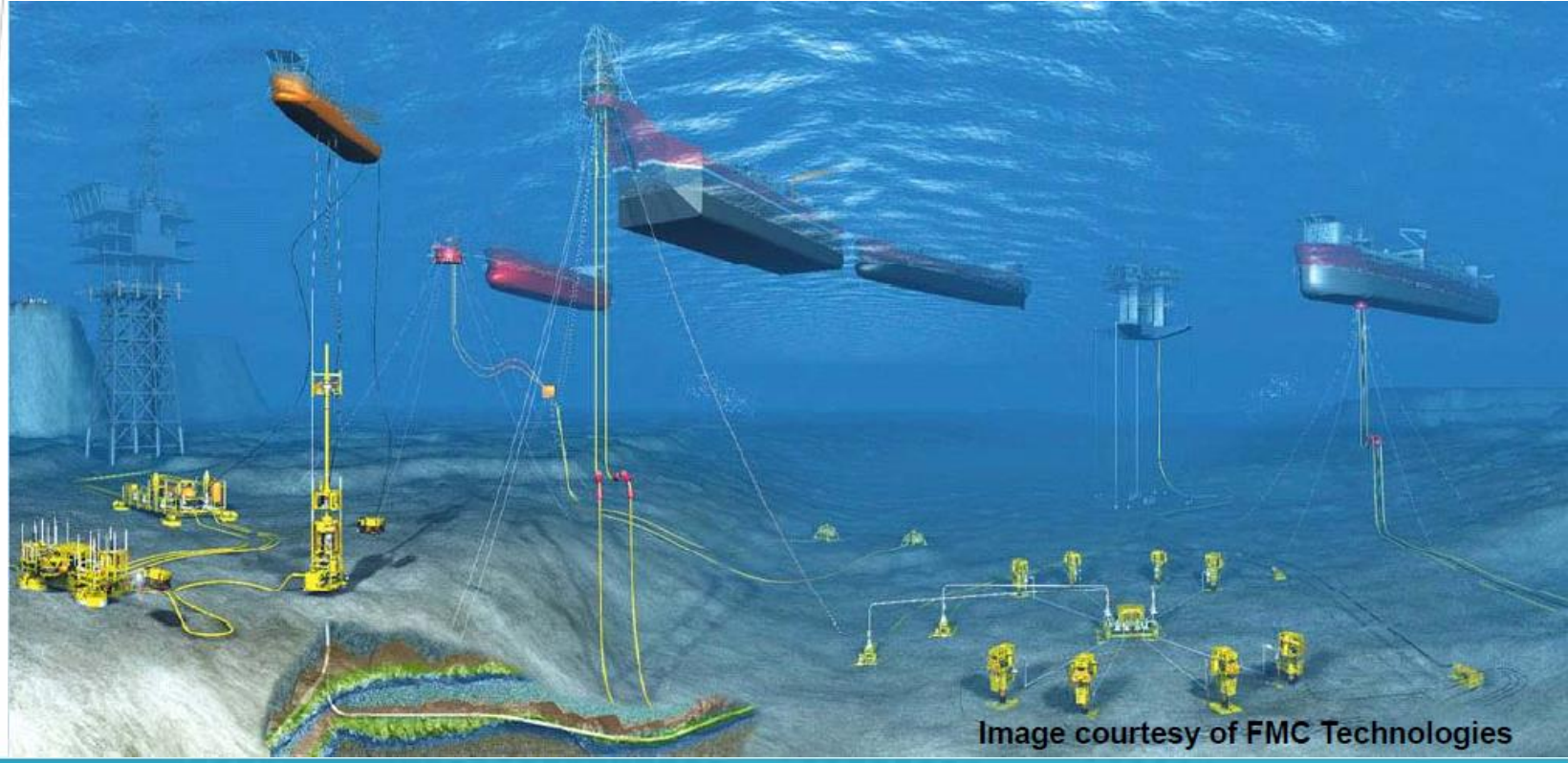
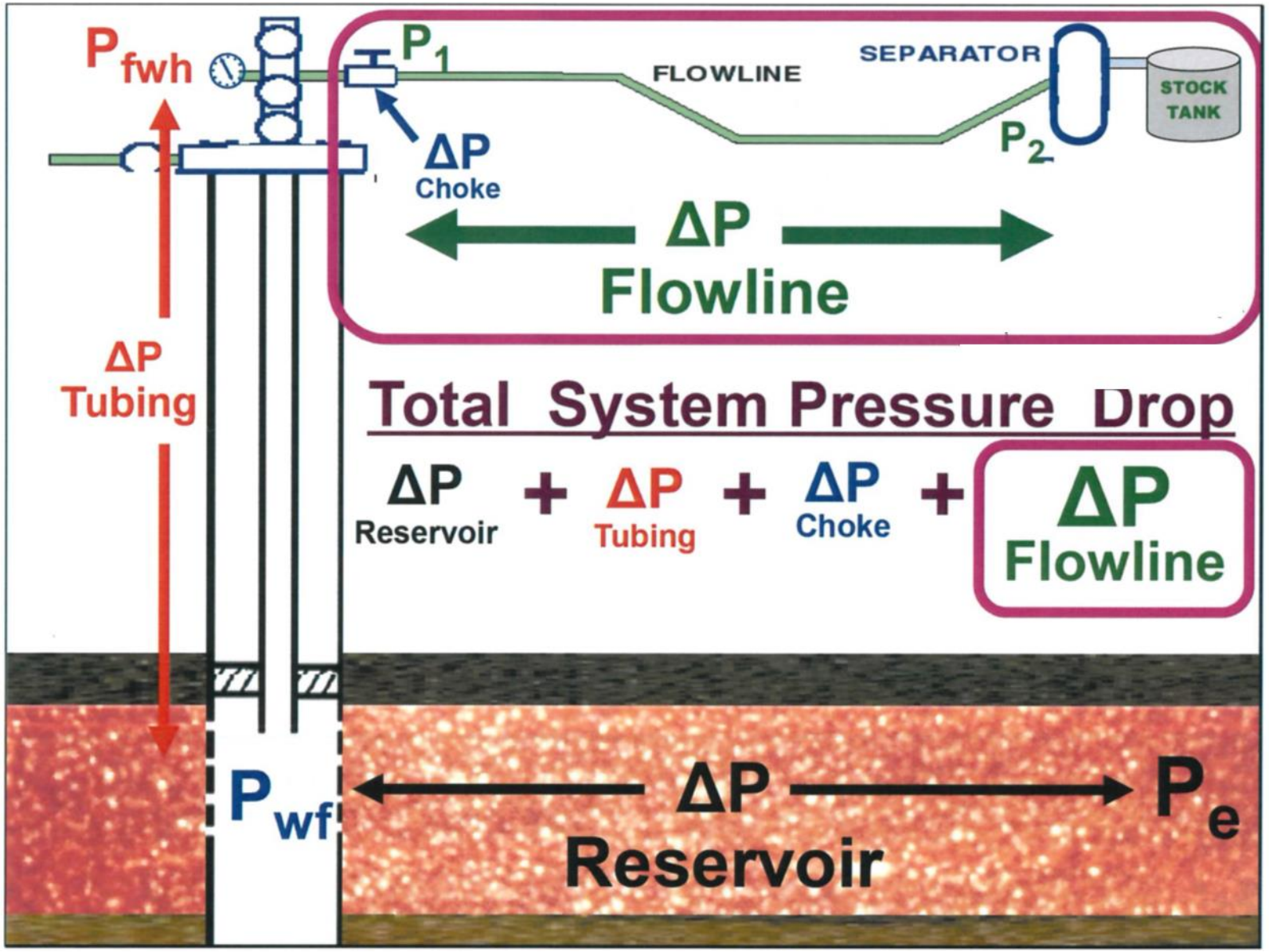


