I. RESEARCHES ON ELASTICITY AND PLASTICITY OF METALS AND STEEL.

A. BEHAVIOUR OF THICK-WALLED CYLINDERS, SUBJECTED TO PRESSURE.

1. Foreword.

When examining the circumstances, which cause thick-walled cylinders to break, because the stresses to which they are subjected exceed the elastic limit, we have observed a phenomenon which is hardly known and of which an accurate description has not yet been given. We mean to say the relative thickness of the walls and its influence upon said circumstances.

In fact, we have been able to ascertain various facts which had not yet been established or wanted to be confirmed by the experience (cracks appearing on the inner or on the outerside of the tube, ductile strain of the metal leading to its rupture, values of the pressure corresponding to the elastic limit of the metal) but we also could observe that the ratio of the outside diameter of a cylinder to the latter's inside one passes through a critical relative value.

This is an experimental fact of which the cause has not yet been found and which deserved to be carefully examined, because it may have far-reaching consequences from the technical point of view. It has been indeed observed that a thick-walled tube does not necessarily withstand the pressure better than a thinner one and that as far as certain grades of steel are concerned, the resistance of the tubes to pressure decreases as the thickness of the wall exceeds a certain critical value. Supposing that cylinders are tested in following circumstances, the ratio of the outside diameter to the inside one being constant and in the present case being equal to 2.2, supposing too that said diameters are gradually increased, it is obvious that the thickness will increase in the same proportion too, but beyond a critical value of the wall thickness, we will observe that the elastic

limit, recorded outside the cylinder by means of electric extensometers as well as the pressure corresponding to the breaking strength of the material, of which said cylinder is made, will decrease too. The following values obtained by making experiments with cylinders made of a half mild steel are extremely typical in this respect (table I).

Table I.

Temperature °C	Diameter (mm) outside	Diameter (mm) inside	Pressure in kg/cm2 Beginning of plasticity	Pressure in kg/cm2 Rupture
20	17.5	38.5	1 750	4 000
	20	44	1 850	4 100
	20	44	1 850	4 200
	23	50.6	1 550	3 700
	23	50.6	1 350	3 800
30	17.5	38.5	1 850	4 800
	17.5	38.5	1 750	4 800
	20	44	1 850	4 800
	23	50.6	1 450	3 700
	38.6	85	1 300	3 200
	45.3	99.7	900	2 500
50	17.5	38.5	1 900	4 600
	20	44	1 850	4 900
	23	50.6	1 450	3 600
200	17.5	38.5	1 900	4 700
	17.5	38.5	1 850	4 700
	20	44	1 450	4 900
	20	44	1 550	4 900
	23	50.6	1 650	4 600
	23	50.6	1 450	4 600

Such observations had not yet been the subject of an accurate description. By testing high pressure apparatuses, other research workers had however observed breakages which could not be accounted for, neither by the calculations nor by the experiments hitherto made. Accidental causes have been brought forward for explaining such

breakages which have been rarely inquired into and it seems that the scale effect has never been correctly brought to light (1, 2).

As the study of the materials strength is not the chief object of our researches, we did not devote at this time a lot of time for more carefully studying the particular aspect of the problem of the thick-walled cylinders. This question was later on discussed again and in 1960 it was decided to set up a committee for studying the thick-walled cylinders, which committee was presided over by the late Professor L. Baes. This committee came to the conclusion that:

1° The research work relating to the thick-walled cylinders should not be discontinued and that the relevant experimental data should be determined under the best conditions by refining the methods for measuring them and by taking the necessary precautions for correctly making the pieces to be tested to that purpose;

2° There was a problem of a much wider significance, this problem consisting in distinguishing the circumstances themselves, which are responsible for the steel, breaking when it is in a state characterized by the presence of three axes, these circumstances being of such a nature that they would help us to understand better how the steel breaks when it is in a state characterized by the presence of one, two or three axes. This leads the research worker to consider that the fundamental problem of the metal breaking strength may be studied by means of tubular test pieces, the tubular form being apparently the simplest one which can ever be met in this field of the engineering science.

Consequently, if the problem of the scale effect is certainly a problem which deserves to be carefully studied and of which the study should not be discontinued, there is an other problem which is

not less interesting, this problem consisting in making use of tubular test-pieces for studying the fundamental problems pertaining to the breaking strength of the different grades of steel.

2. Scheme of the research work.

The first part of this scheme was carried out from October 1960 to the end of December 1961. It consisted in experimental works done in the laboratories of our Institute and also in the problems being approached by the research workers of the Metallurgical Research National Center and carefully examined by them on the basis of theoretical considerations, and in making the most of the results obtained.

The execution of the second part of this scheme started in 1962 and will be completed in 1965. The experiments have been carried out by applying the same methods as those applied for carrying out previous works, these methods essentially consisting in carefully examining the behaviour of thick-walled cylindrical test pieces subjected to inside hydraulic pressures with a view to showing how these pressures vary with the elastic limit and the tensile stresses to which the steel grades tested are subjected.

With a view to obtaining results, which are beyond question following rules have been strictly complied with:

a. As regards each type of steel to be examined, the test pieces have been strictly taken from the same lot, this with a view to eliminating errors which may come from slight differences in quality between said test pieces.

b. The cylindrical test pieces have been carefully made and subjected to a slight, well defined heat treatment, after they have been made. Their length was nearly equal to 4 outside diameters, the ratio of the outside diameter to the inside one being 1.5 and 2.