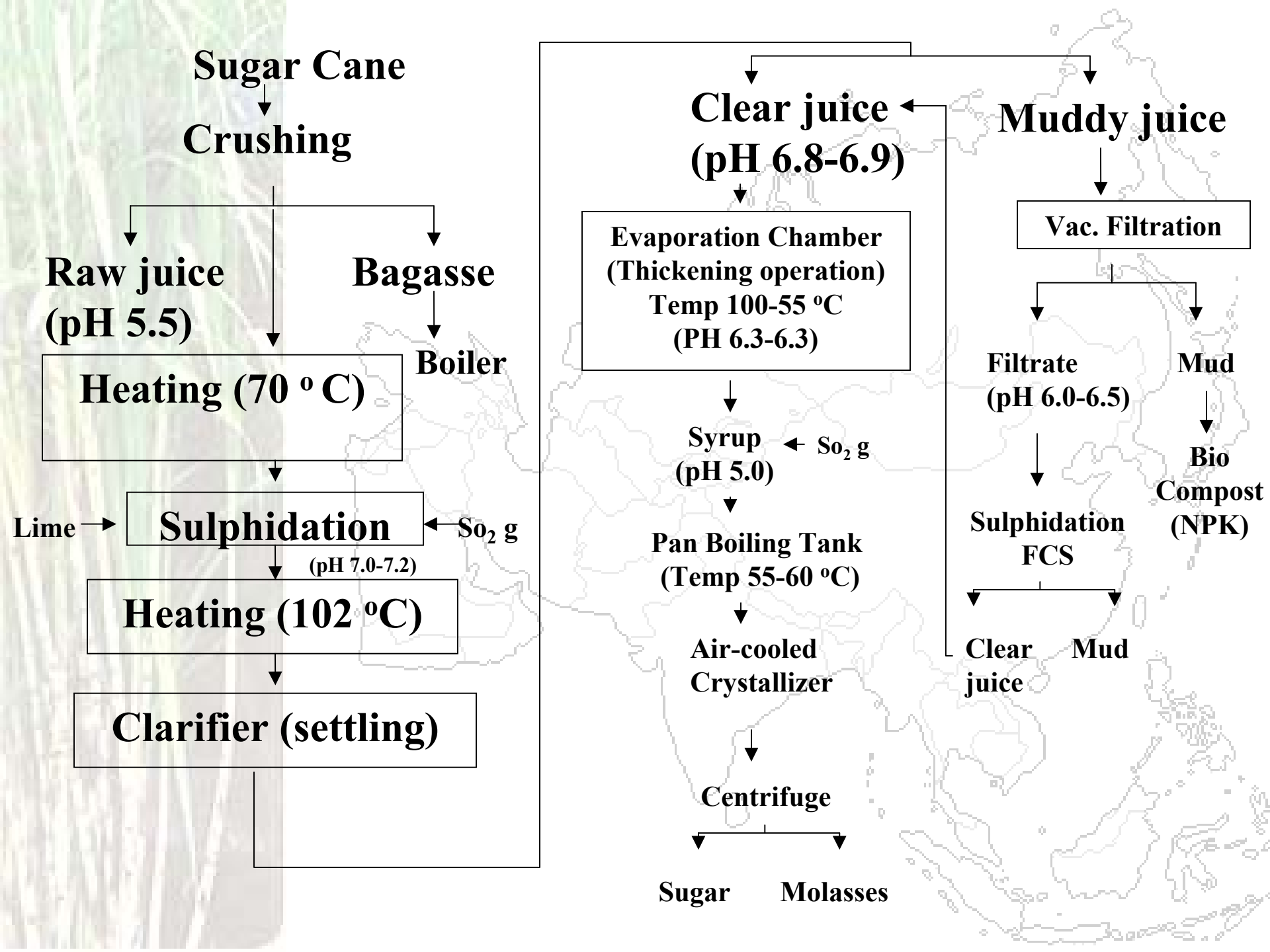




*USE OF CHROME MANGANESE  
AUSTENITIC STAINLESS STEEL  
IN SUGAR INDUSTRY –  
A CONCEPTUAL APPROACH*

**D.Kamila, L.N.Dash, Dr.L.K.Singhal**

**Jindal Stainless Limited**



# Requirement for Sugar Manufacturing

- **SEASONAL CYCLIC ACTIVITY**

**UNINTERRUPTED PRODUCTION ESSENTIAL**

**EMPHASIS ON**

- **INCREASING LIFE OF COMPONENTS**
- **REDUCING UNPLANNED DOWNTIME**
- **MINIMIZING ANNUAL MAINTENANCE COST**
- **IMPROVED HYGIENIC CONDITION OF MILL**
- **SUPERIOR QUALITY OF PRODUCT**

# Properties Required in Material of Construction

- CORROSION & EROSION RESISTANCE
- ABRASION RESISTANCE
- HIGH STRENGTH & LIGHT WEIGHT
- GOOD FABRICABILITY
  - SHEARING
  - BENDING
  - FORMING
  - WELDING
- GOOD WHITE COLOURATION OF SUGAR
- AVAILABLE AT AFFORDABLE COST

# Material Currently Used

**MILD STEEL**

**BRASS**

**409 - 11CR FERRITIC STAINLESS STEEL**

**304 - 18CR-8NI AUSTENITIC STAINLESS STEEL**

⌚ 304 FULFILLS ALL THE ABOVE ATTRIBUTES BUT EXPENSIVE

⌚ 409 USED IN HANDLING DRY OR SEMIDRY CONDITIONS  
- FABRICABILITY IS A CONSTRAINT FOR SOME APPLICATIONS

## Comparative corrosion rates encountered in various stages of processing in MS & Brass

S.No.	Station/medium	pH	Temp. oC	Av.Corrosion rate of MS(mdd)	Corrosion rate of brass(mdd)
1	Condenser water	6.8	41	401.91	26.75
2	Mixed (raw) juice	5.5	29	942.33	53.54
3	Sulphitated juice	7.1	64	213.18	24.3
4	Classified juice	6.9	98	655.5	38.79
5	Filtered juice	6.5	76	734.89	67.06
6	Sulphitated juice	5.1	46	405.18	84.75
7	Final molasses	5.7	45	100.65	22.95

