Newfangled Ideas in LTC DGA

(adapted from talk given at 2008 Cascade User Conference)

By Dr. Jim Dukarm

Delta-X Research Inc.

Victoria BC Canada

Statistical methods in LTC DGA

- Recently there has been actual progress in the application of statistical methods to DGA for LTC's, OCB's, and regulators.

- The latest draft of the IEEE C57.139 Guide for DGA of Load Tap Changers is based on the new method.

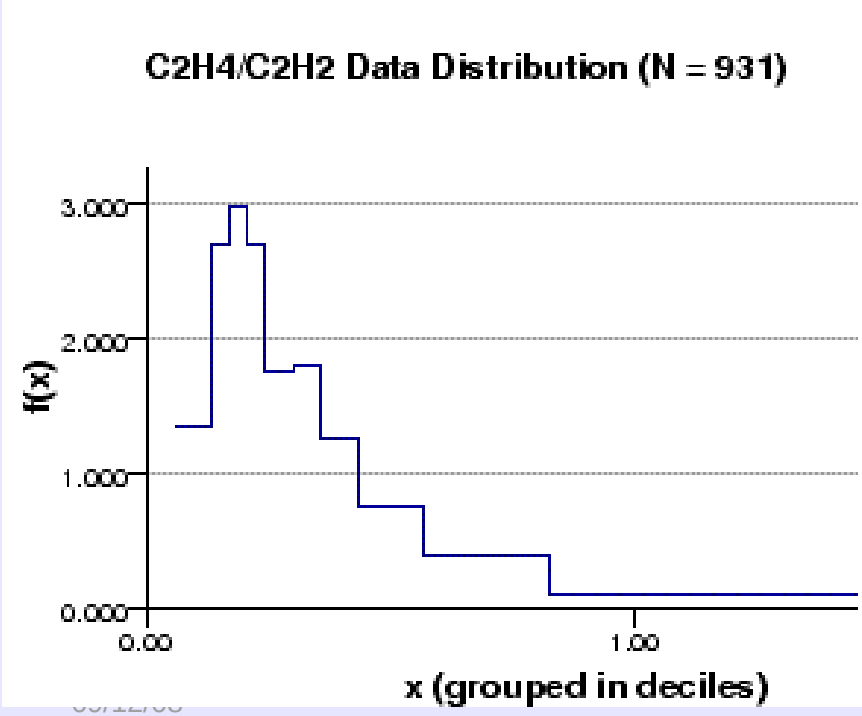
Statistical methods in LTC DGA

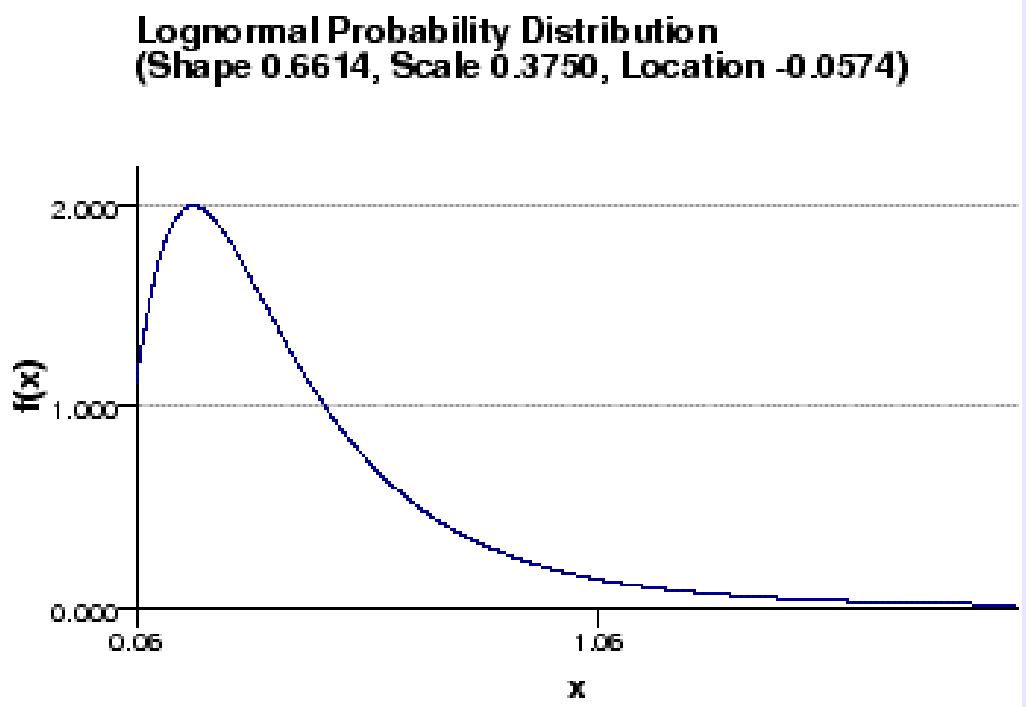
- **Dissolved-gas concentrations and gas ratios are both needed for LTC fault detection.**
  - Gas ratios -- especially ethylene/acetylene -- tell us when heat gases are being formed at an unusually high rate compared to the main arcing gas, acetylene. Usually this is because of arcing contact degradation or coking.
  - Usually LTC gas concentrations are unimportant, but there are cases where mechanical or other faults cause abnormal gas production without abnormal gas ratios.

Statistical methods in LTC DGA

What values of ethylene/acetylene are "abnormal"?

