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Evaluation of Failed Contactor Chill Blocks Due to Corrosion / Erosion

By Bruce G. Kelly P.E.[1] and David J. Darrah [2]

Abstract

"Evaluation of failed SCR cooling blocks due to corrosion/erosion."

When SCR's were first used in resistance spot welding controls, they were installed in a directly cooled package. This exposes the water in the connecting hoses to line voltage, which causes heating problems, and deterioration of the hose. In addition, the SCR's have generally been substantially oversized which makes a very robust package, but comes with a high cost.

In the early 1990's, weld control manufacturers responded to these complaints by using an "indirectly cooled" design that insulated the line voltage from the cooling blocks, thus solving the hose problem. In addition, as a cost reduction measure, the SCR size was reduced and the cooling block was changed to aluminum.

During the years since, a substantial number of cooling blocks have failed due to leakage. Two causes have been identified; corrosion and erosion. The corrosion is a material issue related to water chemistry, cooling block and fitting material. The erosion issue is related to high water velocity caused by flow greater than the minimum required.

Specifications have been changed to eliminate these problems in the future, and we have recommendations for those still using the aluminum block to reduce the risk of leaking.

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Introduction

Although Thyristors (SCR's) have proven to offer advantages over Ignitron tubes as used in Resistance Welding, they still require cooling. Throughout the years, changes have been made to improve efficiency and reduce costs of the SCR cooling blocks. Not all of the changes provided dependable results.

Large copper, direct water-cooled blocks were first used. As users defined accurate duty cycle requirements, sizes were reduced. Less and less copper was used in the cooling blocks. Indirect water-cooled SCR Contactors were then introduced. Originally copper or brass was used. In response to cost reduction requests, aluminum was often substituted for copper.

The sizes of the cooling blocks were not increased for the softer metal, and as a result premature leaking began to occur. At first everyone looked to water quality as the source of the corrosion. It wasn’t until leaking chill blocks were found at plants with good water treatment that erosion was considered a source of the problem. Maximum flow rates were not specified for SCR Contactors. Erosion and leaking contactors were showing up in as little as two months.

This paper begins with Ignitron tubes and moves into the Thyristor (SCR) as a method of controlling heat or amperage for resistance welding. The evolution of water cooling methods for SCR Contactors is discussed. The paper covers copper and aluminum, direct and indirect, cooling blocks. Corrosion and erosion in the contactor cooling blocks is identified and solutions are discussed.

History

From the inception of resistance welding until the late 1940’s, the resistance welding process was controlled by a mechanical or electromechanical switch to control time and the use of tap switches and impedance management controlled the current level. In the late 1940’s, electronic switches in the form of ignitron tubes were introduced. These devices could delay turn-on of the current each half cycle and thus could provide easy adjustment of the voltage applied to the transformer and thus current adjustment. In addition, they provided the switching function to control weld time. While they were a great improvement over the previous technology, they had a few disadvantages:

Some of the internal parts were fragile and easily damaged by improper handling.

The igniter was subject to wear and would eventually wear out.

They contained mercury.

Cooling water and hoses were exposed to line voltage and created special maintenance requirements.

The ability to obsolete ignitron tubes was due to the introduction of Silicon Controlled Rectifiers (SCR’s), also called Thyristors. SCR’s, introduced in the early 1960’s have proven to be dependable and offer precise control for resistance welding. Two SCR’s are used for single – phase lines and are connected in inverse parallel: one to pass current during the positive half cycle and the other during the negative half cycle.

