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DEPARTMENT OF LABOR AND WORKFORCE DEVELOPMENT
DIVISION OF BOILER AND ELEVATOR INSPECTION
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Boiler Accident
Dana Corporation, Paris Extrusion Plant
Paris, Tennessee
June 18, 2007

Report Date: July 9, 2007

Report Prepared by:
Chief Boiler Inspector
Division of Boiler and Elevator Inspection
Tennessee Department of Labor and Workforce Development

INTRODUCTION

This accident was investigated by a team of State of Tennessee Boiler Inspectors, headed by Chief Boiler Inspector Martin R. Toth. Chief Toth was assisted in the investigation by Deputy Boiler Inspectors Randall Kelley and Richard Dickerson. Inspectors Kelley and Dickerson were dispatched by Chief Toth to carry out a preliminary investigation of the accident at the accident site on June 19, 2007. Chief Toth conducted the final investigation with the assistance of Inspector Kelley at the Dana Corporation plant in Paris, Tennessee on June 20, 2007. Various representatives were available during the investigation to offer assistance and expertise when requested. Several factors were considered to determine the probable cause of the accident and to make recommendations.

The findings and recommendations are made independently of any findings or recommendations proposed by other investigating individuals or agencies. The findings and recommendations will be provided to the company and all affected parties. To assure public knowledge through freedom of information, all such findings and recommendations are available for public review when requested.

SYNOPSIS

About 1:50 pm (CDT) on June 18, 2007, boiler #2 (TN#: T24059) located at the Dana Corporation plant in Paris, Tennessee, exploded causing extensive damage to the facility and surrounding area, and seriously injuring one (1) employee. The 2000 built Cleaver-Brooks high-pressure firetube boiler was operating concurrently with a second high-pressure boiler (boiler #1). Both boilers were online to handle the steam demand of plant operations.

The investigation team considered many factors during the investigation including the operation of the boilers at the time of the explosion, past and current maintenance, boiler attendance and operation logs, audible and visual alarms, past inspections and findings, installation and condition of controls and safety devices, and witness accounts.

It is determined that the probable cause of this accident was the sudden introduction of feed water to the boiler that at the time of the explosion was operating in a dry-fired state. Before the explosion, inoperative controls and safety devices allowed boiler #2 to continue to fire even though water levels in the boiler were at a dangerously low point. The excessive, rapid expansion of pressure that was created due to the introduction of feed water to the overheated surfaces of the boiler imposed dynamic forces on the boiler furnace tube, causing it to collapse and subsequently explode the boiler.

There were a number of factors that contributed to the accident: lack of standard training and boiler operation procedures, inadequate boiler attendance and record keeping, inadequate and improper boiler maintenance, and inoperative and improper operating controls and safety devices.

INVESTIGATION

The Accident

From interviewed witness accounts, about 1:50 pm (CDT) Mr. Leslie Evans, III, plant maintenance man was making his rounds of the plant boiler room. The plant's boiler room is separated from the manufacturing floor by a cement block wall with a pedestrian door and an industrial roll up door. Mr. Evans entered the room to find boiler #1 "down". Later it was interpreted by Maintenance Supervisor Matt King that this meant the boiler was in a "low water condition". It appeared through interviews that the boilers (#1 & #2) had been having difficulty with both high and low water conditions in the past.

Shortly after Mr. Evans entered the boiler room, boiler #2 exploded, sending the boiler through the industrial roll up door, knocking down a portion of the wall and resting over one-hundred (100) feet from its original location into the center of the manufacturing room floor (see Photos #1, #2, #3,& #4). The explosion hurled the rear door of the boiler through the opposite cement block wall, creating a thirty (30) foot hole in the outer wall of the plant (see Photos #5 & #6). The rear door and debris damaged many vehicles in the parking lot, as well as a pedestrian walkway, before coming to rest in a ditch one-hundred (100) feet from the boiler room (see Photos #7 & #8). The internal south wall of the boiler room also collapsed during the explosion, causing additional damage to property and equipment (see Photo #9).

