ARE THE STEAM TABLES DEAD?

ERICH A. MÜLLER
Imperial College London • London, SW7 2AZ, U.K.

Are the steam tables dead?

I have recently had two strong hints that appeared to indicate that what we know as the "steam tables" (tabulations of volumetric and energetic properties of saturated and superheated water) have slowly but surely died. In the first place I managed to buy, through a used book dealer, a very nice copy of the Keenan steam tables. This is a 1930 edition that included in an inside flap a beautiful Mollier diagram as large as my own desk. The book is in pristine condition, properly printed and beautifully hardbound, and all—for the staggering price of 50 cents. This is not only a collector's item, but also a very useful tool still. Extensive tables with a very fine grid of temperatures and pressures allow precise calculation of the thermodynamic properties of water. Looking up, for example, at 520 °F and 39 psi, this table reports a specific volume of 14.838 ft^3/lb. Considering that the density of water has not changed with time, the result is still of acceptable accuracy for most purposes (a reliable[1] value today would be 14.845 ft^3/lb—a difference of less than 0.05%). The other parallel event that sparked my imagination was that I managed to download to my PDA a steam table program[2] (which also gave me the expected 14.84424 ft^3/lb answer for the state point in question). So, why have my steam tables not gone the same way as logarithm tables, which disappeared sometime after I left high school?[3] For some reason thermodynamic tables have endured the passage of time, and most major modern thermodynamic textbooks have abridged versions as appendices. You can buy many versions of these "smaller" classroom tables[4] (so they must be used extensively by someone). Furthermore, you can buy a "new" edition[5] of my recently acquired Keenan tables. In fact, they are obviously not things of the past, if one notices that this year a new version of the International Steam Tables was published.[6]

A rapid (non-exhaustive) search[7] showed me that steam tables are also available as spreadsheet plug-ins,[8] as commercial[9] and academic[10] stand-alone programs for PCs, and as phone[11] applications, just to mention a few. Special mention has to be made to the NIST Webbook.[1] This is an outstanding resource that allows the precise and efficient determination of thermophysical properties of a rather significant amount of fluids with all the usual features one would typically require: choice of units, choice of conditions, display of an array of volumetric, energetic, and derivative properties, generation of tables and graphs that can be "cut and pasted" to other places, etc. Three things make it stand out among all other options, however

a) It is accessible through the Internet via a Web page, so it is not device-specific. All calculations are done on the remote machine, so it is also fast.

b) It is free, with no needless registration procedure or cost to the user. A very generous and highly appreciated gesture.

c) It is state-of-the art and in constant update in terms of the equations of state used to generate the data. All this means that any computer connected to the Web can automatically be converted into a "steam e-table," therefore the utility of the site cannot be underestimated.

So, is there any point in continuing the discussion? A common argument in favor of insisting on the use of "paper" tables is that learning to use them will teach students about the different regions of the phase diagram (since the boundaries where the tables end usually coincide with the boundaries of the change of behavior: saturation, ideal gas, etc.). It is hard to think that this is not a biased opinion, for the programs have limits also. I started to look at other data points using my palm-held program, for example raising the pressure at the given temperature. For 2500 psi (@520 °F) it refused to give me an answer. Granted, the table did not have an answer either. It would take some basic knowledge on thermophysical properties to recognize that by increasing the pressure above the saturation line the system would be in the liquid state, and

About the Author: ***Erich A. Müller*** *is a Reader in Thermodynamics at the Department of Chemical Engineering at Imperial College London with 20 years of experience teaching university-level thermodynamics. His research interests lie in the application of molecular simulation to determine thermophysical properties of complex fluids. He is the author of more than 50 papers and an undergraduate textbook on thermodynamics.*

if no other information were available, the low compressibility of the liquid phase would allow one to use the specific volume at saturation (0.37693 ft^3/lb) as a likely estimate.[12] Another repeated argument is that given a computational tool—be it a process simulator or simply a spreadsheet add-in—a lecturer can focus on more elaborate problems which may involve, for example, taking the thermodynamics into its context for typical engineering applications.

