Boilers and superheating

This document was written by Peter Gardner and was originally published by Frimley and Ascot Locomotive Club in February 2008.

There has recently been an article in Model Engineer analysing the performance gains by superheating followed by correspondence in the same journal, also in others such as the 7¼ Gauge News.
The original article, by D.A.G. Brown, aimed to show, on mainly theoretical grounds, that superheating is unnecessary. It is claimed that the principle benefit of superheating is from the drying of what would otherwise be steam contaminated with water carried over due to the inadequate steam space, particularly in the case of models of large locomotives, with boilers close to the loading gauge. The arguments are highly theoretical and guaranteed to be over the heads of 99% of model engineers (including me) and so difficult to challenge. The author concludes that a narrow gauge prototype boiler with ample steam space is just as efficient as a locomotive built to a main line prototype fitted with a superheater. Others have supported the view that superheating is unnecessary but on the grounds that 'efficiency doesn't matter' or 'you get better steam effects with wet steam'. What they seemed to ignore are two crucial factors:
1. Efficiency should be of interest to all, not just IMLEC competitors. A given mass of steam occupies a greater volume at the higher superheated temperature, which means that a smaller quantity is needed to do a given amount of work and therefore less water has to be boiled. Less water boiled means less scaling in the boiler. Less coal is burned to boil less water, which means less clinker. Conversely, greater power can be extracted with a given boiler with superheat.
2. Unless the cylinders' temperature is above boiling point of water at the exhaust pressure (say 110degC), there will be condensation, which will limit the degree to which efficient expansive working can be used. When the cylinders are relatively cool, they are kept warm by condensing the steam to water and the latent heat is given up to the cylinders. This is a waste and, in addition, less exhaust steam is available for the blast, which leads to the need for a narrow blast orifice and yet further loss of efficiency. None of this is easy to model theoretically but is no less important for all that and probably accounts for the observed poor performance with saturated steam.
In practice, due to both of the above effects, the amount of water to be boiled for the same amount of work can be two or three times greater for the non-superheated engine compared to the superheated and this has been confirmed in experimental laboratory work by Prof. Hall and from the results of a large number of efficiency trials on the track.
My conclusions and recommendations are:
1. Avoid water carry-over by using a perforated steam collector. Water droplets do not pass through a sieve and Stirling's domeless boilers provided dry steam due to the steam pick-up being through lots of little perforations. (Also, see how well a 'Spatter Guard' works in the kitchen.) The worst possible arrangement is a large upward facing aperture designed to catch water droplets.
2. Lag your cylinders if you can although insulation cannot be scaled and losses inevitably increase in small scale.
3. Efficiency may not have [many] financial implications [for small locomotives] but it makes driving more pleasant and can extend the period between services for the boiler.
An alternative strategy, theoretically, could be to design a boiler to operate at high pressure, and therefore high temperature, and to use a restricting aperture, at the regulator say, to reduce the pressure to the working figure. If the temperature is maintained high and the pressure is reduced then

this is in effect superheated steam. Henry Greenly recommended this approach for small locomotives but it was rightly scorned by LBSC. The increase in boiler pressure needed to generate an equivalent superheat is horrendous. For example, I don't think many of us would consider building a boiler pressed to 300 psi in order to achieve the equivalent of 50 deg C of superheat!
Finally, IMLEC results and laboratory trials conducted by Prof. W B Hall and others have demonstrated clearly and practically the benefits of superheating. The author of the recent article seems to have forgotten that when observed results and theory are at odds, then it is the theory that needs adjusting.