24th DOE/NRC NUCLEAR AIR CLEANING AND TREATMENT CONFERENCE

EFFECTS OF WELDING FUMES ON NUCLEAR AIR CLEANING SYSTEM CARBON ADSORBER BANKS

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Abstract

Standard Technical Specifications for nuclear air cleaning systems include the requirement to perform a full battery of surveillance tests following "fire, painting, or chemical release" in areas communicating with the affected system. In order to conservatively implement this requirement, many plants have categorized welding as a chemical release process, and instituted controls to ensure that welding fumes do not interact with carbon adsorbers in a filter system.

After reviewing research data that indicated that welding had a minimal impact on adsorber iodine removal efficiency, McGuire Nuclear Station decided to pursue further testing with the goal of establishing a "welding threshold". It was anticipated that some quantity of weld electrodes could be determined that had a corresponding detrimental impact on iodine removal efficiency for the exposed adsorber. This value could then be used to determine a conservative sampling schedule that would allow the station to perform laboratory testing to ensure system degradation did not occur, without incurring the penalty of a full battery of surveillance tests.

A series of tests was designed to demonstrate carbon efficiency versus cumulative welding fume exposure. Three series of tests were performed, one for each of the three different types of commonly encountered weld electrodes (E7018, E308 and E309). Each test series used a test filter train with a freshly loaded carbon adsorber and 20 pounds of electrode. Welding was performed with all airborne welding by-products directed through the filter train. Carbon sampling was performed at baseline conditions, and every five pounds of electrode thereafter. Two different laboratory tests were performed for each sample; one in accordance with ASTM 3803/1989 at 95% relative humidity and 30 degrees C, and another using the less rigorous conditions of 70% relative humidity and 80 degrees C.

Review of the test data for all three types of electrodes failed to show a significant correlation between carbon efficiency degradation and welding fume exposure. Accordingly, welding is no longer categorized as a 'chemical release process' at McGuire Nuclear Station, and limits on welding fume interaction with ventilation systems have been eliminated.

Introduction

Historically, at McGuire Nuclear Station, the generation of welding fumes has been considered to have a potentially detrimental effect on the carbon adsorbers of nuclear air cleaning system filter packages. Accordingly, their communication with operating filter systems has been administratively controlled; if welding fume exposure for a given system is unavoidable, that system would conservatively be considered inoperable and subject to the full battery of surveillance tests to demonstrate its return to operability.

Normally, these administrative controls do not place an undue burden on coordination between work and system operation. However, upcoming steam generator replacement projects at two of Duke Power Company's nuclear sites led to a re-examination of the welding fume impact issue.

During an outage, the Containment Purge filter trains at McGuire are essentially under continuous operation, either in 100% (dual train), or 50% (single train) mode. There are no designed system bypasses, so it is anticipated that essentially ALL of the gases generated by welding processes in containment will communicate with the operating filters. In order to avoid unnecessarily declaring filter trains inoperable based on 'suspected impact,' a site project was undertaken by the System Engineering and Operations groups to attempt to establish a correlation between the amount of fumes generated by welding and the resulting degradation in filter system methyl iodine removal efficiency.

Project Goal and Scope

The original project goal was to determine the point at which filter system adsorber performance deterioration occurred in a small test system, and then correlate this point to the cumulative weld fume exposure. Conservative extrapolations of this small test filter package data to actual systems would then be developed. It was anticipated that a 'pounds of electrode consumed per filter system flow rate' limit could be devised. This would be analogous to the painting 'rule of thumb' of 100 sqft per 1000 cfm that is widely used in the nuclear industry to perform carbon sampling and laboratory testing.

It was recognized that many hundreds of pounds of welding electrode would be used during the steam generator replacements, (and in the preceding outage, which incorporated as much structural prestaging as possible). Much of this welding would be 'stick', or electrode welding, (more formally called 'shielded metal arc welding', or SMAW). Other welding processes using an inert gas purge (i.e., MIG, TIG) are comparatively insignificant fume producers, and are not generally considered to be 'chemical releases.' Electrode welding was the only issue considered unresolved, and therefore was the sole focus of the project.

