the machine now before you, which are at your disposal. Also, some specimens of rough bricks, full size; compressed iron ore, roasted and some unroasted; and as a curiosity, some specimens of "Terra Cotta lumber," not made by our machine, but which can be. We will undertake to produce *joist, scantling, cornice,* or *square saw logs* at the rate of thirty thousand feet per ten hours.

EXPERIENTIAL PRINCIPLES OF CONTROLLED COMBUSTION.

By E. J. Mallett, Jr.

[A paper read at the Stated Meeting of the Franklin Institute, held Oct. 18, 1882.]

I shall confine the remarks which you have kindly invited me to make to a consideration of the industrial consumption of fuel when used in steam generators, and will endeavor to present a new aspect of the subject.

The chemical statics of combustion, that is, the laws governing the cause of the formation of certain resulting gases, which are the products of combustion, are too well known to be adverted to. The chemical dynamics of combustion and inflammation, that is, the intermediate causes brought into action before the final products of combustion escape, are less clearly understood.

Even at present no uniform opinion exists as to why ordinary illuminating gas, issuing from a Bunsen burner, should lose luminosity by the admixture of air with the flame. The general belief is that air, gaining access to all parts of the flame, oxidizes the carbon of the gas, thus destroying luminosity by the instantaneous combustion of the carbon.

The fact, however, that if nitrogen, carbonic acid, or other inert gas, instead of air, enters the openings of a Bunsen burner, the flame will become non-luminous, indicates that it is not oxidation that destroys luminosity.

For our purpose it is useless to advert to the present state of knowledge relative to the chemical dynamics of combustion; the vastness of the subject would tire us. I have endeavored, after thought and experiment, to arrive at some general conclusions, and to contribute towards the elevation of industrial combustion from art to science.

Possibly I should be permitted with justice to enunciate these results as experiential principles.

If fuel energy could be developed through combustion only, unattended with possible inflammation, the problem of rendering such combustion practically perfect might be readily solved. Carbon, however, when insufficiently oxidized, produces flaming carbonic oxide, and, as hydro-carbon fuel always evolves flaming gases, it is the combustion of these flaming gases that presents graver difficulties than would arise if fuel was solely carbon capable of but one combination with oxygen, namely, carbonic acid. To create a science of industrial combustion of fuel we must be able to predict with certainty what furnace devices shall be employed to reduce fuel waste to its minimum.

In searching to remedy the admitted loss of fuel, as universally burned, my method was,

1st, to review and study each cause of fuel loss;

2d, to formulate and prescribe certain principles or necessary and possible conditions essential to perfect combustion, and

3d, to construct mechanical appliances which should be subservient to the principles considered essential.

I will, therefore, this evening treat our subject in conformity with the three classifications just mentioned, and will first refer to causes of fuel waste.

Coal gas, whether generated in a retort or a furnace, is essentially the same. Again, strictly speaking, it is not inflammable; as, *by itself*, it can neither produce flame nor permit the continuance of flame in other bodies. A lighted taper introduced into a jar of carburetted hydrogen (coal gas), so far from inflaming the gas, is itself instantly extinguished. Effective combustion, for practical purposes, is, in truth, a question more as regards *the air* than the gas. Besides, we have no control over the gas, as to quantity, after having thrown the coal on the furnace, though we can exercise a control over that of the air, in all the essentials to perfect combustion. It is this which has done so much for the perfection of the *lamp*, and may be made equally available for the *furnace*.

With reference to the *mode* of introducing the air, it is not a little remarkable that many overlook, or even dispute, the difference in effect, when it is introduced through *one* or *numerous* orifices.

The body of air, by passing through a single aperture, produces the action of a strong current, and obtains a direction and velocity antagonistic to that lateral motion of its particles which is the very element of diffusion. In this case, passing along the flue, the stream of air pursues its own course at the lower level, while the heated products fill the *upper one.* It is here evident, according to the laws of motion, that the two forces, *acting in the same direction,* prevent the two bodies impelled by them (the air and the gas) from amalgamating.

