To all whom it may concern:

Be it known that I, HARRY D. RANKIN, a citizen of the United States, and a resident of Coronado, in the county of San Diego, State of California, have invented a certain new and useful Process of and Apparatus for Treating Materials, of which the following is a specification.

The invention relates to a process of and apparatus for treating materials and relates particularly to the fixation of gases, vapors, liquids or solids, or combinations thereof, and more specifically to the fixation or oxidation of nitrogen or the production of endothermic compounds.

An object of the invention is to provide a process of producing endothermic gaseous or vaporous compounds economically.

Another object of the invention is to provide an apparatus for producing endothermic gaseous or vaporous compounds economically.

A further object of the invention is to provide for abrupt and rapid cooling of the gases after the endothermic reaction has occurred.

The invention relates to the fixation of gases, vapors, liquids or solids, or combinations thereof, by the subjection of the materials to an electric arc flame, whereby they are raised to extremely high temperatures, which produce rearrangement of the elements of the materials and then fixing the elements in their resultant rearrangement. I have found it advantageous to economic fixation that the resultant compounds at temperatures of thousands of degrees centigrade be abruptly and rapidly reduced in temperature, to a temperature below that at which any great percentage of the compounds produced would either dissociate or decompose. For example, in the fixation of nitrogen or the formation of oxides of nitrogen, the temperature of the resultant gas, should be instantaneously reduced to about 1900 degrees centigrade. In my prior United States Letters Patent No. 1,150,786, dated August 17, 1915, to which reference is hereby made, I have set forth the necessity of rapidly cooling the resultant material by any suitable means or method, such as bringing the material into contact with a cold surface, expanding the material or bringing it in contact with a cold or expanding gas, and in my United States Patent No. 1,150,786 of August 17, 1915, I have disclosed a means of cooling, comprising a rheostat for decreasing the electrical energy fed to the arc to reduce the temperature of the arc itself during the cooling part of the cycle. In said patents I have shown several methods of cooling the gases, but I have found that in some instances any one method alone of cooling the gases does not produce a sufficiently abrupt drop in temperature to produce the most economical results. In order to accomplish the desired abrupt drop in temperature of the gases immediately after they leave the arc, I have found it desirable to employ two or more cooling methods or means acting substantially simultaneously on the hot gas, each method supplementing the other. I have found that in addition to bringing the hot gases in contact with a cooled surface that it is advisable to produce a substantially concurrent instantaneous expansion of the gases, the instant they leave the arc flame, and if the combination of these two methods is not sufficient, to further and concurrently contact the hot gases from the arc with a material having a great heat absorbing capacity, such as air, or water spray or steam or SO₂ gas or acetic ether or other comparable materials, and if further aid is necessary to reduce energy, i.e., temperature of the arc during the cooling part of the cycle. The effect of these two or three or four cooling methods concurrently applied, cools the gaseous material sufficiently to fix the elements in their rearranged combination or form.

This invention possesses other advantageous features, some of which, with the foregoing, will be set forth at length in the following description, where I shall outline in full the process of my invention and that form of apparatus for carrying out the process which I have selected for illustration in the drawings accompanying and forming part of the present specification.

In said drawings, I have shown one form of apparatus of my invention, but it is to be understood that I do not limit myself to such form since the invention, as set forth in the claims, may be embodied in a plurality of forms.

Referring to said drawings:

Figure 1 is a vertical section through one form of apparatus of my invention.

Figure 2 is a vertical section of the upper
portion of the apparatus on an enlarged scale.

Figure 3 is a vertical section thru the nozzle.

The apparatus comprises a metallic shell 2 provided, if necessary, with a lining 3 of refractory material, such as magnesite brick, of such thickness to form an arc chamber or furnace chamber 4 of the diameter desired. The chamber 4 is preferably circular in cross-section slightly conical, taping to its narrower diameter at the top, but the conical construction is not essential and the chamber may be cylindrical when desired.

Seated on the upper end of the shell 2 and spaced therefrom by a ring of electrical insulating material 5, if electrical insulation is essential, and extending into the shell, is a vessel or housing 6 having a throat or passage 7 therein, opening at its lower end into the furnace chamber 4 and opening at its other end into an expansion chamber 8. The space between the inner and outer walls 12 and 13 of the vessel 6 constitutes a water jacket and means are provided for establishing an adequate flow of water through the jacket to keep the wall 12 of the throat and expansion chamber cool. That is, ordinarily, accomplished by a water inlet pipe 14 discharging adjacent the bottom of the throat and a water outlet pipe 15. The vessel 6 is provided with a flange 16 seating on the insulating ring 5, and is held in place by a clamping plate 17 connected by bolts 18 to a similar clamping plate 19 at the bottom of the shell 2.

