NASA’s Electical Power-Only Steam Analysis

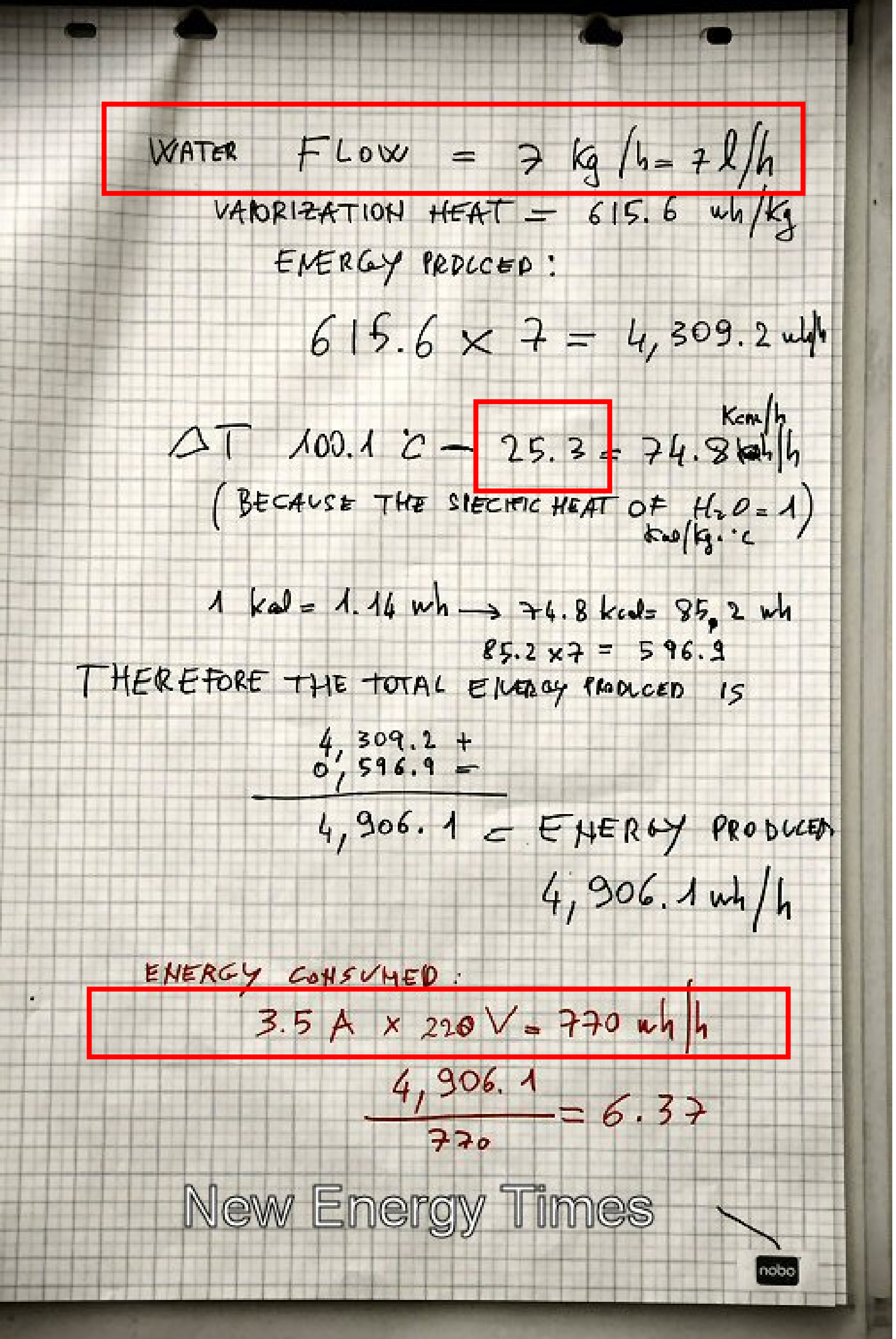
New Energy Times received this document in a PowerPoint file format on July 22, 2011 from Michael A. Nelson of NASA's Marshall Space Flight Center.

One of Nelson’s staff members prepared this document, however, the staff member asked to remain anonymous. We agreed because we have confirmed Nelson’s identity, we consider his staff member’s information useful, and Rossi has recently publicly threatened and attempted to intimidate several qualified critics.

The dialouge in the yellow boxes was written by Nelson.

Rossi Device Analysis Assuming No Ni-H Participation

July 20, 2011



From Rossi's notes:

