Heat Exchanger IRIS Wall Thickness And Gumbel Smallest Distribution

Paul Barringer, P.E.
Barringer & Associates, Inc.
P.O. Box 3985
Humble, TX 77347-3985

Phone: 281-852-6810
FAX: 281-852-3749

Email: hpaul@barringer1.com
Web: http://www.barringer1.com

January 24,2002

What's The Issue? How To Resolve?

- Heat exchanger is 17 years old—460 tubes
- At turnaround eddy current wall thickness inspection occurred—we're worried
- Did an IRIS inspection on 10% of tubes—now we're more worried—what does the data say?
- Retube now? Retube next turnaround in 3 years (age 20 years)? Retube at second turnaround in 6 years (age 23 years)?

Time Issues

What Are Cost Consequences?

- Failure is dependent on outside temperatures:
  - Summer failure = $750,000 lost margins & retube
  - Fall failure = $500,000 lost margins & retube
  - Winter failure = $100,000 lost margins & retube
  - Spring failure = $250,000 lost margins & retube
- Another key issue is environmental impact along with the cost issues if failure occurs

Money Issues

Why Did They Inspect?

- Rule of thumb for this facility-
  - Inspect tubes if wall thickness has been reduced by 1/3, i.e. from 0.083" to 0.055"
  - Consider retubing heat exchangers when tube wall thickness has been reduced to ½ of original wall thickness, i.e. from 0.083" to 0.0415"
- This exchanger has environmental concerns

Eddy Current vs IRIS Inspection

- Eddy current inspection is a quick and inexpensive inspection of each tube—min wall is reported for each tube
- IRIS inspection is a more detailed and more expensive inspection with a rotating head ultrasonic tool—min wall is reported for each tube and tube ID's must be very clean

What Did IRIS Inspection Find?

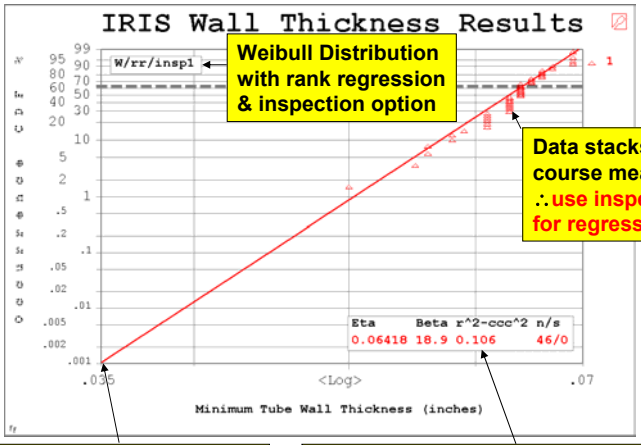
- The minimum wall thickness report shows:

Wall*qty	
0.050*1	**0.063*9**
0.055*1	**0.064*9**
0.056*2	**0.065*4**
0.058*2	**0.066*5**
0.059*1	**0.067*2**
0.061*6	**0.069*4**

Wall thickness measured in inches

- **Minimum allowed wall thickness is 0.036"**

Competing Models: Weibull or Gumbel Distributions?



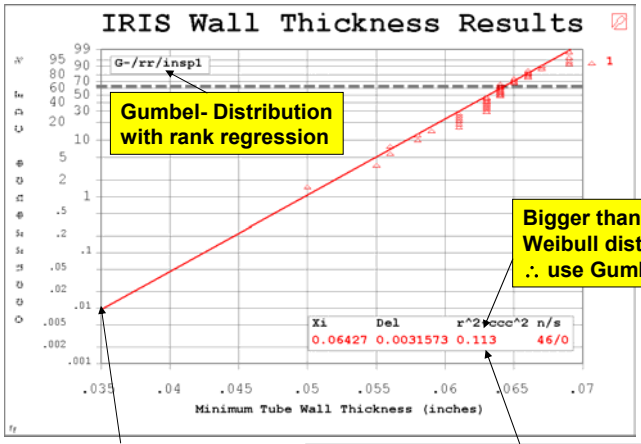
Weibull Distribution with rank regression & inspection option

Data stacks from course measurements ∴use inspection option for regression

Small risk of wall thickness less than min allowed

R= Coefficient of regression ccc= critical correlation coefficient

Competing Models: Weibull or Gumbel Distributions?



