Long Term Strength – And It's Consequences for PEX

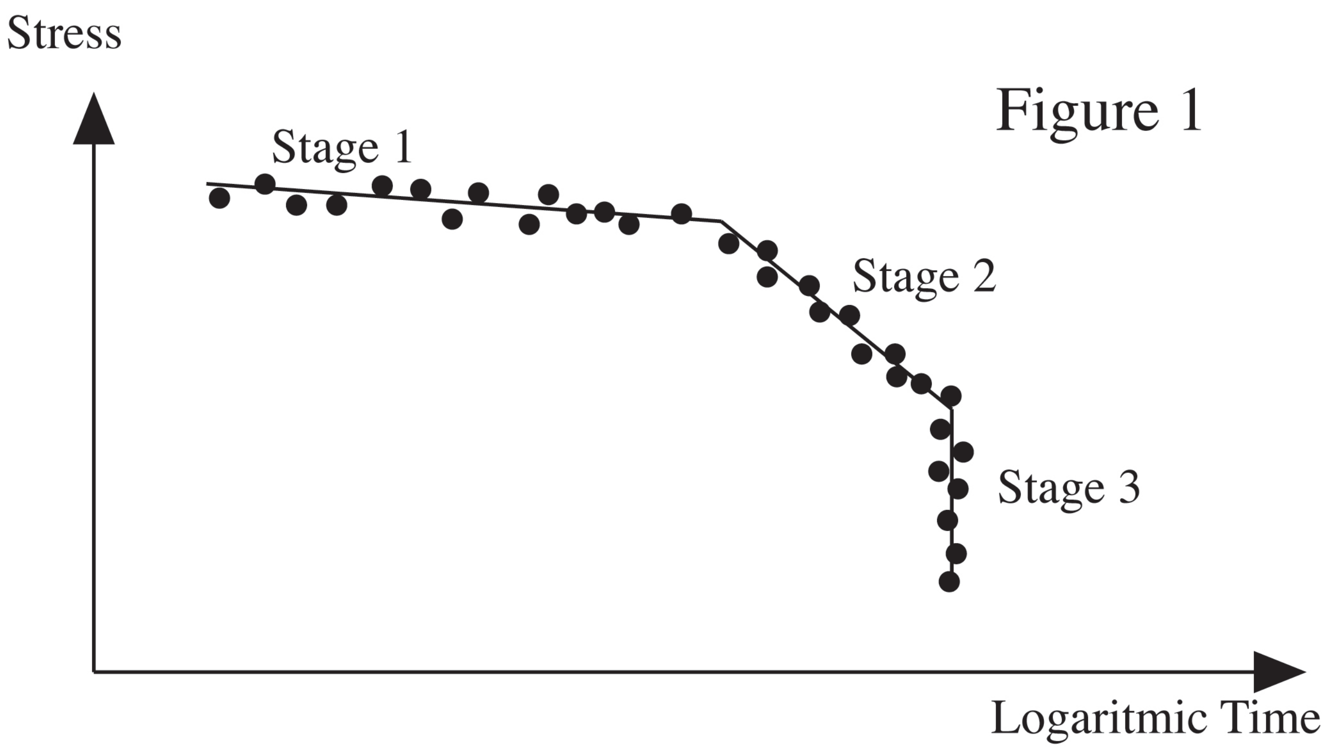

Figure 1

Figure 1 is a chart displaying Long Term strength of a polymer pipe. To find these curves you start a large number of pressure tests at different stress (inside pressure) levels. And you wait until most samples have failed (pressure disappeared). Each black dot in Figure 1 represents such a failure. By entering the data in mathematical formulas (see for example ASTM D 2837 or ISO 9080) you can calculate the average line that describes the strength (the three lines in chart 1). As you see, you will normally be able to find 3 lines with different slopes describing the material's long term strength. At short times you will see a line with comparatively small slope. All failures here are ductile (the pipe "bubbling out" quite much before it bursts. This is called Stage 1. For intermediate to long term you will find a line with larger slope. The early failures on this line have mixed mode (some expansion of the pipe before it bursts), but most failures (all but the first few on this line) will be brittle (a longitudinal crack in the pipe). This is called Stage 2. The line describing the strength at long term is approximately vertical. That means that the failure is virtually independent of the stress applied. Pipes with very different pressures fail at approximately the same time. All failures are very brittle. This is Stage 3. It is caused by thermal degradation of the material.

