C57.104 Draft 11d

Evaluation of proposed gas-in-oil limits of Table 1 and section 7.3

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Proposed gas level

In Table 1 of section 6.1, the revised C57.104 present a set of ppm limit value for each combustible gases used for the classification of Type 1 transformer status (Normal, Caution, Warning)

In this statistical study of DGA, data from one laboratory is compared to the proposed limits

Proposed gas level

Source of Data:	DGA performed at GE Canada laboratory (Montreal)
Number of samples:	35240
Period covered:	May 1990 to October 2000
Source of samples:	North-East of North America, mixed sources (Industrial and Utilities), mixed population of breather and sealed type transformers of all size

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Proposed gas level

Methodology of analysis:

All sample of the period included in the study

- No discrimination for:
  - Transformer size
  - Sampling point
  - Utility VS Industrial
  - “Fault” VS “No fault”

Population is typical of a transformer Type 1 DGA result

Proposed gas level

Methodology of analysis:

For each gas, all samples were sorted by increasing value

A population curve was prepared
(% of total population <= x ppm Value)

% of population of DGA less than each proposed ppm limits was determined

Proposed gas level

Methodology of analysis:

Limit value used for this study were as follow (from draft 10):
Table 1 of section 6.1:

	H_2	CH_4	C_2H_2	C_2H_4	C_2H_6	CO	TDCG
Caution:	*100*	*120*	*2*	*50*	*65*	*350*	*700*
Warning:	*700*	*400*	*5*	*100*	*100*	*570*	*1900*

Section 7.3

Ratio CO_2/CO : 3 < normal > 10

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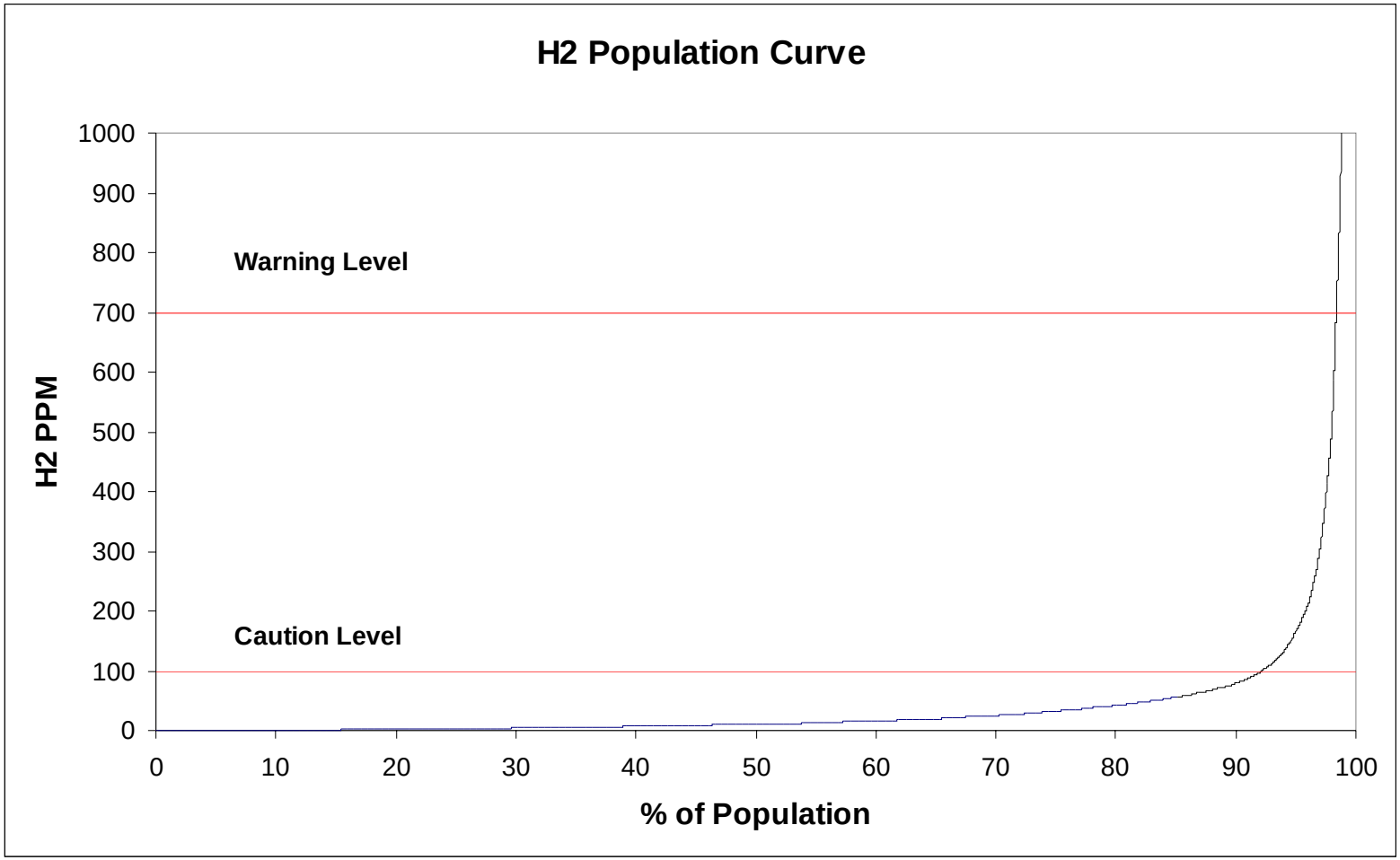
Population curve for H_2



