

A Nomograph for Interpretation of LTC-DGA Data

Fredi Jakob, Karl Jakob, Simon Jones

Weidmann-ACTI

Rick Youngblood

Cinergy

NETA Conference, San Antonio

March 15, 2004

Normal and Abnormal Processes

Equipment	Normal	Abnormal
Transformers	Heating	Excessive Heating, Partial Discharge and Arcing
LTCs, OCBs and Regulators	Arcing	Excessive Heating and Partial Discharge

Data Interpretation

- **Empirical in Nature**
- **Key Gases**
- **Threshold Levels**
 - Generic – Youngblood, Weidmann-ACTI
 - Model Specific – Baker, Doble
- **Gas Concentration Ratios**

Important Gas Concentration Ratios

Heating to Arcing Ratios

$\frac{\text{Ethylene}}{\text{Acetylene} + \text{Hydrogen}}$	$\frac{\text{Ethylene}}{\text{Acetylene}}$	$\frac{\text{Methane} + \text{Ethylene} + \text{Ethane}}{\text{Acetylene} + \text{Hydrogen}}$	$\frac{\text{Methane} + \text{Ethylene} + \text{Ethane}}{\text{Acetylene}}$
--	--	---	---

Temperature Dependent Ratios

$\frac{\text{Ethane}}{\text{Methane}}$	$\frac{\text{Ethylene}}{\text{Ethane}}$
--	---

Ratio Attributes

- **Independent of Operation Count**
- **Resistant to Change due to Loss of Gases to Atmosphere**
- **Change with Contact Condition**

Gas Formation as a Function of Operation Count (Duval)

Operations:		500	3600	49000	Gas Produced/Operation		
					Gas/500	Gas/3600	Gas/49000
Hydrogen		6870	12125	14320	13.74	3.37	0.29
Methane		1028	5386	10740	2.05	1.50	0.22
Acetylene		5500	35420	53670	11.00	9.84	1.10
Ethylene		900	6400	35839	1.80	1.78	0.73
Ethane		79	400	3944	0.16	0.11	0.08
Ratio:	$\frac{\text{Ethylene}}{\text{Acetylene}}$	0.16	0.18	0.66			

Generic 90th Percentile Fault Gas Ratios

<i>R1</i>	<i>R2</i>	<i>R3</i>	<i>R4</i>	<i>R5</i>	<i>R6</i>
$\frac{\text{Ethylene}}{\text{Acetylene}}$	$\frac{\text{Ethylene}}{\text{Acetylene} + \text{Hydrogen}}$	$\frac{\text{Ethylene} + \text{Ethane} + \text{Methane}}{\text{Acetylene} + \text{Hydrogen}}$	$\frac{\text{Ethane}}{\text{Methane}}$	$\frac{\text{Ethylene}}{\text{Ethane}}$	$\frac{\text{Methane} + \text{Ethylene} + \text{Ethane}}{\text{Acetylene}}$
<i>0.36</i>	<i>0.24</i>	<i>0.38</i>	<i>0.31</i>	<i>7.51</i>	<i>0.56</i>

Model Specific Ratios

Charles Baker's Data

WESTINGHOUSE LTC UTT

	Ethylene	Ethane	Methane	Acetylene	Hydrogen
LT3	3,000	250	1,000	5,000	5,000
	Ratio 1	Ratio 2	Ratio 3	Ratio 4	Ratio 5
	<i>Ethylene</i>	<i>Ethylene</i>	<i>Ethylene</i> <i>+ Ethane</i> <i>+ Methane</i>	<i>Ethane</i>	<i>Ethylene</i>
	<hr/> <i>Acetylene</i>	<hr/> <i>Acetylene</i> <i>+ Hydrogen</i>	<hr/> <i>Acetylene</i> <i>+ Hydrogen</i>	<hr/> <i>Methane</i>	<hr/> <i>Ethane</i>
	0.60	0.30	0.43	0.25	12.00

