gases, it has been impossible to use them at all.

It is therefore an object of the invention to provide a more effective heating flame exhibiting a higher degree of heat transfer from flame to workpiece. It is a further object to provide an improved method for preheating a metal surface prior to initiating a cutting operation thereon. Another object is to provide an apparatus for facilitating such operation by directing a flow of preheating gas at supersonic velocities toward the metal surface. A still further object is to provide an apparatus for delivering a flow of preheat gas comprising a mixture of fuel gas and oxygen at supersonic speeds toward a metal surface, even though the fuel gas is supplied from a low-pressure source. As hereinafter used, the term "supersonic" or "supersonic flames," refers to the exit velocity of preheat gases measured by the previously noted Q/A value in excess of sonic velocities.

In the figures:

FIG. 1 is a longitudinal view in cross-section through a blowpipe nozzle;

FIG. 2 is an enlarged fragmentary view in cross-section of the nozzle discharge portion;

FIG. 3 is an end view taken along line 3—3 of FIG. 2;

FIGS. 4 through 8 are graphical representations of the results obtained utilizing the disclosed process in metal-cutting operations.

In brief, one embodiment of the apparatus of the invention contemplates an elongated blowpipe tip or nozzle having a central axial passage for cutting oxygen, and an annular, longitudinal passage for conducting a preheat gas mixture toward the nozzle discharge orifice. The inlet end of the nozzle is provided with a customary suitable configuration of surfaces for gas-tightedly engaging corresponding surfaces in the head of a blowpipe; the nozzle discharge end is provided with an outlet port for the cutting oxygen, and preheat gas ports substantially surrounding the outlet port. Each of the preheat gas ports at the nozzle discharge consists essentially of a constricted, gas-metering inlet, preceded by a tapered passage for funneling gas thereto, and a forward flame port passage of gradually increasing cross-sectional area in proportion to the downstream distance from the metering inlet.

In accordance with the invention and referring to FIGS. 1 and 2, the embodiment of blowpipe cutting nozzle illustrated consists of an inner member or core **12** and an outer jacket **14** substantially surrounding and spaced from the inner member to define an annular chamber **16** therebetween. The gas inlet end of the inner member is provided with suitable seating means such as frusto-conical surface **18** which may be brought into gas-tight relationship with the blowpipe head to provide a flow of cutting oxygen to the central passage **20**. Oxygen from this central passage is normally directed onto a metal surface which has been sufficiently preheated for cutting or metal removal purposes.

A second frusto-conical surface **22** substantially concentric with said first frusto-conical surface, likewise engages the blowpipe head to form a gas-tight seal for preheat gases. This gas mixture, according to practice, may consist of a fuel gas such as acetylene, propane, or natural gas, and a combustion-supporting gas such as oxygen. A plurality of bores or passages **24** provide means for conducting preheat gas from the blowpipe head to the annular chamber **16**. These passages may form a ring about the central oxygen passage and are preferably equi-spaced to promote uniformity of flow of preheat gas into said chamber.

The jacket **14** comprises an elongated cylindrical member having a central bore **23** which tapers toward the nozzle discharge end, and terminates in a short cylindrical opening **28**. The short cylindrical opening **28**, which is often termed a "skirt" is not required when the fuel gas used is acetylene, and in such case, the nozzle front face would be formed flush with respect to the forward face of core **12**. Thus, the jacket **14** would not extend forwardly beyond the forward end of core **12**, as shown in FIGS. 1 and 2. The jacket member **14** is disposed substantially concentric with and surrounding the inner member **12**; when properly assembled, the jacket **14** bears rearwardly against a peripheral shoulder **26** on said member **12**, forming a gas-tight connection to axially position the respective members in the blowpipe head. Conventional fastening means such as a ring nut, not shown in the figures, may be employed to retain the two-piece nozzle with sufficient firmness in the blowpipe head to assure proper passage of oxygen and the preheat mixture without leakage. The forward ends of the respective inner and outer members are so formed as to be in sliding contact when properly aligned. Referring to FIG. 1 and enlarged FIG. 2, the central bore **23** of jacket **14**, substantially conforms in shape to the profile of the core **12** to define the annular passage **16**. The downstream end of said bore **23** terminates in the cylindrical forward opening **28** which cooperates with and circumferentially positions the forward portion of the core **12**. Immediately to the rear of opening **28**, the central bore sharply increases in diameter to define the shoulder approach **38** to the flame ports which extend therefrom, to the nozzle face and which will be herein described with particularity. This approach is preferably formed with an included angle of about 120° to inwardly direct gas toward the core member and to reduce resistance or pressure drop along the approach to said ports.

