



**PLYMOUTH TUBE CO** USA<sup>®</sup>



[WWW.PLYMOUTH.COM](http://WWW.PLYMOUTH.COM)



**PLYMOUTH TUBE CO** USA<sup>®</sup>

# Balancing High Strength Tubing Selection and Cost in Hydraulic System Design

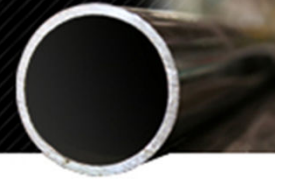
IFPE 2014

[WWW.PLYMOUTH.COM](http://WWW.PLYMOUTH.COM)

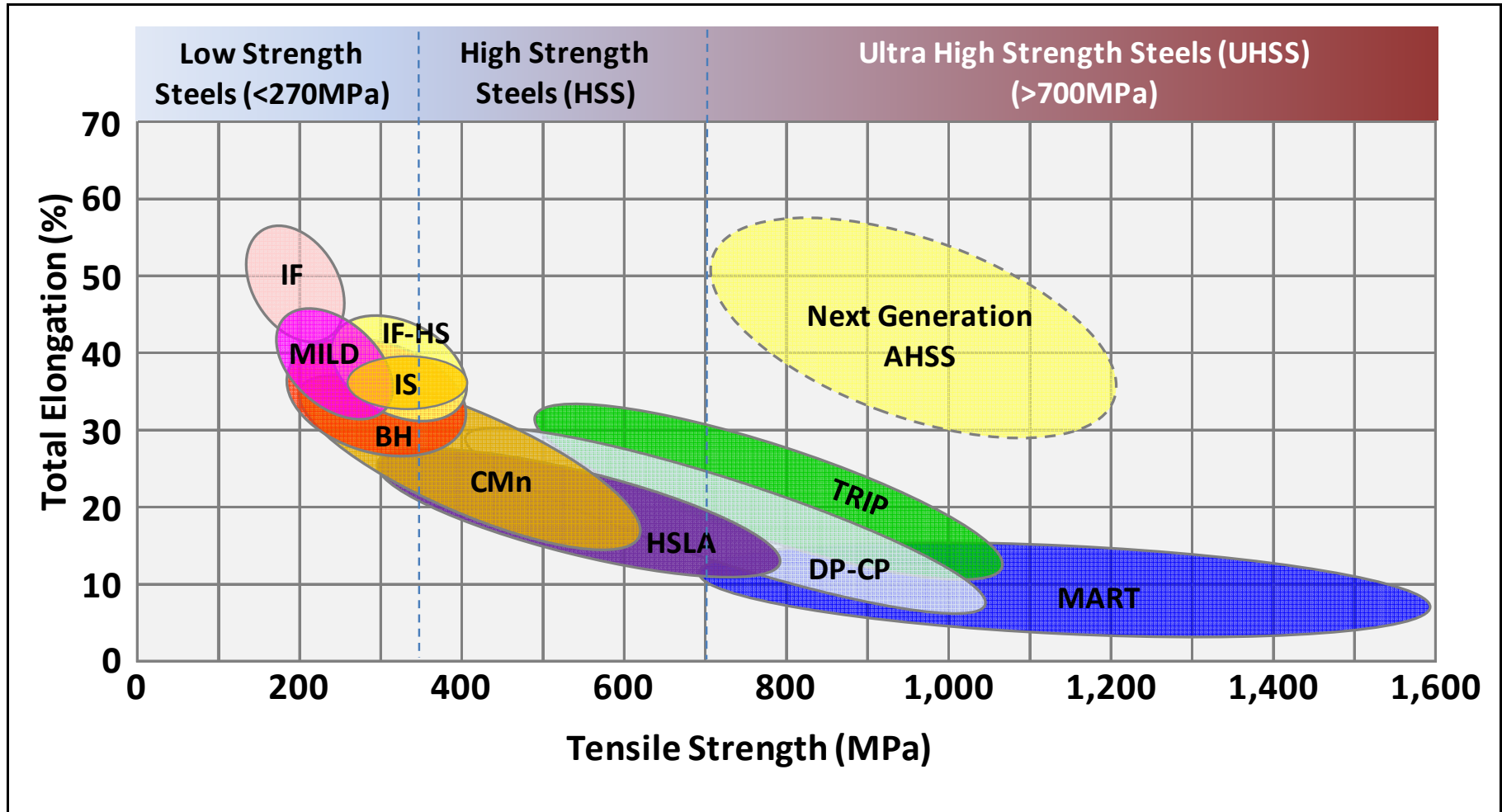


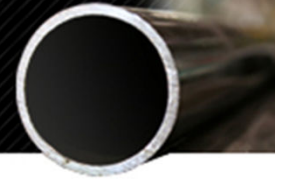
# Objectives

- Review the development of High Strength Steels and how that relates to hydraulic tubing development
- Explore various SAE specifications related to welded hydraulic tubing
- Discuss new developments in high strength hydraulic tubing
- Discuss the advantages of high strength hydraulic tubing in system design