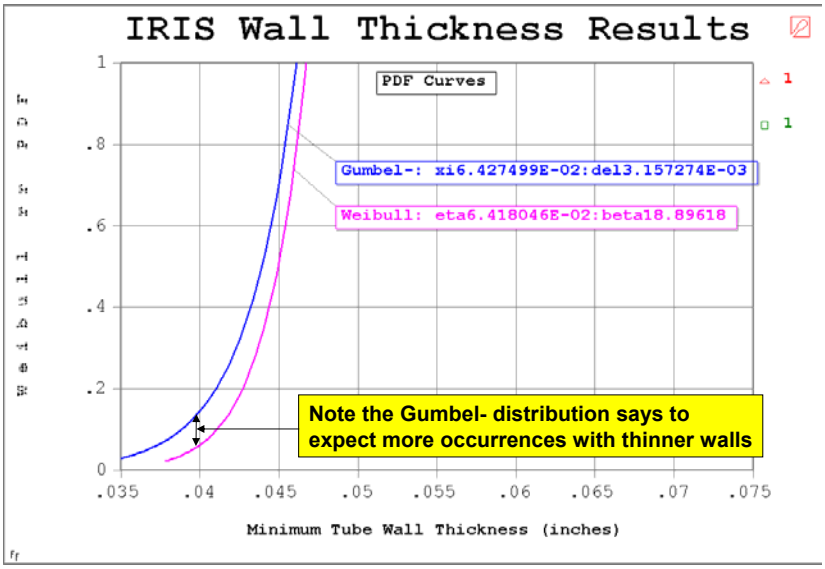
Gumbel- Distribution with rank regression

Bigger than for Weibull distribution ∴ use Gumble-

Higher risk of wall thickness less than min allowed ∴more conservative

R= Coefficient of regression ccc= critical correlation coefficient

PDF Curves



Why Gumbel Lower Distribution?

$$F(x) := 1 - e^{-e^{\frac{(x-\Psi)}{\delta}}}$$

Emphasizes results in the smaller sizes
Use for minimum wall thicknesses, etc.

Extreme Value
Gumbel **Smallest** or Lower Extreme
Cumulative Distribution Function

$$F(x) := e^{-e^{\frac{-(x-\Psi)}{\delta}}}$$

Emphasizes results in the larger sizes
Use for gust loads and floods, etc.

Extreme Value
Gumbel **Largest** Extreme
Cumulative Distribution Function

The Gumbel smallest extreme value CDF is given by:

$$F(t) = 1 - e^{-e^{\frac{(t-\psi)}{\delta}}}$$

Rearanging the equations to read

$$1 - F(t) = e^{-e^{\frac{(t-\psi)}{\delta}}} = \frac{1}{e^{e^{\frac{(t-\psi)}{\delta}}}} \quad \text{Or} \quad \frac{1}{1 - F(t)} = e^{e^{\frac{(t-\psi)}{\delta}}}$$

Taking the log of both sides you get:

$$\ln\left(\frac{1}{1 - F(t)}\right) = e^{\frac{(t-\psi)}{\delta}}$$

Again, taking the log of both sides you get:

$$\ln\left(\ln\left(\frac{1}{1 - F(t)}\right)\right) = \frac{(t - \psi)}{\delta} = \frac{t}{\delta} + \frac{\psi}{\delta}$$

