THE INTERNATIONAL NICKEL COMPANY, INC.

ONE NEW YORK PLAZA · NEW YORK, N. Y. 10004

→ IN REPLY PLEASE ADDRESS
WELLS FARGO BANK BUILDING, SUITE 224
21535 HAWTHORNE BOULEVARD
TORRANCE, CALIFORNIA 90503
(213) 542-1626

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Mr. William R. Veliquette
Sales Manager
Mission Clay Products Corporation
P. O. Box 391
Whittier, California 90608

Dear Mr. Veliquette:

This letter is in answer to our recent telephone conversation and your letter to my associate, Mr. Tom Landig.

I enjoyed the opportunity of getting briefly acquainted at the recent Western States Corrosion Seminar. I hope my talk at that meeting was of some value to you.

You have asked a list of pertinent questions about 316 in relation to other metals and the effects of stray currents. I will answer them in that order to make the letter easy to follow preceded in each case by your orginal question.

It is our sincere hope that these short discussions will help you and your industry in explaining the virtues of stainless steel bands in soil.

If we can be of service when you are trying to explain the nature of corrosion to some of the skeptical Public Works people give us a call.

Yours very truly,

G. E. Moller

G. E. Moller
Los Angeles District Office

GEM:jk
Encl.

Questions and answers with respect to 316 and noble metals in the ground.

1. What is the life expectancy of Type 316 stainless steel for general application in underground use compared to cast iron, copper and other materials?

   To be as objective as possible in presenting corrosion rate data with regard to metals performance in soils, all comments are based on the National Bureau of Standards Circular 579 and technical articles published by the author, Melvin Romanoff, in trade journals.

   Type 316 stainless steel may be the optimum material for fitting in soil when one considers long term performance in the light of reasonable cost. Quoting Romanoff in Technical Bulletin No. 86.

   "High-Alloy Irons and Steels - Also included in the field exposures were higher alloy steels containing up to 18 percent chromium, with and without the additions of nickel and molybdenum. Increasing the chromium content of steels caused a gradual decrease in weight loss, but pitting was accelerated by additions of chromium beyond 6 percent. In fact, steels of AISI types 410 and 430, which contain about 12 and 17 percent o chromium, respectively, but no nickel, were observed to have deeper pits than plain steel in most of the soils. THE TENDENC OF CHROMIUM TO ACCELERATE PITTING APPEARS TO BE NEUTRALIZED BY ADDING SUFFICIENT NICKEL TO PRODUCE STEELS OF THE AUSTENITIC TYPE, SUCH AS 302 (18% Cr. 9% Ni), WHICH WERE FOUND TO BE ALMOS WHOLLY RESISTANT TO CORROSION. TYPE 316, WHICH ALSO CONTAINS MOLYBDENUM, IN ADDITION TO CHROMIUM AND NICKEL SHOWED NEGLIGIBL WEIGHT LOSS AND NO PITTING IN ALL OF THE 15 CORROSIVE SOILS TO WHICH IT WAS EXPOSED FOR 14 YEARS."

   Actually, when reviewing Romanoff's work in Circular 579, it is found that one sample of 316 in the fifteen tests had pits, but they were less than 6 mils deep.

   In four of the same soils, copper was found to have average penetrations of 1-15 mils and maximum penetrations of 5-40 mils. Copper is a fairly good metal in soil. It tends to suffer a slov general corrosion rather than pitting. Copper will suffer badly in soils that contain sulfides, organic compost, organic or inorganic acids and chlorides in combination with poor aeration.

   Iron in the same soils was found to have average penetration of 12 mils to perforation of 40 mils in six years. (All comments be ing made are on a 14 year time scale.) Iron has maximum penetration of 80 mils to 147 mils in 7 years.

   This data seems to indicate that Type 316 stainless steel can hav life expectancies from well over 14 years to hundreds of years. Copper in the majority of soils is a very adequate material. The use of unprotected steel and cast iron in soil, except in occasional locations, is not advised.

2. <u>What effect will electrochemical action (electrolysis) have on type 316 stainless steel?</u>

The terms electrochemical attack and electrolysis are synonomous. They refer to the cell action or battery-like analogy in the electrochemical attack. The requirements are an anodic zone, a cathodic area, an electrolyte (moisture) and a metallic path through the metallic pipe or structure. Electrochemical attack is also known as corrosion.