The *appearance or non-appearance of visible smoke* is no test either for or against the admission of air, *as to quantity.* The consequences of regulating and varying the quantity of air admitted, so as to suit the varying state of the furnace, as regards the quantity of gas given off, also deserves attention. It is quite certain that, to effect the perfect combustion of all the combustible gases produced in a furnace, a large demand for air (distinct from the air entering the grate) *always exists;* also that by entirely *excluding air* smoke is produced, and the heat diminished in all states of the fire.

Chimney draught, operating through the levity of hot air, causes a fuel loss, varying with the rate of combustion, and which may amount in practice to 35 per cent. of the total heat produced.

A FIRST fuel loss arises from air entering the furnace, and absorbing a much larger amount of heat than it gives back before it passes out of the chimney.

Of the two combustible constituents of coal, the carbon and the hydrogen, the former is a solid and the latter is a gas. When coal is sufficiently heated the hydrogen escapes and the carbon, for the most part, remains behind. This is what occurs in a retort in the manufacture of illuminating gas.

The same thing occurs to a certain extent when a fresh charge of coal is thrown into a furnace. The cold fuel at first chills the fire, and after the expulsion of its moisture becomes hot enough to decompose and unite with oxygen. A most important fact must here be observed, namely, that the carbon does not burn until after the hydrogen. A fire box of a furnace thus simulates a gas retort, producing volatile hydrogen, which passes up a big gas pipe, the chimney, and is lost in space, unless we contrive to bring enough oxygen in contact with it to burn it before it enters the chimney.

A SECOND fuel loss is caused by unburnt hydrogen and hydrocarbons distilled from the coal passing up the chimney into space.

A THIRD fuel loss arises from furnace suffocation, or too little air.

A deficiency of air simply means a production of carbonic oxide and loss of heat. It must not be assumed, however, that it is only all-sufficient to admit a full supply of air through the grate of a furnace to produce a perfect combustion of the fuel.

A FOURTH fuel loss is caused by all the necessary air entering only through the ash-pit of a furnace.

Suppose, as is always the case in a firebox, that another stratum of coal or carbon is above the first tier. The carbonic acid produced by the burning of the lower layer, in passing through the superimposed layer, unites with more carbon and becomes converted into carbonic oxide. It is evident, therefore, that when coal is burning in layers the property possessed by carbon of uniting with carbonic acid produces the same effect, in a less degree, however, as if too little air was being supplied.

If, however, this escaping carbonic oxide could meet an additional supply of oxygen above the fuel it would be burned and pass off as carbonic acid.

Although carbonic oxide will burn when mixed with air and produce heat, this can only occur at a certain temperature; if, therefore, cold air comes in contact with carbonic oxide, escaping above the fuel, it will mix with it without inflaming it, consequently,

A FIFTH fuel loss arises from the admittance of air above the fuel at a temperature below the burning point of the escaping carbonic oxide.

The supply of air to fuel must be divided into two volumes, one to maintain the combustion of the solid fuel and the other to burn not only the carbonic oxide passing off the surface of incandescent fuel, but also to ignite the gases produced from the hydrogen of the fuel.

As a fresh charge of coal cools a fire, and as cold air entering beneath a grate is also a cooling agency, it is evident that at the moment a fresh charge of coal enters a furnace the proportion of air entering beneath and above the grate should be changed. More air should enter above the fuel to burn the rapidly forming gases, and less should enter through the grate, because less is required, and a diminished supply will prevent the cooling of the fire.

A SIXTH fuel loss, therefore, arises from unvarying volumes of air entering beneath and above the fuel.

As the volume of air entering a furnace in a given time depends upon the velocity with which it travels it is evident that

A SEVENTH fuel loss is caused by the existing adequate means of regulating the amount of air entering a furnace, owing to its variable velocity.

It is therefore necessary to know the rate of a current of air when entering a furnace before we can decide on the necessary area for its admission. As the furnaces in use operate with open ash-pit, an attempt is made to make the grate-bars answer for dampers. That is, so many square inches of area of aperture between the grate-bars is allowed for so many square feet of grate surface.

If, for example, six square inches of opening is allowed for each square foot of grate surface, with air moving at six feet a second, the same amount of air moving at forty feet a second would enter one square inch of opening. Therefore, without knowing the velocity of the air, no regulation of air can be made by the grate openings. In practice, the importance of knowing how much air enters between grates is entirely ignored.

