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BUREAU OF CONSTRUCTION AND REPAIR

WASHINGTON, D. C.

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RESEARCH MEMORANDUM

July 27, 1934.

Subject: Corrosion Resisting Steel - Survey of the situation as regards use.

1. On my return from examination of the CHICAGO'S defective corrosion resisting steel piping, I relieved Mr. Jeffries of all duties except that of conducting a thorough and complete investigation into the technical considerations involved and gave him the directive to guide this investigation. His report is now nearing completion, but since I will be away for all of next week, it is advisable to summarize the situation before my departure in order that the facts and recommendations may be promptly considered and, in light of our extensive commitments, an early decision reached regarding the action to be taken.

2. The behavior of corrosion resisting steel may be reviewed under the following headings:

1. Direct attack by chemical reaction.
2. Corrosion by oxidation.
3. Intergranular corrosion due to carbide precipitates.
4. Corrosion by electrolysis in contact with other metals.
5. Corrosion by electrolysis in contact with nonmetallic substances.
6. Corrosion by electrolysis due to "oxygen concentration cells".
   (a) Due to porosities and pits.
   (b) Caused by organic deposits.

3. As regards heading No. 1: i.e.—direct chemical attack—examination of the defective gasoline tanks and of the defective salt water piping has shown the metal to be sound over the areas between the regions where attack has occurred due to the other causes. It is to be

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judged, therefore, that no general chemical attack on the metal takes place in the media to which it is exposed in services under our cognizance.

4. As regards heading No. 2; i.e.—corrosion by oxidation; this is the type of corrosion which the material is particularly well adapted to withstand and the one which it is conclusively known to resist very satisfactorily.

5. As regards heading No. 3; i.e.—intergranular attack due to carbide precipitates—the susceptibility of the material to this attack under certain conditions is well known and the conditions leading to this attack, together with the proper means of avoiding the attack, are now better known than in even the recent past. Consequently, although some of the difficulties encountered in the defective gasoline tanks can almost unquestionably be laid to this type of attack, there is very good reason to believe that failure due to this cause can be avoided in the future under the specifications as now revised, if particular pains are taken to follow any substantial heating for shaping by the proper anneal and quench. I believe that the revised specifications will, without further heat treatment, protect us against intergranular disintegration after welding in the corrosive media with which we are concerned. This type of attack has been a most important one and I now believe that it has been allowed, both by us and by the industry, to overshadow the other types to which the material is susceptible and to deprive them of the emphasis they should have received.

6. With regard to heading No.4; i.e.—corrosion by electrolysis in contact with other metals—I found no research data available upon my arrival in the Bureau but several ideas very definitely held, among which was the opinion that corrosion resisting steel stood near medium steel in the electropotential scale and would not cause corrosion of the latter through galvanic action. Very shortly there were several indications to my mind, that this opinion was erroneous and I initiated tests both at Annapolis and at Munhall to try to get a more substantial basis for judgment on this matter, in so far as corrosion in salt solutions was concerned. These tests have not been running long enough to give definite results, but the indications from preliminary reports from both stations indicate that corrosion resisting steel is noble to all of the metals with which we are likely to use it, with the possible exception of copper, the preliminary findings at Annapolis and Munhall differing in regard to this metal.

Therefore, although the research background is still too meagre to give complete assurance on this point, it is definitely indicated that corrosion resisting steel will not suffer in contact with the ferrous or nonferrous materials with which it is likely to be employed. It is very definitely indicated that the presence of corrosion resisting steel in contact with medium steel or wrought iron invites corrosion of the latter metals.