When experience or laboratory testing shows us that iron, steel, cast iron, and other metals corrode in their environment, we look for a remedy. Ways of combatting corrosion can be with coatings, cathodic protection, or by the use of <u>corrosion resistant metals</u>. Gold is corrosion resistant. A metal that is highly corrosion resistant, although not as good as gold, is stainless steel. However stainless steel is economical for many applications. By the addition of chromium, nickel and molybdenum, this iron base alloyed metal becomes passive in many environments such as sulfuric acid, neutral and oxidizing salts, nitric acid and also in most soils. Passivity means that the surface is stable and no anodic sites form to permit electrochemical deterioration.

The alloying of iron is a well known and widely used method of avoiding electrolysis for components or mechanical parts that do not lend themselves to coating.

3. <u>What effect will difference in 305 Bolt and 316 Band have?</u>

There should be no significant effect between a 305 bolt and a 316 band. Type 305 is a chrome-nickel stainless without molybdenum. The chrome-nickel stainlesses are excellent in soil also, except that they are a little more prone to pitting. The fact is that under most circumstances the two alloys, 316 and 305 are passive, and therefore have little, if any, electromotive difference in potential between them. Neither alloy harms the other because they are of the same electrochemical nature. If a pit developed on Type 305, it would be the same as if a pit developed on 316.

Based on the National Bureau of Standards data for 304 which is slightly inferior to 305, very little trouble would ever be expected of 305. If any corrosion were to take place on the 305 bolt, a great deal would have to occur before the integrity of the band were affected. It is doubtful if a corroded bolt would ever be of any significance to the band per se because the rough fastener would still hold fast.

4. <u>How will HVDC affect type 316 underground</u>?

Tests performed by members of the American Water Works Association the Cast Iron Pipe Research Association, and by the Oil Companies and Gas Companies have shown HVDC to be of no significance to major pipelines.

If HVDC is of no concern over long lengths of large pipe with thousands of square feet of surface to accept stray currents, then it certainly is of no concern on a little noble stainless steel band which is electrically isolated from a non-conductor of electricity, to wit, ceramic soil pipe.

5. Does type 316 need cathodic protection.

   Noble metals such as 316 and copper are selected to avoid the requirements of coating and cathodic protection.

6. How would type 316 be affected by galvanic couples?

   In most cases, if any galvanic couple developed inadvertently, the couple would be caused by connection to steel or cast iron. Stainless steel is higher on the galvanic series than steel or cast iron so the 316 (although it needs no help) would actually gain in the exchange. That is to say, it would receive galvanic cathodic protection.

7. Under what conditions would soil induce corrosion?

   Soils that are corrosive to steel have low resistivities, are poorly aerated, are moist, have acid reactions and have fine particle size. A very corrosive soil is one that has a resistivit under 700 ohm-centimeters. A corrosive soil has a resistivity of 700-2000 ohm centimeters whereas a mildly corrosive soil would be from 2000-5000 ohm centimeters.

   Corrosive soils have low corrosivity by virtue of sulfate, chlorides an bicarbonates.

   As an example, Type 304 stainless was found to pit significantly in four tests out of 15 conducted by Romanoff. Type 316 did not suffer at all except in the one instance when pits were less than 6 mils. The soils that affected 304 were clay and cinders. They have very poor drainage, resistivities below 406 ohm centimeters, and free acid reactions. Pore space or void space was low which goes along with poor drainage so aeration would be poor. Chloride was present in all cases.

   I would expect soils near the ocean which might be affected by high tide, sea spray or storms with high levels of sodium chloride to be corrosive to stainless steel.

8. What makes type 316 stainless steel best to use.

   This question is relative in nature. The best metals to use underground would be gold and platinum, but of course, this is impractical and ridiculous. Hastelloy C would be perfect also but too expensive. The 20 chromium, 35-42 nickel, 3 moly-3 copper materials such as Alloy 20 and Incoloy 825 showed absolutely no effect in soil tests. They are expensive also. Type 316, in only one case out of 15, showed any measurable penetration in 14 years.

This alloy appears nearly optimum in terms of corrosion versus cost. Type 304 statistically shows some corrosion in about 26% of the soils tested by NBS. It is not quite as universal as Type 316. Type 304 would have to be used with more discretion if the service requirements were rather rigid.

What tends to differentiate between 304 and 316 is the molybdenum addition which is known to confer added corrosion resistance to stainless steel.