



A Permanent Metal CoatingTM That Resists Zebra Mussels

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1. INTRODUCTION

Zebra Mussels were first identified in the fresh waters of **North America**....

*(You may have already read the rest of this section, in almost every other paper written about **Zebra Mussels**. It will not be repeated here.)*

Zebra Mussels attach to hard objects, **grow**, and **multiply**. Hard objects include rocks, piers, boat bottoms, trash racks, intake pipes, buoys, fire protection strainers, intake screens, concrete, logs, discarded cans, tires, rope, cable, chain, and the shells of other **Zebra Mussels**.

This paper discusses the research, development, and testing performed in conjunction with the **Copper Development Association** and with the much appreciated cooperation of: **Tritown Water District** and **Vergennes Water District**, both water utilities serving northern **Vermont**; a U.S. Government agency responsible for aids to navigation; and two electric utilities serving the State of Michigan. The result of the work is a permanent metal coating, trade named Jacquelyn™ that resists the attachment of **Zebra Mussels**. The coating is now commercially available from **Cook Legacy Coating Co.**

1.1 Summary

Jacquelyn™ is corrosion and **Zebra Mussel** resistant copper alloy metal coating. The coating involves **no binders, carriers, or VOC's**. It can be applied to complex shapes, such as **welded stainless steel profile wire screens**; and more accessible shapes, such as trash racks, buoys, and boat bottoms. **Copper** leach rates are below practicable detection limits using standard NSF protocols and **U.S. EPA** certified test procedures. **Zebra Mussels** do not attach to coated materials.

2. THE WORK

There were four primary steps in developing the coating:

2.1 Selecting a material application technique.

The application technique must be suitable for application to profile wire screens with small screen openings. If such a technique could be developed, it was clear that the technique would also be suitable for structures with less complex geometry's such as trash racks, bar racks, fire protection system strainers, and other primary protective screening on water supply systems as well as other surfaces such as boat bottoms and buoys.

2.1.1 Selecting a material.

The material chosen must resist the attachment of **Zebra Mussels** and be **corrosion** resistant to provide long-term service life.

If an application technique and material could be identified for testing, then test applications had to be performed, the characteristics of the coating had to be characterized, and the coating had to be performance tested to verify that it did, indeed, resist **Zebra Mussel** attachment.

If an application technique could be identified, a suitable coating material could be identified, and the coated test pieces did resist **Zebra Mussel** attachment, then it was necessary to perform leach testing to provide information on the material-leaching rate. A material and coating application technique was identified for testing. Test material was secured for the testing; a facility capable of performing test application was identified. Welded profile wire screen material for substrate was obtained and test application of the material was successfully attempted. Further, more advanced testing augmented the initial testing of copper leach rates. The testing was carried out at **Bowser-Morner Laboratories**, an **A2LA** Certified Laboratory in Dayton, Ohio. The results of this test were extremely favorable. The copper leach rate was taken at two **pH** levels, **pH** of **8.0**, and **pH** of **6.5**. The **pH** of **8.0** had a leach rate of **0.004ppb** and **pH** of **6.5** had a rate of **0.005ppb**. A normalization calculation was applied to these two test specimens resulting in a leachable copper rate of **0.003ppb**.

The coating development was successful and a patent was applied and obtained on Aug. 31, 1999. Before receiving the patent, we felt it necessary to keep our application process proprietary; however with the patent now being issued, we feel it is an important part of this paper. In our testing method, we used wire of nominal composition of 90% copper and 10% nickel. Coating, using this material and applied using the method describe below, produces a coating that is resistant to the attachment of **Zebra Mussels**. The coating is also **corrosion resistant** and resistant to the attachment of biofouling organisms. The wire is mounted in a "**dual wire electric arc spray device**". The dual wire feeder pushes the two wires, one with a **positive** electrical charge and the other with a **negative** charge, through the arc spray gun causing the two wires to melt when they meet at the end of the spray gun. Finally, compressed air blows the molten particles onto the surface to be coated.

Metallographic Examination and **Mechanical Testing** of the coating confirmed that a uniform coating could be applied to the complex geometry of welded profile wire screens. The application technique would allow the coating to be applied even to the sharp corners and narrow notches that are inherent in the geometry of the test screen substrate. The testing also indicated that the coating was well bonded to the test screen substrate. Adhesion testing was conducted in accordance with **ASTM Standard D 4541 - 93 “Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers.”** Four (4)-loading fixtures, referred to as dollies, were secured to the testing panel with adhesive. Following the recommended three-day curing period for the adhesive, a portable adhesion testing apparatus was used to apply perpendicular tension to the fixtures. This tension is applied continuously until the bond between the coating material and substrate is interrupted or a specified value is achieved. The apparatus used in this testing, possesses a maximum registering value of **1,000 psi** (pounds per square inch). Adhesion values above **600 psi** are normally considered optimal. The pull-off values achieved by the **Jacquelyn Corrosion** and **Zebra Mussel Resistant Coating** are listed below.

