

DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY
STEEL COMMITTEE

Cancels & replaces the same document of 04 May 2006

INDIA

STAINLESS STEELS RECENT DEVELOPMENTS AND OUTLOOK: DEMAND, CAPACITY AND
PRODUCT DEVELOPMENT

Joint India/OECD/IISI Workshop, New Delhi (India), 16-17 May 2006.

Presentation by Dr. L.K.Singhal, Director, Jindal Stainless

Contact: Wolfgang Hübner, Head of Structural Policy Division and Steel Unit
Tel: +33 1 45 24 91 32 Fax: +33 1 44 30 62 63 E-mail: wolfgang.hubner@oecd.org

JT03208630

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

**STAINLESS STEELS RECENT DEVELOPMENTS AND OUTLOOK:
DEMAND, CAPACITY & PRODUCT DEVELOPMENT**

Presentation by Dr. L.K.Singhal, Director

Growth Scenario:

1. Globally stainless steels have been witnessing an average growth rate exceeding 5% per year during the last three decades (Fig.1). Production of stainless steels in different regions of the world, in recent years, exhibits impressive growth in Asia (Fig. 2). Though developed less than 100 years ago, stainless steels have emerged as the fastest growing metallic material (Fig. 3) and in recent years their growth rate has even surpassed plastics (Fig.4). The drivers for such impressive growth are sterling characteristics of stainless steels: corrosion & oxidation resistance, high strength to weight ratio, excellent press formability, weldability, low temperature toughness to name a few (Fig. 5).

2. During last 10 years consumption of stainless steels in China and India has grown at an average rate exceeding 20% and 10% respectively (Fig.6). However, per capita consumption at 4.1 kg and 1.1 kg is still relatively very low indicating ample scope for growth (Fig.7). China has been at the centre of developments in the world stainless markets in recent times. Rapid additions to its stainless steel capacity are continuing and crude steel production is expected to be in the vicinity of 10 million tons in 2010. The estimates of CRU1 for slab and cold rolled capacity additions during 2006-10 are given in Fig. 8 indicating China and India to be the two countries, which will witness significant growth in stainless capacity. Due to such phenomenal build up of capacity in China, the net imports of stainless steel into the country are expected to plunge leading to lower capacity utilization in many exporting countries (Fig. 9).

Consumption of different varieties of stainless steels:

3. The consumption trend in different sectors in the developed western world and in India is shown in Fig. 10. Such wide ranging applications in diverse sectors are achieved by a large and growing family of stainless steels. Based on crystal structure, stainless steels are of four varieties: Ferritic, Martensitic, Austenitic and Duplex (Ferritic+Austenitic). Austenitics are further subdivided into chrome-nickel (AISI 300 series) and chrome-Manganese (AISI 200 series) based on dominant alloying additions of nickel and manganese respectively (Fig. 11). Chrome-nickel stainless steels currently account for two third of world production (Fig.12). Since Chrome-manganese stainless steels also have identical crystal structure and lots of similarities in respect of physical and mechanical properties, their production has been steadily increasing in recent years due to high price of nickel. In the last five years, the percentage of Chrome-Manganese stainless steels has nearly doubled (Fig.12). Nickel supplies have not been able to keep pace with increased demand. Nickel ores are very lean with mostly 1-3% Ni content and new projects for nickel extraction require huge investments. Cost per kilogram of input elements in stainless steel as prevailing in April 06 in India (Fig.13) highlights the vast differential in price of manganese and nickel though both elements play similar role of austenitizing element in stainless steel. As a consequence, the price of a chrome-nickel stainless steel closely follows the trend of nickel price (Fig.14). Therefore for good health

and cost competitiveness of stainless steel industry there are continuing efforts to use nickel free/low nickel ferritic, chrome-manganese austenitic and duplex stainless steels wherever appropriate.

4. Since apart from attributes such as strength, formability and weldability, the corrosion resistance of candidate materials should be suitable for intended use, PREN (Pitting Resistance Equivalent Number) has emerged as a measure of resistance to corrosion in many environments. It has been found that the following relationship provides a good comparative assessment

$$\text{PREN} = \% \text{Cr} + 3.3 \times \% \text{Mo} + 16 \times \% \text{N}$$

5. Various stainless steels of different series have been plotted in Fig 15 on the basis of their PREN. Alloys falling in the same horizontal band indicate possibilities for substitution by a more cost effective grade. Efficacy of PREN is illustrated in Figs 16-18 wherein Chrome- Manganese grade J 204 is compared with Chrome-Nickel grade 304 in a variety of media of nitric acid, orthophosphoric acid and saline solution (at low pH) and almost identical behaviour is evident in both alloys. Similarly Condylis et al ² have highlighted striking resemblance in corrosion behaviour of 304L with 204L and of 316 L with 216L in sulfuric, phosphoric and organic acids (Figs.19-20). They also noted relatively superior corrosion resistance of manganese grades in chloride environment and stated that replacement of these 300 series grades by their counterparts in 200 series is feasible. Thus, there exists enormous scope for reduction of pressure on nickel demand by switching over to 200 series of stainless steels.

Trends in Product Development, in Stainless Steels

Duplex, Super Duplex and Lean Duplex Stainless Steels:

6. Addition of nitrogen and lowering of carbon content has enabled development of duplex stainless steels into readily weldable materials. Use of duplex stainless steels is gradually expanding in oil and gas, petrochemicals, paper and pulp, desalination plants and pollution control equipment on account of their superior resistance to stress corrosion cracking. Duplex 2205 with 22% Cr, 5% Ni and 3% Mo has replaced austenitic grades such as 317L and 904L of higher nickel contents for several applications³.

7. Superduplex grades with PREN exceeding 40 such as alloy 2507 have been used for marine, chemical and oil applications requiring high strength as well as resistance to corrosion in extremely aggressive environments such as chloride containing acids³. In spite of their lower nickel and molybdenum levels, corrosion resistance of superduplex is equivalent to highly alloyed superaustenitic steels containing 5-6% Molybdenum. On account of their higher yield strength, duplex and superduplex stainless steels lead to weight savings as well.

8. In recent years, several lean duplex stainless steels have been developed where part of nickel is substituted by manganese and nitrogen. These include alloy 19D (UNS S32001) with 20% Chromium, 1.6% Nickel, 5% Manganese, 0.02% Carbon and 0.13% Nitrogen which has been used for oil fields and sub-sea umbilical tubing. LDX 2101 (UNS S32101) with 21% chromium, 1.5% Nickel, 5% Manganese and 0.22% Nitrogen has found applications in desalination plants, paper industry, flood gates of dams and bridges. Other molybdenum free low nickel duplex include 2304 with 23% chromium and 4% nickel which matches costlier 316 with added advantage of superior mechanical strength, wear and cavitation resistance coupled with weight savings in plant equipment. It is being used in paper and pulp as well as offshore applications.

Superferritic stainless steels

9. Superferritics, with very low interstitial levels having high chromium and 1-2% molybdenum content with carbide stabilizers, exhibit vastly superior corrosion resistance compared to traditional ferritic grades. Carbon and nitrogen contents have to be very low (usually less than 100 ppm each) to reduce ductile-brittle transition temperature. This is achieved on commercial scale by vacuum oxygen decarburization process. Grades with 22%, 24%, 26% & 30% chromium with molybdenum and carbide stabilizers Ti/Nb have been developed⁴. Out of these, 22% Cr – 1.5% Mo grade matches 316 in corrosion resistance and those with higher chromium content are superior. These grades are preferred materials for roof and exterior buildings in sea side environments due to their high resistance to corrosion and lower coefficient of thermal expansion compared to austenitic grades.

Chrome-Manganese Stainless Steels

10. These stainless steels were commercially produced in Germany during forties. Further stimulus to their development was provided during Korean war when nickel shortages were experienced. When the war ended, nickel shortages eased and focus shifted back to chrome-nickel grades. Those days, 200 series required expensive low carbon ferro- manganese, nitrided ferro-chrome and/or nitrided electrolytic manganese for their manufacture. Consequently financial incentive was limited. With advent of Argon-Oxygen Decarburization process, it became possible to utilize cheaper high carbon ferromanganese and gaseous nitrogen for alloying. In fact the consumption of costly argon could be simultaneously lowered in the process for chrome-manganese grades as compared to standard chrome-nickel stainless steels. Chrome-manganese grade AISI 201 has been in production in a large number of countries including USA and Japan. It has been successfully utilized⁵ in the following sectors:

Food & Beverages

Tableware, kitchenware

White Goods

Toasters, washing machines, microwave ovens, refrigerators, ice water & beverage dispensers.

Architecture Building Construction

Thermal window spacers, hand rails, structural support framework.

Transport

Rail car, Trucks, Trailers, Subways, Trolleys, Piston Rings.

11. Chrome-Manganese grades have further benefited by way of improved drawability on alloying with copper. By addition of 1.5-2% copper⁶ to AISI 201, a stainless steel with even superior drawability has emerged:

Type 211 / JSL – AUS / NIPPON NAR 200

	C	Mn	Cr	Ni	Cu	N	S
Type 211	≤ 0.07	5.5-6.5	16-17	5-6	1.5-2.0	≤ 0.05	0.03
JSL-AUS	≤ 0.08	6-8	16-18	4-6	1.5-2.0	≤ 0.10	≤ 0.005
Nippon NAR 200	≤ 0.07	5.5-6.5	16-17	5.5-6.5	1.8-2.3	N.A.	≤ 0.03

12. AISI 201 and 202 were developed when ingot route was practiced. With continuous casting, Argon-Oxygen-Decarburization, use of ladle furnace for close compositional control and better control of

reheating temperature before rolling, it has been possible to manufacture leaner alloy strips successfully. Two such compositions are:

	C	Mn	Cr	Ni	Cu	N	S
J-4	≤ 0.1	8.5-10	15.5-16.5	1.0-2.0	1.5-2.0	≤ 0.2	≤ 0.005
204 Cu	≤ 0.1	6.5-9.0	16.0-17.5	1.5-3.5	2-4	0.1-0.2	≤ 0.005

13. These alloys are endowed with high strength, good drawability, weldability and corrosion resistance. These have been successfully used in several applications covered earlier by AISI 201,301 and 304.

