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PRCI Research Exchange

Pragmatic Study of Dent Restraint Conditions for ILI-Reported Dents: Insights from API RP 1183

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Background & Objective

- **Background**
  - Determining the restraint condition of the dent is an important factor in estimating the fatigue life of the dented pipe.
  - API RP 1183, Assessment and Management of Pipeline Dents, drawing upon the findings of the PRCI MD-4-9 research project, provides a systematic framework for assessing dent restraint based on dent shape data obtained from In-Line Inspection (ILI) caliper tools.
- **Objective**
  - evaluate the effectiveness of RP methodology for determining restraint condition
  - investigated the implications of varying the threshold value recommended by recently completed PRCI NDE-4-18 and MD-5-3 projects.

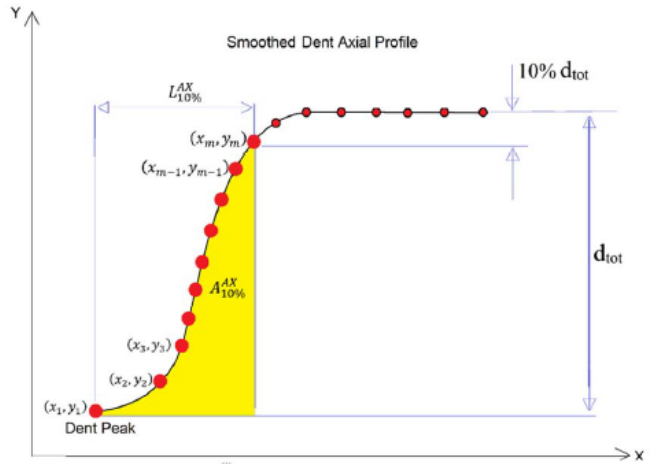
Dent Restraint Assessment Guidance per API RP 1183

Table 2—Single-peak Dent Geometric Parameters Required to Capture Dent Shape at Dent Peak and the Restraint Parameter and the Shape Parameter Calculation

Axial Length	Transverse Extent or Width	Axial Area	Transverse Area
$L^{AX}_{95\%}$	$L^{TR}_{90\%}$	$A^{AX}_{85\%}$	$A^{TR}_{85\%}$
$L^{AX}_{90\%}$	$L^{TR}_{85\%}$	$A^{AX}_{75\%}$	$A^{TR}_{75\%}$
$L^{AX}_{85\%}$	$L^{TR}_{80\%}$	$A^{AX}_{60\%}$	$A^{TR}_{60\%}$
$L^{AX}_{75\%}$	$L^{TR}_{75\%}$	$A^{AX}_{50\%}$	$A^{TR}_{50\%}$
$L^{AX}_{60\%}$	$L^{TR}_{70\%}$	$A^{AX}_{40\%}$	$A^{TR}_{40\%}$
$L^{AX}_{50\%}$	$L^{TR}_{60\%}$	$A^{AX}_{30\%}$	$A^{TR}_{30\%}$
$L^{AX}_{40\%}$	$L^{TR}_{50\%}$	$A^{AX}_{20\%}$	$A^{TR}_{20\%}$
$L^{AX}_{30\%}$	$L^{TR}_{40\%}$	$A^{AX}_{15\%}$	$A^{TR}_{15\%}$
$L^{AX}_{20\%}$	$L^{TR}_{30\%}$	$A^{AX}_{10\%}$	$A^{TR}_{10\%}$
$L^{AX}_{15\%}$	$L^{TR}_{20\%}$	—	—
$L^{AX}_{10\%}$	$L^{TR}_{15\%}$	—	—
$L^{AX}_{5\%}$	$L^{TR}_{10\%}$	—	—

NOTE 1 All the parameters listed above (axial and transverse) should be calculated based on the Maximum Total Dent Deformation Depth determined from the axial profile as illustrated in Figure 5 which shows that the total dent deformation depth measured from the axial dent profile may be different from that inferred from the circumferential profile. Report maximum total dent deformation depth (that includes ovality, see Section 6.3 and Figure 7) based on which of the above parameters have been calculated.