[The definition and description of Stage 1, 2 and 3 was first internationally introduced in the book "Water & Pipes" Lenman/Skarelius 1982. Then also at the International Plastics Pipes Conference V in York, UK, 1983, Paper 35, 9 pages "Flexible Plastics Pipes for Hot Water, and the Effects of Oxygen Diffusion"; T Lenman].

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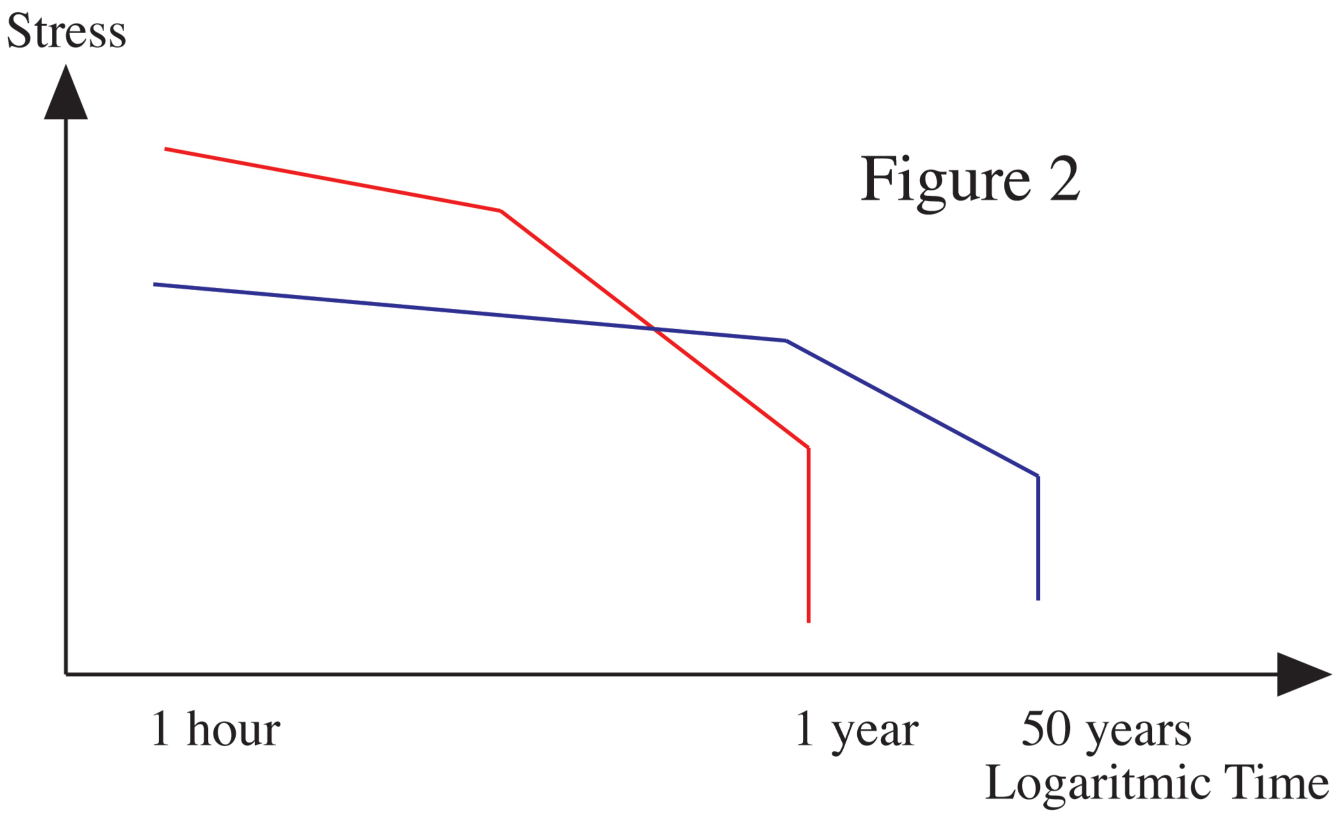