*Higher corrosion rates in mixed raw juice handling area*

**Mdd=milligram/dm<sup>2</sup>/day**

\* Ram Kumar et al, Indian sugar, Sugar technology,july 1993, pp 223-228

# Areas subjected to more aggressive corrosion conditions

**MIXED JUICE HANDLING**

**VACUUM FILTRATION**

**SULPHITATED JUICE**

**TUBES CARRYING CORROSIVE ACIDIC FUMES  
CONSISTING  $SO_2$ ,  $CO_2$ ,  $O_2$**

**AREAS ENCOUNTERING ABRASION AND WEAR**

**SUGAR CANE HANDLING & CRUSHING**

**HOPPERS**

**VACUUM FILTRATION**

# Extensive Lab Studies done in JSL

For identifying measures for

- **Exercising Cost Economy in Building New Plants**
- **Reducing replacement Costs**

**Grades Selected for Study :**

**JSL AUS : 16Cr-4Ni-1.5Cu Austenitic Stainless Steel**

**J204 Cu : 16Cr-1.5Ni-2Cu Austenitic Stainless Steel**

**J4 : 15.5Cr-1Ni-1.5Cu Austenitic Stainless Steel**

**JSL-Tube : 15Cr-Nickel free-1.5Cu Austenitic Stainless Steel**

**409 : 11Cr Ferritic Stainless Steel for Comparison**

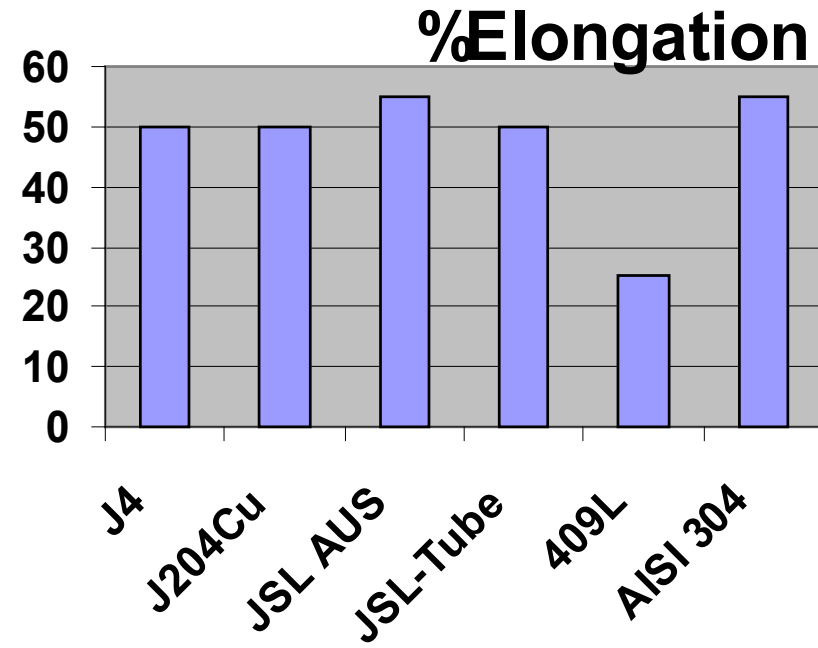
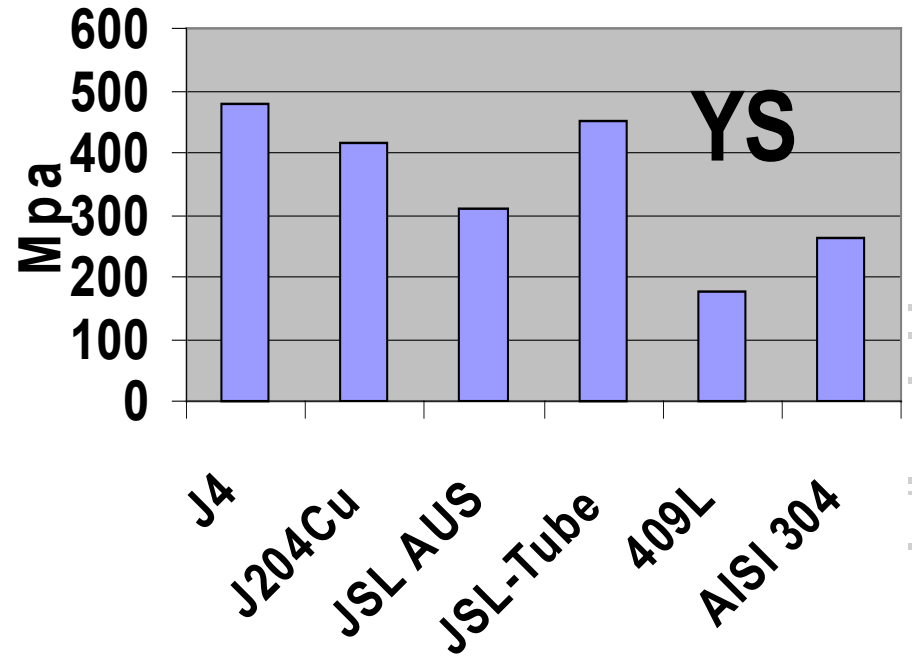
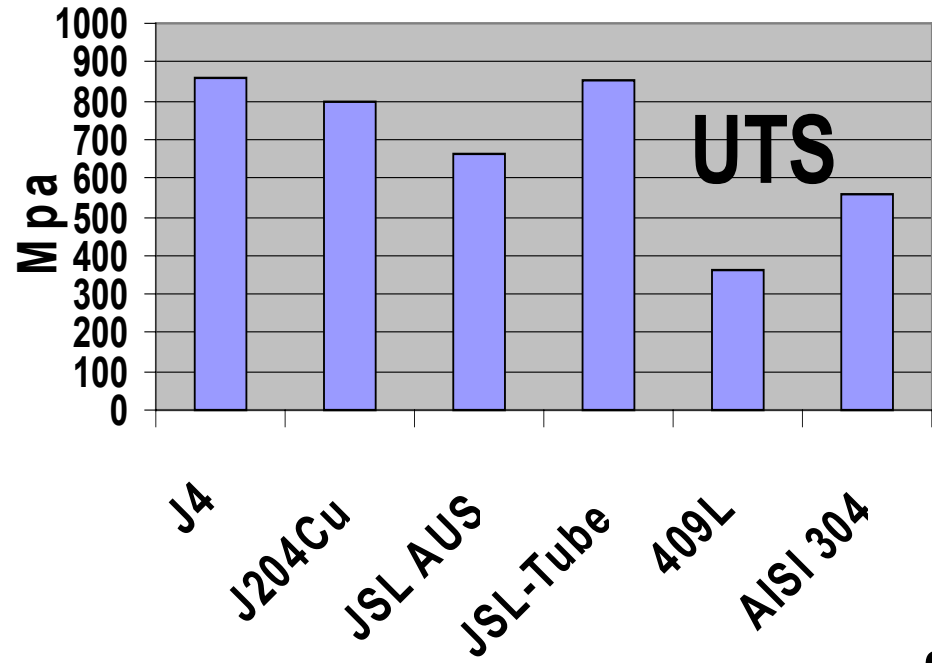
**304 : 18Cr-8Ni Austenitic Stainless Steel for Comparison**