Flow Assurance

서유택

Gathering system



Long pipeline may induce phase change

Flowlines, Manifolds and Piping

- Equipment used to transmit produced fluids from wellhead through treating equipment
  - Piping
  - Connections
  - Valves
  - Fittings
- Flowlines: Usually 2” to 16”
  - API steel line pipe
    : Standard 5 L < 1000 psi
    : Strandard 5 LX > 1000 psi
- Pipe:
  - Closed conduit
  - Circular cross-section
  - Constant internal diameter (ID)

Pipeline sizing

- Consider fluid velocity
  - Limit noise / corrosion / erosion
  - Prevent solids build-up in liquid lines
  - Prevent liquid build-up in gas lines
- Contain internal pressure
  - Pipe wall thickness and material strength
- Minimize pressure drop
  - Minimize pump / compression cost
  - Optimize installed cost

Fluid velocity

- Flowline size – internal diameter

- Pipe internal diameter
  - Larger diameter ⇨ fluids move slower
  - Smaller diameter ⇨ fluids move faster

- Line size criteria

  (Liquid)

$$d^2 = \frac{0.012\ QBLPD}{v}$$

d: pipe ID, inches,
v: liquid velocity, ft/sec

  - Max velocity = 15 ft/sec (Noise and Erosion)
  - Min velocity = 3 ft/sec (Solids buildup)

  (Gas)

$$d^2 = \frac{60\ QMMSCFDTz}{Pv}$$

d: pipe ID, inches,
T: temperature, ^oR
z: compressibility factor
P: pressure, psia
v: fluid velocity, ft/sec

  - Max velocity = 60 ft/sec (Noise and corrosion)
  - Min velocity = 10 ~ 15 ft/sec (Liquid buildup)

Exercise: Liquid line size

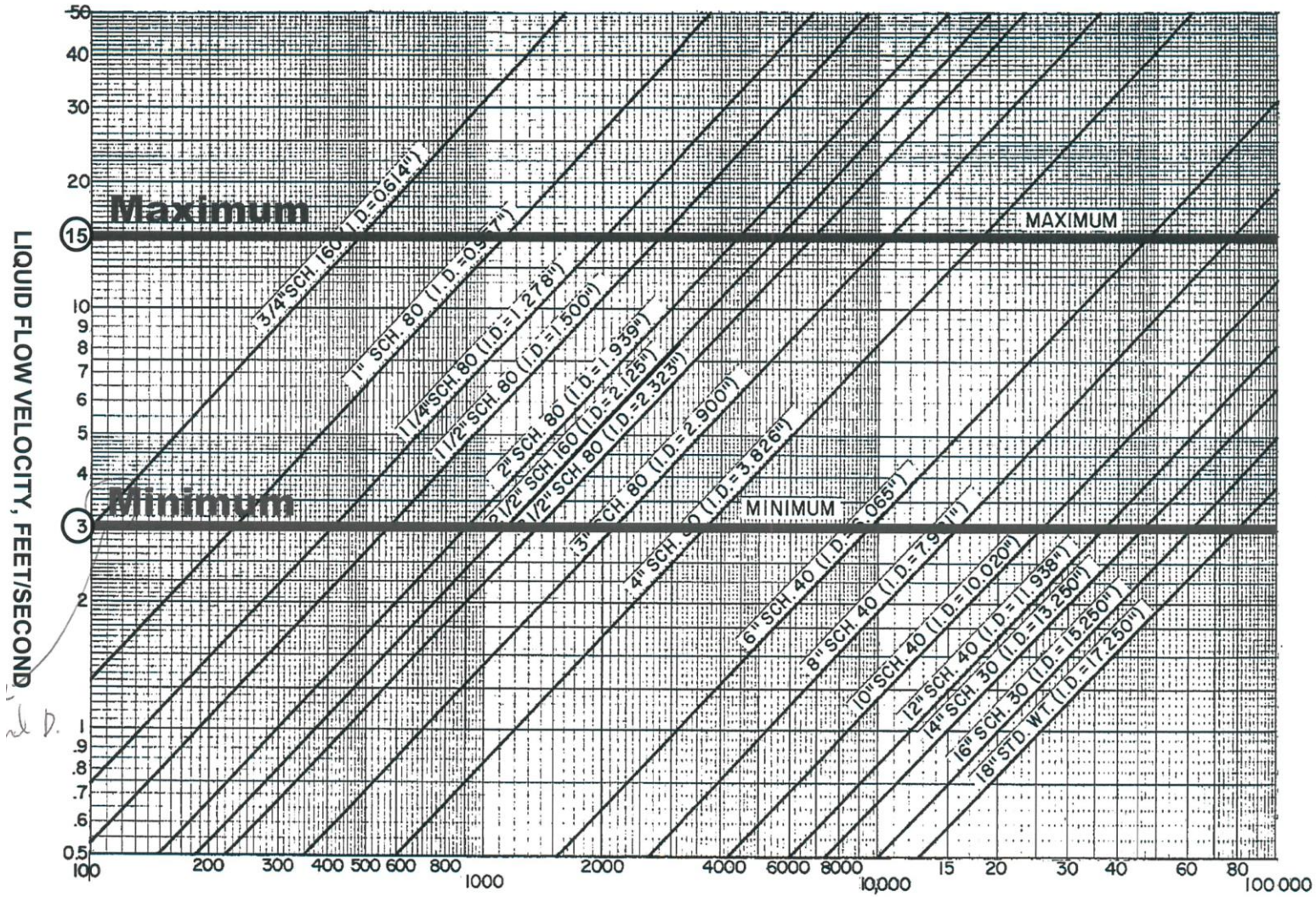
- Choose a pipeline size to handle: 1000 blpd