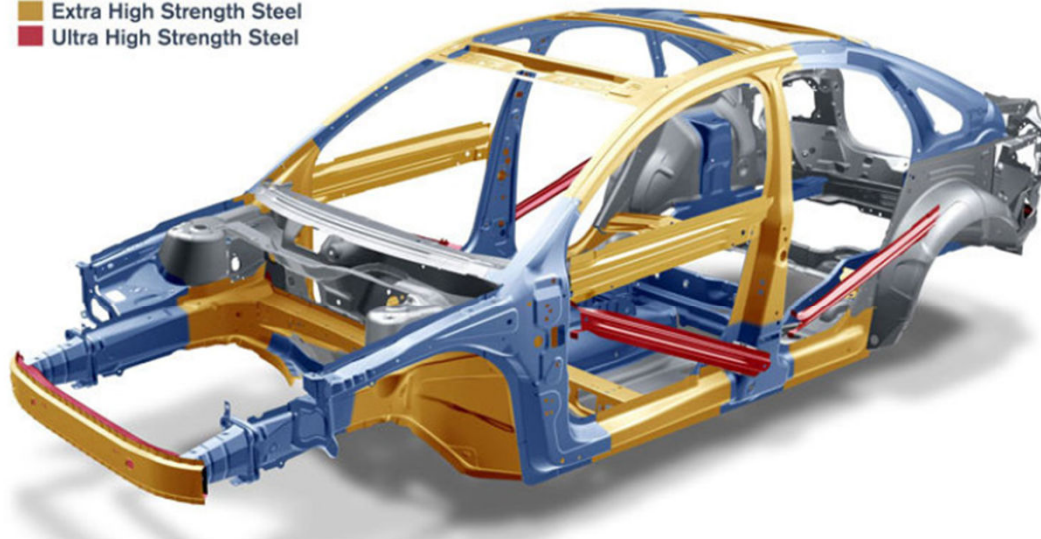
# High Strength Steels





# High Strength Steels

■ Mild Steel  
■ High Strength Steel  
■ Extra High Strength Steel  
■ Ultra High Strength Steel



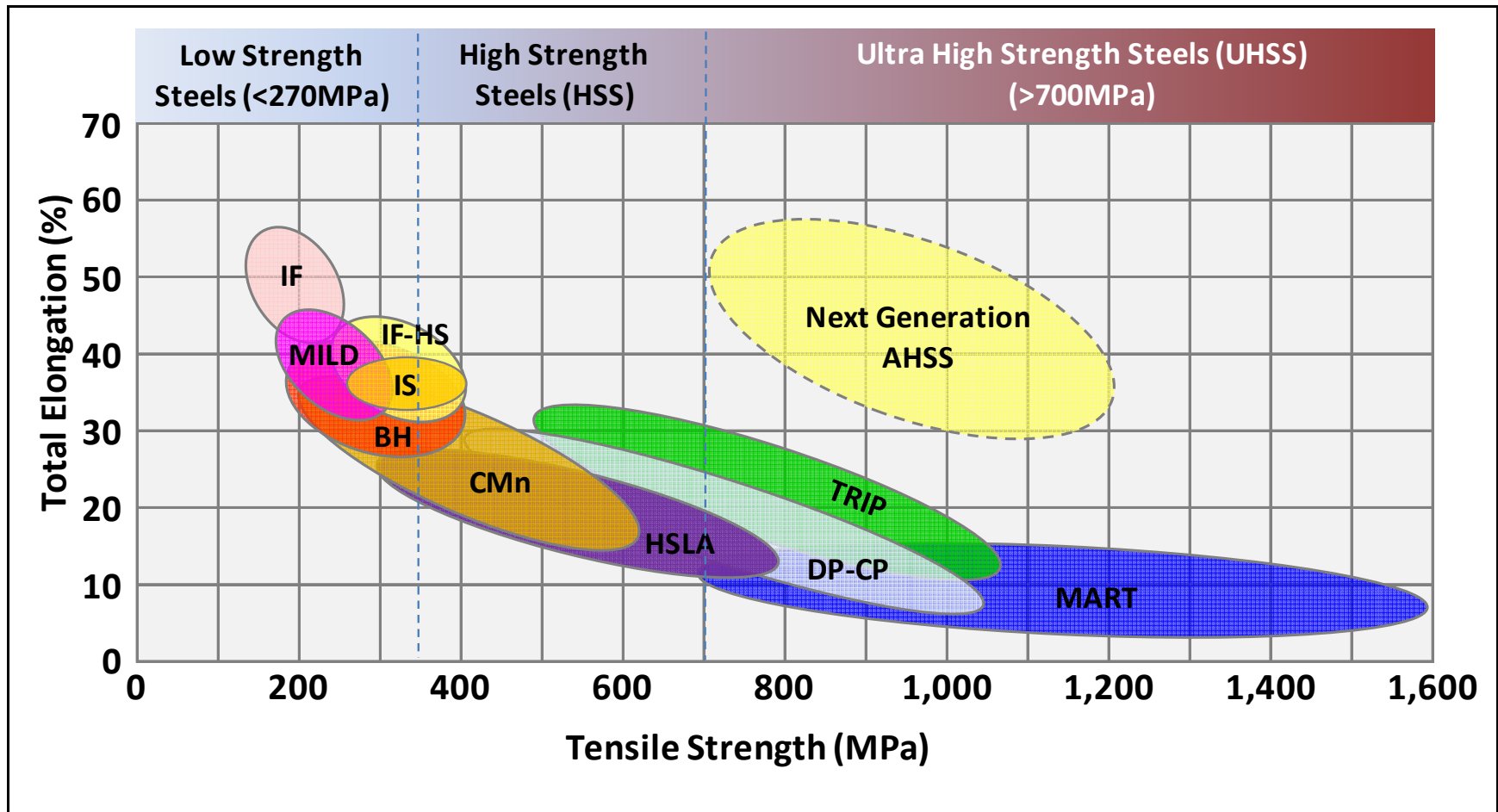
*Typical Structural Steel application in passenger vehicle chassis design, Source: worldautosteel.org<sup>1</sup>*