# Chemical Composition

GRADE	Elements	%C	%Mn	%S	%P	%Si	%Cr	%Ni	%N	%Cu
<b>J4</b>	Min.	-	8.5	-	-	-	15.5	1	-	1.5
	Max.	0.1	10	0.005	0.06	0.75	16.5	2	0.2	2
<b>J204Cu</b>	Min.	-	6.5	-	-	-	16	1.5	0.1	2
	Max.	0.1	9	0.005	0.06	0.75	17.5	3.5	0.2	4
<b>JSLAUS</b>	Min.	-	6	-	-	-	16	4	-	1.5
	Max.	0.08	8	0.005	0.06	0.75	18	6	0.1	2
<b>JSL- Tube</b>	Min.	-	9.5	-	-	-	15	-	0.1	1.5
	Max.	0.1	10.5	0.01	0.08	0.5	15.5	0.4	0.2	2
<b>409L</b>	Min.	-	-	-	-	-	10.5	-	-	-
	Max.	0.03	1	0.03	0.04	1	11.8	0.6	-	-
<b>AISI 304</b>	Min.	-	-	-	-	-	18	8	-	-
	Max.	0.08	2	0.03	0.045	0.75	20	10.5	0.1	-

# Mechanical Properties

GRADE		UTS (Mpa)	YS (Mpa)	% Elongation	Hardness (HRB)
<b>J4</b>	Co. Std	650 min.	325 min.	40 min.	100 max.
	Typical	860	480	50	96
<b>J204Cu</b>	Co. Std	650 min.	310 min.	40 min.	100 max.
	Typical	795	415	50	96
<b>JSL AUS</b>	Co. Std	620 min.	265 min.	40 min.	95 max.
	Typical	665	310	55	87
<b>JSL-Tube</b>	Co. Std	650 min	325 min	40 min	100 max
	Typical	850	450	62	98
<b>409L</b>	Co. Std	360 min.	175 min.	25 min	80 max.
	Typical	418	260	28	75
<b>AISI 304</b>	Co. Std	515 min.	205 min.	40 min.	92 max.
	Typical	560	262	55	83



# Corrosion Tests in Sugar Cane Juice

at 25 °C mmpy

<b>MS</b>	<b>0.19</b>
<b>409L</b>	∅ <b>0.001</b>
<b>JSL-TUBE</b>	∅ <b>0.001</b>
<b>J4</b>	∅ <b>0.001</b>
<b>204Cu</b>	<b>NIL</b>
<b>JSL AUS</b>	∅ <b>0.001</b>
<b>304</b>	<b>NIL</b>

at 70 °C mmpy

<b>MS</b>	<b>0.46</b>
<b>409L</b>	<b>0.003</b>
<b>JSL-TUBE</b>	∅ <b>0.001</b>
<b>J4</b>	∅ <b>0.001</b>
<b>204Cu</b>	<b>NIL</b>
<b>JSL AUS</b>	∅ <b>0.001</b>
<b>304</b>	<b>NIL</b>

at 100 °C mmpy

<b>MS</b>	<b>3.12</b>
<b>409L</b>	<b>0.003</b>
<b>JSL-TUBE</b>	∅ <b>0.001</b>
<b>J4</b>	∅ <b>0.001</b>
<b>204Cu</b>	∅ <b>0.001</b>
<b>JSL AUS</b>	∅ <b>0.001</b>
<b>304</b>	<b>NIL</b>