It was reported that Mr. Evans was in the vicinity of the feed tank and pumps whenever the explosion occurred. During interviewing, Mr. King stated that after the explosion Mr. Evans was seen running out of the boiler room through the hole created in the outer wall of the plant (east wall), where he collapsed. Mr. King stated that Mr. Evans told him that when he noticed that boiler #1 was "down", he proceeded to the feed tank and pump area. At the feed tank and pump area, Mr. Evans reported hearing a loud whistling noise just before the boiler blew. There is no account of what actions Mr. Evans took once he found boiler #1 "down".

It was also reported that when the boiler came to rest in the center of the manufacturing room floor, parts of the boiler were still on fire, and the tube sheet and furnace tube were "glowing cherry red".

Company Information

The accident occurred at the Dana Corporation, Paris Extrusion Plant, 100 Plumley Drive, Paris, Tennessee. Dana Corporation is a rubber products manufacturer for the automotive industry. The extrusion plant, which employs about 115 people, is part of a four-plant compound outside Paris and about 125 miles northeast of Memphis, Tennessee.

Boiler Information

The boiler involved in the accident was a 2000 built Cleaver-Brooks CB Packaged high-pressure steam, gas/oil fired, 400 horsepower, and 150 pounds per square inch (psi) firetube boiler. The boiler bears the ASME "S" stamp and National Board registration number 10409. The boiler is registered with the State of Tennessee with Tennessee Boiler Number T24059. At the time of the explosion, the boiler was insured and inspected by Arise Incorporated, Brecksville, Ohio.

Inspection History

Boiler T24059 was placed in operation by an internal inspection that occurred by Special Boiler Inspector Baltazar P. Cartagena on March 2, 2001. Inspector Cartagena is employed by Arise Incorporated. The subsequent inspections were as follows:

Date	Inspection Type	Inspector	Agency
September 14, 2002	Internal	Billy J. Packett	Arise Incorporated
June 14, 2003	Internal	Billy J. Packett	Arise Incorporated
September 16, 2003	External	Billy J. Packett	Arise Incorporated
October 10, 2004	Internal	Baltazar P. Cartagena	Arise Incorporated
October 8, 2005	Internal	Baltazar P. Cartagena	Arise Incorporated
October 29, 2006	Internal	Baltazar P. Cartagena	Arise Incorporated
January 10, 2007	External	Baltazar P. Cartagena	Arise Incorporated

It appears that the required external inspections were not performed between September 16, 2003 and January 10, 2007. Even with that finding, the last inspection reported to the State of Tennessee was an external inspection performed on January 10, 2007. The external inspection should and would have consisted of an operational inspection while the boiler was fired and operating. All controls and safety devices would have been tested during that inspection.

There was no evidence of findings or violations noted on any report submitted to the State of Tennessee. There is a current valid Certificate of Inspection that will expire on September 14, 2007, the date when the next inspection would have been due.

Maintenance History

During the interview with Mr. King, most maintenance and replacements to the boiler controls and safety devices were performed by Dana Corporation maintenance personnel. However, some boiler services were handled by outside vendors. Some of the controls and safety devices had been replaced after the January 10, 2007 external inspection conducted by Inspector Cartagena.

Mr. King stated that the primary low-water fuel cutoff (LWCO)/pump controller was scheduled to be replaced due to improper operation. A replacement for the McDonald & Miller (M&M) Series 193-7B mechanical combination low water cut-off/pump controller was ordered incorrectly and a replacement was scheduled at the time of the accident. According to Mr. King, the initial need for the replacement of the controller was due to the controller not "turning off the feed" to the boiler. This was subsequently causing boiler "flooding".

Due to the reoccurring high water condition (i.e., flooding), the decision was made by maintenance to disconnect the modulating feed controller (Honeywell) from the feed valve (Worchester ball valve) (see Photos #10 & #11). The disconnection of the controller arm was performed by Dana Corporation maintenance personnel. By disconnecting the modulating feed controller, the boiler operator would be required to throttle the feed valve to allow feed water to be introduced into the boiler. During the investigation, it was found that the bypass valve connected to the modulating feed valve had been opened halfway (see Photo #12).

It was found that the auxiliary low-water fuel cutoff relay had been replaced by Dana Corporation maintenance personnel. The auxiliary LWCO serves as an emergency back-up to the primary LWCO. If the primary LWCO fails to operate properly, the auxiliary LWCO is intended to ensure that the fuel will be turned off to the boiler. On the Cleaver-Brooks CB Packaged Boiler, the

auxiliary LWCO is intended to be installed with the Code required manual reset switch. If the auxiliary LWCO is activated, the boiler operator would have to manually reset the safety device before the boiler would operate.