The velocity of air entering a furnace by chimney draft varies with the heat of the fire, therefore when a fresh and cold charge of fuel is thrown into a furnace the draft diminishes at the exact time when more air is required to burn gases and prevent smoke.

An EIGHTH fuel loss arises from the admission of air to furnaces in bulky instead of divided currents.

It is obvious that air entering the ash-pit becomes thoroughly subdivided in passing upwards through the grates, but this does not obtain with air introduced above the fuel, unless special provision is made.

The necessity of having hot air in fine currents to complete the combustion of fuel gases indicates the serious objection of permitting air to enter through the furnace door opening, or even through the door itself. If we carefully consider that for the combustion of fuel gases the desideratum is to have the necessary oxygen at the right place at the right moment, it is evident that any air entering beneath the bars or through the door is necessarily a little in arrear of the gases to be burned in the combustion chamber of a furnace.

Although the entering air may move with the same velocity as the unconsumed gases, it *connot catch up with them,* because the start is uneven.

A NINTH fuel loss consequently arises from the admission of air for the combustion of fuel gases at any point except just where it was wanted at the moment, namely, in the hottest part of the combustion chamber.

A TENTH cause of fuel loss is the cooling effect of heat-absorbing surfaces in proximity to the burning fuel, and the sequel to this is

An ELEVENTH cause of fuel loss, arising from lack of capacity of the combustion chamber to burn fuel gases before they are forced through a steam boiler.

The dilution of oxygen by nitrogen in our air is very nicely suited to industrial combustion; if, by further dilution, the amount of oxygen in a cubic foot of air becomes decreased, the rate of combustion diminishes. After a certain dilution, combustion cannot be maintained at all. It follows, therefore, that every additional volume of steam or other non-supporter of combustion which gains access to the combustion chamber of a furnace interferes with combustion. Therefore

A TWELFTH fuel loss arises from steam, in addition to the air necessary for combustion, gaining access to the combustion chamber of furnaces.

A THIRTEENTH fuel loss arises from the escape of carbonic oxide and smoke.

When smoke is once produced in a furnace it is as impossible to burn it or convert it to heating purposes as it would be to convert the smoke issuing from the flame of a candle to the purposes of steam and light.

The presence of smoke being noticeable no test other than the eye is required. Carbonic oxide, however, is invisible and inodorous, and must be sought for by other means.

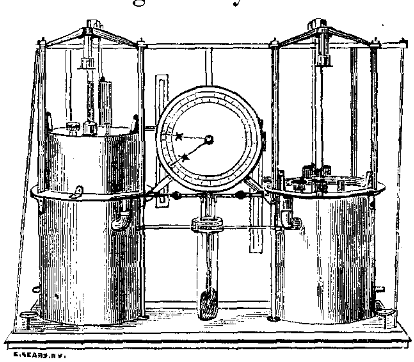

Fig. 1.

Again, the presence of free oxygen in the gases of combustion indicates that more air than necessary is being supplied to the furnace. In order to readily detect the presence or absence of these gases in furnace products I constructed an apparatus called a differential furnace gas meter which records on a dial the per cent. in volume of any gas existing in escaping flue products.

Fig. 1 represents two gas-holder tanks, in which two cylinders of equal capacity are counterpoised. Geared to each cylinder is a separate index-needle, which is caused to revolve around the dial by the upward or downward motion of the cylinder. Between the cylinders is a glass receptacle in which any gas-absorbing material can be placed. When it is desired to test furnace gases a small pipe introduced into the furnace flue permits the gases of combustion to enter one of the cylinders by aspiration, when the cylinder is caused to ascend. Now, while the cylinder is at its greatest height, the corresponding cylinder rests within the tank entirely filled with water. If, now, the first cylinder is caused to descend by being weighted and the induction pipe is closed, while the pipe leading to the intermediate glass vessel is opened—the gases contained in the first cylinder being expelled, pass through the absorber into the second cylinder, which in turn begins to rise.