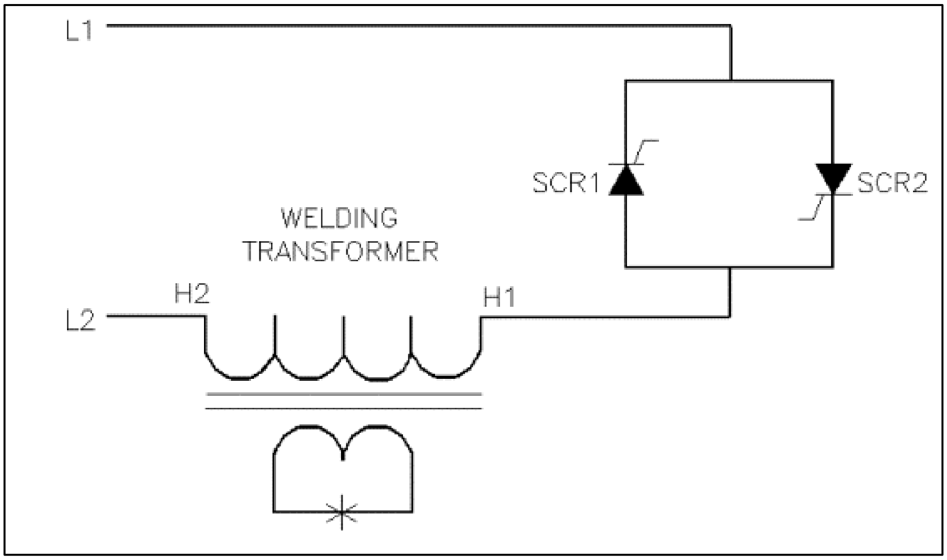

Figure 1. Diagram of SCR Contactor and Welding Transformer

When connected in this way and used in resistance welding controllers, SCR's are typically called a Contactor or A.C. Switch. [1]

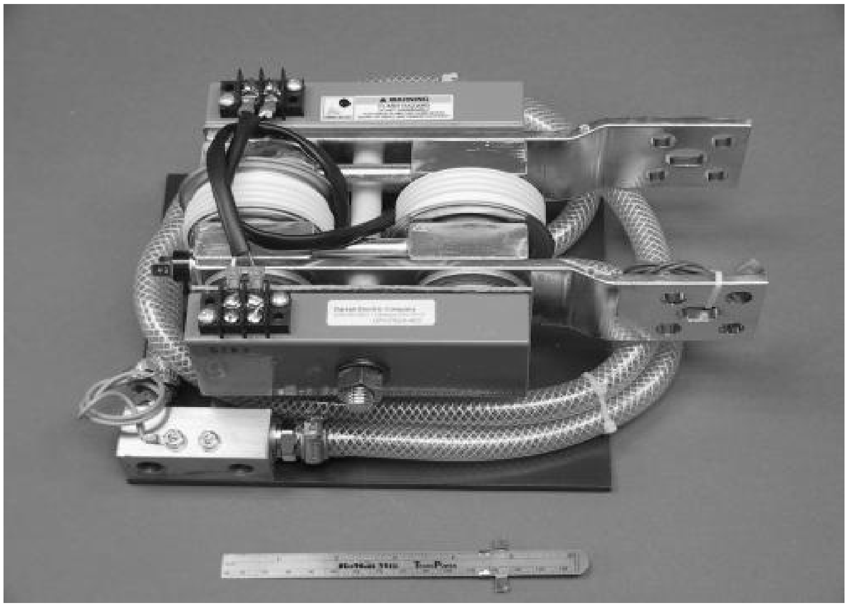

Figure 2. Photo of direct water-cooled contactor – double side cooled

While the efficiency of the SCR Contactor is very high when conducting current, there is a problem of losses that produce heat. Excessive heat is one cause of damage to SCR's;

therefore, they must be operated below damage temperature, described by SCR manufacturers as “ junction temperature”. The junction is the internal region between the positive and negative layers of the silicon wafers.

These wafers are connected to the anode and cathode terminals of the SCR. Maximum junction temperatures for typical SCR’s used for resistance welding are 125 degrees C (257 degrees F). Since SCR’s are used to control high currents, they can heat up and exceed the maximum junction temperature within milliseconds.

Therefore, the SCR Contactor requires a heat exchanger, or heat sink, to dissipate the heat. SCR’s are typically kept cool by either air or water cooling methods.

Air-cooled methods are quite simple. The SCR’s are packaged or sandwiched between aluminum or copper extrusions (Figure 3).

