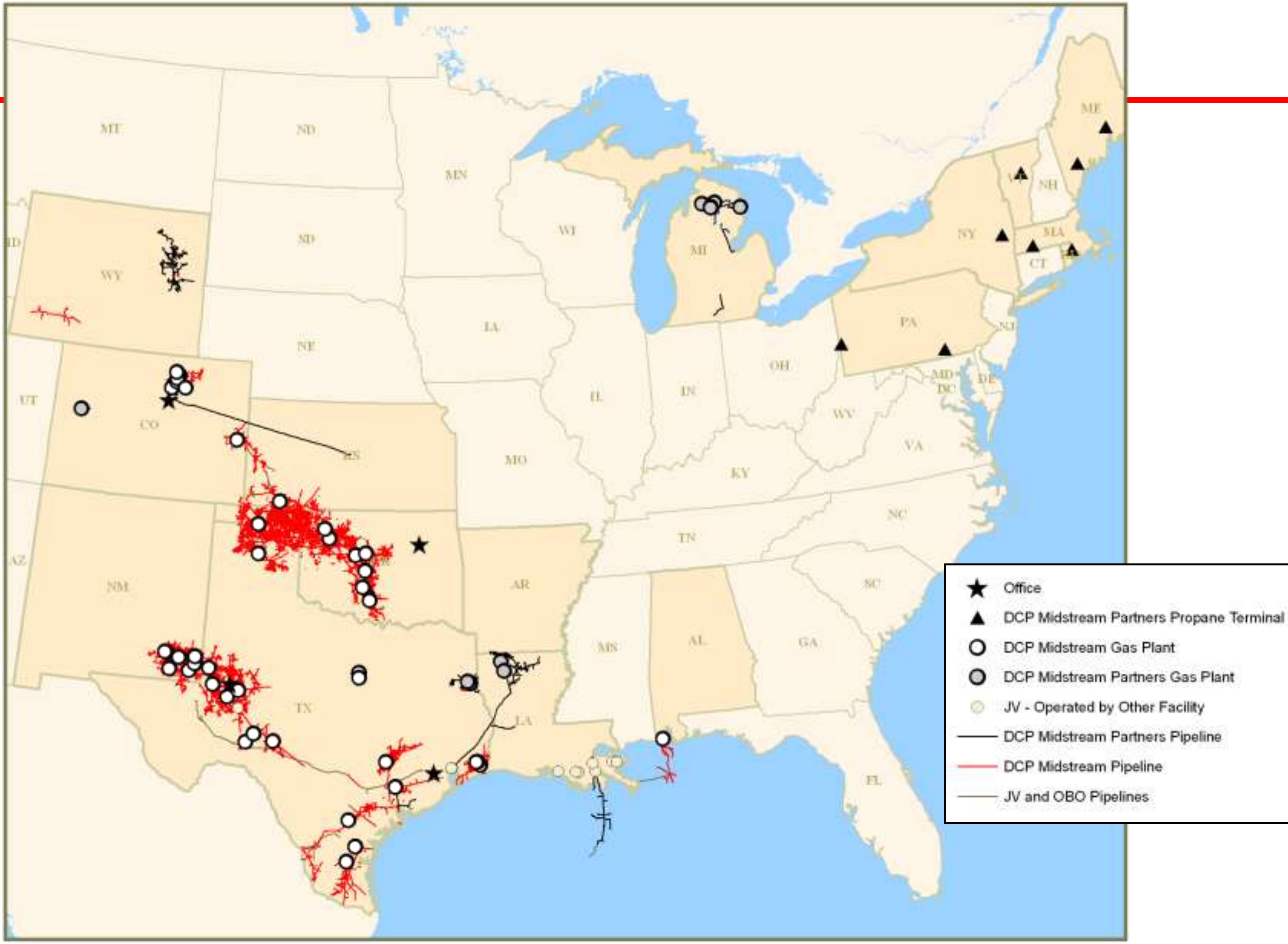
Determining Remaining Strength of Corroded Pipelines

Houston Section
April 10, 2012

Who is DCP Midstream?