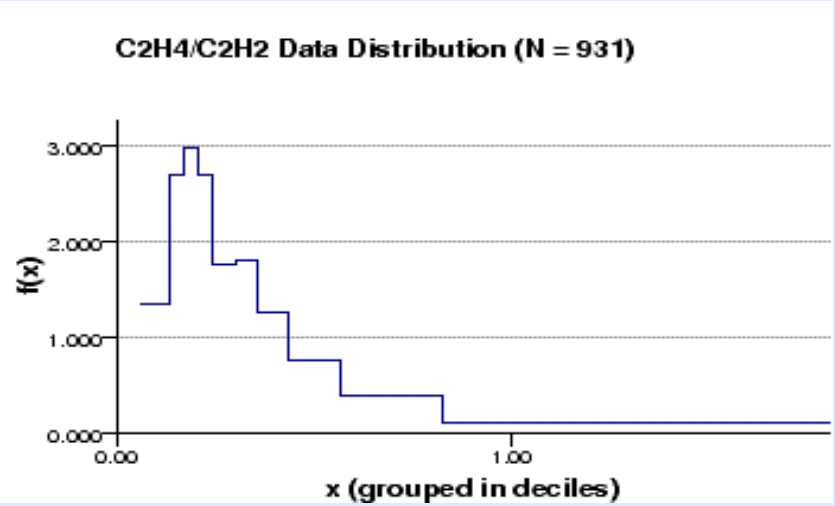
- Ethylene/acetylene is usually very low, but can infrequently be high, in a fault-free LTC.
- The distribution of ethylene/acetylene values for a population of fault-free nonvacuum LTC's fits a **log-normal probability distribution**.

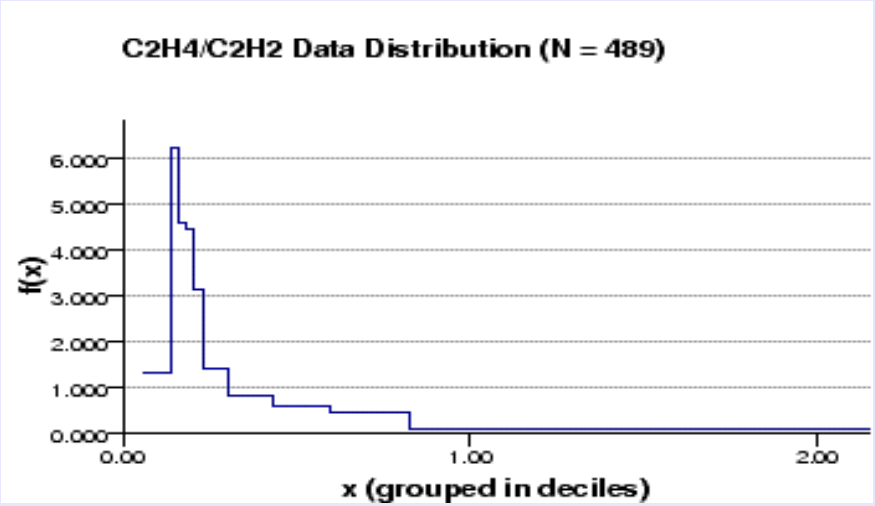


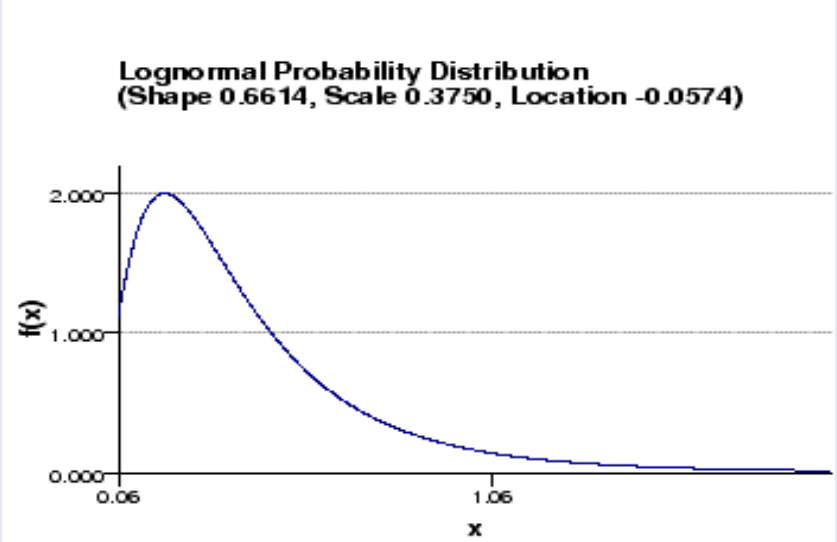


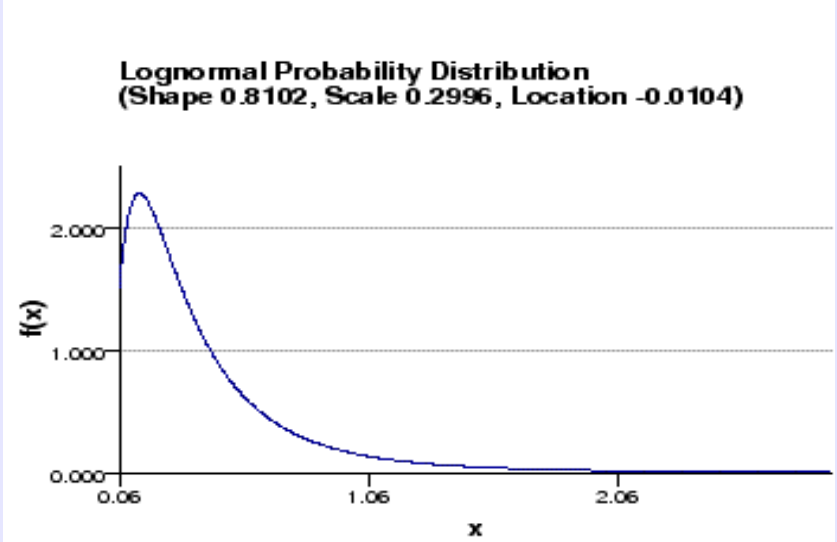
Statistical methods in LTC DGA

- **Different LTC models/types typically have different-looking distributions of gas ratios. Each gas ratio has a different distribution of values from the other ratios. This procedure has to be applied separately for each of them.**