2.1.2 Table 1 - Pull-Off Strength of Jacquelyn Corrosion and Zebra Mussel Resistant Coating

Dolly Number	Pull-Off Value (psi)	Comments
1	950	Complete separation between coating and substrate
2	>1,000	Complete separation between coating and substrate
3	1,000	Complete separation between coating and substrate
4	700	Complete separation between coating and substrate

Test locations for the coated screen sections were identified in conjunction with water supply utilities on **Lake Champlain** and power-generating utilities in **Michigan**. These facilities deployed the samples and performed the inspections.

In addition to the application on welded profile wire screen, working with a U.S. Government agency responsible for aides to navigation, we were able to secure a **Class V** navigational buoy. The buoy surface was cleaned, the surface prepared, coating was applied, and the top of buoy was painted consistent with its function. In addition to confirming that the coating could be applied on a commercial size and scale (the buoy was about **9 feet** tall, **3 feet** in diameter at the waist, and weighed about **900 pounds**), this testing process revealed that the coating also was a very effective substrate (**primer**) if portions of the surface required painting to fulfill their function. This was of particular interest because the coated surface was dry and ready to paint within an hour of coating application.

Test location for the buoy was selected, and the buoy was commissioned and inspected by agency.

3. THE RESULTS

The accompanying photo images provide visual evidence of the results of the **Zebra Mussel** resistance tests. These images are from the underwater inspections at **Tritown Water District** on **Lake Champlain** in **Vermont**. The resistance to **Zebra Mussel** attachment is representative of the results of testing reported at all sites.

At the **Tritown** site, test pieces were installed in two neighboring locations in **Lake Champlain**. One of the locations was also participating in a simultaneous test of a sonic device that was being evaluated for its ability to control the attachment of **Zebra Mussels**.

Underwater inspections were carried out in July of 1997, on October 7th, 1997, and again on October 27th, 1997. The results of the inspections were recorded using an underwater camera.

The first set of images (1, 2, & 3) shows the “**uncoated stainless steel bar grating**” at the intake site. The sonic control device was in use at this location. The bar grating consists of **1/2"** diameter stainless steel bars welded together to create a **2" x 2"** grid with **1 1/2" x 1 1/2"** opening. All three images are of the same area of the grating.

3.1.1 Image 1 - Zebra Mussels Attach At the Corners

Image-1 shows that in July the **Zebra Mussels** had begun to attach at the corners of the openings, but that, in general, the bars are clear of **Zebra Mussels**, and that flow through the grating does not seem to be significantly impaired.



Image 1

3.1.2 Image 2 - Accumulations

Image-2 shows that by October 7th the accumulations on the corners have increased substantially and that the bars themselves are covered with **Zebra Mussels**. Still, it would not seem that flow through the opening would be noticeably impaired.