As both cylinders are of exactly the same capacity, the one descends proportionately as the other ascends. If, however, any of the gases passing through the absorber are taken up, it is evident that the ascending cylinder will not rise as rapidly as the first cylinder descends. As each index needle is geared independently to each cylinder, any difference of motion in the cylinders is registered on the dial; and the divergence between the two needles, when the descending cylinder has reached the bottom of the tank, indicates the per cent. of gas which has been absorbed, and, consequently, the amount present in the gases is thus analyzed. This apparatus diminishes the risk of error to the minimum, owing to the large capacity of the cylinders, each holding eight hundred cubic inches. The apparatus was invented for the purpose of verifying the results which were anticipated would be produced by the system of "Controlled Combustion."

The "Experiential Principles," which may be reduced to twelve, naturally do not embrace all the necessary conditions of combustion.

I. Hydrocarbon fuel tends to burn with less carbonic oxide and smoke, proportionately as its environing atmosphere diminishes in tension.

II. Hydrocarbon fuel tends to evolve carbonic oxide and smoke, if burned in a furnace, until the temperature of the fuel reaches a certain elevation.

III. The tension of fuel gases within a furnace is never less than that produced by the burning of the fuel itself by natural draft, and is never sufficiently low, when compared with the rate of combustion, to prevent the origination of smoke.

IV. What was considered probable by Rankine, Peclet and others is demonstrated in "Controlled Combustion," namely, that air for dilution in furnace combustion would be rendered unnecessary, providing chimney draft could be dispensed with, and providing also that without such draft a supply of sufficiently heated air, in divided currents, could enter the combustion chamber in regulable quantities.

V. To maintain an atmosphere of the desired tension within a fire-box, an air exhauster must supplant the chimney, and the influx of air into the ash pit must be throttled.

VI. When combustion is urged by a blast fan, causing furnace air tension to be greater than normal barometric pressure, both physical and chemical actions result, differing from those created by a draft or flue fan, incompatible with perfect combustion.

VII. Hydrocarbon fuel, freshly charged into a furnace, must not be supplied with air to initiate its burning until the temperature of the fuel is sufficiently elevated; *i. e.*, the fuel must begin to distil before it begins to burn.

VIII. To compel a rapid and intimate mixture of hot air with combustible fuel gases, generated within a boiler fire box, these gases must not be allowed to ascend or envelope the boiler until after they enter the combustion chamber through channels in close proximity to those conducting fresh heated air into the combustion chamber.

IX. The heat from escaping furnace gases, after leaving a steam boiler, is more completely radiated for additional heating and boiling of water, if such gases are rendered athermous by being kept at their dew point.

X. It is possible, in practice, to superheat all the feed water required by a steam generator, from the waste heat of escaping gases, to a temperature equal to that of the water within the generator, and also to supply a portion of the feed in the form of steam.

XI. The potential power of a steam generator may be increased to a hitherto greater limit without diminishing the economic result

XII. To burn fuel rapidly, without creating a too high localized temperature, it should not be supplied with sufficient air to burn it at once to carbonic acid only, but considerable carbonic oxide should be produced, to be afterwards burned in the combustion chamber.

The application of these experiential principles in "Controlled Combustion" is effected by the following mechanical devices. With reference to the First Principle, it is known that as air becomes compressed it more nearly approaches the solid condition, and as its tension is decreased, so in direct proportion is its molecular mobility increased. An alcohol flame, which burns almost invisibly, is rendered quite luminous if burned in an atmosphere much above normal barometric pressure, and by a continual compression of the air the flame becomes smoky. Conversely, a candle flame burns almost invisibly at great altitudes. When by air compression its molecular mobility is increased, it penetrates a flame less rapidly than air of less tension. Smoke and carbonic oxide tend to originate whenever the atmosphere in which a hydrocarbon fuel is burning is not sufficiently mobile to rapidly penetrate flame and oxidize the carbon before it escapes. Part of the equipment required with "Controlled Combustion" consists of a register which can completely close the openings in the door of the ash pit, as represented in Fig. 2. When bituminous coal is first thrown into the furnace the temperature of the fuel must become elevated before the fuel is permitted to burn, as set forth in Principle VII. To this end the lever shown in Fig. 5, and actuating the ash pit opening, is caused to completely close it. Now, as the flue fan (see same Fig.) is at all times exhausting the furnace gases, and as no air can enter the ash pit, the fresh fuel cannot burn, but merely begins to distil as it would in a gas retort. After the temperature of the fuel is sufficiently high its burning is allowed to begin by the admittance of air through the ash pit. As, however, the air gaining access to the fire box through the ash pit is throttled, the atmosphere within the fire box is kept at a lower tension than is possible with chimney draft. By this means the coal burns without originating carbonic oxide and smoke, and the demands of Principles I, II and VII are responded to.