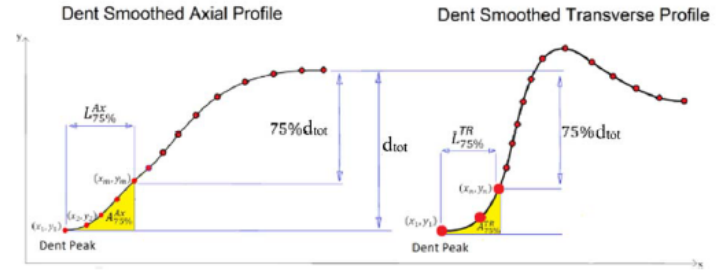
NOTE 2 The internal pressure when the dent shape is measured should be collected, reported, and applied, as part of the characterization.



$$A^{AX}_{10\%} = \frac{1}{2}\sum_{k=2}^{m}(x_k - x_{k-1})\left|(y_k - y_1) + (y_{k-1} - y_1)\right|$$

where

m is the number of data points from the deepest point to $L^{AX}_{10\%}$ location.



$$A^{AX}_{75\%} = \frac{1}{2}\sum_{k=2}^{m}(x_k - x_{k-1})\left|(y_k - y_1) + (y_{k-1} - y_1)\right| \qquad A^{TR}_{75\%} = \frac{1}{2}\sum_{k=2}^{n}(x_k - x_{k-1})\left|(y_k - y_1) + (y_{k-1} - y_1)\right|$$

m: number of data points from the deepest point to $L^{AX}_{75\%}$ location

n: number of data points from the deepest point to $L^{TR}_{75\%}$ location

Figure 5—Schematic Showing 10 % Axial Length and Area (top) and 75 % Axial and Transverse Length and Area (bottom)

Restraint Parameter (RP) Calculation

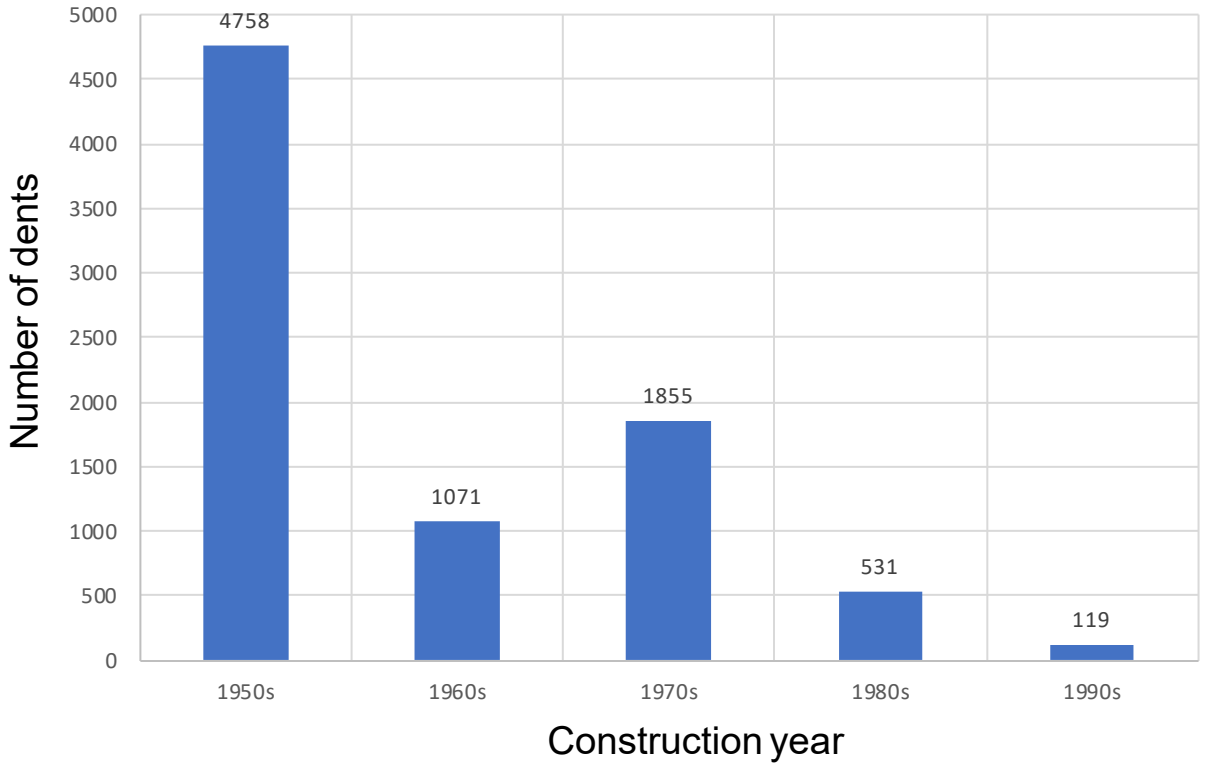
- API RP 1183 states: ILI data describing the dent shape may be used to evaluate the restraint condition. The shape of the dent will change in response to the removal of the indenter. Based upon this understanding of this change in dent shape, a restraint parameter has been developed to evaluate the dent restraint condition.

