IMOA®

INTERNATIONAL MOLYBDENUM ASSOCIATION

NEWSLETTER

JULY 2004

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The company produces molybdenum oxide from the recycling of spent hydro-treating catalyst and for use by an affiliate to manufacture new hydro-treating catalyst.

IMOA Website

As presaged in the last issue, the IMOA website has been re-designed and is much easier to navigate.

Improvements and updates will be introduced at regular intervals.

Now included is a computer programme for stainless steel selection, based in the IMOA brochure "Which Stainless Steel Should Be Specified for Exterior Applications?"

Annual General Meeting 2004

The Association's 16th AGM will be held in the Hilton Hotel, Düsseldorf from 5-8 September, kindly hosted by Metherma and FW Hempel Metallurgical.

Papers and speakers include:

- HSE issues, including REACH.
- "The Wind of Change in the Global Steel Industry", Professor Dieter Ameling, Chairman of the German Steel Institute and President of the German Steel Federation.
- "Why and Where – Moly in Steels", Dr Ing Jacques Charles, Innovation Vice-President, Arcelor Stainless Steels.
- "Molybdenum Market Update", Mr Terry Adams, Managing Director of Adams Metals Ltd.
- "Chemical Applications of Molybdenum", Dr Philip Mitchell, Professor of Chemistry at the University of Reading.
- Ms Clare Hammond, Advisor China Affairs at HSBC, on economic issues in China.
- "Substitution Trends in the Stainless Steel Industry – What is in there for Moly", Dkfm. Ing. Marcus Moll, Managing Director of Steel & Metals Market Research (SMR).
- IMOA's Market Development Programme, Dr Nicole Kinsman, Technical Director of IMOA.

Moly Does the Job

During a visit to Japan last year, the Technical Director of IMOA, Nicole Kinsman, was shown some very good examples of the use of 6% molybdenum stainless steel in Soy Sauce and Mirin production, in hot spring water storage and for offshore structures. She therefore invited one of her hosts, Dr Koichiro Osozawa who is a Consultant to Yakin Kawasaki Co Ltd (part of the Nippon Yakin Group) to adapt an example for a "Moly Does the Job" article in the Newsletter.

This series of articles uses cases where a non- or lower molybdenum stainless steel (or other material) has been used in the past but has failed or was too costly to maintain, and where a moly-containing stainless steel or nickel base alloy has helped reduce cost.

Dr Osozawa has kindly written the article which follows, specially for this Newsletter.

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"Table Salt Manufacturing Plants"

Author: Dr Koichiro Osozawa, Consultant to Yakin Kawasaki Co Ltd

SUMMARY

Table salt manufacturing plants in Japan use several kinds of materials, depending on the environment encountered in the process.
The conventional evaporation vessels, lined with Type 316L stainless steel suffered from pitting corrosion and stress corrosion cracking and required frequent repair work. As a result of laboratory and field corrosion tests a high molybdenum austenitic stainless steel was selected as a liner for the evaporator, the piping and the concentrated storage tank. No corrosion troubles were encountered for seven years.

THE PROCESS

Table salt is manufactured today mainly by the following process:

Sea water (3.5% salt) -
Sand filter -
Electro-dialyzer -
Brine (18% salt) -
Vacuum evaporator -
Slurry - Centrifuge
Product.

The most corrosive conditions are encountered in the evaporating process, which consists of several stages with different temperatures and pressures. The temperature ranges from 30 to 125°C. The concentration of the chloride ion increases to over 20%.

THE CORROSION

Some stages of conventional evaporation vessels were made of mild steel lined with Type 316L stainless steel. They were connected with Type 316 stainless steel piping. In the evaporation process the conditions in the vessel are very corrosive. Magnesium and calcium chlorides in the solution are highly concentrated and at an elevated temperature.

The 316L lining and the 316 piping suffered from pitting corrosion and transgranular stress corrosion cracking within two years.
Weld repair work introduced further stresses and therefore even more stress corrosion cracking in a short time.

Figure 1:

The concentrated salt storage tank in a table salt production facility is fabricated from SUS836L.
(Photo: Nippon Yakin Kogyo Co. Ltd.)

THE SOLUTION

Laboratory tests on spot welded specimens of three kinds of stainless steel were conducted in a simulated chloride solution at 70°C for 1000hr. The test results are shown in *Table 1*.

