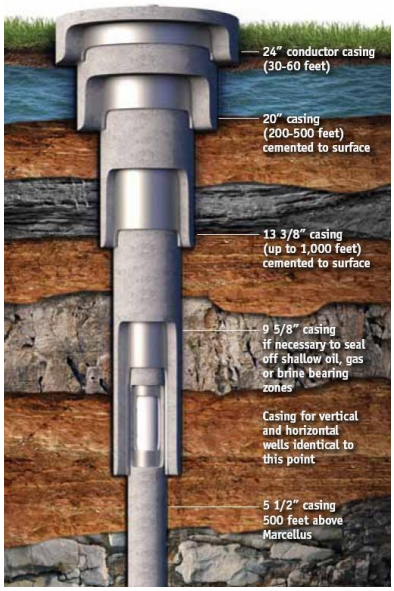
Ultrasonic Wall Thickness Measuring of Oil Country Tubular Goods

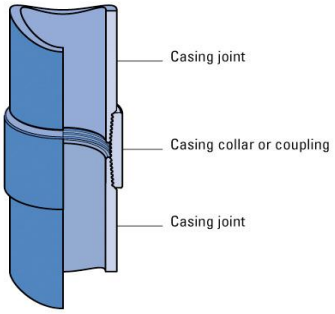
ABSTRACT

The inspection market for tubular products used in critical oil field applications requires highly sophisticated equipment with great accuracy providing wall thickness measurements for the full tube body of Casing, Tubing and Drill Pipe. NDT techniques play an important role of measuring actual wall thicknesses and detecting flaw indications that may reduce remaining wall per pipe. Software has been designed to gather each data point and create a detailed map unique to each pipe showing its minimum and maximum wall thicknesses. By knowing actual pipe dimensions the engineer now has the ability to design a more effective casing string using API RP 5C3 (ISO 10400) recommended formulas. On the economic front an API 5CT tubular product when correctly inspected can eliminate the need for higher cost exotic products and also may allow for the reduction of a string's diameter or weight while maintaining safety factors.

Introduction

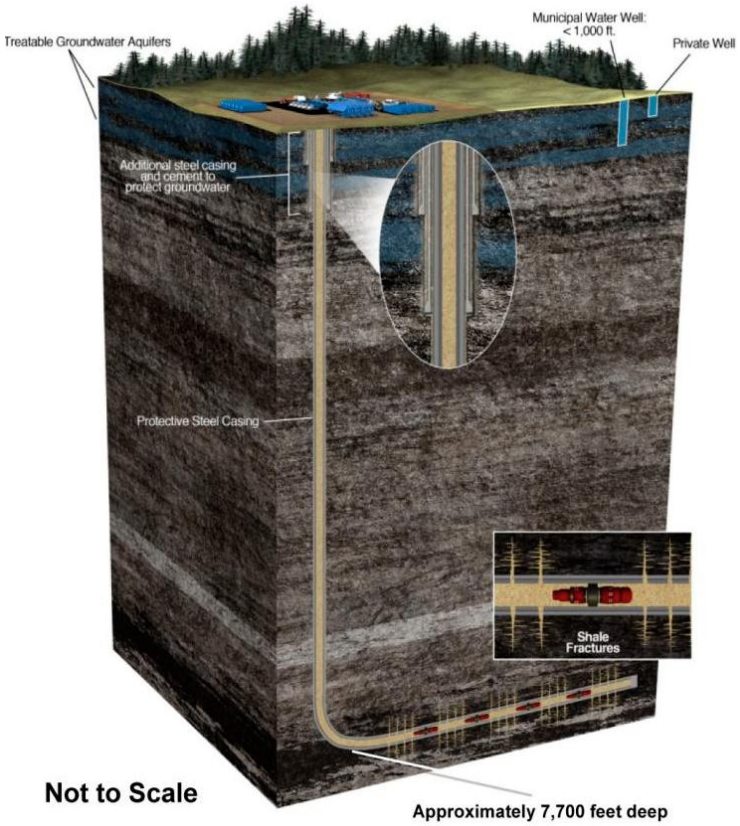
For this paper we will focus on casing and will leave tubing and drill pipe for another occasion. To retrieve oil and gas from down deep in the earth petroleum engineers have developed a safe manner by using multiple layers of protective steel called **Casing.** Under the strictest regulations from both state and federal agencies the wellbore must be secured in place with layers of concrete. Casing is very large diameter pipe in 40ft lengths using threaded and coupled connections to make long strings which hang down in the wellbore. Conductor Casing is at the very top of wellbore to protect ground from caving in and providing strength for wellhead equipment including BOP (blow out preventer) safeguarding drilling activities. Typical casing diameters are 24 inch to 60ft deep, then 20 inch diameter runs through conductor pipe and goes 500 feet deep for additional protection through the fresh-water aquifer. Surface Casing 13 3/8 inch diameter runs inside conductor pipe cemented in place up to 1000 feet with Intermitted Casing 9 5/8 inch diameter continuing vertical part of well down to 8000 feet deep. Production Casing 5 ½ inch diameter is used to make the bend into horizontal direction connecting targeted pay zones of oil and gas. Some wells still produce "Open Hole" but most wells are being completed with "Horizontal Direction" extended reach techniques using "Hydraulic Fracturing" to stimulate product flow in what's called Shale Plays. NDT plays an extremely important role in reducing risk with these very expensive projects. Most Casing receives NDT at pipe manufacturer's facility as part of their quality program. As casing integrity requirements increase for deeper higher pressure wells "Post Mill" NDT inspections are performed in addition to manufacturer's inspections to verify material meets specification.