$$\rho = \max\left\{\frac{18\times\left|A_{15\%}^{AX} - A_{15\%}^{TR}\right|^{1/2}}{L_{70\%}^{TR}}, 8\times\left(\frac{L_{15\%}^{AX}}{L_{30\%}^{AX}}\right)^{1/4}\times\left(\frac{L_{30\%}^{AX} - L_{50\%}^{AX}}{L_{80\%}^{TR}}\right)^{1/2}\right\}$$

- ρ > **20** indicates restrained dents and ρ ≤ **20** indicates unrestrained dents.

Summary of Data

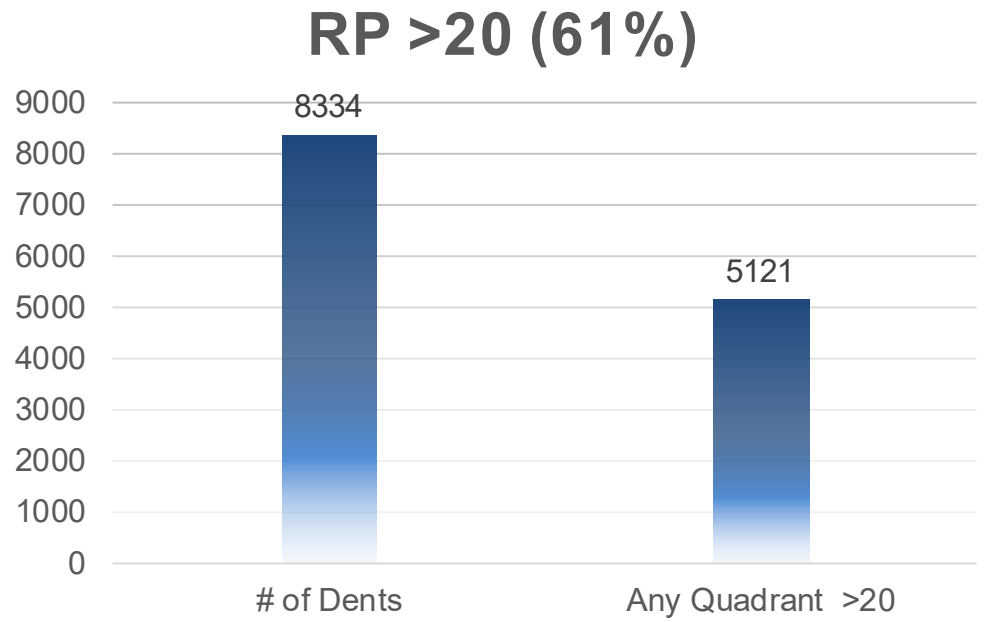
# of ILIs	ILI year	# of Vendors	Pipe OD	# of dents	ILI length
20	2015-2023	4	6" - 48"	8334	3391 km