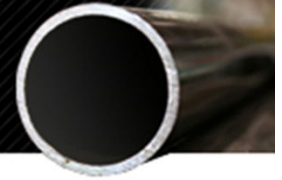
## ULSAB Consortium

- Strength
- Impact Resistance
- Energy Absorption
- Fuel Efficiency
- Weight Reduction
- Cost Reduction



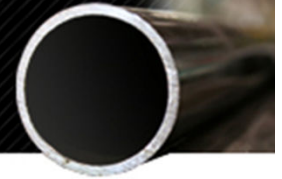
# What About Hydraulic Tubing?



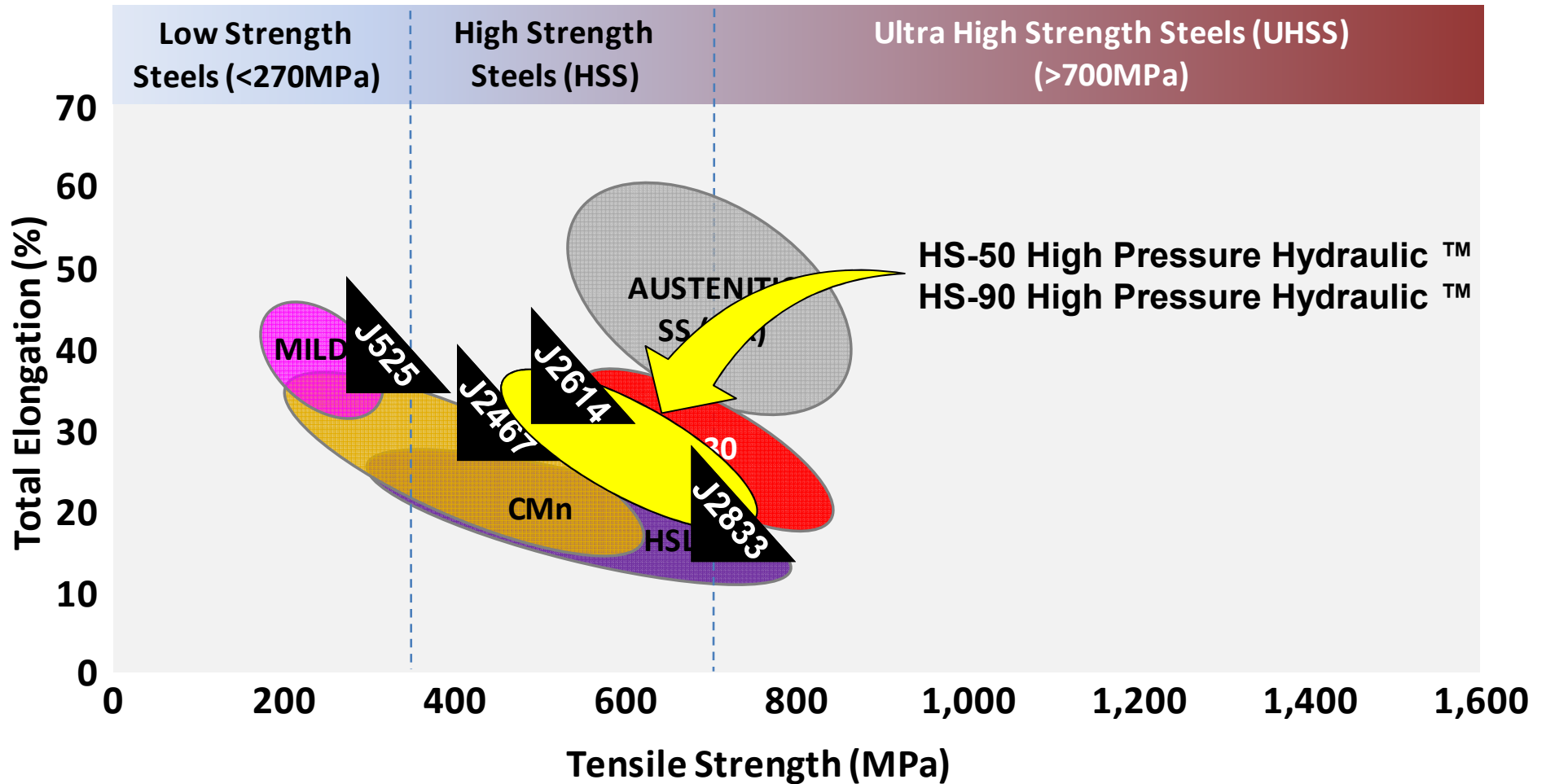


# Spec Comparison

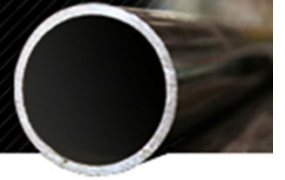
		SAE J-525	SAE J-2467	SAE J-2614	SAE J-2833
<b>Comparison of SAE Hydraulic Standards</b>		ERW, Cold Drawn, Low-Carbon, Annealed for Bending and Flaring	ERW, Cold-Drawn, SAE 1021, SAN for Bending and Flaring	ERW, Cold-Drawn HSLA, Sub-Critical Anneal for Bending and Flaring	ERW, Cold-Drawn HSLA, SRA for Bending and Flaring
<i>Year Published</i>		<i>1958</i>	<i>1999</i>	<i>2003</i>	<i>2009</i>
<b>Chemistry</b>	Carbon (C)	0.06 min/0.18 max	0.17min/0.23 max	0.18 max	0.26 max
	Manganese (Mn)	0.30 through 0.60	0.60 through 0.90	1.50 max	1.60 max
	Phosphorus (P)	0.04 max	0.04 max	0.035 max	0.035 max
	Sulfur (S)	0.05 max	0.05 max	0.035 max	0.035 max
	Silicon (Si)	n/a	n/a	0.35 max	0.35 max
	Aluminum (Al)	n/a	n/a	0.020 min	.020 min
	Micro Alloying Elements	n/a	n/a	0.15 max	0.15 max
<b>Mechanical</b>	Mpa Yield Strength (min)	170	275	345	620
	Mpa Tensile Strength (min)	310	415	500	690
	Elongation in 50mm (min)	35%	25%	30%	15%
	Hardness (max)	Rockwell B65	Rockwell B75	Rockwell B90	Rockwell B100
	Hardness (target)	None stated	None stated	Rockwell B85	Rockwell B92