The overall nozzle, as above described, represents a general construction rather conventional in the art of cutting nozzles. The particular feature of the present invention by which it derives its utility resides in the unique discharge portion of the nozzle and more especially in the configuration of the preheat gas ports **30**.

As previously mentioned, one method for achieving a faster preheating of a metal to be cut, is to deliver a greater quantity of gas to the cutting area and thereby provide a greater number of effective heating units. This could be accomplished, of course, by providing a sufficiently large discharge port or ports, and/or by increasing the gas pressure required to achieve a desired increased flow. However, the effectiveness of preheating flames has been found to be much less a function of the volume of preheat gases delivered to the metal workpiece, than the velocity and ratio of oxygen to fuel gas at which these preheat flames are delivered to the workpiece. Primarily, we have found that by utilizing certain oxygen to fuel gas ratios, depending on the particular fuel gas, and by delivering the preheat gas mixture at velocities of about 1000 feet per second, we can realize a much reduced preheat period.

The preferred method of the invention comprises essentially the combined use of highly oxidizing flames characterized by a high oxygen to fuel gas ratio delivered at supersonic gas velocities for preheating a metal surface. The optimum ratio of oxygen-to-fuel gas, as mentioned above, varies from fuel gas to fuel gas and is that ratio which provides the highest flame temperature. For example, tests have shown that the most effective natural gas preheat flames, as measured in terms of the preheat time required to initiate the cutting reaction, are produced when the oxygen-to-natural gas ratio (by volume) is approximately 2 to 1. This is graphically illustrated in FIG. 4. From this graph it will be seen that for the same conditions—namely, pierce starting on 2-in. plate with a preheat gas velocity of 1000 f.p.s. and natural gas flow of 65 c.f.h., raising the oxygen-to-natural gas ratio from the almost universally used 1.7 to 1 to 2.0 to 1 results in a decrease in preheat time from 12 seconds to less than 5.5 seconds, or in effect, a decrease of over 50 percent. Again referring to the curve, when the ratio of oxygen-to-natural gas is increased beyond 2.1 to 1, the preheat time begins to increase, primarily due to the effect of the excess oxygen which tends to cool the flame.

Similarly, as shown in the curve of FIG. 5, a reduction in preheat time is realized when the ratio of oxygen-to-natural gas is held constant at 2 to 1, and the exit-gas velocity of the preheat flames is increased. We have determined from the results of the tests, as indicated by the curve, that there appears to be decreasing, if any, advantage gained by increasing the gas velocity beyond 1600 f.p.s., and the largest percentage of preheat time reduction is achieved at about 1000 feet per second.

For comparison purposes, the curve shown in FIG. 6, illustrates the relatively minor effect on the preheat time realized by merely increasing the volume of gas flow; this is contrasted to the combined effect of oxygen-to-fuel gas ratio, and exit-gas velocity.

Though natural gas, due to its cost advantage, is the most widely used fuel gas at the present time, propane and acetylene are also still widely used for many applications. Our tests have shown that an oxygen-to-propane ratio of about 5 to 1, as shown on the graph in FIG. 7, produces the most effective oxy-propane preheat flames. It has also been determined in this respect that an oxygen-to-acetylene ratio of 1.5 to 1 produces the most effective oxy-acetylene flames. At these prescribed ratios, the flame temperatures are maximum.

In each instance, as noted above, about 1000 f.p.s. has been determined as the most practical exit-gas velocity since the most practical reduction in preheat time, occurs at approximately this velocity. Further, there is the added advantage that this velocity can be readily attained utilizing the disclosed nozzle of the invention even with acetylene and the low-pressure fuel gases maintained at supply pressures of about ½ p.s.i. and less.