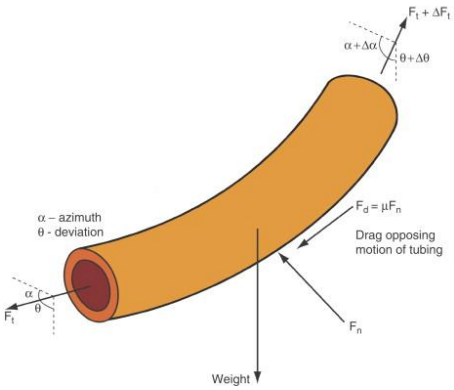
Material

Design of the Casing Strings start with material choices from American Petroleum Institute Specification 5CT, the well engineer has determined specific pipe outside diameter, wall thickness, material grade, threaded connections required to resist expected tension, burst and collapse conditions for a safe productive well. Hydraulic Fracturing has additional risk to the well's mechanical integrity making it mandatory for the engineer to provide operational personnel with maximum allowable loads while optimizing well cost. Industry standards are set by American Petroleum Institute (API) and Organization for International Standards (ISO) who share a Technical Report "API TR 5C3 / ISO TR 10400" for performance design of Oil Field Tubular Goods anticipating loads and resistance or both. Technical Report 5C3 is not a design code and only provides formulas and equations for engineers to calculate the properties of tubulars intended in downhole applications.

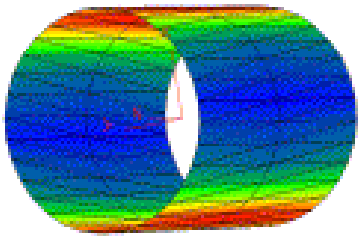


API Casing tube bodies are made using two manufacturering processes seamless and electric welding with each method having a different effect on the actual wall thickness around the circumference. Seamless pipe thickness contiously varies sometimes drasticlly referred to as Eccentric Wall. Electric welded casing has a more consistant wall thickness due to its made as flat plate before rolled / bent to shape for welding, producing a uniform wall product referred to as Concentric Wall.

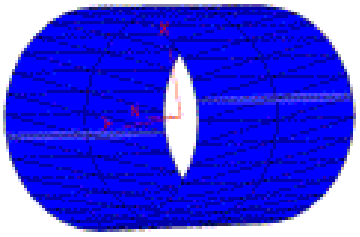
Poor assumption about pipe, they are shaped perfectly round internally and externally with only specified wall thickness