# High Pressure Hydraulic

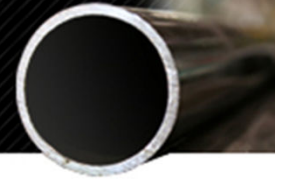






# HS-50™ Advantage

- Meets Chemistry and Mechanical requirements of J2614
- 61% increase in working pressure over J525 for like-sized tubes
- 28% decrease in weight when sizing wall to meet standard pressures
- Improved flow volume when sizing wall to meet standard pressures

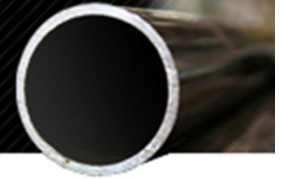


# HS-50™ Advantage

Questions about this table?  
Call us at 662-273-2220

<b>.500" OD Tubing (Size 8)</b>							
Spec	Design Working Pressure	% Working Pressure Increase	Wall Size				% Flow Increase
			0.083	0.065	0.056	0.042	
<b>J525</b>	4,534	-	6.81				-
<b>J2467</b>	6,090	34%		8.36			23%
<b>J2614</b>	7,313	61%			9.19		35%
<b>J2833</b>	10,092	123%				10.56	55%
Theoretical Weight			0.370	0.302	0.266	0.205	
% Weight Decrease			-	18%	28%	45%	

All calculations assume 25 fps flow velocity (recommended for steel pressure lines)

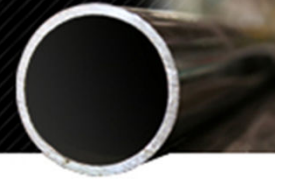


# HS-50™ Advantage

Questions about this table?  
Call us at 662-273-2220

<b>.750" OD Tubing (Size 12)</b>							
Spec	Design Working Pressure	% Working Pressure Increase	Wall Size				% Flow Increase
			0.095	0.074	0.063	0.047	
J525	3,283	-	19.14				-
J2467	4,395	34%		22.12			16%
J2614	5,295	61%			23.77		24%
J2833	7,307	123%				26.27	37%
Theoretical Weight			0.411	0.337	0.294	0.227	
% Weight Decrease			-	18%	28%	45%	