Extending into the furnace chamber through the expansion chamber 8 is the electrode 25, which also extends upwardly through a suitable stuffing box 22. The electrode 25 is preferably metallic and hollow and is preferably provided with means for keeping it cool, but may be made of any suitable material. Extending down into the electrode to the enlarged tip 23 thereof is a water or other cooling medium inlet conduit through which the cooling medium discharges into the electrode. The cooling medium discharges from the electrode through the outlet passage 24 and a sufficient amount of cooling medium is flowed through the electrode to keep it cool.

Extending into the furnace chamber from below is the lower electrode 25, which has a head 26 of suitable material (according to the reaction sought), which vaporizes at the temperature of the arc to increase the conductivity of the arc gap, or to supply material for reaction, or both. Instead of incorporating these materials in the head of the electrode, they may be introduced into the chamber through a suitable conduit 20 or conduits. These materials, suitable for fixation of nitrogen, are described in my United States Patent No. 1,056,830 of March 25, 1913, to which reference is hereby made. The electrode 25 passes through a suitable stuffing box 26 clamped in position by the plate 19 and spaced from the shell 2 by the insulating ring 27.

The gases, vapors or other materials to be treated, are introduced into the furnace chamber under pressure, so that a condition of pressure exists in the chamber. The materials resultant from contact with the arc flame, or these materials and matter in lower electrode, discharge from the furnace chamber, immediately after they leave the flame, through a relatively narrow opening into the expansion chamber, wherein the materials expand abruptly and rapidly to many times their former volume. The narrow or small opening through which the materials discharge may be formed in several ways. In Figs. 1 and 2 I have shown a narrow annular opening formed between the tip 23 of the upper electrode and the upper edge of the throat. The narrow opening is thus formed between the electrode and the throat so that the hot resultant material passes abruptly and rapidly from the flame through the narrow opening and is expanded and cooled. The expansion chamber is provided with a large outlet passage 31 to permit the free discharge of the cooled gaseous matter therefrom to other devices or containers, to be dealt with as desired. By providing a large expansion chamber outlet, little or slight pressure exists in the expansion chamber, so that the gaseous matter is free to expand as it issues from the small opening. The issuing gaseous matter is, therefore, abruptly cooled, immediately after leaving the arc flame, by expansion and by contact with the water-cooled surface to a temperature below that at which any great percentage of the materials produced would either dissociate or decompose.

When the cooling effect of these two cooling methods acting concurrently, is not sufficient to cause a sufficiently large and abrupt drop in temperature, the temperature of the gaseous matter may be further reduced by concurrently bringing it into contact with other cooling media, such as set forth hereinbefore. This may be accomplished by arranging an annular chamber 38, provided with an elongated annular discharge 39, in the expansion chamber in such relation to the narrow annular opening through which the gaseous matter discharges from the throat, that the cooling media discharging from the nozzle impinges against and mixes with the hot gaseous material. The cooling media, which may be air, steam, water spray or other material, as set forth, is introduced into the annular chamber 38 through the conduit 33 under sufficient pressure so that it will discharge against the discharging
stream of hot gaseous matter. In the event that the combination of these methods does not produce the desired abrupt temperature drop, the supply of energy to the arc may be cyclically reduced to decrease the temperature of the arc itself.

The gases, liquids, vapors or solids, or combinations thereof, to be acted upon under greater pressure, are introduced into the furnace chamber in any suitable manner. Gases, liquids or vapors, may be introduced through pipes extending through the shell and its lining and these pipes may be disposed at their discharge ends so that they discharge the materials tangentially into the furnace chamber, causing them to swirl therein, or they may be disposed so as to discharge the material in streams parallel to the arc flame, formed between the electrodes, or the materials may be discharged transversely of the arc flame, or in any desired direction or combination of directions. Solid matter to be acted on by the arc flame may be introduced in any suitable manner, preferably into the head 26 of the lower electrode. For this purpose a feed conduit extends through the casing in proximity with the lower electrode head and this conduit is provided with a suitable check or closure to prevent release of the pressure in the chamber through the conduit. It is not essential that solid material be introduced into the electrode head 26, but when it is introduced there, it is vaporized readily by the arc and mixes with the other material in the chamber.