Model Specific Ratios

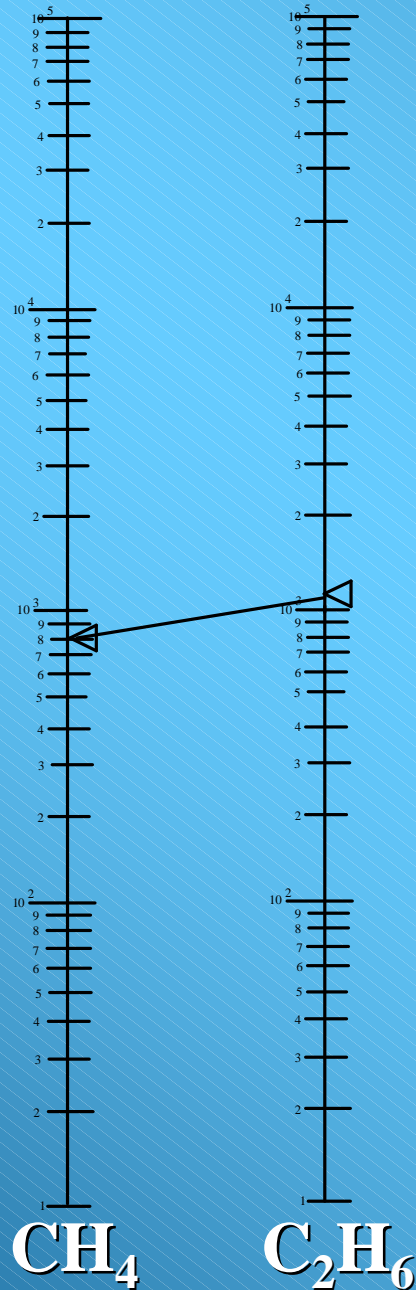
Charles Baker's Data

McGRAW EDISON LTC 550-BL

	Ethylene	Ethane	Methane	Acetylene	Hydrogen
LT3	2,000	400	400	400	500
	Ratio 1	Ratio 2	Ratio 3	Ratio 4	Ratio 5
	<i>Ethylene</i> <hr/> <i>Acetylene</i>	<i>Ethylene</i> <hr/> <i>Acetylene</i> <i>+ Hydrogen</i>	<i>Ethylene</i> <i>+ Ethane</i> <i>+ Methane</i> <hr/> <i>Acetylene</i> <i>+ Hydrogen</i>	<i>Ethane</i> <hr/> <i>Methane</i>	<i>Ethylene</i> <hr/> <i>Ethane</i>
	5.00	2.22	3.11	1.00	5.00

