

March 12, 1940.

J. M. AVERY

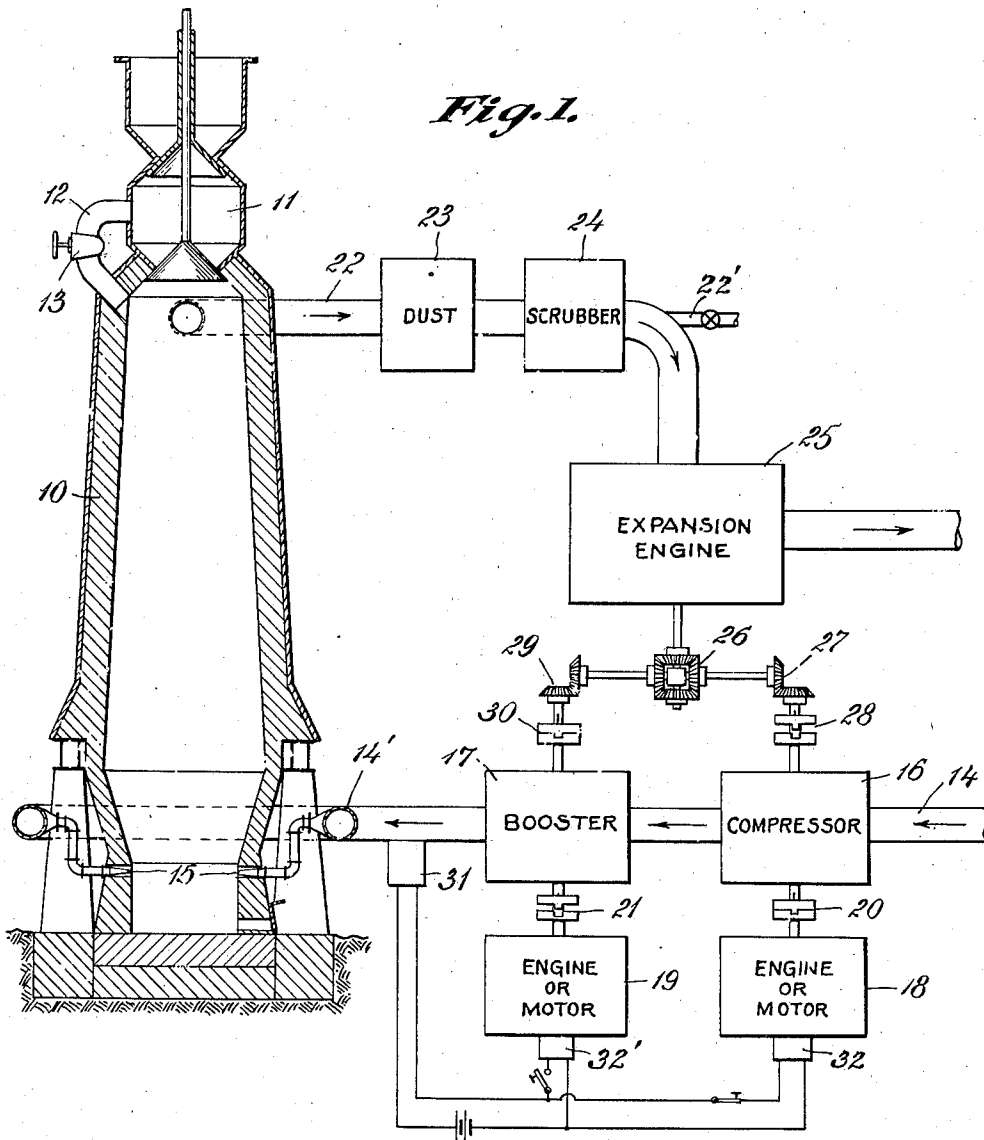
2,192,885

BLAST FURNACE POWER SYSTEM

Filed March 10, 1938

2 Sheets-Sheet 1

Fig. 1.