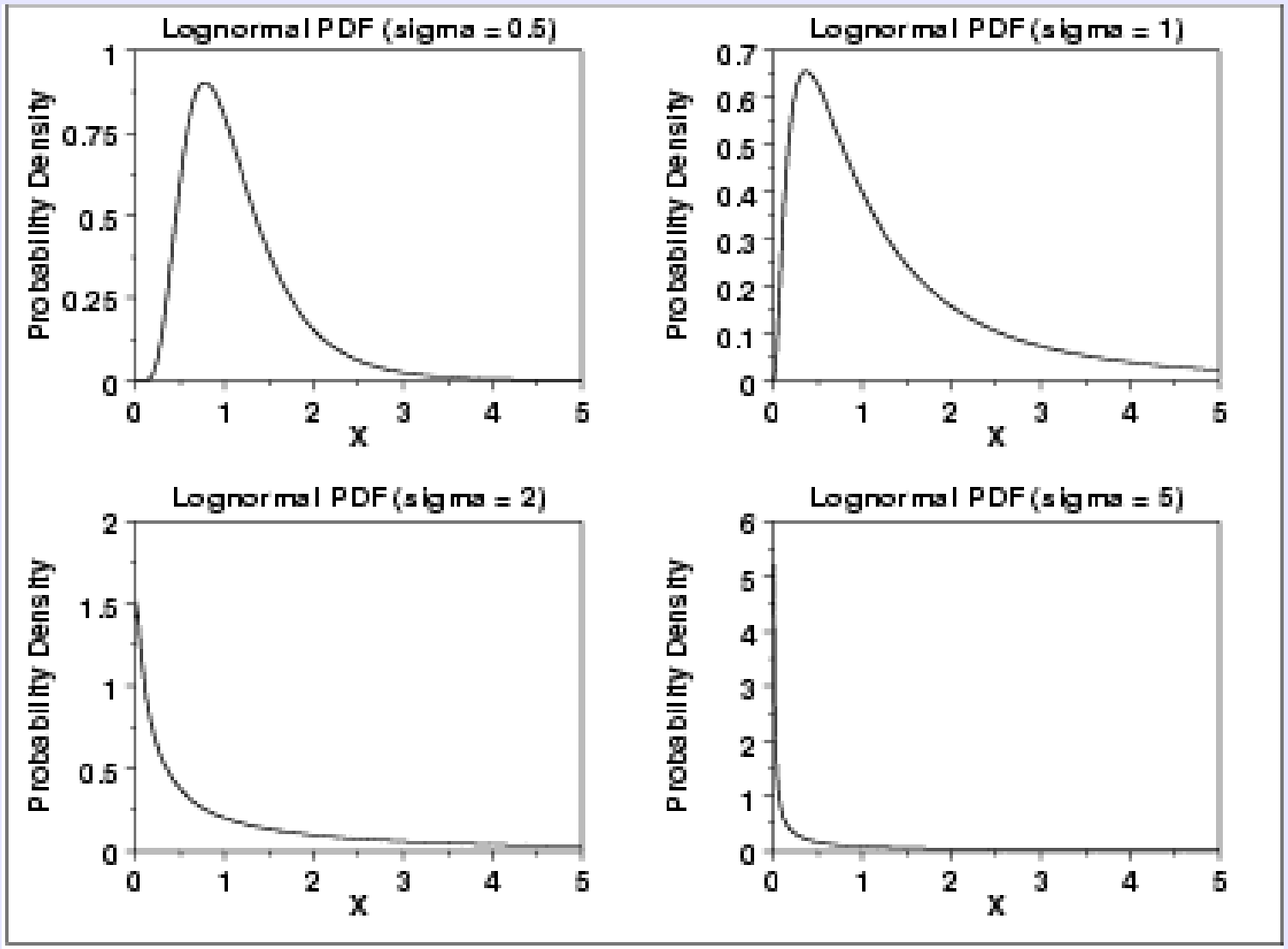






Statistical methods in LTC DGA

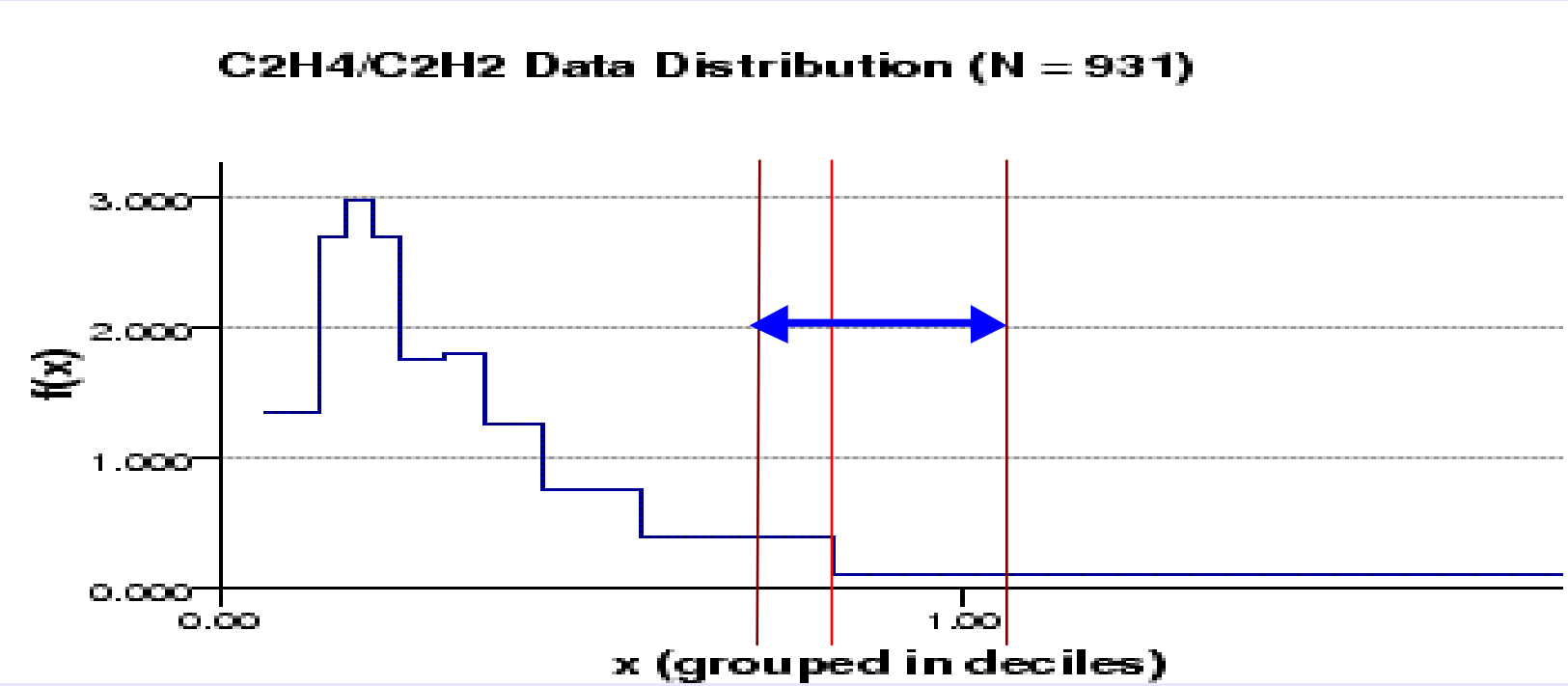
- There are a lot of different shapes of lognormal distributions:



