Before dwelling in greater detail on the work of the Association, it is necessary to enumerate the different kinds of test to which metals, and in particular iron and steel, are subjected, or to which it has been proposed to subject them. We can adopt the plan of the French Committee on methods of testing, and divide them into three groups:—

(1) *Chemical Tests.*—These are more especially carried out during the progress of manufacture, in order to ascertain the composition and degree of purity of the products. They are, however, also carried out by the purchaser as a check on the specifications controlling the sale.

(2) *Physical Tests.*—These consist of the examination of the exterior of the products and noting their fracture. The superficial examination may yield, to an expert, a general idea. The examination of the fracture, however, particularly when the surface can be projected, under strong illumination, on a screen and suitably enlarged, can yield more definite indications as to the qualities of steel and of cast iron, and as to the defects they may possess. Of late this method has been improved by polishing the surface of fractures and etching it with a dilute solution of acid, or of iodine, potassium iodide, alcoholic solution of hydrochloric acid, chloride of iron solution, or, finally and preferably, with a 10 per cent. ammoniacal copper solution which allows of a micrographic examination being made forthwith.

(3) *Mechanical Tests*, which were for long the only ones to which recourse was to be had in studying metals, still remain some of the most important and practical of tests. The rules or recommendations published by the International Association classify these tests, so far as metals are concerned, into resistance tests on subjection to various forms of stress (tensile, compressive, shearing, bending, and torsional) either applied gradually or suddenly, and workshop tests (bending double, bending single, hammering down, up-setting, punching, and drift tests). They differentiate besides the tests undertaken with a definite object in the case of (1) rolled and forged iron and steel rails, axles, tires, bridge sections, boiler material, shipbuilding material, wire, and wire ropes; (2) for cast iron; (3) for copper; and (4) for other metals and alloys.

The necessity of using, for tests of this nature, accurate and very costly machines, of taking rather large test-pieces from the materials to be tested, of subjecting these test-pieces to most careful and therefore somewhat expensive preliminary treatment, and of entrusting the tests themselves to an expert staff, renders the expense and the time required for such tests relatively large. Many inventors have sought to supersede them by more rapid and cheaper methods, even at the expense of sacrificing some degree of accuracy. Amongst such methods may be instanced the Frémont punch test, with automatic recorder, and the hardness test. The latter in particular has been for many years the object of numerous researches, and has given rise to lively discussions in the technical papers at Congresses of the International Association and at meetings of the National Testing Associations.

As Professor Martens points out in his important work on the testing of materials, "hardness" has been made the subject of many definitions amongst which it is not easy to make a satisfactory selection, and which have led to a number of methods for measuring it. He classifies these methods into two groups:—

(1) In the first group the hardness is ascertained by the penetration of a given body by another at a fixed point, the penetration being effected either by pressure or by impact.

(2) In the second group the penetrating body makes space for itself at the surface of the other body, which it scratches.

When penetration is effected by pressure, penetrants of various shapes are employed. In 1900 Brinell suggested the employment of a very hard spherical steel ball applied by the instrumentality of a hydraulic press, or by a weight, to the surface of the metal to be tested. It produces a depression of semi-spherical shape. If S be the area of this depression in square millimetres and P the pressure in kilogrammes applied to the ball, the ratio $\frac{P}{S}$, called the coefficient or hardness number, may be taken as a measure of the resistance of the metal to the ball, as it increases in proportion as the metal is harder. The ratio $\frac{P}{S}$ increases in any given metal when S is increased, or when the diameter of the ball is diminished. It also depends, within certain limits, on the time taken in making the test. To obtain comparable results it is necessary, therefore, to employ a ball of constant diameter, generally 10 millimetres, and a constant pressure, generally, in the case of iron and steel, 3,000 kilogrammes. On the other hand, from experiments made by Captain Grard, of Paris, it would appear that five minutes is sufficient for S to attain its maximum.

By carrying out numerous tensile tests on steel and comparing the results with those of the ball test, Brinell believed himself able to show that a definite relation exists between the breaking strain and the hardness number. If this be so, the ball hardness test would furnish an easy, rapid and cheap means of ascertaining the strength of a steel. It would also have the advantage of being capable of being applied to finished parts without injuring them, or to ascertaining the homogeneity of metal by making depressions at various situations. It would also furnish the manufacturer or user with an easy means of controlling the influences of thermal or of mechanical treatment, such, for example, as hardening or planishing. The interest which this process aroused may therefore be readily understood. Numerous investigators have sought to verify the relationship. In some instances it may be made to yield results very closely approximating to the truth by adopting the process of multiplying the hardness number by various coefficients in the case of hard or mild steels, and according as the impression is made in the direction of rolling or across the grain. Other observers, such as Mr. Breuil, have found that this method may result in very erroneous results, and the Brussels Congress would not consent to the substitution of the ball hardness test for the tensile test in specifications. The Congress, nevertheless, recognized the value of the process by recommending the determination of the hardness number in testing supplies. Since that time numerous other researches have been made and have given rise to another process of ascertaining the hardness by a method suggested by Martens and Heyn, which consists of taking the depth of the depression as indication of the hardness instead of its diameter.

At the Copenhagen Congress Mr. Ludwik, of Vienna, who had been deputed to report on hardness tests, con-