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Fig. 2

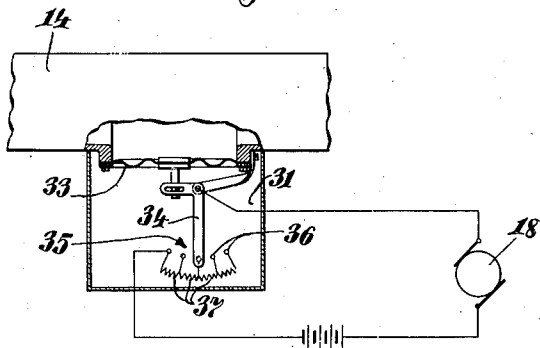
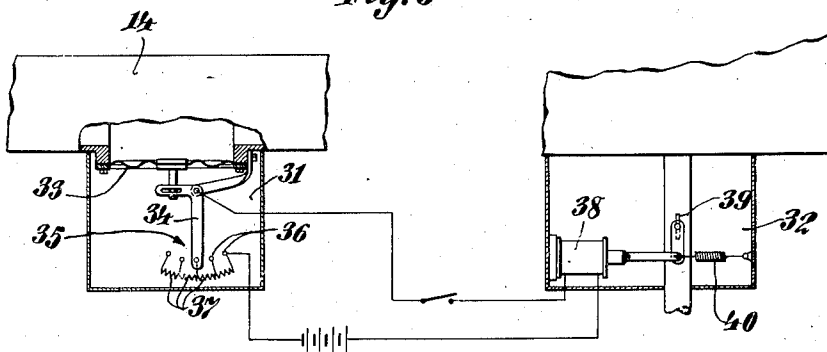


Fig. 3



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BLAST FURNACE POWER SYSTEM

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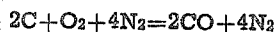
Application March 10, 1938, Serial No. 194,920

13 Claims. (Cl. 75-41)

This invention relates to the operation of blast furnaces under internal pressure substantially greater than atmospheric pressure, and has particular reference to the provision of means whereby power may be recovered by expansion in an engine of the resulting high pressure furnace output gases, without seriously affecting the operation of blast gas blowers, compressors or the like, when the blast pressure and volume are altered.

In my copending application Serial No. 84,797, filed June 12, 1936, now Patent No. 2,131,031, issued September 27, 1938, there is described a novel method of operating blast furnaces under internal pressures substantially in excess of those employed in normal practice. Normally, the pressure of gases leaving a blast furnace, i. e., the pressure in the furnace top, usually called "top pressure", is, as stated in the aforementioned application, merely that resulting from back-pressure developed by the frictional resistance to the flow of the gases through pipes, conduits, stoves, gas burners and the like, and it is well known that the top pressures thus developed are ordinarily less than about one-fourth atmosphere gauge. In the proposed method of pressure operation, the internal pressure, and consequently the top pressure, is increased by controlling the back pressure on the gases leaving the furnace, hereinafter called the furnace gases, by any convenient means such as a throttle or expansion valve, or expansion engine. As the top pressure is thus increased, it will be obvious that to maintain a given blast rate the blast pressure must also be increased, which requires additional blast power for a given blast rate. However, as the top pressure is increased, it will be evident that at some pressure, the exact value of which will depend upon local conditions, it becomes economically advantageous to recover power from the furnace gases by expanding them through a suitable engine, which may be an expansion engine or an internal combustion engine, or the like.

As pointed out in the aforementioned copending application, the volume of furnace gases is always greater than the blast volume, because each molecule of oxygen in the blast is converted by combustion in the tuyère zone into two volumes of carbon monoxide:



the resultant increase in volume being approximately in the ratio

$$\frac{6}{5} = 1.2$$

or about 20%. This minimum increase in volume is further considerably augmented by the volatile matter of the carbonaceous fuel charged, by decomposition of moisture in the blast, by direct oxidation of carbon to carbon monoxide by the oxygen contained in the charge, by carbon dioxide evolved from the limestone in the charge, and by water vapor driven off in drying the charge, a considerable portion of which, together with the blast moisture, usually reacts with carbon to form hydrogen and carbon monoxide. Thus, while the minimum increase in volume of furnace gases as compared with blast volume is about 20%, the increase may be and usually is very much greater, i. e., on the order of 40%, depending upon conditions of operation.