mdot = 7 kg/hr = 1.944e-3 kg/sec

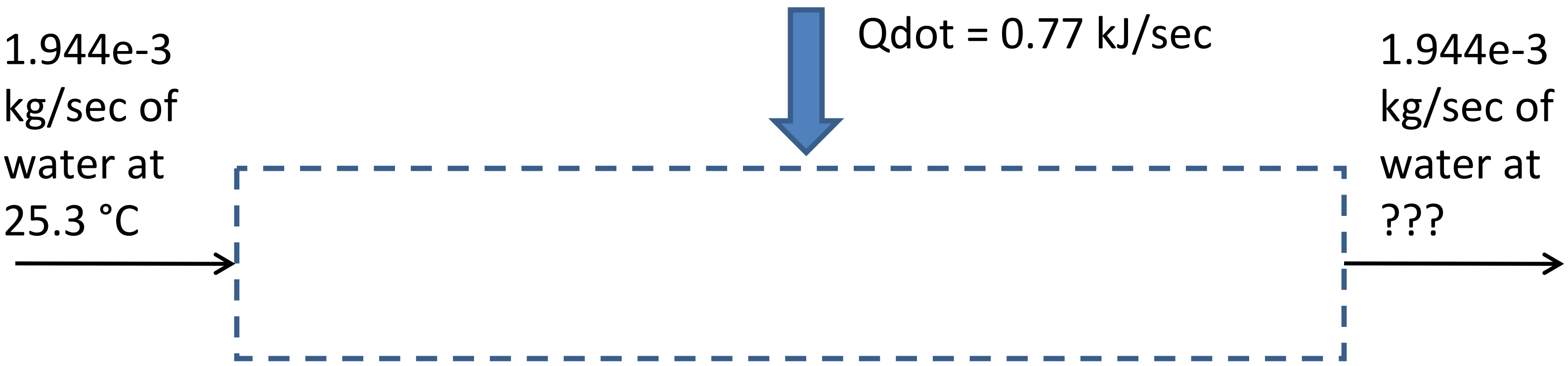
T_{inlet} = 25.3 °C

Start with information from Rossi's notes and assuming no heat from a LENR process. Determine what quality of steam can be produced if the only input power in is the 770 W heating element built into Rossi's device.

Assume that the heat exchanger for the resistance heater is 100% efficient.

Input Power = 770 W = 0.77 kJ/sec

What happens if I add 770 W to water in a pipe flowing at 7 kg/hr (1.944e-3 kg/sec)?



Assume:
-1 atm (constant pressure process)
- steady-state (mass in = mass out)

Treat Rossi's device like a pipe, as shown above, with water flowing in one end of the pipe. Steam of some unknown quality is flowing out the other end.

Starting temperature of the water flowing in is given by Rossi. The rate of heat into the volume of water internal to the device is Qdot. The mass flow through the device is Mdot. Constant pressure of 1 atmosphere on water flow in and out of the device.

$$\frac{dU}{dt} = \dot{Q} - P\frac{dV}{dt} + \dot{m}h_{in} - \dot{m}h_{out}$$

Abbreviated 1st Law

$$\dot{Q} = \dot{m}h_{out} - \dot{m}h_{in}$$

Steady-state, no work.

$$\frac{\dot{Q} + \dot{m}h_{in}}{\dot{m}} = h_{out}$$

Use the first law of thermodynamics. Solve for the enthalpy of the water mass exiting the device. This is an abbreviated expression of the 1st law with the kinetic and potential energy of the system already zeroed out. Also terms related to work done by the system are zeroed out since no work is being done.

From REFPROP v8, water at P=1 atm, T= 25.3 °C, h_{in} = 106.17 kJ/kg

$$h_{out} = \frac{\dot{Q} + \dot{m}h_{in}}{\dot{m}}$$

$$h_{out} = \frac{0.77\frac{kJ}{\sec} + \left(1.944e-3\frac{kg}{\sec}\right)\left(106.17\frac{kJ}{kg}\right)}{\left(1.944e-3\frac{kg}{\sec}\right)}$$

$$h_{out} = 502.26\frac{kJ}{kg}$$

4: water: Specified state points

	Temperature (°C)	Pressure (atm)	Density (kg/cm^3)	Volume (cm^3/kg)	Enthalpy (kJ/kg)	Quality (kg/kg)	Therm. Cond. (mW/m-K)	Viscosity (µPa-s)	Prandtl
1	25.300	1.0000	0.00099697	1003.0	106.17	Subcooled	607.71	884.04	6.0824
2	99.974	1.0000	0.000015949	62700.	502.26	0.036873	Undefined	Undefined	Undefined
3									

Adding 770 W to 25.3 C water flowing at 7 kg/hr at 1 atm will yield saturated water at a quality of 0.037 or 3.7 % vapor by mass.

Saturation properties at 1 atm (for later use)

5: water: Saturation points (at equilibrium)

	Temperature (°C)	Pressure (atm)	Liquid Density (kg/cm^3)	Vapor Density (kg/cm^3)	Liquid Volume (cm^3/kg)	Vapor Volume (cm^3/kg)	Liquid Enthalpy (kJ/kg)	Vapor Enthalpy (kJ/kg)
1	99.974	1.0000	0.00095837	0.00000059766	1043.4	1673200.	419.06	2675.5
2								

(See next page for dialogue)

Use the specified state points feature of the Reference Properties (REFPROP) database that is available from the National Institute for Standards and Technology (NIST). Plug in any two pieces of information about water and it will give you all other properties for those two pieces of information.

Plug in the pressure and enthalpy of water. It will give you the quality of the water by mass as well as other properties that you choose under your REFPROP options. The quality given is defined as the mass of the vapor divided by the mass of the vapor plus the mass of the liquid of the water exiting the device.

Switch to the saturated points properties table in REFPROP (since we know the water has reached its saturation temperature because it is boiling inside the device). You can use a single property to obtain all other properties of water in a saturated state. In this case we want to know the density of water vapor and water liquid at saturation for 1 atmosphere so we can show how the mass quality of the output steam compares to the volume quality of output steam.

Quality (x) is defined as:

$$x = \frac{M_{vapor}}{M_{total}} = \frac{M_{vapor}}{M_{liquid} + M_{vapor}}$$

$$x = \frac{\rho_{vapor} V_{vapor}}{\rho_{liquid} V_{liquid} + \rho_{vapor} V_{vapor}} * \frac{\frac{1}{V_{total}}}{\frac{1}{V_{total}}}$$

$$x = \frac{\rho_{vapor} \frac{V_{vapor}}{V_{total}}}{\rho_{liquid} \frac{V_{liquid}}{V_{total}} + \rho_{vapor} \frac{V_{vapor}}{V_{total}}}$$

Start with the definition of steam quality by mass. State all mass in terms of volume and density. Now define what is meant by quality of steam in terms of volume with a variable y.