Boiler Attendance

Dana Corporation maintenance personnel served as the boiler operating staff. Since the Dana Corporation, Paris Extrusion Plant did not have a Remote Attendance Variance from the Tennessee Board of Boiler Rules, the monitoring of the boiler was required every twenty (20) minutes. According to Mr. King, the boiler room was visited by Dana Corporation maintenance personnel every hour to an hour and a half.

At the time of the explosion, Dana Corporation did not maintain a boiler operation log. There is no record of visits to the boiler room by plant personnel. There is no record of incidences with boiler operations (e.g., alarms, low-water/high-water conditions, etc.). There are no written procedures for boiler operator training or certification.

Investigation Exit Meeting

Upon the conclusion of the final investigation of the accident site on June 20, 2007, Chief Toth conducted an exit meeting with Dana Corporation management. A brief discussion of the findings was presented and questions were answered. Those in attendance are listed below:

State of Tennessee Investigation Team
Mr. Martin R. Toth, Chief Boiler Inspector
Mr. Randall Kelley, Deputy Boiler Inspector

Dana Corporation Personnel
Mr. Andy Doll, Plant Manager
Mr. Davor Musap, Advanced Engineering Manager
Mr. Tommy Patterson, SSC Manager
Mr. Jason Almond, H&S Manager – Sealing Products
Mr. Ed Pack
Mr. Eric Haiss

Other Attendees
Mr. Ed Stewart, Boiler Service Manager, *Power Equipment Co. (Memphis, TN)*
Mr. David Goode, Executive Vice President, *GMW, Inc. (Memphis, TN)*
Mr. Al Kubek, Factory Service, *Cleaver-Brooks Boiler (Thomasville, GA)*

CONCLUSIONS

Findings

1. The float assembly on the McDonald & Miller (M&M) Series 193-7B mechanical combination low water cut-off/pump controller located on the boiler had a bent and broken spring (see Photo #13).
2. When the float arm assembly of the M&M Series 193-7B mechanical combination low water cut-off/pump controller was manipulated up by hand to simulate a high-water condition, the stem for the float would stick on the guide plate (see Photo #14).
3. The modulating feed controller was disconnected from its feed valve (see Photos #10 & #11). *The feed system for the boilers is a continuous system, which means the feed pumps operate constantly and the modulating feed valve opens and closes per the demand of the boilers for feed water. The operation of the modulating feed controller is controlled from the M&M controller.*
4. The modulating feed valve bypass was opened approximately halfway. This shows evidence of throttling the feed water inlet that in essence bypassed the modulating feed valve (see Photo #12).

5. An improper relay (1d1d0) for the auxiliary low-water cutoff was installed by Dana Corporation maintenance personnel (see Photo #15). Due to a dissimilar connect configuration, the different wire line-up caused the circuit to remain closed, which gave a misreading of the boiler water level. Since the circuit was continuously closed, no matter if water was in the boiler or not, the safety device would read that the water level was at a safe operating level. Photos #16a and #16b illustrate the 1c1d0a and 1d1d0 relays. The 1c1d0a is the proper relay for the boiler in question; 1d1d0 was the improper relay that was installed by Dana Corporation maintenance personnel. Note the different contact configuration diagrams.
6. The manual reset for the auxiliary low water cut-off was removed when the improper relay was installed. On the Cleaver-Brooks CB Packaged Boiler, the auxiliary LWCO is intended to be installed with the Code required manual reset switch. Photo #17a Illustrates the proper relay that should have been installed, Note the manual reset button and compare with Photo #17b that has no manual reset.
7. The light bulb for the visual alarm light outside of the boiler room for boiler #1 was blown. Boiler #1 has no audible alarms per the maintenance supervisor. Boiler #2 appears to have audible alarms, but there was no indication that they were or were not operating during the time of the accident.
8. The company does not have a boiler operation log to record boiler operator visits, times of visits, readings, incidents, or conditions of the boilers and boiler related equipment.
9. The maintenance man (boiler operator) visits the boiler room ever hour to an hour and a half, rather than every twenty (20) minutes as required by Tennessee Board of Boiler Rule 0800-3-3-.04 (22).
10. The two Kunkle pressure relief valves appeared to be of proper size, pressure setting and relieving capacity. They also appeared to have no physical defects during visual examination. A pressure test was not performed at the time of the investigation.