Summary – All Dents With RP > 20

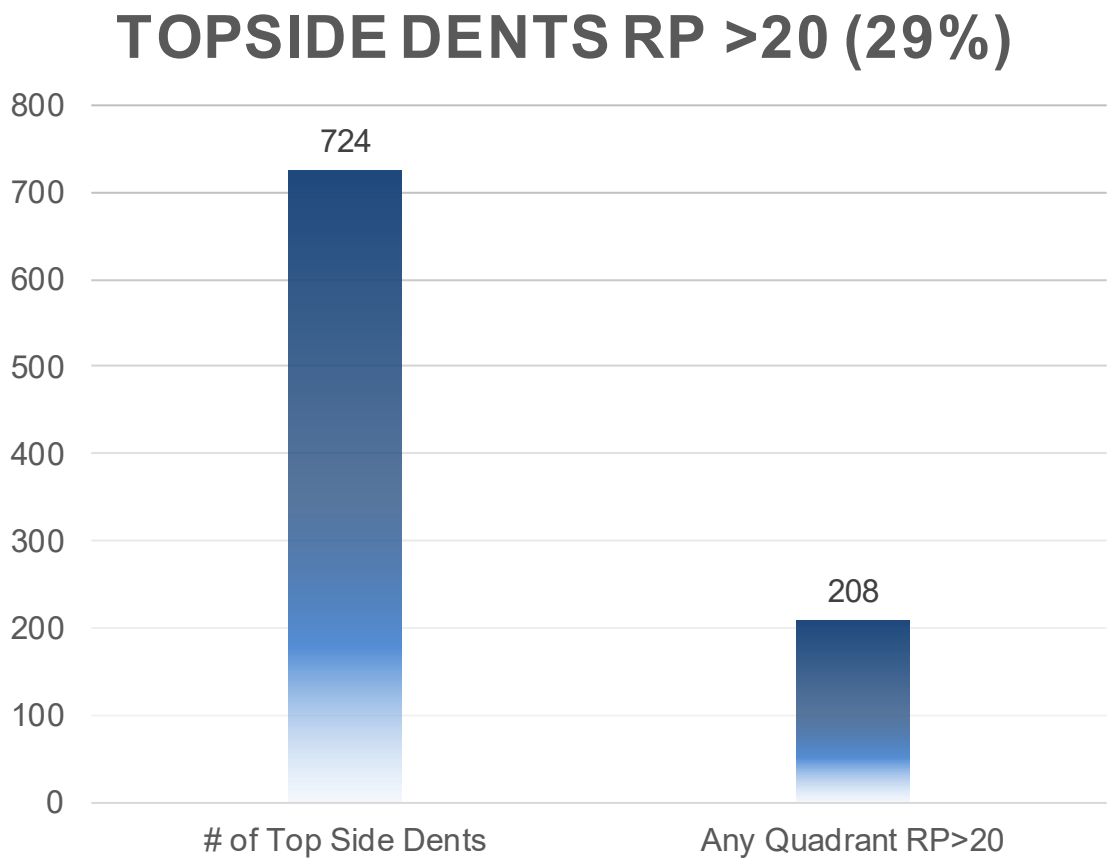
- The restraint parameter was developed and is applicable to single-peak symmetric and asymmetric dents in various pipe geometries at pressures producing 10 % to 100 % SMYS hoop stresses.
- If a dent is asymmetric, all four combinations of upstream (US)/downstream (DS) axial profiles with clockwise (CW) and counterclockwise (CCW) transverse profiles need to be included when evaluating the dent restraint parameter and the dent shape parameter.

NPS	# of Dents	# of dent with any quadrant RP >20	% of dent with any quadrant RP>20
6	48	21	44%
8	316	153	48%
10	138	72	52%
12	185	127	69%
16	276	201	73%
20	1652	1327	80%
24	450	386	86%
30	2921	1501	51%
36	1809	1036	57%
42	374	183	49%
48	165	114	69%
	8334	5121	61%