Substitute the term for quality of steam by volume into the expression for quality of steam by mass.

NOTE: I cannot tell you that there is such a term called "quality of steam by volume" in any text book anywhere on this subject. I'm just telling you what we've defined it as. You can substitute the phrase "fraction of vapor by volume" if its inappropriate to say quality by volume.

$$Define\_vapor\_volume\_fraction\_as: y = \frac{V_{vapor}}{V_{total}}$$

$$x = \frac{\rho_{vapor} y}{\rho_{liquid} (1 - y) + \rho_{vapor} y}$$

$$x = \frac{\rho_{vapor} y}{\rho_{liquid}(1-y) + \rho_{vapor} y}$$

Solve this equation for y

$$x\left[\rho_{liquid}(1-y) + \rho_{vapor} y\right] = \rho_{vapor} y$$

Express the term for quality of steam by volume in terms of the quality of steam by mass and the density of both the liquid and vapor at the saturation point for one atmosphere.

$$x\rho_{liquid}(1-y) + x\rho_{vapor} y = \rho_{vapor} y$$

$$x\rho_{liquid} - xy\rho_{liquid} + xy\rho_{vapor} = \rho_{vapor} y$$

$$\rho_{vapor} y + xy\rho_{liquid} - xy\rho_{vapor} = x\rho_{liquid}$$

$$y\left[\rho_{vapor} + x\rho_{liquid} - x\rho_{vapor}\right] = x\rho_{liquid}$$

$$y\left[(1-x)\rho_{vapor} + x\rho_{liquid}\right] = x\rho_{liquid}$$

$$y = \frac{x\rho_{liquid}}{(1-x)\rho_{vapor} + x\rho_{liquid}}$$

Volume fraction of vapor can then be determined from mass quality (x) and the saturated liquid and vapor densities.

4: water: Specified state points

	Temperature (°C)	Pressure (atm)	Density (kg/cm³)	Volume (cm³/kg)	Enthalpy (kJ/kg)	Quality (kg/kg)	Therm. Cond. (mW/m-K)	Viscosity (µPa-s)	Prandtl
1	25.300	1.0000	0.00099697	1003.0	106.17	Subcooled	607.71	884.04	6.0824
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2								