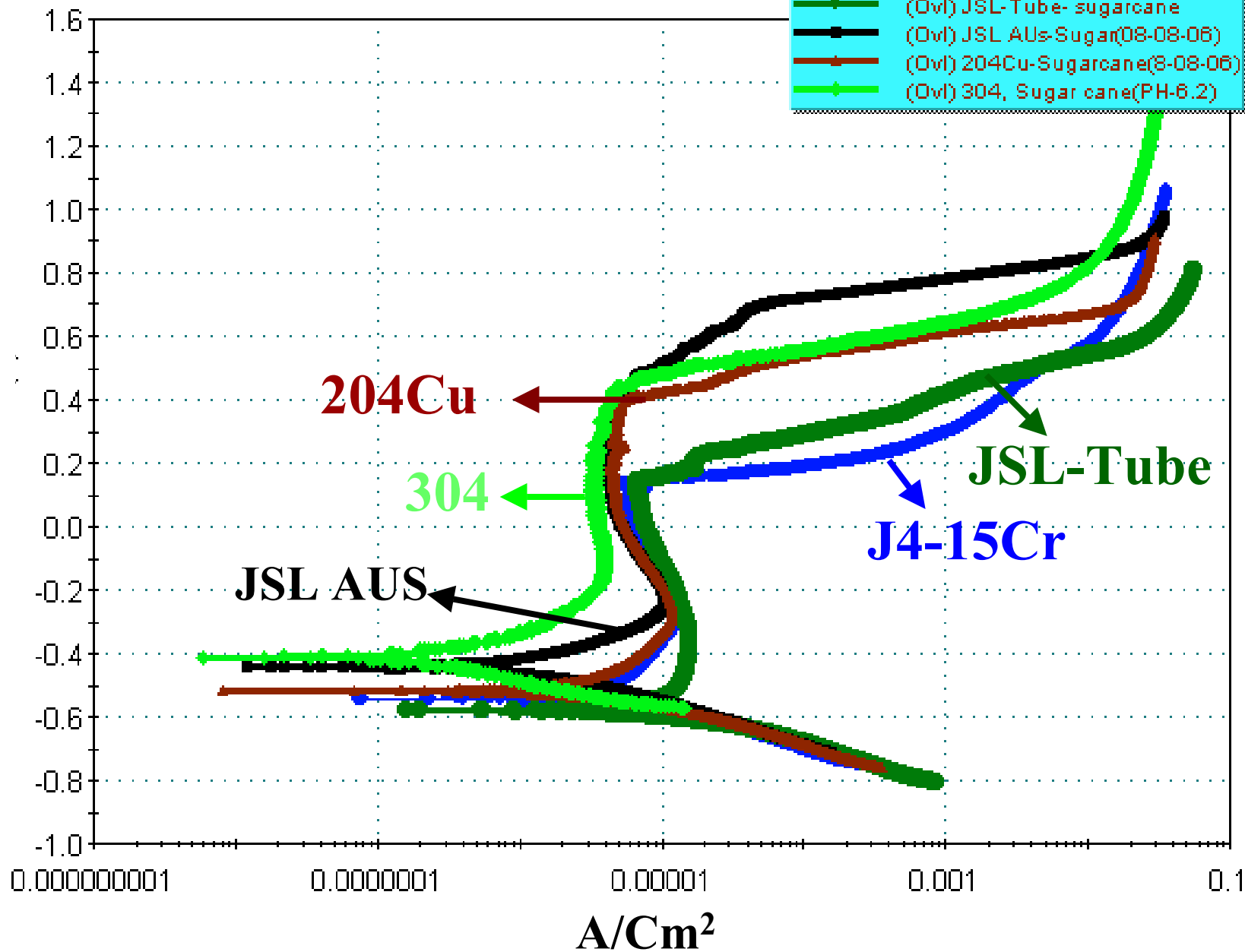
\* MG FONTANA CORROSION  
ENGINEERING, MC GRAW HILL

MMPY (MILLIMETER  
PENETRATION PER YEAR) IS  
THE MOST COMMONLY USED  
CORROSION EXPRESSION

<b>RELATIVE CORROSION RESISTANCE</b>	<b>MMPY</b>
<b>OUTSTANDING</b>	<b>&lt;0.02</b>
<b>EXCELLENT</b>	<b>0.02-0.1</b>
<b>GOOD</b>	<b>0.1-0.5</b>
<b>POOR</b>	<b>1.0-5.0</b>

E vs log(I)

Potential (V)



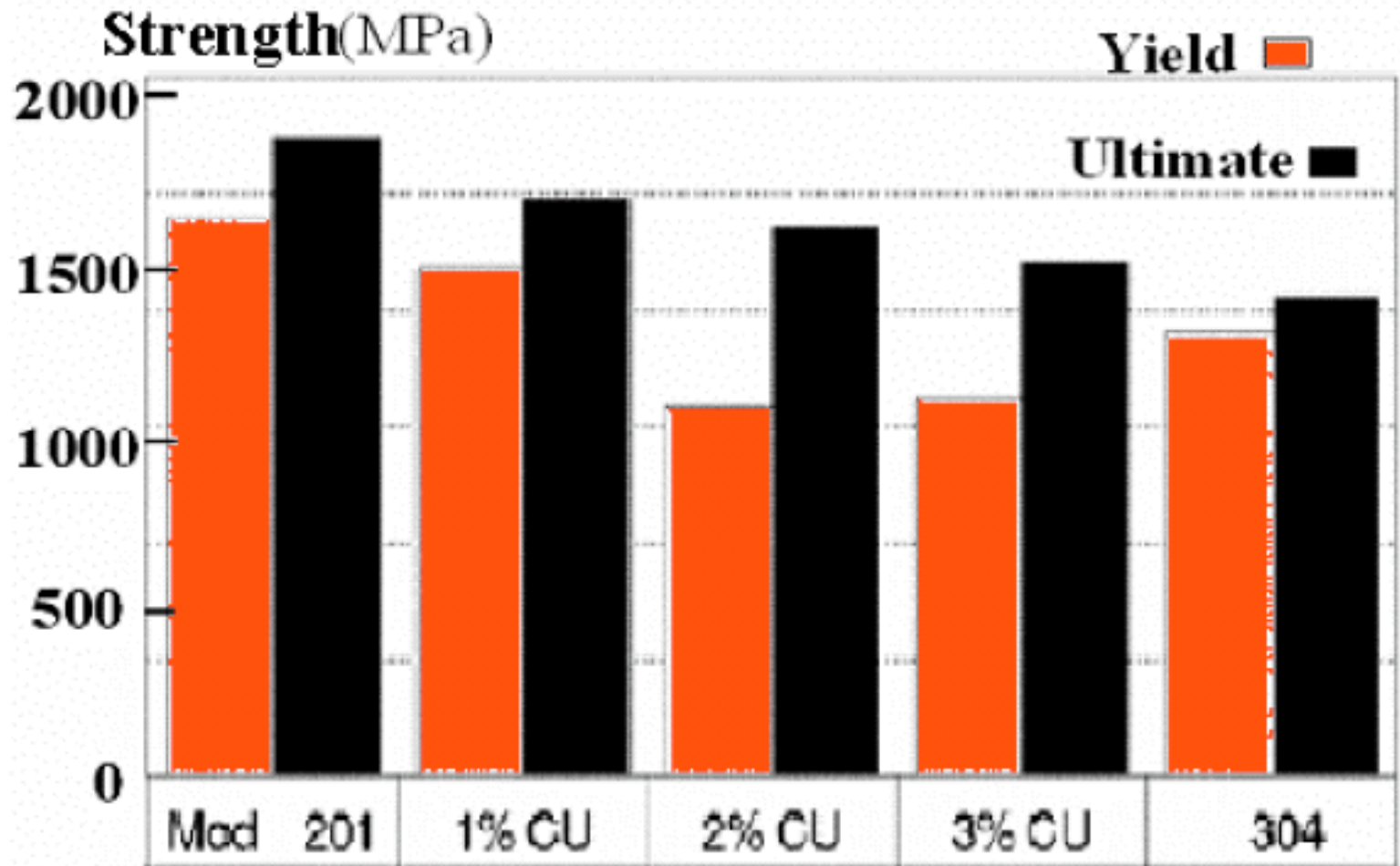




# Some Characteristics of Chrome Manganese Stainless Steels

- HIGH STRENGTH TO WEIGHT RATIO
- EXCELLENT DRAWABILITY
- SUPERIOR WEAR RESISTANCE
- GOOD WELDABILITY
- GOOD CORROSION RESISTANCE
- HIGH LUSTRE