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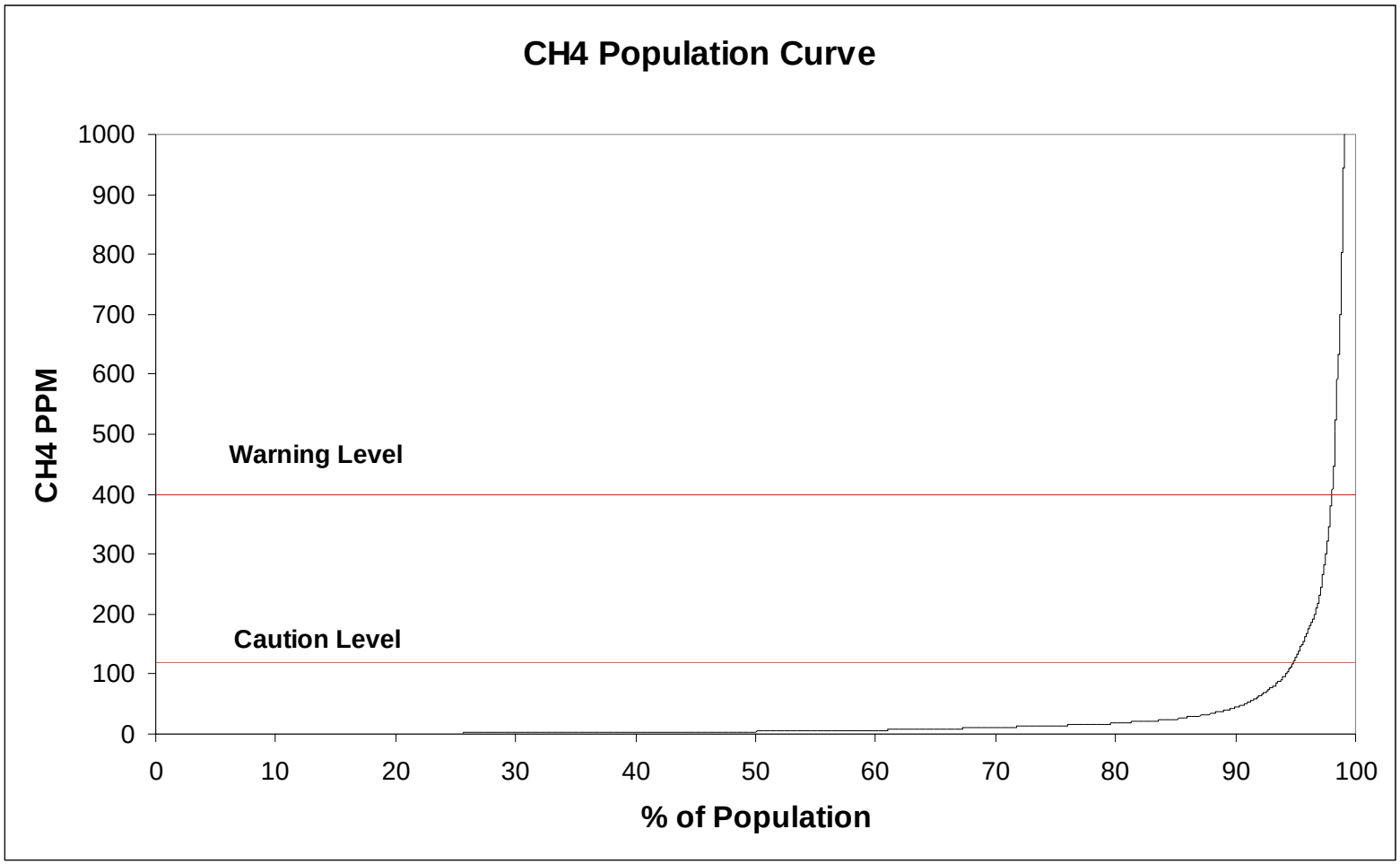
Population curve for CH_4



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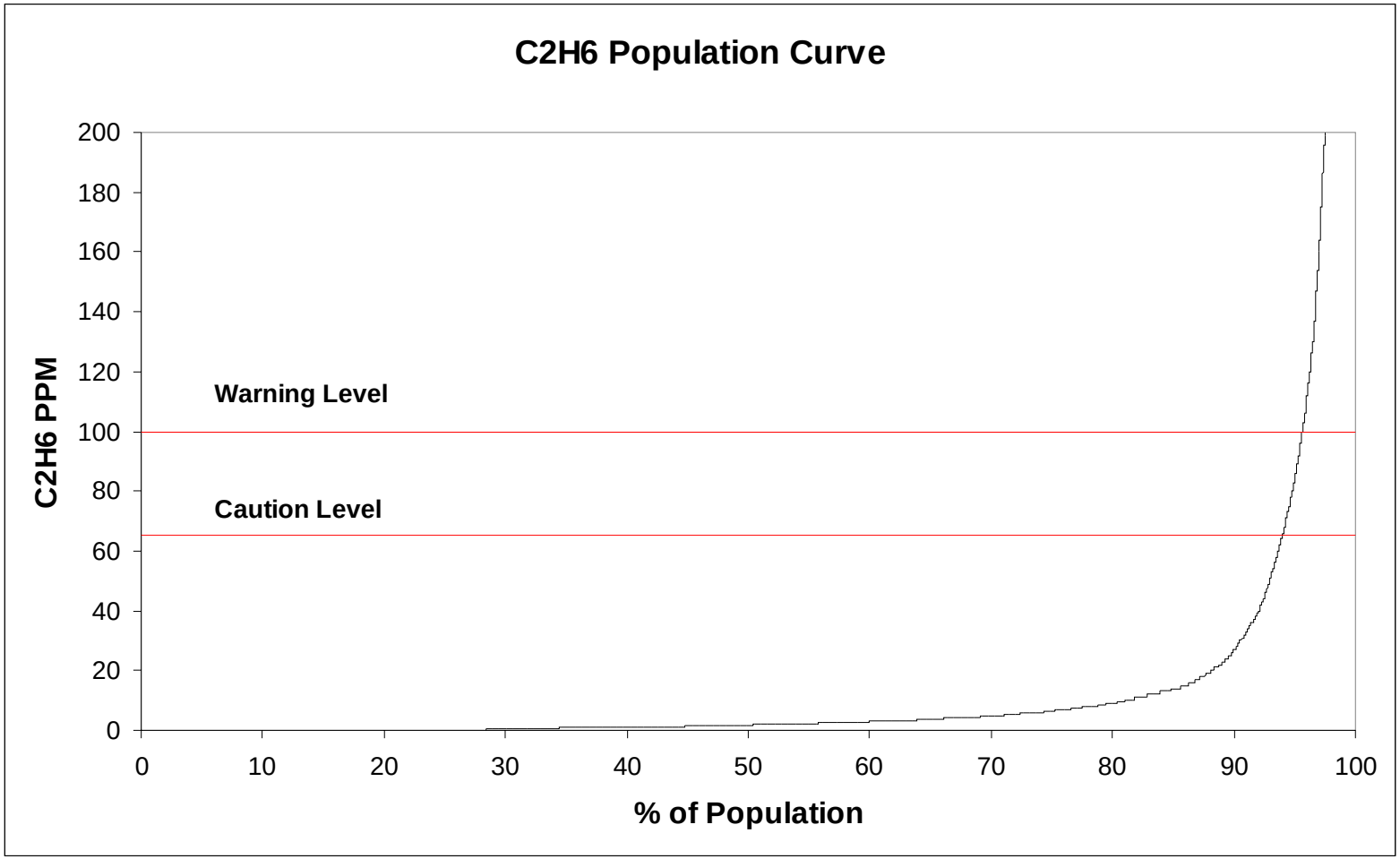
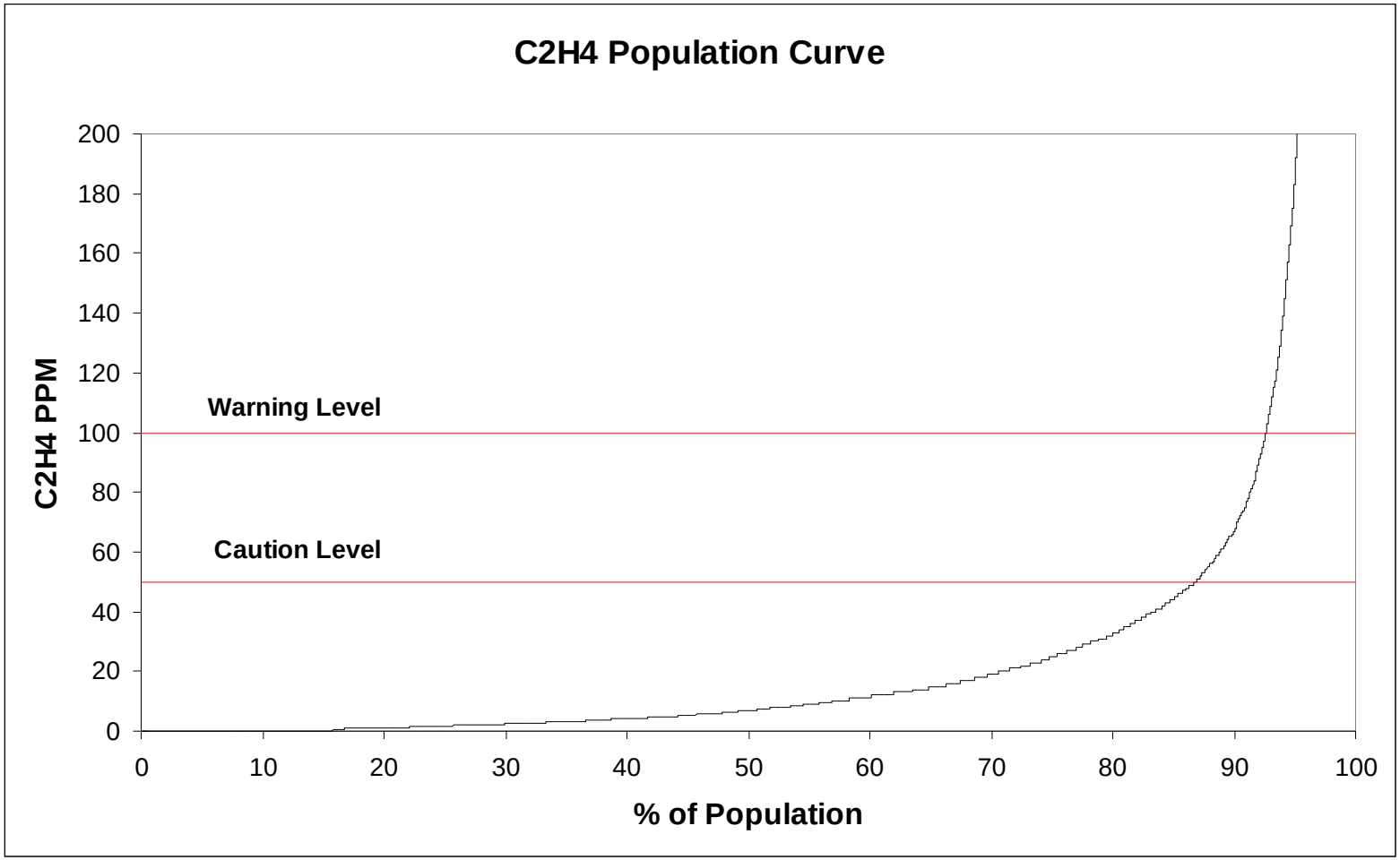
Population curve for C_2H_6