The increased rate of heat transfer realized by virtue of the preheat gases exiting from the flame ports at supersonic velocity, and the resulting reduction in preheat time required to initiate the cutting reaction, are due in part to the more intimate contact of the hot gas molecules with the surface of the workpiece due to their high velocity. This more intimate contact results in a scrubbing action along the work surface, which tends to more rapidly displace the cooler gases from the surface.

The increased effectiveness of the oxidizing preheat flames, as measured in terms of decreased preheat time, is not only the result of the higher flame temperature, due to the presence of the greater quantity of oxygen, but also to a chemical combination of a portion of this oxygen with the metal of the workpiece. It has been noted, for example, that the chemical oxidizing reaction takes place at the earliest possible time after start of preheat and creates a rapid heat rise in the metal. Consequently, it is no longer necessary for a metal such as steel to be brought up to a "sweat" temperature of about 1800° F. before rapid oxidation of the metal takes place. With the high-ratio, i.e., high oxygen-to-fuel gas ratio, preheat flames of the invention, it has been found that the actual cutting reaction takes place automatically at a temperature of about 1400°, and furthermore, the process has the added advantage of being clearly discernable by the operator. Therefore, even an inexperienced operator will know exactly the instant that the cutting oxygen should be turned on. Another even more important factor in promoting this higher heat-transfer rate with the supersonic velocity hot gas molecules, is the greater mass concentration of heat per unit area of work surface being heated.

The rapid preheat made possible by the use of preheating gas exiting from the flame ports at supersonic velocities and at high ratios of oxygen-to-fuel gas according to the invention has resulted in preheat times of five seconds or less for pierce starts on all ferrous metal thicknesses of ½ in. or over. For example, a pierce start was made in the interior of a 2-in. thick ferrous metal plate using 25 c.f.h. of acetylene at an oxygen-to-acetylene ratio of 1.5 to 1 and a velocity of 1000 f.p.s. in 1.1 seconds. A similar pierce start was made using 30 c.f.h. of propane at an oxygen-to-propane ratio of 5 to 1 and a velocity of 1000 f.p.s. in 3.4 seconds.

Referring again to FIG. 1, in order to obtain the desired supersonic preheat gas velocity at the nozzle discharge, it has been found that the discharge coefficient of any preheat gas outlet orifice is an important factor. The term "discharge coefficient," as we utilize it and as is generally accepted, refers to that characteristic of the nozzle as determined by the ratio of actual flow through the nozzle divided by the theoretical flow, the maximum coefficient of course being 1.0. For instance, in conventional nozzles, it is not unusual to have gas ports in which the coefficient of discharge is about 0.5 to 0.6, but in such an instance, in order to achieve supersonic velocity discharge, it is necessary to increase the gas gage pressure to 20 or 30 p.s.i. We have found that with the presently disclosed preheat gas outlet in which the discharge coefficient approaches 1.0, it is possible to obtain a velocity of 1000 f.p.s. and upward with nozzle head pressures as low as 14 p.s.i. This is particularly advantageous when a low-pressure fuel gas supplied from a line at ½ p.s.i. or less is used as the fuel source. With the advent of more efficient injectors in torch apparatus, it is now possible to aspirate the required low-pressure fuel gas flows into the mixed gas stream in the torch apparatus, against a developed head pressure in the nozzle of 14 to 15 p.s.i. Thus, the preheat flame port configuration of the invention, having a discharge coefficient approximating 1.0 (0.90 or better), makes it possible to quite readily achieve supersonic preheat gas discharge velocities when using the low-pressure (½ p.s.i. or less) fuel gases.

Of course, generally speaking, critical velocity of any gas may be attained across the mouth of an orifice or port by adjusting the gas pressure such that the absolute pressure upstream of the mouth of the orifice is equal to or greater than 1.89 times the absolute pressure downstream of the mouth of the orifice. This requires a minimum of approximately 13.5 p.s.i. gage upstream of the mouth of the orifice when discharging to the atmosphere. In the case of the conventional cylindrical type of preheat ports, for which the discharge coefficient is between 0.5 and 0.6, the pressure drop through the cylindrical section of the port ahead of the mouth must be added to the 13.5 p.s.i. mouth pressure to arrive at the total upstream pressure ahead of the orifice required to achieve the acoustic critical velocity of the gas across the mouth of the orifice. In the instance of oxygen, the acoustic critical velocity is approximately 980 feet per second.