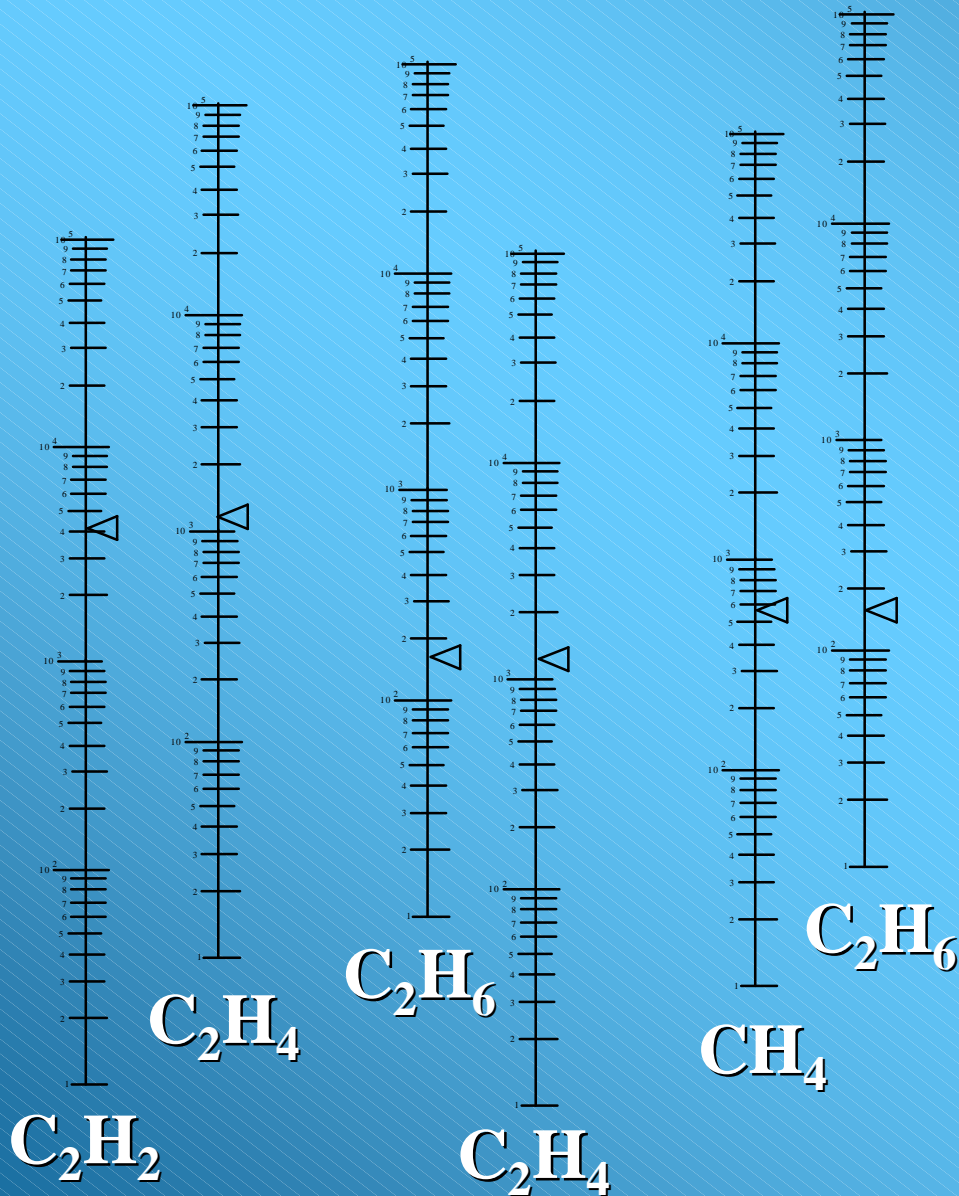
The Nomograph Concept

Logarithmic
Representation
of Methane/Ethane
Gas Concentration
Ratios



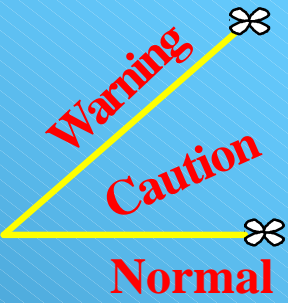
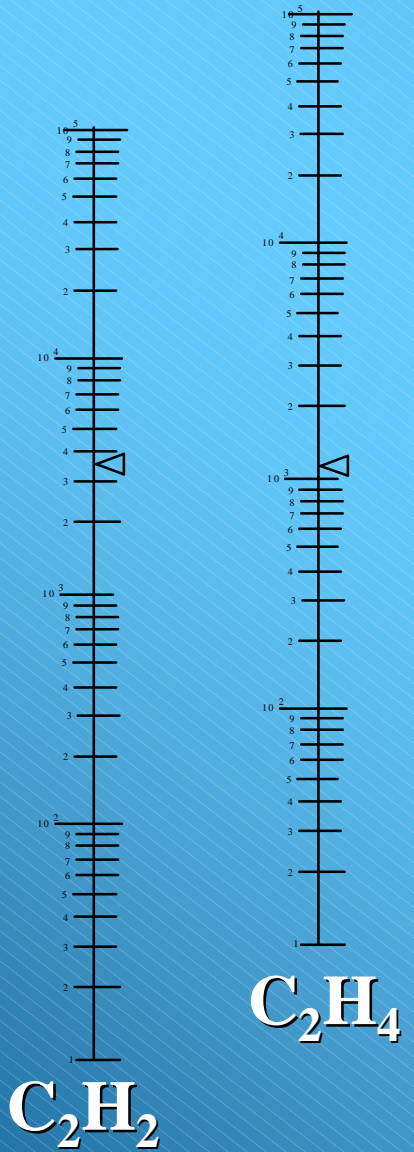
The Complete Nomograph

