Onshore Pipeline Design

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Pipeline design

- **This is subdivided into**
- **Why perform design**
- **Design documentation**
- **Design process**
- **Design Codes and issues**
- **Pressure Testing**
- **Summary**

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Why Design pipelines

- **No two pipelines are the same**
- **Possible variations are in the range 100 X 10^9**
- **Legal requirements**
- **Cost effectiveness**
- **Safety**
- **Compliance with regulations**

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System design

- **Pipelines should be designed as part of an overall SYSTEM to obtain the optimum design.**
- **This means challenging the input and output conditions and flow regime where possible.**
- **Pipeline design incorporates pump and compressor design and operational control philosophy.**

Pipeline design documentation

- **Pipeline design documentation consists of:**
- **Design Basis**
- **Route maps / alignment sheets**
- **Reports (design, mechanical, stress etc)**
- **Philosophies (Control, Operation, Isolation etc)**
- **Drawings inc P & IDs, PFDs, Civil, Layout,…..**
- **Specifications**
- **Data sheets**
- **C & I design (C & E, loop diagrams …..)**

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Pipeline Design Basis

- **Also called BoD, this is a key document to develop as soon any design work commences and keep up to date as the design progresses.**
- **It is NOT a design report, therefore should not include the result of calculations determined as a result of the data used.**
- **Changes to the design basis will gradually cost more and more as design progresses due to the number of documents, drawings, calculations, tenders, orders etc that would require revision or consequential re-design.**

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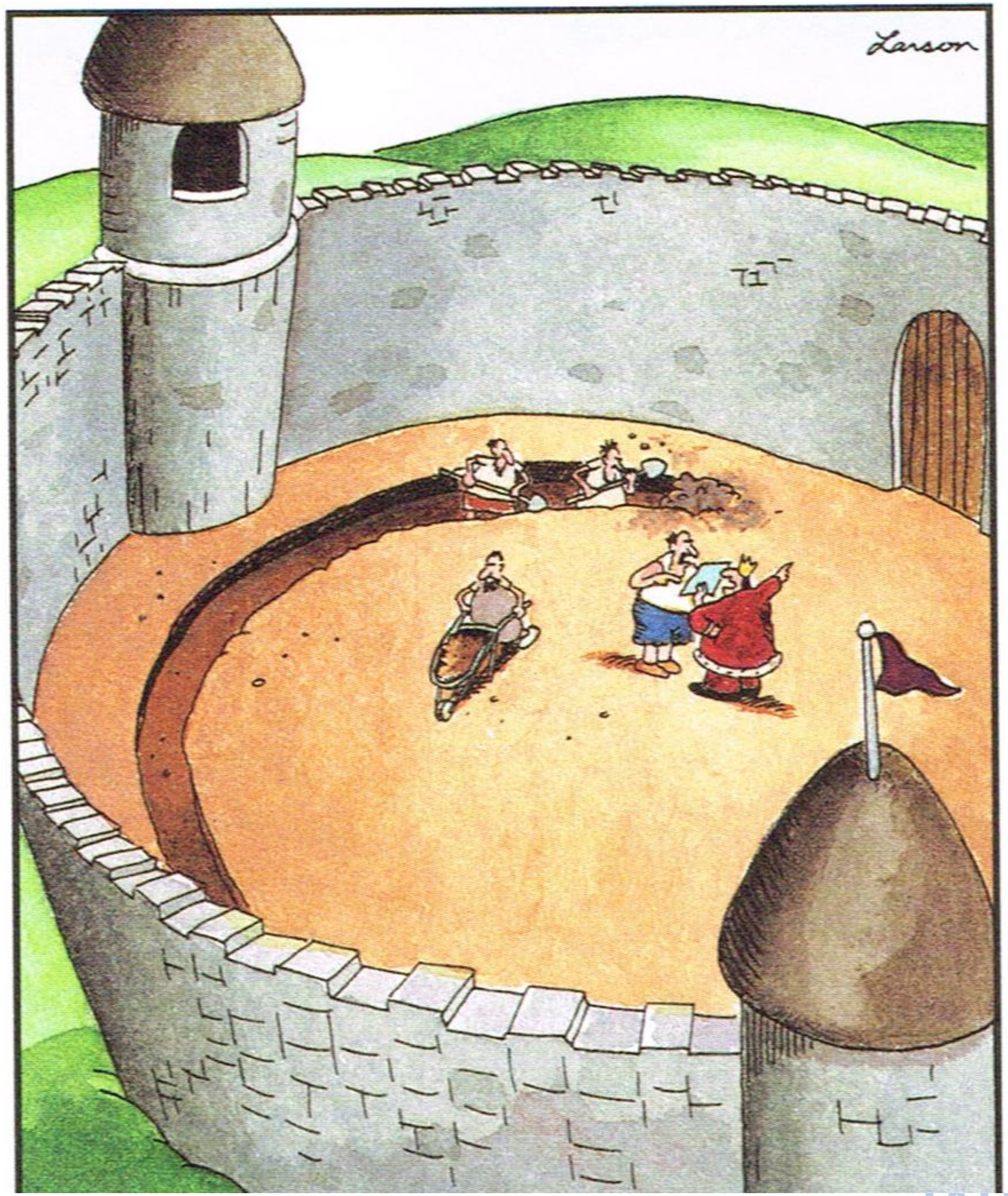
Design Basis

