COMBUSTION.

C.A.S.E. Executive Office,
Lesson Paper No. 4.

Heat and motion are so intimately connected together that you cannot have one without the other. Any body of matter that is absolutely still would be at absolute zero, or 461° below zero on Fahrenheit's scale. Tyndall tells us that heat is motion; and by combustion we mean the combination of chemical elements commonly called burning. All matter or any body of any material is either an element, a compound or a mixture. Iron, gold, silver and oxygen are elements, wood, water and carbonic acid are compounds. Any substance that can be decomposed or divided into other substances is called a compound. Lime may be divided into two other substances, calcium and oxygen, and is a compound. There are many substances that cannot by any known process be subdivided into other substances, such as gold, sulphur, iron and arsenic; this being the case they are called elements. The elements we will consider are hydrogen, and its symbol is H; oxygen, O; nitrogen, N; carbon, C; sulphur, S. In referring to these elements the symbol is the first letter of its name; as C for carbon, etc. When two or more elements are brought together under favorable circumstances, they will combine and form a new substance entirely different from either of the elements.

Hydrogen is a very light gas and burns with a steady blue flame, and it burns because of a chemical combination with the oxygen of the air, and the product of this combination is water. Just as chemical combination produces heat, so will chemical separation absorb heat. If carbon and oxygen are brought together at a high temperature they form carbon dioxide; hydrogen and oxygen form water; hydrogen, nitrogen and oxygen when combined under certain proportions form nitric acid. Ammonia is formed by a combination of nitrogen and hydrogen, and is a very different gas from either of its components. In making these combinations a certain amount of heat is produced, and if these elements are separated they will absorb exactly the same amount of heat produced by their combination. It is supposed by chemists that equal volumes of all gases, whether simple as elements or compounded, contain the same number of molecules, and that each molecule is composed of two atoms. Suppose that hydrogen and oxygen are in contact with each other and are heated, they will combine and form steam or water. It will be found that two atoms of hydrogen will be seized by one atom of oxygen to form one molecule of water, therefore the volume of hydrogen must be double that of the oxygen. Hence we have for a symbol H_2O, that is two parts of hydrogen to one of oxygen. Hydrogen and carbon also form a compound, each atom of carbon seizes four atoms of hydrogen and forms a molecule of marsh gas, the symbol for which is CH_4.

Mixtures may be formed of two or more elements that may be mixed together, but will not combine to form a new substance. The ordinary atmospheric air is an example. It is composed of oxygen and nitrogen; 23 parts by weight of O to 77 parts of N; these two gases are not chemically combined, they are only mixed. Combustion is only a very rapid chemical combination, in which the oxygen of the air combines with the carbon in the fuel. Oxygen has an attraction for nearly all the elements, but more especially for carbon, and when they meet at their igniting temperature they combine with great rapidity, and make a roaring fire, and give out a great quantity of heat, as in a boiler furnace.

The elements that enter into combustion are carbon, oxygen and hydrogen. When carbon and oxygen combine they form CO_2, or carbon dioxide, and when oxygen and hydrogen combine they form water, H_2O. These are the products of combustion.

In our furnaces we take the oxygen from the air, and the nitrogen passes through the fire with it, but takes no part in the combustion. Now CO_2 or carbon dioxide is composed of 12 parts by weight of carbon to 32 of oxygen. Hence to burn a pound of carbon requires $32 \div 12 = 2\ 2\text{-}3$ lbs. of oxygen, but it will take 11.6 lbs. of air to supply the 2 2-3 lbs. of oxygen, because only 23 per cent. of the air is oxygen; 1 lb. of carbon, if combustion is complete, will give 14,580 B T U., and the product is CO_2, or carbon dioxide; but if carbon oxide, CO, is the product the result is only 4,451 B T U. At the commencement of combustion 1 lb. of carbon (C) unites with 2.66 lbs. of oxygen, and forms 3.66 lbs. of carbon dioxide, setting free 14,580 heat units. The volume of the CO_2 is the same as that of the air from which it was formed, but its density is greater and the combustion is complete, but if the air is wanting in quantity the 3.66 lbs. of CO_2 absorbs 1 lb. of carbon, making 4.66 lbs. of carbonic oxide, CO, or marsh gas, and the heat set free by these 2 lbs. of carbon is 8,902.8 heat units, or 4,451.4 per lb. of carbon. The combustion of a lb. of carbon to make (CO) only requires ½ the quantity of oxygen that is necessary to form (CO_2), because in the gas (CO) one atom of carbon seizes only one atom of oxygen instead of two. To burn 1 lb. of carbon to carbon dioxide (CO_2), requires 11 6 lbs. of air, while to burn it to carbon oxide (CO) would only require 5.8 lbs. of air. The quantities of air required for combustion of fuel can be seen from the following table:

1 lb.	Air at 62°	Product.
Hydrogen	34.8 lbs. or 457 cu. ft.	Water, nitrogen.
Carbon burned to CO_2	11.6 lbs. or 152 cu. ft.	Carbon dioxide, nitrogen.
Carbon burned to CO	5.8 lbs. or 76 cu. ft.	Carbon monoxide, nitrogen.

The air required for the combustion of a pound of fuel is easily determined if you know the percentages of carbon and hydrogen it contains. Example: Your coal contains 90 per cent. carbon, and 10 per cent. hydrogen; now to burn the carbon you would need $152 \times 90 \div 100 = 136.8$ cu. ft. of air, and for the hydrogen, $457 \times 10 \div 100 = 45.7$, $45.7 + 136.8 = 182.5$ cu. ft. of air.

Rule to find the air required to burn a given fuel: To the carbon in the fuel add three times the hydrogen, multiply the sum by 1.52, and the result will be the cubic feet of air required. Example: Composition of coal being carbon, 84; hydrogen, 5; oxygen, 7; ash, 4; to perfectly burn 1 lb. of such a fuel by the above rule: Ans. $= 1.52 \times (C + 3H) = 1.52 \times (84 + 3 \times 5) = 150.8$ cubic feet.

The quantities of heat produced by complete combustion of the elements composing fuels are for

Hydrogen—62,000 B T U per lb.
Carbon to CO_2—14,580 B T U per lb.
Carbon to CO—4,400 B T U per lb.

The chief consideration for economical combustion is the correct air supply. It is not possible to attain perfect combustion with the theoretical amount of air, which is 11.6 or 150 cubic feet per lb. of coal, because in the conditions obtained in our furnaces we cannot get the air into perfect contact with the burning carbon of the coal, for this reason we have to supply about double the quantity of air or 24 lbs. If more air than is actually needed is allowed into the furnace it simply carries heat from the furnace to the chimney, while if too little is used we get marsh gas instead of carbon dioxide. If it were possible to heat the air during the short time it is going through the fuel up to the heat of the fuel the theoretical amount would be all we would require for perfect combustion; one of our losses in the furnace is the driving off by the heat of the hydrocarbons contained in all our bituminous coals, before these coals really begin to burn. These gases are driven off, and are very likely to escape unburned up the chimney. The admission of a small quantity of air above the fire will sometimes burn them. If they are not burned they escape as black smoke.

The best smoke burner in the world is a fireman that knows how to handle his fires in well set boilers with ample draft.

A. M. Wickens, Secretary.

—The new addition to the works of the B. F. Sturtevant Co., Boston, Mass., which was designed to meet the requirements of its rapidly growing electrical department, is already overcrowded, although completed only a few months ago. Numerous special orders for electric fans and generating sets for the U. S. navy are being filled, and the construction of a complete line of enclosed motors of new design is now under way.