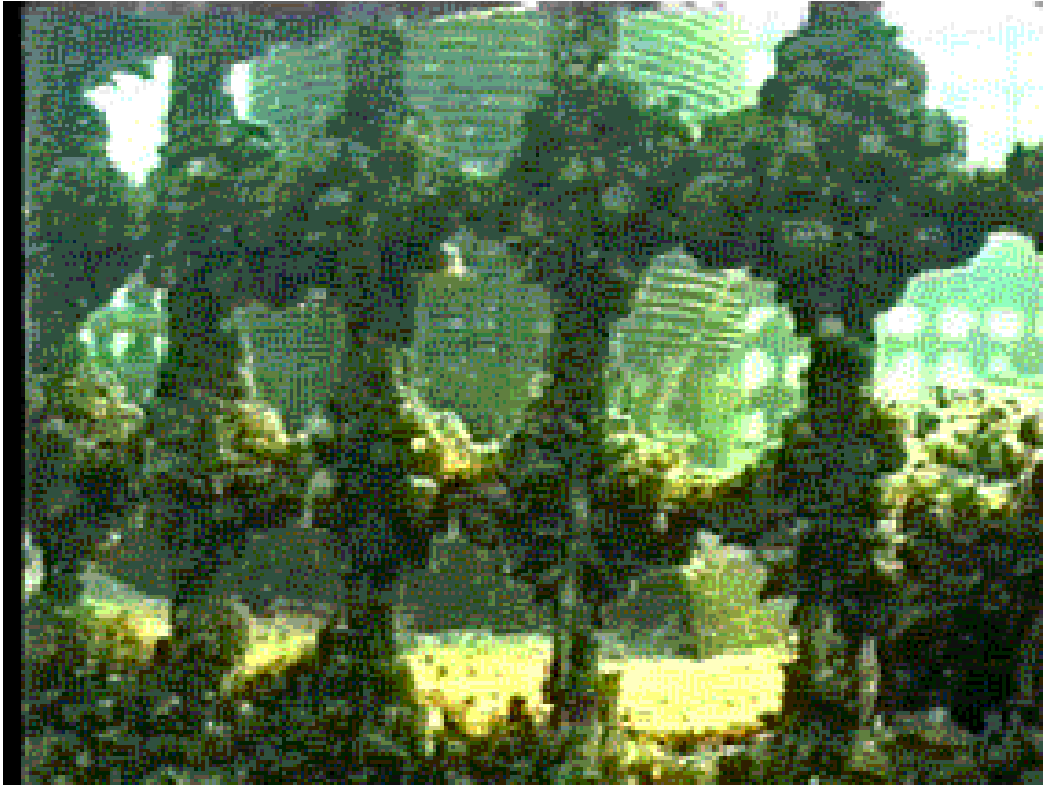


Image 2

3.1.3 Image 3 - Build Up Of Zebra Mussels

Image-3 is a closer view of the same general area shown in **Image 2**, which was recorded less than 3 weeks later on October 27th. In this brief period, the build up of **Zebra Mussels** has increased dramatically and the available flow area of the grating has been reduced by more than **60%**.

The images in the second set (**4, 5, & 6**) show an “**uncoated stainless steel welded profile wire screen**” at the site where the **sonic control** device was in use. The screen was nominally **18"** in diameter and **36"** long with a **carbon steel flange** on one end and a **solid plate** at the other. The screen construction commonly used for water well screens of this diameter. The screen opening (**slot**) was $\frac{1}{4}$ " and the width of the triangular wire at its base (the outer surface) was about $\frac{5}{32}$ ". Initial open area at the screen surface was about **60%**. Unlike most “**welded profile wire screens**” used as intake screens, this screen had no internal flow balancing system to control maximum through screen velocity. [Such flow balancing systems are normally employed to minimize debris accumulation and impingement or entrainment of fish at the water intake.] Vendors of the **Sonic Zebra Mussel Control Device** have advised that their system seems to work better when an intake screen is mounted on the end of the intake pipe. The new intake screen was installed in Mid July of 1997.



Image 3

3.1.4 Image 4 - Zebra Mussel Attachment

Image-4, the screen is clear of all **Zebra Mussel** attachment. One adult **Zebra Mussel** was found on the screen during the inspection, but it was removed by the diver during the inspection.



Image 4

3.1.5 Image 5 - Juvenile Zebra Mussels

Image-5, recorded on October 7th, a large number of **Juvenile Zebra Mussels** can be observed attached to the uncoated screen surface. While it may simply be an artifact of the light or the camera angle, it seems from the image that the mussels tend to accumulate preferentially on the corners of the wire and in the flow path of the incoming water.