The "Experiential Principles" formulate, as it is believed, absolute conditions demanded for a perfect combustion of fuel and a greater utilization of the heat of escaping gases, and, as practice fully sustains the ideas advanced, force is given to the following statement, namely:

That it is impossible to burn by hydrocarbons, either in a furnace, a lamp or gas burner, without the production of carbonic oxide and smoke, unless more air environs and dilutes them than is theoretically required for their combustion, and that proportionately as the density of the environing atmosphere decreases, within limits, so will the amount of air required to burn fuel without smoke diminish and approach nearer to the amount theoretically required for a perfect combustion. If it were possible by any device to only mix the theoretical amount of hot air with sufficient rapidity and intimacy with fuel in a furnace, it is obvious that no carbon could escape oxidation; as, however, this is as yet practically unattainable, we must either use a surplus amount of air required theoretically, and thereby produce waste, or endow air with greater molecular mobility by reducing its density, and thus favor its mixing capacity.

With reference to Principle III, it should be appreciated that the tension of furnace gases depends upon the rate at which the fuel is burned.

It therefore follows that the tension is limited and uncontrollable. If we attempt to prevent carbonic oxide and smoke by lessening the air tension, then we must increase the rate of combustion. What is required, however, is to lessen the tension in a greater ratio than is possible by increasing the rate of combustion. It is obvious that natural or chimney draft, *i. e.*, draft produced by the fuel itself, depending as it does upon the rate of combustion, can only be increased at a fixed ratio.

To enforce the requirements of Principles IV and V, chimney draft is entirely dispensed with in "Controlled Combustion," being replaced by mechanical draft. A suction fan, as represented in Fig. 2, is employed, requiring a power to actuate it amounting to about three per cent. of the total fuel power.

Although various methods have been adopted to introduce hot air in subdivided currents into a combustion chamber, experience has shown that such air never really reached a sufficiently high temperature. In the present system tubular grate bars are employed, open at both ends. The boiler front is perforated, as shown in Fig. 2, such perforations being coincident with the front opening of the grate bars. The rear end of the bars passes through an iron box within the bridge wall, or rather septum wall, as shown in the furnace, Fig. 3.

As the air openings to the ash pit can be throttled, the air necessary for the combustion of the fuel gases can be compelled to pass through the tubular grate bars, and thus enter the combustion chamber in divided currents of a high temperature.

As it is necessary to regulate the air entering the ash pit simultaneously with that passing through the grate bars, the lever is made by one motion to actuate the air resisters of the grate bars, and also the ash pit door registers.

With reference to Principle V, it may be stated that although an air exhauster diminishes the tension of fuel gases in the fire box, still, if the influx of air through the ash pit is not properly regulated, a sufficiently low air tension will not result.

With respect to Principle VI, it should be noted that if air is supplied to a furnace by a blast fan it is obvious that the air pressure within the fire box is greater instead of less than normal barometric pressure. The physical result of forced air is to cause the flame from the fuel to tend to rise at right angles to a grate surface, and to impinge directly upon that part of the boiler situated directly over the fire box. The chemical result of hydrocarbon fuel, burning in an atmosphere of greater or less tension than the normal, has already been adverted to.

There are two causes that produce the liberation of carbon from fuel in an unoxidized condition, *i. e.*, as smoke, namely, a low temperature of the fuel, and an insufficiently low air tension within the fire box. To respond to the demands of Principle VII, a fresh charge of bituminous coal is not allowed to burn when first thrown into the fire box. At this time the lever is caused to close the air openings of the ash pit. The fresh fuel, from the heat derived from the already incandescent fuel, begins to distil, and the chemical actions resulting in a gas retort are simulated. The draft fan, inducing powerful currents of air to enter the combustion chamber through the hollow bars, permits the fuel gases distilled from the fuel to be burned. After a certain lapse of time, depending on the grade of fuel, the ash pit air registers are opened, whereby a real burning of the fuel begins.