Most Probable Cause

It is determined that the most probable cause of this accident was the sudden introduction of feed water to the boiler that at the time of the explosion was operating in a dry-fired state.

It is believed that when Mr. Evans discovered that boiler #1 was in a low water condition, he proceeded to the vicinity of the boiler feed pumps. It is believed that during this time boiler #2 was at full fire. Unbeknownst to Mr. Evans, boiler #2 was operating in a low-water condition. Feed water was then introduced back to the boilers. Whether this was due to the maintenance actions, or not, of Mr. Evans has not been determined.

From the evidence, it is deduced that the primary low-water fuel cutoff (LWCO)/pump controller float was wedged in the up position. This could have accounted for the boiler continuing to fire even though the boiler was experiencing a low water condition. Past experiences of high water in the boiler, which in turn lead to the disconnection of the modulating feed control for the feed valve, could have lead to the float becoming wedged.

Since the modulating feed valve bypass was opened halfway, the boiler water level would have fluctuated as the boiler fired, causing the primary LWCO to operate more as a control than a safety device. This could account for the need to remove the required manual reset on the auxiliary LWCO. With the feed valve bypass open, there would be no automatic control of the amount of feed water that enters the boiler. This could account for the high-water conditions. On the other hand, if the boiler calls for more feed water than what is delivered through the opened bypass, the boiler would subsequently go to a low-water condition; because of the manual reset, maintenance personnel would be required to manually reset the boiler in the boiler room. By removing the relay with the manual reset with one that is automatic, once the boiler water reaches a safe level, the boiler will begin to fire without any interaction from maintenance personnel. This is not allowed per the Code. (Ref. CSD-1, CW-140)

Given that the auxiliary LWCO relay was replaced with the incorrect model, the primary LWCO did not respond and cut-off the fuel supply to the boiler, the boiler continued to fire until the accident occurred. Without corroboration, it can only be speculated that operation of the boiler's

feed pumps had discontinued. Since the light bulb for the visual alarm for boiler #1 was blown, there is no way to know exactly how long boiler #2 was in dry-fry.

Conclusion

Based on the foregoing, it is concluded that the main cause of the boiler accident was improper maintenance and the lack of operational procedures of the boilers. In addition, removal and replacement of critical controls and safety devices, along with the lack of proper training and qualified personnel equally contributed to the occurrence of the accident.

RECOMMENDATIONS

- Dana Corporation should develop procedures for the training and certification of all boiler operators.
- Dana Corporation should invest in a remote monitoring system that will monitor the boiler operations while the boiler operators are performing their maintenance responsibilities.
- All maintenance to the boiler and boiler associated equipment's controls and safety devices should be performed by an experienced and qualified outside vendor knowledgeable in their operation and function.
- Boilers and boiler associated equipment's controls and safety devices should be tested annually by an experienced and qualified outside vendor knowledgeable in their operation and function.
- All steam pressure relief valves should be removed, inspected, and pressure tested annually to ensure proper nameplate set pressure and operation.
- It is crucial that all boiler operator daily operational tests, duties, and responsibilities recommended by the boiler manufacturer are adhered to, followed, and performed.
- The audible and visual alarm system for the boiler plant should be overhauled to ensure notification throughout the plant.
- Emergency and evacuation procedures should be developed by Dana Corporation in the case of a boiler incident or accident. All company employees should be made aware of these procedures.
- Dana Corporation should ensure that all mandatory inspections to the boilers are performed per the requirement of the State of Tennessee Laws, Rules and Regulations by a certified commissioned boiler inspector.
- Any future incident or accident involving a boiler, pressure vessel (e.g., autoclave, air storage tank, etc.), or boiler related equipment should be reported to the Tennessee Boiler Inspection Division immediately.