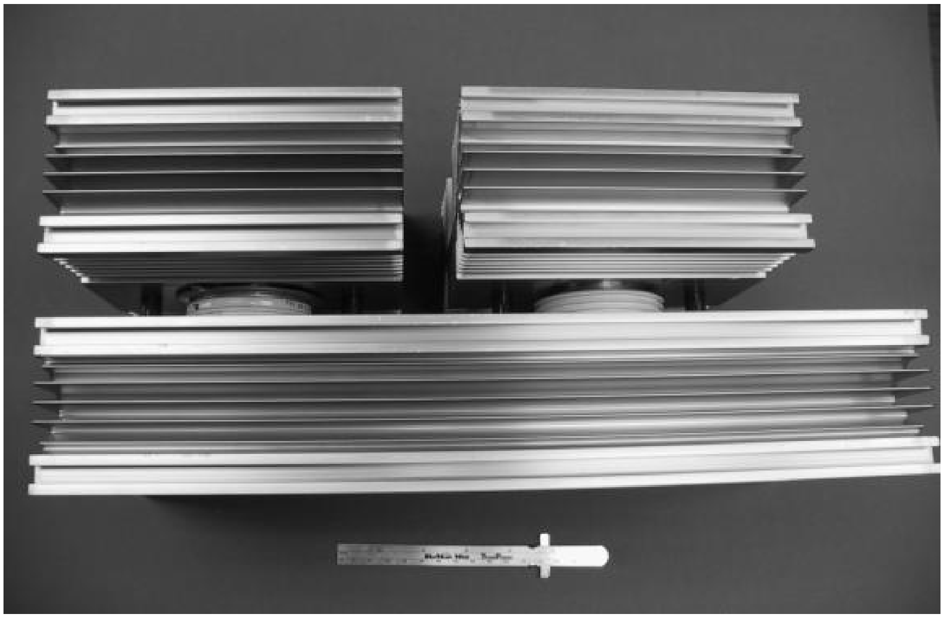

Figure 3. Photo of Air Cooled SCR Contactor

These extrusions typically have many fins, to increase surface area. The more the surface area the higher the heat dissipation or the lower the thermal resistance from the heat sink surfaces to ambient air. Adding fans or blowers increases the efficiency as well.

Although air cooled Contactors are less complex, they are not commonly found in resistance welding due to the high current requirements. Control cabinets would need to be larger and more costly. Fans or blowers would be needed in many applications as well.

Resistance welding applications require water to cool the welding tips and power transformer, hence water cooling the SCR Contactor is a logical choice. SCR Contactors for the first 20 years were direct water-cooled (Figure 4).

