From: Aynsley [mailto:buildingenergetics@gmail.com]
Sent: Tuesday, 20 April 2010 8:28 AM
To: Dawson, Geoffrey (SEN)
Subject:

Geoff

I have attached a paper by Peter Harris detailing important issues with regard to economic justification of thickness of bulk insulation (dated 1985). This is the key procedure which should have been used for the Regulation Impact Statement, not computer simulation using flawed software. The study should have included naturally ventilated buildings with ceiling fans in warm humid climates and evaporatively cooled buildings in hot dry climates, in addition to air conditioned buildings.

Regards

Economic thickness of insulation: an easier way

By Peter Harris

In this article, the Director of Services of the UK Energy Users Research Association suggests a method of calculating the economic thickness of insulation which is more efficient than methods presently being used.

When we delve into it, what we find is not only mounting disquiet on the reliability or usefulness of methods for the calculation of the economic thickness of insulation among the few people who ever do use them, but an even greater number of people who seem to have abandoned such methods altogether as too complicated and not worthwhile. This particularly comes out in an article published by McChesney and McChesney in *Chemical Engineering*, May 3, 1982, pages 70-79.

What they say is that they have examined several of the commonly adopted techniques for doing the calculation, find that a real dilemma arises in trying to decide what is the actual thickness which is 'economic'. In fact, they wonder if there is such a quantity at all! Put another way, they say they have a sneaking suspicion that the 'economic' thickness of insulation is what any plant engineer wants it to be.

They also say that from frank talks they have had with insulation contractors, when put in the hot seat many will admit that their costing procedures do not go by the book, because they do not have the staff, or the time to use the computer programmes for every pipe length or flange. One supplier is quoted as saying that to do so would be commercial suicide!

Present methods unsatisfactory

At the root of the problem is the fact that the recommended methods are extremely tedious to use. For the simplest job they can take the best part of a day, and in the end you find the answer depends very largely on the initial assumptions you put in. Most of the efforts to resolve this involve more sophisticated economic arguments such as discounted cash flow, total lifetime costing and the like. However, these do not resolve anything, but with nothing to put in their place few people would be prepared to abandon them.

What is needed is to examine why the calculation is so sensitive to the assumptions we use and to see if there is any way to get round that and to see if, at the same time, we cannot simplify the calculation rather than just building complications into it. A pipe-dream? Well let's see.

What economic thickness is about

For the benefit of those who are unfamiliar with it, or who have managed to avoid getting involved with it in the past, let me first explain how the calculation is usually done. I think it will help you appreciate the simplicity and reliability of the solution I am going to suggest.

The basic premise behind the calculation is that even an insulated pipe loses some heat. It is much less than for a bare pipe, but it happens, and it is possible to assign a cost to it. It also costs money to insulate a pipe. For any given thickness of insulation there are therefore two cost components, but the important point about them is that whilst one — the heat loss — comes down with increasing thickness of insulation, the other — the cost of applying it — increases with thickness. If you add the two costs together for various thicknesses there must be a minimum total cost somewhere. This is usually shown in the form presented in Figure 1.

The heat loss curve is either calculated from a formula or obtained from a set of tables and converted to money value by multiplying the cost of fuel and conversion efficiencies. It is a smooth monotonic curve which sweeps down from high cost at no insulation, to lower cost at high thickness. We will find that the key thing about the line is in fact its slope, which we see is steep at low thicknesses and reduces as we go to higher thicknesses.

The cost of insulation is usually represented as a straight line which rises from an intercept at no insulation and has a constant slope. When the lines are added together they produce a curve which has a minimum. *BS.5422* described alternative ways of doing the calculation, which involve using tables, graphs or nomograms, but they all amount to the same thing. In these days of desk-top computers there is a tendency to do the calculation by computer because the programme is easy to write and to repeat the calculation by hand for different assumptions is tedious.

The basic calculation usually evaluates the heat losses over a year at current fuel costs. Naturally, we expect our insulation, once we have applied it, to last for some time and we would expect the price of fuel to change in the future too. To take these into account means calculating a new cost of heat loss curve for the new assumptions and doing the addition again. We then find the minimum is at a different thickness. This is where the problems start. Which answer do you take as the right one? Which answer, or which assumption, do you like best?

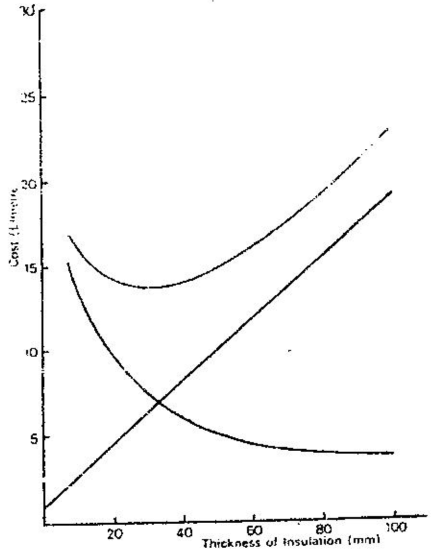

***Figure 1:** Economic thickness of insulation by graphical summation.*

About the minimum

The main feature of any graph which contains a minimum is the fact that above the minimum the curve has two values — in this case it means there are two thicknesses which give rise to the same cost of £16.00 per metre. You can see that if we were to spend £3.60 on 15 mm of insulation, or £10.40 on 58 mm, it would still cost the same over the year. The reasons why Accounts are interested in economic cost calculations is because they do not like to spend more capital than is necessary for a given result.