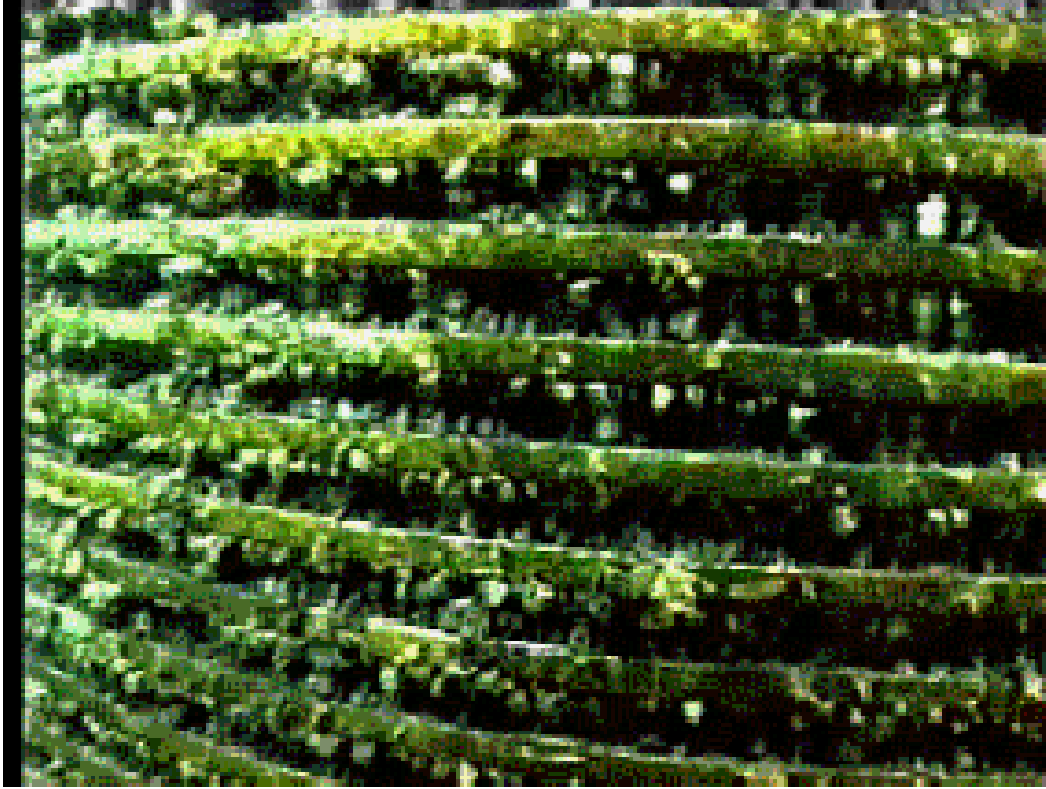


Image 5

3.1.6 Image 6 - Substantial Increase in the Size and Number

Image-6, recorded on October 27th, shows a substantial increase in both the size and number of **Zebra Mussels** on the screen. Again, it appears that the preferred attachment locations are in the water flow path. A number of mussels can also be observed on the flat wire face, as well as those that seem to be bridging over and blocking the screen openings. Available flow area through the screen is again substantially reduced.