Proposed Nomograph for the 90th Percentile Gas Thresholds



Normal, Caution or Warning

Nomograph Diagnosis of LTC Condition



Sliding Legend

Cinergy Case History

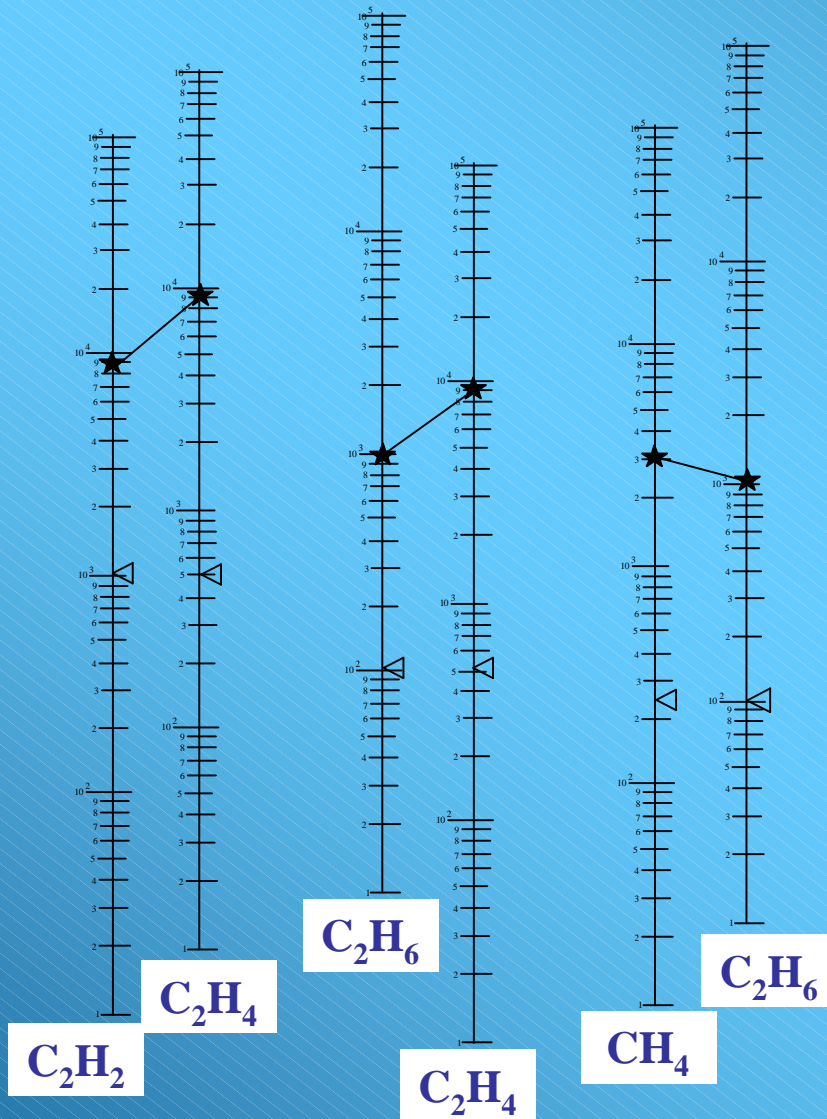
Westinghouse UTT-A 138KV x 69KV x 13.8KV Sealed

Date	Comments	C2H2	CH4	C2H6	C2H4	H2
8/31/1992	Removed from Service	8527	3279	1135	9606	9083
12/17/1993	Post Repair	501	387	16	375	2883
5/1/1994	Normal	541	534	9	313	3800
8/17/1995	Placed on 6 Month Watch	648	590	52	836	3995

Date	Comments	Ratio 1	Ratio 2	Ratio 3	Ratio 4	Ratio 5
8/31/1992	Removed from Service	1.13	0.55	0.8	0.35	0.15
12/17/1993	Post Repair	0.75	0.11	0.23	-	-
5/1/1994	Normal	0.58	0.07	0.2	-	-
8/17/1995	Placed on 6 Month Watch	1.29	0.18	0.32	0.06	0.09