$$d^2 = \frac{0.012\ QBLPD}{v}$$

  - Max velocity = 15 ft/sec (Noise and Erosion)
  - Min velocity = 3 ft/sec (Solids buildup)

- What if pipeline is too small?
  - Velocity too high: Noise or erosion
  - What can be done?

- What if pipeline is too large?
  - Velocity too low: Solid drop out
  - What can be done?

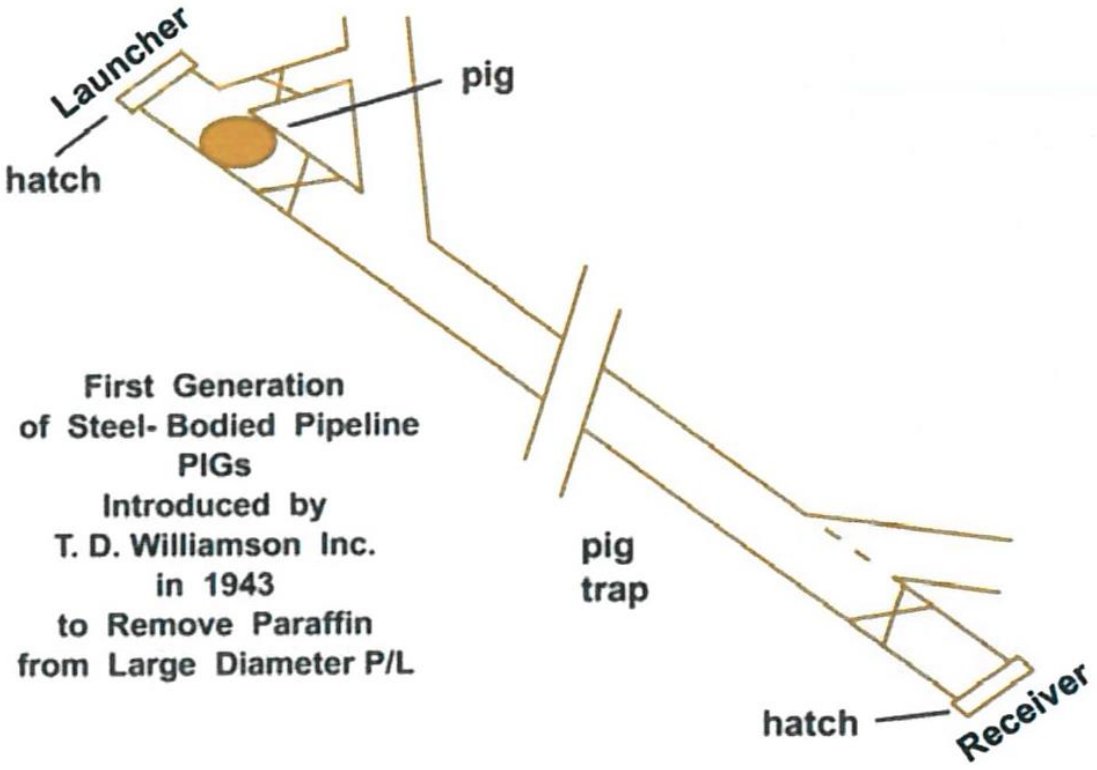


VELOCITY IN LIQUID LINES

From API RP14E

Pipeline Pigging System

- PIG: Pipeline Internal Gauge



Petroleum Industry PIG

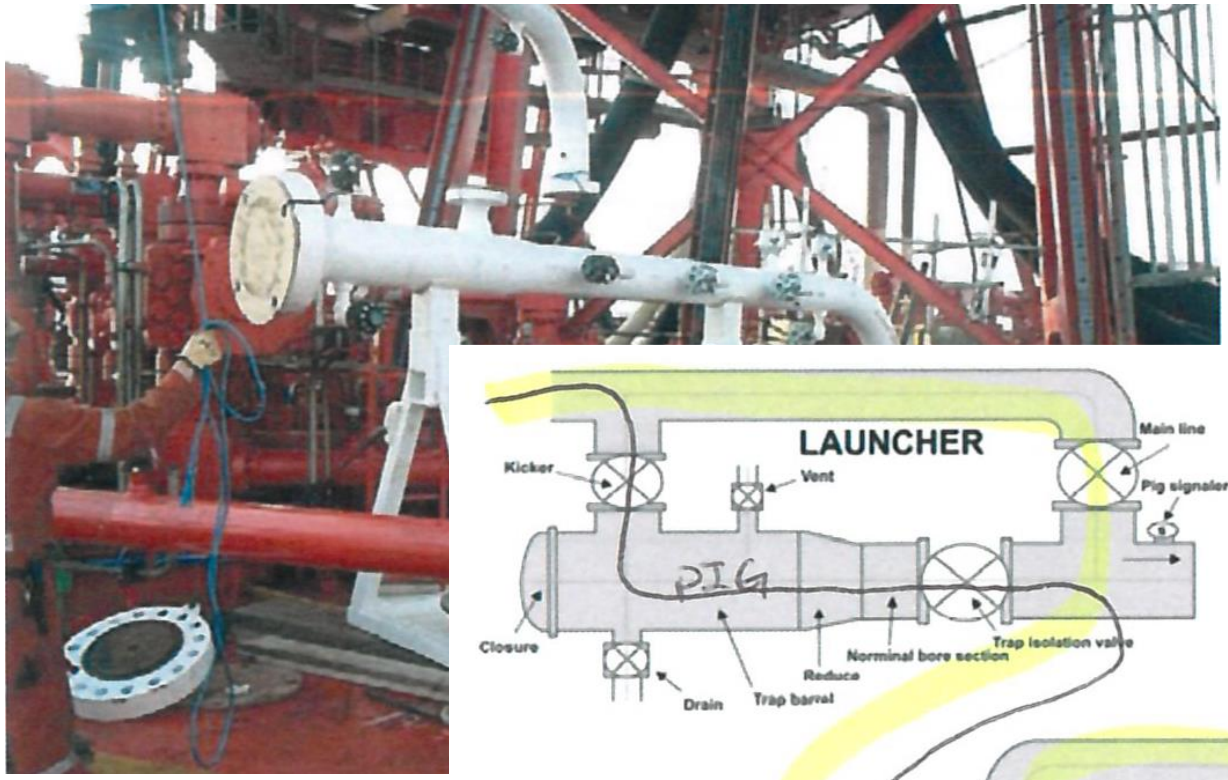
- Pipeline Internal Gauge
  - Check internal condition for pipeline
  - Cleaning: Solids (wax, asphaltene etc)
  - Check or remove obstruction
  - Check for deformation / corrosion / erosion

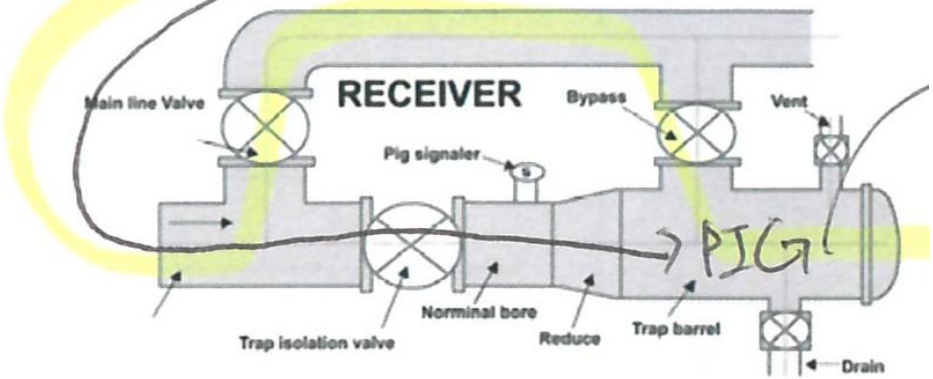
- Intelligent PIG
  - Measure: Remaining wall thickness
  - Establish: Location and type of defects