The configuration of the preheat port of the invention, which constitutes an essential feature, is the fact that the length of the metering inlet has been kept to an absolute minimum. This inlet, essentially a point as measured on the longitudinal axis of the port, results in an orifice having a discharge coefficient approaching 1.0 (0.9 or better). Thus, the pressure drop through the orifice itself is virtually eliminated. Consequently, the pressure upstream of the orifice and the pressure upstream of the mouth of the orifice, are one and the same such that an upstream pressure of only 13.5 p.s.i. will produce critical velocity flow through the preheat ports of the invention.

As shown in FIGS. 1 and 2, the discharge end of the inner member 12 is provided with a plurality of grooves 32 formed into the periphery of said member to surround the central oxygen port 20. The grooves extend rearwardly into annular passage 16 and are preferably tapered inwardly toward the central axis of member 12 on the order of 1° to 3° as indicated at angle $a°$ of FIG. 2 to provide for controlled lateral expansion of existing gas streams.

The peripheral grooves 32, as here shown, may be formed with a roughly triangular or V cross-section having a radius bottom; alternately, though, they may be formed with a flat or curved bottom such as a U-shaped groove would provide. The grooves may be internally formed as shown on core 12 or may be externally formed on the inner wall of the jacket 14. It is essential in any event that the groove be so formed as to provide an expansion chamber having a configuration in which the flame port passage or chamber 30 defined by the groove and the surface 40 of forward opening 28 on the jacket 14, is of particular proportions. For instance, in order to permit supersonic gas velocities to be achieved by the preheat gas stream as it emerges downstream of the metering inlet point 34 and into the flame port passage or expansion chamber 30, the said passage 30 must gradually widen in cross-sectional area such as provided by taper $a°$, to permit controlled uniform lateral expansion of the preheat gas stream. This controlled expansion provides for a uniform velocity buildup exceeding the gas' critical velocity. On the other hand, though, if the passage 30 is too divergent, the stream will have a tendency to collapse due to over expansion of the gas, which action produces turbulent flow along the gas stream's outer edge and, of course, decreases flow velocity.

By incorporating in a nozzle the type of preheat passage shown in FIG. 2, it has been found that when the outer passage wall **30** is substantially parallel to the nozzle central axis, a taper of about 1° and not exceeding 3° will afford the V-shaped passage **30**, a sufficient rate of increase in cross-sectional area to permit the desired controlled expansion of the preheat gas as it leaves the metering port **34** so as to achieve uniform velocity buildup to supersonic velocity. A taper in excess of 3° will permit the passage to widen too abruptly and as a consequence over expansion of the gas stream will result in a decreased flow velocity. By maintaining the outer passage wall **30** relatively parallel to the nozzle central axis, controlled expansion of the gas stream is substantially confined to a radially inward directon toward the nozzle central axis. Thus, the preheat flames tend to converge toward a point forward of the nozzle and thereby localize the concentration of heat on the plate surface.

It has been found that not only does the cross-sectional area of the expansion passage **30** constitute a vital factor in preheat gas velocity, but the length L of said passage as measured between the metering inlet point **34** and the outer face **42** of core **12** is important. Best results in terms of outlet velocity are obtained when the head pressure immediately upstream of metering point **34** is about 14 p.s.i. and the ratio of passage length L to the largest linear dimension at the metering inlet point **34** is within the range of about 2 and 4 to 1. With this ratio, which may be referred to as the aspect ratio, the ½ p.s.i. pressure excessive of the required 13.5 p.s.i. to produce critical velocity, is available. Said pressure, in combination with the controlled divergent port passage section, serves to increase the velocity of gas discharging from the ports, to a supersonic value (above critical velocity), rather than being utilized to overcome friction that would be present in an excessively long port. For example, referring to FIG. 3, if the height "*h*" of each groove, as measured at the metering inlet point **34**, is approximately 1/16 of an inch, a proper length L for the flame passage **30** is within the range of about 5/32 to 3/16 of an inch.