Principle VIII indicates that although every possible provision may be made for the admittance of hot air, in divided currents, into the combustion chamber of a furnace, an imperfect admixture of the air results unless special provision is made to prevent the unconsumed gases from rising upwards, and thus get cooled before they come in contact with the air necessary for their combustion.

To this end the furnace in the present system is divided by a septum wall into the fire box proper and the combustion chamber, as shown in the sectional views, Figs. 3 and 4.

As the openings of the septum wall, through which flame and unignited fuel gases pass, are only slightly above the rear openings of the hollow grate bars through which fresh hot air is flowing, a rapid and intimate mixture of gases and air results.

We are indebted to the interesting experiments of Professor Tyndall (see "Heat as a Mode of Motion"), which show how air entirely freed of moisture permits radiant heat to pass through it without absorbing any of such heat; and, conversely, how air saturatud with moisture is a rapid absorbent of radiant heat. Tyndall also shows that in proportion as the radiant heat absorbing power of moist air increases is its power to radiate its own heat increased. It should be remembered, also, that moist air conducts and convects heat with infinitely greater facility than dry air.

Now, as fuel gases obey the same law, it is obvious that in order to compel them to radiate, conduct and convect their heat with the utmost rapidity they should be saturated with moisture and be maintained at their dew point. Air rendered by moisture opaque to radiant heat is in an "athermous" condition. As fuel gases, after having imparted say seventy per cent. of their heat to a steam boiler cannot liberate the balance with equal facility, owing to their reduced temperature, the process of moistening such gases is resorted to in "Controlled Combustion."

In practice, such escaping fuel gases, before they are drawn through the fan to be delivered into space, pass through what is termed an "Athermous Superheater."

This appliance, represented in Fig. 2, consists of an air-tight case, containing iron pipe of any desired amount. The gases, just previous to entering the superheater, are moistened to saturation by the water spray shown in the same figure. The exhaust steam from the engine that actuates the fan, together with the water spray, maintains the air at its dew point, which is evidenced by the constant dropping of water from the pipe seen to project from the side of the superheater near its base.

The effect of this is to cause the escaping gases to be cooled down to a lower temperature than has been hitherto possible. The amount of water supplied by this spray is quite an insignificant quantity.

The superheater effectually fulfills the requirements of Principles X and XI. It is most desirable to heat feed water to as high a temperature as possible, each 100° Fahr. being equivalent to about ten per cent. saving of fuel. The "Athermous Superheater" receives the cold water supply from a pump at the base of the packed tubes. The water here enters a manifold, and distributes itself through the layers of pipe, passing in an upward course. The moistened heated gases enter the superheater at the top, and pass between the piping which is at right angles to the current of gases, and then enter the exhaust fan.

The upper manifold of the superheater connects with what is termed a "Separator," which consists of a steam-tight cylinder, into which the superheated water separates into steam, which enters the steam space of the boiler, and boiling water, which is forced into the feed water pipe of the boiler. The "Separator" is seen in Fig. 2, placed between the superheater and the boiler. As the superheater is, in fact, an auxiliary steam generator, it is provided with a steam gauge, the pressure of which is always slightly above that of the steam boiler itself. The feed water, before entering the boiler, becomes heated to the same temperature as the water within the boiler, and, as a part of the feed enters the boiler as steam, a great saving of fuel is realized.

The facility with which furnace gases at their dew point are made to part with their heat permits of a rapid rate of combustion without a corresponding loss. It is thus that what is said in Principle XI, relative to the potential power of boilers, becomes realized.

The question of localized temperature is an important one when fuel is being rapidly burned under a steam generator. Principle XII indicates that the fuel should in part be burned in stages. If more than twelve pounds of air to the the pound of fuel enters a furnace, the temperature will be less than with just the theoretical amount; and if less air than is required for the perfect transformation of the fuel into carbonic acid enters the furnace, this will also produce a lower temperature of combustion. What is required, therefore, is to supply fuel with as nearly twelve pounds of air as possible, and to divide the weight of air between the fuel and the fuel gases, so that while, for example, eight pounds of air is supplied through the ash pit, the remaining four pounds will enter the combustion chamber. Thus the fuel does not receive enough air to entirely burn it to carbonic acid, whereby a too intense localized temperature would result, but a supply so gauged as to produce considerable carbonic oxide, to be afterwards consumed by the air entering the combustion chamber. In the present practice under consideration this is what is undertaken. The air registers in the ash pit throttle the supply from that quarter, and the hollow bars admit air into the combustion chamber to make up for the deficiency.