- Foam Pigs for cleaning

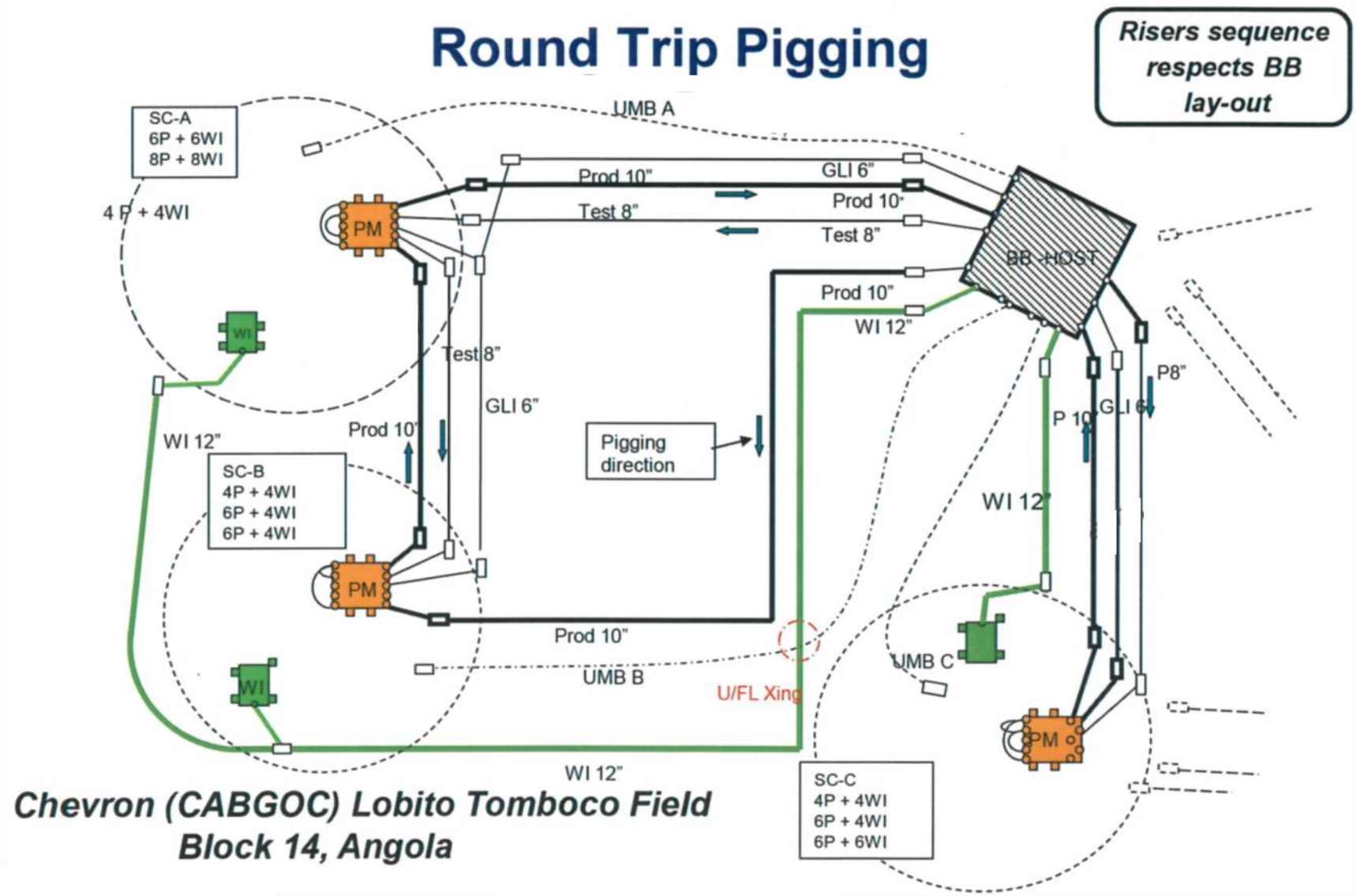
- Bi-Di pigs: Gauging and Cleaning

Offshore platform PIG launcher / receiver





Typical offshore field layout



Exercise: Gas line size

- Size a flowline for

  10 mmcfd, SG = 0.7, P (3000 → 2000 psia), T (580 ^{o}R)

  z = 0.78 at 2000 psia, 0.79 at 3000 psia

$$d^2 = \frac{60\ QMMSCFDTz}{Pv}$$

  - Max velocity = 60 ft/sec (Noise and corrosion)
  - Min velocity = 10 ~ 15 ft/sec (Liquid buildup)

Solution

- **Maximum Velocity**

$$d^2_{min} = 60\,(10)\,(580°R)(.78) / (2000)(60\ ft/sec) \quad or$$

$$d^2_{min} = 60\,(10)\,(580°R)\,(.79) / (3000)\,(60\ ft/sec)$$

$$d^2_{min} = 2.26 \text{ at } 2000 \text{ psia} \quad d_{min} = 1.50$$

$$d^2_{min} = 1.53 \text{ at } 3000 \text{ psia} \quad d_{min} = 1.24$$

- **Minimum Velocity**

$$d^2_{max} = 60\,(10)\,(580°R)(.78) / (2000)(15\ ft/sec) \quad or$$

$$d^2_{max} = 60\,(10)\,(580°R)\,(.79) / (3000)\,(15\ ft/sec)$$

$$d^2_{max} = 9.05 \text{ at } 2000 \text{ psia} \quad d_{max} = 3.00$$

$$d^2_{max} = 6.11 \text{ at } 3000 \text{ psia} \quad d_{max} = 2.47$$

$d_{min} = 1.5$ Largest Minimum

$d_{min} = 1.24$

- Lowest Pressure