- Formerly *Duke Energy Field Services* the Company was renamed on January 1, 2007 to align with DCP Midstream Partners.
- DCP Midstream, LLC is a private company. A 50-50 joint venture between Spectra Energy and ConocoPhillips.
- One of the nation's largest natural gas gatherers and processors (7 Bcf/day), the largest natural gas liquids (NGLs) producer and one of the largest NGL marketers in the U.S.
- Operates in 26 states, gathers raw natural gas through ~62,000 miles of pipe and processes gas through 61 plants, produces 360,000 bbls/day NGLs
- Over 3,000 employees



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FL
Office
DCP Midstream Partners Propane Terminal
DCP Midstream Gas Plant
DCP Midstream Partners Gas Plant
JV - Operated by Other Facility
DCP Midstream Partners Pipeline
DCP Midstream Pipeline
JV and OBO Pipelines

Introduction

- Pipeline Design
- ASME B31G
- Limits for B31G
- Misc

Pipeline Design

Barlow's formula relates pressure to pipe attributes

$$P = 2\,St / D$$

- P = Design pressure
- S = Yield strength in psi
- D = Outside diameter
- t = Nominal wall thickness

Pipeline Design

- Barlow's formula

- $P = (2\ St/D) \times F \times E \times T$

P = Design pressure

S = Yield strength in psi

D = Outside diameter

t = Nominal wall thickness

F = Design factor

E = Longitudinal joint factor

T = Temperature derating factor…

Peter Barlow

Peter Barlow

Peter Barlow

Self-educated, Peter Barlow (1776-1862) became assistant mathematics master at the Royal Military Academy, Woolwich, in 1801. He published numerous mathematical works, including New Mathematical Tables (1814). Later known as Barlow's Tables, this compilation of factors and functions of all numbers from 1 to 10,000 was considered so accurate and so useful that it has been regularly reprinted ever since.

Woolwich -SE of London.   Active   1741–1939

Pipeline Design

Design factor (F)

- Liquid Pipelines 0.72

- Gas Pipelines
  - Class 1 0.72
  - Class 2 0.60
  - Class 3 0.50
  - Class 4 0.40

Pipeline Design

Example: Liquid line

6”   .219 wt   X42

P = (2 x 42000 x .219 / 6.625)