Figure 2

Figure 2 is provided in order to show that there are wide variations to different Polymer properties. The molecular chains can be more or less branched. These branches may be long or short. There may be some other chemical groups inserted in the molecular chains. These "disturbances" may come regularly, or at random. All these factors (and some more) give different properties to the material. Compare the two tubing qualities in the Figure 2. The material described by the red line has much higher strength at short term exposure. But the material described by the blue line has much better Long Term Strength. I would say that it is better. I inserted some sample times in the Figure 2. Then that chart could be true at 180°F for two different Polyethylene or Polybuthylene qualities.

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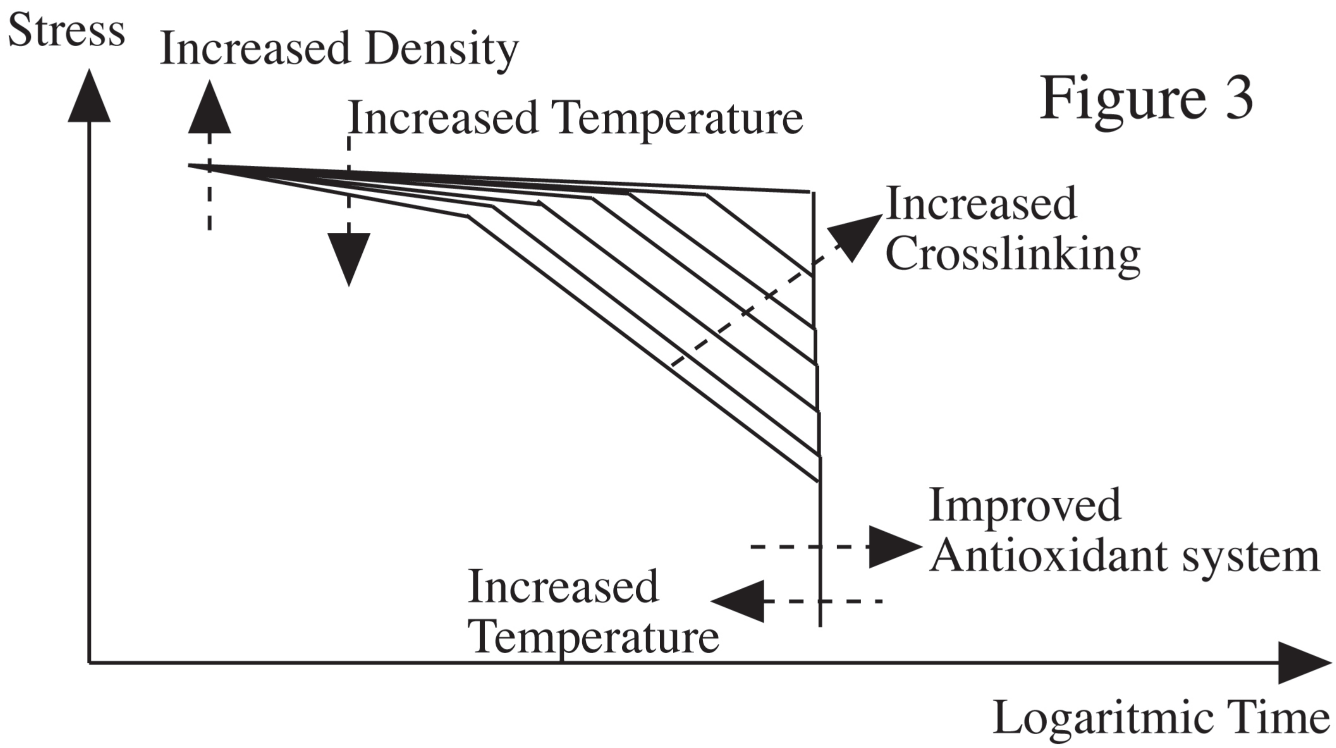