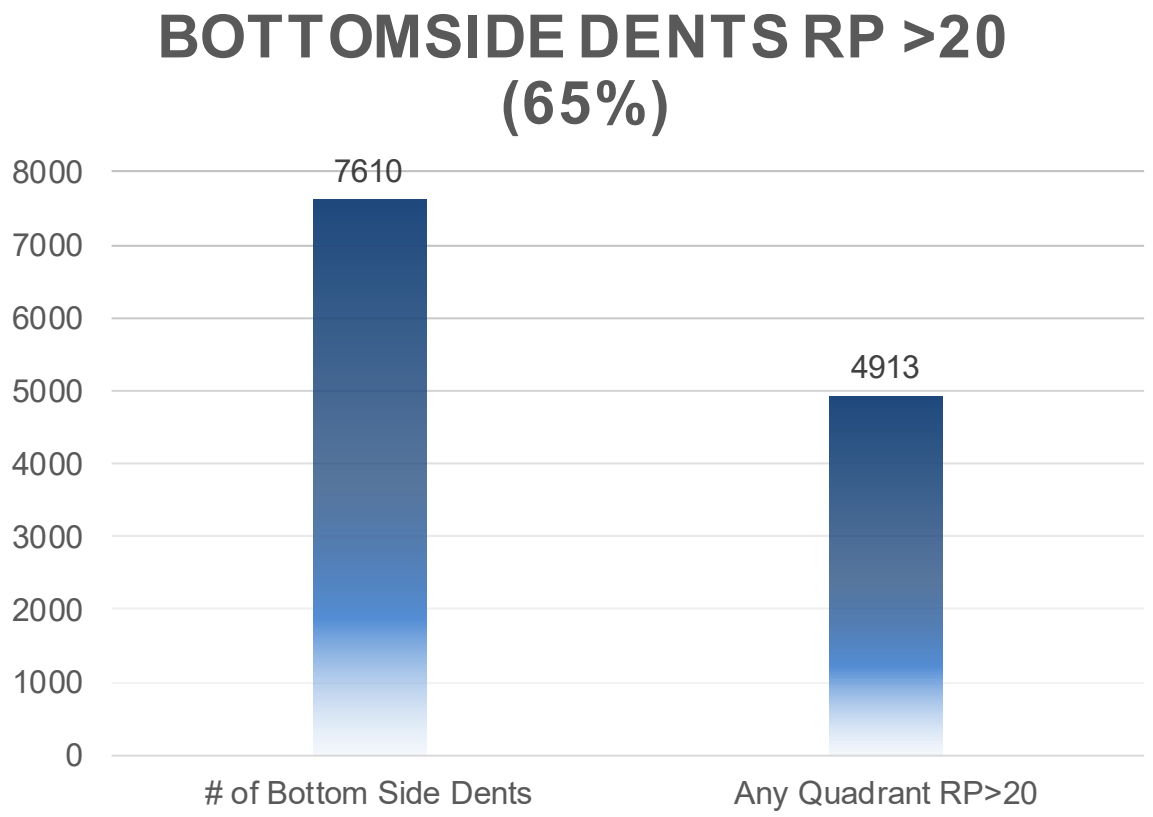
Summary – Topside Dents With RP > 20

NPS	# of Dents	# of Top Side Dents	# of dents with any quadrant RP>20	% of dents with any quadrant RP>20
6	48	31	14	45%
8	316	182	60	33%
10	138	51	9	18%
12	185	37	11	30%
16	276	23	10	43%
20	1652	112	39	35%
24	450	5	3	60%
30	2921	264	54	20%
36	1809	8	3	38%
42	374	11	5	45%
48	165	0	0	NA
	8334	724	208	29%



Summary – Bottom Side Dents With RP > 20

NPS	# of Dents	# of Bottom Side Dents	# of dents with any quadrant RP>20	% of dents with any quadrant RP>20
6	48	17	7	41%
8	316	134	93	69%
10	138	87	63	72%
12	185	148	116	78%
16	276	253	191	75%
20	1652	1540	1288	84%
24	450	445	383	86%
30	2921	2657	1447	54%
36	1809	1801	1033	57%
42	374	363	178	49%
48	165	165	114	69%
	8334	**7610**	**4913**	**65%**



Study of Variable RP Values

- PRCI NDE 4-18 and MD 5-3 suggest an RP range of 15-25 to account for the uncertainty in restraint parameter prediction due to ILI shape variation.
- The estimated restraint condition of a dent applies to the dent as a whole (i.e., the restraint condition does not change from one quadrant to the other).
- If all the RP values for all four combinations of dent profiles are lower than 15, that is a strong indication the dent is unrestrained.

		Restrained based on RP				Un-Restrained based on RP	
		# of dent with any quadrant RP>20	% of dent with any quadrant RP>20	# of dent with any quadrant RP>25	% of dent with any quadrant RP>25	# of dent with all quadrant RP<15	% of dent with all quadrant RP<15
# of Dents	8334	5121	61%	3249	39%	1465	18%
# of Topside Dents	724	208	29%	115	16%	374	52%
# of Bottomside dents	7610	4913	65%	3134	41%	1091	14%