All calculations assume 25 fps flow velocity (recommended for steel pressure lines)

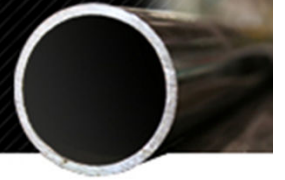


# HS-50™ Advantage

Questions about this table?  
Call us at 662-273-2220

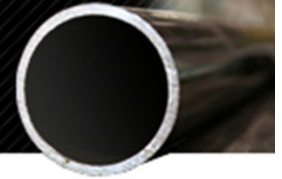
1.000" OD Tubing (Size 16)							
Spec	Design Working Pressure	% Working Pressure Increase	Wall Size				% Flow Increase
			0.105	0.081	0.068	0.051	
J525	2,649	-	38.09				-
J2467	3,549	34%		42.86			13%
J2614	4,272	61%			45.56		20%
J2833	5,896	123%				49.22	29%
Theoretical Weight			0.443	0.362	0.314	0.245	
% Weight Decrease			-	18%	29%	45%	

All calculations assume 25 fps flow velocity (recommended for steel pressure lines)



# System Design Criteria

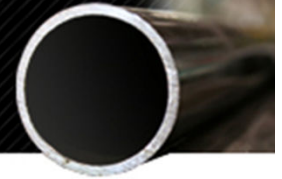
- Meet design pressure minimums
- Minimize pressure drop
- Minimize heat generation
- Reduce fluid turbulence
- Eliminate cavitation on suction lines
- Minimize system cost
- Maximize overall system efficiency



# System Design – allowable stress

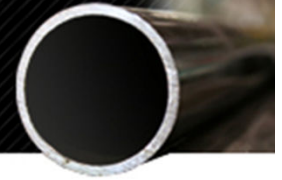
Material and Type	Allowable Design Stress, psi	Tube Specification
Steel C-1010	12,500	SAE J356, J524, J525
Steel C-1021	15,000	SAE J2435, J2467
Steel, HSLA <b>HS-50</b>	18,000	SAE J2613, J2614
Stainless Steel, 304 & 316	18,800	ASTM A213, A449, A279
Alloy Steel C-4130	18,000	ASTM A519
Copper, K or Y	6,000	SAE J528, ASTM B75

(Design Factor of 4 @ 72° F)



# System Design – design pressure

Tube OD, in.	Wall thickness, in.	Tube ID, in.	Design pressure, psi (4:1 design factor)			
			Steel 1010 (SAE J524 and J525)	Steel 1021 (SAE J2467)	Stainless Steel (304, 316) 4130, HSLA, HS-50	Copper
0.500	0.049	0.402	2,700	3,250	4,050	1,300
0.500	0.058	0.384	3,250	3,900	4,850	1,550
0.500	0.065	0.370	3,650	4,400	5,500	1,750
0.500	0.072	0.356	4,100	4,900	6,150	1,950
0.500	0.083	0.334	4,800	5,750	7,200	2,300
0.500	0.095	0.310	5,550	6,650	8,350	2,650
0.500	0.109	0.282	6,450	7,750	9,750	3,100
0.500	0.120	0.260	7,200	8,650	10,800	3,450

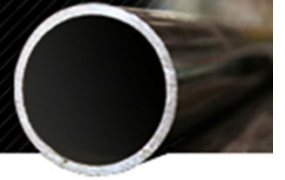


# System Design – flow diameter

Maximum flow rate, gpm	Recommended flow diameter, in.		
	Pressure Lines	Return Lines	Suction Lines
4.00	0.256	0.404	0.640
4.50	0.272	0.429	0.679
5.00	0.286	0.452	0.716
5.50	0.300	0.474	0.750
6.00	0.314	0.495	0.784
6.50	0.326	0.515	0.816
7.00	0.339	0.534	0.847
7.50	0.351	0.553	0.876

Maximum flow rate, gpm	Recommended flow diameter, in.		
	Pressure Lines	Return Lines	Suction Lines
8.00	0.362	0.571	0.905
8.50	0.373	0.589	0.933
9.00	0.384	0.606	0.960
9.50	0.395	0.623	0.986
10.00	0.405	0.639	1.012
11.00	0.425	0.670	1.061
12.00	0.433	0.700	1.109
13.00	0.462	0.728	1.154





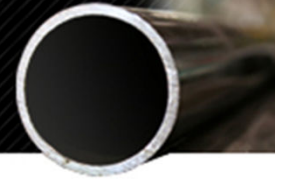
# Design Example 1

## Existing design:

- 0.500" OD x 0.083" Wall J525 tube
- 4,800 psi design pressure
- 7 gpm flow

## Objective:

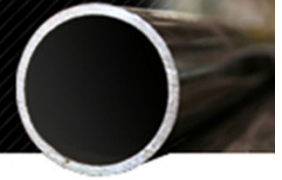
- Increase design pressure to 7,200 psi
- Maintain flow volume