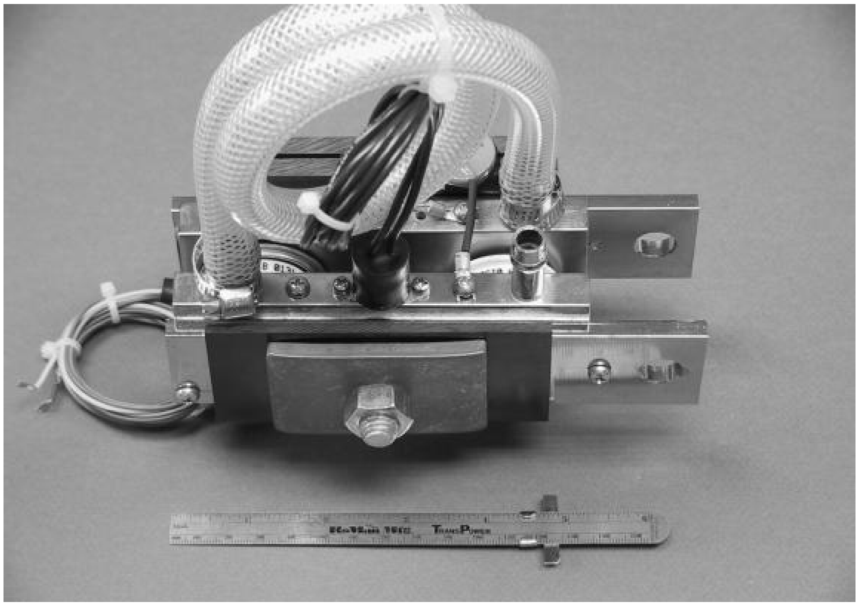

Figure 4. Photo of Direct Water Cooled Contactor – double side cooled

With this method, SCR's are mounted or clamped directly to water-cooled heat sinks. The heat sinks are electrically connected to the bus tangs (H1, L1). The water helps keep the electrical connection cool. The heat sinks are at line voltage potential. Heat sinks are typically copper and sometimes brass.

The water that passes through the SCR Contactor heat sinks, or chill blocks, is in contact with the line voltage. The hoses and water must have a high resistance to the flow of electricity across the H1 and L1 busses and also the control cabinet bulkhead connection.

Throughout the years, special attention was given to the hoses and water quality. Non-conductive and reinforced hoses are required for direct cooled SCR Contactors. Connections between H1 and L1 chill blocks and between the cabinet bulkhead have to exceed a minimum length (typically > 460mm [18 inches]) to avoid excessive leakage current. Welding control cabinets were often crowded with hoses.

Besides the obvious problems of having water hoses, fittings and connections in an electrical cabinet, a major concern in typical resistance welding applications is hoses bursting. Often times, between shifts and to conserve water, the electrical power was left on while the water flow was turned off. As the water sat in the hose lines, eventually carrying more and more current, the hose would heat, bubble and then burst.

Water quality is always a concern. The Resistance Welder Manufacturers' Association, RWMA, publishes a Water Quality Specification for SCR Contactors. See Annex 1.

Cost Savings

When the transition occurred from ignitron tubes to direct water-cooled SCR Contactors, the Contactors were typically sized based on 100% duty cycle to be sure there would be no failures. Copper chill blocks were the norm. In the mid 1980's and early 1990's to save welding control costs, manufacturers began looking seriously at duty cycle requirements. SCR's were more and more dependable as well as control circuits and safety devices were better able to protect the SCR's from potentially damaging transient voltages. The size or current rating of the SCR Contactor was reduced dependant upon the application, therefore lowering the cost. An application that would previously have used a 1200 Amp Contactor at 100% duty cycle could now use a smaller unit rated at 1200 Amps at 50% duty cycle, and be dependable and save dollars.

As control manufacturers looked more and more at customers welding schedules, the size of the SCR kept shrinking with no loss of dependability.

The smaller SCR Contactors were dependable and costs were down. Now if they could only eliminate the hoses, which crowded cabinets and sometimes leaked water on other control components.

The Indirect-Cooled SCR Contactor was born (Figure 5).