Photo #1 – Final Location of Boiler after Explosion (Roll Up Door on Boiler)

Photo #2 – Final Location of Boiler After Explosion

Photo #3 – Final Location of Boiler after Explosion (Exposed Furnace Tube)

Photo #4 – Hole Created by Boiler through Roll Up Door Wall (West Wall)

Photo #5 – Knocked Down Exterior Wall Viewed from Inside Boiler Room (East Wall)

Photo #6 – View of East Wall from Outside Plant

Photo #7 – View of East Wall from Outside Plant (Note Rear Boiler Door in Ditch)

Photo #8 – View of Pedestrian Walkway Bridge

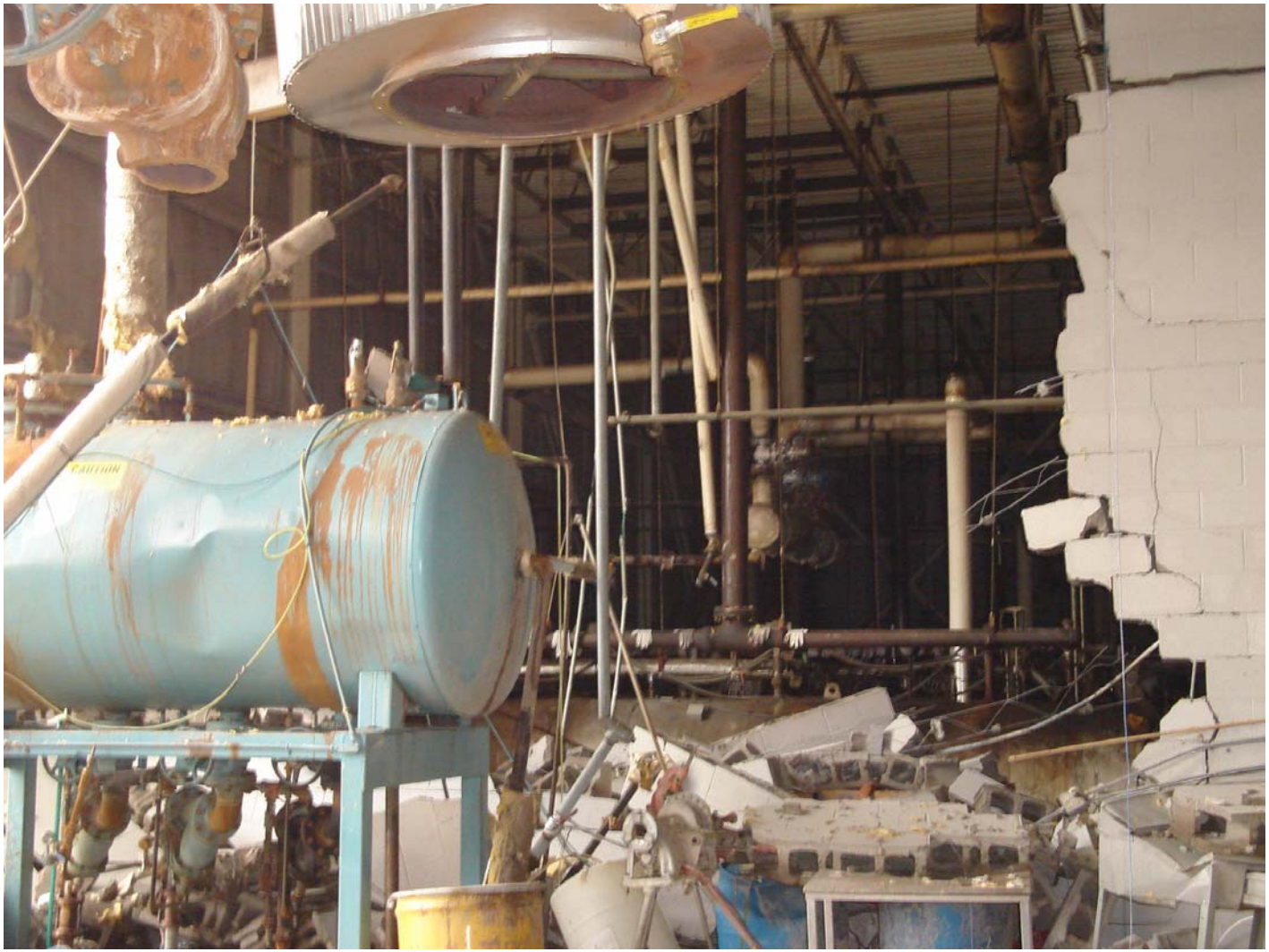

Photo #9 – Interior Wall of Boiler Room (South Wall)

Photo #10 – Modulating Feed Controller, Valve, and Bypass (Note Disconnected Operating Arm)

Photo #11 – Modulating Feed Controller and Valve with Disconnected Operating Arm

Photo #12 - Bypass to the Modulating Feed Valve. Valve was found in the half open position.