Within economical ranges of operating pressure, when handling reasonably large volumes of gas at suitable initial temperatures, modern expansion engines, as for example, gas turbines show efficiencies on the order of 70%. It follows that if the extra blast power required to compress the blast for pressure operation, as compared with that required for normal operation, is A, the amount of power recoverable by expanding the furnace gases at suitable initial temperature and with reasonably high initial pressure, is on the order of $A \times 1.40 \times 0.70 = 0.98$, or approximately the amount of extra blast power required. As a matter of fact, the ratio of recoverable power to blast power is somewhat greater than this rough calculation would indicate, because, as pointed out in said patent, as the top pressure is increased the pressure drop through the furnace for a given blast rate decreases, so that a part of the "normal" blast power which is ordinarily absorbed by frictional resistance, and is thus entirely wasted, becomes available for recovery by expansion in the manner mentioned. It will thus be evident that as top pressure and the blast pressure are increased, the extra power required to compress the blast increases as compared with normal operation, while the power recoverable from the furnace gases increases roughly in like quantity; and conversely.

In accordance with the present invention, advantage is taken of the condition of increased potential energy in the furnace gases as the result of operation at a top pressure in excess of about one-fourth atmosphere gauge, by "floating"

across the blast gas line and the furnace gas line a blast gas compressor, hereinafter called a booster, and an expansion engine respectively, the two machines being mechanically or electrically linked together so that the power recovered by expanding the furnace gases in the engine is employed in whole or in part, either to boost the initial blast gas pressure to the desired blast pressure, or to compress the blast gas to some desired initial pressure, in which case the final blast pressure may be obtained by means of a separate auxiliary booster. In either case, one or both of the blast gas compressors or blowers may be and is preferably equipped with other driving means, such as an electric motor, in order to provide control of the blast gas pressure without necessarily relying upon the power recovered from the furnace gases.

In carrying out the invention I prefer to compress the blast gas to an initial pressure on the order of from $\frac{1}{2}$ to $1\frac{1}{2}$ atmospheres gauge, as in normal furnace practice, by means of a compressor of conventional type. This makes possible the useful employment of present blowing equipment on a furnace converted for pressure operation, and at the same time facilitates operation under normal conditions if for any reason pressure operation is discontinued, or the pressure is temporarily sharply decreased, as, for example, during the tapping period. When using this preferred system of operation, the additional blast gas pressure is developed by a booster, preferably of the centrifugal type, and this booster may be alternatively connectible to an expansion engine of the turbine type driven by the furnace gases, and to an auxiliary engine or electric motor. By controlling the discharge pressures of the compressor and blower, either automatically or by hand, it is then possible to distribute the total work of blast gas compression between the compressor and the booster, so that the booster uses to maximum advantage all of the power delivered by the expansion engine, while variations in the total blast power required, not automatically compensated by the action of the expansion engine, are taken care of by variations in the power consumed by the initial compressor.

For a more complete understanding of the invention, reference may be had to the accompanying drawings, in which

Figure 1 illustrates diagrammatically a preferred arrangement of the present invention, whereby the potential power of the furnace gases produced by a blast furnace operated under pressure may in large part be recovered and employed to maximum advantage;

Figure 2 is a diagrammatic showing of a pressure-actuated control mechanism for a compressor motor; and

Figure 3 is a diagrammatic showing of a modified form of pressure-actuated control mechanism.

In the drawings, numeral 10 designates a blast furnace of more or less conventional design and construction, but modified in the manner described in the aforementioned patent to operate under a top pressure in excess of about one-fourth atmosphere gauge. So modified, the furnace 10 may include the double bell and hopper arrangement 11 at the top of the furnace, adapted to serve as a pressure lock whereby pressures built up in the shaft of the furnace 10 may be maintained by proper manipulation of the pressure lock 11. Preferably, a by-pass 12, provided with a valve 13, connects the furnace with the

pressure lock so as to equalize the pressure between the furnace 10 and the lock 11 during charging operations, whereby the lower bell may be readily lowered without the additional force which would otherwise be required to lower it against the furnace pressure.

The bustle pipe 14' supplying the tuyères 15 may be also of conventional construction and supplied with blast air or other gas by the blast feed duct 14 connected to the compressor 16, with or without an auxiliary booster 17 between the compressor 16 and the bustle pipe 14', depending upon pressure and other operating requirements. Preferably such an auxiliary booster 17 is provided and may be of the centrifugal type. Both the blast gas compressor 16 and the booster 17 may be provided with auxiliary driving engines or motors 18 and 19, respectively, connectible and disconnectible at will by means of respective clutches 20 and 21.