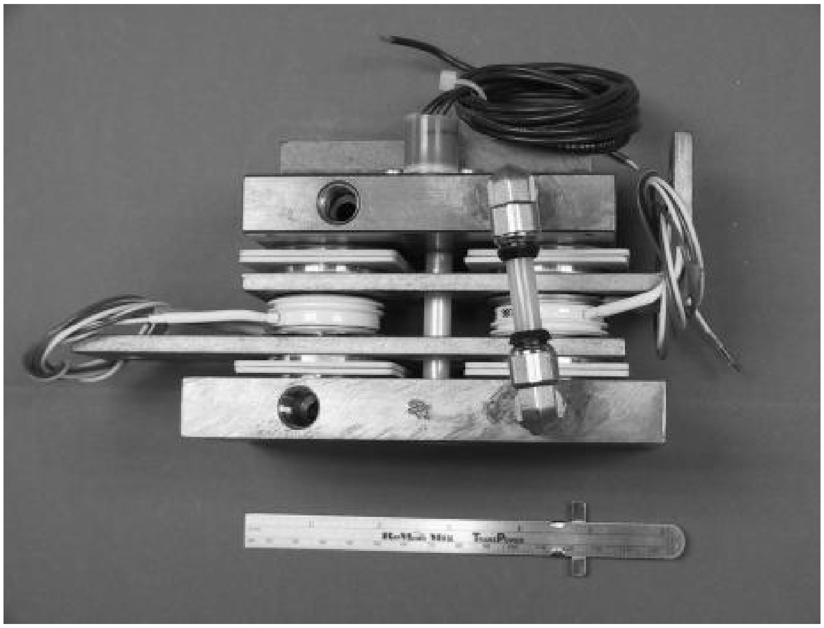

Figure 5. Photo of indirectly cooled SCR contactor – double side cooled - copper

The water-cooled chill blocks are electrically isolated from the line voltage. This type of Contactor virtually eliminated any need for hoses in the control cabinets. Contactors were designed to be edge mounted to the side of the control. Water connections from the plant could be connected directly to the SCR Contactor chill block through the cabinet wall. Bulkhead fittings were eliminated as well.

The first Indirect-Cooled Contactors used copper chill blocks as a carry over from their direct cooled predecessors. As customers demanded additional cost reductions, aluminum was tried as a copper replacement (Figure 6).

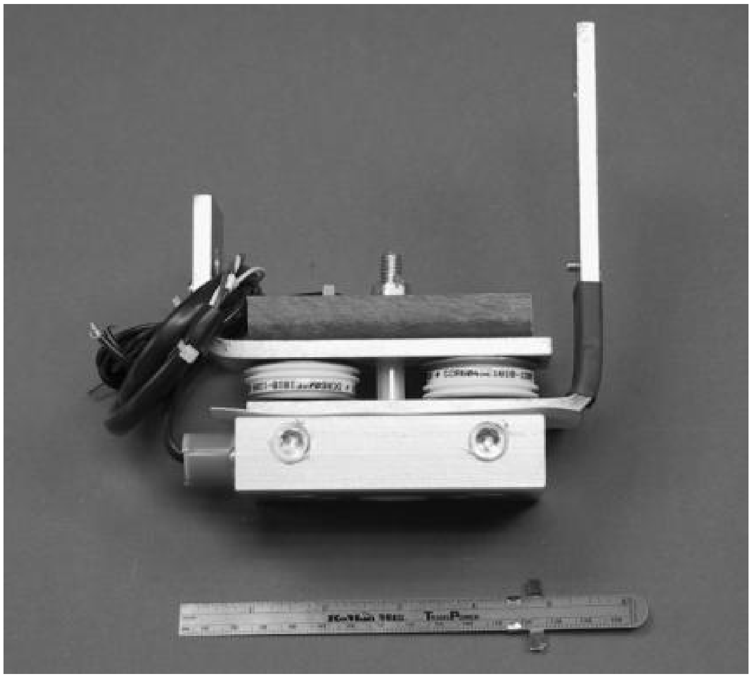

Figure 6. Photo of indirectly cooled SCR – single side cooled - aluminum

Thermal ratings were reduced using aluminum, but more and more attention was paid to duty cycles and welding schedules. It was further felt that by coating the aluminum with a chromate, anodized or irridite, its corrosion resistance would be enhanced. After all, water quality would be the responsibility of the CUSTOMER.

Corrosion

Customers were now receiving a smaller more compact welding control. The SCR's were proven to be more dependable and did not contain any of the hazardous materials found in ignitron tubes such as mercury. Circuit boards became microprocessor based, offering greater dependability and reliability. Hundreds of weld schedules could be ordered in the same control. There were no more hoses in the cabinet. Surely leaks were eliminated. Best of all, costs were lower.

While many improvements added reliability and longevity to welding controls, a new problem was forthcoming. Brass or steel fittings were frequently used to connect water lines. Corrosion began to occur at the threaded connection (Figure 7).