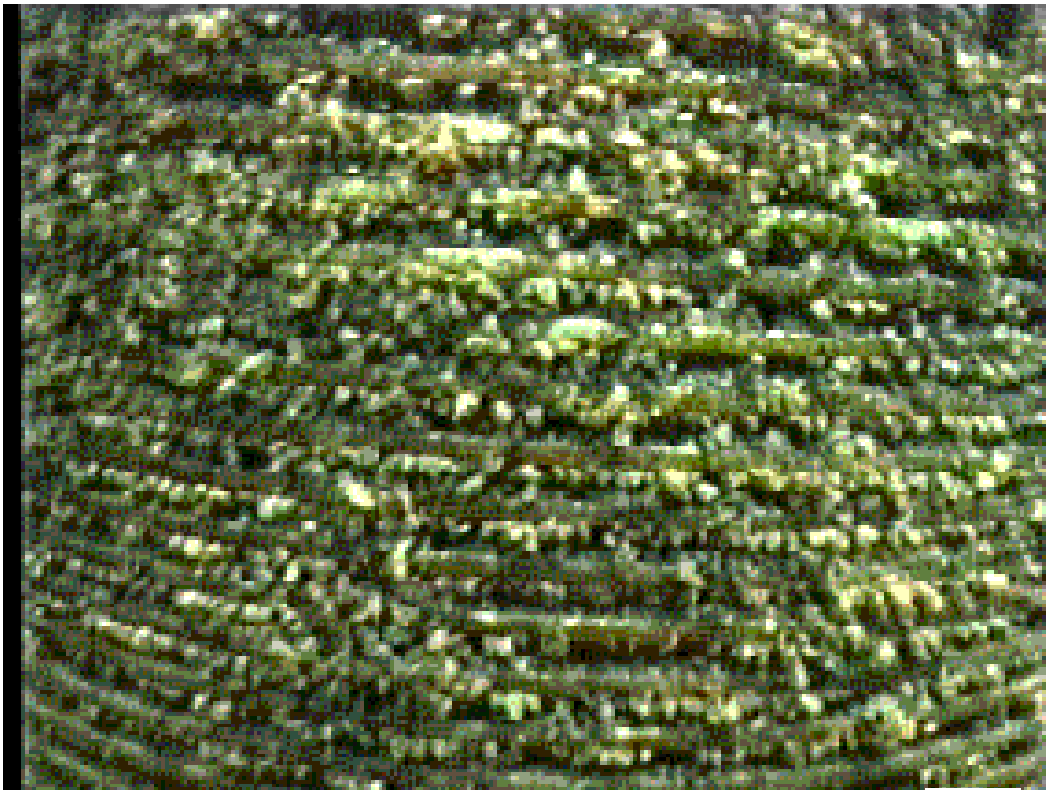


Image 6

The third set of images (7, 8, & 9) also shows a welded, “**stainless steel profile wire screen**”. This screen section has been coated with **Jacquelyn™**, the selected test material. Coating thickness is in the range of **0.005"**. The screen is a section typical of screens commonly used for water intake screening applications. The screen opening size is nominally $\frac{1}{8}$ " prior to coating application. The wire face width (after coating) is nominally **0.080"**. The support bars are **14 ga.** (0.075") thick and **1"** deep on **1"** spacing. This screen section is approximately **3" x 3"**. This section of coated test screen was placed on the flange, which connected the screen in images 4, 5, & 6 over the intake pipe. A rope was connected to the screen to keep it at the test site.

This coated test screen was installed in mid July of 1997 along with the uncoated screen.

3.1.7 Image 7 - Zebra Mussels July Inspection

Image-7 shows the screen free of **Zebra Mussels** during the July inspection.



Image 7

3.1.8 Image 8 - Slipped From Its Original Position

Image-8, recorded on October 7th, shows that the screen has slipped from its original position. Of much greater importance, it shows that the screen is still free of **Zebra Mussel** attachment including attachment by **Juvenile Zebra Mussels**.



Image 8

3.1.9 Image 9 - Free Of Zebra Mussel Attachment

Image-9, of the coated screen, section was recorded on October 27th. This image along with the diver's report of his observations shows the screen to continue to remain free of **Zebra Mussel** attachment. While the “**uncoated bar grating**” and the “**uncoated welded profile wire screen**” display **Zebra Mussel** attachment that would significantly obstruct the water flow path, there is no attachment on the coated test screen section at the same site.