- Gas Molecules farthest apart
- Take up most space

$d_{max} = 3.0$

- Highest Pressure
- Gas Molecules closest together
- Take up least space

$d_{max} = 2.47$ Smallest Maximum

∴ Choose Between 1.5" and 2.5"

Line size criteria – Two phase

- Max velocity = 60 ft/sec (Noise, corrosion, erosion) (50 if CO_2)
- Min velocity = 10 ~ 15 ft/sec (Minimize slugs)

$$d^2 = \frac{\left[11.9 + \frac{R\ z\ T}{16.7\ P}\right] Q_{BLPD}}{1000\ v}$$

R: Gas/Liquid ratio, scf/bbl

- Erosional velocity for two phase

$$Ve = \frac{C}{\sqrt{\rho_{mix}}}$$

Ve: Erosional velocity, ft/sec
ρ:Combined fluid density,lbm/ft3
C:constant between 75 and 200
150~200 for continuous non-corrosive servies
Up to 250 used successfully by industry for non-continuous services

Two phase flow

1. **Determine Density of the Mix (ρ_{mix}):**

$$\rho_{mix} = \frac{(12\,409\,SG_L\,P) + (2.7\,SG_g\,R\,P)}{(198.7\,P) + (R\,z\,T)}$$

2. **Calculate Erosional Velocity:**

$$V_e = \frac{C}{\sqrt{\rho_{mix}}}$$

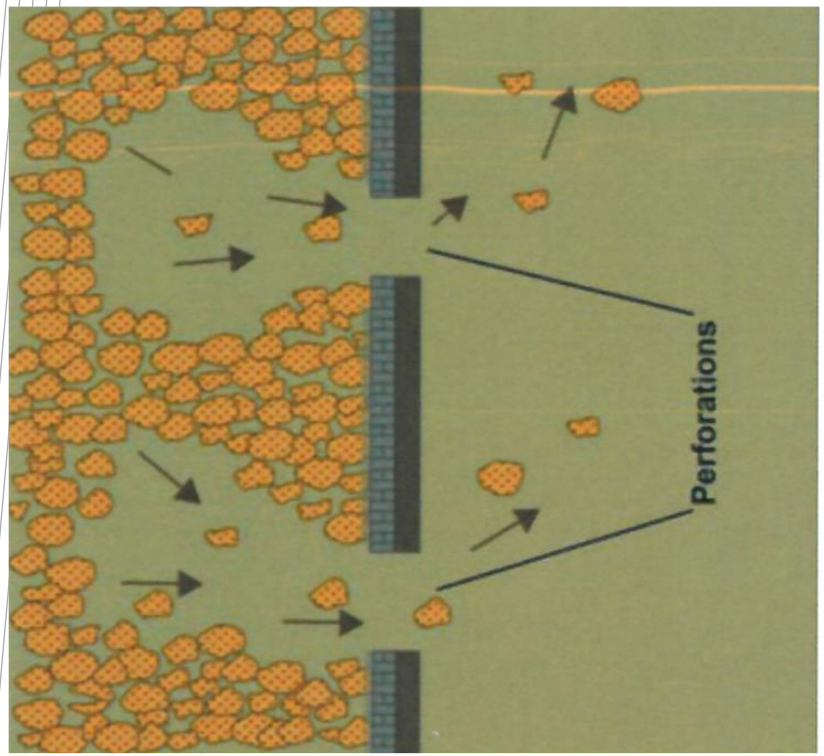
3. **Calculate Minimum Pipe Diameter:**

$$d^2_{min} = \frac{\left(11.9 + \frac{R\,z\,T}{16.7\,P}\right) Q_{BPD}}{1000\,v_e}$$