Statistical methods in LTC DGA

What values of ethylene/acetylene are "abnormal"?

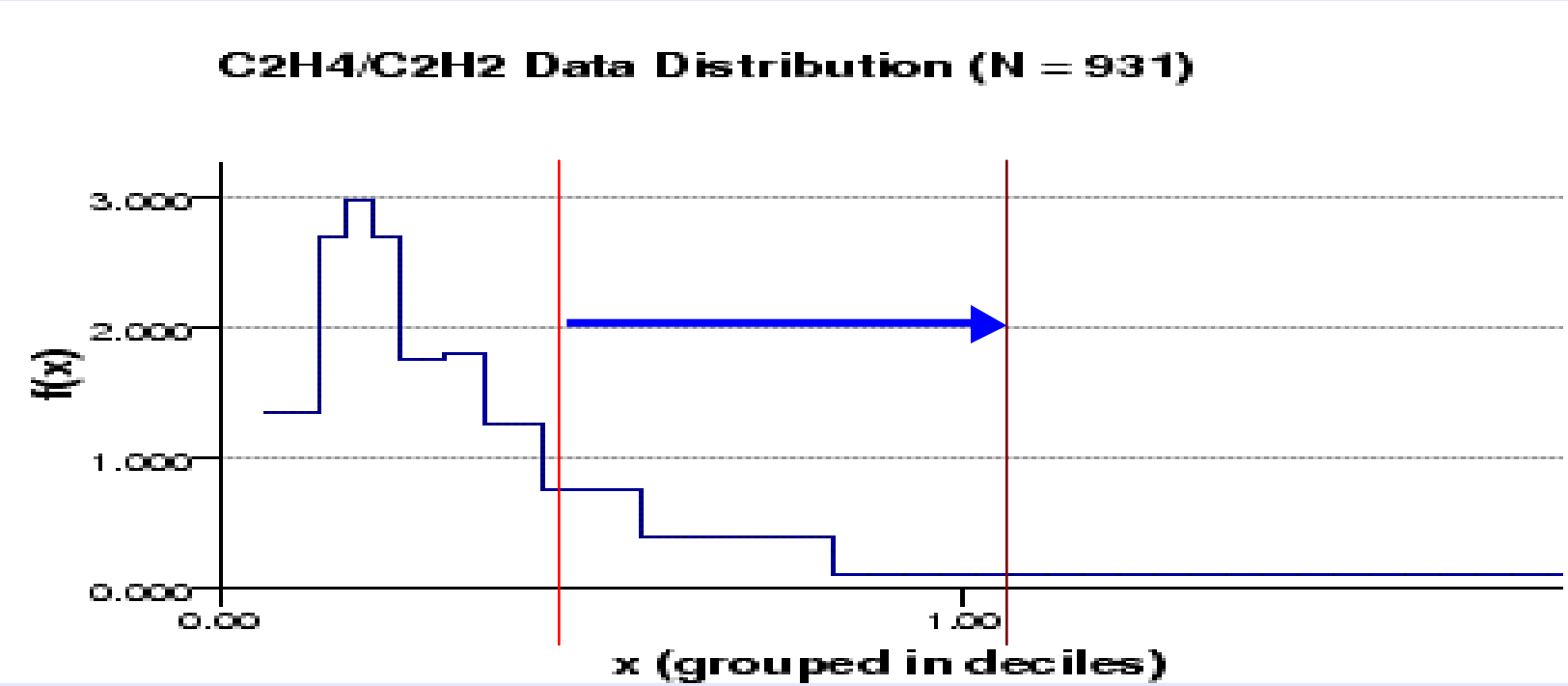
- The use of 90th percentiles of data to define ratio limits is not a good idea. (The upper percentiles of these ratios have high variance -- they are not reliable for defining what in general would be an unusually high value for the ratio).



Statistical methods in LTC DGA

What values of ethylene/acetylene are "abnormal"?