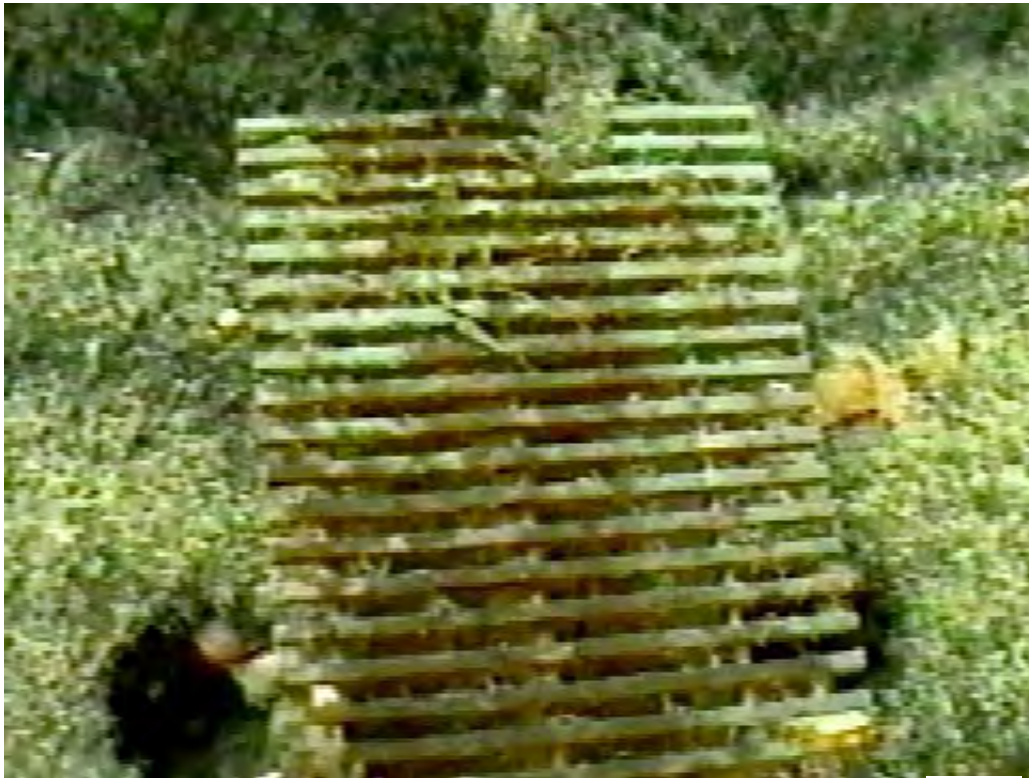


Image 9

3.1.10 Images 10 & 11 - Coated Test Screen Section

Images 10 & 11, the final set, shows a coated test screen section identical in construction and approximately the same size as the screen in Images 7, 8, & 9. Unlike that screen, this screen section was located in the same general vicinity, but away from the impact of the **Sonic Control Device**. The screen in Images 10 and 11 was also installed in mid July of 1997. Image 10 was recorded on October 7th and image 11 was recorded on October 27th. It was suspended by rope from a marker buoy anchored to the lake bottom by a concrete weight. The buoy was connected to the weight by a heavy rope. (A portion of the rope can be seen in the upper right hand corner of Image 10. It is heavily covered with **Zebra Mussels**.)

There were no images of this test screen section was recorded during the July inspection. It is reasonable to conclude that such an image would not be noticeably different from the October 7th or October 27th images. There are no **Zebra Mussels** on the coated screen surface.

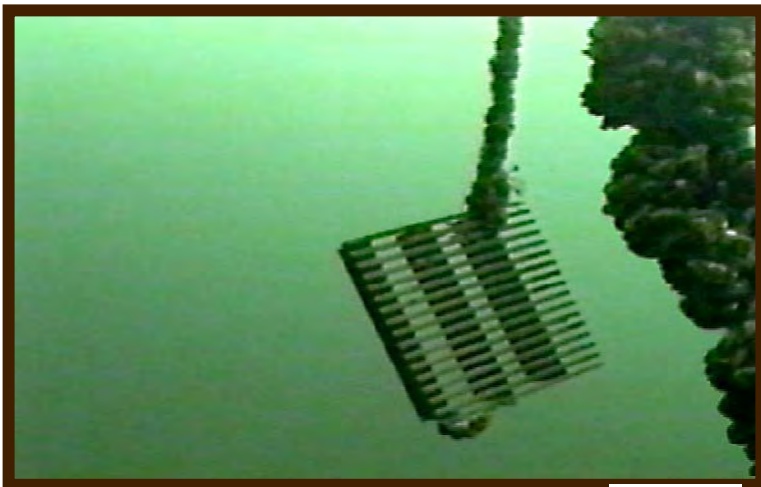


Image 10

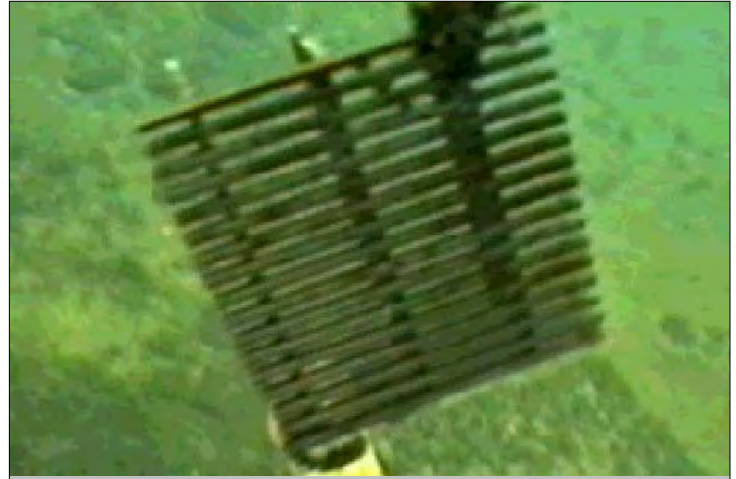


Image 11

Of additional interest in images 10 & 11 are the one adult **Zebra Mussel** that can be observed at the lower left corner of the test screen. The process of test screen section preparation involved application of the coating to larger sections of screen -- approximately **18"** long and **3"** wide. These sections were cut after coating so that the ends of the support bars and a portion of the side of the surface wire were free of coating. The adult **Zebra Mussel** has attached to one of these uncoated areas. This suggests that while the coating resists the attachment of **Zebra Mussels** it does not repel the mussels.

4. LEACH TESTING

As might be inferred from the **Copper Development Association's**, support of the work done in development and testing of the **Jacquelyn™** coating, the material used in the coating is a copper based material. For a number of reasons, we deemed it important to obtain information on copper release from the coated test screens. All testing and measurements were performed at an independent, **U.S. EPA** certified testing facility.

The results have been listed earlier in this paper and are available upon request.

5. APPENDIX A

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