exception is the wire H, but the cause of this is clearly the small difference be ween its magnetic capacity as annealed and as tempered.

Leaving aside all theoretical considerations and hoped-for improvements in the methods of observation, the author believes he has demonstrated clearly that, by the aid of the instrument and methods described, we can at once determine the physical state of iron, as influenced by tempering and by mechanical hardening, from the ultimate degree of softness to that of hardness: and that we can at once determine the best iron for the electro-magnets, and the best methods of softening it, as well as the best steel for permanent magnets, and the best temper to be given to it. He therefore ventures to hope that the Magnetic Balance will prove an aid of no small value in all researches into the physical state of iron and steel.

THE PANAMA CANAL.—It is affirmed that of 90,000,000 cubic mètres of earth which have to be excavated from the Panama Canal, only 2,500,000 cubic mètres had been removed up to October, 1883. In that month more than 10,000 men were employed on the work. It is now proposed to increase the working force to 15,000 men, and it is expected that with better weather the extraction will be materially increased. It is still hoped that the canal will be inaugurated in 1889.

HEAT-ACTION OF EXPLOSIVES.*

BY CAPT. ANDREW NOBLE, C.B., F.R.S., M. INST. C.E.

The lecturer commenced by pointing out that the salient peculiarities of some of the best known explosives might roughly be defined to be the instantaneous, or at least the extremely rapid, conversion of a solid or fluid into a gaseous mass occupying a volume many times greater than that of the original body, the phenomenon being generally accompanied by a considerable development of measurable heat, which heat played a most important part not only in the pressure attained, if the reaction took place in a confined space, but in the energy which the explosive was capable of generating. Fulminates of silver and mercury, picrate of potassa, gun-cotton, nitro-glycerine and gunpowder, were cited as explosives of this class. The lecturer asserted that substances such as those just named were not the only true explosives. In these solid and liquid explosives, which consisted generally of a substance capable of being burnt, and a substance capable of supporting combustion, in, for example, gun-cotton or gunpowder, the carbon was associated with the oxygen in an extremely condensed form. But the oxidisable and oxidising substances might themselves, prior to the reaction, be in the gaseous form; as, for instance, in the case of mixtures of air or oxygen with carbonic oxide, of marsh gas with oxygen, or of hydrogen and oxygen. He added that these bodies did not complete the list, and that, under certain circumstances, many substances ordinarily considered harmless, must be included under the head of explosives, making a reference to finely divided substances capable of oxidation, or certain vapours which when suspended in, or diluted with atmospheric air, formed mixtures which had been the cause of many serious explosions.

These instances served to show that an explosive might be either solid, liquid or gaseous, or any combination of these three states of matter. In the first place, a brief account was given of the substances of which some explosives were composed, illustrated by the composition of one or two well-known types. In the second place, the lecturer showed the changes which had occurred when explosives were fired, and gave the substances formed, the heat developed, the temperature at which the reaction took place, and the pressure realized, if the products were absolutely confined in a strong enough vessel; relating the experiments which had been made, and the apparatus which had been used, either to ascertain or to verify the facts required by theory. He further supposed all the explosives to be placed in the bore of a gun, and traced their behaviour in the bore, their action on the projectile, and on the gun itself. He also described the means and apparatus that had been employed, to ascertain the pressure acting on the projectile and on the walls of the gun, and to follow the motion of the projectile in its passage through the bore.

He mentioned that the potential energy stored up in a mixture of hydrogen and oxygen forming water was, if taken with reference to its weight, higher than that of any other known mixture, and explained why such an explosive, whose components were so readily obtainable, was not employed as a propelling or disruptive agent, the main objection being that if a kilogram of gunpowder, forming a portion of a charge for a gun, was assumed to occupy a litre or a decimetre cubed, a kilogram of hydrogen, with the oxpgen necessary for its combustion, would at zero and at atmospheric pressure occupy a volume sixteen thousand times at great.

The lecturer next passed to gun-cotton, described its composition and the various forms in which it was manufactured, referring especially to the forms which were so largely due to Sir Frederick Abel. The various forms of gun-cotton were exploded, and the lecturer remarked on the small quantity of smoke formed, as an indication of the small amount of solid matter in the production of combustion. Also, that instead of the explosions which took place when gaseous mixtures were fired, gun-cotton appeared rather to burn violently than explode. This was due to the ease with which the nascent products escaped into the atmosphere, so that no very high pressure was set up; but it was pointed out that by a small charge of fulminate of mercury, or other means, a high initial pressure was produced, and the harmless ignition shown would be converted into an explosion of the most violent and destructive character. This transformation differed materially from those which he had hitherto considered. In both of these the elements were, prior to ignition, in the gaseous state, and the energy liberated by the explosion was expressed directly in the form of heat. In the present instance a very large but unknown quantity of heat disappeared in performing the work of bringing the products of explosion to the gaseous state.

Captain Noble then showed that gunpowder, the last and most important example selected, was also by far the most difficult to experiment with, as well as the most complicated and varied in the decomposition which it underwent. One great advantage for the artillerist which gunpowder possessed, in being a mixture not a definite chemical combination, was that when fired it did not explode in the strict sense of the word. It could not, for example, be detonated as could gun-cotton or nitro-glycerine, but it deflagrated with great rapidity, that rapidity varying with the pressure under which the explosion was taking place. As a striking illustration of the effect of pressure in increasing or retarding combustion, he showed an experiment devised by Sir Frederick Abel. It consisted in endeavouring to burn powder *in vacuo*, and he demonstrared that it would not burn until sufficient pressure was reached. He exhibited the various forms under which gunpowder was manufactured, and ignited some samples of powder, pointing out the essential difference between their combustion and that of gun-cotton, namely, the large quantity of what was commonly called smoke slowly diffusing itself in the air. He also exhibited a portion of the so-called smoke of a charge of 15 lbs. of powder collected in a closed vessel.

Captain Noble next described at some length the experiments made with gun-cotton and gunpowder by Sir Frederick Abel and himself. With reference to the latter he reiterated their opinion that, except for instructional purposes, but little accurate value can be attached to any attempt to give a general chemical expression to the metamorphosis of a gunpowder of normal composition.

He further pointed out that heat played the whole *rôle* in the phenomena. He explained that a portion of this heat, to use the old nomenclature, was latent; it could not be measured by a calorimeter; that was, it had disappeared or been consumed in performing the work of placing a portion of the solid gunpowder in the gaseous condition. A large portion remained in the form of heat, and performed an important part in the action of the gunpowder on a projectile.

After describing the apparatus used by Sir Frederick Abel and himself, Captain Noble illustrated the progress that had been made in Artillery by mentioning that thirty years ago the largest charge used in any gun was 16 lbs. of powder. The 32-pounder gun, which was the principal gun with which the Navy was armed, fired only 10 lbs.; but he had fired and absolutely retained in one of these vessels, no less a charge than 23 lbs. of powder and 5 lbs. of gun-cotton.

The lecturer next referred to erosion and its effects, and added that he was not one of those who advocated or recommended the use of gunpowder giving very high initial tensions. If such a course were followed, much would be lost and little gained. The bores of guns would be destroyed in a very few rounds. There was no difficulty in making guns to

* A paper read before the Institution of Civil Engineers.