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CORROSION PROBLEMS ASSOCIATED WITH SPACE LAUNCH VEHICLES

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When considering corrosion and corrosion prevention procedures for space launch vehicles, several factors must be recognized. In order to obtain as light a vehicle as possible, the lighter more active metals comprise the major portion of the vehicle. For this same reason, the trend has been to higher and higher strength alloys. Generally, these high strength alloys have low corrosion resistance. The low factors of safety used during design make even small amounts of corrosion a very serious problem. All of these factors, coupled with the increasing complexity of space launch vehicles, make the task of a corrosion engineer increasingly important.

It might be expected that the atmospheric environment to which present-day space launch vehicles are exposed would be comparatively mild. It is true that long time exposure at launch sites, such as those experienced by military missiles, are not normally involved. However, closer examination reveals that environmental conditions are anything but mild. I am sure most of you are aware that space launch vehicles are becoming larger and more complex with every new vehicle system that is developed. This fact of large size and increasing complexity has an important influence on the environments to which a space vehicle is exposed. Many components are fabricated several years prior to the time they are finally assembled into a vehicle ready for testing. Added to this is a period of several months required for checking out the operation of the many complex vehicle systems, static testing of the individual stages, and a final checkout prior to shipping to the launch site.

Another rather severe environmental condition is imposed on the vehicle during transportation to the launch site. Due to the large size of the vehicle, transportation is by water, first along river routes and finally by ocean barge to the launch site. Then the launch site itself presents an extremely severe atmospheric environment since it is on the sea coast. Here again, size and complexity play an important role. Final assembly of the individual stages must be done at the launch site. The time required to do this, plus the final systems checkout prior to launch, result in several months of exposure in a very corrosive sea coast atmosphere. The total of all of these operations results in environmental exposure conditions of considerable magnitude.

Now to discuss a few of the protective treatments which are important in combating corrosion. One of the most important is the protective treatment of aluminum structural members. All members are first given a chemical surface treatment to provide a good paint base. Then a coat of zinc chromate primer is applied. This is all done on each individual component prior to assembly. Whenever possible, rivets are dipped in zinc chromate paste prior to installation. After assembly, the exterior surfaces are coated with an appropriate top coat of enamel.

Exterior surfaces of the propellant tanks are treated similarly except that, since welded structures are involved, surface treatment and painting is done after fabrication. Interior tank surfaces may or may not be surface treated, depending on the alloy. However, close control of the relative humidity inside the propellant tanks is maintained to further reduce the possibility of corrosion in these critical areas. Where aluminum contacts stainless steel surfaces, the joint is separated by a 10 mil film of plastic tape to reduce the possibility of galvanic corrosion.

The most troublesome problems are at areas where paint cannot be applied. Anodizing of aluminum is used extensively, particularly on valve components. Where dissimilar metals are involved, electroplating is used to minimize galvanic corrosion. Cadmium plating with a chromate conversion coating is preferred for all steel parts which contact aluminum surfaces. Preservative oils are used in selected areas but are limited due to compatibility problems. Because of compatibility problems, as well as other considerations, wide use is made of materials such as stainless steel which are inherently corrosion resistant and require no additional protective treatment. However, the surface condition of stainless steel is very important. In order for the normal passive surface to form, all residues and any foreign metal pick-up from fabricating operations must be eliminated by appropriate surface treatment.

There are a few problems which have arisen during initial fabrication of an advanced space launch vehicle which, I think, will serve to illustrate the type of corrosion that can occur and show the evaluation necessary to overcome and prevent similar problems.

In one instance, a failure of a large, forged aluminum component was found to be due to stress corrosion cracking. The material was 7079 aluminum, heat treated to the -T6 condition. Several factors were found which contributed to this problem. In the first place, all aluminum alloys of the 7000 series are very susceptible to stress corrosion cracking in the short transverse direction of grain orientation. However, the primary cause for this particular failure was an error in the processing sequence. During heat treating of any massive component, compressive stresses are set up in the outer surfaces of the material.

This is due to the fact that during quenching, the outer surfaces cool first. Then, when the inner portions cool, contraction tends to pull the outer surfaces in compression and leaves the inner portion in tension. However, in order for stress corrosion to occur, tensile stresses must be present on the outer surfaces. The component in question was forged, partially machined and then heat treated. However, a considerable amount of machining was done after heat treating. This machining was enough to remove the outer, compressively stressed material and exposed material under tension. Even though the surfaces had been anodized, these stresses were enough to cause stress corrosion when the component was exposed to rather mild atmospheric conditions. After determining the cause of the problem, a solution was fairly obvious. First, forging techniques were altered so that grain orientation was as favorable as possible. Most important, the major machining operation was done prior to final heat treating to avoid exposing tensile stresses at the surface. To further insure that only compressive stresses were exposed, the entire outer surfaces, including all drilled holes, were shot peened. The component was then finally anodized.

Another problem, which was also a result of a combination of several factors, involved a stainless steel component. In this case, corrosion was intergranular and resulted in pinhole leaks in thin walled 304 stainless steel tubing. The primary cause was found to be carbide precipitation resulting from an improper stress relief treatment. Corrosion was thought to be caused by the breakdown of trapped residual cleaning solvent, in this case trichloroethylene. Correction of this problem was achieved by first reducing the possibility of carbide precipitation. This was done by changing the material to 304L stainless steel and elimination of the stress relief treatment. In addition, the cleaning procedures were altered to eliminate all residual cleaning solutions.

Our experience has indicated that there are several important principles to be followed for combating corrosion in space launch vehicles. First, and most important, corrosion must be considered in the initial design. The proper preventative measures to be applied must be considered prior to initial fabrication. Material selection and protective treatments must be carefully chosen by persons thoroughly familiar with corrosion and its principles. Almost as equally important, and many times overlooked, is the fact that fabricating and processing techniques must also be carefully examined. Cleaning procedures must be controlled so that corrosive residues are eliminated. Heat treating and fabricating techniques must be analyzed to eliminate improper metallurgical conditions. Maintenance procedures must be set up to control and eliminate harmful residues which might result from the assembly and checkout operations. In other words, not only must the design be examined for proper materials and protective treatments, but fabrication techniques and assembly operations must also be evaluated to prevent conditions from occurring which may be conducive to corrosion.

As with almost every other phase of space vehicle design, the corrosion problems of the future seem to be initially one of size. Already, problems of surface treating large complex components are apparent. Dangers from entrapment of cleaning fluids in large complicated components are becoming more and more prevalent. In order to avoid some of these dangers, compromises have to be made with surface treating procedures. The use of large components made of high strength, heat treatable alloys will increase the probability of stress corrosion cracking. Welding of thick aluminum sections, besides being a problem in itself, will also induce stresses in the surrounding material which may create additional stress corrosion problems.

Another factor which will have a major impact on the future requirements for corrosion protection of space launch vehicles is the development of recoverable stages. Sea water recovery has probably received the most consideration to date. This method will certainly impose exacting requirements on the protective treatments and the maintenance and reclamation procedures necessary for corrosion protection. Because of the anticipated corrosion problems connected with sea water recovery, studies have been made of other methods for recovery. Even when considering the most favorable method of recovery, the longer exposure times which are involved will make corrosion protection and maintenance more and more important in the design of space launch vehicles of the future. This not only means closer attention to protective treatments, but also a better understanding of the factors influencing corrosion of huge, complicated components made of high strength alloys.