A field test using the super austenitic stainless steel SUS836L and a duplex stainless steel SUS329J4L (UNS S32506-25Cr-6Ni-3Mo-0.12N), showed that the super austenitic stainless steel performed well, but that the welded part of the duplex stainless steel showed some pitting and stress corrosion cracking.

As a result of these tests the super austenitic grade was selected as an appropriate material for the process operating at lower temperatures (below 100°C). The inside of the vessel was lined with SUS836L plates using a high-molybdenum, nickel-base welding rod (Hastelloy C-276) and all Type 316 stainless steel piping was replaced with SUS836L. The concentrated salt storage tank (slurry tank) was constructed with the same grade of stainless steel. Titanium or Hastelloy C-276 was applied for the process at higher temperatures. There have been no corrosion problems since the installation seven years ago.

THE COST SAVINGS

Although the initial cost of the material is higher than before, no repair is needed and the equipment can be operated with higher reliability. Furthermore, the quality of the salt product was improved since there is no contamination from the rust of the equipment. The success of this plant convinced other salt manufacturers and high molybdenum austenitic stainless steel is now also being installed and used in other plants.

Table 1: Laboratory stress corrosion cracking test results and chemical compositions of tested stainless steels

Steel type	Composition (weight %)				Test result*	
	Ni	Cr	Mo	N	Vapor phase	Liquid phase
SUS304 (UNS S30400, EN 1.4301)	8.6	18.1	-	-	TGSCC	TGSCC
SUS316L (UNS S31603, EN 1.4404)	12.1	17.5	2.0	-	TGSCC	TGSCC
SUS836L (NAS254N) (UNS S32053)	24.9	23.1	5.4	0.17	No corrosion	No corrosion

*TGSCC= transgranular stress corrosion cracking

IMOA's Market Development Programme

The Association continues to focus on architecture, building and construction (ABC) and on drinking water piping as the principal targets for increasing the usage of moly-containing stainless steels.

On the ABC front, three new case studies deal with the problems faced by installations which have to cope with moderate to high urban pollution and coastal salt exposure. A brief description of the locations begins with the first study, entitled "Singapore Stainless Steel Roofing"

The Singapore Turf Club, Kranji, Singapore, was completed in August 1999. Molybdenum-containing Type 316 (UNS S31600, EN 1.4401, SUS 316) stainless steel was used for the unique roof, entrance canopies, and walkway covers. The curved, 400-meter (1,312 ft) long grandstand roof design was inspired by the graceful and powerful image of a horse in motion *(Figure 1).*

The design architect was Ewing Cole, a Philadelphia firm specialising in racecourse design. The architect of record was Indeco, a Singapore firm. Chadwick Technology of Sydney was the roofing contractor. Singapore's high temperatures and humidity levels make the environment even more corrosive. John Chase of Ewing Cole said, "we did not think twice about using stainless steel, because it is a corrosive, tropical island environment. Stainless steel roofing is widely used in Singapore for that reason." Type 316 contains 2% molybdenum, which improves the pitting and crevice corrosion resistance of stainless steel. Molybdenum is particularly helpful in preventing salt and pollution corrosion.

A 2D finish was selected for the roof. This finish is dull enough to prevent unwanted glare and smooth enough to provide added corrosion protection.

Figure (1): This photo shows the unique roof design and the corrosion-free performance of the Type 316 stainless steel.
(Courtesy of Ewing Cole,)
Photographer: Erhard Pfeiffer

The standing seam roof on the curved grandstand building appears complex, but it is actually a simple, cost-effective design. Each 6 meter (20 ft) wide undulating section is a gabled roof made from identical 3 meter (10 ft) long standing seam panels. The gabled sections gradually rise along their length until they reach the top of the grandstand. There are maintenance walkways that double as gutters between the roof sections.

The second study is entitled "Hong Kong Building Exteriors and Railings"

Hong Kong's 63-story Cheung Kong Centre was completed in 1999. The exterior is glass and Type 316 (UNS S31600, EN 1.4401, SUS 316) stainless steel *(Figures 2 and 3)*. The building is less than 1.6 km (1 mile) but more than 30 m (100 ft) from the harbour. It is exposed to the sea salt in the air and rain, but not salt spray. Both a coined HyClad Cambric and a fine No 4 finish were used on the exterior. Rain and regular maintenance cleaning remove the corrosive contaminants and dirt from these smooth finishes. Cheung Kong Centre was designed collaboratively by the architect firms Cesar Pelli, Leo A Daly, and Hsin-Yieh and has retained its original attractive appearance.