Super Martensitic Stainless Steels.

14. These are latest entrants to 'super' family. Despite extremely low carbon and martensitic structure, they offer a combination of high strength and weldability with good low temperature toughness and adequate corrosion resistance for many applications. Containing 13%-17% Chromium with varying nickel and molybdenum content, supermartensitics find increasing applications in oil and gas industry⁷.

Indian Stainless Steel Scene

15. During the last 15 years, Indian stainless steel production has grown at an average rate of 14% per annum (Fig. 21) against the world average rate of 6%. During this period India's share of world production has increased from 2% to around 7% and the pattern of production of 200 series has changed drastically with ratio of 300 series dropping from 95% in 1990-91 to 22% in 2004-05 (Fig.22). Availability of a large number of AOD units in the country has facilitated production of chrome-manganese stainless steels.

16. At 75% market share, Tableware, Kitchenware and White goods sector continue to be a major user of stainless in India. In the late 80's this sector had a market share of 85%. With greater emphasis on austenitic, infrastructure and transport sectors, the trend for use of stainless steel in Architecture, Building & Construction and Automotive sectors is exhibiting upswing on account of greater concern for environment and aesthetics(Fig.23).

ABC Sector

17. The scene in metropolitan cities is gradually transforming. Our political leadership has taken lead with copious use of stainless sheet for beautiful Parliament Library (Fig.24). Multiplexes (Fig.25), Malls and Entertainment plazas (Fig26) are making increasing use. Buildings with stainless claddings (Fig27), interiors, staircases, escalators and roofs are coming up. Major investments in high quality construction in shopping malls, showrooms, multiplexes, fast food outlets, commercial complexes, IT parks, metro-stations, retail outlets and airports offer great opportunities for stainless usage. The use in construction sector is expected to rise from the present 23,000 tons to around 5,00,000 tons by 2015-16. The demo house project of ISSF is inspiring us to introduce stainless steel in a bigger way in house construction as well as in other sectors of white goods, LPG cylinders, etc.

Transport Sector

18. Similarly in transportation sector also from present level of 23,000 tons, the consumption is expected to rise to 250,000 tons by 2015-16. The autosector is witnessing extremely high growth rate with a total of 8.46 million vehicles manufactured during 2004-05. Since the auto component industry has emerged as globally competitive, the exports are also rising sharply. Due to stricter emission norms, the use of stainless steel in exhaust systems of cars and motor cycles is increasing rapidly.

19. All railway coaches consume stainless steel for furnishing. In addition, for prestigious train services, all stainless variety coaches are being built. Similarly each metro coach consumes nearly 12 tons of stainless steel. While there is a growing requirement of upto 1000 coaches by Delhi metro itself by 2010, other cities like Bangalore, Hyderabad, Mumbai, Ahmedabad and Chennai are also planning to opt for Delhi Metro model. The merit of stainless steel on account of their better payload ratio due to higher strength to weight ratio and longer life as a consequence of superior corrosion/abrasion resistance compared to Corten steel has been recognized by none other than our Hon'ble Minister in his budget speech this year. All new coal wagons will be either of stainless steel or aluminum. So the continuing challenge before stainless steel is to provide greater value to customer and retain numero uno position in growth rate.

Conclusions

1. Consumption of stainless steels is exhibiting high growth rate in Asia.
2. On account of over all global overcapacity, new capacity creations in next few years will be mostly confined to China and India.
3. Based on fascinating technologies of Argon-Oxygen-Decarburization and Vacuum-Oxygen-Decarburisation, there is continuous evolution of new superior grades:
 - i) Supermartensitic and Superferritic alloys with very low carbon and nitrogen levels on one hand.
 - ii) Newer Austenitic, Duplex, Superaustenitic and Superduplex grades with significant nitrogen content for economy as well as superior properties.
4. Significant substitution of costlier grades by cost effective appropriate alternatives
 - i) Replacement of Duplex stainless steels by less alloyed Supermartensitics
 - ii) Substitution of Chrome-Nickel and Chrome-Nickel-Moly austenitic grades by Ferritic, Chrome-Manganese Austenitic and Lean-Duplex grades.
 - iii) Replacement of Superaustenitics by Superduplex grades having lower alloy content.

References:

1. V. Davidson, Global Outlook for Stainless Flat Products: A market in transition, 8th International Stainless Steel Conference, November 2005, New Delhi.
2. Condylis, F. Bayon, A. Desestret, Aciers Inoxydables austenitiques chrome-nickel-manganese-azote, Revue de Metallurgie, May 1970, 427-442.
3. J. Charles, Why and where Duplex Stainless Steels, Duplex Stainless Steels 97, 5th World Conference, KCI Publishing, p 29-42.
4. T. Kawasaki, Stainless Steel Production Technologies at Kawasaki Steel- Features of Production Facilities and Material Developments, Kawasaki Technical Report No. 40, May 1999, 5-15.
5. D. S. Bergstrom, C. A. Botti, AL 201 HPTM (UNSS20100) alloy: A high-performance, lower nickel alternative to 300 series alloys, Stainless Steel World November 2005, Maastricht, P5119
6. R. H. Kaltenhauser, Where to Consider the 200 and 400 grades, Source Book on Stainless Steel, ASM, 1976, p 67-71.
7. Turnbull and A. J. Griffiths, Corr. Eng. Sci. Technol., 2003, 38, 21-50