The furnace gases, issuing from the furnace top through down-take duct 22, are led through a conventional dust catcher 23 and scrubber 24 or the like, for removing the entrained dust and foreign material, so that the gases may be directly employed for operating the expansion engine 25, which may be a reciprocating engine or a turbine, depending upon requirements. The expansion engine 25 thus replaces internal combustion engines or the like customarily supplied with furnace gas cleaned in any conventional manner, and at the same time performs the function of creating a back pressure on the furnace gases and thus building up pressure within the furnace 10 to the desired amount for pressure operation.

The expansion engine 25 may be connected through a differential 26, gearing 27 and clutch 28 to the compressor 16 and through a differential 29, gearing 30 and clutch 31 to the booster 17. It will be understood that as clutches 28 and 30 are disengaged the corresponding side of the differential 26 is locked, either by locking the clutch or otherwise, and that when clutches 28 and 30 are engaged the respective clutches 29 and 31 are disengaged, and vice versa. Alternatively, engine 25 may be an internal combustion engine, whose developed power will inherently vary with the initial pressure and thus the engine automatically develops more or less blast power as required. In either case, instead of direct mechanical connection between the engine 25 and the compressor 16 and/or the booster 17, the engine 25 may be used to drive an electric generator, and the compressor 16 and/or booster 17 driven by electric motor or motors actuated by the generator or by other source of electric power.

In operation, the compressor 16 may, for example, be driven by an engine or motor 18 with clutch 28 disengaged as shown. Compressor 16 then may compress the blast air or other gas to an initial pressure on the order of $\frac{1}{2}$ to $1\frac{1}{2}$ atmospheres gauge, as in normal furnace practice. The expansion engine 25, or the equivalent internal combustion engine, by its resistance to motion, develops the requisite back pressure on the furnace gases to create the desired internal pressure within the furnace 10, as described, requiring increasing blast pressure as the back pressure develops through the system and increases to the desired degree. The booster 17 may accordingly be placed into operation by connecting it through clutch 21 to its auxiliary motor 19, clutch 30 being disengaged. As the ex-

expansion engine 25 develops power under operation by the furnace gases, the booster may then be disconnected from the auxiliary engine or motor 19 by disengaging clutch 21, and connected to the expansion engine 25 by engaging clutch 30, so that the requisite pressure of the blast feed gas for pressure operation of the furnace 10 is maintained by the expansion engine 25 operating on the furnace gases in the manner described. Alternatively, the initial compressor engine or motor 18 may be adapted to provide pressure to cause the expansion engine 25 to become effective in driving the booster 17, in which case the booster automatically develops the required additional pressure without provision of auxiliary engine or motor 19.

With such arrangements the existing blowing equipment, i. e. the compressor 16, of a blast furnace converted to pressure operation according to the invention of the aforementioned application, may be usefully employed. It also enables the return to normal operation or reduced blast pressure during the tapping period, simply by cutting out the booster 17, which may then be positioned in a valve-controlled by-pass of the blast gas duct 14 in a manner readily understood. A by-pass 22' may also bleed off some of the furnace gases for blast preheating equipment or the like.

Since the engine 25 and booster 17 "float" between the furnace gas and blast gas lines, the booster 17 may supplement the compressor 16, by performing its booster function and also part of the initial compression work of the compressor 16, at times when the power output of the expansion engine 25 exceeds that necessary for operation of the booster alone. In that case the speed or pressure control of the compressor 16 and engine or motor 18 may be adjusted, such as with a throttle 32 in the case of an engine or with a rheostat in the case of a motor, either manually or automatically by an electric control 31 operated in response to changes in pressure in the blast gas duct 14 above and/or below a predetermined degree. Typical mechanisms responsive to pressure in the blast duct 14 for controlling operation of the motor 18 are disclosed in Figures 2 and 3. In the device disclosed in Figure 2, the automatic control 31 includes a diaphragm 33 responsive to variation in pressure in duct 14 and connected to a pivotally supported arm 34 of a rheostat 35, which includes contacts 36 and interposed resistances 37. As the diaphragm is moved inwardly or outwardly in response to variation in pressure in the blast duct 14, the resistance in circuit with the electric motor 18 is varied, reducing the speed of the motor 18 as the pressure in the duct 14 increases and increasing the speed of the motor 18 as the pressure decreases.