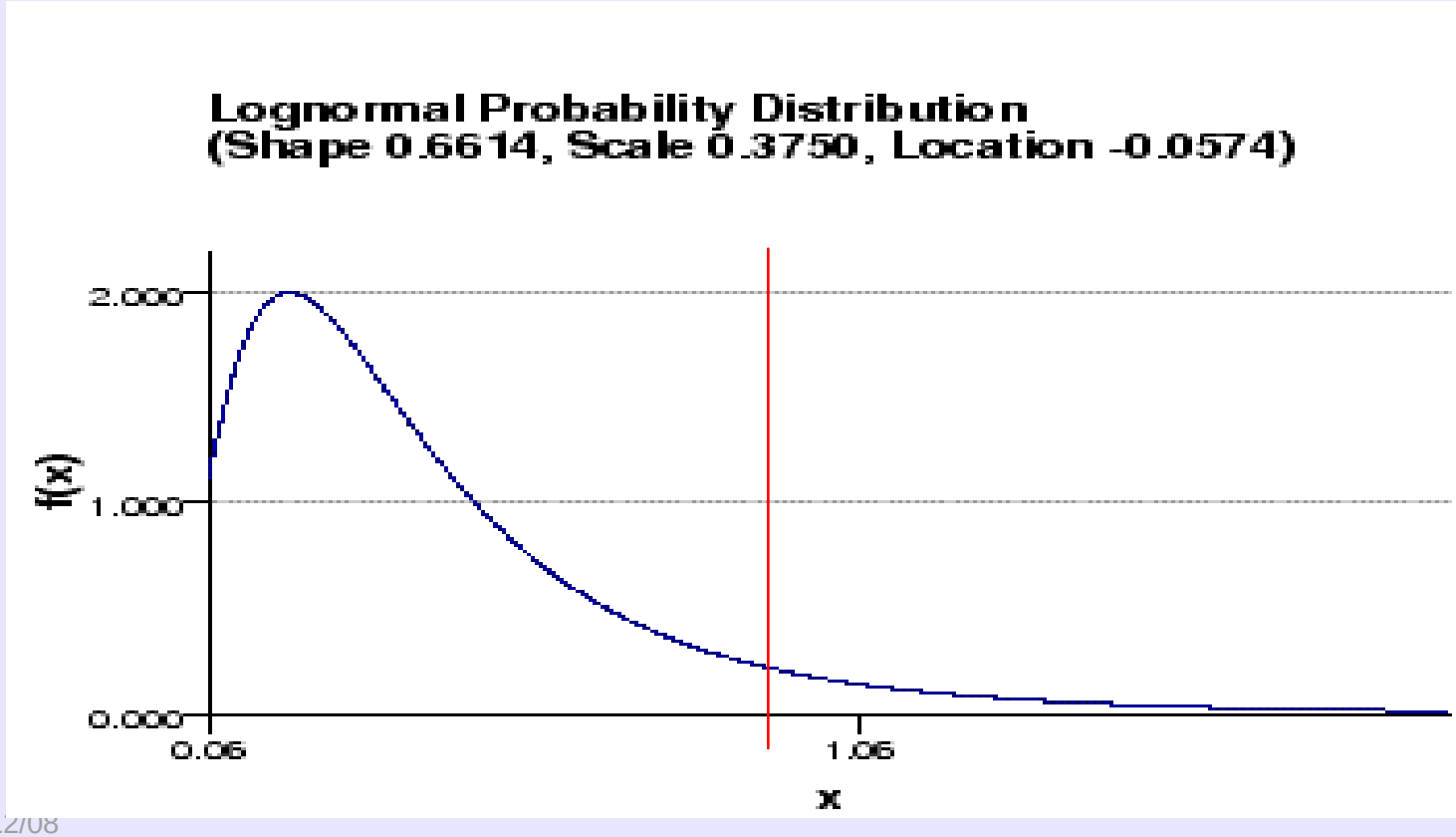
- The "mean plus 1.96 standard deviations" formula is no good for defining fault detection limits in skewed data distributions.



Statistical methods in LTC DGA

What values of ethylene/acetylene are "abnormal"?

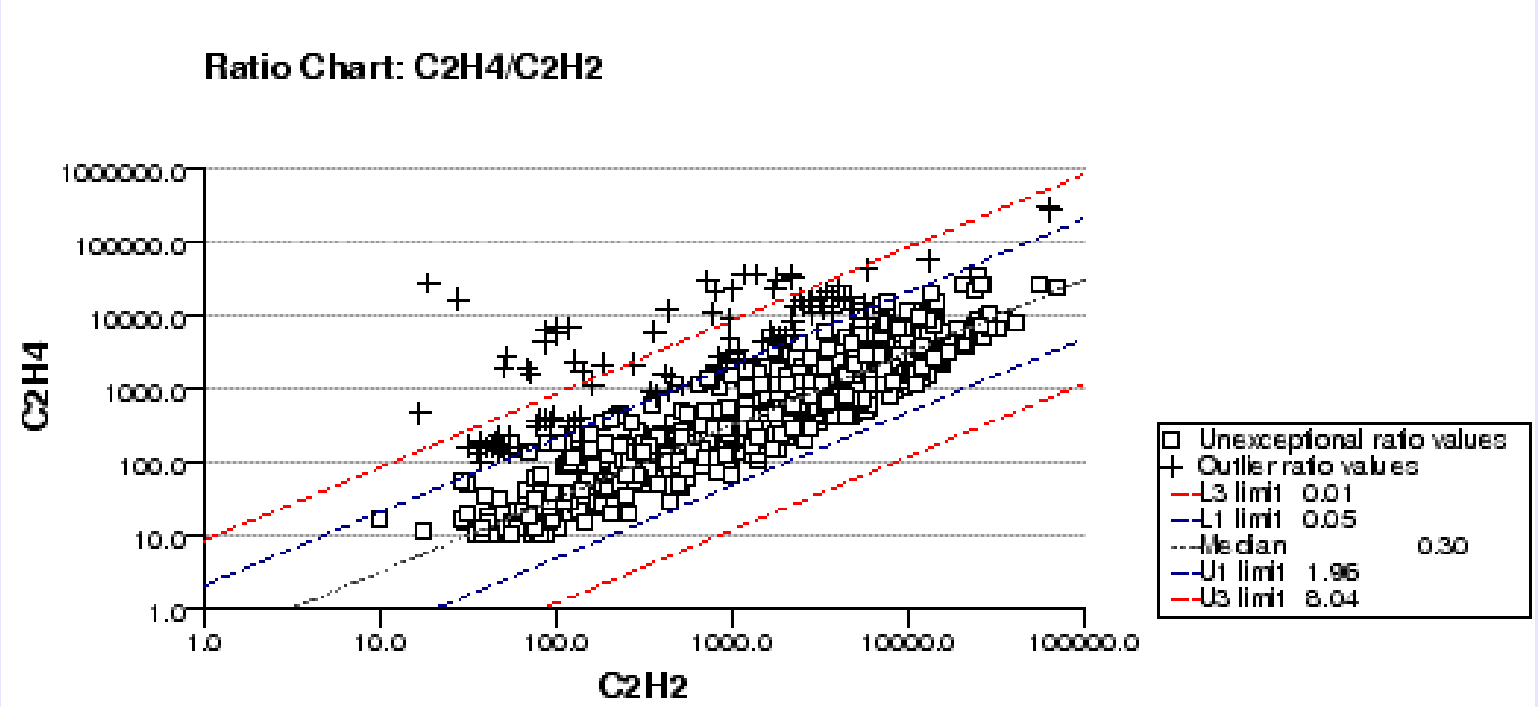
- The trick is to figure out which lognormal probability distribution fits the data best and use its "percent points" for defining limits.