Test Method, Execution and Observations

Test Parameter Determination

The McGuire Training Support division has a small test filter train which was made available for use in project. The system is a portable and self-contained filter package manufactured by Charcoal Service Corporation of Bath, NC. This package consists of:

a) an 8" diameter intake duct (including flow orifice and manual throttle damper),
b) a filter housing, containing:
   one 24"x24"x2" prefilter,
   one 24"x24"x12" HEPA filter, and
   one carbon adsorber with approximately 75 pounds of carbon arrayed in 1 and 3/8" thick pleats, and
c) a belt driven centrifugal fan with a 120 VAC, 1.5 HP motor.

The nominal flow rate through the system is 500 cfm; manufacturer's supplied data for the adsorber states a residence time of 0.125 seconds at a flow rate of 1000 cfm (or, 0.25 seconds at 500 cfm).

Each of the two containment purge filter package carbon adsorbers holds approximately 2200 pounds of activated impregnated carbon, and has a nominal individual train flowrate of 14,000 cfm and 0.25 second residence time. A conservative approximation of the actual amount of welding electrode that might be consumed during an outage was 500 pounds. Comparing sizes of the test filter package to an individual containment purge package (based on either flow rate or the roughly equivalent carbon weight ratio) led to the choice of 20 pounds of electrode as the appropriate challenge for the test filter package. This equates to subjecting a single containment purge package to the fumes of approximately 585 pounds of welding electrode. Added conservatism is given by the fact that containment purge train operation is normally rotated during an outage, and routine lab tests of representative carbon samples are required after every 720 hours of system operation..

At McGuire, three different types of electrodes are used in 'stick welding' applications. They are:

1) AWS Classification E7018 for carbon steel to carbon steel welding,
2) AWS Classification E308 for stainless steel to stainless steel welding, and
3) AWS Classification E309 for stainless steel to carbon steel welding.

Due to the questions about the varying chemical compositions of the fluxes and the possibility of differing carbon degradation trends, it was decided that all three types would be tested (20 pounds of each). The carbon adsorber would be reloaded prior to each test series to quantify individual impacts.

Carbon to be used in each test series was the same nuclear grade-adsorbent as used in McGuire's safety filter systems. Purchase specifications state that it shall be impregnated to a range of 4.8 to 5% TEDA, and conform to all the physical and test standards as required by ANSI N509-1980, Table 5.1. The supplier for the carbon used was Carbon Applications, Inc. of Columbus, Ohio.

In order to add further conservatism and fully allow for any interaction between the welding fumes and the adsorber bed, a maximum test filter package flow rate of 250 cfm was established, which translates into a residence time of at least 0.50 seconds. In order to trend and correlate carbon degradation versus welding exposure, a carbon sampling frequency of a) prior to exposing the carbon to fumes, as a baseline, and b) following the consumption of every five pounds of electrode was assigned.

Test Execution

The general approach for each of the three test series was the same. The adsorber was loaded with new carbon, a baseline sample was obtained, and the filter package was started. The flow rate was throttled to a nominal 240 cfm. Welding was performed in the inlet plenum of the 8" ductwork to ensure that all fumes were drawn into the test filter package. The full length of the electrode was used for welding, regardless of whether restriking was required (impurities in the weld beads being generated were of no consequence to the test program). Representative carbon samples were removed from the adsorber following the consumption of each 5 pounds of electrode.

E308 Test Series: The original loaded carbon weight was 79 lbs. A gradually increasing prefilter differential pressure was observed during welding; its affect on flow was offset by adjusting the manual throttle damper in the inlet duct. Flow varied from 236 to 246 cfm. The total weight of E308 electrode was made up of 15 lbs. of 1/8" dia. and 5 lbs. of 3/32" dia.