It should be clearly understood at this point, that while we have shown the preheat openings **30** as formed by grooves **32**, the openings may alternatively be formed by a plurality of spaced drillings. In such case, however, the relationship of the length L to the largest dimension across the passage **30** at the metering inlet point should be maintained. The aspect ratio, as it is termed, should be maintained between about 2 and 4 to 1, regardless of the shape of the discharge openings. The proper area at the metering inlet point is determined by dividing the designed flow rate by the desired velocity of about 1,000 f.p.s. or higher.

An unexpected advantage residing in the unique combination of features present in the nozzle, is one which permits retention of the flame at the discharge end in spite of supersonic exciting velocities. This is accomplished by proper positioning of the individual preheat ports with respect to each other. The close, ring-like disposition, as shown in FIG. 3, permits the flame from one port to hold the flame of adjacent ports so that there is a mutually supporting beneficial action. Satisfactory flame retention is also fostered by virtue of individual flame port divergency, as previously mentioned, a certain degree of taper or divergency is essential to permit controlled lateral expansion of the gas stream, but it has been found that the fringe of each stream is sufficiently retained to afford a peripheral film which flows at a velocity less than supersonic. This film, in effect, has a rate of discharge below the rate of flame propagation for the particular preheat gas mixture.

Also, with respect to the gas mixture, because of the high oxygen-to-fuel gas ratio utilized, the rate of flame propagation is increased and consequently the tendency for the flame to blow off the nozzle is reduced.

In achieving supersonic preheat velocities, we have found that the disposition and nature of the metering inlet **34** is one of the most pertinent factors of the invention. For example, and referring to FIGS. 1 and 2, the metering inlet **34** is located in the chamber **16** at that point where the approach or shoulder **38** meets the forward cylindrical opening **28**. In that the grooves **32** are inwardly biased toward the core axis, the metering inlet constitutes the smallest cross-sectional area of a flame port and is in effect a section with no actual length at all. In reducing the critical metering inlet passage length to essentially a point, pressure loss, due to friction as the gas passes through the metering inlet passage, has been reduced to virtually zero. Therefore, 13.5 p.s.i. pressure immediately upstream of the metering inlet point **34** will result in critical velocity through the metering inlet. Consequently, an available pressure of 14 p.s.i., in combination with the relatively short narrow-angle divergent passage downstream of the metering inlet, will assure the desired supersonic velocity of gas discharge from the preheat flame ports.

While the respective preheat gas ports, as herein described, are defined by cooperating core and outer members, it should be understood that the unique port configuration is not limited to nozzles having multiple ports but may readily be incorporated into unitary type nozzles. For example, the preheat passages of a single piece nozzle may constitute a plurality of bores extending longitudinally through the nozzle and terminating at the discharge face in flame ports as herein described. In such an instance, the flame ports may be fashioned having a circular cross-sectional metering inlet point and expansion chamber, by a reaming or swaging operation. Hereto, the expansion passage is provided with the desired degree of taper to assure controlled lateral expansion, and the preferred length as dependent on the metering inlet point diameter.

One of the advantages of the method and apparatus of the invention is that adjusting the gas ratio for the most effective preheat flames is a simple matter. Thus, even the most inexperienced operator is assured of achieving the most effective preheat without recourse to flowmeters, or similar devices, in the gas supply lines. To adjust the preheat flames to the proper ratio, it is merely necessary to start with a flame on the fuel-rich side having approximately the desired volume of fuel gas. The oxygen supply is then gradually increased until the flame defining the inner cones are at their shortest length and additional oxygen causes them to start to lengthen out again. The proper ratio of adjustment is at that point where the flames are shortest on the fuel-rich side. An improper setting of the preheat flame cones will fan out from the center line of the nozzle. On the other hand, when properly adjusted, the flames fall in symmetrical alignment around the cutting jet and are well formed, pointed cones.

In addition, it has been found that the location of the tip of the flame cones with respect to the surface of the workpiece is an important contributing factor in achieving the most effective preheat. The optimum location, that is, when preheat time is at a minimum, occurs where the inner cones of the preheat flames just touch the surface of the plate being heated. The flame cones impinging on the plate by as little as 1/16 in. or off the surface as little as 1/16 in. will result in an increase in preheat time of as much as 30 percent.

