the stresses can be very easily expressed in a mathematical form. In less idealized cases, which most frequently happen in practice the equations get more complicated or stay roughly approximative. For instance, a superheater tube of which a side is exposed to furnace radiations is the seat of unsymmetrical axial stresses, which incurvate the axis of the tube. An other example which gives rise to a lot of theoritical difficulties is the thermal shock effect. Some other unpleasant things may sometimes happen such as jamming, cold tightenings becoming loose or simply the difficulty of finding a suitable, heat resisting packing.

b) When its temperature rises, a vessel gradually loses its elastic properties and begins to creep. The duration of its life becomes necessarily limited. When the pressure to which it is submitted, is kept constant,this duration is the shorter as the temperature reaches a higher level. One would be wrong to believe that a material only creeps at a furnace temperature. Lead already creeps at the room temperature. In fact, the temperature at which the material begins to creep, is "grosso modo" equal to half the temperature corresponding to the melting point of the material, the temperatures being read on the Kelvin scale. Such a temperature is equal to 20°C for the lead and approximately 600°C for the alloys with high nickel content. For the time being, among the nickel alloys, it is the "nimonic" which best withstands the temperature but cannot be easily machined at room temperature. A very fine colloïdal dispersion of refractory oxides is actually made use of, by metallurgists with a view to improve the high temperature performance of the metal in which the oxides are incorporated. This process is applicable to numerous metals (copper, aluminium, cobalt, iron, wolfram, molybdenum, nickel and nickel-chromium) to which sundry dispersion agents are incorporated, among which we mention the thorium and aluminium oxides, and the titanium and lanthanium ones. The sole metal, which is so consolidated and sold on the market is the "T.D. Nickel" (98% nickel and 2% thorium oxide). Its tensile strength is equal to 7 kg/mm; at 1 315°C, the nickel melting point being 1 453°C. As the thorium oxide is insoluble, the "T.D. Nickel" keeps its strength at very high temperatures, whereas the more classical superalloys lose it because the hardening agent dissolves in them. The "T.D. Nickel" is a very good conductor of heat and electricity. It withstands the fatigue, the corrosion the oxidation at high temperatures and can be easily machined.

Let us now mention by the way the "Maraging steel" of which the mechanical properties and the ductility at the room temperature are absolutely noteworthy. As soon as this steel will come into general use, the efficiency of the classical pressure apparatuses will be increased in the range of the elastic strain and perhaps will it be attractive to overstrain such apparatuses, so that the attention of our contemporaries would again be drawn to the problem of the autofrettage. These iron-nickel alloys with a nickel content amounting to 18-30% have a martensitic structure. The hot ageing of this martensite accounts for the mechanical properties of this nickel steel and justifies its commercial name.

As far as we know, there is actually no theory which can be relied on and is capable of estimating how long a thick-walled cylinder creeping under pressure at a high temperature can live. The theory about creep expounded by MANNING [1957] deserves to be mentioned to the reader, although the opinions expressed about it are divided.

c) In general the elastic limit of a steel, its ultimate strength its fatigue endurance increase at low temperatures. However if the yield strength draws too much nearer to the tensile strength, the steel becomes dangerously brittle. All things happen as if we had to do at the room temperature, with a steel which would have been too much hardened and it has been explained in the preceding section, why a vessel cannot be excessively hardened. Fortunately some rustless austenitic steel grades do not become brittle at low temperatures. It is a long time since we know that a good correlation exists between the crystalline structure of a material, its brittleness or its ductility at low temperature. Metals with body centered cubic lattice become brittle, whereas those with face-centered cubic lattice remain sufficiently ductile. The question of how the different steel grades behave at low temperatures has been very clearly dealt with by SCOTT [1958] in his treatise in which the reader will find references to a more specialized literature.

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