Figure 3

Lets first see what crosslinking does to the material. The uncrosslinked material is the line to the very left and lowest. The same material with 70% or more of crosslinking is highest/most at right. In between these lines you have gradually higher crosslinking. Crosslinking makes two things: It decreases the slope of Stage 1, and it delays the occurance of Stage 2. It does not noticeably affect the occurance of Stage 3. Note that Stage 2 completely disappears when 70% of crosslinking is achieved. According to internationally published papers also for Silane crosslinked PEX.

The time of occurrence of stage 3 is mainly dependent on the type and amount of Antoxidants in the material. It is true that fewer "disturbances" in the molecular chains (fewer tertiary carbons) may contribute to delay the occurrence of Stage 3, but the antioxidants recipe is the most important parameter.

Density of a material will directly affect the level of the Stage 1 line. Increased Density would move the Stage 1 level upwards. To be able to hold higher pressures.

Test temperature will directly affect the level of Stage 1. Decreased Temperature would move the Stage 1 level upwards and Increased temperature downwards.

Temperature will also move the timing of occurrence of Stage 3. Increased temperature towards shorter time and decrease of temperature towards longer time.

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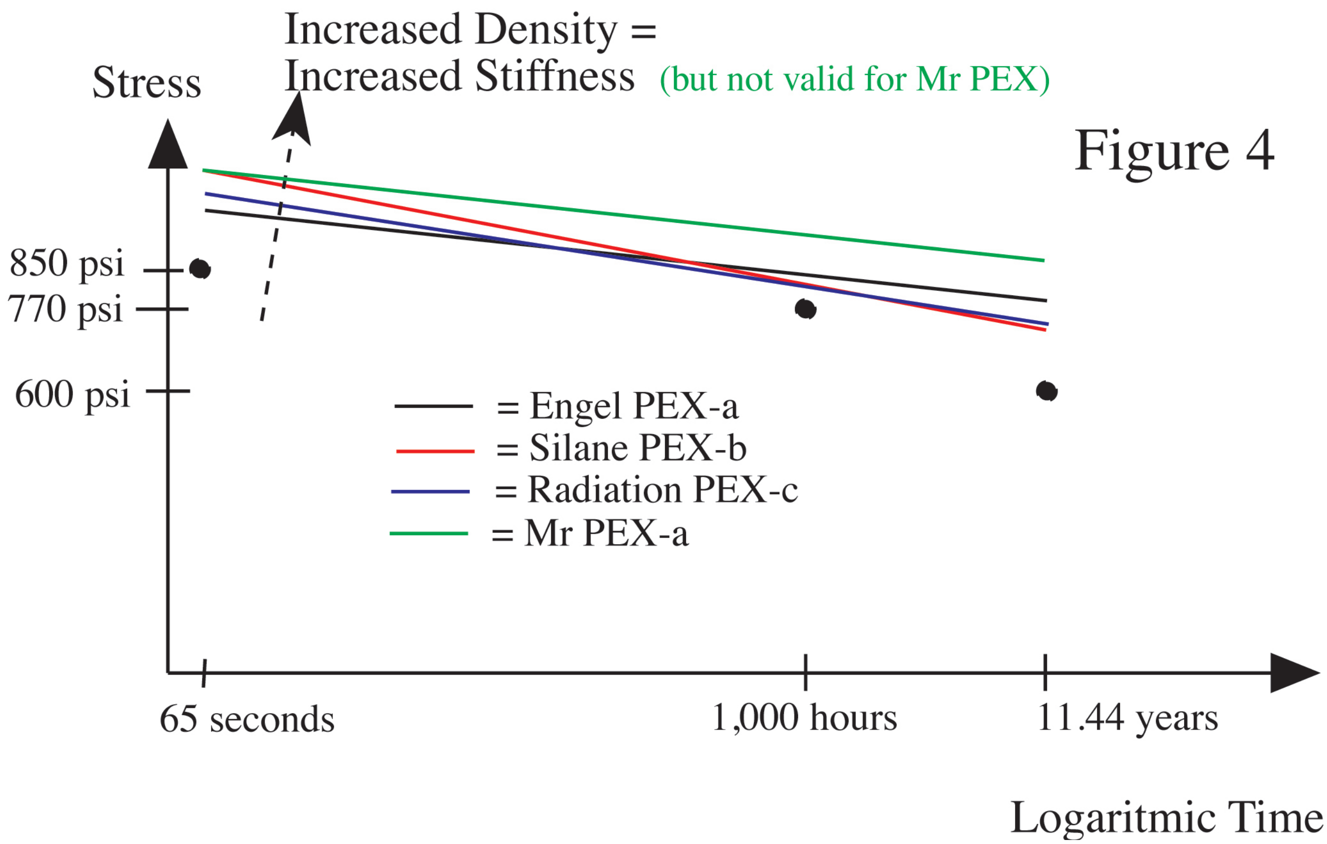