$$y = \frac{x\rho_{liquid}}{(1-x)\rho_{vapor} + x\rho_{liquid}}$$

$$x = 0.036873$$

$$\rho_{liquid} = 0.00095837 \frac{kg}{cm^3}$$

$$\rho_{vapor} = 0.00000059766 \frac{kg}{cm^3}$$

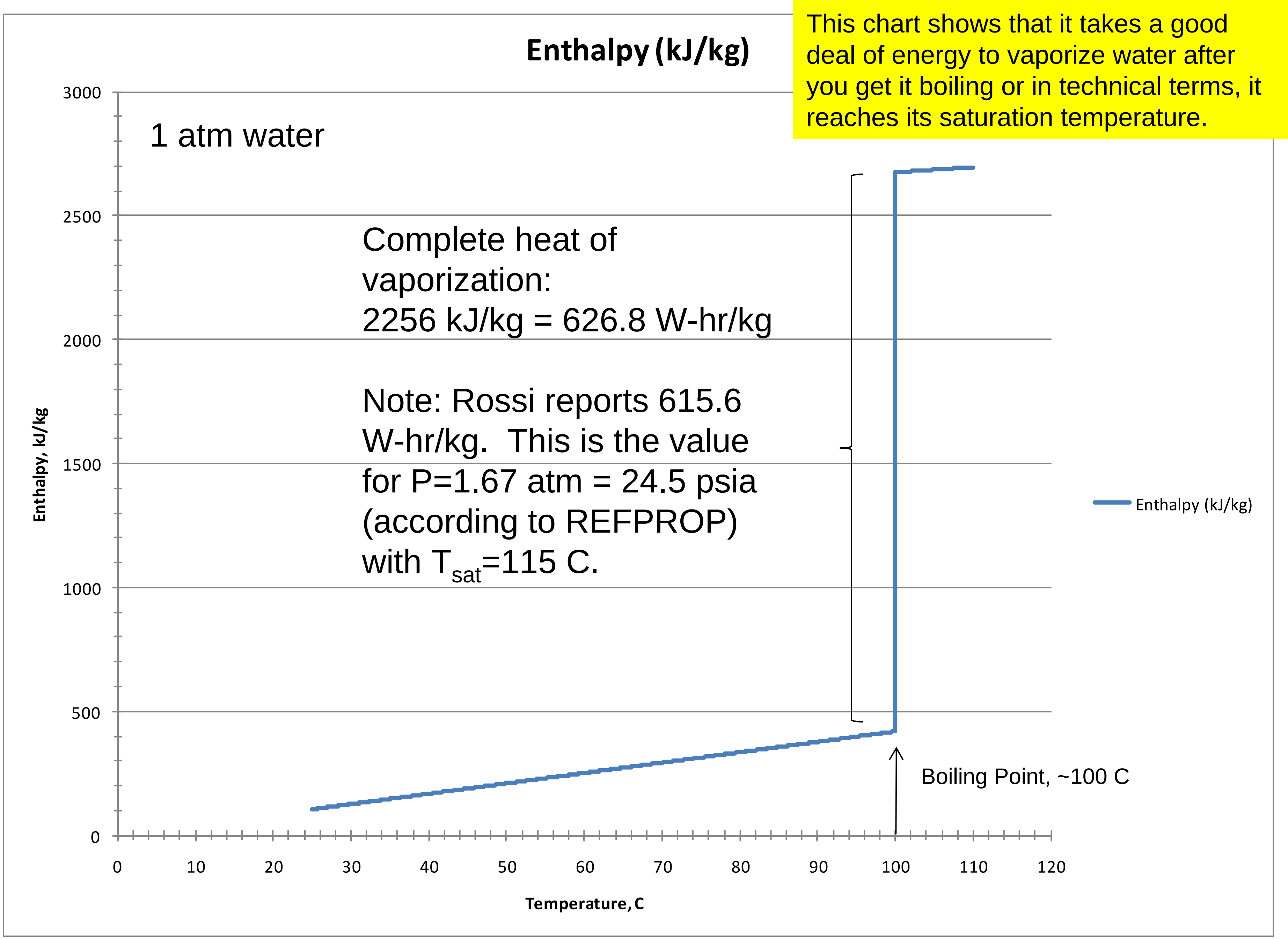
$$y = 0.984$$

Adding 770 W to 7 kg/hr water flow will produce 3.7 % vapor by mass, but 98.4% vapor by volume.

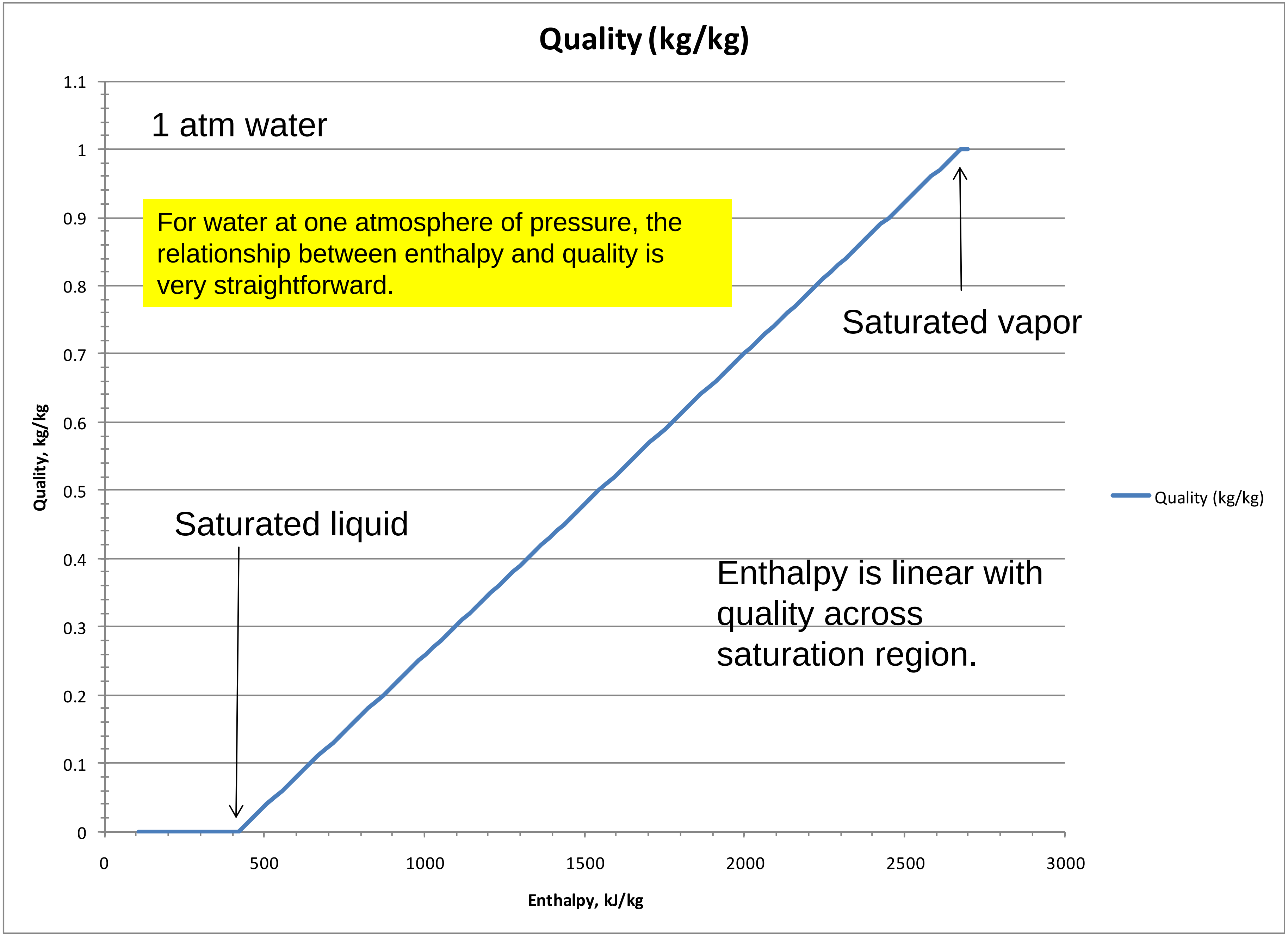
Plug in the values for quality by mass and liquid density of water at saturation and the vapor density of water at saturation from REFPROP. You get the quality of the steam by volume.

As stated above, an input energy of 770 W can yield steam with a vapor fraction of 98.4 % by volume.