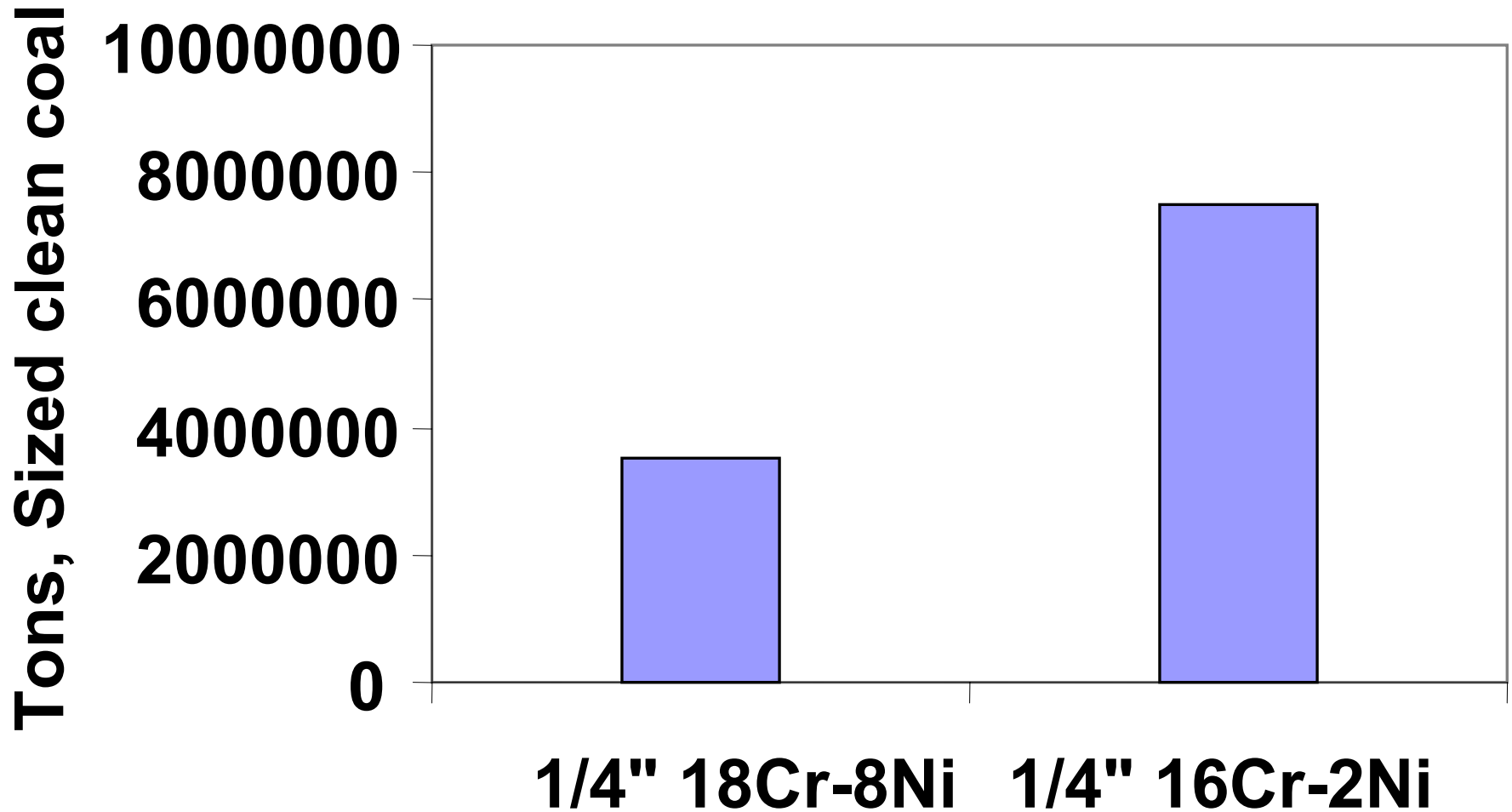
# DUCTILITY AFTER 80% COLD WORK



Mod 201- 0.15maxC, 15-17Cr, 7-9Mn, 1.5-3.5Ni, 0.15-0.3 N