- R : Gas / Liquid Ratio in scf / Bbl
- v_e : Velocity in feet / second
- d : I. D. inches
- P : Pressure in psia
- T : Temperature in °R

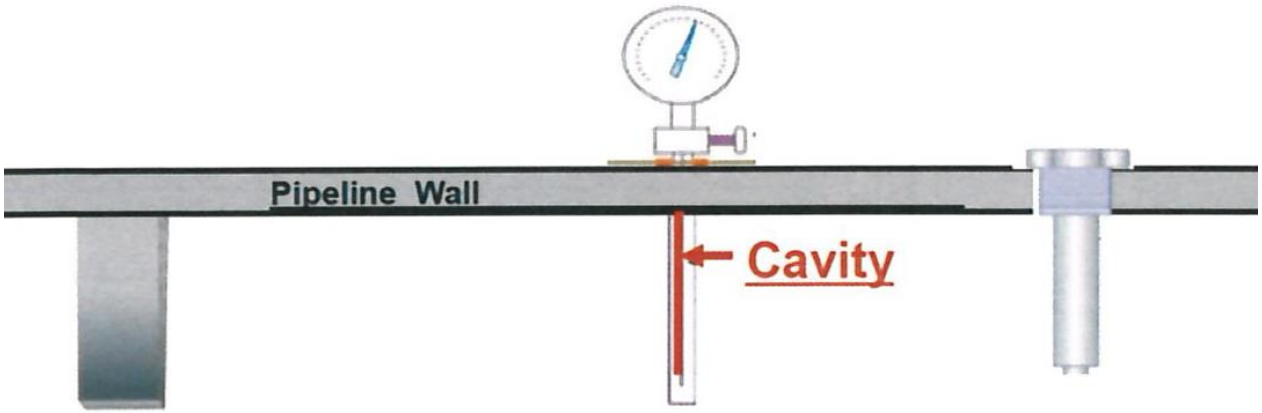
Erosional velocity with solids in flowstream

- Minimum flowrate to prevent erosion: not known
- Sand production induces erosion of surface equipment

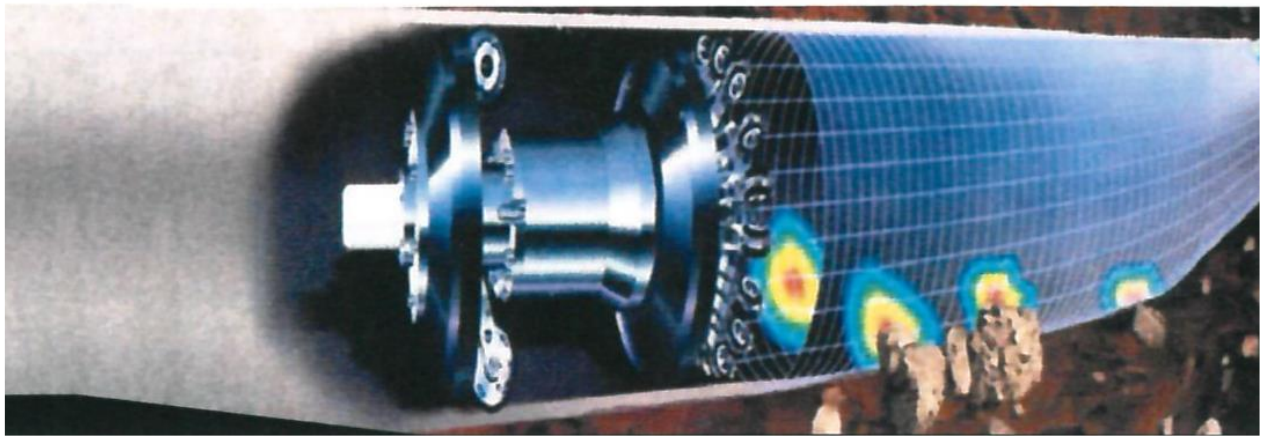


- Use sand probes
- Measure / Inspect wall thickness
- Use 3+ feet of straight pipe after turns / choke
- Use long radius ells or Target tees
- Monitor solids with sand detectors
- Control solid production (Sand control)
- Remove solids from flow (Desander)