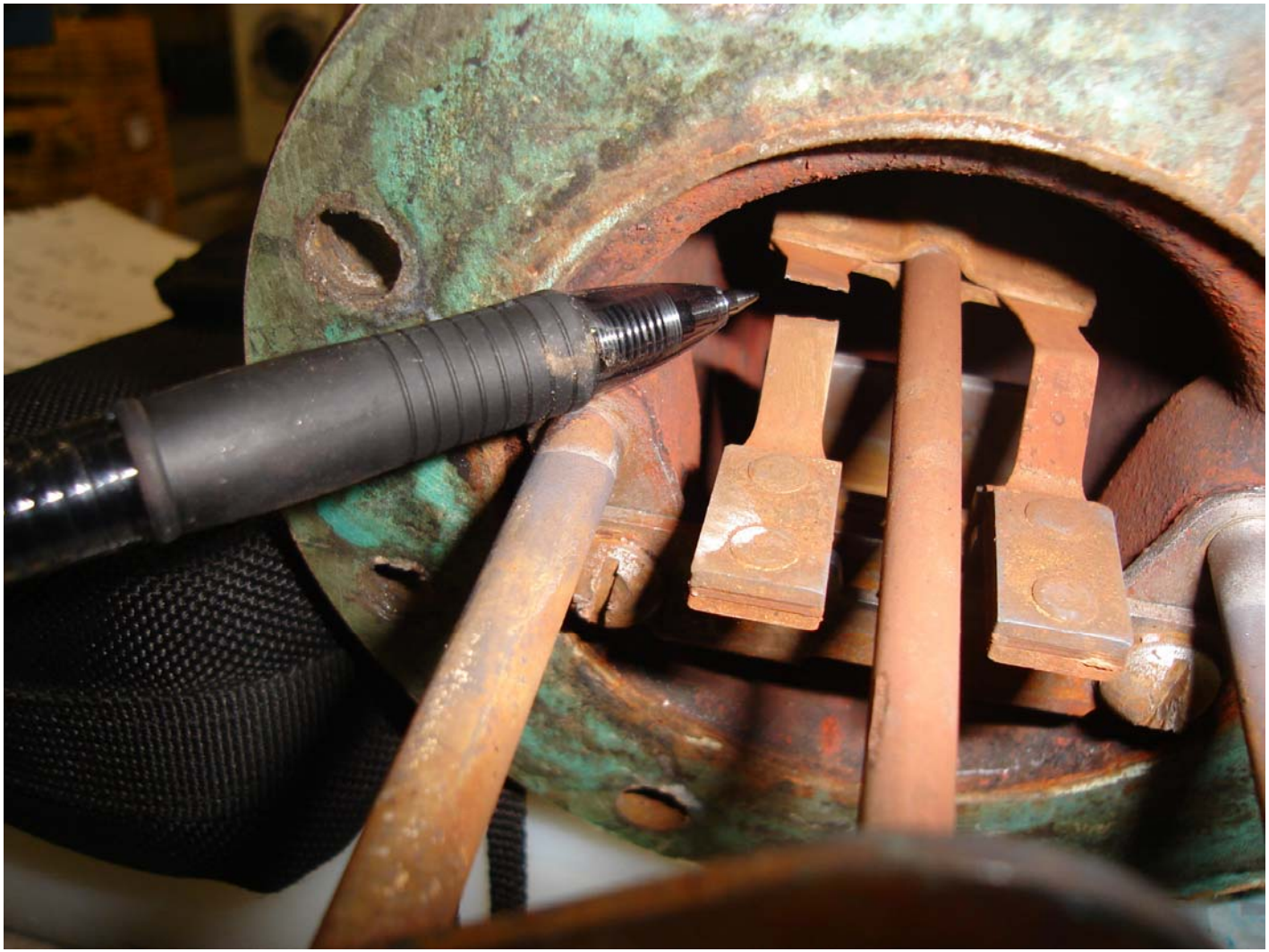

Photo #13 – Bent and Broken Spring on McDonald & Miller (M&M) Series 193-7B Mechanical Combination Low Water Cut-Off/Pump Controller