If a gas engine 18 is used, the rheostat 35 is connected in circuit with a solenoid 38 which controls a throttle valve 39 in the fuel line of the engine, as illustrated in Figure 3. In this device as the pressure in the duct 14 increases the resistance of the rheostat is decreased so that the throttle is partially or completely closed against the tension of the spring 40. As the pressure in the duct 14 decreases, the resistance of the rheostat 35 is increased, thus reducing the attraction of the solenoid and allowing the spring to open the throttle 39 and increase the speed of the motor. In this way, the booster 17 may be caused to employ to maximum advantage all of

the power delivered by the expansion engine 25.

If desired or feasible, as previously intimated, the auxiliary motor 18 for booster 17 may be dispensed with by providing the initial compressor 16 of sufficient capacity to build up a pressure substantially in excess of its normal operating pressure, and if this method is followed, the discharge pressure of the initial compressor 16 will necessarily be varied to compensate for the pressure developed by the booster 17 as soon as it begins to function under operation by engine 25, as determined by the automatic pressure responsive control 31, for example. Thus, as the top pressure begins to increase, the power developed by the engine 25 and transmitted to booster 17 will increase, so that the pressure developed by compressor 16 may be gradually decreased in order to maintain the desired blast pressure. This is the ideal method of operation of the arrangement of the invention, for variations of blast pressure and of top pressure are automatically compensated with only slight variations in the operating conditions of the initial compressor 16. This is especially advantageous in case it is desired to decrease the blast pressure when slag or metal is tapped from the furnace.

Alternatively, the furnace 10 may be started and operated with the booster 17, disconnected by disengaged clutch 30 from the expansion engine 25 and connected by engaged clutch 21 to a motor 18, while compressor 16 may be connected by engaged clutch 26 to the expansion engine 25 and disengaged from its motor 18 by disengaged clutch 20. Depending upon the pressure conditions required, a large capacity compressor 16 may provide all of the blast from the power furnished by the expansion engine 25, the automatic pressure-responsive cut-out or control 31 regulating the operation of the booster motor 18 in accordance with the blast pressure requirements by adjusting the throttle or rheostat 32'.

It will be seen that the arrangement of the present invention provides a very effective means for recovering potential power of expansion from the furnace gases as the result of operation of a blast furnace under pressure in accordance with the invention of said patent, and while certain preferred arrangements of the invention have been illustrated and described herein, it is to be understood that the invention is not limited thereby, but is susceptible of changes in form and detail within the scope of the appended claims.

I claim:

1. The method of operating a sealed blast furnace, which comprises supplying the blast feed gas at superatmospheric pressure by means of a compressor, maintaining the furnace under superatmospheric top pressure in excess of about one-fourth atmosphere gauge, operating a pressure-responsive engine with the furnace discharge gases, and utilizing the power output of said engine to aid in driving said compressor.

2. The method of operating a sealed blast furnace, which comprises supplying the blast feed gas at superatmospheric pressure by means of a compressor, maintaining the furnace under superatmospheric top pressure in excess of about one-fourth atmosphere gauge, operating a combustion engine with the combustible furnace discharge gases, and utilizing the power output of said engine to aid in driving said compressor.

3. The method of operating a sealed blast furnace, which comprises supplying the blast feed

gas at superatmospheric pressure by means of a driven compressor, creating back pressure on the gas discharged from the furnace by means of an expansion engine to maintain a superatmospheric top pressure within the furnace in excess of about one-fourth atmosphere gauge, and utilizing the power output of said engine to aid in driving said compressor.

4. The method of operating a sealed blast furnace, which comprises starting the furnace by supplying the blast feed gas with a driven compressor, increasing the pressure of the blast feed gas with a driven auxiliary compressor, maintaining the furnace under superatmospheric top pressure in excess of about one-fourth atmosphere gauge, operating an engine with the furnace discharge gases, using the power output of said engine to drive the auxiliary compressor when the power output of the former substantially equals the power required by the auxiliary compressor, and disconnecting the original drive of the auxiliary compressor to allow said engine to operate the auxiliary compressor.

