In this Case from the F-Files, a food manufacturing facility owner insisted that, despite the use of three different lining systems, the aggressiveness of the service environment caused all three lining systems to fail in less than 10 years. Until a formal failure investigation was performed, the owner was ready to pay for a fourth lining system without knowing the real culprit.

Several years ago, the food manufacturing company contracted to have the interior of a clarifier relined. The clarifier was approximately 50 feet in diameter and 17 feet high. The original lining in the tank was an epoxy novolac and failed approximately one year after the clarifier was placed into service. The tank was relined with another type of epoxy system, but the new lining lasted only about three years before significant rusting occurred. The tank was again relined with a 100% solids epoxy system at a recommended total dry film thickness of 16 to 20 mils. The same contractor performed the original application and both relining operations. About five years after the third system was applied, multiple tank wall spot failures with external leakage were noticed, and upon a short decommission of the tank, it was found that the lining had once again failed. The food manufacturing company was certain that some material in the clarifier content was attacking the lining and decided to have an independent investigation performed to determine the cause of the lining failure.

Site Investigation

A site visit was conducted to examine the lining in the clarifier. A light blue coating had been applied to the interior of the clarifier. At the time of the investigation, the interior sidewalls had not been thoroughly cleaned, and, in most areas, a brown residue was attached to the coating to some degree. When the brown residue was removed, the blue coating exhibited gloss and showed no sign of chemical attack.

The clarifier sidewall had two shell rings with many areas of coating delamination. The majority of the delamination occurred on the second (top) shell ring. Widespread pinpoint rusting was most severe on the second shell ring but also appeared sporadically on the first shell ring (Figs. 1 and 2).

In areas immediately adjacent to spots of delamination and in areas of pinpoint rusting, a close examination of...
the coating revealed that it was extremely rough. The lining had a dry spray appearance (Fig. 3), and globules of coating were visible on the surface. In these rough areas, rust was bleeding from the coating in many spots. Where the coating was smooth, however, there was no coating delamination and very little pinpoint rusting. There was a notable correlation between coating failure and the smoothness of the coating: the rougher areas exhibited quite severe failure while the smooth areas exhibited almost no failure.

The lining was removed, and the substrate surface was examined in several areas. In areas with noticeable pinpoint rusting, the surface of the steel was covered with black corrosion spots, indicating permeation through the coating in those spots. Where the lining was smooth, the surface of the steel was dark gray, but free of corrosion spots. Both areas exhibited a sharp, angular surface profile, and there was no evidence that the steel surface had not been properly abrasive blast cleaned.

The dry film thickness of the coating was measured using a calibrated electronic dry film thickness gage. The dry film was found to vary considerably. Generally, the thickness measurement was between 16 and 40 mils, although because of the roughness of the coating, the thickness gage measured the coating from the tops of peaks of the surface profile to the valleys of the profile, making the thickness appear greater than it actually was. Often, rust could be seen in depressions in the coating, and it was very likely that the coating thickness approached zero in small spots (Fig. 4). In fact, when pieces of coating were forcibly removed and held up to the sunlight, the light could be seen through holes in the coating.

**Laboratory Examination**

Samples of the coating were taken to the laboratory for analysis along with a wet sample of the lining most recently applied. The samples were examined with a digital microscope with magnification ranging from 20X to 100X. In summary, the examination revealed that the dry film thickness of most of the lining samples varied considerably. Samples had a thickness range of 0 (voids) to 24 mils, and there were numerous holes through several of the samples. The lining
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The lining material was glossy on top, with no visible indication of chemical breakdown. Additionally, the cross sectional examination revealed that there was no discoloration of the coating below the surface, which would have indicated permeation into the coating.

Infrared spectroscopic analysis of several samples was performed with a Fourier transform infrared spectrometer. Additionally, a wet sample of the lining material was properly mixed and allowed to thoroughly cure, then analyzed. The spectra of all the samples, including the laboratory-prepared samples, were nearly identical. There was no noticeable evidence of chemical degradation in any of the lining samples removed from the clarifier interior.