Photo #14 - McDonald & Miller (M&M) Series 193-7B Mechanical Combination Low Water Cut-Off/Pump Controller stuck in the up position

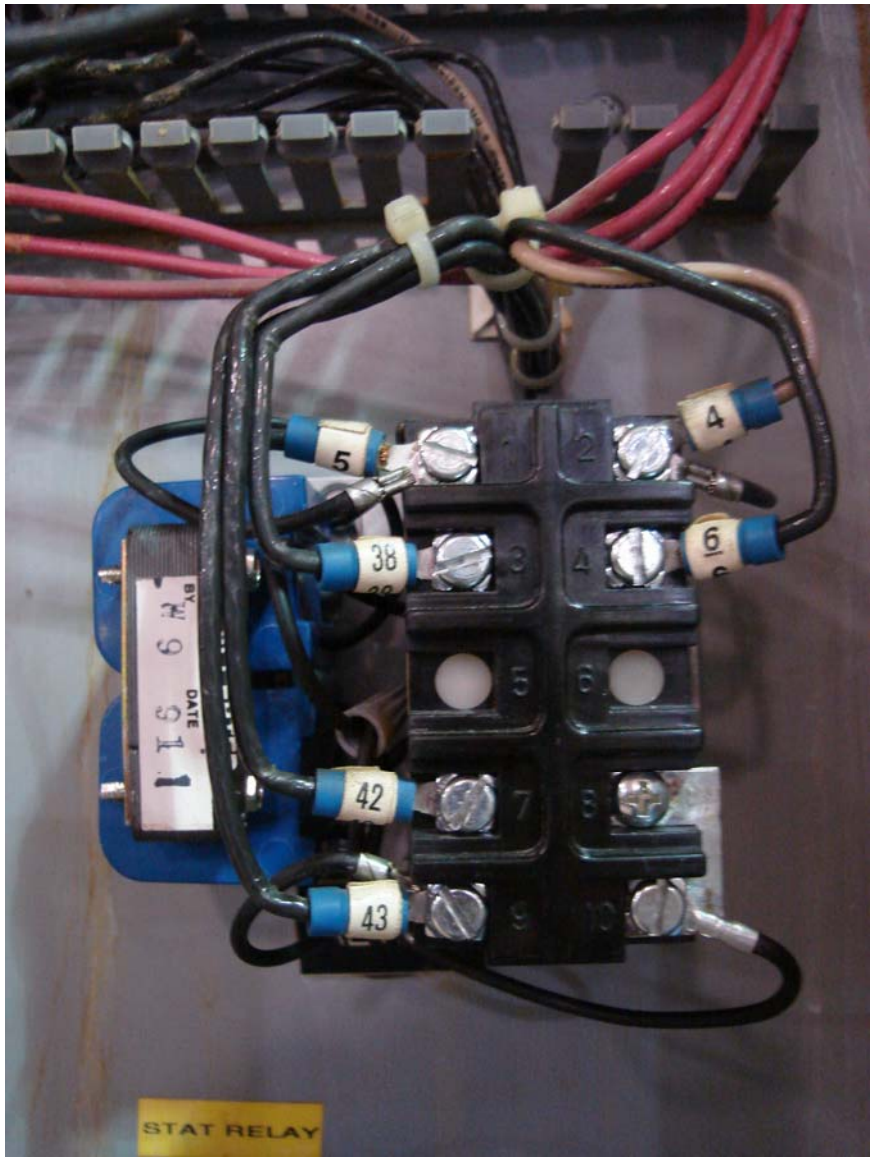

Photo #15 – Improper relay that was installed by Dana Corporation maintenance personnel for the Auxiliary LWCO