- **This is one reason**
- **why you need one….**

- **“Suddenly a heated exchange took place between the King and the moat contractor….”**



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Pipeline Design Basis

Key issues in Pipeline design basis include:

- **Design code to be used**
- **Process data (max / min flowrate, pressures,, temperature, corrosion allowance)**
- **Fluid data (composition, density, viscosity, compressibility (gas), range of properties over life time,**
- **Route data (length, elevation changes, profile, population (gas), crossings,)**
- **Environmental data (height, rainfall, ground temperature, ground / soil type)**

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Pipeline design sequence

- **<u>Design sequence</u>**
- **Pipeline design revolves around line pipe wall thickness.**
- **Initial hydraulic design generates design pressure**
- **Design pressure can allow for future expansion. It is not ASME class driven**
- **Initial design thickness is generated from pressure containment, fluid type, corrosivity, location and pipe material strength.**
- **Checks for allowable stress, bending, risk assessments use the design thickness as the start point to assess if thickness is sufficient.**
- **Changes to route, pressure, flow require iteration of design.**

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Pipeline vs Piping design

- **Pipeline design optimises pipe thickness (30-40% of cost vs < 10)**
- **Allows use of higher strength pipe and works on Yield Stress not UTS**
- **Variable design pressure vs stepped approach**
- **Buried, fully supported vs point loads**
- **Lower additional stresses (wind, snow, seismic etc)**
- **Higher design factor**
- **Interfaces between two approaches can be troublesome**
- **Different terminology and approach**

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Pipeline Design Codes

- **International design codes available**
- **Liquid only**
  - **ASME B 31.4**
- **Gas Only**
  - **ASME B 31.8**
  - **EN 1594**
  - **IGEM TD/1 (UK gas pipeline code)**
- **Liquid & Gas**
  - **PD8010**
  - **ISO 13623 (also EN 14161)**
  - **ASME B 31.3 (piping)**

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Design basis scope of application

- **Well fluids (wellhead to processing plant) in definition section of code.**
- **PD 8010, ISO 13623, EN 14161,**
- **DNV OS F-101 – Offshore with "short" onshore sections**
- **Use of B 31.8 & 31.4 in upstream design should be checked against other codes.**

- **Treated fluids (after separation) only**
- **ASME B 31.8, 31.4, EN 1594**
- **IGE TD/1 (Onshore only)**

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ASME B 31.8 definitions and interpretations

- **ASME B 31.8 has published certain interpretations which are relevant here:**

- **Interpretation 16-13 (2)**

- **“..***does the code exclude flow lines between gas production wells and gas separation facilities***?”**
- **Reply (2): Yes**

- **Interpretation 16-16 (2) & (4)**

- **“***Can gas pipelines be designed (2) or operated (4) at transient overpressure up to 10% above MAOP, similar to ASME B 31.4***?”**
- **Reply (2) & (4): No**

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Pipeline Line Pipe

- **Pipelines commonly use higher grade (higher SMYS) pipe than piping to reduce wall thickness**
- **Most common line pipe code is API 5L / ISO 3183.**
- **Commonly used designations are Grade B (SMYS 35,000 psi), then X grades. Number denotes SMYS in ,000 psi, e.g X60 – SMYS 60,000 psi**
- **Grades now nominal in MPa to nearest 5 MPa**
- **E.g X60 is now officially L415 (now a standard grade)**
- **Use of grades up to X80 more common**
- **Issues remain with lowered UTS/SMYS ratio**
- **Pipe 12” Nom diameter and less has OD different (larger) than ND, but 14” and above it is the same.**
- **Wall thicknesses can be bespoke, but often “standard” wall thicknesses used as listed in ASME B 36.10M – also lists weight per m**