Statistical methods in LTC DGA

Fitting a lognormal distribution to the gas ratio data

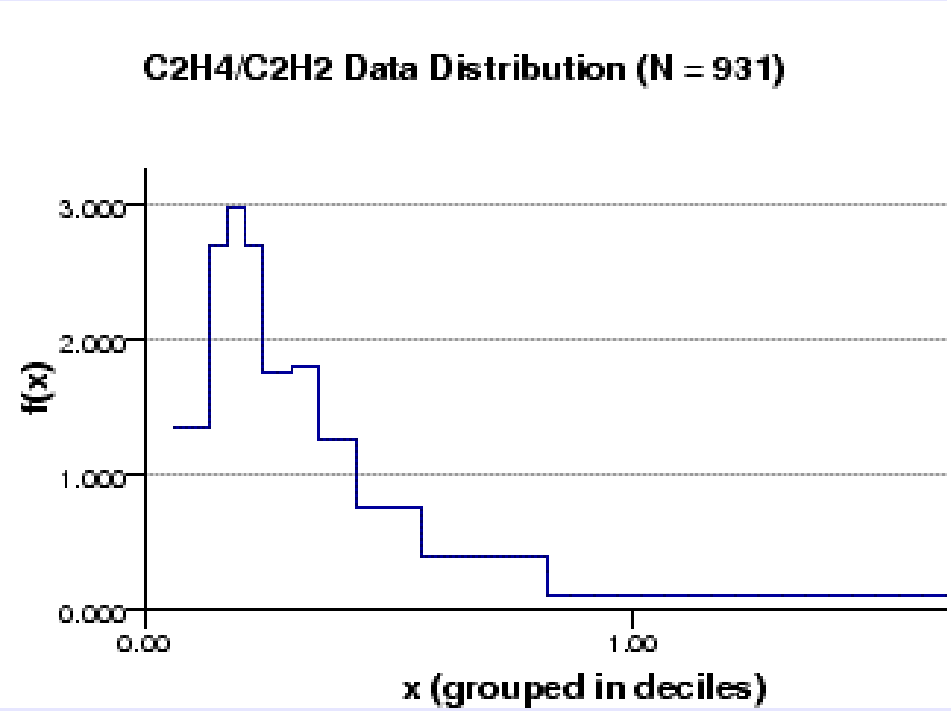
- Many of the highest ratio values found in the data are fault-related, and we don't want them included when we try to fit a lognormal model to the data.
- Ratios calculated with very small gas concentration values are also too wonky and have to be excluded.

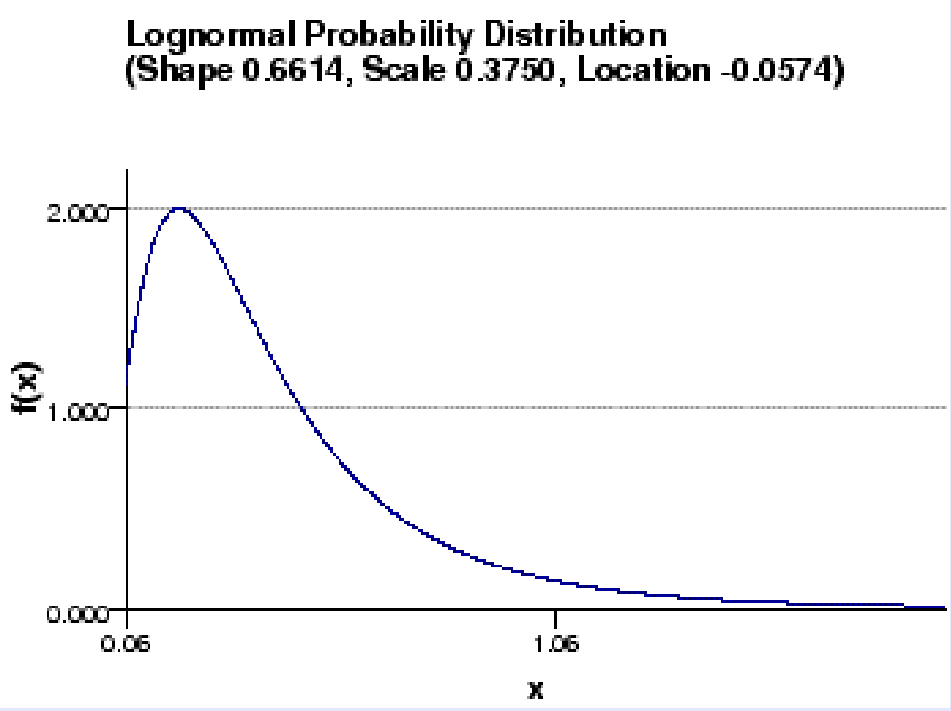


Statistical methods in LTC DGA

Fitting a lognormal distribution to the gas ratio data

- After brutalizing the data so much, the textbook formulas for fitting the lognormal distribution to the data are not applicable, so we have to use alternates. But "luckily" the fit is usually pretty good.