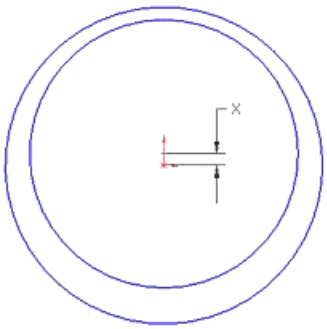


Seamless



Electric Welded





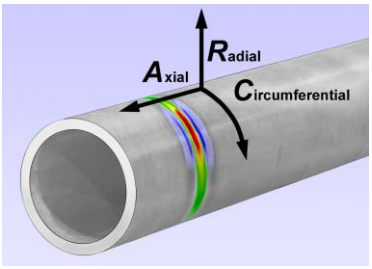
Seamless

Inspection

Why is new pipe being inspected? Pipe always looks picture perfect until NDT is applied to detect hidden imperfections such as seams, laps, gouges, cracks, mashed threads, improper threads, improper make-up, internal defects and wall too thin. In spite of the best efforts by the pipe manufacturer's to control wall thickness with good quality control programs, seamless material has eccentric type walls that required measuring to know actual values. For example the API 5CT specifies 7" OD seamless casing to have a .453" wall thickness. Do to the seamless process the actual wall thickness constantly changes above and below .453" within a large range of 87 ½% (.396") for minimum tolerance and no maximum tolerance resulting with unknown values (ex: .560") an Ovality of .164" wall thickness changing to some degree full length and full circumference. Since new pipe continues to contain manufacturing process defects and damage consistent with handling and transit activities, both of these facts increase the risk of putting an unfit pipe into service. The stakes are high it's smart to have non-destructive inspections provide the assurance needed to help reduce risk of pipe and coupling failures.

The focus is on wall thickness, in many cases the life expectancy of Casing is shorten due to thin wall areas and damaged wall areas. When the thickness of tube body is received near 87½% of specified in API 5CT there is less material for strength. There is no repairing by adding to wall thickness, once it is below acceptable requirements the whole length becomes scrap and must be removed from supply. The ultrasonic method is used to measure in a methodical process wall thickness at high resolution in multi-directional orientations Axial, Radial and Circumferential. In order for an engineer to know and rely on higher tensile capacities of pipe comprehensive wall information is required beyond normal required inspections.

Thin Wall Area



Wall Thickness Reporting – Wall Data

Wall Data Report is the deliverable from measuring the wall thickness each .040" (1mm) pulse density with an automated full body ultrasonic testing system processing each reading with the output for specific characteristics. **Minimum Wall**, **Maximum Wall** and **Average Wall** are needed to analyze tubular performance ratings to anticipated loads. It is very important to know the actual wall values for each pipe to be used when creating ratings with yield strength, internal pressure for burst and external pressure for collapse. **Wall Data** values are unique for each pipe so a spread sheet format is used for convenience to sort through a large amount pipes picking specific ones for their actual minimum wall, maximum wall and average wall for placement deep in the earth at precise locations in the wellbore.

Run Order Seq

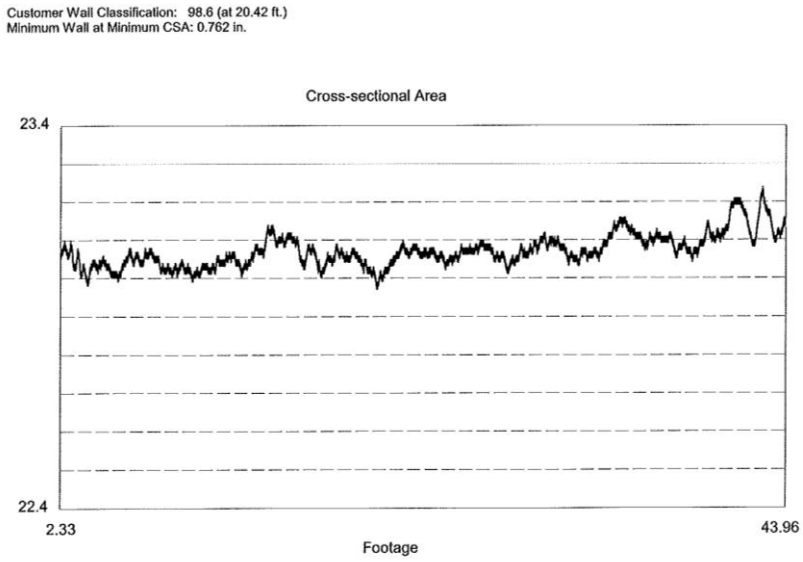
SETTING DEPTH:
Casing/PBD:
WT: 88.2 ID:
WT: 88 1/5 ID:
O.D. 13 5/8 Thrd:

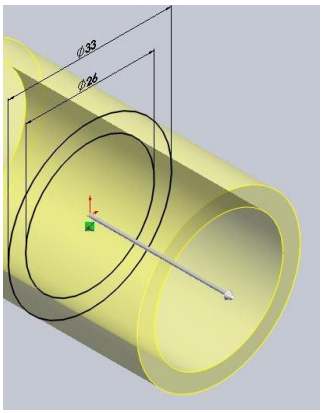
TUBO Orig Jt No	Tuboscope Wall Data					Run Order	TOT JTS	JTS RAN (Calc)	JT. LENGTH
	avg wall	min wall	max wall	tubo tally	tally dif				
185	655	599	718	46.29	1.21	1	1	2	45.08
173	649	611	711	46.38	0.90	2	2	3	45.48
174	651	607	710	46.08	0.69	3	3	4	45.39
156	653	599	712	44.38	-0.60	4	4	6	44.98
189	652	605	714	47.21	0.97	5	5	7	46.24
190	650	614	709	46.62	1.45	6	6	8	45.17
187	655	614	718	46.75	1.12	7	7	9	45.63
232	648	613	713	46.88	1.12	8	8	10	45.76
154	651	611	711	46.38	1.87	9	9	11	44.51
227	649	597	703	46.12	1.18	10	10	12	44.94
225	651	599	711	46.62	1.20	11	11	13	45.42
224	649	609	710	46.29	1.16	12	12	14	45.13
243	646	602	729	47.04	1.26	13	13	15	45.78
200	650	605	721	44.54	1.21	14	14	16	43.33
198	654	608	726	46.21	1.13	15	15	17	45.08
199	651	612	717	44.67	1.29	16	16	18	43.38
245	648	598	720	46.79	1.14	17	17	19	45.65
243 dup						18	18	20	45.53
237	651	601	720	46.75	1.04	19	19	21	45.71
217	651	616	727	45.83	1.03	20	20	22	44.8
226	653	614	711	46.12	1.17	21	21	23	44.95
236	649	601	715	46.88	1.18	22	22	24	45.7

Sorting Wall Data allows for grouping in many different ways by absolute heaviest for deviated well areas and top of hole to support a million pounds of pipe hanging in tension. Sort for thinner walls to be placed in less critical areas of well and to have a bench mark for minimum string strength. Sort to know actual wall values in pipe rating formulas.

Wall Thickness Reporting – Cross Sectional Area

In addition to "Wall Data" Cross Sectional Area can be calculated for each pipe with the remaining wall thickness reported at minimum CSA providing a "Customer Wall Classification" rating on each pipe. This gives the end user greater characteristic knowledge for each length allowing risk management programs greater success.





	WALL STATISTIC DATA				CROSS SECTIONAL AREA DATA		
JOINT NUMBER	MIN. WALL	MAX. WALL	AVG. WALL	ECC.	MIN. WALL @ MIN. CSA	CUSTOMER MIN. CSA % @ MIN. WALL	ESTIMATE TUBE MIN. CSA sq. in.
1	0.334	0.406	0.373	26.830	0.364	100.3%	3.6318
2	0.351	0.417	0.375	24.330	0.362	100.8%	3.6499
3	0.338	0.422	0.379	18.170	0.364	101.1%	3.6608
4	0.353	0.414	0.380	28.500	0.356	98.6%	3.5702
5	0.343	0.399	0.371	28.430	0.360	100.3%	3.6318
6	0.343	0.419	0.378	28.500	0.359	100.5%	3.6390
7	0.351	0.412	0.377	28.420	0.364	100.8%	3.6499
8	0.343	0.427	0.379	21.000	0.357	100.5%	3.6390
9	0.346	0.419	0.380	27.830	0.370	101.1%	3.6608
10	0.346	0.414	0.381	27.170	0.362	101.1%	3.6608

Wall Thickness Reporting – Rolling Wall Statistics

Rolling Wall Data is designed to help calculate burst and collapse pressures over large surface areas. The data used to generate the Rolling Wall Statistics are averaged over an axial distance equal to four pipe diameters. The axial distance used to define the rolling average has been established and verified by specific user criteria. The data used to find the statistical values is filtered before the algorithms are applied. The first rolling measurements are collected with the first wall measurements and averaged, then for all successive rolling averages, the oldest measurement is dropped, the newest is added and a new average is obtained. The rolling wall data uses an interval of four pipe diameters sliding down the joint one revolution at a time. The rolling wall statistics is in addition to actual wall data.