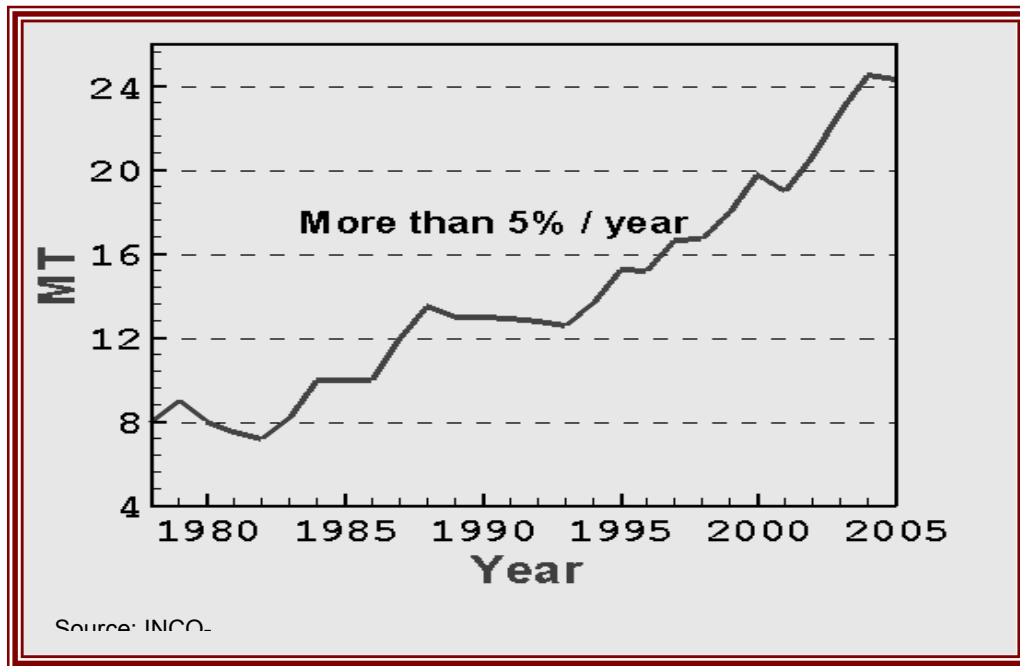


Figure 1

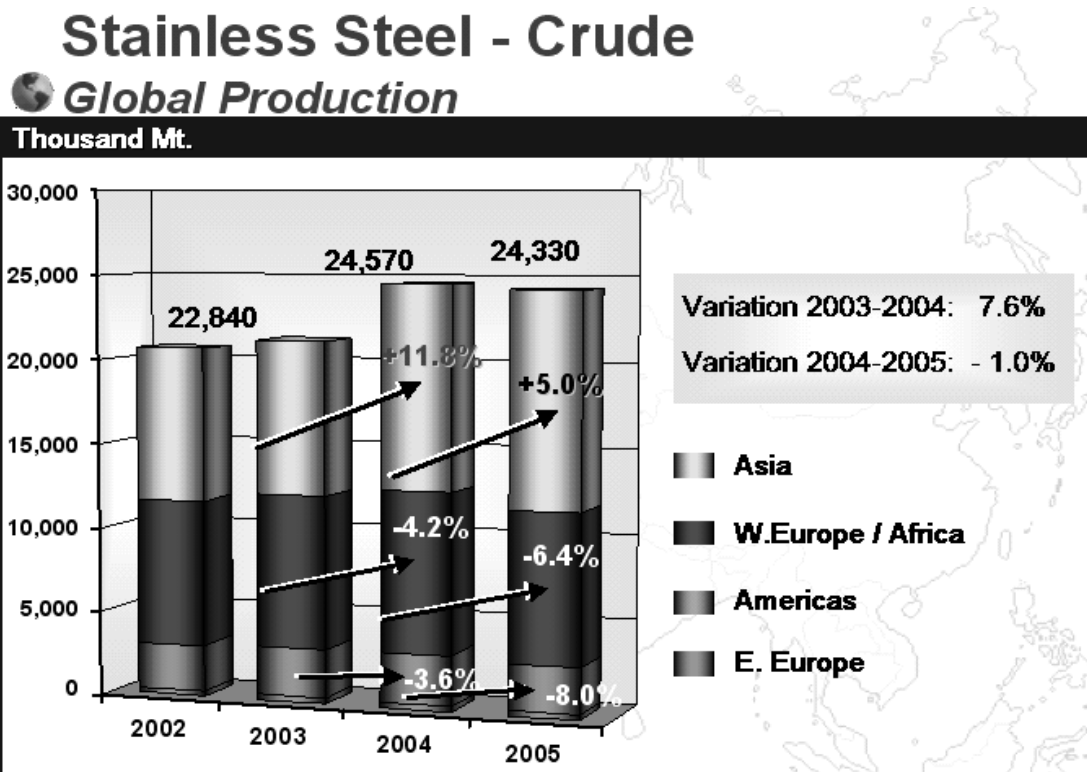
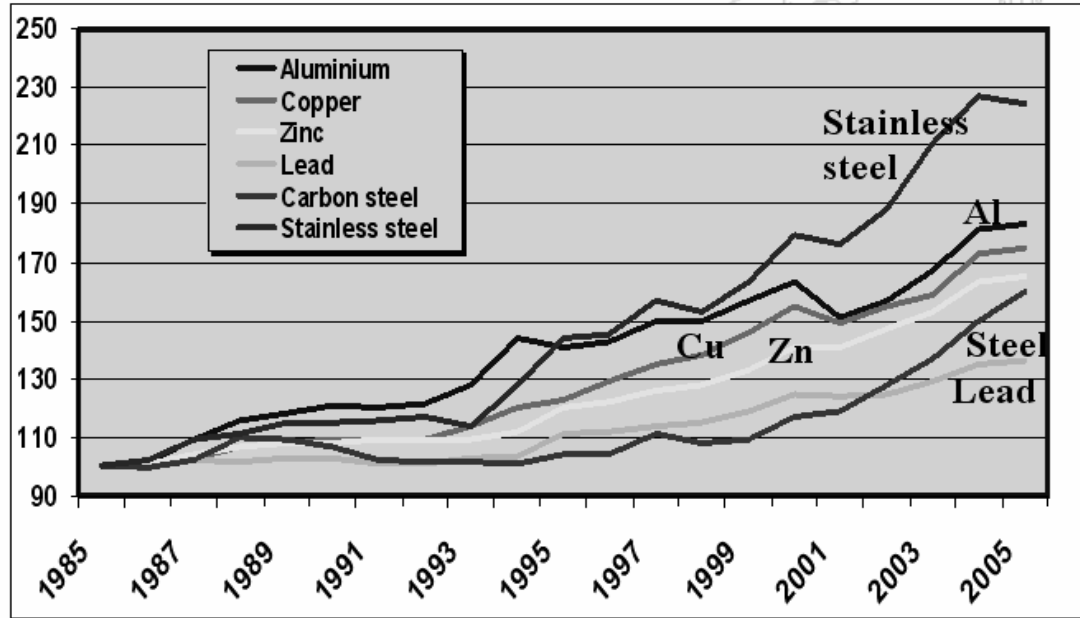