Does this then back the hypothesis that we should shelve our tables forever? Please think again. A problem with using computer programs (or Web pages, or phones), apart from the fact that they are useless when no electricity is present, is that one can easily fall prey of the "black box syndrome," a condition in which the brain ceases to perform its usual analytical functions while the user simply inputs numbers and accepts the response from his or her electronic instrument without questioning. Prausnitz[13] warned us of this many years ago when he stated, in the onset of the computer age, "Never be impressed by calculated results merely because they come out of a computer. The virtue of a computer is speed, not intelligence." I think, however, that the student who recently reported reading from a table the density of liquid water at STP to be "roughly 1, *umm*, kg/m^3" wasn't actually thinking much anyway.

Although it is not the subject matter of these lines, computers offer (at least in theory) the ability to visualize 3-D thermodynamic surfaces (for example the P-v-T surface) interactively. This is particularly useful when studying phase equilibria of mixtures, where the usual graphs are slices of a more elaborate and complex surface. Prof. K. Jolls (Iowa State) has made a lifetime effort of providing thermodynamics students with such interactive and pictorial representations.[14] In spite of the fact that there is no doubt about the enormous pedagogical value of these and similar representations, it is clear that they are still emerging technologies, and e-tables still dominate the field.

An important argument is that while for water the thermophysical properties are well known and documented, they are not so for many other simple fluids, let alone the more complex or exotic ones. Therefore, even today, the chemical engineer will have to deal with sometimes just a few sparse data or an odd table, from which he or she must interpolate, correlate, and sometimes even estimate data. This is a daily task for any practicing engineer, and it is up to the thermodynamics lecturer to train students for this awful reality. Perhaps the best course of action is to do both: teach the use of the programs and resources while simultaneously showing students the "facts of engineering life"—one of them being that you will never have as much information as one would desire for a given system. Probably we still have to teach them some "old school" methods. So with this in mind, I sent my dutiful students out to buy their abridged steam tables sold in the bookstore, wondering if next year the answer to the question will be different.

REFERENCES AND NOTES

1. Taken from the NIST Webbook, <http://webbook.nist.gov/chemistry/fluid/>
2. I downloaded version 2.2.0 of "Steam Properties" from Process Ace Software, (<http://www.processacesoftware.com/>). There is a free 15-day demo and a full version is retailed at US$14.99.
3. Quite some time ago, I fear.
4. For example: *Engineering Steam Tables*, by A. Malhotra, Lulu.com (2006); *Physical Property Data Book for Engineers and Scientists*, D. C. Shallcross, IChemE (2004); *Thermodynamic and Transport Properties of Fluids*, 5th Ed., by G.F.C. Rogers and Y.R. Mayhew, Blackwell (1994); *Thermodynamic Tables in SI (Metric) Units*, 3rd Ed., R.W. Haywood, Cambridge University Press (1990)
5. It is actually a 1992 reprint of the 1978 edition of *Steam Tables* by J.H. Keenan, F.G. Keyes, P.G. Hill, and J.G. Moore, Kreiger Publishing Company (1978)
6. Wagner, W., U. Overhoff, and H.-J. Kretzschmar, *International Steam Tables for Industrial Use*, 2nd Ed., Springer (2006)
7. I would like to stress the point that my search is very incomplete, and that I am just placing some examples to make a point. There is an incredible amount of steam table resources available varying from small-scale amateur ideas to some very commercial ones, with all degrees of professionalism in between.
8. See for example SteamTab v3.0 from Chemicalogic (<http://www.chemicalogic.com/steamtab/>)
9. Wagner, W., U. Overhoff, and H.-J. Kretzschmar, *Extended Iapws-If97 Steam Tables* (v2.0) , Springer (2006)
10. For example the CATT program bundled with *Fundamentals of Thermodynamics*, 6th Ed., by R.E. Sonntag, C. Borgnakke, and G.J. Van Wylen, Wiley (2006)
11. *Steam Table for Smartphone 2003* v1.0 by TA Cybernetic Solutions (<http://www.smartphone.net/software_detail.asp?id=610>)
12. It compares well with the reported (NIST) volume of 0.36927 ft^3/lb
13. In Reid, R.C., J.M. Prausnitz, and T.K. Sherwood, *The Properties of Gases and Liquids*, 3rd Ed., McGraw Hill (1977)
14. See an example at <http://www.public.iastate.edu/%7ejolls/> ❐