7. As regards heading No. 5; i.e.—corrosion by electrolysis in contact with nonmetallic substances—the susceptibility of the material to this type of attack has been definitely demonstrated. The nonmetallics concerned are quite likely to be inclusions, such as oxides, dirt, or any type of foreign matter, in the steel or they may be oxide accumulations carried into the corrosion resisting steel piping from more corrosive materials exposed with this material in the same piping system. Furthermore, they may consist of particles of scale left on the material due to ineffective pickling after annealing, or scale rolled in the surface of the material in the mill. When these substances are present in the presence of an electrolyte, it is definitely indicated that local galvanic action results. This action may cease as soon as the material has been eaten away sufficiently to allow the inclusion to drop out and be carried away. If the material is thick enough, this condition may obtain, and local attack in any particular region may cease, before an actual leak occurs. It is quite possible, however, that the type of attack to be mentioned under the next paragraph may begin in the pit resulting from the type of corrosion now under discussion, in which case there is always the possibility that corrosion will continue in this small area until a leak has occurred. In case of thin material, such as corrosion resisting steel tubing, now employed in the salt water systems, it is quite likely that sufficient wastage to permit the inclusion to drop out will not occur before the wall of the tube has been eaten through in the small area involved. I have been unable to obtain advice regarding, and have been unable to devise, a method of test that will assure our purchasing material sufficiently free of inclusions of the nature described to insure the avoidance of leaks due to this type of corrosion. Despite the opposition of a large proportion of the manufacturers, we have greatly strengthened our nitric

acid test in the hope that material clean enough to pass the more rigorous test will be suitable in service. It seems impossible to hope, however, that this test, when conducted, as it must be, on a sample, will prevent the purchase and installation of material that will show corrosion of this type at least in spots, and this corrosion is quite likely to produce at least a few leaks. It is quite true that the leaks are small and the tubing will continue to carry by far the greater portion of the water to the desired destingtion; but it must also be realized these leaks will be, at best, inconvenient and that they may cause a substantial amount of damage before they are discovered, and can be repaired.

8. As regards heading No. 6; i.e.--corrosion by electrolysis due to the formation of oxygen concentration cells--(a) this type of corrosion may be expected to start immediately wherever there are porosities, as in welds, or pits of small cross sectional area in relation to their depth. Under such circumstances, the bottom of the hole, crack, or pit is poorer in oxygen than the entrance: the oxygen-poor area becomes anodic to the other and electrolytic attack begins. The products of corrosion are carried to the cathode, i.e., the entrance to the hole or pit--where they are unable to protect metal at the bottom of the pit from further attack, with the result that corrosion continues until a leak occurs. (b) Also, attack based on this same theory can occur when organic material is deposited on the surface of the corrosion resisting steel, where it serves locally as a reducing agent, with the result that the material under it becomes anodic and electrolytic attack starts. The thicker the material, the more chance there is that the deposit will become displaced and that attack will stop before a leak occurs; but, on the other hand, there is always a possibility that a concentration cell will result from the formation of the initial pit and that attack under 6(a) will result and will continue until the leak is present. It is further to be noted that corrosion of type 5 may change into that of type 6(a), and continue through the metal.

9. Although laboratory results show definitely that this material is unique in its ability to withstand concentrated solutions, as well as other corrosive media, without appreciable loss of weight, and without gathering corrosive products, it has been definitely indicated, both

in the laboratory and in service, that corrosion of the pitting type does occur and that it may continue until leaks result. Despite the general excellence of corrosion resisting steel against corrosion of types 1, 2 and 4, and the confidence that we can now avoid harmful attack of type 3, I feel that the susceptibility of the material to corrosion under headings 5 and 6 is so pronounced as to make it unwise to continue to use it, at the very high price we have to pay for it, for purposes where it will be exposed to salt water, particularly in locations where small leaks, if and when they occur, can do appreciable damage and will be difficult or expensive to repair. Although there is reason to hope that, once leaks due to types 5 and 6(a) have been discovered and repaired, there will be no further failure of the article concerned, the correction of a few or several leaks can give no assurance that more due to the same causes will not shortly occur; and particularly, there is no assurance that leaks due to organic deposits, type 6(b), will not recur from time to time throughout the life of the installation, as new deposits occur.

10. There are a great many among the steel industry's technical personnel who feel that the difficulties thus far encountered are due to conditions which should have been avoided in making the installations and who believe that corrosion resisting steel is able to give and will give satisfactory service in a majority of the salt water installations for which we have adopted it. It must be acknowledged that the material was placed under a disadvantage when installed in systems from which less noble ferrous metals had not been entirely removed. It must also be acknowledged that a great deal of the pitting observed in the CHICAGO tubing is quite probably due to insufficient pickling after the heat treatment which followed the shaping of the tubing. To get the maximum benefit from the material, it should be installed in a system entirely of corrosion resisting steel and the processes of shaping, fabrication and assembly should be followed by the proper heat treatments and by thorough removal of the scale resulting from the heat treatments; but pitting occurs even on laboratory samples, which have not been subjected to these hazards, and I can find no basis for any confidence that, under the best of treatments, this material will not show leaks in service, possibly in a very short time after installation. If the material were not so expensive, I would feel inclined to continue our present policy of installing it, and would await further service experience before attempting to judge regarding the advisability of our continuing its use. However, in view

of the large amounts of money involved, not only in the construction already underway, but also in the program for which bids will be asked next month, I feel that the continued use of corrosion resisting steel for salt water purposes should receive immediate consideration and decision.