Field Verification

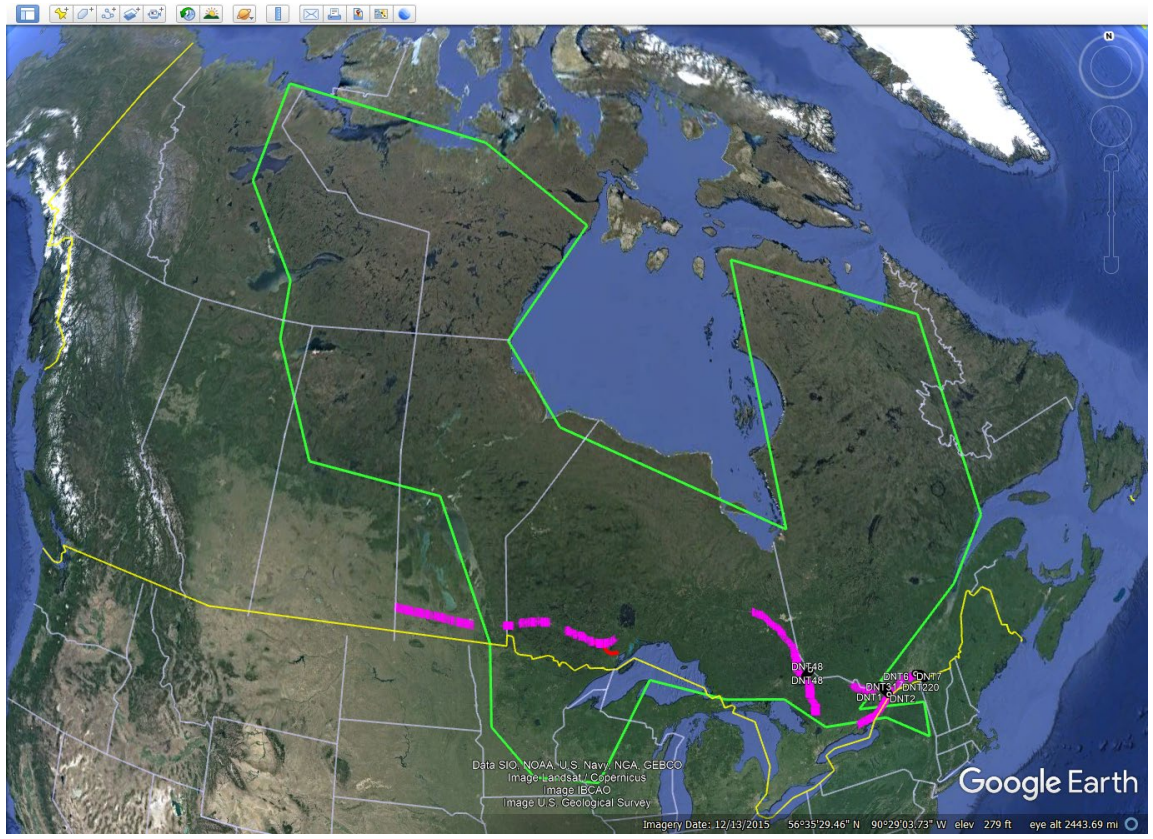
- **58 dent excavations**
- **17 bottom side dents with comments "Rock Impact"**
  - Restraint condition was calculated based on pre-dig ILI data
- **33 excavated dents were reinspected**
  - Restraint condition was calculated with post dig ILI data

	Cause of the dents found in the field			
	Rock Impact	Mechanical	Third Party	Other
All	24	4	1	29
Top	7	2	0	12
Bottom	17	2	1	17