Gumbel- Distribution has uniform X-axis

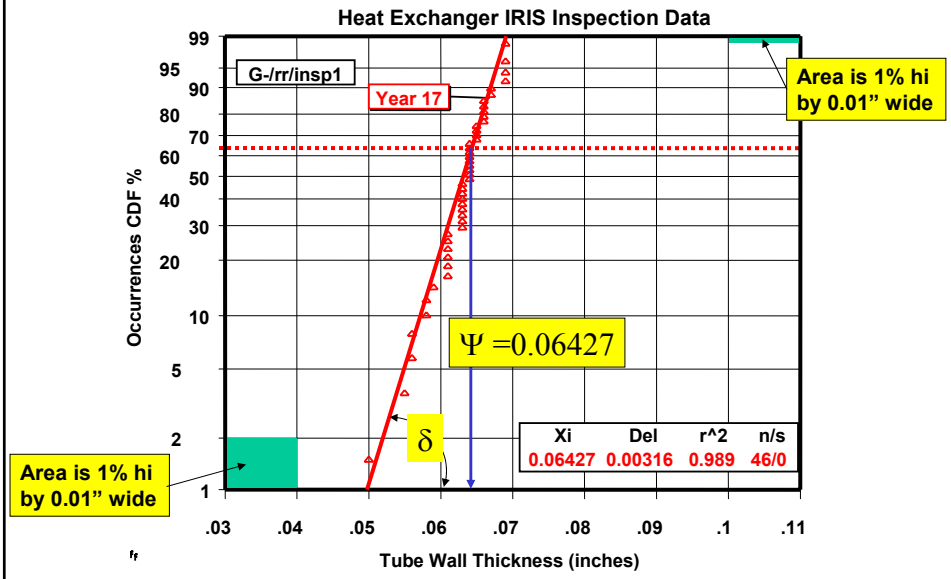
Same Y-axis

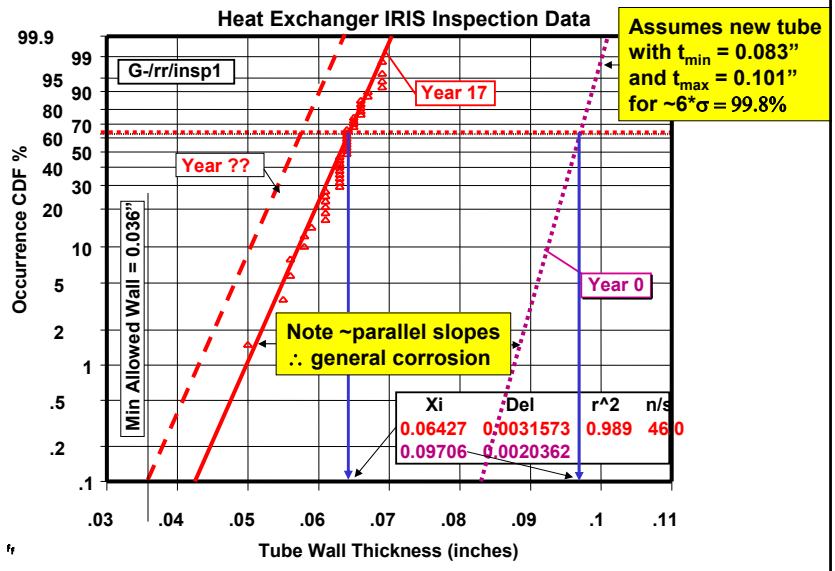
This has the equation form of y = mx+b for a straight line where the Y-axis is the same as for the Weibull distribution which has the following form for a straight line equation

$$\ln\left(\ln\left(\frac{1}{1 - F(t)}\right)\right) = \beta \cdot \ln(t) - \beta \cdot \ln(\eta)$$

Weibull Distribution has logarithmic X-axis

So you could get from the Gumbel smallest plot to the Weibull plot with some math complications.





Corrosion rate = (0.09706-0.06427)/17 = 0.00193"/yr

Retube Or Not Retube Now?

- At year 20 (next turnaround) the characteristic wall thickness will decline to 0.05848"
- The risk for falling below 0.036" min wall is 8.075E-04
- The $risk exposure = 8.075E-04*$750,000 = $606

Time & Money Issues Converge

- ∴ take the risk for running 3 more years **—do not retube now and run to TA at yr 20.**

Retube Or Not Retube To Reach Yr 23?