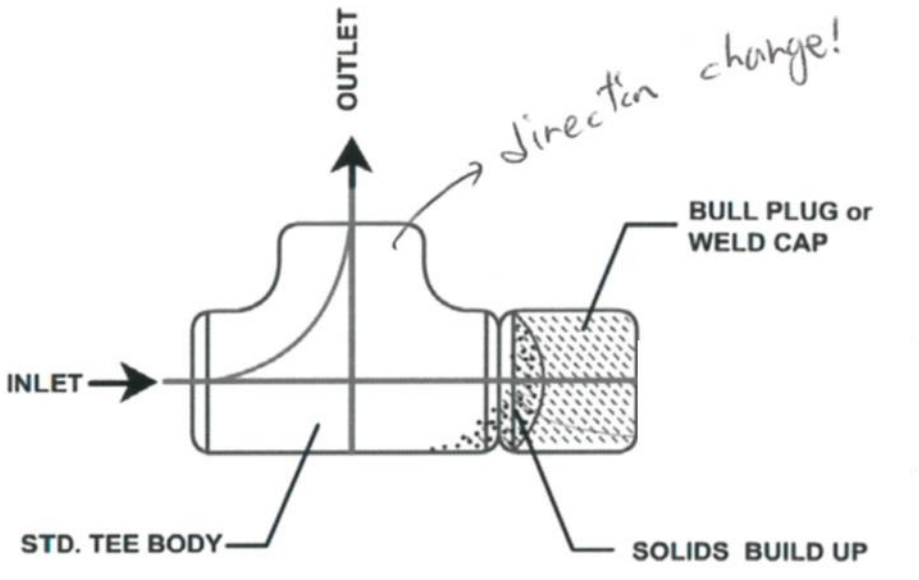
Using Sand Probes or Coupons



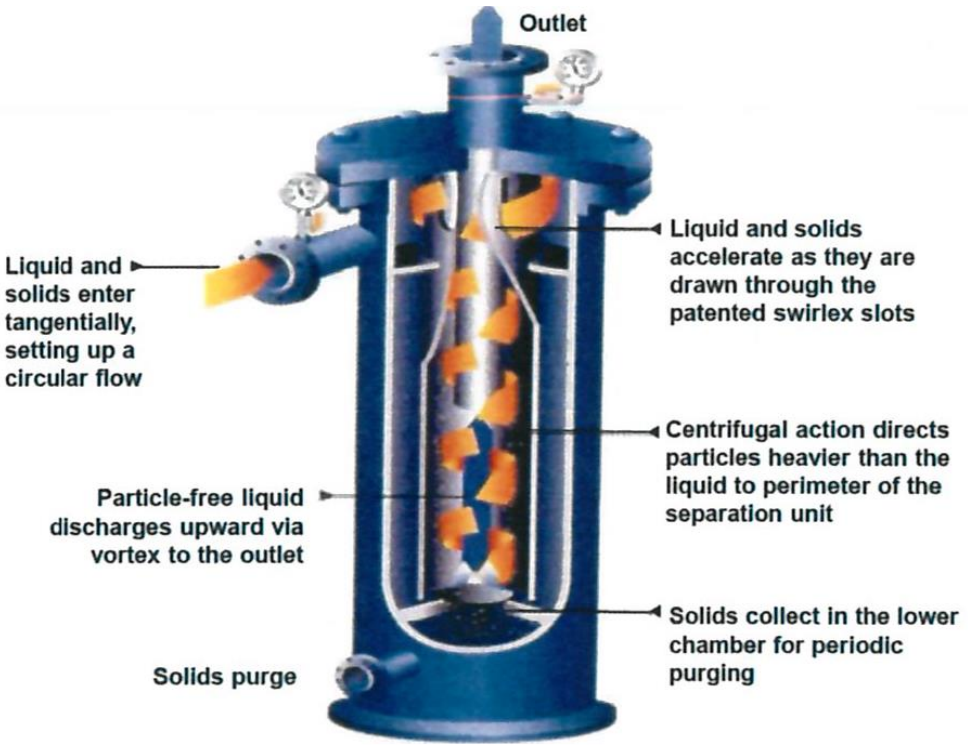
- Monitor erosion by measuring pipeline wall thickness



- Target tee – measure how much welded cap eroded



- Acoustical detection of solid particles as pipe hit
  - Built-in computer calculates sand velocity and concentration
- Surface centrifugal desander



Pipeline sizing

- Consider fluid velocity
  - Limit noise / corrosion / erosion
  - Prevent solids build-up in liquid lines
  - Prevent liquid build-up in gas lines
- Contain internal pressure
  - Pipe wall thickness and material strength
- Minimize pressure drop
  - Minimize pump / compression cost
  - Optimize installed cost

All piping, connections, valves and fittings must withstand maximum possible internal pressure or be protected by a pressure relieving system

Flowline design pressure

- Maximum allowable working pressure

$$P = \frac{2\,S\,t\,F\,E\,T}{d}$$

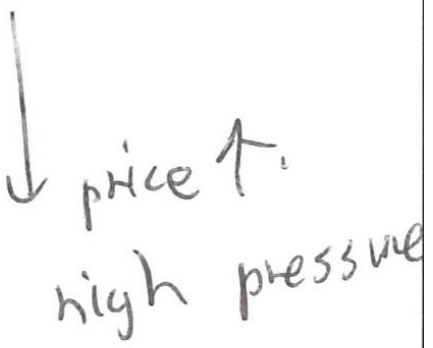
S: Specified minimum yield strength (psia)
t: pipe wall thickness (inches)
F: Design factor (0.72 or less)
E: Longitudinal joint factor
1.0 seamless
0.8 Fusion/Spiral weld
0.6 Butt weld
T: 1.0 if -20 oF to 250 oF
d: Nominal diameter, inches

S: API Minimum specified yield strength

(API Standards 5L, 5LX, 5LU)

PIPE GRADE	SPECIFIED YIELD, psia
A-25	25,000
A	30,000
B	35,000
X-42	42,000
X-46	46,000
X-52	52,000
X-56	56,000
X-60	60,000
X-65	65,000
X-70	70,000
U-80	80,000
U-100	100,000

Typical Structural Steel = 38,000 psi



F: Piping design factor

F: Construction Type Design Factor (ANSI B31.8)

Construction Type	Design Factor, F	General Description
A	0.72	Oil field and Sparsely Populated Area
B	0.6	Semi-developed Areas and Lease Facilities
C	0.5	Commercial and Residential Sub-Divided Areas and Compressor Stations
D	0.4	Heavily Congested Areas with Multi-Story Buildings

T: Temperature derating factor

Temperature °F	Derating Factor – T
- 20 to + 250	1.000
300	0.967
350	0.933
400	0.900
450	0.867