Figures (2) and *(3)*: Cheung Kong Centre is the high-rise building in the foreground of *Figure 2*. The entrance and other details are visible in *Figure 3*. Type 316 with smooth surface finishes was an excellent choice because it is exposed to pollution and coastal salt. Window washing tracks were built into the building for easy cleaning. As shown in *Figure 2*, it is in close proximity to the harbour.
(Photos courtesy of Outokumpu)

The Hong Kong Convention Centre addition was completed in 1997. It is on the man-made peninsula in the harbour shown in *Figure 2*. The Convention Centre is surrounded by a landscaped park with a Type 316 stainless steel railing along the perimeter. The railing is subjected to seawater spray and occasional splashing. In addition, the salt aerosol levels in the air are high. Type 316 will experience corrosion staining when exposed to sea spray unless a smooth finish is specified and it is washed frequently.

The third study is entitled "Canary Island Railings and Lamp posts" The beautiful Canary Islands are a popular vacation destination because of their clean air and warm climate. Maintaining railings and other equipment in public areas can be challenging, because coastal salt (chloride) exposure will corrode most architectural metals, including some stainless steels.

In the 1980s the government began replacing galvanised carbon steel railings and lamp-posts with stainless steel to reduce long-term municipal costs. Two stainless steels were used, 2205 (S32205, EN 1.4462, SUS 329J3L) and Type 316 (UNS S31600, EN 1.4401, SUS 316) which both contain molybdenum.

Type 316 was initially used for both railings and lamp-post applications. Light corrosion staining appeared on the railings which were exposed to occasional salt spray or splashing.

This staining did not cause structural deterioration, but it was unsightly. Subsequent coastal railing installations were upgraded to 2205, which contains more molybdenum than Type 316. They have remained attractive *(Figure 4)*. The much higher strength of 2205 can be used to reduce structural section size, and this weight saving can offset the higher cost of the more corrosion resistant stainless steel.

Figure (4): These 2205 stainless steel railings are exposed to salt spray and occasional splashing. They are in the town of San Augustin in the Canary Islands. There has been no corrosion staining despite exposure to sea spray.
(Photo courtesy of Outokumpu)

Type 316 with a smooth finish is usually the most cost effective choice for low- or no-maintenance applications which are exposed to coastal air but not to seawater spray or splashing. The Type 316 railings and lamp-posts which are not exposed to sea spray have retained their attractive appearance.

If an architectural metal is susceptible to salt corrosion, regular maintenance is required to ensure long-term structural integrity and appearance. But public works maintenance budgets are usually limited. Carbon steel will corrode rapidly in coastal applications once the protective galvanising or paint coating is gone. Even with maintenance, replacement due to structural deterioration of carbon steel is sometimes needed in less than ten years. Although its corrosion is less visible, aluminium is also susceptible to rapid corrosion in coastal environments.

Selecting the right stainless steel for each application eliminates maintenance cleaning and painting, ensures long-term structural integrity, and avoids the high replacement and liability costs associated with metal failure due to corrosion.

Printed copies of all the Case Studies are available on request from IMOA's office or they may be downloaded from the website. Further case studies are in the course of preparation, with locations in Sao Paulo, Barcelona and an Australian city.

Workshops have been conducted by TMR Stainless (IMOA Consultants) in San Francisco, and are planned for later this year in New York and Miami.

These are all cities with large architectural communities located in marine environments. And a computer program for stainless steel selection, based on the "Which Stainless Steel Should be Specified for Exterior Applications" brochure has been developed and is available on the IMOA website.

Regarding piping for drinking-water, the appositely named "SPLASH" is a loosely-knit group of stainless steel producers, the Nickel Institute and IMOA which has small stands at industry exhibitions, gives presentations at conferences and works on specifications and standards. SPLASH will shortly be incorporated as a non-profit trade association in the USA and is developing its own website.

IMOA is examining several projects on which to co-operate with the US government and other organisations in the USA in relation to moly-containing stainless steel piping to carry drinking water.