- At year 23 (2nd turnaround) the characteristic wall thickness will decline to 0.0527”
- The risk for falling below 0.036” min wall is 5.036E-03

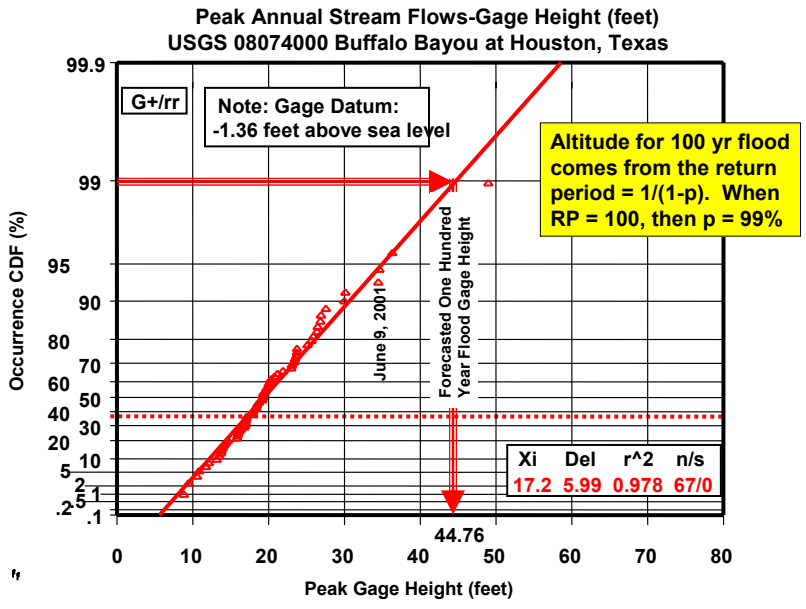
Time & Money Issues Converge

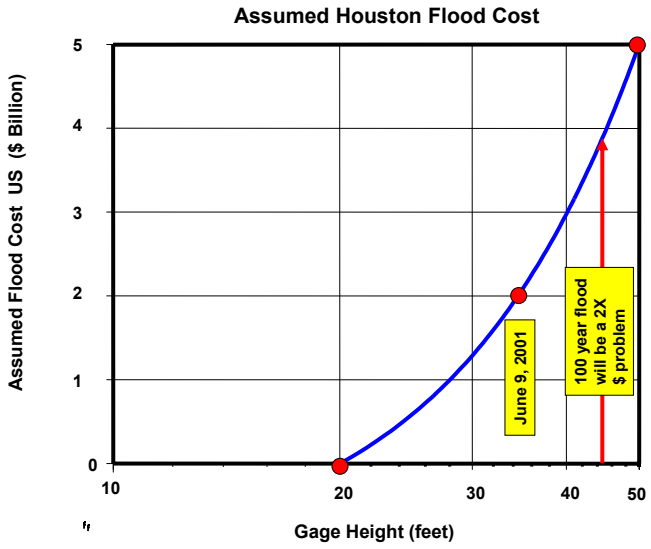
- The $risk exposure = 5.036E-03*$750,000 = $3,777 which is OK for business risk but maybe not OK for environmental risk
- **∴ retube at year 20 if risk adverse, run to year 23 if the organization is a risk taker**

Now, For Grins

- Consider a case of the Gumbel **larger** distribution for Houston

Remember June 9, 2001?





Want More Details?

- Got to **http://www.barringer1.com**
- Look at **Problems of the Month**
- For software to make the calculations, look at **WinSMITH Weibull** (which also includes Gumbel large and small distributions)
- Also look at the biography of **Dr. Weibull** and **Dr. Abernethy** (the world's leading expert in Weibull analysis—formerly with Pratt & Whitney Engines)
- Dr. Weibull got many of his ideas on extreme values while working at Bofors Steel in Sweden—you can see Bofors antiaircraft guns at the **Museum of the Pacific** in Fredricksburg, TX.