P = 2777 psi

$P_{max\ mop}$ = 2777 psi x .72 = 1999

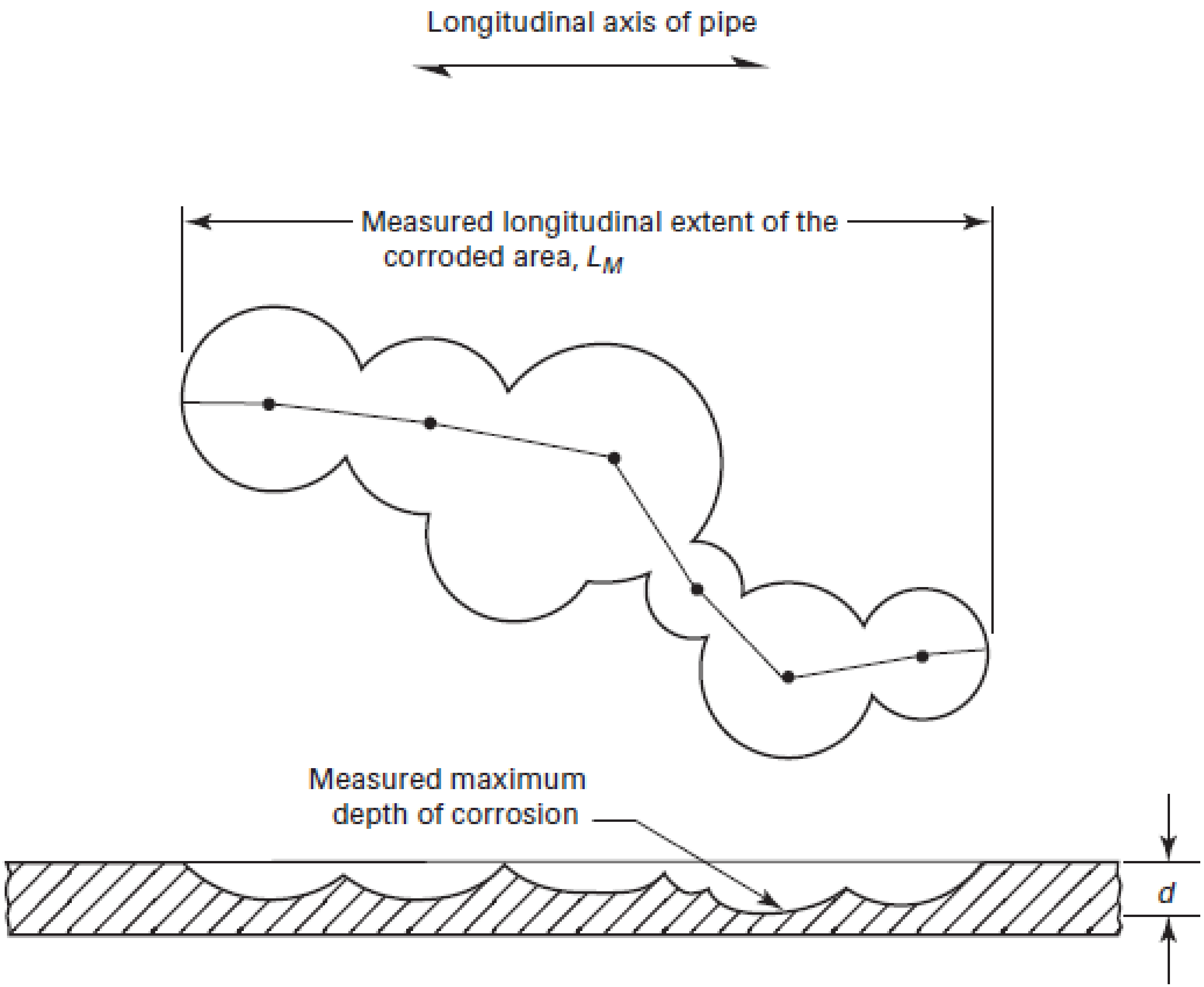
ASME B31G

A supplement to ASME B31

Calculates Burst pressure with pipe parameters and metal loss >>

- Length - L
- depth - d

ASME B31G



Longitudinal axis of pipe
Measured longitudinal extent of the corroded area, L_M
Measured maximum depth of corrosion
d

ASME B31G

Corroded Pipe Assessment

Failure Criterion

$$\sigma_{Failure} = \bar{\sigma}\left[\frac{1 - \frac{A}{A_O}}{1 - \frac{A}{A_O} M^{-1}}\right]$$

Where:

$\sigma_{Failure}$	Predicted Failure Stress
$\bar{\sigma}$	Flow Stress, f{SMYS}
A	Effective Area of Missing Metal
A_O	Original Area, {L x t}
M	Folias Factor, f{L, D, t}
L	Effective Length

ASME B31G

Folias Factor

$$\text{For } L \le \sqrt{50\,D\,t}\,,\quad M = \sqrt{1 + 0.6275\,\frac{L^2}{D\,t} - 0.003375\left(\frac{L^2}{D\,t}\right)^2}$$

$$\text{For } L > \sqrt{50\,D\,t}\,,\quad M = 0.032\,\frac{L^2}{D\,t} + 3.3$$

ASME B31G

- Based on Battelle Institute work July 1971
- ASME Guide
- ASME B31G - 1984
- Modified B31G - 1991
- Current edition B31G-2009