Practicing the method of the invention using the novel blowpipe nozzle not only provides for greatly reduced preheat times of five seconds or less, for pierce starts in the interior surface of a ferrous metal plate to be cut, but also permit instantaneous edge starting, assuming that the starting edge is relatively sharp. This means that for edge starting a relatively simple procedure is followed in mechanized cutting. For example, it is only necessary to set the proper speed on the cutting machine to that specified for the particular material thickness, adjust the preheat flames as outlined above for critical velocity and high ratio, turn on the cutting oxygen, and start the machine travel to approach and traverse the workpiece. The preheat and cutting reactions start simultaneously, with no pause or hesitation as is normally required to initiate the cut.

A further advantage derived from the employment of such rapid heat transfer and pin point concentration of heat over a very short period, metal warpage is substantially avoided. This is, of course, noteworthy for thin gage or sheet metal cutting.

Another advantage residing in the use of supersonic gas velocity through the preheat port is the fact that generally for plate thicknesses in excess of ½ in., thickness itself is not a factor effecting preheat time. In other words, the preheat time required to initiate the cutting reaction is entirely independent of plate thickness and remains the same for all thicknesses greater than ½ inch. In the instance of prior art low-velocity, low-ratio preheat, the preheat period is considerably longer and therefore causes a wasteful dissipation of heat by conduction through the workpiece. Thus, with the prior art preheat method, plate thickness is more of a contributing factor in the total preheat time in that the thicker the plate the longer it takes to preheat it. Also, for cutting application, the high-ratio supersonic velocity flames provide the shortest possible preheat time in order to initiate the cutting reaction. Once the cut is started, the preheat flames may be cut back to provide the desired soft flame to carry the cut and preserve good cut quality and provide a sharp top edge on the kerf.

It is understood that the method and apparatus herein disclosed and described accomplished a decided improvement in the art of thermo-chemical metal removing; it is also apparent that modifications in the unique method and nozzle may be made without departing from the spirit and scope of the invention.

This is a continuation-in-part of our application Serial No. 25,417, filed April 28, 1960, and now abandoned.

What is claimed is:

1. Method for thermotreating a metal surface by directing thereon heating flames which comprises, providing a combustible gas mixture, at least a portion of said mixture being a low-pressure fuel gas, forming said gas mixture into a stream under a head pressure up to about 15 p.s.i.g., constricting said stream at a constricted metering inlet having essentially no horizontal length to increase the velocity thereof to the critical velocity of said gas mixture, thereafter permitting controlled lateral expansion of said stream and directing said stream toward the surface to be treated.

2. Method for thermotreating a metal surface by directing thereon heating flames which comprises, providing a combustible gas mixture consisting of a fuel gas chosen from the group consisting of acetylene, propane and natural gas together with a combustion supporting gas, forming said mixture into a stream under a head pressure up to about 15 p.s.i.g., constricting said stream at a constricted metering inlet having essentially no horizontal length to increase the velocity thereof to a value approximating the critical value of said gas mixture, controllably expanding said stream downstream of the constricted metering inlet to provide said stream with a velocity exceeding said critical velocity and directing the flames produced by the ignition of said stream upon the surface to be treated.

3. In a nozzle having a discharge face for thermo-chemically treating a metal surface by directing thereon heating flames produced by an ignited supersonic velocity stream of a combustible gas mixture issuing from the nozzle discharge face, at least a portion of said gas mixture being a gas supplied at low pressure, said nozzle comprising: an elongated member having a gas inlet end in opposed relation to the discharge face, a passage means communicating said inlet end with the discharge face for directing a flow of the combustible gas mixture thereto, means defining an orifice at said face, means defining a throat rearward of said discharge face, said throat adapted to receive a flow of gas from the passage, said throat having inwardly convergent walls to direct said gas flow to a metering inlet having essentially no horizontal length constituting the smallest cross-sectional area of the throat, an expansion chamber extending forward of said metering inlet and having outwardly divergent walls to provide an increasing cross-sectional area toward the discharge face, said orifice characterized by a discharge coefficient within the range of 0.9 to 1.0.