The gases, liquids, vapors or solid material is introduced into the furnace chamber under pressure, generally of from three to ten atmospheres, or greater, and passes into the arc flame or is acted on by the arc flame and the resultant materials discharge through the small opening which is of such constricted area and short length that the velocity of the gas flow is greatly increased so that the gas passes from the arc flame through the opening in the shortest possible time and is expanded and cooled substantially instantaneously. The tip of the upper electrode is preferably disposed in the throat 7, which is made as short as possible, so that the hot gaseous matter passes at great velocity from contact with the arc flame, directly and immediately into the cooled expansion chamber.

Other methods than those set forth hereinbefore may be employed for cooling the hot gaseous medium. The arc itself may be interrupted so that it is extinguished for a brief time during a cycle, and during this time the products will cool with great rapidity. The interruption and reignition of the arc may be carried out at suitable frequency during the total cycle of burning and cooling, and hence the time of burning to the time of cooling may be chosen as desirable. The reignition of the long arc, however, presents certain difficulties in practice, and, instead of letting the arc go out, I prefer to manipulate the power supplied to the arc so that the usual fat arc of high energy, which I employ, is reduced to a thin line arc, merely sufficient to keep the arc burning. This may be accomplished either by simply greatly reducing the energy supplied to the arc, or by changing the form of energy to higher voltage and lower amperage, or use of both simultaneously. By manipulating the energy supply, fat arcs and thin arcs may be caused to succeed each other at suitable frequency to produce the desired rapid cooling effect. When the arc is reduced to the thin line, the heat supply to the gaseous matter is abruptly interrupted and the temperature of the gaseous matter falls abruptly. The supply of material under pressure to be acted on by the arc may be supplied continuously or intermittently in time with the interruptions of the fat arc.

It is understood that the electrodes are connected to a suitable source of electrical energy to produce the arc and that the arc is controlled by suitable electrical apparatus, such as both ohmic and inductive resistance, etc. This is set forth in my prior Patent No. 1,056,830, but it is to be understood that I do not limit myself to the forms of electrical control there shown. It is also to be understood that one or both of the electrodes are movable longitudinally, so that they may be brought into contact or proximate contact to start the arc, after which they are separated the required distance to produce the desired arc flame.

While this invention is particularly adapted to the fixation of nitrogen, which may be accomplished by introducing air, or mixture of oxygen and nitrogen, under pressure into the furnace chamber to produce oxides of nitrogen, it is to be understood that it is not limited to such use, since it may be used to combine nitrogen and hydrogen to form ammonia gas, or to combine carbon with nitrogen to form cyanogen gas and other compounds.

I claim:

1. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc flame whereby gaseous matter is produced, and immediately and abruptly cooling the gaseous matter out of contact with the arc by concurrently subjecting it to two or more cooling methods.

2. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure to an electric arc flame whereby
other forms of material are produced, removing the resultant material from the arc and simultaneously and rapidly cooling the resultant gaseous material by concurrent expansion and conductive cooling thereof.

3. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc whereby other forms of material are produced and very hot resultant gaseous matter is produced removing the hot resultant gases from the arc and simultaneously, and rapidly expanding and cooling the hot resultant gaseous matter to reduce the temperature thereof below the temperature at which any great percentage of the resultant gaseous matter will dissociate.

4. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc flame whereby very hot resultant gaseous matter is produced and abruptly and concurrently expanding and cooling the gaseous matter as it leaves the flame to reduce its temperature.

5. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc flame whereby very hot resultant gaseous matter is produced and abruptly reducing the temperature of the gas as it leaves the flame to a temperature at which no great percentage of the gas will dissociate, by subjecting the gaseous matter to a plurality of cooling methods acting concurrently.

6. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc flame whereby very hot resultant gaseous matter is produced, and immediately thereafter abruptly expanding the gaseous matter and contacting it with a cool surface whereby its temperature is abruptly reduced.

7. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc in the presence of suitable agents to increase the conductivity of the subjected mixture removing the resultant gases from the arc flame and abruptly expanding and cooling the resultant gaseous matter as it leaves the flame.

8. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc in a closed vessel and discharging the resultant gaseous matter immediately thereafter from the arc through a small orifice into a cooled chamber in which a much lower pressure obtains.

9. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc in a closed vessel and discharging the resultant gaseous matter immediately thereafter from the arc through a small orifice into a cooled chamber in which a much lower pressure obtains, and concurrently contacting the gaseous matter with a cooling medium.

10. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc whereby very hot resultant gaseous matter is produced and immediately thereafter removing the matter from the arc expanding the gaseous matter, contacting it with a fluid cooling medium and contacting it with a cooled surface.

11. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc whereby very hot resultant gaseous matter is produced and immediately thereafter expanding the gaseous matter, contacting it with a fluid cooling medium, contacting it with a cooled surface and reducing the temperature of the arc.