Population curve for C_2H_4



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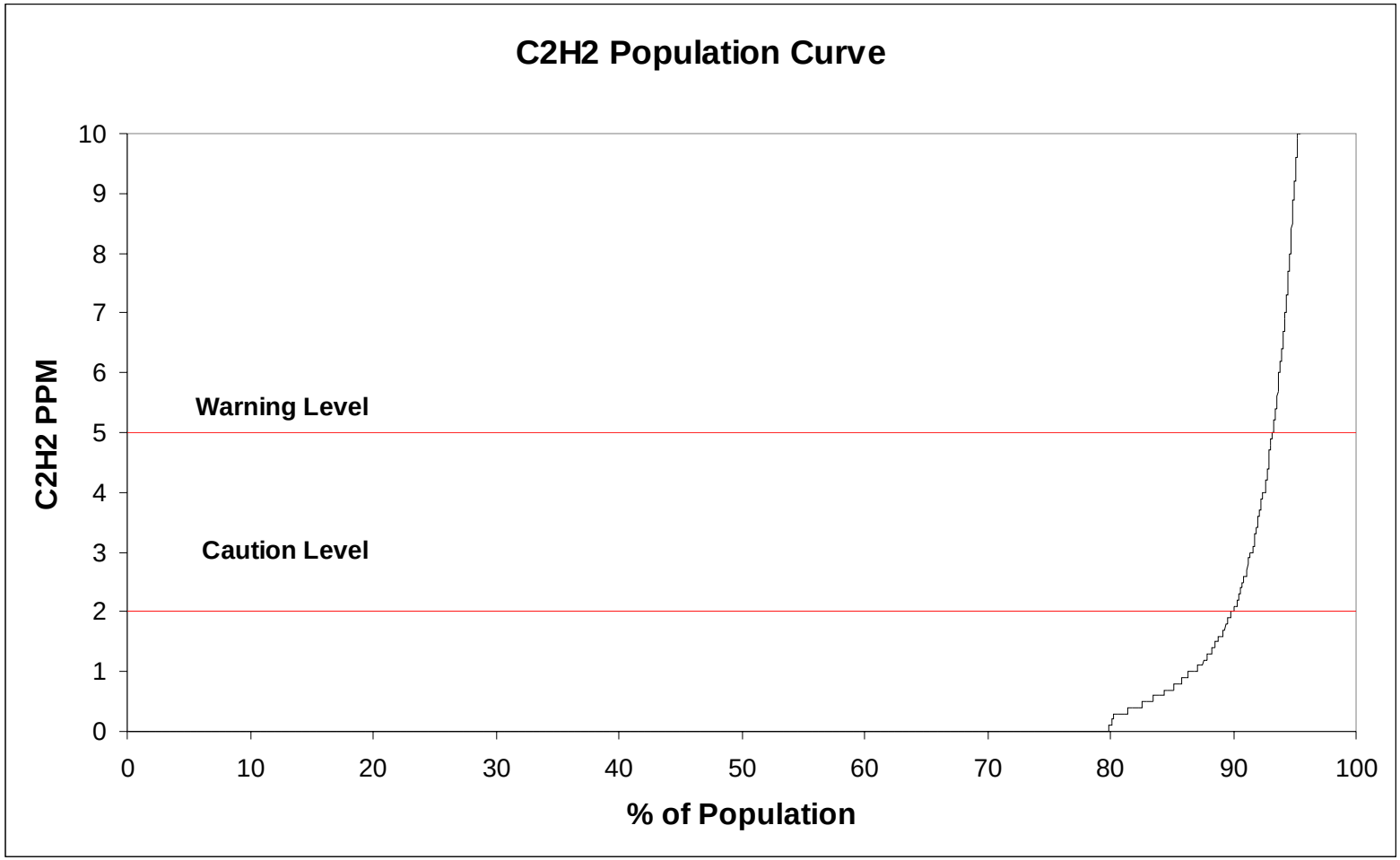
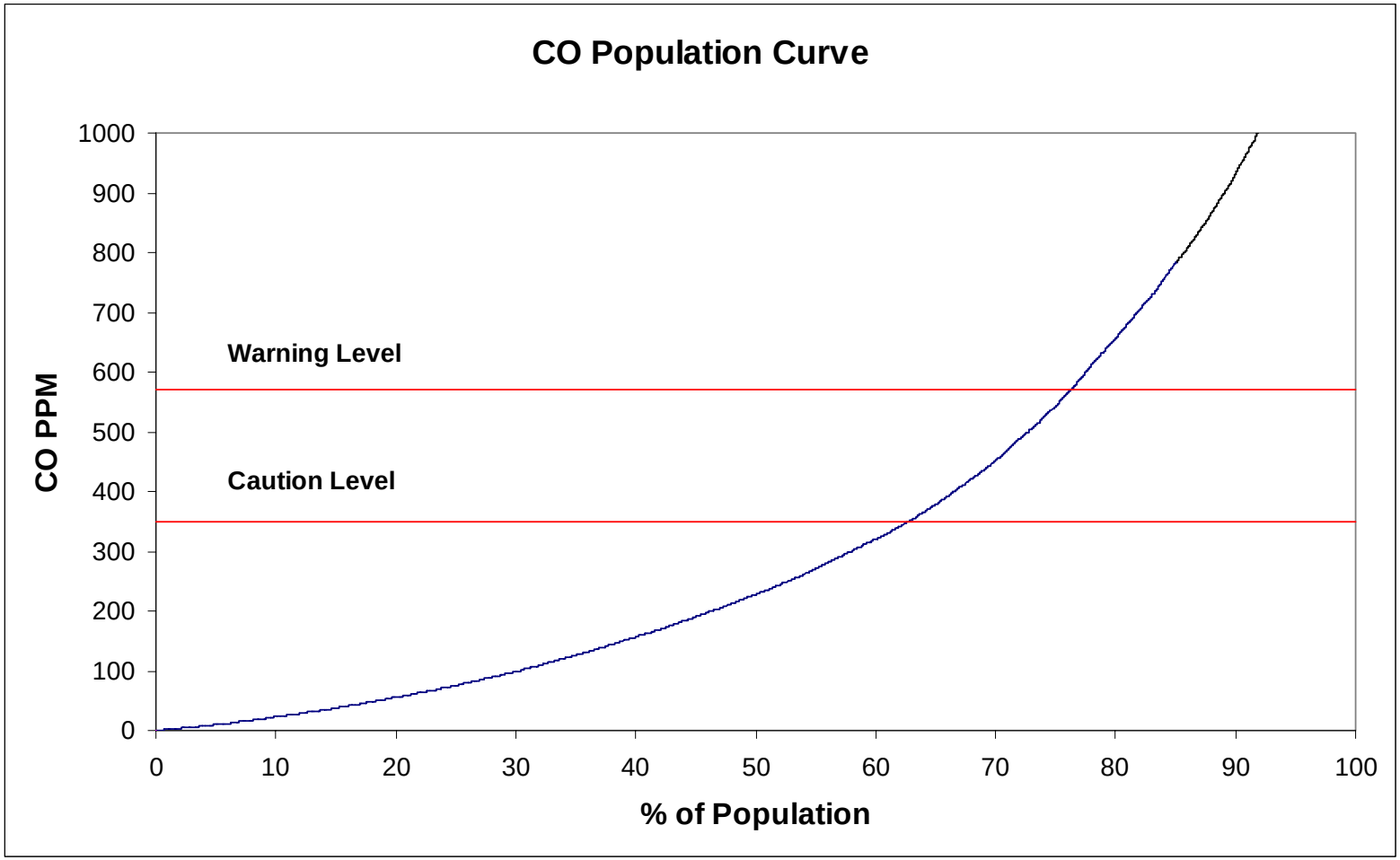