Figure 2

Stainless Steel - fastest Growing Metal By Demand



Index of Annual Growth in Metals Consumption, 1985=100

Source: CRU

Figure 3

Stainless Steel Production

More recent: even stronger growth than plastics

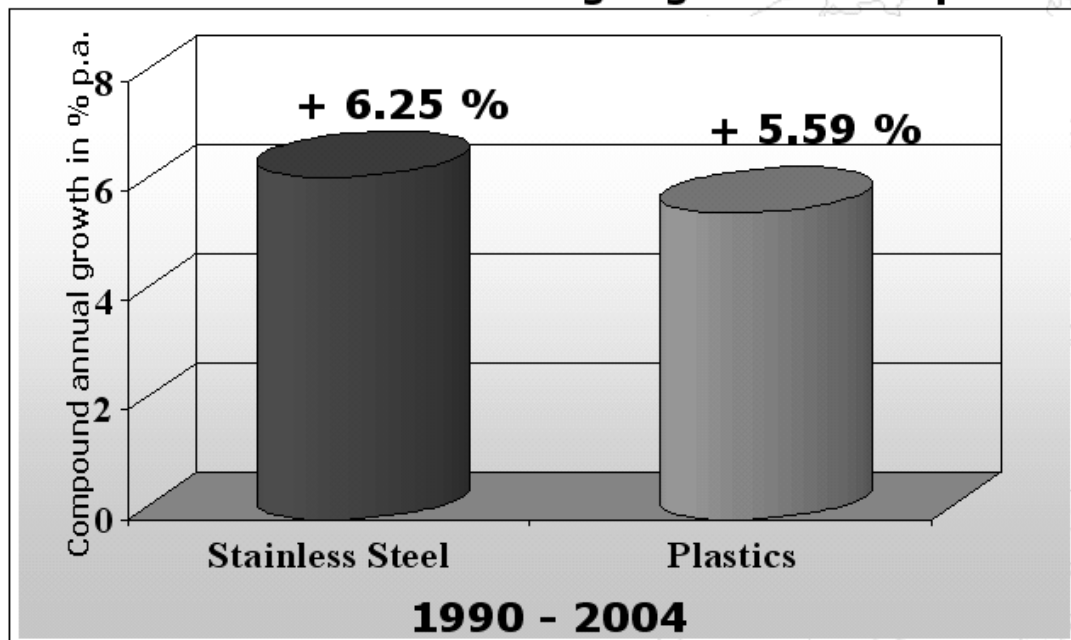
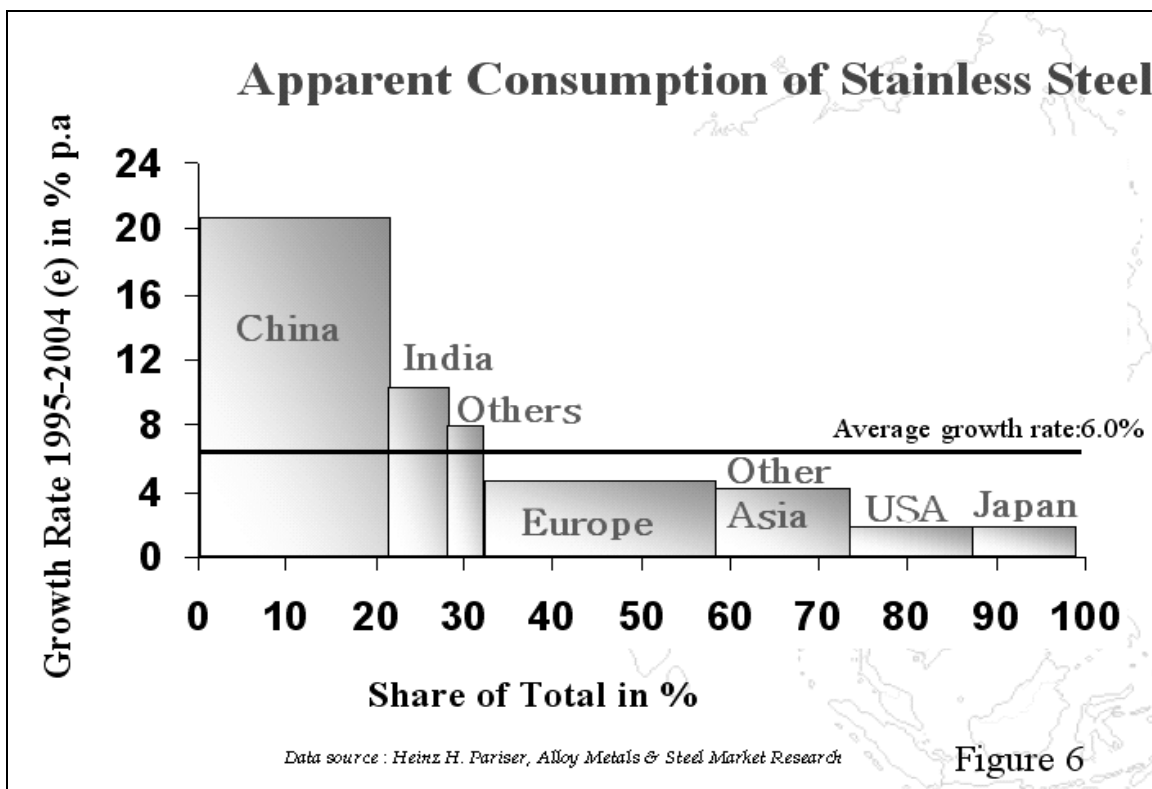