E309 Test Series: The newly loaded carbon weight was 75 lbs. Prefilter differential pressure continued to rise during the test. Manual throttle damper adjustment was still sufficient to maintain nominal flow. Calculated flow for the series held steady at 242 cfm. E309 electrode weight was comprised of 16 lbs. of 1/8" and 4 lbs. of 3/32" dia.

E7018 Test Series: The test filter package prefilter was changed out along with carbon. Reloaded carbon weight was 80 lbs. The starting position for the throttle damper was further closed to account for the decreased D/P of the new prefilter. Flow varied from 229 to 239 while compensating for the initial particulate loading of the prefilter with damper adjustment. The breakdown of electrode sizes for the E7018 series was 5 lbs. of 3/32" dia., 7 lbs. of 1/8" dia., and 8 lbs. of 5/32" dia.

Test Results

Laboratory analysis of the carbon samples was performed by NCS Corporation of Columbus, Ohio. Each carbon sample was tested under two sets of conditions. The first was the Technical Specification dictated test of 80°C/95% Relative Humidity. The acceptance limit for this test is 99.00 % efficiency. The second test was the more conservative ASTM D3803-1989 test which incorporates a 16 hour pre-equilibration period and 30°C/95% RH test conditions.

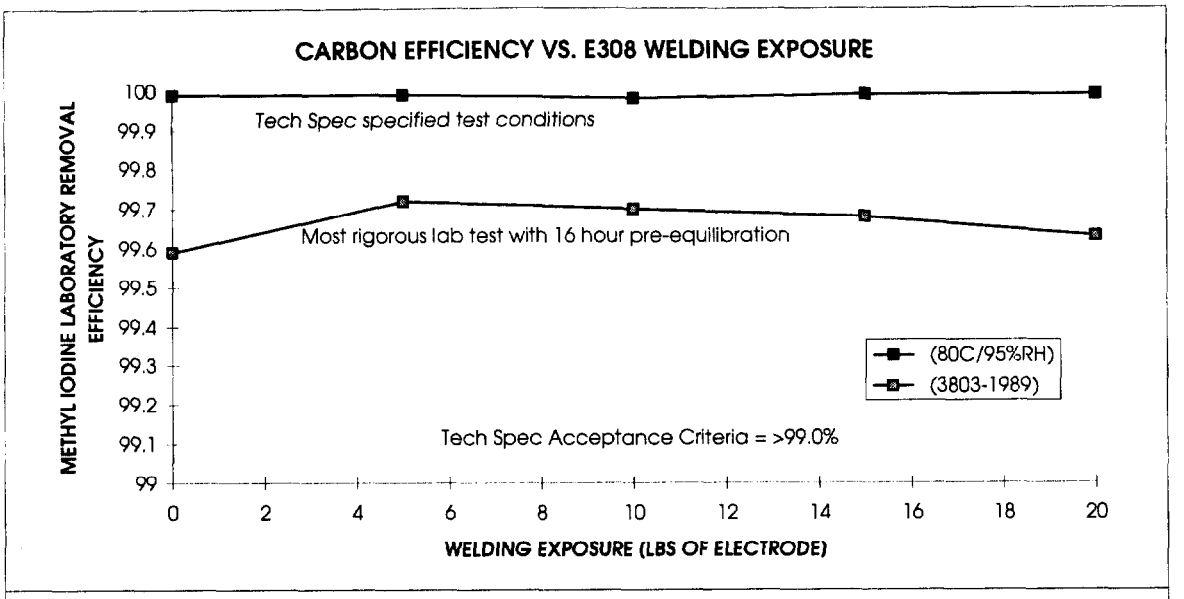
The results of the laboratory testing performed at five pound intervals for the three types of electrodes are presented in the following table.