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Pipeline Line Pipe

14”+ OD = nom size
12” OD = 12.75” - 323.8 mm
10” OD = 10.75” – 273.0mm
8” OD = 8.625” – 219.1mm
6” OD = 6.625” – 168.3 mm
4” OD = 4.5” – 114.3 mm
Material strengths (SMYS) in MPa

Grade B	**- L 245**
X52	**- L 360**
X60	**- L 415**
X65	**- L 450**
X70	**- L 485**

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Pipeline Flanges and fittings

- **Pipelines using higher grade (higher SMYS) pipe results in thinner wall than similar piping connections including flanges requiring higher strength flange material**
- **ASME B 16.5 does not list the most common material used (A694 FXX) – XX = API 5L grade of pipe**
- **Recommended flange code is ASME/MSS SP-44. Allows use of high grade steel forging to match high grade pipe.**
- **Higher pressure temperature allowance**
- **Dimensions to ASME B 16.5**
- **Many systems get this wrong**

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Design basis scope of application

- **Pumping / Compressor stations**
- **All pipeline codes**
- **Normative references need to be followed unless not explicitly stated**
- **Line pipe codes**
- **Convergence of API 5L and ISO 3183 in 2008 to create single pipe code with altered SMYS limits and tolerances. Now separate again, but essentially identical. PSL 2 normally specified for line pipe**
- **EN 10208 previously applicable for EN codes now withdrawn and replaced by EN ISO 3183 – 2013**
- **One global Line pipe standard has arrived**

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Design pressure definition

- **Inlet pressure required for flowrate**
- **Highest pressure experienced by pipeline at any stage of its life (except hydrotest)**
- **Elevation changes - “telescoping”**
- **Overpressure protection systems (surge)**
- **Overpressure permitted varies**
  - **ASME B 31.4, PD 8010, ISO 13628 all 10%**
  - **EN 1594 15%**
  - **ASME B 31.8 0%**
  - **ASME B 31.1 can be 33% for limited duration per year (5 hours) and lower for longer**

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Pipeline pressure relationships

- **<u>Read the definitions in each code</u>**
- **MOP – Maximum Operating Pressure**
- **MAOP – Maximum Allowable Operating Pressure**
- **Design pressure is always >= MOP, MAOP**
- **Test pressure has an effect in some codes - ASME links MAOP to test Pressure and location class**
- **Test pressure is <u>always</u> higher than MOP + surge**
- **MOP needs to take account of safety relief systems and accuracy or pressure trips**

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ASME B 31.4 / 31.8 relationship

Test pressure = MOP x 1.1 to 1.4

Test Pressure

Surge Pressure	Always >0		
DESIGN PRESSURE	ASME B 31.4 = 10% ASME B 31.8 = 0%		
MAOP	Can be zero	MAOP = Test P / 1.1 to 1.4	
MOP	Can be zero		