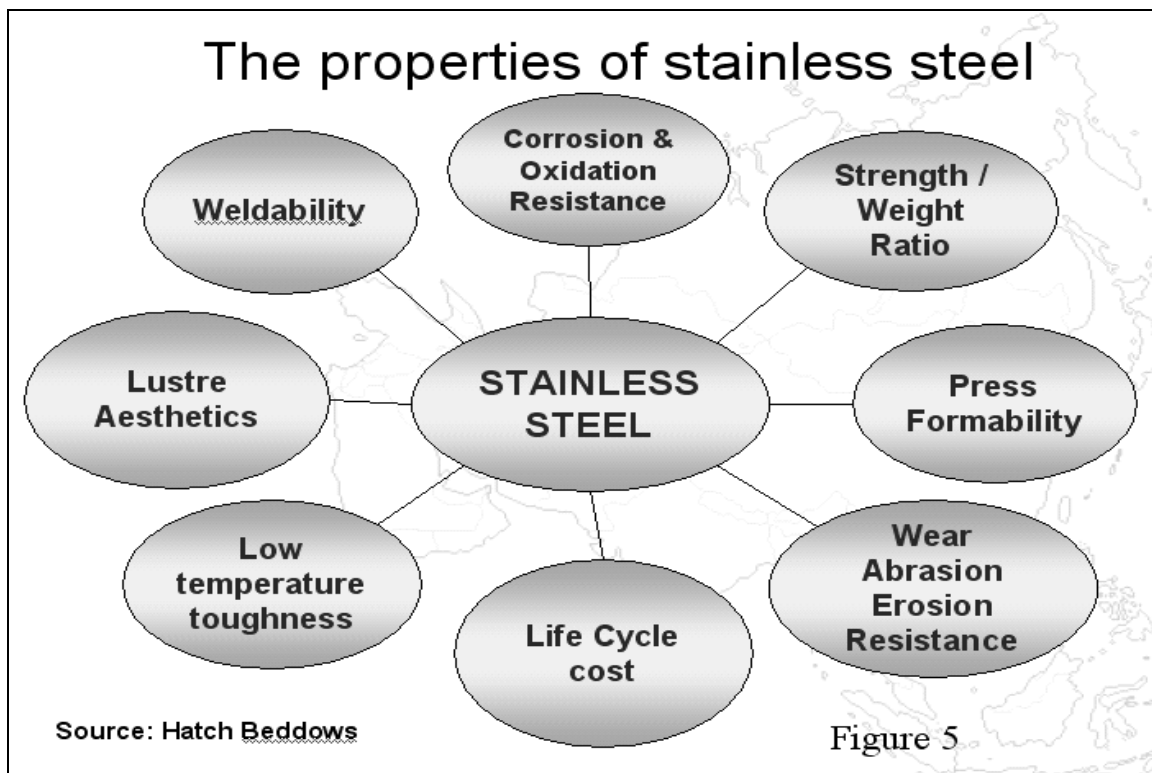
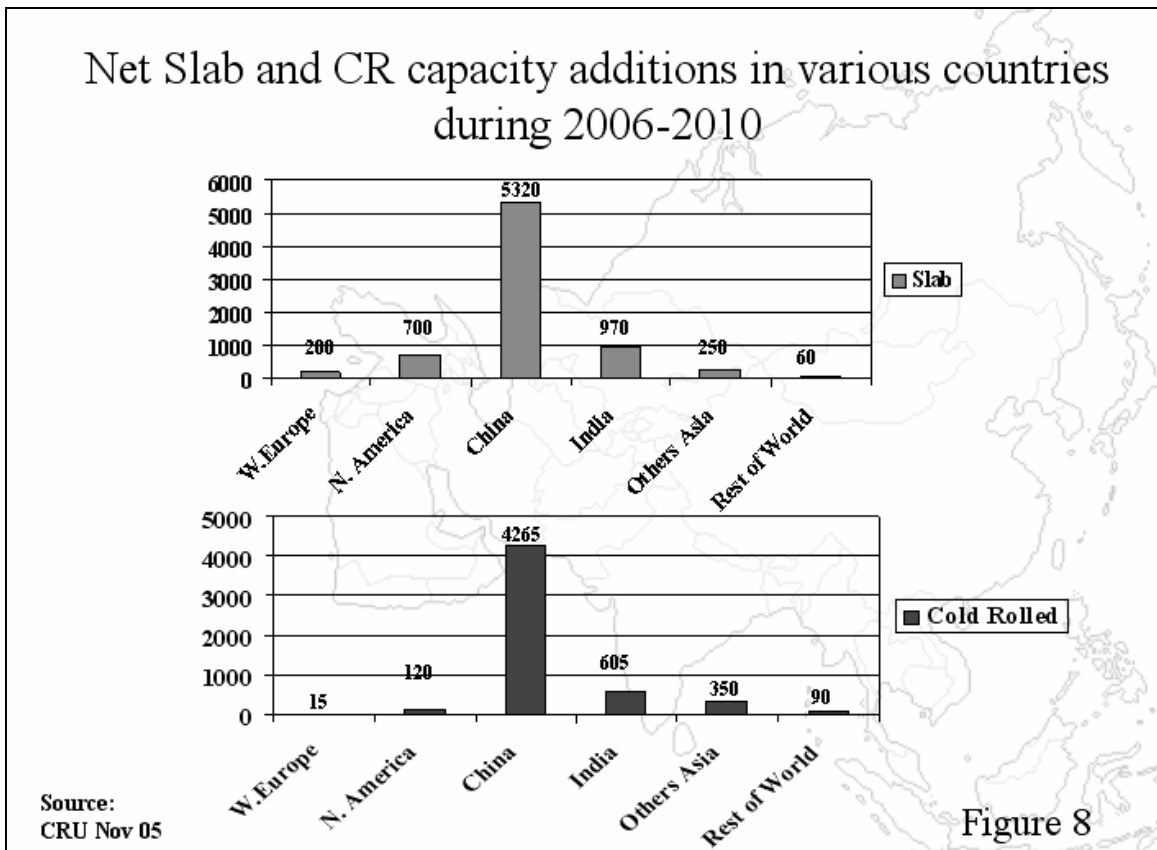
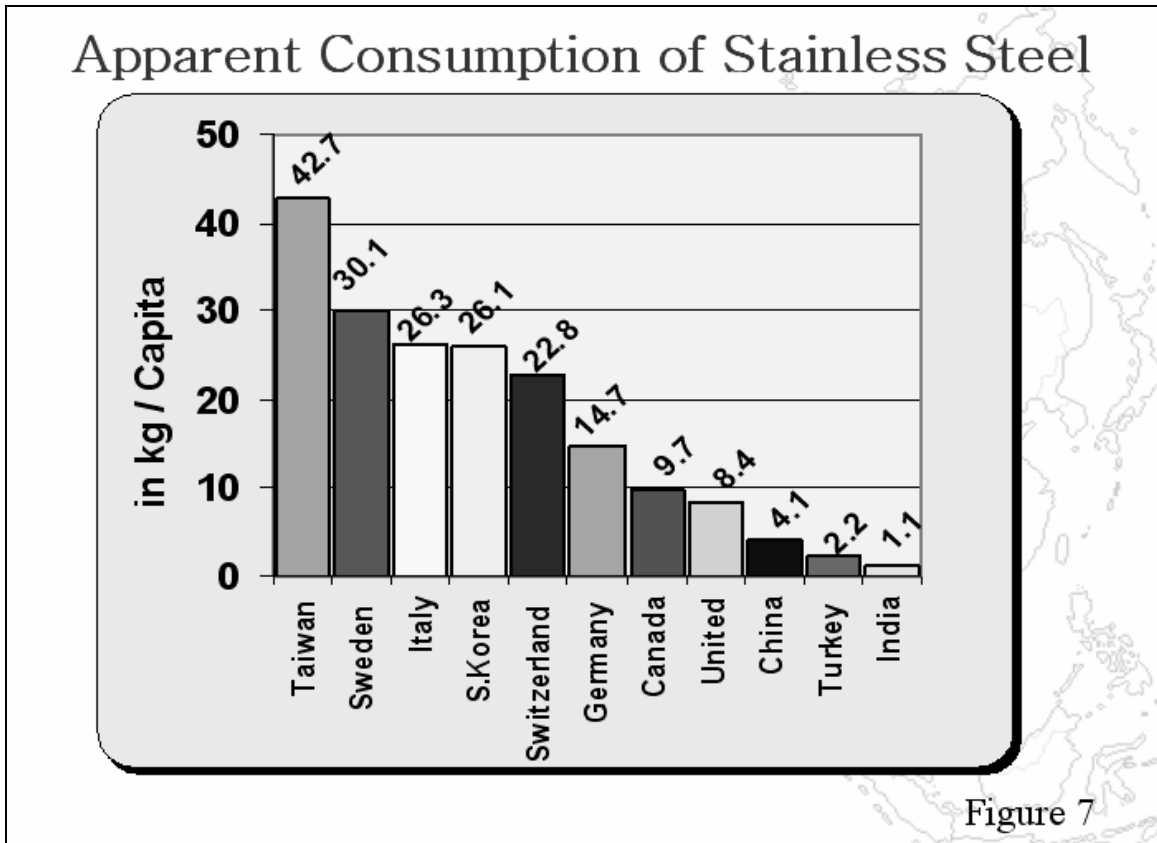
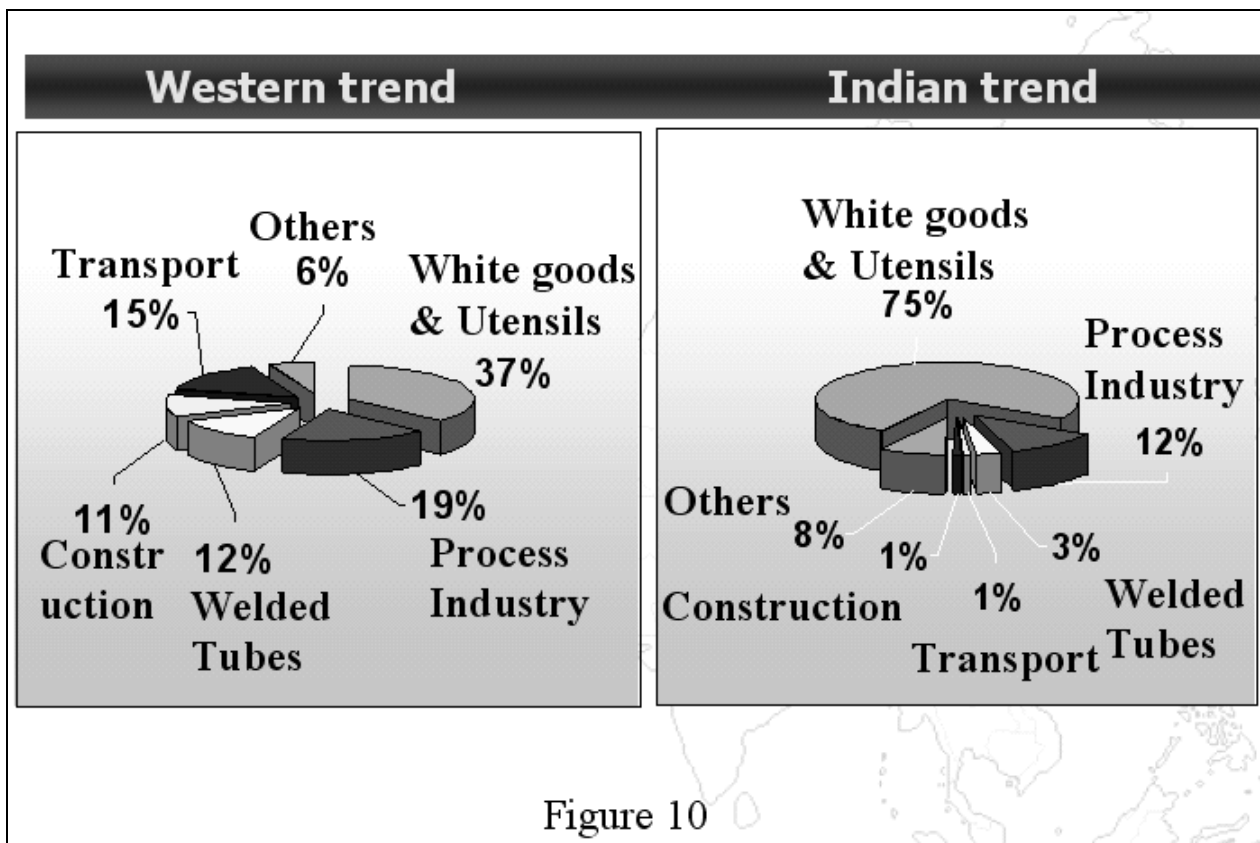
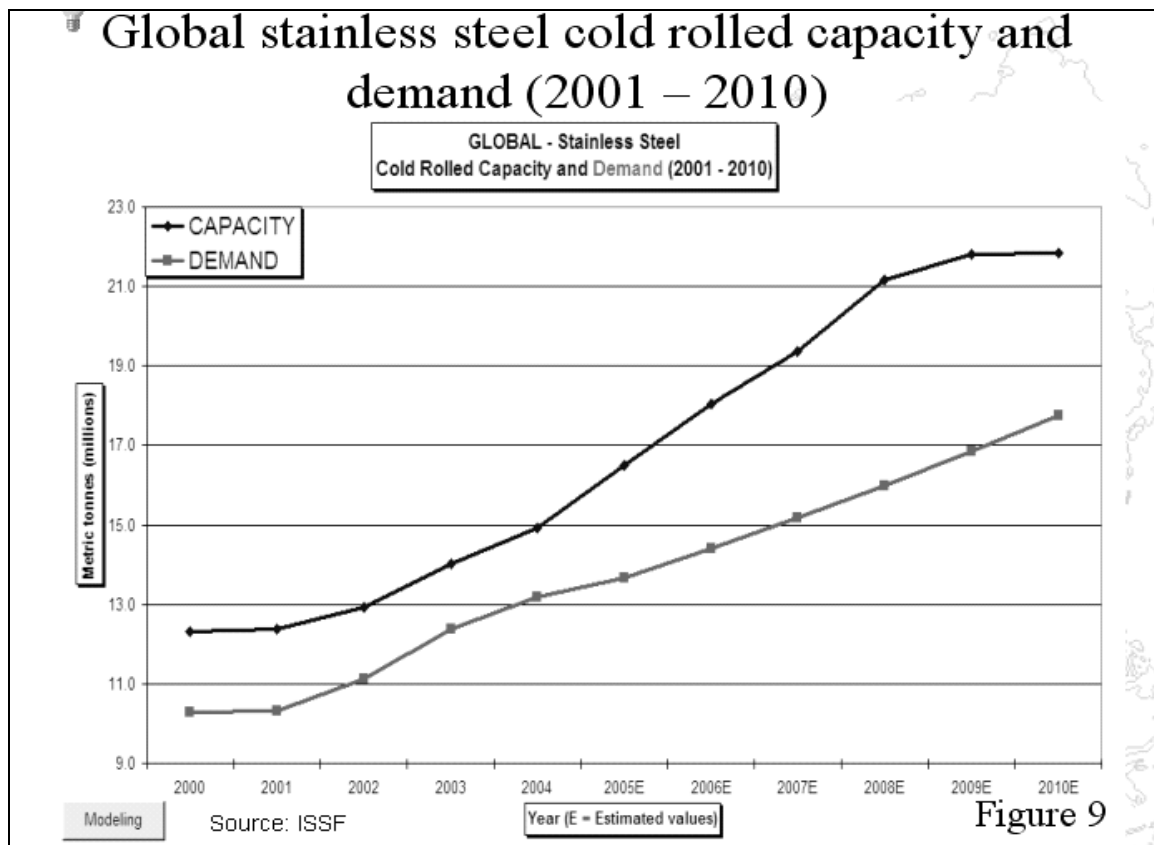
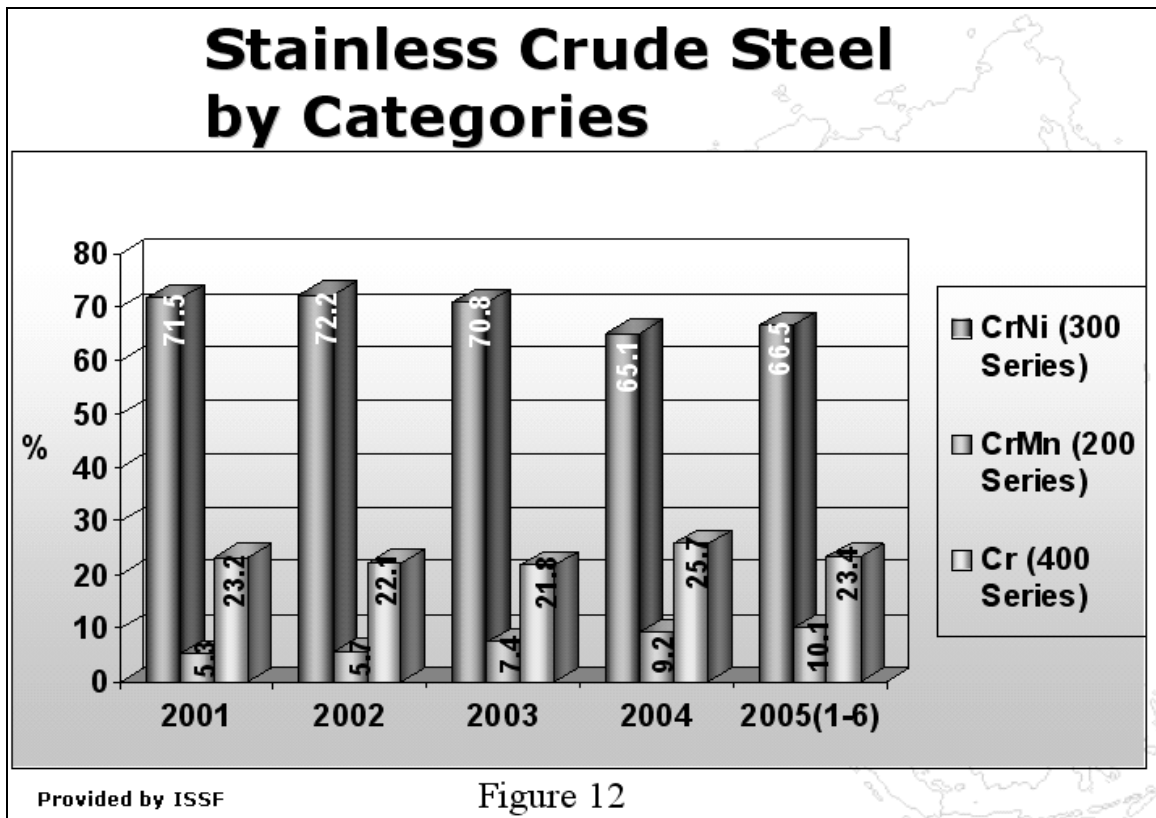
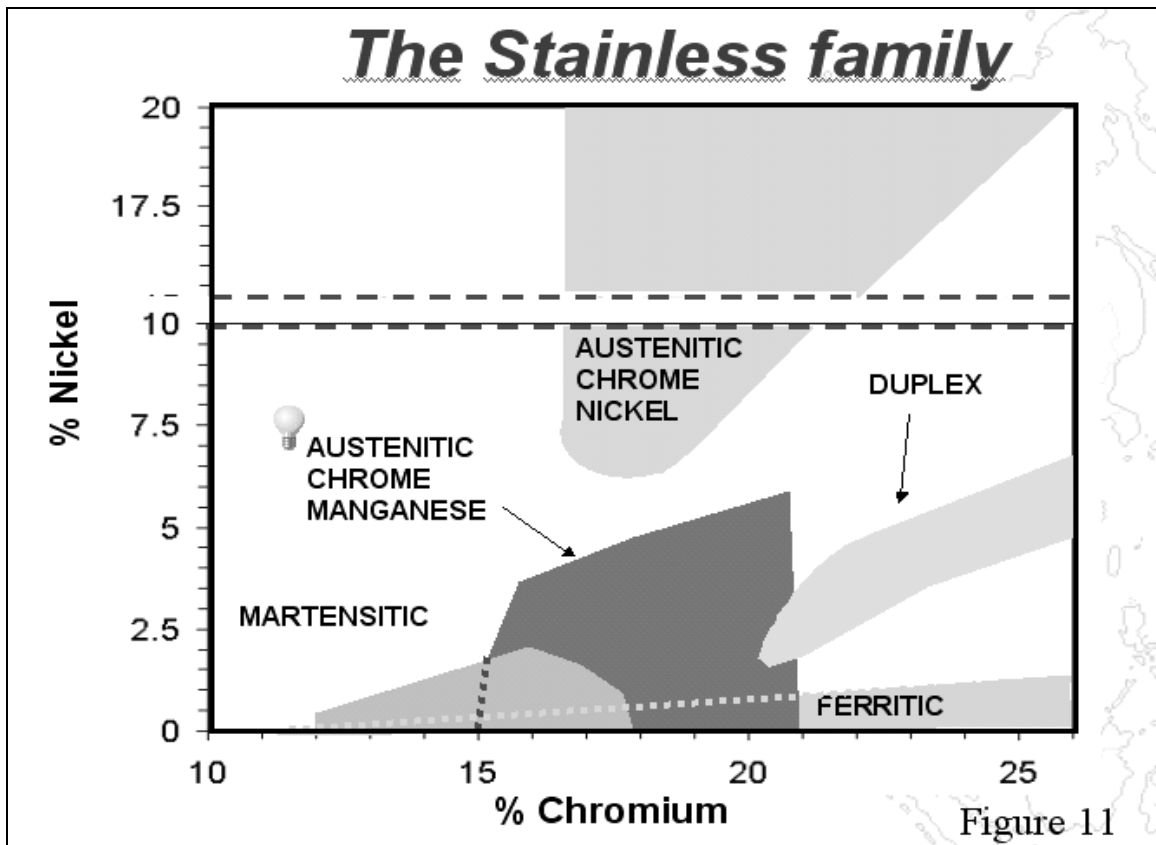