ASME B31G

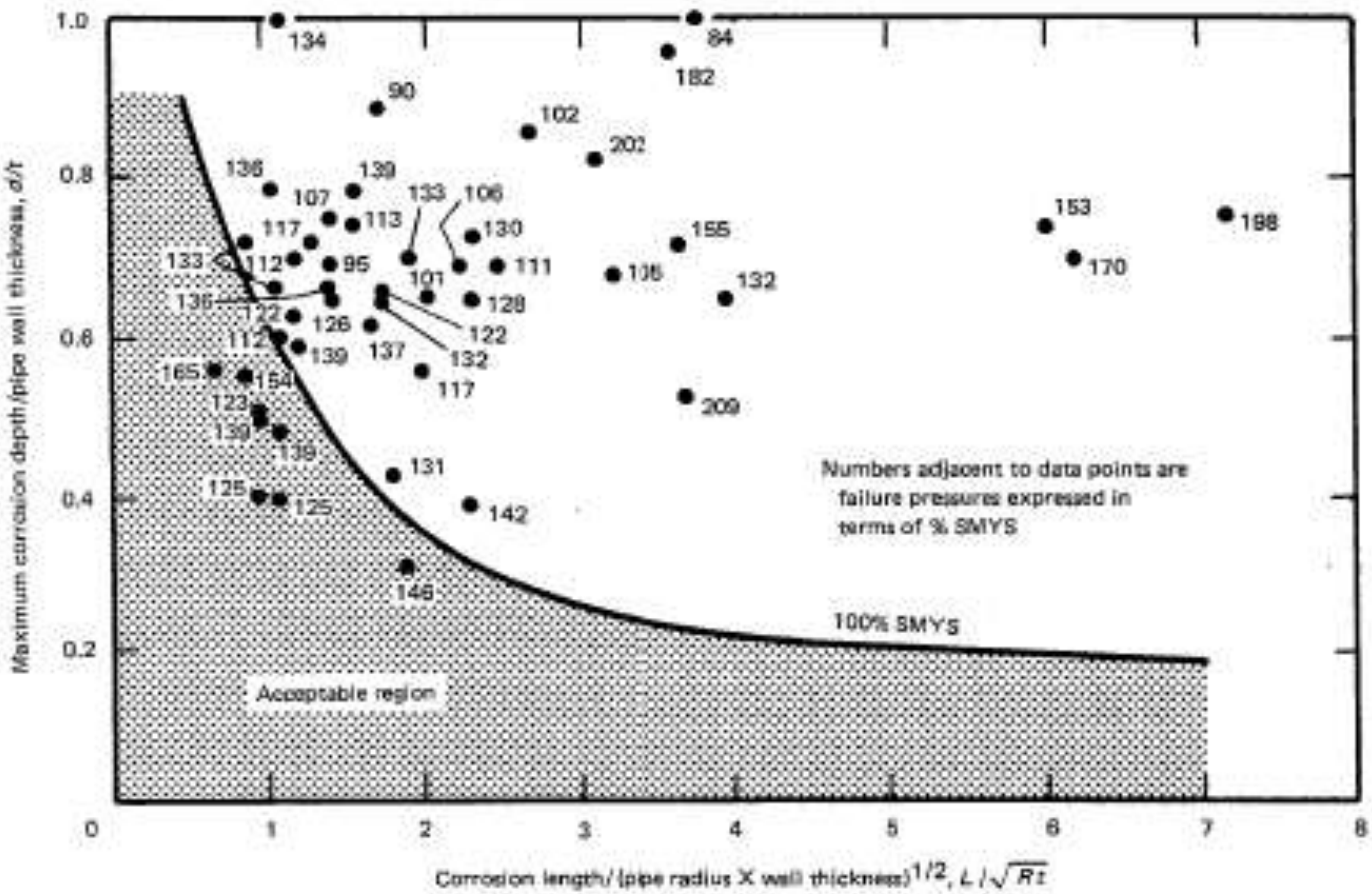


FIG. 1-1 PARABOLIC CRITERIA FOR CLASSIFYING CORROSION DEFECTS ACCORDING TO PREDICTED FAILURE STRESS

ASME B31G

Equations are empirical or in some cases semi-empirical.

What is this?

Empirical knowledge comes from observation only. You don't know why or have any idea of why reaction A follows situation B but you have seen it happen so many times that you KNOW that is what is going to happen.

People knew that things fell down long before there was a theory of gravitation. Such knowledge was empirical.

Empirical knowledge not only comes from observation but also by testing.

Read more: cp http://wiki.answers.com/Q/What_is_empirical_knowledge#ixzz1rfGSpoND