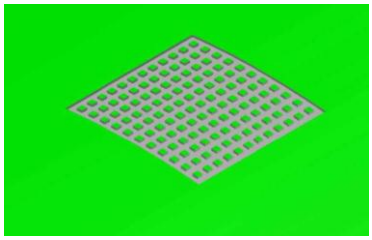
1) Absolute minimum wall
2) Absolute maximum wall
3) Absolute maximum eccentricity
4) Average minimum wall
5) Average average wall
6) Minimum rolling average of minimum wall values
7) Minimum rolling average of maximum wall values
8) The number of revolutions over which the moving averages was obtained
9) Minimum moving average of average wall values
10) Pipe identification number
11) Amount of Flaws indications which broke threshold level
12) Amount of compression wave measurements which fell below thin wall threshold

Grade	Wall	Diameter	Heat Number					Operator	Date	Time	Salv Lmt
	0.545	9.62	980612					MWT	Jun 12 98	17:26	0.0
Feet	Long ID	Long OD	Trans ID	Trans OD	Obliq ID	Obliq OD	Feet	Wall Thin	Wall Max	Wall Ecc	Status
2/041	----FF-F-F-F-F-F-F--F-F-F-----								30.04 (	0.00)	
/002	------_----------										

							OneRev	0.486	0.580	0.070	
							Avg	0.511			0.537
							Filter	0.502	0.571	(85)	
							Avg	0.534			
4.96	--	66T 1-24	--	--	--	--	4.96	--	--	--	
4.96	--	60T 2-24	--	--	--	--	4.96	--	--	--	REJ
5.00	--	67T 1-24	--	--	--	--	5.00	--	--	--	REJ
5.00	--	63T11-24	--	--	--	--	5.00	--	--	--	REJ
5.00	--	56T12-24	--	--	--	--	5.00	--	--	--	REJ
5.12	100T10-36	--	--	--	--	--	5.12	--	--	--	REJ
5.29	100T 9-24	--	--	--	--	--	5.29	--	--	--	REJ
5.71	71T 5-24	53T 4-24	--	--	--	--	5.71	--	--	--	REJ
5.75	54T 4-24	51T 4-24	--	--	--	--	5.75	--	--	--	REJ
6.21	--	--	--	--	--	--	6.21	486T 5- 5	--	--	REJ
6.25	--	--	--	--	--	--	6.25	490T 5-15	--	--	REJ
7.00	--	--	54T10-11	--	--	--	7.00	--	--	--	REJ
7.21	--	100T 3-24	--	--	--	--	7.21	--	--	--	REJ

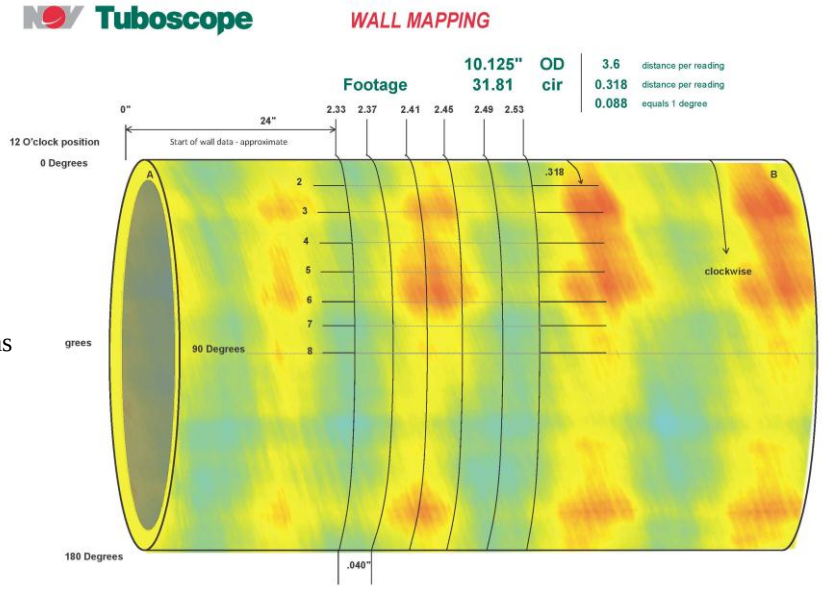
Preventing collapse conditions by knowing the actual wall thickness and culling pipe prior to service since not all pipe are exactly the same strength and the weakest link should be known.