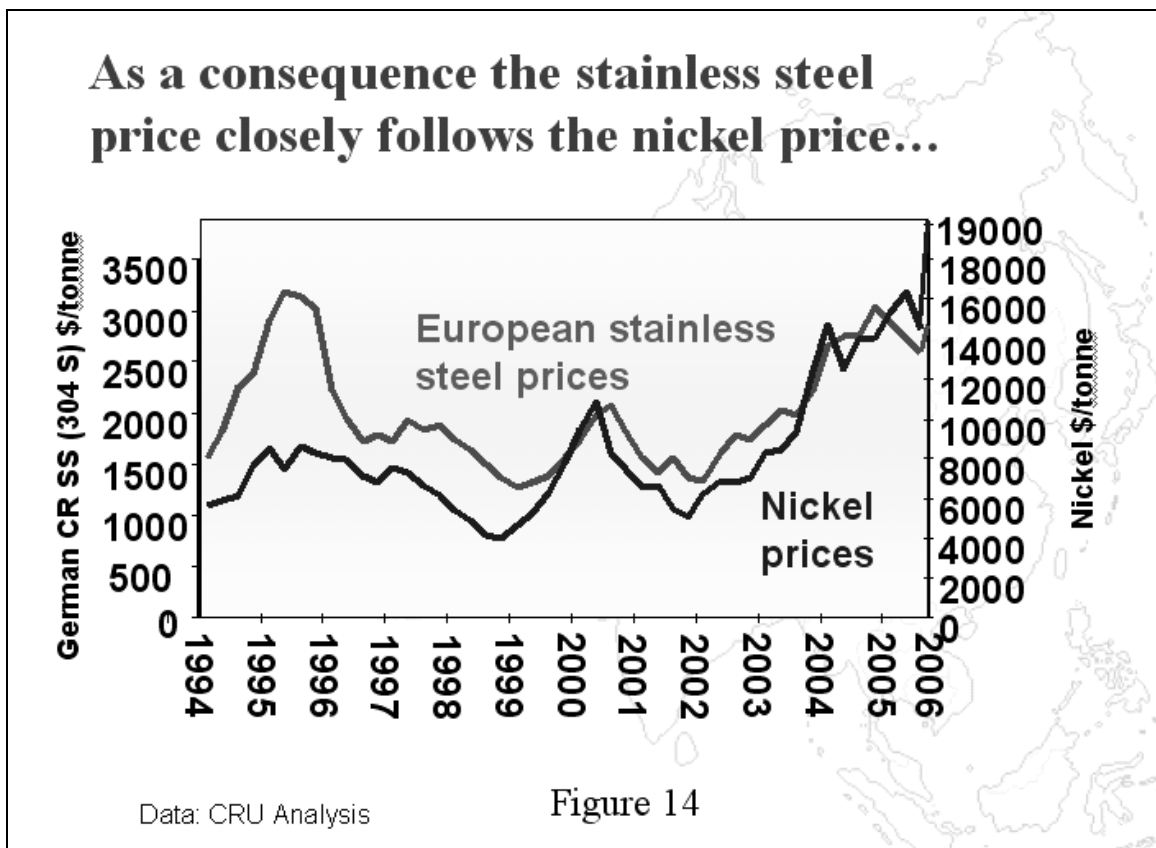
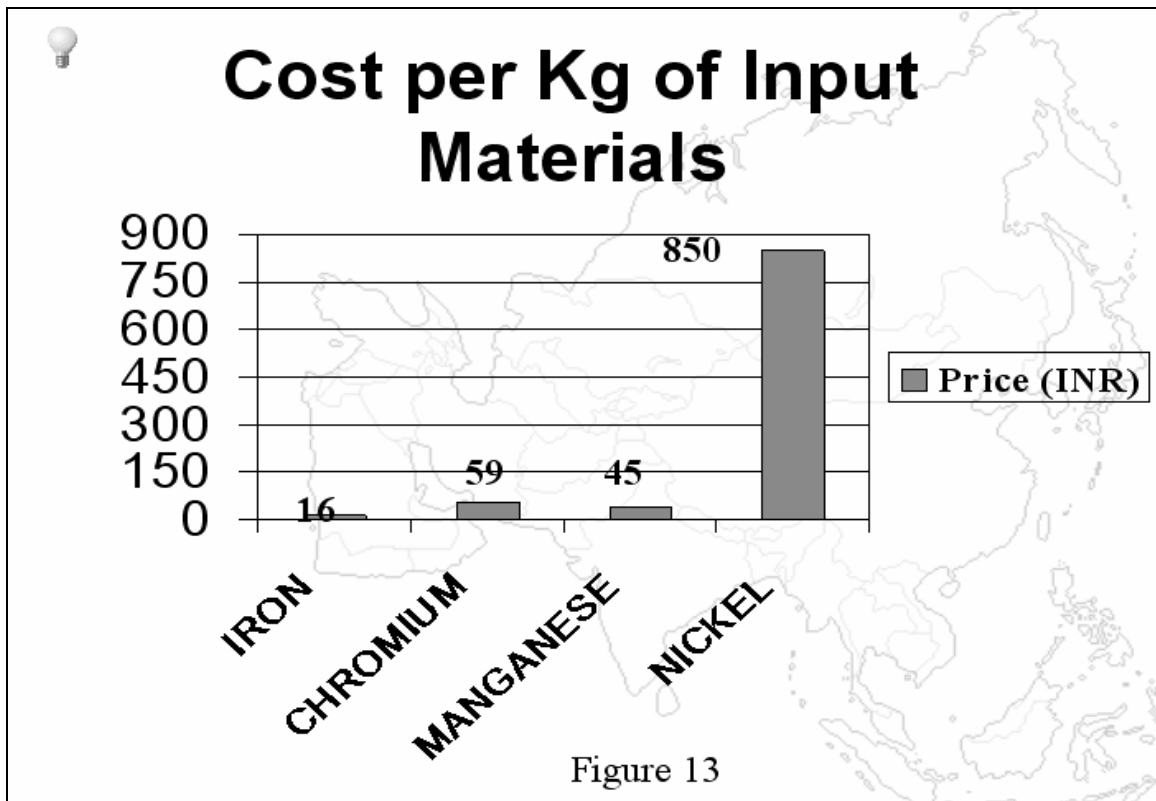
Figure 4

