# Superpressures: The Next Step to Top Efficiency

**Using pressures above the critical makes steam behave differently. The usual boiling process disappears completely. Here's a quick rundown on steam facts and figures**

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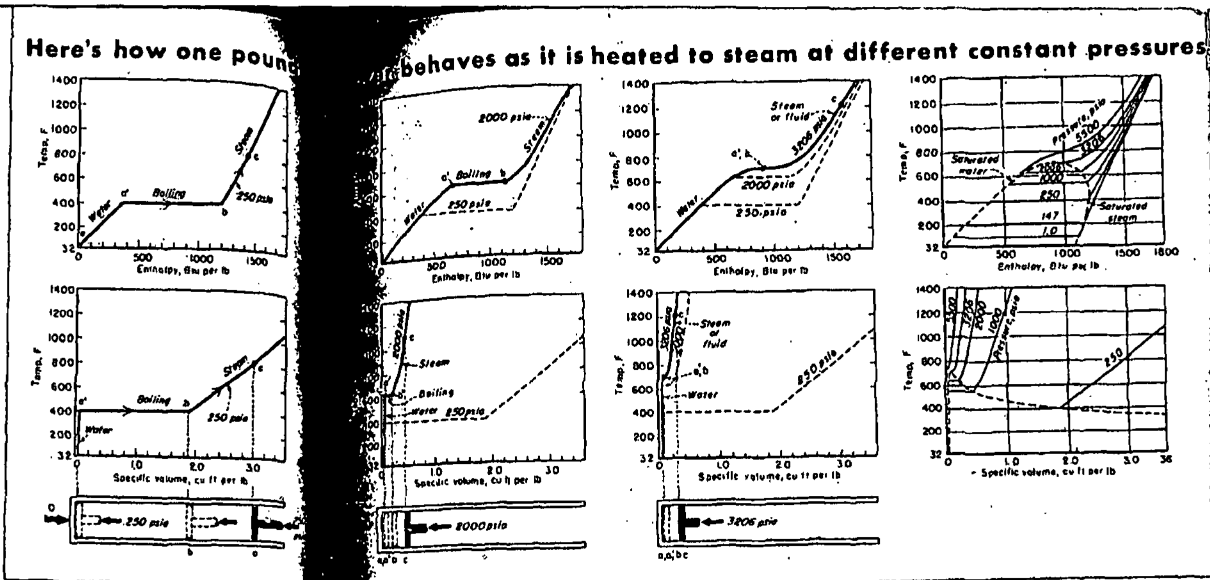
► RECENT ANNOUNCEMENTS reveal we're at the start of a great stride forward in power-plant conditions—a move *into the region far above the critical pressure. For years* our attention centered on the steady advance of throttle temperature. Now the focus shifts to pressure—to a region about which most of us are somewhat hazy.

So we believe most engineers will welcome a refresher on the physics and thermodynamics of steam at pressures *above the critical. On the first two pages, we review the behavior of one pound of water as it's heated under constant pressure.* On the next two pages, we study the action of steam in different cycle layouts and compare thermal efficiencies and other characteristics. On the last two, there are preliminary details of a projected steam plant to run at superpressure, together with an outline of some of the problems being studied.

*In the continuing struggle to hold down power cost in* spite of rising fuel prices we naturally look for ways of improving thermal efficiency. We well know, however, that this usually means using more complicated equipment in the power plant. Often this entails greater investment and consequent carrying charges. So the fuel saving we realize by using more efficient apparatus is partly *offset by the additional financial burden.* In any event, to achieve our aim, the total production and investment *charges against a kwhr must be reduced. That this has* been consistently done in the past is the greatest tribute to the genius of our power-plant design engineers.




## Big Volume Marks Low Pressure

Let's pour one pound of 32-F water in our cylinder and put a total pressure of 250 psi on the piston. *That places the* piston at *a*. Now we'll heat the water and find it expands very slightly to *a'*, while its temperature goes up to 400.95 F as shown above in the lower graph. The upper graph shows that we have put in 375.2 Btu of heat, which is the *enthalpy of the water*.

As we heat beyond this point, boiling begins and the volume increases greatly to *b*, while the temperature stays constant. We also find that we have put in a great deal of heat to boil off the water to steam, as shown in the upper graph, *825.1 Btu*.

After all the water has changed to steam, the volume continues increasing *on further heating, and the temperature* again increases. We call this superheating. The upper graph shows us that for each Btu put into the superheated steam we get a greater *temperature rise* than for an equal amount put into the water.

If we could look into our cylinder during the boiling process, we would see water covering the lower part. In the water small steam bubbles form, which rise and break through the water surface to join the steam filling the upper part of the cylinder. Steam formation causes large volume increase.

## Pressure Rise Ups Temperature

Starting again with one pound of 32-F water, let's now load our piston to *develop a pressure of 2000 psia*. As we heat the water it again expands very slightly while its temperature rises, the pressure staying constant. The water becomes saturated at 635.82 F. Upper graph shows we have put in 665.7 Btu of heat to bring it to the boiling point, compared to 375.2 *Btu* at 250 psia.

Heating the saturated water to boil it off to steam, we find that the volume expands by only 0.1621 cu ft, compared to 1.8251 cu ft at 250 psia. Comparing the total heat input from 32 F, it has required *1129.1 Btu to form saturated* steam at 2000 psia and 1200.3 *Btu* at 250 psia—not very different even though the volumes differ greatly.

Adding heat to the saturated steam, we superheat it as shown by the rising temperature. Getting up into the high-temperature range we find that the enthalpy is not greatly different at the different pressures. For instance, at 1200 F, 2000-psia steam has 1596.1 Btu per lb while 250-psia steam has 1632.7 Btu.

The heat or enthalpy of vaporization for water has decreased markedly for the higher pressure. It is only 463.4 Btu for the 2000-psia steam, but 825.1 Btu for 250-psia steam, nearly double.

## No Boiling at Critical Pressure

Now let us really load our piston by applying the critical pressure of 3206.2 psia. We start heating our 32-F water and again the volume increases slightly while the temperature rises. As we reach a temperature around 680 F the rate of volume increase rises slightly till we reach the *critical temperature* of 705.4 F. After that, the volume-increase *rate drops off somewhat* with the temperature still rising.

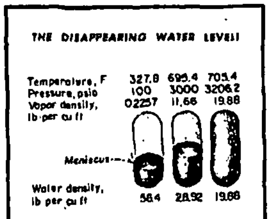
*At the critical pressure* we didn't get any volume increase at a constant temperature. Looking at the heat-input graph above, we find a point of inflection in the 3206.2-psia pressure curve, but no horizontal, constant-temperature boiling process. In other words, the boiling or evaporation process has disappeared.

Just what does this mean? We start off with a fluid we recognize as water at moderate room temperatures. As it is heated, molecules of the water keep expanding the space they need to maintain a constant pressure. Finally, we get to temperatures at which we know the fluid acts like steam or a vapor. At no time does a water level or *meniscus* appear. Neither do we see any formation of steam bubbles. As we heat the water it simply keeps expanding in a smooth manner *until it* becomes steam.

## Water or Steam Above Critical?

At superpressures it's a matter of arbitrary definition whether we call the fluid water or steam. We could adopt *the rule that at temperatures* above the critical we call the fluid steam, while below, it's water. The graphs above summarize $H_2O$ behavior at many states.

The experiment below demonstrates the disappearance of water level because water and steam densities become equal at superpressures.




Heating water and its vapor, sealed in quartz tube, raises the pressure and temperature. *Water level becomes indistinct, disappears at critical point*



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