Population curve for C_2H_2



Population curve for CO



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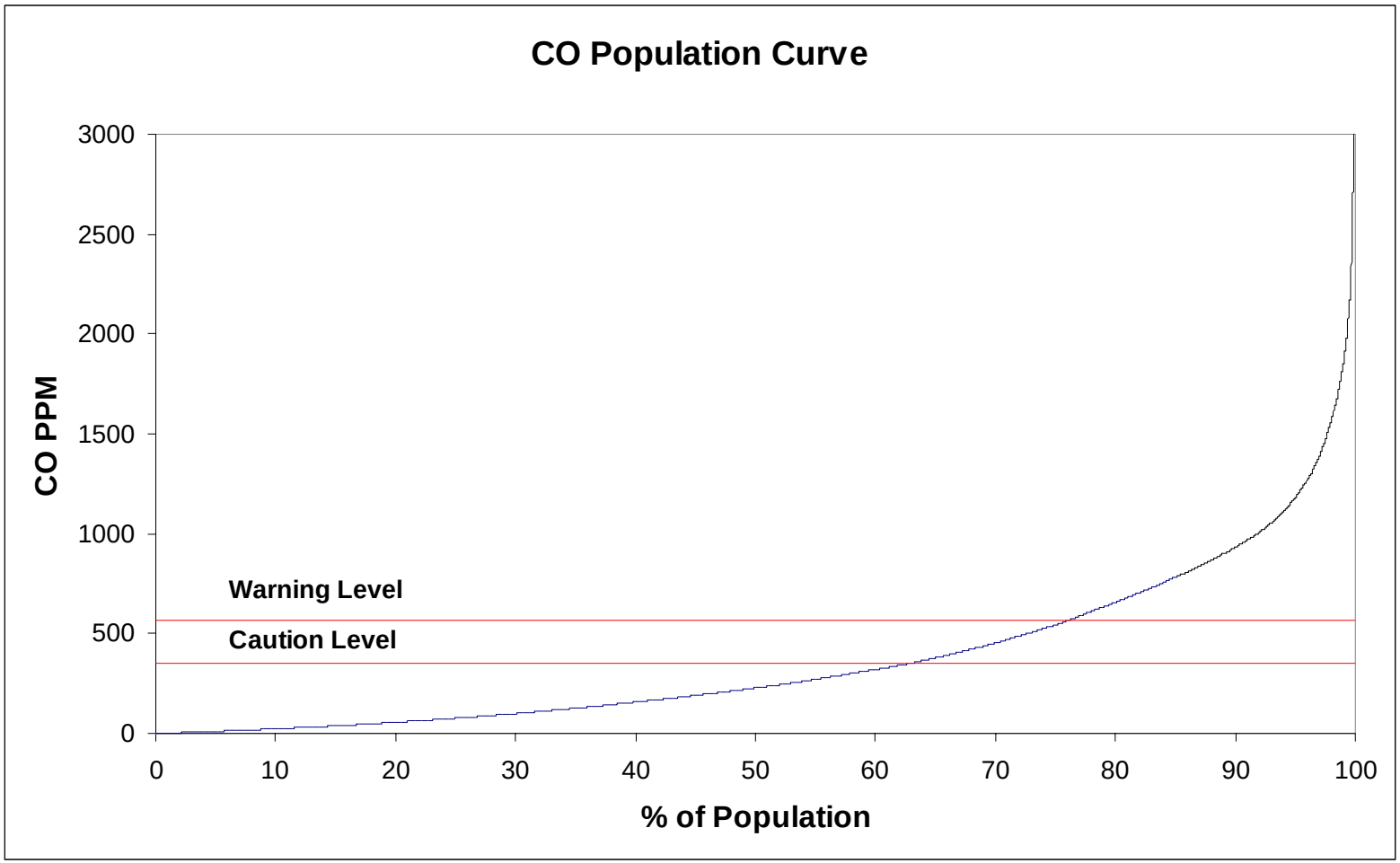
Population curve for CO



