The Properties of Steam

Caltech engineers are pushing steam up to new high pressures and temperatures in an attempt to squeeze more energy and greater efficiencies from this prime source of the world's industrial power.

The project is part of an international steam research program by industrial nations – especially the United States and Russia – looking for new ways to step up their power output.

In Caltech's chemical engineering laboratory, steam is gradually being heated to an ultimate high of about 1500 degrees Fahrenheit and 15,000 pounds per square inch (psi) pressure. Top operating levels in industry are now about 1000 degrees and 3000 psi.

Higher pressures will mean that smaller equipment can be used. And higher temperatures will produce higher efficiencies – or more electricity per pound of oil in a steam power plant. Engineers are also interested in the development of smaller steam power units for nuclear engines such as are used in submarines, where the space factor and efficiency are vital.

Caltech's role in the international project is to study the behavior of steam at various extreme temperatures and pressures. The results are reduced to sets of figures which make up the international steam tables. These are used in the design of boilers, turbines, and heat exchange units of nuclear reactors.

The international steam tables now in use were compiled in 1936, and they are based on data that only go up to 850 degrees F. and 5000 psi. But engineers throughout the world are beginning to build equipment for steam that goes well beyond these figures.

So Caltech engineers are extending the tables, as part of a $350,000 program instigated by the American Society of Mechanical Engineers. The U.S. Commission on the Properties of Steam is cooperating in this research program. Under the international study, Russian engineers are also extending the tables, though they are using a different method.

The Caltech steam project is under the direction of Bruce H. Sage, co-director of the chemical engineering laboratory and an international authority on steam. George N. Richter, assistant professor of chemical engineering, is in charge of the actual test program.

Caltech's study has been under way for four years. It may be completed by the end of this year, though the work has been slowed considerably by metallurgical problems. The engineers have found that, as pressures and temperatures go up, steam becomes increasingly corrosive to steels. This is partly due to the fact that some of the steam decomposes into oxygen and hydrogen. And the oxygen quickly reacts within the steel chamber.

Of course, this problem might be solved by lining the chamber with gold, which does not oxidize – but this would cost something like $10,000. Research in metals to resist the oxidization by high temperature steam has been in the direction of chrome nickel steels.

At present, Caltech engineers are studying steam in the range of 800 to 1000 degrees and at 7000 psi and a little above. Several metals are being tested at the same time for corrosive-resistant qualities.

To do the job, the engineers have built a huge and intricate steam temperature measuring device called a calorimeter. This massive piece of equipment consists of two chambers, one inside the other, to enable it to withstand the pressures.

Between the two chambers is a "wall" of helium gas, whose pressure is maintained equal to that of the steam in the inner chamber. Helium pressing inward prevents the red-hot inner chamber from expanding outward. The inner chamber is 22 inches tall by 8 inches in diameter, and the outer one – which has 5-inch-thick walls – is 23 inches in diameter by 54 inches long. Electric coils put heat into the inner chamber. Oil circulating in a pipe coiled around the outer chamber carries off excess heat and thus maintains an even temperature.

An eight-stage centrifugal pump, with heat-resistant titanium carbide bearings, forces the superheated steam through its cycle. The steam moves slowly through a porous, thimble-shaped piece of aluminum oxide which, like gold, does not tarnish when in contact with steam. It is near the thimble that temperature and pressure-measuring instruments are located. Attempts are made to measure the temperature within an accuracy of 0.0005 of a degree.

Steam is observed at each temperature for about a month and then the temperature is elevated 100 degrees and the study is resumed.