However, the thing which should interest us about the minimum is why it occurs at all, and why it is where it is. It is a fact that when you add two lines like

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this, if there is to be a minimum at all, the minimum occurs where the two lines have equal and opposite slopes. (You can prove this mathematically as a general rule.) If the cost of insulation line is straight, i.e., its slope does not change, then the answer we get is a result of the slope of the heat cost line drifting down to the right value. We then get a broad minimum at a thickness whose exact value depends on what assumptions we built in to the heat cost calculation.

A way out

Note that in talking of the cost of insulation line I said that the way it is *usually represented* is a straight line. I chose my words carefully because although it is shown as such in *BS.5422,* in the Department of Energy's *'Energy Efficiency Booklet'* and the Rockwool *'Insulation for Industry Manual',* in truth it is not so. And what is more, it is very important to us that it is not so. Firstly, manufacturers do not sell a continuous range of thicknesses, they sell only discrete thicknesses — 19, 25, 38, etc. millimetres. If the answer to your calculation came out to 28 mm you would probably find you could not buy it. You would have to choose something close to it. Secondly, manufacturers and installers do not charge on a constantly rising scale of prices; the line usually has kinks in it. (Figure 2).

This has important consequences for our calculation. The minimum we recall, occurs when the heat loss curve has an equal and opposite slope to the cost of insulation line. If the cost of insulation line is straight, i.e. its slope does not change, then the answer we get is a result of the slope of the heat cost line drifting down to the right value. We then get a broad minimum at a thickness whose exact value depends on what assumptions we built into the cost calculation.

But when the insulation line has kinks in it and is abruptly changing slope; if you like, at some point it comes up to meet the other curve, this will precipitate a sharp minimum. What is more, since the point where the minimum occurs is within broad limits mainly determined by the slope of the cost of insulation line, it follows it is not sensitive to the assumptions built into the heat loss curve. This is shown in Figure 3. We see that although we have lengthened the evaluation period by factors of two and three, the minimum appears *at the same thickness value.* The same result would happen if we kept the evaluation period at one year and trebled the cost of fuel. The same would happen if we raised the temperature of the pipe with the other factors constant. In other words, we can get an answer that does not depend on the assumptions we use.

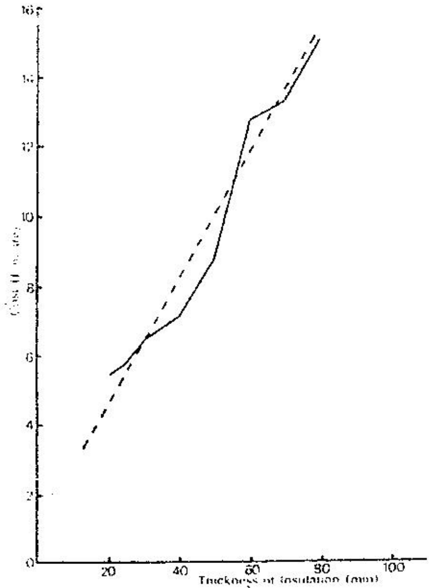

Figure 2: *Actual cost of insulation for 48mm pipe.*

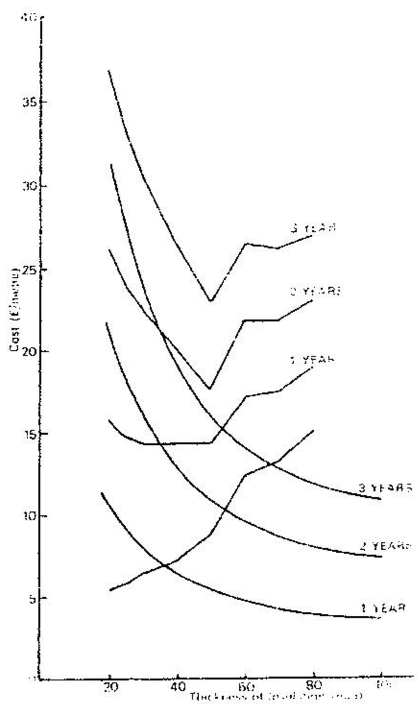

Figure 3: *Economic thickness based on manufacturer's costs.*

Also we know where the minimum will be without even drawing the heat loss curve, essentially irrespective of the length of the evaluation period or cost of fuel. All we need to do is get in the suppliers quotes, plot them on a graph, look for the steepest part of the graph and select that thickness at the bottom end of this segment. That is all. Simplicity itself. We do not have to calculate the heat loss curve, so we do not need to use a computer.

A warning about computer programs

Indeed, one of the features of computer or calculator programs written for this calculation is that they artificially straighten out the cost of the insulation line. The McChesneys actually commented that they found that their line was kinked and they went ahead and straightened it before starting their assessment. Not only does this get you right back to the old problem, it can also create a new one.

We said that one way of stating the economic significance of the minimum in the total cost curve is that it is the thickness beyond which it does not make sense to spend more capital. This is because beyond this point there must be a smaller thickness where the same overall cost can be achieved by spending less. In the data used to derive the smoothed line some points will lie above the line and some below. If the computer answer comes out at a thickness where the actual price the user will have to pay lies above the smoothed line, *he is bound to pay more than makes sense!* ■