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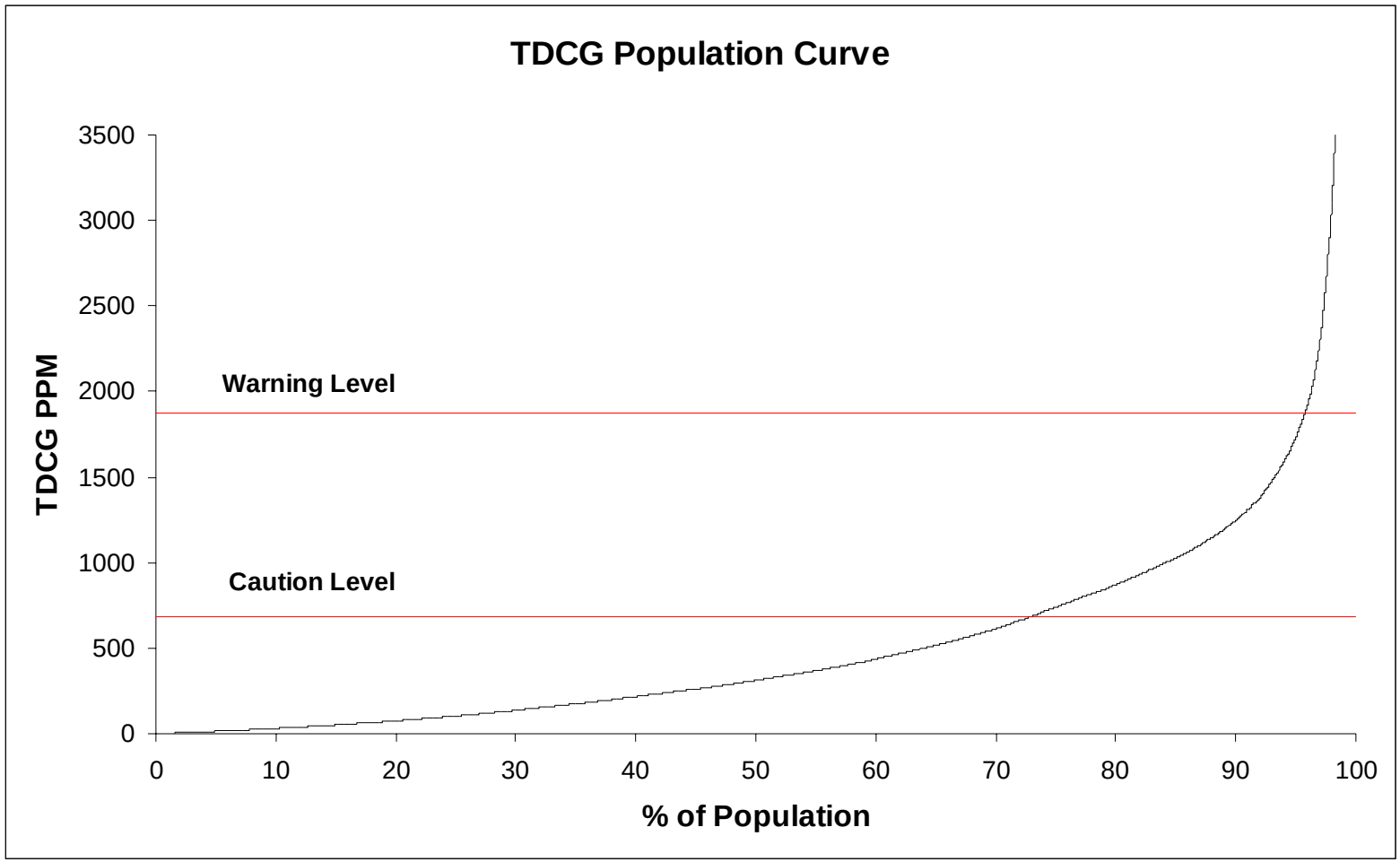
Population curve for TDCG



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Proposed gas level

Correlation between each level limit and the % of DGA population below the limit:

	H_2	CH_4	C_2H_2	C_2H_4	C_2H_6	CO	TDCG	Avrg
Caution ppm:	*100*	*120*	*2*	*50*	*65*	*350*	*700*	
% DGA	**92.1**	**94.8**	**89.7**	**86.6**	**93.6**	**62.3**	**73.5**	**86.5**
Warning ppm:	*700*	*400*	*5*	*100*	*100*	*570*	*1900*	
% DGA	**98.4**	**98**	**93.1**	**92.5**	**95.6**	**80**	**95.9**	**92.9**

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Proposed gas level

First question: What is the % of population that should be used for “Caution” and “Warning” ?