API LINE PIPE – OIL TRANSPORTATION

INTERNAL PRESSURE DESIGN LIMIT VALUES FOR -20° TO 250° F

LINE PIPE					DESIGN PRESSURE LIMITS								
SIZE		WEIGHT CLASS	SCHEDULE NUMBER	WALL THICK-NESS	PLAIN END						THREADED & COUPLED		
NOM.	OD				BUTT-WELD	GRADE A	GRADE B	GRADE X42	GRADE X46	GRADE X52	BUTT-WELD	GRADE A	GRADE B
INCHES				INCHES	POUNDS PER SQUARE INCH						POUNDS PER SQ. INCH		
1 ¼	1.660	STD.	40	.140	1820	3640	4250	...	...	...	960	1920	2240
		X	80	.191	2490	4970	5800	...	...	...	...	...	...
		XX		.382	4970	9940	11600	...	...	...	...	...	...
1 ½	1.900	STD.	40	.145	1650	3300	3850	...	...	...	900	1790	2090
		X	80	.200	2270	4550	5310	...	...	...	...	...	...
		XX		.400	4550	9090	10610	...	...	...	...	...	...
2	2.375	STD	40	.154	1400	2800	3270	...	...	...	800	1600	1870
		X	80	.218	1980	3970	4630	...	...	...	...	...	...
		XX		.436	3970	7930	9250	...	...	...	...	...	...
2 ½	2.875	STD	40	.203	1530	3050	3560	...	...	...	810	1620	1890
		X	80	.276	2070	4150	4840	...	...	...	...	...	...
		XX		.552	4150	8290	9680	...	...	...	...	...	...
3	3.500	SPEC.		.125	...	1540	1800	...	...	...	...	...	...
		SPEC.		.156	...	1930	2250	...	...	...	...	...	...
				.188	1160	2320	2710	...	...	...	...	...	...
		STD.	40	.216	1330	2670	3110	...	...	...	750	1490	1740
				.250	...	3090	3600	...	...	...	...	...	...
				.281	...	3470	4050	...	...	...	...	...	...
		X	80	.300	1850	3700	4320	...	...	...	...	...	...
		XX		.600	...	7410	8640	...	...	...	...	...	...
3 ½	4.000	SPEC.		.125	...	1350	1580	...	...	...	...	...	...
		SPEC.		.156	...	1680	1970	...	...	...	...	...	...
		SPEC.		.188	1020	2030	2370	...	...	...	...	...	...
		ST & SP	40	.226	1220	2440	2850	...	...	...	710	1410	1650
		SPEC.		.250	...	2700	3150	...	...	...	...	...	...
		SPEC.		.281	...	3030	3540	...	...	...	...	...	...
		X	80	.318	1720	3430	4010	...	...	...	...	...	...
4	4.500	SPEC.		.125	600	1200	1400	1680	1840	2080	...	...	...
		SPEC.		.141	...	1350	1580	1900	2080	2350	...	...	...
		SPEC.		.156	750	1500	1750	2100	2300	2600	...	...	...
				.172	...	1650	1930	2310	2530	2860	...	...	...
				.188	900	1800	2110	2530	2770	3130	...	...	...
				.203	...	1950	2270	2730	2990	3380	...	...	...
				.219	1050	2100	2450	2940	3220	3640	...	...	...
		STD.	40	.237	1140	2280	2650	3190	3490	3940	680	1360	1590
				.250	...	2400	2800	3360	3680	4160	...	...	...
				.281	...	2700	3150	3780	4140	4680	...	...	...
		X		.312	...	3000	3490	4190	4590	5190	...	...	...
			80	.337	1620	3240	3770	4530	4960	5610	...	...	...
			120	.438	...	4200	4910	5890	6450	7290	...	...	...
		XX	160	.531	...	5100	5950	7140	7820	8840	...	...	...
				.674	...	6470	7550	9060	9920	11220	...	...	...
5	5.563	SPEC.		.156	...	1210	1410	...	...	...	...	...	...
		SPEC.		.188	...	1460	1700	...	...	...	...	...	...
		SPEC.		.219	...	1700	1980	...	...	...	...	...	...
		ST & SP	40	.258	...	2000	2340	...	...	...	...	1270	1480
		SPEC.		.281	...	2180	2550	...	...	...	...	...	...
		SPEC.		.312	...	2420	2830	...	...	...	...	...	...
		SPEC.		.344	...	2670	3120	...	...	...	...	...	...
		X	80	.375	...	2910	3400	...	...	...	...	...	...
		SPEC.	120	.500	...	3880	4530	...	...	...	...	...	...
		SPEC.	160	.625	...	4850	5660	...	...	...	...	...	...
		XX		.750	...	5820	6790	...	...	...	...	...	...
6	6.625	SPEC.		.125	...	820	950	1140	1250	1410	...	...	...
		SPEC.		.141	...	920	1070	1290	1410	1590	...	...	...
		SPEC.		.156	...	1020	1190	1420	1560	1760	...	...	...
				.172	...	1120	1310	1570	1720	1940	...	...	...
				.188	...	1230	1430	1720	1880	2120	...	...	...
				.203	...	1320	1540	1850	2030	2290	...	...	...
				.219	...	1430	1670	2000	2190	2480	...	...	...
		STD.		.250	...	1630	1900	2230	2500	2830	...	...	...
			40	.280	...	1830	2130	2560	2800	3160	...	1210	1410
				.312	...	2030	2370	2850	3120	3530	...	...	...
				.344	...	2240	2620	3140	3440	3890	...	...	...
		X		.375	...	2450	2850	3420	3750	4240	...	...	...
			80	.432	...	2820	3290	3940	4320	4880	...	...	...
				.500	...	3260	3800	4560	5000	5650	...	...	...
			120	.562	...	3660	4280	5130	5620	6350	...	...	...
				.625	...	4080	4750	5710	6250	7060	...	...	...
			160	.719	...	4690	5470	6560	7190	8130	...	...	...
				.864	...	5630	6570	...	...	...	...	...	...
1	2	3	4	5	6	7	8	9	10	11	12	13	14

CHART based on EQUATION: P = 2stFET/d with F = .72 and T =1

- 6” Plain end GRADE B, Thickness .188”,
  → what is maximum pressure limit?

- 6” linepipe: pressure = 4000 psi
  → what pipe do you order?

		X	80	.318	1720	3430	4010	...	...	...
		SPEC.		.125	...	820	950	1140	1250	1410
		SPEC.		.141	...	920	1070	1290	1410	1590
		SPEC.		.156	...	1020	1190	1420	1560	1760
				.172	...	1120	1310	1570	1720	1940
				.188	...	1230	1430	1720	1880	2120
				.203	...	1320	1540	1850	2030	2290
				.219	...	1430	1670	2000	2190	2480
		STD.		.250	...	1630	1900	2230	2500	2830
			40	.280	...	1830	2130	2560	2800	3160
6	6.625			.312	...	2030	2370	2850	3120	3530
				.344	...	2240	2620	3140	3440	3890
		X		.375	...	2450	2850	3420	3750	4240
			80	.432	...	2820	3290	3940	4320	4880
				.500	...	3260	3800	4560	5000	5650
			120	.562	...	3660	4280	5130	5620	6350
				.625	...	4080	4750	5710	6250	7060
			160	.719	...	4690	5470	6560	7190	8130
				.864	...	5630	6570	...	...	...
1	2	3	4	5	6	7	8	9	10	11

CHART based on EQUATION: $P = 2stFET/d$ with $F = .72$ and $T = 1$

Thank you