# Design Example 1

- Option 1 – increase wall thickness**
- Meets Pressure Requirement
  - Reduces ID to 0.260”
  - Restricts flow to 4.0 gpm

Tube OD, in.	Wall thickness, in.	Tube ID, in.	Design pressure, psi (4:1 design factor)			
			Steel 1010 (SAE J524 and J525)	Steel 1021 (SAE J2467)	Stainless Steel (304, 316) 4130, HSLA, HS-50	Copper
0.500	0.049	0.402	2,700	3,250	4,050	1,300
0.500	0.058	0.384	3,250	3,900	4,850	1,550
0.500	0.065	0.370	3,650	4,400	5,500	1,750
0.500	0.072	0.356	4,100	4,900	6,150	1,950
0.500	0.083	0.334	4,800	5,750	7,200	2,300
0.500	0.095	0.310	5,550	6,650	8,350	2,650
0.500	0.109	0.282	6,450	7,750	9,750	3,100
0.500	0.120	0.260	7,200	8,650	10,800	3,450

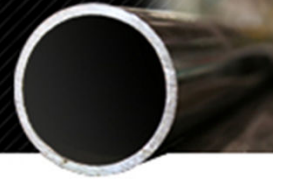


# Design Example 1

**Option 2 – use HS-50, SS, or 4130**

- Meets pressure requirement
- Maintains 7.0 gpm flow

Tube OD, in.	Wall thickness, in.	Tube ID, in.	Design pressure, psi (4:1 design factor)			
			Steel 1010 (SAE J524 and J525)	Steel 1021 (SAE J2467)	Stainless Steel (304, 316) 4130, HSLA, HS-50	Copper
0.500	0.049	0.402	2,700	3,250	4,050	1,300
0.500	0.058	0.384	3,250	3,900	4,850	1,550
0.500	0.065	0.370	3,650	4,400	5,500	1,750
0.500	0.072	0.356	4,100	4,900	6,150	1,950
0.500	0.083	0.334	4,800	5,750	7,200	2,300
0.500	0.095	0.310	5,550	6,650	8,350	2,650
0.500	0.109	0.282	6,450	7,750	9,750	3,100
0.500	0.120	0.260	7,200	8,650	10,800	3,450



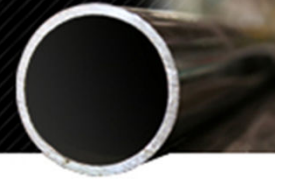
# Design Example 2

## Existing design:

- 0.500" OD x 0.083" Wall J525 tube
- 4,800 psi design pressure
- 7 gpm flow

## Objective:

- Maintain design pressure of 4,800 psi
- Increase flow by 25%



# Design Example 2

## Option 1 – increase tube OD

- Meets pressure and flow targets
- Significant design change
- Cost

Tube OD, in.	Wall thickness, in.	Tube ID, in.	Design pressure, psi (4:1 design factor)			
			Steel 1010 (SAE J524 and J525)	Steel 1021 (SAE J2467)	Stainless Steel (304, 316) 4130, HSLA, HS-50	Copper
0.625	0.072	0.481	3,200	3,850	4,800	1,550
0.625	0.083	0.459	3,750	4,500	5,650	1,800
0.625	0.095	0.435	4,350	5,200	6,550	2,100
0.625	0.109	0.407	5,050	6,050	7,600	2,450
0.625	0.120	0.385	5,600	6,700	8,450	2,700
0.625	0.134	0.357	6,350	7,600	9,550	3,050