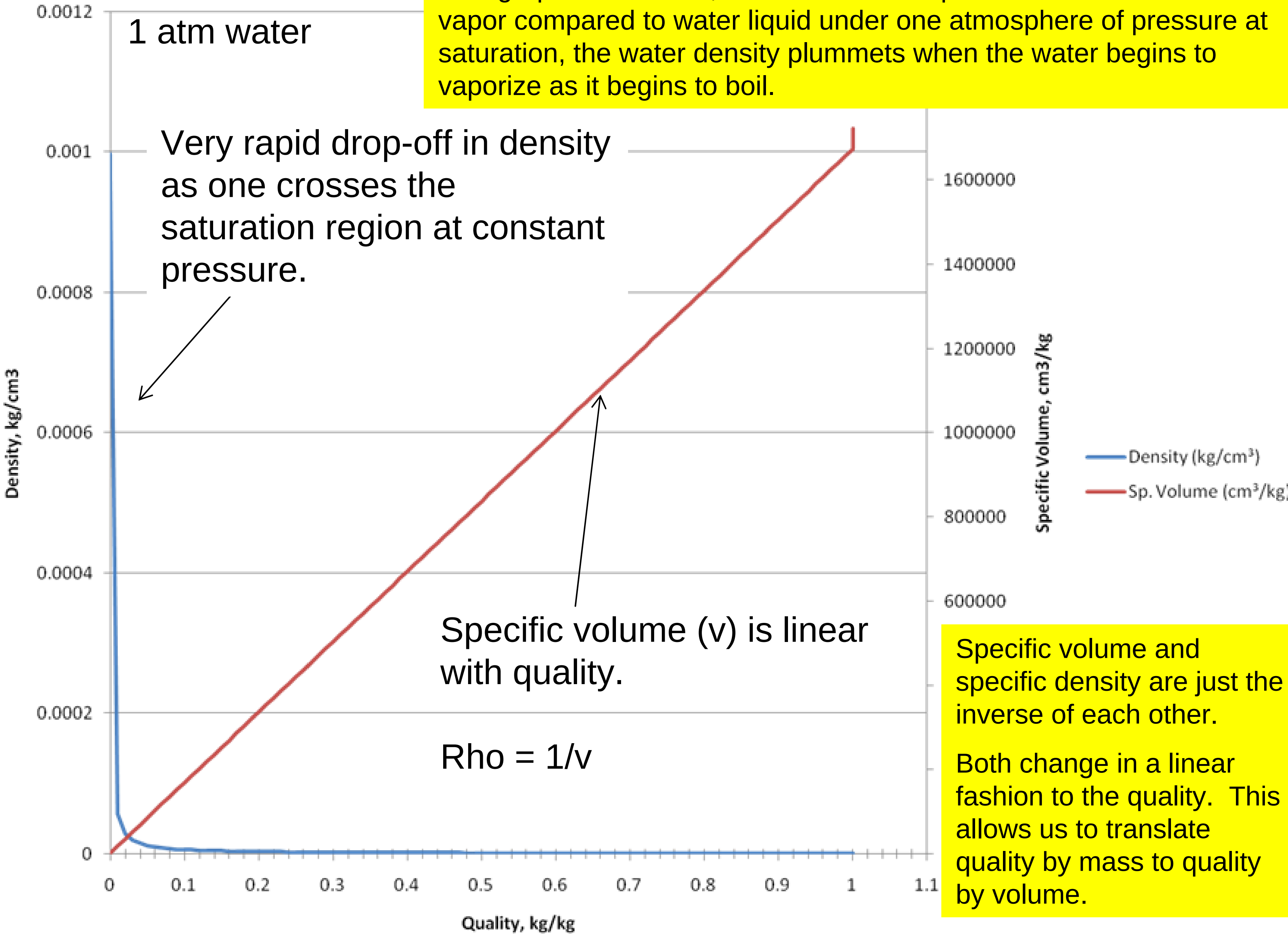
This is because the expansion fraction of water under one atmosphere of pressure at saturation temperature from liquid to vapor is 1603.6036.



Enthalpy (kJ/kg)
This chart shows that it takes a good deal of energy to vaporize water after you get it boiling or in technical terms, it reaches its saturation temperature.
1 atm water
Complete heat of vaporization:
2256 kJ/kg = 626.8 W-hr/kg
Note: Rossi reports 615.6 W-hr/kg. This is the value for P=1.67 atm = 24.5 psia (according to REFPROP) with T_{sat}=115 C.
Boiling Point, ~100 C
Enthalpy, kJ/kg
Temperature, C
Enthalpy (kJ/kg)
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
90
100
110
120