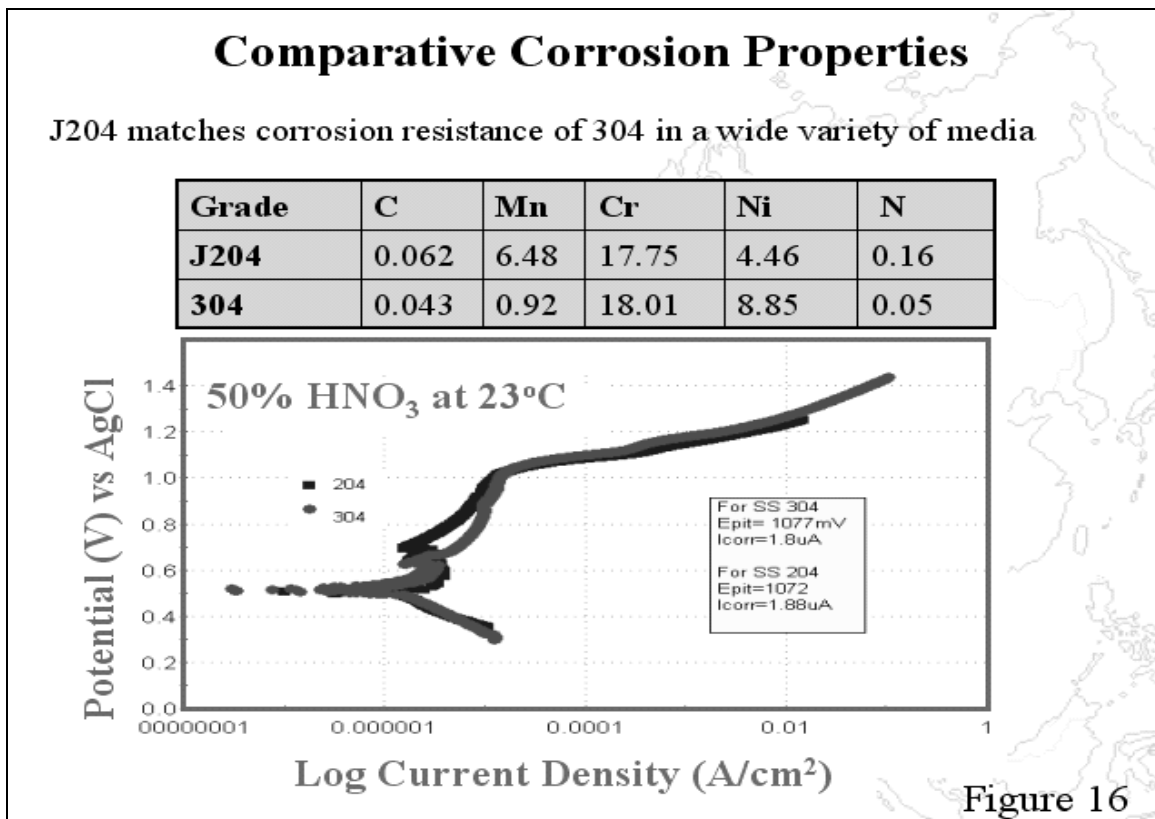
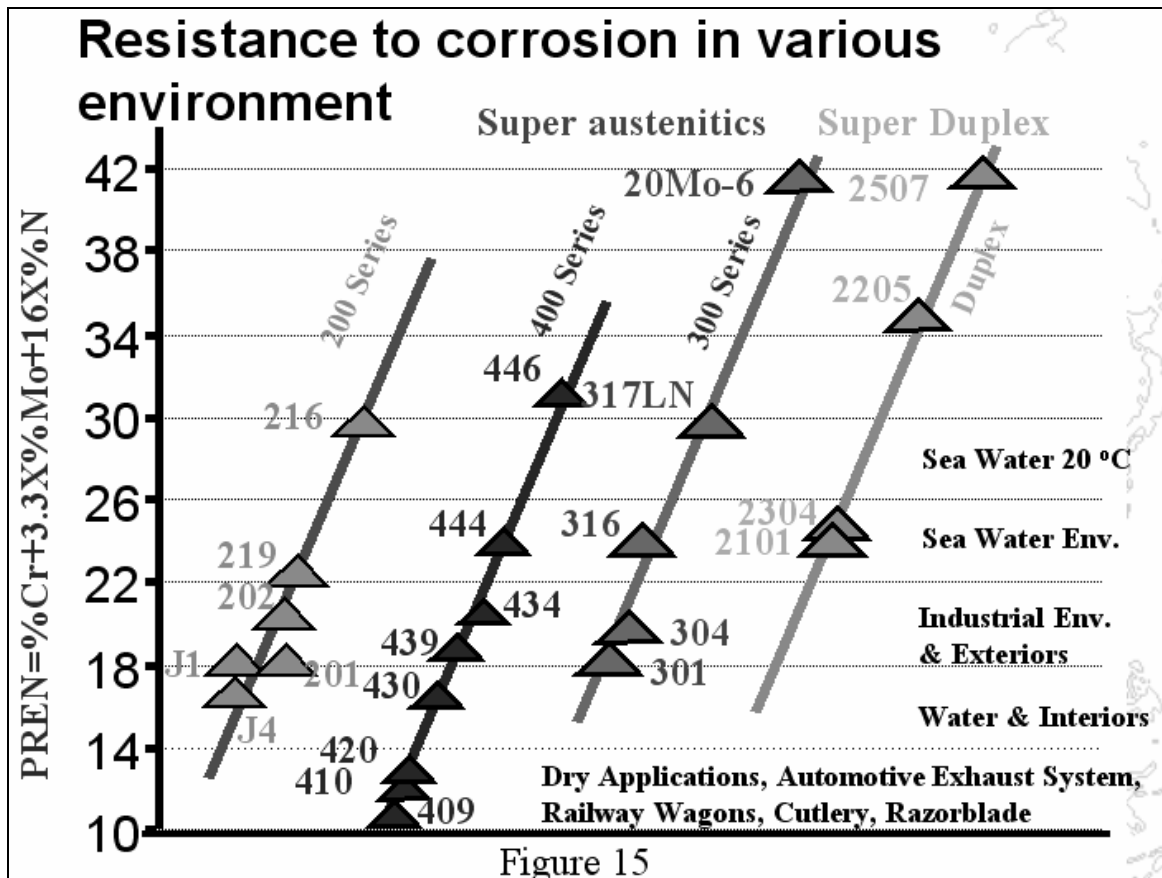