The average of all limits for “Caution” is 86.5% of population for (H_2 + Hydrocarbon + CO) and 91.4% for (H_2 + Hydrocarbon) only

The average of all limits for “Warning” is 92.9% of population for (H_2 + Hydrocarbon + CO) and 95.5% for (H_2 + Hydrocarbon) only

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Proposed gas level

On average, the “Caution” limits used seems to be in line with a value of 90% of the population, but there is several exceptions, as a small change of % population correlate with a large Change of ppm:

CH_4:	90% = 44 ppm for a limit of 120 (94.8%)
C_2H_6:	90% = 27 ppm for a limit of 65 (93.6%)
CO:	90% = 932 ppm for a limit of 350 (62.3%)
TDCG:	90% = 1246 ppm for a limit of 700 (73.5%)

Proposed gas level

If instead we take 95% for the “Caution” limits, then we have the following exceptions:

C_2H_2: 95% = 9.1 ppm for a limit of 2 (89.7%)
C_2H_4: 95% = 189 ppm for a limit of 50 (86.6%)
CO: 95% = 1180 ppm for a limit of 350 (62.3%)
TDCG: 95% = 1730 ppm for a limit of 700 (73.5%)

Proposed gas level

We see the same situation for the “Warning” limits which seems to be in line with a value of 95% of the population. But in fact virtually all gases are “out of range”, to the exceptions of C2H6 and TDCG

H_2:	95% = 166 ppm for a limit of 700 (98.4%)
CH_4:	95% = 126 ppm for a limit of 400 (98%)
C_2H_4:	95% = 189 ppm for a limit of 100 (92.5%)
C_2H_2:	95% = 9.1 ppm for a limit of 5 (93.1%)
CO:	95% = 1180 ppm for a limit of 570 (80%)

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Proposed gas level

If instead we take 98% for the “Warning” limits, then we have the following exceptions:

C_2H_6:	98% = 258 ppm for a limit of 100 (95.6%)
C_2H_4:	98% = 773 ppm for a limit of 100 (92.5%)
C_2H_2:	98% = 58 ppm for a limit of 5 (93.1%)
CO:	98% = 1564 ppm for a limit of 570 (80%)
TDCG:	98% = 3106 ppm for a limit of 1900 (95.9%)

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Proposed gas level

Actual PPM value for 90%, 95% and 98% population:

	H_2	CH_4	C_2H_2	C_2H_4	C_2H_6	CO	TDCG
Caution ppm:	*100*	*120*	*2*	*50*	*65*	*350*	*700*
90 % DGA	**79**	**44***	**2**	**67**	**27***	**932***	**1246***
or							
95 % DGA	**166**	**126**	**9.1***	**189***	**84**	**1180***	**1730***
Warning ppm:	*700*	*400*	*5*	*100*	*100*	*570*	*1900*
95 % DGA	**166***	**126***	**9.1***	**189***	**84**	**1180***	**1730**
or							
98% DGA	**509**	**391**	**58***	**773***	**258***	**1564***	**3106***

* Significant discrepancy

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Proposed gas level

It seems these limit are too low in general and give high number of “abnormal” DGA

This is compound by the fact that ANY limit being exceeded will lead to the classification of a sample as “Caution” or “Warning”, increasing the percentage of “abnormal” results

Proposed gas level

With the set of DGA results used in this study:

49% of samples would be classified as "Caution" or "Warning"

33% of samples would be classified as "Warning"

(not counting the CO2/CO ratio limit)

Conclusion

Therefore, based on this study alone (which is limited in its geographical distribution), some revision of limits value seems required.

More statistic studies in other location and from other laboratories are probably needed to confirm this data

We also need to determine which % threshold to use.

Any volunteers?

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Proposed gas level

Second question: Is there some discrimination we should use to determine these limits?

Age?
Size?
Sealed or not?
OLTC or not?
....

This question is particularly important for CO

The CO question

The situation with CO and the proposed limits is as follow:

Close to 40% of samples are in “Caution”

20 % of samples are in “Warning”

Also, the CO_2 / CO ratio give between 60% to 80% of samples as “abnormal” (less than 7 or more than 10) depending of the level of CO or CO_2 selected.

Even if we limit analysis to CO > 500 ppm and CO_2 > 5000 ppm, the proportion is still 66% of samples

The CO question

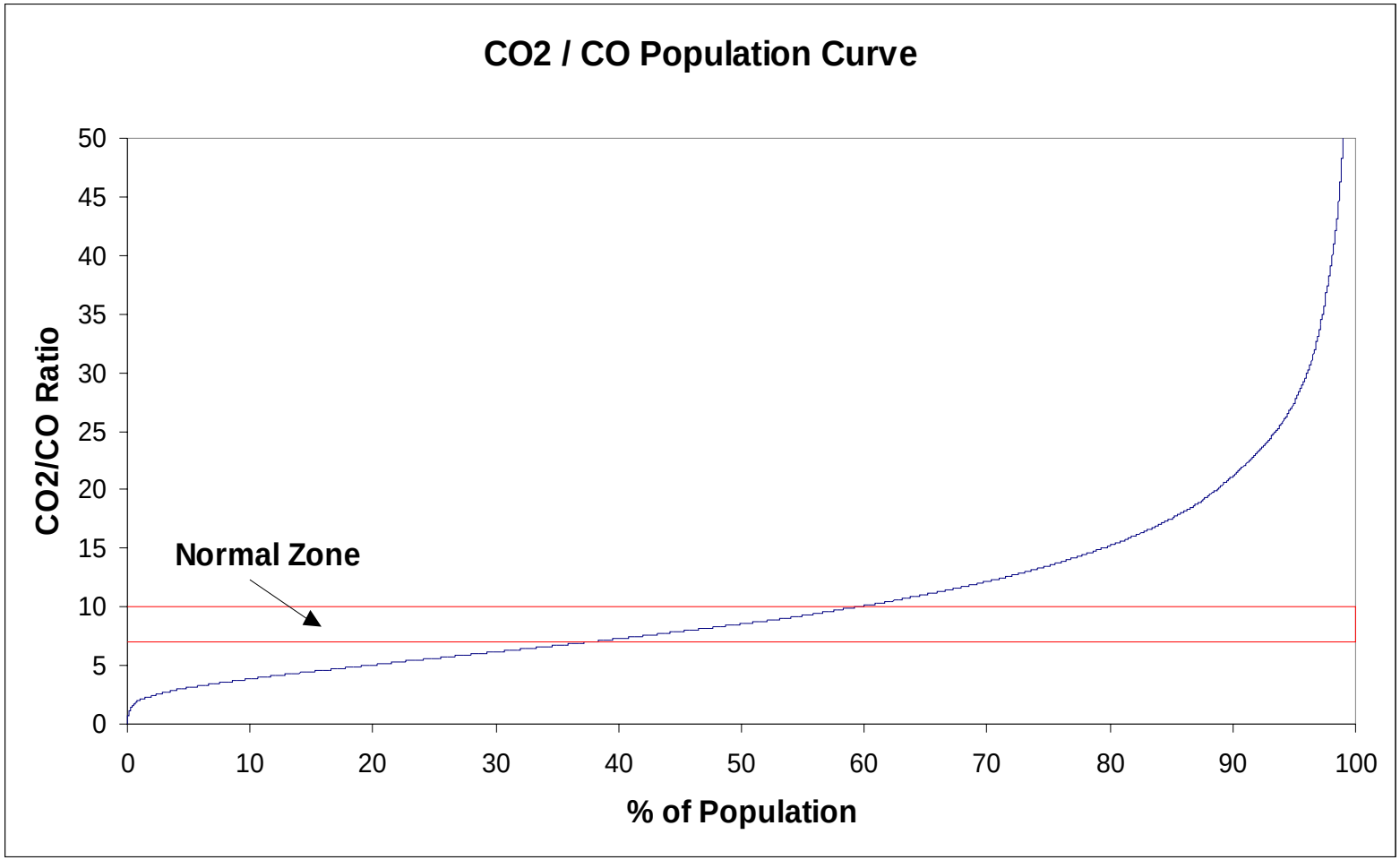
If we use the limit of 3 to 10 for a “normal” CO_2 / CO ratio, then we could reduce the level of “abnormal” DGA (less than 3 or more than 10) to “just” 33%

However, only 0.3% of the sample have a ratio below 3, which is suspiciously too low.