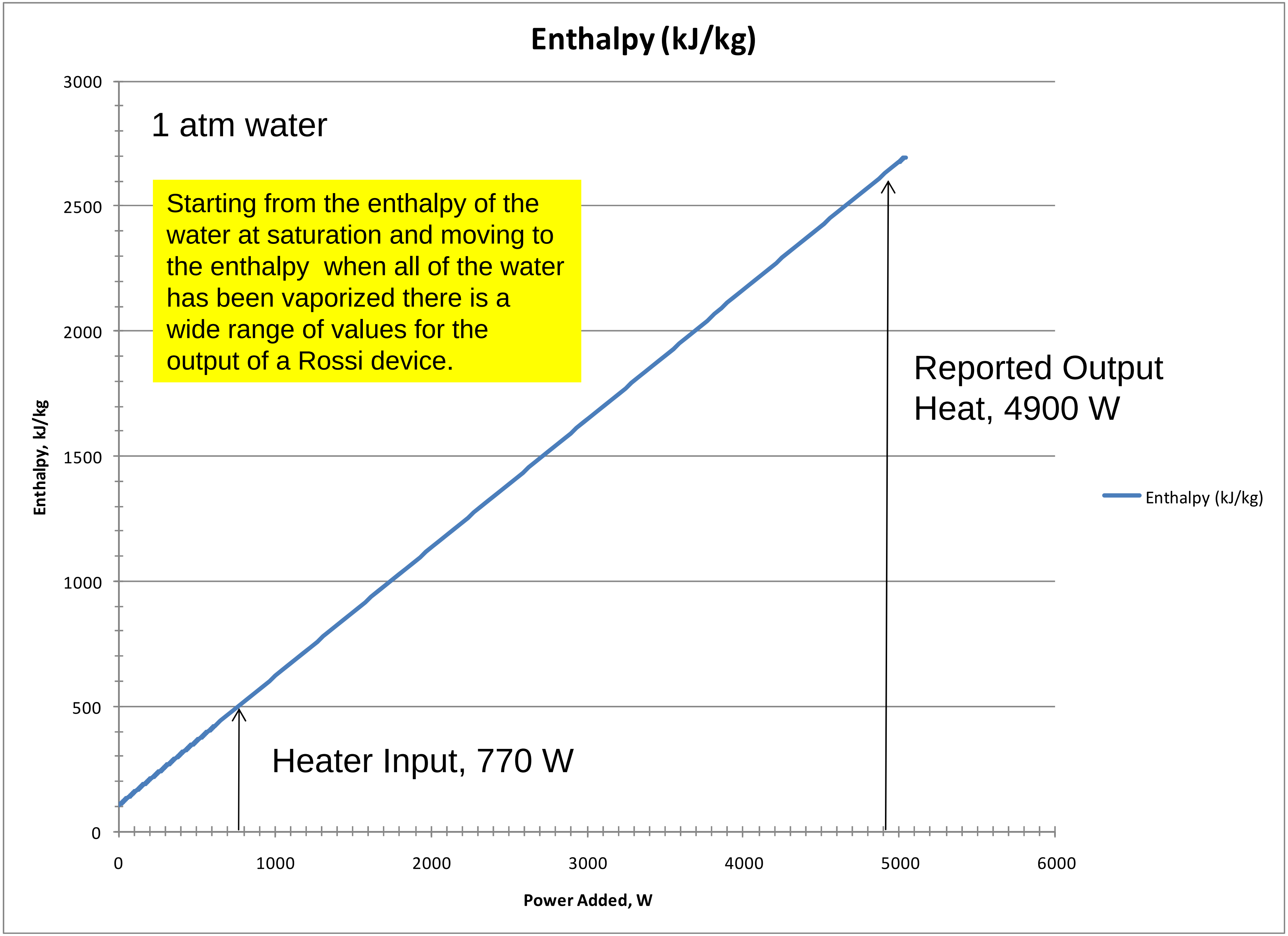

Quality (kg/kg)
1 atm water
For water at one atmosphere of pressure, the relationship between enthalpy and quality is very straightforward.
Saturated vapor
Saturated liquid
Enthalpy is linear with quality across saturation region.
Quality, kg/kg
Enthalpy, kJ/kg
Quality (kg/kg)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
500
1000
1500
2000
2500
3000

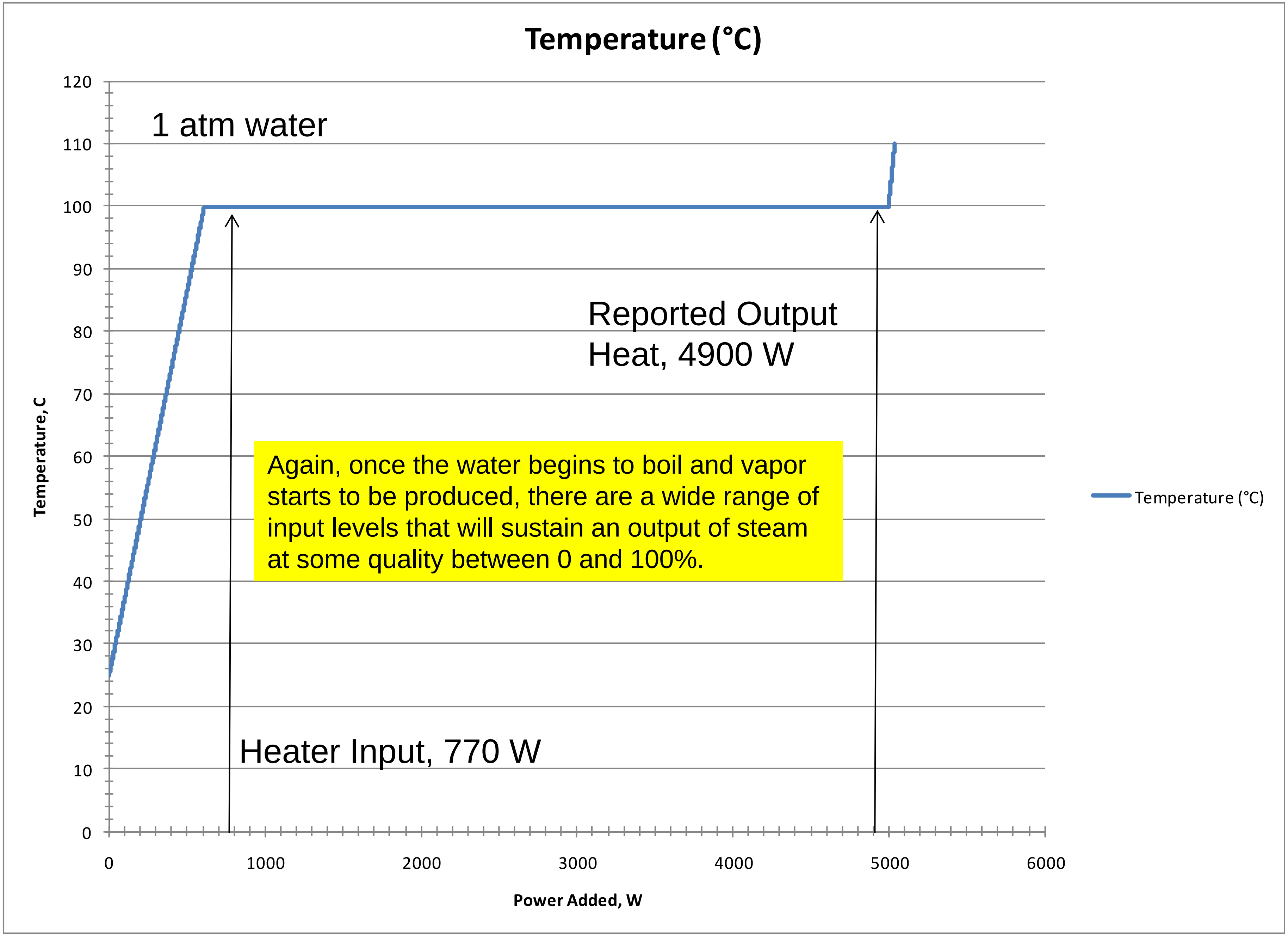
This graph shows how, because of the expansion coefficient of water vapor compared to water liquid under one atmosphere of pressure at saturation, the water density plummets when the water begins to vaporize as it begins to boil.