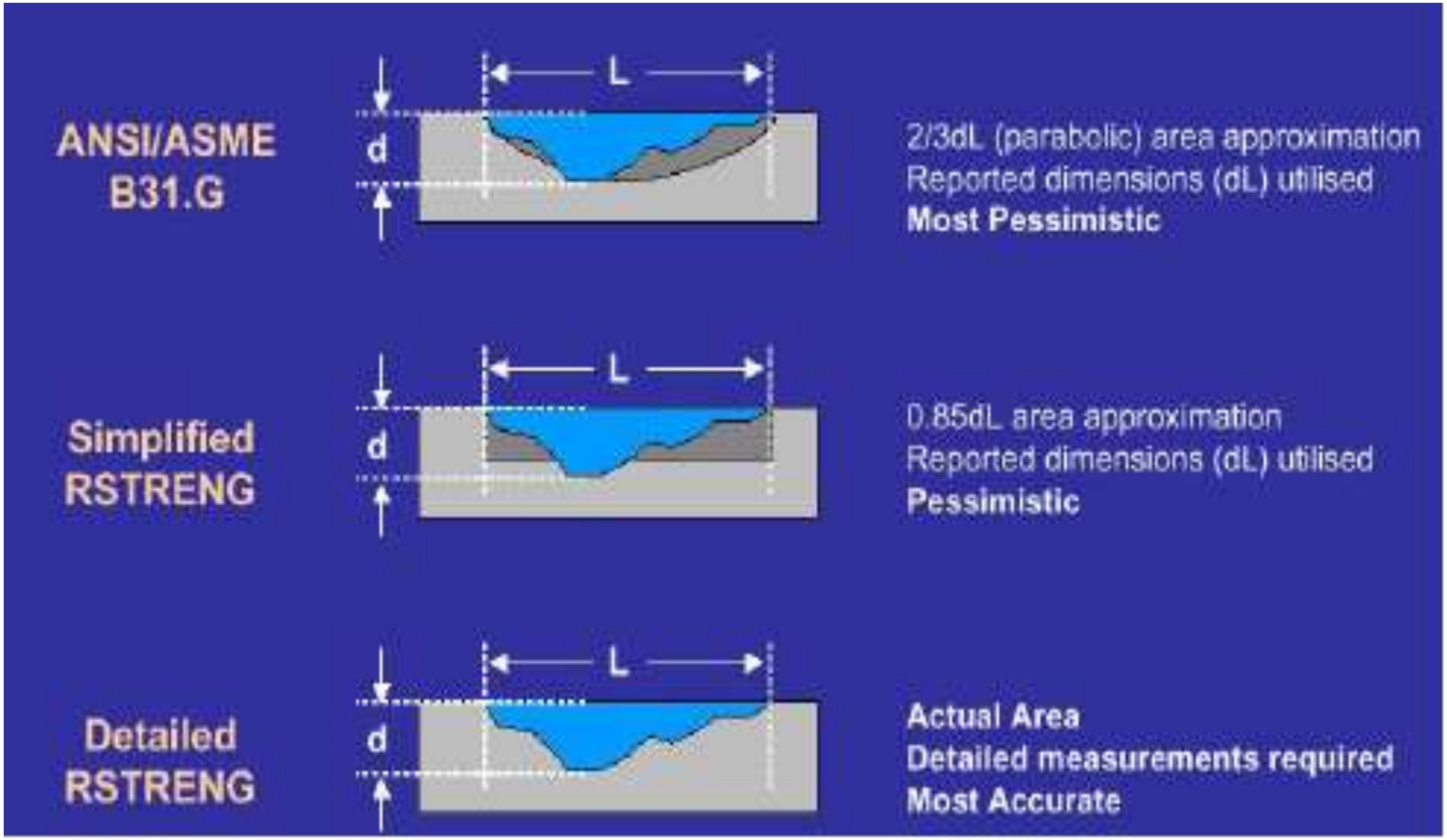
ASME B31G

3 versions

- ASME B31G
- Modified B31G
- Effective Area Method

ASME B31G

Difference in methods



ASME B31G

Application

- Yes for blunt metal loss
- Yes for external corrosion
- Yes for internal corrosion

ASME B31G

Limitations (RULES)

- Depth less than 80% wt
- **No** Cracks
- **No** gouges
- **No** stress Concentrator
- **No** selective seam corrosion
- **No** selective weld corrosion
- Apply operating characteristics P_{safe}

ASME B31G

In operations, always

- Identify cause of metal loss
- Mitigate cause of metal loss

B31G

- Company Operating Manuals
- KAPA (“KAPA” is an acronym for “Kiefner & Associates Pipe Assessment”)
- RSTRENG®