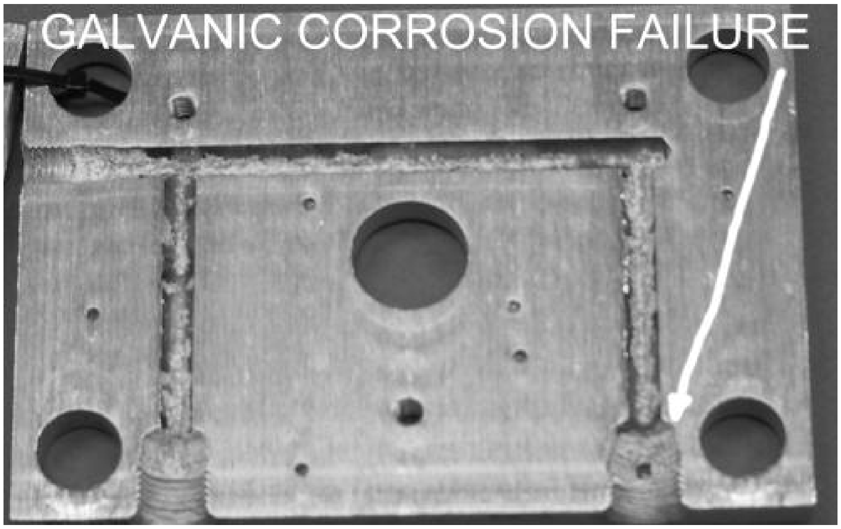

Figure 7. Photo of an aluminum SCR cooling block showing Galvanic Failure

Aluminum itself is sensitive to water quality, especially chlorides. High amounts of chlorides in the weld water systems were causing rapid deterioration of the aluminum chill blocks. Coatings that were applied to the aluminum chill blocks were found to be ineffective. It was found that the coating processes were not adequately covering the inside water passages. There was no guarantee that all of the walls could be covered.

Chill blocks began leaking from the inside out. In systems where water quality was not monitored, leaks sometimes occurred in as little as 6-8 weeks. Normal life expectancy with correct water chemistry should be about 6 years.

Flushing and cleaning water lines often caused more problems. Typically the materials that are used for removing rust and scale are quite corrosive to aluminum. In many cases the personnel doing the cleaning were not aware that aluminum was present in the weld controls. In some cases where they were aware of the aluminum, attempts to isolate the weld controls during the cleaning were only partially successful.

Control manufactures for years looked to water quality as the cause of all the problems. In many cases it was true. It wasn't until leaking chill blocks were found at plants with good water treatment that erosion was considered a source of the problem. Blocks were cut open for analysis. One of the earliest failures of this type is the one shown in Fig 8. It was pretty obvious from the internal wear, that some form of erosion due to water velocity was the problem.

Erosion

SCR Contactor manufacturers publish a water flow rate at a specific water temperature with RMS Current rating for each Contactor. Typically these flow rates are 4.5 L (1.2 Gallons) per minute, and sometimes as high as 6.8 L (1.8 gallons) per minute with larger diameter water passages. No maximum flow rates were specified. Consequently, high flow rates were not recognized as a concern. Dependant upon the location of the welding control to the water supply, flow rates often exceeded 11.5 L (3 gallons) per minute.

To further complicate the problem, reducing the size of water passages also raised water velocity.