Putting the Pieces Together

The field investigation and the laboratory analysis revealed that the cause of coating delamination, cracking, and pinpoint rusting was poor application of the 100% solids epoxy lining. The coating was applied inconsistently, and in numerous pinpoint spots, there was no coating on the steel. The surface of the coating was extremely rough in areas of pinpoint rusting and coating delamination.

The type of epoxy lining applied to the clarifier interior prevents corrosion on the steel surface by forming a protective barrier that greatly reduces the amount of moisture that comes in contact with the steel. Without this moisture, the steel does not corrode. To effectively protect the steel, the coating must be applied so that it covers all of the steel at or greater than the minimum thickness. The minimum thickness depends on the particular coating and its moisture permeability characteristics.

In this case, the way the coating was applied created numerous holes in the cured system (Fig. 5). In many areas, a dense pattern of pinpoint rusting occurred where the holes in the coating were numerous and densely packed. Water penetrated the coating through the numerous holes and caused the steel to corrode. In some areas, the corrosion undercut the coating until the entire surface was covered with rust. In areas where the pinpoint rusting was less dense, only isolated spots of rust were present on the steel.
The laboratory microscope examination confirmed that the coating was full of pinholes. In many spots, there were voids in the coating, even though the average thickness of the coating was greater than 20 mils.

The site examination revealed no evidence that the lining applied to the clarifier was subjected to any kind of chemical degradation. As noted above, when the residue from the tank contents was removed from the coating, the surface was glossy. Generally, when a coating experiences chemical degradation, the coating loses its gloss. In areas where the coating was applied in a smooth and consistent manner, it protected the steel surface adequately. Additionally, no chemical degradation was detected during the laboratory microscopic examination or the infrared spectroscopic analysis of the samples. It is thought that if this coating been applied in a smooth and consistent manner in all areas, no significant coating failure would have occurred.

The failure of the lining system was the third failure in a relatively short period; each of the three different lining systems failed prematurely. The clarifier owner assumed that the culprit was the clarifier content. The failure investigation pointed to the application of the lining as the problem, not the lining itself. Interestingly, the same contractor applied all three lining applications and may have made the same application errors in each instance.

**Recommendations**

The extent of the cracking, delamination, and rusting was too great to attempt a spot repair approach to remediate the failure. The failure investigators recommended removing all of the interior lining and reapplying the same product or a different epoxy coating system suitable for this environment.

They also recommended that a qualified inspector closely monitor the application.
cation. In addition to monitoring environmental conditions, abrasive quality and cleanliness, surface cleanliness and roughness, mixing (as appropriate), coating thickness, and curing, the inspector should perform holiday testing to verify continuous lining application and to identify necessary repairs before putting the system in service.

Rick Huntley is the manager of Consulting Services for KTA-Tator, Inc., where he has been employed for 18 years. He is certified by SSPC as a Protective Coatings Specialist and is a certified NACE International Coatings Inspector. His work with KTA includes coating failure analysis, specification preparation, and coating project management. He earned a Bachelor of Science degree from Washington State University.

Did you miss an article in the Cases from the F-Files series, which premiered a year ago in JPCL? Here’s a list of the first 12 articles in the series.

- “Introducing a Series on Analyzing Coating Failures,” March 2009
- “The Case of the Yellowed Water Tank Lining,” April 2009
- “The Case of the Perplexed Paint Shop,” May 2009
- “Accelerated Corrosion of a Pedestrian Bridge,” June 2009
- “The Case of Hurry Up and Wait” (Premature Rusting of Newly Coated Structural Steel in a Chemical Plant), July 2009
- “The Fix That Was Worse than the Problem” (Catastrophic Disbonding of an Encapsulating Coating Applied to Hot Dip Galvanizing), August 2009
- “The Case of the Job Shop” (Coated Equipment Sent North but Coating Performance Went South), September 2009
- “The Cost of Going Green?” (Filiform Corrosion of Powder-Coated Aluminum on the Gulf Coat), October 2009
- “Coating Failures on Galvanized Mast Arms,” November 2009
- “Who Reads Instructions Anyway?” (The Case of the Failing Floor Coating), December 2009
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