4. In a nozzle having a discharge face for thermo-chemically treating a metal surface by directing thereon heating flames produced by an ignited supersonic velocity stream of combustible gas issuing from the nozzle discharge face, at least a portion of said mixture being a gas supplied at low pressure, said nozzle comprising: an elongated member having a gas inlet end in opposed relation to the discharge face, and a chamber formed therein adjacent the discharge face, passage means communicating said gas inlet with said chamber, means forming a plurality of orifices communicating said discharge face with the said chamber, said orifices being circularly arranged to converge the gas streams issuing therefrom at a point forward of said face, means defining a throat rearward of said discharge face, said throat opening into said chamber, said throat decreasing in cross-sectional area to a metering inlet constituting the most constricted portion of the throat, an expansion chamber commencing at said metering inlet and having outwardly divergent walls to provide an increasing cross-sectional area toward the nozzle face, said orifice characterized by a discharge coefficient within the range of 0.9 to 1.0.

5. In a cutting nozzle for thermo-chemically treating a metal surface by directing against said surface a preheating flame produced by an ignited supersonic velocity stream of a combustible gas mixture, a portion of said mixture being a fuel gas supplied at low pressure, said nozzle including a gas inlet end and an opposed discharge face and comprising: an elongated jacket having an axial bore extending therethrough, a core coaxially registered in said bore to define an annular passage therebetween, passage means in said core communicating the gas inlet with the discharge face to conduct a flow of oxidizing gas, means forming a plurality of orifices communicating the annular passage with the discharge face, said orifices surrounding said passage means to form a plurality of circularly arranged outlets at the discharge face, each of said orifices being formed with its axis inwardly directed to converge the preheat flames issuing therefrom at a point forward of the discharge face, means defining a throat rearward of said discharge face, said throat adapted to receive a flow of gas mixture from the annular passage, said throat being formed by inwardly tapered walls to converge the gas flow at a constricted metering inlet constituting the smallest cross-sectional area of the throat, an expansion chamber downstream of said metering inlet to receive a high velocity constricted flow of gas therefrom, said expansion chamber having outwardly divergent walls to provide an increasing cross-sectional area toward the discharge face, the length of said expansion chamber between the metering inlet and discharge face being about 2 to 4 times the largest distance across said metering inlet, the length of said metering inlet being substantially without dimension.

6. In a cutting nozzle for thermo-chemically treating a metal surface by directing against said surface a preheating flame produced by an ignited supersonic velocity stream of a combustible gas mixture, a portion thereof being a fuel gas supplied at low pressure, said nozzle comprising: an elongated outer jacket having at one end a gas inlet and at the other end a discharge face, said jacket having an axial bore extending therethrough, said

bore terminating in a cylindrical opening at the jacket forward end, a core coaxially registered in said bore to define an annular passage, said passage being terminated rearwardly adjacent the nozzle face, means forming a passage extending through said core communicating the gas inlet with the discharge face to conduct a flow of oxidizing gas, the discharge face of said core terminating in a recess from the extreme forward end of said jacket, the forward portion of said core having a diameter slightly smaller than the jacket cylindrical opening, said core forward portion being slideably received in said opening and closely fitted therewith, a plurality of grooves formed into said core forward portion extending to the face, thereof, said grooves together with the jacket forward opening defining a plurality of orifices for conducting preheat gas streams, each of said orifices being formed with its axis directed to converge the gas streams issuing therefrom at a point forward of the nozzle face, means defining a throat rearward of said discharge face, said throat having convergent walls to receive gas from the annular passage, and an expansion chamber having outwardly divergent walls which terminate in a recessed outlet at the core face, said throat and expansion chamber being joined at the smallest cross-sectional area of each of said

convergent and divergent walls respectively to define a metering inlet, the length of said expansion chamber between the discharge face of the core and the metering inlet being from 2 to 4 times the largest distance across the opening at the metering inlet.

7. In a cutting nozzle substantially as described in claim 6 wherein the core forward portion is provided with a plurality of adjacent longitudinal grooves having a V shaped cross-section, said grooves being inwardly tapered at an angle between 1 and 3 degrees, to define the divergent wall expansion chamber.

References Cited by the Examiner

UNITED STATES PATENTS

2,531,006	11/50	Smith	158—27.4
2,861,900	11/58	Smith et al.	158—27.4
2,993,531	7/61	Spies et al.	158—27.4
3,042,106	7/62	Werner	158—27.4

FOREIGN PATENTS

820,576	8/37	France.

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