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PD 8010

Key

1 Pressure

2 Test pressure

3 1.10 × design pressure

4 Design pressure

5 Maximum allowable operating pressure

6 Static head pressure

7 Hydraulic gradient

8 Ground profile

9 Surge pressure, thermal and other variations

10 Pressure recommended to overcome friction losses

11 Recommended backpressure

12 Distance along pipe

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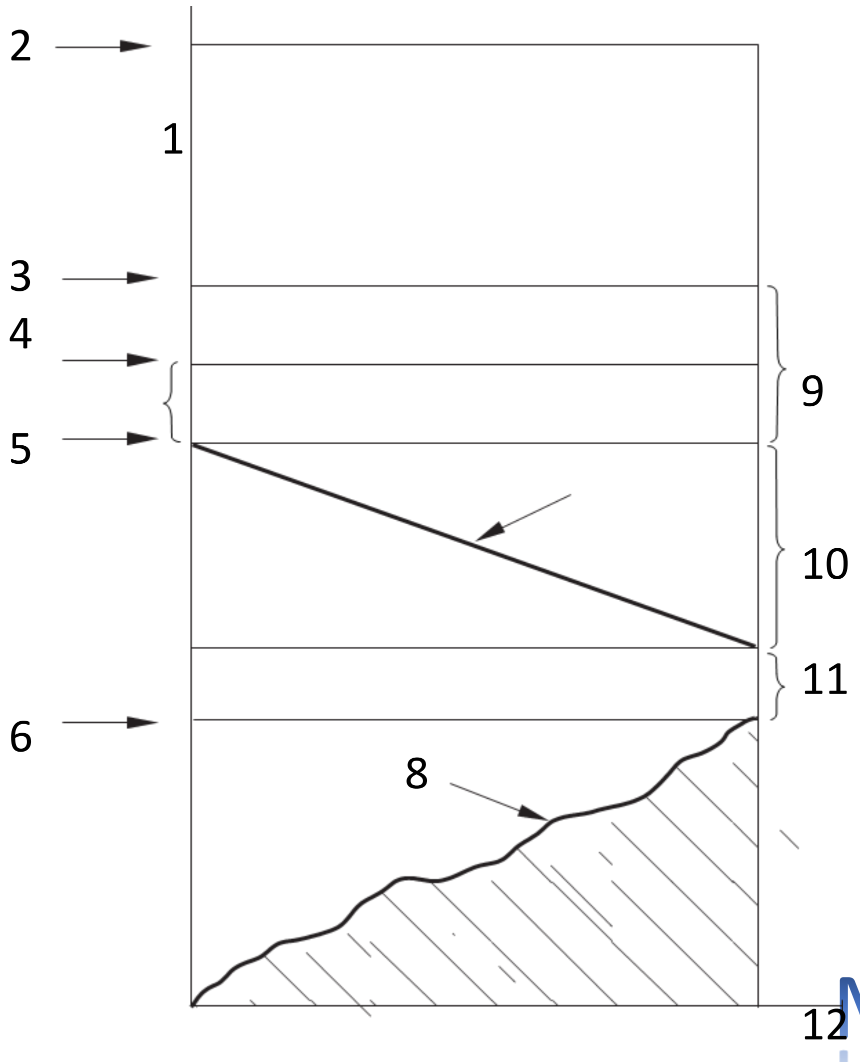

Pipeline Design

Stress based design codes are the only currently issued codes available for land pipelines.

Once a design code is chosen, you must stay with it in all aspects unless it is silent on a particular issue.

Obtaining wall thickness - Metric Version

$$t = \frac{P\ D}{20\ S\ E\ F\ T}$$

$$t = \frac{P\ D}{((20\ SEFT) + P)} \qquad \text{ISO 13623 / EN 14161}$$

S= SMYS, E = joint factor, F = Design Factor, T = temperature de-rating factor

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Nominal wall thickness

- **No manufacturing tolerance added to ASME B 31.4 / 31.8**
- **Tolerance must be added to the design thickness plus corrosion allowance (if any) by dividing by (100 - tolerance) in percent. Do not add the tolerance as a direct percentage. Effect may be small but could be significant.**

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Design Factors

- **Design factors vary between codes and types of pipelines.**
- **Table list maximum and ranges for gas and hydrocarbon contents.**

Code	ASME B 31.8	ASME B 31.4	PD 8010	TD/1	ISO 13623	EN 1594
Design Factor Liquid	-	0.72	O.72	-	0.77	-
Design Factor Gas	0.4-0.8	-	0.3-0.72	0.3-0.8	0.45-0.83	0.3-0.72

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Location Class – Gas pipelines

Gas pipeline design codes use location class as a form of risk analysis and control based on historical information, standard risk analysis and experimental data.

All use a measure of population density in a zone around the pipeline to register different design factors for general routes, road/rail crossings and vulnerable areas.

Location class definition needs to be used with discretion, erring on the cautious side.

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Location Class – Gas pipelines

The only codes to require minimum proximity are IGE TD/1 and PD 8010. The distance is variable depending on pipe size, design factor and Maximum Operating Pressure . Area classification is based on a zone 10 times (PD8010) or 8 times (TD/1) this distance.

Other codes use a fixed 400m wide corridor. All use a length of 1500m or 1 mile (ASME).

ASME counts number of dwellings, other codes count people and then average them out over the box. This determines the location class.

There is a Canadian code which can calculate a High Consequence Area, $R=0.685\ (PD^2)^{½}$, where r is in feet, d in inches and p in psig. Either extra protection is required or no dwellings in this area. For a 30”, 800 psig / 55 barg pipeline this equates to approx. 175m radius example next slide.