B31G

B31 G Interaction

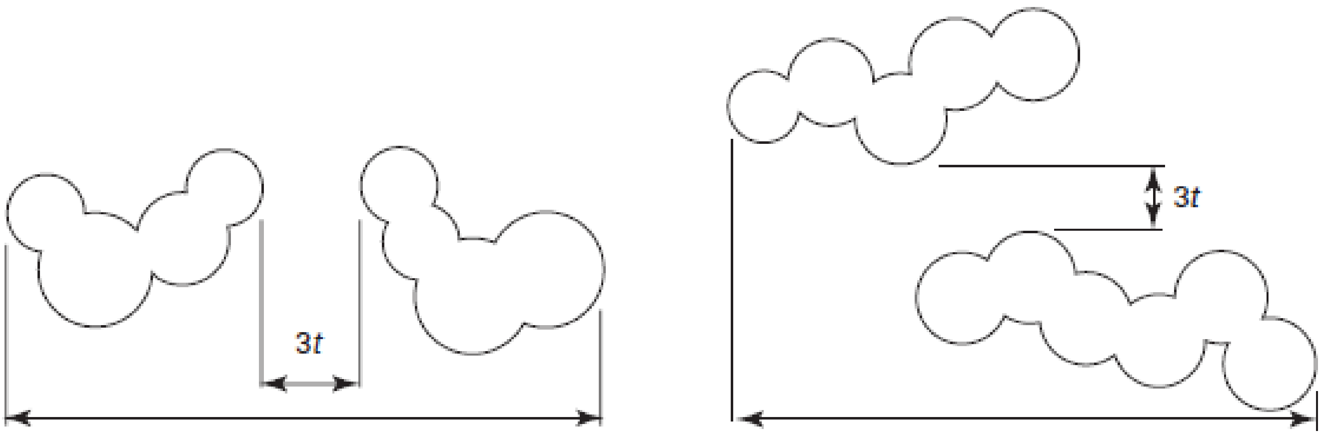
Interaction rule

Commonly used **1" x 6t interaction**

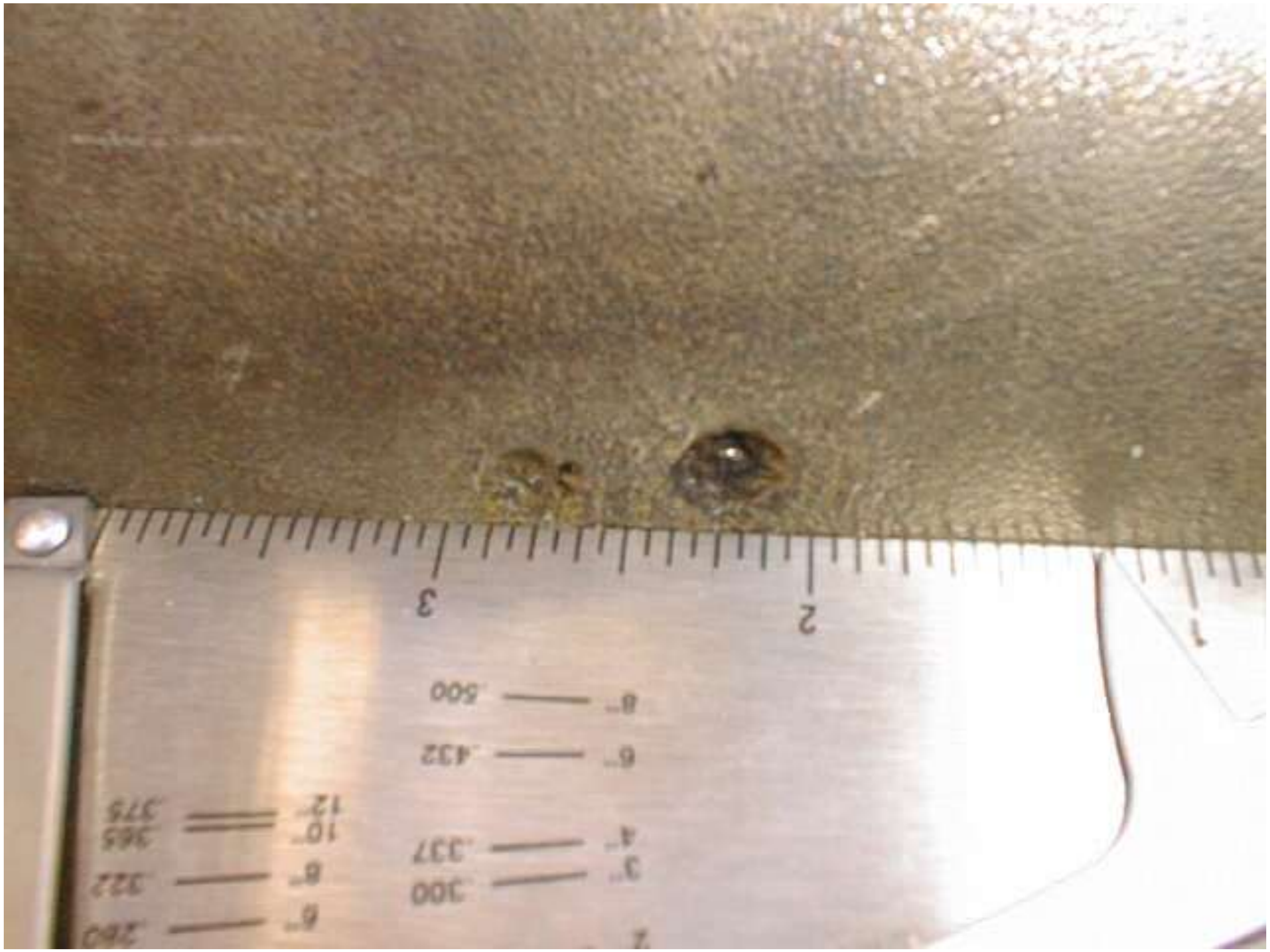
- 1 inch in axial length separation
- 6 times pipe wall thickness for width separtion (.250 wt = 1.5 in)
- If separation < 1" x 6t group or cluster the anomalies together.

Interaction B31G

Fig. 1.12-1 Corrosion Pit Interaction Distances



B31G



B31G

ASME B31G

Table 3-2 Values of L for Pipe Sizes ≥ NPS 6 and < NPS 10

Depth, d, in.	Wall Thickness, t, in.							
	0.083	0.125	0.156	0.188	0.203	0.219	0.250	0.312
0.01	3.32	No limit	No limit	No limit	No limit	No limit	No limit	No limit
0.02	1.53	4.08	4.55	3.83	No limit	No limit	No limit	No limit
0.03	0.88	1.89	3.37	5.00	5.20	5.40	5.77	No limit
0.04	0.65	1.25	1.90	2.91	3.61	4.65	5.77	6.44
0.05	0.51	0.97	1.40	1.97	2.30	2.73	3.86	6.44
0.06	0.42	0.80	1.13	1.54	1.77	2.04	2.67	4.77
0.07	...	0.68	0.96	1.29	1.46	1.66	2.11	3.37
0.08	...	0.59	0.83	1.11	1.25	1.42	1.77	2.68
0.09	...	0.52	0.74	0.98	1.10	1.24	1.54	2.26
0.10	...	0.46	0.66	0.88	0.99	1.11	1.37	1.97
0.11	...	...	0.59	0.80	0.90	1.01	1.24	1.76
0.12	...	...	0.54	0.73	0.82	0.92	1.13	1.60
0.13	...	...	...	0.66	0.75	0.85	1.04	1.46
0.14	...	...	...	0.61	0.69	0.78	0.96	1.35
0.15	...	...	...	0.56	0.64	0.72	0.89	1.26
0.16	...	...	...	...	0.59	0.67	0.83	1.18
0.17	...	...	...	...	...	0.63	0.78	1.10
0.18	...	...	...	...	...	...	0.73	1.04
0.19	...	...	...	...	...	...	0.69	0.98
0.20	...	...	...	...	...	...	0.65	0.93
0.21	...	...	...	...	...	...	...	0.88
0.22	...	...	...	...	...	...	...	0.84
0.23	...	...	...	...	...	...	...	0.80
0.24	...	...	...	...	...	...	...	0.76