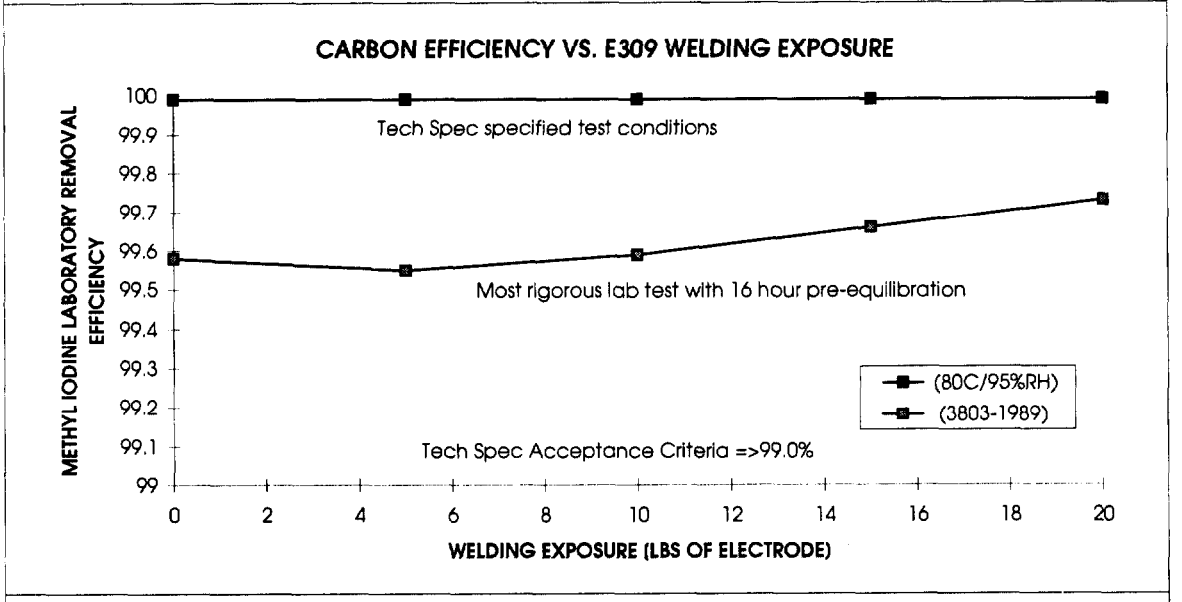
Welding Exposure	Carbon Laboratory Efficiencies (%): Electrode Type / Lab Test Conditions					
(Lbs. of	E308		E309		E7018	
Electrode)	(80C/95%RH)	(3803-1989)	(80C/95%RH)	(3803-1989)	(80C/95%RH)	(3803-1989)
0	99.99	99.59	99.99	99.58	99.99	99.81
5	99.99	99.72	99.99	99.55	99.99	99.72
10	99.98	99.70	99.99	99.59	99.99	99.76
15	99.99	99.68	99.99	99.66	99.99	99.75
20	99.99	99.63	99.99	99.73	99.99	99.79

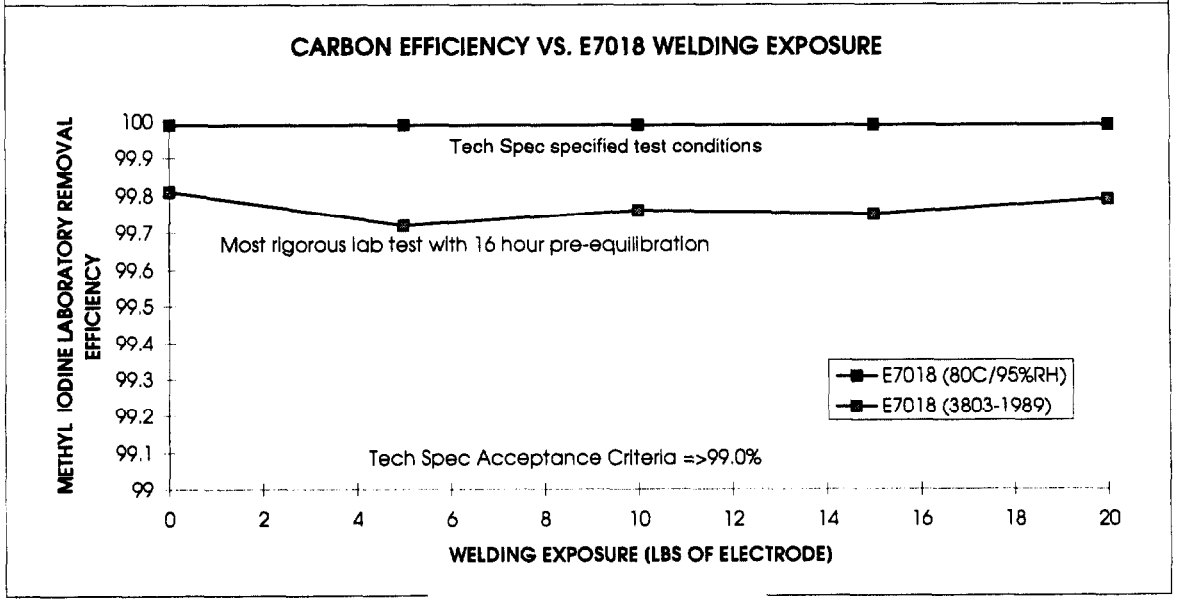
Review of the above data shows that even under heavy exposure to welding fumes, the ability of the adsorber to filter methyl iodine was not significantly affected. This general observation is applicable to the test results of each of the three types of electrodes.