Reporting - Wall Mapping



Wall Mapping takes inspection to the top level, this is a very sophisticated inspection requiring 400% scanning coverage to know the true wall measurements collecting all raw data in very small increments .040”(1mm) producing a color coded visual of the tube body wall. These measurements are documented in a methodical process. The pipe is rotated at a high rate of surface speed 80 inches per second while a scanning head is traversed measuring wall thickness. This system software has been engineered and designed for gathering each data point from 4 transducers covering the same path verifying reading with a tolerance of .002” creating detailed pipe map. Several hundred data points per transducer, per revolution provide the most accurate wall thickness representation. Mapping output can be specifically designed in color coded maps, large spread sheet data pages or raw data can be transferred for custom consultant customizing.

Actual wall thickness as it changes
- Blues are thicker areas
- Yellow is nominal wall areas
- Reds are thinner areas



RAW DATA POINTS OUTPUT IN SPREAD SHEET 783,290 readings for whole tube

⇨ to 500 spots around circumference

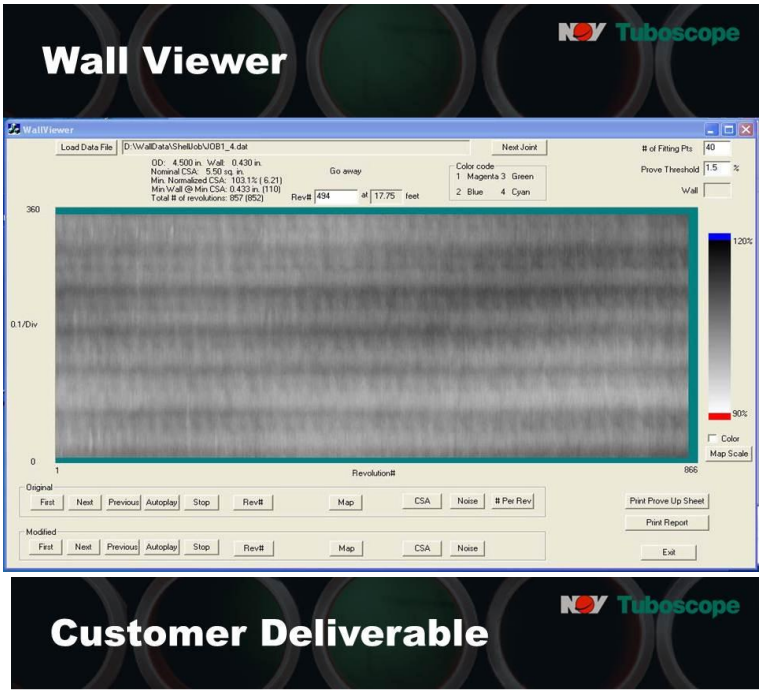
Footage	1	2	3	4	5	6	7	8 ……..500	
2.33	800	799	797	797	798	797	795	793	793
2.37	800	799	798	798	797	797	795	792	792
2.41	800	799	799	799	798	798	796	794	794
2.45	801	801	800	799	798	798	798	796	796
2.49	802	801	801	801	800	799	797	796	796
2.53	804	803	802	802	802	801	800	798	798
2.58	805	803	803	803	803	802	801	799	799
2.62	806	805	804	804	804	804	802	799	799
2.66	808	807	805	805	805	804	803	801	801
2.7	809	808	807	807	806	805	805	803	803
2.74	809	807	807	807	806	806	805	804	804

⇩

to 40 feet length or more

Conclusion

Each pipe should be considered like a finger print having its own signature wall pattern with different wall thickness variations full length of tube. Wall Viewer shows total map signature allowing all areas mapped to be searched providing wall thickness measured and location from end of pipe with clock position around circumference. Due to the various risk management programs all forms of Wall Mapping, Cross Sectional Area, Rolling Statistics and Wall Data are available to help support and identify actual characteristics for each Casing length of Oil Country Tubular Good.



This a representation of one Pipe with 98,500 readings from 783,290