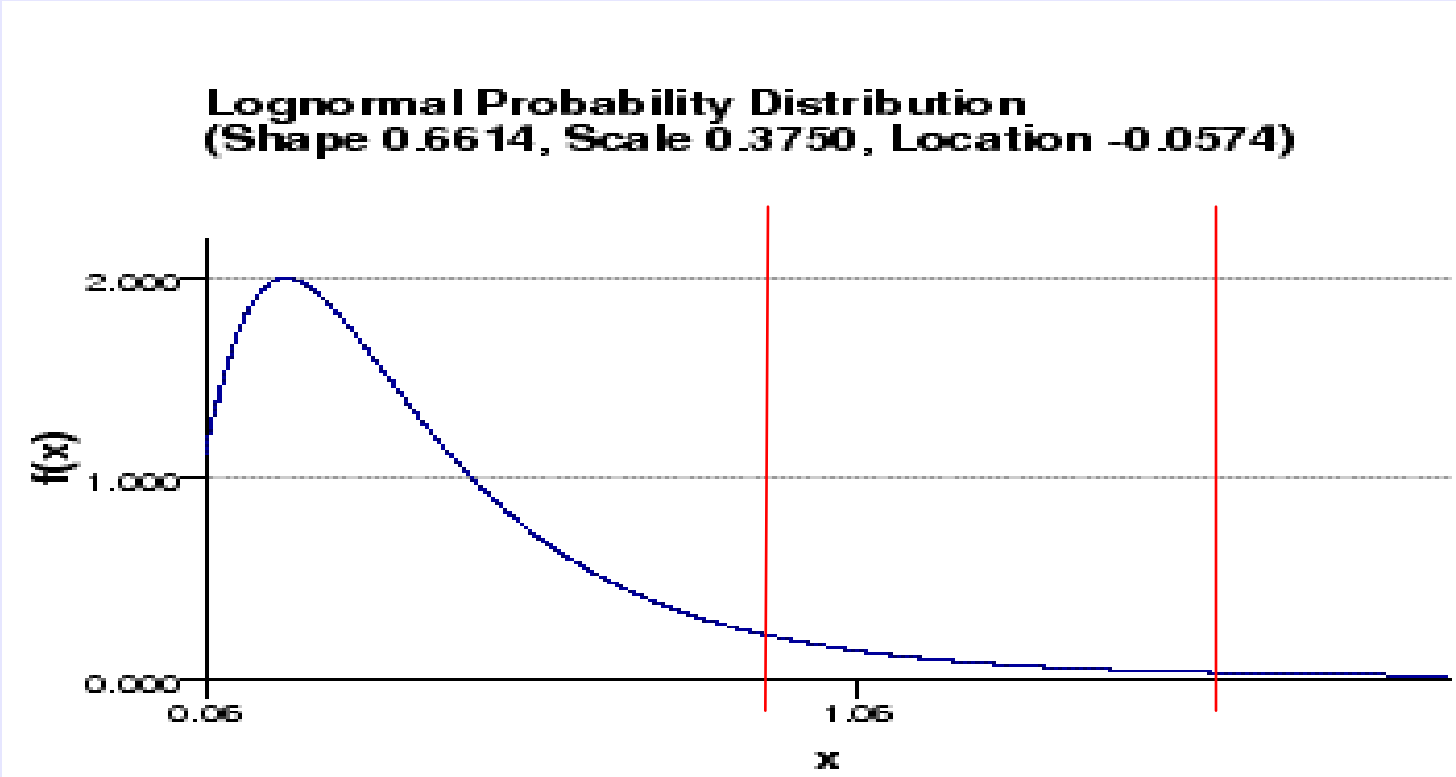




Statistical methods in LTC DGA

What values of ethylene/acetylene are "abnormal"?