The graphical presentation of the same data is provided for each electrode test series on the facing page; Graphs 1, 2, and 3.

Graphs 1, 2, and 3







Conclusions

Review of the laboratory test data for the three test series showed uniformly non-existent impact for the methyl iodine penetration tests performed at Tech Spec dictated conditions. With one exception (whose results were 99.98% efficient), all test results following increasing exposure to welding fumes showed the same performance as the baseline. This consistency, and lack of an identifiable deterioration trend, was a pleasant surprise.

Turning to the results for the carbon samples when tested according to ASTM 3803-1989, more variation was noted. An average efficiency for each test series was calculated, along with a standard deviation. For the 15 samples, 10 fell within a single standard deviation of the average, and for the remaining five, the worst "outlier" was 1.5 standard deviations off the average. It is interesting to note that this point (Series E309, Sample #5) showed an increase in efficiency over the baseline test.

Based on the trends established by the sampling and lab results for each test series, it does not appear that the airborne byproducts of electrode welding have a statistically significant impact on the performance of a filter package adsorber. No correlation of adsorber performance degradation vs. welding exposure was established. It was, however, noted that the visible smoke from electrode arcing is a particulate that does have a cumulative effect on prefilters, and therefore, potentially, on total system flow and/or HEPA filter D/P. The routine monitoring of operating filter systems at McGuire is considered adequate to identify any flow impacts of increasing D/P due to welding or other dust/particulate generating activities.

Accordingly, electrode welding is no longer considered a chemical release process at McGuire Nuclear Station.

Acknowledgments

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References

ANSI-N509-1980, "Nuclear Power Plant Air Cleaning Units And Components"

ASTM D3803-1989, "Standard Test Method for Nuclear Grade Activated Carbon".

American Welding Society, "Characterization of Arc Welding Fumes", 1983.

Ghosh, D. "Effects on the efficiency of activated carbon on exposure to welding fumes"; Proceedings of the 23rd DOE/NRC Nuclear Air Cleaning Conference, Conf-940738, Pg. 639, (1994).

DISCUSSION

ADAMS: Was there an interval after you exposed the carbon to the electrode contaminants when there was free flow of air through it? For example, after you exposed it for five electrodes, after you exposed it for ten electrodes, etc. After you completed five electrodes, for example, how much air flowed, or how soon did you pull a sample before you began the next electrode exposure?

ROBERSON: Let me clarify the question; as opposed to five electrodes it is five pounds of electrodes. We are looking in the neighborhood of fifteen electrodes per pound, so it's a little heavier exposure than that. We did not allow any specified amount of time between when the welder finished and we were ready to open the package up and pull the adsorber sample. It did not exceed 15 min.

ADAMS: Did flow continue through the unit while you were pulling the sample?

