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Tensile Properties of Iron Alloys

By Edward P. Gillett, Ch.E. 1

During the past several years much has been written about the "short-time" tension test and the "long-time" or "flow" tension test for determining the tensile properties of certain alloys at elevated temperatures. The reason for the extensive study along this line is the fact that many of the modern industrial installations are being run off at higher temperatures and pressures than before. Among these are the steam boilers, turbines, extrusion liners, ceramic products, and internal combustion engines operating at high speeds. The oil industry is using higher and higher temperatures and is in need of alloys that will stand up under the intense heat. The tensile properties of all common alloys at normal temperatures are known, but the properties of metals become complex at a rise in temperature. For example, the retorts for the reburning of bone char were formerly made of cast iron. The influence of the very great heat cracked, warped, and buckled them, and in some cases even broke the setting and made them useless for further work. Alloys are wanted that are inexpensive and yet will stand up under terrific temperatures and not creep and eventually break. This report attempts to deal only with the effect of elevated temperatures upon the tensile properties of the alloys of iron.

There are two different kinds of tension tests that can be given a specimen, the "short-time" test and the "long-time" or "flow" test. At present, engineers are in favor of the flow test for determining the tensile strength of materials. The tension specimen is maintained under a constant load at some desired temperature for a long period, sometimes thousands of hours. The short-time test is carried out for only a period of from three to five hours. The main purpose of this test is to determine the amount of stress at which the material ceases to act elastically at any given temperature and load. Obviously the flow method is much more expensive than the other.

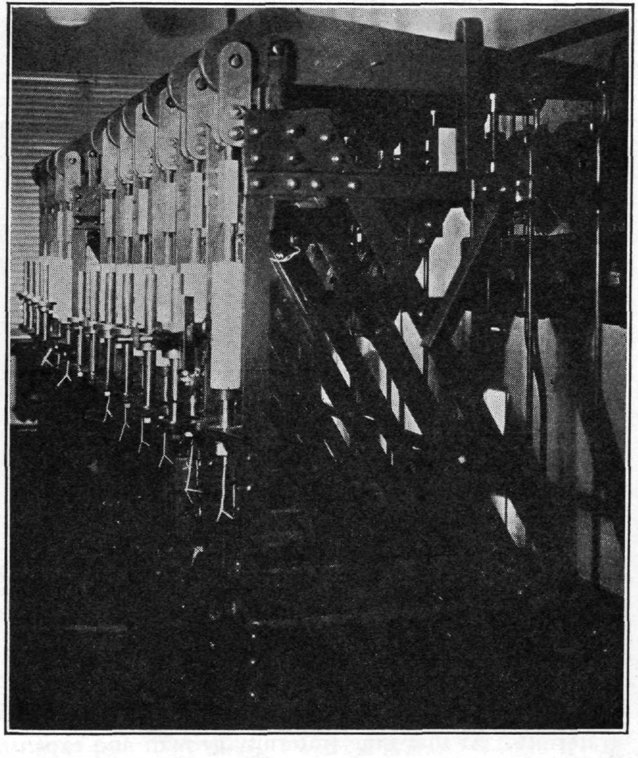
The following is a list of some of the high-temperature furnace processes grouped into general classifications:

Class I.—*Low-Temperature Furnaces* Temperatures 700 to 1300°F.	Drawing Nitriding Low-temperature annealing (steel and glass)
Class II.—*Medium-Temperature Furnaces* Batch and converter types. Temperatures 1350 to 1950°F.	Hardening Vitreous enameling Carburizing Normalizing High-temperature annealing
Class IIa.—*Pot Type Furnaces* Temperatures 1100 to 1650°F.	Lead Cyanide Other salts
Class III.—*High-Temperature Furnaces* Temperatures 1900 to 2500°F.	Forging High-speed steel hardening Ceramic firing

From this it can be seen that materials are needed that will stand up under terrific heat.

The specimens used in the test are cylindrical in shape with threads at each end which fit into the specimen holder. A shallow groove is cut close to the fillet at the end of the specimen, into which a platinum wire is inserted. A platinum strip is attached along the side of the test bar. These are used as reference marks. Platinum is used because it is unaffected by the high temperature.

