3. Discussion of the results.

The analysis of the results obtained, is facilitated by the following diagrams showing how the resiliency varies with the temperature as regards each type of metal analysed. In this respect, each diagram shows separated curves, one relating to the central part of the bomb namely to a part of the latter, where the metal is subjected to the action of the hydrogen and to stresses, induced by putting the metal under pressure, whereas the other one relates to a metal of the external zone, where the thermal stresses are practically the only ones, which may alter the characteristics of the metal. Consequently the distance between both curves can be considered as measuring the action of the hydrogen when this gas is put into contact with a metal subjected to mechanical forces.

A third curve shows how the resiliency of a separated test-piece varies when said piece has been put into the corresponding bomb. This curve compared to the first one, shows how the internal stresses influence the behaviour of the metal in the presence of hydrogen, at a high pressure.

These results will now be discussed by first dividing the different steel grades into three classes:

A. First class - steel with a Cr-content reaching 2.25 %.
B. Second class - steel with a Cr-content ranging from 4 % to 9 %, with variable Mo- and eventually variable Va-content.
C. Third class - steel with a Cr-content exceeding 12 % and austenitic alloys.

A. Alloys with a 2.25 % Cr-content and a 1 % Mo-content.

The carbide phase, rich in Fe (iron) reacts upon the hydrogen at a temperature exceeding 550°C so that the metal loses at this temperature all the properties of the metallic state.

B. Alloys with a Cr-content ranging from 5 % to 9 % and with variable Mo-contents.

a) Let us now consider the steel with a 5 % Cr-content Mo being not present in said steel. Although the carbide phase of this steel is richer in Cr and although no lack of cohesion is revealed by the optical microscope at the joints of the grains, the steel becomes brittle at a temperature exceeding 550°C.

The presence of internal stresses speeds up the process of the steel destruction, which depends upon the structural state of this metal and the presence of ferrite, which makes the steel the more brittle as this ferrite has become considerably less richer in Cr. (A simple calculation shows that if the carbon is entirely precipitated in the form of carbides, there is practically no more Cr left in the base metal after slow cooling and subsequent tempering).

It seems that the fragility of this type of steel comes from the hydrogen atoms being inserted in the iron lattice. The metal becomes ductiles again when it is heat-treated.

b) In the presence of Mo, the Cr-content of the carbide decreases; generally a new type of carbide, rich in Mo, makes its appearance. The Cr-content of the ferrite increases and the fragility develops more slowly.

In fact, we have observed that:

1) as regards the steel with 6 % and 0,5 % Mo-content, the Cr- and Mo-contents are respectively equal to 40 % and to 8 to 9 % (atomic state) in the carbide phase after a normalizing and tempering treatment; these contents amount respectively to 40 and 6 % after slowly cooling said steel and after annealing it

at a temperature of 725°C.

After the first heat-treatment, the separation of the carbide α phase is not completed, because a maximum quantity of Cr is kept dissolved in the base metal. This separation is however complets after the second heat-treatment.

After a normalizing and tempering treatment, the fragility appears at temperatures exceeding 600°C without reaching a dangerous level if we take into consideration that the test is carried out within a relatively short time.

On the other hand, after a complets annealing treatment, the ductility disappears at a temperature exceeding 550°C, whereas the micrographs do not reveal any intercrystalline disintegration.

2) As regards steel containing following percentages of alloying additions, namely 5, 4 % Cr, 0,6 Mo and 0,35 % Va the greater part of Cr, owing to the carbide phase containing a high percentage of Va, remains dissolved in the ferrite, which consequently has not been made brittle by the hydrogen. This steel grade has remained remarkably stable, both structurally and physicochemically.

3) As regards steel containing following percentages of alloying additions namely 5 % Cr, 1 % Mo its staying in an enclosure at the temperatures at which the tests have been carried out, has caused a carbide phase, rich in Mo, to be separated, whereas the Cr-content of the ferritic metal base has not decreased so that the alloy has remained stable in the presence of H_2 even at temperatures exceeding 600°C.

As signs of fragility have been revealed by carrying out cross resilience tests at a temperature of 650°C, it is no recommandable to use this steel grade at this temperature.

The same conclusions apply to the steel containing 7 % Cr and 1 % Mo. This steel grade, previously heat-treated, had engendered a carbide phase, less rich in Mo (5 - 6 % in the atomic state) so that the metal was in a more stable state, as it contained a ferrite, less alloyed with Cr. The cross resilience which brings out the fragility of the metal, shows that said metal at the temperature of 650°C is less stable in the presence of H_2.

4) These conclusions also apply to steel grades with 9 % Cr-content, which after subjecting them to an air-hardening and tempering treatment show no evident signs of fragility at temperature of 600°C. These steel grades after heat-treating them this way engender a carbide, rich in Cr but after annealing them and entirely separating the carbide phase show some fragility at the temperature of 600°C and a tendency of becoming brittle at the temperature of 650°C.

C. Alloys containing more than 12 % Cr and austenitic Ni-Cr alloys.

Such alloys are entirely stable as well from the physical point of view as from the physicochemical one. Temperatures amounting to 700°C can easily be reached provided the apparatuses are dimensioned so that they do not creep, when being put into use.

4. Conclusions.

a) Between the temperatures of 550 and 600°C, steel grades containing 5 to 9 % Cr and some alloying metals are physicochemically stable