ROBERSON: Flow continued for an unspecified but relatively insignificant amount of time. The overall consumption of the weld rod, i.e., the number of pounds of weld rod, would take several hours between each sample, but when the welding was completed, sampling was promptly scheduled right after that.

ADAMS: Was the charcoal and filter package unit that you used a qualified ANSI N-509 unit?

ROBERSON: Yes.

ADAMS: How long did air pass through the unit after pulling a sample and beginning the next loading set?

ROBERSON: Unspecified, but in general the run time did not exceed an additional 15 minutes.

HAYES: Was the charcoal that you utilized brand new charcoal?

ROBERSON: Yes.

HAYES: Can you estimate the impact of welding on the charcoal if the test charcoal had not been new but aged for a year or longer?

ROBERSON: Although I would not expect different behavior, the project scope did not focus on carbon age impact. On a practical level, we have applied this relaxed policy on welding through the past outage, which included significant structural pre-staging work for the upcoming S/G outage. Ages of the carbon beds for the two trains of containment purge are approximately one and eight years. Sampling and lab results based on system run time confirmed no degradation on either train, new or old.

HAYES: You indicated that there was a trend that once you got initial degradation the efficiency may have picked up slightly, although within the error that you are talking about, you might even say it was flat. I am wondering if the deterioration, once the charcoal has been exposed, caused the process to somehow speed up one way or the other.

PEST: Can you elaborate on the sampling process? Did you use a grain thief, did you use a test canister?

ROBERSON: We used a grain thief and used a blended sample pulled from a number of pleats to obtain a standard sample.

FRANKLIN: Did you sample the air leaving the filter unit during or after welding?

ROBERSON: No, there was no attempt to quantify what kind of effluent came out of the filter package after all the weld fumes had passed through the pre-filter, HEPA filter, and adsorber.

HARRIS: There is a perceptible dust loading on the pre-filter. Was there an additional loading on the HEPA filter?

ROBERSON: It was minor. There was some but, I do not recall the exact number. From recollection, if the filter pressure drop started at 1.0 in. w., it was 1.1 in. w. at the conclusion.

GOLDEN: Regarding Jack Hayes' question on the aging of charcoal and how that was affected, I want to refer to a paper presented at the last air cleaning conference. The same conclusion was reached.

GHOSH: We did not check into the aging effects of the carbon in the test you are referring to. We used new carbon. We had test canisters and kept pulling the test canisters out. We did a combination of different tests and we tried to use the same type of carbon. The aging effect has not been addressed.

ROBERSON: At a practical level, we have been through one outage while constructing prestaging of structural steel with a lot of welding. We have done the required monthly sampling and continue to see good performance by the containment purge systems with five to seven year old carbon.

BARROW: In both units, we have reloaded carbon on "A" train but the Bravo train of each unit is approximately eight years old. Neither train has shown any degradation by carbon testing.

GHOSH: We use a test to validate that the building fumes had no effect on carbon. We have had two or three tests since we gave our paper and we did not show any degradation of the carbon. That confirms your results. In response to one of the questions somebody asked during my test, we monitored the gases in the inlet and outlet and found that the welding fumes were passing through the bed.

PEST: On the basis of the tests that you have done on your containment purge systems, do they seem to be operating well? What test parameters on your radioiodine test are you referring to, the regulatory required (80°C/70 % RH, or the new D3803-1989?

ROBERSON: We do dual testing with all of our systems. D3803 is used for trending and predicting end-of-life.

CASS: How "clean" was the material that was used as the base for the welding? Burnished, sandblasted clean or oily, dirty, rusty, painted metal, as is usually found in operating plants? Could obscure fumes, i.e. burnt smoke, affect the carbon? Was this considered or evaluated?

ROBERSON: Over the full range of the electrode test series (60#), a variety of welding "base metal" was used, some was painted, some rusty, and (for the stainless steel) some clean. Differences based on different base metal conditions was not specifically identified as a variable, but (by sheer coincidence), a range of base metal conditions was used. Specific documentation (or reconstruction) cannot be provided concerning which 5# increment of electrode consumption used which base metal.