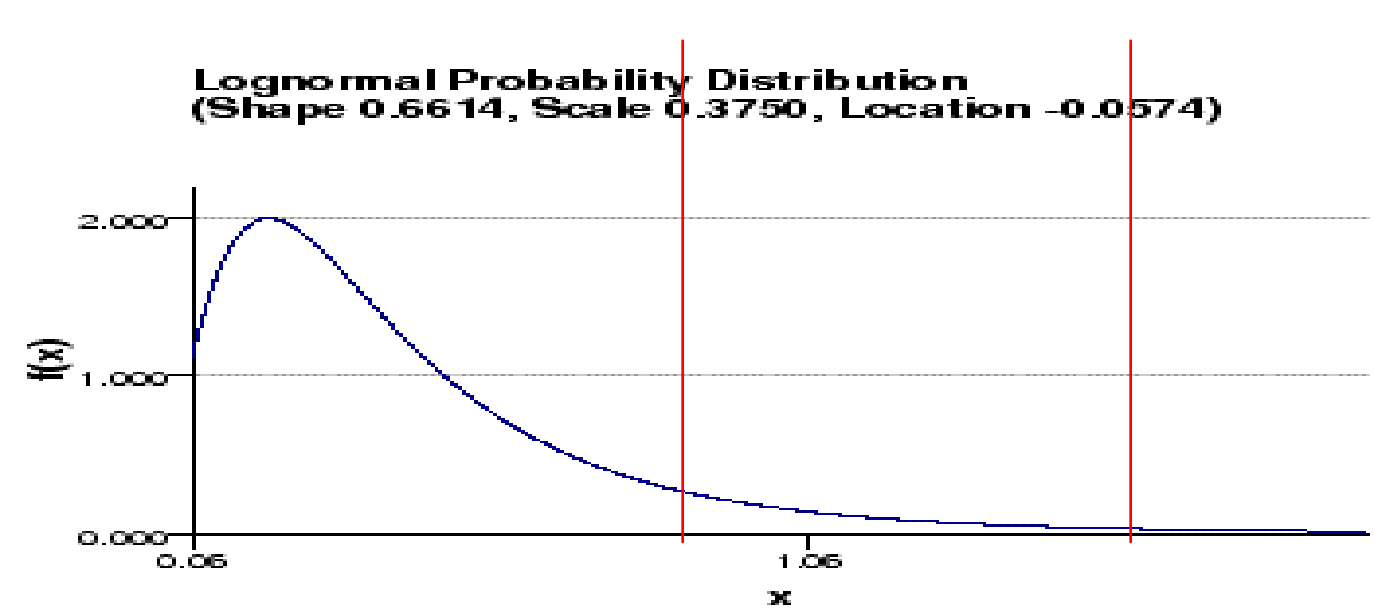
- The trick is to figure out which lognormal probability distribution fits the data best and use its "percent points" for defining limits.
- We use the 0.95, 0.99, and (optionally) 0.999 points as limits.



Statistical methods in LTC DGA

Statistical meaning of the percent point limits

- The lognormal distribution we fitted is an idealized model of all the ethylene/acetylene ratio values we would get from **healthy** LTC's in this particular population.
- If we test an LTC and find its ethylene/acetylene value exceeds the C0.95 limit, there is only a 5% probability that this value is from a healthy LTC.



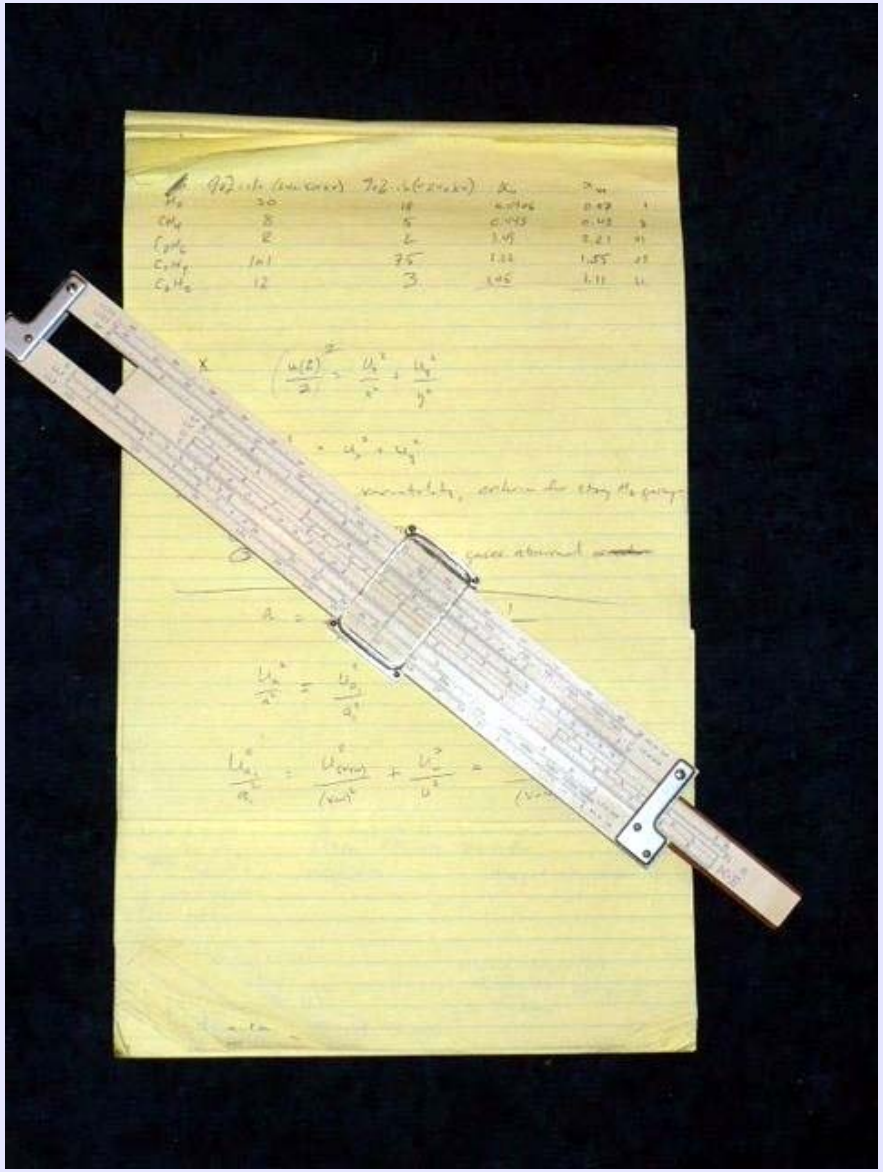
Statistical methods in LTC DGA

The really, really good news . . . .

- This method (for both gas ratios and gas concentrations) can be written down as a simple 10-step spreadsheet-based procedure.
- The procedure, plus some example limits derived by this method, plus some case histories illustrating the effectiveness of the limits for fault detection, are to be included in the latest draft C57.139.
- In many cases the limit derivation procedure, or a simple variant of it, also produces reasonable limits for vacuum-type LTC's.

Questions and comments?

Then . . .



Now . . .