Ratio 1	$C2H4 / C2H2$
Ratio 2	$C2H4 / (C2H2 + H2)$
Ratio 3	$(CH4 + C2H4 + C2H6) / (C2H2 + H2)$
Ratio 4	$C2H6 / CH4$
Ratio 5	$C2H4 / C2H6$

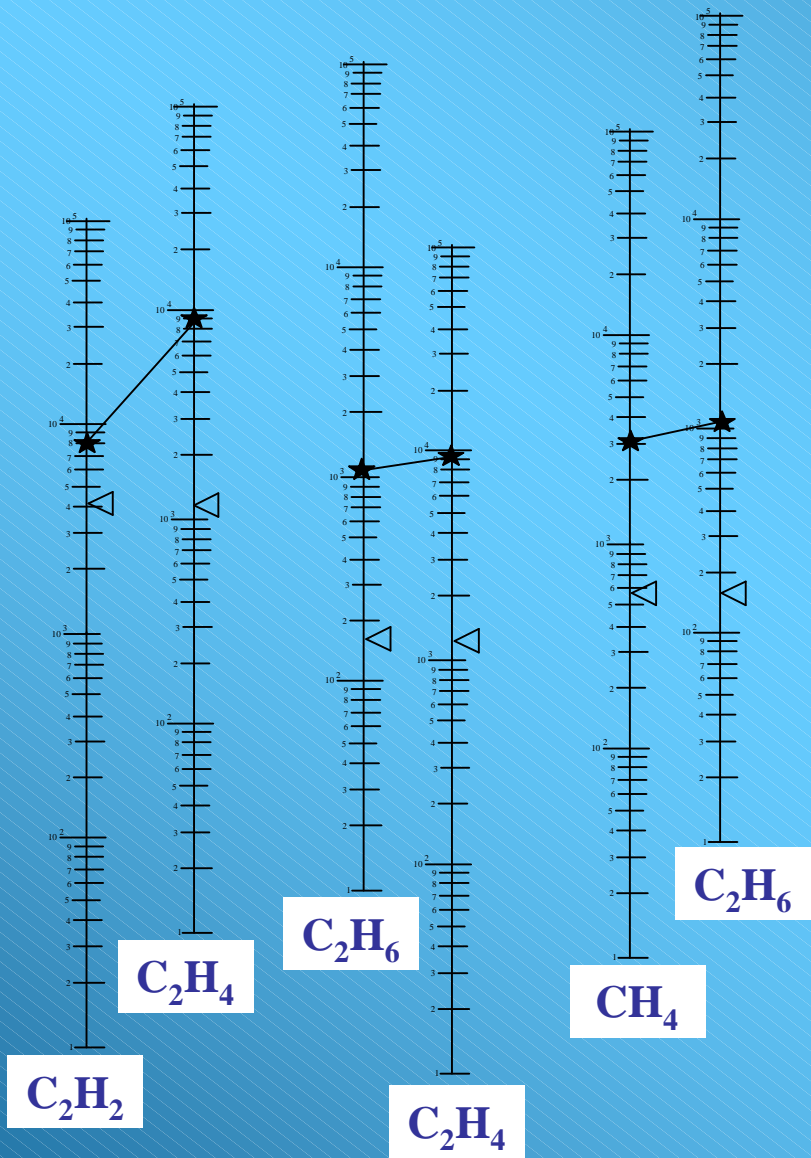
Nomographic Representation of Case II Utilizing Bull Baker's Unit Specific LT3 Threshold Values



◁ Baker's LT1 Threshold Values

★ Gas concentrations at time of removal from service

Nomographic Representation of Case II Utilizing 90th Percentile Threshold Values



◁ 90% Threshold Values

★ Gas concentrations at time of removal from service

Data Normalization

Ethylene
(due to heating)

Total Ethylene –
(Ethylene produced during
normal arcing)

=

Acetylene
(due to arcing)

Acetylene