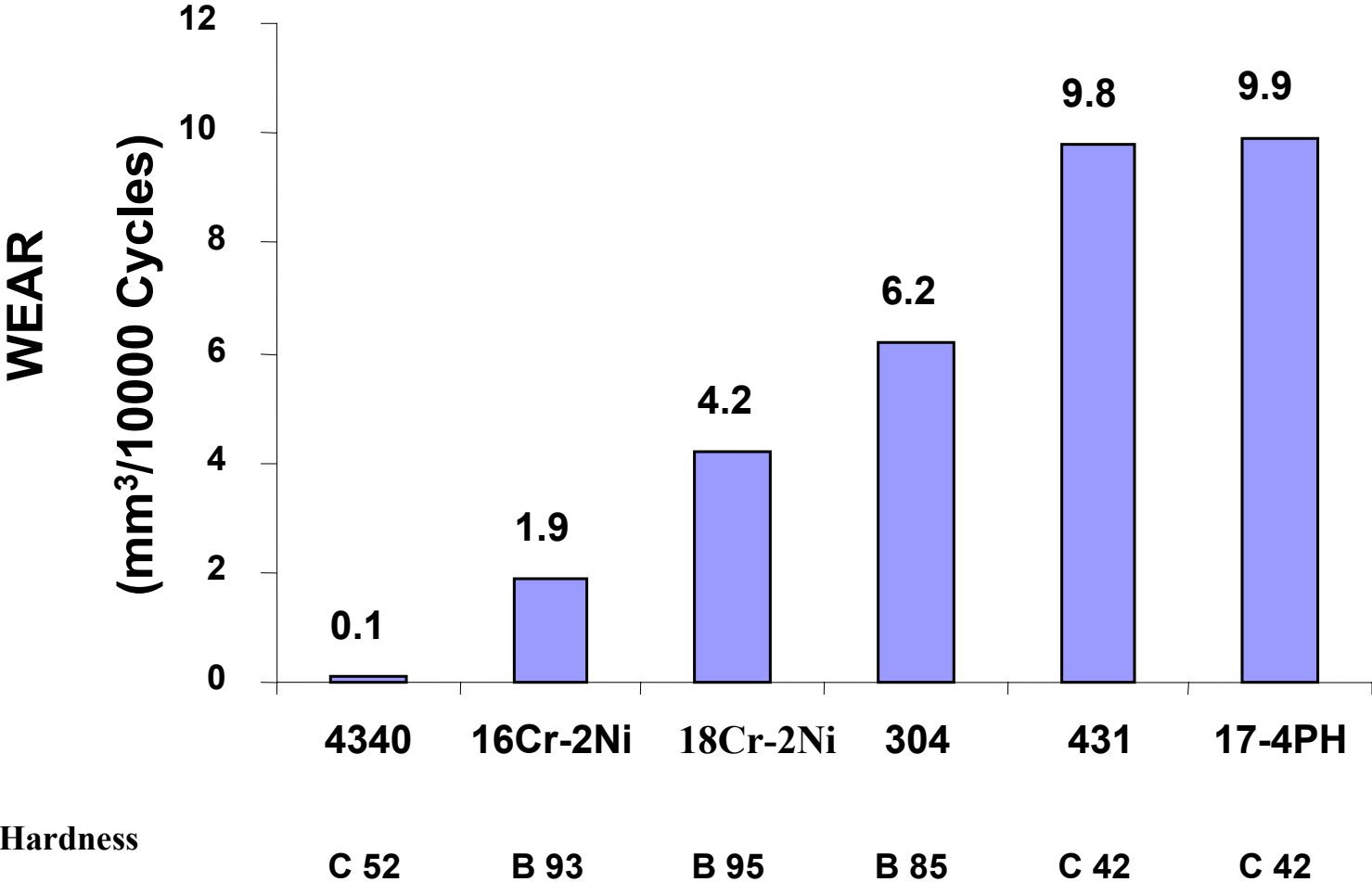
**EXCELLENT DRAWABILITY**

# Wear in Material Handling



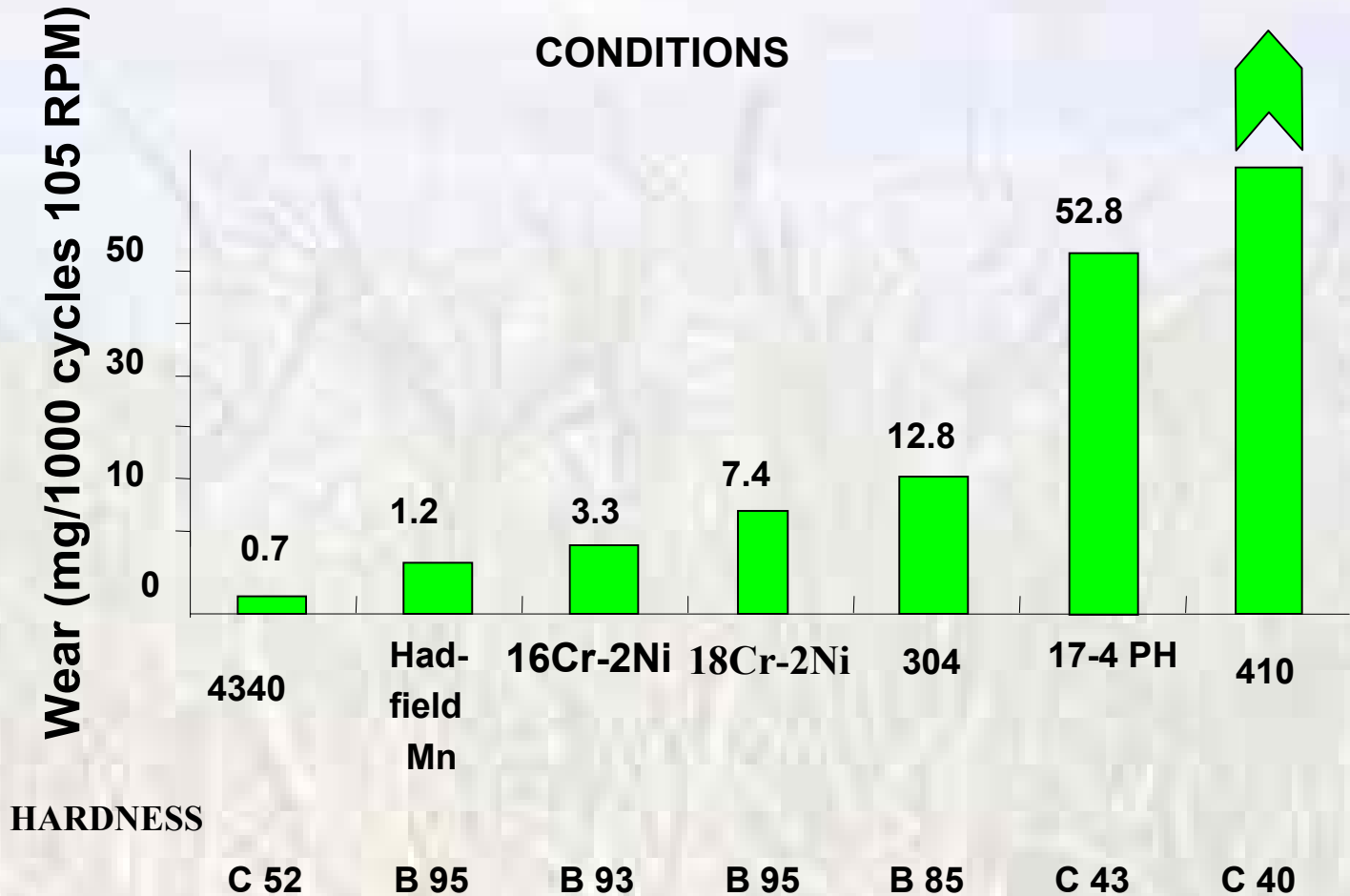
(Ref: A.K.Steel)