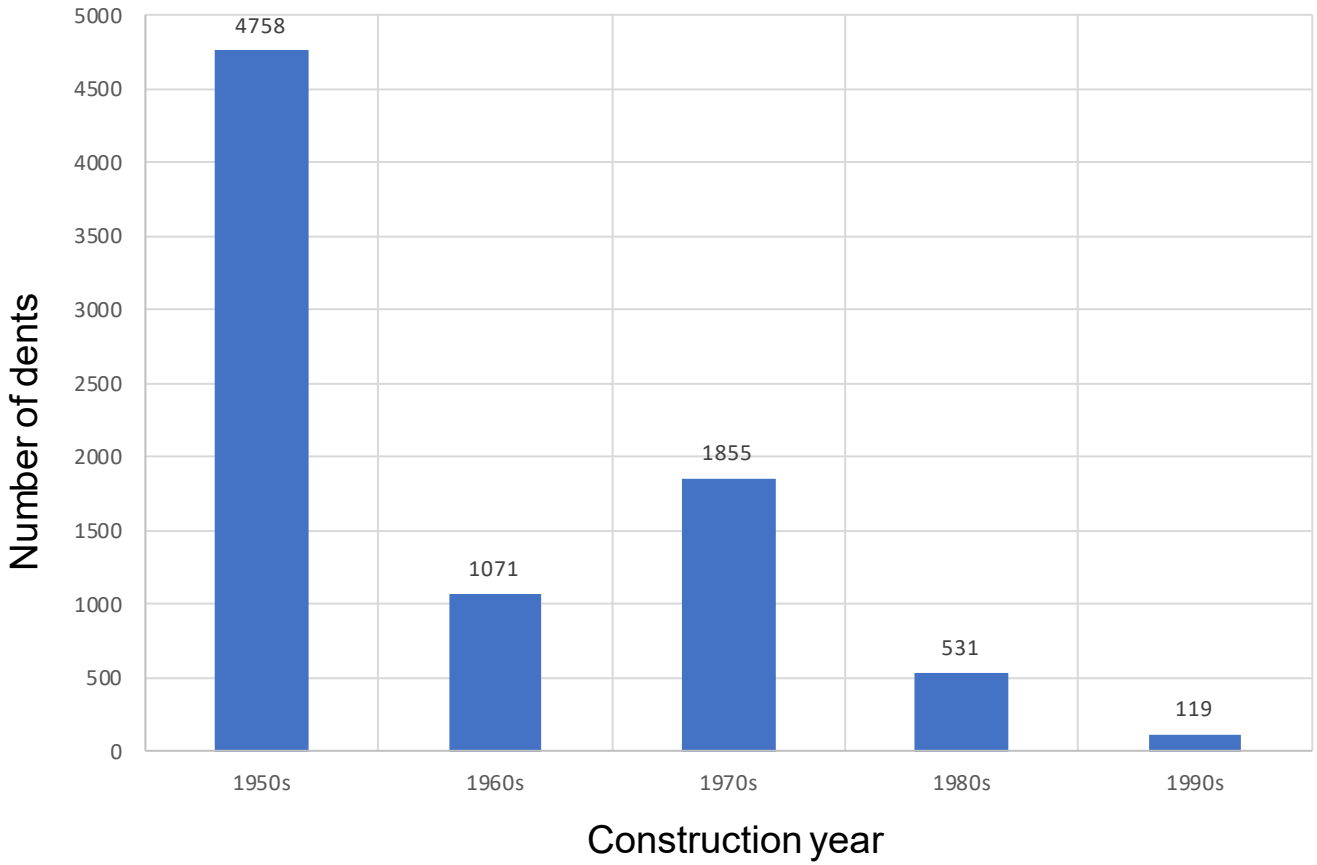
	Cause of the dents found in the field	# of Restrained dents based on RP		# of Unrestrained dents based on RP
	Rock Impact	Any Quadrant RP>25	Any Quadrant RP>20	All Quadrant RP<15
All	24	6	14	7
Top	7	0	1	4
Bottom	17	6	13	3

		# of Restrained dents based on RP		# of Unrestrained dents based on RP
	Dent Number	Any Quadrant RP>25	Any Quadrant RP>20	All Quadrant RP<15
All	33	2	5	18
Top	14	0	1	10
Bottom	19	2	4	8

Geospatial - Canadian Shield vs Studied Lines



Number of Dents vs. Pipeline Construction Year



Installation on the Canadian Shield

Figure 2-1 1958 Video – Canadian Mainline Canadian Shield Construction: Pipe Lowered Onto Bedrock

Field Excavation

Photo 1: GWD Excavation feature Dent area

Photo 2: GWD Excavation Large rock against pipe with no fractures

Field Excavation

Summary

- **8334 ILI-called dents on 11 various ODs**
  - 7612 bottom side dents and 723 topside dents
- **Based on RP=20:**
  - 61% of the total number of dents are restrained
  - 29% of topside dents are restrained, 65% of bottom side dents are restrained
- **Based on RP=25:**
  - 39% of the total number of dents are restrained
  - 16% of topside dents are restrained, 41% of bottom side dents are restrained
- **Based on all the RP values for all four combinations of dent profiles are lower than 15 that is a strong indication the dent is unrestrained**
  - 52% of topside dents are unrestrained, 14% of bottom side dents are unrestrained
- **Analysis results of excavated dents showed the as-found restraint condition is inconsistent with that determined by the calculated RP**

thank you

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