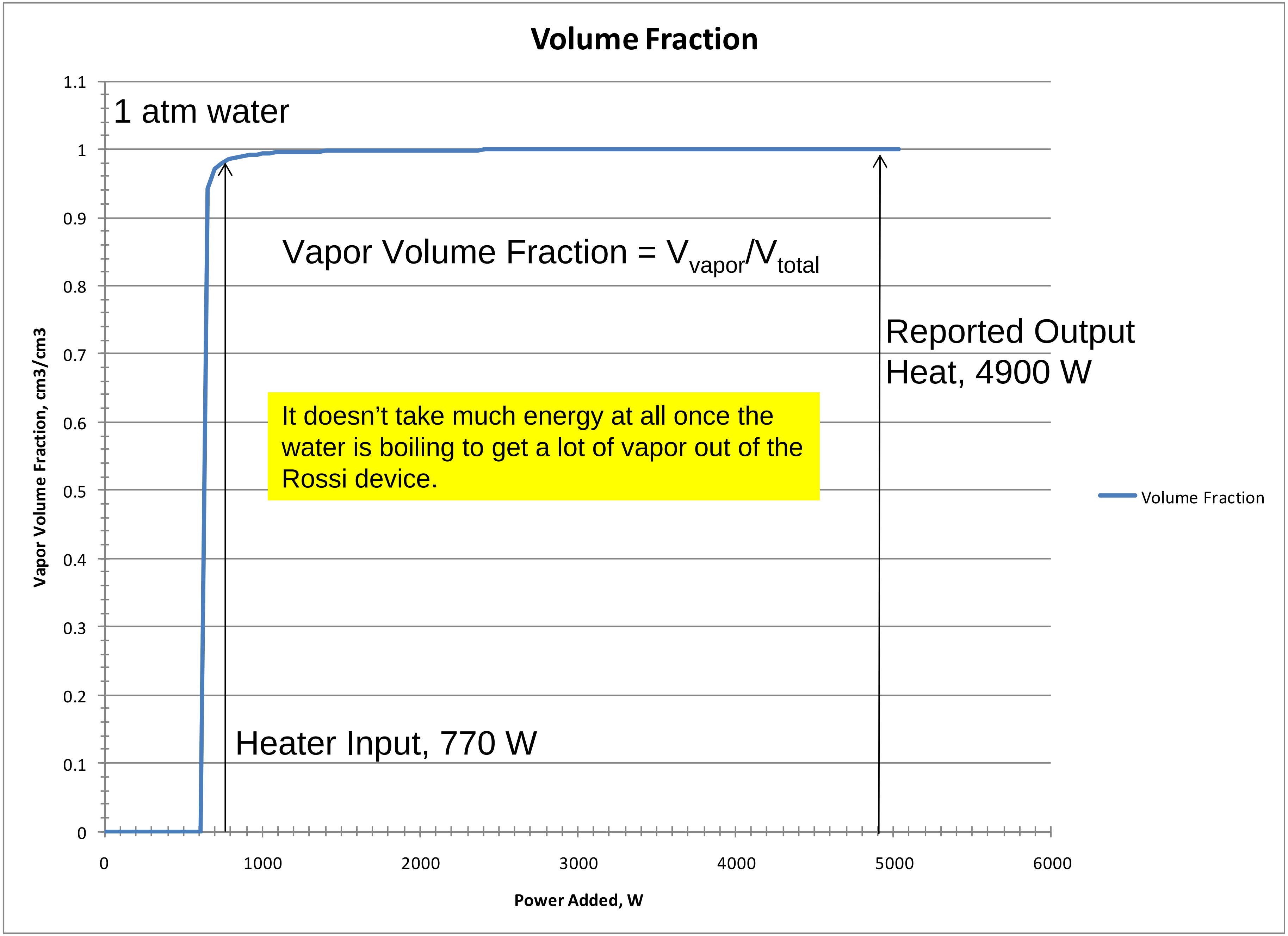
Specific volume and specific density are just the inverse of each other.