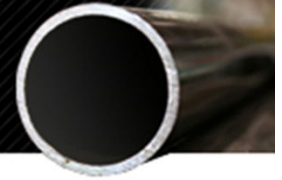


# Design Example 2

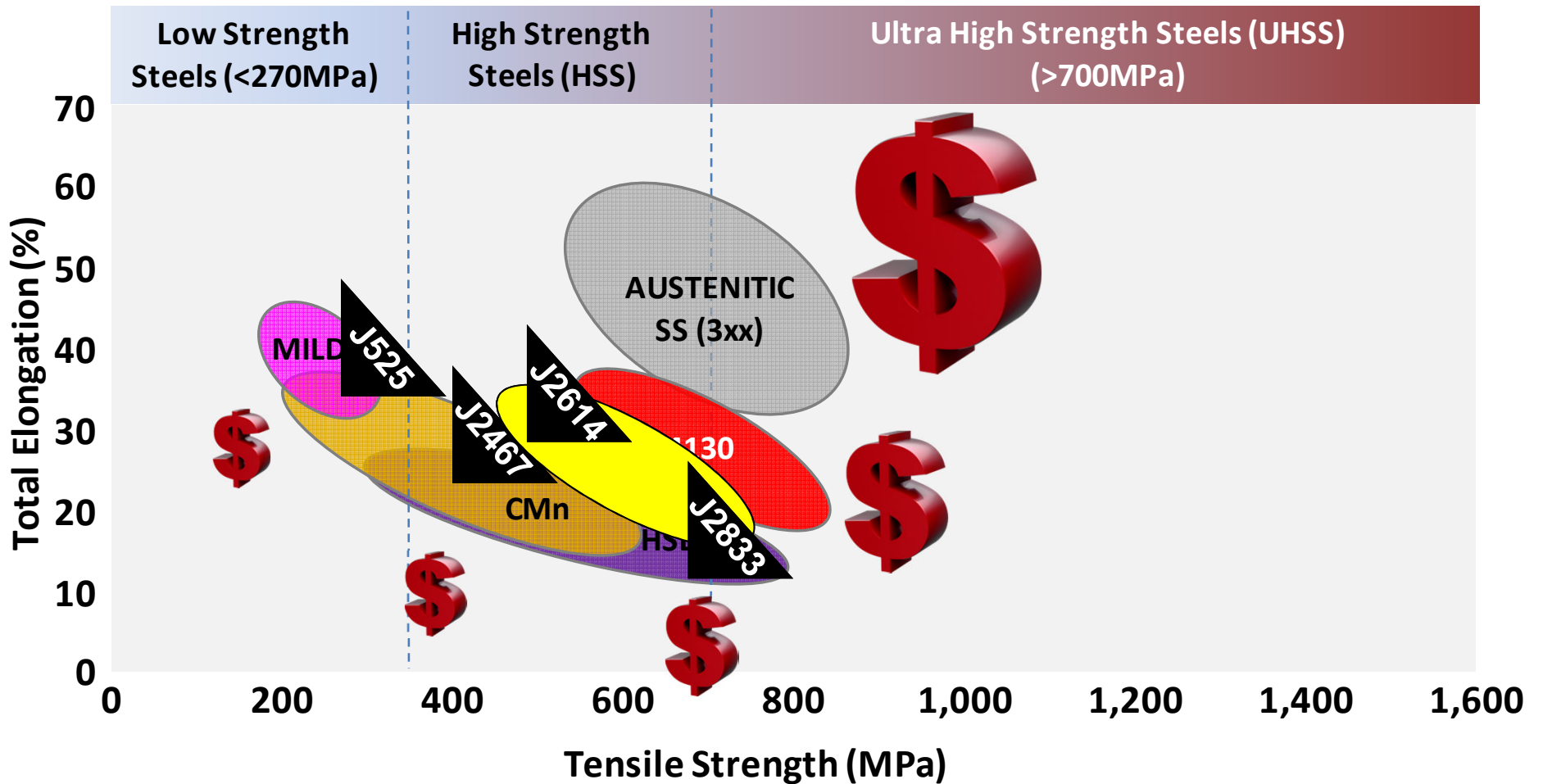
**Option 2 – use HS-50, SS, or 4130**

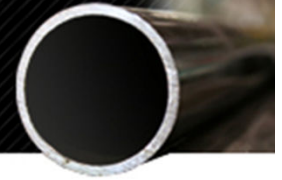
- Increase flow to 9.0 gpm
- Meets pressure requirement
- Reduced weight

Tube OD, in.	Wall thickness, in.	Tube ID, in.	Design pressure, psi (4:1 design factor)			
			Steel 1010 (SAE J524 and J525)	Steel 1021 (SAE J2467)	Stainless Steel (304, 316) 4130, HSLA, <b>HS-50</b>	Copper
0.500	0.049	0.402	2,700	3,250	4,050	1,300
0.500	0.058	0.384	3,250	3,900	4,850	1,550
0.500	0.065	0.370	3,650	4,400	5,500	1,750
0.500	0.072	0.356	4,100	4,900	6,150	1,950
0.500	0.083	0.334	4,800	5,750	7,200	2,300
0.500	0.095	0.310	5,550	6,650	8,350	2,650
0.500	0.109	0.282	6,450	7,750	9,750	3,100
0.500	0.120	0.260	7,200	8,650	10,800	3,450