Figure 4

Figure 4 displays my experience regarding the Long Term Strength of different PEX makes at 180°F. (Slight deviations may be at hand for different makes.)

You can see three black dots in the chart. These represent the ASTM F 876/877 strength requirements. The dot at left is the Burst Pressure strength requirement. The one in the middle is the Sustained Pressure requirement. The one at right is the Pressure Rating requirement (see also ASTM D 2837 and/or PPI-TR3). If we made a straight line through the left and right dots we can see that the middle dot is at a considerable higher level than that line. That means that this is the most difficult control point to meet. That is the point that will decide the exact composition of the PEX material to be selected for each process.

Let's disregard the green line for now and compare the other three. The black line (Engel PEX-a) has the smallest slope of the three. That means that this material can have lesser density than the other two and still meet the strength control point at 1,000 hours. And be somewhat more flexible. Radiation crosslinked has bigger slope and needs higher density to "make it." And Silanes slope is biggest and needs the highest density. And becomes the stiffest material.

Now we see the green Line representing Mr PEX® Tubing. Here the same relation between strength and density is not valid any more. That is because many of the PEX molecular chains are oriented around the tubing. In the same direction as the stress. So a much lower density material will still be able to hold higher stress. A much more flexible material. The slope of the Long Term Strength line is little—typical for PEX-a materials.

The strength is still quite much higher than other materials for all long term times. Possible around the same as Silane for very short times.

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MrPEX® SYSTEMS

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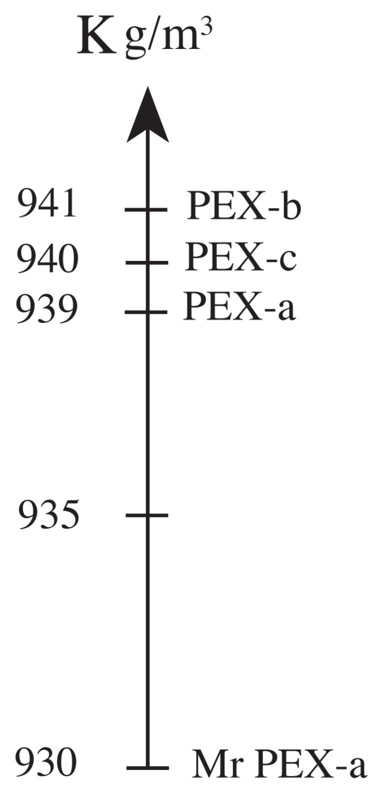

Figure 5

Figure 5 outlines the difference in Density for the four materials discussed. As you can see there is a vast difference between Mr PEX® Tubing and the others. I believe you have noticed the difference in flexibility between conventional PEX a, b, and c. Since density and stiffness follow virtually proportionally—you can SEE the flexibility of Mr PEX® Tubing.