The saving of fuel in "Controlled Combustion" originates from three distinct sources:

1st. A practically perfect combustion.

2d. A utilization of heat from furnace gases hitherto allowed to escape.

3d. A use of cheap fuel, such as anthracite, buckwheat or dust, or bituminous dust, permissible by the increased draft.

The equipment for the system of "Controlled Combustion" can be applied to the existing forms of locomotive, marine, and stationary boilers. Fig. 5 illustrates the exterior of a locomotive. It will be noticed that the smoke funnel is dispensed with. The invisible products of combustion escape through an opening on the periphery of the extended boiler casing, not shown in the engraving. The exhaust nozzles are not used, the draft being produced by the exhaust fan, shown within the boiler casing in Fig. 4. By this plan a powerful draft can be produced, even when the locomotive is at rest, by the small engine which actuates the fan. The engines of the locomotive are relieved from the back pressure caused by exhausting steam through the nozzles, and the resonant noise is avoided. The exhaust steam is delivered through the pipe seen along the side of the locomotive, from whence it passes into the exhausting compartments of of the tender, to be described.

Fig. 4 represents the interior view of the boiler, where the fire box is seen to be separated from the combustion chamber by a fire-brick division or septum, as already alluded to.

The tender is divided into three compartments. The upper one is the receptacle for the fresh water; the middle one contains copper tubes, communicating with the external air in front, and with a suction fan in the rear. The exhaust steam circulates around the upper tubes, and becomes in part condensed, the resulting hot water falling into the lower compartments. The uncondensed steam then comes in contact with a spray of water falling from the upper compartment, and the condensed water also enters the lower compartment, from whence hot water is pumped into the boiler.

The air used to condense the steam is employed for HEATING AND VENTILATING CARS, being delivered through a conduit, which, with coupled ends, passes beneath the cars. Three registers in the floor of the car admit the heated air. This system does away with coal stoves or heaters, and supplies the car with fresh air and warm air.

Figs. 2 and 3 represent the equipment for stationary boilers, already described. The lever is seen to actuate both the ash pit, air registers and those controlling the air passages through the tubular bars. The Athermous Superheater, seen on the right of the boiler, superheats the feed water, and then, by means of a Separator, seen between the superheater and the boiler, together with some steam, passes into the steam space and water space of the boiler. The exhaust fan can be operated either by a small engine or by one already in operation. A small amount of boiling water taken from the feed pipe is caused to constantly moisten the hot gases which enter the superheater, and thus maintains them at their dew point, so as to facilitate the radiation of their heat to the stacked pipes. The superheater, being in effect an auxiliary steam boiler, is supplied with a steam gauge, the pressure on which is always slightly greater than that of the boiler.

OLSEN'S TESTING MACHINES.

From the Report of the Secretary, November 15, 1882.

UNIVERSAL TESTING MACHINE.—The illustration (Fig. 1) represents a testing machine of 50,000 pounds capacity, combining certain novel and useful features, introduced for the purpose of subjecting materials used in construction to every variety of strain. The machine was designed and constructed by Mr. Tinius Olsen of Philadelphia, a member of the Institute, for the Renssalaer Polytechnic Institute of Troy, and was made especially with the object of universal service, for scientific investigation and instruction. It is adapted for making tensile, crushing, transverse, and torsional tests.

The strain is applied with screws and gearing, and is operated by a crank shown in front of the cut. It is also provided with quick return motion. To bring this into play the large crank and small pinion is removed, and the larger intermediate gear-wheel turned by a handle on the same.

For convenience, and with the object of enabling the machine to be easily operated by the experimenter without help, an arrangement is added for operating the gears and screws by foot. This arrangement is represented in the illustration by the long lever crossing the lower gear-wheel of the machine.

The strain to which the specimen of material operated upon is subjected will bear upon the platform of the machine, which is supportod on a system of scale levers, and the amount of the strain balanced