# DRY ABRASIVE WEAR OF ALLOYS MATED TO TUNGSTEN CARBIDE



(Ref: A.K.Steel)

# METAL TO METAL WEAR UNDER SLIDING CONDITIONS

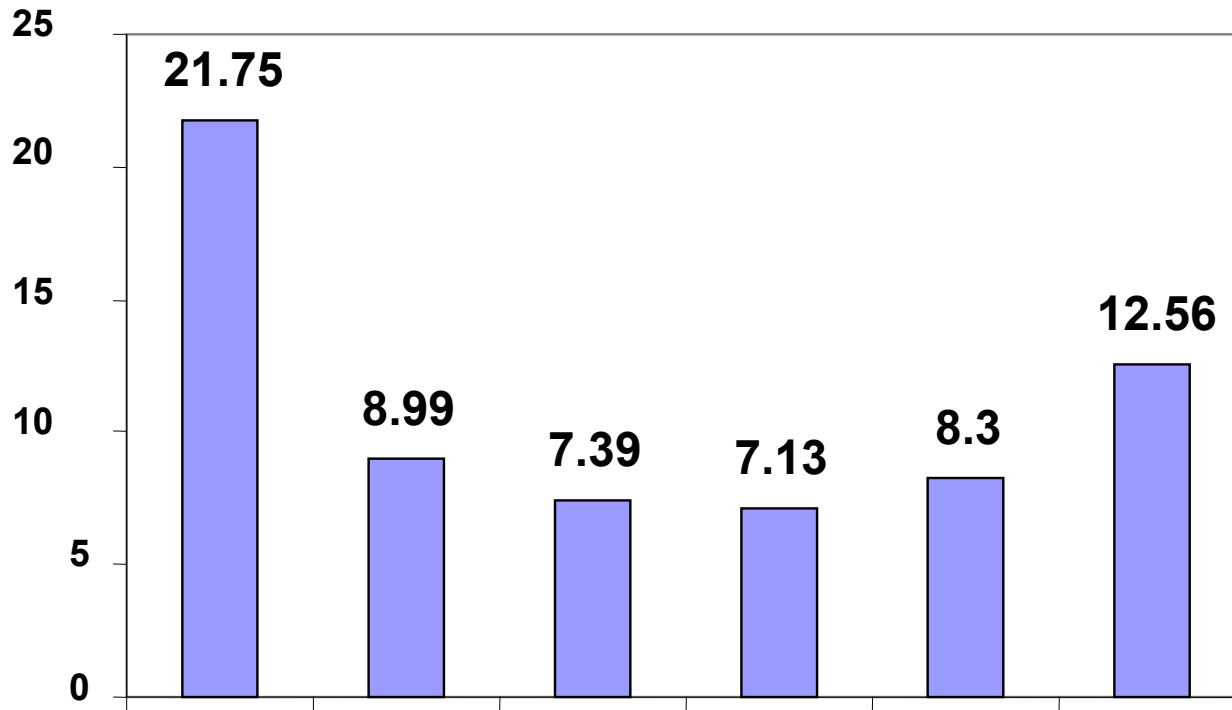


Self-mated cylinders, unlubricated in air at room temperature

(Ref: A.K.Steel)

## Corrosive Wear in Coal Mine Effluent

Cumulative Volume Loss, (mm<sup>3</sup>)



Alloys

4340

409

17-4  
PH

16Cr-2Ni

304

316

Hardness

C 48

B 85

C 44

B 90

B 75

B73

(Ref: A.K.Steel)

# Equivalence of 204 Cu and 304

- **Crevice corrosion resistance in chloride solution: 204 Cu is equivalent to 304 (Arcelor)**
- **Intergranular corrosion tests as per ASTM 262 practice E after thermal treatment at 650° C and 700° C show that both 204 Cu and 304 are immune from intergranular corrosion (Arcelor)**
- **Corrosion tests in 2M H<sub>2</sub>SO<sub>4</sub> at 23° C indicate that 204 Cu and 304 are similar in their uniform corrosion behaviour and their corrosion rates are far below that of AISI 430 (Arcelor)**
- **Corrosion resistance in neutral solution of 5% NaCl, pH 6.6 at 35° C: Corrosion did not occur in either 204 Cu or 304 whereas in contrast 430 exhibits stable pits with corrosion (Arcelor)**

• **Stress corrosion resistance in boiling  $MgCl_2$  at  $155^\circ C$  as per ASTM G48: The results show that 204 Cu & 304 are equivalent (Arcelor)**

• **High Temperature Oxidation resistance: The maximum operating temperature determined as per EN 10295 shows that  $T_{max}$  is  $870^\circ C$  for both 204 Cu and 304 (Arcelor)**

• **Resistance to thermal cycling – characterization at  $800^\circ C$  upto 1200 cycles showed similar results for both 204 Cu and 304 (Arcelor)**

• **Salt spray resistance of 204 Cu is similar to 304 (Carpenter Tech)**

## **204 Cu has been used for**

- Conveying food into baking ovens**
- Screen wire for coal handling**
- Equipments for tobacco processing industry**
- Kitchenware etc.**

**Copper Containing 18-8 Stainless Steel – developed by POSCO for Antibiosis**

# **J4**

- **LARGEST SELLING CHROME MANGANESE STAINLESS STEEL IN THE WORLD**
- **PRODUCED IN INDIA, CHINA, TAIWAN, BRAZIL & JAPAN**
- **HIGH STRENGTH TO WEIGHT RATIO**
- **GOOD DRAWABILITY & WELDABILITY**
- **CORROSION RESISTANCE & MECHANICAL PROPERTIES INTERMEDIATE TO 204CU & JSL-TUBE**

## **JSL-TUBE**

<b>0.1C</b>	<b>15.0Cr</b>	<b>10.0Mn</b>	<b>1.5Cu</b>	<b>0.15N</b>
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## **Nisshin Grade(NHS 104)**