11. Certain improvements in this material are underway in the Industry and it is quite likely that its value will be much enhanced by the developments now in prospect. It is by no means certain, however, that such improvements as may be made will suffice to avoid entirely all the types of corrosion I have mentioned, and it is quite likely that the improvements may be accompanied by increased charges for the already expensive material. I do not feel that we should remain committed to large expenditures for the material, while we wait to see whether or not our present conclusions are too pessimistic. I do not feel that we should jump precipitately to some equally expensive, or nearly as expensive, substitute material. I do recommend as a policy that we go back to one of the cheap ferrous materials, galvanized, either steel or wrought iron, and preferably the latter, for our piping systems, avoiding the use of composition or corrosion resisting steel valves in contact with the piping, by adopting cast steel or even cast iron valves and fittings; this to apply to the bulk of our installations and the step to be taken with the realization that repairs and, eventually, replacements will be necessary but that the much lower cost of the material will largely compensate for the corrective measures.

12. Meanwhile, I would propose that individual ships be chosen in each of which to install a complete system of one of the several materials, which, on the basis of laboratory experiments, offer promise of being satisfactory substitutes for corrosion resisting steel. In this way, we can get service experience on promising materials at the minimum of expense, and can avoid jumping whole-heartedly to an expensive substitute until we are convinced that actual service does not uncover "bugs" which the laboratory experiments have not disclosed. I would propose installations, for service test, of the following materials:

(a) Molybdenum bearing 18-8 CRS.
(b) Manganese bearing 18-8 CRS.
(c) Monel metal
(d) Copper-nickel alloy (70% copper 30% nickel)

13. I have been flirting with the idea of proposing rubberlined piping but have refrained from recommending a trial installation due to the fact that each section of piping, after being shaped and tried in place, would have to be shipped to a rubber manufacturing plant for lining and then returned for installation on the ship. Except for this practical drawback, a scheme of taking thin-walled medium steel tubing and lining it with rubber is attractive, as comparing favorably in weight with corrosion resisting steel; avoiding electrolytic troubles; giving some saving in cost under corrosion resisting steel; and promising long life, with the possible discouragement of fouling. It is worth considering.

14. As concerns gasoline stowage tanks, I think it probable that we will continue to have some attack so long as water, and particularly salt water, is used in association with gasoline. Our difficulties should be much decreased, and they may be avoided entirely, in the cases of tanks built in the future to our new specifications. There is always the possibility, however, that our protective measures will not entirely suffice and I propose that the Bureau discard the hydraulic displacement system for an inert gas displacement system. If this is not done, I believe a considerable measure of improvement would result from adoption of the New York Shipbuilding Company's proposal that fresh water, instead of salt water, be used in the hydraulic system. If this is done, and the water is distilled water, as it presumably will be, we would certainly minimize, and probably even avoid, the deposit of organic matter on the corrosion resisting steel, and would thus remove one of the causes of corrosion of this material. Although supposedly expert opinion differs on the subject, it would appear that, even with fresh water, there would still remain the hydrolization of ethylene dibromide to change the fresh water into at least a weak electrolyte. Consequently, attack under headings 3, 5, and 6(a), might be expected to continue in areas where conditions conducive to these types of corrosion exist, but it is quite likely that it will be less severe than with salt water. The ethyl gasoline people insist that only minute quantities of hydrobromic acid are formed by the interaction of water, either salt or fresh, with the tetraethyl lead--ethylene dibromide. They also insist that there is no disintegration of the anti-knock ingredient with the water to precipitate lead, except when exposed to light. We have indications, at least, that they are wrong on both counts and it seems safer, while awaiting proof and definite conviction, to adopt a procedure that promises the greater protection regardless of the later developments on these points.