5. The method of operating a blast furnace, which comprises starting the furnace by supplying the blast feed gas at superatmospheric pressure with a primary compressor and an auxiliary compressor, maintaining the furnace under superatmospheric top pressure in excess of about one-fourth atmosphere gauge, operating an expansion engine with the furnace discharge gases, driving said auxiliary compressor with said engine, and reducing the blast of said primary compressor as the auxiliary compressor increases the blast feed gas pressure in response to the increasing power output of said engine.

6. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, means for compressing the blast feed gas supplied to the blast feed pipe to superatmospheric pressure, an engine connected to the gas discharge pipe for operation by the furnace discharge gases and exerting a back pressure to maintain a superatmospheric internal pressure in said furnace, and driving connections between said engine and said compressing means, said engine supplying at least part of the power required to drive said means during operation of the furnace.

7. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, a compressor for compressing the blast feed gas supplied to the blast feed pipe, driving means for said compressor, a booster compressor between said furnace and the compressor for increasing the blast feed gas pressure, an expansion engine connected to the gas discharge pipe for operation by the furnace discharge gases, driving connections between said engine and said booster compressor, and means for decreasing the rate of operation of said compressor as the power supplied by said engine increases.

8. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, a compressor for compressing the blast feed gas supplied to the blast feed pipe, a booster compressor between said furnace and the compressor for increasing the blast feed gas pressure, driving means therefor, an engine connected to the gas discharge pipe for

operation by the furnace discharge gases, driving connections between said engine and said booster compressor, and means responsive to a predetermined degree of pressure in the blast feed pipe for disconnecting said driving means from the booster compressor, said engine, only, then driving said booster compressor.

9. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, a compressor for compressing the blast feed gas supplied to the blast feed pipe, a booster compressor between said furnace and the compressor for increasing the blast feed gas pressure, driving means therefor, an engine connected to the gas discharge pipe for operation by the furnace discharge gases, driving connections between said engine and said booster compressor, and means responsive to predetermined higher and lower degrees of pressure in the blast feed pipe for respectively disconnecting and reconnecting said driving means to the booster compressor, said engine supplying all of the power for driving said booster compressor when the driving means is disconnected and part of the power when the driving means is connected to the booster compressor during operation of the furnace.

10. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, a compressor for compressing the blast feed gas supplied to the blast feed pipe to superatmospheric pressure, driving means therefor, an expansion engine connected to the gas discharge pipe for operation by the furnace discharge gases, a booster compressor connected to said blast feed pipe between said furnace and the compressor, driving connections between said engine and said booster compressor, and means for decreasing the output pressure of said compressor as the supplemental output pressure supplied by said booster compressor increases.

11. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, a compressor for compressing the blast feed gas supplied to the blast feed pipe to superatmospheric pressure, driving means therefor, an engine connected to the gas discharge pipe for operation by the furnace discharge gases, a booster compressor connected to said blast feed pipe between said furnace and the compressor, driving connections between said engine and said booster compressor, and means for regulating the speed of said compressor driving means to compensate for variations in the pressure output of said booster compressor.

12. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, a compressor for compressing the blast feed gas supplied to the blast feed pipe to superatmospheric pressure, driving means therefor, an engine connected to the gas discharge pipe for operation by the furnace discharge gases, a booster compressor connected to said blast feed pipe between said furnace and the compressor, driving connections between said engine and said booster compressor, and means responsive to a predetermined increased blast feed pressure for reducing the speed of said compressor driving means.

13. In a blast furnace having a blast feed pipe and a gas discharge pipe, the combination of a sealed furnace shaft capable of operation at superatmospheric pressure, a compressor for compressing the blast feed gas supplied to the blast feed pipe to superatmospheric pressure, driving means therefor, an engine connected to the gas discharge pipe for operation by the furnace discharge gases, a booster compressor connected to

said blast feed pipe between said furnace and the compressor, operative connections between said engine and said booster compressor, and means responsive to predetermined increased and decreased pressures in the blast feed pipe for respectively decreasing and increasing the speed of said compressor driving means.

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