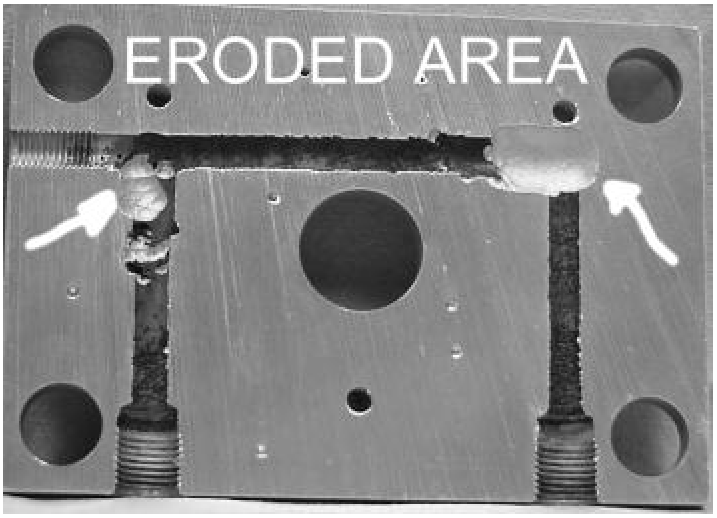

Figure 8. Photo of an aluminum SCR cooling block showing Erosion

When designing a water-cooled chill block, manufacturers are trying to get rid of as much heat as possible from the SCR anode and cathode terminals. Chill blocks are often rectangular, with water passages drilled with sharp 90-degree corners. These sharp corners add a little turbulence in the water, which helps remove heat. Everything is fine as long as the flow rate does not erode the inside wall. Air bubbles and particulates in the water further cause erosion, thus proving that more is not always better.

Typical designs used drilled passage sizes that produced turbulent flow in the 2-3 m/sec (6.5-9.8 ft/sec) range at 4.5 L (1.2 gallons) per minute. Erosion due to particulates becomes a concern at about 3-4 m/sec (9-13 ft/sec) [3]. When these blocks that were optimized for 4.5 L (1.2 gallons) per minute, were abused by operating at 11-12 L (3 gallons) per minute, flow velocity could be as high as 7 m/sec (23 ft/sec)– well above the velocity that can cause erosion.

<u>Corrosion Assisted Erosion</u>

Welding water is typically treated to reduce the risks of corrosion. The aluminum inside the chill block will use these treatment chemicals to form an aluminum oxide coating. It also must use some of the aluminum to form this coating. This coating is easily worn away by water flow and/or erosion while additional aluminum is consumed to replace the aluminum oxide coating. This cycle continues until a hole is worn completely through the chill block. Notice the dark coating on the eroded area in Figure 9.

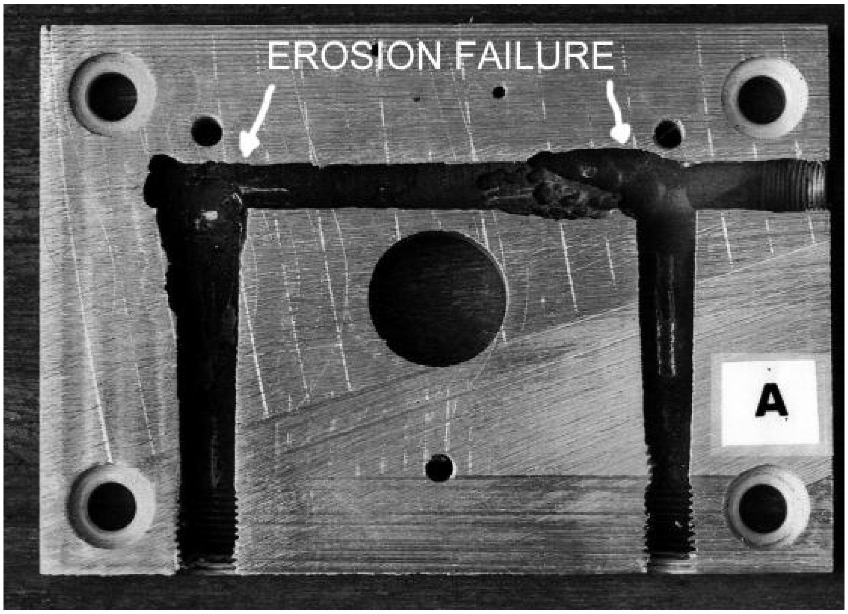

Figure 9. Photo of an aluminum SCR cooling block showing Corrosion Assisted Erosion

<u>Contributing Factors of Erosion and Corrosion by Plant Environments</u>

Most problems with leaking chill blocks begin during plant start up. If the water flow required by the tools that have been installed is small compared to pump capacity, there may be higher than normal pressure differential, causing abnormally high flow. New piping also contains scale, which not only effects water chemistry but also adds damaging particulates in the water system. The system is usually not balanced until all installations are complete. During this time there is often a wide variation in pressure differential compounded by the addition of new tools and piping which cause even more difficulty in managing water chemistry. This condition can last for as long as one year or more until installations are complete.