2% of DGA have ratio below 3.98

5% of DGA have ratio below 4.4

The CO question



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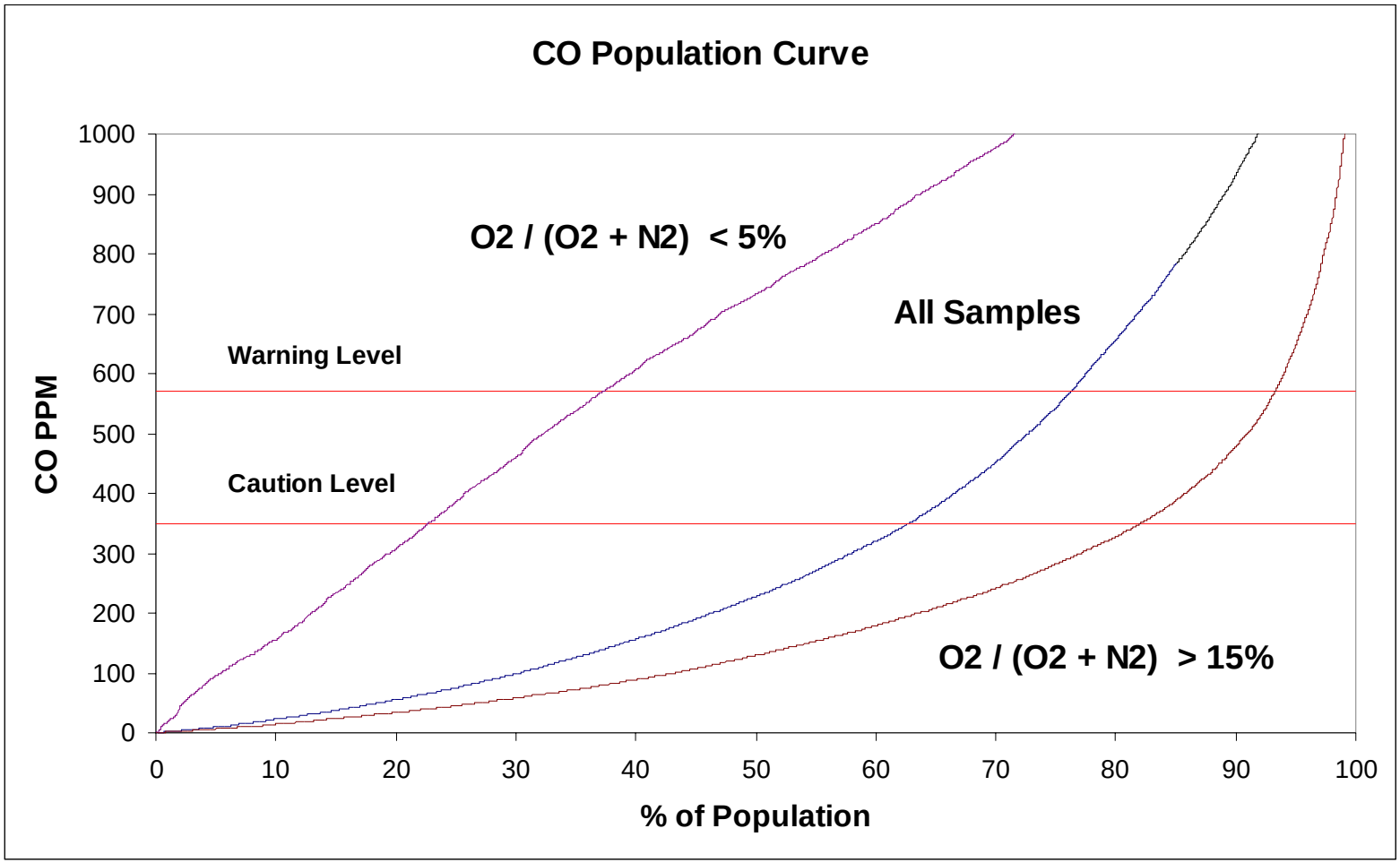
The CO question

Discriminating between samples from sealed type and breather type transformer

Large difference in CO and CO_2 behavior between the two populations of samples

For purpose of data analysis, sample is presumed coming from sealed transformer if $O_2 < 5\%$ of the total $O_2 + N_2$ and is presumed coming from open breather transformer if $O_2 > 15\%$ of the total $O_2 + N_2$