Another area on which IMOA has begun to direct its attention is bridges. We have arranged to submit a number of abstracts of papers on stainless steel in bridges for the International Bridge Conference in Pittsburgh and IMOA consultant Frank Smith will write articles for bridge magazines, organise booths at important bridge conferences and create an IMOA page on the website www.stainless-rebar.com.

Frank Smith, who is based in Kingston, Ontario, introduces the subject to Newsletter readers in the article which follows.

Molybdenum-containing stainless steels extend the life of reinforced concrete bridges.

When it comes to building or repairing reinforced concrete bridges so that life-cycle costs are minimized, many authorities are specifying the use of stainless steel reinforcing bars (rebars) instead of the traditional carbon steel rebars.

Stainless steels containing two to three percent molybdenum (Mo) are the alloys of choice when "stainless rebar" is specified. The most commonly specified alloys are shown in *Table (1)*.

These stainless steels can provide improved long-term corrosion resistance when concrete is exposed to chloride-containing environments, e.g., road salts and sea water. They have been used as rebar in highway bridges, ramps and barrier walls, parking garages, sea walls and marine facilities, building foundations and restorations, and tunnels. An example of the installation of molybdenum containing stainless steel rebar is shown in *Figure (1)*. The US Federal Highway Administration (FHWA) organized extensive corrosion testing to find rebar materials that could extend the lifetime of reinforced concrete bridges to 75-100 years, when the concrete was contaminated with

Grade	UNS No	EN No	Type	Cr	Ni	Mo	N	C (max.)
Type 316	S31600	1.4401	Austenitic	17	12	2.5		0.08
Type 316L	S31603	1.4404	Austenitic	17	12	2.5		0.03
Type 316LN	S31653	1.4406	Austenitic	17	12	2.5	0.13	0.03
Alloy 2205	S31803	1.4462	Duplex	22	5	3.0	0.14	0.03

Table (1) Stainless steels used most frequently for rebar in the US and Canada (nominal compositions in weight %, balance iron)

chlorides. Their 1998 report concluded that Type 316 stainless steel rebars would be capable of providing that required lifetime.

In Europe, Mo-containing stainless steel rebars were first used over 20 years ago. In North America, their use in highway bridges has been steadily growing over the last 10 years, with many large bridges being constructed or extensively repaired. Two bridge projects that are currently underway help to illustrate the use of stainless rebar in the USA. They are the Driscoll Bridge in New Jersey and the Woodrow Wilson Bridge linking Virginia and Maryland.

The Driscoll Bridge.

This highway bridge spans the Raritan River in New Jersey, just west of Perth Amboy. Construction started in Fall 2002 on the new bridge which is being built next to the Garden State Parkway's existing Alfred E. Driscoll Bridge. When completed, the new bridge will carry southbound vehicles and its 8 lanes will accept traffic from I287, Route 440 and the Turnpike. Type 316LN and Alloy 2205 stainless steel rebar was specified for use in the bridge deck and other elements. Thus far, a total of 1300 tons of stainless rebar (which contains around 65,000 lbs of molybdenum) has been specified.

The Woodrow Wilson Bridge

This new highway bridge system will span the Potomac River to link Virginia and Maryland. The first 12-lane bridge of the twin bridges is scheduled for completion in late 2005/early 2006. The second bridge should be completed in late 2007/early 2008. When finished, this 7.5 mile project will connect Virginia, Maryland and D.C. along I95 on the Capitol Beltway. Thus far, 1100 tons of stainless steel rebar (Type 316LN and/or Alloy 2205) have been specified.

The use of Mo-containing stainless steel rebar is expected to continue to increase as Federal, State, Provincial (Canada) and municipal authorities demand much lower maintenance costs and longer lifetimes for their road and highway bridges. Along with the stainless rebar, other stainless steel products such as tie-wire, couplers and dowels are used to complete these corrosion resistant structures.

For more information on stainless steel rebar, visit www.stainless-rebar.org. An aerial view of the Woodrow Wilson bridge project can be found at: www.roadstothefuture.com/Woodrow_Wilson_Bridge.html

Figure (1): King Road Bridge over French Creek in the town of French Creek, New York. The project used Type 316LN stainless steel rebar.

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