Comparative Corrosion Properties

J204 matches corrosion resistance of 304 in a wide variety of media

Grade	C	Mn	Cr	Ni	N
J204	0.062	6.48	17.75	4.46	0.16
304	0.043	0.92	18.01	8.85	0.05

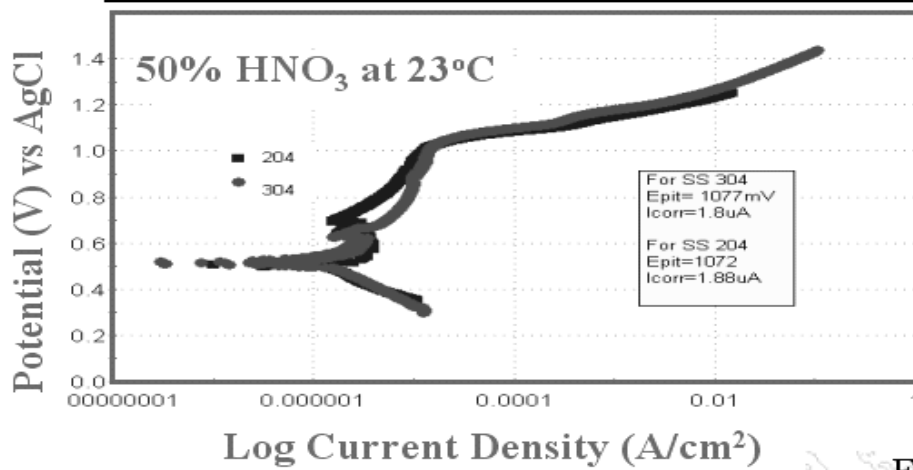


Figure 16

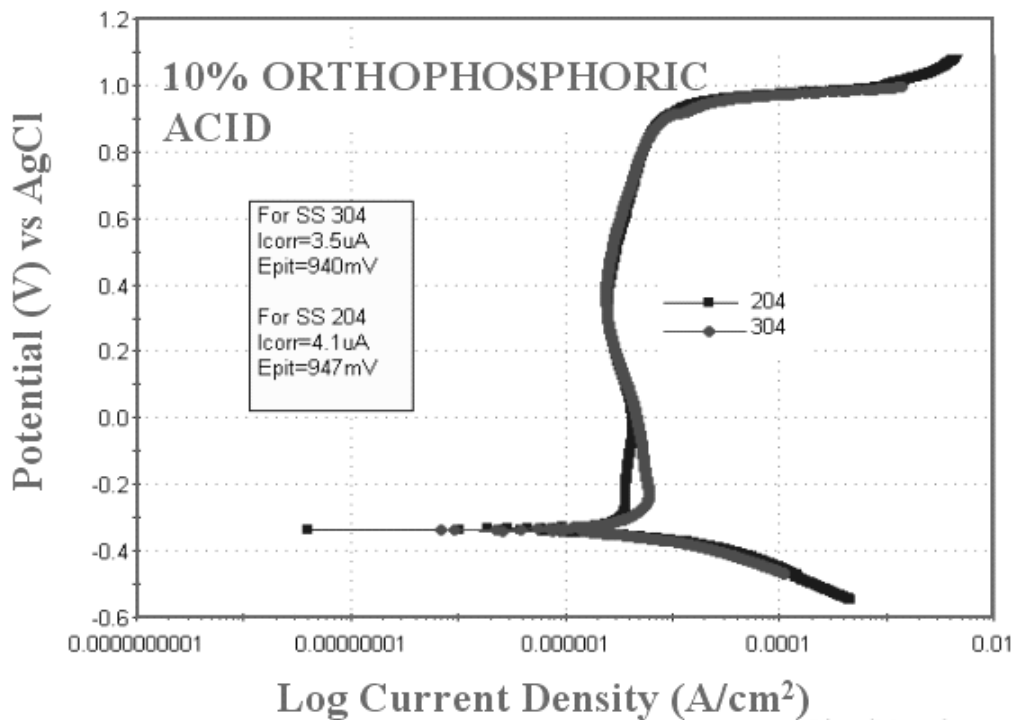


Figure 17

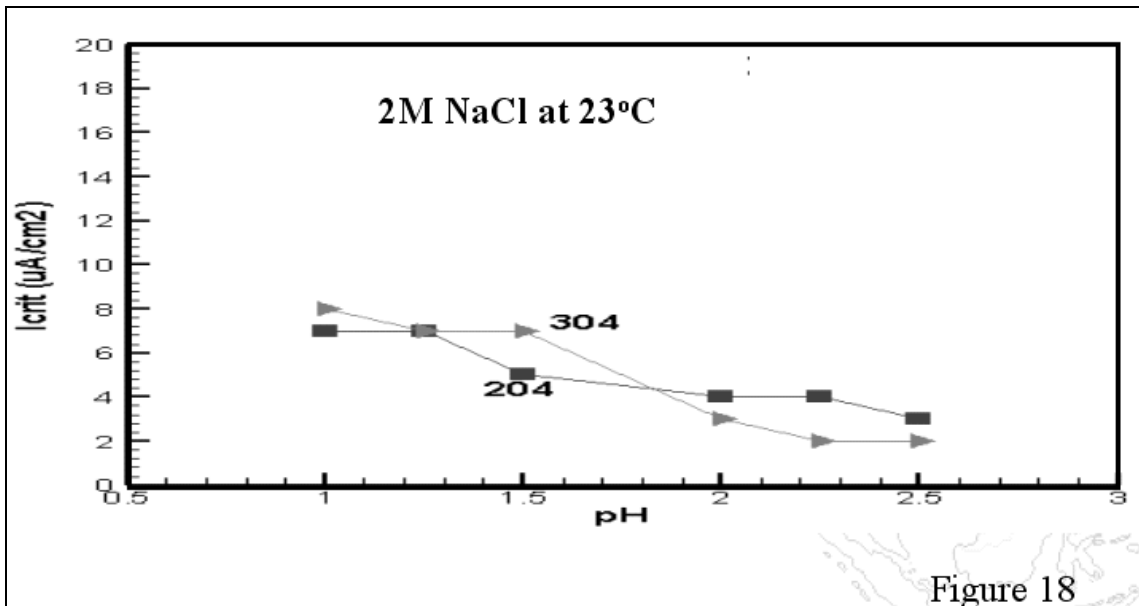


Figure 18

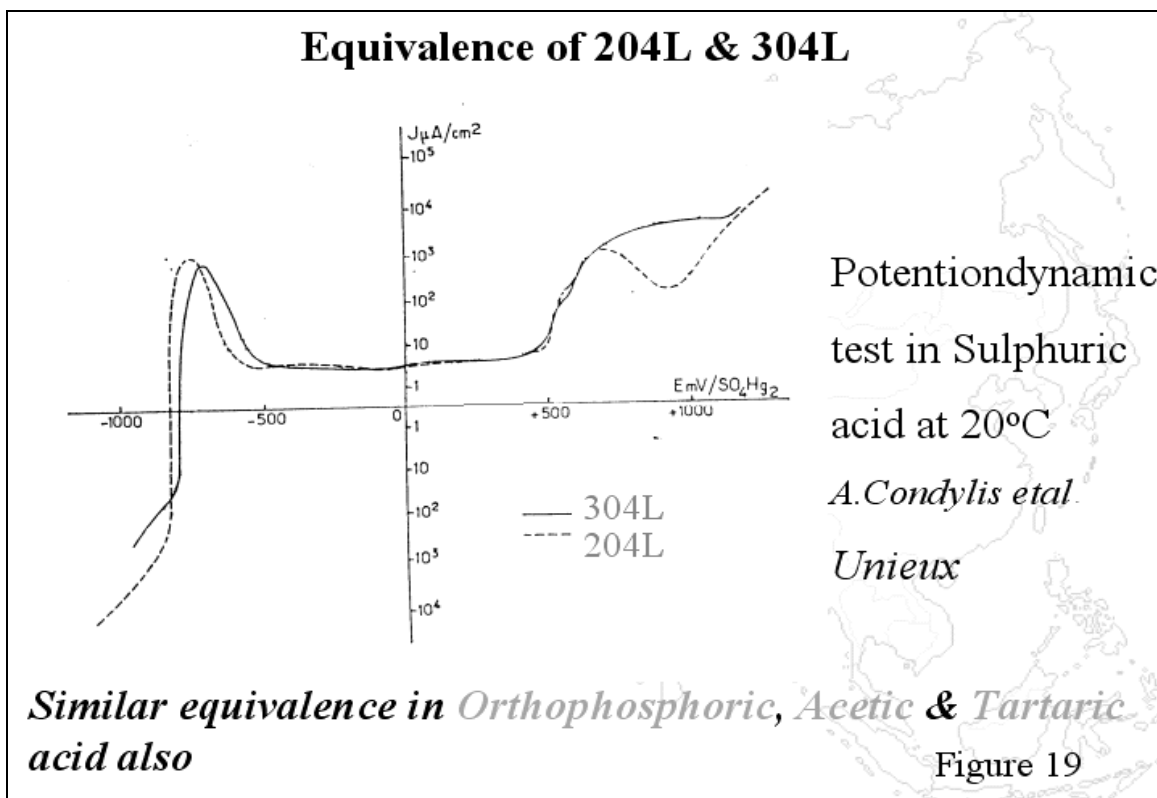


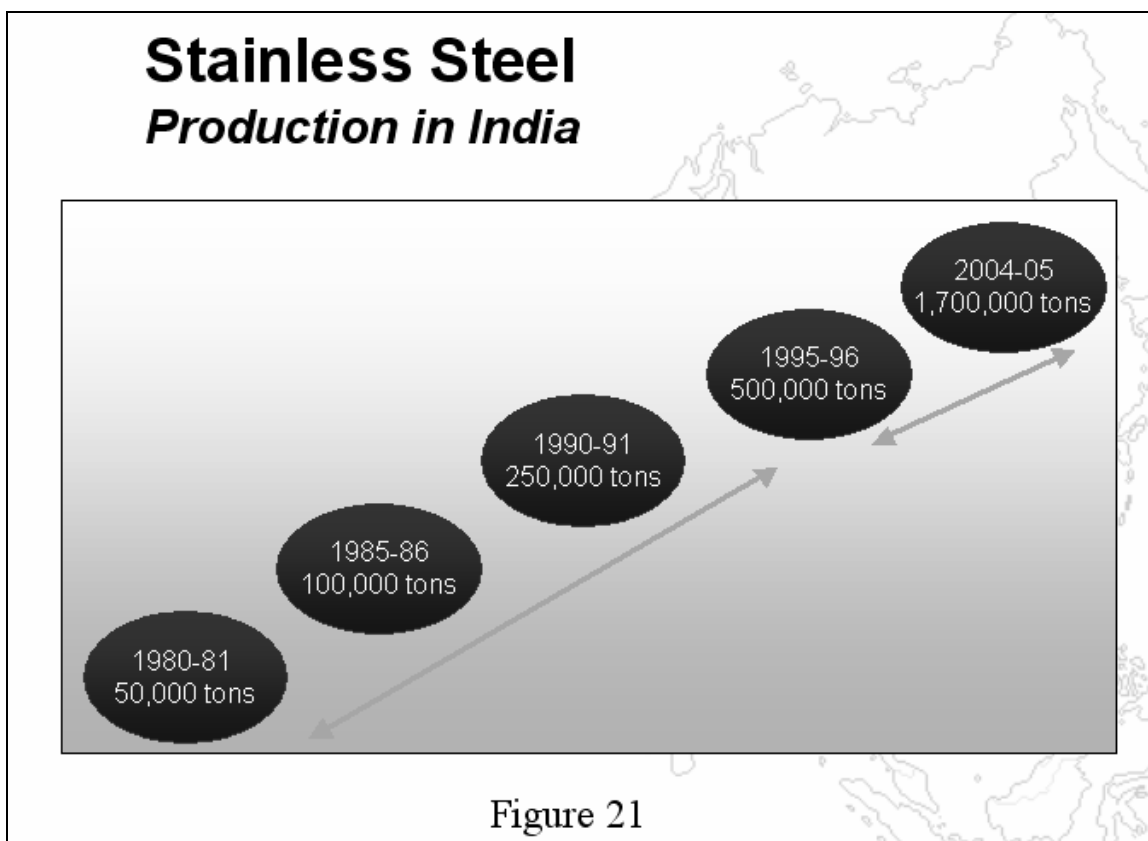
Figure 19

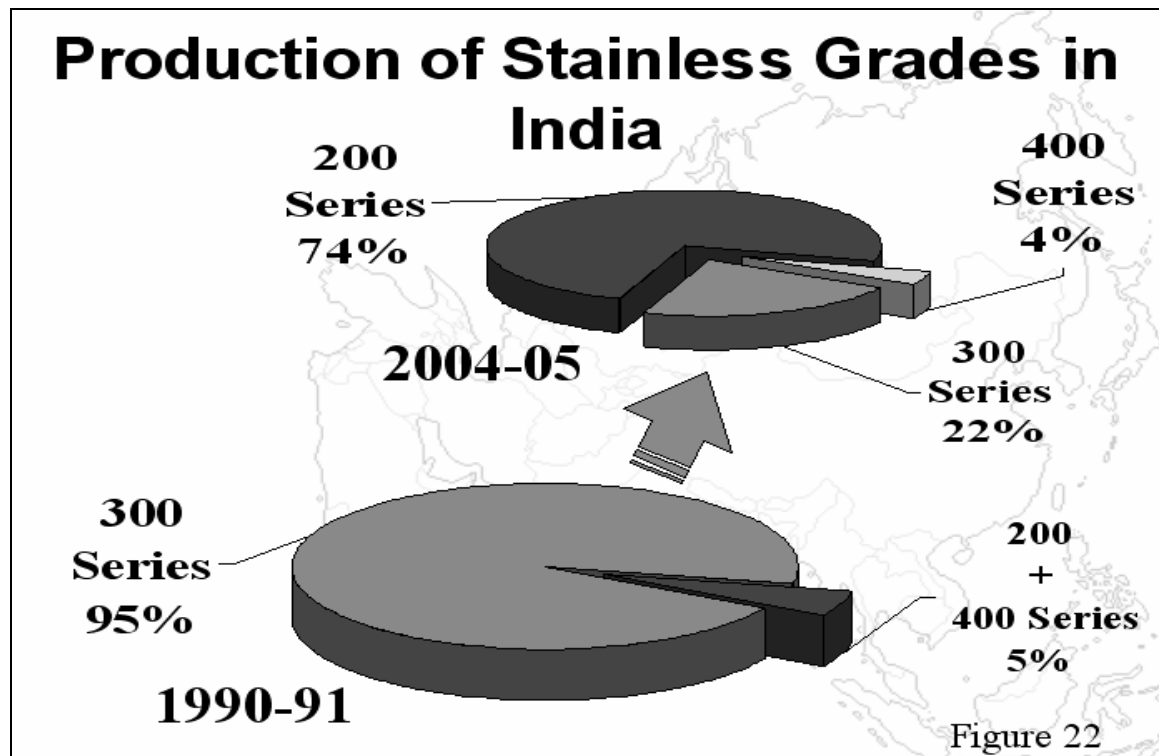
Equivalence of 216L & 316L in hydrochloric acid
(5 period for 48 hrs, with renewal of acids)

Temp. (°C)	Concentration	Grade	Welded Non-welded	Nature of electrode	Average loss (mg/dm ² /24 h)
20	10	216 L (with copper)	Non welded	-	48
			Welded	316 L	36
		316 L	Non welded	-	52
			Welded	316 L	67

Similar equivalence in Sulphuric, Nitric & Phosphoric acid also

Figure 20





Growth Potential for Stainless Steel in India

- ARCHITECTURE, BUILDING & CONSTRUCTION
 - HOTELS & HOSPITALS
 - FAST FOOD CHAINS
 - ENTERTAINMENT PLAZAS
 - SHOPPING MALLS
 - AIRPORTS
 - RAILWAY STATIONS
 - FUEL RETAIL OUTLETS
 - AUTOMOTIVE, RAILWAYS & TRANSPORT
 - CARS, MOTORCYCLES, SCOOTERS
 - METRO COACHES
 - RAIL COACHES
 - COAL WAGONS
- Fig 23