12. The process of treating a mixture of materials to produce other forms of material, which comprises subjecting the mixture under pressure greater than atmospheric pressure to the action of an electric arc in a closed vessel, discharging the resultant hot gaseous matter immediately thereafter from the arc through a small orifice into a cooled chamber in which a much lower pressure obtains and directing a stream of cooling media into the discharging gaseous matter.

13. The process of producing oxides of nitrogen which comprises subjecting a mixture of oxygen and nitrogen under pressure greater than atmospheric pressure to the action of an electric arc removing the resultant oxides from the arc and immediately thereafter expanding and cooling the resultant oxides to lower the temperature thereof to prevent dissociation and decomposition.

14. The process of producing oxides of nitrogen which comprises subjecting a mixture of oxygen and nitrogen under pressure greater than atmospheric pressure to...
the action of an electric arc removing the resultant oxides from the arc and immediately thereafter abruptly expanding the resultant oxides and bringing them into contact with a cool surface.

15. The process of producing oxides of nitrogen which comprises subjecting a mixture of oxygen and nitrogen under pressure greater than atmospheric pressure to the action of an electric arc in the presence of suitable agents to increase the conductivity of the subjected mixture removing the resultant oxides from the arc and abruptly expanding and cooling the oxides produced to prevent dissociation and decomposition.

16. The process of producing oxides of nitrogen, which comprises subjecting a mixture of oxygen and nitrogen under pressure greater than atmospheric pressure to the action of an electric arc flame whereby oxides of nitrogen are formed removing the resultant oxides from the arc and immediately thereafter expanding the oxides and contacting them with a fluid cooling medium.

17. The process of producing oxides of nitrogen, which comprises subjecting a mixture of oxygen and nitrogen under pressure greater than atmospheric pressure to the action of an electric arc flame whereby oxides of nitrogen are formed and immediately thereafter expanding the oxides, contacting them with a fluid cooling medium, and reducing the temperature of the arc.

18. The process of producing oxides of nitrogen, which comprises subjecting a mixture of oxygen and nitrogen under pressure greater than atmospheric pressure to the action of an electric arc flame whereby oxides of nitrogen are formed and removing the oxides from the arc and then immediately expanding them, removing heat therefrom by conduction and contacting them with a fluid cooling medium.

19. An apparatus of the character described, comprising a closed vessel, means for producing an electric arc entirely within said vessel, means for introducing materials into said vessel under pressure so that they are subjected to the arc and an expansion chamber communicating with said vessel through a small orifice.

20. An apparatus of the character described, comprising a closed vessel, means for producing an electric arc entirely within said vessel, means for introducing materials into said vessel under pressure so that they are subjected to the arc, and a water cooled expansion chamber communicating with said vessel through a small orifice.

21. An apparatus of the character described, comprising a closed vessel, electrodes in said vessel between which an arc is formed, means for introducing material under pressure into said vessel so that it is subjected to the arc and an expansion chamber communicating with the vessel through a small orifice, the orifice being disposed adjacent to and formed partly by one of said electrodes.

22. An apparatus of the character described, comprising a closed vessel, electrodes in said vessel between which an arc is formed, means for introducing material under pressure into said vessel so that it is subjected to the arc, a water cooled expansion chamber, and a water cooled throat on said chamber connecting the chamber with the vessel, one of said electrodes and said throat cooperating to form an orifice through which the material passes at high velocity.

23. An apparatus of the character described, comprising a closed vessel, electrodes in said vessel between which an arc is formed entirely in said vessel, means for introducing material under pressure into said vessel so that it is subjected to the arc, an expansion chamber communicating with said vessel through a small orifice through which gaseous matter passes from the vessel to the expansion chamber and means for directing a stream of cooling material into the gaseous matter as it passes through said orifice.

24. An apparatus of the character described, comprising a closed vessel, electrodes in said vessel between which an arc is formed, means for introducing material under pressure into said vessel so that it is subjected to the arc, an expansion chamber communicating with said vessel through a small orifice through which gaseous matter passes from the vessel to the expansion chamber, and means in the expansion chamber for directing a stream of cooling material into the discharging gaseous matter at the orifice.

25. An apparatus of the character described, comprising a closed vessel, electrodes in said vessel between which an arc is formed, means for introducing material under pressure into said vessel so that it is subjected to the arc, a water cooled expansion chamber communicating with said vessel through a small orifice through which gaseous matter passes from the vessel into the expansion chamber said orifice being partly formed by one of said electrodes, and means in the expansion chamber for directing a stream of cooling material into the gaseous matter entering the expansion chamber.

In testimony whereof, I have hereunto set my hand.

HARRY D. RANKIN.