c. The measurement of the strains has been made at the outer side of the tube and in some cases, at the inner side of the same. These measurements have been made by means of an apparatus measuring the strains at ten places that is to say by means of strain-gauges sensible to one millionth (i.e. a microdeformation).

d. The pressures have been measured by means of a manometric balance sensible to 0,5 thousandth.

As regards the different grades of steel, the dimensional effect of the thickness of the walls upon the circumstances under which the strains are no more elastic ones and upon the circumstances under which the steel breaks has been carefully determined. To this purpose :
a) the ratio of the outside diameter to the inside one (k)
b) the thickness of the walls
have been varied, said ratio k being kept constant.

3. Experimental researches.

a. General measurements.

The tests carried out up to now, related to a soft steel and a half hard steel. They been carried out by using test- pieces with different values of the ratio $\frac{\text{outside diameter}}{\text{inside diameter}} = \frac{de}{di} = k$ and for each of these ratios, with different thicknesses of the wall. Said tests have been carried out at the ambient temperature and at different temperatures, below the ambient one: namely -20°, -40°, -60°, -80°C. In the course of these tests, the pressure under which the plastic deformation reaches the extrados (p_e) has been determined as well as the maximum pressure to which the test-piece was subjected before breaking (p_m). The résults of these tests are classified in the figures 1 to 3. The three first figures show the influence of the thickness of the wall at the ambient temperature and at the temperature of -80°C for cylinders of which the diameters ratio k is equal to 2 and 1.5.

Fig. 1 shows the influence of the temperature for a half hard steel, said ratio k being in this case equal to 2 and the thickness of the wall equal to 8 mm. Fig. 2 makes a scale effect apparent as regards the soft steel, because the pressure p_e as well as the pressure p_m slightly decrease when the thickness of the wall increases. As regards the half-hard steel, the pressure p_e varies in the same direction, but p_m varies in the opposite direction, which means that it increases as the thickness of the wall increases. Fig. 3 shows a scale effect without anomaly as regards the cylinders, for which k is equal to 1.5.

b. Measurements of the deformation.

1. Each tested cylinder had been provided with a certain number of strain gauges, adhering to its outer surface so that the circumferential and longitudinal deformations could be measured at any time, during the test. As regards the first series of soft steel cylinders of which the diameters ratio k is equal to 2, one has studied how the circumferential deformation varies with the pressure. This study mainly aimed at examining if it was possible to detect the moment when the plastic deformations set in at the intrados, on the unique basis of the deformation measurements at the extrados. The deformations, resulting from theoretical calculations applying to the extrados, have been compared on the assumption of a plastic deformation progressing by concentrical layers as shown on fig. 4; with the deformations measured in the particular case of a cylinder, for which the experimental data had been made available in the greatest number. This comparison shows that the assumption of a plastic deformation progressing by concentrical layers leads to deformations definitely smaller than the real ones (nearly 50 times smaller). This result suggests that the real deformation is not progressing by cylindrical layers, but is rather connected to more localized deformations of a

bigger amplitude, of which the mechanism is similar to this one relating to the Lüders bands, appearing in the course of the tensile test, as shown on figure 5.

The problem of the scale effect is consequently connected to the progression of these bands plastically strained. In the tensile test, the stress condition is the same at each point of the test-piece and the Lüders bands grow without difficulty, whereas the tensile stress is kept constant. On the contrary, in the cylinder subjected to a lower pressure, the stress condition continuously changes when passing from the extrados to the intrados. A Lüders band appearing at the intrados and showing a tendency to progress towards the extrados meets than stress conditions less and less favourable to its progressing and is rapidly stopped. It will continue progressing in this direction only after the inside pressure has been increased. The progression of the Lüders bands slowed down by the stress conditions characterizing the outside layers of said cylinder could account for the scale effect observed, when the plasticity state sets in. In fact, it has been observed that, when two cylinders geometrically similar are subjected to the same inside pressure, the gradient of the stresses is higher in the small cylinder. It can reasonably by expected that the progression of the Lüders bands is better slowed down in this cylinder and that it will be necessary to apply a higher pressure with a view to obtaining that the plasticity state sets in.

2. The measurements of the deformation, made on the first series of soft steel cylinders of which the diameters ratio k is equal to 2 have thus shown that it was possible to obtain a valuable information by making use of the measurement deformations at the extrados. Taking this possibility into account, one has made deformation measurements greater in number, which have been systematically utilized by dividing the deformation measured, by the pressure reigning at this time in the cylinder and be graphically showing how this ratio varies. So long as

the deformations remain purely elastic ones in the whole cylinder, the ratio obtained by dividing the deformation by the inside pressure remains constant. The variations of this ratio show thus the possibility of disclosing any anelastic or plastic behaviour of the cylinders.

c. Interpretation of the results obtained.

Briefly, we observe in all the cylinders examined that an anelastic behaviour of the metal appears as far as lower pressures are concerned, when the stress to which the metal is subjected exceeds the elastic limit at the intrados. When we compare different cylinders, geometrically similar together, we observe that the aspect of this anelastic behaviour varies with the thickness of the wall. The differences shown by cylinders for which the ratio k is the same, are connected to the scale effect appearing when the plasticity state sets in. On the other hand, it is highly probable that the anelastic behaviour of the cylinder is in fact due to microdeformations, that is to say to a phenomenon which is actually carefully studied by the Metallurgical Research National Center in the case of the "one-axis traction", said phenomenon being due to small displacements of the dislocations in respect of their "Cottrell clouds".

d. Such a study has been conducted with an other one of a more technological character namely a study of which the results will be explained on the basis of the results already known and of those, which will be obtained after carrying out tests on smooth test-pieces.

In the course of the present study, it is suggested to study the transition phenomenon on one type of cylindrical V notched test-piece. The attention of the research worker shall be particularly drawn to carefully studying the test-piece during its breaking but in