The apparatus used in these tests is known as the creep-testing apparatus. It consists of twelve separate testing units, the loading for each being accomplished by means of a simple, knife-edge, supporter lever. The ratio of the load on the specimen to the load put on the weight arm is ten to one. For example, if a load of 10,500 lbs. per sq. in. is required, 1050 pounds are put on the weight arm. (A few of the weight arms can be seen on the right-hand side of the photograph. The furnaces are the white objects on the left.) The heat is supplied to the specimen by means of a resistance furnace.



Creep Testing Apparatus

The furnace itself is built about a silver core, which has a very great thermal conductivity. These furnaces are round and are one foot high and about three inches in diameter. They are capable of furnishing any intensity of heat up to 1400°F., and are accurate to within two degrees. Usually each pair of furnaces is operated by a separate controller with the aid of an outside rheostat.

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The specimen is enclosed in the furnace and the proper load and temperature are applied. A very small rectangular window for observing the elongation or creep of the specimen is cut into the side of the furnace near the lower end of the test bar.

The measurement of elongation is taken by means of a telescope fitted with a filar eyepiece and mounted on a micrometer slide. The telescope is used by attaching it to a steel post fixed in each lower cross head casting. The measurement is taken at various regular intervals of time. Creep can be measured accurately to within .00004 of an inch. The creep is measured by taking the distance between the fine platinum strip and the platinum ring. Another way to measure the creep is by the photographic method. Instead of a telescope, a camera is used. This method has one advantage in that it records the results permanently, while in the telescope method there might be an inaccuracy in taking the creep. The main disadvantage in this method is that the window in the side of the furnace has to be much larger than the one in the other method. The loss of heat due to the larger window is much greater, and so makes it more difficult to keep the temperature constant.

There are several precautions taken to insure accuracy in results. The entire apparatus is built upon several layers of tough rubber to decrease the vibration as much as possible. There is also an emergency rest for the weight lever. In case the specimen being tested breaks, the weight arm falls on the rest and prevents the whole apparatus from being jarred. If the arm were allowed to drop, the jar would make the other experiments being conducted on the same creep-testing apparatus inaccurate.

When gray cast iron was subjected to a force of 10,500 lbs. per sq. in. at 700°F., it crept slowly but surely. After 2000 hours it showed no signs of stopping to stretch under the pressure, so the tests were discontinued, as the specimen would continue to creep until it eventually broke. High test cast iron showed the same characteristics of gray cast iron. The tests were also discontinued after 2000 hours, as the graph curve showed no tendency to straighten out. When molybdenum cast iron was loaded with 10,500 lbs. per sq. in. at 700°F., there was very little creep throughout the whole 2000 hours. The molybdenum cast iron was then loaded to three higher pressures at the same temperature. In each case the specimen showed tendencies to creep at first, but gradually the graph curve straightened out. The tests were run up to 1200 hours, and stopped because of no creep in the specimen. These tests show clearly that molybdenum cast iron is far superior to gray and high test cast iron at elevated temperatures.

The purpose of these tests was to determine how much pressure the alloy could stand without breaking at 800°F. When the specimen was under a load of 10,500 lbs. per sq. in., the curve straightened out after 1200 hours and remained the same for the next 400 hours. Then the

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load was increased to 35,000 lbs per sq. in. The initial stretch was of course very great, but it continued to creep, and after 2700 hours the specimen was still stretching. Likewise, when a load of 17,500 lbs. per sq. in. was put on the specimen, the graph curve straightened out at 1200 hours. At 1600 hours the load was increased to 28,500 lbs. per sq. in. This curve also shows that the specimen will not stand up at this temperature under this pressure. When loads of 19,500 lbs. per sq. in. and 24,000 lbs. per sq. in. were placed on molybdenum specimens, the graph curves straightened out after about 1700 hours. This experiment proves that the maximum load for molybdenum cast iron at a temperature of 800°F. is somewhere between 24,000 lbs. per sq. in. and 28,500 lbs. per sq. in.

These tests show conclusively that molybdenum cast iron has the best tensile properties of the iron alloys tested at elevated temperatures at the Battelle Memorial Institute. The increased strength of the molybdenum cast iron, the superiority of its properties at high temperatures, and its resistance to creep at high temperatures under heavy loads make the alloy a very useful material where severe service conditions are encountered.

Creep testing experiments have been made of numerous alloys, the write-up of which would take thousands of pages. This report has attempted to describe the creep-testing process, and enlighten the reader upon the experiments conducted with the alloys of iron only.