ASME B31G

Since L >15/16” must repair

What about Modified B31G?

Links and Reference

http://www.kiefner.com/downloads.asp

http://www.ttoolboxes.com/Products/

Duane Cronin
https://uwspace.uwaterloo.ca/bitstream/10012/478/1/NQ51187.pdf

V050125

Kiefner & Associates, Inc.
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Worthington, Ohio 43085
Phone (614) 888-8220 | Fax (614) 888-7323
www.kiefner.com

Diameter	6.625	inches
Wt	0.219	inches
SMYS	42,000	psi
MOP	1440	psi
CVN	20	ft-lb
Design Factor	0.72	
Percent Operating Stress	51.9%	
Maximum Allowable Pressure	1,999.3	psi

☑ US Customary
☐ Metric

Line Number	N-1
Station Number	236+45
Mile Post	4.5

		Envelope Defect Profile	Grid 1									
Effective Area Method	Predicted Failure Pressure (P_f)	2867.7	2867.7									
	Factor of Safety (P_f/MOP)	1.99	1.99									
Modified B31G	Predicted Failure Pressure (P_f)	3007.8	3007.8									
	Factor of Safety (P_f/MOP)	2.09	2.09									
B31G	Predicted Failure Pressure (P_f)	2743.8	2743.8									
	Factor of Safety (P_f/MOP)	1.91	1.91									
Calculated Parameters	Total Length	1.00	1.00									
	Eff. length	1.00	1.00									
	Start Length	0.00	0.00									
	Stop Length	1.00	1.00									
	Max Pit Depth	0.120	0.120									
	Max. Depth/Thick	0.548	0.548									
	Eff. Area	0.12	0.12									

Released: April 29, 2005

Printed: 4/9/2012

Kapa

V050125

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Line Number	N-1	
Station Number	236+45	
Mile Post	4.5	

Diameter	6.625	inches
Wt	0.219	inches
SMYS	42,000	psi
MOP	1440	psi
CVN	20	ft-lb
Design Factor	0.72	
Percent Operating Stress	51.9%	
Maximum Allowable Pressure	1,999.3 psi	

☑ US Customary
☐ Metric

		Envelope Defect Profile	Grid 1									
...e Area ...od	Predicted Failure Pressure (P_f)	2867.7	2867.7									

Kapa p2

		Envelope Defect Profile	Grid 1									
Effective Area Method	Predicted Failure Pressure (P_f)	2867.7	2867.7									
	Factor of Safety (P_f/MOP)	1.99	1.99									
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Limits for B31G

- Depth less than 80% wt
- Apply operating characteristics P_{safe}
- **No** Cracks
- **No** gouges
- **No** stress Concentrator
- **No** selective seam corrosion
- **No** selective weld corrosion

Limits for B31G

OK for blunt metal loss

- Internal Corrosion
- External Corrosion
- Welds if metal loss not selective

Must stop cause of metal loss – remember identify the cause, and fix

ILI spreadsheets -example B31G calcs

EVENT LOCATION				ANOMALY DESCRIPTION				ANOMALY REPAIR FACTORS			
EVENT	WHEEL COUNT (ft.)	DIST FROM U/S WELD (ft.)	DIST TO D/S WELD (ft.)	CLOCK	DEPTH %	LENGTH (in.)	INT / EXT	W.T (in.)	CALC. PFAIL .85dl (psi)	CALC. PFAIL .85dl / MAOP	COMMENTS
Anomaly	103397.81	27.42	30.81	1:50	50	22.9	I	0.175	990	1.16	
Anomaly	111302.51	32.43	30.94	1:00	54	10.3	I	0.175	989	1.16	
Girth Weld ID	Relative Distance (ft)	Absolute Distance (ft)	Comments	Peak Depth (%)	Length (in)	Width (in)	Local Wall Thickness (in)	SMYS (psi)	RSTRENG Burst (psi)	Orientation (clock)	Orientation (Degrees)
	19.51	211,621.20	Metal Loss EXTERNA	41%	7.86	1.39	0.250	42000	1509	6:30	195
	20.61	211,622.30	Metal Loss EXTERNA	39%	10.06	2.84	0.250	42000	1538	5:45	171
Pipeline Feature	INT/ EXT	Odometer (ft)	W. T.	Pipe Grade	Depth (%)	Depth (in.)	Length (in.)	Width (in.)	O'Clock Orient'n	Burst Pressure (psi)	ERF
Metal Loss	EXT	519.01	0.312	X52	40%	0.125	0.8	0.6	3:01	2965	1.165
Metal Loss	EXT	523.04	0.312	X52	36%	0.112	0.6	0.6	3:31	2999	1.179