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Location Class – Gas pipelines – Fire
Virginia 2009

Location class and design factor

	ASME B 31.8		ISO 13623		PD 8010/TD1	
	No buildings	Design Factor	No people/ km2	Design Factor	No people/ km2	Design Factor
1.1	0	0.8	0	0.83	< 250	0.72
1.2	<10	0.72	<50	0.77		
2	10 < 46	0.5	50 < 250	0.67		
3	>46	0.5	> 250	0.55	>250	0.3
4	Subjective	0.4	Subjective	0.45	Subjective	< 16 barg

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Pipe Design Examples

- **Liquid pipeline, 16”, DP 85 barg, Pipe grade B, X 60**
- **API and ISO manufacturing tolerances used**

	Grd B	X60
ASME B 31.4	**9.95mm**	**5.8mm**
PD8010	**11.05mm**	**6.45mm**
ISO 13623	**9.42mm**	**5.61mm**

- **Check D/t for smaller pipe sizes / pressures. Max 70-80**

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Pipe design examples

- **Gas (methane) pipeline, 30", DP 85 barg, Pipe grade X 60. High, med and low location class.**
- **API and ISO tolerances used**

More complex comparison due to location class

Low location (remote) wt of 8.6mm for B 31.8 / ISO vs 10.7 for TD/1

Medium location wt of 9.3 to 9.6 vs 10.7

Higher class (suburban) 12.9 to 13.8 vs 25.8 (19.1)

Choice of codes matters

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Pressure Testing

- **Hydrostatic Pressure testing is required by all design codes, but the test pressure, test duration, application point and acceptance of pneumatic testing vary between each code to such an extent that comparison is not simple. The main areas to be addressed are:**
- **Air tests permitted. To be used only when water is not available or where intense elevation changes cause pipeline to be divided into multiple sections. Codes that permit this are ANSI B 31.8 (but not for class 1 division 1), EN 1594 (provided P x V is "limited") & ISO 13623.**
- **PD 8010, IGE TD/1 and ASME B 31.4 do not allow air tests.**

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Pressure Testing

- **ASME B 31.4 - 1.25 x DP at any point (i.e. highest), no maximum pressure, min 4 hours**
- **PD 8010 - 90% of SMYS at highest point, no more than yield at lowest point, 24 hours at test pressure**
- **ISO 13623 - 1.25 x MAOP at highest point, no maximum, 1 hr min, followed by strength test for 8 hours, at 1.1 x MAOP.**
- **EN 1594 - 0.15 x DP above MIP at lowest point, 0.05 x DP above MIP at highest point, min 15 mins. Tightness test 24 hrs at not less than DP.**

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Pressure Testing

- **ASME B 31.8 - varies by location class - 1.1 is 1.25, 1.2 is 1.1, 2 is 1.25, 3 & 4 is 1.4 all multiplied by MOP for minimum of 2 hours. Air is 1.1 x MOP. MAOP is reverse linked to test pressure, i.e. MAOP = test pressure/ factor or DP, whichever is lower. Assumed to be at the highest point, but not defined. No upper limit.**
- **IGE TD/1 - Uses a factor of 0.9 to 1.05 SMYS at the lowest point depending on type of pipe, SAW-1.05, seamless - 0.9, ERW - 1.0. All for 24 hours. May be reduced to 1.5 times MOP for low fatigue or low design factor pipelines. Test sections limited to 60 m elevation change. Test pressure limited on half slope if achieved first.**

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Pressure Testing

- **Common items:**
- **Use design thickness when calculating test pressure using stress limits (ISO 13623 requires multiply TP by t_{min} + CA / t_{min}).**
- **Where not expressly stated do not exceed SMYS at lowest point, or 1.05 at most.**
- **PD 8010 & IGE TD/1 provide calculations, graphs and guidance for evaluating changes in pressure due to temperature fluctuations.**
- **Tie in ("golden") welds not required to be hydrostatically tested, but need two types of NDT.**
- **Max air percent 0.2% by volume**

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Summary

- **This section has shown**
- **Why pipeline design is required.**
- **What you produce as a result of design**
- **International design codes available and effect of different codes and definitions**
- **Outline of pipeline design**
- **Test pressure considerations**

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Thank You

Any questions?