<b>0.1C</b>	<b>14.5Cr</b>	<b>10Mn</b>	<b>2Cu</b>	<b>0.15N</b>
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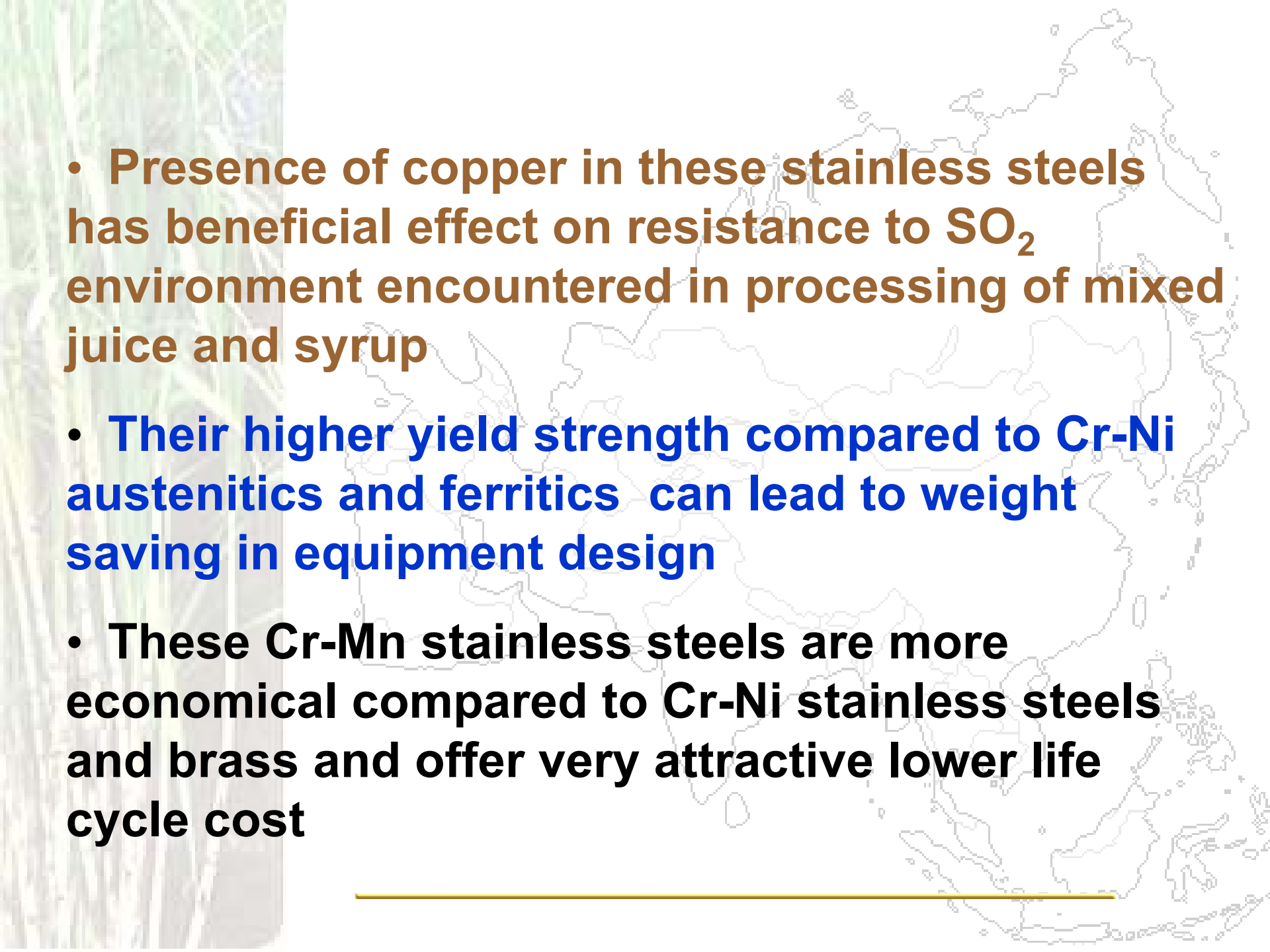
- **FULLY AUSTENITIC IN ANNEALED CONDITION LIKE 304**
- **BECOMES SLIGHTLY MAGNETIC ON COLD WORKING LIKE AISI 304**
- **0.2% PROOF STRESS AND UTS OF THIS ALLOY ARE HIGHER THAN 304**
- **WELDABILITY & FORMABILITY SIMILAR TO 304**
- **PRESSURE OF CUSHION IN DEEP DRAWING IS HIGHER BY ALMOST 15-35% COMPARED WITH AISI 304**
- **IN SO<sub>2</sub> GAS TEST THIS STAINLESS STEEL IS SUPERIOR TO 304 ON ACCOUNT OF PRESENCE OF COPPER**

\* K.Hoshino & H.Kanezashi, Nisshin Steel Co, Tool & Alloy Steel, ,1976,Vol 8, p 84-94

# Conclusion

- **Austenitic stainless steels of Cr-Mn-Ni-Cu and Cr-Mn-Cu variety possess very attractive combination of properties for conditions encountered by materials of construction in cane sugar industry**
- **Like Cr-Ni austenitic stainless steel AISI304, they exhibit 'outstanding' resistance to corrosion in mixed sugar cane juice at various processing temperatures**
- **In processing of sugar cane, condition of dry abrasive wear and corrosive wear in presence of muddy solutions is encountered with pH ranging from 5 to 7.2. On account of their higher strength, Cr-Mn stainless steels are generally characterized by higher resistance to abrasion, erosion and erosion-corrosion compared to Cr-Ni stainless steel counterparts in similar mildly corrosive conditions**

- These stainless steels have superior toughness and ductility compared to ferritic stainless steels such as 409
- Like AISI 304, these stainless steels can be bent and drawn extensively. Their press formability and fabricability are far superior to ferritic stainless steels
- The weldability of Cr-Mn-Ni & Cr-Mn stainless steels JSL-AUS, J204Cu, J4, JSL-TUBE is generally at par with Cr-Ni austenitic stainless steel AISI 304 and superior to ferritics
- These stainless steels can be conveniently welded into tubes which are far superior to brass in corrosion resistance

- 
- **Presence of copper in these stainless steels has beneficial effect on resistance to SO<sub>2</sub> environment encountered in processing of mixed juice and syrup**
  - **Their higher yield strength compared to Cr-Ni austenitics and ferritics can lead to weight saving in equipment design**
  - **These Cr-Mn stainless steels are more economical compared to Cr-Ni stainless steels and brass and offer very attractive lower life cycle cost**
-



**THANKS!**