The CO question



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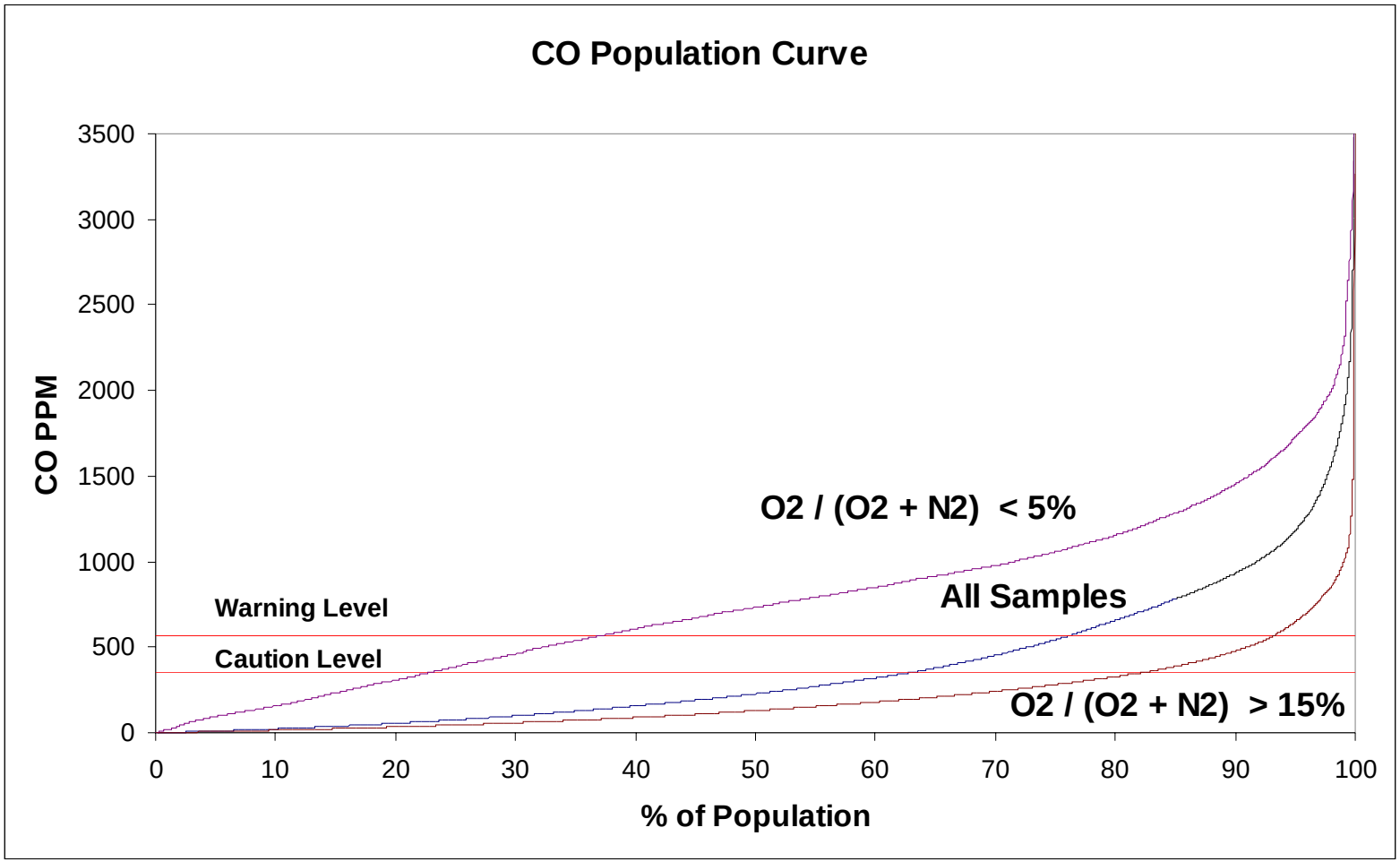
The CO question



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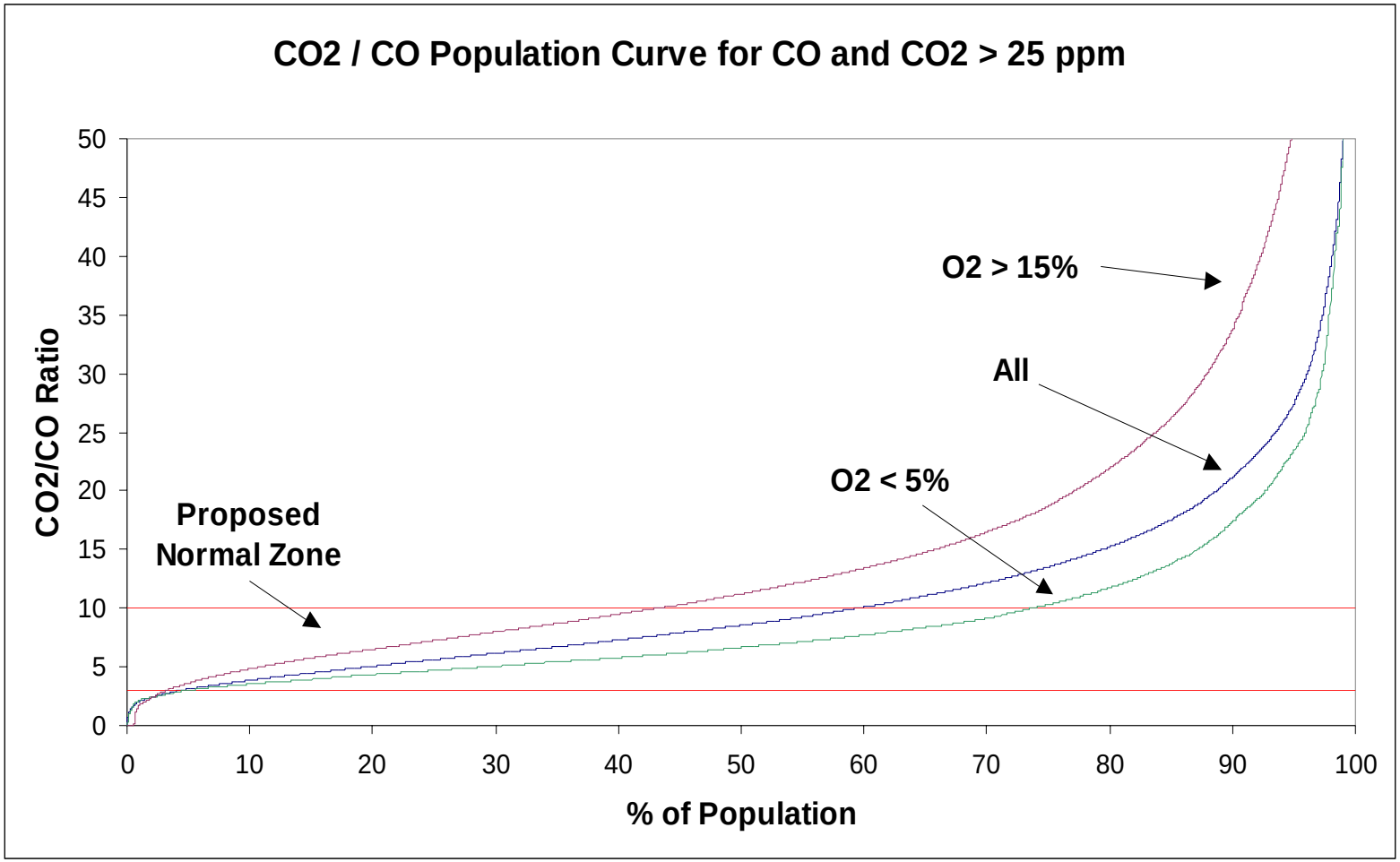
The CO question



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The CO question

If we discriminate between the two populations then:

For “sealed” transformer 90% of DGA are below 1454 ppm of CO and for “open breather” transformer 90% of DGA are below 478 ppm of CO:

3 to 1 ratio !!

If this is confirmed, we obviously need to take it into account for the determination of the “Caution” and “Warning” limit.

Conclusion

The actual set of limits in section 6.1 and 7.3 probably need to be revised

More set of data will be required to refine the limit value

In the set of data presented here, too many transformer will be classified as “Caution” or “warning”

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