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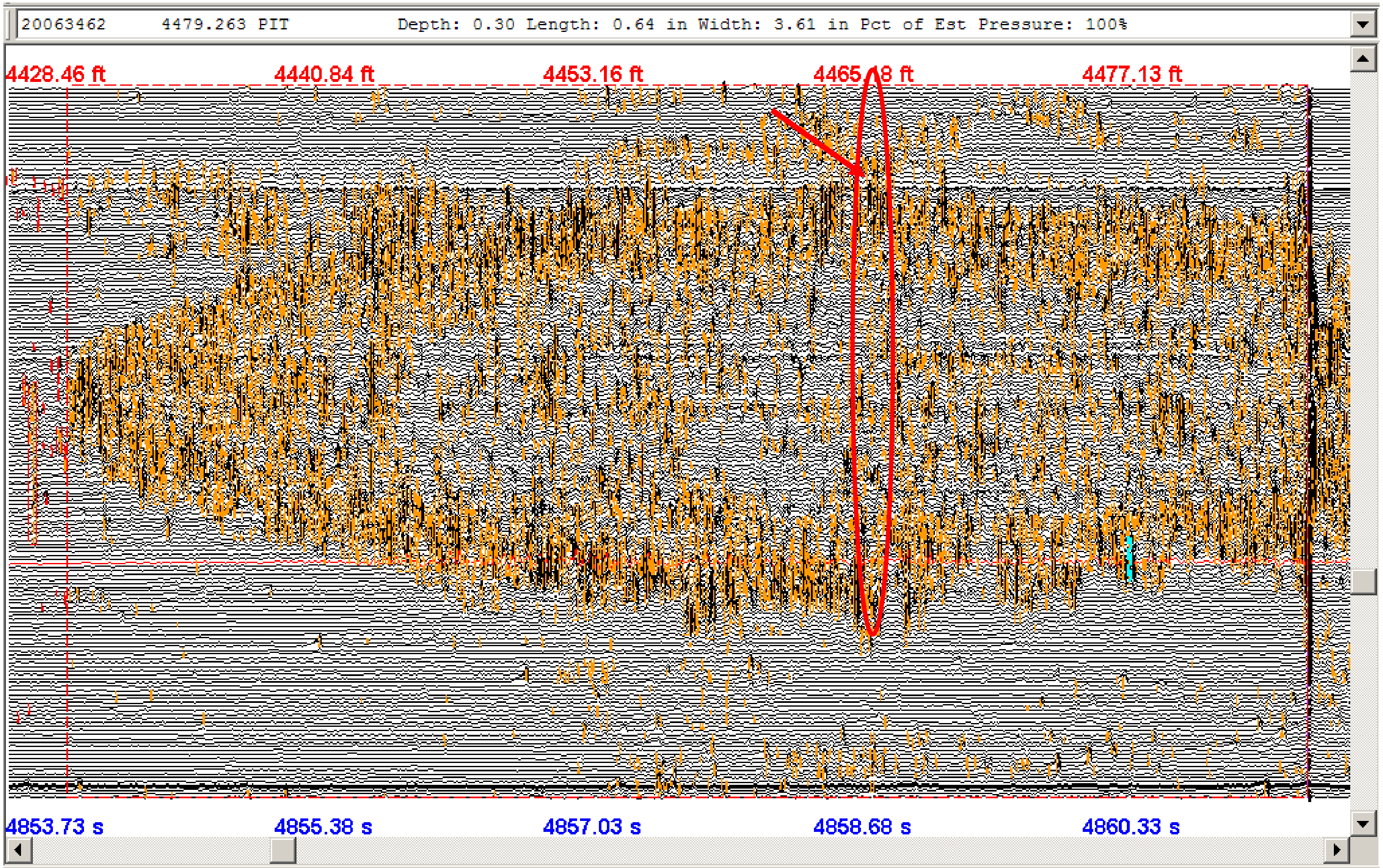
Joint
15.52

Test Section 3 bottom view, typical pitting 20-40 %




3 4 5 6 7 8 9 10


25 DEGREES
TOP OF PIPE