# Cost Comparison

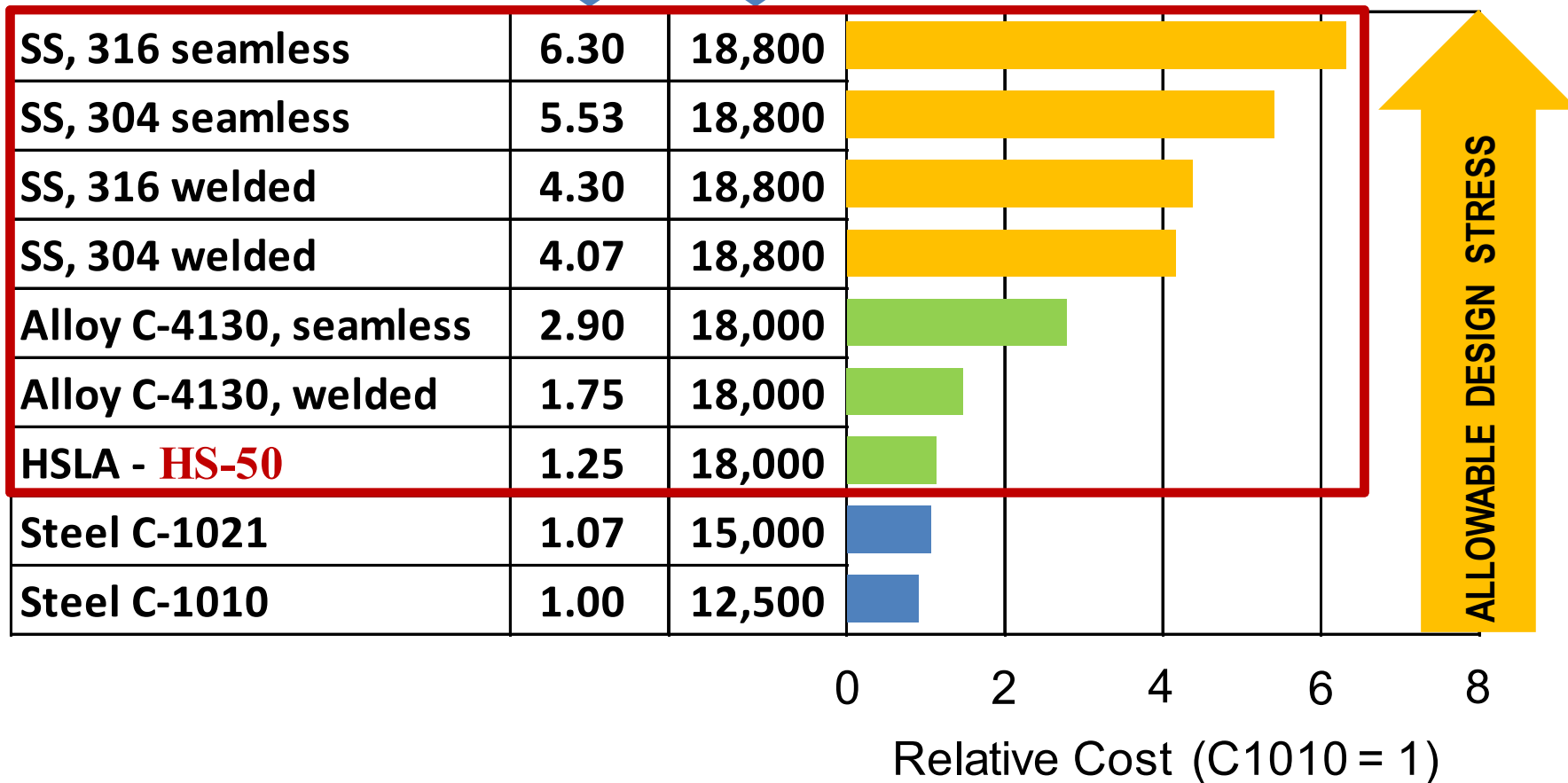




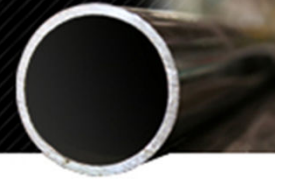
# Cost Comparison

Relative Cost

Allowable Design Stress



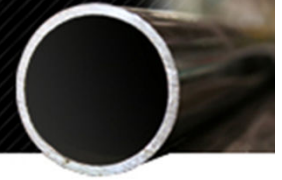




# Chemistry and Mechanicals

CHEMICAL COMPOSITION	C% max	Mn% max	S% max	P% max	Si% max	Al% max	Micro Alloying elements (Nb, Cb, Ti, V) max
HS-50 & HS-90 High Pressure Hydraulic™	0.18	1.5	0.035	0.035	0.35	0.02	0.15

MECHANICAL REQUIREMENTS	Yield Strength		Tensile Strength		Elong	Applicable Specification
	MPa min	psi min	MPa min	psi min	% min	
HS-50 High Pressure Hydraulic™	345	50,025	500	72,500	30	SAE J2614
HS-90 High Pressure Hydraulic™	620	89,900	690	100,050	15	SAE J2833



# Standard Sizes

Plymouth HS-50 and HS-90 High Pressure Hydraulic™ - Standard Size Offerings

Tube OD (in.)	Tube Wall (in.)											
	0.035	0.049	0.054	0.058	0.065	0.083	0.088	0.095	0.100	0.109	0.120	0.134
0.250												
0.375												
0.500												
0.625												
0.750												
0.875												
1.000												
1.125												
1.250												
1.375												
1.500												
1.625												
1.750												



**PLYMOUTH TUBE CO** USA<sup>®</sup>

Questions about this  
presentation?

Contact John Wilbanks at

[jwilbanks@plymouth.com](mailto:jwilbanks@plymouth.com)  
662-273-2220

**[WWW.PLYMOUTH.COM](http://WWW.PLYMOUTH.COM)**