Summary and Conclusions

The problems with aluminum cooling blocks on SCR Contactors came up as a result of general lack of knowledge of the real environment that the weld controls would be expected to operate in. With this additional knowledge, it is possible to specify weld controls that can be expected to resist the effects of incorrect water chemistry and excessive flow that have caused problems in the past.

Specification Changes

As a result of what has been learned from recent experiences there have been certain changes to specifications. Maximum water flow rate must now be considered along with water chemistry. In areas where it's difficult to control chemistry or flow rate, copper or brass chill blocks should be used. Some users will not accept aluminum chill blocks. SCR Contactor manufacturers have introduced chill blocks that can tolerate 4.5 – 12 L (1.2-3 gallons) per minute continuously.

What Can You Do To Increase the Life of Aluminum Chill Blocks?

Be aware of water quality specifications and take care to meet the specification. Chlorides are especially harmful to aluminum and must be controlled. Even city water is usually too high in chlorine to use with aluminum. Avoiding the use of steel or brass fittings will also slow the corrosion process. PVC or aluminum fittings would be preferred. Finally, follow the recommendations of the SCR Contactor or the weld control manufacturer for water flow and pressure rates. Most will suggest the RWMA specification shown in Fig. 4. If your specifications do not show a maximum flow rate, limiting flow to no more than 1-½ times the minimum will usually prevent flow velocity related damage.

References:

1. Darrah, David, "SCR Contactors Vital to Resistance Welding Controllers", Welding Journal, Volume 74/ Number 8: 53-55, August 1995.

2. Resistance Welding Manufacturers' Association, Resistance Welding Control Standard, Bulletin # 5, October 1995.

3. Olsson, A. & Newman, Mark B., "SAF2507 For Sea Water Cooled Heat Exchangers", Chemical Engineering World, Volume XXXII No. 11, November 1997.

Annex 1 - Resistance Welder Manufacturer's Association: [2]

BUL 5-005.04 SPECIFICATION FOR DIRECT WATER COOLED SCR CONTACTORS

.01 Water flow rate shall be 1.2 G.P.M. minimum. Some larger SCR contactors require greater flow rates.

.02 Maximum water pressure shall be 90 P.S.I.G.

.03 Resistivity greater than 2000 ohms/cm at 25^{o}C (77^{o}F).

.04 Power should be removed from the SCR in less than 10 minutes if the cooling water is not flowing and the resistivity of the water is less than 5000 ohms/cm. If the water circulation is stopped when the power is still on, current through the water will eventually heat the hose material and embed contamination resulting in destruction of the hose. The use of water savers for Contactor cooling are not recommended for the above reasons. If Isolation Contactors remove the power from the SCR module, hose destruction is eliminated as there is no current to cause damage.

.05 Hoses for directly water cooled SCR's should be a non-conductive type of 3/8" inside diameter. This hose must not be shorter than 18 inches in length.

.06 Cooling Water temperature should be no greater than 104^{o}F (40^{o}C), without derating the devices.

.07 To prevent condensation on the cooled components, water temperature should not be less than the existing dew point of the ambient air (approximately 70^{o}F).

.08 Maintain a pH between 7.0 and 8.0.

.09 Maximum Chloride content of 20 PPM.

.10 Maximum Nitrate content of 10 PPM.

.11 Maximum Sulfate content of 100 PPM.

.12 Maximum solids content of 250 PPM.

.13 Maximum Calcium Carbonate content of 250 PPM.

BUL 5-005.05 SPECIFICATIONS FOR INDIRECT WATER COOLED SCR CONTACTORS

.01 Minimum water flow rate of 1.2 G.P.M.

.02 Maximum water pressure shall be 90 P.S.I.G.

.03 Water temperature no greater than 104^{o}F (40^{o}C).

.04 To prevent condensation on the cooled components, water temperature should not be less than the existing dew point of the ambient air (approximately 70^{o}F).

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.10 Maximum Calcium Carbonate content of 250." [2]