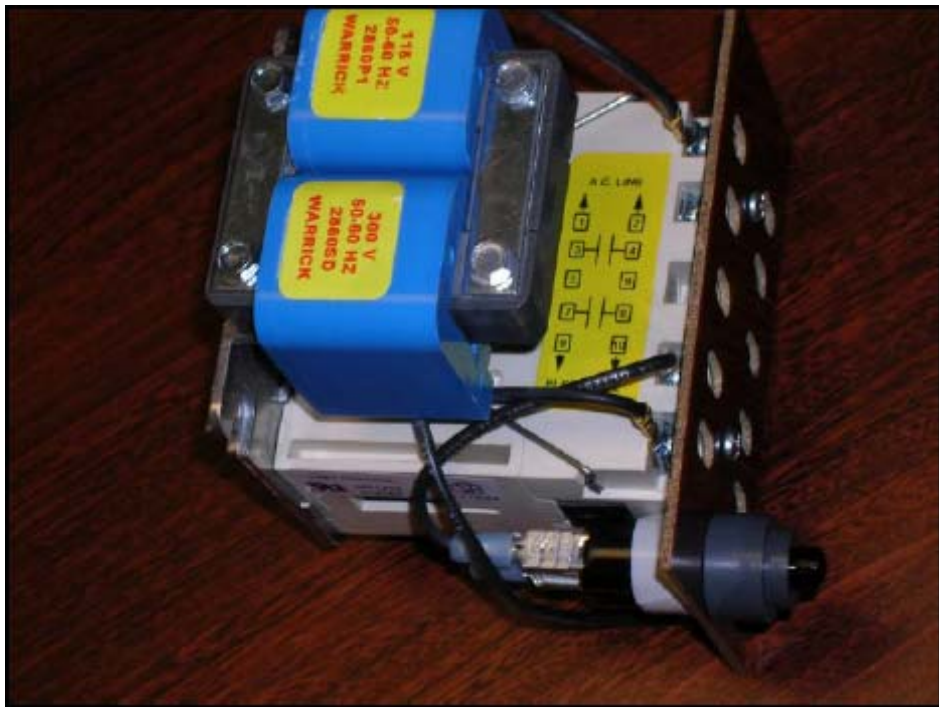

Photo #16a – 1c1d0a Relay with Manual Reset

Photo #16b – 1d1d0 Relay without Manual Reset

***Note the difference in the contact configuration diagrams**

Photo #17a –1c1d0a (Proper Relay with Manual Reset)

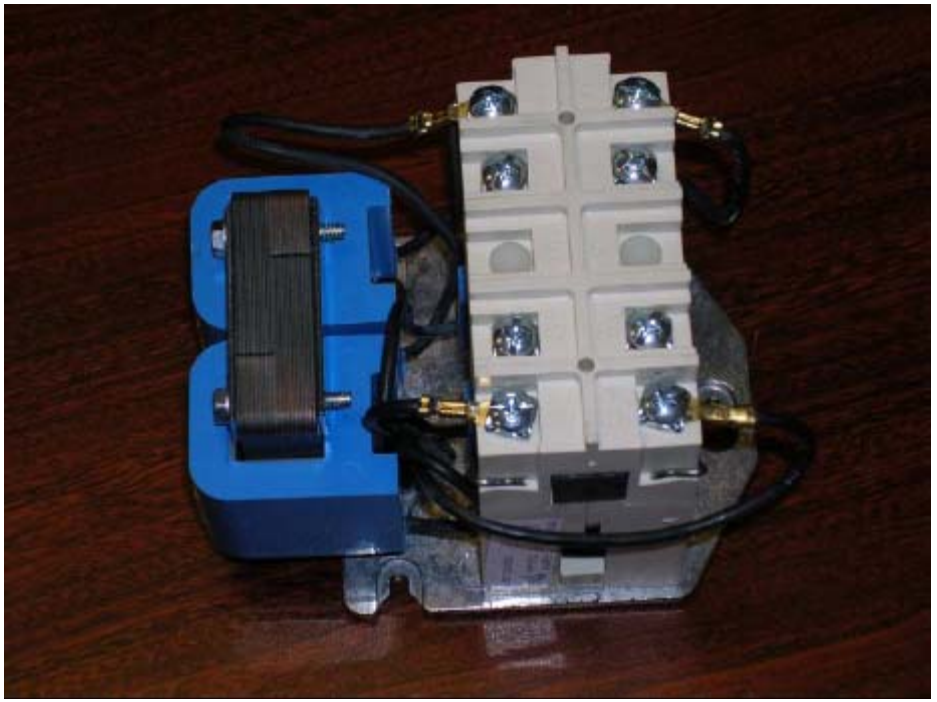

Photo #17b – 1d1d0 (Improper Relay without Manual Reset)