Both change in a linear fashion to the quality. This allows us to translate quality by mass to quality by volume.

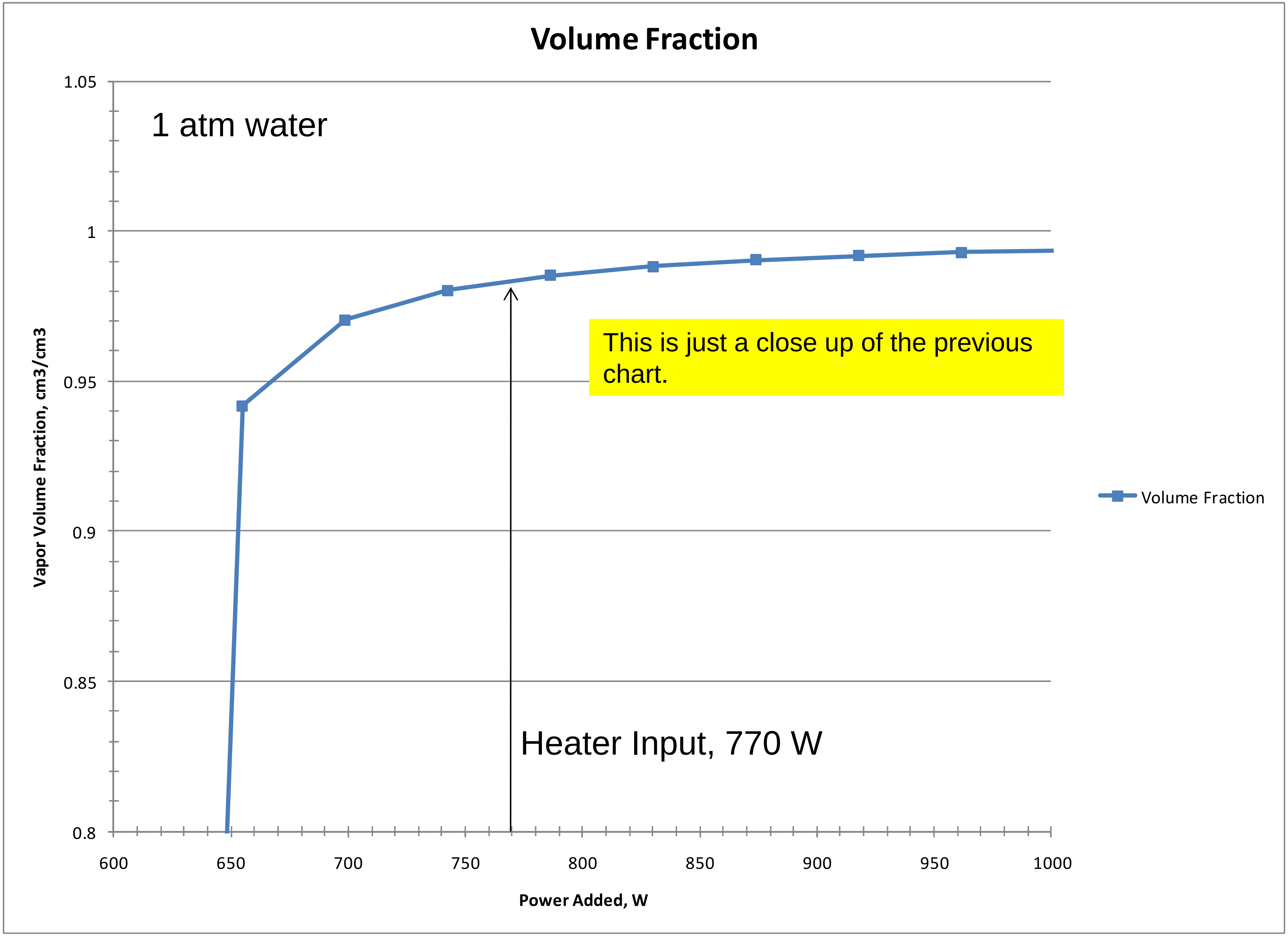

Enthalpy (kJ/kg)
1 atm water
Starting from the enthalpy of the water at saturation and moving to the enthalpy when all of the water has been vaporized there is a wide range of values for the output of a Rossi device.
Reported Output Heat, 4900 W
Heater Input, 770 W
Enthalpy, kJ/kg
Power Added, W
Enthalpy (kJ/kg)
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000



Temperature (°C)
1 atm water
Reported Output Heat, 4900 W
Again, once the water begins to boil and vapor starts to be produced, there are a wide range of input levels that will sustain an output of steam at some quality between 0 and 100%.
Heater Input, 770 W
Temperature, C
Power Added, W
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
1000
2000
3000
4000
5000
6000



Volume Fraction
1 atm water
Vapor Volume Fraction = V_vapor/V_total
Reported Output Heat, 4900 W
It doesn't take much energy at all once the water is boiling to get a lot of vapor out of the Rossi device.
Heater Input, 770 W
Vapor Volume Fraction, cm3/cm3
Power Added, W
Volume Fraction
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
0
1000
2000
3000
4000
5000
6000


Volume Fraction
1 atm water
This is just a close up of the previous chart.
Heater Input, 770 W
Vapor Volume Fraction, cm3/cm3
Power Added, W
Volume Fraction
1.05
1
0.95
0.9
0.85
0.8
600
650
700
750
800
850
900
950
1000

Summary:

Heat input from heater alone will create 98% vapor by volume.

Accurately measuring steam quality at the exit of the device is vital to understanding the performance of the device. Temperature alone will not suffice.